MARINE FISHERIES COMMISSION BUSINESS MEETING
Doubletree by Hilton University Brownstone, Raleigh, N.C.
August 21 - 23, 2019

N.C.G.S. 138A-15(e) mandates at the beginning of any meeting of a board, the chair shall remind all members of their duty to avoid conflicts of interest under Chapter 138. The chair also shall inquire as to whether there is any known conflict of interest with respect to any matters coming before the board at that time.

N.C.G.S. 143B-289.54.(g)(2) states a member of the Marine Fisheries Commission shall not vote on any issue before the Commission that would have a "significant and predictable effect" on the member's financial interest. For purposes of this subdivision, "significant and predictable effect" means there is or may be a close causal link between the decision of the Commission and an expected disproportionate financial benefit to the member that is shared only by a minority of persons within the same industry sector or gear group. A member of the Commission shall also abstain from voting on any petition submitted by an advocacy group of which the member is an officer or sits as a member of the advocacy group's board of directors. A member of the Commission shall not use the member's official position as a member of the Commission to secure any special privilege or exemption of substantial value for any person. No member of the Commission shall, by the member's conduct, create an appearance that any person could improperly influence the member in the performance of the member's official duties.

Commissioners having questions about a conflict of interest or appearance of conflict should consult with counsel to the Marine Fisheries Commission or the secretary's ethics liaison. Upon discovering a conflict, the commissioner should inform the chair of the commission in accordance with N.C.G.S. 138A-15(e).

Aug. 21

6 p.m. Public Comment Period

Aug. 22

9:00 a.m. Swearing in of New Commissioners
Call to Order*
Moment of Silence and Pledge of Allegiance
Review Ethics Evaluations of New Commissioners
Conflict of Interest Reminder
Roll Call
Approval of Agenda**
Approval of Meeting Minutes**

9:30 a.m. Public Comment Period

11:00 a.m. Petition for Rulemaking by the N.C. Wildlife Federation/SELC
- Presentation of the Petition
- Response from the Division of Marine Fisheries
  - **Vote to Initiate Rulemaking Process****

12:15 p.m. Lunch Break

1:30 p.m. Chairman's Report
- **Elect Vice Chair****
- Letters
- Ethics Training and Statement of Economic Interest Reminder
- 2020 Meeting Schedule
- Senate Bill 648, S.L. 2019-37 MFC Requirements
- **Recreational hook-n-line modifications****

2:30 p.m. Committee Reports
- Southern Flounder Fishery Management Plan Advisory Committee
- Blue Crab Fishery Management Plan Advisory Committee
- Finfish, Southern, and Northern joint advisory committees

- N.C. Commercial Fishing Resource Fund Committees
- WRC/MFC Joint Committee on Delineation of Water Boundaries Update – Chairman Rob Bizzell

3:30 p.m. Director's Report – Director Steve Murphey
Reports and updates on recent Division of Marine Fisheries activities
- Division of Marine Fisheries Quarterly Update
- Update on Federal Fisheries Disaster Assistance
- Update on Revised FMP process – Kathy Rawls
- Use Conflicts in Public Trust Waters
- Atlantic States Marine Fisheries Commission – Chris Batsavage
- Mid-Atlantic Fishery Management Council Update – Chris Batsavage
- South Atlantic Fishery Management Council Update - Steve Poland
- Highly Migratory Species – Randy Gregory
- Informational Materials
  - Landings Update for Red Drum and Southern Flounder
  - Protected Resources Update
    - Observer Program
    - Incidental Take Permit Updates

4:30 p.m. Standard Commercial Fishing License Eligibility Report/Set Eligibility Pool Cap – Capt. Garland Yopp and Stephanie McInerny
- **Vote of setting temporary cap on the number of licenses in the Eligibility Pool****

<u>Aug. 23</u>
8:30 a.m. Stock Overview Report – Lee Paramore

9:00 a.m. 2018 Landings Overview – Stephanie McInerny, Alan Bianchi and Chris Wilson

10:00 a.m. Fishery Management Plans
- Status of ongoing plans– Catherine Blum
- 2018 Fishery Management Plan Review
  - **Vote on five-year schedule****
- Southern Flounder Fishery Management Plan Amendment 2 – Mike Loeffler and Anne Markwith
  - Review comments from DEQ Secretary and legislative commission and committee
  - **Vote on final approval of Amendment 2****
- Blue Crab Fishery Management Plan Amendment 3 – Jason Rock and Corrin Flora
  - Presentation
  - **Vote to send Amendment 3 out for advisory committee and public review and comment****

12:30 p.m. Periodic Review and Expiration of Existing Rules – Catherine Blum
- 15A NCAC 03 Rules
  - 2019/2020 rulemaking cycle
  - **Vote on 2019/2020 Notice of Text for Rulemaking to Readopt Rules per G.S. 150B-21.3A****

Review and vote on the following proposed rules and associated fiscal analyses for Notice of Text for Rulemaking to readopt rules per G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules

- Tarpon, 15A NCAC 03M .0509
- License and Commercial Fishing Vessel Registration 15A NCAC 03O .0108

1:00 p.m. Rule Suspension Update – Kathy Rawls
The commission must vote to continue suspension of the following rule(s):

- **Vote on continued rule suspension of portions of N.C. Marine Fisheries Commission Rule 15A NCAC 03L .0103 Prohibited Nets, Mesh Lengths and Areas ****

1:15 p.m. Issues from Commissioners

1:30 p.m. Meeting Assignments and Preview of Agenda Items for November Meeting

1:35 p.m. Adjourn

***** Times indicated are merely for guidance. The commission will proceed through the agenda until completed.***
*****Potential Action Items***

Minutes

Marine Fisheries Commission Business Meeting Minutes
Beaufort Hotel
Beaufort, North Carolina
June 6, 2019

The commission held a special meeting June 6 at the Beaufort Hotel in Beaufort, North Carolina.

The briefing book, presentations and audio from this meeting can be found at http://portal.ncdenr.org/web/mf/060619-special-meeting .

Actions and motions from the meeting are listed in **bolded** type.

SPECIAL MEETING - MOTIONS AND ACTIONS

Chairman Rob Bizzell convened the Marine Fisheries Commission special meeting at 1 p.m. on June 6 and reminded commissioners of their conflict of interest and ethics requirements.

The following commission members were in attendance: Rob Bizzell-Chairman, Mike Blanton, Cameron Boltes, Doug Cross, Tom Hendrickson, Pete Kornegay, Brad Koury, Chuck Laughridge and Sam Romano.

Motion by Chuck Laughridge, to approve agenda. Second by Cameron Boltes.
Motion carries with no opposition.

Public Comment Period
The following individuals spoke:

- **Ken Seigler,** a commercial fisherman from Hubert and a member of the Finfish Advisory Committee, said that a large number of people prefer a two-year moratorium instead of a ten-year reduction. This solution would be easier for commercial fishermen. Working for a fourth of your pay will not work for most fishermen. With escapement, if you did a two-year moratorium, you will have all the year classes in the water plus two additional year classes, which would help the population of striped bass. The problem is there are no adult fish and this is confirmed by Division. We have a spawning and recruitment problem and the quickest way to address that is to let those fish go and grow for two years. At the end of two years, the division can reassess and take samples to know what fish are out there. Another concern he had was with red drum. He suggested that the division move the limit back to five fish a day with no required bycatch allowances for the commercial fishermen.

- **Randy King,** a commercial fisherman, doesn't see any decreases in his catches. He said each year it gets better. In New Hanover County, the flounder were "so thick" they were laying on top of each other. Even though some were only 14 inches, he thought that was a good indicator for the future. Last year he had some of the biggest catches he has seen since 1996 using less nets and fishing less days. He also said there is no shortage of red drum. His catches have not decreased. He's 58 years-old and a 'good' commercial fisherman. He's concerned about getting another job if he can't fish. He said 80 miles out in the ocean, he found a lot of spots and supposed that maybe all the fish have moved out to the ocean.

- **David Inscore,** a commercial fisherman from Hampstead, NC, has not seen a decrease in flounder. He has seen an increase of red drum especially in overslot areas. Much of problem is people are culling their fish while out gigging. There are many 15-17" fish plus he has seen dead fish thrown back in the water. Spearfishing in the ocean is another issues and he wants the division to get better records on that. There are plenty of summer flounder in the water and he doesn't think "fishing" has slowed down. Participants are down because they are aging out and 'younger folks' are not coming into the fishing business. He wants the markets to be restructured on the retail side because the fish are there but there are a lot of new fish that need to be introduced into the markets.

- **George Leone,** seafood dealer in Carteret County, feels the proposed Amendment 2 to the Southern Flounder Fishery Management Plan is inappropriate due to the 62% and 72% recommended reductions. And to implement it right before the start of the fall season is "unconscionable". The fishermen aren't given time to prepare financially and this decision will impact the economy. Food, clothing, habitation, education, utilities all costs money and it is being torn from fishermen's grasp. This not only affects the fishermen's family but the seafood dealers, markets, restaurants, gas stations, net makers, convenience stores, and countless others will be affected. He suggested reducing the gear instead of the number of days. If the season is abbreviated, the risk outweighs the reward, especially if a hurricane strikes. All four states need to take an active role so that North Carolina is not punished to allow the other states to reap the benefits. He concluded saying that this is not a recreational vs commercial issue; it affects everyone.

- **Ron McCoy,** a member of the Southern Advisory Committee, began by quoting an excerpt from the 1997 Fisheries Reform Act (FRA). He reminded the group of the duties of the commission including to "manage, restore, develop, protect, cultivate and regulate the marine resources." He commended the commission for following its purpose and duty. This was the first commission to hold true to resource management. Past commissions only manage though "catch" and to "sustain catch" and Southern Flounder is a prime example of managing to sustain catch. He completely supports the Division's proposed 62% and 72% reductions. Why do we wait until a stock is in dangerous levels of decline before taking action? He implored the commission to hold true to their duties and functions outlined in the FRA.

- **Van Cuthrell,** a life-long commercial fisherman from Pamlico County, spoke on behalf of his brother Shelton of S & S Seafood and 22 other commercial fishermen. Fishable shoreline in the Pamlico, Pungo and Neuse rivers have been reduced by half due to striped bass protection measures this year. The closure has reduced participants and decreased flounder landings. The reduction of the take needs to be quantified before more restrictions are put in Management Area C. Towns in this area are some of the most economically depressed areas. Jobs outside the fishing industry in our areas are very limited. He pleaded not to take the profit out of commercial fishing by reducing the yardage. The average fisherman uses 1800 yards per fishing operation which is necessary to make the trip profitable. Time rules were instituted for sea turtle interactions is not needed in Management Area C. Time restraints will make the jobs of fishermen more dangerous by forcing them on the water before daylight. Please do not endanger lives with rules that have no biological basis. Use science to quantify the reduction of landings before making these decisions about Area C. It can not be dismissed that 50% of the fishable shorelines have been taken away this year. These decisions by the commission were made against the best available science and the against the support of the DEQ Secretary and Director of the Division. More data is needed before making additional changes. Fishermen will not relocate as previously mentioned.

- **Johnathan Robinson,** is a Carteret County Commissioner, and chairs a county marine fisheries advisory board. He stated the County Board of Commissioners strongly opposes any more rules to commercial and recreational fishing in addition to the Amendment 2 to the Southern Flounder Fishery Management Plan. All management options in the amendment will cause extreme economic hardship. Fisheries are just a shadow of what they once were. The flounder fishery is still viable. Amendment 2 is driven by the statue of the state, but he doesn't like the accelerated timeframe of the amendment. The threshold that is proposed has a 50/50 chance of success, and is unattainable; it depends on the participation of other states.

  Problems with the amendment include not accounting for reduced effort in the commercial fishery, uncertainty in the stock assessment, lack of data about offshore adult female flounder, inter-annual variation in recruitment, and environmental conditions that affect the proportion of males and females in the southern flounder population. He concluded his talk by saying "This is a fisheries hoax."

- **Glenn Skinner,** Executive Director of the N.C. Fisheries Association, said the magnitude of these reductions was never seen by industry until the last couple of months. The fishermen he has spoken to realize that a reduction is necessary, but they have already purchased and invested in their webbing for this year – the cost ranging from $10,000 to $40,000. He requested the MFC wait until the first week of December to make any changes to they can fish for at least three months this year. They need this fall to fish. Fishermen just struggled through a hurricane and lost their homes and everything they owned. Fishermen understand the statutes and needs for a reduction but to do something this year isn't necessary. To do something "this year" came strictly from the commission wanting to take action this year. There is also no way that visitors coming in the fall will know or understand the new laws or rules. There will be tickets written "left and right" and the harvest of fish will still occur because no one will know what is happening. As soon as Amendment 2 to the Southern Flounder Fishery Management Plan passes, the clock starts for the next review of the plan to occur within five years, even without action by the other states. All four states need to implement reductions together or North Carolina carries the burden. The statutory requirements for ending overfishing in two years and rebuilding the stock in 10 years do not start until the adoption of the amendment, not the completion of the stock assessment. The process needs to slow down, and work needs to focus on the management measures for Amendment 3.

- **Chris Elkins**, recreational fisherman and member of the CCA-NC, thanked the division and commission for their hard work and knows their decisions are not easy. Only 3% of the ocean caught flounder are southern flounder. We believe non-federally permitted SCFL holders (commercial and recreational fishermen) should have access to other species of fish, since the fishing would NOT impact the southern flounder stock. Regulations for both sectors should remain in compliance under current and future ASMFC/Mid-Atlantic summer flounder rules. It would be unfair to allow commercial in the ocean and not recreational and vice-versa.

- **Ron McPherson**, an inshore charter boat captain, and recreational fisherman, said the 62% and 72% figures seems 'awful', but someone thinks it is what needs to be done. He asked the commission to at least back it off to 52%. He agrees that the commission should wait until December to implement the rules so commercial fishermen can use their gear. Overfishing has been going on for 28 years but the fish keep surviving and people keep catching them. Fishing may not be as good as it was 10 years ago, but the fish are not all gone.

- **Stanley Warlen,** a retired biologist from the Beaufort Lab and Carteret County resident, said the Southern Flounder has a geographic range from Florida to Virginia plus the Gulf of Mexico to Texas. To manage fisheries, we don't manage fish, we manage people. To have a fishery management plan, you must consider the entire range of species. We need a science-based coordinated plan with the other states. It's like changing only one tire on a car that has four flat tires. It doesn't help the car drive. We need a management strategy not just for "one state" but for the entire East Coast.

- **Clark Hutchinson,** a 50-year Carteret County resident, recreational fisherman and a CCA member, said the Division has come up with the science that we need to make the decisions on. The mechanisms have been put in place with the Fisheries Reform Act, but the past Commissions have failed to act, so this Commission needs to act now. There needs to be a balance from the economic interest as well as the recreational interest, but the Commission needs to act on the public resource, not only on flounder but also on all the other fisheries that you are charged to manage. Follow the science, follow the law and make the tough decisions. That is what managers do.

- **Tom Roller,** a full-time fishing guide from Carteret County for the past 17 years and serves on the southern flounder advisory committee, said the commission had opportunities to curtail harvest in the past and if they had acted then, this may not be required now. Also, he noted the low attendance in the room. If this meeting occurred in 2000 or 2005 there would be 400 people in attendance. With only 12 comments received, virtually no one is here. Flounder is not as controversial as it once was because the fishery is depleted. He explained the Advisory Committee's motion. The committee voted for a 72% reduction. It was a 7-2 vote. The gears that takes the most should have "to pay" the most. Amendment 2 to the Southern Flounder Fishery Management plan is a good plan and he encouraged the commission to support it so we can protect southern flounder for future generations.

- **Curtis Edgerton,** a flounder gigger from Johnston County, said he has been flounder gigging since he was a boy. Considers the Division a friend not a foe and appreciates all the science that the Division provides. Noticed that the flounder population is not as big as it was, but there are a lot of people who like to flounder gig. He doesn't think everyone is as smart as they think they are when it come to the flounder regulations because if they were, we wouldn't be where we are today. Fifteen hundred years ago, everyone thought the earth was flat, but they were wrong. There has got to be a way to keep the enjoyment and the tradition of fishing alive so generations can enjoy flounder gigging. There is no way that flounder giggers are the problem. That is not what has destroyed the fish. Other things like, sewer spills and storms are factors. Please be fair across the board and don't let big government and big money cut out the little man for a man who spends big money on a big boat. And don't destroy my heritage.

- **Bert Owens,** a recreational angler from Beaufort, said that he understood the commission is trying to save fish. If there are no fish, there will be no tradition or heritage. But we must do what needs to be done, and he supports Amendment 2. Since people are already fishing this year, there will not be a 62% reduction this year. In regards to the ocean flounder fishery, please manage those separately; only 3% of flounder in the ocean are southern flounder and recreational fishermen should be able to go into the ocean to fish for southern flounder.

Chairman Bizzell asked the commission's counsel, Shawn Maier, to review G.S. 143B-289.52(c)(e1). Maier reviewed the statute that states a supermajority of the commission shall be necessary to override a recommendation from the division regarding measures needed to end overfishing or to rebuild overfished stocks and that a supermajority is six members.

Southern Flounder Fishery Management Plan Amendment 2

Mike Loeffler and Anne Markwith, the co-leads for the Southern Flounder Fishery Management Plan Amendment 2, reviewed public and advisory committee recommendations.

Public Comment

Public comments were accepted through three formats: mail, online, and at the joint advisory committee meeting. This meeting was held on June 3, 2019 and allowed for a maximum of 90 minutes of public comment. Mail and online comments were collected from May 23 through June 3, 2019 at midnight. Eleven comments were received through the mail, all (100%) were opposed to draft Amendment 2. Two hundred and forty-one responses were received through online tools, 91 in favor and 150 opposed to draft Amendment 2. Of those that indicated support for draft Amendment 2 the most indicated option for 2019 and 2020 was for Option C (62%

reduction) in 2019 (38% of responses), Option D (72% reduction) in 2020 (44% of responses). In addition, trip limits, fishing times, and gear changes received more responses than the no preference option for the additional non-quantifiable management measures (Table 1). Thirteen comments were received during the public comment period at the joint advisory committee meeting, three (23%) were in favor of and 10 (77%) were opposed to draft Amendment 2. The commission was provided with copies of the comment.

Advisory Committees

Southern Flounder FMP Advisory Committee Recommendation

At the June 3, 2019 Southern Flounder FMP Advisory Committee meeting, the following recommendation was approved by the committee for the 2019 and 2020 fishing year and forward. For further information, including proposed seasons, see Section VIII, Recommendations of Draft Amendment 2. The committee voted to establish a season for the commercial and recreational fisheries to reduce *F* and allow the SSB to rebuild to the threshold in 2019 (Option B, 52% reduction) with the following additional modifications.

<u>FMP AC Management Option for 2020 and forward</u>

Starting Jan. 1, 2019 adopt a recommendation for a 52% reduction for the commercial and recreational fisheries with the following changes for the commercial fishery, calculated by the northern, central, and southern areas proposed by the division:

• Commercial pound net fishery, 40% reduction
• Commercial gig fishery, 40% reduction
• Commercial large-mesh gill net fishery, a reduction of approximately 71% would be needed to make up the difference to yield a 52% reduction for the commercial fishery overall. The AC recognizes that the division proposal for the Recreational Commercial Gear License large mesh gill net season of Sept. 15-Sept. 30 may be changed by this final percent reduction.

The committee recommendation also includes that management measures from Amendment 1 and Supplement A to Amendment 1, as stated above in the NCDMF recommendation, be carried forward. The recommendation also maintains regulations from the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII for recreational size and bag limit for flounder and approves the continued development of Amendment 3.

In addition, the committee recommends prohibiting the use of picks, gaffs, gigs, and spears when removing flounder from pound nets. As of Jan. 1, 2020, the committee also recommends implementing a 1,500-yard limit for large mesh gill nets in Management Unit A, a 1,000-yard limit for large mesh gill nets in Management Units B and C, and a 750-yard limit for large mesh gill nets in Management Units D and E. Finally, the committee recommends a 52% reduction be applied to the recreational fisheries. The season for the recreational hook-and-line and gig fisheries will be July 16 through Sept. 30.

Southern Advisory Committee Recommendation

The Southern Advisory Committee met on June 3, 2019 and failed to reach consensus on a recommendation for draft Amendment 2.

Northern Advisory Committee Recommendation

The Northern Advisory Committee met on June 3, 2019 and passed a motion supporting the NCDMF recommendation of the 62% reduction in 2019 and 72% percent reduction from 2020 forward to include management carried forward from Amendment 1 and Supplement A to Amendment 1, maintaining the size and bag limits established by the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII, and the continued development of Amendment 3. In addition, the Northern AC passed a motion asking the MFC to consider dividing the allowable days for gill netting amongst allowable fishing months for a given area due to the Sea Turtle ITP.

Finfish Advisory Committee Recommendation
The Finfish Advisory Committee met on June 3, 2019 and recommended a reduced harvest of 52%, not to exceed 52%, until Amendment 3 is completed. This recommendation includes management carried forward from Amendment 1 and Supplement A to Amendment 1, maintaining the size and bag limits established by the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII, and the continued development of Amendment 3. The committee also recommended that the MFC ask the Secretary of DEQ to allow the Director of DMF to go out of compliance with ASMFC Summer Flounder Plan and adopt a 12-inch size limit and a 4-fish bag limit for southern flounder in North Carolina waters. The committee also requested the Southern Flounder AC look at a moratorium on all southern flounder harvest from Nov. 1, 2019 to Sept. 1, 2022.

Draft Amendment 2 to the Southern Flounder Fishery Management Plan, that contains options for several seasonal harvest closure scenarios to achieve up to a 72% reduction in southern flounder harvest for the commercial and recreational fishing sectors. Additionally, at the request of the commission, the draft amendment includes an option for a partial moratorium.

Options for non-quantifiable management measures to constrain effort, such as yardage and time restrictions for gill nets and daily harvest limits for pound nets and gigs, were also included in the draft amendment.

Loeffler then reviewed the division's recommendations to end overfishing and rebuild the overfished southern flounder stock.

The following management measures from Amendment 1 and Supplement A to Amendment 1 will be incorporated upon adoption of Amendment 2.

- From the Southern Flounder Fishery Management Plan Amendment 1: − Management measures, including restrictions that limit the number of days per week and the amount of yardage allowed for large mesh gill nets in various areas of the state;
  - A minimum distance (area dependent) between gill net and pound net sets, per rule 15A NCAC 03J .0103 (d); and
  - A recreational minimum size limit of 15 inches total length.

- From Supplement A to the Southern Flounder Fishery Management Plan Amendment 1:
  - A commercial minimum size limit of 15 inches;
  - A minimum mesh size of 6-inch stretch mesh to harvest southern flounder from a gill net; and
  - A minimum mesh size of 5.75-inch stretch mesh for flounder pound net escape panels.

- From N.C. Fishery Management Plan for Interjurisdictional Fisheries to maintain compliance with the Atlantic States Marine Fisheries Commission Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan Addendum XXVIII: − The recreational bag limit of no more than four flounder per person per day is maintained in Amendment 2.

Reduce fishing mortality in the commercial and recreational fisheries to a level that ends overfishing within two years and allows the SSB to increase to between the threshold and the target within 10 years via a 62% reduction (F=0.26) in total removals in 2019 and beginning in 2020, via a 72% reduction (F=0.18) in total removals.

- The commercial and recreational harvest seasons will close by proclamation immediately following the August 2019 Marine Fisheries Commission meeting and will re-open with the following schedule:
  - 2019 (62% reduction)
    - Commercial
      - Northern – Sept. 15 through Oct. 13;
      - Central – Sept. 15 through Oct. 17; and
      - Southern – Sept. 15 through Nov. 2.
    - Recreational Hook and Line and Gig Fishery ▫ Will not reopen in 2019
    - Recreational Commercial Gear License Gill Net Fishery ▫ Will not reopen in 2019
  - 2020 (72% reduction):
    - Commercial
      - Northern – Sept. 15 through Oct. 6;
      - Central – Sept 15 through Oct. 11; and
      - Southern – Sept 15 through Oct. 20.
    - Recreational hook and line and gig fishery ▫ Aug. 16 through Sept. 30
    - Recreational Commercial Gear License Gill Net Fishery ▫ Sept. 15 through Sept. 30 (the recreational and commercial seasons must both be open to allow this gear)

- Remove all gears that target southern flounder from the water (e.g., commercial and Recreational Commercial Gear License anchored large mesh gill nets, gigs) or make them inoperable (flounder pound nets) in areas and times outside of seasons implemented where southern flounder discards are likely to occur, with exceptions for the shad and catfish fisheries.

- Adoption of Amendment 2 authorizes concurrent development of Amendment 3 and more robust management strategies.

- The following non-quantifiable measures:
  - Reduce commercial anchored large-mesh gill net soak times to single overnight soaks where nets may be set no sooner than one hour before sunset and must be retrieved no later than one hour after sunrise the next morning in the Neuse,

Tar/Pamlico rivers and the Albemarle Sound areas that have previously been exempt;

- Reduce the maximum yardage allowed in the commercial anchored large mesh gill net fishery by 25% for each Management Unit; allowing a maximum of 1,500-yards in Management Units A, B, and C, and a maximum of 750-yards in Management Units D and E unless more restrictive yardage is specified through adaptive management through the sea turtle or sturgeon Incidental Take Permits; and
- Prohibit use of any method of retrieving live flounder from pound nets that cause injury to released fish (no picks, gigs, gaffs, spears, etc.).

This presentation can be found at:
http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=32926130&name=DLFE-140725.pdf .

The commission voted to accept the division recommendations in their entirety and to forward the draft Amendment 2 to the Secretary of DEQ and the legislature for comment**.**

Motion by Cameron Boltes to accept the recommendations of the DMF and DEQ in their entirety. Second by Pete Kornegay.
Motion carries 5-4.

> **Motion by Doug Cross to amend the previous motion so that the reduction percentage on the flounder harvest be set at 52% beginning Dec. 1, 2019. Also, that the reduction percentage not exceed 58% until such time that the states that share this resource – SC, GA, FL – make reductions in catch that equal or surpass the reductions in this Amendment 2 plan now under consideration. This will stay in place in Amendment 2 until the data from additional measures can be calculated and a future reduction percentage considered, if necessary, to satisfy the 10 year stock required plan in Amendment 3. Second by Tom Hendrickson**
> **Motion fails 4-4**

Motion by Chuck Laughridge to send Draft Amendment 2 to the Secretary of DEQ and the legislature for comment. Second by Pete Kornegay.
Motion carries 6-3

The meeting adjourned.

Marine Fisheries Commission Business Meeting Minutes
Courtyard by Marriott
Jacksonville, North Carolina
May 15-17, 2019

The commission held a business meeting May 15-17 at the Courtyard by Marriott in Jacksonville, North Carolina.

The briefing book, presentations and audio from this meeting can be found at http://portal.ncdenr.org/web/mf/05-2019-briefing-book.

Actions and motions from the meeting are listed in **bolded** type.

BUSINESS MEETING - MOTIONS AND ACTIONS

On May 15, a public comment session was held beginning at 6 p.m. Chairman Rob Bizzell called the meeting to order. The following individuals spoke:

Glenn Skinner, Executive Director of the N.C. Fisheries Association, said the N.C. Fisheries Association opposes Amendment 2 to the Southern Flounder Fishery Management Plan. They do not oppose amending the plan, but they oppose the process; this is basically a supplement, which is prohibited in the settlement agreement. He stated that the Southern Flounder Advisory Committee was not allowed to explore their own options; they were only handed one option to vote on. He said the biggest concern is that we are harvesting almost 100% on females and there is nothing in the amendment to address this, like a slot limit.

Stuart Creighton, a recreational fisherman from Oriental, stated the Commission is scheduled to vote on the draft Amendment 2 for southern flounder to address a problem that has been ignored for 30 years. He can support the season closure management measure as proposed by the Division of Marine Fisheries as long as they incorporate sustainable measures of harvest in Amendment 3. He said he supports the following proposed management measures: ban use of recreational gill nets, require use of circle hooks, incorporate slot limit of 14-20" and a creel limit of two fish per person. For commercial, he supports banning the use of gill nets while allowing gigging and pound netting, a strict quota with paybacks, and prohibit spearing as a means of releasing fish from pound nets. He also suggested taking proactive measures for speckled trout if effort switches to that fishery.

John Robbins, a shoreline property owner from Dare County, said the shellfish lease program is beneficial, but the process is flawed. He said there is a proposed lease located 80 feet from his developed shoreline and 100 feet is the minimum. He said he is not trying to keep the applicant from having a lease, but the lease needs to be farther offshore. The area is already heavily used recreationally, such as for kiteboarding. The Dare County Commission passed a resolution against the oyster lease based on conflicts with historical use, asking the Division of Marine Fisheries to deny the lease. It is a months-long process for the outcome and he is losing lot sales in the meantime because the proposed lease is at the end of the docks for the development.

David Sneed, Executive Director of the Coastal Conservation Association of North Carolina, stated he has concerns with the current stock status of southern flounder. North Carolina General Statutes mandate the fishery management plan end overfishing and achieve sustainable harvest, but the Marine Fisheries Commission has never met this requirement in over 20 years. State statutes do not contain accountability measures, so there are no consequences for failing to properly manage this public trust resource. He said the CCANC supports the Division of Marine Fisheries recommendation to recover the fishery, not just end overfishing. He thanked the division staff and the Southern Flounder Advisory Committee for their hard work.

The meeting recessed at 6:16 p.m.

Chairman Rob Bizzell convened the Marine Fisheries Commission business meeting at 9 a.m. on May 16 and reminded commissioners of their conflict of interest and ethics requirements.

The following commission members were in attendance: Rob Bizzell-Chairman, Mike Blanton, Cameron Boltes, Doug Cross, Tom Hendrickson, Pete Kornegay, Brad Koury, Chuck Laughridge and Sam Romano.

Motion by Chuck Laughridge to accept the agenda, allowing the chairman to move non-action items as needed for time management. Second by Brad Koury.
Motion carries with no dissention.

Motion by Doug Cross to approve minutes from the February 20-22, 2019 meeting and the March 13, 2019 emergency meeting. Second by Chuck Laughridge.
Motion carries with no dissention.

<u>Public Comment Period</u>
Chris Elkins, with the Coastal Conservation Association of North Carolina, stated that CCANC recommends reductions to recover, not just end overfishing of southern flounder. It is important to include a conservation buffer in all measures to account for uncertainty. He said CCANC strongly supports the Division of Marine Fisheries reductions of 62% in 2019 and 72% in 2020. In developing Amendment 3, he suggested applying these reductions to specific gear types to minimize bycatch and waste. He thanked the staff and the Southern Flounder Advisory Committee for their work.

Due to the Commission being ahead of schedule with the published agenda, a second opportunity for public comment was provided later in the meeting. There was one additional member of the public who provided comments.

Bob Lorenz, a private boat recreational fisherman from Wilmington, serves on the South Atlantic Fishery Management Council Snapper Grouper Advisory Panel. He requested the commission's endorsement on two items for sensible regulations in federal waters (greater than three miles)for snapper grouper. First, he said there is a need for a permit or stamp to be added to the N.C. Coastal Recreational Fishing License for snapper grouper, similar to obtaining information about recreational crabbing effort when someone currently buys a license. He said recreational snapper grouper fishermen are unaccounted for in the Marine Recreational Information Program and both sectors are interested in collecting this information. The second item is the need for a Joint Enforcement Agreement with the federal government, especially to enforce dead releases of snapper grouper species. He would like the commission's endorsement for release equipment that will soon be required to be carried on vessels.

Chairman's Report

Chairman Bizzell reviewed correspondence that had been sent and received by the commission since the last business meeting and the commission was reminded of their ethics education and their Statement of Economic Interest requirements.

Commissioners were reminded of the meeting schedule for 2019:

Feb. 20-22 in Williamston
May 15-17 in Morehead City/New Bern area
Aug. 21-23 in Raleigh area
Nov. 13-15 in Morehead City/New Bern area

Chairman Bizzell advised he wanting to have the commission consider conservation measures to avoid dead discards with recreational hook-n-line gears. First he wanted to get input from some of the advisory committees and then he planned on bringing recommendations forward at the August 2019 commission meeting.

Director's Report

Division of Marine Fisheries Director Steve Murphey provided the commission with a detailed overview of fisheries-related bills being considered by the N.C. General Assembly.

Director Murphey then updated the commission on division activities occurring since the February 2019 business meeting, including:

- An update on the meeting he had organized with fisheries directors and staff from South Carolina, Georgia and Florida to discuss managing southern flounder on a regional basis, given that fishery management decisions are based on regional data for this species.
- New requirements that the commission had previously approved for gear configurations for shrimp trawls that go into effect July 1 for areas of the Pamlico Sound and portions of the Pamlico and Neuse rivers.
- A status report on the Hurricane Florence Commercial Fishing Assistance Program. The General Assembly authorized $11.6 million to compensate commercial fishermen and shellfish harvesters for equipment and income losses from harvest reductions due to Hurricane Florence. Losses from harvest reductions were based on trip tickets compared over a prior comparable period for the months of September, October and November.
- The closure to harvest of more than 2,500 acres of shellfish waters due to high fecal coliform bacteria pollution.
- Implementation of a no gill net corridor along the ocean surf zones to reduce bottlenose dolphin interactions.
- Hiring of Thom Teears, a new stock assessment scientist.
- Promotion of Garland Yopp to Captain of Marine Patrol's southern district.

Staff also updated the commission on activities of the Atlantic States Marine Fisheries Commission and the Mid- and South Atlantic Fishery Management Councils and Highly Migratory Species.

Status of Rule Development to Clarify Standard Commercial Fishing License Transfers
The commission had expressed interest in clarifying the circumstances under which standard or Retired Standard Commercial Fishing License transfers are allowed. Concern had been raised about third-party transfers allowing individuals to get a license without going through the eligibility board. Stephanie McInerny, the chief of the division's License and Statistics Section, updated the commission on continuing rule development to clarify Standard Commercial Fishing License transfers.

Biological Data Collection Programs and Sampling Design
Division biologist Lee Paramore provided the commission with a presentation on the division's biological data collection programs and sampling design.

This presentation can be found at:
http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=32890414&name=DLFE-140522.pdf .

Stock Assessment Fundamentals
Laura Lee, the division's chief stock assessment scientist, reviewed the basis of stock assessments with the commission

This presentation can be found at:
http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=32890414&name=DLFE-140524.pdf .

Rulemaking
Catherine Blum, the division's rulemaking coordinator, updated the commission on the status of rulemaking in support of the Period Review and Expiration of Existing Rules per G.S. 150B-21.3A.

The meeting recessed for the day.

The meeting reconvened at 9 a.m. on May 17.

Fishery Management Plan Update
Catherine Blum, the division's Fishery Management Plan Coordinator, gave the commission an update on the status of North Carolina's ongoing fishery management plans.

Blue Crab Fishery Management Plan Amendment 3 Update
Jason Rock and Corrin Flora, the co-leads for the Blue Crab Fishery Management Plan, updated the commission on the status of the ongoing plan development and the progress of the advisory committee.

Southern Flounder Fishery Management Plan Amendment 2
Mike Loeffler and Anne Markwith, the co-leads for the Southern Flounder Fishery Management Plan, reviewed Draft Amendment 2 to the Southern Flounder Fishery Management Plan, that contains options for several seasonal harvest closure scenarios to achieve up to a 72% reduction

in southern flounder harvest for the commercial and recreational fishing sectors. Additionally, at the request of the commission, the draft amendment includes an option for a partial moratorium.

Options for non-quantifiable management measures to constrain effort, such as yardage and time restrictions for gill nets and daily harvest limits for pound nets and gigs, were also included in the draft amendment.

This presentation can be found at:
http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=32890414&name=DLFE-140523.pdf .

Reductions in harvest are required because a 2019 South Atlantic Southern Flounder Stock Assessment found that southern flounder is overfished and overfishing is occurring throughout the region. Overfished means the population is too small. Overfishing means the removal rate is too high. North Carolina law mandates that fishery management plans include measures to end overfishing within two years of adoption and rebuild the stock to achieve sustainable harvest within 10 years of adoption. A harvest reduction of at least 52% is needed to meet the statutory requirements.

To increase the probability of successfully rebuilding the resource, the division proposes a 62% reduction in southern flounder harvest (compared to 2017) in North Carolina this year and a 72% reduction in harvest beginning in 2020 until adoption and implementation of Amendment 3 to the Southern Flounder Fishery Management Plan, scheduled for completion in 2021.

The commission voted to accept the draft goal and objectives of the plan and to send draft Amendment 2 out to the commission's advisory committees and the public for review and comment.

Motion by Pete Kornegay to accept the goal and objectives of draft Amendment 2 to the Southern Flounder Fishery Management Plan as presented by the Division of Marine Fisheries. Second by Cameron Boltes.
Motion carries with no dissention.

Motion by Tom Hendrickson to send draft Amendment 2 as presented by the division to the advisory committees and out for public comment with the addition of data pertaining to a partial moratorium. Second by Chuck Laughridge.
Motion carries 7-2.

> **Motion by Doug Cross to amend the previous motion to include the following measure as an option in draft Amendment 2: All hook and line gear directed at the capture of southern flounder be restricted to one barbless circle hook, including gear for live bait, cut bait, artificial bait (including all plastic and rubber baits, spoons, mirror lure type baits and any other artificial bait, regardless of type), and that each setup (rod and reel or hand line) has only one rig per setup. This measure**

will stay in place until the completion and implementation of the Southern Flounder Fishery Management Plan Amendment 3. Second by Sam Romano.
Motion fails 2-5 with two abstentions.

Under ***Issues from Commissioners***, there was discussion about the logistics of the upcoming advisory committee meetings, the need to write a letter regarding the dredging of Barden's Inlet and the desire of Commissioner Laughridge to have revenues from the Coastal Recreational Fishing License and the N.C. Commercial Fishing Resource Fund provide funding to Dr. Chris Dumus to do an economic study of the economic benefit of North Carolina's coastal fisheries.

The meeting adjourned.

SOUTHERN ENVIRONMENTAL LAW CENTER

Telephone 919-967-1450 | 601 WEST ROSEMARY STREET, SUITE 220 CHAPEL HILL, NC 27516-2356 | Facsimile 919-929-9421

May 20, 2019

Via U.S. Mail and E-mail

Mr. Rob Bizzell
Chairman, N.C. Marine Fisheries Commission
3441 Arendell Street
Morehead City, NC 28557
r.bizzell.mfc@ncdenr.gov

Re: Petition for Rulemaking to Amend 15A N.C. Admin. Code 3L .0101, 3L .0103 and 3J .0104, and to Add 3R .0119

Dear Chairman Bizzell:

On behalf of its client the North Carolina Wildlife Federation, the Southern Environmental Law Center submits the attached Petition for Rulemaking to the North Carolina Marine Fisheries Commission asking that the Commission amend its rules to do the following:

- Designate all Internal Coastal Waters not otherwise designated as Primary Nursery Areas, Secondary Nursery Areas, Special Secondary Nursery Areas, or otherwise closed to shrimp trawling as Shrimp Trawl Management Areas;
- Establish criteria for the opening of shrimp season in Shrimp Trawl Management Areas;
- Prohibit shrimp trawling in all Shrimp Trawl Management Areas on Tuesdays and Thursdays once the season has been opened; and
- Restrict the headrope length for shrimp trawls in Shrimp Trawl Management Areas and the other areas designated in 15A N.C. Admin. Code 3L .0103(d) to 110 feet total.

We have enclosed with this letter a Petition for Rulemaking, the text of the proposed rules, and supporting materials. By submitting this Petition, the Federation does not abandon its objections to the Commission's and Division of Marine Fisheries' handling of its November 2016 petition. This Petition for Rulemaking replaces the petition submitted by the Southern Environmental Law Center on behalf of the North Carolina Wildlife Federation in November 2016, as amended in January 2017.

Please contact us at 919-967-1450 or bhildebrand@selcnc.org with any questions or if you need additional information to process this request. Hard copies of the Petition and supporting materials will follow. Thank you for your consideration of this petition.

Respectfully submitted,

Blakely E. Hildebrand   Elizabeth Rasheed

Blakely Hildebrand
Staff Attorney

Elizabeth Rasheed
Associate Attorney*

**licensed to practice in NY and CO; not yet licensed to practice in NC*

CC:
Cameron Boltes, Commissioner, N.C. Marine Fisheries Commission
Tom Hendrickson, Commissioner, N.C. Marine Fisheries Commission
Pete Kornegay, Commissioner, N.C. Marine Fisheries Commission
Brad Koury, Commissioner, N.C. Marine Fisheries Commission
Chuck Laughridge, Commissioner, N.C. Marine Fisheries Commission
Mike Blanton, Commissioner, N.C. Marine Fisheries Commission
Doug Cross, Commissioner, N.C. Marine Fisheries Commission
Sam Romano, Commissioner, N.C. Marine Fisheries Commission
Nancy Fish, Liaison to N.C. Marine Fisheries Commission
Shawn Maier, Assistant Attorney General, Counsel to N.C. Marine Fisheries Commission

Enclosures

BEFORE THE NORTH CAROLINA MARINE FISHERIES COMMISSION

North Carolina Wildlife Federation,	)	PETITION FOR RULEMAKING
Petitioner	)	PURSUANT TO N.C. GEN. STAT. §
	)	150B-20 AND 15A N.C. ADMIN CODE 3P
	)	.0301 TO AMEND 15A N.C. ADMIN.
	)	CODE 3J .0104, 3L .0101, 3L .0103 &
	)	TO ADD 15A N.C. ADMIN. CODE
	)	3R.0119

On behalf of the North Carolina Wildlife Federation ("Petitioner"), the undersigned file this Petition for Rulemaking ("Petition") pursuant to and in accordance with the North Carolina Administrative Procedure Act, N.C. Gen. Stat. § 150B-20, and 15A N.C. Admin. Code 3P .0301. These provisions require any person wishing to adopt, amend, or repeal a rule of the North Carolina Marine Fisheries Commission ("MFC" or "the Commission") to submit a rulemaking petition addressed to the Chairman of the Commission and outlines requirements for a petition for rulemaking.

The amended rules would create a new designation for Internal Coastal Waters—Shrimp Trawl Management Areas—to be delineated under 15A N.C. Admin. Code 3R .0119; designate all Internal Coastal Waters not otherwise designated under 15A N.C. Admin. Code 3R .0103 (Primary Nursery Areas), 3R .0104 (Permanent Secondary Nursery Areas), 3R .0105 (Special Secondary Nursery Areas), 3J.0104(b)(3) (Trawl Net Prohibited Area), 3R .0106 (Trawl Net Prohibited Areas), or 3R .0114 (Shrimp Trawl Prohibited Areas) as Shrimp Trawl Management Areas; close Shrimp Trawl Management Areas from 12:00 a.m. until 11:59 p.m. on Tuesdays and Thursdays; establish criteria for the opening of shrimp season in Shrimp Trawl Management Areas; and reduce total headrope length for shrimp trawls operating in Shrimp Trawl Management Areas and other areas described in 15A N.C. Admin. Code 3L .0103(d) from 220 feet to 110 feet.

The North Carolina Wildlife Federation is a nonprofit organization with a mission to protect, conserve, and restore North Carolina wildlife and habitat.

Pursuant to 15A N.C. Admin. Code 3P .0301, this Petition is addressed to the Chairman of the MFC. Fifteen (15) copies of this Petition will be submitted to the Chairman via U.S. mail. The following sections of this Petition shall be organized by and shall provide the information that is required of rulemaking petitions set forth in 15A N.C. Admin. Code 3P .0301(b)(1)-(8).

I. TEXT OF THE PROPOSED RULE

The text of the proposed rules is attached as Exhibit A.

II. STATUTORY AUTHORITY FOR THE COMMISSION TO PROMULGATE THE RULES

The Federation urges the adoption of amendments to the following sections of Title 15A of the North Carolina Administrative Code: 3J .0104, 3L .0101, and 3L .0103; and the adoption of a new section: 3R .0119.

The Commission's rulemaking authority is plainly stated in state statute. The MFC must "[m]anage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources within its jurisdiction."[1] The Commission has a mandatory duty to "adopt rules to be followed in the management, protection, preservation, and enhancement of the marine and estuarine resources within its jurisdiction."[2] The MFC has jurisdiction over the "conservation of marine and estuarine resources . . . and all activities connected with the conservation and

[1] N.C. Gen. Stat. § 143B-289.51(b)(1) (2019).
[2] N.C. Gen. Stat. § 143B-289.52(a) (2019); *see also* N.C. Gen. Stat. § 113-182(a) (2019).

regulation of marine and estuarine resources" in North Carolina.[3] The Commission's rulemaking authority includes regulation of the "[t]ime, place, character, or dimensions of any methods or equipment that may be employed in taking fish" and "[s]easons for taking fish."[4] The Commission must adopt rules to "provide a sound, constructive, comprehensive, continuing, and economical coastal fisheries program" for the State.[5] All regulation of commercial and recreational fishing must be "in the interest of the public,"[6] as the marine and estuarine resources of North Carolina "belong to the people of the State."[7]

The proposed rules are consistent with—and further the objectives of—the Coastal Habitat Protection Plan ("CHPP"), which was mandated by the Fisheries Reform Act.[8] The MFC, together with the North Carolina Coastal Resources Commission and the Environmental Management Commission, adopted the CHPP and must implement the recommendations contained in the CHPP.[9] The CHPP catalogues and describes the diversity of habitats and ecosystems on North Carolina's coast, identifies threats to important coastal habitats, and recommends management actions "to protect and restore habitats" vital to the State's fishery resources.[10] Among the CHPP's many stated goals is that of enhancing and protecting habitats from adverse physical impacts. Affording important habitats additional protection furthers the goals of the CHPP.

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[3] N.C. Gen. Stat. § 113-132(a) (2019); *see also* N.C. Gen. Stat. § 143B-289.51(b)(1) (2019); N.C. Gen. Stat. § 113-134.1 (2019) (clarifying that the MFC has regulatory authority over the conservation of marine fisheries "in the Atlantic Ocean to the seaward extent of the State jurisdiction over the resources").
[4] N.C. Gen. Stat. § 143B-289.52(a)(1)(a)-(b) (2019); *see also* N.C. Gen. Stat. § 113-182(a) (2019).
[5] N.C. Gen. Stat. § 143B-289.51(b)(2) (2019).
[6] N.C. Gen. Stat. § 143B-289.52(a)(2) (2019).
[7] N.C. Gen. Stat. § 113-131(a) (2019).
[8] *See* N.C. Gen. Stat §§ 143B-289.52(a)(11), 143B-279.8 (2019). *See also North Carolina Coastal Habitat Protection Plan: Source Document*, N.C. DEP'T OF ENVT'L QUALITY 2 (2016), *available at* http://portal.ncdenr.org/c/document_library/get_file?uuid=5d02ccd2-3b9d-4979-88f2-ab2f9904ba61&groupId=38337 [hereinafter *CHPP*].
[9] N.C. Gen. Stat. § 143B-279.8(c) (2019).
[10] N.C. Gen. Stat. § 143B-279.8(a) (2019).

The proposed rules will ensure that important habitat areas for commercially and recreationally valuable species are adequately protected by: (1) designating Shrimp Trawl Management Areas in Internal Coastal Waters, and (2) limiting effort and restricting gear within these newly designated areas. These measures are consistent with and fulfill the MFC's statutory duties to manage, protect, preserve, and enhance the marine and estuarine resources of North Carolina. Moreover, the proposed rules will advance the objectives of the Fisheries Reform Act of 1997.

The MFC is statutorily authorized to enact the proposed rules. Establishing the areas open for fishing, regulating the opening of shrimp season, and managing the use of gear within its jurisdictional waters fall squarely within the MFC's authority to regulate the appropriate areas and methods for the taking of fish.[11] In addition, the MFC has explicit authority to establish seasons for the taking of fish.[12] Neither the Fisheries Reform Act nor any other legislation restricts when the Commission may take action on these critical issues.[13]

III. STATEMENT OF THE REASONS FOR THE ADOPTION OF THE PROPOSED RULES

The goals of the Petition are to support a sustainable shrimp trawl fishery and significantly reduce the mortality of bycatch associated with that fishery. The measures proposed in the Petition will achieve these goals by managing the areas open to shrimping, the

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[11] *See* N.C. Gen. Stat. § 143B-289.52(a)(1)(a) (2019).
[12] *Id.* § 143B-289.52(a)(1)(b).
[13] The Fisheries Reform Act, N.C. Gen. Stat. §§ 113-181, *et seq.*, requires the adoption of fishery management plans for "all commercially or recreationally significant species or fisheries that compromise State marine or estuarine resources." N.C. Gen. Stat. § 113-182.1(a) (2019). Fishery management plans may be species-specific, or may be based on gear or geographic areas; all fishery management plans are based on harvest of the target stock. *Id.* § 113-182.1(b). The proposed rules are not species-specific management measures and do not fall under this scheme. Instead, the proposed rules designate Shrimp Trawl Management Areas and provide for appropriate practices designed to protect these areas for numerous species, including those non-target species taken as bycatch. All of the proposed rules may be adopted by the MFC outside of the fishery management plan process outlined by the Fisheries Reform Act.

appropriate times when shrimp may be taken, and the gear used for shrimping. The measures proposed in this Petition will ensure that shrimp trawling is conducted in a responsible manner that minimizes the bycatch of juvenile finfish species and macroinvertebrates from estuarine waters and facilitates the rebuilding of overfished and depleted finfish populations.

The lack of adequate habitat protections and declining and depleted status of many of our coastal fish stocks suggests a failure of the MFC to meet its duties to "conserve, protect, and regulate" marine and estuarine resources. While environmental factors such as habitat loss and poor water quality may affect the status of fish stocks, fishing practices also contribute to the decline and depletion of several stocks and are more controllable. Excessive bycatch of juvenile fish and other non-target species in the shrimp trawl fishery in estuarine and near shore waters contributes to the current unknown or depleted status of several commercially and recreationally valuable species, including but not limited to Atlantic croaker, spot, weakfish, southern flounder, and blue crabs.

North Carolina has the largest and most productive estuarine system of any state on the east coast.[14] Estuarine-dependent species account for more than 90 percent of the State's commercial fisheries landings and over 60 percent of the recreational harvest.[15] The success and viability of these fisheries requires protection of important habitat areas on which these species rely for survival. North Carolina's existing nursery program provides important protections to larval and early juvenile populations that inhabit shallow, protected habitat areas. Later stage juveniles—those juveniles that have not yet reached adulthood and therefore have not spawned—however, lose habitat protection once they move into the sounds and ocean waters

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[14] *Estuarine Benthic Habitat Mapping Program – Shellfish and Submerged Aquatic Vegetation*, N.C. DEP'T OF ENV'TL QUALITY, http://portal.ncdenr.org/web/mf/shellfish-habitat-mapping (last visited May 10, 2019).

[15] *See CHPP*, *supra* note 8, at 11.

and are exposed to shrimp trawls and other fishing gear. North Carolina is the *only* state on the Atlantic coast that permits extensive trawling in inshore estuarine waters. It is no surprise that the highest levels of bycatch of juvenile species in North Carolina waters are found in the Pamlico Sound, which is a highly productive nursery area for several species of finfish and other invertebrates such as blue crabs and horseshoe crabs.[16]

Commercially and recreationally valuable species, including Atlantic croaker, spot, weakfish, and southern flounder are in unknown, depleted, and/or overfished status, and fisheries managers have struggled to mitigate further decline in these stocks.[17] In fact, these species also account for the vast majority of finfish bycatch in North Carolina waters.[18] As noted in the attached expert reports, bycatch mortality in North Carolina's shrimp trawl fishery contributes to the declining status of these important populations.[19] Currently, hundreds of millions of juvenile fish fall victim to shrimp trawl bycatch each year, and therefore do not spawn, replace

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[16] Despite repeated claims by the Division of Marine Fisheries and industry representatives that North Carolina has made progress in shrimp trawl bycatch reduction as the result of Bycatch Reduction Device ("BRD") testing and implementation, the Federation is unaware of any science that indicates these devices function as anything other than a trawl efficiency device. The Federation has not found evidence to suggest that BRD use increases the number of juvenile fishes that escape the estuarine trawling grounds and enter the adult stock. In fact, the sole reliance on these devices to reduce bycatch has borne little fruit and provided few quantifiable benefits to affected fish populations (e.g., spot, croaker, southern flounder). The Federation welcomes the opportunity to discuss these issues in detail with the Division of Marine Fisheries and the Commission.

[17] *Weakfish*, N.C. DIV. MARINE FISHERIES, http://portal.ncdenr.org/web/mf/Weakfish-sso (last visited May 20, 2019); *Atlantic croaker*, N.C. DIV. MARINE FISHERIES, http://portal.ncdenr.org/web/mf/atlantic-croaker (last visited May 20, 2019); *Spot*, N.C. DIV. MARINE FISHERIES, http://portal.ncdenr.org/web/mf/Spot-sso (last visited May 20, 2019); *Southern Flounder*, N.C. DIV. MARINE FISHERIES, http://portal.ncdenr.org/web/mf/southern-flounder#Stock (last visited May 20, 2019)

[18] Kevin Brown, *Characterization of the commercial shrimp otter trawl fishery in the estuarine and ocean (0-3 miles) waters of North Carolina: Final Report to the National Fish and Wildlife Foundation and the National Oceanic and Atmospheric Administration, National Marine Fisheries Service*, N.C. DEP'T OF ENVTL. QUALITY 14, 17 (Oct. 2015).

[19] *See* Jack Travelstead & Louis Daniel, *A technical review of a proposal submitted by the North Carolina Wildlife Federation to reduce mortality of juvenile fishes in North Carolina* (Nov. 2016) (Exhibit B), at 2.

themselves, and contribute to the adult population. Increasing juvenile recruitment is critical to rebuilding the stock and age structure of these species.[20]

Critical ecosystem services are also lost as a result of sustained high bycatch levels.[21] Atlantic croaker, spot, weakfish, and southern flounder serve an important role in the trophic structure of the state's fisheries resources. Spot and Atlantic croaker, for example, transfer energy from benthic species (their primary diet component) to other economically valuable species, including spotted seatrout, red drum, and southern and summer flounder.[22] Removing significant levels of juvenile fish in shrimp trawls disadvantages higher-level species. The trawling activity itself compounds this effect, as bottom disturbing gear disrupts bottom habitat and bottom-dwelling benthic communities.[23]

Habitat protection for juvenile fish is also lacking. Nursery areas serve as vital habitat areas for the development of finfish and shellfish species from early larval to late juvenile life stages. Nursery habitat supports high abundance levels and diversity of fish species, and the ecological processes that occur in nursery habitat support growth of individual fish. For decades, researchers have recognized the importance of nursery areas for juvenile life stage development. Estuarine nursery areas have been shown to contribute disproportionately to the production of individual fish that recruit into adult populations.[24]

Atlantic croaker, spot, weakfish, and southern flounder, among other estuarine-dependent species, spawn in coastal and near-shore ocean waters and recruit as early juveniles in estuarine

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[20] *Id.*

[21] *See* Luiz Barbieri, *Technical Review: The Need to Reduce Fishing Mortality and Bycatch of Juvenile Fish in North Carolina's Estuaries* (Nov. 2016) (Exhibit E), at 9.

[22] *See* Travelstead & Daniel, *supra* note 19, at 12.

[23] *See id.* at 15; *see also* Barbieri, *supra* note 21, at 11.

[24] *See* Barbieri, *supra* note 21, at 5 (citing Able 2005, Beck, et. al., 2001, Heck and Crowder 1991); *see also* Lefcheck, et al., *Are coastal habitats important nurseries? A meta-analysis*, CONSERVATION LETTERS (2019); e12645. https://doi.org/10.1111/conl.12645 (attached hereto as Exhibit M).

habitats like the Pamlico Sound.[25] The majority of the individuals found in the Pamlico Sound are juvenile fish that have yet to spawn or have not reached their full spawning potential.[26] Harvesting or otherwise subjecting these juveniles to high levels of fishing mortality before first spawning leads to recruitment overfishing and growth overfishing, and may ultimately impact fishery yields and long-term stock productivity.[27]

The results of the annual Pamlico Sound Survey consistently indicate high levels of abundance of Atlantic croaker, spot, and weakfish in the Pamlico Sound.[28] Moreover, length frequency data suggests that the vast majority of the fish found in the Pamlico Sound are juveniles that have not yet reached maturity.[29] These results are consistent with the Division of Marine Fisheries' characterization studies conducted in inshore waters south of the Pamlico Sound and in ocean waters.[30] In addition, physical habitat characteristics, including bottom type, salinity, and temperature, support the growth of juveniles into adulthood in inshore and ocean waters.[31]

Juvenile populations of Atlantic croaker, spot, and weakfish, among many other species, are subjected to intense fishing pressure in the shrimp trawl fishery in North Carolina waters. Ninety-two percent of shrimp landings in state waters are harvested with otter trawls.[32] Otter trawls catch essentially everything in their path, leading to extraordinarily high levels of bycatch,

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[25] *See* Barbieri, *supra* note 21, at 9 (citing Lowerre-Berbieri et al. 1995, Barbieri et al. 1994a, Weinstein and Walters 1981, Chao and Musik 1977).
[26] *See id.*
[27] *See id.* at 11-12.
[28] *See* Travelstead & Daniel, *supra* note 19, at 10-11 (citing Knight and Zapf 2015).
[29] *See id.* Abundance is the most important variable in determining the presence of nursery areas. *See Amendment 1 to the North Carolina Shrimp Fishery Management Plan*, N.C. DIV. MARINE FISHERIES, 170 (2015), http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=24626903&name=DLFE-134540.pdf [hereinafter *Amendment 1*], at 169.
[30] *See* Travelstead & Daniel, *supra* note 19, at 11 (citing Brown 2015, Knight 2015, Knight and Zapf 2015, Brown 2009, Johnson 2006, Logothetis & McCuiston 2004, Johnson 2003, Diamond-Tissue 1999).
[31] *See id.* at 12.
[32] *See* Brown, *supra* note 18, at 1.

even when bycatch reduction devices are properly installed. In addition, otter trawls disturb the sea or sound floor, which are fragile and productive ecosystems. A legislative panel pre-dating the Fisheries Reform Act found that bottom trawling gear, including shrimp trawls, had the greatest potential to impact bottom habitats in estuarine and coastal waters.[33] These impacts include physical disruption of habitat, changes in functional organization of species, increases in total suspended solids and turbidity, destruction of submerged aquatic vegetation, and decreases in habitat complexity.[34]

In North Carolina, designated Primary Nursery Areas, Permanent Secondary Nursery Areas, and Special Secondary Nursery Areas are afforded protection; however, existing designations fail to account for all habitat areas that serve as nurseries. This is in spite of the fact that the MFC has recognized that "nursery areas need to be maintained . . . in their natural state, and the populations within them must be permitted to develop in a normal manner with as little interference from man as possible."[35]

The MFC's efforts to minimize bycatch of juvenile finfish have proven unsuccessful to date. The MFC fell far short of taking meaningful action to protect important habitat areas and reduce bycatch of juvenile fish in Amendment 1 to the Shrimp Fishery Management Plan and has done little since the adoption of Amendment 1 to address this important issue.[36]

The Federation proposes to designate all Internal Coastal Waters not already closed to trawling as Shrimp Trawl Management Areas. The proposed rules would also provide clear guidance to the Fisheries Director in his/her exercise of proclamation authority to open shrimp season in these newly designated areas. The proposed rules would additionally reduce effort in

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[33] *See CHPP*, *supra* note 8, at 163.
[34] *See id.* at 163-67.
[35] *See Amendment 1*, *supra* note 29, at 168; *see also* 15A N.C. Admin. Code 3N .0104-0105 (2019).
[36] *See generally Amendment 1*, *supra* note 29.

Shrimp Trawl Management Areas by limiting shrimp trawling to Mondays, Wednesdays, and Fridays every week and reducing the maximum headrope length to 110 feet in all Shrimp Trawl Management Areas and other areas listed under 15A N.C. Admin. Code 3L .0103(d).

a. Shrimp Trawl Management Areas

The newly designated Shrimp Trawl Management Areas will still allow commercial shrimping to take place in areas where juvenile fishes are known to occur, but at a reduced level and capacity.

While we do not seek to designate additional nursery areas in the Petition, the Federation strongly encourages the Commission to examine the Division of Marine Fisheries' juvenile fish sampling data and, should the data support such a move, to expand designations of Secondary Nursery Areas. It is critical to provide greater protection in areas where juvenile fishes are most abundant and in corridors that facilitate their movements into offshore coastal waters.[37]

b. Opening of shrimp season

Currently, the Fisheries Director must open each shrimp season by proclamation. Commission rules, however, provide no guidelines for the opening of the season. The Director should be guided by conservation principles in exercising proclamation authority under MFC rules. The Federation proposes opening shrimp season in Shrimp Trawl Management Areas once the shrimp count reaches 60 shrimp per pound (heads on) during sample tows in the Pamlico Sound, or once the harvest of shrimp exceeds the harvest of juvenile fish during sample tows in the Pamlico Sound, or June 15, whichever is earliest.[38]

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[37] Petitioners have included a map of the proposed Shrimp Trawl Management Areas as Exhibit N. The Southern Environmental Law Center will provide the Division of Marine Fisheries and the Commission GIS data needed to map this area under separate cover.

[38] *See* Travelstead & Daniel, *supra* note 19, at 18-19. Shrimp season typically opens in mid-May. *See, e.g.*, *Proclamation: Re: Crab Trawling and Taking of Shrmp with Nets – Central and Northern Regions (SH-3-2017)*, N.C. DIV. MARINE FISHERIES,

c. Three day shrimping week

Reducing the number of fishing days each week will reduce overall effort and, thus, bycatch of juvenile species in state waters. Under existing rules, shrimp trawling is prohibited in inshore waters from 9:00 p.m. on Friday until 5:00 p.m. on Sunday evenings.[39] An additional two-day closure would reduce overall bycatch, provide fish species the opportunity to move out of trawling areas, and allow fish to potentially recover from encounters with shrimp trawls during fishing days.[40] Shrimp landings are highest immediately after the opening of trawling for the week, suggesting that an additional two days of closure could improve overall efficiency in the fishery.[41]

In its original petition, the Federation did not specify closure days in order to maximize flexibility to the Fisheries Director. In its fiscal note evaluating the economic and fiscal impacts of the original petition, the Division suggested it would be difficult and expensive to enforce this proposed rule without specifying closure days.[42]

To address these concerns, the Federation proposes limiting the number of days for trawling in designated Shrimp Trawl Management Areas to three specific days each week: Monday (12:00 a.m. until 11:59 p.m.), Wednesday (12:00 a.m. until 11:59 p.m.), and Friday (12:00 a.m. until 8:59 p.m.).

d. Maximum headrope of 110 feet

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http://portal.ncdenr.org/c/document_library/get_file?uuid=8b8fd8bc-d962-4017-a6a3-e8c7b3b8a6ce&groupId=38337.

[39] 15A N.C. Admin. Code 3L .0102.

[40] *See* Travelstead & Daniel, *supra* note 19, at 18; *see also Amendment 1*, *supra* note 29, at 302 (discussing Ingraham's (2003) evaluation of nighttime closure off the coast of Brunswick County and noting that finfish bycatch was higher during nighttime trawling).

[41] *See Amendment 1*, *supra* note 29, at 301 (citing Johnson 2006); *see also* Travelstead & Daniel, *supra* note 19, at 18.

[42] As noted in its July 2018 and February 2019 letters to the Commission, the Federation disagrees with the Division of Marine Fisheries' economic and fiscal analyses.

Average headrope length in otter trawls has increased steadily over time, which in turn has increased overall yield and led to higher levels of bycatch.[43] In 2012, average maximum headrope length on commercial otter trawls measured 94 feet.[44] By 2015, average maximum headrope length increased to 134 feet.[45] As discussed in detail in the attached expert reports, a headrope length restriction will reduce the total amount of bycatch by reducing the overall net size on all shrimp trawls in state waters.[46] Reductions in headrope length may also reduce the adverse habitat impacts of trawling by reducing the surface area swept by trawl nets.[47] Currently, combined headropes may be as long as 220 feet in some Internal Coastal Waters, while headrope length is restricted to 90 feet in other Internal Coastal Waters.[48]

Other states with significant commercial shrimping industries have established combined headrope length limits well below the current 220 feet maximum in North Carolina waters. For example, the maximum combined headrope length for shrimp trawls in Mississippi waters is 100 feet.[49] In Alabama, recreational shrimp trawl nets cannot exceed 16 feet (only one net per boat) and commercial trawl nets cannot exceed a combined 50 feet in length (limit of two nets per boat).[50]

The Federation proposes a maximum headrope length on all shrimp trawls in newly designated Shrimp Trawl Management Areas and all other areas listed under 15A N.C. Admin.

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[43] *See id.* at 17-18.
[44] *Id.* (citing Brown 2015). *See also Amendment 1*, *supra* note 29, at 312-313.
[45] Travelstead & Daniel, *supra* note 19, at 17 (citing Brown 2015).
[46] *See id.* *See also North Carolina Shrimp Fishery Management Plan*, N.C. DIV. OF MARINE FISHERIES 315 (2006), http://portal.ncdenr.org/c/document_library/get_file?uuid=7dc55c67-c6df-4a39-9ffc-32471c055c23&groupId=38337 (stating that limiting headrope sizes will lead to reduction in bycatch).
[47] *See, e.g.*, J. Hiddink, et al., *Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance*, PNAS Vol. 114 (2017) (developing a tool for estimating "depletion and recovery of seabed biota after trawling" and encouraging managers to use this tool to analyze "tradeoffs between harvesting fish and wider ecosystem effects of such activities.").
[48] *Compare* 15A N.C. Admin. Code 3L .0103(c) *with id.* 3L .0103(d).
[49] *See* 22 Miss. Admin. Code Pt. 2, R. 05 (2019) (restricting individual trawl net sizes in different coastal areas to twelve, twenty five, and fifty feet and placing limitations on the size of trawl doors).
[50] *See* Ala. Admin. Code. r. 220-3-.01(8) (2019).

Code 3L .0103(d) not to exceed 110 feet. A consistent maximum headrope length not to exceed 110 feet in internal waters will provide clarity and consistency for all fishermen and result in more efficient fishing practices in state waters.

IV. STATEMENT OF THE EFFECT ON EXISTING RULES OR ORDERS

The proposed rules will amend the following sections of 15A of the N.C. Administrative Code: 3J .0104, 3L .0101, and 3L .0103; and will add a new section: 3R .0119. The proposed changes are not expected to affect any other existing rules.

V. COPIES OF ANY DOCUMENTS AND DATA SUPPORTING THE PROPOSED RULES

Supporting materials, including peer-reviewed research papers, are attached hereto as Exhibits B through M and summarized below:

- **Exhibit B:** J. Travelstead & L. Daniel, *A Technical Review of a proposal submitted by the North Carolina Wildlife Federation to reduce mortality of juvenile fishes in North Carolina*, submitted to the N.C. Marine Fisheries Commission (Nov. 2016).

This technical review, which was submitted in support of the North Carolina Wildlife Federation's November 2016 petition for rulemaking, details the important role of nursery areas in juvenile fish development, the stock status of several commercially and recreationally important species, and the contribution of bycatch mortality in nursery areas to overall stock status. The authors recommend several management strategies, some of which are proposed by the underlying petition, that the MFC should adopt to provide adequate protection to important habitat areas and mitigate bycatch levels in North Carolina waters.

- **Exhibit C:** Curriculum Vitae for Jack Travelstead

- **Exhibit D:** Curriculum Vitae for Dr. Louis Daniel

- **Exhibit E:** L. Barbieri, *Technical Review: The Need to Reduce Fishing Mortality and Bycatch of Juvenile Fish in North Carolina's Estuaries*, submitted to the N.C. Marine Fisheries Commission (Nov. 2016).

This technical review, which was submitted in support of the North Carolina Wildlife Federation's November 2016 petition for rulemaking, discusses the need to reduce fishing and bycatch mortality of juvenile fish in North Carolina's estuaries.

- **Exhibit F:** Curriculum Vitae for Dr. Luis Barbieri

- **Exhibit G:** E. Barbier, et al., *The value of estuarine and coastal ecosystem services*, 81(2) ECOLOGICAL MONOGRAPHS 169 (2011).

The authors report that the value of coastal habitats that support fisheries is greater at the seaward edge or fringe of coastal ecosystems than further inland. The authors raise concerns about the rate and scale at which these important habitats are lost and conclude that failing to take the benefits of these habitats into account is detrimental to fisheries management and planning.

In North Carolina, nursery areas, including Primary Nursery Areas, Permanent Secondary Nursery Areas, and Special Secondary Nursery Areas, are all located further upstream and away from the most important environments for coastal fisheries nursery habitat according to this research. Reducing effort in the proposed Shrimp Trawl Management Areas, which encompass important habitats, is consistent with the literature. Further, expanding secondary nursery habitat designations into higher salinity habitats closer to the inlets is crucial for protecting habitat and preserving ecosystem services.

- **Exhibit H:** M. Islam & M. Tanaka, *Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: A review and synthesis*, 48 MARINE POLLUTION BULLETIN 624 (2004).

This paper summarizes pollution effects on coastal ecosystems and concludes that coastal and marine pollution have caused major changes to fisheries and associated ecosystems. Protection of existing habitats and expansion of protected areas is crucial to offset these negative impacts.

While coastal and marine pollution is a measureable problem, the authors suggest that strategies aimed at protecting ecosystems—e.g., reduced exploitation and habitat enhancement/protection—are essential to restoring fisheries and cannot be ignored. Scapegoating pollution as the problem is inconsistent with the literature.

- **Exhibit I: I.** Nagelkerken, et al., *The seascape nursery: a novel spatial approach to identify and manage nurseries for coastal marine fauna*, 16 FISH AND FISHERIES 362 (2015).

This paper addresses "ecosystem corridors," which are "highways connecting nurseries to adult populations." This paper suggests that a significant roadblock exists between the low salinity, lower value nurseries in the uppermost reaches of the estuary and the offshore or nearer shore, high salinity nurseries. Reducing the roadblocks through decreased impacts to the nursery habitats, including shrimp trawling, and providing protection for migration corridors, e.g., nursery area expansion, are critical considerations for the proposed seascape nursery concept.

The authors conclude by stressing that most inshore bodies of water around the world—for example, the Pamlico Sound in North Carolina—require young fishes and other marine resources to pass through bay mouths or openings between barrier islands, inlets, or deeper tidal channels to reach offshore waters where they join the adult stock and spawn. The authors indicate that these specific areas should be given high conservation importance, as they maintain that connectivity among inshore and offshore ecosystems is critical.

- **Exhibit J:** M. Sheaves, et al., *True Value of Estuarine and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics*, 38 ESTUARIES AND COASTS 401 (2015).

This paper supports the argument that North Carolina's nursery program is rudimentary and fails to consider a broad assessment of nursery habitat value. The authors expand on Beck, et al. (2001) and Dahlgren et al. (2006), both cited by the Division of Marine Fisheries in its fiscal note, which only focus on one aspect of nursery ground value. The authors stress the need to provide protection in critical transition zones between refuge and feeding areas. The authors specifically state that predatory activities—which may include shrimp trawling—in these important habitat corridors can control the supply of recruits.

It is also important, and they point out, that nursery ground values differ depending on the species involved and the current system. In other words, a one-size-fits-all scenario fails to take into account the needs of many critical ecosystem components.

The authors conclude that failure to incorporate the various complexities and needs of species into conservation approaches can risk incomplete or inaccurate identification of key habitats and connectivity that lead to significant potential for unexpected negative outcomes.

This paper describes the current situation in North Carolina, where the nursery area program is rudimentary and generic and fails to take into account any species-specific requirements of connectivity or ecosystems function of the juvenile fishes that are transporting estuarine production in the form of fish flesh to the coastal ecosystem. This research also supports the Federation's contention that the shrimping grounds located between the currently designated nursery areas and the offshore stock represent a critical bottleneck to this productivity, and when combined with natural predation, can dramatically reduce productivity.

- **Exhibit K:** J. Bellido, et al., *Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management?*, 670 HYDROBIOLOGIA 317 (2011).

The authors state that "fishery discard practices constitute a *purposeless waste of valuable living resources*, which plays an important role in the *depletion of marine populations*. Furthermore, discarding may have a number of adverse ecological impacts in marine ecosystems, provoking changes in the overall structure of trophic webs and habitats, which in turn could pose risks for the sustainability of current fisheries." The authors call out shrimp fisheries in particular to illustrate this point.

The authors describe the "core" features of the Ecosystems Approach to Fisheries Management (EAFM): "(a) keeping fleet capacity and fishing mortality rates low enough to prevent ecosystem-wide overfishing, (b) reducing or eliminating bycatch and discards and (c) avoiding habitat-destroying fishing methods."

The EAFM takes into account trophic interactions and area-based management. As the authors describe, such management objectives are not exclusive to EAFM, and most fisheries management agencies around the world attempt to meet at least some of these objectives as part of existing single-species management regimes. The authors cite the recent FAO International Guidelines on Bycatch Management and Reduction of Discards (FAO, 2010), in support of management measures to mitigate bycatch and discard problems. These guidelines advised that "States and [Regional Fisheries Management Organizations or Arrangements] should, where appropriate, map seabed habitats, distributions and ranges of species taken as bycatch, in particular rare, endangered, threatened or protected species, to ascertain where species taken as bycatch might overlap with fishing effort."

The primary aspects of EAFM are central to the goals of the Petition.

- **Exhibit L:** N. Graham, et al., *Fishing practice, gear design, and the ecosystem approach—three case studies demonstrating the effect of management strategy on gear selectivity and discards*, 64 ICES JOURNAL OF MARINE SCIENCE 744 (2007).

The authors state plainly that "[a] basic tenet of the ecosystem approach to fisheries management is that harvesting is conducted with *minimal impact on juvenile fish, non-target species, and marine habitats*."

Therefore, the authors suggest, the tendency to maintain fishing opportunities has to be linked with the longer-term aim of improving sustainability through reducing discards and/or bycatch. In the first instance, it is necessary to define the limits of the quantities of fish of sublegal size or bycatch levels that are acceptable. It is also necessary to shift the monitoring, surveillance, and control onus from landings to catches. By providing the correct incentives and defining realistic targets, the authors suggest that it should be possible to reduce unwanted bycatch and discards.

- **Exhibit M:** J. Lefcheck, et al., *Are coastal habitats important nurseries? A meta-analysis*, CONSERVATION LETTERS (2019).

The authors provide a compelling analysis of 160 peer-reviewed papers that evaluate the importance of structured nursery habitats for marine resources. Their most basic conclusion is that almost all structured habitats, including seagrasses, marshes, submerged aquatic vegetation, oyster beds, and shell hash bottoms, significantly enhance juvenile density, growth, and survival.

These habitats are critical because they provide a complex three-dimensional space as opposed to unstructured habitats, such as sand and mud, which provide none of the aforementioned structure or protection.

The vast majority of areas within the estuaries of North Carolina which currently serve as nursery habitats for most of the commercially and recreationally important species of fish, crabs, and shrimp, as well as forage species important to the ecosystem, are the unstructured habitats that provide less benefit to juveniles. A primary cause of this lack of structure in the North Carolina estuaries is the lack of protection from bottom disturbing gears such as shrimp trawls, crab trawls, and dredges. As a result, much of the three-dimensional structure, so critical for juvenile growth and survival, has been converted to unstructured habitats and provides less function.

This paper best illustrates the critical needs for the reform sought by the Petition. The paper refutes statements by the Division in the fiscal note analysis for the previous petition.[51] Further, it most certainly challenges the concept that "turning over the bottom" by trawling enhances long term production and survival as presented by Deehr (2014).[52] The Petition strives to address the destruction and two-dimensionality of our once-important estuarine ecosystem that ultimately leads to long-term habitat protection and a return to a productive nursery area system through a more holistic approach to habitat protection.

VI. A STATEMENT ON THE EFFECT OF THE PROPOSED RULE ON EXISTING PRACTICES IN THE AREA INVOLVED, INCLUDING AN ESTIMATE OF COST FACTORS FOR PERSONS AFFECTED BY THE PROPOSED RULES

The proposed rules are designed to minimally affect the commercial and recreational fishing industries. Commercial and recreational fishermen would be expected to see increases in the availability and value of fishes available for harvest under the proposed rules. Commercial fishermen with large boats and nets exceeding the total headrope maximum may be required to discontinue the use of one or two nets while in estuarine waters. The reduction in weekly

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[51] *Compare* Exhibit M *with* Division of Marine Fisheries Fiscal Note at 68-69 (citing R.A. Deehr, et al., *Using stable isotope analysis to validate effective trophic levels from Ecopath models of areas closed and open to shrimp trawling in Core Sound, N.C., USA*, 282 ECOLOGICAL MODELING 1–17 (2014)).

[52] *Cf.* R.A. Deehr, et al., *Using stable isotope analysis to validate effective trophic levels from Ecopath models of areas closed and open to shrimp trawling in Core Sound, N.C., USA*, 282 ECOLOGICAL MODELING 1–17 (2014).

shrimping days will apply to all commercial fishermen engaged in shrimping. Finally, fish dealers may be impacted if the availability, quantity, or price of harvested shrimp is positively or negatively affected by the proposed rules.

Efficiencies in terms of reduced effort and associated costs would be measureable. As pointed out in the attached expert reports, limiting commercial shrimp trawling to three days per week allows shrimp to re-congregate during lay days, resulting in greater shrimp harvest on open days, thereby making up for losses but measurably reducing bycatch. It is important to keep in mind that the shrimp trawl fishery is the only fishery where the dominant catch is not the target species. In fact, shrimp are actually a bycatch when compared to the much higher catches of unwanted and discarded juvenile fishes.

Delaying the opening of shrimp season will allow shrimp size to increase, and therefore increase the value of shrimp harvested in North Carolina waters, which would benefit the commercial fishing industry. Moreover, all commercial and recreational fisheries will benefit if fish stocks currently in depleted or declining status rebound as a result of the proposed rule.

Cost factors associated with the proposed rule include, but are not limited to, the following: (1) benefits of increased catch per unit of effort of shrimp resulting from increased lay days; (2) increase in quality and size of shrimp; (3) enforcement and patrol expenses; (4) possible cost of new or amended gear, including a headrope meeting the proposed rule requirements; and (5) costs and benefits of delaying the shrimp season by a short time to allow shrimp count to reach 60 shrimp per pound (heads on) or to allow the harvest of shrimp to exceed the harvest of juvenile fish in sampling tows in the Pamlico Sound.

The Division of Marine Fisheries is expected to develop a fiscal analysis to evaluate the fiscal and economic impact of the proposed rules. The Federation submitted two detailed letters to the Commission outlining its objections to the Division's attempts to evaluate the fiscal and economic impacts of the proposed rules in the November 2017 petition for rulemaking. The Federation stands by those objections, and encourages the Commission to direct the Division to develop the fiscal analysis with an attention to those objections.

VII. A DESCRIPTION OF THOSE MOSTLY LIKELY TO BE AFFECTED BY THE PROPOSED RULES

As described above, the proposed rules will affect a portion of commercial fishing license holders that participate in the commercial shrimp trawl fishery. The majority of commercial fishermen, those that harvest finfish and crabs, the recreational fishing industries, as well as the general public will be positively impacted by the proposed rules. Ultimately, the proposed rules will protect juvenile fishes until they either contribute to the spawning stock, the saleable or legal harvest, or the ecosystem, which will benefit all users in the fishery. Economically valuable North Carolina and coast-wide fish stocks have struggled to rebound after several years, and in some cases decades, of decline. Bycatch mortality in the absence of adequate habitat protection has contributed to declining and depleted stock statuses. By protecting valuable habitats and reducing bycatch levels, the proposed rules will protect marine and estuarine resources for all citizens of the State.

VIII. THE NAME AND ADDRESS OF PETITIONERS

Tim Gestwicki
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Respectfully submitted this the 20th day of May, 2019.

[signature page follows]

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EXHIBIT A

TEXT OF PROPOSED RULES

The added text is denoted by underline and deleted text is denoted ~~by strike through~~ below.

15A N.C. Admin. Code 3L .0101: SHRIMP HARVEST RESTRICTIONS

(a) It is unlawful to take shrimp until the Fisheries Director, by proclamation, opens the season.

(b) ~~The~~ Subject to the provisions of this subchapter, the Fisheries Director may, by proclamation, impose any or all of the following restrictions on the taking of shrimp:

(1) specify time;

(2) specify area;

(3) specify means and methods;

(4) specify season;

(5) specify size; and

(6) specify quantity.

(b) The Fisheries Director may not open the shrimping season for the areas designated in 15A NCAC 3R .0119 until the earliest of the following occurs:

(1) the harvest of shrimp exceeds that of juvenile fishes during sample tows in the Pamlico Sound; or

(2) shrimp count exceeds 60 head per pound during sample tows in the Pamlico Sound or

(3) June 15.

15A N.C. Admin. Code 3L .0103: PROHIBITED NETS, MESH LENGTHS AND AREAS

(a) It is unlawful to take shrimp with nets with mesh lengths less than the following:

(1) Trawl net--one and one-half inches;

(2) Fixed nets, channel nets, float nets, butterfly nets, and hand seines--one and one-fourth inches; and

(3) Cast net--no restriction.

(b) It is unlawful to take shrimp with a net constructed in such a manner as to contain an inner or outer liner of any mesh length. Net material used as chafing gear shall be no less than four inches mesh length, except that chafing gear with smaller mesh may be used only on the bottom one-half of the tailbag. Such chafing gear shall not be tied in a manner that forms an additional tailbag.

(c) It is unlawful to take shrimp with trawls that have a combined headrope of greater than 90 feet in Internal Coastal Waters in the following areas:

(1) North of the 35° 46.3000' N latitude line;

(2) Core Sound south of a line beginning at a point 34° 59.7942' N--76° 14.6514' W on Camp Point; running easterly to a point 34° 58.7853' N--76° 9.8922' W on Core Banks; to the South Carolina State Line;

(3) Pamlico River upstream of a line from a point 35° 18.5882' N--76° 28.9625' W at Pamlico Point; running northerly to a point 35° 22.3741' N--76° 28.6905' W at Willow Point; and

(4) Neuse River southwest of a line from a point 34° 58.2000' N--76° 40.5167' W at Winthrop Point on the eastern shore of the entrance to Adams Creek; running northerly to a point 35° 1.0744' N--76° 42.1550' W at Windmill Point at the entrance of Greens Creek at Oriental.

(d) ~~Effective January 1, 2017 i~~It is unlawful to take shrimp with trawls that have a combined headrope of greater than ~~220~~ 110 feet in Internal Coastal Waters in the following areas:

(1) Pamlico Sound south of the 35° 46.3000' N latitude line and north of a line beginning at a point 34° 59.7942' N--76° 14.6514' W on Camp Point; running easterly to a point 34° 58.7853' N--76° 9.8922' W on Core Banks;

(2) Pamlico River downstream of a line from a point 35° 18.5882' N--76° 28.9625' W at Pamlico Point; running northerly to a point 35° 22.3741' N--76° 28.6905' W at Willow Point; and

(3) Neuse River northeast of a line from a point 34° 58.2000' N--76° 40.5167' W at Winthrop Point on the eastern shore of the entrance to Adams Creek; running northerly to a point 35° 1.0744' N--76° 42.1550' W at Windmill Point at the entrance of Greens Creek at Oriental.

(4) Other areas described in 15A NCAC 3R .0119.

(e) It is unlawful to use a shrimp trawl in the areas described in 15A NCAC 3R .0114.

(f) It is unlawful to use channel nets except as provided in 15A NCAC 3J .0106.

(g) It is unlawful to use shrimp pots except as provided in 15A NCAC 3J .0301.

(h) It is unlawful to use a shrimp trawl in the areas described in 15A NCAC 3R .0119 except as provided in 15A NCAC 3J .0104(b)(7).

(~~h~~i) It is unlawful to use a shrimp trawl that does not conform with the federal rule requirements for Turtle Excluder Devices (TED) as specified in 50 CFR Part 222.102 Definitions, 50 CFR Part 223.205 (a) and Part 223.206 (d) Gear Requirements for Trawlers, and 50 CFR Part 223.207 Approved TEDs. These federal rules are incorporated by reference including subsequent amendments and editions. Copies of these rules are available via the Code of Federal Regulations posted on the Internet at http://www.gpoaccess.gov/cfr/index.html and at the Division of Marine Fisheries, P.O. Box 769, Morehead City, North Carolina 28557 at no cost.

15A N.C. Admin. Code 3J .0104: TRAWL NETS

(a) It is unlawful to possess aboard a vessel while using a trawl net in Internal Coastal Waters more than 500 pounds of finfish from December 1 through March 1, and 1,000 pounds of finfish from March 2 through November 30.

(b) It is unlawful to use trawl nets:

(1) in Internal Coastal Waters from 9:00 p.m. on Friday through 5:00 p.m. on Sunday, except:

(A) from December 1 through March 1 from one hour after sunset on Friday to one hour before sunrise on Monday in the areas listed in Subparagraph (b)(5) of this Rule; or

(B) for a holder of a Permit for Weekend Trawling for Live Shrimp in accordance with 15A NCAC 3O .0503;

(2) for the taking of oysters;

(3) in Albemarle Sound, Currituck Sound, and their tributaries, west of a line beginning on the south shore of Long Point at a point 36° 2.4910' N-75° 44.2140' W; running southerly to the north shore on Roanoke Island to a point 35° 56.3302' N-75° 43.1409' W; running northwesterly to Caroon Point to a point 35° 57.2255' N-75° 48.3324' W;

(4) in the areas described in 15A NCAC 3R .0106, except that the Fisheries Director may, by proclamation, open the area designated in Item (1) of 15A NCAC 3R .0106 to peeler crab trawling;

(5) from December 1 through March 1 from one hour after sunset to one hour before sunrise in the following areas:

(A) in Pungo River, north of a line beginning on Currituck Point at a point 35° 24.5833' N-76° 32.3166' W; running southwesterly to Wades Point to a point 35° 23.3062' N-76° 34.5135' W;

(B) in Pamlico River, west of a line beginning on Wades Point at a point 35° 23.3062' N-76° 34.5135' W; running southwesterly to Fulford Point to a point 35° 19.8667' N-76° 35.9333' W;

(C) in Bay River, west of a line beginning on Bay Point at a point 35° 11.0858' N-76° 31.6155' W; running southerly to Maw Point to a point 35° 9.0214' N-76° 32.2593' W;

(D) in Neuse River, west of a line beginning on the Minnesott side of the Neuse River Ferry at a point 34° 57.9116' N-76° 48.2240' W; running southerly to the Cherry Branch side of the Neuse River Ferry to a point 34° 56.3658' N-76° 48.7110' W; and

(E) in New River, all waters upstream of the N.C. Highway 172 Bridge when opened by proclamation; and

(6) in designated pot areas opened to the use of pots by 15A NCAC 3J .0301(a)(2) and described in 15A NCAC 3R .0107(a)(5), (a)(6), (a)(7), (a)(8), and (a)(9) within an area bound by the shoreline to the depth of six feet.

(7) in the shrimp trawl management areas described in 15A NCAC 3R .0119, except that the Fisheries Director may, by proclamation open the areas designated in 15A NCAC 3R .0119, or any portion thereof, to shrimp trawling, subject to the provisions of 15A NCAC 3L .0100 with the following additional restrictions:

(A) it is unlawful to trawl outside of the shrimping season, as determined by 15A NCAC 3L .0101;

(B) it is unlawful to take shrimp by any method from 12:00 a.m. – 11:59 p.m. on Tuesdays and Thursdays.

(c) Mesh sizes for shrimp and crab trawl nets shall meet the requirements of 15A NCAC 3L .0103 and .0202.

(d) The Fisheries Director may, with prior consent of the Marine Fisheries Commission, by proclamation, require bycatch reduction devices or codend modifications in trawl nets to reduce the catch of finfish that do not meet size limits or are unmarketable as individual foodfish by reason of size.

(e) It is unlawful to use shrimp trawl nets for recreational purposes unless the trawl net is marked by attaching to the codend (tailbag) one floating buoy, any shade of hot pink in color, which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than five inches in length. The owner shall be identified on the buoy by using an engraved buoy or by attaching engraved metal or plastic tags to the buoy. Such identification shall include owner's last name and initials and, if a vessel is used, one of the following:

(1) gear owner's current motor boat registration number; or

(2) owner's U.S. vessel documentation name.

(f) It is unlawful to use shrimp trawl nets for the taking of blue crabs in Internal Coastal Waters, except that it shall be permissible to take or possess blue crabs incidental to shrimp trawling in accordance with the following limitations:

(1) for individuals using shrimp trawl nets authorized by a Recreational Commercial Gear License, 50 blue crabs per day, not to exceed 100 blue crabs if two or more Recreational Commercial Gear License holders are on board the same vessel; and

(2) for commercial operations, crabs may be taken incidental to lawful shrimp trawl net operations provided that the weight of the crabs shall not exceed the greater of:

(A) 50 percent of the total weight of the combined crab and shrimp catch; or

(B) 300 pounds.

(g) The Fisheries Director may, by proclamation, close any area to trawling for specific time periods in order to secure compliance with this Rule.

15A N.C. Admin. Code 3R .0119: SHRIMP TRAWL MANAGEMENT AREAS

The shrimp trawl management areas referenced in 15A NCAC 3J .0104 (b)(7) are delineated in the following Internal Coastal Waters:

(a) All areas not otherwise designated as Primary Nursery Areas under 15A NCAC 3R.0103, Secondary Nursery Areas under 15A NCAC 3R.0104, Special Secondary Nursery Areas under 15A NCAC 3R.0105, or otherwise closed to trawling under 15A NCAC 3R.0106, 15A NCAC 3R.0114, or 15A NCAC 3J.0104(b)(3).

EXHIBIT B

A Technical Review of a proposal submitted by the North Carolina Wildlife Federation to reduce mortality of juvenile fishes in North Carolina

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Submitted to the North Carolina Marine Fisheries Commission

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I. INTRODUCTION

The level of bycatch and discard mortality of juvenile marine fishes in shrimp trawls in the coastal and estuarine waters of North Carolina is extraordinary. Though other fisheries contribute to juvenile bycatch, shrimp trawls are the largest source of bycatch mortality, and proper management would have a significant and measureable impact in restoring overfished and declining stocks.

North Carolina is the only state on the east coast of the United States that still allows shrimp trawls to operate in estuarine nursery areas, and its trawling regulations are the most lax nationwide. Despite efforts to reduce the documented bycatch that occurs in this fishery through the use of bycatch reduction devices ("BRDs"), closed seasons, and restricted areas, hundreds of millions of juvenile fish continue to die each year from shrimp trawls, which contributes to declining stocks. The critical importance of all these species to the recreational and commercial fisheries of North Carolina, as well as their ecosystems function as forage and energy transfer, cannot be overstated.

Viable fish populations depend on the recruitment of juvenile fish into the adult population so that they can spawn and replace themselves before being harvested or dying. This is the essential tenet behind the "sustainable harvest" objective of North Carolina's Fisheries Reform Act of 1997. Juvenile fishes first enter the estuary at the larval or early juvenile stage and move into shallow protected habitats inside North Carolina's expansive estuarine system. In defined Primary and Secondary Nursery Areas, these fishes are partially protected from recognized, destructive fishing practices such as shrimp trawling. Natural mortality during these early life stages is extremely high. Fishes that survive the high natural mortality rates during these stages move out of the confines of North Carolina's limited nursery area system and into the open rivers and sounds where fish receive far less regulatory protection. Though natural mortality declines during this time, mortality in the form of discard mortality from shrimp trawls progressively increases, thus depressing recruitment of juvenile fish into the adult population.

Many of the adult populations of fish stocks subjected to shrimp trawl bycatch have declined significantly, which means that increased juvenile recruitment to rebuild those populations is more important today than ever. Specifically, spot, Atlantic croaker, and weakfish were critical components of North Carolina's estuarine commercial and recreational fisheries prior to their dramatic declines in the late 1980s. In 1981, the commercial landings of these three species were 37.6 million pounds. In 2015 that number dropped to 2.3 million pounds, a 95 percent decline. The recreational fishery shows a similar trend: in 1981 recreational landings were 5.3 million pounds compared to 1.6 million pounds in 2015, a 70 percent decline. This precipitous decrease comes despite increases in angler effort in terms of numbers of fishermen. Primarily, the high juvenile mortality from bycatch, along with overfishing of adult stocks in directed fisheries, confound efforts to rebuild these populations. Declining spawning stock biomass and continued high discards must be addressed immediately to restore the viability of these important fisheries to North Carolina and the east coast.

The purpose of this paper is to provide a review of the management history, concerns, and impacts of the shrimp trawl fishery on important stocks. In addition, this paper proposes solutions to existing issues that should be considered and addressed to restore severely depleted fish stocks in the estuarine waters of North Carolina.

II. BACKGROUND

The Atlantic Coastal Fisheries Cooperative Management Act (1993) and the North Carolina Fisheries Reform Act (1997) were passed 20 years ago. The intent of these legislative mandates was to restore overfished fish stocks and provide ongoing protections to facilitate responsible and sustainable fishing. The general concept is simple: coordinated management of fish stocks would yield healthy fishery resources that benefitted all users as well as the ecosystem. A review of the stock status of many of the fisheries managed under these laws indicates these goals have not been achieved. Today, many stocks remain in an overfished or overfishing status or fall into a category of concern as population measurements either languish at low levels or are in decline.

Government agencies and stakeholders involved in the early development and passage of this legislation expected more tangible results than what has been achieved. Whether the issue is uncertainty in stock assessments, continued overharvest, failure to adequately characterize and address substantive bycatch issues, or the inter- and intra-state concerns over allocation, many south and mid-Atlantic fish stocks are no better off, and are likely in worse condition, than they were 20 years ago. Most nearshore, state waters fisheries of importance to North Carolina and the mid- and south Atlantic states have declined to either concern, depleted, or unknown status. The common thread for these fish stocks is that virtually all are subjected to intense juvenile mortality and many lack any protective size limits.

Alverson et al. (1996) indicate that the global impacts of trawl bycatch are enormous. Shrimp trawls generate more bycatch than any other gear leading to declining fish stocks on a global scale. It is undisputed that discarded finfish species rarely survive their encounter with a shrimp trawl. Moreover, the research consistently indicates that discards from fisheries that impact large quantities of juvenile fish can generate significant population effects. The combined effects of overfishing, discard mortality on natural species assemblages, altered predator/prey dynamics, and modified structure and function of benthic communities contribute to population declines. Even 20 years ago, it was believed that Atlantic croaker in the Gulf of Mexico declined by more than 40 percent as a result of shrimp trawl bycatch. Estimated bycatch during the 1980s was 7.9 billion fish per year. In addition, the Gulf of Mexico Fishery Management Council recognized that shrimp trawl bycatch was the primary source of mortality for red snapper in 1990 (Alverson et al. 1996). Despite the implementation of BRDs since the 1990s, the evidence presented in Alverson et al. (1996) indicates that many of the ecological impacts of shrimp trawl bycatch and other bycatch fisheries have yet to be studied but likely have negative consequences on stock dynamics. Researchers suggest that "[t]he single action that will provide the greatest improvement to the bycatch and discard problem will be the reduction in these efforts levels. Without such control, other solutions to the bycatch and discard problem will be less effective and real success in our efforts to better manage the ocean's resources much more difficult" (Alverson et al. 1996). Bycatch and discard mortality continue to negatively impact fish stocks along the east coast, especially in North Carolina waters.

North Carolina is unique along the east coast in that it allows significant fishing effort in its estuaries, which results in excessive fish mortalities, especially among juvenile fish. In fact, North Carolina is the *only* state on the east coast that permits trawling in inshore waters. Despite efforts to mitigate those impacts by fisheries managers, North Carolina shrimp trawling is the leading contributor to bycatch mortality (Brown 2015, ASMFC Fishery Management Plans for spot, Atlantic croaker, weakfish). However, it is worth noting that other fisheries also contribute to high levels of bycatch. For example, hook and line, large and small mesh gill nets, long haul seines, and unlimited crab pot efforts contribute to bycatch mortality. Though some of these fish are sold, many others are discarded. Many of these fisheries are either prohibited or significantly limited in other states.

Many of the stocks deemed overfished, overfishing, or of concern in the North Carolina Stock Status Report are impacted by shrimp trawl bycatch, including spot, Atlantic croaker, weakfish, summer flounder, and southern flounder. The hundreds of millions of juvenile fishes discarded from fishing activities prior to reaching adulthood and having the opportunity to contribute to the spawning stock biomass are a significant threat to the health and productivity of these important fish populations.

III. METHODS

We relied heavily on published reports, stock assessments, journal articles, and data sets from the North Carolina Division of Marine Fisheries ("NC DMF") and the Atlantic States Marine Fisheries Commission ("ASMFC") to conduct this review. The ASMFC is a compact of the east coast states that manage fisheries that migrate up and down the coast. The ASMFC's mission is to ensure healthy, self-sustaining fisheries. All data sources are readily available to the public and most, if not all, have undergone peer-review or ASMFC approval. In several cases, we used our experience and expertise in managing east coast fisheries to make suggestions or point out issues that are unavailable in the literature we reviewed.

IV. DATA REVIEW

What follows is an examination of the status of the three finfish species—Atlantic croaker, spot, and weakfish—that are most impacted by shrimp trawl bycatch in North Carolina.

A. <u>Atlantic croaker</u>

The life history of most members of the drum family (*Sciaenidae*), including Atlantic croaker, is characterized by cyclical abundance: it is natural for these fish populations to fluctuate over time. However, periods of low abundance have lasted longer than normal in recent years. While landings may be naturally cyclical as a result of environmental conditions and population abundance, fishing effort also plays a role. At periods of high abundance, effort increases and Atlantic croaker are harvested in large amounts with no constraints. Catches can exceed 100,000 pounds in a single trip. The most recent landings peak in 2001 (43 million pounds) has been followed by a persistent decline through 2014 (10 million pounds). The ASMFC (2015) recently raised concern over declining trends in fishery-independent indices and commercial and recreational landings of Atlantic croaker.

a. Stock Status of Atlantic croaker

North Carolina and Virginia account for approximately 90 percent of the commercial landings of Atlantic croaker along the east coast (ASMFC 2015). Trawling is prohibited in Virginia state waters, while neither state has any size or possession limits. From the mid-1960s until the early 1990s, North Carolina dominated landings with a single year high of 21.1 million pounds in 1980. By 2015, however, that number had fallen to 1.8 million pounds. Today, Virginia ranks number one in Atlantic croaker commercial landings while landings in the south Atlantic, including North Carolina, South Carolina, Georgia, and Florida, have significantly declined.

The recreational fishery for Atlantic croaker in North Carolina and the south Atlantic has also declined. In 1990, North Carolina accounted for 22 percent of the recreational Atlantic croaker harvest, while all the south Atlantic states accounted for 48 percent of recreational landings. By the last year of the benchmark stock assessment, North Carolina recreational harvest had fallen to 4 percent, and the recreational harvest in the south Atlantic to just 12 percent of the coast wide harvest (ASMFC 2010a).

Ideally, one would see a distribution of all sizes and ages in a healthy fishery. However, the 2010 ASMFC stock assessment's (ASMFC 2010a) summary of information on reproductive ecology based on fish collected in North Carolina and Virginia shows that state fisheries are increasingly relying on juvenile fishes. The midpoint of the published estimates of L100%[1] for Atlantic croaker is approximately 270 mm TL. In 2004, Atlantic croaker taken below L100% in the North Carolina recreational fishery comprised 68 percent of the harvest. In 2015, 90 percent of the Atlantic croaker harvest had yet to reach L100%. This increasing reliance on juvenile fish in the catch is indicative of a stock in decline.

To address concerns with declining landings, the ASMFC developed and approved Addendum II to the Atlantic croaker Fishery Management Plan ("FMP") in 2014. Addendum II takes a precautionary approach in managing the Atlantic croaker in light of the current and persistent decline in the stock. The addendum tracks trends in abundance, life history characteristics, and responses to fishing pressure. Based on the 2015 stock status review (ASMFC 2015b) all characteristics are trending down with some above the threshold for management action. While further action may be forthcoming from the ASMFC, it will likely not address the biggest source of mortality in the fishery—shrimp trawl—because those concerns rest primarily within the jurisdiction of North Carolina.

b. Impact of bycatch on Atlantic croaker stock

The estimated bycatch of Atlantic croaker in the south Atlantic peaked in 1995 at approximately 46.3 million pounds. Since 1950, estimates of Atlantic coast bycatch in all fisheries has exceeded harvest (ASMFC 2010a). Atlantic croaker are extremely resilient and can be very productive when environmental conditions are favorable, hence the boom and bust fisheries we have observed. By reducing the level of discards, especially for those fish that have yet to contribute to the population through at least one spawning event, the busts become more

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[1] L100% is the length at which 100 percent of the sampled fish were mature as evidenced by developing, developed, or spent gonads.

infrequent and the fishery becomes more stable. More spawning fish impact not only the ecological value of Atlantic croaker but generally produce higher average recruitment. Higher recruitment means more yield for the benefit of the fishery and the ecosystem.

Atlantic croaker are the dominant bycatch species by number and weight in the North Carolina shrimp trawl fishery. In fact, Brown et al. (2015) found that Atlantic croaker dominated the shrimp trawl catches during virtually every season from 2012 to 2015 in their estuarine and coastal ocean bycatch characterization study, regularly exceeding the harvest of shrimp. During the four-year study period (August 2012 toAugust 2015), observers covered 1.2 percent of all commercial estuarine and ocean (0-3 miles) trips (n = 388, including 227 estuarine and 161 ocean trips). The total number of commercial trips reported to the North Carolina trip ticket program during the study period was 32,388. The total weight of all Atlantic croaker taken from observed trips during the study period was 322,883 pounds, which amounts to approximately 5.1 million fish. All of these fish were discarded as unmarketable and ranged in size from 70 to 200 mm TL, and were primarily juvenile fish (Brown 2015).

Brown et al. (2015) estimated that the average at-net mortality of Atlantic croaker was 23.4 percent. These estimates, including those for spot and weakfish, should be viewed with caution as extremely low. By contrast, the 2010 benchmark stock assessment for Atlantic croaker by the ASMFC uses a discard mortality rate of 100 percent for fish discarded from both gill nets and trawls (ASMFC 2010a). Brown (2015) characterized fish on deck as alive or dead immediately upon dumping the nets. However, as Brown (2015) correctly points out, "delayed mortality associated with discarded bycatch in the commercial shrimp otter trawl fishery will likely be much higher than at-net mortality due to factors including sorting time of catch, physical injury associated with capture, and indirect predation from birds, sharks, and dolphins." Culling time, delayed mortality from injuries, and increased predation once discarded likely result in these estimates being unreasonably optimistic.

The magnitude of unmarketable Atlantic croaker discards in the North Carolina estuarine and ocean shrimp trawl fishery greatly exceeds the directed harvest. Assuming that observer data are representative of the fishery, summary tables in Brown (2015) indicate that 322,883 pounds of Atlantic croaker representing approximately 5,141,487 individuals were observed in the shrimp trawl during the study period. Expanding the observed trips to approximate total fishery-wide bycatch based on average catch per trip (322,883 pounds per 388 trips = 832 pounds per trip) and total trips reported during the four-year study period (n = 32,388), indicates that nearly 27 million pounds of Atlantic croaker were taken in the shrimp trawl fishery during the study period. The average weight of Atlantic croaker varied by year and season (0.05-0.11 lbs.) and averaged .076 lbs. (Brown 2015). Larger juveniles were taken in the ocean fishery. Employing a range of estimates (10-20 fish/pound) provides a total estimated bycatch of Atlantic croaker during the study period from 270 to 540 million fish. Using discard mortality rates ranging from 23.4 percent (Brown 2015) to the more defensible 100 percent estimated for trawls in the benchmark stock assessment (ASMFC 2010a), Atlantic croaker mortality in the North Carolina shrimp trawl fishery during the study period ranges from 63 to 540 million dead fish.

B. Spot

Spot have been a very popular and culturally important fish along the east coast for decades. The North Carolina Spot Festival occurs in Hampstead, North Carolina each September to celebrate the arrival and significance of this little fish. Many of the coastal ocean fishing piers were constructed, in part, so that anglers could intercept their fall runs. Like Atlantic croaker and weakfish, spot appeal to a huge demographic in the fishery because they are easy to catch and inexpensive to pursue when they are abundant.

a. Stock Status of Spot

A coast-wide stock assessment is underway for spot and results are expected in late 2016. Current data indicate concerns related to declines in the juvenile abundance index for spot from 1990 until the mid-2000s, with improvements noted in 2011 and 2012. While the ASMFC technical committee report for spot indicates that triggers were not tripped for management action in 2014, analysis shows concerning declining trends in abundance indices and harvest (ASMFC 2015).

The most recent status review for spot continues to show that spot harvest varies in terms of quantity landed and fishing sector. In some years, the recreational harvest dominates and, in other years, the commercial fishery catches the larger amount. North Carolina currently accounts for just 14 percent of the current commercial landings of spot on the east coast, down from 50 percent in the 1980s. North Carolina landings have steadily declined from 3.0 million pounds in 2001 to 0.76 million pounds in 2014. As with Atlantic croaker, North Carolina dominated commercial landings up until the early 1990s when Virginia took over the top spot (ASMFC 2015a).

Recreational landings data show a similar, but less pronounced, declining trend since data was first recorded in 1981. The recreational contribution of North Carolina to coast-wide spot landings in 1985 was 52 percent (3.1 million pounds), compared to 24 percent (704,445 pounds) in 2014. Coast-wide recreational landings have declined by 50 percent since 1985, however, the decline in the south Atlantic is the most pronounced. In 1985, the south Atlantic states accounted for 64 percent of the coast-wide recreational catch, compared to 34 percent in 2014 (ASMFC 2015a).

Spot mature at sizes between 184 and 292 mm TL for both sexes. Males mature at slightly smaller sizes, and full maturity (the L100%) for both sexes is 220 mm TL or greater (ASMFC 2010b). Length-frequency information on the commercial gill net fishery for spot in North Carolina indicates an average size of 213 mm TL, with 65 percent of the harvest less than the L100%. Because there is no size limit in North Carolina, unmarketable spot and Atlantic croaker can be included as bait and are typically sold to participants in both the crab pot and recreational fisheries. Sizes of spot taken in the recreational fishery range from 120 to 410 mm TL. In 2005, 2 percent of the spot harvested were greater than 300 mm TL, compared to 0.04 percent in 2015. Recreational landings statistics from 2015 in North Carolina indicate that 69 percent of the spot harvested were less than its L100% value (NC DMF Marine Recreational Information Program

("MRIP") data request), compared to 58 percent in 2005. It should be noted that in a healthy population, a significant percentage of the population should be larger than the L100%. The fact that so few mature fish have occurred in the population for over a decade raises concern about maintaining a healthy, spawning stock biomass.

b. Impact of bycatch on spot stock

While juvenile spot are known to be a bycatch component of many fisheries, "the largest bycatch component for spot comes from the south Atlantic shrimp trawl fishery" (ASMFC 2015). Spot are second only to Atlantic croaker in abundance among bycatch species in the North Carolina shrimp trawl observer program (Brown 2015). During the study period, researchers observed 110,113 pounds of spot as unmarketable discards in the observed trips (284 lbs./trip). Sizes generally ranged from 70 to 200 mm TL, and mean weight for all years and seasons was 0.065 pounds (ranging from 10 to 25 fish per pound). Researchers observed a total of 2 million spot. The at-net mortality of spot was much higher than for Atlantic croaker at 66 percent, without factoring in delayed mortality as described above for Atlantic croaker. Using the same method as above for Atlantic croaker, the number of spot observed in the North Carolina shrimp trawl fishery (32,388 trips) during the four-year study period ranged from 92 to 230 million fish.

C. Weakfish

The management history of weakfish is complex. The states took significant actions to reduce the directed and by-catch mortality of weakfish in the mid-1990s with Amendment 3 to the Interstate FMP for Weakfish (ASMFC 1996). Many felt certain that increased size limits, reduced bag limits, bycatch reduction in the south Atlantic shrimp trawl fishery, and the closure south of Cape Hatteras to flynets would result in recovery. While monitoring of the fishery showed positive early signs, the stock had lost all gains by the mid-2000s and was again declared depleted. Years of technical analysis indicated something had changed in terms of natural mortality as fishing mortality was estimated to be very low. Addendum IV to the Weakfish FMP closed the fishery to all but a minimal bycatch allowance, which is where it has remained since (ASMFC 2009).

a. Stock status of Weakfish

North Carolina and Virginia have historically dominated the commercial fishery for weakfish. Throughout the 1980s and 1990s, North Carolina accounted for 60 to 70 percent of the coast wide commercial harvest. The percentage declined to 19 percent in 2007. Since 2010, commercial fisheries have been limited to a 100 pound bycatch allowance likely resulting in an increase in discards in many fisheries that go unreported (ASMFC 1996, 2009).

The commercial fishery in North Carolina operates under a 12 inch TL minimum size limit, except the estuarine long haul seine and pound net fisheries, which are held to a 10 inch TL size limit. The recreational fishery operates under a 12 inch TL limit and a one fish bag limit. These size limits, unique among the three fishes reviewed, prevent directed harvest of juvenile fish, however, undersized and regulatory discards still consist of juvenile fish (ASMFC 1996; 2009).

Age frequency distribution of weakfish in the North Carolina recreational fishery is truncated. The current size distribution taken in the North Carolina recreational fishery range from 310 to 480 mm TL. Weakfish can live well into their teens, however, current catch levels reveal less than 5 percent of the catch is greater than 430 mm TL (age IV) (NC DMF MRIP data request). Analysis of the coast wide recreational fishery likewise shows a truncation in the age structure with 0.01 percent of weakfish harvested recreationally at age V+ compared to 46 percent in 1998 (ASMFC 2016). Similar to Atlantic croaker and spot, the weakfish harvest is increasingly reliant on smaller fish, many of which are juveniles or the least fecund.

Though weakfish grow rapidly and often mature and spawn at age I, their fecundity greatly increases with age. The 2016 peer review report on weakfish (ASMFC 2016) cited Nye et al. (2008) and noted that "despite maturing early, first spawn weakfish at age I spawned less frequently, arrived later to the estuarine spawning grounds, and had lower batch fecundity than older fish, likely resulting in an overly optimistic assumption about the contribution of age I fish to the overall reproductive success of the stock. This is currently amplified by the fact that larger, older fish comprise a small proportion of the overall population." Lowerre-Barbieri et al. (1996) found that 90 percent of weakfish were mature at age I and that the eggs to female ratio significantly increased with both total length and weight. Specifically, batch fecundity (the number of eggs per spawning event) estimates ranged from 75,289 to 517,845 eggs per female. Lowerre-Barbieri noted that the fecundity increased significantly with both total length and weight. Consequently, while weakfish are afforded more protection to spawn at least once in the directed fisheries, the reproductive capacity of these young fish is slight compared to the larger and older fish.

b. *Impacts of bycatch on weakfish*

There is significant bycatch of weakfish associated with the south Atlantic shrimp trawl fishery. Brown (2015) reported 29,688 pounds of weakfish in the North Carolina shrimp trawl characterization study (77 lbs. per trip) over four years. Additionally, the at-net mortality for weakfish was the highest of the three species examined in their analysis at 87 percent. Like Atlantic croaker, the less conservative ASMFC benchmark assessment employs a 100 percent mortality rate for trawls. The weakfish taken in the Brown (2015) study were all characterized as regulatory discards with sizes ranging from approximately 70 to 280 mm TL, with most falling between 110 and 180 mm TL size classes (age 0). Weakfish averaged 7 to14 fish per pound during the study period, yielding an estimated number of weakfish observed from 17 to 34 million fish over the four-year study period. Based on the most conservative estimates, weakfish mortality due to trawling during Brown's study period totaled over 15 million fish, most of them age 0 and juvenile. However, it is worth noting that, while less common, higher fecundity weakfish age I and age II are also subjected to shrimp trawl mortality (Brown 2015).

D. Importance of Nursery Areas to Juvenile Fish

The abundance and distribution of juvenile fishes reported by Brown (2015) are supported by the data collected during the time series of the NC DMF Pamlico Sound Survey that has occurred for decades (e.g., Knight 2015, Knight and Zapf 2015). Numerous Pamlico Sound Survey reports are available and consistently provide evidence that the majority of the species encountered in the Pamlico Sound are juvenile finfishes. The Brown (2015) study occurred over a four-year period in the primary shrimping grounds of the state (Figures 3 and 4), including the Pamlico Sound and waters south. Another characterization study was conducted from Carteret County to Brunswick County in North Carolina (Brown 2009), which found results similar to the more recent study (Brown 2015). In the 2009 study, Spanish mackerel and flounders were taken in higher numbers in the southern estuaries and catches were dominated by juvenile fishes, primarily Atlantic croaker and spot. Multiple surveys and characterization studies referenced in Brown (2015) and NCDMF (2006, 2015) have also occurred in these same general locations. NCDMF (2015) points out that blue crab, weakfish, Atlantic croaker, and spot have accounted for the majority of all shrimp trawl bycatch since studies began in the 1950s and that situation continues today. All available data reviewed provide solid evidence that all regions and locations surveyed using trawls are dominated by the presence of juvenile fishes.

The Pamlico Sound Survey occurs in June and September each year within Pamlico Sound and has the following objectives:

(1) To determine and monitor the distribution, relative size abundance, and size composition of fish, shrimp, and crab in the survey area and how they vary temporally and spatially.

(2) To provide data to ascertain fishery-independent estimates of mortality and population size to compare to commercial fishery samples and landings data.

(3) *To determine which species utilize (and to what extent) the sound during their early life development and identify nursery areas for those species (i.e.* Cynoscion sp., Paralichthys sp. *etc.).*

(4) To determine if catch rates of various species are correlated with indices of juvenile abundance derived from the juvenile trawl survey.

(5) To determine if species distributions are correlated with each other or with some other measured parameter(s).

(6) To monitor the movement of organisms out of the nursery area and into the open waters of Pamlico Sound where they are available for commercial and recreational exploitation.

(Knight and Zapf 2015). The survey is conducted within Pamlico Sound and extends up into the Neuse, Pamlico, and Pungo Rivers. Stations are sampled during each cruise period from an established survey grid (Figure 2). As an example, during a single nine day cruise in September 2014, 54 randomly selected stations were sampled with two 30-foot mongoose nets outfitted with small mesh (approximately 1 inch) for 20 minutes. The estimated area of the sound floor swept by each net was estimated at 97,500 square feet. Forty-seven species of finfish were observed, and the most abundant species observed are considered economically important and include: spot, Atlantic croaker, blue crab, weakfish, brown shrimp, summer flounder, southern flounder, bluefish, southern kingfish, white shrimp, and pink shrimp. Spot were present in all strata, and were the most abundant species collected. Atlantic croaker were also present in all strata, and were the second most abundant species collected. Weakfish were present in all but the Neuse River stratum, and were the sixth most abundant species collected and fourth most abundant amongst the economically important species. Length frequency data for the species listed above indicate that all specimens were juvenile fish taken within the Pamlico Sound during shrimp season (e.g., Casey and Zapf 2015).

The Pamlico Sound Survey data (e.g., Knight 2015, Knight and Zapf 2015), combined with the shrimp trawl characterization studies of Brown (2009, 2015), and numerous other studies and surveys provide substantial evidence that all estuarine and nearshore ocean waters of North Carolina function as important nursery habitat for hundreds of species of finfish and crustaceans. Many of these species (e.g., spot, Atlantic croaker, weakfish, flounders, blue crab) are valuable components of the commercial and recreational fisheries of North Carolina and are all in decline. The persistent loss of these fishes at juvenile life stages as discard mortality greatly affects fishing success and yield.

The studies of Brown (2009, 2010, 2015), Diamond-Tissue (1999), Johnson (2003, 2006), and Logothetis and McCuiston (2004) all corroborate our concerns that shrimp trawl bycatch in waters south of the Pamlico sound, in addition to the Pamlico Sound and nearshore coastal ocean, is comprised of primarily juvenile fishes. The bycatch levels found in these studies are extraordinary and exceed the directed harvest for many species impacted, particularly spot, Atlantic croaker, and weakfish. From the Intracoastal Waterway in Brunswick County to the upper reaches of the Pamlico Sound and various water bodies in between, the problem is systemic and must be addressed if the affected stocks are to show meaningful recovery.

While we understand the difficulties in quantitatively assessing the impacts of juvenile bycatch in shrimp trawls and other fisheries in stock assessments, the issue is a matter of scale. Diamond (2003) suggests that bycatch estimates are meaningless without an estimate of population abundance. However, when the bycatch of juvenile fishes approaches or exceeds the annual, directed removals, particularly for stocks in decline or depressed, the likelihood of negative impacts is great. Additionally, when a large percentage of the fishes harvested are also juvenile fishes, the problem is magnified. We believe it unwise to ignore this major component of fishing mortality any longer, based on simulated modeling exercises that fail to provide a direct link to the magnitude of this problem or require an unattainable population abundance estimate in order to act. If even a fraction of the 15 million pounds of spot, Atlantic croaker, and weakfish taken as shrimp trawl bycatch in 2014 had been afforded the protection to grow to maturity and spawn, it is hard to imagine a scenario in which the stocks would not respond favorably.

Nursery areas in North Carolina are currently defined (15A NCAC 03I.0101) as

> "areas that for reasons such as food, cover, bottom type, salinity, temperature, and other factors, young finfish and crustaceans spend the major portion of their initial growing season. Primary nursery areas are those areas where in the estuarine system where initial post-larval development takes place. These are areas where populations are uniformly early juveniles. Secondary nursery areas are those areas in the

estuarine system where later juvenile development takes place. Populations are comprised of developing sub-adults of similar size that have migrated from an upstream primary nursery area to the secondary nursery area located in the middle portion of the estuarine system."

Based on our analysis, it is evident that all estuarine and nearshore ocean waters of North Carolina meet these criteria and function as secondary nursery areas. All of North Carolina's estuarine and nearshore waters provide the necessary physical conditions in terms of salinity and temperature required for development of several commercially and recreationally valuable species. Further, the soft organic sediments, along with shell bottom, oyster reefs, live bottom, and other structures present in inshore and nearshore areas provide essential habitat for feeding and cover. The currently designated secondary nursery area contain but a small fraction of those important habitats. Consequently, growth, development, and maturity of these sensitive life history stages are severely compromised by the lack of protection afforded to these nursery areas, limiting the ability of these fisheries to measurably improve. In addition, the failure to protect these juvenile fishes by significantly reducing the anthropomorphic sources of mortality compromises the ecosystems effects of these life stages by their premature loss and inability to either provide energy exchange to higher trophic levels or contribute to the spawning stock.

We believe that further protection of these vital nursery habitats from harm is critical. Moreover, additional protection of nursery areas is consistent with the recommendations of the North Carolina Coastal Habitat Protection Plan (NC DEQ 2015) and the ASMFC.[2] Specifically, the ASMFC designates all estuaries as Habitat Areas of Particular Concern for spot and Atlantic croaker and advises that any fishing gear determined by management agencies to have a negative impact on the habitat for these species should be prohibited. The ASMFC states that "in addition to losses of abundance as target and bycatch some fishing gears, particularly dredges and trawls, can impact sciaenid habitats. These gears remove epifauna, alter bathymetry, re-distribute substrates, and change organism assemblages. Habitat loss by fishing gears can take months to years to recover."

E. Ecosystems impacts of shrimp trawl bycatch

The value of the hundreds of millions of juvenile finfish and crustaceans to the ecosystem as forage is high. The Food and Agriculture Organization of the United Nations ("FAO") Technical Guidelines for Responsible Fisheries adopted an ecosystem approach to fisheries management and suggested that where there are threats of serious and irreversible damage, lack of scientific certainty should not be used as a reason for postponing measures to prevent degradation (FAO 2003).

The ecosystems approach to fisheries management recognizes that fisheries should be managed to limit their impact on the ecosystem and that management strategies should be

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[2] *See* Atlantic Sciaenid Habitats: A review of utilization, threats, and recommendations for conservation, management, and research (2016). This document is available in the meeting materials contained on the ASMFC website for the Annual Meeting in 2016, but has not yet been published. Proceedings of the 2016 ASMFC Annual Meeting may be accessed at the following link: http://www.asmfc.org/home/2016-annual-meeting.

precautionary because our knowledge of the ecosystem is incomplete. The impacts of shrimp trawls on bottom habitat, particularly structural components such as live bottom and shell bottom habitats, is well established.

Numerous studies have been conducted that demonstrate that juvenile spot and Atlantic croaker are important components in the diet of many fishes of importance to commercial and recreational fisheries (Mercer, 1987). Specifically, juvenile spot and Atlantic croaker are important ecosystem components for energy transfer because their early diets consist mostly of benthic invertebrates that they convert into fish flesh for higher trophic level predators. In a study of juvenile red drum and spotted seatrout, Daniel (1988) found that spot was the second most important prey item to the diet of young-of-the-year red drum, second only to grass shrimp in the tidal creeks of coastal South Carolina. Spot were also documented as an important prey item to juvenile spotted seatrout. In a broader study, Wenner et al. (1990) found spot to be the most important component of the diet of southern flounder by frequency, volume and number, while spot also contributed to the diet of summer flounder. Fish and crustaceans dominate the diet of spotted seatrout. Grass shrimp were the dominant crustacean and spot were the dominant finfish species observed. The diet of red drum is more varied than the other species in this study. Various species of shrimp and crabs dominated the red drum diet. Fishes (Atlantic menhaden and spot) were second in importance to larger red drum. Additional diet studies, mostly lacking in North Carolina, would further show the importance of many shrimp trawl bycatch components to the diets of most estuarine and nearshore predators so important to east coast fisheries (*see* Mercer 1987 for review).

In summary, more conservative management of important forage based fishes (e.g., spot, Atlantic croaker, weakfish), to provide for maximum abundance rather than maximum yield, is necessary to allow them to achieve their important role in the trophic balance of the ecosystem, as well as provide the necessary surplus production to support valuable fisheries in North Carolina and elsewhere.

V. ANALYSIS

All states in the mid-Atlantic and south Atlantic regions have taken different approaches to fisheries management. North Carolina stands alone as the only state on the east coast that allows trawling in estuarine waters. The specific impacts of this fishery on several species are provided above. Virtually all east coast states have some type of juvenile survey in estuarine waters to document the abundance and diversity of fishes that occur there. These surveys provide solid evidence that estuarine waters are critical nursery habitat. Other states have acted on these data by protecting those important areas. For example, the Virginia Institute of Marine Science trawl survey has occurred since 1955. The species composition and relative abundance of fishes in Virginia waters are similar to those found in trawl research conducted in North Carolina. Atlantic croaker, weakfish, and spot were exceeded in abundance only by bay anchovy, hogchoker, and white perch during their survey periods. Trawling has been prohibited in the Chesapeake Bay for decades.

The bycatch associated with shrimp trawling confounds fisheries managers in North Carolina and impacts fisheries along much of the east coast that rely on spillover from the important nursery that is North Carolina's sounds. The persistent harvest and mortality of juvenile fishes in North Carolina upsets the natural migration of inter-jurisdictional fishes that move to feeding and spawning areas outside of North Carolina waters. In many instances, these fish would normally return to North Carolina as larger fish. North Carolina also receives recruits from sister states to its south and north, which have provided far greater protection for its juvenile fish resources in the past.

The data is clear that substantive rule changes to minimize mortality, particularly juvenile mortality, in the North Carolina shrimp trawl fishery are necessary in order to build on the management programs already in place at the interstate level. The amount of effort and the bycatch that continues in the commercial fisheries is extraordinary and especially concerning for stocks in decline or at low levels of abundance. Likewise, the discard mortality in the growing recreational fishery and lack of controls such as size and bag limits, particularly on the larger juveniles, is a concern. Though progress has been made— turtle excluder devices and BRDs are required in shrimp trawls, the long haul seine fishery has declined in participants, and gill nets have been much reduced in some areas as a result of Incidental Take Permits for Atlantic sturgeon and sea turtles—efforts to control substantive bycatch issues to date, particularly in the shrimp trawl fishery, are inadequate.

North Carolina's important, but rudimentary, nursery area program, illustrated in Figure 1, fails to consider and protect those areas in the estuarine and nearshore coastal waters where juveniles are abundant and need protection in order to develop into adults, and where habitat conditions are ideal for juvenile life stage development. Outside of the designated nursery areas of North Carolina, fish populations in Pamlico Sound and other estuarine areas are clearly comprised of larger juveniles that will soon put energy into reproductive growth for their first spawn (e.g., Casey and Zapf 2015). These largest juveniles have migrated out of the designated Primary and Secondary Nursery Areas located in the more upper and middle portion of the estuarine system to the middle and lower portions of the estuarine system and waters. Juveniles of species important to commercial and recreational fishermen dominate commercial and fishery-independent trawl catches. Fishes generally remain in these areas until they spawn or move to overwintering nursery areas offshore. The fact that extensive commercial and recreational fisheries are allowed in these critical areas compromises the ability of numerous fish stocks and forage species to rebuild.

It is counterproductive to protect the smallest juveniles that already face high natural mortality rates in the current nursery area and not continue that protection until these individuals actually contribute to the health of the population by spawning. The only difference between the limited areas currently defined as nursery habitat in North Carolina and the rest of North Carolina's estuarine and nearshore coastal ocean waters is the size of the juveniles encountered. Multiple sampling efforts in North Carolina, which include extensive trawl and gill net surveys, along with samples of recreational and commercial catches show a very large and variable preponderance of juvenile fishes throughout North Carolina waters. The survey grid for the Pamlico Sound Survey (Figure 2) is expansive and catches are almost exclusively juvenile fishes, in much the same area as the commercial shrimp trawl fishery operates (Figures 3 and 4). As juvenile fishes, "protected" in the current and geographically limited nursery areas grow in North

Carolina, their natural tendency is to move to the more open, higher salinity waters of larger sounds and bays. It is at this time that these fishes, fit enough to survive, are subjected to intense anthropomorphic sources of mortality in the form of shrimp trawls. In some circumstances, fishes with healthy abundance levels can withstand high levels of mortality and still produce a surplus. Such is not the case for most species of concern in North Carolina's estuaries. Consequently, all North Carolina inshore and nearshore waters are indeed nursery areas and should be afforded maximum protection. Doing so would allow the vulnerable species currently subjected to shrimp trawls the opportunity to spawn at least once.

Some might suggest that fishing mortality of juvenile fishes has a negligible impact on population viability and that those fishes would have likely died anyway. During various opportunities for public comment others suggest that bycatch provides a service to the ecosystem by providing needed food to the members of the system. However, diet studies of most predatory fishes indicate that these fishes are visually-oriented, opportunistic predators that focus on the weakest of the particular prey items for their meal, e.g., the survival of the fittest (*see* Mercer 1987 and Wenner et al. 1990 for review). With bycatch and discards the fittest are no more fit than the weakest, throwing the ecosystem off balance. Species that reportedly benefit from this "free lunch" do not appear to be benefiting as one might expect. For example, the North Carolina Marine Fisheries Commission recently revised their FMP schedule to update the blue crab FMP sooner than expected as a result of the fishery decline and concerns over the health of the stock. One might expect that if blue crab were a beneficiary of the significant bycatch in North Carolina fisheries, the stock would be viable. We are unaware of any positive link between bycatch in shrimp trawls and stock status.

Because absolute estimates of age-specific discard mortality are highly variable and difficult to quantify, some argue that the absence of this data in quantitative stock assessments lessens its importance or cautions against management actions. This conclusion is erroneous and dangerous, particularly when one reviews the stock status and landings history of many of the species that are particularly vulnerable to significant bycatch and discard mortality. Spot, Atlantic croaker, and weakfish all suffer from low trends in biomass and harvest (*see* ASMFC FMP citations above). During the shrimp trawl characterization study alone, during a time when all three of these key species were at low and declining abundance, the estimated number of discards from the shrimp trawl fishery was conservatively estimated at approaching ½ billion fish. This is despite the fact that shrimp trawl nets were outfitted with turtle excluder devices and BRDs (Brown 2015). The Atlantic croaker, spot, and weakfish stocks are highly productive and could provide tremendous access, opportunity, economic value, and ecosystem function if further protected.

This analysis focused on spot, Atlantic croaker, and weakfish, however, concern is not limited to those three species. The impacts on numerous other components of the ecosystem that succumb to pre-spawn mortality are likely in the same position, not to mention the disruption to the bottom structure and critical benthic communities resulting from fishing efforts. Other species of recreational and commercial importance taken in the North Carolina shrimp trawl fishery include kingfishes, pigfish, southern and summer flounder, and king and Spanish mackerel (Brown 2009, 2015).

The concept that first spawn fishes that may naturally spawn over a decade or more can somehow rebuild populations is outdated. The reproductive capacity of first spawn fishes is but a fraction of their true capacity (Lowerre-Barbieri et al. 1995, Nye et al. 2003). The fecundity, fitness, and survivability of the eggs of a virgin spawner simply cannot compare to the fecundity of their larger counterparts in the population. The more fecund, and presumably valuable, older fishes in the population are mostly absent from these populations today (see ASMFC annual reports on spot, Atlantic croaker, and weakfish for review, NC DMF MRIP data request 2016). Proper management should be implemented that allows for an expansion in the age structure of these populations, and thereby spawning stock biomass, by utilizing measures that allow these fishes to spawn at least once, and preferably twice, before any allowable harvest.

In summary, bycatch and discard mortality, along with the directed harvest, of juvenile and pre-spawn adult fishes in North Carolina is alarming. Current trawling practices lead to the discard of billions of juvenile fish each decade, decimating populations and seriously impacting local, fishery dependent economies and communities. Using only the data from 2014 in Brown (2015), when observer coverage was greatest and covered all seasons, the estimated discards of spot, Atlantic croaker, and weakfish from shrimp trawls was 15 million pounds of nearly all juvenile fish. For comparison, the commercial and recreational harvest of these three species in North Carolina in 2014 was 4.6 million pounds and greater than 50 percent were juvenile fishes. The coast wide commercial and recreational harvest of these three species, all designated as depleted or depressed, was 18.7 million pounds. The potential yield of these small fishes, if they were afforded the protection to grow to adulthood, is staggering: the benefits of protecting juvenile fish far outweigh the costs in terms of fishery yield and success for commercial and recreational fisheries alike. Furthermore, an expansion of the range of these fishes into other jurisdictions, which will come with further regulation of bycatch, is entirely consistent with the basic tenants of inter-jurisdictional fisheries management.

The commercial fishery in the estuarine waters of North Carolina has limited restrictions on extraordinary amounts of commercial gear. The health of both species that exclusively call North Carolina home and many inter-jurisdictional fisheries depends on the concerted conservation efforts of all.

VI. MANAGEMENT RECOMMENDATIONS

The need to substantially reduce discards in North Carolina fisheries cannot be overstated. While measures to date have helped, they have fallen short of meaningful changes in bycatch rates. Based on this review, the following recommendations are offered to measurably address this systemic problem in North Carolina. The recommendations are based on what is best for the long-term economic viability of these fish stocks. Closing the shrimp trawl fishery in North Carolina inshore and nearshore waters, as other states on the east coast have done, would be the most effective single strategy to protect important nursery areas and juvenile fishes. This solution, however, is unreasonable; thousands of North Carolinians rely on the commercial shrimp industry for their livelihood. These measures balance conservation goals with current fishing practices to mitigate the effects of bycatch mortality while still providing for a productive commercial and recreational fishery.

A. Designate all inshore and ocean (0-3 miles) waters as nursery habitat

Because these areas function as important nursery habitats, bycatch and mortality issues from the shrimp trawl fishery in estuarine waters is unique to North Carolina in the south Atlantic. Data collected by NC DMF regarding the occurrence of juvenile fishes in inside waters is adequate, appropriate, and clear to support nursery area designation for all inshore, estuarine and ocean waters (0-3 miles offshore). The preponderance of data regarding juvenile life stages of fishes in these programs illustrate that all inside waters serve as important locations where juvenile fishes feed and grow to maturity. Juvenile fish are defined here as fishes that have yet to spawn at least once. While some fishes may be harvested and possess mature gonads, if they are harvested prior to spawning, their contribution to the population is zero, threatening population stability and population growth. In fact, there is no evidence that any areas within the estuarine system of North Carolina do *not* function as a nursery area. These data, along with the Pamlico Sound survey and the decline of Atlantic croaker and spot in the south Atlantic, provide unequivocal support to the argument that the area functions as critical nursery habitat.

B. Implement strategies to reduce shrimp trawl bycatch of juvenile fishes in all designated nursery areas

Shrimp trawl bycatch, particularly in nursery areas, confound efforts to protect important inter-jurisdictional fishes. Although limited data are available to unequivocally prove the effectiveness of various strategies to reduce bycatch, the critical importance of such reductions is logical, particularly for species of concern. The only estuarine shrimp trawl fishery on the east coast exists in North Carolina; however, concerns related to its impact on fish stocks are enormous.

While no shrimp trawling in newly designated nursery areas would yield the best result biologically, if it is to continue, effort needs to be significantly reduced by employing the following suite of management strategies.

a. Reduce maximum headrope length in shrimp trawl fishery

First, reduce the maximum combined headrope length from 220 feet to 90 feet for all nets combined. Headrope length is a measure of the size of the shrimp trawl, with larger vessels tending to use larger nets to catch more shrimp. While improved efficiency and overall yield are the primary objectives, bycatch also increases. A reduction in the allowable headrope length is necessary to reduce effort, and subsequent bycatch in this fishery.

During the development of the original North Carolina Shrimp FMP (NC DMF 2006), the recognition of specific problems related to juvenile southern flounder bycatch resulted in rules to limit sensitive areas to trawling by closing some areas and limiting others to a 90 foot headrope maximum. The NC DMF points out in their plan (NC DMF 2006, p. 315) that headrope restrictions reduce bycatch and the fishing power of larger vessels. Further, no other south Atlantic or Gulf Coast state allows shrimp trawls over 60 feet in their jurisdictional waters. During the Brown (2015) study, maximum headrope lengths ranged from 220 to 240 feet. The average headrope length increased from 94 feet in 2012 to 134 feet in 2015. While this increase in headrope size may not be completely reflective of all fleet activities, the study reports these trips as representative of the fishery. These data also suggest that many vessels in the fleet already employ nets less than 90 feet, thereby mitigating the impacts of the proposed reduction. A 90 foot maximum headrope for all nets combined in all estuarine and nearshore ocean waters is recommended to reduce the bycatch of *all* fishes impacted by shrimp trawls.

b. Require the use of two bycatch reduction devices ("BRDs") on all shrimp trawls

Second, require the mandatory use of a second, federally certified BRD or device tested by DMF and certified to further reduce bycatch by at least 25 percent. Recent studies by NC DMF, pursuant to Amendment 1 to the N.C. Shrimp FMP (NC DMF 2015), indicate that a second Florida Fish Eye BRD placed next to the currently required single BRD shows great promise in further reducing bycatch in the brown shrimp fishery while limiting shrimp loss. The N.C. Marine Fisheries Commission ("MFC") contemplated the requirement of a second BRD in Amendment 1. The MFC should require the use of a second BRD with documented, additional bycatch reduction.

c. Limit tow times to 45 minutes

Third, limit tow times to 45 minutes. Reducing tow times to a maximum of 45 minutes would reduce bycatch, culling time, and discard mortality. Logothetis and McCuiston (2006) reported that survivability of bycatch increased with reduced culling time. Shorter tow times generally mean less catch and shorter culling time. This regulation is especially important in light of rapidly increasing tow times in recent years: Brown (2015) reported an increase in average tow times over his study period from 100 minutes in 2012, 142 minutes in 2013, 187 minutes in 2014, and 181 minutes in 2015. Maximum tow times likewise increased from 240 minutes in 2012 to 360 minutes in 2015.

d. Limit shrimp trawl effort to three days per week, during daylight hours only

Fourth, limit all shrimp trawl effort to three days per week during daylight hours only. Fishermen are known to fish harder in the wake of restrictions to make up for lost opportunities due to measures such as tow times and reduced net size. A limit of three days per week of trawling during daylight hours would significantly reduce attempts at fishing harder and allow some fishes to move out of trawling areas or recover from encounters during open days. Lay days may also serve to limit the number of out of state vessels that may travel to North Carolina in order to participate in this unique estuarine fishery.

This time restriction would both reduce bycatch and improve the efficiency of the shrimp trawl industry. Finfish bycatch is significantly higher at night while shrimp catches are higher during the day (Ingraham 2003). Additionally, Johnson (2003) reported that far more shrimp are taken early in a fishing week than later (cited in NC DMF 2015).

Brunswick County provides a template for success: it is currently unlawful to shrimp during nighttime hours in the ocean off Brunswick County. This rule was implemented to reduce bycatch (NC DMF 2015). The current restrictions off of Brunswick County should be expanded to all estuarine and coastal waters of North Carolina.

e. Delay the opening of shrimp season

Seasonal openings should be based on a shrimp count size. Delaying the harvest season until shrimp are larger provides not only a more valuable product to the industry, but reduces the length of the season when gear is in the water, thereby reducing bycatch. While determining count size for all North Carolina waters is impractical, delaying harvest in Pamlico Sound until shrimp count reaches 60 shrimp per pound (heads on) is prudent and reduces concerns from fishermen and dealers that shrimp are either too small or that bycatch is too high when the fishery traditionally opens in early to mid-May.

These five actions must be implemented together in order to achieve the desired effect of meaningful bycatch reduction in the shrimp trawl fishery. While it is beyond our ability to determine, or even speculate, on the absolute reductions that would be realized by taking this course of action, it is a step in the right direction and would measurably reduce bycatch in our judgment.

f. Establish size limits and bag limits for spot and Atlantic croaker

In the event North Carolina makes these important changes in the shrimp trawl fishery, the abundance and subsequent encounters with juvenile fishes in other fisheries should dramatically increase. Hilborn and Walters (1992) point out the need to allow fish to grow to a reasonable size before they are harvested. Size limits developed to delay harvest to allow juvenile fish to spawn at least once has been a common sense management approach used for decades. The fishery management plans of the ASMFC, federal Councils, and North Carolina are replete with examples of the impacts, not only on increasing spawning stock biomass, but yield per recruit as well. We recommend strategies to reduce this potential increase in the bycatch of juvenile and pre-spawn adult fishes in all fisheries. Many of the species of concern in North Carolina and coast wide either have no size limits or size limits have proven to be ineffective. This is certainly the case for Atlantic croaker and spot. An 8 inch size limit for spot and a 10 inch size limit for Atlantic croaker in all North Carolina fisheries are slightly below the L100% for these two species and would allow nearly all fish to reach maturity and spawn at least once. An alternative to size limits in the higher volume commercial fisheries could be changes to mesh sizes in primary gears such as gill nets and trawls to minimize interactions altogether in those fisheries. The positive impacts in terms of increased spawning stock biomass and yield to the fishery would be enormous and go a long way towards sustainable fishing in the future.

VII. CONCLUSION

The only difference between the limited areas currently defined as nursery habitat in North Carolina and the rest of North Carolina's estuarine and nearshore coastal ocean waters is the size of the juveniles encountered. The majority of fishes in the unprotected areas of North Carolina's estuarine and nearshore waters are juveniles, have not yet reached maturity, and therefore have not yet reproduced and contributed to the population. It makes no sense to protect the smallest juveniles that already face high natural mortality rates in the current nursery area and not continue that protection until they actually contribute to the health of the population by spawning at least once.

Spot, Atlantic croaker, and weakfish were critical components of North Carolina's estuarine commercial and recreational fisheries prior to their dramatic decline in the fisheries late 1980s.

The combined landings of these three species in the commercial fishery in 1981 were 37.6 million pounds. In 2015, commercial landings were 2.3 million pounds, a 95 percent decline. A similar trend is observed in the recreational fishery when, in 1981, recreational landings were 5.3 million pounds compared to 1.6 million pounds in 2015, a 70 percent decline.

During the 2014 season, 149 of the 8,670 (1.72 percent) reported shrimping days in the estuary and ocean waters were observed. Spot, Atlantic croaker, and weakfish accounted for 268,116 pounds of the 415,283 total pounds, or 65 percent, of catch observed, including shrimp. Expansion of these observed numbers to the total estimated catch of the shrimp trawl fishery in 2014 yields 15.6 million pounds of spot, Atlantic croaker, and weakfish, primarily juveniles, discarded as bycatch by shrimp trawlers. This level of bycatch is four times the combined commercial and recreational harvest in North Carolina (3.9 million pounds) and nearing the coast wide harvest of all three species in 2014 (18.7 million pounds).

This goal of sustainable and healthy fisheries is severely compromised by the magnitude of juvenile mortality that occurs in North Carolina fisheries. The fact that North Carolina remains the lone state to allow shrimp trawl activity in coastal and estuarine nursery areas provides a common denominator that may explain the dramatic shift in landings from the south Atlantic to the mid-Atlantic region. The current boom or bust cycle in our fisheries will persist with longer gaps between boom years unless measures are taken to reduce juvenile mortality and improve spawning stock biomass.

Sound science points to shrimp trawl bycatch, despite efforts to reduce it, as the primary factor that is impacting North Carolina's fisheries. Measures taken to date to reduce shrimp trawl bycatch in North Carolina have skirted around the edges of a complex problem. The data provided in the North Carolina Shrimp FMP and Amendment I clearly indicate that the magnitude of shrimp trawl bycatch is significant and impacts to fish populations are concerning. The North Carolina Shrimp FMP (NC DMF 2015) states that it is commonly known that harvesting a fish before it matures and spawns can lead to recruitment overfishing and impair the stock's ability to sustain itself. Further, harvesting a fish before it reaches some optimal size leads to growth overfishing and reduced overall yield from the fishery. Measureable improvements in North Carolina fisheries and the fragile ecosystems they rely on for food, protection, growth, and reproduction will languish until shrimp trawl bycatch is properly addressed.

Figure 1. Nursery area map, with locations of the various nursery area locations for estuarine waters of North Carolina. The N.C. Marine Fisheries Commission prohibits trawling in primary nursery areas, however, the mesh sizes and size constraints of these areas preclude significant activity or potential juvenile fish mortality. Further, the fishes utilizing these areas are typically far too small to be retained in traditional shrimping gear. Consequently, we argue that the nursery area protections are far more habitat-related than fisheries-resources related.

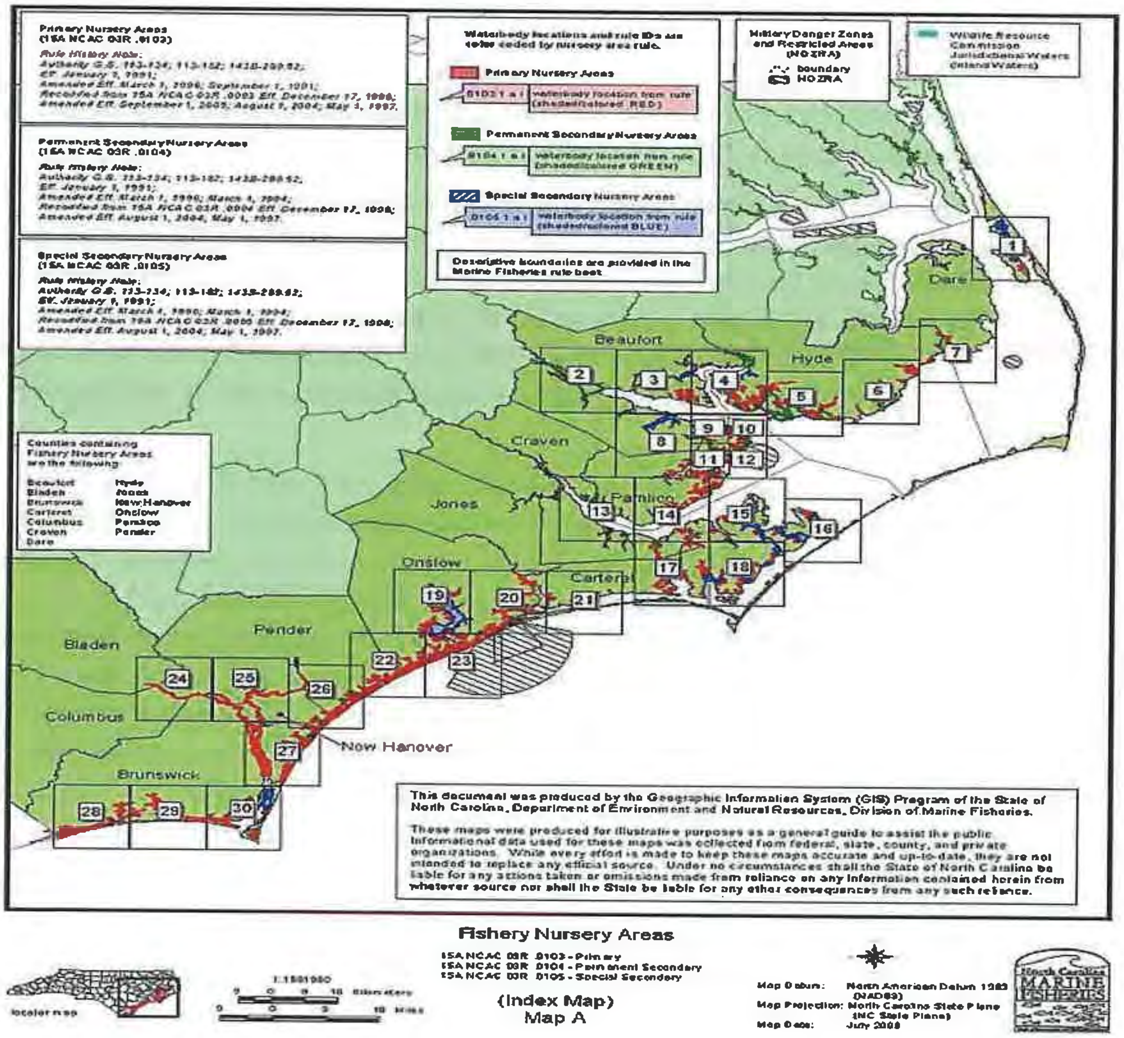


Figure 2. Randomized sample locations of the Pamlico Sound survey are obtained from areas outside of any of the designated nursery areas. With few exceptions, these areas are subjected to intense fishing pressure by all sectors of the fishery, including trawls, long haul seines, gill nets, and hook and line, all of which harvest and/or discard substantial quantities of juveniles fishes.

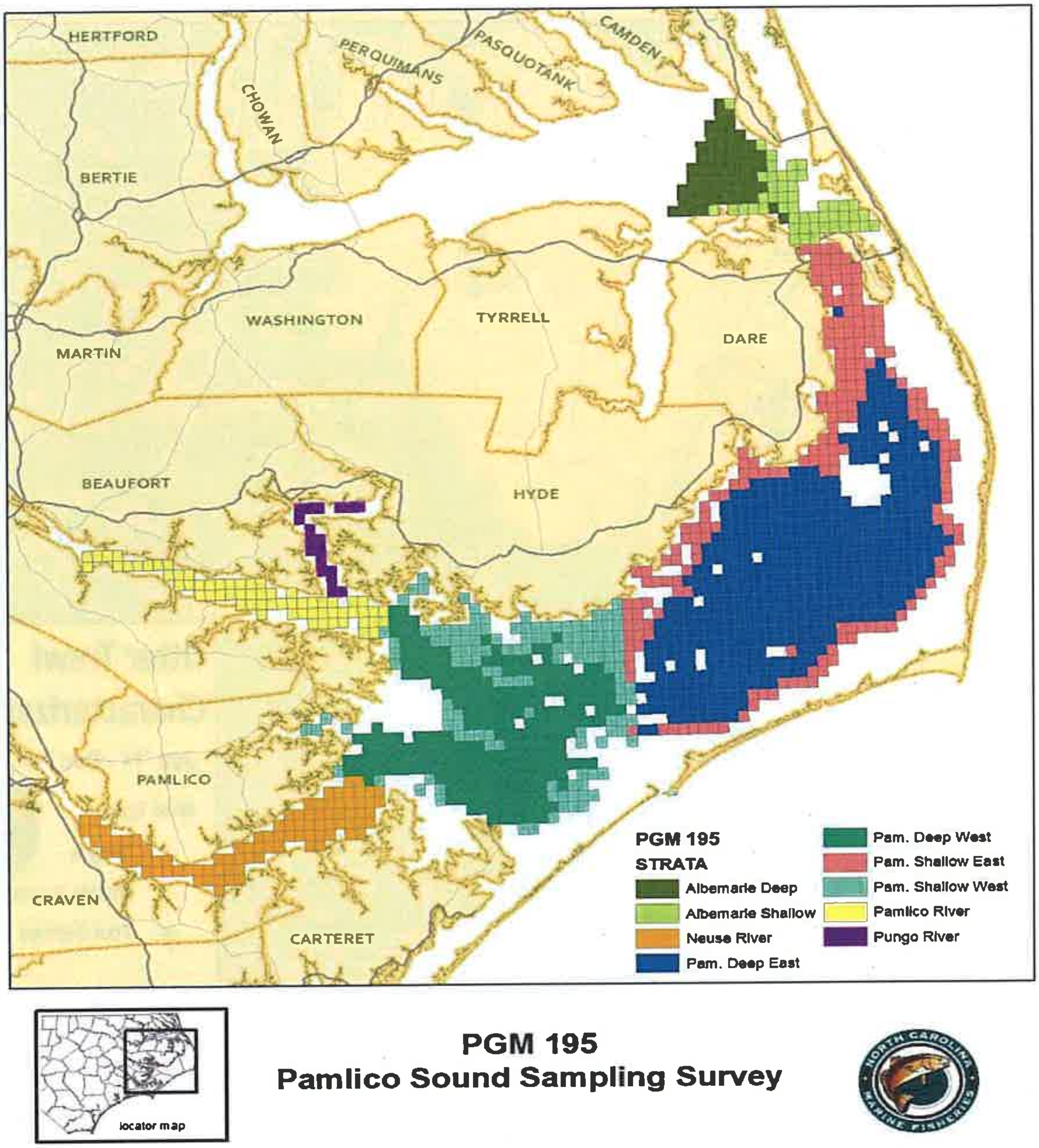


Figure 3. Location of commercial shrimp trawl observations made in northern North Carolina, January–December 2014 (Brown 2015).

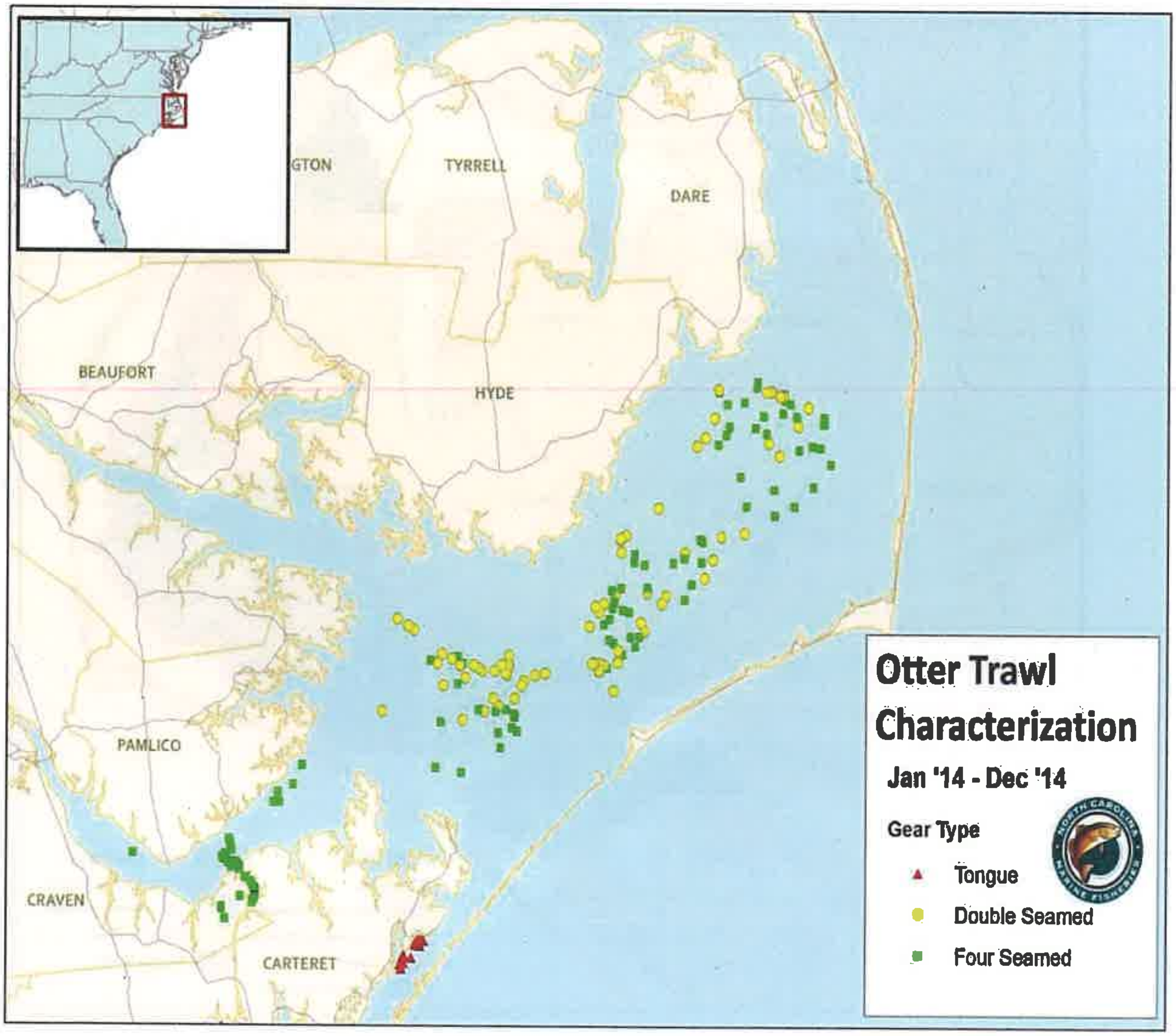
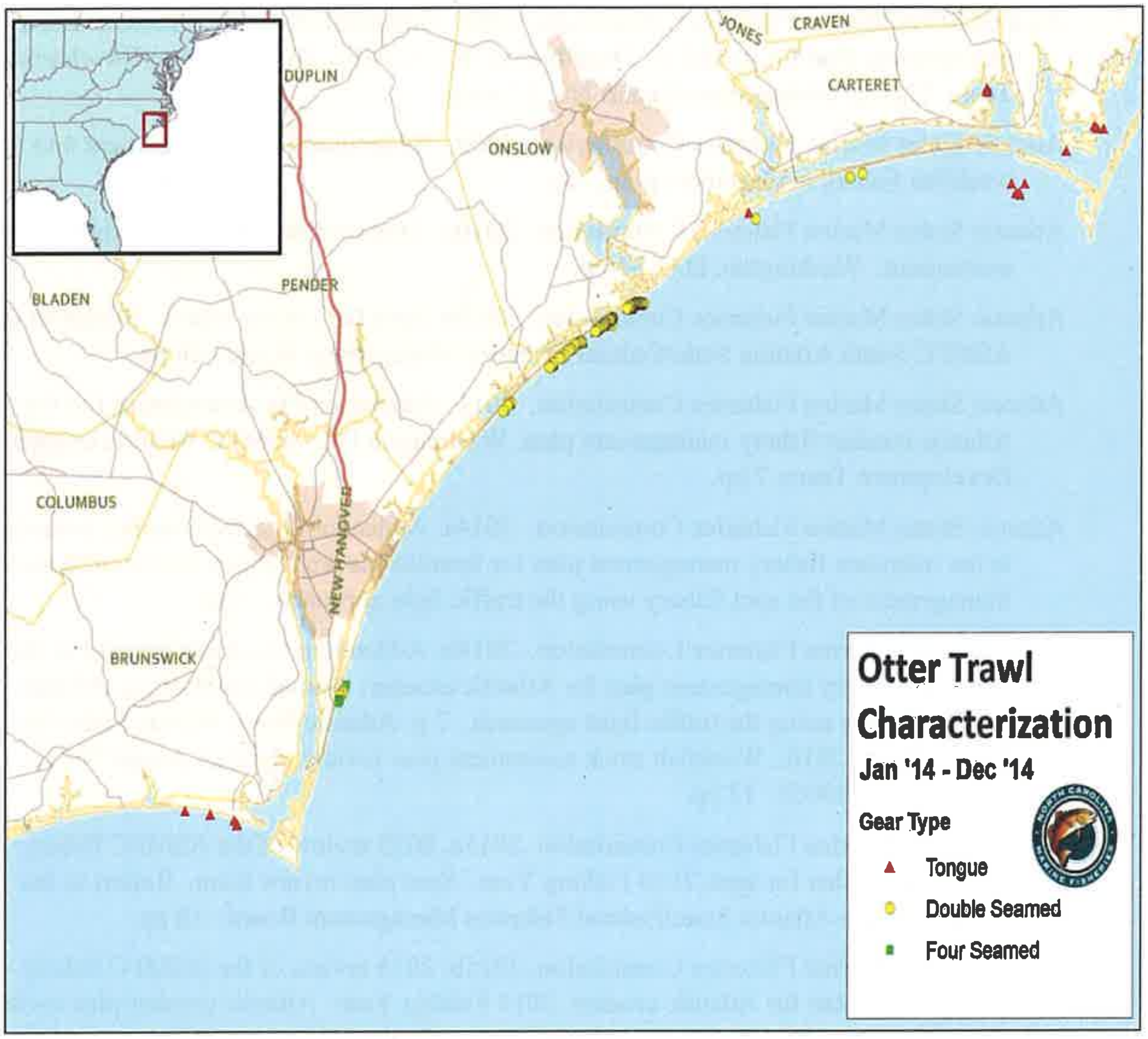


Figure 4. Location of commercial shrimp trawl observations made in southern North Carolina, January–December 2014 (Brown 2015).



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EMPLOYMENT HISTORY:

2014-2016 Consultant to the Coastal Conservation Commission and other organizations. Monitor activities of the Atlantic States Marine Fisheries Commission.

2012-2014 Commissioner, Virginia Marine Resources Commission. Served as Agency Head and Chairman of the Agency's dual regulatory board. Directed the work of four Divisions, consisting of 160 employees: Fisheries Management, Habitat Management, Law Enforcement (Virginia Marine Police), and Administration and Finance. Responsible for an annual agency budget of $23 million.

2006-2012 Chief Deputy Commissioner, Virginia Marine Resources Commission. Served as second in command of the agency. Advised the Commissioner and Regulatory Board on agency policies and programs. Provided policy guidance to the Division Chiefs.

1984-2012 Chief, Fisheries Management Division, Virginia Marine Resources Commission. Directed the Fisheries Management Division of the Agency. Provided fishery management guidance to the Regulatory Board. Directed the collection and analysis of scientific, biological, economic and sociological information pertaining to Virginia fisheries. Supervised departments pertaining to fishery planning and statistics, fishery management plan development, shellfish conservation and replenishment, artificial reef construction

	and the promotion of recreational fisheries. Served as the agency's representative to the Atlantic States Marine Fisheries Commission and the Mid-Atlantic Fishery management Council.
1982-1984	Fisheries Manager, Head of the Department of Fisheries Plans and Statistics, Virginia Marine Resources Commission. Investigated and reported on the conditions of Virginia's commercial and recreational fisheries. Recommended regulatory options for the conservation and management of Virginia's fisheries to the agency regulatory board. Served as the agency alternate to the ASMFC and MAFMC.
1981-1982	Fisheries Liaison Officer, Virginia Marine Resources Commission. Served as agency alternate to the MAFMC. Investigated and reported to the Commissioner on special fishery issues.

AWARDS AND COMMENDATIONS

2003, Captain David H. Hart Award of the Atlantic States Marine Fisheries Commission, for outstanding leadership and contributions to the management of Atlantic coastal fisheries.

2009, Commander's Award for Public Service, Department of the Army. For outstanding effort and dedication while serving on the Management Team for the production of the Chesapeake Bay Oyster Programmatic Environmental Impact Statement.

2011, Conservation Award, Tidewater Chapter, American Fisheries Society.

2012, Ricks E. Savage Award of the Mid-Atlantic Fishery Management Council, for positive influence and contributions to the conservation and management of mid-Atlantic fisheries.

EXHIBIT D

CURRICULUM VITAE

LOUIS BROADDUS DANIEL, III

Current Address: 1705 Lennoxville Road, Apt 10, Beaufort, North Carolina 28516

Telephone: 252-342-1478

Email: *sciaenops1@gmail.com*

Education:

College of William and Mary, School of Marine Science, Virginia Institute of Marine Science, Gloucester Point, Virginia, Ph.D., Marine Science, Graduated 1995.

College of Charleston, Charleston Higher Education Consortium, Charleston, South Carolina, M.S., Marine Biology, Graduated 1988.

Wake Forest University, Winston-Salem, North Carolina, B.A., Biology, Graduated 1985.

Employment History:

June 2016 to present
Position: Marine Scientist
Description: Serve as marine scientist for the North Carolina Wildlife Federation's Sound Solutions program. Develop issue papers and technical responses for fisheries management issues.
Supervisor: Tim Gestwicki
Employer: North Carolina Wildlife Federation

June 2016 to present
Position: Special Projects
Description: Develop and implement plan for engagement of the Atlantic States Marine Fisheries Commission into aquaculture efforts. Develop RFPs and review proposals for funding. Serve as technical monitor for funded projects. Develop issue papers and technical responses for fisheries management issues at the request of the Executive Director.
Supervisor: Bob Beal
Employer: Atlantic States Marine Fisheries Commission

January 2016 to present
Position: Adjunct Professor
Description: Developed a marine resources policy and management curriculum for the sea semester at the NC State Center for Marine Sciences and Technology.
Supervisor: Dave Eggleston
Employer: North Carolina State University

March 2016 to June 2016
Position: Assistant Section Chief, Shellfish Sanitation
Description: Transitioned out of Director role, assisting section in day to day operations and sampling programs. Developed good understanding of general program requirements.
Supervisor: Shannon Jenkins
Employer: North Carolina Division of Marine Fisheries

February 2007 to March 2016

Position: Director of the North Carolina Division of Marine Fisheries

Description: Represent North Carolina on the ASMFC that oversees the management of fisheries resources along the Atlantic coast. Implement the North Carolina Fisheries Reform Act, Coastal Recreational Fishing License, Waterfront Access and Marine Industry Fund. Coordinate the development of Fishery Management Plans and Coastal Habitat Protection Plan. Responsible for management of Marine Fisheries headquarters and 5 field office with nearly 300 staff in 8 sections including Marine Patrol and a $30+ million budget.

Supervisor: Secretary Donald van deer Vaart

Employer: North Carolina Division of Marine Fisheries

February 1998 to 2007

Position: Executive Assistant for Councils

Description: Represent North Carolina on the South Atlantic Fishery Management Council that oversees the management of fisheries resources in the south Atlantic EEZ. Assist the Fisheries Director in implementation of the North Carolina Fisheries Reform Act and serve as a technical advisor to the North Carolina Marine Fisheries Commission (NCMFC). Coordinate the development of Fishery Management Plans. Write and present numerous technical issue papers for action by the NCMFC and Joint Legislative Committee on Seafood and Aquaculture. Serve as the North Carolina representative on several ASMFC management boards.

Supervisor: Preston P. Pate, Jr.

Employer: North Carolina Division of Marine Fisheries

April 1995 to February 1998

Position: Marine Fisheries Biologist Supervisor

Description: Supervise 5 biologists and 5 technicians in various studies on North Carolina finfish and shellfish fisheries (i.e., long haul seine, otter trawl, gill net, pound net), bycatch reduction, and the population dynamics of important commercial and recreational fish species. Serve as the North Carolina representative on numerous ASMFC and SAFMC technical committees, stock assessment subcommittees, and plan development teams. Serve as the Chairman of the North Carolina Division of Marine Fisheries Biological Review Team, whose purpose is to review all biological activities performed by the Division.

Supervisor: David L. Taylor

Employer: North Carolina Division of Marine Fisheries

Selected Presentations, Reports, and Publications:

Hildebrand et. al. 2016. Shrimp Trawl petition for rulemaking to the North Carolina Marine Fisheries Commission.

Daniel and Travelstead. 2016. Technical review of issues related to the NC shrimp trawl petition.

From 2002-2016, prepared, edited, and reviewed approximately 40 fishery management plans, amendments, and supplements for public hearings and recommendations to the Marine Fisheries Commission.

From 2002-2016 have given numerous presentations to academic, public, and legislative gatherings related to the management of marine fisheries.

Daniel, L.B., III. 2002. North Carolina Interjurisdictional Fisheries Management Plan. North Carolina Division of Marine Fisheries, Morehead City, NC 28557.

Daniel, L.B., III and Lee Parramore (with Plan Development Team). 2001. North Carolina Red Drum Fisheries Management Plan. North Carolina Division of Marine Fisheries, Morehead City, NC 28557.

Daniel, L.B., III and J.L. Armstrong. 2000. Reproductive ecology of selected marine recreational fishes in North Carolina: weakfish, *Cynoscion regalis.* Completion Report Grant F-60. North Carolina Division of Marine Fisheries, Morehead City, NC 28557.

Vaughan, D.S., L.B. Daniel, and R.W. Gregory. 1998. Assessing Weakfish Using Biased Historical ageing Data. 1998 Annual Meeting of the American Fisheries Society, Hartford Connecticut.

Daniel, L.B. 1997. Moderator and speaker for a symposium on the North Carolina weakfish fishery and its management. Tidewater Chapter, American Fisheries Society, Beaufort, North Carolina.

Daniel, L.B., III. 1995. Spawning and Ecology of early life stages of black drum, *Pogonias cromis*, in lower Chesapeake Bay. Ph.D. Dissertation, College of William and Mary, Williamsburg, VA., 167p.

Daniel, L.B.,III and J.E. Graves. 1994. Morphometric and genetic identification of eggs of spring spawning sciaenids in lower Chesapeake Bay. Fish. Bull. U.S. 92(2): 254-261.

Daniel, L.B. 1992. Reproductive ecology and the fate of the spawning products of black drum, Pogonias cromis, in lower Chesapeake Bay. 72nd Annual Meeting, ASIH, Champaign-Urbanna, Illinois

Olney, J.E. and L.B. Daniel, III. 1992. Spawning and recruitment of black drum, Pogonias cromis, in lower Chesapeake Bay. Final Report. Va. Mar. Res. Co., U.S. Fish and Wildlife F-95-R.

Wenner, C.A., W.A. Roumillat, J.E. Moran, Jr., M.B. Maddox, L.B. Daniel,III and J.W. Smith. 1990. Investigations on the life history and population dynamics of marine recreational fishes in South Carolina: part 1. Mar. Resources Res. Inst., Charleston, S.C.

Daniel, L.B. 1990. Aspects of the early life history of red drum, Sciaenops ocellatus, in South Carolina. 14th Larval Fish Conference, Early Life History Section, American Fisheries Society, Beaufort, North Carolina.

Daniel, L.B., III. 1988. Aspects of the biology of juvenile red drum, Sciaenops ocellatus, and spotted seatrout, Cynoscion nebulosus (Pisces: Sciaenidae) in South Carolina. M.S. Thesis, College of Charleston, Charleston, S.C., 58p.

Daniel, L.B. 1987. Aspects of the early life history of the spotted seatrout, Cynoscion nebulosus, in South Carolina. 67th Annual Meeting, ASIH, Albany, New York.

Field Experience:

January 2016 to present

Conduct various field trips for students, staff, and others. Mostly small boat, fishing and tours.

March 1998 to June 2016

Participated in various aspects of division operations as needed and available. Lead or participated in various field trip exercises for legislative members and staff.

April 1995 to February 1998

Supervise and assist in sampling programs including a juvenile trawl survey, seine survey for juvenile red drum, fishery dependent port and on-water surveys, gear development, shrimp sampling, by-catch reduction, and tagging studies.

1989 to 1991

Chief scientist on 20 cruises aboard the R/V Bay Eagle to sample ichthyoplankton using an in situ silhouette photography system.

1986 to 1988

Participated in weekly rotenone, stop net, trammel net and gill net collections for juvenile and adult inshore recreational fishes in South Carolina. Extensive small (<25 ft.) boat use.

Selected Awards and Professional Offices:

2011-2015

Chairman and vice-Chairman of Atlantic States Marine Fisheries Commission

2002-2006

Chairman and vice-Chairman of the South Atlantic Fishery Management Council

1998 to 2007

North Carolina representative on South Atlantic Fishery Management Council.

1998 to 2016

North Carolina representative on Atlantic States Marine Fisheries Commission Management Boards (Weakfish (Chairman 2003-2006), Coastal Sharks, Horseshoe Crabs, South Atlantic Board (Chairman 1999-2002)).

2002 to 2007

North Carolina representative on the National Marine Fisheries Service Highly Migratory Species Advisory Panel.

2000

DENR Distinguished Service Award

1995

USFWS Outstanding Service Award

1997 to Present

Adjunct Assistant Professor with the University of North Carolina at Chapel Hill, Institute of Marine Science.

2003 to Present

Adjunct Assistant Professor with North Carolina State University. Developed and taught Marine Resources Management and Policy (ES 295-2) during spring 2016.

1998 to 2007

Chairman of the North Carolina DMF Management Review Team

1995 to 1998

North Carolina Division of Marine Fisheries (NCDMF) representative on the ASMFC weakfish technical (Chairman) and stock assessment committees, bluefish technical and stock assessment committees and alternate for Science and Statistics Committee. Member of SAFMC Science and Statistics Committee, Bycatch Reduction Subcommittee, and Red Drum Assessment Committee.

1995 to 1998

Chairman of the North Carolina Division of Marine Fisheries Biological Review Team.

1998 to 2003

South Atlantic Representative on MARFIN Panel

Selected References:

Mr. Robert Beal
Executive Director
Atlantic States Marine Fisheries Commission
1050 N. Highland Street
Suite 200 A-N
Arlington Virginia 22201
(703) 842-0741

Gregg Waugh
Executive Director
South Atlantic Fishery Management Council
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405
(843) 571-4366

Mr. Tim Gestwicki
Executive Director
North Carolina Wildlife Federation
1346 St Julien Street
Charlotte, NC 28502
(704) 332-5696

EXHIBIT E

TECHNICAL REVIEW: THE NEED TO REDUCE FISHING MORTALITY AND BYCATCH OF JUVENILE FISH IN NORTH CAROLINA'S ESTUARIES

Prepared by Dr. Luiz Barbieri

Submitted to the North Carolina Marine Fisheries Commission

November 2, 2016

I. INTRODUCTION

The recreational and commercial fisheries in the state of North Carolina play an important role in the state's economy and culture, supporting a multi-million-dollar industry. Unfortunately, these fisheries have been facing increasing stressors caused by habitat alteration, juvenile bycatch, high levels of discards, and the effects of climate change. Given the recurrent concerns regarding population status and decreased fisheries landings for economically important species such as Atlantic croaker, spot, and weakfish (ASMFC 2010, 2015, 2016), a critical review of the factors contributing to long-term fisheries sustainability and population health is warranted. However, the problems caused by high levels of juvenile bycatch and nursery habitat alteration go beyond just these species. Even species that are not directly impacted by these stressors are likely affected by the removal of a substantial proportion of their prey biomass and the emergence of other ecosystem-level impacts (Hall 1999).

In North Carolina, the lack of sufficient nursery habitat protection and the need for a more rigorous and scientifically-informed process for protection of habitats not only for very early life stages (e.g., eggs, larvae, and post-settlement early juveniles) but also for juveniles, sub-adults, and first-time spawners is clear. From a fisheries management perspective, the problem of juvenile bycatch is a major impediment to sound practice, primarily because the magnitude of discards is not usually recorded and, therefore, not properly incorporated in fisheries stock assessments. Since most fisheries assessment methods rely on catch data for their operation, the uncertainty associated with unknown levels of bycatch can be enormous. Indeed, the problems are so great that some assessment scientists feel that without proper integration of bycatch mortality, the data used to conduct assessments is of questionable utility (Hall 1999, Walters and Martell 2004). From a practical perspective, this means that the true condition of croaker, spot, and weakfish stocks is likely to be even worse than we know because a significant source of mortality is not properly accounted for.

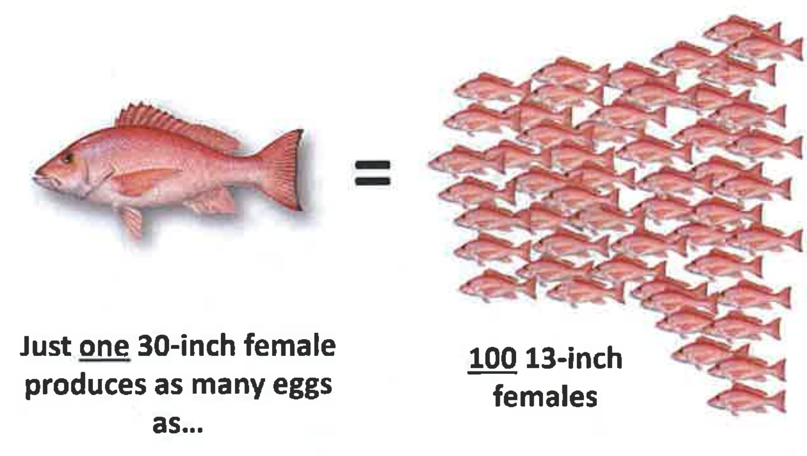
On many grounds, therefore, finding solutions to the high discard and bycatch problem is highly desirable by many sectors of the fisheries that depend on the long-term sustainability of fisheries resources. This paper provides a summary technical review of *how* and *why* a more comprehensive and inclusive designation of nursery habitat in North Carolina estuarine waters would greatly benefit not just the greater Pamlico Sound ecosystem but the many fisheries that depend on its productivity and health.

II. SCIENTIFIC DEFINITION OF "JUVENILE" AND "ADULT" FISH

In the scientific literature that deals with fisheries biology, the term "juvenile" is used to designate the young and relatively small individuals in the population that have not yet reached sexual maturity and therefore are not capable of spawning—i.e., they have not yet developed active reproductive organs such as ovaries and testes. It follows from this that individuals in the population reach "adulthood" (i.e., turn into adults) when they become sexually mature and are capable of reproducing (Lowerre-Barbieri 2009, Brown-Peterson et al. 2011).

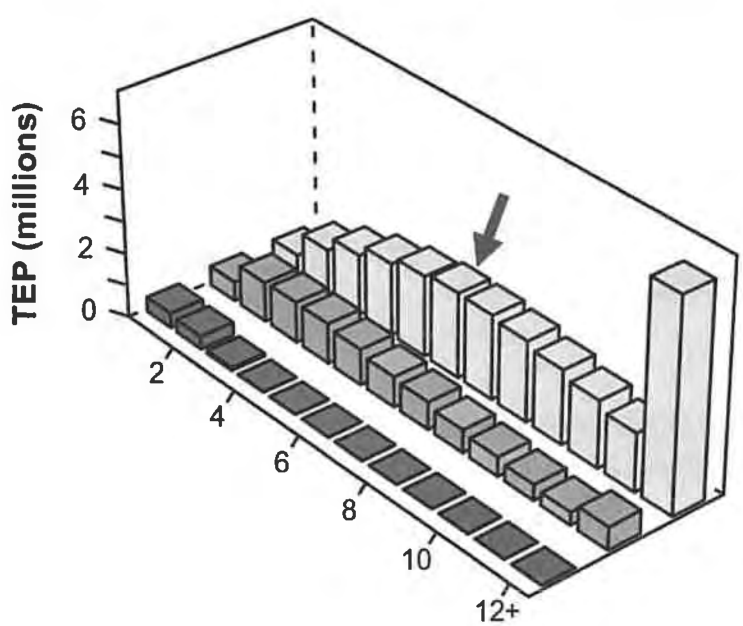
Some species reach sexual maturity relatively early in life (e.g., in weeks, months, or one year), while others can take from a few years to decades to become sexually active (Stearns 1992, Lowerre-Barbieri, 2009). The specific reproductive strategy utilized by each individual species results from evolutionary processes and selective pressures that take place over millions of years (Stearns 1992, Lowerre-Barbieri 2009, Brown-Peterson et al. 2011, Lowerre-Barbieri et al. 2011, Lowerre-Barbieri et al. 2016). For example, common species found in North Carolina estuaries such as Atlantic croaker, weakfish, and spot mature relatively early in life. About 50 percent of individuals are sexually mature at age 1, and 80 to 90 percent are mature by age 2 (Barbieri et al. 1994a, Lowerre-Barbieri et al. 1996). However, first time spawners—females just reaching sexual maturity and spawning for the first time—have significantly lower fecundity and, therefore, much lower reproductive value than larger, older females (Stearns 1992, Lowerre-Barbieri 2009, Lowerre-Barbieri et al. 1998, Lowerre-Barbieri et al. 2016). Here the term "reproductive value" is used to denote higher reproductive capacity, usually measured by higher fecundity, higher egg quality, and the production of better fit larvae that have a higher probability of survival (Stearns 1992, Berkeley et al. 2004, Lowerre-Barbieri et al. 2016). The consequence is that by killing large numbers of juvenile, sexually immature, or even first time spawners, bycatch and discard mortality in North Carolina estuaries is likely to be severely impacting the egg production and reproductive capacity of these stocks. How does this work?

The example in the graphic below illustrates the concept of "size, age, and reproductive value" for red snapper, another important commercial and recreational fisheries species in the southeastern United States. Since body weight increases as a power function of fish length, the egg production of larger, older females is disproportionally larger than that of smaller, younger females (Berkeley et la. 2004, Hixon et al. 2014). The results are astonishing. Just one 30-inch female red snapper can produce as many eggs as 100 13-inch females (Porch *et al.* 2015).



Further, the idea of relying on first time spawners to maintain a population's egg production and reproductive capacity is completely flawed and without scientific support (Cooper et al. 2013, Hixon et al. 2014, Lowerre-Barbieri et al. 2015). As seen in the red snapper example above, the reproductive capacity of first time spawners is exponentially lower than that of older females. A growing body of fisheries research shows that big, old, fat, fertile female fish—what scientists call BOFFFF's—are critically important to sustainable management of marine fisheries because their reproductive capacity is so large (Hixon et al. 2014). BOFFFF's are so vital because they produce a higher quantity of larger eggs that have a better chance of developing into larvae that can withstand environmental impacts and other threats (Berkeley et al. 2004, Hixon et al. 2014). BOFFFF's also tend to have longer spawning sessions, may spawn in a wider range of locations than smaller fish, and are more likely to survive bad years, reproducing feverishly when conditions improve (Cooper et al. 2013, Hixon et al. 2014). Since smaller females are also more susceptible to predation they are usually more restricted to safer habitats and thus different food supplies (Hixon et al. 2014). Smaller, younger females must also devote more energy to growth than larger females, which can devote more energy to reproduction (Stearns 1992, Cooper et al. 2013, Hixon et al. 2014, Lowerre-Barbieri et al. 2015, 2016).

Another example of the importance of letting enough fish mature, grow, and age to achieve their maximum reproductive potential can be found in the spotted seatrout (speckled trout), a close cousin to the weakfish or gray trout. A recently published study (Cooper et al. 2013) looked at the effect of age truncation and size-dependent timing on the spawning potential of spotted seatrout. In the fisheries biology scientific literature, the term "age truncation" means the removal of older age classes, leaving the population "juvenesced," or lacking the larger, older fish that produce the most eggs. Size-dependent timing of spawning means that females of different sizes (and presumably different ages) spawn at different time intervals during the



spawning season. The results of the Cooper et al. (2013) study are consistent with the pattern shown by red snapper: larger, older females were reported to have disproportionally larger total egg production (TEP) than their smaller, younger counterparts (Lowerre-Barbieri et al. 2015, Porch et al. 2015). The graph above shows the estimated TEP of spotted seatrout by age for different fishing mortality regimes: the light gray bars indicate stocks under no fishing pressure; the middle, a bit darker gray bars show results under a moderate level of fishing mortality; and the darker gray bars represent stocks under a relatively high level of fishing mortality. First, it is clearly noticeable that fish under no fishing pressure reach maximum TEP between the ages of five and seven years (red arrow) (Cooper et al. 2013). As seatrout stocks are subject to higher fishing mortality, fewer of the older fish survive and the population's egg production becomes progressively more dependent on younger females that, as shown above, have much lower reproductive capacity.

III. THE IMPORTANCE OF HABITAT PROTECTION FOR JUVENILE FISH

The nursery-role concept was first applied nearly a century ago to motile invertebrates and fishes with complex life cycles, in which larvae are transported to estuaries, metamorphose, grow to sub-adult stages, and then move to adult habitats offshore (Heck and Crowder, 1991). Some scientists trace this idea to work done between the early to mid-1900s on blue crabs, shrimp, and several finfish species (Beck et al. 2001). The concept became so pervasive that from a fisheries ecology perspective it has been termed a "law." For example, Deegan (1993) states that "estuarine fish faunas around the world are dominated in numbers and abundance by species which move into the estuary as larvae, accumulate biomass, and then move offshore."

Nearshore estuarine ecosystems—e.g., seagrass meadows, marshes, and mangrove forests—serve many important functions in coastal waters. Most notably, they have extremely high primary and secondary productivity and support a great abundance and diversity of fish and invertebrates. Because of their effects on the diversity and productivity of macrofauna, these estuarine and marine ecosystems are often referred to as nurseries in numerous papers, textbooks, and government-sponsored reports (Beck et al. 2001, Able 2005). The underlying premise of most studies that examine nursery-role concepts is that some nearshore, juvenile habitats contribute disproportionally to the production of individuals that recruit to adult populations (Heck and Crowder 1991, Beck et al. 2001, Able 2005). Therefore, the ecological processes operating in nursery habitats, as compared with other habitats, support greater contributions to adult recruitment (Beck et al. 2001). Indeed, the role of these nearshore ecosystems as nurseries is an established ecological concept accepted by scientists, conservation groups, managers, and the public, and is cited as justification for the protection and conservation of these areas (Able 2005).

IV. REVIEW OF NORTH CAROLINA'S NURSERY AREA PROGRAM

North Carolina regulations define "nursery areas" as "those areas in which for reasons such as food, cover, bottom type, salinity, temperature and other factors, young finfish and crustaceans spend the major portion of their initial growing season." 15A N.C. Admin. Code 3I.0101. Nursery areas in North Carolina are categorized based on various stages of juvenile development and life history strategy. The map below (Fig. 1) provides the locations of the various nursery areas mapped for estuarine waters of North Carolina, which includes a very small fraction of the vast estuarine habitats of the state. For fisheries management purposes these areas are designated as:

(1) Primary Nursery Areas (PNAs), which are those areas of the estuarine system where initial post-larval development takes place. These areas are located in the uppermost sections of a system where populations are uniformly very early juveniles. 15A N.C. Admin. Code 3I.0101. Since 1978, PNAs have been designated by the N.C. Marine Fisheries Commission to protect areas where initial post-larval development takes place. The PNA designation is intended to maintain these habitats, as much as possible, in their natural state to allow juvenile populations to develop in a normal manner with as little interference from man as possible. Approximately 80,000 acres have been designated as PNAs in North Carolina.

(2) Secondary Nursery Areas (SNAs) are those areas of the estuarine system where later juvenile development takes place. Populations are usually composed of developing sub-adults of similar size which have migrated from upstream primary nursery areas to the secondary nursery areas located in the middle portion of the estuarine system. 15A N.C. Admin. Code 3I.0101.

(3) Special Secondary Nursery Areas (SSNAs) are areas adjacent to secondary nurseries. It is unclear how SSNAs are distinguishable from SNAs. North Carolina rules do not define SSNAs.

The logical conclusion after examination of the definitions above is that North Carolina regulations does not include habitat designations to protect larger juveniles (i.e., sub-adults in pre-spawning condition) or the very young fish and shellfish that have perhaps spawned once but have not yet reached even a fraction of their reproductive potential (Barbieri et al. 1994a, Lowerre-Barbieri et al. 1995, Lowerre-Barbieri et al. 1998). This raises a major fisheries management concern because it is these sub-adults and first time spawners that will eventually recruit into the main spawning stock to maintain the egg production and juvenile recruitment needed for sustainable fisheries (Lowerre-Barbieri et al. 1998, Lowerre-Barbieri 2009, Cooper et al. 2013).

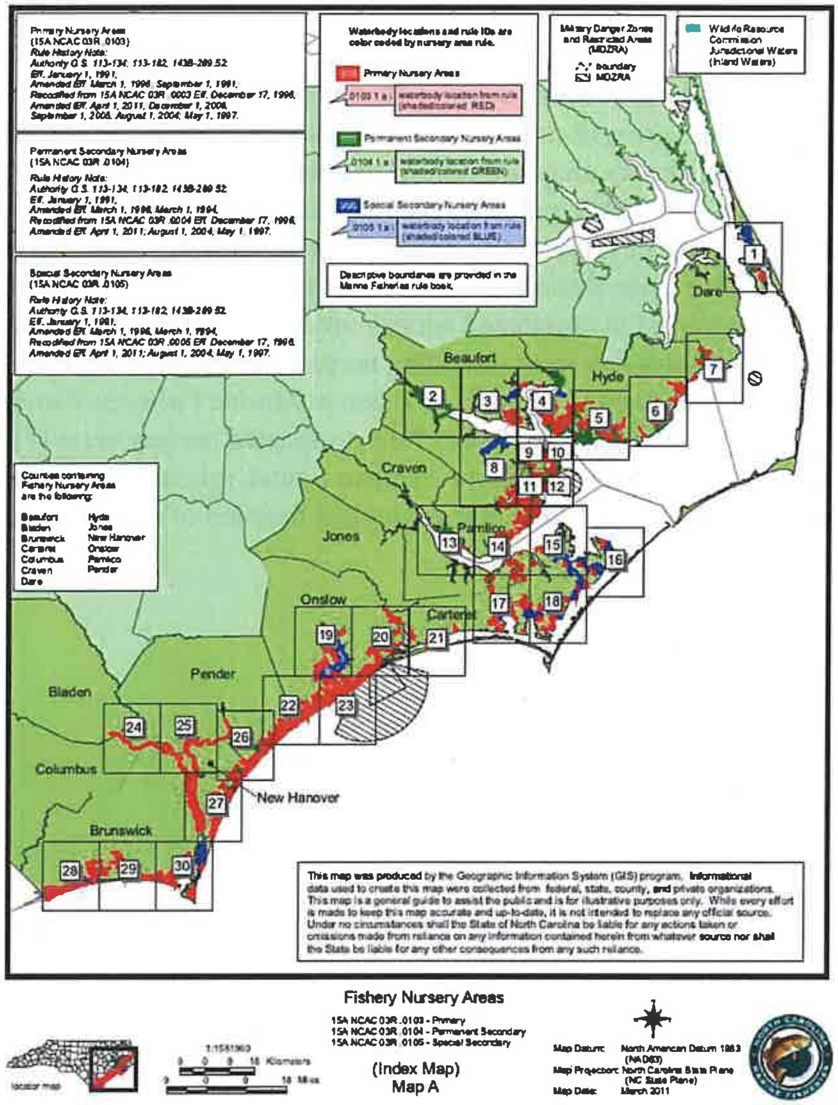


Fig. 1 – Locations of the various nursery areas for estuarine waters of North Carolina

Even a cursory review of the main fisheries that operate in North Carolina estuaries unequivocally indicate that the current nursery habitat designations do not provide adequate protection to the early life history stages of finfish and crustaceans that use these systems as nursery habitats (Broome et al 2011). Specifically, the North Carolina Division of Marine Fisheries Primary Nursery Area Designation Protocol, (also known as the P120 protocol) issued in 2002 mentions that of the approximately 2.1 million acres of open water and 200,000 acres of wetlands in coastal North Carolina, only 162,265 acres (or approximately 8 percent of the total estuarine waters) have been designated as nursery areas. Designations of estuarine areas that consistently support populations of juvenile shrimps, crab, and finfish—and, therefore, provide the basis for nursery area designation—is based on surveys conducted in the early 1970s (NCDMF 2002) and have not been substantially updated since.

People from other states are usually surprised by these facts. Most states prohibit trawling inside bays or other inshore areas deemed as estuarine nursery habitats. In North Carolina, with few exceptions, estuarine nursery areas are subject to intense fishing pressure by all sectors of the fishery (trawls, long-haul seines, gill nets, and hook and line), all of which harvest and/or discard substantial quantities of juvenile fish species such as Atlantic croaker, spot, weakfish, summer flounder, and blue crabs (Murray et al. 1992, Broome et al. 2011). Technically, trawling in North Carolina is prohibited in designated nursery areas. However, the problem is that Pamlico Sound and other estuarine areas providing nursery habitat have not been designated as nursery areas. Data derived through the N.C. Division of Marine Fisheries Pamlico Sound Survey are obtained from areas outside of any of the designated nursery areas (Fig. 2). In other words, although DMF conducts surveys in the Pamlico Sound, scientific sampling to properly designate the location, geographic extent, and ecological function of estuarine nursery areas in the Sound is lacking.

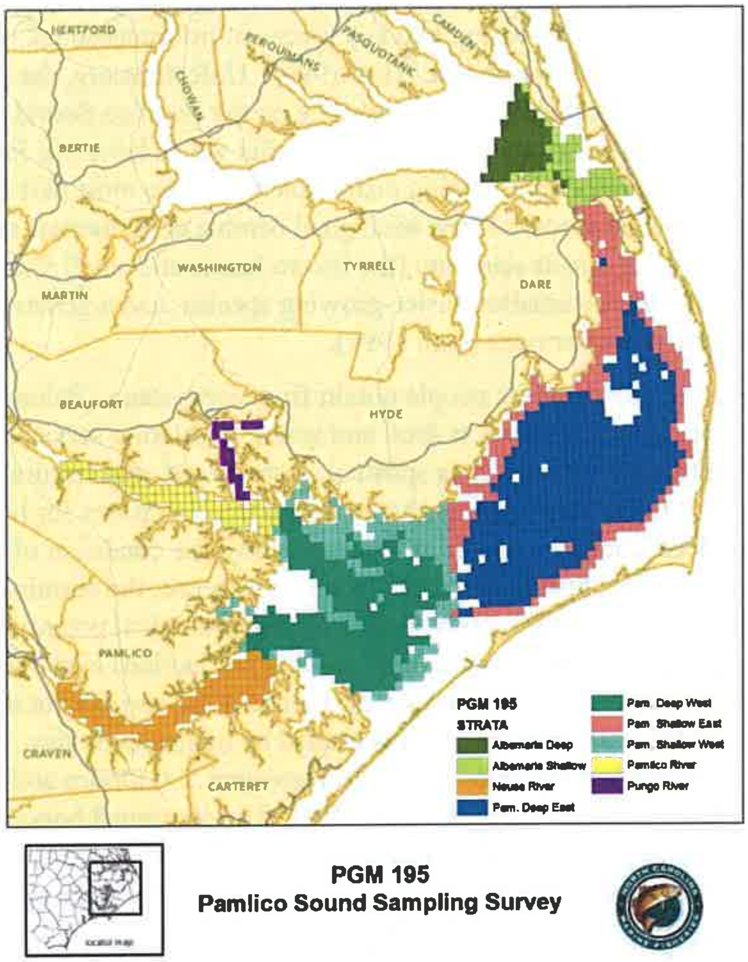


Fig. 2 – Locations of the North Carolina DMF random-stratified sampling program for estuarine waters of North Carolina.

Because of the estuarine-dependent nature of their life history, Atlantic croaker, spot, and weakfish spawn primarily in coastal and nearshore shelf waters (Barbieri et al. 1994a, Lowerre-Barbieri et al. 1995) and recruit as early juveniles into Pamlico Sound nursery habitats (Chao and Musick 1977, Weinstein and Walters 1981). Although adults of these species use open waters of the Sound as feeding grounds, the bulk of croaker, spot, and weakfish found in Pamlico Sound are small, young fish that have not had a chance to spawn or have spawned perhaps once before reaching maximum egg production and spawning capacity. If we follow the nursery habitat concept described by Heck and Crowder (1991) in which larvae are transported to estuaries, metamorphose, grow to sub-adult stages, and then move to adult habitats offshore, then there is no question that Pamlico Sound constitutes a major nursery habitat for these species.

Another serious concern with the current lack of protection for the main areas of Pamlico Sound and other inshore waters is the impact of shrimp trawling on the bottom. When attempting to assess the impact of trawling, two key pieces of information are required—the type of gear used and the frequency of disturbance (Hall 1999). Unfortunately, the lack of data on rates, distributions and intensities of fishing disturbance on the Pamlico Sound floor prevents a more quantitative analyses of these impacts. However, what we do have is a fairly clear picture of how bottom communities respond to fishing disturbance. For the most part this response is consistent with the generalized model of how biological benthic communities respond to perturbation: loss of erect and sessile *epifauna* (the invertebrates and small fishes that live on the bottom), increased dominance by smaller, faster-growing species, and a general reduction in species diversity and ecosystem services (Hall 1999).

Ecosystem services are the benefits people obtain from ecosystems (Palumbi et al. 2008). These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth. People seek many services from ecosystems and thus perceive the condition of an ecosystem in relation to its ability to provide desired services. In a narrow sense, the sustainability of a particular ecosystem service can refer simply to whether the biological potential of the ecosystem to sustain the yield of that service (such as food production) is maintained. Thus, a fish provision service is sustainable and promotes resilience if the *surplus* but not the *resource base* is harvested, and if the *fish's habitat* is not degraded by human activities. In fisheries management, this is what we call "sustained yield management." (Hilborn and Walters 1992, Walters and Martell 2004, Lowerre-Barbieri et al. 2016). The continued bottom trawling impacts on Pamlico Sound estuarine communities (Broome et al. 2011) and habitats is likely to seriously impact ecosystem health and interfering with essential ecosystem services.

V. THE CONSEQUENCES OF NOT PROTECTING JUVENILE, PRE-SPAWNING FISH IN PAMLICO SOUND

By imposing significant mortality on juvenile and pre-spawning fish, contributions to their respective populations in terms of both fishery yield and spawning potential are severely compromised. How and why does this happen?

A. Losses in Fishery Yield

In general, fishery harvest is similar to agriculture or farming. For example, to raise chickens, the farmer must wait until the chicks reach a certain size and weight before selling the chicks for meat. Obviously, killing small chicks for meat would be incredibly unprofitable because the chicks have not grown to the point that they have enough meat to be of any marketable value. Most fish follow this same rule of thumb. Fish grow fast when they are young, and it is much better to wait until fish reach an ideal size and weight to be harvested (Barbieri et al. 1997, Walters and Martell 2004). Growth overfishing results when a fish is harvested before it reaches this ideal weight (Hilborn and Walters 1992). Growth overfishing a stock is literally throwing away or wasting fishery yield production, not unlike the example with the chicks and chickens above (Hilborn and Walters 1992, Barbieri et al. 1997, Walters and Martell 2004). It's that simple. Now, multiply this loss in fishery yield (actual pounds of fish meat) by the hundreds of millions of juvenile Atlantic croaker, weakfish, and spot killed by fishing gear in Pamlico Sound, and one gets an idea of the huge economic loss this is causing in North Carolina (Broome et al. 2011). A study conducted by the North Carolina Sea Grant program determined that of the top ten bycatch species by weight, five were commercially or recreationally important species such as blue crab, Atlantic croaker, weakfish, spot, and summer flounder (Broome et al. 2011).

B. Losses in Spawning Potential

Perhaps the greater concern is the extraordinary quantities of Pamlico Sound forage and food fishes that succumb to fishing-induced mortality prior to spawning at least once. Drawing on the same chicken farm example, it is easy to see that to have sustainable long-term production some level of egg production to generate enough chicks that can grow into full size chickens must be maintained. Killing a large number of chicks before they can lay eggs will eventually lead to trouble. In fisheries, this is what we call "recruitment overfishing" (Hilborn and Walters 1992, Walters and Martell 2004). This type of overfishing is just as detrimental to the fishery as growth overfishing, but it is much more dangerous because it depresses annual fishery yields, damages long-term stock productivity, and renders fisheries as economically unviable (Hilborn and Walters 1992, Lowerre-Barbieri 2009, Walters and Martell 2004, Lowerre-Barbieri et al. 2016). In other words, killing so many juveniles before their first spawning severely reduces the stocks' reproductive capacity and compromises the annual production of new recruits (i.e., fingerlings coming into the population). The consequences are manifold, but can be summarized into two main impacts: (1) the amount of spawning is inadequate to generate new recruits and keep the stock in a sustainable state, and (2) the reduced spawning and juvenile recruitment cause a reduction in the populations to a small fraction of its original size and allows other species (competitors) to take advantage of the open space and fill in the void (Botsford et al. 1997). For example, starting in the early 1900s, the California sardine fishery became the largest fishery in North America and supported a major industry (Radovich 1982). Due to overfishing, sardine populations in the area declined until it was no longer economical to fish sardines in Pacific North America. With the decline in the population of the California sardine came an increase in the population of its primary competitor, the anchovy (Radovich 1982). This only added fuel to the problem. The California Fish and Game Commission took lessons from the death of the sardine industry and since then has embraced scientifically-based fisheries management (Radovich 1992)

Although direct scientific evidence is lacking, the similarity with the phenomenal collapse of the weakfish fishery in the mid-Atlantic is instructive. Once a thriving commercial and recreational fishery throughout the mid-Atlantic, weakfish stocks started to steadily decline in the 1980s and by the mid-1990s were considered to be in serious trouble—landings dropped from over 19 million pounds in 1982 to roughly 200,000 pounds in 2014 (ASMFC 2016). The majority of landings occur in North Carolina and Virginia and, since the early 1990s, the primary gear used to harvest has been gillnets (ASMFC 2016). Discarding of weakfish by commercial fishermen is known to occur, especially in the northern trawl fishery, and the discard mortality is assumed to be 100 percent (Broome et al. 2011).

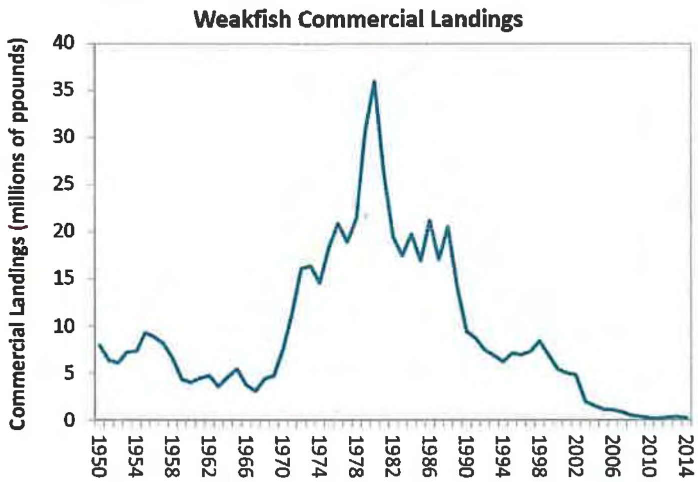


Fig. 3 – Weakfish Commercial Landings, 1950 – 2014

By 1996, the Atlantic States Marine Fisheries Commission (ASMFC) had adopted Amendment 3 as a long-term recovery plan to restore weakfish to healthy levels in order to maintain commercial and recreational harvests consistent with a self-sustaining spawning stock (ASMFC 2016). Unfortunately, while managers were preparing for a weakfish resurgence, something else was happening—unbeknownst to anyone—which would eventually cause a rapid increase in weakfish mortality. Increased predation from other species such as striped bass and spiny dogfish as well as competition with Atlantic croaker, decreasing prey items such as bay anchovy and Atlantic menhaden, and increasing water temperatures may all have been playing key roles in the weakfish decline (ASMFC 2016).

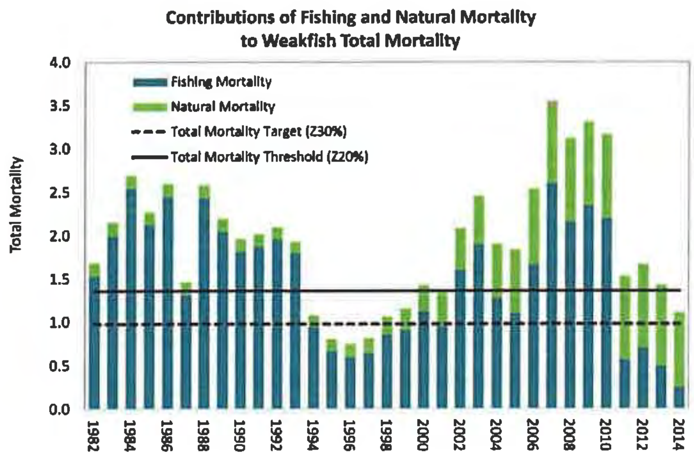


Fig. 4 – Fishing and Natural Mortality of Weakfish, 1982 - 2014

How many more productive North Carolina fisheries must go through this same precipitous decline before managers recognize that sustained injury to nursery habitats and the lack of adequate protection for juveniles and first time spawners is likely causing serious harm to the very ecosystem responsible for keeping North Carolina fisheries in business? In other words, although the main fisheries for weakfish and croaker take place in nearshore waters (Barbieri et al. 1994a, 1994b, Lowerre-Barbieri et al. 1995,1996), juvenile bycatch and nursery habitat destruction in Pamlico Sound will impact the fisheries by either increasing mortality of juvenile life stages or by destroying the habitats they inhabit (Broome et al. 2011).

VI. SOURCES OF MORTALITY FOR WEAKFISH, SPOT, CROAKER, AND OTHER SPECIES COMMONLY FOUND IN NORTH CAROLINA WATERS

Some people suggest that high fishing mortality on juvenile fishes has a negligible impact on population viability because natural mortality is already so high that, most likely, those fish would have died anyway. The key difference here is natural mortality versus fishing mortality. Natural mortality is the mortality fish populations experience due to natural causes such as old age, predation, disease, and environmental impacts. Fishing mortality is the mortality caused by any kind of fishing-related activity, including harvest, bycatch, and release mortality, to name a few (Hilborn and Walters 1992, Stearns 1992, Walters and Martell 2004). There is no question that early juvenile stages (i.e., young-of-the-year fingerlings) of weakfish, spot, croaker, and other species commonly found in Pamlico Sound have very high natural mortality (Barbieri et al. 1994b, Lowerre-Barbieri et al. 1995). This is due to a life history strategy selected (by natural selection) to produce huge numbers of eggs and larvae that can account for the high predation most fish species experience in early life. In other words, to compensate for the fact that most eggs, larvae, and early juveniles will be heavily preyed upon by larger-sized fish (sometimes other species but cannibalism is not uncommon) these fish have, over millions of years, evolved to produce very large numbers of young (Lowerre-Barbieri 2009). A good way to look at natural mortality in animals is to compare what is called their "Survivorship Curves" (Deevey 1947, Stearns1992, Walters and Martell 2004). Figure 3 below shows the typical shapes of survivorship curves for fish, reptiles, and mammals. Type I survivorship curves are characterized by high age-specific survival probability in early and middle life, followed by a rapid decline in survival in later life. They are typical of species that produce few offspring but care for them well, including humans and many other large mammals (Deevey 1947, Stearns 1992, Walters and Martell 2004). Type II curves are an intermediate between Types I and III, where roughly constant mortality rate/survival probability is experienced regardless of age. Some birds and some lizards follow this pattern (Deevey 1947, Stearns 1992). In Type III curves, the greatest mortality (lowest age-specific survival) is experienced early in life, with relatively low rates of death (high probability of survival) for those surviving this bottleneck. This type of curve is characteristic of species that produce a large number of offspring (see r/K selection theory, Stearns 1992, Winemiller and Rose 1992). This includes most fish and marine invertebrates.

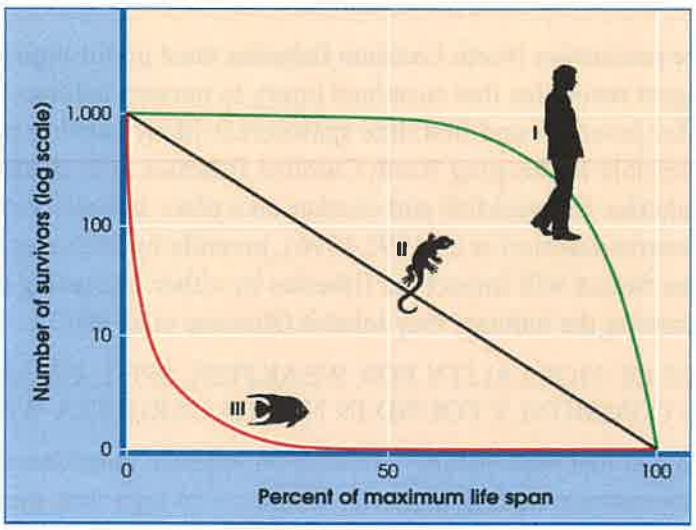


Fig. 5 – Most fishes (including Atlantic croaker, spot, and weakfish) have a type III natural survivorship curve, i.e., they experience exponentially higher mortality early in life (egg, larval, and juvenile stages).

Extrapolating this expected high rate of natural mortality to these species' ability to also withstand large rates of fishing induced mortality is nonsensical. Why is that?

Many decades of studies on fish population dynamics (e.g., Beverton and Holt 1957, Hilborn and Walters 1992, Walters and Martell 2004) clearly indicate that:

$$Z = M + F$$

Where, Z = total mortality, M = natural mortality, and F = fishing mortality.

Clearly, fishing mortality is *additive* to natural mortality, not a replacement for it. In other words, even though larvae and early juveniles of species that utilize nursery habitats in Pamlico Sound have been selected to have high rates of natural mortality this doesn't mean they are capable of also withstanding an additional source of mortality, especially at the magnitudes observed in North Carolina estuaries (Murray et al. 1992, Broome et al. 2011). The result is literally the meaning of adding insult to injury. As juveniles inhabiting more protected nursery areas grow, their natural tendency is to move to more open, higher salinity waters of the larger sounds and bays (Barbieri et al. 1994b). These fishes have survived during periods of the highest natural mortality and the level of mortality drops exponentially as they grow (Deevey 1947, Winemiller and Rose 1992; Walters and Martell 2004; Able 2005). It is at this time that these fishes, fit enough to have survived the early period of high mortality, become subjected to intense sources of fishing mortality—either by direct harvest or bycatch mortality (Murray et al. 1992, Broome et al. 2011).

The fish and invertebrate species that inhabit North Carolina estuaries are part of a complex ecosystem that fuels the productivity of fisheries in state waters and beyond (Barbieri et al. 1994a, 1994b, 1997; Lowerre-Barbieri et al. 1995, 1996, 1998). With adequate management and habitat protection—i.e., designation of Pamlico Sound as nursery habitat—these fisheries can support long-term sustainable harvest, generating fresh local seafood, business opportunities and jobs for millions of people. The consequences of continuing the current pattern of juvenile bycatch and discard mortality in North Carolina estuaries is irreparable harm to the ecosystem and destruction of the businesses that rely on fish and shellfish species that use these areas as nursery habitats.

VII. THE STATUS OF SPOT, CROAKER, AND WEAKFISH IN NORTH CAROLINA WATERS

Juvenile spot, croaker and weakfish dominate the finfish bycatch, making up a majority of the total bycatch in North Carolina estuaries (Broome et al. 2011). Not surprisingly, the stock status of these three species is considered poor (ASMFC 2010, 2015, 2016). Spot and croaker are classified by the North Carolina Division of Marine Fisheries as being of "concern," and weakfish are classified as "depleted." Stock assessments and other data summary reports conducted by ASMFC show the same pattern (ASMFC 2010, 2015, 2016). This is not surprising. It is estimated that each year, approximately 100 million juvenile Atlantic croaker, 50 million juvenile spot, and 25 million juvenile weakfish are caught and killed by otter trawls in Pamlico Sound (Broome et al. 2011). All are shoveled back into the Sound where they either get eaten or rot (Broome et al. 2011). The impact of this bycatch is uncertain, but because of the large number of pre-spawning age fish that are killed, common sense points to it being a major factor in the decline of these fish populations (ASMFC 2010, 2015, 2016; Broome et al. 2011).

In fisheries management the practice of implementing a minimum size limit is based on the concept that stock productivity relies on having enough spawning and egg production to maintain the surplus production above the replacement line (see Figure 6 below).

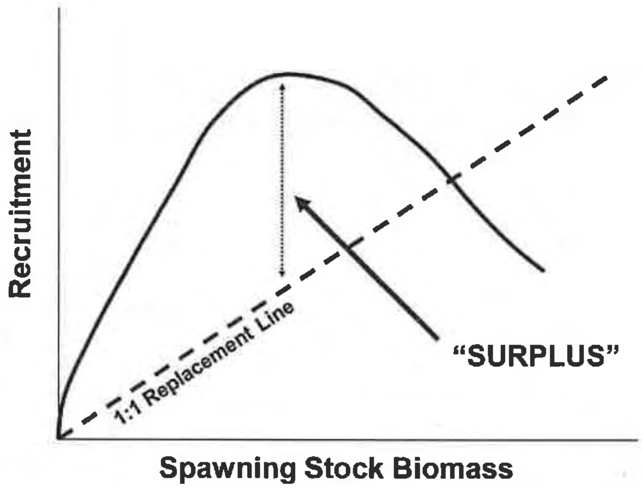


Fig. 6 – Recruitment and spawning stock biomass.

When fishing mortality removes too many young fish from the population, the result is a much smaller proportion of the population reaching sexual maturity and contributing to future stock productivity. Tropical and temperate fish populations like croaker, spot, and weakfish have the ability to withstand this type of negative impact for a short time given their high compensatory capacity (Kindsvater et al. 2016), but over time the ability of the stock to maintain long-term resilience is severely compromised (Lowerre-Barbieri et al. 2016). Consider the reproductive output (i.e., spawning potential, egg production) produced by a cohort of fish over its lifespan (by "cohort" we mean the fish born in a certain year). The equilibrium spawning potential (SP) per recruit is given by:

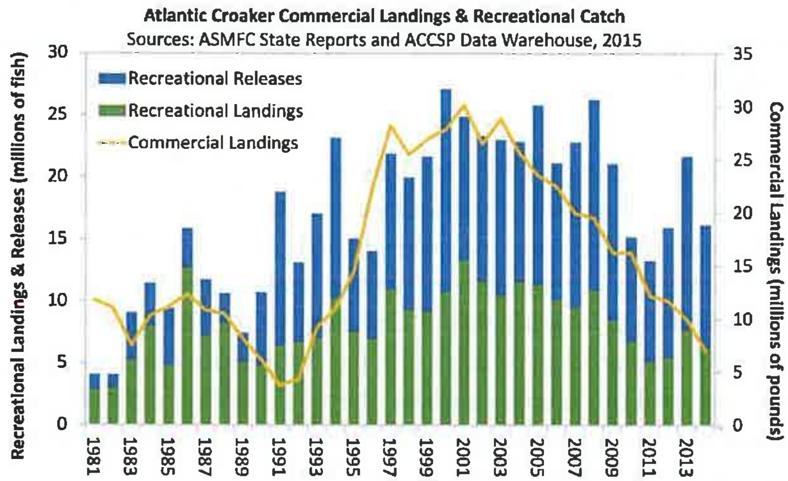
$$SP = \int_0^{\infty} B(a) \cdot Mat(a) \cdot \%Eggs \, da$$

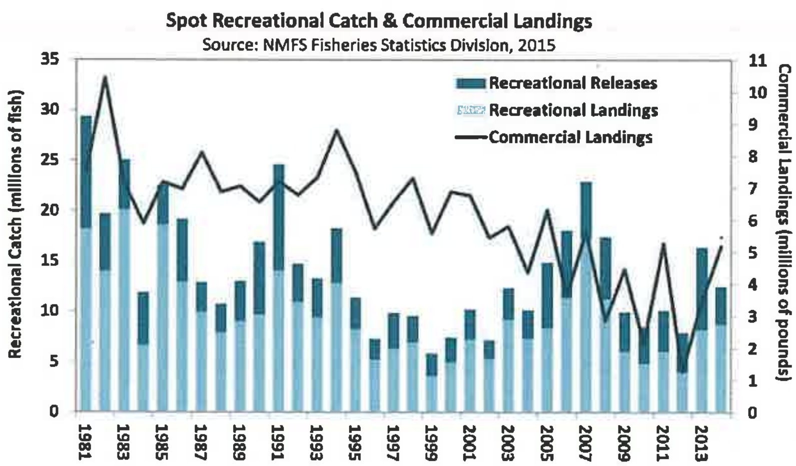
$$\frac{SP}{R} = \int_0^{\infty} \exp[-(M + F(a)) \cdot a] \cdot W(a) \cdot Mat(a) \cdot \%Eggs \, da$$

Where: **B(a) is biomass at age of females, Mat(a) is the proportion mature at age, %Eggs is the proportion of a female's body mass that is ovaries.**

It is clear from the equation above that the biomass of females at age, the proportion of females sexually mature at age, and the proportion of a female's body mass dedicated to reproduction (i.e., ovary tissue mass) are very important factors in maintaining the levels of reproduction needed to support long-term fisheries sustainability. Further, as discussed above, preventing fish from growing to their ideal size and weight has tangible consequences in terms of fisheries yield. For example, the figure below shows the equilibrium fishery yield expected under two scenarios. The levels of yield produced at different fishing mortality rates are much higher when the fish selected by the gear have grown to their ideal size and weight (black line). When the fish selected by the fishing gear are too young—and therefore too small—the yields produced are much lower.

Unfortunately, the negative impact on weakfish has been massive. Although Atlantic croaker and spot are not in such critical condition as compared to weakfish, landings of both these species are a fraction of what they once were (ASMFC 200, 2015). For all practical purposes, stocks of Atlantic croaker and spot in North Carolina and the mid-Atlantic region are in a state fisheries biologists call "sustainably overfished." (Walters and Martell, 2004). This means that although their current level of depletion has not reached catastrophic levels and these stocks still support some level of fisheries harvest, the productivity of these stocks has been sapped to the point that they no longer support the fisheries and associated businesses that once thrived in the region (Hall 1999, Walters and Martell 2004).





Figs. 7, 8 - Atlantic Croaker and Spot Recreation and Commercial Landings, 1981 - 2013

As a result, the future of sustainable fisheries in North Carolina is at stake. Even with some fish populations displaying an extraordinary capacity for recovery, human interferences should never cause such drastic changes in the marine ecosystems we depend on (Walters and Martell 2004, Lowerre-Barbieri et al. 2015). Besides, the impacts caused by juvenile bycatch and discard mortality are multidimensional. For the economist, the impacts of these practices generate additional costs without affecting the revenues, and may hinder profitability. For the fishermen, these fishing practices cause conflicts among fisheries, give fishers a bad public image, generate regulations and limitations on the use of resources, and effect future yield.

In an article entitled "The Historical Collapse of Southern California Fisheries and the Rocky Future of Seafood," Katie Lee describes how economically valuable southern California fisheries (kelp and barred sand bass) collapsed "right under the noses of management agencies." Though the media tends to focus on the effects of pollution, climate change, or overfishing, outdated systems of management that do not explicitly incorporate habitat protection as part of a broader conservation strategy are actually the main cause of the collapse in many cases. In the particular case of North Carolina, a combination of improved and updated regulations that can provide the habitat protection needed for early life stages, late juveniles, and first time spawners throughout Pamlico Sound and other estuarine waters must be incorporated into fisheries management *before* fish populations collapse. Further, this added habitat protection would certainly benefit stocks already impacted and at low abundance and greatly assist their rebuilding to a healthy condition.

VIII. CONCLUSION

Dead discards and bycatch are major problems for fisheries in the southeastern United States. In North Carolina, extensive trawling and the use of other non-selective fishing methods are likely impacting the abundance and productivity of important commercial and recreational species such as Atlantic croaker, spot, and weakfish. These fishing practices lead to high levels of juvenile bycatch and discards, as well as ecosystem-level impacts such as the destruction of bottom habitats and the disruption of trophic interactions.

It is difficult to imagine that fishermen and fisheries managers are not very aware of this problem and have a strong desire to do something about it. The scientific evidence discussed throughout this paper shows clear evidence that:

(1) There is a definite need for a more inclusive, expanded nursery habitat designation in North Carolina estuarine systems. The system currently in place is outdated and does not follow a rigorous and scientifically-informed process.

(2) This problem is causing large bycatch mortality of economically and ecologically important species that support valuable fisheries (e.g., Atlantic croaker, spot, weakfish, and summer flounder). Further, shrimp trawling in large expanses of Pamlico Sound is very likely disrupting the bottom and negatively impacting the benthic communities needed to maintain ecosystem health.

(3) The Primary Nursery Areas (PNAs) designation in North Carolina affords some level of protection to upper estuarine habitats used by the very early life stages of fishes and macroinvertebrates (e.g., eggs, larvae, and post-settlement early juveniles). However, late juveniles, sub-adults, and first-time spawners moving into more open areas of Pamlico Sound are still subject to fishing mortality due to shrimp trawl bycatch and discards by other fisheries activities.

(4) Designation of the entire Pamlico Sound as a nursery habitat area would expand the protection of larger juveniles, sub-adults, and first-time spawners from shrimp trawling and other fishery mortality impacts. This action would also prevent or substantially decrease the ecosystem-level impacts of habitat alteration and food-web disruptions in

Pamlico Sound caused by bycatch, discards, and physical damage to benthic communities.

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EXHIBIT F

CURRICULUM VITAE

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EDUCATION

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PROFESSIONAL EXPERIENCE

2003-present	Program Administrator, Marine Fisheries Research Program, Fish and Wildlife Research Institute, FWC
2000- present	Adjunct Graduate Faculty, Division of Marine and Environmental Systems, Florida Institute of Technology
1999-2003	Senior Research Scientist, Florida Marine Research Institute, FWC
1997-1999	Research Administrator, Florida Marine Research Institute, FWC
1995-1997	Assistant Research Scientist, Marine Institute, The University of Georgia
1993-1995	Postdoctoral Research Associate, Marine Institute, The University of Georgia

SCIENTIFIC PANELS AND COMMITTEES

2016-present	Co-Chair, 2016 Committee on Review of the Marine Recreational Information Program, Ocean Studies Board, National Academies of Science
2015-present	Chair, Scientific and Statistical Committee (SSC), Gulf of Mexico Fisheries Management Council
2012-present	Member, SSC, South Atlantic Fisheries Management Council
2012-2016	Chair, SSC, South Atlantic Fisheries Management Council
2010-2015	Florida Institute of Oceanography, Oil Spill Research Advisory Committee
2008-2012	Vice-Chair, SSC, South Atlantic Fisheries Management Council
2009-2010	Chair, ABC Control Rule Working Group, Gulf of Mexico Fishery Management Council
2009-2011	National SSC Working Group on Development of ABC Recommendations for Data Poor Stocks
2002-2008	Management and Science Committee, Atlantic States Marine Fisheries Commission

1998-2000 Marine Protected Areas Advisory Panel, South Atlantic Fisheries Management Council

SYNERGISTIC ACTIVITIES AND SERVICE

2015-present Fisheries Forum Advisory Group – Fisheries Leadership & Sustainability Forum, Nicholas Institute for Environmental Policy Solutions at Duke University.

2014-present Steering Committee – Southeast Marine Resource Education Program (MREP)

2013-present Board of Directors – Gulf Wild Program, Gulf of Mexico Reef Fish Shareholders Alliance.

2009 Keynote Speaker – Ibero-American Symposium on Reproductive Ecology, Recruitment, and Fisheries Management (SIBECORP), Nov. 23-27, Vigo, Spain.

HONORS AND AWARDS

2015 Captain Phil Chapman Conservation Award – awarded by the Florida Guides Association.

2013 The Aylesworth Award – awarded by the Southeastern Fisheries Association for outstanding service as a government employee.

RESEARCH GRANTS

Synthesizing spatial dynamics of recreational fish and fisheries to inform restoration strategies: red drum in the Gulf of Mexico – Gulf Research Program Data Synthesis Grant. Co-PI with K. Lorenzen, C. Adams, R. Ahrens, M. Allen, E. Camp, J. Dutka-Gianelli, S. Larkin, W. Pine, J. Struve, S.K. Lowerre-Barbieri, M. Murphy, and J. Tolan. October 1, 2015-September 31, 2018. $480,000.

Is low male abundance limiting stock productivity? Assessing factors affecting reproductive potential of gag, *Mycteroperca microlepis,* in the Gulf of Mexico – National Marine Fisheries Service, NOAA, Marine Fisheries Initiative (MARFIN) Program. Co-PI's S.K. Lowerre-Barbieri, T. Switzer, A. Collins, and C. Koenig. September 1, 2015 - August 31, 2018. $495,555.

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EXHIBIT G

REVIEWS

Ecological Monographs, 81(2), 2011, pp. 169–193

The value of estuarine and coastal ecosystem services

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Abstract. The global decline in estuarine and coastal ecosystems (ECEs) is affecting a number of critical benefits, or ecosystem services. We review the main ecological services across a variety of ECEs, including marshes, mangroves, nearshore coral reefs, seagrass beds, and sand beaches and dunes. Where possible, we indicate estimates of the key economic values arising from these services, and discuss how the natural variability of ECEs impacts their benefits, the synergistic relationships of ECEs across seascapes, and management implications. Although reliable valuation estimates are beginning to emerge for the key services of some ECEs, such as coral reefs, salt marshes, and mangroves, many of the important benefits of seagrass beds and sand dunes and beaches have not been assessed properly. Even for coral reefs, marshes, and mangroves, important ecological services have yet to be valued reliably, such as cross-ecosystem nutrient transfer (coral reefs), erosion control (marshes), and pollution control (mangroves). An important issue for valuing certain ECE services, such as coastal protection and habitat–fishery linkages, is that the ecological functions underlying these services vary spatially and temporally. Allowing for the connectivity between ECE habitats also may have important implications for assessing the ecological functions underlying key ecosystems services, such coastal protection, control of erosion, and habitat–fishery linkages. Finally, we conclude by suggesting an action plan for protecting and/or enhancing the immediate and longer-term values of ECE services. Because the connectivity of ECEs across land–sea gradients also influences the provision of certain ecosystem services, management of the entire seascape will be necessary to preserve such synergistic effects. Other key elements of an action plan include further ecological and economic collaborative research on valuing ECE services, improving institutional and legal frameworks for management, controlling and regulating destructive economic activities, and developing ecological restoration options.

Key words: coral reef; economic value; ecosystem service; estuarine and coastal ecosystem; mangrove; salt marsh; sand beach and dune; seagrass; seascape.

Introduction

Estuarine and coastal ecosystems (ECEs) are some of the most heavily used and threatened natural systems globally (Lotze et al. 2006, Worm et al. 2006, Halpern et al. 2008). Their deterioration due to human activities is intense and increasing; 50% of salt marshes, 35% of mangroves, 30% of coral reefs, and 29% of seagrasses are either lost or degraded worldwide (Valiela et al. 2001, MEA 2005, Orth et al. 2006, UNEP 2006, FAO 2007, Waycott et al. 2009). This global decrease in ECEs is known to affect at least three critical ecosystem services (Worm et al. 2006): the number of viable (non-collapsed) fisheries (33% decline); the provision of nursery habitats such as oyster reefs, seagrass beds, and wetlands (69% decline); and filtering and detoxification services provided by suspension feeders, submerged vegetation, and wetlands (63% decline). The loss of biodiversity, ecosystem functions, and coastal vegetation in ECEs may have contributed to biological invasions, declining water quality, and decreased coastal protection from flooding and storm events (Braatz et al. 2007, Cochard et al. 2008, Koch et al. 2009).

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Such widespread and rapid transformation of ECEs and their services suggest that it is important to understand what is at stake in terms of critical benefits and values. The purpose of this paper is to provide an overview of the main ecological services across a variety of ECEs, including marshes, mangroves, nearshore coral reefs, seagrass beds, and sand beaches and dunes. Where available, we cite estimates of the key economic values arising from the services provided by these ECEs. In addition, we discuss how the natural variability in these systems in space and time results in nonlinear functions and services that greatly influence their economic value (Barbier et al. 2008, Koch et al. 2009) and some of the synergistic properties of ECEs. Because they exist at the interface between the coast, land, and watersheds, ECEs can produce cumulative benefits that are much more significant and unique than the services provided by any single ecosystem. Finally, we finish by highlighting the main management implications of this review of ECE services and their benefits, and provide an "action plan" to protect and/or enhance their immediate and longer term value to humankind.

Methods: Assessing ECE Services and Values

In identifying the ecosystem services provided by natural environments, a common practice is to adopt the broad definition of the Millennium Ecosystem Assessment (MEA 2005) that "ecosystem services are the benefits people obtain from ecosystems." Thus, the term "ecosystem services" is usually interpreted to imply the contribution of nature to a variety of "goods and services," which in economics would normally be classified under three different categories (Barbier 2007): (1) "goods" (e.g., products obtained from ecosystems, such as resource harvests, water, and genetic material), (2) "services" (e.g., recreational and tourism benefits or certain ecological regulatory and habitat functions, such as water purification, climate regulation, erosion control, and habitat provision), and (3) cultural benefits (e.g., spiritual and religious beliefs, heritage values).

However, for economists, the term "benefit" has a specific meaning. Mendelsohn and Olmstead (2009:326) summarize the standard definition as follows: "The economic benefit provided by an environmental good or service is the sum of what all members of society would be willing to pay for it." Thus, given this specific meaning, some economists argue that it is misleading to characterize all ecosystem services as "benefits." As explained by Boyd and Banzhaf (2007:619), "as end-products of nature, final ecosystem services are not benefits nor are they necessarily the final product consumed. For example, recreation is often called an ecosystem service. It is more appropriately considered a benefit produced using both ecological services and conventional goods and services." To illustrate this point, they consider recreational angling. It requires certain "ecosystem services," such as "surface waters and fish populations," but also "other goods and services including tackle, boats, time allocation, and access" (Boyd and Banzhaf 2007:619). But other economists still prefer a broader interpretation of ecosystem services, along the lines of the Millennium Ecosystem Assessment (MEA 2005), which equates ecosystem services with benefits. For example, Polasky and Segerson (2009:412) state: "We adopt a broad definition of the term ecosystem services that includes both intermediate and final services," which they justify by explaining that "supporting services, in economic terms, are akin to the infrastructure that provides the necessary conditions under which inputs can be usefully combined to provide intermediate and final goods and services of value to society." Thus, unlike Boyd and Banzhaf (2007), Polasky and Segerson (2009) consider recreation to be an ecosystem service.

Economists do agree that, in order to determine society's willingness to pay for the benefits provided by ecosystem goods and services, one needs to measure and account for their various impacts on human welfare. Or, as Freeman (2003:7) succinctly puts it: "The economic value of resource–environmental systems resides in the contributions that the ecosystem functions and services make to human well-being," and consequently, "the basis for deriving measures of the economic value of changes in resource–environmental systems is the effects of the changes on human welfare." Similarly, Bockstael et al. (2000:1385) state: "In economics, valuation concepts relate to human welfare. So the economic value of an ecosystem function or service relates only to the contribution it makes to human welfare, where human welfare is measured in terms of each individual's own assessment of his or her well-being." The key is determining how changes in ecosystem goods and services affect an individual's well-being, and then determining how much the individual is either willing to pay for changes that have a positive welfare impact, or conversely, how much the individual is willing to accept as compensation to avoid a negative effect.

In our approach to identifying the key services of estuarine and coastal ecosystem (ECEs) and their values, we adopt this consensus economic view. That is, as long as nature makes a contribution to human well-being, either entirely on its own or through joint use with other human inputs, then we can designate this contribution as an "ecosystem service." In other words, "ecosystem services are the direct or indirect contributions that ecosystems make to the well-being of human populations" (U.S. EPA 2009:12). In adopting this interpretation, (U.S. EPA 2009:12–13) "uses the term ecosystem service to refer broadly to both intermediate and final end services," and as a result, the report maintains that "in specific valuation contexts...it is important to identify whether the service being valued is an intermediate or a final service."

For example, following this approach, the tourism and recreation benefits that arise through interacting with an ECE can be considered the product of a "service" provided by that ecosystem. But it should be kept in mind, as pointed out by Boyd and Banzhaf (2007:619), that the role of the ECE is really to provide an "intermediate service" (along with "conventional goods and services") in the production of the final benefit of recreation and tourism. In selecting estimates of the "value" of this "intermediate" ecosystem service in producing recreational benefits, it is therefore important to consider only those valuation estimates that assess the effects of changes in the ECE habitat on the tourism and recreation benefits, but not the additional influence of any human inputs. The same approach should be taken for those "final" ecosystem services, such as coastal protection, erosion control, nutrient cycling, water purification, and carbon sequestration, which may benefit human well-being without any additional human-provided goods and services. But if "final" services do involve any human inputs, the appropriate valuation estimates should show how changes in these services affect human welfare, after controlling for the influence of these additional human-provided goods and services. Although this approach to selecting among valuation estimates of various ECE services seems straightforward, in practice there are a number of challenges to overcome. These difficulties are key to understanding an important finding of our review: Whereas considerable progress has been made in valuing a handful of ECE services, there are still a large number of these services that have either no or very unreliable valuation estimates.

The most significant problem faced in valuing ecosystem services, including those of ECEs, is that very few are marketed. Some of the products arising from ECEs, such as raw materials, food, and fish harvests, are bought and sold in markets. Given that the price and quantities of these marketed products are easy to observe, there are many value estimates of the contribution of the environmental input to this production. However, this valuation is more complicated than it appears. Market conditions and regulatory policies for the marketed output will influence the values imputed to the environment input (Freeman 2003:259–296, McConnell and Bockstael 2005, Barbier 2007). For example, one important service of many ECEs is the maintenance of fisheries through providing coastal breeding and nursery habitat. Although many fisheries are exploited for commercial harvests sold in domestic and international markets, studies have shown that the inability to control fishing access and the presence of production subsidies and other market distortions can impact harvests, the price of fish sold, and ultimately, the estimated value of ECE habitats in supporting commercial fisheries (Freeman 1991, Barbier 2007, Smith 2007).

However, the majority of other key ECE services do not lead to marketed outputs. These include many services arising from ecosystem processes and functions that benefit human beings largely without any additional input from them, such as coastal protection, nutrient cycling, erosion control, water purification, and carbon sequestration. In recent years, substantial progress has been made by economists working with ecologists and other natural scientists in applying environmental valuation methodologies to assess the welfare contribution of these services. The various nonmarket valuation methods employed for ecosystem services are essentially the standard techniques that are available to economists. For example, Freeman (2003), Pagiola et al. (2004), NRC (2005), Barbier (2007), U.S. EPA (2009), Mendelsohn and Olmstead (2009), and Hanley and Barbier (2009) discuss how these standard valuation methods are best applied to ecosystem services, emphasizing in particular both the advantages and the shortcomings of the different methods and their application. However, what makes applying these methods especially difficult is that they require three important, and interrelated, steps (Barbier 1994, 2007, Freeman 2003, NRC 2005, Polasky and Segerson 2009).

The first step involves determining how best to characterize the change in ecosystem structure, functions, and processes that gives rise to the change in the ecosystem service. For instance, the change could be in the spatial area or quality of a particular type of ECE habitat, such as a mangrove forest, marsh vegetation, or sand dune extent. It could also be a change in a key population, such as fish or main predator. Alternatively, the change could be due to variation in the flow of water, energy or nutrients through the system, such as the variability in tidal surges due to coastal storm events or the influx of organic waste from pollution upstream from ECEs.

The second step requires tracing how the changes in ecosystem structure, functions, and processes influence the quantities and qualities of ecosystem service flows to people. Underlying each ecosystem service is a range of important energy flow, biogeochemical and biotic processes and functions. For example, water purification by seagrass beds is linked to the ecological processes of nutrient uptake and suspended particle deposition (Rybicki 1997, Koch et al. 2006). However, the key ecological process and functions that generate an ecosystem service are, in turn, controlled by certain abiotic and biotic components that are unique to each ecosystem's structure. The various controlling components that may affect nutrient uptake and particle deposition by seagrasses include seagrass species and density, nutrient load, water residence time, hydrodynamic conditions, and light availability. Only when these first two steps are completed is it possible to conduct the final step, which involves using existing economic valuation method to assess the changes in human well-being that result from the change in ecosystem services.

As summarized by NRC (2005:2) this three-step approach implies that "the fundamental challenge of valuing ecosystem services lies in providing an explicit description and adequate assessment of the links between the structure and functions of natural systems, the benefits (i.e., goods and services) derived by humanity, and their subsequent values." This approach is summarized in Fig. 1. Human drivers of ecosystem change affect important ecosystem processes and functions and their controlling components. Assessing this change is fundamental yet difficult. However, "making the translation from ecosystem structure and function to ecosystem goods and services (i.e., the ecological production) is even more difficult" and "probably the greatest challenge for successful valuation of ecosystem services is to integrate studies of the ecological production function with studies of the economic valuation function" (NRC 2005:2–3). Similarly, Polasky and Segerson (2009:422) maintain that "among the more practical difficulties that arise in either predicting changes in service flows or estimating the associated value of ecosystem services" include the "lack of multiproduct, ecological production functions to quantitatively map ecosystem structure and function to a flow of services that can then be valued."

We find that, for many key ECE services, the integration of the "ecological production function" with the "economic valuation function" is incomplete. In many instances, how to go about making this linkage is poorly understood. However, for a handful of services, considerable progress has been made in estimating how the structure and functions of ECEs generate economic benefits. Thus, the main purpose of our review is to illustrate the current state of identifying, assessing, and valuing the key ecosystem services of ECEs, which is motivated by an important question: What is the current state of progress in integrating knowledge about the "ecological production function" underlying each important ECE service with economic methods to value changes in this service in terms of impacts on human welfare? To answer this important question, we adopt the following approach.

First, for each of five critical ECEs, coral reefs, seagrass beds, salt marshes, mangroves, and sand beaches and dunes, we identified the main ecosystem services associated with each habitat. Second, we provided an overview of the "ecological production function" underlying each service by assessing current knowledge of the important ecosystem processes, functions, and controlling components that are vital to this service. Third, where possible, we cited estimates of economic values arising from each service, and identified those services where there is no reliable estimate of an economic value. Fourth, we discussed briefly the main human drivers of ecosystem change that are affecting each ECE habitat. Finally, the results of our review are summarized in a table for each ECE. This facilitates comparison across all five habitats and also illustrates the important "gaps" in the current state of valuing some key ECE services. To keep the summary table short, we selected only one valuation estimate as a representative example. In some cases, it may be the only valuation estimate of a particular ecosystem service; in others, we have tried to choose one of the best examples from recent studies.

Note that our purpose in reviewing valuation estimates of ECE services is, first, to determine which services have at least one or more reliable estimate and which do not, and, second, to identify future areas of ecological and economic research to further progress in valuing ECE services. We do not attempt to quantify the total number of valuation studies for each ECE service, nor do we analyze in detail the various valuation methods used in assessing an ecosystem service. Instead, we selected those examples of valuation studies that conform to the standard and appropriate techniques that are recommended for application to various ecosystem services, as discussed in Freeman (2003), Pagiola et al. (2004), NRC (2005), Barbier (2007), Hanley and Barbier (2009), U.S. EPA (2009), and Mendelsohn and Olmstead (2009). The interested reader should consult these references for a comprehensive discussion of economic nonmarket valuation methods and their suitable application to ecosystem services.

Because our aim is to assess the extent to which reliable valuation estimates exist for each identified ECE service, we have reported each estimate as it appears in the original valuation study. This is for two principal reasons. First, many of the studies are for specific ECE habitats in distinct locations at different time periods, such as the recreation value of several coral reef marine parks in the Seychelles (Mathieu et al. 2003), the value of increased offshore fishery production from mangrove habitat in Thailand (Barbier 2007), or the benefits of beach restoration in the U.S. states of Maine and New Hampshire (Huang et al. 2007). Each study also uses specific measures and units of value appropriate for the relevant study. For example, in the Seychelles study, the value estimate was expressed in terms of the average consumer surplus per tourist for a single year, the Maine and New Hampshire study estimated each household's willingness to pay for an erosion control program to preserve five miles of beach, and the Thailand study calculated the capitalized value per hectare of mangrove in terms of offshore fishery production. Although it is possible to make assumptions to transform the valuation estimate of each study into the same physical units (e.g., per hectare), temporal period (e.g., capitalized or annual value), or currency (e.g., US$), we do not think such a transformation is warranted for the purposes of this study.

Second, we do not alter the original valuation estimates into a common unit of measure (such as US$$\cdot$ha$^{-1}\cdot$yr^{-1} in 2010 prices) because of the concern that such standardizing of values will be misused or misinterpreted. For example, one might be tempted to "add up" all the ecosystem service values and come up with a "total value" of a particular ECE habitat, such as a salt marsh. Or, one might take the estimate for a specific location, such as the recreation value of several

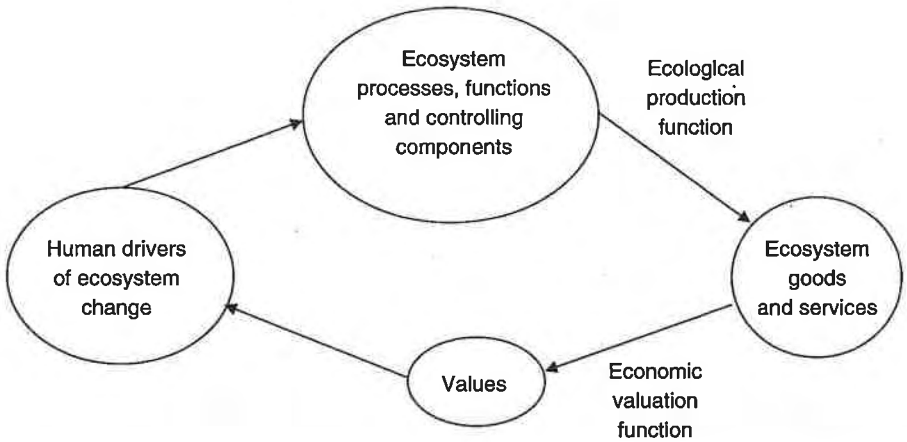

FIG. 1. Key interrelated steps in the valuation of ecosystem goods and services. This figure is adapted from NRC (2005: Fig. 1-3).

coral reef marine parks in the Seychelles (Mathieu et al. 2003), and "scale it up" by all the total hectares of coral reefs in the Indian Ocean or even the world to come up with a regional or global value of the recreational value of coral reefs. As argued by Bockstael et al. (2000:1396), when "the original studies valued small changes in specific and localized components of individual ecosystems ... it is incorrect to extrapolate the value estimates obtained in any of these studies to a much larger scale, let alone to suppose that the extrapolated estimates could then be added together."

Finally, because our efforts here focus on identifying individual ECE services and any reliable estimates that value changes in these specific services, we do not emphasize valuation studies that estimate the value of entire ecosystems to human beings or assessing broader values, such as many nonuse existence and bequest values, that relate to the protection of ecosystems. However, we do recognize that such values are an important motivation for the willingness to pay by many members of society to protect ecosystems, including ECEs.

For example, Fig. 2 is a more detailed version of Fig. 1, emphasizing the economic valuation component of the latter diagram. As indicated in Fig. 2, there are a number of different ways in which humans benefit from, or value, ecosystem goods and services. The first distinction is between the "use values" as opposed to "nonuse values" arising from these goods and services. Typically, use values involve some human "interaction" with the environment, whereas nonuse values do not, as they represent an individual valuing the pure "existence" of a natural habitat or ecosystem or wanting to "bequest" it to future generations. Direct-use values refer to both consumptive and nonconsumptive uses that involve some form of direct physical interaction with environmental goods and services, such as recreational activities, resource harvesting, drinking clean water, breathing unpolluted air, and so forth. Indirect-use values refer to those ecosystem services whose values can only be measured indirectly, since they are derived from supporting and protecting activities that have directly measurable values.

As is apparent from Tables 1–5, the individual ECE services that we identified and discuss contribute to consumptive direct-use values (e.g., raw materials and food), nonconsumptive direct-use values (e.g., tourism, recreation, education, and research), and indirect-use values (e.g., coastal protection, erosion control, water catchment and purification, maintenance of beneficial species, and carbon sequestration). When it comes to valuing whether or not to create national parks from ECEs, or to protect entire ecosystems, assessing non-users' willingness to pay is also important. For example, Bateman and Langford (1997) assess the nonuse values of households across Great Britain for preserving the Norfolk and Suffolk Broads coastal wetlands in the United Kingdom from salt water intrusion. Even poor coastal communities in Malaysia, Micronesia, and Sri Lanka show considerable existence and other nonuse values for mangroves that can justify the creation of national parks and other protection measures (Naylor and Drew 1998, Othman et al. 2004, Wattage and Mardle 2008). As our review highlights how ECEs globally are endangered by a wide range of human drivers of change, it will be important that future studies assess all the use and nonuse values that arise from ecosystem goods and services to determine whether it is worth preserving or restoring critical ECEs.

RESULTS: THE KEY SERVICES AND VALUES OF ECEs

In the following sections, we provide an overview of the results of our review of the main ecological services for five ECEs, arranged in order of most to least submerged: coral reefs, seagrass beds, salt marshes, mangroves, and sand beaches and dunes. To give an indication of the "ecological production function" underlying the ecological services generated by each

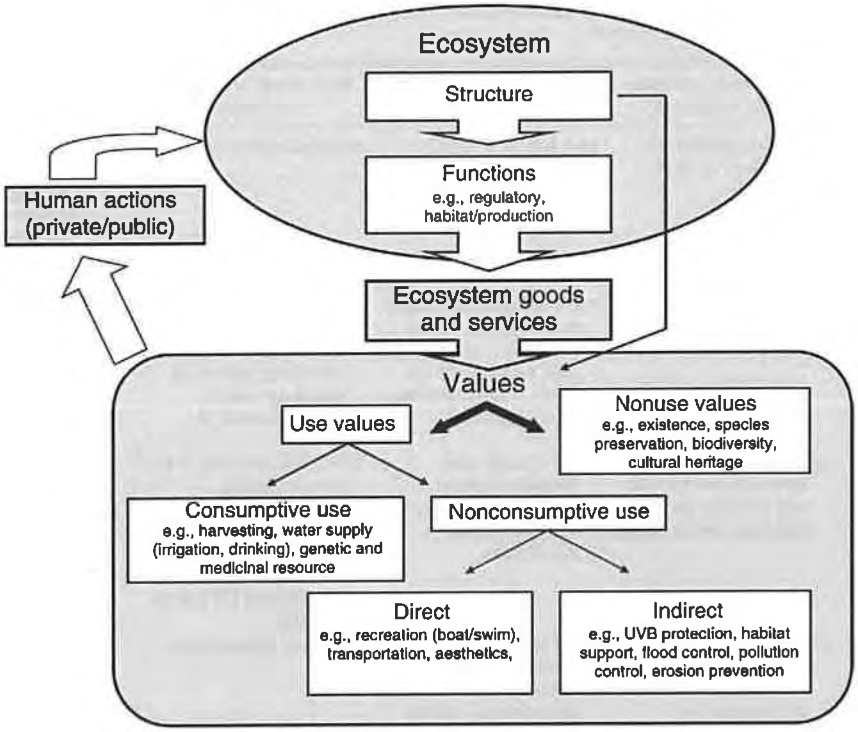

FIG. 2. Economic valuation of ecosystem goods and services. UVB is ultraviolet-B radiation from sunlight, which can cause skin cancer. This figure is adapted from NRC (2005: Fig. 4-1).

ECE (see Fig. 1), we outline briefly its key ecological structure, processes and functions, and identify the main controlling abiotic and biotic components. When available, we cite estimates of economic values from these services. The results give an indication as to the level of progress in valuing key ECE services and, equally important, where more integrated work on ecological and economic assessment of ecosystem services needs to be done.

Coral reefs

Coral reefs are structurally complex limestone habitats that form in shallow coastal waters of the tropics. Reefs can form nearshore and extend hundreds of kilometers in shallow offshore environments. Coral reefs are created by sedentary cnidarians (corals) that accrete calcium carbonate and feed on both zooplankton and maintain a mutualistic symbiosis with photosynthetic dinoflagellates. Thus, the majority of the reef structure is dead coral skeleton laid down over millennia, covered by a thin layer of live coral tissue that slowly accretes new limestone. In addition, coralline algae play an important role in stabilizing and cementing the coral reef structure. The community composition of reefs depends on global, regional, and local factors, which interact to produce the wide variety of coral reefs present on earth (Connell et al. 1997, Glynn 1997, Pandolfi 2002, Hughes et al. 2005).

As outlined in Table 1, coral reefs provide a number of ecosystem services to humans including raw materials, coastal protection, maintenance of fisheries, nutrient cycling, and tourism, recreation, education, and research. The table indicates representative examples of the values of some of these services, where they are available.

Historically, live reefs have served as a source of lime, which is an essential material in the manufacturing of mortar and cement and road building, and is used to control soil pH in agriculture (Dulvy et al. 1995). Presently, excavation of live reefs for lime is uncommon due to the obvious destructive nature of this resource extraction. As there are no examples of such coral mining being conducted sustainably, we have not included any value estimates in Table 1.

An important ecosystem service provided by coral reefs is coastal protection or the buffering of shorelines from severe weather, thus protecting coastal human populations, property, and economic activities. As indicated in Table 1, this service is directly related to the economic processes and functions of attenuating or dissipating waves and facilitating beach and shoreline retention. By altering the physical environment (i.e., reducing waves and currents), corals can engineer the physical environment for entire ecosystems, making it possible for other coastal ecosystems such as seagrass beds and mangroves to develop, which in turn serve their own suite of services to humans. Despite the importance of this coastal protection service, very few economic studies have estimated a value for it. Those

Table 1. Ecosystem services, processes and functions, important controlling components, examples of values, and human drivers of ecosystem change for nearshore coral reefs.

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials	generates biological productivity and diversity	reef size and depth, coral type, habitat quality	estimates unavailable	climate change, blast or cyanide fishing, lime mining, eutrophication, sedimentation, coastal development, dredging, pollution, biological invasion
Coastal protection	attenuates and/or dissipates waves, sediment retention	wave height and length, water depth above reef crest, reef length and distance from shore, coral species, wind climate	US$174·ha^{-1}·yr^{-1} for Indian Ocean based on impacts from 1998 bleaching event on property values (Wilkinson et al. 1999)	
Maintenance of fisheries	provides suitable reproductive habitat and nursery grounds, sheltered living space	coral species and density, habitat quality, food sources, hydrodynamic conditions	US$15–45 000·km^{-2}·yr^{-1} in sustainable fishing for local consumption and $5–10 000·km^{-2}·yr^{-1} for live-fish export, the Philippines (White et al. 2000)	
Nutrient cycling	provides biogeochemical activity, sedimentation, biological productivity	coral species and density, sediment deposition, subsidence, coastal geomorphology	estimates unavailable	
Tourism, recreation, education, and research	provides unique and aesthetic reefscapes, suitable habitat for diverse fauna and flora	lagoon size, beach area, wave height, habitat quality, coral species and density, diversity	US$88 000 total consumer surplus for 40 000 tourists to marine parks, Seychelles (Mathieu et al. 2003) and meta-analysis of recreational values (Brander et al. 2007)	

studies that do exist tend to use benefit transfer and replacement cost methods of valuation in an ad hoc manner, which undermine the reliability of the value estimates (see Chong 2005 and Barbier 2007 for further discussion). However, the widespread reef destruction caused by catastrophic events and global change, such as hurricanes, typhoons, and coral bleaching, gives some indication of the value of the lost storm protection services. For example, as a result of the 1998 bleaching event in the Indian Ocean, the expected loss in property values from declining reef protection was estimated to be US$174·ha^{-1}·yr^{-1} (hereafter all values in US$, unless otherwise stated; Wilkinson et al. 1999).

Coral reefs also serve to maintain fisheries through the enhancement of ecologically and economically important species by providing shelter space and substrate for smaller organisms, and food sources for larger epibenthic and pelagic organisms. Increases in fishing technology and transport have transformed reef fisheries that initially functioned solely for subsistence into commercial operations that serve international markets. Coral reef fisheries consist of reef-associated pelagic fisheries (e.g., tuna, mackerel, mahi-mahi, and sharks), reef fishes (e.g., jacks, snappers, groupers, and parrot fishes), and large invertebrates (e.g., giant clams, conch, lobsters, and crabs). The commercial value of these fisheries can be significant for some economies. For example, fish harvested from Hawaiian coral reefs are estimated to contribute $1.3 million yearly to the Hawaiian economy (Cesar and van Beukering 2004). From 1982 to 2002, small-scale, predominantly coral reef, fisheries contributed $54.7 million to the economies of America Samoa and the Commonwealth of the Northern Mariana Islands (Zeller et al. 2007).

Additional fishery harvests consist of the live-animal aquarium trade, based on corals, small fishes, and invertebrates collected from reefs. The aquarium trade has substantially expanded in the past 20 years, listed in 1985 as making $20–40 million/yr as a world market (Wood 1985) and expanding to an estimated $90–300 million/yr in 2002 (Sadovy and Vincent 2002). The export and sale of shells and jewelry also makes up a substantial portion of fisheries on reefs; giant clams, conch shells, coral, and pearls are all among the many heavily harvested byproducts.

Reliable values for the sustainable production of coral reef fish for local consumption and the aquarium trade are rare. White et al. (2000) provide some estimates for the Philippines. The potential annual revenue for sustainable fish production could be \$15–45 000/km^2 of healthy coral reef for local consumption and \$5–10 000/km^2 for live fish export. Zhang and Smith (*in press*) estimate the maximum sustainable yield to the Gulf of Mexico reef fishery (mainly grouper and snapper species, amberjack, and tilefish) to be ~1.30 million kg/month (~2.86 million pounds/month). Though the reefs in the Gulf of Mexico are generally exposed limestone or sandstone and not coral, the habitats are similar in their structural complexity, which is an important factor in protecting young fish and smaller species from predation.

Coral reef ecosystems also perform important services by cycling organic and inorganic nutrients. Despite housing a great deal of inorganic carbon in the limestone skeleton that makes up the structure of the reef, coral reefs may actually be a net source of atmospheric carbon dioxide (Kawahata et al. 1997). Reefs do, however, contribute significantly to the global calcium carbonate ($CaCO_3$) budget, estimated as 26% of coastal marine $CaCO_3$ and 11% of the total $CaCO_3$ precipitation (Hallock 1997, Gattuso et al. 1998). Reefs additionally transfer excess nitrogen production from cyanobacteria and benthic microbes on the reef to the pelagic (water column) environment (Moberg and Folke 1999). Though poorly quantified, the sequestering of $CaCO_3$ to form the foundation or habitat of the reef is the primary reason for such high abundance and diversity of organisms. Unfortunately, as indicated in Table 1, there are no reliable estimates of the economic value of the nutrient cycling and transfer services of coral reefs.

Coral reefs and associated placid lagoons are also economically valuable for the tourism and recreational activities they support. Resorts depend on the aesthetically turquoise lagoons, white sandy beaches, and underwater opportunities on the reef to attract tourists. The high biological diversity and clear waters of tropical reefs also support an abundance of recreational activities such as SCUBA diving, snorkeling, island tours, and sport fishing. These activities can be highly lucrative for individual economies; for example, in 2002, the earnings of ~100 diver operators in Hawaii were estimated at \$50–60 million/year (van Beukering and Cesar 2004). Revenues from coral reef tourism in the Pulau Payar Marine Park, Malaysia, are estimated at \$390 000/year (Yeo 2002), and coral reef diving earns gross revenue of \$10 500–45 540/year in the Bohol Marine Triangle, the Philippines (Samonte-Tan et al. 2007).

However, estimates of the recreational value of individual reefs should be interpreted with caution as a recent review of such studies found substantial bias in the estimates of individual recreation values (Brander et al. 2007). Reliable estimates can be made if such biases are controlled. For example, Mathieu et al. (2003) found that the average consumer surplus per tourist visiting the marine national parks in the Seychelles is \$2.20, giving a total consumer surplus estimate of \$88 000 for the 40 000 tourists to the coral reefs in 1997. Tapsuwan and Asafu-Adjaye (2008) were able to estimate the economic value of scuba diving in the Similan Island coral reefs in Thailand, controlling for diver's attitude toward the quality of the dive site, frequency of dive trips, and socioeconomic characteristics, including whether divers were Thai or foreign. The authors estimated a consumer surplus value of \$3233 per person per dive trip.

In addition to tourism and recreation, reefs also provide substantial services through research opportunities for scientists, work that is essential to basic and applied science (Greenstein and Pandolfi 2008). There are no reliable estimates of this value for coral reefs. As a rough indication of this value, expenditures for field work, primary data gathering, boat/vessel rental, supplies, and diving equipment amount to \$32–111$\cdot$ha$^{-1}\cdot$yr^{-1} in Bohol Marine Triangle, the Philippines (Samonte-Tan et al. 2007).

Despite the numerous economic benefits coral reefs provide, reef ecosystems are under threat of irrevocable decline worldwide from a suite of anthropogenic stressors. Localized stressors (i.e., within reefs or archipelagos) include overfishing, dynamite or cyanide fishing, pollution, mining, eutrophication, coastal development, dredging, sedimentation, and biological invasion (e.g., Hoegh-Guldberg 1999, Gardner et al. 2003, Bellwood et al. 2004, Hoegh-Guldberg et al. 2007). A variety of reef ecosystem services may be affected by coral degradation. For example, areas in Sumatra where dynamite fishing had occurred suffered 70% greater wave heights than undisturbed areas during the 2004 Indian Ocean Tsunami (Fernando et al. 2005). Blast fishing can also have negative effects on local economies by reducing the amount of available reef for tourisms; in Indonesia, blast fishing led to the loss of a reef that was valued at \$306 800/km^2 (Pet-Soede et al. 1999). Overfishing has important cascading consequences on both reef ecosystem function and sustainable production by inducing phase shifts (Mumby et al. 2006, 2007). Overharvesting by the aquarium industry has also been documented on local levels (Lubbock and Polunin 1975, Warren-Rhodes et al. 2004). Moreover, eutrophication-induced algal blooms led to millions of dollars of lost tourism revenue in Hawaii (van Beukering and Cesar 2004).

Global-scale climate change is also threatening reefs through coral bleaching, disease, and ocean acidification, leading to both reef destruction and structural degradation (Graham et al. 2007, Hoegh-Guldberg et al. 2007, Carpenter et al. 2008). Several important reef ecosystem services are likely to be affected. Though the economic impacts of climate change on fisheries remain somewhat unclear, the benthic composition of reefs is likely to shift, thus affecting overall fish productivity and

TABLE 2. Ecosystem services, processes and functions, important controlling components, examples of values, and human drivers of ecosystem change for seagrasses.

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials and food	generates biological productivity and diversity	vegetation type and density, habitat quality	estimates unavailable	eutrophication, overharvesting, coastal development, vegetation disturbance, dredging, aquaculture, climate change, sea level rise
Coastal protection	attenuates and/or dissipates waves	wave height and length, water depth above canopy, seagrass bed size and distance from shore, wind climate, beach slope, seagrass species and density, reproductive stage	estimates unavailable	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, subsidence, tidal stage, wave climate, coastal geomorphology, seagrass species and density	estimates unavailable	
Water purification	provides nutrient and pollution uptake, as well as retention, particle deposition	seagrass species and density, nutrient load, water residence time, hydrodynamic conditions, light availability	estimates unavailable	
Maintenance of fisheries	provides suitable reproductive habitat and nursery grounds, sheltered living space	seagrass species and density, habitat quality, food sources, hydrodynamic conditions	loss of 12 700 ha of seagrasses in Australia; associated with lost fishery production of AU$235 000 (McArthur and Boland 2006)	
Carbon sequestration	generates biogeochemical activity, sedimentation, biological productivity	seagrass species and density, water depth, light availability, burial rates, biomass export	estimates unavailable	
Tourism, recreation, education, and research	provides unique and aesthetic submerged vegetated landscape, suitable habitat for diverse flora and fauna	biological productivity, storm events, habitat quality, seagrass species and density, diversity	estimates unavailable	

harvests, as well as the availability of the most valued fishes collected in the aquarium trade (Pratchett et al. 2008). Reductions in tourism due to recent climate change-driven coral bleaching events are estimated in the billions (Wilkinson et al. 1999, Pratchett et al. 2008). The overall estimated economic damages from lost fisheries production, tourism and recreation, coastal protection, and other ecosystem services from the 1998 Indian Ocean coral bleaching event have ranged from $706 million to $8.2 billion (Wilkinson et al. 1999).

Seagrass beds

Seagrasses are flowering plants that colonize shallow marine and estuarine habitats. With only one exception (the genus *Phyllospadix*), seagrasses colonize soft substrates (e.g., mud, sand, cobble) and grow to depths where ~11% of surface light reaches the bottom (Duarte 1991). Seagrasses prefer wave-sheltered conditions as sediments disturbed by currents and/or waves lead to patchy beds or their absence (Koch et al. 2006). Despite being among the most productive ecosystems on the planet, fulfilling a key role in the coastal zone (Duarte 2002) and being lost at an alarming rate (Orth et al. 2006, Waycott et al. 2009), seagrasses receive little attention when compared to other ECEs (Duarte et al. 2008).

As indicated in Table 2, seagrass beds provide a wide range of ecosystem services, including raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, recreation, education, and research, yet reliable estimates of the economic values of most of these services are lacking.

Although in the past seagrasses were highly valued as raw materials and food, modern direct uses of seagrasses are rather limited. For example, seagrasses are still harvested in Tanzania, Portugal, and Australia, where they are used as fertilizer (Hemminga and Duarte 2000, de la Torre-Castro and Rönnbäck 2004). In the Chesapeake Bay, USA, seagrass by-catch or beach-cast is used to keep crabs moist during transport. In East Africa, some species are served as salad, while others are used in potions and rituals (de la Torre-Castro and Rönnbäck 2004). In the Solomon Islands, roots of the seagrass *Enhalus acoroides* are sometimes used as food, while leaf fibers are used to make necklaces and to provide spiritual benefits such as a gift to a newborn child, for fishing luck, and to remove an aphrodisiac spell (Lauer and Aswani 2010). However, currently there are no reliable estimates of the values of these food and raw material uses of harvested seagrasses.

Coastal protection and erosion control are often listed as important ecosystem services provided by seagrasses (Hemminga and Duarte 2000, Spalding et al. 2003, Koch et al. 2009). Seagrasses can attenuate waves and, as a result, smaller waves reach the adjacent shoreline (Fonseca and Cahalan 1992, Koch 1996, Prager and Halley 1999). Coastal protection is highest when the plants occupy the entire water column, such as at low tide, or when plants produce long reproductive stems (Koch et al. 2006). When small seagrasses colonize deeper waters, their contribution to wave attenuation and coastal protection is more limited. Sediment stabilization by seagrass roots and rhizomes, as well as by their beach-casted debris is important for controlling coastal erosion (Hemminga and Nieuwenhuize 1990). The benefits seagrasses provide in terms of coastal protection and erosion control via sediment stabilization and wave attenuation are yet to be valued satisfactorily.

Water purification, or the increase in water clarity, by seagrasses occurs via two processes: nutrient uptake and suspended particle deposition. Seagrasses not only remove nutrients from the sediments and water column (Lee and Dunton 1999), but also their leaves are colonized by algae (epiphytes), which further remove nutrients from the water column (Cornelisen and Thomas 2006). The nutrients incorporated into the tissue of seagrasses and algae are slowly released back into the water column once the plants decompose or are removed from the nutrient cycle when buried in the sediment (Romero et al. 2006). In addition to reducing nutrients, seagrass beds also decrease the concentration of suspended particles (e.g., sediment and microalgae) from the water (Gacia et al. 1999). Leaves in the water column provide an obstruction to water flow and, as a result, currents and waves are reduced within seagrass canopies causing particles to be deposited (Koch et al. 2006). This water purification effect can be quite dramatic with clearer water in vegetated areas compared to those without vegetation (Rybicki 1997). No reliable economic estimates exist for the water purification service provided by seagrass beds.

Seagrasses also generate value as habitat for ecologically and economically important species such as scallops, shrimp, crabs, and juvenile fish. Seagrasses protect these species from predators and provide food in the form of leaves, detritus, and epiphytes. The market value of the potential shrimp yield in seagrass beds in Western Australia is estimated to be between \$684 and \$2511$\cdot$ha$^{-1}\cdot$yr^{-1} (Watson et al. 1993). In Bohol Marine Triangle, the Philippines, the annual net revenue from gleaning mollusks and echinoderms (e.g., starfish, sea urchins, sea cucumbers, etc.) from seagrass beds at low tide ranges from \$12–120/ha and from fishing \$8–84/ha (Samonte-Tan et al. 2007). The fish, shrimp, and crab yield in southern Australia is valued at US\$1436$\cdot$ha$^{-1}\cdot$yr^{-1} (McArthur and Boland 2006). Based on the latter estimate, a loss of 2700 ha of seagrass beds results in lost fishery production of AU\$235 000 (Table 2).

Seagrasses are involved in carbon sequestration by using carbon dissolved in the seawater (mostly in the form of CO_2, but also HCO_3^-) to grow. Once the plants complete their life cycle, a portion of these materials is then buried in the sediment in the form of refractory detritus. It has been estimated that detritus burial from vegetated coastal habitats contributes about half of the total carbon burial in the ocean (Duarte et al. 2005). Therefore, the decline in seagrasses could lead to an important loss in the global CO_2 sequestration capacity, although this effect has yet to be valued.

Anthropogenic influences such as eutrophication, overharvesting, sediment runoff, algal blooms, commercial fisheries and aquaculture practices, vegetation disturbance, global warming, and sea level rise are among the causes for the decline of seagrasses worldwide (Orth et al. 2006, Waycott et al. 2009). With the disappearance of seagrasses, valuable ecosystem services are also lost (McArthur and Boland 2006). Yet, as very few of these benefits have been estimated reliably (see Table 2), we have only historical and anecdotal evidence of the likely economic impacts. For example, the disappearance of most seagrasses in Long Island, USA, in the 1930s due to wasting disease led to the collapse of the scallop industry (Orth et al. 2006).

Salt marshes

Salt marshes are intertidal grasslands that form in low-energy, wave-protected shorelines along continental margins. Extensive salt marshes (>2 km in width) establish and grow both behind barrier-island systems and along the wave-protected shorelines of bays and estuaries. Salt marshes are characterized by sharp zonation of plants and low species diversity, but extremely high primary and secondary production. The structure and function of salt marsh plant communities (and thus their services) were long thought to be regulated by physical processes, such as elevation, salinity, flooding, and nutrient availability (Mitsch and Gosselink 2008). Over the past 25 years, however, experiments have shown that competition (Bertness 1991) and facilitation (Hacker and Bertness 1995) among marsh plants is also critically important in controlling community structure. More recently, research has revealed the presence of strong trophic cascades driven by habitat-destroying herbivorous grazers (Silliman and Bertness 2002, Silliman and Bortolus 2003, Silliman et al. 2005, Henry and Jefferies 2009).

Among coastal ecosystems, salt marshes provide a high number of valuable benefits to humans, including raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, recreation, education, and research. Some of these important values have been estimated (Table 3).

For over 8000 years, humans have relied on salt marshes for direct provisioning of raw materials and food (Davy et al. 2009). Although harvesting of marsh grasses and use of salt marshes as pasture lands has decreased today, these services are still important locally in both developed and developing areas of the world (Bromberg-Gedan et al. 2009). For example, in the Ribble estuary on England's west coast, annual net income from grazing in a salt marsh nature reserve is: £15.27$\cdot$ha$^{-1}\cdot$yr^{-1} (King and Lester 1995).

For thousands of years, salt marshes have provided coastal protection from waves and storm surge, as well as from coastal erosion, for humans (Davy et al. 2009). By stabilizing sediment, increasing the intertidal height, and providing baffling vertical structures (grass), salt marshes reduce impacts of incoming waves by reducing their velocity, height, and duration (Morgan et al. 2009; Bromberg-Gedan et al., *in press*). Marshes are also likely to reduce storm surge duration and height by providing extra water uptake and holding capacity in comparison to the sediments of unvegetated mudflats. This storm protection value can be substantial, as a study of the protection against hurricanes by coastal wetlands along the U.S. Atlantic and Gulf coasts reveals (Table 3; Costanza et al. 2008). However, there are no reliable estimates of the economic value of salt marshes in controlling coastal erosion.

Salt marshes act as natural filters that purify water entering the estuary (Mitsch and Gosselink 2008). As water (e.g., from rivers, terrestrial runoff, groundwater, or rain) passes through marshes, it slows due to the baffling and friction effect of upright grasses (Morgan et al. 2009). Suspended sediments are then deposited on the marsh surface, facilitating nutrient uptake by salt marsh grasses. This water filtration service benefits human health, but also adjacent ecosystems, such as seagrasses, which may be degraded by nutrients and pollutants. In southern Louisiana, USA, treatment of wastewater by predominantly marsh swamps achieved capitalized cost savings of \$785 to \$15 000/acre (1 acre = 0.4 ha) compared to conventional municipal treatment (Breaux et al. 1995).

Salt marsh ecosystems also serve to maintain fisheries by boosting the production of economically and ecologically important fishery species, such as shrimp, oysters, clams, and fishes (Boesch and Turner 1984, MacKenzie and Dionne 2008). For example, salt marshes may account for 66% of the shrimp and 25% of the blue crab production in the Gulf of Mexico (Zimmerman et al. 2000). Because of their complex and tightly packed plant structure, marshes provide habitat that is mostly inaccessible to large fishes, thus providing protection and shelter for the increased growth and survival of young fishes, shrimp, and shellfish (Boesch and Turner 1984). For example, the capitalized value of an acre of salt marsh in terms of recreational fishing is estimated to be \$6471 and \$981 for the east and west coasts of Florida, USA, respectively (Bell 1997). The contribution of an additional acre of salt marsh to the value of the Gulf Coast blue crab fishery ranges from \$0.19 to \$1.89/acre (Freeman 1991).

As one of the most productive ecosystems in the world (up to 3900 g C$\cdot$m$^{-2}\cdot$yr^{-1}), salt marshes sequester millions of tons of carbon annually (Mitsch and Gosselink 2008). Because of the anoxic nature of the marsh soils (as in most wetlands), carbon sequestered by salt marsh plants during photosynthesis is often shifted from the short-term carbon cycle (10–100 years) to the long-term carbon cycle (1000 years) as buried, slowly decaying biomass in the form of peat (Mitsch and Gosselink 2008, Mayor and Hicks 2009). This cycle-shifting capability is unique among many of the world's ecosystems, where carbon is mostly turned over quickly and does not often move into the long-term carbon cycle. However, to our knowledge, there is no valuation estimation of this carbon sequestration service. Based on an estimate of permanent carbon sequestration by global salt marshes of 2.1 Mg C/ha by Chmura et al. (2003), and employing the 23 September 2009 Carbon Emission Reduction (CER) price of the European Emission Trading System (ETS) of €12.38/Mg converted to \$2000, we calculated a value of \$30.50$\cdot$ha$^{-1}\cdot$yr^{-1} as an approximate indicator of this benefit, but this is likely to vary greatly depending on latitude, as warmer marshes do not accumulate peat like their colder counterparts.

Salt marshes provide important habitat for many other beneficial species, which are important for tourism, recreation, education, and research. For example, estimates from land sales and leases for marshes in England suggest prices in the range of £150–493/acre for bird shooting and wildfowling (King and Lester 1995). Respondents were willing to pay £31.60/person to create otter habitat and £1.20 to

TABLE 3. Ecosystem services, processes and functions, important controlling components, examples of values, and human drivers of ecosystem change for salt marshes.

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials and food	generates biological productivity and diversity	vegetation type and density, habitat quality, inundation depth, habitat quality, healthy predator populations	£15.27· ha^{-1}·yr^{-1} net income from livestock grazing, UK (King and Lester 1995)	marsh reclamation, vegetation disturbance, climate change, sea level rise, pollution, altered hydrological regimes, biological invasion
Coastal protection	attenuates and/or dissipates waves	tidal height, wave height and length, water depth in or above canopy, marsh area and width, wind climate, marsh species and density, local geomorphology	US\$8236·ha^{-1}·yr^{-1} in reduced hurricane damages, USA (Costanza et al. 2008)	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, tidal stage, coastal geomorphology, subsidence, fluvial sediment deposition and load, marsh grass species and density, distance from sea edge	estimates unavailable	
Water purification	provides nutrient and pollution uptake, as well as retention, particle deposition	marsh grass species and density, marsh quality and area, nutrient and sediment load, water supply and quality, healthy predator populations	US\$785–15 000/acre capitalized cost savings over traditional waste treatment, USA (Breaux et al. 1995)†	
Maintenance of fisheries	provides suitable reproductive habitat and nursery grounds, sheltered living space	marsh grass species and density, marsh quality and area, primary productivity, healthy predator populations	US\$6471/acre and \$981/acre capitalized value for recreational fishing for the east and west coasts, respectively, of Florida, USA (Bell 1997) and \$0.19–1.89/acre marginal value product in Gulf Coast blue crab fishery, USA (Freeman 1991)†	
Carbon sequestration	generates biogeochemical activity, sedimentation, biological productivity	marsh grass species and density, sediment type, primary productivity, healthy predator populations	US\$30.50·ha^{-1}·yr^{-1}‡	
Tourism, recreation, education, and research	provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	marsh grass species and density, habitat quality and area, prey species availability, healthy predator populations	£31.60/person for otter habitat creation and £1.20/person for protecting birds, UK (Birl and Cox 2007)	

† One acre = 0.4 ha.
‡ Based on Chumra et al. (2003) estimate of permanent carbon sequestration by global salt marshes of 2.1 Mg C·ha^{-1}·yr^{-1} and 23 September 2009 Carbon Emission Reduction (CER) price of the European Emission Trading System (ETS) of €12.38/Mg, which was converted to US\$2000.

protect birds in the Severn Estuary Wetlands bordering England and Wales (Birol and Cox 2007).

Current human threats to salt marshes include biological invasions, eutrophication, climate change and sea level rise, increasing air and sea surface temperatures, increasing CO_2 concentrations, altered hydrologic regimes, marsh reclamation, vegetation disturbance, and pollution (Silliman et al. 2009). As indicated in Table 3, a growing number of valuable marsh services are lost with the destruction of this habitat. Approximately 50% of the original salt marsh ecosystems have been degraded or lost globally, and in some areas, such as the West Coast of the USA, the loss is >90% (Bromberg and Silliman 2009, Bromberg-Gedan et al. 2009). This is likely to be exacerbated by the recent Gulf of Mexico oil spill in 2010.

TABLE 4. Ecosystem services, processes and functions, important controlling components, examples of values, and human drivers of ecosystem change for mangroves.

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials and food	generates biological productivity and diversity	vegetation type and density, habitat quality	US$484–585·$ha^{-1}·yr^{-1}$ capitalized value of collected products, Thailand (Barbier 2007)	mangrove disturbance, degradation, conversion; coastline disturbance; pollution; upstream soil loss; overharvesting of resources
Coastal protection	attenuates and/or dissipates waves and wind energy	tidal height, wave height and length, wind velocity, beach slope, tide height, vegetation type and density, distance from sea edge	US$8966–10 821/ha capitalized value for storm protection, Thailand (Barbier 2007)	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, tidal stage, fluvial sediment deposition, subsidence, coastal geomorphology, vegetation type and density, distance from sea edge	US$3679·$ha^{-1}·yr^{-1}$ annualized replacement cost, Thailand (Sathirathai and Barbier 2001)	
Water purification	provides nutrient and pollution uptake, as well as particle retention and deposition	mangrove root length and density, mangrove quality and area	estimates unavailable	
Maintenance of fisheries	provides suitable reproductive habitat and nursery grounds, sheltered living space	mangrove species and density, habitat quality and area, primary productivity	US$708-$987/ha capitalized value of increased offshore fishery production, Thailand (Barbier 2007)	
Carbon sequestration	generates biological productivity, biogeochemical activity, sedimentation	vegetation type and density, fluvial sediment deposition, subsidence, coastal geomorphology	US$30.50·$ha^{-1}·yr^{-1}$†	
Tourism, recreation, education, and research	provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	mangrove species and density, habitat quality and area, prey species availability, healthy predator populations	estimates unavailable	

† Based on Chumra et al. (2003) estimate of permanent carbon sequestration by global salt marshes of 2.1 Mg C·$ha^{-1}·yr^{-1}$ and 23 September 2009 Carbon Emission Reduction (CER) price of the European Emission Trading System (ETS) of €12.38/Mg, which was converted to US$2000.

Mangroves

Mangroves are coastal forests that inhabit saline tidal areas along sheltered bays, estuaries, and inlets in the tropics and subtropics throughout the world. Around 50–75 woody species are designated as "mangrove," which is a term that describes both the ecosystem and the plant families (Ellison and Farnsworth 2001). In the 1970s, mangroves may have covered as much as 200 000 km^2, or 75% of the world's coastlines (Spalding et al. 1997). But since then, at least 35% of global mangrove area has been lost, and mangroves are currently disappearing at the rate of 1–2% annually (Valiela et al. 2001, Alongi 2002, FAO 2007).

The worldwide destruction of mangroves is of concern because they provide a number of highly valued ecosystems services, including raw materials and food, coastal protection, erosion control, water purification, maintenance of fisheries, carbon sequestration, and tourism, recreation, education, and research (Table 4). For many coastal communities, their traditional use of mangrove resources is often closely connected with the health and functioning of the system, and thus this use is often intimately tied to local culture, heritage, and traditional knowledge (Walters et al. 2008).

Of the ecosystem services listed, three have received most attention in terms of determining their value to coastal populations. These include (1) their use by local coastal communities for a variety of products, such as fuel wood, timber, raw materials, honey and resins, and crabs and shellfish; (2) their role as nursery and breeding habitats for offshore fisheries; and (3) their propensity to serve as natural "coastal storm barriers" to periodic wind and wave or storm surge events, such as tropical storms, coastal floods, typhoons, and tsunamis. Assigning a value to these three mangrove ecosystem services has been conducted for Thailand by Barbier (2007), who compared the net economic returns per hectare to shrimp farming, the costs of mangrove rehabilitation, and the value of mangrove services. All land uses were assumed to be instigated over a nine-year period (1996 to 2004), and the net present value (NPV) of each land use or ecosystem service was estimated in 1996 US$ per hectare. The NPV arising from the net income to local communities from collected forest and other products and shellfish was $484 to $584/ha. In addition, the NPV of mangroves as breeding and nursery habitat in support of offshore artisanal fisheries ranged from $708 to $987/ha, and the storm protection service was $8966 to $10 821/ha.

Such benefits are considerable when compared to the average incomes of coastal households; a survey conducted in July 2000 of four mangrove-dependent communities in two different coastal provinces of Thailand indicates that the average household income per village ranged from $2606 to $6623/yr, and the overall incidence of poverty (corresponding to an annual income of $180 or lower) in all but three villages exceeded the average incidence rate of 8% found across all rural areas of Thailand (Sarntisart and Sathirathai 2004). The authors also found that excluding the income from collecting mangrove forest products would have raised the incidence of poverty to 55.3% and 48.1% in two of the villages, and to 20.7% and 13.64% in the other two communities.

The Thailand example is not unusual; coastal households across the world typically benefit from the mangrove services, indicated in Table 4 (Ruitenbeek 1994, Bandaranayake 1998, Barbier and Strand 1998, Naylor and Drew 1998, Janssen and Padilla 1999, Rönnbäck 1999, Badola and Hussain 2005, Chong 2005, Brander et al. 2006, Walton et al. 2006, Rönnbäck et al. 2007, Aburto-Oropeza et al. 2008, Walters et al. 2008, Lange and Jiddawi 2009, Nfotabong Atheull et al. 2009). Mangroves also provide important cultural benefits to coastal inhabitants. A study in Micronesia finds that the communities "place some value on the existence and ecosystem functions of mangroves over and above the value of mangroves' marketable products" (Naylor and Drew 1998:488).

Since the 2004 Indian Ocean Tsunami, there has been considerable global interest in one particular service of mangroves: their role as natural barriers that protect the lives and properties of coastal communities from periodic storm events and flooding. Eco-hydrological evidence indicates that this protection service is based on the ability of mangroves to attenuate waves and thus reduce storm surges (Mazda et al. 1997, 2006, Massel et al. 1999, Wolanski 2007, Barbier et al. 2008, Koch et al. 2009). Comprehensive reviews of all the field assessments in the aftermath of the Indian Ocean Tsunami suggest that some areas were more protected by the presence of healthy mangroves, provided that the tidal wave was not too extreme in magnitude (Montgomery 2006, Braatz et al. 2007, Forbes and Broadhead 2007, Alongi 2008, Cochard et al. 2008). For other major storm events, there is more economic evidence of the protective role of mangroves. For example, during the 1999 cyclone that struck Orissa, India, mangroves significantly reduced the number of deaths as well as damages to property, livestock, agriculture, fisheries, and other assets (Badola and Hussain 2005, Das and Vincent 2009). Das and Vincent estimated that there could have been 1.72 additional deaths per village within 10 km of the coast if the mangrove width along shorelines had been reduced to zero. Losses incurred per household were greatest ($154) in a village that was protected by an embankment but had no mangroves compared to losses per household ($33) in a village protected only by mangrove forests (Badola and Hussain 2005).

The ability of mangroves to stabilize sediment and retain soil in their root structure reduces shoreline erosion and deterioration (Daehler and Strong 1996, Sathirathai and Barbier 2001, Thampanya et al. 2006, Wolanski 2007). But despite the importance of this erosion control service, very few economic studies have been conducted to value it. Existing studies tend to use the replacement cost methods of valuation, due to lack of data, which can undermine the reliability of the value estimates (Chong 2005, Barbier 2007). In Thailand, the annualized replacement cost of using artificial barriers instead of mangroves is estimated to be $\$3679 \cdot ha^{-1} \cdot yr^{-1}$ (Sathirathai and Barbier 2001).

Mangroves also serve as barriers in the other direction; their water purification functions protect coral reefs, seagrass beds, and important navigation waters against siltation and pollution (Wolanski 2007). In southern China, field experiments have been conducted to determine the feasibility of using mangrove wetlands for wastewater treatment (Chen et al. 2009). Mangrove roots may also serve as a sensitive bio-indicator for metal pollution in estuarine systems (MacFarlane et al. 2003). The economic value of the pollution control service of mangroves has not been reliably estimated, however.

Because mangroves are among the most productive and biogeochemically active ecosystems, they are important sources of global carbon sequestration. To date, the value of mangroves as a carbon sink has not been estimated. Based on an estimate of permanent carbon sequestration by all mangroves globally (Chmura et al. 2003), following the same approach described above for salt marshes (see *Salt marshes*), we calculate a value of $\$30.50 \cdot ha^{-1} \cdot yr^{-1}$ as an approximate indicator of this benefit for mangroves.

Although many factors contribute to global mangrove deforestation, a major cause is aquaculture expansion in coastal areas, especially the establishment of shrimp farms (Barbier and Cox 2003). Aquaculture accounts for 52% of mangrove loss globally, with shrimp farming alone accounting for 38%. Forest use, mainly from industrial lumber and woodchip operations, causes 26% of mangrove loss globally. Freshwater diversion accounts for 11% of deforestation, and reclamation of land for other uses causes 5% of decline. The remaining sources of mangrove deforestation consist of herbicide impacts, agriculture, salt ponds, and other coastal developments (Valiela et al. 2001). The extensive and rapid loss of mangroves globally reinforces the importance of measuring the value of such ecological services, and employing these values appropriately in coastal management and planning.

Sand beaches and dunes

Coastal sand beaches and dunes are important but understudied arbiters of coastal ecosystem services. They form at low-lying coastal margins where sand transported by oceanic waves and wind combine with vegetation to produce dynamic geomorphic structures. Thus, sandy-shore ecosystems include both marine and terrestrial components and vary, depending on sand supply, in the extent to which the beach vs. the dune dominates (Short and Hesp 1982). Sandy beaches and dunes occur at all latitudes on earth and cover roughly 34% of the world's ice-free coastlines (Hardisty 1994).

For centuries, due to their unique position between ocean and land, coastal beaches and dunes have provided humans with important services such as raw materials, coastal protection, erosion control, water catchment and purification, maintenance of wildlife, carbon sequestration, and tourism, recreation, education, and research (Table 5; Carter 1990, Pye and Tsoar 1990). However, very few of these services have been valued, with the exception of erosion control and recreation and tourism (Table 5).

Beaches and dunes provide raw materials in the form of sand that has been mined for centuries for multiple uses, including extraction of minerals such silica and feldspar for glass and ceramic production, infill for development, amendments for agriculture, and base material for construction products. Although sand is a valuable resource, its extraction through mining can have obvious negative effects, especially on coastal protection and aquifers.

Coastal protection is arguably one of the most valuable services provided by sand shore ecosystems especially in the face of extreme storms, tsunamis, and sea level rise. As waves reach the shoreline they are attenuated by the beach slope and, at high tide, also by the foredune, a structure immediately behind the beach where sand accumulates in hills or ridges parallel to the shoreline. Beaches vary in their ability to attenuate waves depending on a continuum in their morphology (Carter 1991, Hesp and Short 1999, Short 1999). Foredunes can vary in height and width, and thus their ability to attenuate waves, depending on the presence of vegetation and sand supply from the beach (Hesp 1989; Hacker et al., *in press*). Measuring the coastal protective properties of sand shoreline systems involves understanding the relationship between beach and foredune shape and wave attenuation, especially in the aftermath of storms, hurricanes, or tsunamis (Leatherman 1979, Lui et al. 2005, Sallenger et al. 2006, Morton et al. 2007, Stockdon et al. 2007, Ruggiero et al. 2010). The economic value, although not calculated previously, is likely to be substantial. For example, Liu et al. (2005) report that, after the 2004 Indian Ocean Tsunami, there was total devastation and loss of 150 lives in a resort located directly behind where a foredune was removed to improve the scenic view of the beach and ocean.

Beaches and sand dunes provide sediment stabilization and soil retention in vegetation root structure, thus controlling coastal erosion and protecting recreational beaches, tourist-related business, ocean front properties, land for aquaculture and agriculture, and wildlife habitat. Although this service has not been valued directly, there have been a growing number of studies that value the benefits gained from erosion control programs that either preserve or "nourish" existing beaches and dunes (Landry et al. 2003, Kriesel and Landry 2004, Huang et al. 2007, Whitehead et al. 2008, Morgan and Hamilton 2010). Such programs often substitute for property owners building their own erosion protection structures, such as seawalls and groins, which can inadvertently accelerate the degradation of the coastal environment (Landry et al. 2003, Kriesel and Landry 2004). However, erosion control programs can also have negative effects on the surrounding environment, including affecting recreational beach use and views, displacing coastal erosion elsewhere, and disturbing wildlife habitat. For example, in the U.S. states of New Hampshire and Maine, a coastal erosion program that preserves five miles of beach is estimated to have net benefits, adjusted for the costs associated with the risk of injury to swimmers from the control measures, disturbance to wildlife habitat, and deterioration of water quality, of $4.45/household (Huang et al. 2007). Landry et al. (2003) find that a one-meter increase in beach width, or equivalently, the prevention of one meter of beach erosion, increased oceanfront and inlet-front property values by $233 on Tybee Island in the U.S. state of Georgia.

Another important service of coastal sand ecosystems is water catchment. Sand dunes are able to store significant amounts of water that can serve as aquifers for coastal populations (Carter 1990). For example, in the Meijendel dunes in The Netherlands, dune aquifers have been used as a source of drinking water for centuries (van der Meulen et al. 2004). The aquifer still supplies enough water for 1.5 million people in

TABLE 5. Ecosystem services, processes and functions, important controlling components, examples of values, and human drivers of ecosystem change for sand beaches and dunes.

Ecosystem services	Ecosystem processes and functions	Important controlling components	Ecosystem service value examples	Human drivers of ecosystem change
Raw materials	provides sand of particular grain size, proportion of minerals	dune and beach area, sand supply, grain size, proportion of desired minerals (e.g., silica, feldspar)	estimates unavailable for sustainable extraction	loss of sand through mining, development and coastal structures (e.g., jetties), vegetation disturbance, overuse of water, pollution, biological invasion
Coastal protection	attenuates and/or dissipates waves and reduces flooding and spray from sea	wave height and length, beach slope, tidal height, dune height, vegetation type and density, sand supply	estimates unavailable	
Erosion control	provides sediment stabilization and soil retention in vegetation root structure	sea level rise, subsidence, tidal stage, wave climate, coastal geomorphology, beach grass species and density	US$4.45/household for an erosion control program to preserve 8 km of beach, for Maine and New Hampshire beaches, USA (Huang et al. 2007)	
Water catchment and purification	stores and filters water through sand; raises water table	dune area, dune height, sand and water supply	estimates unavailable	
Maintenance of wildlife	biological productivity and diversity, habitat for wild and cultivated animal and plant species	dune and beach area, water and nutrient supply, vegetation and prey biomass and density	estimates unavailable	
Carbon sequestration	generates biological productivity, biogeochemical activity	vegetative type and density, fluvial sediment deposition, subsidence, coastal geomorphology	estimates unavailable	
Tourism, recreation, education, and research	provides unique and aesthetic landscapes, suitable habitat for diverse fauna and flora	dune and beach area, sand supply, wave height, grain size, habitat quality, wildlife species, density and diversity, desirable shells and rocks	US$166/trip or $1574 per visiting household per year for North Carolina beaches, USA (Landry and Liu 2009)	

surrounding cities. Because of the importance of this water source, the Meijendel dune is managed as a nature reserve that serves both drinking water and recreation needs. In 1999, the cost of management was $3.8 million/year, while the yearly income of the reserve was $99.2 million/year.

Coastal dunes can provide maintenance of wildlife in the form of habitat for fish, shellfish, birds, rodents, and ungulates, which have been captured or cultivated for food since humans first colonized the coast (Carter 1990, Pye and Tsoar 1990). In Europe, protection and restoration of dune wildlife and habitat has become a priority (Baeyens and Martínez 2004). In other regions of the world, dunes have been used for agricultural purposes (Pye and Tsoar 1990). However, there are no reliable estimates on the value of beaches and dunes as a source of habitat for wildlife.

Dunes that encourage vegetation growth and productivity will also assist in carbon sequestration, although this process is likely to vary with the type of vegetation, sediment deposition and subsidence, and coastal geomorphology. There are currently no estimates of the value of this service provided by dunes, however.

Beaches and dunes also supply important recreational benefits. Boating, fishing, swimming, scuba diving, walking, beachcombing, and sunbathing are among the numerous recreational and scenic opportunities that are provided by beach and dune access. In the USA alone, 70% of the population visits the beach on vacation, and 85% of total tourism dollars come from beach visits (Houston 2008). An analysis of North Carolina beaches shows that implementation of a beach replenishment policy to improve beach width by an average of 100 feet would increase the average number of trips by visitors in the subsequent year from 11 to 14, with beach-goers willing to pay \$166/trip or \$1574 per visiting household per year (Landry and Liu 2009). Another study of North Carolina beaches found that widening beach width increases the consumer surplus of visitors by \$7/trip (Whitehead et al. 2008). However, overuse of dune habitat due to beach recreation can also cause significant damages. The impacts to beach and dune function have been mostly in the form of changes in sand stabilization and distribution. Trampling of native vegetation by pedestrians or vehicles can destabilize sand and result in the loss of foredunes and thus coastal protection. Therefore, as with all coastal systems, reducing the damages caused by overuse of certain services such as the recreation and tourism benefits provided by beaches and dunes, requires thoughtful management and planning (e.g., Heslenfeld et al. 2004, Moreno-Casasola 2004).

Many of the services provided by sand beaches and dunes are threatened by human use, species invasions, and climate change (Brown and McLachlan 2002, Zarnetske et al. 2010; Hacker et al., *in press*). In particular, the removal or disruption of sand and vegetation coupled with increased storm intensity and sea level rise threaten critical services provided by this ecosystem, specifically those of coastal protection (Ruggiero et al. 2010) and coastal freshwater catchment. The fact that no reliable estimates of these services are currently available is worrisome.

Discussion: Issues for Future Research

Our review of economic values of key ecosystem services for five estuarine and coastal ecosystems (coral reefs, seagrass beds, salt marshes, mangroves, and sand beaches and dunes) reveals that progress has been made in estimating these benefits for some systems and services, but much work remains. For example, reliable valuation estimates are beginning to emerge for the key services of some ECEs, such as coral reefs, salt marshes, and mangroves, but many of the important benefits of seagrass beds and sand dunes and beaches have not been assessed properly. Even for coral reefs, marshes, and mangroves, important ecological services have yet to be valued reliably, such as cross-ecosystem nutrient transfer (coral reefs), erosion control (marshes), and pollution control (mangroves). Although more studies valuing ECE services have been conducted recently, our review shows that the number of reliable estimates is still relatively small.

Measurement issues, data availability, and other limitations continue to prevent the application of standard valuation methods to many ecosystem services. In circumstances where an ecological service is unique to a specific ecosystem and is difficult to value, often the cost of replacing the service or treating the damages arising from the loss of the service is used as a valuation approach. Such methods have been employed frequently to measure coastal protection, erosion control, and water purification services by ECEs (Ellis and Fisher 1987, Chong 2005, Barbier 2007). However, economists recommend that the replacement cost approach should be used with caution because, first, one is essentially estimating a benefit (e.g., storm protection) by a cost (e.g., the costs of constructing seawalls, groins, and other structures), and second, the human-built alternative is rarely the most cost-effective means of providing the service (Ellis and Fisher 1987, Barbier 1994, 2007, Freeman 2003, NRC 2005).

As summarized in our tables, ECE habitats tend to generate multiple ecosystem services. These typically range from tourism and recreation benefits to coastal protection, erosion control, nutrient cycling, water purification, and carbon sequestration to food and raw-material products. Where studies are aware of such multiple benefits, the current approach is still to value each service as if it is independent, as was done for coastal protection, habitat–fishery linkages, and raw materials for mangroves in Thailand (Barbier 2007). However, as our tables indicate, similar ecological processes and functions, as well as controlling components, may influence more than one ecosystem service. Such ecological interactions are bound to affect the value of multiple services arising from a single habitat, which is an important direction for future research in valuing ECE services.

For a growing number of services, there is evidence that ecological functions vary spatially or temporally, and thus influence the economic benefits that they provide (Peterson and Turner 1994, Petersen et al. 2003, Rountree and Able 2007, Aburto-Oropeza et al. 2008, Aguilar-Perera and Appeldoorn 2008, Barbier et al. 2008, Meynecke et al. 2008, Koch et al. 2009). For example, wave attenuation by coral reefs, seagrass beds, salt marshes, mangroves, and sand dunes provides protection against wind and wave damage caused by coastal storm and surge events, but the magnitude of protection will vary spatially across the extent of these habitats (Barbier et al. 2008, Koch et al. 2009). In particular, ecological and hydrological field studies suggest that mangroves are unlikely to stop storm waves that are greater than 6 m in height (Forbes and Broadhead 2007, Wolanski 2007, Alongi 2008, Cochard et al. 2008). On the other hand, where mangroves are effective as "natural barriers" against storms that generate waves less than 6 m in height, the wave height of a storm decreases quadratically for each 100 m that a mangrove forest extends out to sea (Mazda et al. 1997, Barbier et al. 2008). In other words, wave attenuation is greatest for the first 100 m of mangroves, but declines as more mangroves are added to the seaward edge.

Valuation of coastal habitat support for offshore fisheries increasingly indicates that the value of this service varies spatially because the quality of the habitat is greater at the seaward edge or "fringe" of the coastal ecosystem than further inland (Peterson and Turner 1994, Manson et al. 2005, Aburto-Oropeza et al. 2008, Aguilar-Perera and Appeldoorn 2008). In the case of mangroves and salt marshes, the evidence suggests that both storm protection and habitat–fishery linkage benefits tend to decline with the distance inshore from the seaward edge of most coastal wetland habitats, such as mangroves and salt marshes. For example, Peterson and Turner (1994) found that densities of most fish and crustaceans were highest in salt marshes in Louisiana within 3 m of the water's edge compared to the interior marshes. In the Gulf of California, Mexico, the mangrove fringe with a width of 5–10 m has the most influence on the productivity of nearshore fisheries, with a median value of $37 500/ha. Fishery landings also increased positively with the length of the mangrove fringe in a given location (Aburto-Oropeza et al. 2008). The tendency for these services to vary unidirectionally across such coastal landscapes has implications for modeling the provision of these services and valuing their benefits (Barbier 2008).

Coastal protection can also vary if damaging storm events occur when plant biomass and/or density are low (Koch et al. 2009). This is particularly important in temperate regions, where seasonal fluctuations of biomass may differ from the seasonal occurrence of storms. For example, along the U.S. Atlantic coast, the biomass of seagrass peaks in the summer (April–June), yet decreases in the fall (July–September) when storm events usually strike. In tropical areas, vegetation in coastal systems, such as mangroves but also seagrasses, has relatively constant biomass throughout the year, so the coastal protection service is relatively unaffected by seasonal or temporal variability.

The value of some ECE services can also vary spatially (i.e., distance from the shoreline) and temporally (i.e., seasonality). This is of particular importance for recreational and property-related benefits (Coombes et al. 2010, Morgan and Hamilton 2010). A study of home values near Pensacola Beach, Florida, found that Gulf-front property owners were willing to pay an annual tax of $5807 for a five-year beach nourishment project that would improve access and shoreline views; however, the tax payment declines to $2770 for a property in the next block, $2540 for a property two blocks away, and $1684 for a property three blocks away (Morgan and Hamilton 2010). Models of beach visitors in East Anglia, UK, reveal that seasonal differences are important. For example, school holidays and temperatures have the greatest influence on visitor numbers, and the visitors' propensity to visit the coast increases rapidly at temperatures exceeding 15°C (Coombes et al. 2010). Spatial characteristics that were also associated with more visitors included wide and sandy beaches, beach cleanliness, the presence of a nature reserve, pier, or an urban area behind the beach, and close proximity of an entrance point, car park, and toilet facilities.

Another unique feature of ECEs is that they occur at the interface between the coast, land, and watersheds, which also make them especially valuable. The location of ECEs in the land–sea interface suggests a high degree of "interconnectedness" or "connectivity" across these systems, leading to the linked provision of one or multiple services by more than one ECE.

As Moberg and Rönnbäck (2003) describe for tropical regions, numerous physical and biogeochemical interactions have been identified among mangroves, seagrass beds, and coral reefs that effectively create interconnected systems, or a single "seascape." By dissipating the force of currents and waves, coral reefs are instrumental for the evolution of lagoons and sheltered bays that are suitable environments for seagrass beds and mangroves. In turn, the control of sedimentation, nutrients, and pollutants by mangroves and seagrasses create the coastal water conditions that favor the growth of coral reefs. This synergistic relationship between coral reefs, seagrasses, mangroves, and even sand dunes, suggests that the presence of these interlinked habitats in a seascape may considerably enhance the ecosystem service provided by one single habitat.

For example, Alongi (2008) suggests that the extent to which mangroves offer protection against catastrophic storm events, such as tsunamis, may depend not only on the relevant features and conditions within the mangrove ecosystem, such as width of forest, slope of forest floor, forest density, tree diameter and height, proportion of aboveground biomass in the roots, soil texture, and forest location (open coast vs. lagoon), but also on the presence of foreshore habitats, such as coral reefs, seagrass beds, and dunes. Similar cumulative effects of wave attenuation are noted for seascapes containing coral reefs, seagrasses, and marshes (Koch et al. 2009). As can be seen from Tables 1–5, each ECE habitat has considerable ability to attenuate waves, and thus the presence of foreshore habitats, such as coral reefs and seagrasses, can reduce significantly the wave energy reaching the seaward edge of mangroves, salt marshes, and sand beaches and dunes. For instance, evidence from the Seychelles documents how rising coral reef mortality and deterioration have increased significantly the wave energy reaching shores that are normally protected from erosion and storm surges by these reefs (Sheppard et al. 2005). In the Caribbean, mangroves appear not only to protect shorelines from coastal storms, but may also enhance the recovery of coral reef fish populations from disturbances due to hurricanes and other violent storms (Mumby and Hastings 2008).

ECE habitats are also linked biologically. Many fish and shellfish species utilize mangroves and seagrass beds as nursery grounds, and eventually migrate to coral reefs as adults, only to return to the mangroves and seagrasses to spawn (Layman and Silliman 2002, Nagelkerken et al. 2002, Mumby et al. 2004, Rountree and Able 2007, Meynecke et al. 2008). In addition, the high biological productivity of mangroves, marshes, and seagrasses also produce significant amounts of organic matter that is used directly or indirectly by marine fishes, shrimps, crabs, and other species (Chong 2007). The consequence is that interconnected seascapes contribute significantly to supporting fisheries via a number of ecosystem functions including nursery and breeding habitat, trophic interactions, and predator-free habitat.

For example, studies in the Caribbean show that the presence of mangroves and seagrasses enhance considerably the biomass of coral reef fish communities (Nagelkerken et al. 2002, Mumby et al. 2004, Mumby 2006). In Malaysia, it is estimated that mangrove forests sustain more than half of the annual offshore fish landings, much of which are from reef fisheries (Chong 2007). In Puerto Rico, maps show fish distributions to be controlled by the spatial arrangement of mangroves, seagrasses, and coral reefs and the relative value of these habitats as nurseries (Aguilar-Perera and Appeldoorn 2008). Stratification of environmental conditions along a marsh habitat gradient, stretching from intertidal vegetated salt marshes, to subtidal marsh creeks, to marsh–bay fringe, and then to open water channels, indicates large spatial and temporal variability in fish migration, nursery habitats, and food webs (Rountree and Able 2007). Finally, indices representing the connectivity of mangroves, salt marshes, and channels explained 30% to 70% of the catch-per-unit effort harvesting yields for commercially caught species in Queensland, Australia (Meynecke et al. 2008).

There are two ways in which current economic studies of ECE services are incorporating such synergies. One approach is to assess the multiple benefits arising from entire interconnected habitats, such as estuaries. A second method is to allow for the biological connectivity of habitats, food webs, and migration and life-cycle patterns across specific seascapes, such as mangrove–seagrass–reef systems and large marine systems.

For example, Johnston et al. (2002) estimate the benefits arising from a wide range of ecosystem services provided by the Peconic Estuary in Long Island, New York, USA. The tidal mudflats, salt marshes, and seagrass (eelgrass) beds of the estuary support the shellfish and demersal fisheries. In addition, bird-watching and waterfowl hunting are popular activities. Incorporating production function methods, the authors simulate the biological and food web interactions of the ecosystems to assess the marginal value per acre in terms of gains in commercial value for fish and shellfish, bird-watching, and waterfowl hunting. The aggregate annual benefits are estimated to be $67 per acre for intertidal mud flats, $338 for salt marsh, and $1065 for seagrass across the estuary system. Using these estimates, the authors calculate that the asset value per acre of protecting existing habits to be $12 412 per acre for seagrass, $4291 for salt marsh, and $786 for mudflats; in comparison, the asset value of restored habitats is $9996 per acre for seagrass, $3454 for marsh, and $626 for mudflats.

Sanchirico and Mumby (2009) developed an integrated seascape model to illustrate how the presence of mangroves and seagrasses enhance considerably the biomass of coral reef fish communities. A key finding is that mangroves become more important as nursery habitat when excessive fishing effort levels are applied to the reef, because the mangroves can directly offset the negative impacts of fishing effort. Such results support the development of "ecosystem-based" fishery management and the design of integrated coastal-marine reserves that emphasize the importance of conserving and restoring coastal mangroves as nursery sites for reef fisheries (Mumby 2006).

In sum, allowing for the connectivity of ECE habitats may have important implications for assessing the ecological functions underling key ecosystems services, such as coastal protection, control of erosion, and habitat–fishery linkages. Only recently have studies of ECEs begun to assess the cumulative implications for these services, or to model this connectivity. This is one important area for future direction of research into ECE services that requires close collaboration between economists, ecologists and other environmental scientists.

Conclusion: Toward a Management Action Plan

Given the rate and scale at which ECEs are disappearing worldwide, assessing and valuing the ecological services of these systems are critically important for improving their management and for designing better policies. Certainly, the various economic values of ECEs should be incorporated into policy decisions that are currently determining the major human drivers of ecological change, such as ecosystem conversion and degradation, resource overexploitation, pollution, and water diversion. As indicated in Figs. 1 and 2, valuation of ECE services is a key step in demonstrating how these human drivers of change alter ecosystem structure and functions, and thus the ecological production of important ecosystem goods and services that benefit human beings.

Yet, as this review has shown, many ECE values are non-marketed. If the aggregate willingness to pay for these benefits is not revealed through market outcomes, then efficient management of such ecosystem services requires explicit methods to measure this social value. Thus, it should not be surprising that the failure to consider the values provided by key ECE services in current policy and management decisions is a major reason for the widespread disappearance of many of these ecosystems and habitats across the globe. Improving the assessment and valuation of ECE services should therefore be a top policy priority for any global management plan for these ecosystems (Granek et al. 2010).

Such a priority is urgent. Our review of five ECEs (i.e., nearshore coral reefs, seagrass beds, salt marshes, mangroves, and sand beaches and dunes) reveals that many of the important benefits of these habitats have not been estimated reliably, and even for those services that have been valued, only a few dependable studies have been conducted. Without more efforts to value the key services of ECEs, and to employ these values appropriately in coastal management and planning, slowing the worldwide degradation of coastal and estuarine landscapes will be difficult. Assessing the values of ECE services is critical, as all coastal interface habitats are facing increasing pressure for conversion to other economic activities, while at the same time, in many coastal areas where ECEs have been degraded or lost, there is often keen interest in restoring these habitats.

Our review also points to other important policy challenges for improving global management of ECEs. For example, there is now sufficient evidence to suggest that some services, such as coastal protection and habitat–fishery linkages, are not uniform across a coastal seascape. Maintaining ECEs for their multiple and synergistic ecosystem services will also invariably involve managing coastal landscapes across different spatial and temporal scales. Incorporating nonlinear and synergistic characteristics of ECEs into management scenarios is likely to result in the most ecologically and economically sustainable management plan possible (Granek et al. 2010). How an ecological function, and thus the ecosystem service it supports, varies nonlinearly across a coastal landscape can have important implications for management at the landscape scale for all ECEs (Koch et al. 2009).

Because the connectivity of ECEs across land–sea gradients also influences the provision of certain ecosystem services, management of the entire seascape will be necessary to preserve such synergistic effects. For example, Mumby (2006) argues that the management of ECE habitats in the Caribbean should take into account the life cycle migration of fish between mangroves, seagrass beds, and coral reefs. He recommends that management planning should focus on connected corridors of these habitats and emphasize four key priorities: (1) the relative importance of mangrove nursery sites, (2) the connectivity of individual reefs to mangrove nurseries, (3) areas of nursery habitat that have an unusually large importance to specific reefs, and (4) priority sites for mangrove restoration projects. Similarly, Meynecke et al. (2008) emphasize that to improve marine protected areas, it is important to understand the role of connectivity in the life history of fishes that likely utilize different ECEs.

Given the perilous state of many ECEs globally and their critically important benefits, there is clearly a need for a global action plan for protecting and/or enhancing the immediate and longer term values of important ECE services. Such a plan should contain the following features.

First, more interdisciplinary studies involving economists, ecologists, and environmental scientists are required to assess the values of the various ECE services identified in this review for coral reefs, seagrasses, salt marshes, mangroves, and sand beaches and dunes (Tables 1–5). A key priority is to value those services identified in this review for which estimates are currently unavailable or unreliable. Although we know less about the economic benefits of seagrasses and sand beaches and dunes compared to the other ECEs, the number of reliable estimates of almost all services remains woefully inadequate.

Second, destruction of these five critical ECEs for coastal economic development can no longer be viewed as "costless" by those responsible for managing and approving such developments. In particular, the widespread global practice of giving away mangroves, salt marshes, and other ECEs as "free land" for coastal aquaculture, agricultural, and residential development needs to be halted. Especially destructive economic activities, such as dynamite fishing of coral reefs, clear-cutting mangroves for wood chips or shrimp farming, mining of sand dunes, extracting seagrasses for shellfish beds, and using salt marshes for landfills, should be banned and the bans enforced. Coastal pollution from aquaculture, tourism activities and infrastructure, agriculture, urban areas and industry need to be monitored, regulated, and where appropriate, taxed.

Third, in many developing countries, the current legal framework and formal institutional structures of ECEs and resource management do not allow local coastal communities any legal rights to establish and enforce control over the ECE goods and services on which the livelihoods of these communities depend. Establishing an improved institutional framework does not necessarily require transferring full ownership of ECE resources to local communities, but could involve co-management by governments and local communities that would allow, for example, the participation of the communities in decisions concerning the long-term management, development and utilization of these resources.

Finally, where appropriate, ecological restoration of key ECEs should be encouraged. However, ecological restoration of these systems is difficult and costly, and requires the right incentives. For example, in Thailand, the full costs of replanting and restoring mangroves in abandoned shrimp ponds is estimated to be around \$9318/ha, which nearly accounts for the entire capitalized value of the restored services of \$12 392/ha (Barbier 2007). This suggests that investors in shrimp farms and other coastal developments that cause widespread mangrove destruction should have the legal requirement to replant mangroves and finance the costs, rather than leaving mangrove restoration solely to governments and local communities. It should be recognized, however, that ex post ecological restoration is no panacea for failed conservation. Such investments are not only costly but risky, and in many cases fall short of recovering the full suite of ecosystem services (Palmer and Filoso 2009). For example, as discussed in the previous section, the Johnston et al. (2002) study of the Peconic Estuary of Long Island found that the asset value of restored salt marsh and seagrass and tidal mudflats in terms of nursery habitat and recreational services were much lower than for conserving the original habitats.

In sum, the more we learn about ECEs and their services, it is apparent that ignoring these benefits is detrimental to coastal management and planning. In addition, more attention needs to be paid to how these services vary across seascapes, as these considerations clearly matter to managing estuarine, coastal, and inshore marine environments (Granek et al. 2010). Coasts and small islands may comprise just 4% of the Earth's total land area, but as this review has shown, the ECEs that dominate these geographic areas provide some of the most important global benefits for humankind.

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Review

Impacts of pollution on coastal and marine ecosystems including coastal and marine fisheries and approach for management: a review and synthesis

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Abstract

The history of aquatic environmental pollution goes back to the very beginning of the history of human civilization. However, aquatic pollution did not receive much attention until a threshold level was reached with adverse consequences on the ecosystems and organisms. Aquatic pollution has become a global concern, but even so, most developing nations are still producing huge pollution loads and the trends are expected to increase. Knowledge of the pollution sources and impacts on ecosystems is important not only for a better understanding on the ecosystem responses to pollutants but also to formulate prevention measures. Many of the sources of aquatic pollutions are generally well known and huge effort has been devoted to the issue. However, new concepts and ideas on environmental pollution are emerging (e.g., biological pollution) with a corresponding need for an update of the knowledge. The present paper attempts to provide an easy-to-follow depiction on the various forms of aquatic pollutions and their impacts on the ecosystem and organisms.

1. Introduction

The United Nations Convention on the Law of the Sea defined pollution as 'the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of the sea water and reduction of amenities'. Williams (1996) criticized the division of pollution into categories (e.g., air, water, land etc.) and commented that there is only 'one pollution' because every pollutant, whether in the air, or on land tends to end up in the ocean. Production and emissions of pollutants are usually derived from human settlements, resource uses and interventions, such as infrastructural development and construction, agricultural activities, industrial developments, urbanization, tourism etc. Contaminants of major concerns include persistent organic pollutants, nutrients, oils, radionuclides, heavy metals, pathogens, sediments, litters and debris etc. (Williams, 1996). Categorization of pollution only facilitates discussion; most contaminants are interrelated and jeopardize the environment and organisms, at a same way and scale, regardless of the source of contamination.

Most of the coastal areas of the world have been reported to be damaged from pollution, significantly affecting commercial coastal and marine fisheries. Therefore, control of aquatic pollution has been identified as an immediate need for sustained management and conservation of the existing fisheries and aquatic resources. Unfortunately, the pollution problem, as described by Williams (1996), is characterized by interconnectedness, complicated interactions, uncertainty, conflicts and constraints, making it difficult to control the problem. Moreover, because scientific knowledge on marine pollution is patchy, knowledge gaps have been identified as one of the major problems in introducing effective management strategies for its control. The present paper focuses on three objectives: (1) to provide

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a review on the major areas of coastal and marine pollution with respect to their impacts on the ecosystem and living resources in general; (2) to synthesize information on the present status of the coastal and marine fisheries affected by pollution; and (3) to synthesize a conceptual model for better management of pollution for sustainable utilization of these resources.

2. Major pollutants and potential impacts

2.1. Fertilizers, pesticides and agrochemicals

Agricultural activities are reported to contribute about 50% of the total pollution source of surface water by means of the higher nutrient enrichment, mainly ammonium ion (NH_4) and NO_3 derived from agricultural inputs. Ammonia constitutes a major contributor to the acidification of the environment, especially in areas with considerable intensive livestock farming. Wastes, manures and sludges, through biological concentration processes, can supply soils with 100 times more hazardous products than do fertilizers for the equivalent plant nutrient content (Joly, 1993). The huge increases in fertilizer use worldwide over the past several decades are well documented. Manure produced by cattle, pigs and poultry are used as organic fertilizer worldwide. To this is added human excreta, especially in some Asian countries where animal and human excreta are traditionally used in fish culture as well as on soils.

In areas where intensive monoculture is practiced, pesticides are used as a standard method for pest control. Although the list of pesticides in use (Table 1) is big enough, the largest usage tends to be associated with a small number of pesticide products. The underlying fact of the pesticides usage in relation to pollution is that only a very small fraction of all applied pesticides becomes directly involved in pesticide mechanisms, i.e., unless the compounds are rapidly degradable, most of the pesticides find their way as residues in the environment (Duursma and Marchand, 1974). In fact, most of the pesticides are not rapidly degradable because of technical reasons, i.e., rapid degradation might reduce their applicability. Therefore, it is likely that a large volume of pesticide residues accumulate into the environment and the process is continuous. Duursma and Marchand (1974) reported an estimated world production of DDT about 2.8×10^6 tons of which 25% (7×10^5 tons) is assumed to be released into the world ocean. Significant contributions to aquatic pollution from agricultural sources are made by a few Asian countries with higher agricultural crop productions. It has been reported that about 9000 metric tons of different pesticides and more than 2 million metric tons of fertilizers are used annually in Bangladesh and at present about 1800 tons $year^{-1}$ of pesticide residues are added to the coastal waters through runoff. Similar figures can be expected from India, Myanmar, Indonesia and China.

Pesticides and their residues are reported to be among the most devastating agents for aquatic ecosystems and organisms affecting all levels of the food chain from the lowest to the top level (Duursma and Marchand, 1974). The two principal mechanisms associated with the effects of agricultural wastes are bioconcentration (accumulation of chemical from the surrounding medium into an organism by virtue of the lipophilicity of many chemicals) and biomagnification (increasing concentration of a chemical as food energy is transformed within the food chain). As smaller organisms are eaten by larger organisms, the concentration of pesticides and other chemicals are increasingly magnified in tissue and other organs. Very high concentrations can be observed in top predators, including man. The occurrence of pesticide residues in different organisms of the food chain starts with the first link of marine phytoplankton in which relatively high levels of DDT and analogues can occur.

The ecological effects of pesticides are varied and are often complex. Effects at the organism or ecological level are usually considered to be an early warning indicator of potential human health impacts. The important point is that many of these effects are chronic, are often not noticed by casual observers, yet have consequences for the entire food chain. Major effects include death of the organism, cancers, tumors and lesions on fish and animals, reproductive inhibition or failure, suppression of immune system, disruption of endocrine system, cellular and molecular damage, teratogenic effects, poor fish health marked by low red to white blood cell ratio, excessive slime on fish scales and gills, etc., intergenerational effects, other physiological effects such as egg shell thinning. These effects are not necessarily caused solely by exposure to pesticides or other organic contaminants, but may be associated with a combination of environmental stresses such as eutrophication and pathogens.

The European Environment Agency (EEG, 1994) reported links with the toxicity of river water caused by runoff of agricultural pesticides to the Zooplankton *Daphnia magna*. In the Great Lakes of North America bioaccumulation and magnification of chlorinated caused the disappearance of top predators such as eagle and mink and deformities in several species of aquatic birds. The World Wide Fund for Nature (WWF, 1993) reported that a significant amount of an estimated 190,000 tons of agricultural pesticides plus additional loadings of non-agricultural pesticides that are released by riparian countries bordering the North Sea, eventually are transported into the North Sea by a combination of riverine, groundwater, and atmospheric processes. WWF further reported that the increased rate of disease, deformities and tumors in commercial fish species in highly polluted areas of the North Sea and

Table 1
Pesticides and agrochemicals that are in use worldwide and are of major environmental concerns

Pesticide	Trade name	Type
Acifluorfen	Blazer, Carbofluorfen	Herbicide
Alachlor	Lasso	Herbicide
Aldicarb	Temik	Insecticide
Aldrin	HHDN, Octalene	Insecticide
Ametryn	Gesapax	Herbicide
Atraton	Gesatamin	Herbicide
Atrazine	AAtrex	Herbicide
Barban	Carbyne	Herbicide
Baygon	Propoxur, Unden, Blattanex	Insecticide
Bentazon	Basagran	Herbicide
Bromacil	Borea, Hyvar, Uragan	Herbicide
Butachlor	Machete	Herbicide
Butylate	Sutan	Herbicide
Carbaryl	Sevin	Insecticide
Carbofuran	Furadan, Caraterr	Insecticide
Carboxin	D-735, DCMO, Vitavax	Fungicide
Chloramben	Amiben, Vegiben	Herbicide
Chlordane	Gold Crest C-100	Insecticide
Chlorobenzilate	Akar, Benzilian	Acaricide
Chloroneb	Terraneb	Fungicide
Chlorothalonil	Bravo, Daconil	Fungicide
Chlorpropham	Chloro IPC, CIPC, Furloe, Sprout NP	Herbicide
Cyanazine	Bladex, Fortrol	Herbicide
Cycloate	Ro-Neet	Herbicide
2,4 Dichloro-phenoxyacetic acid	Aqua Kleen	Herbicide
Dalapon	Dowpon, Ded-Weed	Herbicide
2,4-DB	Butyrac, Embutox	Herbicide
DCPA	Chlorthal-dimethyl Dachtal	Herbicide
4,4-DDD and DDT	TDE, Rothane	Insecticide
Diazinon	Spectracide, Basudin, AG-500	Insecticide
3,5-Dichlorobenzoic acid	Dalapon	Herbicide
1,2-Dichloropropane	Propylene, Dichloride, 1,2-DCP	Soil fumigant
cis-1,3 Dichloropropene	Telone II	Nematocide
Dichlorprop	Maizeox RK	Herbicide
Dichlorvos	Herkol, Nogos, Phosvit	Insecticide
Dieldrin	Heod, Dielorex, Octalox	Insecticide
Dinoseb	DNBP, Dinitro, Premerge	Herbicide
Diphenamid	Dymid, Enide	Herbicide
Disulfoton	Dysyston, Dithiodemeton, Ditio-systox	Insecticide
Diuron	DCMU, Karmex	Herbicide
Endosulfan I	Thiodan, Cyclodan, Malix	Insecticide
Endrin	Nendrin	Insecticide
EPTC	EPTAM	Herbicide
Ethoprop	Prophos, Ethoprophos	Insecticide
Ethylene dibromide (EDB)	Bromofume, Nephis	Insecticide
Ethylene thiourea (ETU)	ETU	Fungicides
Etridiazole	Koban, Terrazole	Fungicide
Fenamiphos	Nemacur Inemacury	Insecticide
Fenarimol	Bloc, Rimidin, Rubigan	Fungicide
Fluometuron	Cotoron	Herbicide
Fluridone	Sonar	Herbicide
Glyphosate (4)	Roundup	Herbicide
Alpha-, beta-, delta-, and gamma-HCH (Lindane)	gamma BHC, Lindane	Insecticide
Heptachlor (2)	Velsicol 3-chlorochlorene	Insecticide
Hexachlorobenzene	Anti-Carie, HCB	Fungicide
Hexazinone	Velpar	Herbicide
Linuron	Afalon	Herbicide
Merphos	Folex	Defoliant
Methiocarb	Mesurol, Draza	Insecticide
Methomyl	Lannate, Nudrin	Insecticide
Methoxychlor	Malate	Insecticide
Methyl paraoxon	E-600, Mintacol	Insecticide

Table 1 (*continued*)

Pesticide	Trade name	Type
Metolachlor	Dual, Primext	Herbicide
Metribuzin	Sencor, Sencorex, Lexone	Herbicide
Mevinphos	Phosdrin	Insecticide
MDK 264	Van Dyke-264	Synergist
Molinate	Ordram	Herbicide
Napropamide	Devrinol	Herbicide
Neburon	Kloben	Herbicide
4-Nitrophenol	–	Fungicide/insecticides
Norflurazon	Zorial, Evital, Solicam	Herbicide
Oxamyl	Vydate, DPX-1410	Insecticide
Pentachlorophenol (PCP)	Dowicide	Insecticide/herbicide
Pebulate	Tillam	Herbicide
Permethrin	Ambush, Perthrine	Insecticide
Picloram	Tordon	Herbicide
Prometon	Gesagram	Herbicide
Prometryn	Gesagard, Caparol	Herbicide
Pronamide	Kerb	Herbicide
Propachlor	Bexton, Ramrod	Herbicide
Propanil	Rogue	Herbicide
Propazine	Gesomil, Milogard, Primatol	Herbicide
Propham	IPC, Beet-Kleen	Herbicide
Simazine	Princep, Aquazine, Gesatop, Weedex	Herbicide
Simetryn	Gy-bon	Herbicide
Stirofos	Gardona, Tetrachlorvinphos	Insecticide
Swep	SWEP	Herbicide
Tebuthiuron	Graslan, Spike	Herbicide
Terbacil	Sinbar	Herbicide
Terbufos	Counter	Insecticide
Terbutryn	Igram, Preban	Herbicide
2,4,5-TP (trichlorophenol)	Silvex	Herbicide
Triademefon	Bayleton	Fungicide
Tricyclazole	Beam, Bim, Blascide	Fungicide
Trifluralin	Treflan	Herbicide
Vernolate	Vernam	Herbicide

coastal waters of the United Kingdom since the 1970s is consistent with effects known to be caused by exposure to pesticides.

2.2. Domestic and municipal wastes and sewage sludge

By far the greatest volume of waste discharged to the marine environment is sewage. Sewage effluent contains industrial waste, municipal wastes, animal remains and slaughterhouse wastes, water and wastes from domestic baths, utensils and washing machines, kitchen wastes, faecal matter and many others. Huge loads of such wastes are generated daily from highly populated cities and are finally washed out by the drainage systems which generally open into nearby rivers or aquatic systems. The industrial areas are generally highly populated or the industries are usually established near highly populated areas. Therefore, higher pollution load from industrial sources is generally accompanied by a higher risk of domestic and sewage pollution. Robson and Neal (1997) studied the water quality in term of pollution from industrial and domestic sources and reported higher pollution loads from domestic sources where the industrial pollution loads are also higher. Cheevaporn and Menasveta (2003) reported BOD loads of 659–34,376 tons $year^{-1}$, resulting from municipal and industrial wastes in the Gulf of Thailand. It is reported that the annual production of sewage is as high as 1.8×10^8 m^3 for a population of 800,000. Taking the organic matter load to be 20 $mg\,l^{-1}$ in the sewage (Duursma and Marchand, 1974), this gives an annual release of 3.6×10^3 tons of organic matter. The approximate amount of sewage produced by the total world population and the organic loads released from that sewage can now be easily calculated.

Sewage contains in itself a diverse array of polluting agents including pathogens (Table 2), organic substances, heavy metals and trace elements (Table 3) and so on, which pose direct and indirect effects on ecosystems and organisms. Sewage is primarily organic in nature and, therefore, subject to bacterial decay. As a result of this bacterial activity, the oxygen concentration in the water is reduced, thus sewage is said to have a high BOD. This can starve aquatic life of the oxygen it needs and also leads to the breakdown of proteins and other nitrogenous compounds, releasing hydrogen

Table 2
Major sewage-related bacterial species recorded from marine mammals (Grillo et al., 2001)

Bacteria species	Host species
Aeromonas hydrophila	Cetaceans
Vibrio cholerae	Cetaceans
Staphylococcus aureus	Cetaceans
Salmonella spp.	Cetaceans/pinnipeds
Pseudomonas aeringinosa	Cetaceans
Proteus mirabilis	Cetaceans
Mycobacterium tuberculosis	Pinnipeds
Leptospira spp.	Pinnipeds
Klebsiella spp.	Cetaceans/pinnipeds
Escherichia coli	Cetaceans/pinnipeds
Enterobacter spp.	Cetaceans
Clostridium spp.	Cetaceans
Citrobacter freundii	Cetaceans
Alcaligens spp.	Cetaceans

Table 3
Concentrations of major heavy metals and trace elements in sewage (Grillo et al., 2001)

Trace metals in sewage	Concentrations ($mg\,l^{-1}$)
Arsenic	<0.1
Cadmium	<0.02
Chromium	0.1–0.5
Copper	0.2–0.5
Lead	0.08–0.4
Mercury	–
Nickel	<0.02
Silver	<0.02
Zinc	0.4–0.7

sulphide and ammonia, both of which are potentially toxic to marine organisms in low concentrations. Solids suspended in sewage may also blanket river and sea beds preventing respiration of the benthic flora and fauna. Decaying organic matter and nutrients in sewage enhance plant growth. Excessive plant growth and oxygen depletion can lead to alterations in ecosystem structure and these are both features of eutrophication. The dumping of sewage sludge at sea is another cause of ecological damage. Dependent on hydrography, sludge can smother the benthos, increase biomass, decrease species biodiversity and increase heavy metal concentrations.

Sewage effluent entering coastal waters contains a variety of harmful substances including viral, bacterial and protozoan pathogens, toxic chemicals such as organochlorines, organotins and heavy metals, and a variety of other organic and inorganic wastes (HMSO, 1990). Domestic sewage discharged into the coastal waters contains a particularly unhealthy mix of both harmless and infectious microorganisms. Pathogens found in sewage include *Salmonella* spp., *Escherichia coli, Streptococcus* sp., *Staphylococcus aureus, Pseudomonas aeruginosa*, the fungi *Candida*, and viruses such as enterovirus, hepatitis, poliomyelitis, influenza and herpes. Bacteria and viruses are present in large concentrations in raw sewage: up to 4×10^9 bacteria 1–1000×10^4 virus per liter of raw sewage (HMSO, 1990). Numerous studies have indicated that the greater the sewage contamination and exposure of people, the higher the risk of contracting ear, nose and throat infections and stomach upsets such as gastroenteritis. Faecal streptococci bacteria are more closely associated with human sewage and their presence in a sample is believed to be a better indicator of sewage contamination than Coliforms. Faecal streptococci can cause illness, especially gastroenteritis. Other disease-causing agents which may be present in sewage include enteric viruses, *Salmonella* and the Hepatitis A virus.

Bossart et al. (1990) suggested that some viruses are transferred to marine mammals by human sewage and are zoonotic in nature. Influenza, respiratory synctial virus, herpes, cytomegalovirus and measles are also zoonotic viruses capable of infecting marine mammals. Bacteria associated with sewage water contaminated with human pathogens (Olivieri, 1982), which have been documented in marine mammals, include: *Escherichia coli, Mycobacterium tuberculosis, Vibrio cholera* and *Salmonella* sp. (Table 2). Sewage-borne fungi could also, theoretically, infect marine mammals living in contaminated waters. *Candida* sp. is a common component of sewage wastes and has been isolated from both captive and wild cetaceans.

A common short-term response by fish to a sewage outfall is an initial increase in abundance around the point of discharge. There is a short-term increase in nutrients and, hence, prey items for the fish and, on occasions an increase in habitat complexity, which may cause an initial population rise in fish species. Yet, as nutrient levels increase so does the chance of algal bloom development, toxin production and a corresponding decrease in dissolved oxygen. Long-term effects include phytoplankton biomass increases and large scale decreases in species diversity with benthic and fish communities (Bonsdorff et al., 1997). Fish species feeding in water contaminated by algal toxins will absorb these toxins and are subject to mass mortality (Hernandez et al., 1998). One of the most crucial problems caused by the sewage wastes is the loss of amenity which, therefore, affects the recreational use of water. Debris associated with sewage probably has the highest monetary cost associated with its presence on beaches and loss of tourism.

2.3. Oils

Oil pollution has been receiving increasing attention since the middle of the 19th century with the increase in tanker operations and oil use and frequent marine tanker collisions and accidents resulting in oil spills. Millions of oils are being added into the coastal and marine

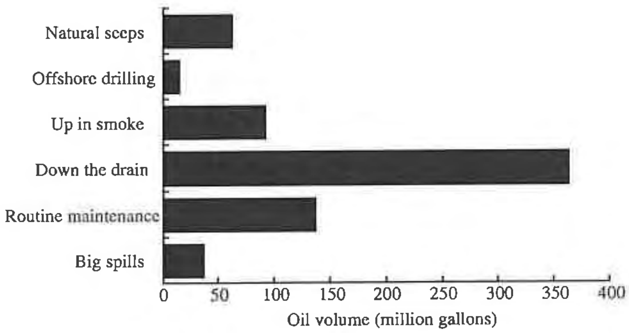

Fig. 1. Millions of gallons of oil put into the coastal and marine environment worldwide each year from different sources.

environments from variety of sources (Fig 1). Considerable tanker accidents were reported during the 1960s of which as many as 78 accidents were reported between 1964 and 1968 resulting in huge volume of oil spilled into the marine environment (Smith, 1970) in addition to the ballast water which is reported to amount 0.3–0.5% of the previous oil loads—about 200 tons in a 50,000-ton tanker (Smith, 1970). Smith (1970) reported that as many as half a million tons of persistent oils are discharged into the sea each year. Reed (1972) suggested a similar figure, and reported that the annual release of hydrocarbon is estimated to be 600,000–1,000,000 tons. Under still conditions, the oil traps silts and other suspended matters and sinks to the bottom where it is deposited. Coastal refineries are another obvious risk of continuous oil pollution because millions of gallons of crude oil and its fractions are processed and stored there. Crude oil is purified and processed in refineries to produce a variety of fuels, lubricants and solvents. During these operations, continuous small-scale pollution occurs through leakages, spills, breakages etc. Water is used in many processes and inevitably become contaminated with oil and derivatives and when discharged, carries appreciable oil loads.

Nelson (2000) described the sources and extent of oil pollution in Australian coasts (Fig. 2A) and reported that in addition to the spills resulting from tanker operations, an estimated volume of 16,000 tons of oil enters the marine environment as run-off and waste from land-based municipal and industrial sources each year. A similar scenario was reported also from the Baltic Sea (Fig. 2B). Continuous discharge and spills of oils pose potential risk of severe pollution in recently increasing but unregulated marine traffic in developing countries. Owing to a lack of waste-reception and treatment facilities in the ports, and a lack of effective legislation and surveillance, foreign and domestic ships and trawlers discharge their oily waste in the sea.

Although Shriadah (1998) reported that temporary elevation of contamination levels due to oil pollution was followed by a rapid reduction of contamination

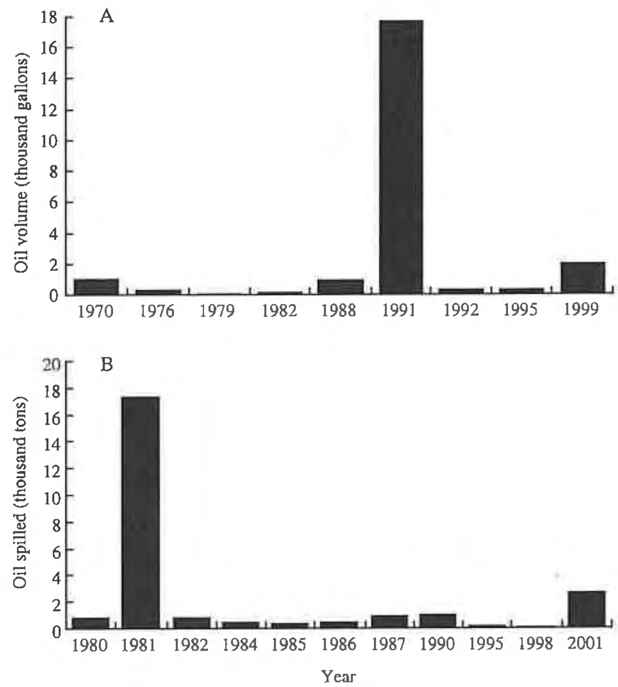

Fig. 2. Time series data of oil volumes released from spills in Australia (only those resulted >100 tons oil lost) (Nelson, 2000); and C: oil pollution and volume of oil spilled in the Baltic Sea.

level and recovery of the ecosystem along the Gulf of Oman, Yamamoto et al. (2003) concluded that the recovery rate depends largely on the pollution sites and intensity. There are enough evidences that oil pollution poses serious adverse effects on aquatic ecosystem and the organisms extending from primary producers level through secondary, tertiary and up to the top levels. The sensitivity of echinoderms and molluscs can be understood from the use of oil slurries to form a barrier around oyster beds to protect them from predatory molluscs and sea-stars. Smith (1970) reported mortality and elimination of sea-stars (*Pisaster* spp.) and sea-urchins (*Strongylocentrotus* spp.) as a result of diesel oil pollution and reported that as little as 0.1% emulsion of the oil may inactivate the tube-feet of the urchins.

Phenol occurring in oil refinery effluents irritates the gills and causes heavy secretion and erosion of the mucus membrane, and also affects the central nervous and endocrine systems. Russel and Kotin (1956) reported carcinomas and papillomas on the lips of bottom-feeding fish caught near an oil refinery and changes in the cell membrane caused by hydrocarbons which could lead to cellular changes and thus to cancer. Among marine mammals, damage to seals has been reported form the Antarctic and Cornwall (Smith, 1970) and during the Santa Barbara Channel spillage in California (California Department of Fish and Game, 1969). Oil damage in seals is frequently said to include severe eye irritation with subsequent blindness.

The aerial and flying birds, e.g., gulls, gannets and their relatives are at relatively lower risk of oil toxicity than those spending most of the time in contact with oil on the water surface, e.g., ducks, auks, divers, penguins etc. The primary effect of oil on sea birds is to penetrate to their plumage; water eventually replaces the air trapping with a resultant elimination of heat insulation and reducing buoyancy and a heavily oiled bird is physically over-weighed and becomes incapable of swimming and flying. Nervous abnormalities also occur which suggest inhibition of anti-cholinesterase activity, probably due to organic phosphate additives in diesel and cutting oils (Smith, 1970). The bird become sensitive and incapable of tolerating environmental fluctuations and little fluctuation induce physiological stress. The population level effects of oil toxicity on aquatic birds occur through the loss of egg viability.

2.4. Heavy metals and trace elements

Heavy metals and trace elements are by-products of many industrial processes, contributing varying amounts of different metals and trace elements (Fig. 3) and as such are discharged as waste into the marine environment (Robson and Neal, 1997). They enter the marine environment through atmospheric and land-based effluent sources. The metals considered toxic and which are of concern have been restricted largely, but not exclusively, to the ten which appear to be most poisonous to marine life. These include, in order of decreasing toxicity (Davies, 1978): mercury, cadmium, silver, nickel, selenium, lead, copper, chromium, arsenic and zinc. Goldberg (1995) reviewed different sources of heavy metal inputs into the sea and their possible role in ecosystems. Heavy metals are non-degradable elements naturally occurring in coastal seas. They are not particularly toxic as the condensed free elements but they are dangerous to living organisms in the form of cations with capacity to bind with short carbon chains. In this form, they bioaccumulate in marine organisms and concentrate year after year.

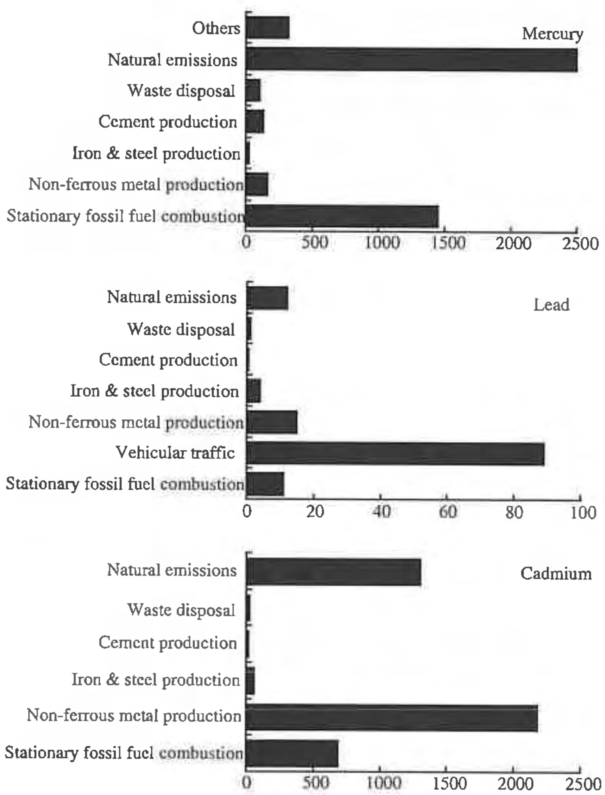

Fig. 3. Contribution of different sources in global emissions of major heavy metals (AMAP, 2002); mercury: tons/year^{-1}; lead and cadmium: thousand tons/year^{-1}.

The effects of metals on organisms is associated with interference in the metabolic processes involving sulphur containing constituents (Davies, 1978) because most of the widely distributed heavy metals (e.g., mercury, silver, copper) have high affinities for sulphur and tend to bind with sulphydryl groups of proteins and enzymes in living beings. Heavy metals interference are reported to cause an increase in the permeability of the cell membrane in phytoplankton and other marine algae, leading to the loss of intracellular constituents and, therefore, cellular integrity. Kayser (1976) reported change in cell shape of phytoplankton as a result of heavy metal incorporations and such changes in shape are much likely to be related to the loss of cellular integrity. Similarly, Davies (1978) reported production of very large cells of phytoplankton as an effect of copper and mercury and found that the size spectrum of cells was related to the mercury concentrations. They concluded that metals inhibit independent cell division in phytoplankton and, therefore, they grow big in size.

Once in the system, metals concentrate in protein-rich tissues such as liver and muscle. High trace element burdens in marine mammals have been associated with a variety of responses. These include lymphocytic infiltration, lesions and fatty degeneration in bottlenose dolphins, and decreasing nutritional state and lung pathology (Siebert et al., 1999). In addition, cadmium, lead and mercury are potential immuno-suppressants; of particular concern is the build-up of mercury, which marine mammals tend to accumulate in the liver to higher levels than other marine organisms (Law et al., 1999) and concentrations exceeding 100–400 $\mu g\,l^{-1}$ wet weight in the liver are a threat to marine mammals. Due to its long persistence and high mobility in the marine ecosystem, mercury shows an age-related accumulation and strong bio-magnification in the food web (Nigro and Leonzio, 1996). Correlations have also been reported between age and cadmium levels in the kidneys of harbor porpoises from the east coast of Scotland (Falconer et al., 1983).

2.5. Organic compounds

Many synthetic organic chemicals (e.g. organochlorines, organophosphates, PAHs and organometals) are of growing environmental concern, because of their high toxicity and high persistence in the environment and in biological systems. Furthermore, the high lipophilicity of many of these xenobiotics greatly enhances their bioconcentration/biomagnification, thereby posing potential health hazards on predators at higher trophic levels (including human beings). Nowadays, persistent xenobiotic compounds have been found in every part of the ocean: from arctic to Antarctic, and from intertidal to abyssal. For example, PCBs, HCH and DDT (and its derivatives) were found in rat-tail fish collected at 3000 m depth in the Atlantic and arctic seals long after the ban of DDT and PCBs in the early 1970s, indicating the persistence of these chemicals in the marine environment (GESAMP, 1990). Longwell et al. (1992) reported as high as 70 organic contaminants in fully ripe spawned eggs of winter flounder *Pseudopleuronected americanus*. Such contaminations result not only in egg mortality and defective embryos but also defects in other periods of fish ontogeny resulting high rate of larval mortality, lowering significantly the recruitment. This is particularly destructive for those populations that have been affected otherwise such as by overfishing.

Most xenobiotic compounds occur only at very low concentrations in the environment, and their threats to marine life and public health are still not well understood. However, sub-lethal effects of these compounds over long-term exposure may cause significant damage to marine populations, particularly considering that some of these compounds may impair reproduction functions of animals while others may be carcinogenic, mutagenic or teratogenic. Many of the environmental oestrogen compounds act as anti-oestrogens by interfering in the activity of the oestrogen receptors or by reducing the number of receptors in the organisms. One of the most serious of the chemicals is the DDT and its derivatives. Some of the effects of such chemicals have been listed among other by Goldberg (1995). These generally include the effects of DDT on the reproductive success of fish eating birds, tributyltin cause sexual changes (imposex) in gastropods and eventually damage of the population. Stone (1994) reported a 90% fall-off in the birthrate of alligators and reduced penis size in many of the young alligators exposed to high level of DDT introduced by an accident spill. The total amount of dissolved organic matter in the world ocean is about 2×10^{12} tons, calculated from the volume of the world ocean of 1.369×10^{9} km^3 multiplied by the average concentration of dissolved organic matter of 1.5 mg l^{-1} (Duursma and Marchand, 1974).

Accumulation of complex organics in different steps of a food chain is well documented from all forms of aquatic ecosystems. Some examples of PCBs and HCHs accumulation in calanoid copepod in different islands and bays and in different species of fishes are given in Figs. 4 and 5. The major ecological concern of xenobiotics is their ability to impair reproductive functions and subsequently threaten survival of the species. For example, white croaker inhabiting contaminated areas near Los Angles have higher body burdens of chlorinated hydrocarbons, lower fecundity and lower fertilization rates (Cross and Hose, 1988). Likewise, endocrine dysfunction and reduced gonad size were reported for the yellow perch (*Perca flavescens*) exposed to sediments in the St. Lawrence River contaminated with PAHs and PCBs (Hontela et al., 1995). Reproductive failure and population decline of the common seal (*Phoca vitulina*) in the Wadden Sea were attributable to their PCB body burden (Reijnders, 1986a,b). High body burden of organochlorines found in seals and sea birds in the Baltics has been related to reduced egg hatching (HELCOM, 1996).

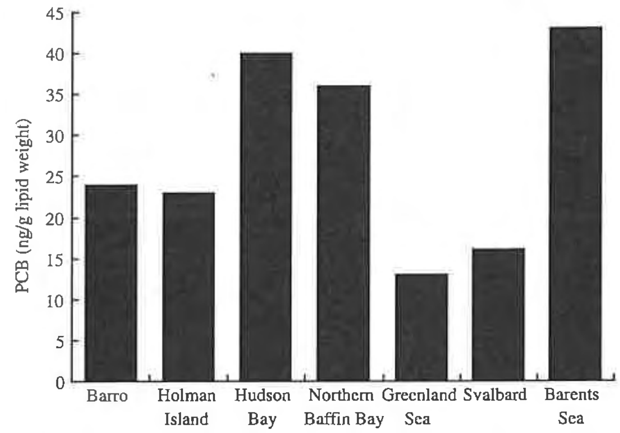

Fig. 4. Concentrations of PCBs (ng g^{-1} of lipid) in calanoid copepod in different bays and seas in the Arctic (AMAP, 2002).

There is growing evidence that exposure to very low levels of certain xenobiotic organic compounds (e.g. halogenated hydrocarbons, PCBs, DDT, TBT) may disrupt normal metabolism of sex hormones (including gonadotropins) in fish, birds and mammals. This in turn, may lead to reproductive dysfunction such as reduction in fertility, hatch rate, alternation of sex behavior and viability of offspring (Crews et al., 1995). Perhaps one of the most well-studied endocrine disrupters is organotin. Exposure to very low levels of TBT (0.5–3 ng l^{-1}) or a body burden of only 10–20 ng TBT/g wet tissue has been shown to cause a significant disruption in sex hormone metabolism/testosterone level, which subsequently leads to malformation of oviducts and suppression of oogenesis in female whelks, e.g. *Nucella lapillus*, *Thais claviger* and *T. bronni* (Gibbs, 1996). Secondary male characteristics, such as induction of spermatogenesis and development of a male penis

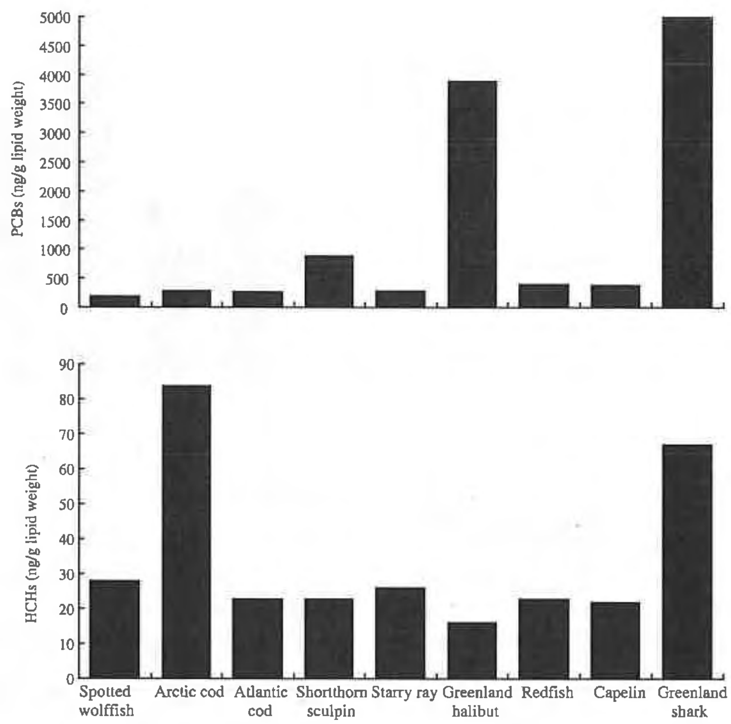

Fig. 5. Concentrations of PCBs and HCHs ($ng\,g^{-1}$ of lipid in different fish species (AMAP, 2002).

and/or vas deferens, begins to develop in the females. This phenomenon, known as imposex, has been reported in some 50 species of gastropods all over the world in areas with high marine activities or where TBT has been used. The frequency of imposex in field populations shows a clear relation to environmental TBT levels, and sex imbalance causes a decline and species extinction in some natural populations (Cadee et al., 1995).

Increasing evidence from laboratory and field studies has shown that trace amounts of many chlorinated hydrocarbons (e.g. PCBs), organophosphates and diethylstilbestrol in the environment may cause significant endocrine disruption and reproductive failure in invertebrates, fish, birds, reptiles and mammals. Chronic exposure to low levels of diethylstilbestrol or pentachlorophenol alters steroid hormone metabolism of the water flea *Daphnia magna* and reduces their fecundity in the second generation (Parks and LeBlanc, 1996). Exposure to very low levels of certain organophosphate pesticides (e.g. elsan, carbaryl) has been shown to inhibit gonadotropin releasing hormones and reduce gonad development in the fish *Channa punctatus* (Bhattacharya, 1993). Likewise, the pesticide kepone has been shown to arrest sperm maturation in many fish, birds and mammals (Srivastava and Srivastava, 1994). Endocrine disruption found for the above freshwater species may well be applicable to marine species. A recent mesocosm study showed a significant elevation of testosterone and 17-*b*-oestradiol in the flounder *Platichthys flesus* exposed to polluted dredged soil (Janssen et al., 1997). Common seals (*Phoca vitulina*) fed with PCB contaminated fish and grey seals (*Halichoerus grypus*) with high body accumulations of PCBs and DDT had significantly lower levels of retinol and free thyroxin. The disturbance in hormonal systems was also related to an increase in microbial infections and reproductive disorders in natural seal populations in the Baltic and North Seas (Jenssen, 1996). Disruption of neuroendocrine functions after exposure to Aroclor 1254 has been demonstrated in Atlantic croaker *Micropogonias undulatus* (Khan and Thomas, 1996). In the Baltic Sea, high levels of DDT, PCBs and organochlorines markedly reduced the hatching rates of eggs (from 72% to 25%) and the nesting success of the fish eating White-tailed eagle (*Haliaeetus albicilla*) in 1960s and 1970s. Nesting and reproductive success showed a steady increase following the ban on DDT and PCBs, and in 1994, the values almost resumed those prior to the occurrence of organochlorines (HELCOM, 1996). Delayed sex maturity, smaller gonads, reduced fecundity and a depression in secondary sexual characteristics were reported in fish populations downstream of bleached pulp mills, and these changes were confirmed in fish exposed to treated effluents under laboratory conditions. The changes were closely related to alternations in endocrine systems controlling the production of sex steroid hormones. Improved reproductive performance was found in feral fish at five sites after the mills improved their waste treatment and pulping processes (Munkittrick et al., 1994).

Hydrocarbons interfere in the production and growth of phytoplankton in many ways. Hydrocarbon molecules disrupt the plasma membrane by displacing those of other lipid compounds, thus affecting its semi-permeability and inhibition of photosynthesis could result form hydrocarbons dissolving in the lipid phase of the chloroplasts and interfering the interactions of the chlorophyll molecules. A similar disruption could occur in mitochondrial membranes with inhibition of the tricarboxylic acid cycle and oxidative phosphorylation. Kerosene causes lipid distortion in the cell membrane with subsequent penetration of toxic agents in different marine red algae and naphthalene causes a reduction in the cellular protein level.

Organochlorin contamination has been well documented in many cetacean species. Levels of contamination are dependent largely upon the diet, sex, age and behavior of the cetacean species in question. Coastal species may accumulate higher levels due to closer proximity to discharge points. The long life span of cetaceans means that they tend to accumulate pollutants over a long period resulting in an accumulation of high contamination levels with age. Many organochlorine substances have been characterized as endocrine disrupters; some are also believed to reduce reproductive success, to interfere with developmental processes, and/or to suppress immune function. Organochlorines compounds are also known to induce vitamin A deficiency in mammals, which may be associated with impairment of immuno-competence, reproduction and growth (Borrell et al., 1999). DDT and PCBs affect steroid reproductive hormones, by prolonging oestrus and decreasing frequency of implantation. Organochlorine contamination can increase mammalian vulnerability to bacterial and viral diseases. It causes a disruption of T-lymphocyte cell growth and function (Vos and Luster, 1989) with, at higher concentrations, B-lymphocyte impairment. Significant relationships were reported between elevated PCB concentrations and mortality due to infectious disease in harbor porpoises which is suggestive of a causal relationship between chronic PCB exposure and infectious disease mortality (Jepson et al., 1999).

Butlyins (BTs) were primarily used as anti-fouling treatments on fish farm cages, ship hulls and marine structures. BTs are extremely toxic and can cause growth retardation and imposex in marine organisms in concentrations as low as 10–20 $ng\,l^{-1}$ and disrupt the immune system of mammals (Gibbs and Bryan, 1986). Kannan and Tanabe (1997) furthermore cited toxicological studies that have unequivocally documented the immuno-suppressive capacity of butyltins. There is concern about the possible toxicological implications for BT pollution on marine cetaceans (Iwata et al., 1995). BTs have been identified in at least 14 species of cetacean from North Pacific and Asian waters, with elevated levels being seen in coastal species, indicating that, species such as harbor porpoise and bottlenose dolphin would be more at risk from BT contamination (Tanabe et al., 1998). BTs are thought to have played a role in mass mortality events of bottlenose dolphins in Florida through suppression of the immune system (Jones, 1997). Butyltins have been reported in harbor porpoises in the coastal waters of England and Wales (22–640 μg/kg wet weight) (Law et al., 1999). Data on organotin residues in sewage indicate a considerable organotin load in several sewage treatment plants, an additional source of organotins to the coastal waters.

2.6. Plastics

Plastics contribute the most significant part of marine litter deposits and solid wastes dumped into aquatic environments. Plastics are dumped in huge volumes in well-used beaches, lakes, navigation channels and other forms of water masses. In the north-western Mediterranean, plastics constituted most of the debris, at an average of about 77% (Goldberg, 1995). Wace (1995) reported that as many as 600,000 plastic containers worldwide were being dumped daily at sea by shipping. In a survey on the stranded and buried litter on beach in Japan and Russia along Japan Sea, Kusui and Noda (2003) reported that plastics contributed 72.9% by number and 53.8% by weight of the total litter deposits in the beaches of Japan and 55.1% by number 23.4% by weight in the beaches in Russia. Similar significant contributions of plastics were reported by Frost and Cullen (1997) form Northern New South Wales beaches, by Walker et al. (1997) from Bird Island, South Georgia, by Whiting (1998) from Fog Bay, Northern Australia, by Debrot et al. (1999) from South Caribbean. The bulk of plastic materials are even bigger in developing countries with poor waste disposal regulations. As well as an aesthetic problem, marine litter threatens wildlife through entanglement, ghost fishing, and ingestion (Gregory, 1999). The eventual fate of the plastic materials generally involves burial in adjacent sediments. The plastics are virtually indestructible and accumulate organic coatings which adsorb shells, sand and other debris and sink to the bottom where they create and act as partition inhibiting the transfer of nutrients and gases between water and sediments. Anoxia and hypoxia are the most common form of phenomena occurring at the sediment–water interface due to plastic partition. Such effects may seriously interfere in the normal functioning of the ecosystem and may alter the topographical and biological make-up of the sea floor. Information on the effects of plastic materials on aquatic organisms is scarce except some reports suggesting the occurrence of plastics in marine birds. Blight and Burger (1997) examined 58 species under three categories of marine birds and reported that 100% of surface-feeding procellriiforms, 75% of the shearwaters and 39% of the purcuit-diving alcids contained plastics in their guts. Similar reports were made by Furness (1985) and Robards et al. (1995).

2.7. Sediments

Global estimates of erosion and sediment transport in major rivers of the world vary widely, reflecting the difficulty in obtaining reliable values for sediment concentration and discharge in many countries. Milliman and Syvitski (1992) estimated global sediment load to oceans in the mid-20th century to be 20,000 million tons per year, of which about 30% comes from rivers of southern Asia. While erosion on mountainous islands and in upland areas of continental rivers reflects natural topographic influences, Milliman and Syvitski (1992) suggest that human influences in Oceania and southern Asia cause disproportionately high sediment loads in these regions. High levels of turbidity limit penetration of sunlight into the water column, thereby limiting or prohibiting growth of algae and rooted aquatic plants. In spawning rivers, gravel beds are blanketed with fine sediment which inhibits or prevents spawning of fish. In either case, the consequence is disruption of the aquatic ecosystem by destruction of habitat. Notwithstanding these undesirable effects, the hypertrophic status of many shallow lakes, especially in developing countries, would give rise to immense growth of algae and rooted plants were it not for the limiting effect of light extinction due to high turbidity.

The role of sediment in chemical pollution is tied both to the particle size of sediment, and to the amount of particulate organic carbon associated with the sediment. For phosphorus and metals, particle size is of primary importance due to the large surface area of very small particles. Phosphorus and metals tend to be highly attracted to ionic exchange sites that are associated with clay particles and with the iron and manganese coatings that commonly occur on these small particles. Many of the persistent, bioaccumulating and toxic organic contaminants, especially chlorinated compounds including many pesticides, are strongly associated with sediment and especially with the organic carbon that is transported as part of the sediment load in rivers. Measurement of phosphorus transport in North America and Europe indicate that as much as 90% of the total phosphorus flux in rivers can be associated with suspended sediment. The affinity for particulate matter by an organic chemical is described by its octanol–water partitioning coefficient (K_{OW}). This partitioning coefficient is well known for most organic chemicals and is the basis for predicting the environmental fate of organic chemicals. Chemicals with low values of K_{OW} are readily soluble, whereas those with high values of K_{OW} are described as "hydrophobic" and tend to be associated with particulates. Chlorinated compounds such as DDT and other chlorinated pesticides are very hydrophobic and are not, therefore, easily analyzed in water samples due to the very low solubility. For organic chemicals, the most important component of the sediment load appears to be the particulate organic carbon fraction which is transported as part of the sediment. Scientists have further refined the partitioning coefficient to describe the association with the organic carbon fraction (K_{OC}). Another important variable is the concentration of sediment, especially the <63 μm fraction, in the water column. Even those chemicals that are highly hydrophobic will be found in trace levels in soluble form. Where the suspended load is very small, the amount of water is so large relative to the amount of sediment that the bulk of the load of the chemical may be in the soluble fraction. This becomes an important issue in the monitoring of hydrophobic chemicals.

Unlike phosphorus and metals, the transport and fate of sediment-associated organic chemicals is complicated by microbial degradation that occurs during sediment transport in rivers and in deposited sediment. Organic chemicals associated with sediment enter into the food chain in a variety of ways. Toxic compounds bioaccumulate in fish and other top predators both directly though sediment ingestion and indirectly through the food web (associated with the particulate C fraction of the sediment). Deltas, mangrove forests, beaches and other coastal habitats are sustained by the supply of sediment, while other habitats, such as coral reefs and seagrass beds, may be smothered or deprived of light. Sedimentation is one of the major global threats to reefs, particularly in the Caribbean, Indian Ocean, and South and Southeast Asia.

2.8. Eutrophication and algal bloom

Cloern (2001) described two broad responses of nutrient loadings in coastal waters: direct responses such as changes in chlorophyll, primary production, macro- and microalgal biomass, sedimentation of organic matter, altered nutrient ratios, harmful algal blooms, and indirect responses such as changes in benthos biomass, benthos community structure, benthic macrophytes, habitat quality, water transparency, sediment organic matter, sediment biogeochemistry, dissolved oxygen, mortality of aquatic organisms, food web structure etc. Increase in phytoplankton biomass and the resultant decrease in transparency and light intensity can become an indirect response that limits growth of submerged vascular plants. Decadal trends of decreasing abundance of benthic macrophytes have been reported in Chesapeake Bay and Laguna Madre (Cloern, 2001). Blooming and finally collapse of algae may lead to hypoxia/anoxia and hence mass mortality of benthos and fish over large areas. Sensitive species may be eliminated and major changes in ecosystem may occur. Deteriorating environmental quality adversely affects the amenity, recreational values and the tourist industry in addition to the ecological and biological losses. Increases in nutrient concentration, phytoplankton biomass and productivity, alternation of nutrient ratios, change of species composition, and large scale hypoxia/anoxia affecting hundreds and thousands of km^2 have been reported in many areas all over the world (Sheppard, 2000a,b,c).

Eutrophication has been shown to cause major changes in species composition, structure and function of marine communities over large areas. The general response of phytoplankton communities to eutrophication involves an increase in biomass and productivity (Riegman, 1995). A general shift from diatoms to dinoflagellates, and also down shift in size in phytoplankton towards a dominance of small size nanoplankton (e.g. microflagellates and coccoids) is generally observed (Kimor, 1992). A similar response is observed in zooplankton communities, with herbivorous copepods being replaced by small-size and gelatinous zooplankton (Zaitsev, 1992). Eutrophication also promotes proliferation of macroalgae and filamentous algae. This often becomes a nuisance, and may affect benthic fauna, nursery and feeding of fish, amenity, recreational uses and tourism (Riegman, 1995; Rosenberg et al., 1996). Eutrophication-induced hypoxia alters the structure, diversity as well as trophic structure and food web of benthic and fish communities (Riegman, 1995). A decrease in dominance of predatory gastropods in the benthic community and a shift from demersal fish species to pelagic species in response to eutrophication have been reported. Changes in species composition of macrobenthos in response to eutrophication have also been reflected in the diet of demersal fish in Sweden waters (Phil, 1994).

Related to the chemical and physical factors that cause eutrophication, one of the most important ecological consequences of aquatic pollution is the occurrence of toxic algal bloom, often called red tides. These massive growths of phytoplankton, mostly dinoflagellates, may contain highly toxic chemicals that can cause illness and even death to aquatic organisms and humans. Large-scale algal blooms cause serious ecological damage and economic loss, while toxic blooms pose additional public health threats. More than 160 red tides have been reported in Chinese waters from 1980 to 1990, and the frequency, magnitude and geographic extent of red tides along the coast of China has increased in the last decade. The area covered ranged from 10 to 6100 km^2 and over 60 causative red tide species have been reported (Qi et al., 1993).

Potential toxins from red tide are able to cause extensive fish kills, contaminate shellfish and create severe respiratory irritation to humans along the shore. When the bloom is severe, fish die rapidly from the neurotoxic effects of the red tide which enter their bloodstream through the gills. Because the fish die immediately after intoxication, the toxins do not have time to build up in their tissue. Fish exposed to even lower concentrations may accumulate toxins in their body. Such bioaccumulation in fish eaten by mammals may have been a major factor in the deaths of marine mammals. People near the shore are likely to experience the characteristic burning sensation of the eyes and nose caused by gas choked in the air, and dry, choking cough. Another serious problem for public heath caused by red tide is through shellfish contamination. Bivalve shellfish, especially oysters, clams and coquinas can accumulate so many toxins that they become toxic to humans. Elevated growth and subsequent decay of phytoplankton has caused widespread areas of seasonally oxygen depleted water. The global distribution of frequently occurring oxygen depleted zones (Malakoff, 1998) dominates the highly developed industrial areas that include much of Europe, central and North America and some parts of the Asia–Pacific.

2.9. Aquaculture activities

Aquaculture as a form of agricultural pollution has received particular attention due to its potential for loading and discharging effluents rich in polluting agents. Effluent controls are possible on land-based systems; however, water-based systems are capable of causing potential problems. Aquaculture is rapidly expanding in most parts of the developed and developing world, both in freshwater and marine environments (Fig. 6). The environmental impact is primarily a function of feed composition and feed conversion, faecal waste generation, organic and inorganic fertilizers, liming materials, algicides and herbicides, disinfectants, antibiotics, inducing agents, osmoregulators, piscicides, probiotics etc. (Tacon et al., 1995). Wastage of feed is estimated to be 20% (Enell, 1995) even with high quality feed used for fish rearing European aquaculture. In Asia, Latin America and Africa, however, aquaculture usually suffers from a general lack of high quality fish feed resulting in poor feed conversion and higher feed loss which ranges as high as 75–80% depending on the culture systems and the degree of management applied. Waste feed and faecal production both add substantial nutrient loadings to aquatic systems and subsequent discharge into receiving waters.

Intense cultivation of fish and shellfish in coastal waters can be a source of environmental disturbance associated with unnaturally high concentrations and deposition of organic matter that alter sedimentary processes and oxygen concentrations. Shellfish culture has a strong influence on the nitrogen cycle by

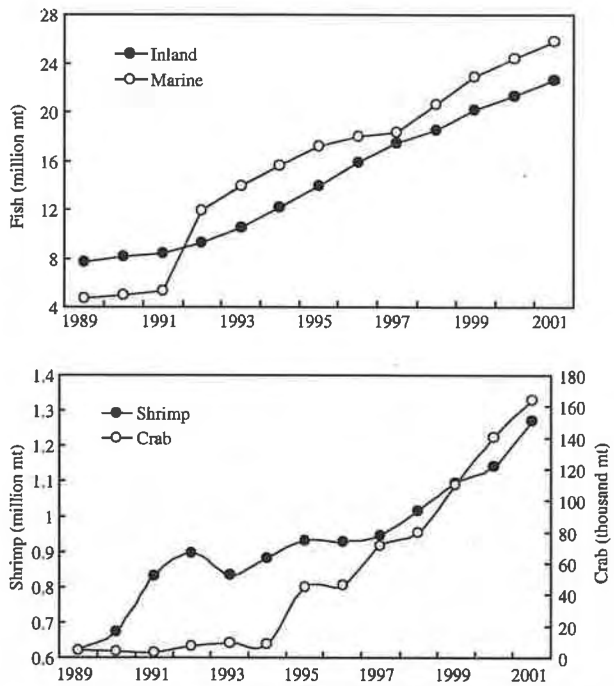

Fig. 6. Global production of fish from aquaculture in both inland and marine environment (upper) and shrimp and crab through coastal aquaculture (lower).

enhancing the deposition of organic matter to the sediments, reducing oxygen availability and promoting dissimilatory processes of N cycling. In the Thau Lagoon, France, used for intense oyster culture, these changes reduce the loss of nitrogen to denitrification and, therefore, retain N available to sustain primary production (Gilbert et al., 1997). Similar responses were measured in Upper South Cove, Nova Scotia, where sediments beneath cultured mussels release large quantities of ammonium and act as a net source of N, compared to reference sites which act as an N sink (Hatcher et al., 1994). Intense shellfish farming, therefore, increases the retention of nitrogen within coastal systems. Finfish culture is growing at an equally rapid rate with similar responses of organic enrichment and enhanced microbial activity of sediments, and also promotes development of toxic algal blooms. In the Aland archipelago, where harvest of farmed rainbow trout (*Oncorhyncus mykiss*) increased >10-fold from 1977 to 1991, fish farms now contribute more P (by 15×) and N (by 3.6×) than treated wastewater (Bonsdorff et al., 1997). This region of the northern Baltic exhibits multiple symptoms of change in response to nutrient enrichment, even during an era of improved wastewater treatment.

In oligotrophic environments such as the Mediterranean, aquaculture has been displacing fishing grounds, attracting dolphins and competing with traditional fisheries. Moreover, there are concerns that biotechnology and/or breeding techniques could have negative impacts on wild species in the event that genetically altered species escape and interbreed. In some cases, aquaculture is a resource intensive enterprise, e.g. salmon farming. Salmon farming in cages requires lots of resources collected by fishing vessels operating over vast marine ecosystems. The marine water surface area required to produce the food given to the salmon in the cages is about 1 km^2 per ton of salmon. The ecological footprint of the salmon farm is as much as 50,000 times larger than the areas of the cages (Folke, 1995). Figures published for 1996 estimate that the 80,000 tons of farmed salmon produced 35,000 tons of fecal waste, i.e. 0.44 tons of waste per ton of produced salmon (Taylor et al., 1998). Using SEPA data for 1999 (SEPA, 2000), 114,638 tons of salmon were produced, meaning that 50,440 tons of fecal waste would have been discharged into the marine environment. Elevated nutrient levels have been bound in many coastal areas and seas hosting fish farming operations (Gillibrand et al., 1996).

Additional environmental problems include risk of disease and its transfer to wild fish, introduction of exotic species, impacts on benthic communities and on the eutrophication of water, interbreeding of escaped cultured fish with wild fish with consequent genetic change in the wild population (the so-called 'biological pollution'; Elliott, 2003). Traditional integrated aquaculture systems, as in China, where sewage-fish culture is practiced, can be a stabilizing influence in the entire ecosystem (Rosenthal, 1992). The environmental impacts of aquaculture and associated activities have been discussed by many authors for different aquaculture systems and regions (Enell, 1995; Paez-Osuna et al., 1998; Selong and Helfrich, 1998; Boyd and Massaut, 1999, Karakassis et al., 2000; Tovar et al., 2000; Elliott, 2003).

2.10. Biological pollution

The terms 'biological pollution' and 'biological pollutants' have been emerging recently with a relatively recently identified impacts of introduction and invasion of species throughout the world; the terms have been used to discuss the problems caused by introduced and invasive species (Boudouresque and Verlaque, 2002). There is an increasing set of case studies regarding the presence and movement of invasive species in marine and estuarine waters as well as in aquaculture and the term biological invasions has become widely accepted (Elliott, 2003). The terms also appear reasonable to describe pollution emanating from organisms, such as nutrients or organic matter, and even pollution affecting biological organisms, i.e., contaminants and/or biological pollutants as agents of change in the marine environment. The central criterion of the definitions of pollutants is their ability to reduce the fitness for survival of some level of biological organization, from cell to ecosystem (Elliott, 2003).

Plants such as the green alga *Caulerpa taxifolia* are well known as an invasive species in the Mediterranean. Fishes such as the lionfish *Pterosis volitans* are also invaders, probably introduced with ballast water or by aquarists (Whitfield et al., 2002). There are numerous examples of fish species introduction around the world with varying degrees of consequences (Middleton, 1982; Amundsen et al., 1999; Shafland, 1999; Mills and Holeck, 2001). However, it is still a question whether these should be termed biological pollutants, i.e. whether they have reduced the fitness of the biological system for survival. In the estuarine and marine field, there are several good examples of introduced species and of the damage caused by them. For example, the Chinese mitten crab *E. sinensis* now extends to a large part of NW Europe from the Tagus Estuary in Portugal to northern Germany and eastern Scotland and it has started causing damage to flood defense walls by burrowing. The damage here is at an ecosystem level as well as affecting local community structure.

Most of the aquaculture industries in the world are biologically polluted in that almost all the suitable aquaculture species are now genetically modified. Deliberate genetic selection and breeding for long period has caused not only numerous consequences in the aquaculture unit itself but also the loss of the original stocks for many species in many parts of the world. In some instances, the modified populations are often released and mixed with the natural populations, breed with them and, therefore, cause biological pollution from molecular level to community and ecosystem level. The carp fishery in Indian subcontinent and China and salmonid fishery in Europe are two examples of large-scale biological pollution. As another example, introduced and in some cases genetically modified species such as non-native oysters, producing spat in South-west Britain and chromosome-modified salmonids escaping from fish farms in Scotland and Norway. It is notable that the recent flooding in central Europe has inadvertently caused the release of hybrid and modified fishes, such as sturgeon (*Acipenser* spp.) from aquaculture installations. In these cases, if the organisms survive and successfully breed then the biological pollutants can be regarded not only as conservative, but also accumulative (Elliott, 2003). Micro- and macroparasites and micropathogens have long been regarded as introduced and invasive. It is likely that the local populations of fish are not resistant to the pathogenic organisms carried by the introduced species and vice versa. Therefore, serious consequences occur for both the local and the introduced population in a deliberate species introduction. Most of the species introduction programs usually lack precautionary approach (FAO, 1995).

3. Global trends in coastal and marine pollution

Disposal into waterways is a very ancient practice of dealing with wastes and the open waterways have been used by people for dumping all kinds of waste produced. Consequently, most of the aquatic environments are now polluted to some extent; situations are even critical near intensive human settlements. Pollution of water-bodies from a large variety of sources and their various impacts has been reported from different ecosystems since long (Table 4). Progressive increases in nutrient concentration and altered nutrient ratio have been reported from the Baltic Sea, Waden Sea, North Sea, Black Sea, Adriatic Sea, Dutch Sea, Japan Sea, the Gulf of Thailand, the Indian Ocean and the bays and coasts of many countries (HELCOM, 1996; Sheppard, 2000a,b). As a result of human intervention and mobilization of nutrients, surface waters and ground waters throughout the developed world now have elevated concentrations of N and P compared to concentrations in the middle of 20th century (Cloern, 2001). For example, concentrations of nitrate have increased five times and phosphate 20 times in the Black Sea from 1960s to 1980s (Gomoiu, 1992). Cloern (2001) reported decadal scale of increasing N and P in the Northwest Black Sea, central Baltic Sea, Archipelago Sea and in the Irish Sea and in three rivers in North America and Europe including the Mississippi River; increasing phytoplankton productivity in Adriatic Sea, Belt Sea and Waden Sea, decreasing dissolved oxygen concentrations and secchi depths in different coastal seas from 1960s to 1990. Likewise, levels of N and P in Dutch Seas have increased four and two times respectively from 1930 to 1980 (GESAMP, 1990). Three to five times increases in N and P export have been reported in Queensland, Australia, in the last 65 years (Moss et al., 1992). Progressive increases in primary productivity and decreases in dissolved oxygen due to eutrophication have been reported in the Baltic Sea from 1958 to 1989 (HELCOM, 1996). A decrease in bottom oxygen was found in northern Adriatic Sea during the period 1911–1984 (Justic et al., 1995). The long-term increase in nutrient in the Baltic has caused an increase in phytoplankton biomass, a decrease in water transparency, proliferation of filamentous algae, and also large scale changes in species diversity of benthic and fish communities (Bonsdorff et al., 1997). Globally, increases in frequency and severity of hypoxia are evident, especially in coastal and estuarine areas; many ecosystems are now near the verge of hypoxia-induced catastrophe (Diaz and Rosenberg, 1995).

In the last two decades, there has been an increased frequency and scale of toxic algal blooms including red tides in coastal waters of Brunei, Malaysia, South Africa, Hong Kong, Japan and Thailand (three examples taken from Cloern, 2001 are given in Fig. 7) and an

Table 4
Effects of pollution on aquatic ecosystems and aquatic living resources in different parts of the world

Causes	Effects	Region	Reference
Pollution	Decrease in species diversity of fish and other aquatic organisms; there are 75 threatened species at present	Coastal Thailand	Chavalit and Siraprapha (2002)
Pollution	Changes in bivalve reef and bed structure	–	Richard et al. (2002)
Polycyclic aromatic hydrocarbons (PAH), chlorinated organic compounds	Decline on ocean and coastal fisheries particularly the Atlantic Salmon, *Salmo salar*; negative impacts on food chain	The Atlantic Ocean	Scott (2001)
Pollution	Loss of nesting sites and habitats of the green turtle, *Chelonia mydas*	Mediterranean	Max et al. (2001)
Pollution	Reduction or depletion of local and/or total population of the Atlantic White-eaked Dolphin	Northeastern and Northwestern Atlantic	Jon et al. (2001)
Pollution	Decline of stock of the Atlantic salmon, *Salmo salar* and brown trout, *Salmo trutta*	Norwegian river systems	Arne and Ove (2001)
Pollution	Degradation of coastal habitats, natural resources and biodiversity	The Indian Coast of Somalia	Federico and Giovanni (2000)
Nonpoint source pollution	Reduction in shellfish population	The west coast of the Pacific	William (2000)
Oil pollution	Decline in populations and colonies of seabirds	The Patagonian coast, Argentina	Pablo et al. (1999)
Pollution	Collapse of lake whitefish (*Coregonus clupeaformis*) population	The Great Lakes	Edsall (1999)
Pollution	Degradation of nursery areas of many fishes	Arabian Sea, Gulf of Oman and Arabian Gulf	Siddeek et al. (1999)
Pollution	Stock decimation of blue crab, *Callinectes sapidus*	South California	Whitaker et al. (1998)
Industrial pollution	Stock decimation of fishes	Bangladesh	Alam et al. (1998)
Pollution	Endangered and threatened (Ganges river dolphins, *Platanista gangetica*)	Bangladesh	Smith et al. (1998)
Pollution	Damage to mollusk producing beds in estuaries and bays	North and Central America and Europe	MacKenzie and Burrell (1997)
Pollution	Diminishing yields of American oysters (*Crassostrea virginica*)	Coastal lagoons of Mexico	Marin et al. (1997)
Pollution	Loss of nesting habitats and population decline of leatherback	Malaysia	–
Pollution	Habitat degradation and decline in salmon population	California	Olin (1996)
Pollution	Decline in the abundance of eggs and larvae of anchovy, *Engraulis encrasicolus*	Black Sea	Niermann et al. (1994)
Pollution due to the Gulf War 1991	Interruptions in the life cycles, morbidity, emigration, and recruitment collapse of penaeid shrimp, *Penaeus semisulcatus* and supporting fisheries	Arabian Gulf	Mathews et al. (1993)
Point sources of pollution	Changes in the water quality	Archipelago Sea and the Finnish part of the Gulf of Bothnia	Lappalainen and Hilden (1993)
Sewage and nonpoint pollution	Increased lake fertility, killing of yellow perch, cisco, white bass, and yellow bass	Yahara River lakes (Mendota, Monona, Waubesa and Kegonsa)	Lathrop et al. (1992)
Pollution	Mortality, malformation, and abnormal chromosome division of fish embryos (Atlantic mackerel, *Scomber scombrus*; windowpane flounder, *Scophthalmus acquosus*; winter flounder, *Pseudopleuronectes americanus*)	US Atlantic coast	Longwell et al. (1992)
Pollution	Poor reproductive success in hard clams (*Mercenaria mercenaria*)	Long Island Sound USA	Stiles et al. (1991)
Pollution by oil, chemicals and rubbish	Reduction in population of seabirds	North Sea	Dunnet et al. (1990)
Pollution from domestic and industrial wastes	Environmental changes; disappearance of endemic fishes in commercial catches particularly Schizothoracids and mahseers	Riverine systems of the north-western Himalaya, India	Sehgal (1985)
Pollution	Chronic shellfish toxicity; decline in anadromous fish stock	St. Lawrence Estuary, Quebec, Canada	Andersen and Gagnon (1980)
Pollution and eutrophication	Significant changes in the water chemistry (increase of BOD and total N content); changes in the structure and abundance of phytoplankton, zooplankton and bottom fauna	Lake Jamno, Poland	Zdanowski et al. (1979)

Table 4 (*continued*)

Causes	Effects	Region	Reference
Industrial, commercial, agricultural and domestic pollution	Massive fish kills and polluted water	Laguna de Bay, Philippines	Oledan (2001)
Pollution	Undefined impacts on the finless porpoise, *Neophocaena phocaenoides*		Reeves et al. (1997)
Pollution from industrial waste discharge, mining, pesticides, and oil residues and spills	Stock declines of fish and other commercially important aquatic organisms; changes in lake ecosystem and water quality	African Great Lakes	
Pollution from different sources	Alteration in population structure of the commercial fishes	USA	Grosse et al. (1997)
Pollution from intensive ship-scrapping activities, sewage disposal and antifouling paints	Bioaccumulation of butyltins and resulting butyltin pollution in fishes	India, Bangladesh, Thailand, Indonesia, Vietnam, Taiwan, Australia, Papua New Guinea and the Solomon Islands	Kannan et al. (1995)

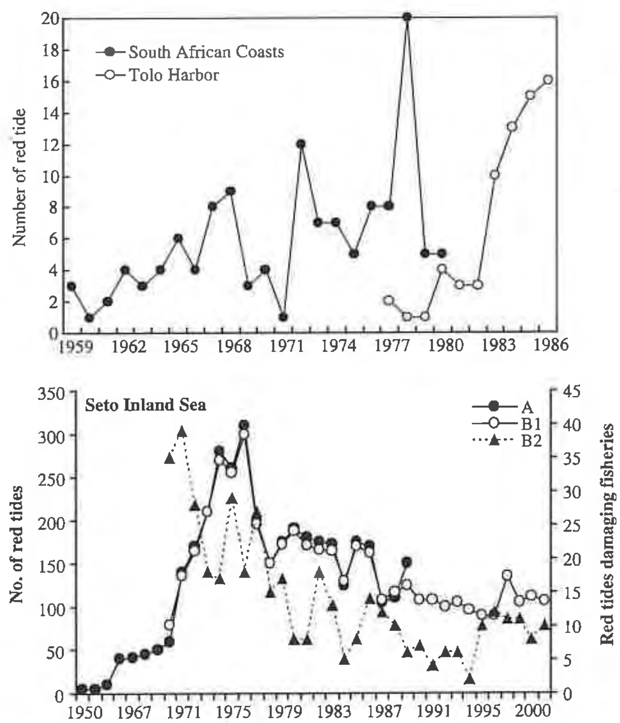

Fig. 7. Number of red tides occurrence in the South African Coast, the Tolo Harbor of Hong Kong and in the Seto Inland Sea of Japan.

increase in PSP frequency has been found in both temperate and tropical regions (Viviani, 1992). The Intergovernmental Oceanographic Commission of UNESCO has reported toxic blooms of *Pseudonitzschia australis* in California coastal waters; multiple species of dinoflagellates in Hong Kong and south China; brown tide species in Saldanha Bay and Langebaan Lagoon, South Africa; *Gymnodinium mikimotoi* in Wellington Harbor, New Zealand; *Alexandrium tamarensis* in Brazil, Uruguay, and Argentina; *Prorocentrum minimum* in Thermaikos Bay, Greece; red tides along the Salalah coast of Oman; *Pyrodinium* in Acapulco, Mexico; *Alexandrium* spp. in Alexandria Harbor, Egypt; *Gymnodinium breve* in south Florida; *Gymnodinium catenata* along the Atlantic coast of Morocco; *Dinophysis* in Loch Long, Scotland; *Pseudonitzschia pungens* in estuaries of Prince Edward Island, Canada; *Alexandrium minuta* in the Bay of Izmir, Turkey; *Dinophysis* along the northeast coast of Kamchatka, Russia; *Pyrodinium bahamens* in the Philippines; and *Gymnodinium nakasagiense* in southwestern India.

Long-term monitoring programs show a general decrease in environmental levels of DDT and PCB in many coastal waters. For example, the annual geometric means of DDT, PCBs and PAHs in mussels at 154 sites in coastal waters of the USA showed a general decrease from 1986 to 1993 (Beliaeff et al., 1997). Likewise, Blomkvist et al. (1992) showed a significant decrease in RDDT and PCB in the blubber of 109 specimens of ringed seals (*Phoca hispida botica*), grey seals (*Halichoerus grypus*) and harbor seals (*Phoca vitulina*) in Swedish waters since the early 1970s. Analysis of sediment core samples in Clyde estuary, UK showed a significant decrease in PAH deposition over time (Hursthouse et al., 1994). The decreased concentration of xenobiotics in the marine environment reflects the general reduction in the use and discharge of these compounds in the northern hemisphere. Unfortunately, very few long-term studies have been carried out in tropical and sub-tropical coastal waters. The decreasing trend observed in temperate regions may not be applicable to tropical and sub-tropical waters, since reduction in use and disposal of toxic organic chemicals in the latter regions may not be the same.

At present, some 65% of existing large cities (with more than 2.5 million people) are located along the coast. The world population has exceeded 6 billion, of whom 60% (3.6 billion) is living within 100 km of coast (UNEP, 1991). It is highly likely that a substantial proportion of wastewater generated from this population will be directly discharged into the coastal marine environment with little or no treatment, thereby adding to the already high nutrient input. Various studies have attempted to estimate the anthropogenic input of nutrients into the marine environment (Cornell et al., 1995; Sheppard, 2000a,b,c). The present anthropogenic emissions and deposition of nitrogen to the North Atlantic Ocean is about five times greater than pre-industrial time (Prospero et al., 1996). At present, atmospheric deposition of N contributes some 10–50% of the total anthropogenic N input ($2–10\times10^4$ $\mu mol\,N\,m^{-2}$ $year^{-1}$), and further increase is expected in the coming years (Paerl, 1993).

There is a worldwide increase in irrigation in arid areas, large scale clearing of land vegetation, and deforestation, which contribute enormously to terrestrial runoff. Intensive farming results in overgrazing, ammonia emission, and farm waste disposal problems. Nutrient export from crop and pasture lands are typically an order of magnitude greater than those from pristine forest (Gabric and Bell, 1993). Mariculture activities have increased dramatically in many coastal areas in the last decade, and such a trend will continue (FAO, 1992). This will further augment the nutrient input into coastal environments, since some 80% of N input into a mariculture system will be lost into the marine environment (Wu, 1995). The volume of wastewater generated by human populations is typically large, and removal of nutrient from such huge amounts of wastewater is expensive. The cost of secondary treatment (which only removes some 30–40% of N and P) for example, is some 3–4 times more expensive that of primary treatment. Due to the high construction and recurrent costs, it is unlikely that building of sewage treatment facilities can match population growth and GNP in developing countries.

PCBs are frequently found in fish liver, seal blubber, bird eggs and human fat in the North Sea. Octachlorostyrenes (OCSs) were found in benthic organisms from the international North Sea (Dethlefsen et al., 1996). Concentrations of HCHs, PCBs, and triazines have been determined in the German Bight within the water column and rain water, and HCHs and PCBs in sediment samples (Huhnerfuss et al., 1997). Concentrations of insecticides and PCBs in sediment from the Thames estuary have been associated with sewage sludge dumping. Disposal of dredged material into the North Sea amounted to approximately 70 million tons per year in the 1990s. Litter and garbage disposal from ships overboard and from tourism is estimated at 600,000 m^3 per year. It is likely that organic inputs will continue, especially in those waters deemed to have sufficient carrying capacity to degrade, disperse and assimilate the materials (Elliott et al., 1998). Shipping in the North Sea is the most intense in the world and the area is a major navigation route for some of the world's most developed and highly populated economies. The effects of TBT, the active constituent of anti-foulant paints, on marine fauna have been extensively demonstrated with work done in this region and adjacent coasts.

Globally, sewage remains the largest source of contamination, by volume, of the marine and coastal environment (GESAMP, 2001), and coastal sewage discharges have increased dramatically in the past three decades. In addition, because of the high demand for water in urban neighborhoods, water supply tends to outstrip the provision of sewerage, increasing the volume of wastewater. Public health problems from the contamination of coastal waters with sewage-borne pathogens are well known, and in many developed countries improved sewage treatment and reduction of the disposal of industrial and some domestic contaminants into municipal systems have significantly improved water quality. In the developing world, however, the provision of basic sanitation, as well as urban sewer systems and sewage treatment, cannot keep pace. High capital costs, explosive pace of urbanization and in many cases, limited technical, administrative and financial capacities for urban planning and management and ongoing operation of sewage treatment systems are barriers to efficient sewage treatment (GESAMP, 2001). Recent evidence suggests that bathing in waters well within current microbiological standards still poses significant risk of gastrointestinal disease, and that sewage contamination of marine waters is a health problem of global proportions.

Human activities now account for more than half of global nitrogen fixation (Vitousek et al., 1997), and the supply of fixed nitrogen to the oceans has greatly increased. Sewage discharges are often the dominant local source near urban areas but global inputs are dominated by agricultural run-off and atmospheric deposition. The highest rates of riverine transport of dissolved inorganic nitrogen to estuaries from all sources occur in Europe and in South and East Asia (Seitzinger and Kroeze, 1998). Nitrogen levels are exacerbated by widespread loss of natural interceptors such as coastal wetlands, coral reefs and mangrove forests. Fertilizer use has stabilized in developed countries but is increasing in developing ones (Socolow, 1999), a trend expected to continue because of enhancement of fertilizer use through widespread subsidies, which reflect the high political priority of increasing food production and reducing food costs.

Another important feature of marine pollution is the existence of increased pollution levels in the enclosed seas and coastal waters as compared with the open ocean. Contamination levels also increase during the transition from the southern parts of all oceans to the north, where the main industrial centers and main pollution sources are concentrated. The existence of elevated levels of contaminants in the zones of high bio-productivity is extremely ecologically alarming. These zones include the water layer up to 100 m from the water surface (photic layer) and boundaries of natural environments (water-atmosphere and water-bottom sediment) as well as enclosed seas, estuaries, coastal and shelf waters. In particular, in shelf and coastal zones, which take only 10% of the World Ocean surface and less than 3% of its volume, the most intense processes of bio-production, including the self-reproduction of the main living resources of the sea, take place. The main press of anthropogenic impact is also concentrated here. In 1994, an estimated 37% of the global population lived within 60 km of the coast—more people than inhabited the planet in 1950 (Cohen et al., 1997). Progress in protecting the marine and coastal environment over the past 30 years has generally been confined to relatively few, mostly developed countries, and to relatively few environmental issues. Overall, coastal and marine environmental degradation not only continues but has intensified. There have, however, been significant changes in perspective, and new concerns have emerged. Marine and coastal degradation is caused by increasing pressure on both terrestrial and marine natural resources, and on the use of the oceans to deposit wastes. Population growth and increasing urbanization, industrialization and tourism in coastal areas are root causes of this increased pressure.

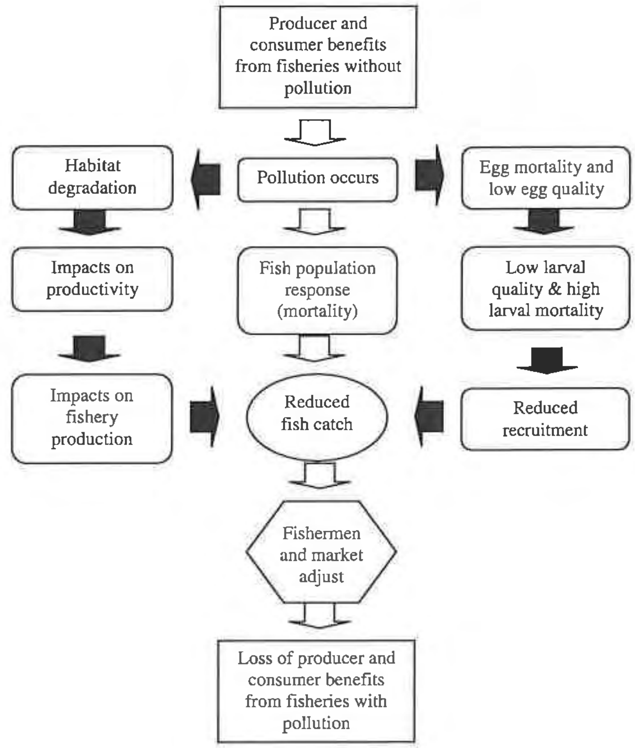

Fig. 8. Generalized scheme showing pollution effects of fish populations are translated into reduced economic benefits for producers and consumers (open and block arrows indicate direct and indirect effects respectively).

4. Fishery degradation

The previous sections discuss how pollution contributes to coastal and marine habitat degradation in general. Being one of the most important parts of the marine food chains, the ultimate effects of all sorts of coastal and marine pollution are seen in fish. Therefore, fishery degradation resulting from pollution deserves particular mention. Fig. 8 shows a generalized schematic diagram of how pollution directly and indirectly impacts on fish populations and fisheries and how these impacts are translated into reduced economic benefits for producers and consumers.

Pollution from different sources and subsequent impacts on commercial use of ecosystems have been reported from many parts of the world including the major fishing areas and have been summarized in Table 4. A comprehensive review of the existing status of the world's most significant fisheries in relation to pollution incidence can also be found in Sheppard (2000a,b). Most of the world's largest fishing industries are reported as either degraded or threatened. General degradation in the fishing industry and decline in catch was reported from the Baltic Coasts, the North Sea Coasts, the Atlantic Coasts and the Mediterranean Coasts. Fish catches have been in decline since the 1980s, and it is unlikely that there will be an increase in total catch in these regions. High seas trawlers have been forced to move closer to shore, competing with inshore artisanal trawling and other activities. As a result, the demand for fish products has exceeded the available catch. Decline in the catch of American Shad (*Alosa sapidissima*) in the Chesapeake Bay and in total US catch (Fig. 9) was reported over a long period; a similar decline in the catch of demersal fish was reported to be associated with water pollution and habitat degradation in the Gulf of Thailand and in the Aral Sea (Fig. 9).

Around 30 species of fish are caught in the Baltic, but commercial fisheries are dominated by just three species: cod (*Gadus morhua*), herring (*Clupea harengus*) and sprat (*Clupea sprattus*), that make up about 93% of total catch in the Baltic Sea and about 75% of the catch in the Belt Sea and the Sound. However, fisheries of all three species are under steady decline over the last two decades. The spawning biomass of cod and herring declined sharply since the early 1970s (Fig. 10) with a corresponding decline in the catch quota in these fisheries until 2003 and the trend is expected to continue (Fig. 11).

Environmental degradation in the East Asian Seas (which include the Yellow Sea, East China Sea, the

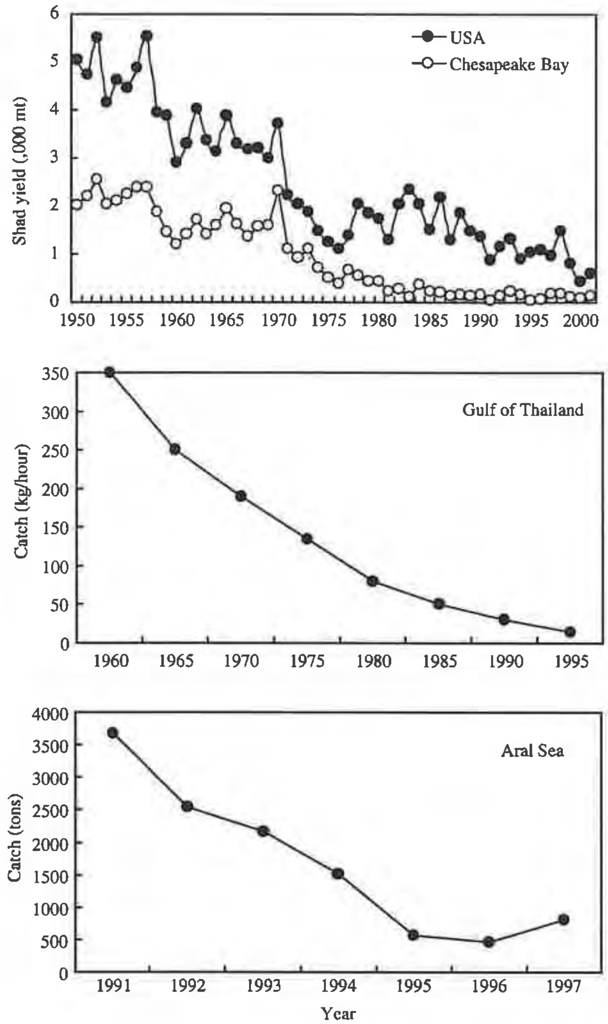

Fig. 9. Decline in the catch of American Shad (*Alosa sapidissima*) in the Chesapeake Bay and in total US catch (upper), catch per unit of fishing effort ($kg\,h^{-1}$) of demersal fish in the Gulf of Thailand (middle) and in the total catch (tons) of fish in the Aral Sea (lower).

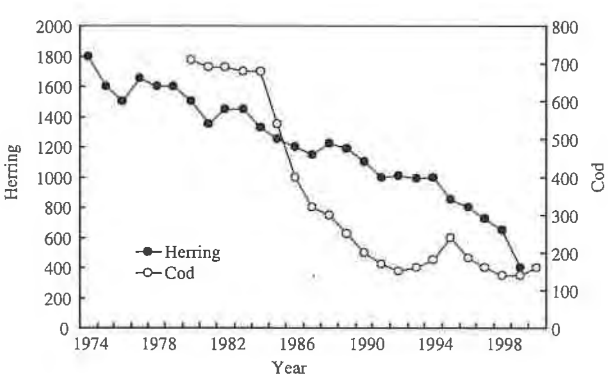

Fig. 10. Trends in the annual spawning stock biomass (thousand tons) of cod (*Gadus morhua*) and herring (*Clupea harengus membras*) in the Baltic Sea, taken from the homepage (www.helcom.fi) of the Baltic Marine Environment Protection Commission/Helsinki Commission.

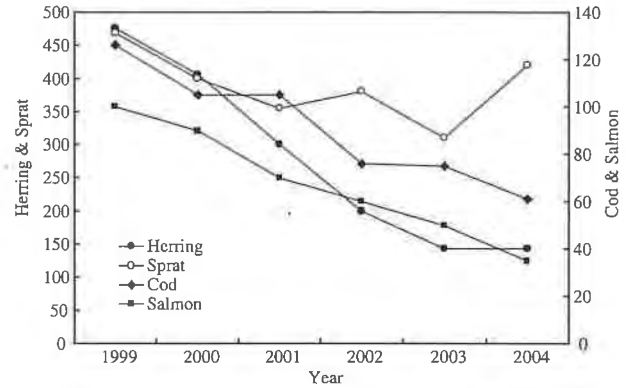

Fig. 11. Reduction in the catch quotas (thousand tons) of principal fish species in the Baltic Sea with a projection for year 2004.

South China Sea, the Sulu-Celebes Seas and the Indonesian Seas) is threatening the world's center for marine biodiversity, affecting the functional integrity of about a third of the world's coral reef, 30% of world's mangrove system and about 40% of the world's fish catch (Thia-Eng, 1999). Decline in fisheries of the Lake Victoria due to pollution was reported among other by Ntiba et al. (2001). Pollution of riverine fisheries both from industrial effluents and agricultural chemicals is a growing concern in developing areas of the world. Several reports are available on the extent of water pollutions and their consequences in South Asian developing countries. In Bangladesh, for example, most of the industries are situated on river banks and do not have waste disposal and treatment plants and thus discharge untreated wastes and effluents which find way directly or indirectly into water bodies. Kumar and Harada (2001) reported loss of biological and ecological sustenance and collapse of a river system near the capital of Bangladesh.

Smith (1970) reported mass killing of clams and abalone from oil toxicity and stated a probability of long-lasting ecological consequences. In the same review, Smith (1970) also reported massive killing of razor clam *Siliqua patula* followed by a serious event of oil pollution which was responsible for more than 90% reduction of the commercial catch of the clam in the north-west coast of US in 1963 resulting in collapse of the clam fishery.

Red tides occur throughout the world, drastically affecting Scandinavian and Japanese fisheries, Caribbean and South Pacific reef fishes, and shell fishing along US coasts. In 1989, a red tide affected large areas of shrimp farms in Bohai, and the total loss was estimated at US$40 million (Xu et al., 1993). In Hong Kong, a red tide caused by a persistent bloom of *Gonyaulax polygramma* (>50 million cells/l) occurred continuously for three months in Tolo Harbour and Channel, covering an area of some 80 km^2, and all fish and benthos were killed in this incidence. In 1998, a

Table 5
Economic losses from red tides in fisheries and aquaculture (Worldwatch Institute, 1999)

Year	Region	Species	Loss in million US$
1972	Japan	Yellowtail	~47
1977	Japan	Yellowtail	~20
1978	Japan	Yellowtail	~22
1978	Republic of Korea	Oyster	4.6
1979	United States	Many	2.8
1980	United States	Many	7
1981	Republic of Korea	Oyster	>60
1985	United States	Scallops	2
1986	Chile	Red salmon	21
1987	Japan	Yellowtail	15
1988	Norway and Sweden	Salmon	5
1989	Norway	Salmon, rainbow trout	4.5
1990	United States	Salmon	4–5
1991	United States	Oyster	15–20
1992	Republic of Korea	Farmed fish	133
1996	United States	Oyster	24
1998	Hong Kong	Farmed fish	32

major and extensive red tide outbreak occurred along the coast of Hong Kong and south China, covering an area of more than 100 km^2. Over 80% (3400 ton) of mariculture fish were killed, and the total loss was over US$40 million. Red tides of *Chatonella antiqua* have caused massive killing of farmed fish, mostly yellowtail in Seto Inland Sea of Japan. A similar event was reported from Antifer, France where the entire stock of a fish farm perished after a red tide, dominated by *Exuvialelola* sp. producing a PSP toxin. Phytoplankton blooms can have major economic impacts on fisheries, aquaculture and tourism (Table 5).

5. Conceptual model for environmental management and restoration

Despite the obvious importance of the linkage between pollution and aquatic production of fish and other commercial species, the literature remains largely anecdotal. Enough baseline information is not available as to the extent of pollution as well as the specific effects in different regions of the world. Griswold (1997) defined the obstacles in identifying relationships between pollution and fish populations as (1) insufficient data, (2) insufficient use of existing data, (3) lack of analytical tools, (4) few direct examples of pollution effects, and (5) institutional constraints. The need for rehabilitation implies that the area under consideration has been altered or degraded in a way that conflicts with defined management or conservation objectives. Hence, rehabilitation is often the result of competition for resource use. It is essential that goals be defined as a first step in the rehabilitation process.

Protection of the aquatic environment from pollution is the most essential theme of environmental management. Based on, and guided by, ecological knowledge, environmental management comprise the judicious and responsible application of scientific and technological knowledge with the aim to achieve the maximum degree of ecosystem protection commensurate with the highest sustainable quality of living for mankind (Kinne, 1984). Problems in dealing with environmental pollution were identified as poor communication between scientists and managers, weak institutional structures and manpower capabilities, lack of sectoral integration and approach to environmental management, lack of cooperation between public and private sectors etc. (Williams, 1996). The management approach may be highly variable depending upon the ecosystem and the degree of deterioration and management problems and goals. However, environmental management approach should involve the following general points (Williams, 1996):

- identifying environmental and economic values of waterbodies;
- establishing objectives and goals for protecting of a particular waterbodies;
- establishing water quality management strategies and standards considering the qualities of all input waters and effluent waters as well as the catchment management;
- developing monitoring and surveillance program to ensure standard water quality for environmental safety;
- gathering scientific information on all aspects of pollution including effects at all levels;
- developing cooperation between all levels of involvement including general people and stakeholders;
- reviewing, amending and formulating local, national, regional and international plans and developing local, national, regional and international cooperation.

To the above points, Kinne (1984) added the following:

- long-term ecological research;
- worldwide international cooperation; and
- adequate interpretation and transposing of scientific knowledge into legislation and effective control measures.

The conceptual model (Fig. 12) should, therefore, have three essential components; the main component, the management body, supported by research, and monitoring and evaluation. Information on the environmental features is the primary to formulate subsequent research and management needs. Suggestions

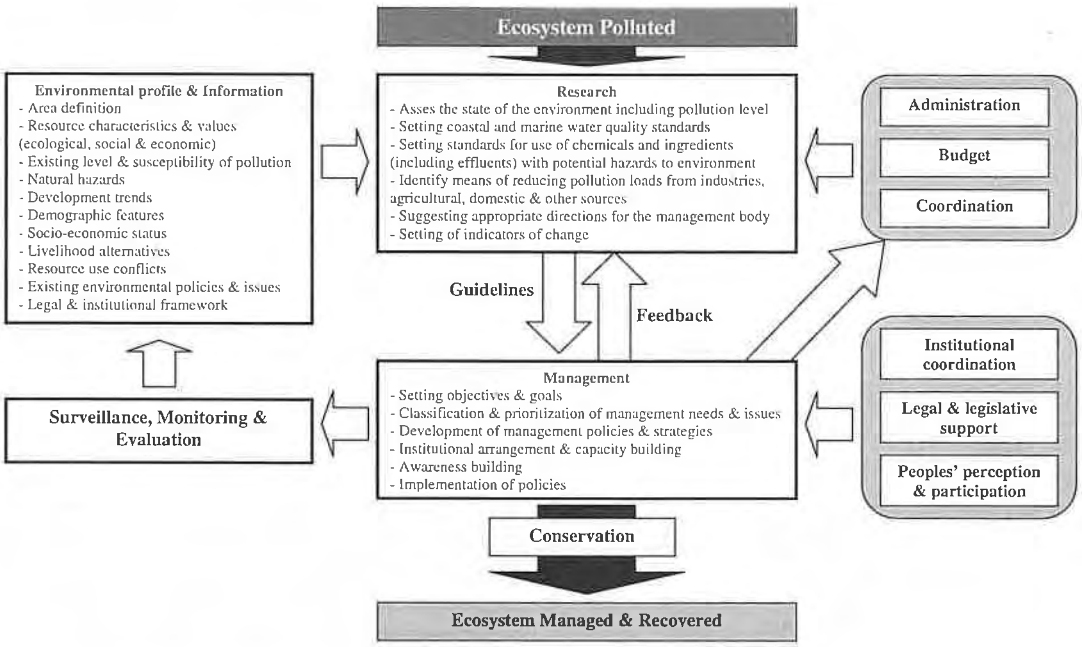

Fig. 12. Conceptual model for different components of management of coastal and marine pollution.

concerning the key points for managements as well the management strategies come from an extensive and effective research and baseline information. The management component must have the capacity to effectively identify objectives, classify the issues, prioritize management needs and formulate management plans. For a successful management, effective coordination with related departments/sectors and institutions (e.g., department of industry, agriculture, forest, social affairs, law etc.) is necessary to overcome management related problems such as land use conflicts and to have legal and legislative supports. The research and management components should be closely related, i.e., the information obtained through research will be used by the managers to formulate management directions and research component will use feedback information from the management component to formulate further research plans.

Environmental pollution cannot be limited by national territorial boundaries. However, effective environmental management on an international scale was considered rarely. Prior to 1972, the crash of some seabird populations caused by DDT, outbreaks of Minamata disease in Japan from mercury-contaminated seafood, and the *Torrey Canyon* and other oil spills focused particular attention on pollution issues. Policy responses included bans on production and use of some substances, regulations to reduce discharges, and the prohibition of ocean dumping, as well as a significant scientific effort to improve the status of knowledge about these pollutants. These responses are enshrined in a number of international agreements, including the 1972 London Dumping Convention and its 1996 Protocol, the 1989 Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal, and the 1995 Global Program of Action for the Protection of the Marine Environment from Land-based Activities.

The reasons for restoration, the goals as well as the success to be gained are case-specific, and are, therefore, depends on particular fishery and the degree to which damage has been caused. One of the major problems in fishery restoration is to quantify the damage caused and to distinguish the role of pollution in the damage both of which are important for the fishery biologists as well as managers to select effective tools for restoration. Another important question in fishery restoration is to what extent the fishery managers can play role to protect their fishery from pollution? The institutional and legal settings in most nations are such that the fishery managers can, in fact, do little even if pollution is identified as the major cause for fishery decline. They can only manipulate their fishery, e.g., gear management, stock enhancement etc. However, as the pollution continues, degradation of fishery also continues. Collins et al. (1998) proposed that although the damage caused by acute pollution to fish stock is followed by a rapid recovery of the stock, the effects of chronic pollution is long-lasting. Although withdrawal of fishing can result in partial recovery of the stock, this may bring about changes in the stock structure by increasing the proportion of smaller size groups in the stock. Therefore, the need for multidisciplinary approach into the effects of pollution on fish stocks becomes evident for best

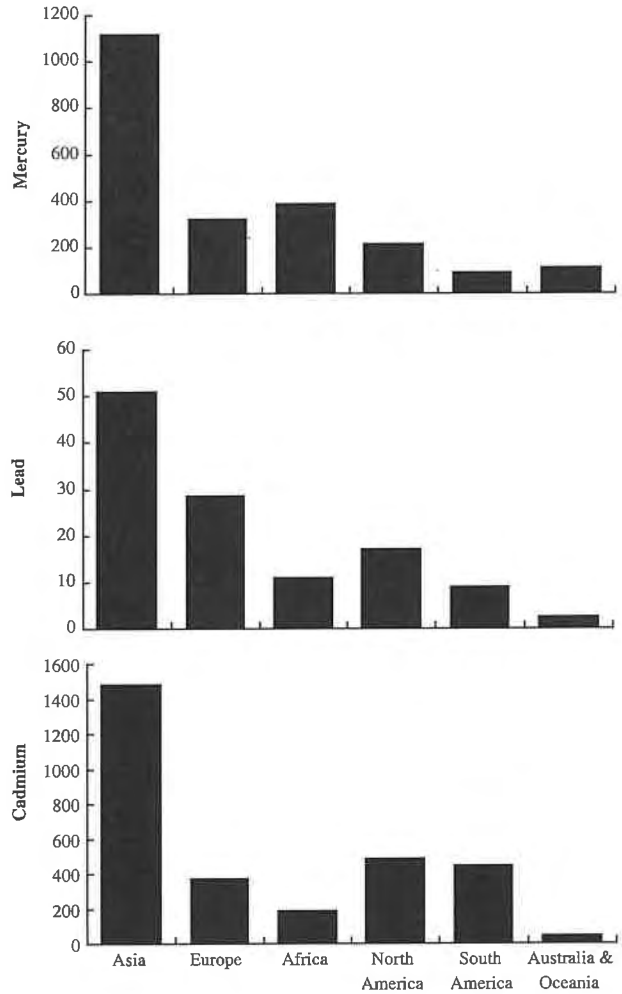

Fig. 13. Regional contribution of anthropogenic heavy metal emissions into the coastal and marine environment (AMAP, 2002).

management and economic gain. At the same time, the polluting bodies should be equally responsible for control and management of pollution.

It was believed that the industrially developed nations produce most of the pollution loads in coastal and marine environments—a scenario of the middle of 19th century when maximum development took place. However, the industrially developed countries are those which are usually characterized by most waste treatment and safest disposal facilities and also by environmental management systems. Therefore, these countries are less likely to produce critical pollution loads. Recent trends suggest that the least developed and the developing nations are more likely to produce threshold levels of environmental pollution due to their poor capacity to treat or recycle waste, poor legislation and regulation and poor management and protective measures. For example, anthropogenic emission of major heavy metals in coastal and marine environment in Asia (mainly dominated by developing nations) is, by several orders of magnitude, higher than Europe, North America and Australia (Fig. 13). This issue is very important because least developed and developing nations comprise the major part of the world (majority of the Asia, Africa and Latin America) and much of the world's future development is likely to take place in these nations. Unfortunately, neither the issues of the developing nations have been considered critically nor they have effective representation in global environmental protection and management programs.

6. Conclusion

The problems of aquatic pollution are likely to exacerbate and pose significant ecological risk/public health risk in the coming years, especially in developing countries. Coastal and marine pollution has already caused major changes in the structure and function of phytoplankton, zooplankton, benthic and fish communities over large areas including impacts on public health. Of particular interest is the impact of pollution caused to fisheries and other commercial use of coastal and marine habitats. Most of the world's important fisheries have now been damaged to varying extent; situations are even more critical in those fisheries that are already overexploited or otherwise vulnerable and, therefore, deserve immediate attention. Effective and sustainable management of coastal and marine environment should be initiated from local to international and global scale to ensure a sustained and best possible utilization of the resources for broader interest of mankind.

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EXHIBIT I

FISH and FISHERIES

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Ghoti

Ghoti papers

Ghoti aims to serve as a forum for stimulating and pertinent ideas. Ghoti publishes succinct commentary and opinion that addresses important areas in fish and fisheries science. Ghoti contributions will be innovative and have a perspective that may lead to fresh and productive insight of concepts, issues and research agendas. All Ghoti contributions will be selected by the editors and peer reviewed.

Etymology of Ghoti

George Bernard Shaw (1856–1950), polymath, playwright, Nobel prize winner, and the most prolific letter writer in history, was an advocate of English spelling reform. He was reportedly fond of pointing out its absurdities by proving that 'fish' could be spelt 'ghoti'. That is: 'gh' as in 'rough', 'o' as in 'women' and 'ti' as in palatial.

The seascape nursery: a novel spatial approach to identify and manage nurseries for coastal marine fauna

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Abstract

Coastal marine and estuarine ecosystems are highly productive and serve a nursery function for important fisheries species. They also suffer some of the highest rates of degradation from human impacts of any ecosystems. Identifying and valuing nursery habitats is a critical part of their conservation, but current assessment practices typically take a static approach by considering habitats as individual and homogeneous entities. Here, we review current definitions of nursery habitat and propose a novel approach for assigning nursery areas for mobile fauna that incorporates critical ecological habitat linkages. We introduce the term 'seascape nurseries', which conceptualizes a nursery as a spatially explicit seascape consisting of multiple mosaics of habitat patches that are functionally connected. Hotspots of animal abundances/productivity identify the core area of a habitat mosaic, which is spatially constrained by the home ranges of its occupants. Migration pathways connecting such hotspots at larger spatial and temporal scales, through ontogenetic habitat shifts or inshore–offshore migrations, should be identified and incorporated. The proposed approach provides a realistic step forward in the identification and management of critical coastal areas, especially in situations where large habi-

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tat units or entire water bodies cannot be protected as a whole due to socio-economic, practical or other considerations.

Keywords Ecosystem connectivity, juvenile fauna, mangrove, ontogenetic migration, salt marsh, seagrass

Introduction

Coastal ecosystems provide a range of valuable ecosystem services, such as fisheries production, protection against coastline erosion and carbon sequestration (Costanza *et al.* 1997). With about 60% of the world's population living within 100 km of the coastline (Vitousek *et al.* 1997), these ecosystems have suffered from rapid degradation (Waycott *et al.* 2009). Coastal and estuarine systems are highly productive and important for food security and livelihoods. Where multiple ecosystems are hydrologically and ecologically connected, a key function is the replenishment of offshore populations of commercially and ecologically important species of fish and crustaceans (Beck *et al.* 2001). The nursery function of these systems has received much attention over the last decade, but current procedures for identifying and evaluating critical habitats lag our scientific understanding of processes that drive nursery function and productivity. In this perspective, we propose a novel approach for delineating nursery areas for mobile fauna, incorporating ecological habitat linkages resulting from animal movements that occur at different spatial and temporal scales.

Three lines of research tackle the issue of coastal ecosystem connectivity for marine fauna, but at different conceptual scales. Firstly, the nursery-role hypothesis is mainly focused on identifying the nursery habitats that contribute most to offshore adult populations (Beck *et al.* 2001; Nagelkerken 2009). Secondly, ecosystem-connectivity studies have largely attempted to correlate a variety of structural metrics of coastal nursery habitats to catches of offshore fishery stocks (Manson *et al.* 2005). Finally, seascape studies have applied techniques and concepts from landscape ecology to understand what drives the spatial patterning of animal communities in coastal nursery habitats (Sheaves and Johnston 2008; Boström *et al.* 2011). While each of these research directions has received increasing attention in the last decade or two, lack of integration between them has led to gaps in the development of appropriate conservation and management strategies.

The nursery-role and ecosystem-connectivity approaches typically consider critical habitats as individual, homogeneous entities. This potentially forces managers faced with conflicting objectives for conservation and alternative uses to evaluate and then trade off entire habitats against one another when determining priorities (Weinstein 2008). Moreover, protected areas with fixed boundaries are ineffective in protecting moving or transient species (Rayfield *et al.* 2008). The seascape-ecology approach points to a different solution, based on mosaics of habitat patches at smaller spatial scales (Simenstad *et al.* 2000). The spatial characteristics of habitat patches play an important role in structuring associated animal communities, but typically are not considered in assessments of nursery value, leaving a critical knowledge and conservation gap (Beck *et al.* 2001; Adams *et al.* 2006; Boström *et al.* 2011).

Previous attempts to define marine nurseries have provided an important, but relatively basic, framework for the identification of nursery habitats. These approaches are static in that they do not indicate how to specifically incorporate dynamic processes, such as ontogenetic habitat shifts, animal movement and spatially explicit usage of habitat patches and corridors within seascapes. This static, single-habitat approach potentially leads to incomplete or incorrect identification of critical habitats. The aim of this study is to take a more holistic approach in identifying nurseries. We view a nursery as a spatially explicit seascape unit (rather than a habitat unit) consisting of functionally connected mosaics of habitats incorporating ecological processes driven by animal behaviour, and define this as the 'seascape nursery'.

Review of nursery-function definitions

Early designations of nursery habitats simply referred to habitats with high densities of juvenile animals. Beck *et al.* (2001) greatly improved the definition by arguing that a nursery is a habitat contributing a higher than average biomass of juveniles per unit area to the adult population than other habitats, resulting from higher densities, higher growth, lower mortality and/or greater movement. However, this approach under-appreciates juvenile habitats that have a large surface area but low density of organisms, even though their overall contribution to the adult population might be larger. Therefore, Dahlgren *et al.* (2006) suggested that identification of nurseries should be based on their total contribution to the adult population. This was criticized as an approach that failed to consider the importance of dynamic processes that underpin nursery function (Sheaves *et al.* 2006), but no specific solutions were offered (Layman *et al.* 2006). While some studies (e.g. Beck *et al.* 2001; Adams *et al.* 2006) have covered important factors that regulate nursery value, no significant steps towards a more comprehensive and realistic method for the identification of nurseries have occurred. Clearly, managing a nursery habitat as a whole unit will not be effective without considering the sequence of habitats that are used throughout ontogeny, while other aspects of nursery habitats (e.g. movement corridors, density hotspots) should be considered to conserve the most productive and important habitat patches within nursery habitats. Some of these aspects have been briefly mentioned in previous studies (Beck *et al.* 2001; Adams *et al.* 2006), but a framework of how to address these issues is still lacking. In the present study, we propose a potential framework to enhance identification and conservation of nurseries.

We concur with the current view that the value of nurseries (as defined by Beck *et al.* 2001) relates to their ultimate contribution to the support of populations. However, we move beyond the approaches that identify nurseries as static habitat units and provide a perspective on how advances in seascape ecology can enhance designation and valuation of nursery habitats for animals that use inshore habitats before migrating offshore ('ontogenetic shifters'; Adams *et al.* 2006). Like previous efforts, our goal is to improve the management and conservation of critical nursery habitats. Here, we build on those efforts to gain an improved measure for nursery habitat designation that captures critical processes and habitat linkages that underpin nursery function and might otherwise be missed by earlier approaches.

Early-juvenile population bottlenecks: identifying critical settlement habitats

Searching for preferred habitat while in the water column is risky and therefore settlement-stage larvae often occupy the first-encountered suitable habitat when entering estuaries or lagoons from the open ocean (Grol *et al.* 2011), with subsequent shifts to other habitats in a stepwise pattern (Cocheret de la Morinière *et al.* 2002). Less structurally complex habitats such as sand patches, macroalgal clumps or dead coral rubble may function as important settlement habitats (Dahlgren and Eggleston 2000), but are often disregarded in their value for settling larvae. The identity of transient settlement habitats is unknown for many species, they may be occupied only briefly, yet they may well form population bottlenecks for early post-settlement stages (Fodrie *et al.* 2009). They are easily missed because of the small sizes at which juveniles occupy these transient habitats and because of the relatively short duration of occupancy. However, many species settle from the plankton during specific seasons of the year, and field surveys should be performed during these seasons to identify important settlement areas. We specifically recommend that these often-missed first-stage habitats be considered in the seascape nursery concept.

Habitat connectivity: predictable diel, tidal and ontogenetic habitat shifts

Few species are confined to a single nursery habitat (Nagelkerken 2007). Seascape studies have shown that many animals utilize a mosaic of habitats on a daily basis (Boström *et al.* 2011). Mobile animals connect adjoining habitats through tidal, shelter-seeking or foraging movements (Hammerschlag *et al.* 2010; Igulu *et al.* 2013; Olds *et al.* 2013; Baker *et al.* 2013). These migrations are highly predictable in timing and routes followed (Krumme 2009), to such extent that some predators in nursery areas have adapted their behaviour to coincide with these migrations (Helfman 1986). Animals pass through non-nursery habitats on a regular basis while moving between patches of core habitat in search of food or shelter (Hitt *et al.* 2011). These movements usually occur within a specified home range around the core area of their shelter sites (Farmer and Ault 2011), which are often located near to structurally complex habitats (Verweij and Nagelkerken 2007). Species often show homing behaviour to such shelter sites, which may persist over periods of weeks to months (Helfman *et al.* 1982). On longer time-scales, many species show ontogenetic shifts among habitats because of changing resource needs (e.g. food, shelter) as well as altered predation risk during different life stages (Dahlgren and Eggleston 2000; Kimirei *et al.* 2013b). Due to strong connectivity among habitat patches, assigning single nursery habitats disregards the role that earlier life-stage habitats or adjoining (feeding/shelter) habitats play in the population dynamics and ultimate stock replenishment of nursery species.

The seascape mosaic: hotspots of animal abundances and productivity

Spatially explicit use of patches within nursery habitats typically has not been quantified in relation to nursery function. In contrast, landscape-focused studies have demonstrated consistent and predictable animal density or productivity 'hotspots' in relation to spatial position within the seascape, for example based on: (i) distance to estuary mouth (Bell *et al.* 1988), (ii) distance to feeding areas (Pittman *et al.* 2007), (iii) proximity to high-volume tidal channels that supply larvae (Ford *et al.* 2010), (iv) density of creek edges within marshes (Kneib 2003), (v) presence and type of adjacent habitats (Nagelkerken *et al.* 2001), or (vi) specific salinity regimes representative of transitional areas between rivers and estuaries (Wasserman and Strydom 2011). Furthermore, habitat transition areas are specific zones within coastal seascapes that often have greater densities of organisms than areas further from edges (Dorenbosch *et al.* 2005). In many cases, the Beck *et al.* (2001) and Dahlgren *et al.* (2006) approaches may well identify the broad nursery habitat(s) used by a population, but miss critical mosaics of habitat patches in the seascape that underpin nursery function (Sheaves 2009).

Ecosystem corridors: highways connecting nurseries to adult populations

The last stage of nursery habitat occupancy during which organisms undertake their final migration to deeper or offshore waters to join the adult population is poorly known (Gillanders *et al.* 2003), but telemetry studies suggest that it can occur over short periods ranging from a few hours to days (Luo *et al.* 2009). Specific routes within estuaries or lagoons may act as preferred corridors that lower predation risk, span the shortest distance to reach deeper water or facilitate tidally enhanced movements due to specific local hydrology (Zollner and Lima 1999). Some studies have indicated the importance of continuous habitat edges (Hitt *et al.* 2011) or unvegetated strips within continuous seagrass beds as corridors (Boström *et al.* 2006), but extensive open shallow areas normally act as barriers for movement (Turgeon *et al.* 2010). In intertidal areas with extensive sand or mud flats, animals will often be funnelled to subtidal habitats through narrow tidal channels. From thereon, fish move to offshore waters by navigating through corridors such as deep channels, through narrow bay mouths or through open spaces among sandbanks, islets and other types of natural barriers situated at the ocean side of river deltas, estuaries and lagoons (e.g. Verweij *et al.* 2007; Luo *et al.* 2009). Incorporation of migration corridors and their temporal usage patterns is a critical consideration for the seascape nursery concept.

The seascape nursery: combining nursery-function and seascape-ecology concepts

Existing approaches to nursery habitat evaluation tend to give more weight to final juvenile stages prior to emigration to offshore adult stocks. Linkages among habitats that affect the critical growth and survival of earlier stages therefore tend to be underplayed. We suggest that the seascape nursery approach incorporates more fully those earlier stages. The importance of our approach is demonstrated in the following example for fishes with a complex life cycle. Consider a microtidal seascape (Fig. 1a) where fish settle largely in first-encountered, non-core habitats such as coral rubble areas along edges of tidal channels or at bay mouths, subsequently progress to seagrass beds, then switch to mangroves, and finally occupy hard-bottom patch reefs or rocky areas, before moving to offshore reefs (example from Nagelkerken *et al.* 2000 and Grol *et al.* 2011). In this example, individuals are also found in other habitats, but those described above are where highest fish aggregation or production occurs. During seagrass and rubble occupancy, small juveniles feed and shelter in the same habitat to reduce predation, but at larger sizes, they use mangroves or patch reefs for shelter and show a diel or tidal migration to nearby seagrass beds to feed (Verweij *et al.* 2006). During these movements, they need to move from one feeding patch to another and pass through secondary habitats, such as algal beds and sand patches, which do not play an important role for feeding or as shelter but are part of their home range (see concentric circles in Fig. 1).

In the above example, the extensive seagrass beds provide the largest overall contribution to the adult populations (e.g. Verweij *et al.* 2008) and would be identified as the main nursery habitats using the Dahlgren *et al.* (2006) approach. In contrast, expressed as a contribution per unit area, the importance of seagrass beds with large surface area would typically be lower compared with other habitats with smaller surface areas where crowding of animals occurs, such as mangrove stands and coral patches. Based on the Beck *et al.* (2001) approach, such habitats that contribute most per unit area could be designated as nursery habitats even though their overall production might not be large. This could in practice lead to a debate about whether mangroves vs. seagrass beds should be managed, what proportion of their total surface area should be conserved, and which areas within the estuary or lagoon should be managed, especially in cases of high usage or exploitation by multiple stakeholders. The seascape nursery would provide a more realistic approach to this problem by revealing that (Fig. 1) (i) transient settlement areas should be conserved, because without these, there is no recruitment to 'nursery' habitats; (ii)

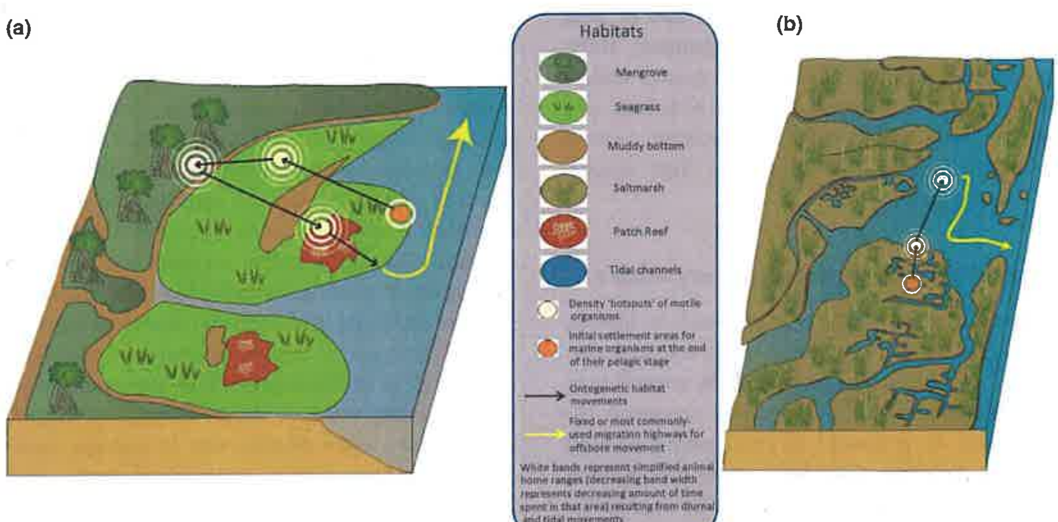

Figure 1 (a) Example as described in the text of a seascape nursery located in a clear water, microtidal lagoon supporting a variety of habitat types; the seascape nursery consists of several habitat mosaics connected through diel and ontogenetic movements. (b) Example of a seascape nursery for penaeid shrimps in a turbid, mesotidal salt marsh estuary. This specific case study refers to coastal salt marsh ecosystems of the northern Gulf of Mexico, which are considered critical in the support of highly productive shrimp fisheries (Turner 1977). Adults spawn offshore and post-larvae recruit to shallow habitats in the marsh complex of coastal bays and estuaries where conditions are favourable (salinity, temperature, food availability) (Rozas and Minello 2011). There is a staged ontogenetic progression of juveniles from the marsh complex to open bays, and subsequent migration to join adult stocks offshore (Lindner and Cook 1970). Although represented as circles for consistency of presentation, a narrow strip at the vegetation–open-water interface represents a density hotspot for juvenile shrimp within the marsh complex (Minello *et al.* 2008). Image credits: Kate Moore, Jane Thomas, Tracey Saxby and Diana Kleine (IAN Image Library – ian.umces.edu/imagelibrary) and Nina McLean (James Cook University).

within the seascape, there are principle areas (habitat mosaics), constrained by animal home ranges, that attract higher densities of mobile organisms and which are more productive than other areas, providing a management tool to prioritize areas of conservation; (iii) successive essential life-stage habitats should be conserved as impacts on one habitat affect productivity in habitats occupied during later life stages; (iv) without conserving migration routes that connect different animal hotpots during ontogeny or that facilitate movement from nurseries to offshore populations, nurseries could experience a switch from acting as sources to becoming juvenile sinks. A similar example from a mesotidal salt marsh system is provided in Fig. 1B.

Not all species show a complex life cycle such as described above. Nevertheless, it is a common observation for a multitude of species that tidal channels are favoured for movement through shallow areas, that animal abundances are highly correlated with spatial position within coastal habitats (e.g. driven by salinity or turbidity gradients) and that animals regularly perform diel or tidal movements (Whaley *et al.* 2007; Krumme 2009; Turgeon *et al.* 2010). So even for species with a relatively simple life cycle, in terms of habitat use, previous approaches fail to incorporate several important dynamic processes other than ontogenetic habitat shifts.

Practical steps to seascape nursery analysis

While there is no single best approach to identify the precise mosaic of habitats most essential during the juvenile stages of animals in coastal marine environments, it is crucial to recognize the importance of a mosaic of contributing habitats and their linkages. Here, we outline the practical steps that can help improve on earlier approaches for identification and evaluation of nursery habitat and ultimately lead to more successful protection and management of nursery function. The order and relative importance of these steps will vary depending on specific situations.

Step 1

Following Beck *et al.* (2001), identify the relative contribution to adult populations of all juvenile habitats at whatever scale they can be identified, for example, using approaches such as otolith microchemistry (Gillanders and Kingsford 1996; Verweij *et al.* 2008). This will typically be at a coarser scale than relevant to management objectives (e.g. whole estuary or whole habitat unit) and fail to identify linkages across the seascape. We therefore recommend subsequent work to identify the smaller-scale patches within each broad-scale nursery that contribute most to the overall population replenishment by that nursery habitat. This will likely, but not necessarily overlap with density hotspots of juvenile animals during their inactive as well as active period (e.g. Ford *et al.* 2010), which can be identified through field surveys. Identification of specific patches that contribute most to the overall production of a nursery habitat is more challenging, but techniques such as stable isotope analysis of muscle tissue, internal and external artificial tags, or genetic and chemical markers can provide the necessary finer-scale information (Gillanders 2009; Kimirei *et al.* 2013a), as well as provide an answer to how this contribution may vary over time (see e.g. Kraus and Secor 2005).

Step 2

Known (from the literature) or field-acquired (through tagging studies) home-range sizes may then be projected onto the identified highest-productivity density hotspots to establish the effective area that is used as a juvenile habitat (the habitat mosaic). The home range includes the seascape that is most used on a daily basis for activities such as sheltering and foraging. Home-range sizes around hotspots of animal abundances could be considered at decreasing levels of importance (see Fig. 1). Using radii of these dimensions should prove to be a more effective way to manage nursery mosaics than a static approach of single complete habitats because it uses broader information on critical habitat use. While tagging juvenile animals is difficult and movement ranges can differ considerably among species and within habitats, home-range size is often a function of body size (Kramer and Chapman 1999) and juveniles of most demersal species show high site fidelity and restrict their movements to distances of no more than a few 100s m from their preferred shelter sites (Tupper 2007; Nagelkerken *et al.* 2008). Home ranges are larger in cases where animals occupy macrotidal habitats, but also in this case, fidelity has been shown to high-tide and low-tide habitat components (Dorenbosch *et al.* 2004; Hering *et al.* 2010).

Step 3

Patterns of ontogenetic habitat shifts should be identified for animals that occupy the above high-productivity hotspots, so that other habitat patches that are previously or subsequently occupied are included in the designation of effective nursery mosaic (Fig. 1). This is based on the principle that patches that contribute most to adult populations can only sustain this productivity as a result of habitat linkages through ontogeny. Approaches such as following the progression of cohorts (abundances and sizes of organisms) in multiple juvenile habitats can identify which habitats are most likely to play a key role in provisioning recruits to next life-stage habitats (e.g. Fodrie *et al.* 2009). A critical consideration in this is to identify primary settlement areas where early life stages occur, typically at sizes at which they have not been included in field surveys.

Step 4

Primary migration routes should be identified (e.g. using telemetry or conventional tagging) that connect animal production hotspots across different spatiotemporal scales. This includes corridors that facilitate animal movement from one habitat mosaic to another through ontogeny, as well as from the seascape nursery to offshore waters (Fig. 1). Migration highways are likely to overlap among species based on the same advantages that they provide for a suite of species, such as structure-rich corridors that facilitate movement under lowered predation risk (Gilliam and Fraser 2001). In deep-water estuaries and lagoons, such migration corridors might be less evident or relevant than in shallower ecosystems dominated by extensive mud or sand flats. However, due to the geomorphology of many inshore water bodies around the world, animals still need to pass through bay mouths, openings between barrier islets, or through deeper tidal channels to reach offshore waters. As such, these areas should be given high conservation importance as they maintain connectivity among inshore and offshore ecosystems.

We have attempted to present an improved framework to identify nurseries for management purposes that we believe will provide an acceptable level of accuracy for a wide range of species in a variety of coastal marine ecosystems. Our approach does not provide a single, best solution for multispecies management, as different groups of species may occupy different combinations of habitats or different areas of estuaries and lagoons. As is the case for previous approaches of nursery identification, trade-offs need to be made in terms of which species and which areas receive most consideration in terms of conservation or management. While for some systems with few, highly abundant fishery species and just one or two habitat types, a coarse approach such as that of Dahlgren *et al.* (2006) and Beck *et al.* (2001) may provide a reasonable amount of information for management purposes, there are many other systems and a multitude of (commercial and keystone) species where such an approach is likely to fail. The seascape nursery approach adds more realism to the identification of core juvenile areas within these systems by incorporating spatiotemporal drivers of animal habitat use. The intention is to achieve a practical advance for the conservation and management of inshore coastal areas that are highly productive for coastal fisheries but also prone to high levels of competing demands and degradation through human activities. We also recommend consideration of more challenging, dynamic management approaches such as mobile protected areas that follow movements of key species across their landscape (Bull *et al.* 2013).

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EXHIBIT J

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True Value of Estuarine and Coastal Nurseries for Fish: Incorporating Complexity and Dynamics

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Abstract Coastal ecosystems, such as estuaries, salt marshes, mangroves and seagrass meadows, comprise some of the world's most productive and ecologically significant ecosystems. Currently, the predominant factor considered in valuing coastal wetlands as fish habitats is the contribution they make to offshore, adult fish stocks via ontogenetic migrations. However, the true value of coastal nurseries for fish is much more extensive, involving several additional, fundamentally important ecosystem processes. Overlooking these broader aspects when identifying and valuing habitats risks suboptimal conservation outcomes, especially given the intense competing human pressures on coastlines and the likelihood that protection will have to be focussed on specific locations rather than across broad sweeps of individual habitat types. We describe 10 key components of nursery habitat value grouped into three types: (1) connectivity and population dynamics (includes connectivity, ontogenetic migration and seascape migration), (2) ecological and ecophysiological factors (includes ecotone effects, ecophysiological factors, food/predation trade-offs and food webs) and (3) resource dynamics (includes resource availability, ontogenetic diet shifts and allochthonous inputs). By accounting for ecosystem complexities and spatial and temporal variation, these additional components offer a more comprehensive account of habitat value. We explicitly identify research needs and methods to support a broader assessment of nursery habitat value. We also explain how, by better synthesising results from existing research, some of the seemingly complex aspects of this broader view can be addressed efficiently.

Keywords Nursery ground · Ecosystem mosaic · Coastal wetland · Estuary · Fish

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Introduction

Coastal wetlands comprise some of the most valuable ecosystems on the planet (van den Belt 2011; Elliott and Whitfield 2011), and yet are among the most threatened (Bassett et al. 2013). Their position at the interface of land and sea means they occupy locations that are highly prized by humans, leading to unprecedented and rapidly increasing threats from intense population pressure, rapid, large-scale development and climate change (Hughes et al. 2009, Corn and Copeland 2010). This conjunction of high value and intense threats makes a detailed understanding of the functioning of coastal wetlands essential if they are to be managed and protected for future generations (Elliott and Kennish 2011).

One value that is increasingly recognised for all types of coastal wetlands, whether they are estuaries, salt marshes, mangrove forests, seagrass meadows or floodplain swamps, is their role as nursery grounds for aquatic species of immense ecological, cultural and economic importance (Beck et al. 2001; Mumby and Hastings 2008). This nursery value stems from the provision of habitat, refuge, food, favourable physical conditions and advantageous hydrodynamics (Nagelkerken et al. 2014). However, the provision of these services is complex. Not only do the values manifest at a variety of scales (e.g. habitat or food provided at a local scale, versus physical conditions at a whole of ecosystems level) but, rather than being a function of a single habitat, their values are usually conferred by a mosaic of interacting habitats (Sheaves 2009; Berkström et al. 2012) and may rely on processes or inputs derived from well beyond the wetlands themselves (Beger et al. 2010). Many of the processes that underpin nursery function may not be a feature of a spatial habitat at all; for example, reliance on the delivery of allochthonous sources of production to support food webs (Connolly et al. 2005), or the temporal coincidence of recruitment and the availability of suitable prey resources (Robertson and Duke 1990). Nursery function is further complicated by the diversity of life-history strategies of the species occupying these systems (Elliott et al. 2007; Potter et al. 2014).

Although estuarine and coastal ecosystems have long been recognised as nurseries for fish and crustaceans (Boesch and Turner 1984), it was not until the seminal work of Beck et al. (2001) that the concept was formalised. However, the ideas of Beck et al. (2001) and their modification by Dahlgren et al. (2006) focus on one aspect of nursery ground value; the supply of juveniles from discrete spatial units of nursery habitat to adult populations. Such approaches only consider contribution that can be measured in terms of the movement of juvenile numbers/biomass, so do not capture the complex dynamics that support nursery function. While these approaches represent a significant step forward, comprehensive nursery identification and valuation requires that the complex, dynamic nature of nursery ground function needs to be recognised (Able 2005; Mumby and Hastings 2008; Sheaves 2009; Potter et al. 2014) and consolidated into identification and valuation if nursery function is to be maintained in the face of ever increasing anthropogenic pressures (Nagelkerken et al. 2014).

There are two aspects to the value of nursery grounds to fish: (1) their value in supporting successful nursery ground occupation, and (2) the value to recipient populations and ecosystems (Fig. 1). Most current concepts of nursery ground value (e.g. Beck et al. 2001; Dahlgren et al. 2006) relate to the output of juveniles from nursery grounds that reach offshore (e.g. Reis-Santos et al. 2012), but the mechanisms that drive this contribution to recipient populations are incompletely understood. Recognition of the significance of the processes which regulate juvenile populations within nursery habitats is nothing new (e.g. Minello et al. 2003), and the need to evaluate this information in the context of entire lifecycles is increasingly recognised (Huijbers et al. 2013; Baker et al. 2014; Vasconcelos et al. 2014). However, current approaches to the valuation of nurseries ultimately treat the processes driving nursery function as a black box by simply measuring what emerges at the end as emigrants to the adult populations. The resulting rankings of nursery grounds fail to provide managers with information on how to protect key processes that underpin nursery value and function. Furthermore, focusing management and further research on the identified 'important' nursery habitats is risky because the habitat units identified will rarely contain all the elements that support the nursery function we aim to protect.

Nursery ground value is the net result of a complex of interacting factors that vary from situation to situation. Some involve seascape structure and function directly (Hammerschlag et al. 2010), but others extend to include complex ecological interactions and resource dynamics, and often involve a complex of cross-habitat and cross-ecosystem movements. This complexity needs to be considered in the context of differences in the composition of fish assemblages using coastal nurseries in different parts of the world (Sheaves 2012; Potter et al. 2014) that is likely to result in different mixes of factors being important in different regions. Understanding this complexity and the relative importance of different factors is the key to meaningful nursery identification and valuation, and is the raw material needed to inform population conservation decision support systems (Beger et al. 2010). Conversely, a lack of evaluation of the complexity is the recipe for superficial assessment (Harris and Heathwaite 2012) that is likely to miss the most critical contributors to value. Consequently, we build on earlier work to develop a framework for a more comprehensive understanding of nursery ground value, by considering the range of contributions of nurseries to sustaining local production, replenishing adult stocks and influencing recipient ecosystems. We also consider approaches available to identify the range of factors underpinning nursery value at a particular site, the extent to which they contribute to nursery value and the factors that need to be taken into account to inform comprehensive, effective and well-grounded management decisions. At face value, recognising and including this complexity seems a difficult task, but most of the research needed to underpin this consolidation is already being conducted; it just needs to be integrated and extended.

Factors Supporting Successful Nursery Ground Occupation

Connectivity and Population Dynamics

At an operational level of supporting the lives of juvenile fish, nurseries comprise a complex mosaic of interacting habitat units and the connectivities enabling their interaction (Sheaves 2009). The importance of juvenile habitat is well recognised and is a key driver for the identification

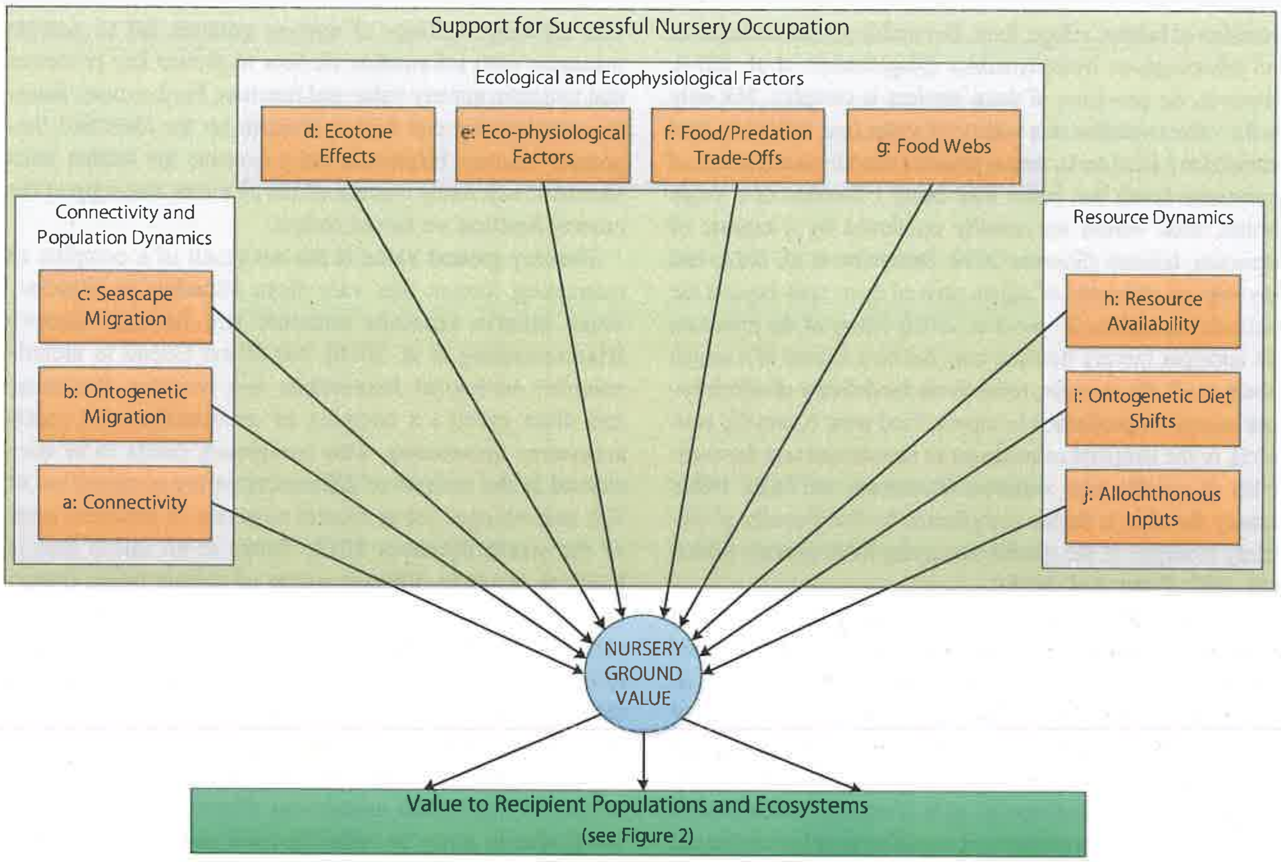

Fig. 1 Components of nursery ground value. Each component is described and discussed in the text

of essential fish habitat in the USA (e.g. Froeschke et al. 2013) and Europe (Vasconcelos et al. 2014). However, current definitions for identifying nursery habitats emphasise the habitats which leave a distinctive chemical signature or are the habitats from which juveniles can be most readily sampled (Gillanders 2005). This disregards the fact that many aquatic species shift habitats during their time within the nursery (Kimirei et al. 2011), and that other critical habitats might only be occupied transiently (Tupper 2007) or indirectly support nursery value (Connolly et al. 2005).

Connectivity (Fig. 1a) Ontogenetic habitat shifts, the use of transitory and temporary habitats (Potter et al. 2014) and the use of a mosaic of habitats within the nursery seascape (Nagelkerken et al. 2014) attest to the central importance of connectivity in supporting nursery ground value (Vasconcelos et al. 2011). Yet connectivity is more than just the movement of individuals among habitats; it is a facilitator that enables a variety of critical ecological functions to support nursery value (Sheaves 2009). For instance, deriving maximal nursery ground value relies on spatio-temporal matching between the functional requirement to use the particular habitat (e.g. refuge), the occurrence of appropriate resources (e.g. flooded marsh surface) and physical conditions in the habitat (e.g. oxygen levels), and it is connectivity that allows this complex matching to occur. The facilitating role of connectivity is pervasive (Beger et al. 2010), and it is a key factor supporting most ecological interactions conferring nursery ground value.

Ontogenetic migrations (Fig. 1b) Ontogenetic migrations occur at a range of scales, from movements along freshwater to marine gradients (Russell and Garrett 1985; McBride et al. 2001; Davis et al. 2012), and movements within local habitat mosaics (Nagelkerken 2009; Grol et al. 2011). Local scale migrations include both easily identifiable meso-term habitat shifts (e.g. seagrass to mangrove to patch reefs (Nagelkerken et al. 2000a)) and ephemeral habitat occupancy (e.g. initial settlement habitats (Dahlgren and Eggleston 2000; Grol et al. 2011)) that is more difficult to detect. Not only do ontogenetic habitat shifts exist across a range of dependencies, from facultative (Milton et al. 2008) to more obligate (Potter et al. 2014), but they may vary spatially (Kimirei et al. 2011). For instance, *Haemulon flavolineatum*, one of the most common Caribbean ontogenetic shifters, moves from rubble habitat to seagrass beds to mangroves to rocky substratum in some geographic locations (Grol et al. 2011), but from rubble habitat to sea urchin spines to seagrass beds to lagoonal patch reefs in others (Ogden 1988).

Seascape Migrations (Fig. 1c) On shorter time scales, feeding migrations and movements to refugia are vital facilitators of key nursery functions and connect multiple habitats within the nursery seascape (Sheaves 2005; Verweij and Nagelkerken 2007). In situations where large tidal differences occur, intertidal habitats such as salt marsh or mangrove roots are only available periodically (Minello et al. 2012), leading to regular tidal migrations. Even in cases where tides do not play a major role, many organisms show predictable diurnal movements between shelter habitats and foraging grounds (Hammerschlag et al. 2010). Seascape structure, the spatial patterning of prey and predator species, and the hydrodynamics and geomorphology of the ecosystem all play important roles in structuring such animal movements across habitats (Nagelkerken 2007; Baker et al. 2013).

Ecological and Ecophysiological Factors

Ecotone Effects (Fig. 1d) Ecotones are important contributors to nursery ground value. Indeed, estuarine nurseries occur in transitional waters between freshwater reaches and the sea and have been defined as traditional ecosystems in their own right (Basset et al. 2013). Animal communities often show strong spatial patterning within the seascape, and it is especially at the edges of habitats where highest species richness and densities are observed (Dorenbosch et al. 2005; Johnston and Sheaves 2007). For example, fish densities in seagrass beds can decrease with distance away from patch reefs (Valentine et al. 2008), and the highest fish and crustacean densities are found at the seaward fringes of salt marsh (Minello et al. 2003) and mangroves forests (Vance et al. 1996). As boundaries that need to be crossed moving between habitats, ecotones are also areas where risks can be greatest (Hammerschlag et al. 2010), and so are points where population structuring factors like predation focus can be particularly influential (Sheaves 2005; Baker and Sheaves 2009b).

Ecophysiological Factors (Fig. 1e) Physical factors and physiological abilities are critical in determining spatial (Sheaves 1996a; Harrison and Whitfield 2006) and temporal (Attrill and Power 2004) patterns of nursery ground occupancy. This manifests at a diversity of scales; for instance relating to ontogeny of habitat use (McBride et al. 2001), seasonal occurrence of necessary physical conditions (Davis et al. 2012) and nutrients (Abrantes and Sheaves 2010), long-term patterns of nursery utilisation (Sheaves 1998), variations in optimal nursery habitats (Hurst and Conover 2002) or responses to multi-year climatic cycles (Sheaves et al. 2007). Consequently, in many systems, nursery provision will change substantially over time (Minello et al. 2012), providing advantage to different species under different conditions. Differing behavioural and physiological abilities allow different species, and even different ontogenetic stages, to access and use different nursery grounds or use nursery grounds in different ways. Air breathing organs in species such as tarpon (*Megalops* spp.) allow them to utilise hypoxic wetland nurseries (Seymour et al. 2008), while barramundi (*Lates calcarifer*) juveniles are able to access hypersaline wetlands from which predators and competitors are excluded (Russell and Garrett 1985). Even in deeper estuarine waters, hypoxia can exclude species from habitats during periodic hypoxic events (Pihl et al. 1991; Switzer et al. 2009). In response, many estuary species can detect and avoid areas of low dissolved oxygen concentration (Wannamaker and Rice 2000). Not only do different salinity preferences contribute to nursery habitat partitioning by co-occurring juvenile fish (Davis et al. 2012), but physical conditions can have substantial influences on growth rates of juveniles (Del Toro-Silva et al. 2008), with salinity and temperature regimes often having more substantial influences on growth than diet (Baltz et al. 1998). Eco-physiological effects can be complex, interacting with ecological processes to effect changes in nursery value for different juvenile stages. For instance, ecophysiological differences allow young juvenile California halibut, *Paralichthys californicus*, to occupy estuaries with abundant prey and few predators from which larger juveniles are excluded because of narrower salinity and temperature tolerances (Madon 2002).

Food/Predation Trade-Offs (Fig. 1f) Juveniles utilising nurseries face a complex trade-off between the need to obtain sufficient, appropriate prey, and minimising predation risk (Sogard 1992; Baker and Sheaves 2007). This trade-off can profoundly affect nursery ground value, and the quantity and quality of sub-adults migrating to adult habitats (Walters and Juanes 1993; Kimirei et al. 2013). The need to access prey-rich areas can initiate or necessitate behaviour that exposes juveniles to increased predation risk (Alofs and Polivka 2004; Sheaves 2005) or to forage in areas that support poor growth rates (Sogard 1992; Harter and Heck 2006). In fact, the underlying mechanisms that drive habitat shifts are often related to minimising the ratio of mortality risk to growth rates (Werner and Hall 1988; Halpin 2000), because profitable habitats for food acquisition are often riskier in terms of probability of predator encounter (Hammerschlag et al. 2010). Predation is usually the largest source of mortality for juvenile fish (Harter and Heck 2006), so high-risk areas, such as transition zones between refuge and feeding areas (Hammerschlag et al. 2010) may represent ecological bottlenecks. For example, predatory activity at these locations can control the supply of recruits to nursery grounds (MacGregor and Houde 1994; Brown et al. 2004) and the supply of juveniles from nursery grounds to adult populations (Yurk and Trites 2000; Friedland et al. 2012), and so provide the opportunity for predatory control of nursery populations (Baker and Sheaves 2009b). In addition, these refuge-food acquisition trade-offs vary between species (Camp et al. 2011) meaning that nursery ground values may differ markedly depending on the species involved.

Food Webs (Fig. 1g) Predators have a strong top-down control on food webs. While nurseries have typically been assumed to harbour few predators, recent studies have shown a more complex picture (Baker and Sheaves 2009a; Dorenbosch et al. 2009). Although standing stock of predators may be low much of the time, immigrating predators from adjacent systems can produce profound predatory effects on nursery fish during their short foraging forays (Baker and Sheaves 2009a). Moreover, many nursery species shift ontogenetically to higher piscivory while still occupying nurseries (Baker and Sheaves 2009a). The spatio-temporal presence of predators and their specific gape sizes will determine to what degree they control fish populations in nurseries. Secondly, inter-specific interactions may determine which species ultimately are responsible for greatest export to adjacent ecosystems. Recruitment of nursery fish may be highly variable in time, and feeding habitat and food availability may be limiting during nursery occupancy (Igulu et al. 2013). Competitive exclusion from optimal foraging habitats among species may be an important determinant of the winners and losers of nursery habitat use in terms of growth, survival and successful movement to consecutive habitats.

Resource Dynamics

The availability, distribution and quality of resources within the nursery are critical parameters underpinning nursery ground value, the pattern of use of resources, and ultimately the outcome of nursery ground residence. Resource use is complex, varying along stage-specific, time-specific and purpose-specific axes.

Resource Availability (Fig. 1h) Nursery grounds are often nutritionally rich ecosystems maximising cohort growth during nursery ground residence (Yanez-Arancibia et al. 1994), and marine organisms invest heavily in rapid growth during their early life stages. Prey quantity and quality affect growth (Sogard 1992; Scharf et al. 2006) because of substantial differences in the energetic value of different prey types (Ball et al. 2007). Although fish may be able to switch to alternative prey (Gartland et al. 2006), there are limits to this ability to adapt (Nobriga and Feyrer 2008), and particular prey may be required at particular life stages (Robertson and Duke 1990; Baker and Sheaves 2005). Consequently, the quality, quantity and availability of food resources is an important factor in nursery value, although food acquisition often necessitates trade-offs with predation avoidance (see above). High-quality nursery grounds are also those that provide optimal habitats relative to the full range of life-history functions (Nagelkerken and van der Velde 2002; Nagelkerken et al. 2014), such as juvenile settlement (Dahlgren and Eggleston 2000; Grol et al. 2011), foraging (Nagelkerken et al. 2000b; Harter and Heck 2006) and refuge (Ellis and Gibson 1995; Sheaves 1996b; Gorman et al. 2009).

Ontogenetic Diet Shifts (Fig. 1i) Complex seascape dynamics, with juveniles obtaining resources from different habitats during different phases of their nursery residence, mean that the development of complicated and variable food webs is inevitable (Nagelkerken et al. 2006). Due to ontogenetic dietary shifts, many juveniles change their trophic identity during nursery occupation. Profound changes in diet over development mean they may not even participate in the same trophic web throughout nursery occupation. For example, juvenile *Platycephalus fuscus* initially feed almost entirely on amphipods and so participate in a food web based on benthic productivity, while larger juveniles in the same habitat switch to feeding extensively on planktivorous fish (Baker and Sheaves 2005). Such ontogenetic diet shifts are widespread among estuarine and coastal fishes (Elliott et al. 2007), and the availability of the different food items that are preferentially selected through ontogeny is an important driver of the realised growth during nursery occupancy.

Allochthonous Inputs (Fig. 1j) In marine systems, water is an effective vector for the movement of energy and nutrients among habitats, allowing substantial trophic subsidies that affect the structure of animal populations in recipient systems (Deegan 1993). In some situations, animals are sustained by food webs based on autotrophic production within their habitat (e.g. juvenile fish in seagrass meadows in the Mediterranean (Vizzini et al. 2002), and animals on salt marshes in subtropical Australia (Guest and Connolly 2004)). Often, however, nutrition is derived ultimately from plants or algae growing elsewhere. Organic matter from seagrass meadows can sustain food webs in adjacent habitats (Heck et al. 2008), supporting production in both temperate (e.g. Connolly et al. 2005) and tropical (e.g. Melville and Connolly 2005) systems, while mangroves also have been shown to support fish production in adjacent estuarine (Abrantes and Sheaves 2009a) or coastal waters (Bouillon et al. 2008) in certain situations. Stable isotope analysis has demonstrated both the detrital pathway for this transfer and the fact that movement of nutrients can also occur through in-welling from coastal to intertidal waters (Connolly et al. 2005).

The Support of Recipient Populations and Ecosystems by Nursery Grounds

The conventional view of nursery ground value (e.g. Heck et al. 1997; Beck et al. 2001) emphasises the contribution of juveniles from inshore nurseries to recipient (usually offshore) populations, and its crucial role in supplying adult populations with new individuals. The migration of juveniles also represents the biologically mediated export of nutrients, incorporated into juvenile biomass during nursery residence, donated to offshore systems (Deegan 1993; Beck et al. 2001). The export of biomass was suggested by Beck et al. (2001) to be the best integrative measure of the contribution of juveniles to future generations. However, the numbers and biomass of individuals that reach adult stocks represent only part of the contribution that juveniles using nursery grounds make to recipient populations and ecosystems (Figs. 1 and 2).

Diverse Trophic Contributions From the moment of recruiting to the nursery ground, the abundance of a cohort is continually and exponentially pruned back by mortality (Yanez-Arancibia et al. 1994; Doherty et al. 2004). As abundance declines, individual biomass increases until a very small number (relative to those recruiting) of large individuals emigrate from the nursery ground (Yanez-Arancibia et al. 1994; Sheaves et al. 2013) transferring their accumulated biomass to offshore habitats (Deegan 1993), where they may be ultimately measured as contributing to adult stocks (Beck et al. 2001) (Fig. 2a). However, most individuals, and a significant proportion of the biomass, do not survive to emigrate (Deegan 1993; Yanez-Arancibia et al. 1994; Baker et al. 2014) and so do not figure in calculations of exported biomass. However, these individuals are critical to nursery ground value by forming what is essentially a sacrificial nursery component that allows other nursery individuals to survive (Sandin and Pacala 2005; Svenning et al. 2005) (Fig. 2b). In doing so, they provide food for juvenile predators within the nursery (Minello et al. 1989; Baker and Sheaves 2005) (Fig. 2c) that ultimately translocate accumulated nutrients offshore during their ontogenetic migrations (Thorson 1971; Werry et al. 2011) (Fig. 2a), and for transient predators from offshore feeding within the nursery (Begg and Hopper 1997) that return offshore exporting biomass accumulated in the nursery ground (Fig. 2d). These juveniles also form critical links in nursery food webs (Abrantes and Sheaves 2009a, b) (Fig. 2e), provide a vehicle for transferring production among habitats (Rozas and LaSalle 1990) and form critical components of trophic relays where intermediate prey link production sources in one habitat with higher consumers in another (Kneib 1997) (Fig. 2f). When viewed this way, the nursery cohort is largely made up of individuals comprising a critical resource in the trophic functioning of the nursery and adjacent connected ecosystems, with the survivors representing surplus individuals not consumed in powering the system. Valuing a nursery based only on the biomass of individuals that reach adult stocks clearly overlooks a diversity of processes critical to the function of these systems (Sheaves et al. 2006) because the relative contributions from different nurseries of individuals that ultimately reach the adult stocks does not reflect the full production output of each nursery or their contributions to the support of other species. Although specifically quantifying all the components of biomass transfer will rarely be practical given our current knowledge bases, quantification is not the primary issue. Recognising that the true value of trophic contributions from nursery grounds is much more extensive than can be measured as exported biomass alone is critical for the effective management of nursery function and to developing approaches to begin to quantify those additional contributions.

Export of Process The influence of nursery grounds on offshore ecosystems is not confined to the contribution of individuals to adult populations or biomass translocation but extends to effects on key processes in the recipient ecosystems (Fig. 2g). Connectivity to mangrove nursery grounds influences overall community structure and resilience on many Caribbean coral reefs. Because dominant herbivores have an obligate mangrove nursery phase, the presence of mangroves has a substantial impact on the numbers of herbivores on adjacent reefs, thus regulating the beneficial effects of herbivory in those systems (Mumby et al. 2004), and greatly increases resilience of mid-shelf reefs to severe hurricane disturbances (Mumby and Hastings 2008). At the other end of trophic webs, as well as contributing to the export of biomass, the movement of juvenile bull sharks, *Carcharhinus leucas*, from coastal nurseries (Curtis et al. 2011; Heupel and Simpfendorfer 2011) represents the supply of sub-adult and adult high-level predators (Marshall and Bennett 2010) that can be major influences on offshore predation dynamics (Hunsicker et al. 2012) and severely impact lower trophic levels through trophic cascades (Myers et al. 2007). The export of process extends to biological controls, with juvenile grouper from mangrove nurseries having the potential to control populations of invasive lionfish on Caribbean coral reefs (Maljkovic et al. 2008). The growing awareness of the complexity of interactions between different environmental realms and the importance of connectivities at all scales in supporting ecological functioning (Beger et al. 2010) suggests

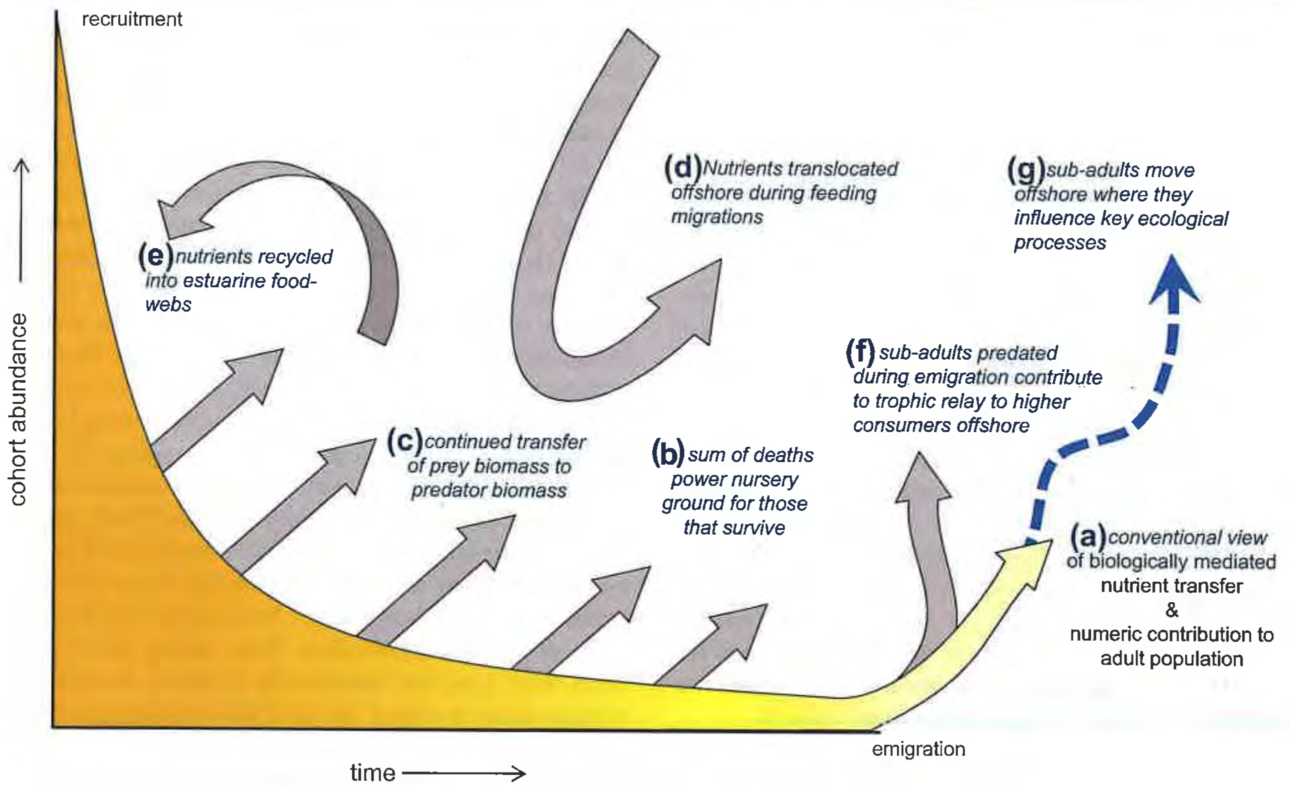

Fig. 2 Support of recipient ecosystems from nursery grounds is more than just export of new individuals to adult stocks and the biologically mediated nutrient translocation they represent (*a*). Individuals lost through mortality within the nursery facilitate the survival of those that ultimately emigrate (*b*), as prey participate in the continued transfer of biomass to local (*c*) and immigrating predators that feed in the nursery and subsequently move to recipient habitats transferring biomass (*d*), form important prey and critical links in food webs that support nursery value (*e*), contribute to trophic relays as they are fed on during emigration (*f*), and influence key processes in recipient ecosystems (*g*)

that many more effects of nurseries on ecological processes in recipient ecosystems are likely to be recognised as our understanding of linkages between ecosystems becomes more sophisticated. As with developing a more complete understanding of the spectrum of contributions from trophic interactions, developing a more complete understanding of the process links emanating from nursery grounds to influence recipient ecosystems is critical to developing a comprehensive understanding of the true value of nursery grounds.

Current Situation: Approaches Available to Identify the Full Value of Nurseries

The value of any juvenile habitat depends on its complex contributions to the sustainability of populations and the functioning of replenishing and recipient ecosystems. Recognising the lack of a framework for identifying valuable nurseries, Beck et al. (2001) proposed an approach to rank nursery grounds based on the total biomass contributed from different putative nursery habitats. This was an important advance, recognising the need to compare contributions across all possible nursery habitats. However, this is only a first step, because comprehensive identification, valuation and management of estuarine and coastal nurseries for fish requires detailed understanding of the range of processes supporting nursery value (Jones et al. 2002) and of the full value of outputs to recipient ecosystems (Mumby and Hastings 2008). Additionally, while ranking nurseries may provide guidance for prioritising areas for conservation very broadly, it is of limited value for managers charged with maintaining nursery function in the face of impacts at specific locations. The increasingly urgent need to understand and maintain ecosystem function across the globe is driven far more by the need to manage ever increasing anthropogenic impacts, and multiple coastal users with conflicting usages, to our environment than by a desire to totally protect functional ecosystem units. It would be better, therefore, if protection and management of nursery grounds is not based solely on a ranking of the relative value of different putative nurseries. The approach we are recommending aligns with the broader shift to managing marine systems to conserve ecosystem functioning rather than focusing on individual species or habitat units (Foley et al. 2010).

Determining the relative contributions of putative nurseries to adult stocks in terms of numbers or biomass can often be

Table 1 Solutions matrix: types of studies (bottom column titles) providing categories of information (top column titles) contributing to resolving aspects of nursery ground value (row information)

					Contributions to Understanding													
		nursery value	***temporal scale***	***spatial scale***	connectivity	nursery food webs	fish-habitat relationships	juvenile population dynamics	target species diet	target species refuge ecology	habitat availability & condition	prey dynamics	predator identification & dynamics	nutrient dynamics	juvenile growth & health	environmental requirements	receiving food webs	receiving ecosystem function
Support for Nursery Occupation	1a	connectivity	all	all	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
	1b	ontogenetic migration	life-history	mosaic	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	1c	seascape migration	short-meso	local	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
	1d	ecotone effects	short	local	✓	✓	✓		✓	✓	✓	✓						
	1e	eco-physiological factors	life-history	mosaic												✓		
	1f	food/predation trade-off	short	local	✓		✓	✓	✓	✓	✓	✓		✓	✓			
	1g	food webs	all	local	✓	✓							✓					
	1h	resource availability	all	all	✓	✓	✓		✓	✓	✓	✓		✓				
	1i	ontogenetic diet shifts	life-history	all	✓	✓			✓			✓		✓				
	1j	allochthonous inputs	life-history	mosaic	✓	✓			✓			✓		✓				
	2c	nutrients recycled into estuarine food webs	short-meso	local		✓							✓					
Support of Recipient Ecosystems	2a	biomass contribution to adult stock	life-history	mosaic	✓		✓											
	2b	sacrificial nursery component	life-history	mosaic				✓					✓					
	2c	contribution to juvenile predator biomass	life-history	mosaic		✓							✓		✓			
	2d	contribution to visiting predator biomass	short	mosaic		✓							✓					
	2f	trophic relay	meso	mosaic	✓	✓						✓	✓				✓	
	2g	export of process	life-history	mosaic	✓												✓	✓
					natural & artificial markers	stable isotope & dietary	observational & capture	capture	dietary	observational & behavioural	habitat survey & acoustic	capture & acoustic	dietary, observational, capture, tethering	water & sediment chemistry, stable isotope	energetics & condition	eco-physiology	stable isotope & dietary	integrated ecological studies
					Study Types													

Numbers at left reflect those in Fig. 1 (a–j) and Fig. 2 (a–e), hence e depicted in Fig. 2 lies in the upper half of the table as part of 'Support for Nursery Occupation.' Temporal scales: short = minutes to hours, meso = days to weeks, life-history = a sequence of changes over time relating to life-history events, all = relevant to all temporal scales. Spatial scales: local = within a local area or habitat, system = relating to a mosaic of habitats used by juveniles or a whole system (e.g. an estuary), all = relevant to all spatial scales achieved via retrospective determination of movement of individuals from particular nurseries to the adult population using artificial or natural markers (Gillanders et al. 2003; Gillanders 2005). For example, otolith chemistry may distinguish occupation of one coastal bay or estuary rather than another (Yamane et al. 2010; Reis-Santos et al. 2012), or differentiate between use of particular salinity zones (Albuquerque et al. 2012; Webb et al. 2012), or distinguish use of particular seascape components (Gillanders and Kingsford 1996). However, while natural markers can be used to define spatial units contributing most biomass to recipient adult populations, they are really only able to identify areas that can be most easily distinguished (e.g. ones that leave an otolith chemical signature) and are unlikely to be able to identify important habitats occupied for short periods (e.g. initial settlement habitats (Dahlgren and Eggleston 2000; Grol et al. 2011)), habitats that are used intermittently (foraging and sheltering habitats (Sheaves 2005; Verweij et al. 2007)) and linkages and pathways among habitats (Nagelkerken 2007; Hammerschlag et al. 2010). Moreover, they provide little information on how habitats are used or on the processes and functions (e.g. food web resilience or resource dynamics) that are critical to nursery value but are not specifically related to a particular spatial unit.

There are also practical limitations to the use of ranking based on the contribution of spatial units. As well as providing scant information on process, approaches such as otolith microchemistry frequently do not allow identification of juvenile habitats at the scale where key processes operate, the scale used by the juveniles themselves, or at a scale amenable to management action (Gillanders et al. 2003). It will often not be feasible for management to protect the entire unit identified; all of one bay, all of one salinity zone or all of one seascape component. As a result, managers will often seek to minimise impacts within the unit identified as a nursery. However, many supporting processes and negative impacts arise well beyond a specific unit of habitat, so unless the specific values and supporting processes of particular sub-units and connectivities are known, such spatial prioritization is likely to fail. Ranking of nurseries assumes that nursery components have independent contributions to nursery value (Beger et al. 2010). However, the complex nature of nursery ground provision, with multifaceted interactions transcending individual spatial units, means that identification of nursery habitat cannot be approached as a static process in which individual habitats and life phases are singled out. Ignoring these interactions could be justified when it is possible to conserve a whole ecosystem (e.g. whole estuary or whole of coastal seascape) containing all units contributing to nursery function; as is the case with large protected areas. More often, management will need to work with much more specific units. The ranking process then provides little help, and may even be misleading because it suggests that one area can be protected at the expense of others. Even if ranking could be achieved at an appropriate scale to enable relative valuation of different spatial units, it intrinsically disregards the critical importance of interactions among ensembles of habitat units (Sheaves 2009; Grol et al. 2011), the importance of connectivity among the habitat units (Beger et al. 2010) and the importance of habitats only occupied transiently (Nagelkerken et al. 2014).

Solutions: Approaches Available to Identify the True Value of Nurseries

Determining how nursery value is influenced by connectivity, habitat type, habitat diversity, ecological interactions and trophic process seems like a complex task, but the type of information needed is already being collected; it just needs to be recombined, extended and refocused specifically on understanding nursery function. Not only can particular techniques contribute to understanding different aspects of nursery value (columns of ticks in Table 1) but combining various approaches can provide rich and extensive detail on specific aspects of nursery value (rows of ticks in Table 1).

To illustrate this, connectivity studies using natural and artificial markers are becoming the principal techniques for determining biomass or numeric contributions from alternative nurseries to adult stocks (see above). However, marker studies have broader applicability (Table 1). Not only can they provide valuable inputs to understanding of nursery values ranging from ontogenetic migration to export of process but, when combined with other techniques, can contribute to a much deeper understanding of many aspects of nursery value. For example, combined with data including food web and fish-habitat relationship information, gleaned from stable isotope, dietary, observational and capture studies, they can provide information on ontogenetic migration, seascape migration, ecotone effects and connectivity itself (Table 1: rows 1a-2a). Similarly, contributions to juvenile predator biomass can be informed by the following: stable isotope and dietary studies used to define nursery food webs; dietary, observational, capture and tethering studies supplying information on predator identification and dynamics; and energetics and condition studies determining juvenile growth and health (Table 1: row 4d).

Many other solutions are indicated in Table 1. These are far from exhaustive and a variety of other possibilities and combinations of approaches are likely to be fruitful. In particular, it will usually be possible to define more specific detail when the ideas are applied to particular cases and the studies are considered in explicit spatial and temporal contexts. The possibilities of the information that can be gleaned using multiple techniques should expand quickly as new combinations of approaches are successfully applied to new problems.

Conclusion

A historical analysis of nursery-function studies shows progressive development of this important field: (1) the recognition that inshore habitats harbour high densities of juvenile fish (1970s; e.g. Weinstein 1979), (2) the study of community structures of individuals nursery habitats (1980s; e.g. Robertson and Duke 1987), (3) the quantification of consecutive habitat usage by different life stages of fish (1990s; e.g. MacPherson 1998), (4) development of conceptual frameworks that identify critical nursery habitats (2000s; e.g. Beck et al. 2001), (5) recent studies that have used these frameworks in a quantitative way to identify primary nursery habitats (Tupper 2007; Huijbers et al. 2013). We are now at a stage where we need to take a step forward, building on these advances by developing an understanding of the processes that drive the productivity and maintenance of these identified key nurseries, and to go beyond valuation based simply on export of number or biomass, by incorporating the complex of factors that contribute to nursery value to provide a more comprehensive understanding of true nursery value. Only through this comprehensive understanding can we confidently identify the habitat mosaics and underlying connectivities/processes that are important to conserve to maintain nursery production and replenishment of recipient ecosystems. Ongoing degradation of coastal ecosystems increases the imperative for more complete understanding. Rapid loss of nursery habitats and escalating habitat fragmentation increase the pressure to conserve critical habitats and maintain ecosystem function. The identification of nursery habitats at a whole of habitat-unit scale, as is currently advocated, will not suffice in fragmented seascapes or in the face of specific impacts at particular locations. Consequently, an understanding of the complex processes that underlie nursery function is needed to support selection of appropriate fragments that can still provide key nursery functions. Failure to incorporate this complexity into conservation approaches and reserve design risks incomplete or inaccurate identification of key habitats and connectivities, and leads to significant potential for unexpected negative outcomes (Harris and Heathwaite 2012). Our current perspective provides a conceptual framework that can aid progress towards more complete understanding of nursery ground value, utilising data that are already available in the literature. It is only by continuing development of detailed understanding of the true value of nursery grounds and their functioning that we can hope to effectively protect these systems into the future.

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EXHIBIT K

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ECOSYSTEMS AND SUSTAINABILITY

Review Paper

Fishery discards and bycatch: solutions for an ecosystem approach to fisheries management?

Jose M. Bellido · M. Begoña Santos · M. Grazia Pennino · Xulio Valeiras · Graham J. Pierce

Abstract It has been widely acknowledged that fishery discard practices constitute a purposeless waste of valuable living resources, which plays an important role in the depletion of marine populations. Furthermore, discarding may have a number of adverse ecological impacts in marine ecosystems, provoking changes in the overall structure of trophic webs and habitats, which in turn could pose risks for the sustainability of current fisheries. The present review aims to describe the current state-of-the-art in discards research, with particular emphasis on the needs and challenges associated with the implementation of the Ecosystem Approach to Fisheries Management (EAFM) in European waters. We briefly review the international and European policy contexts of discarding, how discard data are collected and incorporated into stock assessments, selectivity in fishing and the main consequences of discarding for ecosystem dynamics. We then review implementation issues related to reducing discards under the EAFM and the associated scientific challenges, and conclude with some comments on lessons learned and future directions.

Keywords Discards · Bycatch · Ecosystem approach to fisheries management · EAFM

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Introduction

Fisheries management has evolved over the years, from being uniquely concerned with single stocks and quotas to the realization that individual fisheries should be managed taking into account their effects on, and interactions with, the ecosystems to which the target species belong, and taking account the human dimensions of fisheries and their relationships with other marine and coastal zone activities, for example, by working in partnership with stakeholders. This has led to the coining of the term 'Ecosystem Approach to Fisheries Management' (EAFM). The EAFM (also named Ecosystem Approach to Fisheries, EAF and Ecosystem-Based Fisheries Management, EBFM) is defined as an integrated approach to management that considers the entire ecosystem, including humans. The goal is to maintain an ecosystem in a healthy, productive and resilient condition so that it can continue to provide the services that humans want and need (FAO Fisheries Glossary, http://www.fao.org/fi/glossary/default.asp).

Discarding is currently one of the most important topics in fisheries management, both from economic and environmental points of view (Alverson & Hughes, 1996; Alverson, 1997; Kelleher, 2005; Catchpole & Gray, 2010). The FAO Fisheries Glossary describes discards as 'that proportion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea, for whatever reason. It does not include plant material and post-harvest waste such as offal. The discards may be dead or alive'. Discarding is an integral part of most fishing operations, since practically all fishing gears catch, at some time, species or specimens that are subsequently thrown back into the sea. Although the two concepts are obviously linked, it is nevertheless not necessarily the same as bycatch, which is the part of a catch that is 'taken incidentally in addition to the target species towards which fishing effort is directed. Some or all of it may be returned to the sea as discards, usually dead or dying'. Another related concept is 'slippage', a common practice in pelagic seine net fishing, whereby unwanted catches are released from the net and not taken on board. This is also destructive because the fish are often killed during the capture process (e.g. FAO, 2010; Huse & Vold, 2010).

Discarding involves a conscious decision made by fishers to reject some part of the catch. Discarding of target species can occur for reasons related to fishing regulations, e.g. if fish are below the minimum landing size or the fisher holds insufficient quota for the species or economic reasons: differences in market prices of different species and size-classes and limited availability of storage space can lead to so-called 'high grading', whereby less valuable species and size-classes are discarded to leave space for more valuable catch (e.g. Punt et al., 2006). Other reasons for discarding include damage or degradation of the catch and catching of non-commercial species. When the quota for a species is exceeded, the decision is often taken, especially in mixed fisheries, to continue fishing for other species even if this implies discarding individuals of the species for which the quota has been exceeded. In most EU fisheries, this is both legally permitted and economically justified (since the alternative would usually be to stop fishing), albeit clearly wasteful. It is generally illegal to sell under-sized fish or catches of protected species such as corals, some sharks or rays, and marine mammals.

Bycatch and discarding have numerous, generally undesirable, consequences. Clearly these are to some extent no different from the consequences of fishing per se, since all fishing causes mortality of marine animals and potentially also affects marine ecosystem structure and function. The main distinction to be drawn therefore is that discards (and any landed bycatch of no economic value) offer no obvious economic benefit to fishers and therefore represent additional 'unnecessary' mortality.

Kelleher (2005) estimated worldwide discards at an average of 7.3 million tonnes per year, or around 8% of the total catch, although the discard rate was much higher in certain fisheries. Thus, shrimp fisheries, particularly in tropical waters, had the highest total amount and highest proportion of discards with a weighted average discard rate of 62% (see Table 1, based on Kelleher, 2005). Demersal finfish trawling had a relatively low discard rate but because of its ubiquity contributed a substantial total amount of discards worldwide. The third most important contribution to total discards was from tuna longlines. Most other line fisheries have low or negligible discards although they may have significant bycatches of seabirds and turtles, an issue which gained prominence in the 1990s (e.g. Brothers, 1991; Cherel et al., 1996; Barnes et al., 1997; Hall et al., 2000). Fisheries with very low or negligible discards included small-scale and artisanal fisheries in general. However, although small-scale and artisanal fisheries usually have low levels of discards per vessel, in certain areas with very large artisanal fleets (e.g. the Mediterranean, some parts of Africa), the total amount of discards can still be very substantial (Stergiou et al., 2003; Nunoo et al., 2009).

Global fishery discards have significantly declined in recent years (Kelleher, 2005; Zeller & Pauly, 2005; Davies et al., 2009). However, there are important exceptions, including (poorly regulated) deepwater fisheries in international waters and some of the most highly regulated fisheries, where severe quota restrictions have resulted in high grading (Kelleher, 2005). There is no unique and simple explanation for the overall decline, but it appears to have been due to, among other factors, improved selectivity of fishing technology and greater utilization of the bycatch for aquaculture and human consumption. Obviously, the

Table 1 Annual landings and discards in the main types of fisheries worldwide (in thousand tonnes), the percentage of discards to catch and the range of discard rates (based on Kelleher, 2005)

Fishery	Landings	Discards	Weighted average discard rate (%)	Range of discard rates (%)
Shrimp trawl	1126.3	1865.1	62.3	0–96
Demersal finfish trawl	16051.0	1704.1	9.6	0.5–83
Tuna and HMS longline (high migratory species)	1403.6	560.5	28.5	0–40
Midwater (pelagic) trawl	4133.2	147.1	3.4	0–56
Tuna purse seine	2679.4	144.2	5.1	0.4–10
Multigear and multispecies	6023.1	85.4	1.4	na
Mobile trap/pot	240.6	72.5	23.2	0–61
Dredge	165.7	65.4	28.3	9–60
Small pelagic purse seine	3882.9	48.9	1.2	0–27
Demersal longline	581.6	47.3	7.5	0.5–57
Gillnet (surface/bottom/trammel)	3350.3	29.0	0.5	0–66
Handline	155.2	3.1	2.0	0–7
Tuna pole and line	818.5	3.1	0.4	0–1
Hand collection	1134.4	1.7	0.1	0–1
Squid jig	960.4	1.6	0.1	0–1

latter is unlikely to have contributed much to reducing fishing mortality or reducing damage to ecosystems. Indeed, the growth of aquaculture potentially represents one of the greatest threats to marine ecosystems through the increased demand for fishmeal derived from so-called 'reduction fisheries'—although Asche & Tveterås (2004) argue that the threat can be avoided by efficient management of such fisheries.

At the time of writing, the European Commission is discussing the banning of discards as part of the reform of the CFP. In the present review, we examine the policy context of discarding in European fisheries and the current state-of-the-art in discards research. We discuss the main consequences of discarding for ecosystem dynamics, fishing exploitation and implications for management, with particular emphasis on the needs and challenges associated with the implementation of the Ecosystem Approach to Fisheries Management (EAFM) in European waters. We and then examine possible solutions to the issue in the context of the EAFM.

International regulations on discarding and bycatch

Before turning to focus on the situation in Europe, we here briefly outline the international context. As noted by Alverson et al. (1994) in their global assessment of fisheries bycatch and discards, awareness of discarding in fisheries can be seen in the bible, in parable of the net (Matthew 13: 47–48): 'Again, the Kingdom of Heaven can be illustrated by a fisherman—he casts a net into the water and gathers in fish of every kind, valuable and worthless. When the net is full, he drags it up onto the beach and sits down and sorts out the edible ones into crates and throws the others away…'. Alverson et al. also point out that incidental catches and discards have received most attention in the USA, relating to primarily to mortality of marine mammals in the Eastern Tropical Pacific purse seine fishery for tuna, high seas driftnetting fisheries (in which seabird and salmon bycatches were also a major issue) and the high level of discarding in shrimp fisheries in the Gulf of Mexico. Two significant pieces of national legislation resulted in the 1970s, the Marine Mammal Protection Act (1972) and the Endangered Species Act (1973). The USA also had a leading role in the adoption in 1989 of United Nations General Assembly Resolution 44/225, which recommended that all members of the United Nations agreed to a Moratorium on all large-scale pelagic driftnet fishing on the high seas by 30 June 1992. The United Nations Convention on the Law of the Sea (UNCLOS) was concluded in 1982, finally coming into force in 1994. This covers, for example, the requirement for fishing within the Exclusive Economic Zones of another country to respect conservation measures and other laws and regulations of the country.

In recent decades, the Fishery and Agriculture Organization of the United Nations (FAO) has provided a range of legislative instruments and guidelines for fisheries, including the 1995 Code of Conduct for Responsible Fisheries, the 1999 FAO International Plan of Action for Reducing Incidental Catch of Seabirds in Longline Fisheries (IPOA-Seabirds, FAO, 1999), the 1999 FAO International Plan of Action for the Conservation and Management of Sharks (IPOA-Sharks, FAO 1999), and the 2009 FAO Guidelines to Reduce Sea Turtle Mortality in Fishing Operations (FAO, 2009). Arising from a Technical Consultation held in Rome in December 2010, FAO issued International Guidelines on Bycatch Management and Reduction of Discards (FAO, 2010). These guidelines are intended to assist States and Regional Fisheries Management Organisations or Arrangements (RFMO/As) in the management of bycatch and reduction of discards in conformity with the FAO Code of Conduct for Responsible Fisheries. Among other initiatives, these Guidelines establish that States and RFMO/As should develop a framework for long-term cooperative work on bycatch management and discard reduction in association with stakeholders, management authorities at all levels, and other agencies and organizations, including providing accurate and timely information on bycatch-related issues, regulations and activities. They also establish the participation of scientists with appropriate expertise to conduct and evaluate bycatch and discard assessments, and propose mitigation strategies.

Discarding and fishery policy in Europe: towards an ecosystem approach

To the extent that obligatory discarding is part of a coherent management framework, it could be regarded as unfortunate but unavoidable collateral damage which nevertheless confers wider benefits for sustainability. In the European Union, however, such a viewpoint is increasingly untenable, not least because the European Common Fishery Policy has, at least in several important respects, failed to deliver sustainable fisheries. Important issues include fleet overcapacity, overexploitation of vulnerable species, wasteful practices such as discarding, environmental degradation and effects on non-target species: see Daw & Gray (2005) and Khalilian et al. (2010) for detailed critiques. Such failings are explicitly recognized in the Green Paper concerning the current process of CFP reform (EU COM, 2009). Some other countries, e.g. Norway, ban discarding and arguably also achieve more sustainable fisheries.

Any implementation of EAFM must consider discarding for several reasons: (a) it directly affects the balance, diversity and functioning of the ecosystem, (b) it potentially leads to reduced income from fisheries and (c) because it is widely perceived as being wasteful and ineffective, it undermines respect of fishers for the governance system and thereby leads to reduced compliance with, participation in and effectiveness of the regulatory system.

According to Hilborn (2011), there are 'core' and 'extended' aspects of EAFM. The 'core' consists of three primary features: (a) keeping fleet capacity and fishing mortality rates low enough to prevent ecosystem-wide overfishing, (b) reducing or eliminating bycatch and discards and (c) avoiding habitat-destroying fishing methods. The 'extended' EAFM takes into account trophic interactions and area-based management. Certainly such management objectives are not exclusive to EAFM and most fisheries management agencies around the world attempt to meet at least some of these objectives as part of existing single-species management regimes. In fact, the recent FAO International Guidelines on Bycatch Management and Reduction of Discards (FAO, 2010), in support of management measures to mitigate bycatch and discard problems, advised that 'States and RFMO/As should, where appropriate, map seabed habitats, distributions and ranges of species taken as bycatch, in particular rare, endangered, threatened or protected species, to ascertain where species taken as bycatch might overlap with fishing effort'.

It is evident that the good intentions of the CFP have not borne fruit. Thus, the current UK government stance (as of April 2011) is that 'The current Common Fisheries Policy is broken. It has not delivered its key objective of an economically viable fishing industry which minimizes impacts on marine ecosystems'. (http://www.defra.gov.uk/environment/marine/cfp/). A significant part of that problem appears to be that the scientific advice, which aims to address the CFP objectives, has been routinely ignored due to a decision-making process that clearly has rather different objectives, short-term political expediency being prominent among them. Cardinale & Svedang (2008) argued that, despite the limitations of using a deterministic single stock modelling framework for assessment, managers and politicians have had the necessary scientific instruments for managing stocks and avoid stock collapses (and by implication for achieving increased economic and social sustainability), but they failed to deliver since they tried to minimize the short-term negative impact of policy on those who are most affected (i.e. the fishing industry). The authors argued that is the practice of ignoring the scientific advice, more than the advice itself, which is to be blamed for the wasteful depletion of formerly abundant marine resources. Khalilian et al. (2010) offer similar arguments when discussing the failure of the CFP from biological, economical, legal and political perspectives. Excessive quotas set by the Council, regularly overriding scientific advice and payment of direct and indirect subsidies by both the EU and Member States, have resulted in too much fishing effort and excessive exploitation rates, leading in turn to low stock sizes, low catches and severely disturbed ecosystems. The lack of transparency of its regulations as well as insufficient control and enforcement of its provisions have contributed to the failure of the CFP. Khalilian et al. (2010) characterize the CFP as an opaque decision-making procedure with little approval by the public, which leads to a culture of non-compliance that undermines the CFP and the final goal of implementing sustainable fisheries management.

Several authors have argued that appropriate application of single-species management could actually achieve some of the goals of EAFM. Froese et al. (2008) show that setting fishing mortalities for several North Sea and Baltic species so as to achieve maximum sustainable yield (MSY) for individual stocks would be an improvement on the current regime, while taking only larger individuals (such that all fish are able to achieve maximum growth rate) would increase yield while at the same time rebuilding stocks and minimizing impact on the ecosystem. Although not specifying how catching smaller fish could be avoided, the authors point to fisheries elsewhere in the world where such objectives have been achieved (Hilborn, 2011). Hilborn (2011) raises the question 'Would EAFM be unnecessary if we had implemented single-species management correctly?' His answer is that successful single-species management could be a major step forward in many areas but, by itself, it is not sufficient because pure single-species management does not consider impacts on non-target species, trophic interactions among species and habitat-destroying fishing practices. However, he also notes that successful single-species management demands understanding of the ecosystem impacts of factors other than fishing, i.e. the need to deal with broader ecosystem concerns is already evident.

Nevertheless, even this latter analysis is based on the implicit assumption that the current assessment, management and governance system, whereby the different components are seen as independent, sequential, processes, is an appropriate framework. Environmental sustainability cannot be achieved in isolation from considerations of socioeconomic sustainability; the implementation of management measures must take into account the responses of the fishers. Thus, stock assessments must extend to offering predictions of stock trajectories under not only a range of possible management measures but a range of realistic outcomes in terms of compliance and enforcement of regulations. Furthermore, fisher buy-into the management and governance regime can itself be managed, through measures such as participatory management and co-management.

Collecting information on discards

Discards account for significant mortality in fisheries. However, few stock assessments take into account information on discards (Mesnil, 1996; Hammond & Trenkel, 2005; Punt et al., 2006; Aarts & Poos, 2009; Fernández et al., 2009). This is mainly due to limitations of the available data: long time series of onboard observation are not available for all the fleets involved in the exploitation of most stocks. In addition, a large amount of monitoring and research effort is needed to obtain this kind of information (Alverson et al., 1994; Kelleher, 2005).

One of the main problems with onboard observer data is the high spatial and temporal variation shown in discard patterns. Aside from the obvious difficulty of obtaining precise estimates for a highly variable phenomenon, if the sampling design does not account for it, this high variation could hide some bias in the estimation, which will be transferred and multiplied when raising estimates to the level of the whole fleet or stratum (Allen et al., 2001, 2002; Borges et al., 2004; Apostolaki et al., 2006). Rochet & Trenkel (2005) concluded that the factors underlying variation in discard rates are complex, noting that the amount of discards is rarely proportional to catch or effort, and commenting that although environmental conditions and fishing methods affect discards stratification, stratification of sampling to take this into account may not improve the precision of estimates.

The above-mentioned conclusions notwithstanding, one solution is to identify and measure auxiliary variables (e.g. environmental, biological, regulatory, market factors) which affect the nature and extent of discarding and use statistical modelling to control for these effects. For example, Stratoudakis et al. (1998) analysed sources of variation in proportions of three gadid species discarded at length by fishers using demersal gears in the North Sea. They found clear differences between inshore and offshore fishing areas (with more high grading observed in the latter) but also showed that discarding practices for haddock and cod were consistent over time and across gears—although discarding of (the less valuable) whiting was more variable and depended on catch composition. Borges et al. (2005) investigated both the best sampling unit and auxiliary variables for estimating discards in Irish fisheries. Their results showed that use of fishing trip rather than haul as sampling unit reduced the overall variability of estimates. Use of different auxiliary variables resulted in different estimates and although the authors observed that number of fishing trips is probably reported more reliably than hours fishing or weight of landings reliable, there was no reason to favour one estimate over another.

While spatial stratification of discard sampling is routinely undertaken (as described, for example, in Stratoudakis et al. 1998), it is worth considering that spatial patterns of discarding can occur at several scales and may differ between species. Such patterns can be quantified using spatial statistical methods, as shown by Sims et al. (2008) and Lewison et al. (2009) in relation to fishery bycatch. In the context of bycatches of megafauna, these authors point out the importance of considering bycatch relative to target catch as well as the relevance of identifying spatial patterns in bycatch to management and mitigation of bycatches. These are conclusions which are equally relevant to discarding.

Another aspect requiring more attention is the change of discarding behaviour over time, e.g. seasonally or over the course of a fishing trip, the latter being particularly important in distant water fleets that make long trips. Several factors, e.g. availability of storage space, temporal variation in abundance of target species or even changes in market price during the fishing trip can lead to changing decisions about which part of the catch to retain. Bellido & Pérez (2007) evaluated alternative sampling strategies for discarding by Spanish trawlers using computer resampling (bootstrapping) and identifying the strategy that minimized the coefficient of variation. They suggested sampling at least one vessel and one trip per vessel, monthly, sampling between 30 to 50 hauls within a trip, and sampling 8–15 hauls at the beginning, middle and end of the trip. Gray et al. (2005) reported seasonal differences in discard rates in an Australian estuarine commercial gillnet fishery. These differences were attributed to a seasonal difference in fishing regulations such that nets could be left in the water only 3 h during summer but could be set overnight in the winter. Although the discarding rate was generally low, the authors concluded that reducing maximum soak time (as well as increasing mesh size) would reduce the discard rate.

Most of the studies cited thus far have involved data collection by on-board observers. Observer programmes are generally thought to be essential for accurate quantification of discards in most fisheries. However, some authors have questioned whether observer at-sea trips can be used to make inferences about catch composition and discards. Thus Benoît & Allard (2009) highlight two issues, 'deployment' bias resulting from non-random distribution of observers among sampling units and observer effects due to changes in fishing practice or location when observers are on board.

A major limitation is the expense of using on-board observers to record discard data. Allard & Chouinard (1997) proposed using a combination of on-board and shore-based sampling, with the latter making use empirically determined changes in the length-frequency distribution of catches when discarding had taken place. The advent of on-board camera technology offers the prospect of a more comprehensive (if perhaps less detailed) picture of discarding practices. FAO (2010) recommend that management of bycatch and reduction of discards should be supported by technological development both in the harvest and the post-harvest and valorization sector.

Incorporating discard data into assessments

The omission of discard data from the stock assessment process may result in underestimation of fishing mortality and can lead to biased assessments, hampering achievement of sustainable resource use (e.g. Punt et al., 2006; Aarts & Poos, 2009). Some progress has been made recently on inclusion of discard data and survival estimates into stock assessment. For example, in the case of the Norwegian lobster (*Nephrops norvegicus*), one of the most valuable crustaceans landed in Europe, with most of the catches taken by bottom trawls, estimates of 25% discard survival rate have been used in the assessment of the stocks by the International Council for the Exploration of the Sea (ICES, 2010).

Several authors have used statistical modelling to estimate discards, based on the assumption that the main driver for discarding is minimum landing size regulations (e.g. Casey, 1996; Cotter et al., 2004; Punt et al., 2006). One limitation in such models has been the assumption that gear selectivity is constant. Aarts & Poos (2009) developed a statistical catch-at-age model with flexible selectivity functions to reconstruct historical discards of plaice in the North Sea and estimate stock abundance. Fernández et al. (2009) developed a Bayesian age-structured stock assessment model for the southern stock of European hake (*Merluccius merluccius*) and showed that incorporating information on discards into the model had an important effect on predicted stock trajectories.

Punt et al. (2006) point out that inclusion of discard data can also permit detection of strong year-classes before they are apparent in landings data—while stressing that discarding remains a poor use of the resource and that conducting pre-recruit surveys is a more appropriate way to predict future recruitment. The few fish stock assessments that include discards assume that all discarded fish die, which is not necessarily the case. Mesnil (1996) incorporated various levels of discard survival into stock assessments based on Virtual Population Analysis (VPA) and showed that this could significantly affect estimates of fishing mortality and stock size. The author also suggests that, from a management point of view, measures to improve the survival of released fish (if feasible and effective) might be as effective as increasing mesh size and potentially more acceptable to fishers. Although the inclusion of discard data into stock assessment models is a major improvement, most of the above-mentioned examples are based mainly on a single-species approach.

Selective fishing

More selective fishing should reduce discards by avoiding unwanted catches and maximizing the marketable portion of the catch. Zhou et al. (2010) refer to six types of selective fishing: by species, stock, size, sex, season and/or space. Increased selectivity is generally favoured by fishers, as they are by nature selective and do not want to catch fish that cannot be sold or that will create sorting difficulties. Recent work in this field covers topics such as mesh size regulation (Suuronen et al., 2007), technical measures (Catchpole et al., 2008; Enever et al., 2009a), mesh size and selectivity modifications (Revill & Holst, 2004; Guijarro & Massuti, 2006; Revill et al., 2007; Massuti et al., 2009), cost-benefit analysis (Macher et al., 2008), new designs to improve escapement of unwanted fish (Graham, 2003; Revill et al., 2006; Catchpole et al., 2007; Moore et al., 2009; Yamashita et al., 2009) and devices to reduce the impact of trawls on benthic communities (Revill & Jennings, 2005). There have also been important advances in reduction of bycatches of marine mammals and seabirds in gears such as purse seines, gill nets and long-lines. National Research Council (1992) describe how a combination of modified fishing gear, modified procedures and education of skippers dramatically reduced dolphin bycatches in the Eastern Tropical Pacific tuna fishery. Several studies have shown that acoustic alarms (pingers) can reduce porpoise bycatch in gill nets (e.g. Gearin et al., 2000), although their efficacy is by no means universally accepted and there is a need to monitor the success of deploying pingers. Goetz et al. (2011)

describe trials of modifications to long-lines to reduce seabird bycatches (see also references therein).

Although bycatch reduction has been achieved in some fisheries by modifying the gear, some well-publicised cases have not been successful. The fishery for Baltic cod (*Gadus morhua*) has been subject to a great number of technical regulations, with the aim of reducing juvenile mortality. However, a large increase in selectivity introduced in a single step may not be commercially acceptable and in this case the measures resulted in substantial short-term economic losses. Suuronen et al. (2007) note that fishers' willingness to comply with new regulations depends largely on their ability to deal with such short-term reductions in catch. When losses are too large, gears will be manipulated and rules will be circumvented. Apparently, a gradual increase in mesh size (or gradual introduction of any restrictive measure) would often be more acceptable to the fishers (Suuronen et al., 2007). In addition, fishers usually prefer mesh size regulations to fishing effort regulation, probably because the former still allows them the opportunity to apply the deep knowledge they have on fishing gears and the way they operate.

Although more selective fishing is always suggested as a key factor in reducing discards, Zhou et al. (2010) argue that less selective fishing gears may help to maintain diversity and functioning in certain marine ecosystems (although they do also point to the importance of the protection of vulnerable species and the need for regulation of fishing effort). This potential inconsistency between promoting more selective fishing and the 'ecosystem approach' requires attention from both theorists and practitioners in order to formulate the best scientific advice (Kelleher, 2005). Hall & Mainprize (2005) recommend diversifying our harvest and learning to utilize a wider variety of products, although they stress that this is not intended as a justification of extending fishing activity to other species, rather it should involve reduced fishing pressure on current target species.

On the impact of fishing and discards in the ecosystem

Knowledge of the impacts of bycatch and discarding at the community and ecosystem levels becomes increasingly necessary in the context of the multi-species and ecosystem-based approaches to fisheries management (Borges et al., 2001).

Disturbance by trawling is well known to affect the species composition and structure of marine benthic communities. Several authors have suggested that trawling disturbance is 'farming the sea'; ploughing the seabed to boost production. To others, trawling is assumed to damage key functional processes (Jennings & Kaiser, 1998). Also, the physical disturbance of the sediment by trawl nets could expose endobenthic organisms which can then be predated by carnivores (Jenkins et al., 2004). However, the effects on ecosystem structure and function (biodiversity, community structure, trophic links) of returning biomass directly to the ecosystem though discarding are not so well known (Dayton et al., 1995; Jennings & Kaiser, 1998; Lindeboom & de Groot, 1998; Hall, 1999; Collie et al., 2000; Kaiser & de Groot, 2000; Borges et al., 2001; Erzini et al., 2002). The effects of discarding on the stability of trophic webs may have negative consequences for commercial stocks due to the disruption of species interactions and cascading effects throughout the trophic chains (Monteiro et al., 2001). Tsagarakis et al. (2008) showed that the composition and/or trophic level of discards in relation to the marketed catch seemed to be indicative of the exploitation state of the demersal community.

Various seabird species use discards and offal as trophic resources, and some species are believed to have increased in numbers as a result of availability of food via discards (Furness, 2003; Valeiras, 2003; Votier et al., 2004). However, Grémillet et al. (2008) argue that, at least for gannets, fishery waste is basically 'junk food' and has a negative impact on growth rates of chicks.

Another fraction of the discards sinks in the water column and its fate is poorly known but some midwater scavengers such as sharks (Sánchez et al., 2005) may benefit from them. Finally, the remaining discarded biomass ends up on the seabed and is consumed by the benthic fauna (Jennings & Kaiser, 1998; Jenkins et al., 2004). The biomass made available by fisheries discards returning to the seabed may produce good conditions for a short-term increase of scavenger benthic species, including fish, crabs, shrimps and other invertebrates.

Long-term studies of the benthos communities in the southern and central North Sea suggest that biomass and production have increased (Kroncke et al., 1998). This could be a response to trawling disturbance, climate change and/or eutrophication (Rijnsdorp & van Leeuwen, 1996; Kroncke et al., 1998). The decrease in abundance of vulnerable species such as elasmobranchs, echinoderms, corals and sponges due to seafloor disturbance caused by trawling could be followed by increases of other benthic species.

Many elasmobranch species are thought to be threatened by bycatch and discarding, and it is also a serious issue for various species of turtles and seabirds (caught on long-lines), and marine mammals (caught in purse seines, gillnets and trawls). Elasmobranch fish have been reported to be more resistant to capture than teleosts, with several species of sharks and rays having a high probability of survival after being discarded from trawlers. Rodríguez-Cabello et al. (2005) quoted a mean survival rate of 78% for spotted catshark *Scyliorhinus canicula* in the Cantabrian Sea, while Enever et al. (2009b) found a short-term rate of survival of 55% for skates discarded in the skate fishery in the Bristol Channel.

Further important related issues that still need further research include the impact of abandoned gears (ghost fishing) and slippage of catches in pelagic fisheries. This is highlighted in the FAO International Guidelines on Bycatch Management and Reduction of Discards (FAO, 2010) which dedicates a section to pre-catch losses and ghost fishing, establishing that States and RFMO/As should consider measures to address the impact of pre-catch losses and ghost fishing on living aquatic resources. Recommendations include development methods for estimating pre-catch losses by various gear types, modification of gears and fishing methods, identification of gear ownership, reduction of gear losses, development of gear retrieval procedures and programs, and reducing, and where possible eliminating, fishing power of lost gear, e.g. through the use of degradable materials. FAO (2010) also remind us that abandoned and discarded gears should be considered as marine pollution and that

> States and RFMO/As should take account of current work at the International Maritime Organization on the revision of Annex V of the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 (MARPOL 73/78) and the Guidelines for the Implementation of Annex V in relation to reducing the impact of lost fishing gear.

Brown & Macfadyen (2007) reports that ghost fishing in depths shallower than 200 m is not a significant problem and declines rapidly once nets have been lost. This is due to lost, discarded, and abandoned nets have a limited fishing life, because many static-net fisheries take place in shallow water, where storm and tide action can quickly roll up the nets, and bio-fouling reduces their catching efficiency (Erzini et al., 1997; Pawson, 2003; Revill & Dunlin, 2003). Large et al. (2009) carried out retrieval exercises to recover lost and abandoned nets from deep-water gillnet fisheries in the Northeast Atlantic. They towed a retrieval gear that basically consisted of three grapnels connected by chains to a steel bar and towed at a speed of 1–2 knots, a technique called 'creeping'. In terms of mitigation, they suggested that information should be collected from fishers and fisher organizations, and creeping should then be carried out at locations where fishers have reported incidences of lost or abandoned nets.

Huse & Vold (2010) showed that (short-term) mortality of mackerel in purse seines could be reduced by avoidance of 'excessive crowding' of the fish. Studies by Stratoudakis & Marcalo (2002) on sardine (*Sardine pilchardus*) taken by purse seiners in Portugal and for another sardine species (*Sardinops sagax*) taken with the same gear in western Australia (Mitchell et al., 2002) indicate that slippage mortality could be much higher in the long-term as, although fish are still alive when released, many are believed to have suffered physical damage (loss of scales, skin abrasions) by contact with other fish and the walls of the net.

Implementation of policy

Pikitch et al. (2004) state that the overall objective of EAFM is to sustain healthy marine ecosystem and the fisheries they support. EAFM is generally considered more conservative and more protective of marine ecosystems than is single-species management. Hilborn (2011) comments that he suspects the general public and legislators believe that if we can manage every species to its MSY level, there would be no significant ecosystem impacts. However, we should be aware that a healthier ecosystem does not automatically imply more productive fisheries. Additionally, EAFM objectives are quite often vague enough that different interpretations could lead to drastically different outcomes. The current legislative frameworks for EAFM often lack clarity, and management agencies will have insufficient guidance on appropriate policy unless international agreements and national legislation are made more specific.

Given that fisheries and conservation tend to be the responsibilities of different and independent government departments, it is perhaps unsurprising that some of the most important contributions to EAFM have arisen from non-fisheries legislation. Hall & Mainprize (2005) review several examples, including the US Marine Mammal Protection Act, which sets monitoring requirements and imposes tough and rigorously enforced limits on fishery bycatch of marine mammals. Other examples include the US Endangered Species Act which limits the incidental capture of the short-tailed albatross in Alaska and the Environmental Protection and Biodiversity Conservation Act in Australia, which requires fisheries to undertake 'threat abatement plans' if they impact on certain marine species, and to become accredited as ecologically sustainable. Aside from illustrating the power of non-fisheries legislation to effect changes in fishing practices, an important precautionary note is that these are all non-European examples. In the European context, it is apparent that fishery and conservation may be contradictory (e.g. the CFP and the Habitats Directive), and indeed, because national governments cede power to regulate fisheries beyond their immediate coastal waters to the European Union, they may be legally powerless to fulfil their species protection obligations under the Habitats Directive (Khalilian et al., 2010).

There is a clear need to take account of the interdependence of stocks and the effects on species associated with or dependent upon harvested species, with a view to maintaining or restoring populations of such associated or dependent species above levels at which their reproduction may become seriously threatened. The 1980 Convention on the Conservation of Antarctic Marine Living Resources provides that 'ecological relationships between harvested, dependent and related species must be maintained'. This principle often refers specifically to endangered, threatened or protected species. A key-related objective is to minimize bycatch and discards. As it is impossible to optimize the exploitation for all species at the same time, compromise solutions will need to be found, reflecting decisions on which species may be more negatively affected. Optimal harvest strategies for multi-species fisheries have for some time been a focus of ICES work. A variety of mathematical approaches has been developed, among which the Fcube (Fleet and Fishery Forecast) model is particularly promising (J. Castro-Pampillon, pers. Comm.)

The Ecosystem Approach to Fisheries Management (EAFM) will provide some impetus to this process, in that it aims for an integral ecosystem-based management of fisheries. One of the main challenges of the EAFM is to understand the trade-offs resulting when a particular approach is chosen, and to develop the institutional and legislative frameworks that recognize and account for these trade-offs (Hall & Mainprize, 2005). While a measure may, at first glance, appear entirely reasonable and may well make fishery managers and conservationists feel better, the complexities of ecological systems and the biology and population dynamics of the species within them, the difficulty of measuring the outcomes, the inability or unwillingness on the part of the fishers to comply with the measure, and the inability of the regulatory agency to enforce compliance, can often conspire against good intentions and render a measure ineffective, unexpectedly costly or simply impossible to evaluate. As with most complex decisions, there are trade-offs that must be carefully weighed.

As is increasingly obvious across the spectrum of different fishery management measures, it is essential to engage fishers and stakeholders in the management system to find appropriate and agreed solutions. Furthermore, as the potential interactions between fisheries and other uses of the seas are increasingly recognized (and captured within concepts such as integrated coastal zone management, marine spatial planning and integrated marine management), there may be a need to involve experts and stakeholders from other management areas.

In very broad terms, there are two different approaches for managing discards in the world: regulating what it is allowed to be caught and regulating what can be retained on board and landed, with the latter being more easily enforceable since it requires inspection only at the landing port. In addition, the full utilization of the catch may be promoted, for example, by developing markets for 'non-commercial' species (e.g. Portela et al., 2004).

Measures to reduce may include modifications of gear and or fishing practices. While it is impossible to legislate against bycatch occurring, it can be discouraged by imposing penalties. Thus, in relation to marine mammal bycatch, measures available under the US Marine Mammal Protection Act include fishery-specific limits on bycatches, time and area closures, gear modifications and deployment of pingers (the latter being a measure originally proposed by the fishers, Bache, 2001). Bisack & Sutinen (2006) explored the idea of introducing Individual Transferable Quotas for porpoise bycatch and argue that it is a potentially more efficient measure than area closures.

One option for regulating discards is to pursue a no-discard policy, as implemented in, for example, Norway, Iceland and New Zealand, whereby all catches, desirable and non-desirable must be landed. However, unless combined with measures to reduce catches of unwanted fish and/or to provide for their utilization, the benefit in terms of environmental conservation and sustainable marine and coastal zones management may be limited or negative. Rather than ensuring zero waste, the policy potentially transfers the problem of marine waste onto the land, where its safe disposal becomes a problem for local authorities. If such waste is stored adjacent to the coast, there is the risk of pollution in the coastal and littoral area. A partial solution (at least providing benefits onshore) may be the development of processing facilities and markets to make use of fish waste, e.g. to produce feed and fertilizer. Catchpole et al. (2005) note that discard bans can create markets for incidental catches. While there may be cases for the development of markets for particular species or size classes, where there is pressure on resources and threats to sustainable fishing activities, the main objective must be reducing the capture of potential discards rather than their utilization. The above discussion highlights the importance of careful analysis before a measure is adopted.

The European Commission is at present reconsidering its discard policy, which represents a major shift in European fisheries management (Green Paper, EU COM, 2009). This is taking place in the context of a bigger and fascinating challenge, to develop holistic approaches to manage the use of the sea and its resources as a whole, as envisaged under EU Marine Strategy (Apitz et al., 2006; Jensen, 2006). EAFM thus represents the 'fishery' component within holistic marine management.

A no-discard policy changes the focus of management from landings to catches, in other words from production to total fishing mortality. This is exemplified in the contrasting Norwegian (it is prohibited to *catch*...) and EU legislation (it is prohibited to *have on board*...). This means that many of the no-discards management measures are designed to ensure that unwanted fish is not caught. Thus, the choice is not between returning unwanted fish to the sea and obligatory landings for fishmeal or animal feed, but between catching and not catching unwanted fish.

While the EU sees reducing excessive fishing effort as the main way to reduce the level of unwanted catch, other measures, already enforced in no-discard countries, should also be considered (Green Paper, EU COM, 2009): (a) temporary area closure for spawning stocks, vulnerable habitats or protecting juveniles; (b) real-time movement of vessels to another fishing area once their unwanted catches exceed a certain level; (c) adapting fishing gear so that threatened species or sizes can escape from nets and (d) reviewing existing management measures which may lead to discarding. The discard ban could be implemented progressively, for example, starting with a discard ban for pelagic species (mackerel, herring, blue withing, etc.) in the first year of the new CFP, and continuing with demersal target (cod, hake, nephrops, sole, etc.) and associated species (haddock, whiting, hake, plaice, etc.) as well as a discard ban in Mediterranean fisheries in the second year of the new CFP (EU High Level Meeting on banning discards, Brussels 1st March 2011).

Scientific challenges to implement an EAFM

How can scientists provide answers and tools to meet such a huge challenge? Hilborn (2011) suggests that EAFM needs to be set in the context of risk analysis. The FAO guidelines for bycatch and discards reduction (FAO, 2010) also identify the need for 'a risk assessment to identify the specific nature and extent of bycatch and discard problems in the fishery as a basis for prioritization and planning'. However, before we can conduct risk analyses, the specific objectives of EAFM must be clear.

It is evident that complete knowledge of fisheries, and the ecosystems in which they take place, is impossible. For example, in some multispecies, multigear fisheries, reporting the full species composition of catches may not be practical. Consequently, alternative methods, such as reporting on indicator species or other suitable proxies, may be necessary. Levin et al. (2009) propose an Integrated Ecosystem Assessment (IEA) as a framework for organizing science in order to inform decisions in marine EAFM at multiple scales and across sectors. IEA comprises five key stages: scoping, indicator development, risk analysis, management strategy evaluation and ecosystem assessment. It develops ecosystem indictors through synthesis and quantitative analysis of information on relevant natural and socioeconomic factors, in relation to specified ecosystem management objectives, and integrates them into management measures.

Implementation of spatial management, with zoning for different kinds of fishing activity and use of seasonal or temporary closures, can be a useful tool for reducing discard rates and controlling effort exerted. Spatial management measures must be underpinned by a good knowledge of the biology, spatial distribution and abundance of both resource species and other species impacted by fisheries, including protected species. The effects of fleet displacement must also be understood, otherwise spatial management results can be disappointing.

There is a huge literature on the pros and cons of marine protected areas (MPAs). In the context of fisheries, successes have been decidedly mixed. Catchpole et al. (2005) note that temporary closure, through establishment of the 'Plaice Box', failed to protect the main nursery grounds for plaice in south-eastern North Sea, even after closure was made permanent, whereas a Norwegian system of temporary closures used in the Barents Sea is regarded as having an important contribution to the recovery of cod and haddock stocks. Robb et al. (2011) comment that 'no-take' MPA, in which all fishing is prohibited, can result in greater productivity of fish stocks. However, they highlight the need for effective management to ensure that only permitted activities occur within MPAs. The authors found that all but one of 161 MPAs on the Pacific coast of Canada are open to some kind of commercial fishing and attribute the mismatch between intent and practice to a lack of coordination between management of protected areas and management of fisheries.

Recent fisheries research has focused on the development of indicators that might underpin the implementation of an EAFM. Such indicators would provide information on the state of the ecosystem, the extent and intensity of effort or mortality and the progress of management in relation to objectives (Jennings, 2005). Papers on ecosystem or ecological indicators in the context of fisheries have flourished over the last 10 years (see, for example, Piet & Jennings, 2005; Piet et al., 2008; Cotter et al., 2009; Rochet & Trenkel, 2009; Van Hoey et al., 2010; Greenstreet et al., 2011). Trenkel et al. (2007) proposed such an approach for the assessment of two anglerfish (*Lophius piscatorious* and *L. budegassa*) stocks in the Bay of Biscay and the Celtic Sea. The authors used a set of indicators derived from scientific survey data and compared the results between traditional model-based and the indicator-based methods. Although their results were somewhat inconclusive, it is clear that the progressive implementation of an EAFM will need to be based on the behaviour of ecological indicators (Piet et al., 2008). Regarding discard and bycatch issues, some relevant pressure indicators have been suggested to address how fishing impacts on the ecosystem. The discarding rates of commercially exploited species and discard rates in relation to landings value have been suggested as pressure indicators to use as measures of the relative environmental impact of different fisheries (Piet et al., 2007). Indicators should guide the management of fishing activities that have led to, or are most likely to lead to, unsustainable impacts on ecosystem components or attributes (Jennings, 2005; Rice & Rivard, 2007).

Currently, the implementation of the Marine Strategy Framework Directive (MSFD Directive 2008/56/EC) is providing a new impetus to the process of indicator development. It calls for completion of an initial assessment of the current environmental status of EU waters and the environmental impact of human activities by 2012 and envisages EU Member States achieving (or maintaining) good environmental status (GES) across all European waters by 2020. In relation to fisheries, populations of commercially exploited fish and shellfish should be within safe biological limits and elements of marine food webs should occur at normal abundance and diversity. Reduction of bycatches and discarding should contribute to both objectives.

Heymans et al. (2011) modelled the deep-sea ecosystem of the Rockall area (200 miles off the west of Scotland) using Ecopath with Ecosim. They identified the lack of discard data from deepwater fisheries in the area as an important limitation and potentially a substantial source of error in the model. This emphasises the importance of having a deep knowledge and good quantification of discards throughout EU waters. This is needed to assess ecosystem status, as required for the implementation of EAFM and the MSFD. A common database of discarded species for different fishing gears and areas would provide a good starting point. Data are needed to make rational decisions, evaluate fisheries performance in relation to management objectives and fulfil regional, national and international obligations. The extent to which management objectives are achieved is assessed using indicators, which are generated from data. Appropriate indicators can be developed which measure the state of the resource, the performance of fishing controls, economic efficiency and social value (e.g. to coastal communities).

Conclusions and future directions

The history of fisheries management, like that of many human endeavours, is a tale of an increasingly detailed and sophisticated understanding of what we are doing wrong, while, on the whole, solutions are developed at a much slower pace. In the case of the EAFM, we increasingly recognize that the damage caused by fishing spreads far beyond the target fish population, and we are developing a range of metrics and indicators to quantify these negative effects and to help identify optimal states (good environmental status). However, it is arguable that (at least so far), we have been much less successful at devising management measures and governance systems that can deliver on these objectives.

There is also a common agreement that reduction of discarding will greatly benefit the health of marine ecosystems. The 'discards problem' is a key point in the EAFM. It is far from being an easy issue to solve, as it involves the 'hard core' of fishing operations, from economic, legal and biological points of view. Assuming that discards are unavoidable, the question of an acceptable level of discards has a moral dimension in addition to the more obvious biological and economic criteria (Kelleher, 2005). Additionally, the legal requirement (as under the current CFP) to carry out such an obviously wasteful practice undermines the legitimacy of the regulatory/management system. However, in spite of all these difficulties, there is a common and positive perception from all sides (citizens, NGOs, the fishing sector, policymakers, scientists, etc.) that discards are negative for all us. We all should work to find a better solution.

Of course, that desirable solution will most probably not come about implementing a few simple management measures, and it would require substantial changes in many fisheries, possibly with substantial economic consequences. Here we suggest the principles and goals that should be met to achieve a reduction of discards and finally a better and healthier marine environment as well sustainable fishing exploitation under the framework of the EAFM:

1. A better balance between fishing intensity exerted and the carrying capacity of the ecosystem: This requires, firstly, a deeper and more detailed knowledge on ecosystem dynamics, including spatial distribution, abundance patterns and fish behaviour, secondly supplementary discards-directed management measures within the EAFM framework, such as requirements to change fishing ground and real-time closures. The basic implementation principle is to regulate what is caught in the first place rather than to regulate landings.
2. Better selectivity without altering biodiversity and ecosystem functioning: Progressive introduction of discard reduction devices and encouragement to improve the selectivity of fishing gears but with a focus on maintaining the functionality of the ecosystem and the protection of vulnerable species or sizes.
3. Establishment of clear, simple and rapid indicators as fishery management tools: Ecosystems are complex and ecological indicators can help describe them in simpler terms that can be

understood and used by non-scientists to make management decisions. The use of indicators has not yet been fully developed in the context of discards and bycatch, but indices related to the species- and size-composition and amount of bycatch and discards could be useful indicators to support an EAFM.

4. Public engagement: Finally, as we commented above, (almost) everybody agrees that discarding is a bad thing. However, greater public awareness of the issues could prove to be the most crucial driver for change. Fox (1992, cited by Alverson et al., 1994) noted that aside from its economic, conservation and legal facets, discarding is a public ethics issue, the latter being the most overlooked as a driving force but undoubtedly important for the establishment of the Marine Mammal Protection Act in the USA. Cod may not be as charismatic as dolphins, but public opinion could also be crucial for success in tackling the discard and bycatch problem in Europe.

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EXHIBIT L

Fishing practice, gear design, and the ecosystem approach—three case studies demonstrating the effect of management strategy on gear selectivity and discards

Norman Graham, Richard S. T. Ferro, William A. Karp, and Philip MacMullen

Graham, N., Ferro, R. S. T., Karp, W. A., and MacMullen, P. 2007. Fishing practice, gear design, and the ecosystem approach—three case studies demonstrating the effect of management strategy on gear selectivity and discards. – ICES Journal of Marine Science, 64: 744–750.

A basic tenet of the ecosystem approach to fisheries management is that harvesting is conducted with minimal impact on juvenile fish, non-target species, and marine habitats. A range of technical modifications of fishing gears aimed at improving their selective properties is available to help achieve these goals, but their effectiveness varies. Through three case studies, we describe how management controls influence fishing behaviour and the adoption of more selective gear, and demonstrate how conservation goals can be discouraged or encouraged by the strategy. In Norway, limits set on the maximum quantity of sublegal fish that may be retained on board, in combination with a ban on discarding, resulted in substantial area closures in the Barents Sea. Therefore, to gain access, fishers developed technical modifications to enhance gear selectivity. In both shrimp and demersal trawl fisheries, the modifications are now being used by virtually the whole fleet. To reduce cod mortality in the North Sea, mesh sizes were increased and effort restrictions introduced, but the measures also affected other fleets, notably those targeting *Nephrops*: fishers for that species reduced their mesh size to prevent loss of target species and to avoid effort restrictions. Although management measures may have resulted in reduced fishing mortality on cod, they placed additional pressure on other stocks by encouraging vessels to switch gears, and it is likely that discard rates have increased. In the eastern Bering Sea fishery for walleye pollock, the adoption of more-selective fishing gears was encouraged by regulations requiring fisheries to be curtailed when bycatch rates of prohibited species are exceeded, leading to underutilization of the target species through premature closures. Fishers now act cooperatively by providing real-time data on bycatch hot spots, allowing tactical fishing decisions to be taken to avoid such areas.

Keywords: bycatch, discards, fisheries management, gear selectivity.

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Introduction

Fishers discard part of their catch for a variety of reasons, generally either for market/economic considerations or to comply with regulations. Lack of marketing opportunities, quality considerations, or large price differentials between or within species (high-grading) all induce discarding (Alverson *et al.*, 1994; Kelleher, 2005). Crean and Symes (1994) note that the management framework has a strong influence on discard rates. Fisheries that are managed extensively by output controls [such as total allowable catch (TAC) and catch composition regulations] are often characterized by high discard rates.

Discarding in multispecies fisheries may be induced by quota regulations. When the quota for one species is exhausted but opportunities remain for others, fishers sometimes continue fishing for other species and discard the first species. Similarly, regulations setting limits on percentage catch composition on board may compel fishers to discard excess catches of certain species.

Fishers are aware that regulatory discarding of marketable dead fish serves no conservation purpose. This undermines their faith in the management system and can lead to non-compliance and illegal landings. Quota-induced discarding may be reduced by restricting effort or by setting lower quota for all species caught in the mixed fishery, to protect the most vulnerable ones. However, this may result in underutilization of the target resource.

Retention of undersized fish results from a mismatch between the selectivity characteristics of the gear (specifically the legal minimum mesh size, MMS; an input control issue) and the legal minimum landing size (MLS; an output control issue). Fisheries targeting species suffering from overexploitation tend to be characterized by relatively high discard rates. Not only is the natural balance shifted towards an excess of relatively small individuals in the population, but fishers may also increasingly target smaller fish to maximize catches of fish above MLS. Increasing the mesh size under such circumstances can result in an unacceptably large loss of landings, and an incentive to reduce gear selectivity to retain as many fish above MLS as possible (Cook, 2003).

This problem is even more acute in multispecies fisheries, in which each target species has its specific MLS that may not be tuned to the size selectivity of the prescribed mesh size. The MMS permitted in the southern North Sea beam trawl fishery for sole and plaice is 80 mm. The MLS of sole (24 cm) corresponds roughly to the 50% retention length at such a mesh size, but the gear retains plaice considerably smaller than the MLS of 27 cm, resulting in high discard rates. However, a simple increase in mesh size to reduce discarding of plaice would result in considerable short-term losses of marketable sole (ICES, 2005). Sole at the MLS tend to have the greatest market value of all size grades.

It is this interplay of fishing gear, species assemblage, market demands, and the regulatory framework that influences the quantity and composition of discards produced. We discuss the influence of the regulatory framework on the type of fishing gear employed by fishers and on their strategic decisions, through three case studies.

Case 1: discard and bycatch management in Norwegian fisheries

Regulatory framework

Before 1983, technical regulations in Norwegian territorial waters were based largely on the North East Atlantic Fisheries Commission (NEAFC) management regime, a combination of MMS, MLS, and TAC regulations. Retention on board and landing of fish less than the MLS was prohibited, resulting in some discarding. During the early 1980s, the Barents Sea cod (*Gadus morhua*) stock was in poor condition, caused by an extended period of low recruitment, and a surveillance programme suggested that seasonal, spatial closures should help to protect juveniles. Such closures were introduced in 1983 along with regulations that made it obligatory to change fishing grounds if catches exceeded specified levels of certain species less than the MLS (Løbach and Veim, 1996; Huse *et al.*, 2003). In the trawl and seine fisheries for cod and haddock (*Melanogrammus aeglefinus*), the trigger was set at 15% by number, whereas in the *Pandalus* (shrimp) trawl fishery, an area closure is triggered by a varying number of cod, haddock, and redfish per tonne of *Pandalus* catch.

The year 1983 produced a strong year class of cod, and when it reached MLS, fishers started taking big catches, suggesting that the area closures and catch limits had provided significant protection to the spawning stock. A sequence of events then unfolded as a direct result of the bycatch restrictions. First, fishers began to high-grade because of the volumes of fish taken. This reduced their confidence in stock assessments, because discarding was not monitored accurately. Discarding was considered by many to constitute a waste of valuable resource and therefore to be a political issue. In 1988, a ban on discarding fish at sea was introduced, a ban that now applies to 16 species of fish and shellfish. The ban was an attempt to obtain better information on total catches (rather than landings) and to outlaw such wastage. Any fish (over quota or sublegal length) caught had to be landed and deducted from the TAC. The conservation philosophy underpinning these regulations represented a shift towards a policy directed at the fishing operation, aimed at imposing a minimum catching size, as opposed to a MLS. This sent a clear signal to those engaged in the fishery that unwanted fish should not be retained by the fishing operation before the catch was brought on board.

Opening and closing areas is effected through observers monitoring catch composition on representative commercial vessels. The process is relatively quick. Once a survey records excessively high concentrations of fish of sublegal size, the Directorate of Fisheries notifies the coastguard and the fishing industry of the closure, which can then be implemented in a matter of hours. Monitoring continues until catch rates fall below the trigger level. Vessels can also be requested to move to alternative fishing areas if their catch exceeds the composition limits determined during a coastguard inspection. Relocation must be to an area at least five nautical miles away, and if the catch composition still exceeds the bycatch limit, the vessel needs to move again.

Impact on fleet behaviour

The discard ban is broadly supported by the fishing industry, but is unlikely to protect sublegal fish to a large extent, because it does not result in a real reduction in mortality. The ban does, however, reduce unaccounted mortality, and therefore a bias in scientific assessments, although the lack of systematic collection of discard data precludes the possibility of evaluating its effect on discard rates. By requiring the landing of all fish of illegal size, the ban overcomes a contentious aspect of current EU policy that requires discarding of over-quota fish. Under the Norwegian system, all catches are counted against the quota, and the sale value is given to the marketing organization.

The introduction of area closures has had a large impact on certain fleets. Large areas in the Barents Sea have been closed because of high rates of retention of small fish and, during certain times and years, this can account for almost half the Barents Sea area. The coastal and offshore shrimp fleets have been severely affected by the small mesh size needed to retain their target species. As a consequence, fishers had a strong incentive to find technical solutions to improve species selectivity of their gear and hence to maintain access to fishing areas by complying with catch composition regulations.

Fishers from the Nordmøre region began experimenting with rigid grids inserted in their trawls. These devices allowed the passage of shrimp through the horizontal bars, while physically inhibiting the passage of larger fish that were guided up the bars and out of an escape hole inserted above the grid (Isaksen *et al.*, 1992). This development was also partly influenced by pressure from coastal gillnet and seine-net fishers, who considered shrimp fishing a "dirty" method that did damage to "their" stocks. Following the initial successes with the device, a dispensation was agreed with the Directorate of Fisheries whereby vessels were allowed to operate in closed areas under supervision. Bycatches were greatly reduced and, within a short time, most shrimp vessels were using the Nordmøre grid voluntarily. In 1993, Norwegian and Russian authorities agreed to mandate the use of the grid throughout the Barents Sea. However, when a low biomass of shrimp coincides with strong year classes of bycatch species, the rates of bycatch can still trigger temporary closures. Research, strongly supported by the fishing industry, is ongoing to improve the sorting efficiency of the Nordmøre grid. The use of this technology has spread beyond the Barents Sea and is now mandatory in all *Pandalus* fisheries in the North

Atlantic, including Canada, the USA, the Faroe Islands, Iceland, and Greenland.

Although the Nordmøre grid provided the shrimp fleet with access to considerably larger areas than before, the demersal trawl fleet still had to contend with large area closures. Following this success story, investigations started to use grid technology to improve the size selectivity of cod trawls. Simply increasing the mesh size to release sublegal fish in sufficient quantities was believed to result in the loss of substantial quantities of marketable fish, because of the large selection range of conventional diamond-mesh codends. Trials conducted in the early 1990s demonstrated that the use of fish grids improved compliance with catch composition regulations sufficiently for the authorities to allow fishers access to closed areas (Isaksen *et al.*, 1992). Consequently, more than 100 Norwegian vessels were using this grid on a voluntary basis by the mid-1990s (Løbach and Veim, 1996). The Norwegian and Russian authorities mandated its use in the entire Barents Sea in 1997.

The effectiveness of the grid and the mesh in reducing the capture of sublegal fish can be judged by comparing the minimum catch size (MCS = 47 cm) with the selectivity of the 135 mm codend and 55 mm grid. The MCS coincides approximately with the length at which a fish has a 15% probability of being retained (Jørgensen *et al.*, 2005).

Case 2: mixed whitefish/*Nephrops* fishery in the North Sea

Types of regulation

The EU *Nephrops* fishery in the North Sea is managed by three regulatory mechanisms. Output is restricted by TACs allocated annually to countries according to their historical shares. Exploitation patterns may be modified by technical conservation measures specifying gear restrictions (e.g. MMS) and MLS, and input has been controlled since 2003 by limiting days at sea by month or year.

Several distinct categories within the *Nephrops* fishery have been identified by cluster analysis of Scottish landings from the North Sea. Based on the proportion landed by weight, they vary from offshore fisheries with 35–40% *Nephrops* to clean inshore fisheries with nearly 100% *Nephrops*. The mixed fisheries have an economically important bycatch of roundfish, anglerfish (*Lophius* spp.), or flatfish, but are required to have at least 30% *Nephrops* in their catch to use mesh sizes <100 mm.

The Fladen area off northeast Scotland (which delivered some half the total North Sea landings of *Nephrops* in 2004) supports such mixed fisheries. Some vessels use a 100 mm mesh to allow for greater flexibility in their catch composition and to reduce discards. The Firth of Forth and Moray Firth support relatively clean *Nephrops* fisheries exploited with a mesh size of 80 mm. The UK fleet is subject to an MLS of 25 mm carapace length.

Historically, discarding of especially juveniles of bycatch species in the mixed fisheries has been high. Data on haddock discards (Figure 1) for two gears, *Nephrops* and whitefish light trawl, have been distorted by the very large 1999 year class, but by 2004, the proportion discarded had dropped below the level observed before 2000, suggesting a trend of improving selectivity, a change in discarding strategy in response to market conditions, poor recruitment, or a combination of some or all of these.

For cod, the proportion discarded (Figure 1) is less than for haddock because cod grow quickly through the sublegal size

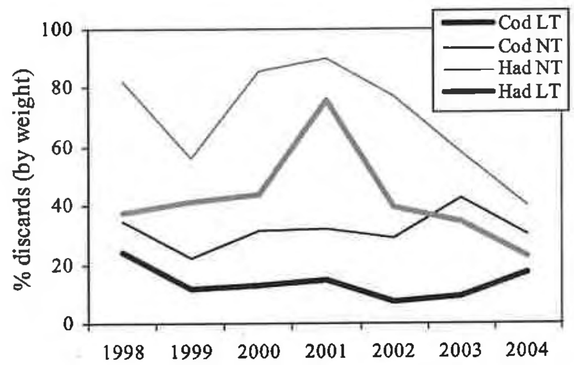

Figure 1. The percentage of the catch by weight of cod and haddock discarded in the Scottish light trawl (LT) and *Nephrops* trawl (NT) fleets operating in the North Sea, 1998–2004.

range, and fishers are less likely to highgrade cod than haddock or whiting (*Merlangius merlangus*) because of the higher price of cod even at MLS. The proportion discarded from *Nephrops* gears is again substantially greater than from light trawls, but the data reveal no major trend.

Technical conservation measures

Stock assessments indicate that North Sea *Nephrops* stocks are healthy and fluctuating about their long-term means (ICES, 2005), and protective measures have not been required. In the absence of a strong need to improve selectivity for *Nephrops*, the high level of whitefish discards has been the main driver for change in *Nephrops* gear design since the 1980s. Table 1 presents MLS, maturity, and selectivity information for cod and haddock in the inshore and offshore fisheries for two types of gear. For cod, the length at 50% maturity is well above the 50% retention length in *Nephrops* trawls of 80 mm mesh, although there is evidence that, in the past three decades, cod and haddock have matured earlier inshore where fishing pressure may have been greater (Yoneda and Wright, 2004; Wright, 2005).

Calls for action on discard levels came not only from national and EU managers, but also from the whitefish fleet, because they linked such discarding with the worsening state of their target stocks. This pressure led, in July 1991, to unilateral measures being taken by the UK. Square-mesh panels and other constraints on codend design were introduced with the aim of releasing more juvenile roundfish (haddock, whiting, cod). Gosden *et al.* (1995),

Table 1. Comparison of MLSs, lengths and age at which 50% are mature (L_{50}^{m} and A_{50}^{m}, respectively), and 50% retention length (L_{50}^{r}; from Anon., 2003, Appendix 5) of typical commercial codends currently used in the *Nephrops* and whitefish fisheries (80 and 120 mm).

Species and capture area	MLS (cm)	L_{50}^{m} (cm)	A_{50}^{m} (Y)	L_{50}^{r} (80 mm) (cm)	L_{50}^{r} (120 mm) (cm)
Cod inshore	35	36	2.7	23.4	38.8
Cod offshore	35	48	2.9	23.4	38.8
Haddock inshore	30	23.8	~2	20.9	34.7
Haddock offshore	30	27.3	~2	20.9	34.7

however, found no evidence of a reduction in discard rate resulting from these measures and suggested that the panel was not in the most effective position.

The revision of the technical regulations contained in EU Reg. 850/98 and brought into force in January 2000 did not address this issue of panel position. In the UK, industry and government agreed on additional unilateral measures to increase panel mesh size to 90 mm, and to reduce twine thickness to 4 mm single twine. In January 2002, further EU measures aimed at enhancing cod recovery were imposed on the *Nephrops* fleet. In the North Sea, MMS was increased from 70 to 80 mm, and the number of meshes around the circumference was limited to 120 for 80–89 mm mesh codends. These initiatives indicated a willingness by all parties to improve the selectivity of *Nephrops* gears.

The 2006 EU effort regulations (Reg. 51/2006) reduced the number of days at sea for the *Nephrops* fleet by ~2 per month as a further measure to limit fishing effort on cod. The North Sea Regional Advisory Council has proposed to offer an incentive in this fishery for the use of the more selective 95 mm codend (currently 80 mm) with a 120 mm square-mesh panel (currently 80 mm) in exchange for two additional days at sea per month (matching the reduction they had suffered from the previous year). The logic of this proposal was that the quota for *Nephrops* should not be curtailed (particularly because the TACs had risen), if mortality on cod could be reduced by other measures. However, the proposal was initially turned down in December 2005, partly because the information available was insufficient to quantify the effect of this new gear on cod selectivity for all EU fleets. The measure was subsequently approved at the December 2006 EU Council of Ministers meeting, and has now been incorporated into legislation.

Effect of effort management

In 2001/2002, more Scottish vessels, in particular twin-riggers in the Fladen area, started using voluntarily codends of mesh size larger than the prescribed 100 mm, to reduce discarding of whitefish. Based on information from *ad hoc* surveys of commercial codend usage, Ferro and Kynoch (2005) showed an increase in selectivity in Scottish twin-rig *Nephrops* gears during the first half of 2003. However, this improvement was short-lived because new effort regulations (EU Reg. 2341/2002) imposed a maximum of nine days at sea per month for trawlers using mesh >100 mm, whereas the 70–99 mm mesh fishery continued to be allowed almost unrestricted fishing (25 days per month). The reasoning behind this move was that the larger-mesh fishery represented the main component of cod mortality. In circumstances where cod recovery was the overriding priority, there was less need to limit effort in the smaller-mesh fisheries. At the time, the high discard rates of other species did not attract notable managerial attention. Remarkably, not only were the smaller-mesh fisheries allowed more days at sea, they were also allowed a larger bycatch limit for cod of 20% (by total volume of the catch) compared with the 5% limit for the fisheries using 120 mm mesh.

As a consequence, the twin-rig *Nephrops* trawlers changed back from >100 to 80 mm mesh to preserve their days at sea. With *Nephrops* densities high in many areas and fish quota suppressed, the incentive to highgrade and to land fish illegally increased. By comparison, management in the Skagerrak/Kattegat (EU Reg. 51/2006) encourages the use of more selective gear in the local *Nephrops* fisheries. Whereas just 103 days at sea are allowed when traditional 90–99 mm mesh gear is deployed, days at sea are unlimited if a 70–89 mm square-mesh codend and grid are used to eliminate all large whitefish. Such a regime tends to promote a clean *Nephrops* fishery, whereas the Fladen fishery remains a mixed fishery with up to 70% of the catch being other species. Maintaining viable mixed fisheries requires novel management, if multiple aims such as reducing whitefish discards and reducing mortality on marketable cod are to be met simultaneously.

Case 3: fisheries for walleye pollock in the eastern Bering Sea

Management frameworks

In Alaska, groundfish fisheries within the US EEZ are managed under two fishery management plans (FMP), one covering the Gulf of Alaska and the other the Bering Sea and Aleutian Islands (BSAI) region. In both regions, species-specific TACs for walleye pollock (*Theragra chalcogramma*) are established annually and are apportioned by season, area, and gear type. Catches (including discards) are monitored through daily observer reports and landing reports from processing plants. Heavy reliance on observer data is supported by a requirement for partial or full observer coverage (depending on vessel size). Conservation and management measures have a goal of reducing bycatch to the lowest practicable level and to minimize mortality of the bycatch if it cannot be avoided.

Bycatch is managed through a complex set of regulations including TAC set-asides to support bycatch requirements for target fisheries, as well as maximum retainable bycatch allowances that may constrain target fisheries as the overall TAC of a bycatch species is approached. Certain bycatch species are designated "prohibited species" (PSC), and this includes all salmonids harvested in the region, Pacific halibut (*Hippoglossus hippoglossus*), and commercially important species of crab. Retention of PSC is prohibited, and regulations require fisheries to be curtailed or relocated when the bycatch of these species exceeds specified levels.

The target fishery for walleye pollock in the BSAI is among the largest single-species fisheries in the world, the annual catch exceeding 1 million tonnes since the mid-1980s (Ianelli *et al.*, 2005). All fishing is conducted by trawlers. The fleet includes catcher vessels (CVs) delivering their catches to onshore or floating processor plants, and catcher/processors (CPs) processing their catches at sea. Although bycatch rates in the fishery have always been relatively low, small percentages can represent large quantities. The North Pacific Fishery Management Council (NPFMC) has taken several actions during the past decade to reduce bycatch.

We consider three factors (management measures and/or operational developments) that have influenced the efficiency of the fishery for walleye pollock in the BSAI and contributed to overall reductions in bycatch.

Progression from non-pelagic/pelagic to pelagic-only trawl gear

Historically, walleye pollock were harvested with non-pelagic (demersal) and pelagic trawls. Demersal fishing, however, had been discouraged to reduce bycatch and impact on the seafloor. Before implementation of the requirement to harvest pollock with pelagic gear (BSAI FMP Amendment 57), the National Marine Fisheries Service (NMFS) twice allocated the TAC among pelagic and non-pelagic gear types: once in the early 1990s, and again in 1999 when the entire pollock TAC was allocated to pelagic gear in anticipation of the approval of

Amendment 57. The NMFS, however, had terminated the temporal use of non-pelagic trawls on many occasions when PSC limits for crab and halibut were exceeded. During the 1990s, these limits were decreased, encouraging the fleet to adopt pelagic trawling (NPFMC, 2000). Therefore, although all directed fishing for pollock with non-pelagic gear was finally banned, earlier management action had encouraged a steady progression towards this goal.

To discourage deploying pelagic gear on the seabed, regulations implementing Amendment 57 limit the number of crab on board at any time; fishing on-bottom is not expressly prohibited.

Pollock and cod discard restrictions

In January 1998, Amendment 75 of the BSAI FMP was implemented. This required all vessels fishing for groundfish to retain all pollock and Pacific cod (*G. macrocephalus*), and to establish minimum standards of utilization, prohibiting codend bleeding (releasing fish into the water from the codend before the net is brought on board) or at-sea discarding of cod.

American Fisheries Act

The American Fisheries Act (AFA) of 1998 mandated significant changes in management of the BSAI fishery for walleye pollock. After setting aside a portion of the pollock TAC for the community development quota programme (requiring a proportion of the TAC for each groundfish species to be allocated to specified Alaska Native Communities under Federal Regulations) and for bycatch needs in the non-pollock groundfish fisheries, the regulations divided the remaining quota among three sectors. Within each sector, fishery cooperatives were established.

As a direct result of AFA implementation, the fleets consolidated, and latent capacity was reduced. Moreover, elimination of the race for fish encouraged the fleet to work collectively on strategies to reduce bycatch, especially in situations where high bycatch levels might restrict fishing opportunities or otherwise increase the costs associated with harvesting. Cooperative and inter-cooperative agreements allowed the fleet to respond collectively and effectively to challenges, such as the implementation of strategies to comply with mitigation measures related to the listing of the Steller sea lion (*Eumetopias jubatus*) and a programme that curtails fishing in areas when salmon bycatch rates are excessive (Karp *et al.*, 2005).

It is important to realize that the regulatory environment is complex and that this constrains our ability to establish cause-and-effect relationships between specific management actions and changes in fishing behaviour and catch composition.

Changes in target and bycatch composition

We examined changes in catch and bycatch composition for a group of 20 CPs that have remained active in the fishery since 1990. Although some differences in performance of the CV and CP components of the fleet are likely, overall trends are similar. Overall catch and catch composition is available for all years, but information on the species composition of discards has only been collected since 1997.

The progression from a two-gear to a one-gear fishery in terms of catch composition is illustrated in Figure 2a. Cleaner pollock catches are easier to achieve with pelagic gear, and the proportion of bycatch in non-pelagic gear varied markedly among years. Also, the proportion of bycatch taken by pelagic gear decreased steadily and levelled off at <2% post-2000.

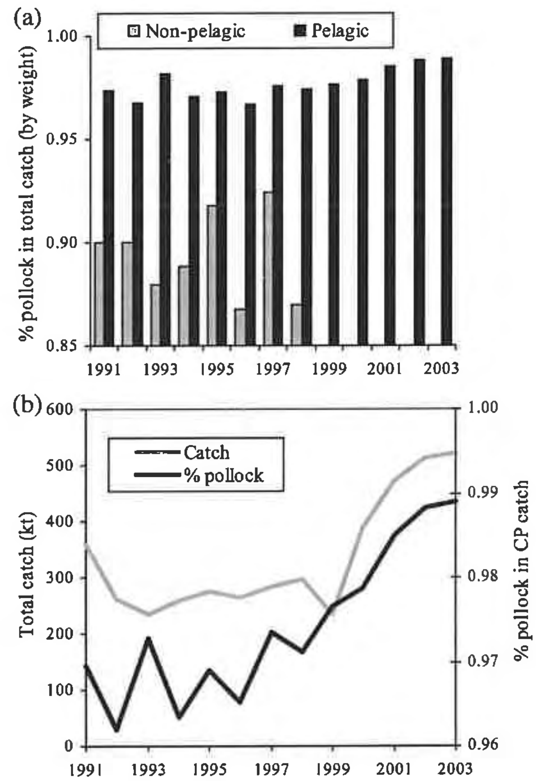

Figure 2. Eastern Bering Sea fishery for walleye pollock: (a) percentage of pollock in aggregate annual catches during targeted hauls of 20 CPs using pelagic gear or non-pelagic gear; (b) total pollock catch and the percentage of pollock caught during targeted hauls of 20 CPs.

Discards of pollock in this directed fishery have decreased steadily since 1997. Between 1997 and 1998, the discard rate for pollock dropped from 3.7 to 0.9%, with small reductions every year. Discards of Pacific cod taken in the fishery declined markedly between 1997 and 1998 (11.7 to 6.8%) and steadily since then (dropping to 0.4% by 2003). During the same period, the total catch of pollock taken by this group of CPs increased steadily (Figure 2b). Bycatch has decreased markedly since 1999, although overall catches have continued to increase. Non-pelagic trawling was prohibited after 1998.

Discussion

The Norwegian and Alaskan case studies present clear examples that restrictions on commercial practice provided incentives for fishers to accept the use of more-selective gears. Both countries also implemented discard bans (or full retention) and bycatch management plans. Regulatory authorities provided rules that determined whether fishing was permissible based on predetermined "acceptable" bycatch proportions, whether consisting of fish below minimum size or bycatch species. In Norway, the system of temporarily closing areas coupled with minimum catch-composition restrictions had the greatest influence on fishers' behaviour and the uptake of more-selective fishing technologies.

Alaskan fishers voluntarily reduced their reliance on demersal trawling, and changed their fishing patterns to stay within the regulatory boundaries. Clearly, the incentive was the prospective closure of highly productive pollock fishing areas when salmon bycatch thresholds were reached. The result is an industry-managed programme that shares bycatch information collected by observers and enforces agreements within and between cooperatives, requiring vessels to avoid areas with a high salmonid bycatch (Gauvin *et al.*, 1996; Karp *et al.*, 2005; Gilman *et al.*, 2006).

In both cases, the industry was faced with choosing between the lesser of two evils: alter strategy and adopt more selective fishing techniques or face the underutilization of resources and substantial economic losses. When managers eventually mandated the use of more selective gears, implementation was facilitated because industry had been closely involved in the formulation of the solutions.

The reduction in mesh size associated with the North Sea mixed fish/*Nephrops* fleet probably could have been avoided if they had not been subjected to regulatory controls aimed at another fleet, which happened to use the same mesh size. This implies that the categories used for defining fleets were too crude. Therefore, it was not possible to distinguish between the two, or at least to manage the two independently.

There is a need to improve the selective characteristics of the fleets targeting *Nephrops*, because the correlation between codend mesh size and minimum fish size is poor (Graham and Ferro, 2004). CEC (2004) suggests that by either adjusting MLS to match selectivity or, conversely, adjusting MMS to better reflect MLS, there could be a solution to reducing discarding. Unfortunately, the latter is not practical in multifleet fisheries where different mesh sizes are used, because this would require a different MLS for each fleet segment. Readjusting an MMS to an MLS may be suitable in some cases, but not if a small mesh size is needed to retain an important catch component. Therefore, there is a need in mixed fisheries to improve selectivity by use of mechanisms in addition to codend mesh size.

Could the Alaskan and Norwegian approaches be utilized to encourage fishers to use better techniques that would result in a reduction of discards and catches of species in need of protection? In cases where fishers know where and when to fish with low discarding of bycatch, specified bycatch limits and observers appear to be management measures, particularly where discarding is relatively infrequent at known times of year. However, if catch composition cannot be predicted with certainty, the use of species-separating gears may be the only option. Where the target species is sufficiently abundant to provide an economic return by itself, the solution may be to create a clean, single-species fishery by designing a gear that lets most bycatch species escape. If the bycatch is an essential component of the landings, a gear must be developed to separate the key species or groups of species so that appropriate selection mechanisms can be applied to each. Although a gear-design solution is unlikely to be 100% effective, it may be more acceptable to fishers than closure of large areas of traditional fishing grounds, and therefore raise less opposition. Regulations can specify the obligatory use of a gear in the area as an alternative to closure.

The use of bycatch quota, or caps, to limit fishing mortality generally depends on the availability of high-resolution, real-time data. However, the cost-effectiveness of observer schemes depends on fleet structure. Covering the North Sea fleets is unlikely to be feasible, because they include a large number of relatively small vessels. The Norwegian system of protecting juvenile fish relies on catch monitoring, but not on full observer coverage. It may be possible to introduce such systems into EU fisheries because a monitoring framework is already in place. Under the EU data-collection regulations (EC 1639/2001, amended by EC 1581/2004), member states are obliged to monitor the rate of discarding in all commercial fisheries. The data are currently used principally for assessment purposes, to provide better estimates of population parameters. A modified scheme could identify the degree of discarding on an appropriate spatial and temporal scale, and by fleet. Monitoring of commercial catches in these sensitive areas could then be used as a mechanism to trigger area closures, as was done in Norway.

Adopting the principle of temporary area closures allows fishery management to become less prescriptive and more incentive-based. Complex legislation specifying detailed construction characteristics of gears might be substituted by suitable triggers for closure, and a range of specified gears may be described in a more general sense to comply with output measures. The use of output measures is common in other industries, such as those generating industrial pollution. In a fisheries context, enforcement agencies monitor the catch composition rather than the gear, and determine whether target levels are met. Gear technologists could assist with the development and formal testing of gears under commercial conditions, fostering science/industry collaboration and promoting the commercial uptake of the gear.

Realistically, fisheries exploiting a limited number of species, such as the Alaskan and Norwegian examples, are more amenable to this approach than fisheries in which many of the species caught represent an economic return and the mix is highly variable. In such cases, a more pragmatic approach is called for, perhaps defining catch limits on just a few key species and providing economic incentives to encourage the use of more-selective fishing techniques. Investigations of economic incentives have been limited and tended to focus on the transfer of techniques, such as game theory to model and predict fisher or fleet behaviours in response to changing circumstances (Kennedy and Pasternak, 1991; Krawczyk and Tolwinski, 1993; Mazalov and Rettieva, 2003). At a microlevel, consideration has been given to access rights, tax incentives, and grant assistance. Detailed investigations of the incentives driving the behaviour of real fishers (as opposed to model fishers) are also rare, but they do reveal relevant information (MacMullen, 1998; Anon., 2002).

Anon. (2002) studied 26 métiers in fishing areas southwest of the UK, in an effort to understand the factors motivating fishers to target and retain, or discard, certain species, and to relate this to the prevailing management and market conditions. Among the findings was that discarding practices were most closely related to economic values, and that there were clear incidences where these economic influences were stronger than those of fishery regulations. Sometimes fish smaller than the MLS were retained because of good local market demand, and in other cases, fish greater than the MLS were discarded because of low demand for certain size grades. When the MLS was decreased for one species, one fleet immediately retained fish that matched the new legal size, whereas another, working on the same grounds, did not. Although both ultimately supplied the same customers, the latter fleet worked through a market that paid only an "all in" price and penalized the landing of smaller fish. By plotting retention lengths by crew members sorting on deck against market prices, it was clear that individual fishers exercised judgements based on market value and subsequent labour requirements. When skippers or mates were also on deck, the behaviour changed.

Anon. (2002) concluded that, in most cases studied, economic influences were paramount and efforts to reduce discarding that failed to take these influences into account were unlikely to be successful. Economic factors also influenced fishers' perceptions of which stocks were priorities for conservation. A pragmatic interpretation of these observations should also take into account the points raised above. Many métiers studied by Anon. (2002) were not subject to any systematic observer regime at sea, and often very little at the point of landing. Even where this was the case, relatively weak sanctions and a lack of incentives produced behaviour that typically sought short-term economic advantage over any consideration of longer-term advantage.

All three case studies demonstrate that maximizing fishing opportunities within specified constraints tends to be a more powerful incentive to fishers than medium- to long-term aims of improving sustainability. That is not to say that such goals are unimportant, but ensuring short-term economic viability tends to override longer-term aims. Therefore, the tendency to maintain fishing opportunities has to be linked with the longer-term aim of improving sustainability through reducing discards and/or bycatch. In the first instance, it is necessary to define the limits of the quantities of fish of sublegal size or bycatches that are acceptable. It is also necessary to shift the monitoring, surveillance, and control onus from landings to catches. By providing the correct incentives and defining realistic targets, it should be possible to reduce unwanted bycatch and discards.

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REVIEW

Are coastal habitats important nurseries? A meta-analysis

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Abstract

Nearshore-structured habitats—including underwater grasses, mangroves, coral, and other biogenic reefs, marshes, and complex abiotic substrates—have long been postulated to function as important nurseries for juvenile fishes and invertebrates. Here, we review the evolution of the "nursery habitat hypothesis" and use >11,000 comparisons from 160 peer-reviewed studies to test whether and which structured habitats increase juvenile density, growth, and survival. In general, almost all structured habitats significantly enhanced juvenile density—and in some cases growth and survival—relative to unstructured habitats. Underwater grasses and mangroves also promoted juvenile density and growth beyond what was observed in other structured habitats. These conclusions were robust to variation among studies, although there were significant differences with latitude and among some phyla. Our results confirm the basic nursery function of certain structured habitats, which lends further support to their conservation, restoration, and management at a time when our coastal environments are becoming increasingly impacted. They also reveal a dearth of evidence from many other systems (e.g., kelp forests) and for responses other than density. Although recent studies have advocated for increasingly complex approaches to evaluating nurseries, we recommend a renewed emphasis on more straightforward assessments of juvenile growth, survival, reproduction, and recruitment.

KEYWORDS
coral reef, density, growth, juvenile, mangrove, marsh, seagrass, survival

1 | INTRODUCTION

A defining feature of all shallow waters of coastal and estuarine regions throughout the world is the presence of one or more structured habitats. These habitats range from foundational autotrophs (seagrasses, mangroves, marshes, other submersed vegetation—including tidal freshwater plants—and macroalgae/kelps) to coral reefs and other animal-derived structures (oysters, mussels, sponges) to abiotic substrates (rock crevices, shell hash, cobble). They are considered "structured" because they have complex three-dimensional shapes that protrude above the benthos compared to unstructured habitats, such as sand and mud, which provide only a relatively flat, two-dimensional surface. Structured habitats are economically and ecologically important to the regions they occupy: they directly or indirectly provide a variety of ecosystem services including carbon sequestration, shoreline protection, nutrient cycling, food products, disease prevention, and recreation (Barbier et al., 2011; Costanza et al., 1997). Perhaps the most cited function of all is as a nursery in which juveniles of numerous species of vertebrates and invertebrates can grow and mature before migrating elsewhere as adults.

The formal conceptualization of a nursery habitat was first proposed by Beck et al. (2001) who clarified that a habitat should be considered a nursery for juveniles if their density, growth, survival, and/or movement to adult habitats is, on average, greater than in other habitats. A series of quantitative meta-analyses testing this new definition quickly followed for seagrasses (Heck, Hays, & Orth, 2003), salt marshes (Minello, Able, Weinstein, & Hays, 2003), and mangroves (Sheridan & Hays 2003). These showed that juvenile density, growth, and survival were indeed higher in structured habitats than unstructured ones, particularly seagrasses. At the time, there were few tests of recruitment to adult populations, but a contemporaneous review of juvenile dispersal potential suggested that this process is highly variable, with juveniles moving anywhere from 10^{-1} to 10^{6} m to reach their adult habitats (Gillanders, Able, Brown, Eggleston, & Sheridan, 2003). More critically, the study by Gillanders et al. (2003) reinforced the idea that, while juvenile and adult habitats can and often do overlap, nurseries should reflect only a subset of potential adult habitats. In other words, a habitat cannot be considered a nursery if a species utilizes it exclusively throughout their entire life history: in this case, the "nursery" would simply be known as its habitat (Beck et al., 2001).

With emerging information on the complex life history strategies of certain species and the multiple interactions that occur during their ontogenetic development to their adult phase, it became clear that the original definition of Beck et al. (2001) required additional nuance. Dahlgren et al. (2006) argued that earlier work ignored habitats that may contribute relatively fewer individuals to the adult population, but are nonetheless critical to maintaining the population, particularly in years of high variability in juvenile recruitment (Kraus & Secor 2005). Dahlgren et al. (2006) thus proposed the "effective juvenile habitat" (EJH), which recognizes the absolute value of certain habitats regardless of their per unit area contributions. A reply by Sheaves, Baker, and Johnston (2006), however, cautioned that the EJH approach was also too simplistic and, like Beck et al. (2001), did not consider the effects of scale, complexity, connectivity, resource availability, and other biotic and abiotic processes occurring within and between habitats, and further did not address reproductive output other than total number of adult recruits. Fodrie, Levin, and Lucas (2009) likewise stressed population growth as a more representative metric of the nursery function of certain habitats.

A penultimate review by Sheaves (2009) formalized the idea that multiple habitats, with all their inherent processes, tightly link to form the "coastal ecosystem mosaic," and this mosaic more than any particular habitat is critical to maintaining the overall nursery function of coastal areas. Multiple habitats, he argued, are necessary to accommodate the varied life histories of organisms, from larva to adult, as well as food web dynamics, differing resources, and abiotic forcing, all of which are central to the growth, survival, and eventual recruitment of juveniles. This idea finally led to the marriage of the principles of the nursery function to landscape ecology to produce the concept of the "seascape nursery" (Boström, Pittman, Simenstad, & Kneib, 2011; Litvin, Weinstein, Sheaves, & Nagelkerken, 2018; Nagelkerken, Sheaves, Baker, & Connolly, 2015). This modern view considers all stages of the life history of an individual, including transient settlement in formerly unrecognized habitats, ascribing each to "hotspots" and establishing migration corridors that connect juvenile and adult populations.

The evolution of this nursery habitat hypothesis, as originally defined by Beck et al. (2001), has occurred rapidly and stimulated considerable reflection and refinement on what constitutes a nursery. At the same time, researchers have been empirically testing this hypothesis both in the field and laboratory. Two synthetic analyses have updated the earlier suite of quantitative reviews (Heck et al., 2003; Minello et al., 2003; Sheridan & Hays 2003) to include more recent studies. First, Igulu et al. (2014) summarized 14 studies testing the use of mangroves, seagrasses, and coral reefs by juvenile fishes, showing that while structured habitats supported higher densities of fauna than coral reefs, abiotic properties such as tidal amplitude and salinity played a much larger role than habitat per se in defining juvenile properties. McDevitt-Irwin, Iacarella, and Baum (2016) analyzed 51 papers focusing only on seagrasses and showed that—like Heck et al. (2003) before—seagrass habitat supported higher densities and increased growth of juveniles relative to bare sediment or other structured habitats. Moreover, these effects were stronger in temperate than in subtropical regions, and more important for invertebrates than for fishes.

Despite the considerable conceptual advances made to the nursery habitat hypothesis over the past two decades—and substantial effort by many state, federal and international organizations to protect and restore many of these important structured habitats in part on the basis of their nursery function—most empirical tests have reported on the three juvenile attributes originally proposed by Beck et al. (2001): density, growth, and survival. With repeated calls for scaling-up to seascape-level investigations, we find it valuable to first assess the current body of evidence that has accumulated since Beck et al. (2001) to see whether their original and simpler definition has been satisfactorily addressed. To that end, we conducted a search of the peer-reviewed literature and identified 160 studies on the role of structured habitats in promoting juvenile performance. We then applied formal meta-analysis to provide the most comprehensive test of the nursery habitat hypothesis to date. Our goals were to assess the strength of evidence for coastal habitats as nurseries based on all available data, and to determine the degree to which empirical tests have or have not kept up with the evolution of the nursery concept in the past several decades.

2 | METHODS

We adhered to the PRISMA standard for meta-analysis reporting (Moher et al., 2009). A flowchart of the evaluation process and PRISMA checklist are available in the Supporting Information. We performed a Google Scholar search on October 3, 2016, using the following search string:

> *(nurser* OR "habitat complex*" OR EJH OR "effective juvenile habitat" OR "structural* complex*") AND (marine OR estuar* OR coast* OR nearshore OR seascape OR seagrass* OR SAV OR mangrove* OR marsh* OR saltmarsh* OR wetland* OR reef* OR macroalga* OR kelp* OR macrophyte* OR lagoon* OR brackish) AND (juvenile* OR recruit* OR post-larva* OR post-settle* OR sub-adult* OR young OR YOY OR anadromous OR age-0 OR natal OR pup OR fry OR fingerling OR smelt) AND (growth OR surviv* OR recruit* OR densit* OR abundance* OR product* OR movement OR connect* OR emigrat* OR migrat*)*

The initial search returned 2,607 abstracts from peer-reviewed journals. We conducted an additional forward search on Beck et al. (2001), which yielded 527 additional unique abstracts. We also added 50 unique abstracts from two recent reviews (McDevitt-Irwin et al., 2016; Nagelkerken, 2009;) for a total of 3,184 abstracts.

To be included in our analysis, a study must have: (a) tested the role of structure relative to an unstructured control or other structured habitat (i.e., the study had to be comparative); (b) identified at least one habitat as a potential "nursery"; (c) not included artificial habitats (e.g., bulkheads, shipwrecks); (d) explicitly stated that at least one of the organisms considered were juveniles; and (e) reported a quantitative measure of performance such as density, growth, etc. If both juvenile and adults were censused, we chose only responses pertaining to juveniles. If studies reported aggregate measures (e.g., total community abundance) but did not discriminate among juveniles and adults, we excluded them from our analysis.

Assessment was conducted by two separate evaluators: if both agreed, the study was retained for further consideration; if both disagreed, the study was rejected; and if there was no consensus, the study was reviewed in committee until a decision was reached. Of the 3,184 initial abstracts, 2,900 were rejected for not meeting our initial criteria based on content in the abstract. We then obtained copies of the 284 remaining references and conducted a second round of evaluation based on the content of the entire paper, of which 123 were deemed unsuitable (Table S1). Our final list for data extraction included 160 references from the peer-reviewed literature.

Means/sums/proportions, sample sizes, and standard deviations (when reported) were extracted from text, figures, or tables presented in the main text or Supporting Information. For graphical presentations, we used the Measure Tool in Adobe PDF Reader (Adobe Systems, Inc.) to estimate the data points. We also collected metadata on the location, experimental design, abiotic environment (e.g., salinity regime), habitat type and their characteristics, response type and units, and characteristics of the response organisms (e.g., taxonomy, trophic group), when reported.

To analyze the response data, we used the log response ratio, hereafter *LRR* (Hedges, Gurevitch, & Curtis, 1999). The *LRR* is computed as follows:

$$LRR = \ln\left(\frac{\overline{X_T}}{\overline{X_C}}\right), \quad (1)$$

where $\overline{X_T}$ is the mean value of a response in one habitat and $\overline{X_C}$ is the mean of the same response in the comparison habitat. These comparisons were only conducted within the same species, in the same treatment, in the same study. Unlike other estimates of effect size, the *LRR* does not require information about the variance of the observations. As we encountered many situations in which variance was not reported or was not estimable (e.g., survival, total density), the *LRR* is the only meta-analytical metric that can harness the full power of our dataset. However, to test the robustness of our conclusions to our choice of metric, we computed several additional effect sizes that do incorporate sampling variance into their calculations: Hedges' *d* (Hedges & Olkin 1985) and bias-adjusted LRR^{Δ} and LRR^{Σ} (Lajeunesse, 2015; see Supporting Information).

We conducted two analyses of the raw data: in the first, we focused only on structured versus unstructured habitats (e.g., submersed aquatic vegetation [SAV] vs. bare sand). In the second, we compared structured against other structured habitats (e.g., SAV vs. mangroves). In both cases, we computed the mean $\overline{LRR}$ for each response category (density, growth, and survival) as the average of individual *LRR*s ± 1 standard error of the mean. We also computed the inverse variance-weighted and sample size weighted *LRR*s (when reported) to assess how the precision of each study influenced our overall conclusions (Hedges et al., 1999). Finally, we performed several tests of bias and sensitivity (see Supporting Information).

We used a modeling approach to identify the important predictors of the structured versus unstructured *LRR*s. For each response category (density, growth, survival), we fit a general linear mixed effects model using the *nlme* package (Pinheiro, Bates, DebRoy, & Sarkar, 2017) in R version 3.5.0 (R Core Team 2017) including the following fixed effects:

$$LRR_{ij} \sim \alpha_{ij} + \text{Habitat} + \text{Salinity Regime} + \text{Latitude} + \text{Trophic Level} + \text{Lab or Field} + \varepsilon_{ij}, \quad (2)$$

where LRR_{ij} is the *i*th observation in the *j*th study. We also allowed the intercept α to vary randomly by study *j* to account for any variation arising from being within a particular study:

$$\alpha_j \sim \alpha_0 + b_0 u_j + \eta_j. \quad (3)$$

For the model of density *LRR*s, we included the additional fixed effect of phylum, which could not be fit for the other responses due to model convergence errors arising from lack of representation in certain phyla. We obtained and plotted the model-estimated partial means for each level of each covariate using the *effects* package (Fox, 2003).

3 | RESULTS

Our final dataset included 160 studies spanning the years 1986–2016 and 11,236 total comparisons for the final analysis. Studies were distributed among six continents but concentrated in North America and Europe (Figures 1A and S1). Studies overwhelmingly reported on juvenile density (e.g., abundance, biomass, etc. per unit area), although a smaller number reported on growth and survival (Figure 1B). No studies reporting on recruitment met our criteria for inclusion, despite being one of the original response variables identified by Beck et al. (2001). Almost all studies reported on data from an unstructured control, and most studies also included SAV (including marine and freshwater grasses) as a structured comparison (Figure 1C). Mangroves, coral reefs, marshes, macroalgae (including both drift and turf), and other biogenic reefs (including oysters, mussels, and sponges) were also represented, while abiotic habitats (such as rubble and shell) and kelp forests (distinguished from macroalgae by the original authors) reported the fewest tests (Figure 1C). Studies considered largely carnivores and omnivores, with a fewer number of studies considering exclusively herbivores or mixed assemblages (Figure 1C). Taxonomically, ray-finned fishes were overwhelmingly represented (85% of all measurements), with fewer values reported for crustaceans (14%), gastropods (1%), and sharks and rays (<1%).

Compared to unstructured habitats, juvenile density was enhanced by the presence of SAV, mangroves, coral reefs, other biogenic reefs, and rubble or shell hash, with macroalgae having no effect and kelp being slightly worse than the unstructured habitat (Figure 2). SAV also enhanced growth and survival, whereas most other structured habitats revealed no significant effect (Figure 2). Exceptions included rubble, shell, and rock, which significantly enhanced growth, and macroalgae, and biogenic reefs, which additionally enhanced survival (Figure 2). We note that the values for many habitats, including biogenic reefs, kelps, and abiotic substrates, reflect averages over only 3–10 independent studies, and thus should be interpreted with caution relative to better represented habitats such as SAV. Regardless of sample size, however, within-study variance tended to be consistent and low across studies (Figure S2).

When we repeated our analysis using Hedges' *d* as our effect size, we observed equivalent or stronger effects: all habitats, for example, significantly enhanced juvenile density, and most enhanced growth and survival (Figure S3). We note, however, that these averages were derived from the 54% of studies that reported sample variances, which may explain deviations from the larger analysis (Figure 2). Similarly, weighting the *LRR* by the inverse of the variance or sample size (Figures S4 and S5), and adjusting the *LRR* for additional sampling bias using the methods in Lajeunesse (2015; Figures S6 and S7), revealed nearly identical trends to the main analysis. Thus, for the studies reporting variances, there appeared to be no systematic bias introduced by low precision or low replication relative to the entire dataset.

Although SAV consistently and generally enhanced density, growth, and survival relative to an unstructured control, it was generally inferior to mangroves (Figure 3). However, SAV did enhance juvenile densities beyond those observed in coral reef, marsh, and macroalgal habitats (Figure 3). In turn, coral reefs also significantly increased juvenile density relative to macroalgae. There was little difference among the habitats in effects on growth or survival, except for coral reefs, which had somewhat greater juvenile growth compared to SAV, mangroves, or macroalgae (Figure 3). Due to low sample sizes, comparisons to other structured habitats were omitted (e.g., rubble, rock). Nearly identical trends were observed for Hedges' *d* and variants of the *LRR* (Figures S8–S10), with the exception of macroalgae being slightly better than coral reefs for juvenile density.

The modeling results revealed few significant predictors for the *LRR* of structure versus no structure for any of the response categories (Table 1). The major exception was habitat, for which we have already described the major differences (Figure 2). One of the few other significant predictors was a positive relationship between latitude and juvenile density, with a stronger effect of structured habitats at higher latitudes (Figure 4). Similarly, there were slightly higher benefits of structured habitats for arthropod invertebrates than for vertebrates, primarily Actinopterygian fishes (Figure 5). Otherwise, there was remarkable consistency in the expected

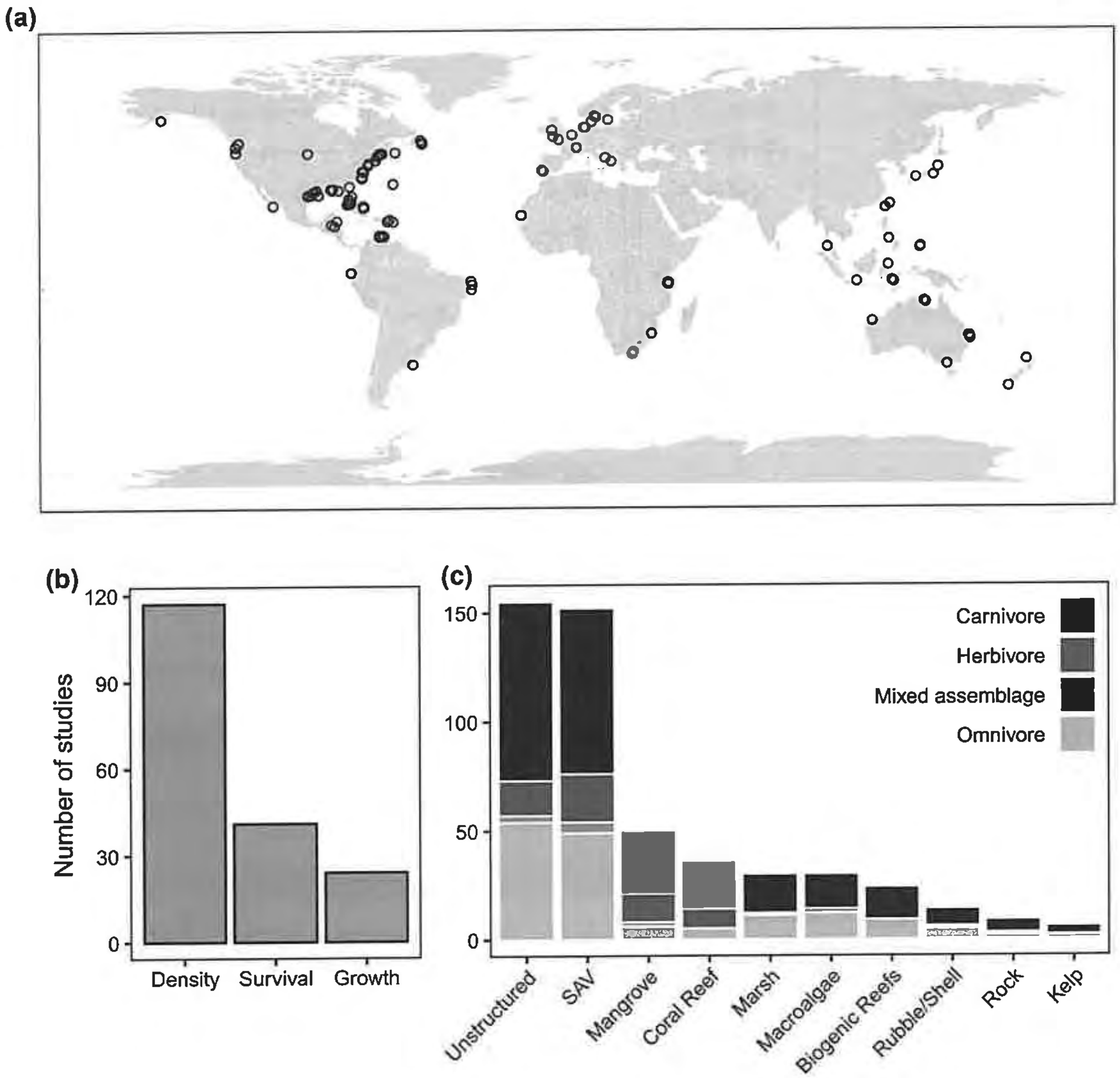

FIGURE 1 (a) Geographic distribution of 160 studies used in the final meta-analysis. (b) The number of studies reporting on each of the three juvenile attributes (density, growth, and survival). (c) The number of studies reporting on different habitats, and the trophic composition within each habitat

effect sizes by trophic level, salinity regime, and whether studies were conducted in the laboratory or field (Table 1 and Figure 5).

4 | DISCUSSION

In our meta-analysis of 160 published articles, we found substantial evidence for the role of structured habitats in enhancing the density, growth, and survival of juvenile fishes and invertebrates. There were, however, differences among habitats in both magnitude of the effect size and degree of support. SAV (including marine and freshwater grasses), for example, had 3× more tests than the next most studied habitat (Figure 1) . Consequently, studies incorporating SAV yielded unequivocal support for the role of this habitat in increasing all three responses variables relative to unstructured habitats (Figures 2 and S3–S7). When compared to other structured habitats, SAV was superior to all habitats other than mangroves (Figures 3 and S8–S10). Thus, based on available evidence, SAV and mangroves appear to confer the greatest nursery benefits, a result that is consistent with several prior syntheses (Heck et al., 2003; Igulu et al., 2014; McDevitt-Irwin et al., 2016).

The next most important structured habitat after SAV and mangroves was coral reefs (Figures 2 and 3). Historically, coral reefs have been ignored as potential nurseries: neither the Beck et al. (2001) paper nor any of the early synthesis efforts considered coral reefs, presumably because, for most fishes, the reef also functions as the final adult habitat. Yet, a handful of studies around the same time showed that shallow coral reefs supported equivalent or higher juvenile

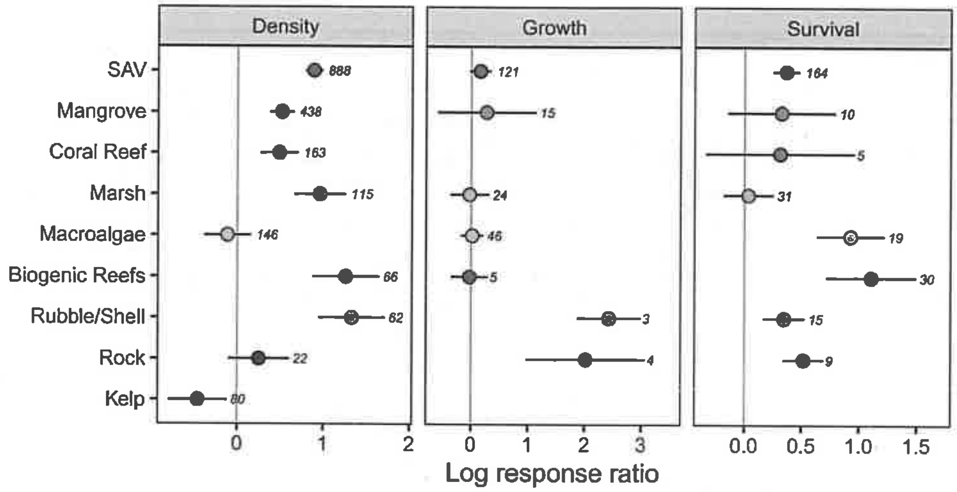

FIGURE 2 Log response ratios (*LRRs*) comparing each structured habitat (*y*-axis) to the unstructured control (e.g., bare sediment). Values are grand means ±95% confidence intervals. Values >0 indicate a positive effect of structure on density, growth, or survival, and values <0 indicate a negative effect of structure on those properties. The number of comparisons is given next to each point

TABLE 1 Analysis of variance (ANOVA) results from general linear mixed effects models predicting the log response ratio of structured versus unstructured habitats

Response	Predictor	Num. *df*	Denom. *df*	*F*-value	*p*-Value
Density	Intercept	1	1,863	58.951	<.001***
Density	Structured habitat	8	1,863	16.717	<.001***
Density	Salinity	2	1,863	0.686	.504
Density	Latitude	1	1,863	8.059	.005**
Density	Trophic level	2	1,863	0.791	.454
Density	Phylum	2	1,863	3.392	.034*
Density	Lab/field	1	1,863	0.111	.739
Growth	Intercept	1	189	4.420	.037*
Growth	Structured habitat	6	189	4.622	<.001***
Growth	Salinity	1	189	1.986	.160
Growth	Latitude	1	189	0.677	.412
Growth	Trophic level	2	17	1.160	.337
Growth	Lab/field	1	189	0.022	.883
Survival	Intercept	1	241	24.166	<.001***
Survival	Structured habitat	7	241	1.323	.240
Survival	Salinity	2	28	0.049	.952
Survival	Latitude	1	28	0.140	.711
Survival	Trophic level	2	28	0.134	.875
Survival	Lab/field	1	28	0.020	.888

Significant predictors are indicated with asterisks (*$.05 > p \geq .01$;**$.01 > p \geq .001$;***$p < .001$).

densities than other habitats such as SAV and mangroves (Nagelkerken et al., 2000, 2002). Several later studies also supported this assertion (Dorenbosch et al., 2004; Eggleston et al., 2004; Kimirei et al., 2011), even showing that density and growth was greater on coral reefs than in other structured habitats (Grol et al., 2008; Tupper, 2007). Such studies might otherwise be excluded under the definition of Beck et al. (2001) due to reef also serving as the adult habitat, except that many fishes appear to partition their use of different subhabitats on the reef throughout their development. For example, several common reef fishes utilize the shallow back reef before migrating to the deeper fore reef as adults (Adams & Ebersole 2002; Nagelkerken et al., 2000).

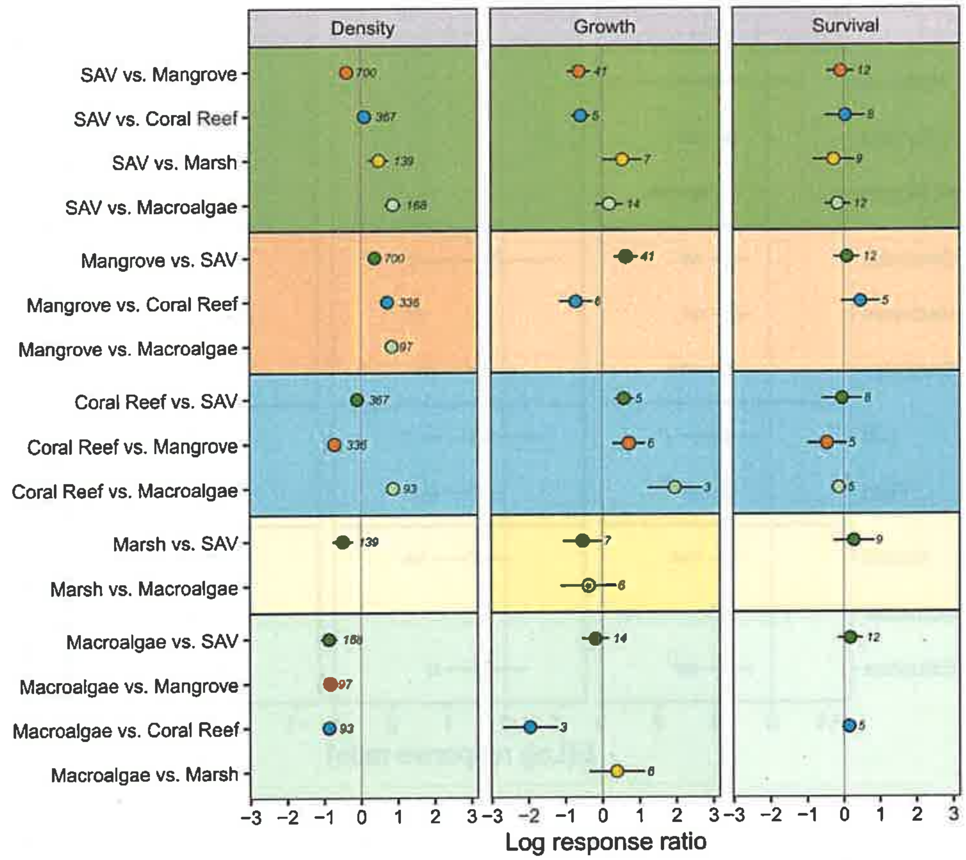

FIGURE 3 Log response ratios comparing each structured habitat to another structured habitat. Values are means ±95% confidence intervals. Values >0 indicate higher performance in the first habitat, while values <0 indicate higher performance in the second habitat. The number of comparisons is given next to each point

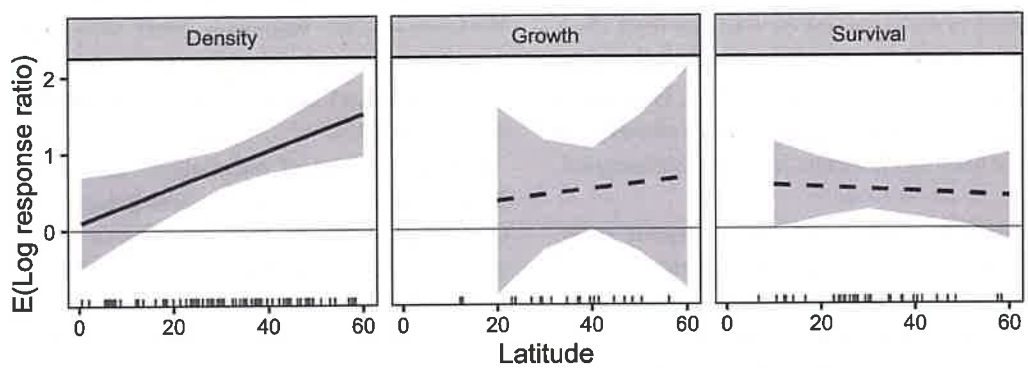

FIGURE 4 The model-estimated (expected) log response ratio as a function of latitude for each of the juvenile response categories. Estimates are (partial) predicted fits ±95% confidence intervals and account for the other covariates in the model. The significant fits are given in solid lines, while dashed lines reflect nonsignificant relationships ($p > .05$). Rug plots along the x-axis reflect the distribution of raw observations

This notion of "subhabitats" complicates the identification of coral reefs as a nursery per se, as a fine understanding of each species' ontogenetic habitat requirements is required. Indeed, many coral reef fishes have complex life cycles, such as those in the families Haemulidae, Lutjanidae, and Serranidae, which utilize different habitats throughout their juvenile development (e.g., seagrass → mangroves → coral reef) or even different subhabitats within those habitats (e.g., coral or rubble embedded within seagrass beds; reviewed in Adams et al., 2006). Similar life histories are also present in other systems such as the ontogenic shift of bay scallops from the seagrass canopy to the benthos at a certain size (Thayer & Stuart 1974). Although our data support the notion that coral reefs can enhance juvenile densities, they were most often invoked

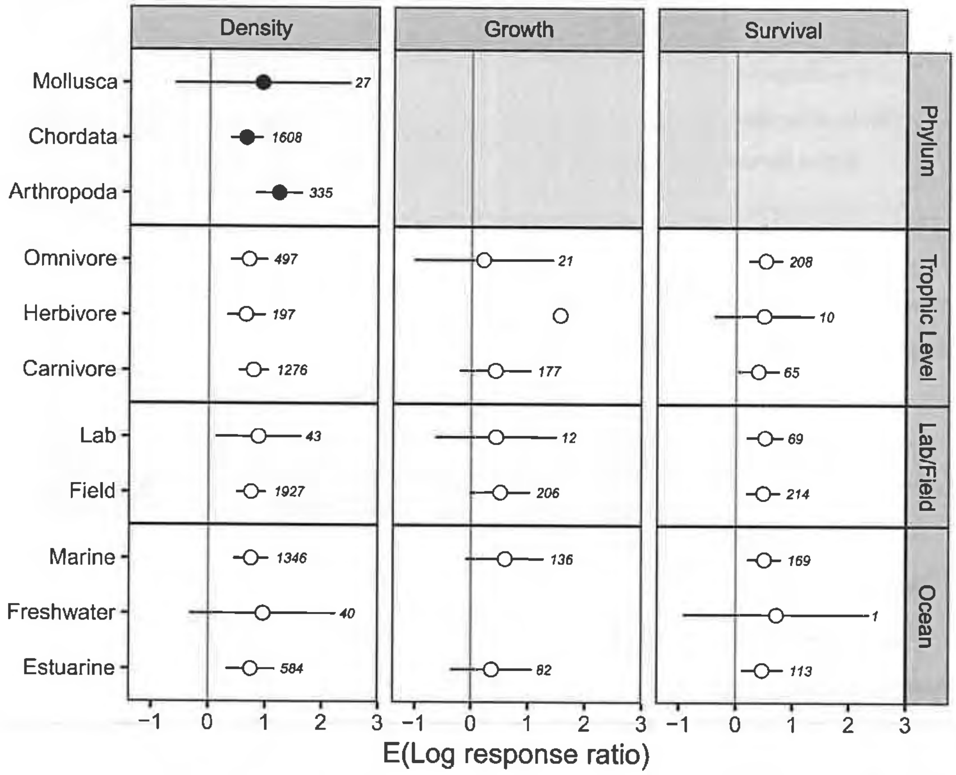

FIGURE 5 The model-estimated (expected) log response ratio as a function of various predictors for each of the juvenile response categories. Estimates are (partial) predicted means ±95% confidence intervals and account for the other covariates in the model. The significant ($p < .05$) covariates are filled in black. Sample sizes are given next to each point

as the "control" case to ensure that juvenile and adult densities were not conflated. On the other hand, coral reefs are among the most complex three-dimensional coastal habitats and thus should not be treated in the same way as sand and mud. Continued exploration of when and how coral reefs function as nurseries, with a particular focus on subhabitats, is a crucial frontier, and may prove analogous to differences observed in edge versus interior habitats (Boström, Jackson, & Simenstad, 2006).

Other coastal habitats, such as marshes, biogenic reefs, and rubble and shell hash, also appear important in our dataset, although they had many fewer tests than SAV or mangroves (Figures 2 and 3). The trends, however, are promising: biogenic reefs and shell/rubble had the strongest effect sizes relative to unstructured controls (Figures 2 and S3–S7), but reduced sample sizes precluded testing them relative to other habitats. Oyster reefs in particular were highlighted by Beck et al. (2001) for needing further research, and although it appears there has been some progress, many more tests are required to generate evidence on par with that of SAV beds. Macroalgae, which includes both upright seaweeds and turf-forming algae, appeared no better than bare substrate, perhaps owing to both high spatial and temporal variance in habitat complexity afforded by their different forms (especially drift macroalgae) and the relatively low sample size. In some cases, macroalgae also reflected an undesirable or degraded state after eutrophication or climate shifts (Aburto-Oropeza, Sala, Paredes, Mendoza, & Ballesteros, 2007; Wennhage, 2002; Wennhage & Pihl 1994), or as an alternative habitat after the preferred habitat had been severely reduced, such as SAV in Chesapeake Bay (Johnston & Lipcius 2012).

Kelps, a subset of macroalgae, appeared to be the only habitat that was worse for juveniles than even bare substrate (Figure 2), although this inference is based on only four studies in the Gulf of Maine (Lazzari, 2008, 2013; Lazzari & Stone 2006; Lazzari, Sherman, & Kanwit, 2003). This result may reflect region-specific patterns in foundational species composition—these four studies consider only laminarian kelps—but also a community-level perspective that obscured responses by individual species. For example, the Atlantic cod *Gadus morhua* tended to have higher densities in kelps (Lazzari, 2013), but its signal was negated, on average, by a diversity of other species. Thus, kelps provide a critical reminder that species of particular commercial interest, such as cod, may require a less community-oriented perspective when evaluating their association with potential nurseries. Although previous work has also demonstrated the benefits of kelp for juvenile fishes (Anderson, 1994; Carr, 1989), these studies were not comparative (often focusing on differing complexities within kelp habitat), and thus were not suitable for inclusion in our analysis. Future efforts in kelp forests should therefore adopt a comparative approach.

Beyond habitat differences, we found very little variation in the effect size of structured versus unstructured habitat as a function of trophic level, laboratory versus field studies, and salinity regime (Table 1). The two notable exceptions were effects of latitude and phyla on density, both of which have been observed previously. The increasing effect of structured habitats on juvenile density with increasing latitude was most recently reported in the meta-analysis by McDevitt-Irwin et al. (2016) in which they proposed the availability of alternative nurseries in tropical regions could explain the weaker effects of seagrass habitat. Removing SAV comparisons from the dataset yielded a nonsignificant effect of latitude ($p = .063$), indicating that this trend in our analysis was also driven primarily by SAV. An alternative but not mutually exclusive explanation might be the paradigm of decreasing predation with increasing latitude (Schemske, Mittelbach, Cornell, Sobel, & Roy, 2009), which leads to higher juvenile survival and increased densities in temperate regions, as has been shown recently in a global comparative seagrass experiment (Reynolds et al., 2017).

Like McDevitt-Irwin et al. (2016) and Minello et al. (2003), we also found a stronger effect of habitat on some invertebrates (arthropods) than vertebrates (Actinopterygian fishes). They attributed these patterns to the greater availability of food resources for invertebrates in seagrass habitats. Invertebrates may also benefit from the vertical structure: higher habitats leave benthic invertebrates less exposed to predators. In our case, the simplest explanation may be mobility: invertebrates are less mobile, especially as they transition to their adult phase (Gillanders et al., 2003), and thus depend more on structure to both hide from predators and provide food. In contrast, juvenile fishes can forage more broadly within a habitat and move to other, more suitable habitats to avoid predation. Invertebrates were also 6× less represented than vertebrates in our dataset, which may have also contributed to the observed difference between the two.

There are undoubtedly many other factors that mediate the nursery function but could not be tested in our dataset. We relied on the authors of the original publications to supply information on such variables, but unfortunately these were not consistently reported enough to support rigorous analysis (see Supporting Information). A recent meta-analysis also suggested that abiotic conditions can greatly influence the nursery function of coastal habitats (Igulu et al., 2014), and other reviews of nurseries along the Northeast Pacific (Hughes et al., 2014) and Northeast Atlantic coasts (Brown et al., 2018) found that numerous human-induced stressors can pose a risk to the nursery function (Toft et al., 2018). To date, however, explicit examples of nursery impairment due to anthropogenic or other environmental factors are rare and should be considered as an important next step for nursery research.

Our study has several implications for conservation and management. First, of the 315 organisms identified to species in our dataset, 230 are considered commercially fished or farmed somewhere in the world according to Food and Agriculture Organization of the United Nations (http://www.fao.org/fishery/collection/asfis/en): 215 fishes, 14 crustaceans (mostly Penaeid shrimps), and 1 gastropod (the queen conch *Strombus gigas*). Although many species were undoubtedly targeted by the original authors specifically because they are of interest to fisheries, this statistic underlies the key role coastal systems play in supporting coastal economies. For example, a recent global analysis revealed that the nursery value of seagrass meadows may account for one fifth of the world's largest 25 fisheries (Unsworth, Nordlund, & Cullen-Unsworth, 2018). Moreover, five species in our dataset are considered "threatened" by the IUCN (http://www.iucnredlist.org/), four are "endangered," and one is listed as "critically endangered" (the European eel, *Anguilla anguilla*, in Polte & Asmus 2006). Although such organisms are, by definition, rare, their inclusion in 13 studies does suggest that nursery habitats can sometimes serve as refuge for juveniles of vulnerable marine species.

Second, our comparative analysis may provide justification for the prioritization of resources toward certain habitats. SAV, for example, provided the greatest benefit to unstructured controls (Figure 2), but was generally inferior to mangroves in cases where only the two were compared (Figure 3). Similarly, SAV conferred greater nursery benefits relative to other temperate habitats, such as marshes and macroalgae, which also happen to be regions where SAV loss is most prominent (Waycott et al., 2009). Thus, maintenance of SAV might be prioritized in temperate areas or in cases where fragmentation or conversion to unvegetated substrate is underway, but less so in tropical regions where SAV and mangroves still coexist.

Finally, despite its prominence in Beck et al. (2001), no study in our 30-year dataset reported on measures of recruitment in a systematic, comparative manner that allowed for inclusion in our analysis. This result likely stems from the historical difficulties in linking adult populations with their juvenile origins, although new techniques—such as stable isotopes (Herzka, 2005), otolith microchemistry (Gillanders, 2005; Gillanders & Kingsford 2000), and environmental or eDNA—may provide some solutions. Yet, the concept of the "nursery habitat" has accelerated to consider the interaction between multiple habitats, the abiotic environment, and human impacts in driving recruitment over increasingly larger temporal and spatial scales (Litvin et al., 2018; Nagelkerken et al., 2015; Sheaves, 2009).

Inarguably, the "seascape nursery" provides the most realistic perspective on the functioning of coastal nurseries.

However, this reality can be sobering and potentially discouraging to managers, especially those in developing countries where the funds to study and unravel multifaceted relationships are limited or nonexistent. Even in the United States, where resources are comparatively very high, a focus on the complexity of the relationship between fish and habitat has arguably not benefited management. The difficulty in managing for increasing realism may be best illustrated in the application of the "Essential Fish Habitat" (EFH) policy. In theory, the EFH concept aimed to clearly prioritize a few key places and habitats. In practice, nearly everywhere was identified as "essential" to some species at some time in their life history, which is to say that there were few to no priority areas identified (Fluharty, 2013; Meissner, German, Aiken, & Wolter, 2000). In contrast, relatively simple characterizations of juvenile success captured in our analysis show a clear and consistent hierarchy in the importance of different habitats for juveniles across a range of locations and taxa.

Although we far from discourage investigations of the multifaceted and complex function of coastal systems, the utility of the original definition by Beck et al. (2001) lies in its simplicity and generality, and the clarity that it provides for prioritization of efforts by resources managers and conservation practitioners. The lack of tests in many habitats for response variables such as growth and survival, no suitable tests of recruitment from any nursery habitat, and overwhelming focus on vertebrate fishes indicate that there is still considerable progress to be made at a fundamental level before advancing to more realistic, and therefore more complicated and challenging, investigations. Thus, we propose that, where the resources exist to adopt a seascape-level perspective, researchers should strive to link these simple measures of density, growth, and survival across space and time to new estimates of adult recruitment, and further test how these relationships change under different scenarios of global change. In places where resources are scarce or in underrepresented habitats, the simpler approach advocated by Beck et al. (2001) can establish a stronger foundation and, beyond that, relevant information for managers. Given that almost all coastal habitats are under threat from human activities, tests of the nursery function—at any level—are critical in protecting this essential service. Our quantitative analysis is the next iteration in empirically validating the most basic tenets of the nursery habitat hypothesis, but there is still much more to be done to reveal and confirm the nursery benefit provided by coastal ecosystems.

ACKNOWLEDGMENTS

We thank Luke Bassett for his assistance in evaluating the original abstracts. ARS and BBH were supported by David H. Smith Conservation Research Fellowships. This is VIMS contribution nos. 3774 and 29 from the Smithsonian's MarineGEO Network.

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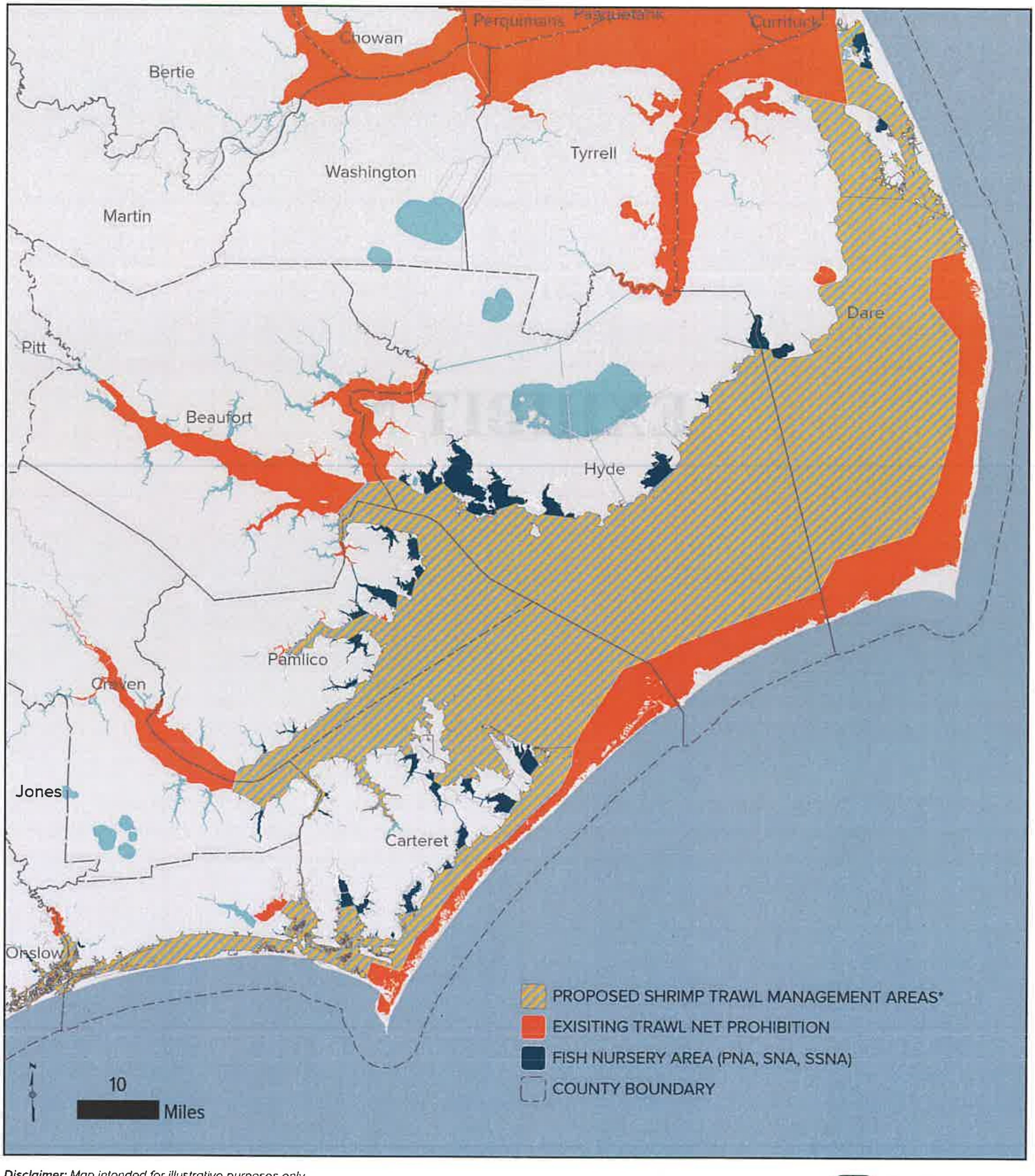
SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Lefcheck JS, Hughes BB, Johnson AJ, et al. Are coastal habitats important nurseries? A meta-analysis. *Conservation Letters*. 2019;e12645. https://doi.org/10.1111/conl.12645

EXHIBIT N

Proposed Shrimp Trawl Management Areas
15A N.C. Admin. Code 3R .0119 (proposed)



Disclaimer: *Map intended for illustrative purposes only.*
** = Coastal Waters described in Descriptive Boundaries for Coastal-Joint-Inland Waters (15A N.C. Admin. Code 03Q .0202), and not currently classified as Primary Nursery Areas (15A N.C. Admin. Code 03R .0103), Secondary Nursery Areas (15A N.C. Admin. Code 03R .0104), Special Secondary Nursery Areas (15A N.C. Admin. Code 03R .0105), Trawl Net Prohibited Areas (15A N.C. Admin. Code 03R .0106), or Shrimp Trawl Prohibited Areas (15A N.C. Admin. Code 03R .0114). Also, Albemarle Sound, Currituck Sound, and their tributaries (15A N.C. Admin. Code 3J .0104(b)(3)).*
Data Sources: DEQ-DMF; US Census Bureau | Map created by Jovian Sackett (jsackett@selcnc.org). Last updated 5/20/2019.

Southern Environmental Law Center

Chairman's Report

NORTH CAROLINA MARINE FISHERIES COMMISSION
DEPARTMENT OF ENVIRONMENTAL QUALITY

June 24, 2019

Roger Bullock
Deputy Chief of Operations
Chief of Navigation Branch
District Diving Coordinator
USACE Wilmington District
69 Darlington Ave.
Wilmington, NC 28403

Dear Mr.Bullock:

It has come to the attention of the North Carolina Marine Fisheries Commission that the channel to and through Barden's Inlet at Cape Lookout will no longer be maintained.

This inlet plays an important role with the optimum utilization of the area's public trust resources. Tourism, commercial and recreational fishing, boating, etc., will be unfairly impacted by the lack of maintenance of this channel, ultimately stopping the access and use of the area. Also Barden's inlet provides a safe passage from the ocean to the sound in times of unexpected bad weather, one I have even used on occasion.

I hope that you will reconsider your decision and maintain the inlet and its channel for the enjoyment and safety of the American boater.

Sincerely,

W. Robert Bizzell, Chairman
N.C Marine Fisheries Commission

NORTH CAROLINA MARINE FISHERIES COMMISSION
DEPARTMENT OF ENVIRONMENTAL QUALITY

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

ROB BIZZELL
Chairman

June 24, 2019

Officer in Charge
USCG ANT
Fort Macon Road
Atlantic Beach, NC 28512

Dear Officer in Charge:

It has come to the attention of the North Carolina Marine Fisheries Commission that the channel to and through Barden's Inlet at Cape Lookout will no longer be maintained.

This inlet plays an important role with the optimum utilization of the area's public trust resources. Tourism, commercial and recreational fishing, boating, etc., will be unfairly impacted by the lack of maintenance of this channel, ultimately stopping the access and use of the area. Also Barden's inlet provides a safe passage from the ocean to the sound in times of unexpected bad weather, one I have even used on occasion.

I hope that you will reconsider your decision and maintain the inlet and its channel for the enjoyment and safety of the American boater.

Sincerely,

W. Robert Bizzell, Chairman
N.C Marine Fisheries Commission

U.S Department of Homeland Security
United States Coast Guard

Officer in Charge
United States Coast Guard
Aids to Navigation Team Fort Macon

Phone (252) 240-8440
Email: Chris.r.winters@uscg.mil

3531
July 16, 2019

North Carolina Department of Environmental Quality
Attn: Chairman Bizzell
Division of Marine Fisheries
PO Box 769, Morehead City, NC 28557

Dear Chairman Bizzell:

Thank you for your letter regarding the Coast Guard's proposal to remove several aids to navigation in vicinity of Barden's Inlet. This proposal was driven by survey data provided by the U.S. Army Corps of Engineers (USACE) from July 2018. This survey indicated the channel was shoaled in two places to an extent that it was unsafe for navigation and too shallow for our vessels to service the aids to navigation.

The USACE re-surveyed the area again in May 2019, enabling us to better assess the current condition of the waterway. The new survey indicated a reduction in shoaling, making the waterway viable for navigation up to Buoy 24. The area beyond this point is still heavily shoaled in and the markers in this stretch of the channel were previously removed or converted to danger beacons in October 2016.

The Coast Guard has decided to leave the markers in place from the inlet to Buoy 24, allowing access to the lighthouse and some of the old channel. If the channel deteriorates again, we will re-evaluate at that time. There is no fully marked federal channel from the inlet to Back Sound, which has been the case since 2016.

The Coast Guard's role in the maintenance of channels is limited. We are able to provide navigation markers in the form of buoys and fixed piles as long as waterway conditions remain stable and navigable. For federal channels, the USACE is the entity charged with dredging and maintaining the available depths of water. In the case of Barden Inlet, the National Park Service (NPS) has an interest in keeping access to Cape Lookout National Seashore open.

The NPS, USACE and Carteret County are working together to secure funds and environmental approvals to dredge areas that are currently shoaled. Aids to Navigation Team Fort Macon remains committed to marking safe, navigable waterways for use by the boating public.

Sincerely,

C. R. WINTERS, BMC
Officer in Charge
U. S. Coast Guard

Copy: Sector North Carolina, District 5 (dpw)

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

NORTH CAROLINA
Environmental Quality

June 17, 2019

Senator Phil Berger and Representative Tim Moore, Co-Chairs
Joint Legislative Commission on Governmental Operations
North Carolina General Assembly
Legislative Building
16 West Jones Street
Raleigh, NC 27601

RE: Draft Southern Flounder Fishery Management Plan Amendment 2

Dear Senator Berger and Representative Moore:

The draft North Carolina Southern Flounder Fishery Management Plan Amendment 2 was submitted to me by the North Carolina Marine Fisheries Commission for review. North Carolina General Statute 113-182.1(e) requires that once I review any proposed fishery management plan, I report that plan to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources. The committee then has 30 days to submit comments and recommendations to me on the proposed plan. Additionally, G.S. 113-182.1(c1) requires the department to review any comment or recommendation regarding a plan that a regional advisory committee submits to the department before submission of a plan to the Joint Legislative Commission on Governmental Operations.

The amendment is located at http://portal.ncdenr.org/web/mf/southern-flounder-topic and an overview of the plan is enclosed for your convenience. While not formally provided for in statute, if your commission has comments or recommendations on the proposed plan, please send them to me within 30 days of the date of this letter.

Thank you for your assistance in this matter. Please contact Department of Environmental Quality Legislative Affairs Director Joy Hicks at 919-707-8618 or Division of Marine Fisheries Director Steve Murphey at 252-808-8013 if you have any questions.

Sincerely,

Michael S. Regan
Secretary

MSR:cb

Enclosure
cc: North Carolina Marine Fisheries Commission
Joy Hicks, Department of Environmental Quality Legislative Affairs Director
Steve Murphey, Division of Marine Fisheries Director

§ 113-182.1. Fishery Management Plans.

(a) The Department shall prepare proposed Fishery Management Plans for adoption by the Marine Fisheries Commission for all commercially or recreationally significant species or fisheries that comprise State marine or estuarine resources. Proposed Fishery Management Plans shall be developed in accordance with the Priority List, Schedule, and guidance criteria established by the Marine Fisheries Commission under G.S. 143B-289.52.

(b) The goal of the plans shall be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Each plan shall be designed to reflect fishing practices so that one plan may apply to a specific fishery, while other plans may be based on gear or geographic areas. Each plan shall:

(1) Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of relevant fish stocks, stock assessments for multiyear species, fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans adopted pursuant to G.S. 143B-279.8, social and economic impact of the fishery to the State, and user conflicts.

(2) Recommend management actions pertaining to the fishery or fisheries.

(3) Include conservation and management measures that will provide the greatest overall benefit to the State, particularly with respect to food production, recreational opportunities, and the protection of marine ecosystems, and that will produce a sustainable harvest.

(4) Repealed by Session Laws 2010-13, s. 1, effective June 23, 2010.

(5) Specify a time period, not to exceed two years from the date of the adoption of the plan, to end overfishing. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.

(6) Specify a time period, not to exceed 10 years from the date of the adoption of the plan, for achieving a sustainable harvest. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.

(7) Include a standard of at least fifty percent (50%) probability of achieving sustainable harvest for the fishery or fisheries. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.

(c) To assist in the development of each Fishery Management Plan, the Chair of the Marine Fisheries Commission shall appoint a fishery management plan advisory committee. Each fishery management plan advisory committee shall be composed of commercial fishermen, recreational fishermen, and scientists, all with expertise in the fishery for which the Fishery Management Plan is being developed.

(c1) The Department shall consult with the regional advisory committees established pursuant to G.S. 143B-289.57(e) regarding the preparation of each Fishery Management Plan. Before submission of a plan for review by the Joint Legislative Commission on Governmental Operations, the Department shall review any comment or recommendation regarding the plan that a regional advisory committee submits to the Department within the time limits established in the Schedule for the development and adoption of Fishery Management Plans established by G.S. 143B-289.52. Before the Commission adopts a management measure to implement a plan, the Commission shall review any comment or recommendation regarding the management measure that a regional advisory committee submits to the Commission.

(d) Each Fishery Management Plan shall be reviewed at least once every five years. The Marine Fisheries Commission may revise the Priority List and guidance criteria whenever it determines that a revision of the Priority List or guidance criteria will facilitate or improve the development of Fishery Management Plans or is necessary to restore, conserve, or protect the marine and estuarine resources of the State. The Marine Fisheries Commission may not revise the Schedule for the development of a Fishery Management Plan, once adopted, without the approval of the Secretary of Environmental Quality.

(e) The Secretary of Environmental Quality shall monitor progress in the development and adoption of Fishery Management Plans in relation to the Schedule for development and adoption of the plans established by the Marine Fisheries Commission. The Secretary of Environmental Quality shall report to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources and the Fiscal Research Division within 30 days of the completion or substantial revision of each proposed Fishery Management Plan. The Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources shall review each proposed Fishery Management Plan within 30 days of the date the proposed Plan is submitted by the Secretary. The Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources may submit comments and recommendations on the proposed Plan to the Secretary within 30 days of the date the proposed Plan is submitted by the Secretary.

(e1) If the Secretary determines that it is in the interest of the long-term viability of a fishery, the Secretary may authorize the Commission to develop temporary management measures to supplement an existing Fishery Management Plan pursuant to this subsection. Development of temporary management measures pursuant to this subsection is exempt from subsections (c), (c1), and (e) of this section and the Priority List, Schedule, and guidance criteria established by the Marine Fisheries Commission under G.S. 143B-289.52. During the next review period for a Fishery Management Plan supplemented pursuant to this subsection, the Commission shall either incorporate the temporary management measures into the revised Fishery Management Plan or the temporary management measures shall expire on the date the revised Fishery Management Plan is adopted.

(f) The Marine Fisheries Commission shall adopt rules to implement Fishery Management Plans in accordance with Chapter 150B of the General Statutes.

(g) To achieve sustainable harvest under a Fishery Management Plan, the Marine Fisheries Commission may include in the Plan a recommendation that the General Assembly limit the number of fishermen authorized to participate in the fishery. The Commission may recommend that the General Assembly limit participation in a fishery only if the Commission determines that sustainable harvest cannot otherwise be achieved. In determining whether to recommend that the General Assembly limit participation in a fishery, the Commission shall consider all of the following factors:

(1) Current participation in and dependence on the fishery.
(2) Past fishing practices in the fishery.
(3) Economics of the fishery.
(4) Capability of fishing vessels used in the fishery to engage in other fisheries.
(5) Cultural and social factors relevant to the fishery and any affected fishing communities.
(6) Capacity of the fishery to support biological parameters.
(7) Equitable resolution of competing social and economic interests.

(8) Any other relevant considerations. (1997-400, s. 3.4; 1997-443, s. 11A.119(b); 1998-212, s. 14.3; 1998-225, s. 2.1; 2001-213, s. 1; 2001-452, s. 2.1; 2004-160, ss. 3, 4; 2007-495, ss. 6, 7; 2010-13, s. 1; 2010-15, s. 1; 2011-291, ss. 2.27, 2.28; 2012-201, s. 1; 2013-360, s. 14.8(r); 2015-241, s. 14.30(v); 2015-286, s. 4.12(b); 2017-57, s. 14.1(d).)

Division of Marine Fisheries' Overview of Amendment 2 to the Southern Flounder Fishery Management Plan June 2019

Issue

The draft Southern Flounder Fishery Management Plan (FMP) Amendment 2 containing the Department of Environmental Quality, Division of Marine Fisheries, FMP Advisory Committee, and Southern, Northern, and Finfish advisory committee positions was presented to the N.C. Marine Fisheries Commission at its special meeting June 6, 2019 for selection of its preferred management strategies. In addition, public comment received from May 23 through June 3, 2019 was provided in a summarized format. The division and advisory committees developed management measures for the commission's consideration to meet statutory requirements to achieve a sustainable harvest* in the southern flounder fishery, to end overfishing by 2021, and rebuild the spawning stock biomass* (SSB) by 2028.

Findings

- The most recent coast-wide stock assessment determined the stock* is overfished* and overfishing* is occurring.
- Reductions in **total coast-wide removals*** are necessary to end overfishing within two years and recover the stock from an overfished state within a 10-year period.
- To reach the fishing mortality* (*F*) threshold* and end overfishing, a 31% reduction in total coast-wide removals is necessary, while a 51% reduction is necessary to reach the fishing mortality target*. Neither of these levels of reduction would rebuild the spawning stock biomass (SSB) by 2028.
- For the SSB to reach the threshold by 2028 and end the overfished status a 52% reduction in total coast-wide removals will be required. To reach the SSB target by 2028 a 72% reduction in total coast-wide removals will be required.
- Static quota, dynamic quota, slot limits, changes in the size limits, gear changes related to size limit changes, and species-specific management are not considered feasible options to address sustainable harvest in draft Amendment 2 due to the accelerated timeline and the need to implement management measures before the fall 2019 fishing season.

Overview

Southern flounder is a commercially and recreationally important fishery currently managed under Amendment 1 and Supplement A to Amendment 1, as modified by the Aug. 17, 2017 settlement agreement, of the N.C. Southern Flounder FMP.

Amendment 2 Goal and Objectives

The goal and objectives for draft Amendment 2 to the N.C. Southern Flounder FMP were reviewed and approved by the commission at its May 17, 2019 business meeting. The goal and objectives for the FMP are:

Goal
Manage the southern flounder fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision-making processes. The following objectives will be used to achieve this goal.

Objectives
1. Implement management strategies within North Carolina and encourage interjurisdictional management strategies that maintain/restore the southern flounder spawning stock with multiple cohorts and adequate abundance to prevent recruitment overfishing.
2. Restore, enhance, and protect habitat and environmental quality necessary to maintain or increase growth, survival, and reproduction of the southern flounder population.
3. Use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the southern flounder fishery and its ecosystem impacts.
4. Promote stewardship of the resource through increased public awareness and interjurisdictional cooperation throughout the species range regarding the status and management of the southern flounder fishery, including practices that minimize bycatch and discard mortality.

Stock Assessment
Southern flounder is assessed as a single biological unit stock occurring from North Carolina through the east coast of Florida. Based on life history information, a multi-state cooperative group performed a stock assessment with a terminal year* of 2017 that determined the stock is overfished and overfishing is occurring.

- The stock assessment estimated biological reference points of $F_{35\%}$ (fishing mortality target) as 0.35 and $F_{25\%}$ (fishing mortality threshold) as 0.53. Estimated F in the terminal year of 2017 is 0.91, which is higher than the threshold and indicates overfishing is occurring.
- The stock assessment estimated an SSB target of 5,452 metric tons (approximately 12.0 million pounds) and threshold of 3,900 metric tons (approximately 8.6 million pounds). Estimated SSB in the terminal year of 2017 is 1,031 metric tons (approximately 2.3 million pounds), which is lower than the threshold and indicates the stock is overfished.

Statutory Requirements
North Carolina General Statute 113-182.1 mandates that fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving a sustainable harvest, and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute 113-129 as "the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished."

In accordance with North Carolina General Statute 143B-289.52(e1) a supermajority of the commission shall be six members. A supermajority shall be necessary to override recommendations from the Division of Marine Fisheries regarding measures needed to end overfishing or to rebuild overfished stocks.

Projections
To meet statutory requirements, calculations were made to determine reductions in total coast-wide removals necessary to end overfishing within the two-year period and recover the stock from an

overfished state within the 10-year period. These projections estimate necessary changes to *F* when compared to the 2017 terminal year fishing mortality estimates identified in the stock assessment. In addition, the projections assumed management would start in 2019 and so the 10-year rebuilding period would need to be met by 2028.

Projections assume all four states implement measures for the reductions required to rebuild SSB. In addition, projections detailing changes in SSB assume the shrimp trawl fleet removals will continue in all scenarios. However, the partial moratorium projection also assumes no removals from the commercial or recreational fisheries, whereas less restrictive scenarios account for the specified volume of removals including harvest and dead discards. These projections provide a mathematically optimistic rebuilding schedule for SSB and are unlikely to be fully achieved given the disparity of regulating commercial and recreational gear removals and without comparable management action from the other southeastern states. For further information on the interjurisdictional nature of this species, please see the *Interjurisdictional Management* sub-section found in Section VI, Management Strategies for Sustainable Harvest of Draft Amendment 2.

To reach the fishing mortality threshold and end overfishing, a 31% reduction in total removals is necessary, while a 51% reduction is necessary to reach the fishing mortality target. However, while both of these reductions are sufficient to end overfishing in two years, neither are sufficient to achieve a sustainable harvest and end the overfished status within the 10-year period.

To reach the SSB threshold and end the overfished status by 2028, as is statutorily required, a fishing mortality of 0.34 achieved via a 52% reduction in total removals is needed. To reach the SSB target by 2028, fishing mortality would need to be lowered to 0.18 by reducing total removals by 72%. All projections are associated with at least a 50% probability of success. Both scenarios for rebuilding SSB meet the requirement to end overfishing in two years.

The projections are based on coast-wide reductions (North Carolina to Florida) necessary for coast-wide rebuilding. However, in developing necessary management measures, the division has applied the reductions for total removals only to North Carolina's portion. To do this, the percent reduction was applied to the total removals for North Carolina from the 2017 terminal year of the assessment. In North Carolina, the commercial fishery accounted for 71.8% of the total removals in pounds while the recreational fishery total removals (from hook-and-line and gigs) accounted for 28.2% in 2017. In addition, commercial removals that occurred through means of "other gears," those non-targeted flounder gear such as fyke nets, crab pots, and trawls are subtracted from the total removals prior to analysis. The impacts from these other gears are approximately 0.6% of the overall removals. While draft Amendment 2 will not impact other states' removals, continued cooperation among the state agencies involved with the stock assessment and their willingness to enact management measures to rebuild the stock within their jurisdictional boundaries is of the upmost importance for the stock.

Proposed Management Options

The list of proposed management options, including the positives and negatives for each option, can be found in Section VII, Proposed Management Options of draft Amendment 2. Department and Division recommendations are in ***bolded italicized*** font below, and additional information on these recommendations can be found in Section VIII, Recommendations of Draft Amendment 2. The FMP advisory committee recommendations are summarized below and found in Section VIII, Recommendations of Draft Amendment 2.

The Department and the Division recognize that these reductions are significant but necessary to increase the probability of successfully rebuilding this important recreational and commercial resource.

Commercial Fishery Options

A. Establish seasonal closures by area for the commercial fishery to reduce *F* to the fishing mortality threshold (31% reduction)
B. Establish seasonal closures by area for the commercial fishery to reduce *F* and allow the SSB to rebuild to the threshold (52% reduction)
C. Establish seasonal closures by area for the commercial fishery to increase SSB between the threshold and target (62% reduction)
D. Establish seasonal closures by area for the commercial fishery to reduce *F* and allow the SSB to rebuild to the target (72% reduction)
E. Establish a partial moratorium for the commercial fishery

Establish seasonal closures by area for the commercial fishery to reduce F and increase SSB to rebuild between the threshold and the target in 2019 (Option C, 62% reduction) and establish seasonal closures by area for the commercial fishery to reduce F and allow the SSB to rebuild to the target in 2020 (Option D, 72% reduction).

Recreational Fishery Options

A. Establish a season for the recreational fishery to reduce *F* to the fishing mortality threshold (31% reduction)
B. Establish a season for the recreational fishery to reduce *F* and allow the SSB to rebuild to the threshold (52% reduction)
C. Establish seasonal closures by area for the recreational fishery to increase SSB between the threshold and target (62% reduction)
D. Establish a season for the recreational fishery to reduce *F* and allow the SSB to rebuild to the target (72% reduction)
E. Establish a partial moratorium for the recreational fishery

Establish seasonal closures by area for the recreational fishery to reduce F and increase SSB to rebuild between the threshold and the target in 2019 (Option C, 62% reduction) and establish seasonal closures by area for the recreational fishery to reduce F and allow the SSB to rebuild to the target in 2020 (Option D, 72% reduction).

Additional Management Options: Non - Quantifiable Harvest Restrictions

These options can be implemented in conjunction with seasons to minimize the potential for overages in total removals by mitigating probable effort changes due to shortened seasons.

A. Trip Limits
    i. Limiting numbers per trip for the commercial gig fishery
    ii. Limiting pounds per trip for the commercial pound net fishery
B. Limiting days per week allowed in the Neuse River, Tar/Pamlico River and the Albemarle Sound areas that have previously been exempt from set restrictions
C. Reducing fishing times allowed in the Neuse River, Tar/Pamlico River and the Albemarle Sound areas that have previously been exempt from time restrictions
D. Gear Modifications
    i. Prohibit the use of picks when harvesting fish from pound nets
    ii. Reducing the maximum yardage allowed in the large mesh gill net fishery

The NCDMF recommendation includes: Reducing commercial anchored large-mesh gill net soak times to single overnight soaks where nets may be set no sooner than one hour before sunset and must be retrieved no later than one hour after sunrise the next morning in the Neuse, Tar/Pamlico rivers and the Albemarle Sound areas that have previously been exempt; reducing the maximum yardage allowed in the commercial anchored large-mesh gill net fishery by 25% for each Management Unit; by allowing a maximum of 1,500-yards in Management Units A, B, and C, and a maximum of 750-yards in Management Units D and E unless more restrictive yardage is specified through adaptive management through the sea turtle or sturgeon Incidental Take Permits (ITP); and prohibiting the use any method of retrieving live flounder from pound nets that cause injury to released fish (no picks, gigs, spears, etc.).

Management measures from Amendment 1 and Supplement A to Amendment 1 will be incorporated into Amendment 2 (see Section VIII, Recommendations in Draft Amendment 2). Additionally, the recreational bag limit of no more than four flounder is maintained in Amendment 2. This bag limit is required through the N.C. FMP for Interjurisdictional Fisheries to maintain compliance with the Atlantic States Marine Fisheries Commission Summer Flounder, Scup, and Black Sea Bass FMP Addendum XXVIII. The December commercial closure period from Amendment 1 would no longer be in effect, as it is encompassed by the seasonal closure periods implemented by the adoption of Amendment 2.

The NCDMF recommendation includes that the adoption of Amendment 2 authorizes continued development of Amendment 3 and more robust management strategies. Amendment 3 will be completed as quickly as possible with the ongoing contributions of the Southern Flounder FMP Advisory Committee members. This will best serve to assist the division in development of Amendment 3, by building on the knowledge, expertise, and cooperation already underway and continue the work uninterrupted from meetings that began in January 2018.

Southern Flounder FMP Advisory Committee Recommendation
At the June 3, 2019 Southern Flounder FMP Advisory Committee meeting, the following recommendation was approved by the committee for the 2019 and 2020 fishing year and forward. For further information, including proposed seasons, see Section VIII, Recommendations of Draft Amendment 2. The committee voted to establish a season for the commercial and recreational fisheries to reduce *F* and allow the SSB to rebuild to the threshold in 2019 (Option B, 52% reduction) with the following additional modifications.

Southern Flounder FMP Advisory Committee Management Option for 2019 and forward
Starting Jan. 1, 2019 adopt a recommendation for a 52% reduction for the commercial and recreational fisheries with the following changes for the commercial fishery, calculated by the northern, central, and southern areas proposed by the division:

- Commercial pound net fishery, 40% reduction
- Commercial gig fishery, 40% reduction
- Commercial large-mesh gill net fishery, a reduction of approximately 71% would be needed to make up the difference to yield a 52% reduction for the commercial fishery overall. The Southern Flounder FMP Advisory Committee recognizes that the division proposal for the Recreational Commercial Gear License large mesh gill net season of Sept. 15-Sept. 30 may be changed by this final percent reduction.

The committee recommendation also includes that management measures from Amendment 1 and Supplement A to Amendment 1, as stated above in the NCDMF recommendation, be carried forward. The recommendation also maintains regulations from the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII for recreational size and bag limit for flounder and approves the continued development of Amendment 3.

In addition, the committee recommends prohibiting the use of picks, gaffs, gigs, and spears when removing flounder from pound nets. As of Jan. 1, 2020, the committee also recommends implementing a 1,500-yard limit for large mesh gill nets in Management Unit A, a 1,000-yard limit for large mesh gill nets in Management Units B and C, and a 750-yard limit for large mesh gill nets in Management Units D and E.

Finally, the committee recommends a 52% reduction be applied to the recreational fisheries. The season for the recreational hook-and-line and gig fisheries will be July 16 through Sept. 30.

Southern Advisory Committee Recommendation
The Southern Advisory Committee met on June 3, 2019 and failed to reach consensus on a recommendation for draft Amendment 2.

Northern Advisory Committee Recommendation
The Northern Advisory Committee met on June 3, 2019 and passed a motion supporting the NCDMF recommendation of the 62% reduction in 2019 and 72% percent reduction from 2020 forward to include management carried forward from Amendment 1 and Supplement A to Amendment 1, maintaining the size and bag limits established by the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII, and the continued development of Amendment 3. In addition, the Northern Advisory Committee passed a motion asking the MFC to consider dividing the allowable days for gill netting amongst allowable fishing months for a given area due to the Sea Turtle ITP.

Finfish Advisory Committee Recommendation
The Finfish Advisory Committee met on June 3, 2019 and recommended a reduced harvest of 52%, not to exceed 52%, until Amendment 3 is completed. This recommendation includes management carried forward from Amendment 1 and Supplement A to Amendment 1, maintaining the size and bag limits established by the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII, and the continued development of Amendment 3. The committee also recommended that the MFC ask the Secretary of DEQ to allow the Director of DMF to go out of compliance with ASMFC Summer Flounder Plan and adopt a 12-inch size limit and a 4-fish bag limit for southern flounder in North Carolina waters. The committee also requested the Southern Flounder FMP Advisory Committee look at a moratorium on all southern flounder harvest from Nov. 1, 2019 to Sept. 1, 2022.

Summary of Public Comment
Public comments were accepted through three formats: mail, online, and at the joint advisory committee meeting. This meeting was held on June 3, 2019 and allowed for a maximum of 90 minutes of public comment. Mail and online comments were collected from May 23 through June 3, 2019 at midnight. Eleven comments were received through the mail; all (100%) were opposed to draft Amendment 2. Two hundred and forty-one responses were received through online tools, 91 in favor and 150 opposed to draft Amendment 2. Of those that indicated support for draft

Amendment 2, the option indicated most for 2019 and 2020 was for Option C (62% reduction) in 2019 (38% of responses) and Option D (72% reduction) in 2020 (44% of responses). In addition, trip limits, fishing times, and gear changes received more responses than the option of no preference for the additional non-quantifiable management measures (Table 1). Thirteen comments were received during the public comment period at the joint advisory committee meeting; three (23%) were in favor of and 10 (77%) were opposed to draft Amendment 2. All public comments can be found in Appendices 1-3.

Marine Fisheries Commission Preferred Management Option
At its June 6, 2019 Marine Fisheries Commission special meeting, the division provided a summary of the advisory committee and public input received. The commission passed a motion to accept the recommendations of the Division of Marine Fisheries and the Department of Environmental Quality, in their entirety, for its preferred management strategy for the draft Southern Flounder FMP Amendment 2. The commission also passed a motion to send the revised draft Amendment 2 to the Department of Environmental Quality secretary for review and comment. The secretary has 30 days to review and will forward it to the appropriate legislative commission and committee.

Timeline
<u>August 2019</u>
The commission will receive any departmental and legislative input provided. The commission is scheduled to vote on final approval of Amendment 2. If approved, management measures will be implemented via the proclamation authority of the division director following the meeting.

<u>*Definitions</u>
Sustainable Harvest – The amount of fish (in weight) that can be taken from a stock at a given fishing intensity and the stock biomass does not change year to year.
Spawning Stock Biomass – Total weight of mature females in the stock.
Stock – A group of fish of the same species in a given area. Unlike a fish population, a stock is defined as much by management concerns (jurisdictional boundaries or harvesting locations) as by biology.
Overfished – State of a fish stock that occurs when a stock size falls below a specific threshold.
Overfishing – Occurs when the rate that fish that are harvested or killed exceeds a specific threshold.
Total removals – In the commercial fishery, the sum of the landings and dead discards; in the recreational fishery, the sum of the observed harvest and dead discards.
Fishing Mortality (*F*) – Rate at which southern flounder are removed from the population due to fishing.
Threshold – The maximum values of fishing mortality or minimum values of the biomass, which must not be exceeded. Otherwise, it is considered that it might endanger the capacity of self-renewal of the stock.
Target – The level of fishing mortality or of the biomass, which permit a long-term sustainable exploitation of the stock, with the best possible catch.
Terminal Year – The final year of estimates being used in an analysis.

Table 1. Summary of responses from public comment on southern flounder draft Amendment 2.

Issue		Mail Response (number; %)	Online Response (number; %)	Public Comment* Response (number; %)
Do you support Draft Amendment 2	Yes	0 (0%)	91 (38%)	3 (23%)
	No	11 (100%)	150 (62%)	10 (77%)
	Total	11 (100%)	241 (100%)	13 (100%)
If you support Draft Amendment 2 which option do you recommend for 2019?	Option A (31%)		8 (9%)	
	Option B (52%)		9 (10%)	
	Option C (62%)		34 (38%)	
	Option D (72%)		11 (12%)	
	Option E (Partial Moratorium)		20 (22%)	
	No Preference		7 (8%)	
	Total		89	
If you support Draft Amendment 2 which option do you recommend beginning in 2020?	Option A (31%)	N/A	N/A	N/A
	Option B (52%)		14 (16%)	
	Option C (62%)		10 (11%)	
	Option D (72%)		39 (44%)	
	Option E (Partial Moratorium)		19 (22%)	
	No Preference		6 (7%)	
	Total		88	
Do you support additional non-quantifiable measures?	Trip Limits		59 (31%)	
	Fishing Times		50 (26%)	
	Gear Changes		74 (38%)	
	None		5 (3%)	
	No Preference		5 (3%)	
	Total		193	

(Method of Public Comment Received: Mail, Online, Public Comment*)

FOOTNOTES

3 instances of two entries with the same first and last name
3 instances of apparent fake first and last name
6 instances of entries indicating support of amendment 2, but did not pick any options
4 instances of entries with no name, 1 in support and 3 opposed. No additional comments were included.

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary

NORTH CAROLINA
Environmental Quality

June 17, 2019

Senator Brent Jackson and Representatives Jimmy Dixon and Pat McElraft, Co-Chairs
Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources
North Carolina General Assembly
Legislative Building
16 West Jones Street
Raleigh, NC 27601

RE: Draft Southern Flounder Fishery Management Plan Amendment 2

Dear Senator Jackson and Representatives Dixon and McElraft:

The draft North Carolina Southern Flounder Fishery Management Plan Amendment 2 was submitted to me by the North Carolina Marine Fisheries Commission for review. North Carolina General Statute 113-182.1(e) requires that once I review any proposed fishery management plan, I report that plan to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources. Your committee then has 30 days to submit comments and recommendations to me on the proposed plan.

The amendment is located at http://portal.ncdenr.org/web/mf/southern-flounder-topic and an overview of the plan is enclosed for your convenience.

Thank you for your assistance in this matter. Please contact Department of Environmental Quality Legislative Affairs Director Joy Hicks at 919-707-8618 or Division of Marine Fisheries Director Steve Murphey at 252-808-8013 if you have any questions.

Sincerely,

Michael S. Regan
Secretary

MSR:cb

Enclosure

cc: North Carolina Marine Fisheries Commission
Joy Hicks, Department of Environmental Quality Legislative Affairs Director
Steve Murphey, Division of Marine Fisheries Director

§ 113-182.1. Fishery Management Plans.

(a) The Department shall prepare proposed Fishery Management Plans for adoption by the Marine Fisheries Commission for all commercially or recreationally significant species or fisheries that comprise State marine or estuarine resources. Proposed Fishery Management Plans shall be developed in accordance with the Priority List, Schedule, and guidance criteria established by the Marine Fisheries Commission under G.S. 143B-289.52.

(b) The goal of the plans shall be to ensure the long-term viability of the State's commercially and recreationally significant species or fisheries. Each plan shall be designed to reflect fishing practices so that one plan may apply to a specific fishery, while other plans may be based on gear or geographic areas. Each plan shall:

(1) Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of relevant fish stocks, stock assessments for multiyear species, fishery habitat and water quality considerations consistent with Coastal Habitat Protection Plans adopted pursuant to G.S. 143B-279.8, social and economic impact of the fishery to the State, and user conflicts.

(2) Recommend management actions pertaining to the fishery or fisheries.

(3) Include conservation and management measures that will provide the greatest overall benefit to the State, particularly with respect to food production, recreational opportunities, and the protection of marine ecosystems, and that will produce a sustainable harvest.

(4) Repealed by Session Laws 2010-13, s. 1, effective June 23, 2010.

(5) Specify a time period, not to exceed two years from the date of the adoption of the plan, to end overfishing. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.

(6) Specify a time period, not to exceed 10 years from the date of the adoption of the plan, for achieving a sustainable harvest. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.

(7) Include a standard of at least fifty percent (50%) probability of achieving sustainable harvest for the fishery or fisheries. This subdivision shall not apply if the Fisheries Director determines that the biology of the fish, environmental conditions, or lack of sufficient data make implementing the requirements of this subdivision incompatible with professional standards for fisheries management.

(c) To assist in the development of each Fishery Management Plan, the Chair of the Marine Fisheries Commission shall appoint a fishery management plan advisory committee. Each fishery management plan advisory committee shall be composed of commercial fishermen, recreational fishermen, and scientists, all with expertise in the fishery for which the Fishery Management Plan is being developed.

(c1) The Department shall consult with the regional advisory committees established pursuant to G.S. 143B-289.57(e) regarding the preparation of each Fishery Management Plan. Before submission of a plan for review by the Joint Legislative Commission on Governmental Operations, the Department shall review any comment or recommendation regarding the plan that a regional advisory committee submits to the Department within the time limits established in the Schedule for the development and adoption of Fishery Management Plans established by G.S. 143B-289.52. Before the Commission adopts a management measure to implement a plan, the Commission shall review any comment or recommendation regarding the management measure that a regional advisory committee submits to the Commission.

(d) Each Fishery Management Plan shall be reviewed at least once every five years. The Marine Fisheries Commission may revise the Priority List and guidance criteria whenever it determines that a revision of the Priority List or guidance criteria will facilitate or improve the development of Fishery Management Plans or is necessary to restore, conserve, or protect the marine and estuarine resources of the State. The Marine Fisheries Commission may not revise the Schedule for the development of a Fishery Management Plan, once adopted, without the approval of the Secretary of Environmental Quality.

(e) The Secretary of Environmental Quality shall monitor progress in the development and adoption of Fishery Management Plans in relation to the Schedule for development and adoption of the plans established by the Marine Fisheries Commission. The Secretary of Environmental Quality shall report to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources and the Fiscal Research Division within 30 days of the completion or substantial revision of each proposed Fishery Management Plan. The Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources shall review each proposed Fishery Management Plan within 30 days of the date the proposed Plan is submitted by the Secretary. The Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources may submit comments and recommendations on the proposed Plan to the Secretary within 30 days of the date the proposed Plan is submitted by the Secretary.

(e1) If the Secretary determines that it is in the interest of the long-term viability of a fishery, the Secretary may authorize the Commission to develop temporary management measures to supplement an existing Fishery Management Plan pursuant to this subsection. Development of temporary management measures pursuant to this subsection is exempt from subsections (c), (c1), and (e) of this section and the Priority List, Schedule, and guidance criteria established by the Marine Fisheries Commission under G.S. 143B-289.52. During the next review period for a Fishery Management Plan supplemented pursuant to this subsection, the Commission shall either incorporate the temporary management measures into the revised Fishery Management Plan or the temporary management measures shall expire on the date the revised Fishery Management Plan is adopted.

(f) The Marine Fisheries Commission shall adopt rules to implement Fishery Management Plans in accordance with Chapter 150B of the General Statutes.

(g) To achieve sustainable harvest under a Fishery Management Plan, the Marine Fisheries Commission may include in the Plan a recommendation that the General Assembly limit the number of fishermen authorized to participate in the fishery. The Commission may recommend that the General Assembly limit participation in a fishery only if the Commission determines that sustainable harvest cannot otherwise be achieved. In determining whether to recommend that the General Assembly limit participation in a fishery, the Commission shall consider all of the following factors:

(1) Current participation in and dependence on the fishery.
(2) Past fishing practices in the fishery.
(3) Economics of the fishery.
(4) Capability of fishing vessels used in the fishery to engage in other fisheries.
(5) Cultural and social factors relevant to the fishery and any affected fishing communities.
(6) Capacity of the fishery to support biological parameters.
(7) Equitable resolution of competing social and economic interests.

(8) Any other relevant considerations. (1997-400, s. 3.4; 1997-443, s. 11A.119(b); 1998-212, s. 14.3; 1998-225, s. 2.1; 2001-213, s. 1; 2001-452, s. 2.1; 2004-160, ss. 3, 4; 2007-495, ss. 6, 7; 2010-13, s. 1; 2010-15, s. 1; 2011-291, ss. 2.27, 2.28; 2012-201, s. 1; 2013-360, s. 14.8(r); 2015-241, s. 14.30(v); 2015-286, s. 4.12(b); 2017-57, s. 14.1(d).)

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Findings

- The most recent coast-wide stock assessment determined the stock* is overfished* and overfishing* is occurring.
- Reductions in **total coast-wide removals*** are necessary to end overfishing within two years and recover the stock from an overfished state within a 10-year period.
- To reach the fishing mortality* (*F*) threshold* and end overfishing, a 31% reduction in total coast-wide removals is necessary, while a 51% reduction is necessary to reach the fishing mortality target*. Neither of these levels of reduction would rebuild the spawning stock biomass (SSB) by 2028.
- For the SSB to reach the threshold by 2028 and end the overfished status a 52% reduction in total coast-wide removals will be required. To reach the SSB target by 2028 a 72% reduction in total coast-wide removals will be required.
- Static quota, dynamic quota, slot limits, changes in the size limits, gear changes related to size limit changes, and species-specific management are not considered feasible options to address sustainable harvest in draft Amendment 2 due to the accelerated timeline and the need to implement management measures before the fall 2019 fishing season.

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Southern flounder is assessed as a single biological unit stock occurring from North Carolina through the east coast of Florida. Based on life history information, a multi-state cooperative group performed a stock assessment with a terminal year* of 2017 that determined the stock is overfished and overfishing is occurring.

- The stock assessment estimated biological reference points of $F_{35\%}$ (fishing mortality target) as 0.35 and $F_{25\%}$ (fishing mortality threshold) as 0.53. Estimated F in the terminal year of 2017 is 0.91, which is higher than the threshold and indicates overfishing is occurring.
- The stock assessment estimated an SSB target of 5,452 metric tons (approximately 12.0 million pounds) and threshold of 3,900 metric tons (approximately 8.6 million pounds). Estimated SSB in the terminal year of 2017 is 1,031 metric tons (approximately 2.3 million pounds), which is lower than the threshold and indicates the stock is overfished.

Statutory Requirements

North Carolina General Statute 113-182.1 mandates that fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving a sustainable harvest, and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute 113-129 as "the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished."

In accordance with North Carolina General Statute 143B-289.52(e1) a supermajority of the commission shall be six members. A supermajority shall be necessary to override recommendations from the Division of Marine Fisheries regarding measures needed to end overfishing or to rebuild overfished stocks.

Projections

To meet statutory requirements, calculations were made to determine reductions in total coast-wide removals necessary to end overfishing within the two-year period and recover the stock from an overfished state within the 10-year period. These projections estimate necessary changes to *F* when compared to the 2017 terminal year fishing mortality estimates identified in the stock assessment. In addition, the projections assumed management would start in 2019 and so the 10-year rebuilding period would need to be met by 2028.

Projections assume all four states implement measures for the reductions required to rebuild SSB. In addition, projections detailing changes in SSB assume the shrimp trawl fleet removals will continue in all scenarios. However, the partial moratorium projection also assumes no removals from the commercial or recreational fisheries, whereas less restrictive scenarios account for the specified volume of removals including harvest and dead discards. These projections provide a mathematically optimistic rebuilding schedule for SSB and are unlikely to be fully achieved given the disparity of regulating commercial and recreational gear removals and without comparable management action from the other southeastern states. For further information on the interjurisdictional nature of this species, please see the *Interjurisdictional Management* sub-section found in Section VI, Management Strategies for Sustainable Harvest of Draft Amendment 2.

To reach the fishing mortality threshold and end overfishing, a 31% reduction in total removals is necessary, while a 51% reduction is necessary to reach the fishing mortality target. However, while both of these reductions are sufficient to end overfishing in two years, neither are sufficient to achieve a sustainable harvest and end the overfished status within the 10-year period.

To reach the SSB threshold and end the overfished status by 2028, as is statutorily required, a fishing mortality of 0.34 achieved via a 52% reduction in total removals is needed. To reach the SSB target by 2028, fishing mortality would need to be lowered to 0.18 by reducing total removals by 72%. All projections are associated with at least a 50% probability of success. Both scenarios for rebuilding SSB meet the requirement to end overfishing in two years.

The projections are based on coast-wide reductions (North Carolina to Florida) necessary for coast-wide rebuilding. However, in developing necessary management measures, the division has applied the reductions for total removals only to North Carolina's portion. To do this, the percent reduction was applied to the total removals for North Carolina from the 2017 terminal year of the assessment. In North Carolina, the commercial fishery accounted for 71.8% of the total removals in pounds while the recreational fishery total removals (from hook-and-line and gigs) accounted for 28.2% in 2017. In addition, commercial removals that occurred through means of "other gears," those non-targeted flounder gear such as fyke nets, crab pots, and trawls are subtracted from the total removals prior to analysis. The impacts from these other gears are approximately 0.6% of the overall removals. While draft Amendment 2 will not impact other states' removals, continued cooperation among the state agencies involved with the stock assessment and their willingness to enact management measures to rebuild the stock within their jurisdictional boundaries is of the upmost importance for the stock.

Proposed Management Options

The list of proposed management options, including the positives and negatives for each option, can be found in Section VII, Proposed Management Options of draft Amendment 2. Department and Division recommendations are in ***bolded italicized*** font below, and additional information on these recommendations can be found in Section VIII, Recommendations of Draft Amendment 2. The FMP advisory committee recommendations are summarized below and found in Section VIII, Recommendations of Draft Amendment 2.

The Department and the Division recognize that these reductions are significant but necessary to increase the probability of successfully rebuilding this important recreational and commercial resource.

Commercial Fishery Options

A. Establish seasonal closures by area for the commercial fishery to reduce *F* to the fishing mortality threshold (31% reduction)
B. Establish seasonal closures by area for the commercial fishery to reduce *F* and allow the SSB to rebuild to the threshold (52% reduction)
C. Establish seasonal closures by area for the commercial fishery to increase SSB between the threshold and target (62% reduction)
D. Establish seasonal closures by area for the commercial fishery to reduce *F* and allow the SSB to rebuild to the target (72% reduction)
E. Establish a partial moratorium for the commercial fishery

Establish seasonal closures by area for the commercial fishery to reduce F and increase SSB to rebuild between the threshold and the target in 2019 (Option C, 62% reduction) and establish seasonal closures by area for the commercial fishery to reduce F and allow the SSB to rebuild to the target in 2020 (Option D, 72% reduction).

Recreational Fishery Options

A. Establish a season for the recreational fishery to reduce *F* to the fishing mortality threshold (31% reduction)
B. Establish a season for the recreational fishery to reduce *F* and allow the SSB to rebuild to the threshold (52% reduction)
C. Establish seasonal closures by area for the recreational fishery to increase SSB between the threshold and target (62% reduction)
D. Establish a season for the recreational fishery to reduce *F* and allow the SSB to rebuild to the target (72% reduction)
E. Establish a partial moratorium for the recreational fishery

Establish seasonal closures by area for the recreational fishery to reduce F and increase SSB to rebuild between the threshold and the target in 2019 (Option C, 62% reduction) and establish seasonal closures by area for the recreational fishery to reduce F and allow the SSB to rebuild to the target in 2020 (Option D, 72% reduction).

Additional Management Options: Non - Quantifiable Harvest Restrictions

These options can be implemented in conjunction with seasons to minimize the potential for overages in total removals by mitigating probable effort changes due to shortened seasons.

A. Trip Limits
    i. Limiting numbers per trip for the commercial gig fishery
    ii. Limiting pounds per trip for the commercial pound net fishery
B. Limiting days per week allowed in the Neuse River, Tar/Pamlico River and the Albemarle Sound areas that have previously been exempt from set restrictions
C. Reducing fishing times allowed in the Neuse River, Tar/Pamlico River and the Albemarle Sound areas that have previously been exempt from time restrictions
D. Gear Modifications
    i. Prohibit the use of picks when harvesting fish from pound nets
    ii. Reducing the maximum yardage allowed in the large mesh gill net fishery

The NCDMF recommendation includes: Reducing commercial anchored large-mesh gill net soak times to single overnight soaks where nets may be set no sooner than one hour before sunset and must be retrieved no later than one hour after sunrise the next morning in the Neuse, Tar/Pamlico rivers and the Albemarle Sound areas that have previously been exempt; reducing the maximum yardage allowed in the commercial anchored large-mesh gill net fishery by 25% for each Management Unit; by allowing a maximum of 1,500-yards in Management Units A, B, and C, and a maximum of 750-yards in Management Units D and E unless more restrictive yardage is specified through adaptive management through the sea turtle or sturgeon Incidental Take Permits (ITP); and prohibiting the use any method of retrieving live flounder from pound nets that cause injury to released fish (no picks, gigs, spears, etc.).

Management measures from Amendment 1 and Supplement A to Amendment 1 will be incorporated into Amendment 2 (see Section VIII, Recommendations in Draft Amendment 2). Additionally, the recreational bag limit of no more than four flounder is maintained in Amendment 2. This bag limit is required through the N.C. FMP for Interjurisdictional Fisheries to maintain compliance with the Atlantic States Marine Fisheries Commission Summer Flounder, Scup, and Black Sea Bass FMP Addendum XXVIII. The December commercial closure period from Amendment 1 would no longer be in effect, as it is encompassed by the seasonal closure periods implemented by the adoption of Amendment 2.

The NCDMF recommendation includes that the adoption of Amendment 2 authorizes continued development of Amendment 3 and more robust management strategies. Amendment 3 will be completed as quickly as possible with the ongoing contributions of the Southern Flounder FMP Advisory Committee members. This will best serve to assist the division in development of Amendment 3, by building on the knowledge, expertise, and cooperation already underway and continue the work uninterrupted from meetings that began in January 2018.

Southern Flounder FMP Advisory Committee Recommendation
At the June 3, 2019 Southern Flounder FMP Advisory Committee meeting, the following recommendation was approved by the committee for the 2019 and 2020 fishing year and forward. For further information, including proposed seasons, see Section VIII, Recommendations of Draft Amendment 2. The committee voted to establish a season for the commercial and recreational fisheries to reduce *F* and allow the SSB to rebuild to the threshold in 2019 (Option B, 52% reduction) with the following additional modifications.

Southern Flounder FMP Advisory Committee Management Option for 2019 and forward
Starting Jan. 1, 2019 adopt a recommendation for a 52% reduction for the commercial and recreational fisheries with the following changes for the commercial fishery, calculated by the northern, central, and southern areas proposed by the division:

- Commercial pound net fishery, 40% reduction
- Commercial gig fishery, 40% reduction
- Commercial large-mesh gill net fishery, a reduction of approximately 71% would be needed to make up the difference to yield a 52% reduction for the commercial fishery overall. The Southern Flounder FMP Advisory Committee recognizes that the division proposal for the Recreational Commercial Gear License large mesh gill net season of Sept. 15-Sept. 30 may be changed by this final percent reduction.

The committee recommendation also includes that management measures from Amendment 1 and Supplement A to Amendment 1, as stated above in the NCDMF recommendation, be carried forward. The recommendation also maintains regulations from the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII for recreational size and bag limit for flounder and approves the continued development of Amendment 3.

In addition, the committee recommends prohibiting the use of picks, gaffs, gigs, and spears when removing flounder from pound nets. As of Jan. 1, 2020, the committee also recommends implementing a 1,500-yard limit for large mesh gill nets in Management Unit A, a 1,000-yard limit for large mesh gill nets in Management Units B and C, and a 750-yard limit for large mesh gill nets in Management Units D and E.

Finally, the committee recommends a 52% reduction be applied to the recreational fisheries. The season for the recreational hook-and-line and gig fisheries will be July 16 through Sept. 30.

Southern Advisory Committee Recommendation
The Southern Advisory Committee met on June 3, 2019 and failed to reach consensus on a recommendation for draft Amendment 2.

Northern Advisory Committee Recommendation
The Northern Advisory Committee met on June 3, 2019 and passed a motion supporting the NCDMF recommendation of the 62% reduction in 2019 and 72% percent reduction from 2020 forward to include management carried forward from Amendment 1 and Supplement A to Amendment 1, maintaining the size and bag limits established by the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII, and the continued development of Amendment 3. In addition, the Northern Advisory Committee passed a motion asking the MFC to consider dividing the allowable days for gill netting amongst allowable fishing months for a given area due to the Sea Turtle ITP.

Finfish Advisory Committee Recommendation
The Finfish Advisory Committee met on June 3, 2019 and recommended a reduced harvest of 52%, not to exceed 52%, until Amendment 3 is completed. This recommendation includes management carried forward from Amendment 1 and Supplement A to Amendment 1, maintaining the size and bag limits established by the ASMFC Summer Flounder, Black Sea Bass, and Scup Addendum XXVIII, and the continued development of Amendment 3. The committee also recommended that the MFC ask the Secretary of DEQ to allow the Director of DMF to go out of compliance with ASMFC Summer Flounder Plan and adopt a 12-inch size limit and a 4-fish bag limit for southern flounder in North Carolina waters. The committee also requested the Southern Flounder FMP Advisory Committee look at a moratorium on all southern flounder harvest from Nov. 1, 2019 to Sept. 1, 2022.

Summary of Public Comment
Public comments were accepted through three formats: mail, online, and at the joint advisory committee meeting. This meeting was held on June 3, 2019 and allowed for a maximum of 90 minutes of public comment. Mail and online comments were collected from May 23 through June 3, 2019 at midnight. Eleven comments were received through the mail; all (100%) were opposed to draft Amendment 2. Two hundred and forty-one responses were received through online tools, 91 in favor and 150 opposed to draft Amendment 2. Of those that indicated support for draft

Amendment 2, the option indicated most for 2019 and 2020 was for Option C (62% reduction) in 2019 (38% of responses) and Option D (72% reduction) in 2020 (44% of responses). In addition, trip limits, fishing times, and gear changes received more responses than the option of no preference for the additional non-quantifiable management measures (Table 1). Thirteen comments were received during the public comment period at the joint advisory committee meeting; three (23%) were in favor of and 10 (77%) were opposed to draft Amendment 2. All public comments can be found in Appendices 1-3.

Marine Fisheries Commission Preferred Management Option
At its June 6, 2019 Marine Fisheries Commission special meeting, the division provided a summary of the advisory committee and public input received. The commission passed a motion to accept the recommendations of the Division of Marine Fisheries and the Department of Environmental Quality, in their entirety, for its preferred management strategy for the draft Southern Flounder FMP Amendment 2. The commission also passed a motion to send the revised draft Amendment 2 to the Department of Environmental Quality secretary for review and comment. The secretary has 30 days to review and will forward it to the appropriate legislative commission and committee.

Timeline
August 2019
The commission will receive any departmental and legislative input provided. The commission is scheduled to vote on final approval of Amendment 2. If approved, management measures will be implemented via the proclamation authority of the division director following the meeting.

***Definitions**
Sustainable Harvest – The amount of fish (in weight) that can be taken from a stock at a given fishing intensity and the stock biomass does not change year to year.
Spawning Stock Biomass – Total weight of mature females in the stock.
Stock – A group of fish of the same species in a given area. Unlike a fish population, a stock is defined as much by management concerns (jurisdictional boundaries or harvesting locations) as by biology.
Overfished – State of a fish stock that occurs when a stock size falls below a specific threshold.
Overfishing – Occurs when the rate that fish that are harvested or killed exceeds a specific threshold.
Total removals – In the commercial fishery, the sum of the landings and dead discards; in the recreational fishery, the sum of the observed harvest and dead discards.
Fishing Mortality (*F*) – Rate at which southern flounder are removed from the population due to fishing.
Threshold – The maximum values of fishing mortality or minimum values of the biomass, which must not be exceeded. Otherwise, it is considered that it might endanger the capacity of self-renewal of the stock.
Target – The level of fishing mortality or of the biomass, which permit a long-term sustainable exploitation of the stock, with the best possible catch.
Terminal Year – The final year of estimates being used in an analysis.

Table 1. Summary of responses from public comment on southern flounder draft Amendment 2.

Issue		Method of Public Comment Received: Mail — Response (number; %)	Online — Response (number; %)	Public Comment* — Response (number; %)
Do you support Draft Amendment 2	Yes	0 (0%)	91 (38%)	3 (23%)
	No	11 (100%)	150 (62%)	10 (77%)
	Total	11 (100%)	241 (100%)	13 (100%)
If you support Draft Amendment 2 which option do you recommend for 2019?	Option A (31%)		8 (9%)	
	Option B (52%)		9 (10%)	
	Option C (62%)		34 (38%)	
	Option D (72%)		11 (12%)	
	Option E (Partial Moratorium)		20 (22%)	
	No Preference		7 (8%)	
	Total		89	
If you support Draft Amendment 2 which option do you recommend beginning in 2020?	Option A (31%)	N/A	N/A	N/A
	Option B (52%)		14 (16%)	
	Option C (62%)		10 (11%)	
	Option D (72%)		39 (44%)	
	Option E (Partial Moratorium)		19 (22%)	
	No Preference		6 (7%)	
	Total		88	
Do you support additional non-quantifiable measures?	Trip Limits		59 (31%)	
	Fishing Times		50 (26%)	
	Gear Changes		74 (38%)	
	None		5 (3%)	
	No Preference		5 (3%)	
	Total		193	

FOOTNOTES

3 instances of two entries with the same first and last name

3 instances of apparent fake first and last name

6 instances of entries indicating support of amendment 2, but did not pick any options

4 instances of entries with no name, 1 in support and 3 opposed. No additional comments were included.

June 7, 2019

Michael S. Regan, Secretary
North Carolina Department of Environmental Quality
1601 Mail Service Center
Raleigh, NC 27699-1601

Dear Secretary Regan,

On June 6, 2019 the North Carolina Marine Fisheries Commission approved the draft North Carolina Southern Flounder Fishery Management Plan Amendment 2 for your review. The amendment is located at http://portal.ncdenr.org/web/mf/southern-flounder-topic and an overview of the plan is enclosed for your convenience. Please submit any comments or recommendations regarding the plan to my office within 30 days.

The Fisheries Reform Act of 1997 [G.S. 113-182.1 (c1) and (e)] requires that you transmit this fishery management plan to the Joint Legislative Commission on Governmental Operations and the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources for review. The commission and committee also have 30 days from the date of receipt of the plan to submit comments. Cover letters for your signature are being prepared for that purpose and will be sent under separate cover.

Thank you for your assistance in this matter and please contact me at 252-808-8013 if you have any questions.

Sincerely,

Stephen W. Murphey, Director
North Carolina Division of Marine Fisheries

Enclosure

cc: North Carolina Marine Fisheries Commission
Joy Hicks, Department of Environmental Quality Legislative Affairs Director

SWM:cb

From: Garry Stutts
To: Gillikin, Dana
Subject: [External] Concerned about Flounder
Date: Wednesday, July 31, 2019 4:27:26 PM

Thank You Dana, just a couple of questions.

(1) In regards to Flounder. Why are commercial fisherman and recreational fisherman inclined to the same rules and regulations.? Clearly they are 180 degrees apart. Please explain to me how the recreational fisherman is affecting the Flounder population **AT ALL?** Please be specific.

(2) After your August 21st meeting, I understand you are closing the Flounder season until August 2020 for a short period, How long are you planning on Keeping this guideline in place?

(3) Lastly, I'm 65 and have been Flounder gigging on our North Carolina beeches since the 1960's. The sport I love is being decimated. We have a group, not a large group but a group of about 21 people that go to our coast around 10 times a year just to Flounder gig. It hurts to know that we are going to take all those earned and taxed dollars and move them to South Carolina.

Sincerly

Garry Stutts

From: moneyopoly
To: Gillikin, Dana
Subject: [External] Attn Chairman Bizzell
Date: Sunday, July 28, 2019 1:27:59 AM

Concerning flounder limits in NC, I would like to see at least a 1 fish per day limit year-round for recreational rod and reel anglers...even if the legal size was raised to 16" or 17".

Personally, I see way more flounder being gigged than caught on rod and reel in recent years. Please ensure that limits are spread fairly across the board.

Thank you,
Paul Nelson
Licensed NC Recreational Angler

From:	Capt Dave Stewart
To:	Gillikin, Dana
Subject:	[External] Chairman Bizzell
Date:	Friday, July 26, 2019 2:01:46 PM

Please assure that if we need a closure that it is closure for ALL - just like Rock. Fair to all and only way to make a gain. A summer closed trout season would also be good for that species to spawn out.

Capt Dave Stewart
KneEDeeP Custom Charters
Minnesott Beach Bait & Tackle
[redacted]

From: Brandon Watson
To: Gillikin, Dana
Subject: [External] flounder proposal.
Date: Friday, July 26, 2019 1:54:20 PM

My name is Brandon Watson I am a full time commercial fisherman from the new river area here in Jacksonville. I am do some fishing in Swansboro an Bogue sound. I haven't fished as much this year for flounder because of damages too our home during the hurricane, we had 3 foot of water in our place. Floundering is usually makes up about 75 percent of my fishing income an fishing is 100 percent of my income. I have two daughters an a wife too support. Those are beside the facts. One thing is I have seen more fish this year , citation flounder, all over the place . So have other fisherman an tackle shops along our plentiful shores. According too NOAA the flounder are doing just fine, an have made a rebound. I have seen no shortage of fish neither has any charter boat captains. I believe we need accurate numbers on the recreational side you have so many fish being taken an we really have no data on how many they take. I very rarely seen the guys are the ramp measuring an weighing fish, an tons of shore fisherman , guys who have there own docks, private boat ramps. Also the size limit should be moved back down too what it was or even 13 inches, put a slot size no flounder above a certain size because all we are catching are spawning females! That was all by design though by louis b. daniel. Less fisherman, different gear, of course the numbers will be different, not too mention its fishing an it has its lulls like everything. I think we need too make decisions on facts not on political pressures. Thank you God Bless

From:	Murphey, Steve
To:	Gillikin, Dana
Cc:	Blum, Catherine; Rawls, Kathy
Subject:	FW: [External] We support the flounder ban!
Date:	Friday, July 19, 2019 11:44:57 AM

From: Bizzell, Rob <r.bizzell.mfc@ncdenr.gov>
Sent: Friday, July 19, 2019 11:44 AM
To: Murphey, Steve <steve.murphey@ncdenr.gov>
Subject: Fwd: [External] We support the flounder ban!

For the meeting notebooks
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From: Anthony Calabria [redacted]
Sent: Thursday, July 18, 2019 11:11 AM
To: Bizzell, Rob; Laughridge, Charles H; Kornegay, K; Boltes, C
Subject: [External] We support the flounder ban!

Hello,
As an avid inshore/offshore fishing family for 22 years in NC, we all want to thank you for the first steps to maintaining a healthy flounder population. Conservation is needed not only for the flounder, but many other species as well! Too many people kill fish, of all sizes, with little to no regard, especially on piers; I just wish they would understand the damage they are doing.

Please consider a ban or a LIMIT of pufferfish, sharks and stingrays as well. It's embarrassing how many people kill them and to what end? The worst part is that they brag about it on social media.

Please know as a high school English teacher of 22 years and a father of two sons, ages 13 and 11, that we, and our family and friends, all who own beach homes and boats in Atlantic Beach and Morehead, support this 100%. Keep up the good work and thank you for supporting conservation! Every single hunter and fisher should be advocates of conservation!

I'm here to help if needed.

Anthony Calabria

The future of saltwater fishing in North Carolina ?

The future of saltwater fishing in our state has a very dismal outlook. The Marine Fisheries has almost managed our trout, flounder,strippers and drum into non existence. Now I hear that the politicians want to get into the cause by setting size limits on spots,croakers and some other species. Both groups have missed the point controlling species size or limits does not work when you are killing the babies before they can develop. N.C. allows long haul shrimping and trawling in our inland waters. These methods destroy the grass beds and bycatch kill the juvenile fish of the species we want to protect. Bycatch is the small undersize fish and aquatic animals not wanted. Bycatch for shrimpers and trawles is 20 to 30 lbs/ 1 lb of target species. The simple thing to do is to join all the other states on the east coast and gulf coast by allowing only hook and line harvesting of fish in state waters. The shrimping also needs to be moved outside the inlets. South Caroline was the last state to do this and their pounds of harvest has increased by allowing the shrimp to get larger. The fish in N.C. are a resource to all its citizens and not to just a few people.

N.C. has the most extensive inland waters of any state, 2,220,161 acres. N.C. issued 4,824 standard commercial license last year and 311,652 recreation saltwater license. Those commercial fishermen caught 134,463 lbs of stripped bass, 128,922 lbs of speckled trout,144,464 lbs of drum. The Marine Fisheries plans to close the flounder to recreational fishermen in August but to allow the commercial industry to fish them for 6 weeks but they say the founders are in distress. They caught 2,560,227 lbs last year. I say if they are in distress; close the flounder season for all. I personally think it will give them a much needed time to recover. Commercial fishing decimates the sea grass and the fish population in our inland waters.

Life does not remain the same, things change. I use to work in the textile industry and it went away. Commercial fishermen in the other states transitioned to other careers,some became fishing guides. I was at Venis, Louiseana; last year fishing. I hired a guide for a 6 hour inshore trip. I caught 20 drum,20 speckles for fillets and 5 big drum 22 to 27 lbs. The trip cost me $500 and a tip. I do not believe I could have had that kind of day in N.C. at any cost. It is incomprehensible that 4,824 people dictate to 311,652 people the uses of our state saltwaters. We could have that kind of success in N.C. if the people in government would do what's right and necessary to protect our saltwater resources. The legislature should understand that there is far more income generated by recreational fishing than commercial.

Fred R. Bonar
[redacted]

From: Bizzell, Rob
To: Gillikin, Dana
Subject: Fwd: [External] Flounder season closure ....
Date: Monday, July 22, 2019 2:30:25 PM

Sending you several for the books. Thanks, Rob

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From: David Lewis [redacted]
Sent: Saturday, July 20, 2019 10:55 AM
To: Bizzell, Rob
Subject: [External] Flounder season closure ....

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Hello Mr. Bizzell,

I'm sure you've already received a lot of feedback on this ... Oddly, I just saw the news today that the commission was going to close flounder season in August and not reopen it until next August for recreational and commercial fisherman (though it looked like season would be re-opened for commercial fisherman in the Fall).

Frankly it's hard to imagine that the recreational fisherman puts too much of a dent in the flounder population. Granted, I only get to fish the OBX while on vacation (from Raleigh), but I do get there for a week in the summer and a month in the Fall. I hardly ever see anyone target flounder from the beach (it's usually just an incidental catch). Most folks are soaking bait on a bottom rig for whatever comes along, or the more "serious" guys target the drum in the Fall.

Of course, I can see the commercial side having a much larger effect and it doesn't really make much sense to me to close the season for recreation, but open the season for the commercial guys to sweep up everything they can. But I'm sure the commercial guys are lobbying hard.

Seems like setting a one or two fish limit on the recreational guys and closing the season for the commercial guys would have the biggest positive effect on the flounder population. But like I say, I'm sure there's a lot of politics involved. Just my 2 cents.

Best,
Dave Lewis
Raleigh, NC

From: Bizzell, Rob
To: Gillikin, Dana
Subject: Fwd: [External] Flounder fishery
Date: Friday, July 26, 2019 8:51:27 AM

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From: Kelly Bordeaux [redacted]
Sent: Thursday, July 25, 2019 9:51 PM
To: Bizzell, Rob
Subject: [External] Flounder fishery

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Howdy
I live in Beaufort, NC and fully support the flounder fishery closure planned for August.
Thank you.
Kelly Bordeaux
[redacted]

From:	Bizzell, Rob
To:	Gillikin, Dana
Subject:	Fwd: [External] Flounder closure in north Carolina
Date:	Tuesday, July 23, 2019 1:00:56 PM

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From: Jeff Smith [redacted]
Sent: Tuesday, July 23, 2019 5:14 AM
To: Bizzell, Rob
Subject: [External] Flounder closure in north Carolina

Mr. Bizzell,

Hello, i am one of the board members of the Carolina beach got em on fishing club. We currently have more than 300 active club members. We host 5 flounder points tournaments a year from june to October. If flounder closes it will drastically effect the fishing tradition that we have done for over 40 years. We understand when theres a need for change to protect our fishery that we all do our part. But we feel a one fish limit would do that and still allow us to fish, spend money to fish and be good all around. In addition to our 5 tournaments, we travel once a year for our road warriors tournament. This year we are booked for a week at the palm suites in Atlantic beach in September. With the looming closure, our members are preparing to cancel this trip. That's a lot of tackle store, hotel, gas, restaurant, money that's not going to be spent. The effects of just closing flounder effects deeply into the sport and the economy as well.

Jeff Smith
[redacted]

From:	Bizzell, Rob
To:	Gillikin, Dana
Subject:	Fwd: [External] Flounder Closure
Date:	Wednesday, July 24, 2019 3:51:29 PM

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From: G Sunderland [redacted]
Sent: Wednesday, July 24, 2019 2:43 PM
To: Bizzell, Rob
Subject: [External] Flounder Closure

Rob,

I am in full agreement that flounder fishing should be closed. The continued over fishing and use of gill nets has greatly reduced the amount of flounder in our waters. When I first came here 5 yrs ago now, I remember being stunned by the amount of bait in the water and by the flounder I was able to catch.

But, each year since then I have seen a noticeable drop off in flounder being caught not only by myself but by other kayak fisherman in the Cape Fear area. Those that I do catch are well below the slot size, and of course I release them back into the water.

My hope is that the flounder will recover and of course if possible I would hope that our State would adopt a ban on gill netting as that technique of fishing has an adverse effect on juvenile fish in our waters

Best regards,

Gerry S.

Gerard Sunderland
Director, Business Development
Gryphon Financial Group Inc.
[redacted]

From: Bizzell, Rob
To: Gillikin, Dana
Subject: Fwd: [External] Flounder closure
Date: Tuesday, July 23, 2019 1:00:36 PM

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From: Bryan Armstrong [redacted]
Sent: Tuesday, July 23, 2019 6:55 AM
To: Bizzell, Rob
Subject: [External] Flounder closure

CAUTION: External email. Do not click links or open attachments unless you verify. Send all suspicious email as an attachment to report.spam@nc.gov<mailto:report.spam@nc.gov>

Hey Rob,
My names Bryan Armstrong I know this may not make much of a difference but on behalf of got-em-on fishing club. A club with over 300 members, and all the other recreational fisherman we believe that making the limit to one fish and even possibly making the size 18 inches... (when they start reproducing) would maybe be a helpful solution. We hold 5 points tournaments every year and one trip. This has been a 40 year long tradition to Carolina beach. It's just hard to see it be broken with such a dramatic change in laws when we believe it could be approached a completely different route
Thanks, Bryan
Sent from my iPhone

From: Mark Burns
To: Gillikin, Dana
Subject: [External] Aug 21-23 Flounder closure public input / Chairman Bizzell
Date: Thursday, July 25, 2019 11:53:05 AM

Chairman Bizzell,

I am an inshore recreational fisherman that enjoys occasional fishing trips with my three sons and grandsons. We are basically limited to Flounder, Red or black drum, spotted trout and Sheepshead inshore. If we do catch a keeper, the shared meal, the memories and photos create special bonds.

Instead of going from a limit of 4 flounder per person per day for the whole year to only a 6 week season, I would like to suggest that, at a minimum, the limit be set as per the Red Drum limit, one per person per day for the entire year (I would prefer a limit of two because one average flounder won't feed many people). If necessary, even change the length requirement from 15" to 16" or 17".

The flounder stock would still greatly improve with the 50% or 75% reduction and the increase in size limit would increase breeders as well. I have not seen any demographic studies about the aging of the fishing public, but as the baby boomers age, they take fewer and fewer fishing trips. I hope this issue is at least reviewed in your decision, because baby boomers have had an enormous influence on society, and fishing stocks will likely increase naturally as boomers quit fishing or reduce their trips. I don't see the following generations being involved in fishing the way the baby boomers have been.

A reduction to a 6 week season will send numerous vacationing fishermen to S. Carolina or Virginia, putting a dent in tourism dollars and state tax receipts. Some individuals specifically cater to flounder fishermen with gigs, flounder lights, rigs, etc. and will negatively effect North Carolina income tax receipts as well.

In addition, I believe it would help foster goodwill toward the regulating agency, as it is difficult to understand why such a drastic change in rules is necessary in a single year. It was just a few years ago that the limit went from 6 to 4. The new 6 week season rule that is being proposed means that a lot of us older guys just won't be able to catch and eat our own flounder in the state we call home, because we cant always get out and fish when we want, we fish when we are able. A lot of us won't even be alive by the time the stocks gets replenished to the point that a year round season is deemed acceptable by the agency.

I hope you will consider a more moderate response to the issue. All the fishermen I know want healthy fish stocks, but we feel a less drastic approach would benefit everyone.

Sincerely,

Mark Burns
Hampstead, NC

From: Martha Stovall
To: Gillikin, Dana
Subject: [External] Chairman Bizzell
Date: Friday, July 26, 2019 8:54:39 AM

I believe ALL public should have access to the public fisheries! Personally I would prefer at least one flounder per person per trip, open season all year, and could even accept a 16" or 17" size limit. Its not ideal, but its better than what they are proposing.

Martha Stovall, recreational fisherman

June 19, 2019

Mr. Rob Bizzell, Chairman
North Carolina Marine Fisheries Commission
c/o North Carolina Division of Marine Fisheries
3441 Arendell Street, Morehead City, NC 28557

RE: Southern Flounder Fishery Management Plan Amendment 2

Dear Chairman Bizzell and Marine Fisheries Commission Members,

My name is Don Kirkman, and I am the Economic Development Director in Carteret County. I understand that the public comment period for commenting on the proposed Amendment 2 of the Southern Flounder Fishery Management Plan has closed and you have previously received both a Resolution of opposition from the Carteret County Board of Commissioners and a very thoughtful opposition letter from the Carteret County Marine Fisheries Advisory Board. However, I have a perspective on this issue that I would like to share with you based on nearly 30 years' experience as an economic development professional.

"Economic development" literally means the development of an economy, and fishing has shaped the development of coastal North Carolina economies for hundreds of years. Nowhere in the state is this more apparent than Carteret County, where thousands of families have earned their livelihoods from the water for many generations. Coastal North Carolina has a distinguished maritime and fishing heritage, made possible by hard-working, independent families who risked much to provide for their families and provide fresh seafood for consumers in North Carolina and elsewhere.

Carteret County, like much of coastal North Carolina, has experienced a significant decline in commercial fishing. The factors contributing to this decline are many, but fisheries regulations are a major reason. And regardless of the causes, rural coastal communities that have been historically reliant on commercial fishing have in recent years experienced massive economic and social dislocations—including loss of employment and income, outmigration, declining school enrollment, increased demands on social services, and higher levels of substance abuse and mental health issues.

Fortunately, in Carteret County these adverse economic impacts have been partially offset by increased tourism and second home investment, and a significant component of this growth is directly tied to recreational fishing, which attracts investment and people to the Crystal Coast. Unfortunately, much of the positive economic benefits of tourism and second home investment

Carteret County Economic Development Department
3615 Arendell Street, Morehead City, NC 28557 | (252) 222-6121 | ED@carteretcountync.gov
www.CrystalCoastED.com

inure to different populations than those adversely impacted by the decline in the commercial fishing industry. Geographically and demographically, most of those adversely impacted by regulations on commercial fishing do not benefit from this new investment and growth.

In Carteret County, for example, we have seen a huge economic downturn and a significant population outmigration in "Down East" Carteret County, where the county's commercial fishing families are largely concentrated. The eastern half of Carteret County has declined as the western end of the county and the Bogue Banks beach communities have prospered with new investment and jobs. As demand for seafood, and locally caught fresh seafood specifically, continues to grow, there are very serious concerns about how the growing demand can be satisfied given the increasing burdens placed on commercial fishing.

While my concerns transcend the southern flounder fishery and management plan, proposed Amendment 2 crystallizes many of the issues I have attempted to highlight in this letter. In fact, in many ways the proposed southern flounder management plan amendment is worse than other fishery management plans because it would have significant adverse economic impacts on commercial and recreational fisheries. Southern flounder is one of North Carolina's most popular recreational fisheries, and the proposed amendment will have draconian impacts on both the commercial and recreational effort, with significant adverse economic impacts.

My overarching concern as it relates to proposed Amendment 2 but also more broadly to the structure of fisheries regulations generally is the absence of an economic impact analysis when regulations are proposed. I embrace the need for data-driven decision-making, and I appreciate that proposed Amendment 2 reflects peer-reviewed stock assessment data. There is another data set, however, that is absent in the Commission's rule-making process. That is consideration of economic impact data that I believe should be part of the Commission's statutory mandate. An evaluation of economic impacts in addition to fishery stock data would likely result in different outcomes, particularly in the timetable for implementing management plans. This is particularly true in the case of the proposed southern flounder plan, where there is significant disagreement about the data and the impact of a single-state approach to species management in the absence of action by other neighboring states.

Thank you very much for your consideration, and please contact me if you have any questions.

Sincerely,

Don Kirkman

Don Kirkman, Director
Carteret County Economic Development

cc: Carteret County Board of Commissioners and Manager
Secretary Michael Regan
Representative Pat McElraft
Senator Norman Sanderson

Board of Commissioners
Earl Pugh, Jr., Chair
Tom Pahl, Vice-Chair
Benjamin Simmons, III
Shannon Swindell
James Topping

COUNTY OF HYDE

30 Oyster Creek Road
PO Box 188
SWAN QUARTER, NORTH CAROLINA 27885
252-926-4400
252-926-3701 Fax

Kris Cahoon Noble
County Manager

Franz Holscher
County Attorney

Lois Stotesberry, CMC, NCCCC
Clerk to the Board

RESOLUTION Against Southern Flounder Amendment 2 and the North Carolina Division of Marine Fisheries Recommendation to the North Carolina Marine Fisheries Commission
June 3, 2019

WHEREAS, the Southern Flounder Amendment 2 and the North Carolina Division of Marine Fisheries are recommending cutting the southern flounder harvest by 62% in 2019 and 72% in 2020;

WHEREAS, the southern flounder fishery is absolutely a cornerstone of the Ocracoke and Hyde County economy;

WHEREAS, Ocracoke Seafood is the only fish house left on Ocracoke Island and is a fishermen owned enterprise that buys fish, oysters and clams from over 30 fishermen;

WHEREAS, the income generated by sales to Ocracoke Seafood Company supports fishing families, Ocracoke's local tourism economy and Hyde County's tax revenue and sustainability;

WHEREAS, Ocracoke's tourism economy is supported by 12 restaurants which depend on fresh, local seafood to satisfy tourists craving for fresh Ocracoke seafood;

WHEREAS, fresh, wild-caught seafood is one of the top tourist attractions on Ocracoke, adding to the $1 billion of tourist revenues North Carolina gains yearly from the coastal region;

WHEREAS, 20% of all tourists visit the coast of North Carolina specifically to eat locally caught seafood;

WHEREAS, Ocracoke Seafood Company depends on the diversity of species that the pound net harvest provides throughout the fall to stock the seafood retail and an October 17th closure will remove the primary source of wholesale landings in the months of October and November;

WHEREAS, the recommendation by the North Carolina Division of Marine Fisheries at the North Carolina Marine Fisheries Commission meeting to cut the southern flounder harvest by 62% in 2019 and 72% in 2020 with an October 17th closure to the flounder season will make Ocracoke Seafood Company unprofitable;

WHEREAS, Ocracoke Seafood Company's payroll to Ocracoke fishermen averages $600,000 annually and supports 4 full-time employees;

WHEREAS, the income generated at Ocracoke Seafood Company is recycled into the Ocracoke economy making an exceptional impact during the winter months when jobs and tourists are non-existent;

WHEREAS, Hyde County is a Tier One, Economically Disadvantaged County and the second most impoverished county in the state of North Carolina generating its sole economic survival from agriculture, commercial fishing and tourism;

WHEREAS, the loss of Ocracoke's flounder fishery would eliminate jobs, decrease tax revenue through commercial fishing sales and erase the presence of a fish house on the Ocracoke harbor which is essential to the tourism market that has evolved from this mutually dependent relationship of tourism and fresh seafood;

WHEREAS, Ocracoke Village would not be the same without a fish house and enacting Amendment 2 would negatively affect all business on Ocracoke Island, endanger the presence of the fish house, and this is unacceptable to Ocracoke and Hyde County;

WHEREAS, the Central Region is too large and diverse in regard to flounder harvest and should be divided into two subregions to allow fishermen on the east and west sides of the Pamlico Sound equal opportunity to participate in the fall pound net fishery;

WHEREAS, over the last five years, setting pound nets along Ocracoke and Hatteras have been delayed due to hurricanes and until mid October the catch is primarily summer species including spade, butterfish and pompano;

WHEREAS, to be economically feasible, pound net fishermen need a 5-week season starting October 1st and ending after the first week of November, which allows the owner a two week period to recover the expenses of fishing and two - three weeks for the owner and crew to make a profit for the months of work it took to prepare for the fishery;

WHEREAS, Ocracoke Seafood Company is recognized as one of the Golden Leaf Foundation's most successful projects in eastern North Carolina and has been studied by multiple national organization and the Food and Agriculture Organization of the United Nations for its unique fishermen owned business model;

WHEREAS, Ocracoke Seafood Company ships seafood throughout North Carolina, specifically targets Raleigh markets and is recognized by companies and tourists who purchase seafood as one of the best examples of fresh, local North Carolina seafood;

WHEREAS, Amendment 2 and the current North Carolina Division of Marine Fisheries recommendation to the Marine Fisheries Commission will place all of the dedication, hard work and funding to rebuild the Ocracoke fish house over the last twelve years in dire economic jeopardy;

WHEREAS, the Southern Flounder Advisory Committee has recommended a 31% reduction in flounder harvest in 2019 and a 52% reduction in 2020 with that recommendation being developed through significant debate of the data and multi stakeholder input and allows commercial fishermen one year to adjust their business models that may keep a portion of the pound net fishery operational;

WHEREAS, the average age of a North Carolina commercial fisherman is approaching the mid 50's and those fishermen hold all of the capital and experience in the fishing industry and as they are continually pressured they will retire and move into other fisheries that creates additional stress on those fisheries as well while endangering the commercial fishing industry and damaging the coastal tourism industry;

WHEREAS, the mainland portion of Hyde County has already lost approximately 95% of its flounder fishery, flounder fishermen, fish houses and the economy that those supported because of restrictions that have already been placed on the fishery over the past years, skewing the numbers on the mainland to create an illusion of decreased harvests and decreased stocks because regulations have reduced the number of fishermen and the effort within the fishery;

NOW, THEREFORE, BE IT RESOLVED, that the Hyde County Board of Commissioners unanimously recommend that Amendment 2 and the current North Carolina Division of Marine Fisheries recommendation to the Marine Fisheries Commission be voted against and that the two entities work to find a compromise that will rebuild the southern flounder stocks and end overfishing without destroying fishing families, fishing communities and the seafood infrastructure needed to get seafood to market in and outside of the Great State of North Carolina.

NOW, THEREFORE, LET IT FURTHER BE RESOLVED, the Hyde County Board of Commissioners unanimously recommend the North Carolina Division of Marine Fisheries and the Marine Fisheries Commission consider the adoption of the recommendation of the Southern Flounder Advisory Committee of a reduction of 31% in 2019 and a 52% reduction in 2020 with a 5-week season starting October 1st and ending after the first week of November.

Adopted this the 3rd day of June, 2019.

Earl Pugh, Jr., Chairman
Hyde County Board of Commissioners

Lois Stotesberry, Clerk to the Board
Hyde County Board of Commissioners

From:	Ginger Midgett
To:	Gillikin, Dana
Cc:	Fish, Nancy
Subject:	[External] Proposed Flounder Regulations for NC
Date:	Thursday, June 13, 2019 10:00:15 PM

To whom it may concern,

I can not understand why the NC Marine Fisheries Commission or the Division of Marine Fisheries would want to regulate the flounder fishery in North Carolina any more than it is regulated at the present time, it is already regulated enough. There is no substantial reason other than putting more commercial fisherman out of work. I believe the fishery is not over fished. As consistently mentioned in the proposal, closing the internal coastal waters to flounder fishing or adding more regulations will only create additional hardships for the commercial fisherman and the inshore charter fisheries. I have commercial and recreational fished in Pamlico Sound for more than fifty years. I have observed more small flounder in the sound now than there were twenty five years ago. Closing the inshore waters to flounder fishing will only add more discards and dead flounder being returned to the waters. It is hard enough for the commercial fishermen to make a living with the current regulations in place now. With the tie down rules, mesh depths allowed, turtle closures, no weekend fishing, and sturgeon regulations in place now, it has already put many fishermen out of the fishery. It would be in the best interest of the State of North Carolina (taxes and sustained jobs) to not create any more hardships on the commercial fisherman or the inshore recreational fishery by passing these ridiculous new proposed regulations.

Thank you for your consideration,

Ray Midgett
Manteo, North Carolina

From: Beverly Grisales
To: Gillikin, Dana
Subject: [External] Chairman Bizzell
Date: Friday, July 26, 2019 6:35:40 AM

I am sad to hear about the closing of flounder fishing. I feel you should end gill netting instead . I think gill netting kills too many small fish thus lowering the number of adult fish . Increase the size until the numbers come back and 1 fish per person. Thank You, Beverly Grisales

From: John Collier Jr
To: Gillikin, Dana
Subject: [External] address to Chairman Bizzell
Date: Thursday, July 25, 2019 1:12:54 PM

I would rather see a restriction on number or even size of flounder rather than have no season at all throughout the year. I just bought evertything needed this year for my flounder fishing and gigging this year only to hear that it will be voted to not have a season at all. Please consider the other options......

-- Thank You;
John Collier
Hampstead NC

July 13, 2019

To: North Carolina Div. of Marine Fisheries
Marine Fisheries Comm.
3441 Arendell st.
Morehead City, N.C. 28557
ATTN. Chairman Bizzell

Dear chairman:

As I Plan my next Trip To N.C. East Coast which always includes in shore Flounder Fishing, I can't believe you are considering catch and release fishing and further That sport Fishing has any effect on total Population compared To Commercial net and Gig Fishing. I've seen more flounder stacked in a Hampstead Fish house Than I believe the entire county kills in a month sport Fishing.

Anyway, if you think sport Fishing is a Problem, I would suggest Daily Possesion limit Reduction from Present 4 Down To 2 or even 1. I don't recall ever cleaning more than one Flounder from a days fishing for over 10 years Fishing The N.C. Coast. IT also seems The economic effect on the economy would be much less, guide service, Pier fishing, Tackle shops.

IT would be interesting how you evaluate the effect of Gig fishing, Catch and release doesn't work Too well, I wouldn't Think.

I get The N.C. Wildlife Resources Commission E Mails, July 9 last one, and it had no mention of This Possible change. For Now, my N.C. Travel Plans and $1,000.00 budget are on hold until I see what you do.

Respectively yours
Thomas E. Laisure
Thomas E. Laisure

From:	Ditch
To:	Gillikin, Dana
Subject:	[External] Flounder
Date:	Friday, June 28, 2019 10:35:18 AM

Thanks Dana,

I am a recreational fisherman who has been fishing the NC coast for over 50 years. I've seen the flounder stocks drop off over time, but the last 10 years this seems to have accelerated.
A couple years ago DMF proposed a total ban on keeping flounder for 6 months I think. It was opposed and nothing happened but the fish stocks continued to decline.
When the recreational Fishing license was first proposed one claim was that it would give the recreational fisherman a voice in how the fishery is managed. I see no sign of that , it's just another Tax and I'm not alone in this impression.
I know that flounder bring a lot of money to our commercial fishermen but if there are none for them to catch it won't help them.   Let's try a total ban for 6 months or a year and see what happens. It will hurt in the short term but if the pain is shared on both sides equally I think we will both be better off in the future. Give them the chance to grow and multiply. It is bound to help in the long run.
Thanks,
Dick Gray
[redacted]

[redacted]

From: Pat breeden
To: Gillikin, Dana
Subject: [External] New propsals
Date: Thursday, June 27, 2019 8:36:27 PM

I am a 63 year old woman who lives to fish. I catch my own bait. I fish. I crab. I follow the rules. I find it hard to believe that your organization wants to punish us and cut off flounder fishing, tell us we cant use our own bait and out size restrictions on a croacker??? A fish as plentiful and as useful as a pin fish. NC sees this to be necessary. Not SC. Not VA. Maybe if net fishing was outlawed it would help. We recreational fishermen are lucky to get 2 flounders a week. We obey the rules.
Why not put a size limit on flounder instead of stopping. Why not raise the size from 15" to 16" and none over 22"
Dont take our enjoyment if using our water for fishing away from us. PAT BREEDEN.
[redacted]

Sent from Yahoo Mail on Android

NORTH CAROLINA
State Board of Elections & Ethics Enforcement

Mailing Address:
P.O. Box 27255
Raleigh, NC 27611-7255

Phone: (919) 814-0700
Fax: (919) 715-0135

Ethics & Lobbying Education

The following information applies to public servants, legislators, legislative employees, and ethics liaisons. For information on lobbying education and awareness presentations for lobbyists and lobbyist principals.

Mandatory Education. The N.C. State Board of Elections and Ethics Enforcement provides mandatory ethics and lobbying education for *public servants*, *legislators*, *legislative employees* and *ethics liaisons*. Topics covered include:

- Filing a Statement of Economic Interest ("SEI")
- Monitoring and avoiding conflicts of interest
- The gift ban and its exceptions
- Prohibition on use of public position for private gain
- Lobbying and how it affects individuals covered by the State Government Ethics Act

Ethics education is the primary way individuals subject to the State Government Ethics Act are made aware of their public duties and responsibilities as well as the consequences for violating the ethics laws.

Who Must Participate

- **Public Servants & Ethics Liaisons.** All public servants and ethics liaisons are required to attend a Commission-approved basic ethics and lobbying education presentation within six (6) months of the person's election appointment, or employment and attend a refresher presentation at least every two (2) years thereafter.

- **Legislators & Legislative Employees.** The Commission, jointly with the Legislative Ethics Committee, makes mandatory ethics education and lobbying presentations to all legislators within two (2) months of the legislator assuming his or her office. Legislative employees must also participate in ethics education within three (3) months of employment and attend a refresher at least every two (2) years.

- **Education Presentations & Schedule.** Ethics and lobbying education presentations for public servants and ethics liaisons are offered online and live at Raleigh-only and distance education sites. Completing an online presentation or attending a live session meets either the basic or refresher mandatory education requirements. Visit https://www.ncsbe.gov/Ethics/Education to access online and live training options.

  Ethics education for **legislators** is conducted in live sessions. Legislative employees may participate in ethics education online through the General Assembly.

- **Consequences for Failure to Attend.** Failure to attend an ethics and lobbying education presentation is a violation of the State Government Ethics Act and may result in the individual being recommended for removal from his or her public position or disciplined in his or her State job.

Contact Information

For education related questions, contact:
NC State Board of Elections and Ethics Enforcement
Phone: (919) 814-3600
E-mail: Education.Ethics@doa.nc.gov

2019 STATEMENT OF ECONOMIC INTEREST REMINDERS:

Completed SEIs must be filed on or before April 15, 2019. If you have already filed a 2019 SEI, do not refile. The forms and instructions can be found at https://ethics.ncsbe.gov/sei/blankForm.aspx.

If you filed a 2018 SEI ***and*** you have had ***no changes*** since your 2018 filing, you may file a 2019 SEI No Change Form, located on the website.

You must file a 2019 Long Form if any of the following apply to you:

a. You filed a 2018 SEI **but** you have had changes since your 2018 filing;
b. You did not file a 2018 SEI; or
c. You are a first-time filer or have been appointed to a new or additional position/board.

This year, the State Board of Elections and Ethics Enforcement will roll out a new electronic process for filing SEIs. That electronic filing option will be available in **early February**.

You are encouraged to file your SEI electronically. However, if you want to file your SEIs before the updated electronic version is available, hard copies are available for filing now at the link above.

New commissioners will need to file a 2019 SEI; however, if you have not had any changes since you last filed, you can use the No Change Form, which is fairly easy to complete.

Please file by April 15th to avoid fines and other penalties.

SEI HELPFUL TIPS

1. PUBLIC RECORDS. The State Board of Elections and Ethics Enforcement (State Board) is required to collect and maintain disclosures from certain persons covered by the State Elections and Ethics Enforcement Act Government Ethics Act (Elections and Ethics Act). By law, the information requested is public record and available to the public upon request. As public records, Statements of Economic Interest (SEI) are available on the Commission's website. Personal contact information, however, is not.

2. CONTACT INFORMATION PAGE. The Contact Information page, which includes your personal contact information, will not be available on the Commission's website, but is a public **record.**

3. CHILDREN'S INITIALS. Only list minor children's INITIALS on the SEI. List each child's full legal name on the Confidential Unemancipated Children's Form. If you are filing electronically, the form will be generated at the end of the SEI from the information that you provided on your electronic SEI. The Confidential Form is not a public record, and the State Board will not make it available to the public.

4. READ EACH QUESTION CAREFULLY. Read each question carefully and pay close attention to the time periods in each question as they do vary.

5. ANSWER EACH QUESTION. It is important to answer each question, including all applicable subparts. Even if your answer is "no" or "not applicable," make certain you answer each question. Many of the questions have "yes" and "no" boxes to check for your convenience. Incomplete SEIs may cause delays and negatively impact your public service on a covered board or as an employee.

6. WHY ARE YOU FILING. You must list the complete name of the state board or state agency employer for which you are filing the SEI. Without this information, your SEI may be delayed and negatively impact your public service on a covered board or as an employee.

7. HOW TO FILE. The State Board strongly recommends electronical on-line filing as it is secure, allows easy information updates, and gives you access to your electronic SEIs previously filed. Filing your SEI on-line is easy, quick, convenient, and reduces the chance of reporting errors. Getting started is easy. Follow the simple steps to create your own account and get access today: https://EFILE.ncsbe.gov/ To file a paper version of the SEI, you must provide the State Board with a signed, original SEI form. Each SEI includes an "affirmation" and is a legally binding document. Faxed or emailed copies of your SEI CANNOT be accepted.

SEI Helpful Tips, continued

8. INCOME. List each source of income as requested on the SEI. The actual dollar amount is not required. Be sure to list your employer as a source of income in Question # 6 of the SEI.

9. READ CAREFULLY. Read each question carefully, as the Elections and Ethics Act requires that you disclose your financial holdings and obligations, personal property, and real property and may also include your knowledge of the holdings of both your immediate family and your extended family. “Immediate family” and “extended family” are defined terms in the Elections and Ethics Act, and those definitions are included with this document.

10. REFLECT. Think carefully about WHY you are filing, and whether it has any relationship to your position. Does your board or commission license or regulate you? For many of the boards, a subject matter expert like a licensee is needed. Answering “yes” does not prohibit your service on the board, and your perspective is valued.

11. MAKE A COPY. Make a copy of the SEI for your own records, and make a note in your calendar when you submit it, whether on-line or by mail or hand delivery. When you successfully submit your SEI electronically on-line, the final screen will provide a confirmation number and will be proof that you have satisfied your filing obligation. Please print the **confirmation screen for your records.**

12. ETHICS LIAISON. Contact your Ethics Liaison to assist you in your obligations under the Elections and Ethics Act. Your Ethics Liaison is good source of information about how to fill out your SEI.

13. ON-LINE HELP. The State Board has on-line resources to answer questions you may have about your SEI. For more information, please visit the State Board website which has education offerings.

14. DEFINITIONS. As noted above, certain terms are defined in the Elections and Ethics Act ("immediate family"). These definitions may be helpful to you in completing your SEI. A complete list of all definitions used in the Elections and Ethics Act is available on the State Board's website, under "Ethics". Some of the more common ones are attached to this document.

15. YOUR INTERNET BROWSER. Consider using Internet Explorer or Chrome to submit your SEI. Some users have had trouble using other browsers. 16. WE ARE HERE TO HELP YOU. In addition to on-line resources and written materials, the State Board has expert staff ready to answer any questions you might have and assist you in completing and filing your SEI. Do not hesitate to contact us at sei@ncsbee.gov (919) 814-3600.

2020 Meeting Planning Calendar

January						
Su	*Mo*	*Tu*	*We*	*Th*	*Fr*	*Sa*
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
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February						
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March						
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April						
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May						
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June						
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July						
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August						
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September						
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October						
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11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

November						
Su	*Mo*	*Tu*	*We*	*Th*	*Fr*	*Sa*
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

December						
Su	*Mo*	*Tu*	*We*	*Th*	*Fr*	*Sa*
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
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27	28	29	30			

- MFC
- ASMFC
- SAFMC
- MAFMC
- State Holiday
- Southern Regional AC
- Northern Regional AC
- Finfish AC
- Habitat and Water Quality AC
- Shellfish/Crustacean AC

GENERAL ASSEMBLY OF NORTH CAROLINA
SESSION 2019

SESSION LAW 2019-37
SENATE BILL 648

AN ACT TO PROVIDE FURTHER SUPPORT TO THE SHELLFISH AQUACULTURE INDUSTRY IN NORTH CAROLINA.

The General Assembly of North Carolina enacts:

AUTHORIZE ESTABLISHMENT OF SHELLFISH AQUACULTURE ENTERPRISE AREAS

SECTION 1.(a) G.S. 113-201.1 reads as rewritten:

"**§ 113-201.1. Definitions.**

As used in this Article:

(1) "Natural shellfish bed" means an area of public bottom where oysters, clams, scallops, mussels or other shellfish are found to be growing in sufficient quantities to be valuable to the public.

(2) "Riparian owner" means the holder(s) of the fee title to land that is bordered by waters of an arm of the sea or any other navigable body of water.

(3) "Shellfish" means oysters, clams, scallops, mussels or any other species of mollusks that the Marine Fisheries Commission determines suitable for cultivation, harvesting, and marketing from public grounds and private beds.

(3a) "Shellfish Aquaculture Enterprise Area" means an area established pursuant to G.S. 113-202(s) or G.S. 113-202.1(j).

(4) "Single family unit" means the husband and wife and any unemancipated children in the household.

(5) "Water column" means the vertical extent of water, including the surface, above a designated area of submerged bottom land."

SECTION 1.(b) G.S. 113-202 is amended by adding a new subsection to read:

"(s) The Secretary may establish Shellfish Aquaculture Enterprise Areas for bottom leasing pursuant to this subsection. The Secretary may establish one or more Shellfish Aquaculture Enterprise Areas that comply with the requirements of this section, including the notice, public hearing, and public comment requirements; any other State requirements for shellfish leasing; and any applicable federal requirements. Leases issued in a Shellfish Aquaculture Enterprise Area shall be nontransferable and shall revert to the State upon relinquishment or termination. The Marine Fisheries Commission may adopt any rules necessary to implement this subsection."

SECTION 1.(c) G.S. 113-202.1 is amended by adding a new subsection to read:

"(j) The Secretary may establish Shellfish Aquaculture Enterprise Areas for water column leasing pursuant to this subsection. The Secretary may establish one or more Shellfish Aquaculture Enterprise Areas that comply with the requirements of this section, including the notice, public hearing, and public comment requirements; any other State requirements for shellfish leasing; and any applicable federal requirements. Requirements under this section include the notice, public hearing, and public comment requirements of this section. Leases issued in a Shellfish Aquaculture Enterprise Area shall be nontransferable and shall revert to the

State upon relinquishment or termination. The Marine Fisheries Commission may adopt any rules necessary to implement this subsection."

SECTION 1.(d) The Division of Marine Fisheries of the Department of Environmental Quality shall identify areas in waters that are under a moratorium for shellfish leasing that could potentially be established as Shellfish Aquaculture Enterprise Areas. The Division shall report its findings to the General Assembly no later than April 1, 2020.

ESTABLISH PAMLICO SOUND SHELLFISH AQUACULTURE PILOT PROJECT

SECTION 2. Notwithstanding any other provision of law, the Secretary of Environmental Quality may grant up to three shellfish cultivation leases or water column leases in Pamlico Sound as provided in the pilot project established by this section. Under the pilot project, each lease may be up to 50 acres in size; each lease must be separated from any other lease and from the shoreline by at least 250 yards; and no person, including a corporate entity, or single family unit, may hold more than 100 acres of leases. The Division of Marine Fisheries of the Department of Environmental Quality shall, to the extent practicable, grant leases in different geographic areas of Pamlico Sound. The Division shall study the advantages and disadvantages associated with leasing such areas within Pamlico Sound. In conducting this study, the Division shall consult with shellfish growers, nearby riparian owners, and other users of the public bottoms and waters. The Division shall submit an interim report of its findings, including any recommendations, to the General Assembly no later than January 1, 2025, and a final report of its findings, including any recommendations, to the General Assembly no later than January 1, 2030. In its final report, the Division shall include a recommendation on whether the pilot project should be terminated, be made permanent, or be expanded. This section shall terminate July 1, 2030, and any leases granted pursuant to this section shall terminate no later than July 1, 2031.

INCREASE PRODUCTION AND PLANTING REQUIREMENTS FOR SHELLFISH LEASES

SECTION 3.(a) Definitions. – For purposes of this section and its implementation:

(1) "Extensive shellfish culture" means shellfish grown on the bottom without the use of cages, racks, bags, or floats.

(2) "Intensive shellfish culture" means shellfish grown on the bottom or in the water column using cages, racks, bags, or floats.

(3) "Shellfish Production and Planting Requirements Rule" means 15A NCAC 03O .0201 (Standards and Requirements for Shellfish Bottom Leases and Franchises and Water Column Leases) for purposes of this section and its implementation.

SECTION 3.(b) Shellfish Production and Planting Requirements Rule. – Until the effective date of the revised permanent rule that the Marine Fisheries Commission is required to adopt pursuant to subsection (d) of this section, the Commission shall implement the Shellfish Production Requirements Rule as provided in subsection (c) of this section.

SECTION 3.(c) Implementation. – Shellfish leases shall be terminated unless they comply with the following requirements:

(1) Franchises recognized pursuant to G.S. 113-206 and shellfish bottom leases shall be terminated unless:

a. They produce a minimum of 20 bushels of shellfish per acre averaged over the previous three-year period beginning in year five of the lease; or

b. For intensive culture bottom operations, the holder of the lease provides evidence of purchasing a minimum of 23,000 shellfish seed per acre annually and for extensive culture bottom operations, the holder of the lease plants a minimum of 15,000 shellfish seed per acre per year.

(2) Water column leases shall be terminated unless:

a. They produce a minimum of 50 bushels of shellfish per acre averaged over the previous three-year period beginning in year five of the lease; or

b. The holder of the lease provides evidence of purchasing a minimum of 23,000 shellfish seed per acre annually.

SECTION 3.(d) Additional Rule-Making Authority. – The Commission shall adopt a rule to amend the Shellfish Production Requirements Rule consistent with subsection (c) of this section. Notwithstanding G.S. 150B-19(4), the rule adopted by the Commission pursuant to this section shall be substantively identical to the provisions of subsection (c) of this section. Rules adopted pursuant to this section are not subject to Part 3 of Article 2A of Chapter 150B of the General Statutes. Rules adopted pursuant to this section shall become effective as provided in G.S. 150B-21.3(b1), as though 10 or more written objections had been received as provided in G.S. 150B-21.3(b2).

SECTION 3.(e) Applicability and Sunset. – This section and rules adopted pursuant to this section apply to all new and renewal shellfish leases granted after July 1, 2019. This section expires when permanent rules adopted as required by subsection (d) of this section become effective.

FACILITATE THE TRANSITION OF TERMINATED LEASES TO PRODUCTIVE USES

SECTION 4.(a) G.S. 113-202(n) reads as rewritten:

"(n) Upon final termination of any leasehold, ~~the bottom in question is thrown open to the public for use in accordance with laws and rules governing use of public grounds generally.~~the Secretary may do any of the following:

(1) Make the bottom available for a new lease application for a period of 18 months.

(2) Designate the bottom as a Shellfish Aquaculture Enterprise Area.

(3) Make the bottom open to the public for use in accordance with laws and rules governing use of public grounds generally.

Within 30 days of final termination of the leasehold, the former leaseholder shall remove all abandoned gear and markers denominating the area of the leasehold as a private bottom. The State may, after 10 days' notice to the owner of the abandoned gear and markers thereof, remove the abandoned structure and have the area cleaned up. The cost of such removal and cleanup shall be payable by the owner of the abandoned gear and markers and the State may bring suit to recover the costs thereof."

SECTION 4.(b) G.S. 113-202(a) reads as rewritten:

"(a) To increase the use of suitable areas underlying coastal fishing waters for the production of shellfish, the Secretary may grant shellfish cultivation leases to persons who reside in North Carolina under the terms of this section when the Secretary determines, in accordance with his duty to conserve the marine and estuarine resources of the State, that the public interest will benefit from issuance of the lease. Suitable areas for the production of shellfish shall meet the following minimum standards:

(1) The area leased must be suitable for the cultivation and harvesting of shellfish in commercial quantities.

(2) ~~The~~ Except as provided under subsection (n) of this section, the area leased must not contain a natural shellfish bed.

…."

SECTION 4.(c) This section becomes effective July 1, 2019, and applies to leases terminated on or after that date.

ALLOW TRANSPLANTING OF SEED OYSTERS AND SEED CLAMS FROM PERMITTED AQUACULTURE OPERATION NURSERY FACILITIES IN PROHIBITED WATERS

SECTION 5. G.S. 113-203 reads as rewritten:

"**§ 113-203. Transplanting of oysters and clams.**

…

(a3) ~~It~~ Unless the Secretary determines that the nursery of shellfish in an area will present a risk to public health, it is lawful to transplant seed oysters or seed clams taken from permitted aquaculture operations that use waters in the ~~restricted~~ prohibited, restricted, or conditionally approved classification to private beds pursuant to an Aquaculture Seed Transplant Permit issued by the Secretary that sets times during which transplant is permissible and other reasonable restrictions imposed by the Secretary under either of the following circumstances:

(1) When transplanting seed clams less than 12 millimeters in their largest dimension.

(2) When transplanting seed oysters less than 25 millimeters in their largest dimension.

…."

ADMINISTRATIVE REMEDY FOR SHELLFISH LEASING APPEALS

SECTION 6.(a) G.S. 143B-289.57 is amended by adding a new subsection to read:

"(f) The Chair of the Commission shall appoint a three-member Shellfish Cultivation Lease Review Committee to hear appeals of decisions of the Secretary regarding shellfish cultivation leases issued under G.S. 113-202. The Committee shall include one Commission member, who shall serve as the hearing officer, and two public members. One public member shall have expertise or other relevant experience in shellfish aquaculture, and the other public member shall have expertise or other relevant experience with respect to coastal property or property assessment. The Commission shall adopt rules to establish procedures for the appeals and may adopt temporary rules."

SECTION 6.(b) G.S. 113-202(g) reads as rewritten:

"(g) After consideration of the public comment received and any additional investigations the Secretary orders to evaluate the comments, the Secretary shall notify the applicant in person or by certified or registered mail of the decision on the lease application. The Secretary shall also notify persons who submitted comments at the public hearing and requested notice of the lease decision. An applicant who is dissatisfied with the Secretary's decision ~~or another person aggrieved by the decision~~ may commence a contested case by filing a petition under G.S. 150B-23 within ~~20~~ 30 days after receiving notice of the Secretary's decision. In the event the Secretary's decision is a modification to which the applicant agrees, the lease applicant must furnish an amended map or diagram before the lease can be issued by the Secretary. A person other than the applicant who is aggrieved by the Secretary's decision may file a petition for a contested case hearing only if the Shellfish Cultivation Lease Review Committee established pursuant to G.S. 143B-289.57(f) determines that a hearing is appropriate. A request for a determination of the appropriateness of a contested case hearing shall be made in writing and received by the Review Committee within 30 days after the disputed decision is made. A determination of the appropriateness of a contested case shall be made by the Review Committee within 90 days after a request for a determination is received and shall be based on whether the person seeking to commence a contested case:

(1) Has alleged that the decision is contrary to a statute or rule.

(2) Is directly affected by the decision.

(3) Has alleged facts or made legal arguments that demonstrate that the request for the hearing is not frivolous.

If the Review Committee determines that a contested case is appropriate, the petition for a contested case shall be filed within 30 days after the Review Committee makes its determination. A determination that a person may not commence a contested case is a final agency decision and is subject to judicial review under Article 4 of Chapter 150B of the General Statutes. If, on judicial review, the court determines that the Review Committee erred in determining that a contested case would not be appropriate, the court shall remand the matter for a contested case hearing under G.S. 150B-23 and final decision on the permit pursuant to G.S. 113A-122. Decisions in such cases shall be rendered pursuant to those rules, regulations, and other applicable laws in effect at the time of the commencement of the contested case.

The applicant or another person aggrieved by a final decision under this section may appeal the decision to the superior court of the county where the proposed lease or any part thereof is located, pursuant to the provisions of Chapter 150B of the General Statutes."

SECTION 6.(c) This section becomes effective July 1, 2019, and applies to decisions of the Secretary made on or after that date.

MORATORIUM ON SHELLFISH LEASING IN THE NEW HANOVER COUNTY AREA

SECTION 7. Notwithstanding G.S. 113-202 and G.S. 113-202.1, a moratorium on new shellfish cultivation leases and new water column leases for aquaculture shall be imposed for all those waters enclosed by a line beginning at 34° 13.10221' N -77° 48.79544' W on the mainland side near Wrightsville Beach Bridge; running southeasterly to a point at 34° 12.51584' N -77° 47.81847' W on Wrightsville Beach; following the shoreline southwesterly to a point at 34° 11.121' N -77° 48.848' W at Masonboro Inlet; running southwesterly to a point at 34° 10.927' N -77° 48.771' W at Masonboro Inlet; continuing southwesterly to a point at 34° 05.04108' N -77° 52.08324' W near IWW marker #159 continuing running southwesterly to a point at 34° 03.64140' N -77° 53.41338' W on the mainland adjacent to the eastern mouth of Snow's Cut; running northeasterly along the shoreline to the point of beginning. The moratorium shall expire July 1, 2021. For purposes of this section, a new shellfish cultivation lease or water column lease shall include applications for either type of lease received by the Secretary, but not granted as of July 1, 2019.

MORATORIUM ON SHELLFISH LEASING IN BOGUE SOUND

SECTION 8. Notwithstanding G.S. 113-202 and G.S. 113-202.1, a moratorium on new shellfish cultivation leases and new water column leases for aquaculture shall be imposed for all those waters enclosed by a line beginning at 34° 43.24641' N -76° 41.68436' W; running easterly following the Highway 70 High Rise Bridge to a point at 34° 43.27819' N -76° 41.22259' W; running southerly to a point 34° 42.375275' N -76° 40.80078' W on the southern tip of Radio Island; running southerly to a point 34° 41.98273' N -76° 40.81929' W; following the shoreline westerly to the Emerald Isle Bridge at a point 34° 40.05410' N -77° 03.80531' W; running northwesterly following the bridge to a point 34° 40.77658' N -77° 04.02674' W on the mainland near the Emerald Isle High Rise Bridge; running easterly following the shoreline to the point of beginning. The moratorium shall expire July 1, 2021. For purposes of this section, a new shellfish cultivation lease or water column lease shall include applications for either type of lease received by the Secretary, but not granted as of July 1, 2019.

STUDY HOW TO REDUCE USER CONFLICT RELATED TO SHELLFISH CULTIVATION LEASES

SECTION 9. The Division of Marine Fisheries and the Marine Fisheries Commission shall study how to reduce user conflict related to shellfish cultivation leases. The

Division and Commission shall complete this study no later than January 1, 2020, and shall adopt rules and reform internal operating procedures consistent with the findings of the study no later than March 1, 2021.

STUDY PENALTIES ASSOCIATED WITH VIOLATIONS OF LAWS REGARDING TAKING SHELLFISH AND SHELLFISH AQUACULTURE OPERATIONS

SECTION 10. The Division of Marine Fisheries of the Department of Environmental Quality, in consultation with the North Carolina Department of Justice and the North Carolina Sentencing and Policy Advisory Commission, shall study the penalties associated with violations of laws regarding taking shellfish and shellfish aquaculture operations. The agencies shall specifically review G.S. 113-207 (Taking shellfish from certain areas forbidden; penalty), G.S. 113-208 (Protection of private shellfish rights), G.S. 113-218 (Protection of private marine aquaculture rights), and G.S. 113-269 (Robbing or injuring hatcheries and other aquaculture operations), and may review other statutes with penalties associated with violations of laws regarding taking shellfish and shellfish aquaculture operations. In their review of the statutes, the agencies shall consider the levels of criminal penalties, fines, and restitution; the consistency and proportionality of the statutes; and whether any of the statutes or their provisions are duplicative. The agencies shall develop recommendations for amendment of the statutes that would make the penalties more consistent and proportional and less duplicative and that would serve to better protect the wild and cultured shellfish resources in the State. The agencies shall report the results of their study, including their recommendations, to the General Assembly no later than March 1, 2020.

STUDY OF SHELLFISH LOAN PROGRAM

SECTION 11. The North Carolina Coastal Federation (Federation) shall study a low-interest loan program to provide start-up and expansion capital to shellfish growers in waters of the State. As part of its study, the Federation shall investigate and recommend optimal loan terms, a recommended administrative structure for the program, and limitations on loan amounts and on uses of loaned funds necessary to maximize public economic benefits and target funding support where need is greatest. The Federation may use administrative funds provided to it under S.L. 2018-5 for the study. The Federation shall submit its report, including funding needs and any legislative proposals, to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources and the Fiscal Research Division no later than March 15, 2020.

STUDY CROP INSURANCE FOR SHELLFISH AQUACULTURE

SECTION 12. The Department of Agriculture and Consumer Services shall study crop insurance and other risk of loss mitigation and protection programs available to persons engaging in shellfish aquaculture in North Carolina. The Department shall include all of the following in its study:

(1) An overview and assessment of currently available State or federal programs, including programs offered in other states, and identification of gaps or shortfalls in the coverage provided by those programs.

(2) The identification of options for insurance or other risk protection programs subsidized or underwritten by the State, including an analysis of feasibility, cost, and whether the option would provide sufficient spread of risk to be an actuarially sound investment of public funds.

(3) If the Department finds that no program limited to this State is actuarially sound, an assessment of legal, practical, or political barriers to a federal or multistate crop insurance or other risk mitigation program for shellfish aquaculture.

The Department shall submit its report, including recommendations for required funding and any legislative changes needed, to the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources and the Fiscal Research Division no later than November 1, 2020.

SEVERABILITY CLAUSE AND EFFECTIVE DATE

SECTION 13.(a) If any section or provision of this act is declared unconstitutional or invalid by the courts, it does not affect the validity of this act as a whole or any part other than the part declared to be unconstitutional or invalid.

SECTION 13.(b) Except as otherwise provided, this act becomes effective July 1, 2019.

In the General Assembly read three times and ratified this the 13th day of June, 2019.

s/ Daniel J. Forest
President of the Senate

s/ Tim Moore
Speaker of the House of Representatives

s/ Roy Cooper
Governor

Approved 2:31 p.m. this 21st day of June, 2019

Committee Reports

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

MEMORANDUM

TO: Marine Fisheries Commission
Southern Flounder FMP Advisory Committee

FROM: Michael Loeffler, Co-lead Southern Flounder Plan Development Team
Anne Markwith, Co-lead Southern Flounder Plan Development Team

DATE: June 3, 2019

SUBJECT: Southern Flounder FMP Advisory Committee Meeting

The Southern Flounder FMP Advisory Committee met on Monday, June 3, 2019 at 6 p.m. at the Division of Marine Fisheries Central District Office located at 5285 Highway 70 West, Morehead City, NC. The following attended:

Advisers: Fred Scharf (chairman), Michael Oppegaard, Tom Roller, Keneth Johnson, Joe Romano, James Williams, Kurt Tressler, Bradley Stryon

Absent: Mary Ellon Ballance

Staff: Catherine Blum, Michael Loeffler, Anne Markwith, Steve Murphey, Charlton Godwin, Katy West, Jesse Bissette, Brandi Salmon, Trevor Scheffel, Jennifer Lewis, Debbie Manley, Carter Witten, Amanda Tong, Alan Bianchi, Tracy Bauer, Tina Moore, Brian Gupton

MFC: Chuck Laughridge, Michael Blanton

Public: Chris Elkins, Allyn Powel, Adam Tyler, Madison Ruff

Fred Scharf called the meeting to order at 6:02 pm. At Dr. Scharf's request, the members of the AC introduced themselves for the benefit of the members of the public present.

APPROVAL OF AGENDA

Motion by Tom Roller to approve agenda, seconded by Kurt Tressler – motion was approved unanimously.

APPROVAL OF MINUTES

Motion by Tom Roller to approve meeting minutes from April 2, 2019, seconded by Mike Oppegaard – motion was approved unanimously.

DISCUSS 2019 ADVISORY COMMITTEE MEETING SCHEDULE

Division staff presented proposed dates for the remaining advisory committee meetings in 2019. The dates are as follows: July 24, August 14, September 11, October 9, November 20 and December 11. There was discussion on the overall timeline of Amendment 3. Though the Southern Flounder Advisory Committee (AC) is appointed by the Marine Fisheries Commission (MFC), staff indicated that since development of the next amendment is included in the recommendation for Amendment 2, work on Amendment 3 with the current AC would move forward based on the meeting schedule above when Amendment 2 is approved. One point of clarification is the purpose of the standing committees is to advise the MFC, whereas the purpose of the Fishery Management Plan (FMP) AC is to assist the Division of Marine Fisheries (DMF) with the FMP process.

REVIEW PUBLIC COMMENT AND ADVISORY COMMITTEE RECOMMENDATIONS

Staff discussed the public comment that had been received on draft Amendment 2 since the MFC had approved the draft to go out for comment at their May business meeting. Thirteen people spoke at the joint meeting of the Finfish, Northern and Southern Advisory Committees that had been held that afternoon. Ten were against Amendment 2 and three were for Amendment 2. Staff then discussed the letters received to date. Three letters had been received, all against Amendment 2. Finally, the constant contact online comments were discussed. One hundred and forty-one comments had been received, 76 people supported Amendment 2 and 60 were against it.

Staff then presented the standing Advisory Committee's motions that were made that afternoon at the joint meeting. The Southern Regional Advisory Committee – Motion by Ron McCoy to accept the DMF recommendation for a 62 percent reduction in harvest in 2019 and a 72 percent reduction in harvest in 2020. Second by Tom Smith. Motion fails 3-5 with one abstention. Motion by Ruth King to recommend the existing Southern Flounder AC's schedule of reductions. Second by Jerry James. Friendly amendment to ask for examination of a slot limit as part of Amendment 3. Motion fails 4-4 with one abstention.

Northern Advisory Committee – Motion by Keith Bruno to recommend a 52 percent reduction in southern flounder harvest until Amendment 3 is adopted. Motion fails for lack of second. Motion by Kenneth Shiver to support the DMF recommendation. Second by Jim Rice. Motion carries 4-2. Motion by Keith Bruno to ask the MFC to consider dividing the allowable days for gill netting amongst allowable fishing months for a given area due to the Sea Turtle ITP. Second by Jim Rice. Motion carries 5-0 with one abstention. Motion by Keith Bruno to recommend the 12-hour soak and current yardage limit for the large-mesh gill net fishery. Second by Roger Rulifson. Motion fails 3-3.

Finfish Advisory Committee – Motion by Ken Seigler to recommend that the MFC include a slot limit in Amendment 2 across all gears and user groups. Second by Brent Fulcher. Motion fails 1-4 with one abstention. Motion by Brent Fulcher to recommend a reduced harvest of 52 percent, not to exceed 52 percent until Amendment 3 is completed. Second by Bradley Styron. Motion carries 5-0 with one abstention. Motion by Brent Fulcher to recommend that the MFC ask the Secretary of DEQ to allow the Director of DMF to go out of compliance with the ASMFC Summer Flounder Plan and adopt a 12-inch size limit and a 4-fish per day bag limit for southern flounder in North Carolina waters. Second by Sam Romano. Motion carries 5-0 with one abstention. Motion by Brent Fulcher to have the Southern Flounder AC look at recommending a moratorium on all southern flounder harvest from November 1, 2019 to September 1, 2022. Second by Ken Seigler. Motion carries 4-2.

AMENDMENT 2: ACHIEVING SUSTAINABLE HARVEST

Staff reviewed slides from the presentation earlier at the Joint AC meeting. The committee expressed concerns with the timeline such as how a reduction could be met in 2019 with only four months left in the year. There was also discussion about the non-quantifiable management options and proposed seasons. Concerns were expressed over the motion that was previously made by this AC as it meets the two-year statute to end overfishing, but it does not meet the mandate to end the overfished status in 10 years.

Dr. Scharf shared Mary Ellon Ballance's letter to the AC in her absence, with her recommendation of 31% reduction for 2019.

Motion to amend the April 2nd Southern Flounder Advisory Committee recommendation was made by Mike Oppegaard, second by Tom Roller.

The Southern Flounder Advisory Committee recommends that starting January 1, 2019 a 52% reduction (*F*=0.34) be adopted with the following changes for the commercial fishery, calculated for the Northern, Central, and Southern areas:

- **40% reduction for the pound net fishery, with a start date of September 15:**
  -Northern – September 15 through October 28;
  -Central – September 15 through November 2; and
  -Southern – September 15 through November 3.
- **40% reduction for the gig fishery, with a start date of April 1:**
  -Northern – April 1 through October 24;
  -Central – April 1 through November 11; and
  -Southern – April 1 through August 25.
- **For the large-mesh gill net fishery a reduction to make up the difference to yield a 52% reduction for the commercial fishery overall, with a start date of September 15 recognizing that the division proposal (as presented on April 2, 2019) for the Recreational Commercial Gear License large-mesh gill net season of September 15-30 may be changed by this final percent reduction.**

The percent reduction for the large-mesh gill net fishery, based on the Southern Flounder Advisory Committee recommendation, would be approximately 71% compared to the 2017

removals. This reduction to the large-mesh gill net fishery is equal to 162,770 pounds in total removals. A start date of September 15 results in the following seasons:

-Northern – September 15 through October 12;
-Central – September 15 through October 5; and
-Southern – September 15 through October 21.

In addition, as of January 1, 2020, the committee recommends:

- **Implementing a 1,500-yard limit for large-mesh gill nets in Management Unit A, a 1000-yard limit in Management Units B and C, and a 750-yard limit for large-mesh gill nets in Management Units D and E.**
- **Prohibiting the use of picks, gaffs, gigs, and spears when removing flounder from pound nets.**

The committee also recommends that starting in 2020 the division season recommendation (as presented on April 2, 2019) be applied to the recreational fisheries. The season for the recreational hook-and-line and gig fisheries will be July 16 through September 30.

Additionally, the committee recommendation includes the management measures from Amendment 1 and Supplement A to Amendment 1, as stated in draft Amendment 2, be carried forward. The recommendation also

maintains regulations from ASMFC Summer Flounder, Black Sea Bass, and Scup Plan for recreational size and bag limits for flounder, and

approves continued development of Amendment 3.

Motion passed 5-2.

Motion was made by Mike Oppegaard to adjourn, seconded by Tom Roller. Motion was approved.

The meeting adjourned at 8:45 p.m.

Cc: John Batherson, Chris Batsavage, Catherine Blum, Larry Boomer, Ellie Davis, Anne Deaton, Christopher Elkins, Nancy Fish, Jess Hawkins, David Hilton, Laura Lee, Dee Lupton, Shawn Maier, Stephen Murphey, Hardy Plyler, Steve Poland, Jerry Schill, Isaiah Smith, Patricia Smith, David Sneed, Jason Walker, William Yingst, Biological Supervisors, Committee Staff Members, District Managers, Marine Fisheries Commission, Marine Patrol Captains, Section Chiefs

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

DRAFT

August 2, 2019

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Jason Rock, Co-lead Blue Crab Plan Development Team
Corrin Flora, Co-lead Blue Crab Plan Development Team

SUBJECT: Blue Crab Fishery Management Plan Advisory Committee Meeting

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The Blue Crab Fishery Management Plan Advisory Committee met on June 27, 2019 at 6 p.m., at the NCDEQ Washington Regional Office located at 943 Washington Square Mall in Washington, NC. The following attended:

Advisers: Joseph Romano, Mike Marshall, Kenneth Seigler, Perry Beasley, Thomas Roller, Robert Bruggeworth

Staff: Jason Rock, Corrin Flora, Debbie Manley, Katy West, Daniel Ipock, Kathy Rawls, Laura Klibansky, Jason Burleson

Public: Sara Hallas, Chad Bond

Chairman Romano called the meeting to order at 6:00 p.m.

APPROVAL OF THE AGENDA AND MINUTES/PUBLIC COMMENT

Chairman Romano entertained a motion to approve the agenda. Marshall moved to approve the agenda and Beasley seconded the motion. The motion passed unanimously. Chairman Romano entertained a motion to approve the draft minutes from the May 23, 2019 meeting. Seigler moved to approve the minutes, seconded by Bruggeworth. The motion passed unanimously.

Members of the public provided comment during the formal public comment period. Sara Hallas, lost fishing gear project administrator for the North Carolina Coastal Federation, introduced herself to the committee and shared the results of the 2019 cleanup period. She gave a brief explanation on the data collected beyond number of pots and possible data sources for future plans. Sara shared her support of the cleanup period remaining closed for the entirety of the set timeframe, but was clear that there is only a set amount of money for the project no matter the timeframe. Chad Bond, a commercial crabber in the Pungo River region, commented on concerns over areas closed to pots including waters around the ICWW and the 6ft rule in the Pamlico and Pungo rivers. He also recommended a designated buoy color for fishermen where they would have one buoy color for hard pots and a different color for peeler pots. Staff indicated this issue is larger than blue crab as conflicts with the shrimp fishery and other boaters initiated the need for the rule.

Kenneth Seigler made a motion that the PDT look into rules 03J 0301 and 03R 0107 and see if the 6ft rule can be amended to open to crab pots. The motion was seconded by Bruggeworth. Motion passed unanimously.

REVIEW CRAB SPAWNING SANCTUARIES BOUNDARIES REQUESTED BY THE COMMITTEE

Division staff (Rock) reviewed the crab spawning sanctuary boundaries requested by the committee. There was discussion on the use of day markers for boundary points at Ophelia and Cape Fear inlets as well as a recommendation to connect the ocean boundaries of inlets from Bogue Inlet south to New River Inlet.

Thomas Roller made a motion to recommend adopting Drum (Ophelia) boundary modified to use Core Sound Light 27 marker (DMF refined map). The motion was seconded by Mike Marshall. Motion passed unanimously.

Kenneth Seigler made a motion to accept red areas from Bogue Inlet through New River, including 100 yds from shore between. From Topsail Inlet through Tubbs Inlet AC recommended boundaries. The motion was seconded by Robert Bruggeworth. Motion passed unanimously.

Staff verified with the committee the intent to keep the closure period for southern inlets which was voted on at their April meeting and the boundaries for northern inlets voted on at their May meeting.

REVIEW SUSTAINABLE HARVEST ANALYSIS REQUESTED BY THE COMMITTEE

Division staff (Rock) reviewed the results of the sustainable harvest analysis requested by the committee. There was discussion on immature female blue crab marketability and the state split closure. Staff reiterated that these closure periods would not have the option to open early.

Mike Marshall made a motion to move that the committee support adoption of management measure combination 17.9 as in Table 1. The motion was seconded by Kenneth Seigler. The motion passed unanimously.

Kenneth Seigler made a motion to keep the 5% cull tolerance in place. The motion was seconded by Thomas Roller. The motion passed unanimously.

REVIEW DRAFT BLUE CRAB FMP AMENDMENT 3

Division staff (Rock) gave a presentation of the full Blue Crab FMP Amendment 3. There was discussion on survey gear and funding, water quality, adaptive management, shoreline definition. The committee agreed to keep all previous issue recommendations as worded.

Thomas Roller made a motion to adopt the adaptive management framework based on the peer-reviewed and approved stock assessment model. The motion was seconded by Mike Marshall. The motion failed 3-3.

Staff reviewed the amendment process moving forward.

Having no further business to conduct, the meeting adjourned at 8:53 p.m.

cc:	John Batherson	Laura Lee	Jason Walker
	Chris Batsavage	Dee Lupton	Biological Supervisors
	Catherine Blum	Shawn Maier	Committee Staff Members
	Ellie Davis	Stephen Murphey	District Managers
	Anne Deaton	Steve Poland	Marine Fisheries Commission
	Nancy Fish	Jerry Schill	Marine Patrol Captains
	Jess Hawkins	Patricia Smith	Section Chiefs

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August 2, 2019

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Jason Rock, Co-lead Blue Crab Plan Development Team
Corrin Flora, Co-lead Blue Crab Plan Development Team

SUBJECT: Blue Crab Fishery Management Plan Advisory Committee Meeting

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The Blue Crab Fishery Management Plan Advisory Committee met on May 23, 2019 at 6 p.m., at the NCDEQ Washington Regional Office located at 943 Washington Square Mall in Washington, NC. The following attended:

Advisers: Joseph Romano, Mike Marshall, Kenneth Seigler, Perry Beasley, Sammy Corbett, Thomas Roller, Robert Bruggeworth

MFC: Doug Cross

Staff: Jason Rock, Corrin Flora, Debbie Manley, Katy West, William Boyd, Odell Williams, Daniel Zapf, Daniel Ipock

Public: Penny Beasley

Chairman Romano called the meeting to order at 6:01 p.m.

APPROVAL OF THE AGENDA AND MINUTES/PUBLIC COMMENT

Chairman Romano entertained a motion to approve the agenda with addition of remarks by Doug Cross on Monterey Bay Aquarium's Seafood Watch listing of the North Carolina blue crab fishery as avoid. Corbett moved to approve the agenda with modification and Seigler seconded the motion. The motion passed unanimously. Chairman Romano entertained a motion to approve the draft minutes from the April 25, 2019 meeting. Corbett moved to approve the minutes, seconded by Beasley. The motion passed unanimously. There was no public comment.

INDUSTRY DISCUSSION ON MONTEREY BAY AQUARIUM'S SEAFOOD WATCH LISTING OF NORTH CAROLINA BLUE CRAB

Commissioner Cross addressed the committee as a blue crab dealer to express concern over the recent listing by the Monterey Bay Aquarium's Seafood Watch of North Carolina blue crab as a species to avoid. He emphasized the effect this is having already on the supply chain and possible further complications. He urged the committee to address the major topic of diamondback terrapin interactions in the crab pot industry when setting forth recommendations. The committee discussed local, regional, and national markets; basket and picking house markets; effects on regional crabbers; excluder devices, gear modification, and combination studies; and reactionary regulations.

FISHERY MANAGEMENT PLAN ISSUE PAPER: EXPAND CRAB SPAWNING SANCTUARIES TO IMPROVE SPAWNING STOCK BIOMASS

Division staff (Rock) gave a presentation to the committee on the fishery management plan issue paper "Expand Crab Spawning Sanctuaries to Improve Spawning Stock Biomass". This was the second-time staff presented this issue paper to the committee. The presentation included potential sanctuary boundaries modified based on previous committee input. There was discussion from the committee about activities in these regions besides commercial crab pots and additional modification to proposed boundaries. Staff clarified the boundaries in the ocean were adjusted based on enforcement input. The committee asked the division to look further into adjusting the boundaries of inlets south of Barden Inlet.

Sammy Corbett made a motion to leave Oregon, Hatteras, and Ocracoke inlets as currently in rule. Change Drum and Barden inlets to the proposed boundaries. The motion was seconded by Bruggeworth. Motion passed unanimously.

REVIEW SUSTAINABLE HARVEST ANALYSIS REQUESTED BY THE COMMITTEE

Division staff (Rock) reviewed the results of the sustainable harvest analysis requested by the committee. There was discussion from the committee on differences between the northern and southern portions of the state and closure times. Staff clarified that reduction values are not cumulative when considering multiple options. The committee asked the division to calculate reductions based on a March 1-15 closure with prohibiting immature female harvest south of the 58 bridge and A January 1-31 closure with prohibiting immature female harvest and a 6.75" mature female maximum size north of the 58 bridge.

OTHER BUSINESS

Ken Seigler brought up an issue with the Intracoastal Waterway opening after the pot cleanup period. After discussion of proclamation language and intent, the committee asked the division to look at the language of the proclamation and Amendment 2 to the Blue Crab Fishery Management Plan for clarification at the next meeting.

Having no further business to conduct, the meeting adjourned at 8:42 p.m.

cc: John Batherson Laura Lee Jason Walker

Chris Batsavage	Dee Lupton	Biological Supervisors
Catherine Blum	Shawn Maier	Committee Staff Members
Ellie Davis	Stephen Murphey	District Managers
Anne Deaton	Steve Poland	Marine Fisheries Commission
Nancy Fish	Jerry Schill	Marine Patrol Captains
Jess Hawkins	Patricia Smith	Section Chiefs

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MEMORANDUM

TO: Marine Fisheries Commission
Northern, Southern, and Finfish Advisory Committees

FROM: Michael Loeffler, Katy West, Kathy Rawls, Lee Paramore, Tina Moore, and Chris Stewart Marine Fisheries Commission Advisory Committee staff leads

DATE: June 3, 2019

SUBJECT: Joint Meeting of the Marine Fisheries Commission's Northern, Southern and Finfish Advisory Committees

The Marine Fisheries Commission's Northern, Southern and Finfish advisory committees held a joint meeting on June 3 at the Crystal Coast Civic Center in Morehead City, North Carolina.

The following Advisory Committee members were in attendance:
Northern – Everett Blake – co-chair, Keith Bruno, James Neely, Jim Rice, Roger Rulifson, and Kenneth Shivaer (Absent -Joseph Kavanagh, Sam Liverman, Floyd Layden, Raymond Pugh and Sara Winslow)

Southern – Fred Scharf – chair, Jerry James – co-chair, Edwin Bebb, Jason Fowler, Ruth King, Ron McCoy, Pam Morris, Tom Smith, and Adam Tyler (Absent – Charles Griffin and Christopher Hunt)

Finfish – Cameron Boltes – chair, Sam Romano – co-chair, Thomas Brewer, Brent Fulcher, Ken Siegler, and Bradley Styron (Absent – Jeff Buckel, Randy Proctor, Scott Whitley and Sara Winslow)

Marine Fisheries Commission Chair Rob Bizzell called the meeting to order at 12:02 p.m.

EXPLANATION OF MEETING PROCESS

Chairman Bizzell called the meeting to order and reminded the committee advisers of their duty to avoid conflicts of interest and asked if there were any known conflict of interest with respect to any matters coming before the commission at this meeting.
Chairman Bizzell advised the purpose of the meeting is for the advisory committees to provide input to the Marine Fisheries Commission on the draft Southern Flounder Fishery Management Plan Amendment 2.

Laura Lee, the Division's chief stock assessment scientist, reviewed the stock assessment and projections of southern flounder in the South Atlantic with the advisers.

This presentation can be found at:
http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=32670395&name=DLFE-140717.pdf

Questions about SEAMAP data was discussed as well as what effect Hurricane Florence had on the stock, the average time it takes a southern flounder to get to 15 inches, and would a slot limit help escapement? All questions were answered by Division staff.

Mike Loeffler and Anne Markwith presented an overview of draft Amendment 2.

Questions such as do all four states have to participate for this to work and will the other states follow suit with North Carolina? Would there be removal of all commercial gear that catch flounder? Why can't this be managed by a quota? What's the difference between a supplement and an amendment? Would a smaller size limit help with some of the dead discards? All questions were answered by Division staff.

PUBLIC COMMENT:

Jonathan Robinson, a Carteret County Commissioner, chairs a county marine fisheries advisory board on issues that may have a detrimental effect on the county. The panel does not support Amendment 2 to the Southern Flounder Fishery Management Plan. He said all management options in the amendment will cause extreme economic hardship. Problems with the amendment include not accounting for reduced effort in the commercial fishery, uncertainty in the stock assessment, lack of data about offshore adult female flounder, interannual variation in recruitment, and environmental conditions that affect the proportion of males and females in the southern flounder population.

Charles Van Salisbury, a commercial fisherman from the mainland side of Hyde County, said the gill net fishery is a fraction of what it once was, and effort is at an all-time low. A Sept. 15 opening for all fisheries will create a derby fishery. He hopes the reductions from the incidental take permit requirements and the effect on the market will be taken into consideration.

Roger Harris, from Atlantic, said to stop trying to fix everything. He said there were no regulations when he grew up and there were plenty of fish and fishermen. With regulations, both are disappearing. What is being done is not working.

C.R. Frederick, a commercial fisherman from Swansboro, said a 52-72% reduction on a family's income will be devastating. He said if a reduction is needed, shut the fishery down for a couple of years. Fishermen will be better able to survive that than a 72% reduction for 10 years. He said there are so many variables involved, including relying on three other states to assist in restoring the stock and the lack of control over the effect of habitat on the fishery. He said the fishery needs something, but a lot of lives depend on this.

Glenn Skinner, Executive Director of the North Carolina Fisheries Association, referenced an earlier comment about not being concerned with what the other three states will do. He said that is admirable, but foolish because as soon as Amendment 2 to the Southern Flounder Fishery Management Plan passes, the clock starts for the next review of the plan to occur within five years, even without action by the other states. He said all four states need to implement reductions together or North Carolina carries the burden. He said the statutory requirements for ending overfishing in two years and rebuilding the stock in 10 years do not start until the adoption of the amendment, not the completion of the stock assessment. The process needs to slow down, and work needs to focus on the management measures for Amendment 3.

George Leone, a seafood dealer, said Amendment 2 to the Southern Flounder Fishery Management Plan is inappropriate due to the 62% and 72% recommended reductions, especially right before the start of the fall season. There is no time to prepare. Seafood dealers, markets, restaurants, gas stations, net makers, convenience stores, and countless others will be affected. He said the risk outweighs the reward, especially if a hurricane strikes. All four states need to take an active role so that North Carolina is not punished to allow the other states to reap the benefits.

Thomas McArthur said he has provided public comment on fisheries for years and this issue is just more of the same. He said the most important measure to implement is a slot limit. He said he thinks a proposed 52% reduction will result in a much greater actual reduction.

Karen Smith, a commercial fisherman from Cedar Island, expressed concern about the financial burden on many of the fishermen in her family. She said some of the younger fishermen will not be able to sustain a 52% reduction. She questioned if the commercial fishing heritage is being valued. She emphasized the financial burden of a 52% reduction for the pound net fishery.

Bert Owens, from Beaufort, thanked the advisory committees and said their job is not easy. He said easy things do not achieve anything. Amendment 2 to the Southern Flounder Fishery Management plan is a good thing and is not expedited when you consider the stock has been overfished for 20 years. He said if we do not act, there will not be a heritage to preserve. He said to follow through with Amendment 2 and save some fish for the future.

Jason Webb, a commercial fisherman from Brunswick County, said there are several problems with Amendment 2 to the Southern Flounder Fishery Management Plan, including economic issues, the effect of water temperatures on the stock, and the harvest of primarily female fish due to the 15-inch minimum size limit. He said flounder in North Carolina come from here, so we do not need to worry about the other three states. He said electronic reporting of trip tickets should help process data more quickly to identify windows for fishing. Fishing guides, mechanics, and countless others will be affected by this amendment.

Phillip Goodwin, a commercial pound-netter for 40 years, said the pound net fishery will not survive the reductions proposed in Amendment 2 to the Southern Flounder Fishery Management Plan. Northern Core Sound used to have a pound net season from Sept. 1 until Christmas and then regulations were implemented. The size limit was increased several times, then a December closure was implemented. He said there is no more to give up and still be able to make a living. The pound net fishery is a clean fishery that has no bycatch and is turtle-friendly. He said he is against Amendment 2. Pound netters might be able to give up a few weeks of fishing at the beginning of the fall season, but they need several weeks of fishing to make a living.

David Sneed, Executive Director of the Coastal Conservation Association of North Carolina, said no one wants to see fisheries close. He said many people say more science-based decision-making is needed for fisheries management until they disagree with the science. He said the struggle for the advisory committees and the Marine Fisheries Commission is that we have been ignoring the science for over 20 years and we are running out of time. We have to act to save our fisheries for future generations.

Tom Roller, a full-time fishing guide from Carteret County, said if this meeting occurred in 2000 or 2005 there would be 400 people in attendance. With only 12 comments received, virtually no one is here because the fishery is gone. He thanked the Marine Fisheries Commission for moving forward with Amendment 2 to the Southern Flounder Fishery Management Plan.

MOTIONS

The following are the motions of the Finfish, Northern and Southern Advisory Committees:

Southern Regional Advisory Committee

Motion by Ron McCoy to accept the Division of Marine Fisheries recommendation for a 62 percent reduction in harvest in 2019 and a 72 percent reduction in harvest in 2020. Second by Tom Smith.

Motion fails 3-5 with one abstention.

Motion by Ruth King to recommend the existing Southern Flounder Advisory Committee's schedule of reductions. Second by Jerry James.

Friendly amendment to ask for examination of a slot limit as part of Amendment 3.

Motion fails 4-4 with one abstention.

Chairman of the Southern Regional Advisory Committee, Dr. Scharf, noted he was confident that the Southern Flounder AC would have reached a consensus if more time had been allotted to them.

Northern Advisory Committee

Motion by Keith Bruno to recommend a 52 percent reduction in southern flounder harvest until Amendment 3 is adopted.
Motion fails for lack of second.

Motion by Kenneth Shivaer to support the Division of Marine Fisheries recommendation. Second by Jim Rice.
Motion carries 4-2

Motion by Keith Bruno to ask the Marine Fisheries Commission to consider dividing the allowable days for gill netting among allowable fishing months for a given area due to the Sea Turtle Incidental Take Permit. Second by Jim Rice.
Motion carries 5-0 with one abstention.

Motion by Keith Bruno to recommend the 12-hour soak and current yardage limit for the large-mesh gill net fishery. Second by Roger Rulifson.
Motion fails 3-3.

Finfish Standing Advisory Committee
Motion by Ken Seigler to recommend that the Marine Fisheries Commission include a slot limit in Amendment 1 across all gears and user groups. Second by Brent Fulcher.
Motion fails 1-4 with one abstention.

Motion by Brent Fulcher to recommend a reduced harvest of 52 percent, not to exceed 52 percent until Amendment 3 is completed. Second by Bradley Styron.
Motion carries 5-0 with one abstention.
Motion by Brent Fulcher to recommend that the Marine Fisheries Commission ask the Secretary of the Department of Environmental Quality to allow the Director of the Division of Marine Fisheries to go out of compliance with the Atlantic States Marine Fisheries Commission Summer Flounder Plan and adopt a 12-inch size limit and a 4-fish per day bag limit for southern flounder in North Carolina waters. Second by Sam Romano.
Motion carries 5-0 with one abstention.

Motion by Brent Fulcher to have the Southern Flounder Advisory Committee look at recommending a moratorium on all southern flounder harvest from November 1, 2019 to September 1, 2022. Second by Ken Seigler.
Motion carries 4-2.

The meeting adjourned at 5:12 p.m.

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Director

MEMORANDUM

TO: N.C. Marine Fisheries Commission Commercial Resource Fund Committee and the Funding Committee for the N.C. Commercial Fishing Resource Fund

FROM: William Brantley, Grants Program Manager
Division of Marine Fisheries, NCDEQ

DATE: June 20, 2019

SUBJECT: MFC Commercial Resource Fund Committee and Funding Committee for the N.C. Commercial Fishing Resource Fund Meeting Minutes

The MFC Commercial Resource Fund Committee and the Funding Committee for the N.C. Commercial Fishing Resource Fund met at 1 p.m. on Wednesday, June 19, 2019 at the N.C. Department of Environmental Quality's Washington Regional Office. The following attended:

MFC Commercial Resource Fund Committee: Doug Cross, Sam Romano, Mike Blanton

Funding Committee for the N.C. Commercial Fishing Resource Fund Members: Ernest Doshier, Glenn Skinner, Steve Weeks, Gilbert Baccus, and Doug Todd

Absent: Andrew Berry

DMF Staff: Dee Lupton, Beth Govoni, William Brantley, Katy West, Mike Loeffler, Tina Moore, Kathy Rawls, and Jason Rock

Public Comment: Chris McCaffity via email

APPROVAL OF AGENDA AND MINUTES

Chairman Doug Cross called the meeting to order for the MFC Commercial Resource Fund Committee.

Chairman Ernest Doshier called the meeting to order for the Funding Committee for the N.C. Commercial Fishing Resource Fund

Chairmen Cross inquired about and noted no conflicts of interest, and William Brantley conducted a roll call.

The meeting agenda was reviewed. Chairman Cross in agreeance with Chairman Doshier noted there would be a change in the order of reviewing funding opportunities.

Minutes from the March 7, 2019 MFC Commercial Resource Fund (CRF) Committee meeting and the Funding Committee for the N.C. Commercial Fishing Resource Fund were reviewed.

PUBLIC COMMENT

Chairman Cross asked for any public comment. There was none. William Brantley read an email from Chris McCaffity that asked for the Committees to consider using extra funds to set up a forum where commercial fishermen could debate and hold votes on how the CFRF was used.

COMMITTEE BRIEF OF RFP REVIEW PROCESS AND PROCEDURES

William Brantley briefed the committees on the current status of the budget with obligations. Fund balance minus current obligations was $1,858,090.46. Brantley discussed the overall intent of the meeting was to vote on funding opportunities and discuss any new business Committee members may have.

ECONOMIC IMPACT ANALYSIS RFP REVIEW

North Carolina State University – Drs. Jane Harrison and Chris Dumas

Application comes from a collaboration of Harrison (NCSU), Nash (NCSU), Sutherland (NCSU), Edwards (NCSU), and Dumas (UNCW). Chairman Cross opened the floor for discussion, with Jane Harrison (NCSU) and Nash (NCSU) available for questions. Mike Blanton questioned incentive costs. Sam Romano stated that the industry should be encouraged to fill out the surveys.

Glen Skinner made a motion to approve the NC Commercial Fishing Economic Impact Analysis project at the proposed $378,960. Doug Todd seconded. Motion passed with 4-Yes votes, 0-No Votes and 1 member was out of the room during the vote.

Sam Romano made a motion to approve funding for the NC Commercial Fishing Economic Impact Analysis project. Mike Blanton seconded. Motion passed unanimously.

NCSU SEAGRANT OYSTER PILOT PROJECT

Chairman Cross called for discussion on the NCSU spat on shell oyster project, which had previously been approved for $40,000 in funds by the Funding Committee for the N.C. Commercial Fishing Resource Fund.

Mike Blanton made a motion to approve matching funds for the Sea Grant Oyster Project. Sam Romano seconded. Motion passed unanimously.

DMF SOUTHERN FLOUNDER TAGGING PROJECT

Chairman Cross stated that he had asked the Division to bring project proposals, to include a southern flounder tagging project, which would enhance flounder data to better understand the migratory movements out of the estuarine areas. Mike Loeffler then presented a DMF multispecies tagging presentation which included satellite tagging of southern flounder. Subsequent to the presentation, both Committees discussed the DMF southern flounder tagging study brought forward by DMF Fisheries Management staff. This study was composed of adding two temporary staff to accomplish four components of southern flounder research; satellite tagging, increasing conventional tagging, acoustic tagging, and a maturity study. Discussion on each component occurred, with Mike Loeffler leading the conversation as the DMF species lead for southern flounder. Satellite tagging proposed would encompass a minimum of 25 tags to study NC flounder, while 200 tags would provide for a coastwide southern flounder migration study with some tagging conducted outside of NC. Discussion occurred with Loeffler on what was already known regarding southern flounder migration patterns, concurrent studies with other agencies, and satellite tag efficiency. Concerns were issued over the efficiency of the tags, and how they were attached. Loeffler reiterated the need of industry involvement in obtaining appropriately sized stock to tag.

Sam Romano made a motion to accept the DMF proposal for the Southern Flounder Tagging Study in the amount of $392,200. This includes funding for 2 temporary DMF staff ($86,000), satellite tagging (200 tags and associated costs, $274,700), increasing conventional tagging efforts ($7,500) and a maturity study ($24,000). Mike Blanton seconded. Motion passed unanimously.

Glen Skinner made a motion to mirror the MFC Committee's motion, to accept the proposal which includes funding for 2 temporary DMF staff ($86,000), satellite tagging (200 tags and associated costs, $274,700), increasing conventional tagging efforts ($7,500) and a maturity study ($24,000). Doug Todd seconded. Motion passed unanimously.

PUBLIC RELATIONS CAMPAIGN

Chairman Cross called for discussion on the NC Commercial Fishing Public Relations (PR) campaign. Sam Romano asked if the Committees would entertain the idea of creating a position for a marketing specialist. Sam Weeks and Glen Skinner issued discussion on the differences between marketing, education, and promotion. Chairman Cross called for a consensus between the two committees on voting.

Steve Weeks made a motion to approve the proposal from S&A Cherokee in the amount of $248,475. Glen Skinner seconded. Motion passed unanimously.

Sam Romano and Mike Blanton shared concerns on the proposal and the overarching benefits the industry would receive.

Mike Blanton made a motion to accept the proposal from S&A Cherokee as-is. Doug Cross seconded. Motion passed with 2-Yes votes and 1-No vote.

NCSU FISH CAMP PROJECT

Chairman Cross called for discussion on the SeaGrant FishCamp project. Sara Mirabilio from SeaGrant was called up by the Committees to discuss the budget. Sam Romano stated this program would be an inherently positive PR program for the industry.

Mike Blanton made a motion to accept the SeaGrant FishCamp proposal in its entirety ($47,512). Sam Romano seconded the motion. Motion passed unanimously.

Glen Skinner made a motion to accept the SeaGrant FishCamp proposal. Doug Todd seconded. Motion passed unanimously.

DMF Bycatch Reduction Survey Project

Chairman Cross asked the Committees to consider the DMF Bycatch Reduction Survey for $40,000.

Sam Romano made a motion to accept the Bycatch Reduction Survey to compliment the Gear Research Project. Mike Blanton seconded the motion. Motion passed unanimously.

Glen Skinner inquired about the specifics of what the survey would entail.

Doug Todd made a motion to approve. Gilbert Baccus seconded. Motion passed unanimously.

TERRAPIN INFORMATION REQUEST

Members voiced concerns over terrapin interactions and how it would affect the supply chain and its economic multipliers. Mike Blanton requested information, possibly a survey, on how interactions could be reduced with input from industry representatives and possibly open a conversation with Seafood Watch. Jason Rock was asked to speak on regional crabbing effort and spatial closures. Committee members also inquired as to recommendations on how to increase North Carolina's standing with Seafood Watch and other organizations that have concern with the species.

Chairmen Cross and Doshier requested a fully developed proposal or RFP on where interactions are occurring, to assist in answering where and whether spatial and/or seasonal closures would work and to examine device improvement that would allow fishing to continue. Sam Romano and Steve Weeks also mentioned a possible study for a terrapin excluder device.

HATCHERY FEASIBILITY DISCUSSION

Chairman Cross stated he had spoken with researchers, such as Dr. Harry Daniels (NCSU) who had previous experience on flounder hatchery operations. Chairman Cross stated that this may offer a supplemental effort to assist the species. He stated he would discuss the feasibility of a NC flounder hatchery with stakeholders and researchers in an effort to potentially begin a pilot program.

Mike Blanton made a motion to adjourn.
Sam Weeks seconded. Motion passed unanimously.

Ernest Doshier made a motion to adjourn.
Steve Weeks seconded. Motion passed unanimously.

Meeting adjourned at 4:17 p.m.

WB

Director's Report

Volume 28, Issue 3
June/July 2019

ASMFC

FISHERIES focus

Vision: Sustainable and Cooperative Management of Atlantic Coastal Fisheries

INSIDE THIS ISSUE

ASMFC Summer Meeting

August 6 - 8

The Westin
1800 South Eads Street
Arlington, VA

Preliminary Agenda

The agenda is subject to change. Bulleted items represent the anticipated major issues to be discussed or acted upon at the meeting. The final agenda will include additional items and may revise the bulleted items provided below. The agenda reflects the current estimate of time required for scheduled Board meetings. The Commission may adjust this agenda in accordance with the actual duration of Board meetings. Interested parties should anticipate Boards starting earlier or later than indicated herein.

TUESDAY, AUGUST 6

8:00 – 10:00 a.m. **Executive Committee**
(*A portion of this meeting may be a closed session for Committee members and Commissioners only*)
- Consider Policy Addressing Non-Payment of State Assessments
- Consider Proposed Revision to the Annual Report
- Update on Transitioning the For-hire Telephone Survey to State/ACCSP Conduct
- Discuss Commission Involvement in Biosecurity and Bait Sources

10:15 a.m. – Noon **South Atlantic State/Federal Fisheries Management Board**
- Consider Approval of Atlantic Cobia Amendment 1
- Progress Update on Draft Addenda for Atlantic Croaker and Spot Traffic Light Analyses
- Review and Consider Approval of 2019 Fishery Management Plan Reviews and State Compliance Reports for Atlantic Cobia, Atlantic Croaker, and Red Drum

Noon – 1:15 p.m. **Legislators and Governors' Appointees Luncheon**

1:30– 2:30 p.m. **American Eel Management Board**
- Review Board Working Group Recommendations on Addressing Coastwide Cap Overages
- Review and Consider Approval of Aquaculture Proposals

SUMMER MEETING PRELIMINARY AGENDA, continued on page 6

Upcoming Meetings

The Atlantic States Marine Fisheries Commission was formed by the 15 Atlantic coastal states in 1942 for the promotion and protection of coastal fishery resources. The Commission serves as the deliberative body of the Atlantic coastal states, coordinating the conservation and management of nearshore fishery resources, including marine, shell and diadromous species. The fifteen member states of the Commission are: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida.

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July 22 (begins at 1 PM) & 23 (ends at Noon)
SEAMAP South Atlantic, Florida Fish & Wildlife Research Institute (FWRI), 100 8th Ave SE, St. Petersburg, FL

July 23 (begins at 1 PM) & 24 (ends at Noon)
Joint SEAMAP Meeting, FWRI, 100 8th Ave SE, St. Petersburg, FL

July 25 (1 - 3 PM)
Horseshoe Crab Advisory Panel Conference Call; see http://www.asmfc.org/calendar/7/2019/horseshoe-crab-advisory-panel-conf-call/1405 for more details

August 6 - 8
ASMFC Summer Meeting, Westin, 1800 South Eads Street, Arlington, VA

August 13 - 15
Mid-Atlantic Fishery Management Council, Courtyard Philadelphia Downtown, 21 N. Juniper St., Philadelphia, PA

August 19 (1 - 5 PM)
Atlantic Menhaden Stock Assessment Subcommittee and Ecological Reference Points Workgroup webinar; see http://www.asmfc.org/calendar/8/2019/Atl-Menhaden-Stock-Assessment-Subcomm-and-Ecological-Reference-Points-Worksgroup-Conf-Call-/1421 for more details

August 19 (1:30 - 3:30 PM)
ASMFC & MAFMC Spiny Dogfish Advisory Panel Webinar; see http://www.asmfc.org/calendar/8/2019/asmfc-and-mafmc-spiny-dogfish-advisory-panel-webinar/1413 for more details

August 26 (9 AM - Noon)
ASMFC & MAFMC Bluefish Advisory Panel Webinar; see http://www.mafmc.org/council-events/2019/bluefish-ap-webinar-aug-26 for more details

August 29 (9 AM - 1 PM)
Assessment Science Committee Conference Call; see http://www.asmfc.org/calendar/8/2019/assessment-science-committee-conf-call/1416 for more details

August 29 (10 AM - 3:30 PM)
ASMFC & MAFMC Summer Flounder, Scup and Black Sea Bass Advisory Panel; DoubleTree by Hilton BWI, 890 Elkridge Landing Road, Linthicum Heights, MD

September 16 - 20
South Atlantic Fishery Management Council, Town and Country Inn, 2008 Savannah Highway, Charleston, SC

September 24 - 26
New England Fishery Management Council, Beauport Hotel, Gloucester, MA

October 8 - 10
Mid-Atlantic Fishery Management Council, Durham Convention Center, 301 W. Morgan Street, Durham, NC

October 27 - 31
ASMFC Annual Meeting, Wentworth by the Sea, 588 Wentworth Road, New Castle, NH

November 19 - 21
SEDAR 58 Atlantic Cobia Peer Review Workshop, location to be determined.

From the Executive Director's Desk

A Continued Commitment to Restoration and Management Can Make a Difference for River Herring

In June, NOAA Fisheries announced the findings of its status review of alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*) stocks (collectively referred to as river herring) along the Atlantic coast. The status review, performed under the auspices of the Endangered Species Act (ESA), determined listing these species under the ESA is not warranted at this time.

The review noted while river herring have declined from historical numbers and overutilization remains a risk while population numbers are low, fisheries management efforts at the state and federal levels have helped reduce the risks from fishing mortality. In particular, implementation of Amendment 2 to the Commission's Interstate Fishery Management Plan for Shad and River Herring, which requires the closure of state river herring fisheries without an approved sustainable fisheries management plan, has been central in managing fishery impacts to these species.

The Commission's 2017 River Herring Stock Assessment Update was an important component of the status review. The Update found while population abundance of river herring within certain rivers continues to be depleted, other river systems are showing signs of improvement, with increasing abundance trends for a number of rivers in the Mid-Atlantic and throughout New England. Although abundance in these river systems remains at low levels, dam removals and improvements to fish passage have had a positive impact on run returns.

- On Maine's Penobscot River, the removal of two dams and the installation of fish passage at others opened nearly 1,000 miles of habitat to migratory fish.
- On Maryland's Patapsco River, the removal of Bloede Dam, a linchpin of a decades-long restoration effort that also included the removal of Simkins and Union Dams, restored more than 65 miles of spawning habitat for blueback herring, alewife, American shad, and hickory shad in the watershed, and more than 183 miles for American eel. In total, Maryland's Fish Passage program has completed 79 projects, reopening a total of 457 miles of upstream spawning habitat in Maryland since 2005.
- In May 2016, the first dam upstream of the confluence with the Hudson River was removed from the Wynants Kill, a relatively small tributary in Troy, New York, down-stream of the Federal Dam. Within days of its removal, hundreds of river herring moved past the former dam location into upstream habitat. Subsequent sampling efforts yielded river herring eggs, providing evidence that river herring were actively spawning in the newly available habitat. This dam removal provides an additional 192 acres of spawning habitat for river herring that has not been available for 85 years.
- In Connecticut, where there are over 500 dams within the historic range of river herring, fishway construction and dam removals have restored access to previously blocked spawning habitat, allowing for increased production. Since 1990, 11 dams have been removed and 53 fishways have been constructed throughout Connecticut, with more projects being completed each year.
- In Pennsylvania, dam removals and fish passage installations have opened up 100 river miles to migratory fish. Other states, such as New Hampshire, Rhode Island, New Jersey, and Delaware have invested in the use of fish passage techniques to aid in river herring restoration by re-opening acres of freshwater spawning and nursery habitat for the species.

The continued recovery of river herring demands the states and our federal partners continue our commitment to improve management policy in tandem with habitat restoration.

While the findings of the status review are encouraging, we still have a long way to go until these species are fully rebuilt throughout their range. A variety of threats, including dams and other barriers to fish passage, continue to limit species recovery. Since 2012, the Commission has partnered with NOAA Fisheries on a number of initiatives to aid in the restoration of river herring populations. These include providing state and local agencies with restoration project funding, leading to dam removals and fish passage improvement projects; coordinating the River Herring Technical Expert Working Group to increase public awareness about river herring and foster cooperative research and conservation efforts; and working with the New England and Mid-Atlantic Fishery Management Councils to establish shad and river herring catch caps in fisheries that are known to incidentally capture these species. The continued recovery of river herring demands the states and our federal partners continue our commitment to improve management policy in tandem with habitat restoration.

Later on in this issue, you can read more about river herring life history, commercial and recreational fisheries and management, as well as some innovative research by scientists at East Carolina University who are exploring the use of environmental DNA to aid in species monitoring.

Species Profile: River Herring

State Management Aiding in Recovery of Depleted River Herring Stocks; NOAA Fisheries Status Review Finds Endangered Species Act Listing Unwarranted

Introduction

The Fishery Management Plan (FMP) for Shad and River Herring, approved in 1985, was among the first FMPs to be developed by the Commission. Since that time, the Commission has undertaken three major amendments to the plan. Amendment 2, approved in 2009, ushered in a new management regime for these important forage fish; one that required Atlantic coastal states and jurisdictions to either document the sustainability of their fisheries or prohibit recreational and commercial fishing for river herring. A 2017 stock assessment update determined that while river herring remain depleted on a coastwide basis, improvements have been observed in several river systems. This update provided significant rationale for NOAA Fisheries' June 2019 status review, which determined that listing river herring under the Endangered Species Act was not warranted at this time. Despite the species' overall low abundance, state management, including dam removals and improvements to fish passage, have helped increase abundance in some locations along the East Coast.

As river herring are migratory species that traverse both state and federal waters, the Commission has also worked closely with the New England and Mid-Atlantic Fishery Management Councils (MAFMC and NEFMC, respectively) to reduce river herring bycatch in small-mesh fisheries. In June 2019, NEFMC established catch caps in the Atlantic herring fishery for 2020-2021 to reduce incidental harvest of river herring, while MAFMC is currently developing Framework 13 to the Atlantic Mackerel, Squid, and Butterfish FMP to set 2020-2021 catch caps for the Atlantic mackerel fishery.

Life History

River herring, which is the collective term for alewife and blueback herring, are anadromous fish that spend the majority of their adult lives at sea, but return to freshwater areas to spawn in the spring. Alewife spawn in rivers, lakes, and tributaries from northeastern Newfoundland to South Carolina, but are most abundant in the Northeast and Mid-Atlantic. Blueback herring prefer to spawn in swift flowing rivers and tributaries from Nova Scotia to northern Florida, but are most numerous in waters from the Chesapeake Bay south.

Photo (c) Jerry Prezioso, NOAA Fisheries

Mature alewife (ages three to eight) and blueback herring (ages three to six) migrate rapidly downstream after spawning. Juveniles remain in tidal freshwater nursery areas in the spring

Species Snapshot

Alewife
Alosa pseudoharengus

General Characteristics

- Adults average 10-11" in length; 8-9 oz. in weight
- Range from Nova Scotia to South Carolina
- Primarily feed on plankton
- Congregate in large schools, numbering in the thousands
- Excellent food fish, marketed both fresh and salted

Interesting Facts

- In the US, alewife are known as sawbelly, grayback, bigeye, and freshwater and spring herring. In Canada, they are known as gaspereau or kiack.
- The origin of the name alewife is a reference to the large belly of the fish, which reminded New England fishermen of alehouse wives.
- The Latin name *pseudoharengus* means "false herring."

Blueback Herring
Alosa aestivalis

General Characteristics

- Adults average 11" in length; 7 oz. in weight
- Range from Nova Scotia to Northern Florida
- Primarily feed on plankton
- Name derived from dark blue/bluish gray coloring on back

Interesting Facts

- Blueback herring are also known as summer herring or black belly.
- Blueback herring have teeth on the roof of their mouths, while alewife do not. The teeth disappear with age.

Stock Status
Varies by river system for both species; see Table 1 on page 10

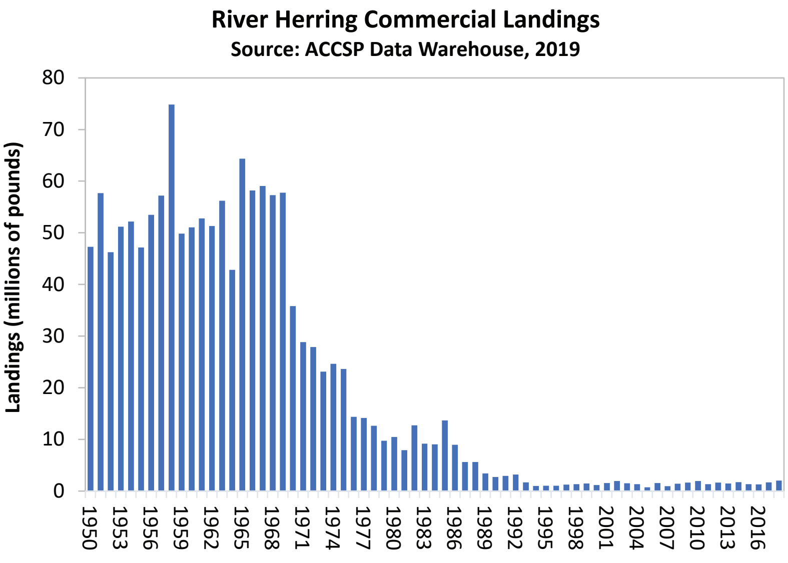
and early summer, but may also move upstream with the encroachment of saline water. As water temperatures decline in the fall, juveniles move downstream to more saline waters. Little information is available on the life history of juvenile and adult river herring between their emigration from freshwater to the sea and their return to their natal river to spawn.

Commercial and Recreational Fisheries

River herring supported one of the oldest documented fisheries in North America, including significant commercial, recreational and subsistence fisheries throughout their range. During colonial times, in-river stocks of anadromous species like river herring became subject to intensive exploitation as well as habitat degradation related to clear-cutting for timber, damming for mills, and wetland conversion to agricultural lands. For Massachusetts, the decline in coastal alewife fisheries had become so extensive that between 1790 and 1860 regulations were adopted for most Massachusetts rivers to manage in-river alewife fisheries. In North Carolina, river herring were the most economically important finfish harvested during the late 1880s, but by 1918 Atlantic menhaden had become more economically viable than river herring.

River herring have shifted from being used as a major local food source for human consumption in the form of smoked, salted and/or pickled fish toward being used primarily for fishmeal, pet food ingredients, and bait for commercial and sport fishing. During the 20th century, river herring also supported a small commercial bait industry in the New England states. These harvests declined considerably throughout New England between the turn of the 20th century and the 1980s.

Commercial landings for both species have declined dramatically from historic highs. Domestic landings reached their peak in 1958



THE RIVER FISHERIES OF THE ATLANTIC STATES.
Haul-seine fishing at Sutton Beach, Albemarle Sound, North Carolina: a large haul of alewives. (Sect. v. vol. I, p. 636.). From a photograph © NOAA Fisheries.

at 74.9 million pounds, while total landings by domestic and foreign fleets peaked at 140 million pounds in 1969. Since 2000, domestic landings have totaled less than two million pounds in any given year, with a historic low of 733,605 pounds landed in 2005. Landings in 2018 were estimated at two million pounds, a 19.3% increase from 2017 levels.

Although recreational harvest data are scarce, most harvest is believed to come from the commercial industry.

Stock Status

The 2012 river herring benchmark stock assessment evaluated the species on a river-by-river basis where data were available. For the vast majority of rivers, insufficient data were available to conduct a model-based stock assessment. Instead, trend analysis was used to identify patterns in the available fishery-dependent and independent data sets. Of the 52 stocks of alewife and blueback herring assessed, 23 were depleted relative to historic levels, one was increasing, and the status of 28 stocks could not be determined because the time series of available data was too short. Estimates of abundance and fishing mortality could not be developed due to lack of data. The “depleted” determination was used instead of “overfished” and “overfishing” because many factors, not just directed and incidental fishing, have contributed to the low abundance of river herring.

The 2017 stock assessment update indicates that river herring remain depleted at near historic lows on a coastwide basis. Total mortality estimates for 2013-2015 are generally high and exceed region-specific reference

continued, see RIVER HERRING on page 10

2:45 – 3:30 p.m. **Horseshoe Crab Management Board**

- Consider Potential Management Response to the 2019 Benchmark Stock Assessment
- Review and Consider Approval of 2019 Fishery Management Plan Review and State Compliance Reports

3:45 – 5:15 p.m. **Atlantic Menhaden Management Board**

- Progress Update on Menhaden Single Species and Ecological Reference Point Benchmark Stock Assessments
- Review and Consider Approval of 2019 Fishery Management Plan Review and State Compliance Reports
- Set 2020 Atlantic Menhaden Fishery Specifications

WEDNESDAY, AUGUST 7

8:30 – 10:30 a.m. **Interstate Fisheries Management Program Policy Board**

- Review 2019 Performance of the Stocks Report
- Review and Consider Approval of ISFMP Guiding Documents
- Update on American Lobster Enforcement Vessel
- Committee Reports
- Consider Noncompliance Recommendations (If Necessary)

9:00 a.m. – 4:00 p.m. **Committee on Economics and Social Sciences**

- Review Ongoing Committee Activities
- Discuss Efforts to Increase the Availability and Use of Socioeconomic Information in Management
- Review Committee Input on the Commission's Draft Risk and Uncertainty Policy

10:30 – 10:45 a.m. **Business Session**

- Consider Approval of Atlantic Cobia Amendment 1
- Consider Noncompliance Recommendations (If Necessary)

11:00 a.m. – Noon **Spiny Dogfish Management Board**

- Consider Approval of Draft Addendum VI for Public Comment
- Review and Consider Approval of 2019 Fishery Management Plan Review and State Compliance Reports

12:45 – 3:30 p.m. **Summer Flounder, Scup, and Black Sea Bass Management Board**

- Review Potential Black Sea Bass Commercial Management Strategies and Consider Initiating Management Action to Address Commercial Allocation
- Progress Update on the Recreational Management Reform Working Group
- Update on Management Strategy Evaluation of Summer Flounder Recreational Fishery Project
- Report from the Atlantic Coastal Fish Habitat Partnership/Mid-Atlantic Fishery Management Council Project: Characterizing Black Sea Bass Habitat in the Mid-Atlantic Bight
- Discuss Discard Mortality

3:45 – 4:45 p.m. **Tautog Management Board**

- Review Implementation Guidelines for the Commercial Harvest Tagging Program
- Review and Consider Approval of 2019 Fishery Management Plan Review and State Compliance Report

SUMMER MEETING PRELIMINARY AGENDA, continued on page 7

Public Comment Guidelines

For issues that are not on the agenda, management boards will continue to provide opportunity to the public to bring matters of concern to the board's attention at the start of each board meeting. Board chairs will use a speaker sign-up list in deciding how to allocate the available time on the agenda (typically 10 minutes) to the number of people who want to speak.

For topics that are on the agenda, but have not gone out for public comment, board chairs will provide limited opportunity for comment, taking into account the time allotted on the agenda for the topic. Chairs will have flexibility in deciding how to allocate comment opportunities; this could include hearing one comment in favor and one in opposition until the chair is satisfied further comment will not provide additional insight to the board.

For agenda action items that have already gone out for public comment, it is the Policy Board's intent to end the occasional practice of allowing extensive and lengthy public comments. Currently, board chairs have the discretion to decide what public comment to allow in these circumstances.

In addition, the following timeline has been established for the submission of written comment for issues for which the Commission has NOT established a specific public comment period (i.e., in response to proposed management action).

1. Comments received 3 weeks prior to the start of a meeting week will be included in the briefing materials.

2. Comments received by 5 PM on Tuesday, July 30th will be distributed electronically to Commissioners/Board members prior to the meeting and a limited number of copies will be provided at the meeting.

3. Following the July 30th deadline, the commenter will be responsible for distributing the information to the management board prior to the board meeting or providing enough copies for management board consideration at the meeting (a minimum of 50 copies).

The submitted comments must clearly indicate the commenter's expectation from the ASMFC staff regarding distribution. As with other public comment, it will be accepted via mail, fax, and email.

Employee of the Quarter: Mike Rinaldi

Mike Rinaldi, Fisheries Data Coordinator with the Atlantic Coastal Cooperative Fisheries Statistics Program (ACCSP), was named Employee of the Quarter for the second quarter of 2019. Mike first started at the Commission in May 2017 in a seasonal position to help with recreational data coordination and management as the ACCSP worked with the states to assume conduct of the Marine Recreational Information Program's Access Point Angler Intercept Survey (APAIS). From the outset, Mike's strong work ethic, diligence and dedication stood out and within six months he was promoted to Fisheries Data Assistant and later to his current position.

For the past several months, Mike has been working with ACCSP partners on implementing the new confidentiality application, an essential component of the ACCSP's Data Warehouse. As the lead staff member on confidentiality, he quickly familiarized himself with the application, database tables, and procedures. He good-naturedly piloted both the security contacts and end users through the new system. Despite the bugs, he supported the security contacts in such a way that, instead of complaining about the system, they complimented him on his efforts and patiently waited as issues were resolved. He demonstrated creativity and judgement by instituting personal processes to accommodate for the situation and ease the lives of users regardless of the extra work to himself. His work with the contractor exhibits outstanding technical knowledge and proficiency.

In addition to this project, he continued to effectively multi-task on other important tasks. Significant among these is his excellent work on the updates to the fish and shellfish common names within the ACCSP Data Warehouse. Due to his comprehensive review of the existing names and structured approach to the necessary standardization, multiple committees were easily able to absorb a great deal of information and approve the changes. The communication scheme he established has kept all partners and users informed and allowed time to incorporate changes from partners and implement updates across the ACCSP. This procedure will serve as a model for future communications with partners. Mike's dedication and knowledgeable approach have contributed substantially to the quality of ACCSP data and the program's interactions with its partners. In appreciation of his efforts, Mike received a cash award and a letter of appreciation to be placed in his personal record. In addition, his name is on the plaque displayed in the Commission's lobby. Congratulations, Mike!

SUMMER MEETING PRELIMINARY AGENDA, continued from page 6

THURSDAY, AUGUST 8

8:30 – 11:30 a.m. **Atlantic Striped Bass Management Board**

- Consider Approval of Draft Addendum VI for Public Comment
- Consider Postponed Motions from April 2019:

Main Motion: Move to initiate an Amendment to the Atlantic Striped Bass Fishery Management Plan to address the needed consideration for change on the issues of fishery goals and objectives, empirical/biological/spatial reference points, management triggers, rebuilding biomass, and area-specific management. Work on this Amendment will begin upon the completion of the previously discussed Addendum to the Management Plan.
Motion made by Mr. Luisi and seconded by Mr. Clark.

Motion to Amend: Move to amend to add reallocation of commercial quota between states.
Motion made by Mr. Pugh and seconded by Mr. Reid.

- Review and Consider Approval of 2019 Fishery Management Plan Review and State Compliance Reports

11:30 a.m. – 12:30 p.m. **Lunch**

12:30 – 5:00 p.m. **NOAA Fisheries Wind Power Workshop for New England and Mid-Atlantic Commissioners**

Researchers Explore Use of eDNA to Survey River Herring

Researchers at East Carolina University (ECU), with funding provided by the Commission and NOAA Fisheries, are exploring a new way to survey river herring (i.e., alewife and blueback herring) using Environmental DNA (eDNA).

The use of eDNA for biological research and monitoring is relatively new. eDNA is DNA collected from a variety of environmental samples such as soil, water, or even air, rather than directly sampled from an individual organism. As various organisms interact with the environment, DNA is expelled and accumulates in their surroundings. Example sources of eDNA include, but are not limited to, mucus, gametes, shed skin, feces, and carcasses.

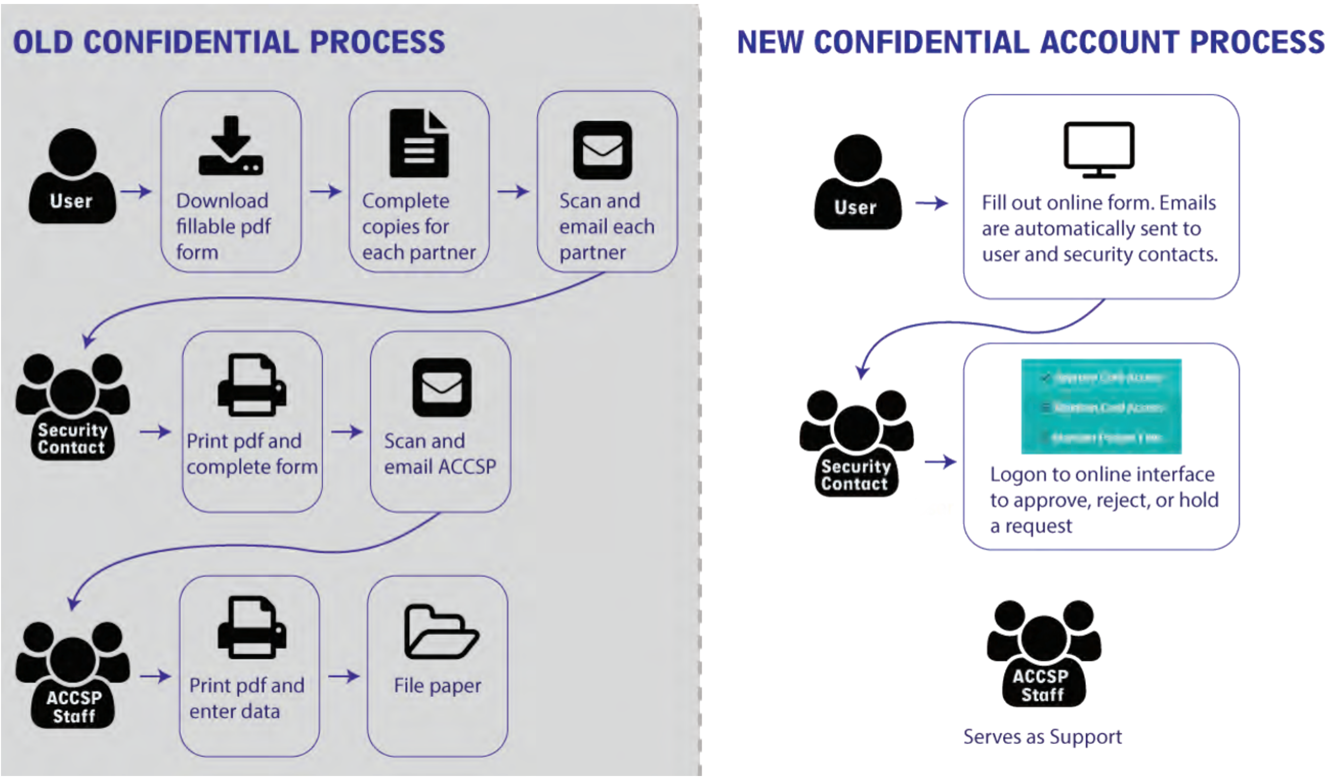
ECU Master's Student Seth Gibbons sampling at the Edenton Fish Hatchery (Edenton, NC).

Researchers Erin Field, Michael Brewer, and Roger Rulifson from ECU's Department of Biology have already completed a pilot study in North Carolina's Chowan River watershed, corroborating the presence of river herring eDNA with actual river herring presence using electrofishing. Recently, they conducted a study in collaboration with the Massachusetts Division of Marine Fisheries in two Massachusetts watersheds (Mystic River and Monument River) to calibrate eDNA methodology with highly accurate fish counts. Hatchery fish studies to measure eDNA shedding and decay rates in collaboration with the USFWS Edenton Fish Hatchery (North Carolina) were also conducted to help develop a quantitative methodology using eDNA. These techniques were then applied to the Neuse River in North Carolina in collaboration with the North Carolina Wildlife Resource Commission. By comparing fish abundance using eDNA quantity and shedding rates with traditional fish counting, the researchers will assess the validity of the new method. The eDNA method can then be applied to other understudied watersheds in the Mid-Atlantic.

"Being able to rapidly monitor spawning habitats is essential for developing and monitoring conservation efforts, sustainability, and population growth." says Erin Field. "In Mid-Atlantic watersheds, traditional survey methods are more difficult due to high turbidity, large run sizes, and vast watersheds. The ability to provide information for previously unsurveyed areas will not only be useful for stock assessments, but will also help us better plan restoration and remediation efforts to bring back river herring."

For more information, please contact Erin Field, Assistant Professor with the ECU Department of Biology, at FIELDE14@ECU.EDU or visit http://www.efieldlab.com/research.html.

Migrating river herring. Photo (c) Greg Wells



The Atlantic Coastal Cooperative Fisheries Statistics Program (ACCSP) has completed updates to its Confidential Fisheries Data Access application. The application represents one of the most integrated, modern, and easy-to-use account management systems for fishery-dependent data access. Instead of a lengthy process involving paper non-disclosure agreements and manual data entry, users and data security contacts are able to interact via multiple pages within the application.

Users can set up accounts, submit requests, or renew existing access with only a couple of clicks. They can view their existing confidential access and any pending requests. Contact information is auto-populated on the request page, thereby streamlining the process and removing the potential for error. Renewal options are limited to partners for whom the user's access expires within the year. This eliminates duplicative requests and reduces the burden on data security contacts.

Administrators have the ability to respond to requests, manage access to their data, and upload additional non-disclosure agreements or other email attachments. All of these actions are reliably archived within the ACCSP system, making review and audit significantly easier.

The Confidential Fisheries Data Access application is directly integrated within the ACCSP Data Warehouse. Once a user receives confidential access approval, it is immediately reflected in their ability to query partner data in the portal. The dynamic link between the confidential and report applications facilitates a fully electronic and efficient information management system for Atlantic coast fishery-dependent data.

WHAT ARE CONFIDENTIAL DATA?

Confidential data are data that can lead to the identification of individuals or individual contributions. Federal and state laws prohibit the disclosure of confidential data, and the ACCSP works diligently and tirelessly to protect proprietary information. The Program Partners of the ACCSP define confidential data using the 'rule of 3' for commercial catch and effort data. This rule requires that any publicly disclosed data summary must include contributions from three dealers, three fishermen, and three vessels to be considered non-confidential.

ACCSP
Good Data, Good Decisions

ACCSP is a cooperative state-federal program focused on the design, implementation, and conduct of marine fisheries statistics data collection programs and the integration of those data into a single data management system that will meet the needs of fishery managers, scientists, and fishermen. It is composed of representatives from natural resource management agencies coastwide, including the Atlantic States Marine Fisheries Commission, the three Atlantic fishery management councils, the 15 Atlantic states, the Potomac River Fisheries Commission, the D.C. Fisheries and Wildlife Division, NOAA Fisheries, and the U.S. Fish & Wildlife Service. For further information please visit www.accsp.org.

RIVER HERRING, continued from page 5

points for some rivers (see Table 1 on page 10). However, there are some positive signs of improvement for some river systems. Total mortality estimates for two rivers have fallen below region-specific reference points for 2013-2015, compared to zero mortality estimates below the reference points at the end of the 2012 stock assessment data time series. Of the 54 stocks for which data were available, 16 experienced increasing abundance, two experienced decreasing abundance, eight experienced stable abundance and ten experienced no discernable trend in abundance over the final ten years of the time series (2006-2015).

Atlantic Coastal Management

In 2009, in response to concerns regarding declining river herring populations, the Commission's Shad and River Herring Management Board approved Amendment 2 to the Interstate FMP. The Amendment has prohibited commercial and recreational fisheries in state waters since January 1, 2012 unless the state or jurisdiction implemented a Board-approved sustainable fishery management plan (SFMP). A sustainable fishery is defined as "a commercial and/or recreational fishery that will not diminish the potential future stock reproduction and recruitment." The plans must describe sustainability targets that are achieved to prevent closure of the fishery.

To date, SFMPs have been approved for Maine, New Hampshire, Massachusetts, New York, and South Carolina. Amendment 2 also requires states to implement fishery-dependent and -independent monitoring programs, and contains recommendations to member states and jurisdictions to conserve, restore, and protect critical river herring habitat.

Abundance Trends of Select Alewife and Blueback Herring Stocks along the Atlantic Coast
Source: 2017 River Herring Stock Assessment Update

State	River	Trends (2006-2015)
NE U.S. Continental Shelf (NMFS Bottom Trawl)^		Increasing[A,B]
ME	Androscoggin	Increasing[A]
	Kennebeck	Increasing[RH]
	Sebasticook	Increasing[RH]
	Damariscotta	Increasing[A]
	Union	No Trend[A]
NH	Cocheco	Increasing[A,B]
	Exeter	Stable[RH]
	Lamprey	Increasing[RH]
	Oyster	Decreasing[RH]
	Taylor	No Returns[RH]
	Winnicut	Unknown[A,B]
MA	Mattapoisett	Increasing[A]
	Monument	Increasing[A,B]
	Nemasket	Increasing[A]
	Parker	Stable[A]
	Stony Brook	Unknown[A]
RI	Buckeye	Increasing[A]
	Gilbert	Stable[A]
	Nonquit	Decrease[A]
CT	Bride Brook	Increasing[A]
	Connecticut	Stable[B]
	Farmington	Unknown[A,B]
	Mianus	No Trend[A], Increasing[B]
	Mill Brook	No Trend[A]
	Naugatuck	Unknown[A,B]
	Shetucket	No Trend[A], Stable[B]
NY	Hudson	Increasing[RH]
NJ, DE, PA	Delaware	No Trend[A,B]
MD, DE	Nanticoke	Stable[A], No Trend[B]
VA, MD, DC	Potomac	Stable[A], Unknown[B]
VA	James	Unknown[A,B]
	Rappahannock	No Trend[A], Increasing[B]
	York	Unknown[A,B]
NC	Alligator	Unknown[A,B]
	Chowan	No Trend[A], Stable[B]
	Scuppernog	Unknown[A,B]
SC	Santee-Cooper	No Trend[B]
FL	St. Johns River	Unknown[B]

^NE shelf trends are from the spring coastwide survey data which encounters river herring more frequently than the fall survey. A = Alewife only; B= Blueback herring only; A,B = Alewife and blueback herring by species; RH = alewife and blueback herring combined.

Federal Action

In support of the sustainable management actions taken by the Commission, both the MAFMC and NEFMC took action regarding the incidental catch of river herring and American shad in federal waters (3-200 miles from shore). MAFMC implemented its first annual cap on incidental catch of river herring and shad in the U.S. Atlantic mackerel fishery in 2014. This catch cap was one of several protective measures implemented through Amendment 14 to the Atlantic Mackerel, Squid, and Butterfish FMP. The Amendment also increased reporting and monitoring requirements for fishermen and dealers. MAFMC is currently developing 2020-2021 catch caps for the Atlantic mackerel fishery through Framework Adjustment 13 to the Atlantic Mackerel, Squid, and Butterfish FMP. In 2014, NEFMC implemented annual river herring and shad catch caps through Framework 3 to Amendment 5 to the Atlantic Herring FMP. The catch cap applies to all trips landing more than the open access possession limit of 6,600 pounds of Atlantic herring. In June 2019, NEFMC maintained the current catch caps for 2020-2021.

In June 2019, NOAA Fisheries published its status review of alewife and blueback herring stocks along the U.S. coast, which determined listing these species under the Endangered Species Act is not warranted at this time. The review noted that while river herring have declined from historical numbers and overutilization remains a risk for reduced populations, fisheries management efforts at the state and federal levels have helped to diminish the impacts of fishing mortality. For more information, please contact Caitlin Starks, Fishery Management Plan Coordinator, at cstarks@asmfc.org or 703.842.0740.

Volume 28, Issue 2
April/May 2019

ASMFC FISHERIES focus

Vision: Sustainable and Cooperative Management of Atlantic Coastal Fisheries

INSIDE THIS ISSUE

ASMFC Presents Annual Awards of Excellence

At its Spring Meeting, the Atlantic States Marine Fisheries Commission presented its Annual Awards of Excellence to an esteemed group of fishery and data managers, scientists, law enforcement officers and environmental attorneys for their outstanding contributions to fisheries management, science, and law enforcement along the Atlantic coast. Specifically, the award recipients are Robert Ballou for management and policy contributions; Geoffrey White, Coleby Wilt, Alex DiJohnson, Sarah Rains, Michael Celestino, and John Sweka for science and technical contributions; and Casey Oravetz, Sara Block, Banumathi Rangarajan, Lauren Steele, Shane Waller, Shennie Patel, and Joel La Bissonniere for law enforcement contributions.

"Every year, a great many people contribute to the success of fisheries management along the Atlantic coast. The Commission's Annual Awards of Excellence recognize outstanding efforts by professionals who have made a difference in the way we manage and conserve our fisheries," said ASMFC Chair Jim Gilmore of the New York State Department of Environmental Conservation. "I am humbled by the breadth and extent of accomplishments of this year's recipients and am grateful for their dedication to Atlantic coast fisheries."

From left: John Sweka, Alex DiJohnson, Mike Celestino, Sarah Rains, Geoff White, Shennie Patel, Casey Oravetz, Lauren Steele, Sara Block, ASMFC Executive Director Robert Beal, Bob Ballou, and ASMFC Chair Jim Gilmore

Management & Policy Contributions

Mr. Robert Ballou, Rhode Island Department of Environmental Management

For nearly a decade, Mr. Robert Ballou has brought a wealth of knowledge and policy acumen to the Commission's fisheries management programs and elevated the decision-making of all species management boards that he has served on through his work ethic, strong leadership, and expertise. In

ANNUAL AWARDS OF EXCELLENCE, continued on page 11

Upcoming Meetings

The Atlantic States Marine Fisheries Commission was formed by the 15 Atlantic coastal states in 1942 for the promotion and protection of coastal fishery resources. The Commission serves as the deliberative body of the Atlantic coastal states, coordinating the conservation and management of nearshore fishery resources, including marine, shell and diadromous species. The fifteen member states of the Commission are: Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Florida.

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June 10 - 14
South Atlantic Fishery Management Council, Hutchinson Island Marriott, 555 NE Ocean Boulevard, Stuart, FL

June 11 - 13
New England Fishery Management Council, Doubletree by Hilton, So. Portland, ME

June 17 (9 AM - 12:30 PM)
Atlantic Striped Bass Technical Committee Webinar; go here - http://www.asmfc.org/calendar/6/2019/striped-bass-technical-committee-conf-call/1401 - for more details

June 18 (9 AM - 12:30 PM)
Atlantic Striped Bass Plan Development Team Webinar; go here - http://www.asmfc.org/calendar/6/2019/striped-bass-plan-development-team/1399 - for more details

June 24 (begins at 9 AM) - 26 (ends at 5 PM)
Atlantic Menhaden Stock Assessment Workshop II, Marriott Residence Inn-Raleigh Downtown, 616 South Salisbury Street, Raleigh, NC

June 26 (begins at 9 AM) - 28 (ends at 4 PM)
Ecological Reference Points Stock Assessment Workshop II, Marriott Residence Inn-Raleigh Downtown, 616 South Salisbury Street, Raleigh, NC

July 2 (9 AM - 12:30 PM)
Atlantic Striped Bass Plan Developmenet Team Webinar; go here - http://www.asmfc.org/calendar/7/2019/Striped-Bass-Plan-Development-Team/1400 - for more details

July 8 (5 - 7 PM)
South Atlantic Species Advisory Panel Conference Call; go here - http://www.asmfc.org/calendar/7/2019/south-atlantic-advisory-panel-conf-call/1403 - for more details

July 10 (9 AM - 12:30 PM)
Atlantic Striped Bass Technical Committee Webinar; go here - http://www.asmfc.org/calendar/7/2019/Striped-Bass-Technical-Committee-Conf-Call/1402 - for more details

August 6 - 8
ASMFC Summer Meeting, Westin, 1800 South Eads Street, Arlington, VA

August 12 - 15
Mid-Atlantic Fishery Management Council, Courtyard Philadelphia Downtown, 21 N. Juniper St., Philadelphia, PA

September 16 - 20
South Atlantic Fishery Management Council, Town and Country Inn, 2008 Savannah Highway, Charleston, SC

September 24 - 26
New England Fishery Management Council, Beauport Hotel, Gloucester, MA

October 8 - 10
Mid-Atlantic Fishery Management Council, Durham Convention Center, 301 W. Morgan Street, Durham, NC

From the Executive Director's Desk

ASMFC's Five-Year Strategic Plan Updates Vision and Addresses Need to Prioritize Limited Resources

On May 1st, during a typically busy Spring Meeting, Commissioners put their unanimous stamp of approval on the 2019 – 2023 Strategic Plan. The Strategic Plan will guide our activities for the next five years and serve as the basis for annual action planning.

The keystone of the new Strategic Plan is an updated vision that emphasizes the cooperative nature of interstate fisheries management on the Atlantic coast: "Sustainable and Cooperative Management of Atlantic Coastal Fisheries." The second major update to the Strategic Plan is a recognition that internal constraints, such as human and fiscal resource limitations, paired with outside forces like changing ocean conditions and ever-increasing political pressures, require us to focus on the most pressing issues. Now more than ever, the Commission and state agencies must dedicate staff time and resources where they are needed most and address less pressing issues only as resources allow.

In 2019, the highest priority species are American lobster, Atlantic striped bass, Atlantic menhaden, summer flounder, black sea bass, Atlantic herring, cobia, horseshoe crab and red drum.

- **American lobster** priorities include adapting management in response to changing ocean conditions and protected species interactions; implementing reporting requirements, bait protocols, and offshore enforcement; and making progress on the 2020 Benchmark Stock Assessment.
- For **Atlantic striped bass**, we are currently responding to the 2018 Benchmark Stock Assessment, and will continue to work with NOAA Fisheries as it considers opening the EEZ for striped bass harvest.
- **Atlantic menhaden** priorities include completing menhaden-specific and ecological reference points-based benchmark stock assessments, setting 2020 specifications, and monitoring compliance of the Chesapeake Bay reduction fishery harvest cap.
- This year, the Commission revised specifications for the 2019 **summer flounder** fishing season, set new specifications for 2020 and 2021, and jointly approved with the Mid-Atlantic Council the Summer Flounder Commercial Issues Amendment. The states will implement Addenda XXXI and XXXII, which address recreational conservation equivalency and specification setting.
- For **black sea bass**, managers will continue to explore new approaches to reform recreational management and reallocation strategies, integrate new MRIP estimates into management decisions, and set 2020-2022 specifications.
- In response to the results of the 2018 Benchmark Stock Assessment which showed reduced levels of **Atlantic herring** recruitment and spawning stock biomass over the past five years, states will implement strengthened spawning protections in the inshore waters of the Gulf of Maine. The Herring Board will work with the New England Council as it considers establishing spawning protections in the offshore waters of Area 3.
- Transitioning **Atlantic cobia** to interstate management continues through the development of Amendment 1. The South Atlantic Board will also be working on a Benchmark Stock Assessment.
- The **Horseshoe Crab** Board approved the 2019 Benchmark Stock Assessment in May and will consider a management response later this year, including specifications for horseshoe crabs of Delaware Bay origin. Other priorities include securing long-term funding for the benthic trawl survey and working with the biomedical community to increase transparency of assessment results.
- The South Atlantic Board is developing a roadmap for the next **red drum** benchmark stock assessment that includes calibrated MRIP data.

As time and resources permit, the care and feeding of the remaining 17 species management programs will continue. And certainly, as issues arise, any of these species can be shifted to high priority status.

The Strategic Plan's eight goals are:

1. Rebuild, maintain, fairly allocate, and promote sustainable Atlantic coastal fisheries
2. Provide sound, actionable science to support informed management actions
3. Produce dependable and timely marine fishery statistics for Atlantic coast fisheries
4. Protect and enhance fish habitat and ecosystem health through partnerships and education
5. Promote compliance with fishery management plans to ensure sustainable use of Atlantic coast fisheries
6. Strengthen stakeholder and public support for the Commission
7. Advance Commission and member states' priorities through a proactive legislative policy agenda
8. Ensure the fiscal stability and efficient administration of the Commission

Goal 3, which focuses on the data collection and data management efforts of the Atlantic Coastal Cooperative Statistics Program (ACCSP), was added to reflect the incorporation of ACCSP as a Commission program in 2017.

The 2019 – 2023 Strategic Plan is available on the Commission website at http://www.asmfc.org/files/pub/2019-2023StrategicPlan_Final.pdf.

New Benchmark Stock Assessment Highlights Challenges in Sustainable Management

Introduction

Atlantic striped bass is regularly referred to as America's greatest game fish on the U.S. Atlantic coast. High demand for this species among fishermen and consumers, coupled with the complexity of its seasonal distribution along the coast, makes sustainable management of the Atlantic coast striped bass population complex and challenging. Stakeholders regularly call for the Commission to implement biologically, economically, and socially sound regulations within each jurisdiction and sector. As a result, the dynamic nature of Atlantic striped bass fishery management will likely continue for many years to come.

The Atlantic Striped Bass Management Board recently approved the 2018 benchmark stock assessment, which indicates the striped bass stock is now overfished and experiencing overfishing. While the stock remains in far better condition than it was in the 1980s, when the stock was collapsed and several states imposed moratoriums to recover the resource and fishery, the Commission is once again facing difficult decisions in striped bass management. Given striped bass' importance to both the coastal marine ecosystem and those who commercially and recreationally fish for it, the Board initiated the development of a Draft Addendum to consider measures aimed at reducing fishing mortality to the target level.

Life History

On the Atlantic coast, Atlantic striped bass range from the St. Lawrence River in Canada to the St. John's River in Florida. The migratory stock under Commission management ranges from Maine through North Carolina.

Atlantic striped bass are an anadromous species spending most of their adult life in oceanic or estuarine waters, and can live up to 31 years old. Mature individuals migrate into freshwater rivers and tributaries in early spring to spawn, releasing millions of eggs into the ecosystem, and then return to the ocean. The fertilized eggs eventually hatch into larvae, which begin feeding on zooplankton. The larvae mature into juveniles and remain in coastal sounds and estuaries for two to four years before joining the coastal migratory population in the Atlantic Ocean.

The rivers that feed into the Chesapeake Bay and the Delaware and Hudson Rivers are the major spawning grounds, with the Chesapeake Bay producing the majority of coastal migratory striped bass. In the ocean, striped bass tend to move north during the summer and south during the winter, but these migrations can be influenced by their age, sex, degree of maturity, and the river in which they were born. Important wintering grounds for the mixed stocks are located offshore from New Jersey to North Carolina.

Commercial & Recreational Fisheries

For centuries, Atlantic striped bass have supported valuable commercial and recreational fisheries on the Atlantic coast. Currently, commercial fisheries operate in eight Atlantic coastal jurisdictions, while recreational fisheries operate in 14. Commercial fishermen harvest Atlantic striped bass with a variety of gears including gillnets, pound nets, haul seines, trawls, and hook and line, while recreational fishermen use hook and line almost exclusively.

Increased fishing pressure in the 1970s coupled with degradation and loss of habitat led to stock collapse in the early 1980s. Commercial landings peaked in 1973 at almost 15 million pounds and then declined abruptly to 2.2 million pounds (271,958 fish) by 1983. During the mid-to-late 1980s, a number of states closed their Atlantic striped bass fisheries in order to initiate stock rebuilding. In the mid-1990s, the commercial fishery slowly grew again

Species Snapshot

Atlantic Striped Bass
Morone saxatilis

Species Range

St. Lawrence River in Canada to St. John's River in Florida

Interesting Facts

- Throughout New England and the Mid-Atlantic, striped bass are also known as striper, rockfish, linesider, rollers, squidhound, or simply "bass."
- In 1669, the first public school in North America (MA) was financed with taxes imposed on striped bass harvest.
- In the 1880s, Atlantic striped bass were successfully transplanted to the Pacific Ocean, and a commercial fishery began in 1889. Commercial fishing was stopped in 1935 when the California coast striper was declared a game fish. The population continues to thrive.
- Atlantic striped bass is the most sought-after sportfish in the Chesapeake Bay, and is the official state fish of Maryland, Rhode Island, and South Carolina.

Largest Recorded

- New world record was caught in CT (2011), weighing 81.88 lbs.
- Historic records confirm a 125 lb female caught off of NC in 1891.

Age at Maturity

- Females - 50% mature at age 6 (25-26"); 100% at age 9 (32")
- Males - 100% mature at age 3 (18")

Age at Recruitment into Fishery

- Chesapeake Bay Fishery = age 4 (19")
- Ocean Fishery = age 8 (28")

Stock Status

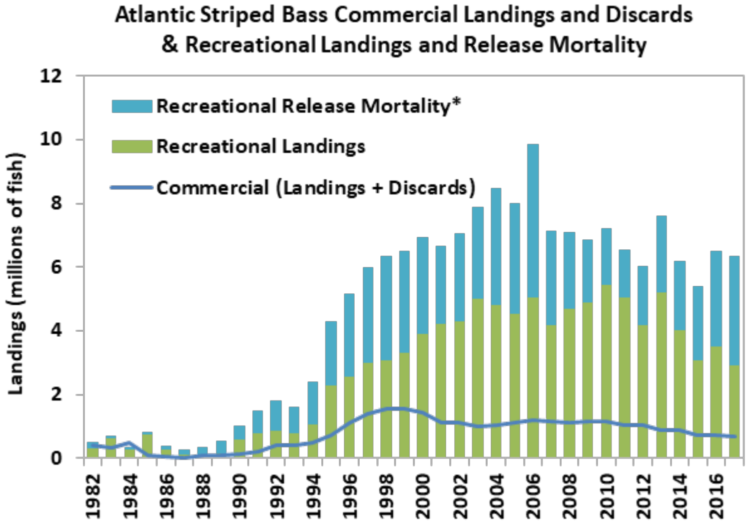
Overfished and experiencing overfishing

under a new management program (Amendment 4). Coastwide commercial landings rose from about 700,000 pounds (94,000 fish) in 1990 to 3.6 million pounds (540,000 fish) in 1995. Under Amendment 5, commercial striped bass harvest grew to 5.6 million pounds (921,000 fish) by 2002. Since the passage of Amendment 6, commercial harvest has been managed through a quota system, and landings averaged roughly 6.5 million pounds (943,000 fish) annually from 2004 to 2014. The commercial quota was reduced starting in 2015 through implementation of Addendum IV. Commercial landings are consistently dominated by Chesapeake Bay fisheries. Total commercial landings were estimated at 4.6 million pounds (592,576 fish) in 2017, of which approximately 56% (by weight) came from the Chesapeake Bay (77% in terms of numbers of fish).

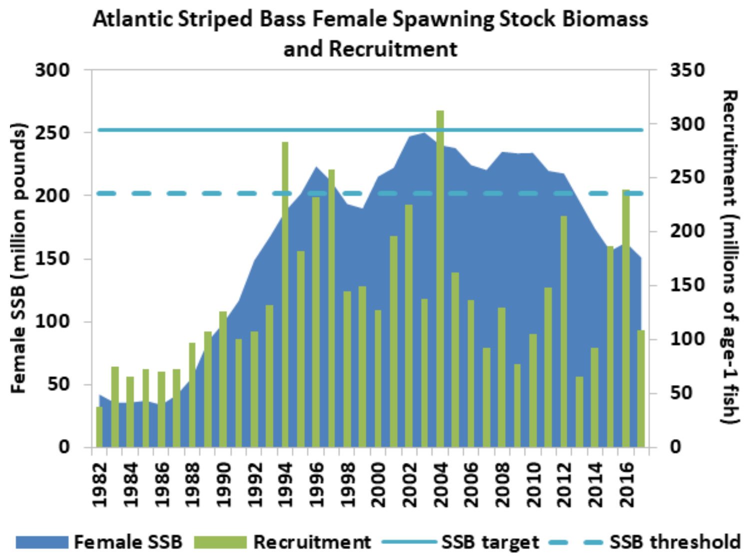
Between 1982 and 1989, recreational anglers landed an annual average of about 325,000 fish due to a combination of low stock abundance and stringent regulations. Under Amendment 4, recreational landings grew from 579,000 fish in 1990 to more than one million fish in 1994. The following year, with the declaration of restored stock status, recreational landings more than doubled to 2.3 million fish, and landings continued to increase to a record 5.4 million fish in 2010. From 2004 to 2014, recreational landings averaged 4.7 million fish annually. From 2015-2017, recreational anglers harvested an estimated 3.2 million fish annually, which can be attributed to implementation of more restrictive regulations via Addendum IV. Of those coastwide recreational landings, Maryland landed the largest proportion (37%) in 2017, followed by New Jersey (21%), New York (16%), Massachusetts (13%), and Virginia (4%). Anglers continue to release the vast majority of striped bass they catch, primarily due to regulation (meaning the fish is not of legal size or the angler has already landed the bag limit). Since implementation of Amendment 6 in 2003, anglers have released roughly 84% of fish caught each year (the proportion of fish caught and released in 2017 was 91%). The number of released fish peaked in 2006 at 53.5 million fish. Total numbers of releases have declined since then, averaging 26 million fish annually from 2007-2017. An estimated 38 million fish were caught and released in 2017.

Stock Status

On a regular basis, female spawning stock biomass (SSB) and fishing mortality rate (F) are estimated and compared to target and threshold levels (i.e., biological reference points) in order to assess the status of the stock. The 1995 estimate of female SSB is currently used as the SSB threshold because many stock characteristics, such as an expanded age structure, were reached by this year, and this is also the year the stock was declared recovered. The female SSB target is equal to 125% female SSB_{1995}. To estimate the associated F threshold and target, population projections were made by using a constant F and changing the value until the SSB threshold or target value was achieved. For the 2018 benchmark, the reference point values have been updated. The female SSB threshold was



*Recreational release mortality assumes that 9% of fish released alive die.



estimated at 91,436 mt (202 million pounds) with a female SSB target of 114,295 mt (252 million pounds). The F threshold was estimated at 0.24 and the F target was estimated at 0.20.

The 2018 benchmark stock assessment estimated female SSB in 2017 at 151 million pounds, which is below the SSB threshold, indicating the stock is overfished. Fishing mortality in 2017 was estimated at 0.31, which is above the F threshold, indicating the stock is experiencing overfishing. Please refer to the science highlight on page 12 for more information on the stock assessment.

Atlantic Coastal Management

Prior to passage of the Atlantic Striped Bass Conservation Act (Striped Bass Act, 1984), the precursor to the Atlantic Coastal Fisheries Cooperative Management Act (1993), the Commission

continued, see ATLANTIC STRIPED BASS on page 8

Atlantic Herring

The Commission's Atlantic Herring Management Board approved Addendum II to Amendment 3 of the Interstate Fishery Management Plan for Atlantic Herring. The Addendum strengthens spawning protections in Area 1A (inshore Gulf of Maine) by initiating a closure when a lower percentage of the population is spawning (from approximately 25% to 20%), and extending the closure for a longer time (from four to six weeks). The Addendum also modifies the trigger level necessary to reclose the fishery, with the fishery reclosing when 20% or more of the sampled herring are mature but have not yet spawned. These changes to spawning protections are in response to the results of the 2018 Benchmark Stock Assessment, which showed reduced levels of recruitment and spawning stock biomass over the past five years, with 2016 recruitment levels the lowest on record.

Under Amendment 3, the Board uses a series of closures to protect spawning aggregations in the Gulf of Maine. Biological samples are used to annually project the start of the spawning closures. Recent analysis by the Atlantic Herring Technical Committee found that while the spawning closure system was significantly improved under Amendment 3, the protocol could continue to be strengthened by considering when, and for how long, a closure is initiated. Specifically, the analysis showed greater protection could be provided by initiating a closure when a lower percentage of the population is spawning and extending the closure for a longer time.

The states are required to implement Addendum II's measures by August 1, 2019. The Addendum is available at http://www.asmfc.org/uploads/file/5cddb296Atl.HerringDraftAddendumIIFinalApprovedRevised.pdf. For more information, please contact Kirby Rootes-Murdy, Senior Fishery Management Plan Coordinator, at krootes-murdy@asmfc.org.

Coastal Sharks

The Commission's Coastal Sharks Management Board approved changes to the recreational size limit for Atlantic shortfin mako sharks in state waters, specifically, a 71-inch straight line fork length (FL) for males and an 83-inch straight line FL for females. These measures are consistent with those required for federal highly migratory species (HMS) permit holders under HMS Amendment 11, which was implemented in response to the 2017 Atlantic shortfin mako stock assessment that found the resource is overfished and experiencing overfishing. Amendment 11 responds to a recent determination by the International Commission on the Conservation Atlantic Tunas that all member countries need to reduce current shortfin mako landings by approximately 72-79% to prevent further declines in the population.

The Board adopted complementary size limits in state waters to provide consistency with federal measures as part of ongoing efforts to rebuild the resource. The states will implement the changes to the recreational minimum size limit for Atlantic shortfin mako by January 1, 2020.

For more information, please contact Kirby Rootes-Murdy, Senior Fishery Management Plan Coordinator, at krootesmurdy@asmfc.org. Information on federal HMS shark regulations can be found at https://www.fisheries.noaa.gov/atlantic-highly-migratory-species/atlantic-highly-migratory-species-fishery-compliance-guides.

States Schedule Public Hearings on Atlantic Cobia Draft Amendment 1

The Commission's South Atlantic State/Federal Fisheries Management Board approved Draft Amendment 1 to the Interstate Fishery Management Plan (FMP) for Atlantic Migratory Group Cobia (Atlantic cobia) for public comment. Atlantic coastal states from Virginia through South Carolina have scheduled their hearings to gather public input on Draft Amendment 1. The details of those hearings follow.

VMRC - June 12 at 6 PM
380 Fenwick Rd, Building 96
Fort Monroe, Hampton, VA
Contact: Pat Geer at 757.247.2200

NC DMF - June 13 at 7 PM
Dare County Commissioners Office
954 Marshall Collins Drive, Room 168
Manteo, NC
Contact: Chris Batsavage at 252.808.8009

SC DNR - July 1 at 6 PM
Port Royal Sound Foundation Maritime Center, 310 Okatie Highway
Okatie, SC
Contacts: Mel Bell at 843.953.9007

****Webinar Hearing - June 18 at 6 PM***
Webinar Registration: https://register.gotowebinar.com/register/3902998396468814081
For audio, dial 1.888.585.9008 and enter the Conference Room Number: 275-479-282
Contact: Dr. Michael Schmidtke at 703.842.0740

*The webinar hearing is intended to primarily accommodate stakeholders in states where an in-person hearing is not being held. Stakeholders in Virginia, North Carolina, and South Carolina are encouraged to provide comments at the in-person hearings in their respective states, rather than the webinar hearing.

Draft Amendment 1 was initiated in anticipation of removal of Atlantic cobia from the South Atlantic and Gulf of Mexico Fishery Management Councils' Fishery Management Plan for Coastal Migratory Pelagic Resources (CMP FMP) through Regulatory Amendment 31. Final approval for CMP FMP Regulatory Amendment 31 was approved earlier this year. Therefore, there is no longer a federal management plan for Atlantic cobia, and the Commission

ATLANTIC COBIA, continued on next page

ATLANTIC COBIA, continued from page 6

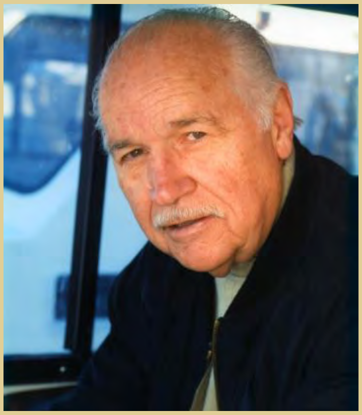
is the sole management body for this stock. This necessitates changes to several portions of the current interstate FMP that are dependent on the CMP FMP and also provides the opportunity for the Board to construct a long-term management strategy in the absence of a federal FMP.

Draft Amendment 1 presents options for addressing 13 issues within the FMP, including additions to the management goals and objectives, establishment of processes to define biological reference points and specify harvest, changes to commercial monitoring of landings, clarification of the process for evaluating recreational harvests against state harvest targets, potential changes to commercial fishery management measures, establishment of de minimis criteria for the commercial fishery, and recommended management measures for federal waters. For some of these issues, multiple options are presented, while for others, only one option is presented. Public input is requested for all issues included in Draft Amendment 1.

Draft Amendment 1 is available at http://www.asmfc.org/files/PublicInput/CobiaDraftAmendment1_PublicComment_May2019.pdf or via the Commission's website, www.asmfc.org, under Public Input. Fishermen and other interested groups are encouraged to provide input on Draft Amendment 1 either by attending state public hearings/webinar or providing written comment. Public comment will be accepted until ***5 PM (EST) on July 15, 2019*** and should be sent to Dr. Michael Schmidtke, Fishery Management Plan Coordinator, 1050 N. Highland St, Suite A-N, Arlington, VA 22201; 703.842.0741 (FAX) or at comments@asmfc.org (Subject line: Cobia Amd 1).

The Board will meet at the Commission's 2019 Summer Meeting in August to review and consider public comment and final approval for Draft Amendment 1.

In Memoriam



On June 1st, EDWARD AUGUSTINE O'BRIEN, 82, of Chesapeake Beach, MD, died peacefully at the Mandrin Chesapeake Inpatient Care Center in Harwood, MD, in the presence of his beloved partner, Diane Martin. A charter fishing captain, a life-long advocate for the Chesapeake Bay, a Marine who served his country with distinction, father of five, grandfather of nine, and great-grandfather of ten, he will be forever missed.

In March of this year, Governor Larry Hogan bestowed the highest honor to Captain O'Brien by naming him "Admiral of the Chesapeake Bay" for committing "his time and talents to improving the management of our natural resources and preserving our state's fishing heritage and the charter boat industry for over 40 years."

It was a recognition characteristic of Ed's lifelong service to his country, his family, and his community. After graduating from Loyola High School in Baltimore, Ed began his young life in the Marines in 1954 and was discharged as Sergeant in 1957 with honor. He advanced our country's security while working at McDonnell Aircraft as part of the Project Mercury Team. While with Martin Marietta, then Universal Match Corporation and as an officer of LaBarge Company, he continued to work with U.S. government agencies and Congress to enhance national security efforts. He also served as a Director of Control Video Corporation, the precursor to AOL.

In 1973, he started his charter fishing business with *Semper Fidelis I* on the Magothy River, *Semper Fidelis II* out of Solomon's Island, and *Semper Fidelis II* and III from Chesapeake Beach with his son Captain John O'Brien, until 2017. This is where he found pleasure, peace, and some of life's deepest meaning while watching sunshine glisten off the backs of striped bass breaking water in the early morning light on the Chesapeake.

In efforts to improve the health of the Bay and to preserve its fishing heritage, Ed hosted Governors, Congresspersons, members of the Maryland General Assembly, and President George W. Bush on the *Semper Fidelis*. He worked closely with the Coast Guard and received its highest civilian honor, the Meritorious Public Services Award. Since 1995, Ed served as Vice President of the National Charter Boat Association.

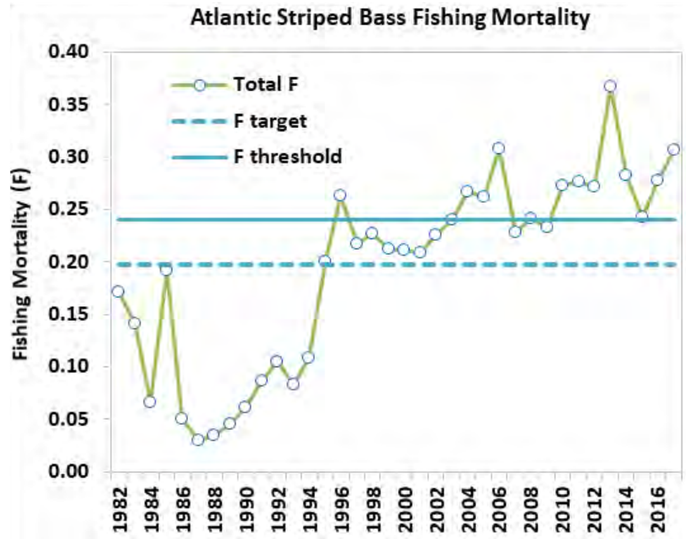
A long-time advocate for the restoration and conservation of striped bass, Ed served for over three decades on the Atlantic States Marine Fisheries Commission's Atlantic Striped Bass Advisory Panel, representing the interests of Maryland anglers and the for-hire industry. For the past several years, he also served as Delegate Stein's ongoing proxy to the ASMFC.

A Mass of Christian Burial was held at St. Andrew by the Bay Catholic Church, 701 College Pkwy., Annapolis, MD on Wednesday, June 5. In lieu of flowers, contributions may be made to Hospice of the Chesapeake, 90 Ritchie Hwy., Pasadena, MD 21122. Online condolences may be made at KalasFuneralHomes.com

"O God, thy sea is so great and my boat is so small."

ATLANTIC STRIPED BASS continued from page 5

did not have the management authority that it does today. The Interstate Fishery Management Plan (FMP) for Atlantic Striped Bass (1981) and Amendments 1 and 2 (1984) only provided recommendations on how to sustainably manage the resource. Amendment 3 (1985) was the first enforceable plan under the Striped Bass Act. The Amendment implemented measures to protect the 1982 year class, the first modestly-sized cohort for nearly a decade. Several states, beginning with Maryland, opted for an even more conservative approach and imposed a total moratorium on striped bass landings. The Amendment contained a trigger mechanism to reopen fisheries based on a juvenile abundance index, which was triggered with the recruitment of the 1989 year class. Subsequently, Amendment 4 (1989) was implemented and aimed to rebuild the resource rather than maximize yield. In 1995, the Commission declared Atlantic coastal striped bass stocks fully recovered.



Currently, striped bass is managed through Amendment 6 to the FMP (2003). The Amendment introduced a new set of biological reference points based on female SSB, and a suite of management triggers based on the biological reference points. The coastal commercial quota was restored to 100% of the historical average landings during the 1970s, and recreational fisheries were required to implement a two fish bag limit and a minimum size limit of 28 inches, except for the Chesapeake Bay fisheries, Albemarle-Roanoke (A/R) fisheries, and fisheries with approved conservation equivalency proposals. At the time, the Chesapeake Bay and A/R regulatory programs were different than the coastal migratory program because these portions of the stock were predicated on a more conservative F target than the coastal migratory stock. The independent F target allowed these jurisdictions to implement separate seasons, harvest caps, and size and bag limits as long as they remained under that target.


Photo (c) Dennis Abbott

A series of four addenda to Amendment 6 were implemented from 2007 to 2014. Addendum I (2007) established a bycatch monitoring program to improve stock assessments, and Addendum II (2010) modified the definition of recruitment failure, a term defined in the FMP and associated with one of its management triggers. Addendum III (2012) addressed illegal striped bass harvest and was developed in response to a multi-year, multi-jurisdictional investigation conducted within the Chesapeake Bay that uncovered over one million pounds of illegally harvested striped bass with an estimated net worth of $7 million. The Addendum required all states and jurisdictions with a commercial striped bass fishery to implement a commercial harvest tagging program whereby each commercially-caught striped bass is affixed with a unique tag that must remain on the fish until purchased by the consumer.

Addendum IV (2014) established one set of F reference points for the coastal migratory population in all management areas. Now, and as it was prior to Amendment 5, the Atlantic striped bass complex (excluding the A/R stock) is managed and modeled as a single stock with one set of SSB and F reference points for the coastal migratory population. Addendum IV was also initiated in response to a steady decline in SSB since 2004. In order to reduce F to a more sustainable level and stabilize SSB, the Addendum implemented regulations to achieve a 25% reduction in removals along the coast and 20.5% reduction in the Chesapeake Bay beginning in 2015. Specifically, commercial quotas were cut and coastal recreational bag limits were reduced from two fish to one. The recreational fisheries in the Chesapeake Bay, as well as several other state fisheries, used the FMP's conservation equivalency process, resulting in a wide range of regulations across the coast. Additionally, since the A/R stock was deemed by the Commission to contribute minimally to the coastal migratory population, Addendum IV defers management of the

ATLANTIC STRIPED BASS, continued on next page

Comings & Goings

COMMISSIONERS

SENATOR PHILIP BOYLE

In April, Senator Philip Boyle stepped down as New York's Legislative Appointee to the Commission. Senator Boyle served in that position since 2013, where he consistently participated in the Commission's fisheries management process through either his own attendance or that of his proxy. We are grateful for Senator Boyle's involvement and wish him great success in all his future endeavors.

SENATOR TODD KAMINSKY

Appointed as New York's Legislative Appointee in April, Senator Todd Kaminsky is a Ranking Member of the State's Senate Environmental Conservation Committee, where he has been a champion for preserving and protecting Long Island's air, soil and water. A Long Island native, Senator Kaminsky has been a strong advocate for lower taxes, good jobs and a strong economy. He secured tax breaks for Sandy victims and has rallied to reform Industrial Development Agencies to protect tax dollars.

During his time as a prosecutor, Senator Kaminsky also worked vigorously as a community advocate for the South Shore. He organized free legal clinics for those affected by superstorm Sandy, and helped bring tens of thousands of dollars in relief funds to local residents. For his efforts, he was awarded the Community Service Award from the U.S. Attorney's Office for the Eastern District of New York and the Long Beach Martin Luther King Center's Sandy Relief Service Award. Senator Kaminsky championed the effort to reopen an emergency room on the Long Beach Barrier Island, succeeded in stopping National Grid from charging Sandy victims for gas connections when rebuilding their homes, and led the opposition to the Port Ambrose offshore Liquefied Natural Gas terminal.

Senator Kaminsky received his law degree, magna cum laude, from New York University, and his bachelor's degree, summa cum laude, from the University of Michigan. He and his wife, Ellen, live in Long Beach with their sons Rafe and Rory. Welcome aboard!

STAFF

MIKE CAHALL

Mike Cahall (center), with ASMFC Executive Director Bob Beal (left) and ASMFC Chair Jim Gilmore this May, having accepted a plaque in honor of his retirement.

In mid-May, Commission staff and the program partners of the Atlantic Coastal Cooperative Statistics Program bid fond farewell to ACCSP Director Michael Cahall. Mike joined the ACCSP in 1999 to work on IT issues and programming, and was promoted to Director in 2007. Under his visionary leadership, ACCSP enjoyed tremedous growth, becoming the principal source of marine fishery statistics for the U.S. Atlantic coast that program partners had envisioned it to be when they created the ACCSP in the mid-1990s. Both innovative in his problem solving and deft at seeking funding, Mike was able to spearhead projects that significantly advanced

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ATLANTIC STRIPED BASS, continued from page 8

A/R stock to the State of North Carolina under the auspices of the Commission, with use of stock-specific biological reference points approved by the Board.

Given that the stock is exeriencing overfishing, the Board initiated the development of a Draft Addendum in May to consider measures aimed at reducing F to the target level. The Draft Addendum will explore a range of management options, including minimum size and slot size limits for the recreational fishery in the Chesapeake Bay and along the coast, as well as a coastwide circle hook requirement when fishing with bait. The Board also provided guidance on how to apply the necessary reductions to both the commercial and recreational sectors. The Draft Addendum will be presented to the Board for its consideration and approval for public comment in August. If approved, it will be released for public comment, with the Board considering its final approval in October for implementation in 2020.

Please visit www.asmfc.org for more information, or contact Max Appelman, Fishery Management Plan Coordinator, at mappelman@asmfc.org.

Horseshoe Crab Board Approves Benchmark Stock Assessment for Management Use

Number of Surveys Below the Index-based 1998 Reference Point in the Terminal (Final) Year of ARIMA Model

Region	2009 Benchmark	2013 Update	2019 Benchmark	2019 Stock Status
Northeast	2 out of 3	5 out of 6	1 out of 2	Neutral
New York	1 out of 5	3 out of 5	4 out of 4	Poor
Delaware Bay	5 out of 11	4 out of 11	2 out of 5	Neutral
Southeast	0 out of 5	0 out of 2	0 out of 2	Good
Coastwide	7 out of 24	12 out of 24	7 out of 13	Neutral

The 2019 Horseshoe Crab Benchmark Stock Assessment evaluated the stock status of the resource by region, finding populations within the Delaware Bay and Southeast regions remaining consistently neutral and good, respectively, through time. The Northeast region population has changed from poor to neutral, while the status of the New York region population has trended downward from good, to neutral, and now to poor. The Benchmark Assessment was endorsed by the Peer Review Panel and accepted by the Horseshoe Crab Management Board (Board) for management use.

To date, no overfishing or overfished definitions have been adopted for management use. For the assessment, biological reference points were developed for the Delaware Bay region horseshoe crab population, although not endorsed by the Peer Review Panel for use in management. However, given the assessment results of low fishing mortality and relatively high abundance, overfishing and an overfished status are unlikely for female horseshoe crabs in the Delaware Bay region.

In the absence of biological reference points, stock status was based on the percentage of surveys within a region (or coastwide) having a >50% probability of the final year being below the model reference point (referred to as the Autoregressive Integrated Moving Average or ARIMA reference point). "Poor" status was >66% of surveys meeting this criterion, "Good" status was <33% of surveys, and "Neutral" status was 34 – 65% of surveys. Based on this criterion, stock status for the Northeast region was neutral; the New York region was poor; the Delaware Bay region was neutral; and the Southeast region was good.

Coastwide, abundance has fluctuated through time with many surveys decreasing after 1998 but increasing in recent years. The coastwide status includes surveys from all regions and indicates a neutral trend, likely due to positive and negative trends being combined.

The Board will consider a possible management response to the assessment at its next meeting in August. A more detailed description of the stock assessment results is available on the Commission's website at http://www.asmfc.org/uploads/file/5ccae597HSC_StockAssessmentOverview2019.pdf. The 2019 Horseshoe Crab Benchmark Stock Assessment and Peer Review Report is available at http://www.asmfc.org/uploads/file/5cd5d6f1HSCAssessment_PeerReviewReport_May2019.pdf. For more information, please contact Dr. Mike Schmidtke, FMP Coordinator, at mschmidtke@asmfc.org.

On the Legislative Front: *U.S. House Committee Advances Funding Bill for Fisheries Programs*

On May 22, the U.S. House of Representatives' Appropriations Committee approved its FY20 Commerce, Justice, Science and Related Agencies Appropriations Act by a vote of 30-22. The legislation provides funding to the Department of Commerce, NOAA Fisheries and some ASMFC programs, including the Atlantic Coastal Act and the ACCSP.

The Committee Report accompanying the legislation includes provisions to fund Interstate Fisheries Management Commissions at the FY19 level; continue the Mid-Atlantic Horseshoe Crab Trawl Survey in FY20; and provide resources to study climate change impacts on American lobster. The Committee Report rejects the President's proposal to eliminate Interjurisdictional Fisheries Act Grants, Joint Enforcement Agreements, and the National Sea Grant College Program.

The U.S. Senate Appropriations Committee has yet to introduce its version of the FY20 Commerce, Justice, Science and Related Agencies Appropriations Act.

National Oceanic and Atmospheric Administration (in $ thousands)

	2019 Enacted	2020 President	2020 House
Protected Resources Science and Management			
Marine Mammals, Sea Turtles & Other Species	118,348	112,509	124,000
Species Recovery Grants	7,000	5,996	7,500
Atlantic Salmon	6,500	6,270	6,500
Pacific Salmon	65,000	61,741	66,420
Fisheries Science and Management			
Fisheries and Ecosystem Science Programs and Services	147,107	135,593	150,000
Fisheries Data Collections, Surveys and Assessments	168,086	157,656	171,000
Observers and Training	53,955	44,047	45,100
Fisheries Management Programs and Services	121,116	113,653	124,000
Aquaculture	15,000	13,005	13,005
Salmon Management Activities	37,000	31,598	37,000
Regional Councils and Fisheries Commissions	40,175	37,653	41,500
Interjurisdictional Fisheries Grants	3,365	0	3,500
Enforcement	69,796	54,072	73,500
Habitat Conservation and Restoration	56,384	37,875	61,625
Other Line Items of Note			
National Sea Grant College Program	68,000	0	73,000
Coastal Zone Management and Services	43,500	44,976	46,500
Coastal Zone Management Grants	75,500	0	81,000
National Estuarine Research Reserve System	27,000	0	29,000

increase from FY19 amount, decrease from FY19 amount, >10% change

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particular, Mr. Ballou has shown outstanding leadership on two very high profile and consequential Commission management bodies – the Summer Flounder, Scup and Black Sea Bass Board and the Atlantic Menhaden Board. Over the past several years and in particular as Board Chair since 2017, Mr. Ballou has been responsible for much of the progress that has been made on summer flounder, scup, and black sea bass management. These species are particularly challenging given they are jointly managed with the Mid-Atlantic Fishery Management Council and are highly influenced by changes in ocean temperatures. As Chair, Mr. Ballou has led the Board through difficult deliberations, leading to the adoption of multiple addenda, as well as approval of the Summer Flounder Commercial Issues Amendment.

Even more noteworthy is the role Mr. Ballou played in the development and approval of Amendment 3 to the Atlantic Menhaden Fishery Management Plan. As Board Chair, Mr. Ballou worked tirelessly with Commission staff, Board members, and technical groups. There are few management actions higher in profile or more complex, and Mr. Ballou's commitment to the integrity of the Commission's process and the sustainable management of this important forage species deserves high commendation.

Science & Technical Contributions

Geoffrey White, Coleby Wilt, Alex DiJohnson and Sarah Rains, Access Point Angler Intercept Survey (APAIS) Team

Due to the herculean efforts of the APAIS Team of Mr. Geoff White, Mr. Coleby Wilt, Mr. Alex DiJohnson and Ms. Sarah Rains over the past two years, the collection of recreational survey data successfully transitioned from a federal contractor to the state fishery agencies from Maine through Georgia. As part of the transition, the APAIS Team worked to shift the collection program from an outdated, paper-based system that included tens of thousands of paper interview forms to an automated system, whereby data is now collected via a tablet-based Dockside Interceptor. The Dockside Interceptor has reduced data transfer from 21 days to 1 day, completely eliminating all the paper steps.

The APAIS Team also assisted in the development and deployment of a Computer Assisted Telephone Interview tool to conduct the for-hire telephone survey, replacing a manual transcription process in the three states conducting the survey. The system was first deployed in North Carolina in January 2019, with the state estimating a 33% increase in efficiency and a better than 80% response rate.

From left: Part of the APAIS Team - Sarah Rains, Geoff White and Alex DiJohnson

These two innovative systems, spearheaded by the APAIS Team, are completely changing the complexion of recreational data collection on the Atlantic coast, resulting in more accurate and timely data with a significantly reduced workload.

Michael Celestino, New Jersey Division of Fish and Wildlife

For the past several years, Mr. Michael Celestino has made his mark as an active participant and chair for numerous Commission science committees. These include the Assessment Science Committee (ASC), the Ecological Reference Points Work Group, and the Science and Data Working Group of the Atlantic Coastal Fish Habitat Partnership, as well as species technical committees and stock assessment subcommittees for bluefish, striped bass and Atlantic sturgeon.

Mr. Celestino's leadership on the 2018 striped bass benchmark stock assessment is of particular note. Midway through the assessment process, Mr. Celestino stepped in as Stock Assessment Subcommittee Chair, skillfully guiding the Subcommittee through the challenges of dealing with newly revised recreational data and new modeling approaches. He was responsible for updating the statistical catch-at-age model with new and improved data and conducting sensitivity analyses, all the while supporting the primary model being developed by another modeler. Ultimately, the model Mr. Celestino spearheaded was accepted as the preferred model by the peer review panel, adding lead modeler to his already long list of accomplishments. With the assessment process completed, Mr. Celestino continues to contribute to the striped bass stock assessment by running projections and responding to Board tasks.

In all that he does, Mr. Celestino exhibits an outstanding work ethic, consistently producing high-quality and meticulous work in a timely fashion. Committed to the Commission's mission and the process of cooperative management, Mr. Celestino analyzes problems carefully from all angles and provides a comprehensive viewpoint of the issues. While it is still early in his career, Mr. Celestino's leadership and efforts of the past several years have made him a huge asset to the Commission's committees and management process.

Dr. John Sweka, U.S. Fish and Wildlife Service (USFWS), Northeast Fishery Center

For more than a decade, Dr. John Sweka has been an invaluable member and chair of several Commission science committees, including the ASC and stock assessment subcommittees for American eel, Atlantic sturgeon, river herring and horseshoe crab. Dr. Sweka served as Chair of the River Herring Stock Assessment Committee, leading the charge in the first coastwide stock assessment of river herring, and he currently chairs the Horseshoe

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Science Highlight: Atlantic Striped Bass Assessment Overview

This overview presents a summary of the 2018 benchmark stock assessment for Atlantic striped bass. The assessment is the latest and best information available on the status of the coastwide Atlantic striped bass stock for use in fisheries management.

What Data Were Used?

The stock assessment used both ***fishery-dependent and -independent data*** collected through state, federal, and academic research programs. The assessment included final catch data through 2017.

Recreational and Commercial Catch

The stock assessment used total catch (harvest, commercial discards and dead recreational discards) and catch-at-age split into two components: Chesapeake Bay removals and ocean removals. Removals include harvest and dead discards from both fishing sectors. Ocean removals include removals from inland areas like the Delaware Bay, Long Island Sound and the Hudson River.

Strict commercial quota monitoring is conducted by states through various state and federal dealer and fishermen reporting systems; landings are compiled annually from those sources by state biologists.

Recreational catch, effort, and length frequency data were obtained from the Marine Recreational Information Program (MRIP) for 1982-2017. MRIP uses surveys to estimate how many fishing trips recreational anglers take every year and how many fish per trip they catch. In 2018, MRIP transitioned from a phone-based survey to a mail-based survey to estimate the number of angler trips. The new, improved survey showed the number of trips taken in recent years was much higher than had been previously estimated, and as a result, estimates of recreational catch were much higher for striped bass (see Figure 1). Overall, the estimates of recreational removals of striped bass (fish that were landed plus fish that died as a result of being released alive) were 2.3 times higher using the new method, with a greater difference in recent years.

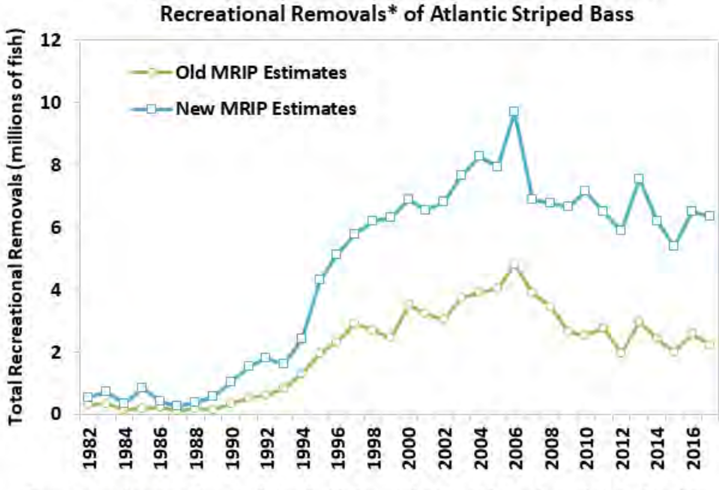
MRIP catch per unit effort data was used as a fishery-dependent index of relative abundance.

Fishery-Independent Surveys & Tagging Data

The assessment used nearly a dozen fishery-independent indices of relative abundance for adults, young-of-year and age-1 fish.

Eight tagging programs have traditionally participated in the U.S. Fish and Wildlife Service (USFWS) Atlantic coast striped bass tagging program and each have been in progress for at least 18 years. The tagging programs are divided into two categories, producer area programs and coastal programs. Producer area tagging programs primarily operate during spring spawning on spawning grounds in New York, Delaware/Pennsylvania, Maryland, and Virginia. Coastal programs tag striped bass from mixed stocks during fall, winter, or early spring in waters off of Massachusetts, New York, New Jersey, and North Carolina. USFWS maintains the tag release and recapture database and provides rewards to fishermen who report the recaptures of tagged fish. From 1985 through August 2018, there were 542,149 striped bass tagged and released, with 92,344 recaptures reported coastwide.

Figure 1. Comparison of Old & New MRIP Estimates of Recreational Removals* of Atlantic Striped Bass



*Recreational removals include landed fish and the 9% of fish released alive that die.

How Were the Data Analyzed?

Statistical catch-at-age (SCA) model

The accepted model for use in striped bass stock assessments is a forward projecting statistical catch-at-age (SCA) model, which uses catch-at-age data and fishery-dependent and -independent survey indices to estimate annual population size and fishing mortality. Indices of abundance track relative changes in the population over time while catch data provide information on the scale of the population size. Age structure data (numbers of fish by age) provide additional information on recruitment (number of age-1 fish entering the population) and trends in mortality.

Tagging model

As a complement to the SCA model, a tagging model (IRCR) was run on data from the USFWS coastwide striped bass tagging program through the 2017 tagging year. The IRCR model compares the numbers of tagged fish that have been recaptured to the numbers of fish that were originally tagged over time to estimate the survival rate of striped bass from year-to-year, fishing mortality rates and natural mortality rates.

What is the Status of the Stock?

In 2017, the Atlantic striped bass stock was overfished and experiencing overfishing relative to the updated reference points defined in the 2018 assessment. Female spawning stock biomass (SSB) was estimated at 151 million pounds, below the SSB threshold of 202 million pounds. Total fishing mortality was estimated at 0.307, above the fishing mortality threshold of 0.240.

Despite recent declines in SSB, the stock is still above the SSB levels observed during the moratorium that was in place in the mid-late 1980s.

Recruitment

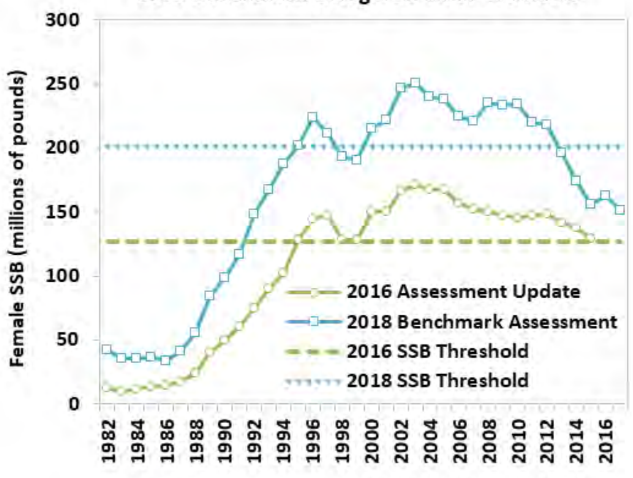
As shown in the lower figure on page 5, striped bass experienced a period of strong recruitment (age-1 fish entering the population) from 1994-2004, followed by a period of lower recruitment from 2005-2011 (although not as low as the early 1980s, when the stock was considered collapsed). This period of low recruitment contributed to the decline in SSB that the stock has experienced since 2010. Recruitment of age-1 fish was high in 2012, 2015, and 2016 (corresponding to strong 2011, 2014, and 2015 year classes), but estimates of age-1 striped bass were below the long-term average in 2013, 2014, and 2017. Recruitment in 2017 was estimated at 108.8 million age-1 fish, below the time series average of 140.9 million fish.

Biological Reference Points

The reference points currently used for management are based on the estimate of female SSB in 1995, the year the stock was declared recovered, as well as the fishing mortality needed to maintain SSB at its threshold and target values.

For the 2018 assessment, the definitions of the targets and thresholds remain the same, but the values have been updated. The new MRIP estimates resulted in higher estimates of SSB and, therefore, higher estimates for the SSB threshold and target (Figure 2). The SSB threshold was estimated at 202 million pounds, with an SSB target of 252 million pounds. The new MRIP estimates did not have a large effect on the estimates of fishing mortality, and the updated fishing mortality threshold and target values are

Figure 2. Comparison of SSB Estimates from the 2016 Update Using Old MRIP Numbers and the 2018 Benchmark Using New MRIP Numbers



very similar to the previous fishing mortality reference points. The fishing mortality threshold was estimated at 0.24, and the target was estimated at 0.20.

Data and Research Priorities

The Technical Committee (TC) addressed several of the recommendations from the 2013 benchmark assessment report, including developing new maturity-at-age estimates for the coastal migratory stock and evaluating stock status definitions relative to uncertainty in biological reference points. The TC also made progress on developing a spatially and temporally explicit catch-at-age model incorporating tag-based movement information. Although the Peer Review Panel did not accept the migration model for management use, it recommended continued work to improve the model for future assessments.

The TC identified several high priority research recommendations to improve the assessment. These included better characterization of commercial discards; expanded collection of sex ratio data and paired scale-otolith samples; development of an index of relative abundance for the Hudson River stock; better estimates of tag reporting rates; continued collection of mark-recapture data to better understand migration dynamics; and additional work on the impacts of Mycobacteriosis on striped bass population dynamics and productivity.

The TC recommends the next benchmark stock assessment be conducted in 2024, which will allow time to work on issues like state-specific scale-otolith conversion factors and directly incorporating tagging data into the two-stock assessment model.

A more detailed description of the stock assessment results is available on the Commission's website at http://www.asmfc.org/uploads/file/5cc9ba4eAtlStripedBassStockAssessmentOverview.pdf. The 2018 Atlantic Striped Bass Benchmark Stock Assessment, Stock Assessment Summary and Peer Review Report can be obtained via the following links:

Full assessment report - https://www.nefsc.noaa.gov/publications/crd/crd1908/crd1908.pdf
Summary Report - https://www.nefsc.noaa.gov/publications/crd/crd1901/crd1901.pdf
Peer Review Report - https://www.nefsc.noaa.gov/saw/saw66/saw-66-summary-report.pdf

From left: ISFMP Director Toni Kerns and former FMP Coordinator Kate Taylor with a striper caught as part of the hook and line tagging survey. Photo (c) Tom Crews, USFWS

ACCSP Announces FY19 Funding Recipients

The Atlantic Coastal Cooperative Statistics Program (ACCSP) is pleased to announce the recipients of its FY19 funding awards. Thanks to NOAA Fisheries, ACCSP is able to fund 13 new and ongoing projects submitted by our state and federal partners to improve fisheries data collection and processing on the Atlantic coast. This year's awards total over $1.6 million.

Partner	Project Title	Approximate Funding
ME DMR	Managing Mandatory Dealer Reporting in Maine	$214,000
ME DMR	Portside Commercial Catch Sampling and Comparative Bycatch Sampling for Atlantic Herring, Atlantic Mackerel, and Atlantic Menhaden Fisheries	$25,500
RI DEM	Maintenance and Coordination of Fisheries Dependent Data Feeds to ACCSP from the State of Rhode Island	$77,000
RI DEM	Advancing Fishery Dependent Data Collection for Black Sea Bass in the Southern New England and Mid-Atlantic Region Utilizing Modern Technology and a Vessel Research Fleet Approach	$133,000
NJ DFW	Electronic Reporting and Biological Characterization of New Jersey Commercial Fisheries	$164,400
SC DNR	ACCSP Data Reporting from South Carolina's Commercial Fisheries	$168,900
ACCSP Recreational Technical Committee	Supplemental At-Sea Sampling for the Recreational Headboat Fishery on the Atlantic Coast	$107,100
SEFSC	Continued Processing and Aging of Biological Samples Collected from U.S. South Atlantic Commercial and Recreational Fisheries	$300,000
NC DMF	An Updated Economic and Social Analysis of the Commercial Seafood Dealers of North Carolina	$19,900
ME DMR & MA DMF	Collaborative Electronic Tracking Pilot Program in the American Lobster Fishery	$19,700
MD DNR	Expanding Accountability in Reporting: A Tool for Comprehensive For-Hire Data Collection and Monitoring in Maryland	$182,900
RI DMF & GA DNR	Development of a Mobile Application to Assist Maritime Law Enforcement Personnel with Fisheries Enforcement Tasks	$60,000

ACCSP Issues Request for FY20 Proposals

The ACCSP is issuing a Request for Proposals to Program Partners and Committees for FY20 funding. ACCSP's Funding Decision Document (FDD) provides an overview of the funding decision process, guidance for preparing and submitting proposals, and information on funding recipients' post-award responsibilities. Projects in areas not specifically addressed in the FDD may still be considered for funding if they help achieve Program goals. These goals, listed by priority, are improvements in:

1 a. Catch, effort, and landings data (including licensing, permit and vessel registration data);
1 b. Biological data (equal to 1a.);
2. Releases, discards and protected species data; and,
3. Economic and sociological data.

Project activities that will be considered according to priority may include:

- Partner implementation of data collection programs;
- Continuation of current Program-funded partner programs;
- Funding for personnel required to implement Program-related projects/proposals; and
- Data management system upgrades or establishment of partner data feeds to the Data Warehouse and/or Standard Atlantic Fisheries Information System.

Initial proposals are due ***June 10, 2019***. Full information can be found at https://www.accsp.org/what-we-do/partner-project-funding

ACCSP is a cooperative state-federal program focused on the design, implementation, and conduct of marine fisheries statistics data collection programs and the integration of those data into a single data management system that will meet the needs of fishery managers, scientists, and fishermen. It is composed of representatives from natural resource management agencies coastwide, including the Atlantic States Marine Fisheries Commission, the three Atlantic fishery management councils, the 15 Atlantic states, the Potomac River Fisheries Commission, the D.C. Fisheries and Wildlife Division, NOAA Fisheries, and the U.S. Fish & Wildlife Service. For further information please visit www.accsp.org.

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From left: Mike Celestino and John Sweka

Crab Stock Assessment Subcommittee and the ASC. For Atlantic sturgeon, Dr. Sweka has made substantial advances in field research, such as hydroacoustic and telemetry tagging studies, which were used in the 2017 sturgeon stock assessment.

Dr. Sweka also acts as a key liaison to the U.S. Geological Survey (USGS) in order to advance the Commission's scientific endeavors, most notably our understanding and management of horseshoe crab and American eel populations. In collaboration with Mr. Dave Smith at the USGS Leetown Science Center, Dr. Sweka was a key contributor in the development of the Adaptive Resource Management framework to balance horseshoe crab harvest policies with the protection of endangered and threatened shorebird populations. He is also working with USGS and the Eel Technical Committee to incorporate habitat variables in a GIS mapping framework for future stock assessments.

Dr. Sweka has exhibited innovation and creativity by introducing new models for stock assessments. He has run ARIMA models for multiple species, which are currently used to evaluate abundance relative to reference points for American eel, river herring, and horseshoe crab. Dr. Sweka also developed a new age-structured operational model for horseshoe crabs as part of the stock assessment completed this spring. The peer review panel found the models to be notable improvements to the assessment process.

Finally, Dr. Sweka is recognized by fellow committee members, Commission staff, and USFWS as a respected and reliable scientific colleague. Federal fisheries agencies have a mandate to provide scientific support to the Commission and John has answered the bell. At a time when demands on our scientific community can be overwhelming, John consistently delivers analytical work on time and at a very high standard.

Law Enforcement Contributions

NOAA Special Agents Casey Oravetz and Sara Block, Assistant US Attorney for the Eastern District of North Carolina Banumathi Rangarajan, and the US Justice Department's Environment and Natural Resources Division's Environmental Crimes Section Trial Attorneys Lauren Steele, Shane Waller, Shennie Patel, and Joel La Bissonniere

Due to the diligence and tenacity of the team of NOAA Special Agents and attorneys with the Eastern District of North Carolina, and the U.S. Justice Department's Environment and Natural Resources Division's Environmental Crimes Section, 13 North Carolina trawl captains were indicted for the illegal harvest and possession of hundreds of thousands of pounds of striped bass from the EEZ in 2009 and 2010. The investigation began from a tip to NOAA Office of Law Enforcement (OLE) and a subsequent U.S. Coast Guard at-sea boarding of the F/V LADY SAMAIRA. The captain provided false information to officers regarding where fishing had occurred, and NOAA conducted a dockside investigation wherein the vessel's navigation computer was seized. Forensic analysis determined the captain caught striped bass illegally from the EEZ on that date and on previous trips, and had deleted evidence on the computer to attempt to conceal this activity. NOAA OLE agents recovered the data and reconstructed the trips using GIS tools. A broader analysis was then performed on other vessels landing striped bass on the same fishing days. Over a period of two years, NOAA OLE conducted over 30 search warrants in four states on vessels and businesses in order to gather evidence. Legal challenges made by the defense counsel resulted in the District Court erroneously dismissing the indictments. The U.S. Department of Justice appealed the case to the 4th Circuit Court of Appeals, who ultimately reversed the decision and reinstated the indictments.

Twelve defendants ultimately pled guilty to violating the Lacey Act. Some additionally pled to false statements, obstruction of justice, tax evasion, and failure to file tax returns. One of the defendants passed away during the investigation. For the 12 defendants, the U.S. District Court Judge imposed sentences totaling over 38 years of probation, 2.5 years of home confinement, 850 hours of community service, $3,000 in fines, and over $1.2 million in restitution.

This team's tenacity, hard work, and commitment to the mission showcase the outstanding work performed as a team to protect and conserve the Atlantic striped bass fishery.

From left: Shennie Patel, Casey Oravetz, Lauren Steele, and Sara Block

ASMFC Seeks New ACCSP Director

The Commission seeks a dynamic and visionary leader to manage and further develop the integrated fisheries statistics programs that include the collection, warehousing and dissemination of commercial and recreational harvest data for the U.S. Atlantic coast. The applicant should have strong skills and experience as a program/project manager. The Atlantic Coastal Cooperative Statistics Program (ACCSP) Director will be responsible for: 1) articulating, advocating for and promoting the vision and mission of ACCSP to a wide range of participants and stakeholders; 2) developing and updating annual operating plans that appropriately reflect the strategic plan, availability of funds and policy guidance from the ACCSP Coordinating Council; 3) providing executive leadership for the program; 4) providing overall programmatic management; and, 5) supervising the day-to-day operations of the Program. The Director will supervise a staff of 13 and work closely with the Chair of the ACCSP Coordinating Council and the Commission's Executive Director on Program policy and administrative issues. ACCSP is a partner-driven program of the ASMFC.

Applications will be accepted until **June 17**. The full job announcement can be found at http://www.asmfc.org/files/JobAnnouncements/19-005_ACCSPDirector_May2019.pdf

Species	FMP Coordinator	Stock Assessment Scientist	ACCSP Data Lead
American Eel	Kirby Rootes-Murdy krootes-murdy@asmfc.org	Kristen Anstead kanstead@asmfc.org	Heather Konell heather.konell@accsp.org
American Lobster & Jonah Crab	Caitlin Starks cstarks@asmfc.org	Jeff Kipp jkipp@asmfc.org	Julie Defilippi Simpson julie.simpson@accsp.org
Atlantic Croaker	Mike Schmidtke mschmidtke@asmfc.org	Kristen Anstead kanstead@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Atlantic Herring	Kirby Rootes-Murdy krootes-murdy@asmfc.org	Katie Drew kdrew@asmfc.org	Joe Myers joseph.myers@accsp.org
Atlantic Menhaden	Max Appelman, mappelman@asmfc.org	Kristen Anstead kanstead@asmfc.org	Julie Defilippi Simpson julie.simpson@accsp.org
Atlantic Striped Bass	Max Appelman, mappelman@asmfc.org	Katie Drew kdrew@asmfc.org	Joe Myers joseph.myers@accsp.org
Atlantic Sturgeon	Max Appelman, mappelman@asmfc.org	Kristen Anstead kanstead@asmfc.org Katie Drew kdrew@asmfc.org	Joe Myers joseph.myers@accsp.org
Black Drum	Mike Schmidtke mschmidtke@asmfc.org	Jeff Kipp jkipp@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Black Sea Bass	Caitlin Starks cstarks@asmfc.org	Jeff Kipp jkipp@asmfc.org	Heather Konell heather.konell@accsp.org
Bluefish	Dustin Colson Leaning DLeaning@asmfc.org	Katie Drew kdrew@asmfc.org	Joe Myers joseph.myers@accsp.org
Coastal Sharks	Kirby Rootes-Murdy krootes-murdy@asmfc.org	Kristen Anstead kanstead@asmfc.org	Joe Myers joseph.myers@accsp.org
Cobia	Mike Schmidtke mschmidtke@asmfc.org	Kristen Anstead kanstead@asmfc.org	Heather Konell heather.konell@accsp.org
Horseshoe Crab	Mike Schmidtke mschmidtke@asmfc.org	Kristen Anstead kanstead@asmfc.org	Heather Konell heather.konell@accsp.org
Northern Shrimp	Dustin Colson Leaning DLeaning@asmfc.org	Katie Drew kdrew@asmfc.org	Heather Konell heather.konell@accsp.org
Red Drum	Mike Schmidtke mschmidtke@asmfc.org	Jeff Kipp jkipp@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Shad & River Herring	Caitlin Starks cstarks@asmfc.org	Jeff Kipp jkipp@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Spanish Mackerel	Mike Schmidtke mschmidtke@asmfc.org	Katie Drew kdrew@asmfc.org	Heather Konell heather.konell@accsp.org
Spiny Dogfish	Kirby Rootes-Murdy krootes-murdy@asmfc.org	Kristen Anstead kanstead@asmfc.org	Heather Konell heather.konell@accsp.org
Spot	Mike Schmidtke mschmidtke@asmfc.org	Jeff Kipp jkipp@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Spotted Seatrout	Mike Schmidtke mschmidtke@asmfc.org	Katie Drew kdrew@asmfc.org	Heather Konell heather.konell@accsp.org
Summer Flounder & Scup	Dustin Colson Leaning DLeaning@asmfc.org	Jeff Kipp jkipp@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Tautog	Kirby Rootes-Murdy krootes-murdy@asmfc.org	Katie Drew kdrew@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Weakfish	Mike Schmidtke mschmidtke@asmfc.org	Katie Drew kdrew@asmfc.org	Mike Rinaldi mike.rinaldi@accsp.org
Winter Flounder	Dustin Colson Leaning DLeaning@asmfc.org	Katie Drew kdrew@asmfc.org	Joe Myers joseph.myers@accsp.org

COMINGS AND GOINGS
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ACCSP's mission and objectives, including tablet and mobile data entry apps for dealers, commercial fishermen and the for-hire industry. Not one to rest on his laurels, Mike will be filling his retirement with a multitude of other pursuits, such as working as an EMT, teaching and performing the violin, and creating a database to aid in mapping the ancient ruins of Pompeii. We wish Mike all the very best.

DUSTIN COLSON LEANING

On June 3rd, Commission staff welcomed Dustin Colson Leaning as its newest Fishery Management Plan Coordinator. Dustin is a recent graduate from Duke University with a Master's in Environmental Economics and Policy. He completed his undergraduate degree from Eckerd College. While at Duke, he examined the effects of community conservation engagement on bush meat hunting in Gabon. Dustin assumes coordination responsibility for summer flounder, scup, bluefish, winter flounder and Northern shrimp. Please join us in welcoming Dustin to the Commission. (See accompanying table for current fisheries management, science and data leads and their contact information.)

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Chris Batsavage, Special Assistant for Councils

SUBJECT: Mid-Atlantic Fishery Management Council Meeting Summary—Jun. 4-6, 2019

Issue
Memo to inform the Marine Fisheries Commission of the issues discussed and actions taken by the Mid-Atlantic Fishery Management Council.

Findings
- The memo highlights management actions of particular interest to the Marine Fisheries Commission.
- Additional information about the meeting can be found in the Mid-Atlantic Fishery Management Council meeting materials in the briefing book.

Action Needed
For informational purposes only, no action is needed at this time.

Overview

2020 Atlantic Mackerel, Squid, and Butterfish Specifications
The Council reviewed Atlantic mackerel, squid (longfin and *Illex*), and butterfish specifications for 2020, which were previously established as part of multi-year specifications. The Council did not recommend any changes to the squid and butterfish specifications. However, the Council recommended an Atlantic mackerel catch limit of 29,184 metric tons, which is a 10 percent reduction from the previously recommended catch limit for 2020. The reduction is based on information that indicates poor recruitment* in recent years and only one dominant year class in the population*. This information also resulted in Canada reducing the Atlantic mackerel catch limit in their waters. The Atlantic mackerel stock* is currently overfished and overfishing* is occurring. A stock assessment update is scheduled for 2020.

River Herring and Shad Catch Cap
The Council took no action on modifying the 2019 river herring and shad catch cap for the directed Atlantic mackerel fishery and will revisit the 2020 catch cap at their August meeting. The catch cap is 129 metric tons in 2019 and 152 metric tons in 2020. To ensure fishermen avoid river herring and shad while fishing for Atlantic mackerel, the cap is initially set at 89

metric tons while Atlantic mackerel landings are below 10,000 metric tons. The cap will only increase if the fishery lands greater than10,000 metric tons of Atlantic mackerel before the 89 metric ton cap is reached. The 2019 river herring and shad catch cap was reached on March 12, which closed the directed Atlantic mackerel fishery when only a small portion of the 2019 quota was landed.

Upcoming Meeting

The next regularly scheduled meeting of the Mid-Atlantic Fishery Management Council is on August 13-15, 2019 at the Courtyard Philadelphia Downtown in Philadelphia, PA.

*Definitions

Stock – A group of fish of the same species in a given area. Unlike a fish population, a stock is defined as much by management concerns (jurisdictional boundaries or harvesting locations) as by biology.
Fishery Dependent – Data derived from the commercial and recreational fisheries and dealers; including catch, landings, and effort information.
Fishery Independent – Data derived from activities such as research and surveys that does not involve the commercial or recreational harvest of fish.
Terminal Year – The final year of estimates being used in an analysis.
Overfishing – Occurs when the rate that fish that are harvested or killed exceeds a specific threshold.
Spawning Stock Biomass – Total weight of mature females in the stock.
Recruitment – The number of fish that survive to the juvenile stage.
Fishing Mortality – Rate at which fish are removed from the population.

June 2019 Council Meeting Summary

June 4-6, 2019
New York, NY

The following summary highlights actions taken and issues considered at the Mid-Atlantic Fishery Management Council's June 2019 meeting in New York, NY. Presentations, briefing materials, and webinar recordings are available at: http://www.mafmc.org/briefing/june-2019.

Atlantic Surfclam and Ocean Quahog

2020 Specifications Review

The surfclam and ocean quahog (SCOQ) fisheries are approaching the third year of multi-year specifications previously set for the 2018-2020 fishing years. The Council reviewed updated catch and landings information for both stocks, as well as recommendations from staff, the surfclam and ocean quahog AP, and the SSC, and determined that no changes to 2020 measures are warranted. To maintain the current measures, the Council also voted to recommend suspending the minimum shell length for surfclams in 2020. These specifications are described in detail in the final rule published February 6, 2018:
https://www.federalregister.gov/documents/2018/02/06/2018-02321/fisheries-of-the-northeasternunited-states-atlantic-surfclam-and-ocean-quahog-fishery-2018-2020

Catch Share Program Review

Council staff presented a summary of public comments received on the Review of the SCOQ Individual Transferable Quota (ITQ) Program. This report was structured around NMFS Procedural Instruction 01-121-01, Guidance for Conducting Review of Catch Share Programs, and constitutes the first program review for the first Limited Access Privilege Program developed in the country. After reviewing public comments, the Council voted to submit the SCOQ ITQ Program Review package to NMFS. In addition, the Council tasked staff to work with NOAA Fisheries to further develop potential actions identified as part of the review for consideration in the Council's 2020 implementation plan. The full report is available at http://www.mafmc.org/s/SCOQ-ITQ-Program-Review-Final-20190517.pdf.

Excessive Shares Amendment

The Council reviewed the Draft Public Hearing Document for the Surfclam and Ocean Quahog Excessive Shares Amendment and considered recommendations from the SCOQ Committee. Although there was some discussion of removing Alternatives 5 and 6 from the document, the Council ultimately voted to approve the public hearing document for public hearings without modification. The Council is planning to hold four public hearings for this action during a 45-day comment period beginning August 1, 2019. Public hearing dates and locations will be posted on the Council's Website. Additional information about this action can be found at http://www.mafmc.org/actions/scoq-excessive-shares-amendment.

Atlantic Surfclam Research for Great South Channel Habitat Management Area

Ms. Michelle Bachman (New England Council staff) provided an update to the Mid-Atlantic Council about recent activities by the New England Council to develop research objectives for the Great South Channel Habitat Management Area.

SSC Overfishing Limit (OFL) Coefficient of Variation (CV) Guidelines

Dr. Tom Miller (SSC Vice-Chairman) presented an overview of the guidelines and process the SSC will use when assigning a coefficient of variation (CV) value to estimates of the overfishing limit (OFL) when the SSC makes acceptable biological catch (ABC) recommendations for Council-managed species. The development of this guidance document was part of the Council's ongoing review of its risk policy and ABC control rule and is intended to provide a clear, consistent, and transparent process in documenting SSC conclusions regarding the scientific uncertainty of the OFL estimate. The Council approved the guidance document for use, and the new process will be used by the SSC at their September 2019 meeting when they make ABC recommendations for black sea bass, scup, and bluefish.

Mackerel, Squid, and Butterfish

2020 Specifications

The Council reviewed Atlantic mackerel, squid, and butterfish (MSB) specifications for 2020, which were previously established as part of multi-year specifications. For squid and butterfish, the Council did not recommend any changes. For Atlantic mackerel, the Council recommended that the 2020 ABC be maintained at the 2019 level, which is a 10% reduction from the earlier multi-year recommendation for 2020. Forgoing a higher ABC in 2020 increases the likelihood of achieving the current rebuilding schedule for Atlantic mackerel (June 2023). An assessment update is expected in 2020 and will inform specifications in future years. The Council will revisit the river herring and shad (RH/S) cap for the 2020 mackerel fishery at the August 2019 meeting and requested that the MSB Monitoring Committee evaluate possible modifications to the 2020 RH/S cap. The Council decided to take no action on possible modifications to the 2019 RH/S cap, which has already closed the Atlantic mackerel fishery at a relatively small portion of its 2019 quota in order to limit RH/S incidental catch.

Illex Working Group and Amendment Update

The Council received an update on a working group tasked with improving quota-setting methods for *Illex squid*. Also related to *Illex*, the Council reviewed scoping comments on an Amendment that will consider modifying the *Illex* squid permitting system as well as the MSB plan's goals and objectives. No specific actions were needed for these agenda items, and development of both efforts will continue throughout 2019.

MAFMC 2020-2024 Strategic Plan

As part of the process for developing its next strategic plan for the years 2020-2024, the Council has been gathering stakeholder input through an online survey, Advisory Panel and SSC meetings, public feedback sessions, and discussions with managements partners. Stakeholders have been asked to comment on how the Council has performed under its current strategic plan and what issues should be addressed in the next plan. During the meeting, the Council reviewed a summary of themes and recommendations that emerged from this process. These results are described in detail in the "Stakeholder Input Report" available at www.mafmc.org/strategic-plan. In the coming months, Council staff will develop a strategic plan framework for Council consideration at the August 2019 meeting.

NMFS Northeast Regional Strategic Plan

Dr. Jon Hare (NEFSC Science and Research Director) presented a draft Greater Atlantic Region Geographic Strategic Plan, which is being developed jointly by the Greater Atlantic Regional Fisheries Office and the Northeast Fisheries Science Center. This plan was developed as part of a national effort to move toward joint regional plans, as opposed to individual plans for regional offices and science centers. All of the regional plans will share the same strategic goals as the NOAA Fisheries National Plan. The Council reviewed the region-specific issues, challenges, and risks identified in the draft plan and agreed to follow up with a formal comment letter.

Unmanaged Species Landings Update

The Council reviewed a report on commercial landings of species that are not managed in the northeast region by the Mid-Atlantic, New England, or South Atlantic Fishery Management Councils, or by the Atlantic States Marine Fisheries Commission. The report also included landings of species managed as ecosystem components through the Council's Unmanaged Forage Omnibus Amendment. The report did not show any notable increases in landings of species caught predominantly in federal waters. The Council will receive annual updates on this report.

NEFSC Fishery Monitoring and Research Division

Several staff members from the Northeast Fisheries Science Center presented an overview of the recently created Fishery Monitoring and Research Division (FMRD). The Division focuses on the collection and use of information from commercial and recreational fisheries to inform fisheries science and management. In addition, Division programs foster engagement between the NEFSC and industry in the development of technology and data products to improve fisheries reporting and availability of data to fishermen, scientists, and managers. The Division includes the Research Set Aside Program, Dockside Monitoring Pilot Program, and Cooperative Research and Fisheries Sampling Branches.

Atlantic Large Whale Take Reduction Team Report

The Council received an update on the outcomes of the April 23-26, 2019 Atlantic Large Whale Take Reduction Team (ALWTRT) meeting in Providence, RI. The goal of the meeting was for team members to identify and recommend modifications to the Take Reduction Plan to further reduce impacts of U.S. fixed gear fisheries on large whales and reduce mortality and serious injury to right whales. The meeting resulted in a package of recommended measures that would achieve at least a 60 percent serious injury and mortality reduction goal in each of the New England lobster management areas. Scoping by states and NMFS will occur over the summer, and a DEIS and proposed rule is anticipated late in the calendar year.

Ricks E Savage Award

Former Council staff member Rich Seagraves was named this year's recipient of the Ricks E Savage award. The award is given each year to a person who has added value to the MAFMC process and management goals through significant scientific, legislative, enforcement, or management activities. Mr. Seagraves retired in 2018 following 26 years of employment with the Council. In his role as Senior Scientist, he served as the liaison with the Scientific and Statistical Committee and oversaw Council activities related to a range of issues, including research planning and prioritization, protected resources, climate change, and collaborative research. Mr. Seagraves was the staff lead on development of the Council's Ecosystem Approach to Fisheries Management Guidance Document

Next Council Meeting

Tuesday, August 13, 2019 – Thursday, August 15, 2019
Courtyard Philadelphia Downtown
21 N. Juniper St., Philadelphia, PA 19107
215-496-3200

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Steve Poland, Executive Assistant for Councils

SUBJECT: South Atlantic Fisheries Management Council Update

Issue

This memo is to update the Marine Fisheries Commission on issues discussed and actions taken by the South Atlantic Fisheries Management Council and bring to their attention items of relevance to the state of North Carolina.

Findings

- Actions under the Snapper Grouper Fishery Management Plan include:
  - Abbreviated Framework Amendment 3 was initiated to establish a new Annual Catch Limit for Blueline Tilefish, increasing the allowable catch over current levels,
  - Continued work on Abbreviated Amendment 33 to modify Red Snapper seasons and provide the Council with additional flexibility in setting season dates, and
  - Selected preferred actions under Regulatory Amendment 29 to establish a requirement for use of descender devices in the fishery and other actions to reduce discard mortality.
- Actions under the Dolphin Wahoo Fishery Management Plan include:
  - Further work on Amendment 10 resulted in the removal of actions authorizing bag limit sales of dolphin, allow fileting at seas for vessels north of North Carolina, and allowance of buoy gear in the commercial fishery for dolphin, and
  - Initiated an amendment to protect bullet and frigate mackerel as forage species under the pan.
- An amendment to the Spiny Lobster Fishery Management Plan was initiated to increase the commercial trip limit for states North of Florida.
- The Council instructed staff to prepare a white paper on potential management options for commercial Northern Zone Spanish mackerel fishery and host port meetings with fisherman to collect additional input on possible actions.
- Further information about these findings and other issues that the Council discussed can be found in the Council meeting report in the briefing book, proceeding this memo.

Action Needed

For informational purposes only, no action is needed at this time.

Overview
The South Atlantic Fishery Management Council met on June 10 – 14, 2019 in Stuart, FL. Highlights of the discussions and management actions taken by the Council are detailed below.

Snapper Grouper actions
Previous actions to address the Blueline Tilefish fishery were delayed due to other Council priorities and delays associated with the incorporation of new recreational catch estimates into updated stock assessments. At the Spring 2019 meeting of the Science and Statistical Committee, the decision was made not to proceed with updating the stock assessment and that recommendations for the Annual Biological Catch from the Committee and a special Blueline Tilefish workgroup from the previous assessment could be used for management. Based on this input the Council initiated Abbreviated Framework Amendment 3 to update the Annual Catch Limit for Blueline Tilefish through the management jurisdiction of the Council. The new proposed Annual Catch Limit will increase from 174,798 pounds to 233,968 pounds.

Work continued on Regulatory Amendment 33 with more discussion on potential actions and alternatives which could provide the Council with more flexibility in setting Red Snapper season in the future. A key action is the removal of the three-day minimum fishing season. Currently under Amendment 43, the red snapper season can only be opened if NOAA Fisheries determines that the recreational sector has three or more fishing days based on the previous year's catch rate. Other actions include changing the start date from July 1st, revise the days of the week harvest is allowed to provide flexibility outside of Friday, Saturday, and Sunday, and modify the start of the commercial season to occur after the recreational season has ended. The council approved sending these actions and alternatives out for public scoping prior to the September Council meeting. Two public hearings will be held in North Carolina at the following date and locations:

- August 14th at 6pm in the Wilmington Regional Office
- August 15 at 6 pm in the Central District Office

The Council continued discussions on Regulatory Amendment 29, Best Fishing Practices and selected preferred alternatives for final action at the September Council meeting. After receiving input from the Snapper Grouper Advisory Panel and Law Enforcement Advisory Panel, the Council modified the actions and alternative as needed. This included removal of the six-month delay in possession and compliance requirements for descending devices, modified the definition of a descending device to improve clarity and intent and hopefully encourage proper use, adjusted the preferred alternatives for circle hook requirements to only require possession and use North of 28 degrees latitude, and remove the prohibition on powerheads off of South Carolina.

Dolphin Wahoo actions
Dolphin Wahoo Amendment 10 is the first comprehensive plan amendment since the original adoption in 2004 which necessitates a review of the goals and objectives from the original plan. The Council chose to change the overall format of this section to a table format, similar to the Snapper Grouper Plan, to ease interpretation by stake holders. Discussions about and modifications to the goals of the plan include a re-affirmation that the Plan is intended to be precautionary and take a risk adverse approach to management of the dolphin and wahoo

resources of the Atlantic and to discourage development of new fisheries, evaluate if maintaining status quo in relation to landings has been successful, emphasize the social and economic importance of both the recreational and commercial sectors, and the addition of language that is inclusive of ecosystem based management and preservation of access to the resources by both sectors. Objectives of the plan were modified to ensure that the new goals could be met.

Actions and alternatives were reviewed and additional modifications were made. Alternatives were added to actions adjusting the Annual Biological Catch and Annual Catch Limit definitions for dolphin to allow for more of a buffer to account for uncertainty in the stock status of the species. Buoy gear was proposed as a new allowable gear in the fishery and an associated incidental trip limit option was added for the commercial fishery for vessels that have this gear on board. After considerable discussion of the pros and cons of allowing bag limit sales of dolphin from dually permitted vessels, the council decided to remove this action from consideration. Vessel limits for both the recreational and commercial sectors of dolphin were discussed and actions were modified to include additional options for reducing these limits. Finally, a request from the Mid Atlantic Fishery Management Council to allow fileting at sea of dolphinfish was debated. The Council modified and accepted the request for vessels fishing North of North Carolina.

Lastly, the Council reviewed scoping comments received about potentially adding bullet and frigate as Ecosystem Component species to the Dolphin Wahoo plan, affording them protection as forage fish for dolphin and wahoo. The Council debated the merits of management of these prey species and decided to initiate an amendment that would designate bullet and frigate mackerel as forage for dolphinfish and wahoo and come back to the Council with potential management options to limit and constrain harvest of these species.

Miscellaneous actions

The Council directed staff to initiate and amendment to adjust the commercial trip limit for spiny lobster north of Florida. The original request came from fisherman in North and South Carolina who expressed frustration with the current low commercial trip limits in the waters off of their states and the fact that the fishery is not overfished. Additionally, stakeholders expressed a desire to capitalize on a lucrative market for the tails in the region.

A report from the April Coastal Migratory Pelagics Advisory Panel meeting was presented to the Council. The panel reviewed issues related to king and Spanish mackerel commercial fisheries in both the Northern and Southern zones and made recommendations to the Council for port meetings to be held in all of the South Atlantic states to gather input from mackerel fisherman on the future of management of the two species. Concerns raised from fisherman in the Spanish mackerel fishery are the early closures in 2017 and 2018 that impacted access during the height of the fishery. The Council instructed staff to gather information about the Spanish mackerel fishery in the Northern zone and prepare a white paper for Council review at an upcoming meeting.

Executive Director Gregg Waugh announced his retirement from the Council after 39 years of service. He will work through the end of 2019 to assist the next Director in the transition to their new role. The Council will interview applicants at their September meeting and make a final decision before the end of the meeting.

Upcoming Events

The Next meeting of the South Atlantic Fisheries Management Council will be September 16 – 20, 2019 in Charleston, FL.

SOUTH ATLANTIC FISHERY MANAGEMENT COUNCIL
4055 Faber Place Drive, Suite 201, North Charleston SC 29405
Call: (843) 571-4366 | Toll-Free: (866) SAFMC-10 | Fax: (843) 769-4520 | Connect: www.safmc.net

Jessica McCawley, Chair | Mel Bell, Vice Chair
Gregg T. Waugh, Executive Director

JUNE 10-14, 2019 COUNCIL MEETING REPORT
REVISION #2 6/26/19
STUART, FLORIDA

The following summary highlights the major issues discussed and actions taken at the South Atlantic Fishery Management Council's June 2019 meeting in Stuart, Florida. Briefing materials, presentations, and public comments are available on the Council's website at: http://safmc.net/safmc-meetings/council-meetings/

Final Committee Reports contain more details of what was accomplished for each committee and are located on the June 2019 briefing book page. In addition, the Summary of Motions on the Council's website includes all motions from the meeting. Read further details and see images and other links at the June 2019 Council Meeting Round-up Story Map: https://www.arcgis.com/apps/MapJournal/index.html?appid=f1f50b22ef0e4130b1fadf1c3c852be8

Issue:	Action Taken:	Schedule:
Mackerel Emergency Action	The Council approved requesting NMFS raise the commercial king mackerel trip limit south of the Flagler/Volusia County line, Florida from 50-fish to 75-fish for the 2019-2020 season via emergency rule. The value of unharvested quota over the last four fishing seasons averaged $3,885,647 per season.	The Council's letter requesting emergency action will be sent to NMFS during the week of June 17th with a request to implement this prior to Season 2 of the 2019-2020 season.
CMP Framework Amendment 8 – the Council approved various alternatives to permanently increase the trip limit in the southern zone.	Alternative trip limits for Season 2 include: 1. 75 fish 10/1-1/31 with increase to 100 fish in Feb if less than 70% of quota landed 2. 100 fish 10/1-1/31 with increase to 150 fish in Feb if less than 70% of quota landed 3. 150 fish 10/1-1/31 with increase to 175 fish in Feb if less than 70% of quota landed	Staff and the IPT will work on CMP Framework Amendment 8 and bring analyses back to the Council at the September Council meeting. The Council's intent is to have these permanent regulations in place prior to the start of the 2020/21 fishing year.

Issue:	Action Taken:	Schedule:
Atlantic Spanish Mackerel Commercial effort	The Council directed staff to prepare a white paper with a thorough analysis of effort in the commercial Spanish mackerel fishery and a discussion of possible avenues to control effort, including: a limited access commercial permit, a limited access gillnet endorsement in the southern zone, and collaboration with state agencies. The Council approved a control date of March 7, 2019 when they began considering effort controls for Atlantic Spanish mackerel.	The Committee & Council will review the white paper in September and determine how to move forward. Once published in the Federal Register, this control date will put everyone on notice that should the Council decide to move forward with an effort limitation program, anyone entering the fishery after this date would not be guaranteed participation in the program.
Visioning Process in the Mackerel Cobia fishery	Prepare for port meetings to get a complete picture of the commercial and recreational king and Spanish mackerel fisheries.	The Council will determine the timing of port meetings at the September meeting.
Issue:	**Action Taken:**	**Schedule:**
Snapper Grouper Abbreviated Framework Amendment 3 (South Atlantic Blueline Tilefish ACL)	The Council directed staff to begin development of framework Amendment 3 to establish a new South Atlantic blueline tilefish Annual Catch Limit (ACL).	The Council will review the document in September and provide guidance. Public comments will be taken at the December 2-6, 2019 meeting in Wilmington, NC. The Council will make any necessary revisions and consider approving for formal review at the December meeting.
Spawning Special Management Zone Story Map	The Council approved the story map for review and comment by the Information & Education, Law Enforcement, and Snapper Grouper Advisory Panels. This is intended as an outreach tool for the public to learn about the areas protected and the target species, the process to create and review the managed areas, the goals and objectives for the areas, and regulations in the areas.	The Advisory Panels will review at their next meetings. The Council will consider any revisions suggested by the advisory panels and will publicize this information.

Issue:	Action Taken:	Schedule:
Snapper Grouper Regulatory Amendment 33 (Red Snapper Season Modifications)	Options being considered: 1.Remove minimum #days (3) for a season – keep or remove. 2.Modify recreational season start date: a. No Action – weekends only (Fri, Sat, Sun) begins on 2nd Friday in July unless otherwise specified. b. May 1st , June 1st or September 1st. 3.Revise days of the week harvest allowed during recreational season a. No Action – Fri, Sat, Sun. b. On consecutive Mondays, Fridays, Saturdays, or Sundays. c. Every other weekend – specify days. d. Last weekend of month – specify days. e. Council specifies at March meeting. f. Allow harvest in May for a portion of the days and resume harvest in the fall is enough ACL remains. 4.Modify commercial season start date: a. No Action – 2nd Monday in July, unless otherwise specified. b. 2nd Monday in May, unless otherwise specified. c. 2nd Monday in June, unless otherwise specified. d. May 1st but no commercial harvest allowed during July and August.	The Council approved Regulatory Amendment 33 for public hearings to be conducted via webinars and listening stations during August. The Council will review public input, make any needed changes, and provide guidance to staff at the September 16-20, 2019 Council meeting in Charleston, SC. The Council's intent is to approve for formal review at the December 2-6, 2019 Council meeting in Wilmington, NC.
Red Grouper Regulatory Amendment 30	The Council reviewed the amendment & regulations, and approved them for formal review. Actions include: • Revise the rebuilding schedule to equal the maximum time allowed to rebuild (Tmax) which is 10 years ending in 2028 with 2019 = Year 1. • Jan thru April no recreational or commercial harvest/possession/sale/purchase of any shallow-water grouper (gag, black grouper, scamp, red grouper, yellowfin grouper, yellowmouth grouper, red hind, rock hind, grasby, or coney) and extend the closure off NC & SC for red grouper in May. • Establish a commercial red grouper trip limit = 200 pounds gutted weight.	The Council will send Regulatory Amendment 30 and regulations to NMFS for formal review and implementations by the end of June 2019.

Issue:	Action Taken:	Schedule:
Snapper Grouper Snapper Grouper Regulatory Amendment 29 (Best Fishing Practices & Powerheads)	The Council reviewed public comments, document and: 1. Removed the 6 month delay in effectiveness from the preferred alternative that would require that a descending device be on board all vessels (commercial, for-hire, & private) fishing for or possessing species in the snapper grouper fishery management unit. 2. Modified the definition of descending device: " For the purpose of this requirement, "descending device" means an instrument, SUFFICIENTLY WEIGHTED, that will release fish at a depth sufficient for the fish to be able to recover from the effects of barotrauma, A MINIMUM OF 33 feet (twice the atmospheric pressure at the surface) or greater AND ideally released at the same depth that it was caught. The device can be, but is not limited to, a weighted hook, lip clamp, or box that will hold the fish while it is lowered to depth. The device should be capable of releasing the fish automatically, releasing the fish by actions of the operator of the device, or by allowing the fish to escape on its own. Since minimizing surface time is critical to increasing survival, descending devices shall be rigged and ready for use while fishing is occurring. 3. Require the use of non-offset, non-stainless-steel circle hooks when using hook-and-line gear and natural baits in the EEZ north of 28 degrees north latitude (about 25 miles south of Cape Canaveral, FL). 4. Require use of non-stainless-steel hooks when fishing with hook-and-line gear and natural baits in the EEZ. 5. Allow powerheads in the EEZ off SC.	The Council will review the draft regulations and document at the September 16-20, 2019 meeting in Charleston, SC and consider approval for formal review.
Wreckfish ITQ Review	The Council received an update and will see a final document in September.	The Council will consider approving the final document at the September 16-20, 2019 meeting in Charleston, SC.

Issue:	Action Taken:	Schedule:
Snapper Grouper Options Paper for removing Almaco Jack from the Jacks Complex	The Council directed staff to begin work on a white paper to consider removing Almaco jacks from the Jacks Complex.	The Council will review the white paper at the December 2-6, 2019 meeting in Wilmington, NC.
Lionfish and traps	SERO notified the committee that the General Prohibitions in the Code of Federal Regulations that specify the authorized gear types by fishery need minor corrections for the South Atlantic Fishery Management Council section. In addition, SERO suggested that Council and SERO staff jointly develop an informational paper for the Council's review in September 2019 that considers the addition of authorized gear types for lionfish (non-FMP) to the regulations to authorize the retention of lionfish taken while legally fishing additional gear types. In addition, the informational paper would consider refining the fish trap definition to authorize the retention of lionfish incidentally taken in legally fished traps when that bycatch exceeds 25% of the trap's catch. The informational paper would outline any unintended consequences of taking these two actions.	The Council will review the white paper at the September 2019 meeting and provide guidance.
Issue:	**Action Taken:**	**Schedule:**
Spiny Lobster Spiny lobster commercial trip limit for vessels with snapper grouper unlimited permit (SG1) and a spiny lobster tailing permit.	The Council directed staff to work on a Regulatory Amendment to create a commercial trip limit for such vessels off NC, SC, and GA: 1.No Action. Commercial possession limit = 2/person. 2.Commercial possession limit of 20, 30 or 40 lobsters/vessel.	• Scoping if necessary in Summer 2019 • Select actions/alternatives to include in the amendment – December 2019

Issue:	Action Taken:	Schedule:
Allocation Trigger Policy	The Council reiterated its desire to apply both indicator-based and time-based criteria as triggers for re-examining allocations and modified them. The Council reviewed a spreadsheet with information regarding the first year a time-based allocation trigger would be reviewed. They reiterated their desire to have time-based criteria triggered every seven years should no other indicator-based criterion trigger a review. When a review is triggered, for any reason, the year of the next review will be set 7 years after the most recent review. For indicator based triggers the Council updated the wording of the triggers: **INDICATOR BASED TRIGGERS:** • Either sector exceeds its ACL or closes prior to the end of its fishing year 3 out of 5 consecutive years. • Either sector under-harvests its ACL or OY by at least 50% 3 out of 5 consecutive years. • After a stock assessment is approved by the SSC and presented to the Council. • After the Council reviews a species Fishery Performance Report.	The Council will send the final allocation trigger policy to NMFS by the end of June 2019. The Council directed staff to prepare an allocation trigger status report to be presented during the Executive Finance Committee for the December Council meeting each year beginning in 2020.
Issue:	**Action Taken:**	**Schedule:**
SSC Selection	The Council reappointed the 6 members who reapplied (Robert Ahrens, Luiz Barbieri, Jeff Buckel, Churchill Grimes, Genevieve Nesslage, and George Sedberry). There is one open seat and the expertise most needed at this time is general ecology, ecosystems, and habitat. The Council appointed Dr. Wilson Laney.	Letters will be sent out by the end of June.

<table>
<tr><th>Issue:</th><th>Action Taken:</th><th>Schedule:</th></tr>
<tr><td>Dolphin Wahoo
Goals & Objectives

Amendment 10</td><td>The Council reviewed the goals and objectives and provided guidance to staff.

The Council reviewed Amendment 10 and provided guidance to staff:
• In Action 1 and 2, provide sub-alternatives that allow for a buffer between the ABC and the ACL.
• In Action 10, add language that would allow options to encompass buoy gear and all trap or pot gear. Also add language to implement incidental trip limits that would apply for dolphin when these gears are onboard. Look at a range of 250 to 1,000 lbs gutted weight by 250 lbs increments.
• Request further information from the Office of Protected Resources on timing of the new biological opinions for Dolphin Wahoo and Highly Migratory Species.
• Add recreational accountability measures.
• Do not allow bag limit sales of dolphin.
• Consider reducing the dolphin vessel limit.
• Allow filleting of dolphin at sea onboard for-hire vessels in the waters north of the Virginia/North Carolina border (skin on entire fillet, 2 fillets = 1 fish, and no frames need to be retained).

The Council reviewed scoping comments on mechanisms and regulatory parameters for adding ecosystem component (EC) species to a fishery management plan (FMP), ways that other Councils have addressed EC species in FMPs, as well as background information on fisheries for bullet mackerel, frigate mackerel, and other major prey species for dolphin and wahoo. The Council directed staff to initiate an amendment that would designate bullet and frigate mackerel as ecosystem component species within the Dolphin Wahoo FMP to acknowledge their role as forage for dolphin and wahoo (intent to include appropriate regulatory actions).</td><td>The Council will review the revised goals/objectives at the September 2019 meeting.

The Council will review a revised Amendment 10 document at the September 2019 meeting.

The Council will review an options paper on adding bullet and frigate mackerel as ecosystem component species (including appropriate regulatory actions) at the September 16-20, 2019 meeting in Charleston, SC.</td></tr>
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Issue:	Action Taken:	Schedule:
SEDAR	The Council made appointments to the SEDAR assessment of scamp and received an update of ongoing assessment projects. Results of the red snapper stock assessment should be available for Council consideration in 2022. The Council concurred that the terms of reference for the MRIP review prepared by the SSC address Council concerns and direction. The Council reviewed the research plan, suggested highlighting the need for acoustic tagging projects in closed areas, and approved the research plan.	Scamp appointments will be notified. The SEDAR Committee will review the black sea bass and red grouper assessment's scopes of work prior to sending to the SEFSC. The research plan will be sent to the SERO and SEFSC, and distributed. The final SSC MRIP workshop terms of reference will be distributed to the Council.
AP Selection	The Council removed the sector-specific seat designation on the Habitat and Ecosystem-Based Management AP and modified the structure of the AP to create an agency seat for the current at-large geologist/research seat. Given that management of Atlantic cobia was transferred to the Atlantic States Marine Fisheries Commission, the Council dissolved the Cobia Sub-Panel on the Mackerel Cobia AP.	These changes will be implemented immediately. The Council acknowledged the valuable contributions of the members of the Cobia Sub-Panel and directed staff to ensure their appreciation is reflected in follow-up communications. The Council will discuss forming a new AP to address species moving northwards at the next meeting.
MyFishCount	Chip Collier, Council staff, gave an update: • 977 users/member profiles (115 increase since last Council meeting). • 817 vessels (increase of 78) logged trips. • 2,709 fish reported. • App & web portal continue to be promoted; Spring 2019 webinar trainings were conducted around grouper opening/ webinar training will continue. • Cooperation with SC Wildlife Federation on a Best Fishing Practices tutorial. • Shiny app (data.safmc.net/MyFishCount) that allows anglers to access information collected through MyFishCount. • Survey to understand angler perceptions & opinions. • Data are being edited and uploaded to ACCSP; the API is now complete.	Bebe Harrison was hired and will work with private recreational fishermen to have them report, especially during the red snapper season openings. This experience will be used by the Council as they continue to work on the permitting and reporting amendment at the December 2-6, 2019 meeting in Wilmington, NC.

Issue:	Action Taken:	Schedule:
Citizen Science Program	John Carmichael, Council staff, gave an update: • Julia Byrd, Program Manager – transition going well. • SAFMC Team led a symposium at the Citizen Science 2019 Conference. • Scamp app to collect discard data for the next assessment – launching soon. • FISHstory, a pilot project to document the historical catch and length distribution for early headboat catches is ongoing. • Collaborator on TNC project in Gray's Reef National Marine Sanctuary. • Continuing Partnership Development.	Work will continue on the program and these two projects. The Scamp app is being rolled-out in June and the photo project is progressing; the first batch of scanned pictures have been received. Scamp results will be available for 2020 scamp assessment. The length data will be available for future assessments once the project is completed.
For-Hire Recreational Reporting	In March, the Council received an update on the amendment: The Amendment was approved on June 12, 2018 and the Final Rule was expected to publish in mid-April 2019 with a 60-day cooling off period.	At the June meeting, the Council was told the final rule is still being reviewed. No specific timing was available. The Council cancelled training workshops previously scheduled for June since the final rule was not available.
Full Council Actions: 1. NC Aquarium EFP request	The Council recommended approval of the request with a recommendation that they purchase, rather than harvest, live rock.	The Council will send letters related to each of these items before the end of June.
2. Highly Migratory Species (HMS)	In reference to Amendment 13 (Bluefin Tuna), the Council approved sending a comment letter to HMS that supports immediate discontinuation of the purse seine fishery with redistribution of that quota as appropriate. Also express continued support to extend the January sub-quota to the end of April.	
3. Council Letter on Bigeye & Yellowfin Tuna Management	The Council approved supporting the bigeye and yellowfin tuna management letter drafted on behalf of the 5 East Coast Councils.	
4. Biscayne National Park	The Council directed staff to send a letter to the Florida Fish & Wildlife Commission indicating that the Council does not want a role in directly managing the portion of the EEZ in the Park and requesting the Council be kept advised of ongoing activities.	
5. Blackfin Tuna in FL	The Council approved sending a letter to the Florida Fish & Wildlife Commission indicating the Council does not intend to regulate blackfin tuna.	
6. China Tariffs on Seafood	The Council directed staff to send a letter to the Secretary of Commerce about the impacts of tariffs on seafood (e.g., spiny lobster).	

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Randy Gregory, Division of Marine Fisheries, NCDEQ

SUBJECT: Highly Migratory Species Update

Issue
Highly Migratory Species activity update.

Action Needed
For informational purposes only, no action is needed at this time.

Overview
The Highly Migratory Species Advisory Panel met May 21-23, 2019 in Silver Spring, Maryland. The Advisory Panel discussed Amendment 7 bluefin tuna management three-year review, a proposed rule and Draft Environmental Impact Statement for pelagic longline bluefin tuna area-based weak hook management measures, and scoping for Amendment 13 (bluefin tuna). In July, NOAA Fisheries held scoping meetings in Morehead City and in Manteo for Amendment 13, Amendment 14 (shark quota management), and a proposed action for Spatial Management Research considering ways to perform research and collect data in closed fishing areas.

<u>Tuna</u>
In May, NOAA Fisheries announced its intent to prepare an environmental impact analysis for Amendment 13 to the 2006 Consolidated Highly Migratory Species Fishery Management Plan. This amendment considers refining the Individual Bluefin Tuna Quota Program for the pelagic longline fishery, reassessing allocation of bluefin tuna quotas (including the discontinuing or phasing out of the Purse Seine category), and other regulatory provisions regarding bluefin tuna directed fisheries and incidental pelagic longline fisheries. Potential changes to the Individual Bluefin Tuna Quota program are based on the recently released Draft Three-Year Review of the Individual Bluefin Tuna Quota Program. In July, NOAA Fisheries held scoping meetings in Morehead City and Manteo; however, both meetings were lightly attended by the public.

In July, NOAA Fisheries announced a proposed rule to adjust regulatory measures put in place to manage bluefin tuna bycatch in the pelagic longline fishery for Atlantic highly migratory species, specifically addressing the Northeastern United States Closed Area, the Cape Hatteras Gear Restricted Area, and the Spring Gulf of Mexico Gear Restricted Area as well as the weak hook requirement in the Gulf of Mexico. Amendment 7 implemented pelagic longline gear restrictions in areas identified as locations of high bluefin tuna concentrations and interactions with pelagic longline gear. The Cape Hatteras Gear Restricted Area was established in 2015 off the coast of Cape Hatteras, North Carolina, and is in place from December 1 through April 30 annually. While the area encompassed by the Cape Hatteras Gear Restricted Area had a high level of bluefin interactions, the majority of interactions were by only a few pelagic longline vessels. Due to this dynamic, NOAA Fisheries implemented performance measures to grant "qualified" fishery participants access to the Cape Hatteras Gear Restricted Area. Amendment 7 also shifted the focus of managing bluefin tuna bycatch in the pelagic longline fishery from fleet-wide management measures to individual vessel accountability through the implementation of a bluefin tuna catch share program (i.e., the Individual Bluefin Quota). A recent Draft Three-Year Review of the Individual Bluefin Quota Program drew preliminary conclusions that the program has successfully reduced bluefin tuna interactions and dead discards in the pelagic longline fishery. The proposed measure would eliminate the Cape Hatteras Gear Restricted Area due to the success of the Individual Bluefin Quota Program.

Sharks

In May, NOAA Fisheries announced the availability of the scoping document on Amendment 14 to the 2006 Consolidated Atlantic Highly Migratory Species Fishery Management Plan and its intent to prepare an environmental impact statement given revisions to the Magnuson-Stevens Fishery Conservation and Management Act National Standard 1 guidelines. NOAA Fisheries is exploring options related to the implementation of those new guidelines as they relate to annual catch limits for Atlantic sharks in the highly migratory species management unit. In the scoping document, NOAA Fisheries begins the process for re-examining how to establish these annual catch limits (determining of how to establish the acceptable biological catch), accounting for uncertainty arising from the stock assessment, and the impacts to management measures.

Red Drum Landings 2017-2019

Landings are complete through April 30, 2019.
2017 and 2018 landings are final. 2019 landings are preliminary.

Year	Month	Species	Pounds	2009-2011 Average	2013-2015 Average
2017	9	Red Drum	28,280	28,991	35,003
2017	10	Red Drum	58,824	43,644	63,662
2017	11	Red Drum	28,201	14,318	27,643
2017	12	Red Drum	4,714	3,428	2,197
2018	1	Red Drum	2,056	5,885	1,699
2018	2	Red Drum	2,176	3,448	3,996
2018	3	Red Drum	4,797	5,699	3,971
2018	4	Red Drum	17,096	7,848	6,528
2018	5	Red Drum	15,656	13,730	9,664
2018	6	Red Drum	11,678	12,681	6,985
2018	7	Red Drum	9,949	13,777	15,618
2018	8	Red Drum	14,995	21,252	15,846
Fishing Year (Sept 1, 2017 - Aug 31, 2018) Landings			**198,421**		

Year	Month	Species	Pounds	2009-2011 Average	2013-2015 Average
2018	9	Red Drum	11,149	28,991	35,003
2018	10	Red Drum	42,805	43,644	63,662
2018	11	Red Drum	10,076	14,318	27,643
2018	12	Red Drum	2,052	3,428	2,197
2019	1	Red Drum	2,101	5,885	1,699
2019	2	Red Drum	1,952	3,448	3,996
2019	3	Red Drum	1,563	5,699	3,971
2019	4	Red Drum	5,530	7,848	6,528
2019	5	Red Drum	9,171	13,730	9,664 *
2019	6	Red Drum	4,303	12,681	6,985 *

Fishing Year (Sept 1, 2018 - Aug 31, 2019) Landings **90,701**

*partial trip ticket landings only
***landings are confidential

Year	Month	Species	Pounds	Dealers	Trips	Average (2007-2009)	
2016	1	SOUTHERN FLOUNDER	2,625	33	264	7,713	
2016	2	SOUTHERN FLOUNDER	1,643	31	291	4,617	
2016	3	SOUTHERN FLOUNDER	9,260	58	915	23,512	
2016	4	SOUTHERN FLOUNDER	10,558	72	628	68,389	
2016	5	SOUTHERN FLOUNDER	24,522	90	821	122,514	
2016	6	SOUTHERN FLOUNDER	44,952	100	1,242	154,090	
2016	7	SOUTHERN FLOUNDER	43,574	102	1,132	170,387	
2016	8	SOUTHERN FLOUNDER	53,057	106	1,409	201,862	
2016	9	SOUTHERN FLOUNDER	246,269	131	3,011	396,301	
2016	10	SOUTHERN FLOUNDER	280,689	117	2,181	781,717	
2016	11	SOUTHERN FLOUNDER	182,768	102	1,479	392,150	
2016	12	SOUTHERN FLOUNDER	14	5	5	37,303	
2017	1	SOUTHERN FLOUNDER	1,677	38	122	7,713	
2017	2	SOUTHERN FLOUNDER	2,758	55	215	4,617	
2017	3	SOUTHERN FLOUNDER	8,254	67	874	23,512	
2017	4	SOUTHERN FLOUNDER	9,591	83	787	68,389	
2017	5	SOUTHERN FLOUNDER	33,105	105	1,121	122,514	
2017	6	SOUTHERN FLOUNDER	74,785	115	1,904	154,090	
2017	7	SOUTHERN FLOUNDER	74,879	108	1,755	170,387	
2017	8	SOUTHERN FLOUNDER	102,751	116	2,364	201,862	
2017	9	SOUTHERN FLOUNDER	235,915	128	2,849	396,301	
2017	10	SOUTHERN FLOUNDER	548,740	142	3,971	781,717	
2017	11	SOUTHERN FLOUNDER	302,286	123	2,003	392,150	
2017	12	SOUTHERN FLOUNDER	166	7	8	37,303	
2018	1	SOUTHERN FLOUNDER	610	14	43	7,713	
2018	2	SOUTHERN FLOUNDER	1,833	34	154	4,617	
2018	3	SOUTHERN FLOUNDER	2,815	43	387	23,512	
2018	4	SOUTHERN FLOUNDER	7,971	72	759	68,389	
2018	5	SOUTHERN FLOUNDER	18,271	89	947	122,514	
2018	6	SOUTHERN FLOUNDER	42,501	105	1,407	154,090	
2018	7	SOUTHERN FLOUNDER	57,273	117	1,495	170,387	
2018	8	SOUTHERN FLOUNDER	72,528	121	1,917	201,862	
2018	9	SOUTHERN FLOUNDER	109,125	114	1,776	396,301	
2018	10	SOUTHERN FLOUNDER	363,339	109	3,062	781,717	
2018	11	SOUTHERN FLOUNDER	226,832	89	1,352	392,150	
2018	12	SOUTHERN FLOUNDER	471	5	5	37,303	
2019	1	SOUTHERN FLOUNDER	524	25	74	7,713	
2019	2	SOUTHERN FLOUNDER	558	23	69	4,617	
2019	3	SOUTHERN FLOUNDER	1,414	45	217	23,512	
2019	4	SOUTHERN FLOUNDER	5,702	65	434	68,389	
2019	5	SOUTHERN FLOUNDER	29,108	57	819	122,514	*
2019	6	SOUTHERN FLOUNDER	43,017	48	1,021	154,090	*
2019	7	SOUTHERN FLOUNDER	283	3	15	170,387	*

*2019 data are preliminary. Data are complete through April 2019.

***data are confidential

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Lara Klibansky, Protected Resources Biologist Supervisor

SUBJECT: Protected Resources Program Update

Issue
Summary information is provided from the division's Protected Resources Program from January through May 2019.

Findings

- Atlantic Large Whale Take Reduction Team reaches near consensus for management recommendations to reach 60-80% reduction in North Atlantic Right Whale mortalities and serious injuries in U.S. fisheries.

Action Needed
For informational purposes only, no action is needed at this time.

Overview

Atlantic Large Whale Take Reduction Team (ALWTRT) Meeting

North Carolina is a member of the ALWTRT, an advisory team established by NOAA Fisheries and composed of fishermen, scientists, conservationists, as well as state and federal officials. The goal of the team is to assist with the development of plans to reduce the risk to marine mammals posed by fishing gear. Division staff attended the April ALWTRT meeting in Providence, RI. The objective of the meeting was to "develop consensus recommendations on a suite of measures that will achieve a 60 to 80% reduction in mortalities and serious injuries of right whales in U.S. fisheries to support NMFS rulemaking that will be initiated in May 2019". The meeting was a success with a near consensus, and only a single dissenter, reached among the fifty-six-member team supporting management strategies that are predicted to achieve the required take reduction. The primary strategies are significant vertical line reductions combined with various versions of weak vertical lines. The focus of these strategies was the lobster pot fishery in the Northeast, as a result the strategies were parsed out by lobster management areas (LMA). LMAs 3 and 5 are offshore of North Carolina and the rule resulting from these recommendations may impact the ocean pot fishery in these areas.

Observer Program

Tables summarizing observer coverage and protected species takes* from January through May 2019 are included. Tables 1–4 provide the estimated trips, observed trips, actual trips as recorded by trip ticket data, observer coverage, and protected species interactions for anchored large and small mesh gill nets by month and management unit. Please note that current observer coverage values are calculated using the average number of trips from previous years' finalized trip ticket data. A final observer coverage value will be calculated when trip ticket data are finalized. Table 5 contains the gill net regulation changes that occurred from January to June 2019.

There were four observed sea turtle takes in large mesh gill nets during the month of May. These takes consisted of two live Kemp's Ridley Sea Turtles, one live Green Sea Turtle and one dead Green Sea Turtle. June data are still being processed and are not reported here, but a number of observed sea turtle takes in Management Unit D2 resulted in its closure to large mesh gill nets for the remainder of the 2019 Incidental Take Permit year. No sea turtle takes were observed in the small mesh gill net fishery and there were no fishermen self-reported sea turtle takes during this time.

There was one observed live Atlantic Sturgeon take in large mesh gill nets and two takes, one live and one dead, in small mesh gill nets between January and May 2019. There were four Atlantic Sturgeon reported by Marine Patrol in illegally set or abandoned gill nets. These four sturgeon were reported and not observed, therefore they are noted but are not included as a part of our annual authorized takes. Marine Patrol also reported an Atlantic Sturgeon carcass which was found on a beach.

***Definitions**
Take, as defined in the Endangered Species Act, means to harass, harm, pursue, hunt, shoot, wound, kill, capture, or collect, or to attempt to engage in any such conduct.
Incidental take means to unintentionally, but not unexpectedly, take.

Table 1. Preliminary data collected for large mesh gill nets by month and management unit through the NCDMF Observer Program through May 2019.

		Trips		Observer Large Mesh				Observed Takes By Species								
								Kemp's		Green		Loggerhead		Unknown	A.Sturgeon	
Month	Unit	Estimated [1]	Actual [2]	AP Attempts [3]	Trips	Yards	Coverage [4]	Live	Dead	Live	Dead	Live	Dead	Live	Live	Dead
January	A	251	264	30	16	5,920	6.4	0	0	0	0	0	0	0	0	0
	B	25	3	14	0	0	0.0	0	0	0	0	0	0	0	0	0
	C	5	10	13	1	100	20.0	0	0	0	0	0	0	0	0	0
	D1	0	0	1	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	0	5	6	0	0	0.0	0	0	0	0	0	0	0	0	0
	E	6	6	46	3	600	50.0	0	0	0	0	0	0	0	0	0
February	A	362	198	45	19	11,108	5.2	0	0	0	0	0	0	0	0	0
	B	39	8	12	0	0	0.0	0	0	0	0	0	0	0	0	0
	C	63	11	18	8	5,230	12.7	0	0	0	0	0	0	0	0	0
	D1	0	0	6	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	2	2	5	0	0	0.0	0	0	0	0	0	0	0	0	0
	E	15	5	48	0	0	0.0	0	0	0	0	0	0	0	0	0
March	A	863	843	25	63	34,156	7.3	0	0	0	0	0	0	0	0	0
	B	44	19	13	0	0	0.0	0	0	0	0	0	0	0	0	0
	C	685	6	16	2	100	0.3	0	0	0	0	0	0	0	0	0
	D1	0	0	2	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	6	1	3	2	800	33.3	0	0	0	0	0	0	0	0	0
	E	44	16	44	1	500	2.3	0	0	0	0	0	0	0	0	0
April	A	714	667	22	22	10,900	3.1	0	0	0	0	0	0	0	0	0
	B	95	92	10	0	0	0.0	0	0	0	0	0	0	0	0	0
	C	165	4	11	9	3,750	5.4	0	0	0	0	0	0	0	0	0
	D1	1	0	10	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	21	4	13	4	1,600	19.2	0	0	0	0	0	0	0	0	0
	E	83	64	39	3	450	3.6	0	0	0	0	0	0	0	0	0
May	A	141	124	41	15	11,140	10.6	0	0	0	0	0	0	0	1	0
	B	126	247	21	29	19,750	23.0	0	0	0	0	0	0	0	0	0
	C	103	13	17	10	1,525	9.7	0	0	0	0	0	0	0	0	0
	D1	1	0	1	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	42	51	11	5	2,730	12.0	0	0	1	0	0	0	0	0	0
	E	126	73	63	26	9,000	20.7	2	0	0	1	0	0	0	0	0
Total		4,027	2,736	606	238	119,359	5.9	2	0	1	1	0	0	0	1	0

[1] Finalized trip ticket data averaged from 2014-2018

[2] Preliminary trip ticket data for 2019

[3] Alternative Platform trips where no fishing activity was found

[4] Based on estimated trips and observer large mesh trips

Table 2. Preliminary data collected for large mesh gill nets by month through the NCDMF Observer Program through May 2019.

	Trips		Observer Large Mesh				Observed Takes By Species								
							Kemp's		Green		Loggerhead		Unknown	A. Sturgeon [5]	
Month	Estimated [1]	Actual [2]	AP Attempts [3]	Trips	Yards	Coverage [4]	Live	Dead	Live	Dead	Live	Dead	Live	Live	Dead
January	287	288	110	20	6,620	7.0	0	0	0	0	0	0	0	0	0
February	481	224	134	27	16,338	5.6	0	0	0	0	0	0	0	0	0
March	1,642	885	103	68	35,556	4.1	0	0	0	0	0	0	0	0	0
April	1,079	831	105	38	16,700	3.5	0	0	0	0	0	0	0	0	0
May	538	508	154	85	44,145	15.8	2	0	1	1	0	0	0	1	0
Total	4,027	2,736	606	238	119,359	5.9	2	0	1	1	0	0	0	1	0

[1] Finalized trip ticket data averaged from 2014-2018

[2] Preliminary trip ticket data for 2019

[3] Alternative Platform trips where no fishing activity was found

[4] Based on estimated trips and observer large mesh trips

Table 3. Preliminary data collected for small mesh gill nets by month and management unit through the NCDMF Observer Program through May 2019.

		Trips		Observer Small Mesh			Observed Takes By Species								
							Kemp's		Green		Loggerhead		Unknown	A. Sturgeon	
Month	Unit	Estimated [1]	Actual [2]	Trips	Yards	Coverage [3]	Live	Dead	Live	Dead	Live	Dead	Live	Live	Dead
January	A	334	183	2	700	0.6	0	0	0	0	0	0	0	0	0
	B	144	181	0	0	0.0	0	0	0	0	0	0	0	0	0
	C	60	87	8	2,800	13.3	0	0	0	0	0	0	0	0	0
	D1	0	0	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	14	8	3	600	21.1	0	0	0	0	0	0	0	0	0
	E	20	28	3	900	15.0	0	0	0	0	0	0	0	0	0
February	A	405	173	6	1,860	1.5	0	0	0	0	0	0	0	0	0
	B	175	196	17	7,530	9.7	0	0	0	0	0	0	0	0	0
	C	102	77	18	7,400	17.6	0	0	0	0	0	0	0	0	1
	D1	1	0	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	8	5	3	500	37.5	0	0	0	0	0	0	0	0	0
	E	14	16	0	0	0.0	0	0	0	0	0	0	0	0	0
March	A	380	405	8	2,050	2.1	0	0	0	0	0	0	0	0	0
	B	288	302	21	10,045	7.3	0	0	0	0	0	0	0	0	0
	C	124	72	10	4,360	8.0	0	0	0	0	0	0	0	0	0
	D1	6	8	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	3	1	0	0	0.0	0	0	0	0	0	0	0	0	0
	E	19	16	2	400	10.5	0	0	0	0	0	0	0	0	0
April	A	270	316	5	1,600	1.9	0	0	0	0	0	0	0	0	0
	B	675	670	20	11,250	3.0	0	0	0	0	0	0	0	1	0
	C	53	12	3	1,300	5.7	0	0	0	0	0	0	0	0	0
	D1	25	26	3	1,300	12.2	0	0	0	0	0	0	0	0	0
	D2	14	0	0	0	0.0	0	0	0	0	0	0	0	0	0
	E	55	25	1	50	1.8	0	0	0	0	0	0	0	0	0
May	A	114	67	0	0	0.0	0	0	0	0	0	0	0	0	0
	B	343	365	2	300	0.6	0	0	0	0	0	0	0	0	0
	C	44	1	3	300	6.8	0	0	0	0	0	0	0	0	0
	D1	5	6	0	0	0.0	0	0	0	0	0	0	0	0	0
	D2	17	4	0	0	0.0	0	0	0	0	0	0	0	0	0
	E	72	11	2	230	2.8	0	0	0	0	0	0	0	0	0
Total		3,785	3,261	140	55,475	3.7	0	0	0	0	0	0	0	0	0

[1] Finalized trip ticket data averaged from 2014-2018

[2] Preliminary trip ticket data for 2019

[3] Based on estimated trips and observer small mesh trips

Table 4. Preliminary data collected for small mesh gill nets by month through the NCDMF Observer Program through May 2019.

	Trips		Observer Small Mesh			Observed Takes By Species								
						Kemp's		Green		Loggerhead		Unknown	A. Sturgeon	
Month	Estimated [1]	Actual [2]	Trips	Yards	Coverage [3]	Live	Dead	Live	Dead	Live	Dead	Live	Live	Dead
January	572	487	16	5,000	2.8	0	0	0	0	0	0	0	0	0
February	704	467	44	17,290	6.3	0	0	0	0	0	0	0	0	1
March	821	804	41	16,855	5.0	0	0	0	0	0	0	0	0	0
April	1,091	1,049	32	15,500	2.9	0	0	0	0	0	0	0	1	0
May	596	454	7	830	1.2	0	0	0	0	0	0	0	0	0
Total	2,098	1,758	101	39,145	4.8	0	0	0	0	0	0	0	1	1

[1] Finalized trip ticket data averaged from 2014-2018

[2] Preliminary trip ticket data for 2019

[3] Based on estimated trips and observer small mesh trips

Table 5. Gill net regulation changes that occurred from January through June 2019 in accordance with the Sea Turtle and Atlantic Sturgeon Incidental Take Permits.

Date	Description of Regulation Change (Proclamation referenced)
January 1	This proclamation supersedes proclamation M-14-2018 dated November 29, 2018. In Management Unit A, it is unlawful to use gill nets with a stretched mesh length other than 3 ¼ inches, or from 5 ½ inches through 6 ½ inches, EXCEPT IN THE AREAS DESCRIBED IN SECTION IV. It also maintains large mesh gill net closures and vertical height restrictions for all anchored gill net sets. This action is being taken to allow various directed gill net fisheries while minimizing interactions with endangered Atlantic sturgeon and to reduce river herring regulatory discards. (M-17-2018)
February 1	This proclamation supersedes proclamation M-17-2018 dated December 21, 2018. In a portion of Management Unit A, it makes it lawful to use runaround, strike, and drop gill nets with a stretched mesh length from 5 ½ inches through 6 ½ inches. It also maintains large mesh gill net closures and vertical height restrictions for all anchored gill net sets. This action is being taken to allow a directed fishery for invasive blue catfish and continue to allow other various directed gill net fisheries while minimizing interactions with endangered Atlantic sturgeon and to reduce river herring regulatory discards. (M-2-2019)
February 15	This proclamation supersedes proclamation M-10-2018 dated September 28, 2018. This proclamation implements gear exemptions for portions of the Internal Coastal Waters south of Management Unit A to allow fishermen to set gill nets for the shad fishery (See Section III.). It opens the remaining portions of Management Unit B to the use of gill nets with a stretched mesh length of 4 inches through 6 ½ inches (except as described in Section III.) in accordance with the Sea Turtle Incidental Take Permit. This proclamation also maintains openings for Management Units C, D2 and portions of Management Unit E (except those described in Section II.) to the use of gill nets with a stretched mesh length of 4 inches through 6 ½ inches. This action is being taken to allow directed gill net fisheries for shad while minimizing interactions with threatened and/or endangered species. (M-3-2019)
March 2	This proclamation supersedes Proclamation M-2-2019 dated January 30, 2019. It opens all of Management Unit A to the use of gill nets and allows gill net configurations for harvesting American shad by removing vertical height restrictions for up to 1,000 yards of gill net with stretched mesh lengths of 5 ¼ through 6 ½ inches. This proclamation also implements additional gill net restrictions for Management Unit A, Subunit A1-South of US-64-BYP/US-64, in accordance with the Sea Turtle and Atlantic Sturgeon ITPs. Proclamation FF-56-2018 makes it unlawful to possess American shad for commercial purposes prior to 12:01 A.M. Sunday, March 3, 2019 and after 12:01 A.M. Sunday, March 24, 2019. (M-4-2019)
March 11	This proclamation implements tie-down (vertical net height restrictions) and distance from shore restrictions for gill nets with a stretched mesh length five inches or greater in the western Pamlico Sound and rivers in accordance with Supplement A to Amendment 1 to the N.C. Estuarine Striped Bass Fishery Management Plan. (M-5-2019)

Table 5. Continued

March 18	During an emergency meeting on March 13, 2019, the N.C. Marine Fisheries Commission directed the N.C. Division of Marine Fisheries Director to issue this proclamation pursuant to N.C. General Statute 113-221.1 (d). The Director has no legal authority to modify or change a proclamation when the proclamation is specifically directed by the Commission under this statute. This proclamation supersedes proclamation M-5-2019, dated March 7, 2019. This proclamation prohibits the use of ALL gill nets upstream of the ferry lines from the Bayview Ferry to Aurora Ferry on the Pamlico River and the Minnesott Beach Ferry to Cherry Branch Ferry on the Neuse River. It maintains tie-down (vertical net height restrictions) and distance from shore restrictions for gill nets with a stretched mesh length 5 inches and greater in the western Pamlico Sound and rivers (excluding the areas described in Section I. B.) in accordance with Supplement A to Amendment 1 to the N.C. Estuarine Striped Bass Fishery Management Plan. (M-6-2019)
March 25	This proclamation supersedes proclamation M-4-2019 dated February 27, 2019. In Management Unit A it removes the use of gill nets configured for harvesting American shad by implementing vertical height restrictions for all stationary gill nets. This proclamation also closes portions of Management Unit A to large mesh stationary gill nets, allows the use of run-around, strike, and drop nets with a stretched mesh length of 5½ inches through 6½ inches in a portion of Management Unit A, and maintains additional gill net restrictions for Management Unit A, Subunit A1, South of US-64-BYP/US-64, in accordance with the Sea Turtle and Atlantic Sturgeon ITPs. (M-7-2019)
April 8	This proclamation supersedes proclamation M-7-2019 dated March 22, 2019. It opens additional portions of Management Unit A to the use of stationary large mesh gill nets with vertical height restrictions. It also maintains the allowance for the use of run-around, strike, and drop nets with a stretched mesh length of 5½ inches through 6½ inches in a portion of Management Unit A, Subunit A2, and maintains additional gill net restrictions for Management Unit A, Subunit A1, South of US-64-BYP/US-64, in accordance with the Sea Turtle and Atlantic Sturgeon ITPs. (M-9-2019)
May 1	This proclamation supersedes proclamation M-3-2019 dated February 12, 2019. This proclamation implements attendance requirements for gill nets with a stretched mesh length less than 4 inches in Management Subunit B.1. It also decreases mesh size allowance for exempted gears in Section III. It maintains openings of Management Units B, C, D2 and E to the use of gill nets with a stretched mesh length of 4 inches through 6 ½ inches. (M-10-2019)
May 1	This proclamation supersedes proclamation M-9-2019 dated April 5, 2019. It implements small mesh gill net attendance requirements in Management Unit A and implements additional gill net restrictions in accordance with the Sea Turtle and Atlantic Sturgeon ITPs. (M-11-2019)
June 13	This proclamation supersedes Proclamation M-10-2019 dated April 26, 2019. This proclamation closes Management Unit D2 to the use of gill nets with a stretched mesh length of 4 inches through 6 ½ inches (except as described in Section III.) in accordance with the Sea Turtle Incidental Take Permit. Take levels for endangered and/or threatened sea turtles for gill nets with a stretched mesh length of 4 inches through 6 ½ inches in Management Unit D2 have been reached and the fishery must be closed. This proclamation maintains attendance requirements for gill nets with a stretched mesh length less than 4 inches in Management Subunit B.1. (M-12-2019)

Issues/Reports

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Captain Garland Yopp, Marine Patrol, Eligibility Board Chair

SUBJECT: Standard Commercial Fishing License Eligibility Pool Determination

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Issue
Determine number of licenses available to the Standard Commercial Fishing License (SCFL) Eligibility Pool.

Action Needed
A vote by the commission is needed to set the number of available licenses in the Eligibility Pool.

Overview
An individual who does not hold a Standard Commercial Fishing License but wants to purchase a license through the Division of Marine Fisheries can apply to receive the license through the Eligibility Pool process. The application goes before a board which determines if the applicant is qualified based on criteria set out in rule. The number of licenses available in this pool is set annually by the commission.

Session Law 1998-225, Section 4.24(f) states that "the number of SCFLs in the pool of available SCFLs in license years beginning with the 2000-01 license year is the temporary cap less the number of SCFLs that were issued and renewed during the previous license year." The temporary cap was set at the number of valid Endorsements to Sell as of June 30, 1999 (8,396 licenses), plus an extra 500 licenses to be included in the Eligibility Pool (8,896 total licenses).

For the 2019-2020 license year, the number of licenses available through the Eligibility Board is 2,973. This number accounts for licenses issued in the 2018-2019 license year and the number of approvals from the Eligibility Board from 2018-2019 that still have the option to purchase a license before June 30, 2020. Individuals approved in the fall (September/October) must purchase their license by June 30 of the same license year, but those approved in the spring (March) have until June 30 of the following license year to purchase their license.

Session Law 1998-225, Section 4.24(f) also states "the Commission may increase or decrease the number of SCFLs that are issued from the pool of available SCFLs. The Commission may increase the number of SCFLs that are issued from the pool of available SCFLs up to the temporary cap. The Commission may decrease the number of SCFLs that are issued from the pool of available SCFLs but may not refuse to renew a SCFL that is issued during the previous license year and that has not been suspended or revoked. The Commission shall increase or decrease the number of SCFLs that are issued to reflect its determination as to the effort that the fishery can support, based on the best available scientific evidence."

From July 1, 2018 to June 30, 2019, the Eligibility Board received 36 applications and approved 28. This is a 62% decline from the 2017–2018 license year which saw a higher than average number of applications due to oyster regulations that had been implemented that year. So far, there are 4 pending applications for review at the fall Eligibility Board meeting.

Over the past three years, the commission has voted to make the number of available licenses in the Eligibility Pool different from the total number of licenses left in the cap. Below is a summary of the licenses made available to the pool by the commission over the last 10 years (Table 1).

Table 1. Number of licenses available and number of licenses approved by the commission in the SCFL Eligibility Pool, FY2010 – 2020.

License Year	Number of Licenses Available	Number of Licenses Approved by MFC
2009–2010	1,507	1,507
2010–2011	1,420	1,420
2011–2012	1,375	1,375
2012–2013	1,358	1,358
2013–2014	1,368	1,368
2014–2015	1,257	1,257
2015–2016	1,238	1,238
2016–2017*	2,417	100
2017–2018	2,592	1,500
2018–2019	2,723	500
2019–2020	2,973	

In summary, there are 2,973 licenses available to the Eligibility Pool for the 2019–2020 license year. The commission needs to determine the number of licenses it wants to place in the pool for the upcoming year.

Eligibility Pool
Commission Report for 2019–2020
August 21–23, 2019

How the Pool Number is Determined:

Session Law 1998-225, Section 4.24(f).

(f) Adjustment of Number of SCFLs. The number of SCFLs in the pool of available SCFLs in license years beginning with the 2000–01 license year is the temporary cap less the number of SCFLs that were issued and renewed during the previous license year. . .

Role of the Marine Fisheries Commission:

Session Law 1998-225, Section 4.24(f).

(f). . . The Commission may increase or decrease the number of SCFLs that are issued from the pool of available SCFLs. The Commission may increase the number of SCFLs that are issued from the pool of available SCFLs up to the temporary cap. The Commission may decrease the number of SCFLs that are issued from the pool of available SCFLs but may not refuse to renew a SCFL that is issued during the previous license year and that has not been suspended or revoked. The Commission shall increase or decrease the number of SCFLs that are issued to reflect its determination as to the effort that the fishery can support, based on the best available scientific evidence.

Temporary Cap:

The maximum number of SCFLs that can be issued is the number of valid Endorsements to Sell as of June 30, 1999 plus 500 for the first eligibility pool, for a total of 8,896.

Eligibility Board Pool Determination 2019–2020:

There are 2,973 SCFLs available through the Eligibility Board for the 2018–2019 license year.

Attachments:

2019–2020 Eligibility Pool Determination Calculations

FY2018 License Sales Report

Summary of Licenses Available and Temporary Cap as Approved by the Commission

Eligibility Board Meeting Summaries

Eligibility Board Open Files

Eligibility Pool Determination Calculations
For
2019–2020 License Year

Below is the current calculation used to determine the number of licenses available in the Eligibility Pool. Corrections were made to this calculation in August 2016 to prevent licenses already existing in the cap from being double counted and removed from the number of licenses remaining.

Licenses removed from the cap in this calculation include the number of SCFLs and RSCFLs issued and renewed in the 2018–2019 license year as well as any Eligibility Board approvals from the spring meeting. Those approved by the Eligibility Board in the spring have until the following license year to purchase their SCFL. These licenses are subtracted from the pool because they represent potential licenses available for purchase.

Current calculation:

Total Number of SCFLs Available in 2019–2020 License Year (Data run date: 7/12/2019)

1)	Total original SCFLs available (Cap)…………………………………………………………………..	**8,896**
2)	Less total number of SCFLs issued and renewed in 2018–2019...………………………………..	**– 5,916**
3)	Total number of SCFLs available in the pool for 2019–2020……………………………………......	**2,980**
4)	Less total number of 2018–2019 approvals through Eligibility Pool not yet issued[1] ………….....	**-7**
5)	**Total SCFLs available for the 2019–2020 license year**…………………………………………	**2,973**

[1] Individuals approved in the spring (March 2019) have until June 30 of the following license year (2020) to purchase their SCFL.

North Carolina Division of Marine Fisheries
Commercial Licenses Sold by License Type
FY2019 License Year

Data Run Date: 7/12/2019

Blanket For-Hire Captain's Coastal Recreational Fishing License:	**135**
Blanket For-Hire Vessel Coastal Recreational Fishing License:	**588**
Commercial Fishing Vessel Registration:	**6,635**
Fish Dealer License:	**683**
Land or Sell License:	**140**
License to Land Flounder from Atlantic Ocean:	**157**
NC Resident Shellfish License without SCFL:	**584**
Non-Blanket For-Hire Vessel License:	**121**
Ocean Pier License:	**19**
Recreational Fishing Tournament License:	**26**
Retired Standard Commercial Fishing License:	**1,371**
Standard Commercial Fishing License:	**4,545**
TOTAL LICENSES FOR ALL LICENSE TYPES:	**15,004**

4,545	**SCFL**
+ 1,371	**RSCFL**
5,916	**Total Number of SCFLs issued for FY2019**

Licenses Available from the Eligibility Pool
Annual Summary

License Year	Number of Licenses Available	Number of Licenses Approved by MFC
1999–2000	500	N/A
2000–2001	1,314	1,314
2001–2002	1,423	1,423
2002–2003	1,458	1,458
2003–2004	1,421	1,421
2004–2005	1,423	1,423
2005–2006	1,536	1,536
2006–2007	1,596	1,596
2007–2008	1,562	1,562
2008–2009	1,557	1,557
2009–2010	1,507	1,507
2010–2011	1,420	1,420
2011–2012	1,375	1,375
2012–2013	1,358	1,358
2013–2014	1,368	1,368
2014–2015	1,257	1,257
2015–2016	1,238	1,238
2016–2017*	2,417	100
2017–2018	2,592	1,500
2018–2019	2,723	500
2019–2020	2,973	

*Calculation to determine number of available licenses changed

Licenses Approved and Denied by the Eligibility Pool Board
Annual Summary

License Year	Approved	Denied
1999–2000	166	133
2000–2001	110	75
2001–2002	46	37
2002–2003	38	23
2003–2004	56	11
2004–2005	35	13
2005–2006	31	9
2006–2007	32	4
2007–2008	49	7
2008–2009	83	5
2009–2010	109	11
2010–2011	63	2
2011–2012	68	17
2012–2013	99	9
2013–2014	96	14
2014–2015	61	13
2015–2016	45	6
2016–2017	32	6
2017–2018	84	13
2018–2019	28	6
Totals	**1,331**	**414**

Eligibility Pool Board Meeting Summary

HEARING DATE	APPRVLS	DENIALS	TABLED **	TOTAL REVIEWED	INCOMP. ***	NON-RESIDENTS TABLED	NON-RESIDENTS APPRV'D	NON-RESIDENTS DENIED
5/5/1999	2	0	2	4		0	0	0
5/19/1999	5	0	1	6		0	1	0
6/17/1999	2	5	3	10		0	0	0
7/1/98–6/30/99	**9**	**5**	**6**	**20**		**0**	**1**	**0**
7/7/1999	12	10	0	22		0	3	0
7/8/1999	23	25	0	48		0	7	0
07/15/1999 MFC	N/A	N/A	N/A	N/A		N/A	N/A	N/A
8/11/1999	18	20	4	42		0	3	0
8/27/1999	17	33	0	50		0	0	1
09/09/1999 MFC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
9/29/1999	18	11	1	30		0	0	0
11/3/1999	13	12	4	29		1	2	0
11/08/1999 MFC	N/A	N/A	N/A	N/A		N/A	N/A	N/A
1/26/2000	9	5	5	19		1	1	0
02/18/2000 MFC	N/A	N/A	N/A	N/A		N/A	N/A	N/A
4/19/2000	19	6	8	33		2	1	0
5/18/2000	18	3	9	30		2	0	1
6/7/2000	10	3	2	15		1	0	0
7/1/99–6/30/00	**157**	**128**	**33**	**318**		**7**	**17**	**2**
7/12/2000	11	1	4	16		0	2	0
7/21/2000 MFC	N/A	N/A	N/A	N/A		N/A	N/A	N/A
9/20/2000	24	15	7	46		0	1	0
10/27/2000	16	8	3	27		0	1	0
12/1/2000	5	16	2	23		0	0	0
1/24/2001	10	14	3	27		0	0	2
3/9/2001	12	12	8	32		0	0	0
4/4/2001	32	9	1	42		0	0	1
7/1/00–6/30/01	**110**	**75**	**28**	**213**		**0**	**4**	**3**
7/26/2001	18	10	2	30		1	3	0
08/21/2002 MFC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11/14/2002	12	15	3	30		0	2	1
2/21/2002	16	12	2	30		0	1	0
7/1/01–6/30/02	**46**	**37**	**7**	**90**		**1**	**6**	**1**
9/11/2002	28	14	6	48		1	2	0
08/19/2003 MFC	N/A	N/A	N/A	N/A		N/A	N/A	N/A
3/5/2003	10	9	1	20		0	2	0
7/1/02–6/30/03	**38**	**23**	**7**	**68**		**1**	**4**	**0**
08/19/2003 MFC	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/9/2003	16	3	1	20		0	2	0
11/4/2003	17	2	0	19		0	3	0
3/19/2004	22	6	0	28		0	2	0
6/22/2004	1	0	0	1		0	0	0
7/1/03–6/30/04	**56**	**11**	**1**	**68**		**0**	**7**	**0**
11/1/2004	22	4	1	27		0	0	0
2/28/2005	11	2	0	13		0	0	1
4/18/2005	2	7	0	9		0	0	0
7/1/04–6/30/05	**35**	**13**	**1**	**49**		**0**	**0**	**1**
9/27/2005	17	7	1	25		0	1	0
3/15/2006	14	2	2	18		0	1	0
7/1/05–6/30/06	**31**	**9**	**3**	**43**		**0**	**2**	**0**

HEARING DATE	APPRVLS	DENIALS	TABLED	TOTAL	INCOMP.	NON-RESIDENTS		
			**	REVIEWED	***	TABLED	APPRV'D	DENIED
10/4/2006	16	3	2	21		**0**	1	**0**
3/14/2007	16	1	2	19		**0**	1	**0**
7/1/06–6/30/07	**32**	**4**	**4**	**40**		0	**2**	**0**
9/10/2007	26	2	4	32		0	**0**	**0**
3/19/2008	23	**5**	**3**	31		**0**	**0**	**0**
7/1/07–6/30/08	**49**	**7**	**7**	**63**		**0**	**0**	**0**
9/30/2008	39	0	3	42		0	4	0
3/24/2009	44	5	1	50		0	3	0
7/1/08–6/30/09	**83**	**5**	**4**	**92**		**0**	**7**	**0**
10/6/2009	52	6	1	59		0	2	1
3/10/2010	36	2	1	39		0	1	0
6/2/2010	21	3	0	24		0	0	0
7/1/09–6/30/10	**109**	**11**	**2**	**122**		**0**	**3**	**1**
9/21/2010	40	2	1	43		0	2	0
3/24/2011	23	0	0	23		0	4	0
7/1/10–6/30/11	**63**	**2**	**1**	**66**		**0**	**6**	**0**
10/4/2011	39	7	0	46		0	2	0
3/15/2012	28	10	0	38		0	2	0
1/13/2012	1	0	0	1		0	0	0
7/1/11–6/30/12	**68**	**17**	**0**	**85**		**0**	**4**	**0**
9/12/2012	53	7	3	63		0	1	1
3/19/2013	46	2	4	52		0	2	0
7/1/12–6/30/13	**99**	**9**	**7**	**115**		**0**	**3**	**1**
9/18/2013	56	7	0	63		0	2	0
3/19/2014	40	7	1	48		0	0	0
7/1/13–6/30/14	**96**	**14**	**1**	**111**		**0**	**2**	**0**
9/17/2014	32	9	0	41		0	1	0
3/18/2015	25	3	5	33		1	0	0
5/12/2015	4	1	0	5		0	1	0
7/1/14–6/30/15	**61**	**13**	**5**	**79**		**1**	**1**	**0**
10/21/2015	16	4	1	21		0	3	0
3/23/2016	29	2	2	33		0	0	0
7/1/15–6/30/16	**45**	**6**	**3**	**54**		**0**	**3**	**0**
9/28/2016	17	3	2	22		0	0	0
3/16/2017	15	3	0	18		0	0	0
7/1/16–6/30/17	**32**	**6**	**2**	**40**		**0**	**0**	**0**
9/28/2017	44	9	0	53		0	1	0
11/1/2017	11	3	0	14		0	1	0
3/28/2018	29	1	0	30		0	3	0
7/1/17–6/30/18	**84**	**13**	**0**	**97**		**0**	**5**	**0**
10/30/2018	15	5	0	22*		0	1	1
4/11/2019	13	1	0	14		0	1	0
7/1/18–6/30/19	**28**	**6**	**0**	**36**		**0**	**2**	**1**
TOTALS ALL	**1,331**	**414**	**122**	**1,869**		**10**	**79**	**10**

*Two applications were withdrawn.
**TABLED files are presented again at the next Board meeting for a final decision of approval or denial and are then accounted for in the Approved or Denied categories. TOTAL REVIEWED does not equal total approved or denied because some files are reviewed in multiple meetings (tabled, etc.).

Standard Commercial Fishing License Eligibility Pool Office
Summary of Open Files beginning July 1, 2019

File Description	Total Number of Files
To be researched/ready for the next board meeting	4
New/being processed	0
Pending responses to letters mailed requesting more information	0
Incomplete – no response to letters	0
Total Open/Pending Applications	**4**

ROY COOPER
Governor

MICHAEL S. REGAN
Secretary

STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Lee Paramore, Biological Review Team Chair

SUBJECT: 2018 Species Stock Overview Report

Issue

Memo is to inform the Marine Fisheries Commission of the 2018 Species Stock Overview Report.

Findings

- Refer to the Division of Marine Fisheries 2018 Species Stock Overview Report. The annual report serves as an overview summarizing available information by species to determine the overall condition of North Carolina's fishery resources.
- The report provides information for each species through 2018.
- This year, the division no longer provides the short one-page synopsis on each species, but alternatively provides the public with the more comprehensive and informative annual Fishery Management Plan Update for each species.
- To better inform the public on management responsibility, the report continues to partition each species into either the 14 species stocks solely managed by North Carolina or the 23 species or species complexes where management is deferred to other principal entities; including the Atlantic States Marine Fisheries Commission, the South Atlantic Fishery Management Council, and the Mid-Atlantic Fishery Management Council.
- For each species where a peer-reviewed stock assessment is available, assignment of stock status is made based on the overfishing and overfished/depleted state of each species. For species without overfished/overfishing determinations provide all pertinent information on trends and management of the species is provided.

Action Needed

For informational purposes only, no action is needed.

Overview

The annual Stock Overview Report was released to the public via the division website on July 22, 2019. This year's report links the public directly to the Fishery Management Plan Update for each species. The Fishery Management Plan Updates were chosen in lieu of the one-page summary provided in past years. This change provides the public with a more in-depth review of both the management and stock status of each species. This change also includes a more comprehensive look at trends in catch and biological data. The division continues to aid in public understanding of management of these species by partitioning the 14 species managed solely by North Carolina from the other 23 species or species complexes where management is deferred to the Atlantic States

Marine Fisheries Commission, the South Atlantic Fishery Management Council, and the Mid-Atlantic Fishery Management Council.

Highlights of this year's stock overview for managed species include:

- **Striped Mullet:** After near historic low commercial landings in 2016 triggered a review of this stock, striped mullet landings rebounded, and no management triggers were met in 2018. The most recent stock assessment, completed in 2018, indicates overfishing is not occurring on this stock.
- **Blue Crab:** The Division of Marine Fisheries continues the development of Amendment 3 to the Blue Crab Fishery Management Plan following results of the 2018 benchmark stock assessment which indicated the stock is overfished and overfishing is occurring. Amendment 3 is scheduled to be adopted in early 2020.
- **Kingfishes:** Results of the annual trend analysis for kingfishes indicates that one management trigger was met in 2018 and no management triggers were met in 2017. No action is required for this stock. In a scenario where two triggers are met for two consecutive years, the plan calls for further evaluation of stock trends and consideration of potential management action.
- **Striped Bass (Central Southern Management Area):** Research has shown that striped bass in the Central Southern Management Area are not a self-sustaining population and that fishermen are mainly catching hatchery-raised fish; however, in 2018, agency data suggested there have been two recent naturally-spawned year classes. To provide additional protection for these non-hatchery fish and to increase natural spawning stock biomass, the Division of Marine Fisheries and Wildlife Resources Commission implemented a year-round commercial and recreational season closure in coastal and joint waters of the Central Southern Management Area.
- **Spotted Seatrout:** A benchmark stock assessment for spotted seatrout is underway in 2019 coinciding with the scheduled fishery management plan review. The prior stock assessment from 2014, indicated the stock is not overfished and is not experiencing overfishing.
- **Southern Flounder:** The 2019 stock assessment of southern flounder in the south Atlantic indicated the stock is overfished and overfishing is occurring. Adoption of Amendment 2 to the Southern Flounder Fishery Management Plan is scheduled for August 2019. Development of Amendment 3 is scheduled to begin upon adoption of Amendment 2.

*Definitions

Stock – A group of fish of the same species in a given area. Unlike a fish population, a stock is defined as much by management concerns (jurisdictional boundaries or harvesting locations) as by biology.
Overfished/Depleted – A stock exploited to a level of abundance considered too low to ensure succsessful annual reproduction..
Overfishing – Harvesting from a stock at a rate greater than the stock's reproductive capacity to replace fish removed through harvest.
Fishing Mortality (*F*) – Rate at which individuals are removed from the population due to fishing.
Threshold – The maximum values of fishing mortality or minimum values of the biomass, which must not be exceeded. Otherwise, it is considered that it might endanger the capacity of self-renewal of the stock.
Target – The level of fishing mortality or of the biomass, which permit a long-term sustainable exploitation of the stock.

A POWERPOINT PRESENTATION WILL BE PROVIDED AT THE MEETING.

A POWERPOINT PRESENTATION WILL BE PROVIDED AT THE MEETING.

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

Aug. 7, 2019

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Catherine Blum, Fishery Management Plan and Rulemaking Coordinator
Fisheries Management Section

SUBJECT: Fishery Management Plan Update

Issue

This memo describes the materials about fishery management plans for the August 2019 commission meeting. There are three items in this section; the first two are for information and the third is scheduled for the commission to take action. Each item is summarized below.

Action Needed

At its August 2019 business meeting the commission is scheduled to vote on preliminary approval of the 2019 Fishery Management Plan Review Schedule.

Overview

Status of Ongoing Plans

The first item is a three-page summary of the status of the fishery management plans. This is a document staff presents to the commission annually at its August business meeting. The document provides background information on the authority and process for fishery management plans, as well as the status of each individual plan. Additionally, staff leads for plans currently under review or development will provide updates to the commission at the meeting.

Fishery Management Plan Review

The second item is a separate publication entitled "2018 Fishery Management Plan Review." It is a compilation of annual updates about state-managed, federally-managed, and Atlantic States Marine Fisheries Commission-managed species for which there are fishery management plans for North Carolina. The updates are based on data through the previous calendar year. Staff provides the document to the commission annually at its August business meeting. It is a useful resource document, especially as a means of providing fishery management plan schedule recommendations based on the latest data. The document also provides a comprehensive list of research recommendations for all fishery management plans. In this year's publication, data for all recreational fishing activity monitored through the Marine Recreational Information Program (MRIP) has been updated based on new MRIP methodology. Estimates across all years are now based on the MRIP new Fishing Effort Survey-calibrated estimates. For more information on MRIP methodology changes see https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

The Fishery Management Plan Review is an invaluable reference document for information about the latest status of fisheries occurring in North Carolina. The document is organized into two primary sections: state-managed species and interstate-managed species, including species managed by the Atlantic States Marine Fisheries Commission and federal fishery management councils. The latter section is further divided into species with and without North Carolina indices. If a species has a North Carolina index, it means that North Carolina data were used by the federal management councils or the Atlantic States Marine Fisheries Commission in their respective plans.

Each update in the Fishery Management Plan Review contains information about the:

- History of the plan;
- Management unit;
- Goal and objectives;
- Status of the stock;
- Status of the fishery, including current regulations and commercial and recreational landings;
- Monitoring program data, including dependent and independent monitoring;
- Management strategy;
- Management and research needs; and
- Recommendation on the timing for the next review of state plans.

Five-year Schedule

The final item in this section is the draft "N.C. Fishery Management Plan Review Schedule (July 2019-June 2024)" presented for the commission's consideration and preliminary approval. The schedule reflects the status of the individual plans in regards to the statutorily mandated plan reviews. Per North Carolina General Statute 113-182.1(d), each plan shall be reviewed at least once every five years. Upon the commission's approval, the schedule will be forwarded to the secretary of the Department of Environmental Quality for final approval, per G.S. 113-182.1(d).

Annual Fishery Management Plan Update
North Carolina Division of Marine Fisheries and Marine Fisheries Commission
Aug. 7, 2019

Authority and Process

The Fisheries Reform Act of 1997 and its subsequent amendments established the requirement to create fishery management plans for all of North Carolina's commercially and recreationally significant species or fisheries. The contents of the plans are specified, advisory committees are required, and reviews by the Department of Environmental Quality secretary, Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources, Joint Legislative Commission on Governmental Operations, and legislative Fiscal Research Division are mandated.

The original 1997 legislation mandated the Blue Crab Fishery Management Plan be completed first. The Marine Fisheries Commission used the Division of Marine Fisheries' (division) annual stock status review to prioritize the order of species that would be addressed in subsequent plans. All initial fishery management plans identified on the priority list have been developed. Fishery management plans normally take about two years to complete and are required to be reviewed at least once every five years. Annually, the division reviews all state fishery management plans, as well as all federally-managed and Atlantic States Marine Fisheries Commission-managed species for which there are fishery management plans for North Carolina. Upon review, amendment of a state plan is required when changes to management strategies are necessary. An information update for a plan, which includes changes in factual and background data only, is completed if there are no management changes. The division and the Marine Fisheries Commission adopted an annual rule making cycle in 2009 to increase efficiency in rule making processes and consolidate efforts in the development of fishery management plans and the associated implementing rules.

Status of State Fishery Management Plans

Four of 13 state plans are currently underway. These are reviews of the Blue Crab, Southern Flounder, Estuarine Striped Bass, and Spotted Seatrout fishery management plans. The review of the **Shrimp Fishery Management Plan** was scheduled to begin in 2018; however, the process was not able to start any sooner than mid-2019 due to the availability of staff. At its August 2019 business meeting, the Marine Fisheries Commission is scheduled to vote on a petition for rulemaking that would establish new shrimp trawl management areas, as well as gear and time restrictions. If approved, the review of the Shrimp Fishery Management Plan will be further delayed.

The review of the **Blue Crab Fishery Management Plan** is ongoing. A stock assessment was completed in 2018 and determined the North Carolina blue crab stock is overfished (stock size is too small) and overfishing (excessive fishing mortality) is occurring. Reductions in total removals of blue crab are required by state law to achieve a sustainable harvest, end overfishing within two years and recover the stock from an overfished condition within 10 years. An advisory committee was formed and assisted the division with development of Amendment 3 to the plan that contains management measures to meet these requirements. At its August 2019 business meeting, the Marine Fisheries Commission is scheduled to vote on approval of the draft plan to go out for review and comment by the public and standing and regional advisory committees. Final approval of the plan is tentatively scheduled for February 2020. Adaptive management measures adopted in 2016 will remain in place until the next amendment is adopted.

The most recent review of the **Southern Flounder Fishery Management Plan** began with a coast-wide (North Carolina to the east coast of Florida) stock assessment for Southern Flounder that determined the stock is overfished (stock size is too small) and overfishing (excessive fishing mortality) is occurring. Reductions in total removals of southern flounder are required by state law to achieve a sustainable harvest, end overfishing within two years and recover the stock from an overfished condition within 10 years. An advisory committee was formed and assisted the division with development of Amendment 2 to the plan that contains management measures to meet these requirements. At its August 2019 business meeting, the Marine Fisheries Commission is scheduled to vote on final approval of the amendment; management measures would be implemented by proclamation following the meeting. Implementation of the season closure management strategy recommended in Amendment 2 is deemed critical to successful rebuilding of the southern flounder stock, so management actions can be implemented during the 2019 calendar year and reducing harvest is not delayed while more comprehensive strategies are developed for Amendment 3. Development of Amendment 3 will begin upon adoption of Amendment 2 and is scheduled for completion in 2021.

The next review of the jointly-developed **Division of Marine Fisheries-Wildlife Resources Commission Estuarine Striped Bass Fishery Management Plan** was scheduled to begin in 2018; however, staff from both state agencies recommended initiating the review in 2017 to address problems with striped bass reproduction in the Central Southern Management Area. Additionally, North Carolina General Statute 113-182.1 provides a supplement mechanism to modify a plan between the five-year scheduled reviews when the Secretary of the Department of Environmental Quality determines it is in the interest of the long-term viability of the fishery. After receiving secretarial approval to proceed, Supplement A to the N.C. Estuarine Striped Bass Fishery Management Plan was adopted by the Marine Fisheries Commission at its February 2019 meeting. The approved supplement contained a no possession measure for striped bass for both commercial and recreational fisheries in coastal and joint waters of the Central Southern Management Area. The supplement was fully implemented by the Marine Fisheries Commission and Wildlife Resources Commission effective March 29, 2019. The Plan Development Team is continuing to work towards completion of the stock assessments to inform the review of the plan and development of Amendment 2.

The **Spotted Seatrout Fishery Management Plan** was adopted in February 2012 and contained management measures to end overfishing (excessive fishing mortality) within two years. A new stock assessment developed in 2014 indicated that the spotted seatrout stock in North Carolina and Virginia was not overfished (stock size is adequate) and that overfishing was not occurring in the terminal year (2012) of the assessment. Due to staff workload for the review of other plans occurring in 2017 and since the stock was at viable levels and removals were considered sustainable for the long-term benefit of the stock, the next review of the plan was moved to 2019. Recreational and commercial landings for 2017 were at average levels compared to the past 10 years and there was no indication that the stock was at risk. In 2018, recreational and commercial landings sharply declined, most likely due to the fishery closure that was implemented from January through mid-June because of cold stun events. A benchmark stock assessment for spotted seatrout is underway, coinciding with the scheduled fishery management plan review.

The **Striped Mullet Fishery Management Plan Amendment 1** was approved in November 2015 and the next review of the plan will begin in 2020. In July 2017, the annual fishery management plan update for striped mullet showed 2016 commercial landings fell below the minimum landings trigger established in Amendment 1. There was also low abundance in division sampling programs. In accordance with the plan, the division reviewed striped mullet data in more detail to determine what factors were responsible for this decline. The review of the data included updating the 2013 stock assessment model with data through 2017 for better assessment of trends in the striped mullet fishery and striped mullet stock abundance. Results of the stock assessment update indicate overfishing (excessive fishing mortality) is not occurring through 2017. Per the plan, management options were brought to advisory committees and their input was provided to the Marine Fisheries Commission at its August 2018 business meeting. The commission voted to continue the current management measures for striped mullet, as recommended by the division. The division continues to monitor the commercial landings trigger and trends in the striped mullet commercial fishery and fishery independent indices. Review of 2018 commercial landings indicated neither the maximum (2.76 million pounds) or minimum (1.13 million pounds) triggers had been exceeded.

The **Bay Scallop Fishery Management Plan Amendment 2** was approved in February 2015. Implementing rules became effective May 1, 2015. The next review will begin in 2020.

The Marine Fisheries Commission gave its final approval of the jointly-developed **Division of Marine Fisheries-Wildlife Resources Commission River Herring Fishery Management Plan Amendment 2** in February 2015 and the implementing rules became effective May 1, 2015 and June 13, 2016. On June 18, 2019, the National Oceanic and Atmospheric Administration Fisheries, after completion of a comprehensive status review, announced its determination not to list alewife or blueback herring under the Endangered Species Act of 1973 at this time. The review noted while river herring have declined from historical numbers and overutilization remains a risk while population numbers are low, fisheries management efforts at the federal and state levels have helped to reduce the risks from fishing mortality. The next review of the state plan will begin in 2020.

The **Fishery Management Plan for Interjurisdictional Fisheries Information Update** and the **Kingfishes Fishery Management Plan Information Update** were approved in November 2015. No change in management strategies was necessary, so the plans were updated with the most current factual and background data. The next review of these plans will begin in 2020.

The **Hard Clam Fishery Management Plan Amendment 2** and the **Oyster Fishery Management Plan Amendment 4** were approved in February 2017 and the implementing rules became effective May 1, 2017. The next reviews will begin in 2022.

At its August 2017 business meeting, the Marine Fisheries Commission approved the division recommendation for the annual fishery management plan update to satisfy the review of Amendment 1 to the North Carolina **Red Drum Fishery Management Plan**. The Atlantic States Marine Fisheries Commission benchmark stock assessment for red drum was approved for management use in February 2017 and showed that management targets set forth by Amendment 2 to the Atlantic States Marine Fisheries Commission Red Drum Fishery Management Plan continue to be met. Thus, the Atlantic States Marine Fisheries Commission opted to keep all management and compliance requirements under Amendment 2 in place with no further action taken. The management targets of the state fishery management plan are consistent with Amendment 2 to the Atlantic States Marine Fisheries Commission plan, which requires that states not adopt a less protective management program than currently in effect. Stock conditions will be monitored and reported through each annual fishery management plan update. The next review of the plan will begin in 2022.

DRAFT

N.C. FISHERY MANAGEMENT PLAN REVIEW SCHEDULE (July 2019 – June 2024) Revised August 2019					
SPECIES (Date of Last Action)	2019-2020	2020-2021	2021-2022	2022-2023	2023-2024
BLUE CRAB (11/13)					
SOUTHERN FLOUNDER (2/13)	Amendment 2	Amendment 3	Amendment 3		
ESTUARINE STRIPED BASS (5/13) *					
SPOTTED SEATROUT (2/12) **					
SHRIMP (2/15) ***					
BAY SCALLOP (2/15)					
RIVER HERRING (2/15)					
INTERJURISDICTIONAL (11/15)					
KINGFISHES (11/15)					
STRIPED MULLET (11/15)					
HARD CLAM (2/17)					
OYSTER (2/17)					
RED DRUM (8/17)					

* In preparation for the review of the Estuarine Striped Bass Fishery Management Plan, the stock assessment process that began in 2017 for the Central Southern Management Area stocks and the Roanoke River Management Area stock is continuing. Supplement A to the Estuarine Striped Bass Fishery Management Plan was developed and adopted during 2018-2019.

** A 2015 stock assessment indicated that the spotted seatrout stock in North Carolina and Virginia was not overfished and that overfishing was not occurring in the terminal year (2012) of the assessment. Due to staff workload for the review of other plans occurring in 2017 and since the stock was at viable levels and removals were considered sustainable for the long-term benefit of the stock, the next review of the plan was moved to 2019.

*** At its August 2019 business meeting, the Marine Fisheries Commission is scheduled to vote on a petition for rulemaking that would establish new shrimp trawl management areas, as well as gear and time restrictions. If approved, the review of the Shrimp Fishery Management Plan will be delayed.

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Michael S. Loeffler and Anne L. Markwith, Southern Flounder Fishery Management Plan Co-Leads

SUBJECT: Southern Flounder Fishery Management Plan Amendment 2

Issue

Draft Amendment 2 (June 7, 2019 version) to the Southern Flounder Fishery Management Plan (FMP) with the Marine Fisheries Commission (MFC) preferred management strategies was sent to the Secretary of the Department of Environmental Quality and legislative Committees as required by statute for review. No additional comments or recommendations were received after review by the Secretary of DEQ or legislative committees. Implementation of the season closure management strategy contained in Amendment 2 is deemed critical to successful rebuilding of the southern flounder stock. Management actions can be implemented during the 2019 calendar year and reduction in harvest is not delayed while more comprehensive strategies are developed for Amendment 3.

Findings

- The most recent coast-wide stock assessment determined the stock* is overfished* and overfishing* is occurring.
- Reductions in total coast-wide removals* are necessary to end overfishing within two years and recover the stock from an overfished state within a 10-year period.
- To reach the fishing mortality* (*F*) threshold* and end overfishing, a 31% reduction in total coast-wide removals is necessary, while a 51% reduction is necessary to reach the fishing mortality target*. Neither of these levels of reduction would rebuild the spawning stock biomass (SSB) by 2028.
- For the SSB to reach the threshold by 2028 and end the overfished status, a 52% reduction in total coast-wide removals will be required. To reach the SSB target by 2028, a 72% reduction in total coast-wide removals will be required.
- Static quota, dynamic quota, slot limits, changes in the size limit, and gear changes related to size limit changes are not considered feasible options to address sustainable harvest in draft Amendment 2 due to the accelerated timeline and the need to implement management measures before the fall 2019 fishing season.

Action Needed

At their August 2019 meeting, the MFC will vote on selection of final management strategies and final adoption of Amendment 2.

Overview

At the June 6, 2019 Marine Fisheries Commission special meeting, the commission passed a motion to accept the recommendations of the Division of Marine Fisheries and the Department of Environmental Quality, in their entirety, for its preferred management strategy for the draft Southern Flounder FMP Amendment 2. Draft Amendment 2 (June 7, 2019 version) to the Southern Flounder FMP with the MFC approved preferred management strategies follows:

Commercial Fishery

Establish seasonal closures by area for the commercial fishery to reduce F and increase SSB to rebuild between the threshold and the target in 2019 (Option C, 62% reduction) and establish seasonal closures by area for the commercial fishery to reduce F and allow the SSB to rebuild to the target in 2020 (Option D, 72% reduction).

Recreational Fishery

Establish seasonal closures by area for the recreational fishery to reduce F and increase SSB to rebuild between the threshold and the target in 2019 (Option C, 62% reduction) and establish seasonal closures by area for the recreational fishery to reduce F and allow the SSB to rebuild to the target in 2020 (Option D, 72% reduction).

Additional Management: Non - Quantifiable Harvest Restrictions

The NCDMF recommendation includes: Reducing commercial anchored large-mesh gill net soak times to single overnight soaks where nets may be set no sooner than one hour before sunset and must be retrieved no later than one hour after sunrise the next morning in the Neuse, Tar/Pamlico rivers and the Albemarle Sound areas that have previously been exempt; reducing the maximum yardage allowed in the commercial anchored large-mesh gill net fishery by 25% for each Management Unit by allowing a maximum of 1,500-yards in Management Units A, B, and C, and a maximum of 750-yards in Management Units D and E unless more restrictive yardage is specified through adaptive management through the sea turtle or sturgeon Incidental Take Permits (ITP); and prohibiting the use any method of retrieving live flounder from pound nets that cause injury to released fish (no picks, gigs, spears, etc.).

Management measures from Amendment 1 and Supplement A to Amendment 1 will be incorporated into Amendment 2 (see Section VIII, Recommendations in Draft Amendment 2). Additionally, the recreational bag limit of no more than four flounder is maintained in Amendment 2. This bag limit is required through the N.C. FMP for Interjurisdictional Fisheries to maintain compliance with the Atlantic States Marine Fisheries Commission Summer Flounder, Scup, and Black Sea Bass FMP Addendum XXVIII. The December commercial closure period from Amendment 1 would no longer be in effect, as it is encompassed by the seasonal closure periods implemented by the adoption of Amendment 2.

The adoption of Amendment 2 authorizes continued development of Amendment 3. Amendment 3 will be completed as quickly as possible with the ongoing contributions of the Southern Flounder FMP Advisory Committee members. This will best serve to assist the division in development of Amendment 3, by building on the knowledge, expertise, and cooperation already underway and continue the work uninterrupted from meetings that began in January 2018.

Statutory Requirements

North Carolina General Statute 113-182.1 mandates that fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving a sustainable harvest, and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute

113-129 as "the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished."

In accordance with North Carolina General Statute 143B-289.52(e1) a supermajority of the Commission shall be six members. A supermajority shall be necessary to override recommendations from the Division of Marine Fisheries regarding measures needed to end overfishing or to rebuild overfished stocks.

Timeline

Draft Amendment 2 was forwarded to the Secretary of DEQ on June 7, 2019 for a 30-day review and comment period. On June 17, 2019, the Secretary of DEQ reported draft Amendment 2 to the Joint Legislative Oversight Committee on Agricultural and Natural and Economic Resources, the Joint Legislative Commission on Governmental Operations, and the Fiscal Research Division of the Legislature. Both legislative committees had 30 days to provide the Secretary of DEQ with comments or recommendations on the plan.

Development of Amendment 3 will begin in September 2019 and monthly meetings are scheduled with the Southern Flounder FMP Advisory Committee through 2019. Static quota, dynamic quota, slot limits, changes in the size limit, and gear changes related to size limit changes are all options that will be considered for long-term management through Amendment 3. Draft Amendment 3 is scheduled to be presented to the MFC in August 2020 for approval to send out for public and committee review. Final adoption of draft Amendment 3 is scheduled for February 2021.

Multi State Southern Flounder Work Group

A Multi-State Southern Flounder Work Group has been created and their first meeting was held July 26, 2019 to continue discussion about a regional management approach for the southern flounder stock. A second meeting is scheduled for August 28, 2019 to discuss how North Carolina's management will move forward based on the MFC's actions from their August business meeting.

*Definitions

Sustainable Harvest – The amount of fish (in weight) that can be taken from a stock at a given fishing intensity and the stock biomass does not change year to year.
Spawning Stock Biomass – Total weight of mature females in the stock.
Stock – A group of fish of the same species in a given area. Unlike a fish population, a stock is defined as much by management concerns (jurisdictional boundaries or harvesting locations) as by biology.
Overfished – State of a fish stock that occurs when a stock size falls below a specific threshold.
Overfishing – Occurs when the rate that fish that are harvested or killed exceeds a specific threshold.
Total removals – In the commercial fishery, the sum of the landings and dead discards; in the recreational fishery, the sum of the observed harvest and dead discards.
Fishing Mortality (*F*) – Rate at which southern flounder are removed from the population due to fishing.
Threshold – The maximum values of fishing mortality or minimum values of the biomass, which must not be exceeded. Otherwise, it is considered that it might endanger the capacity of self-renewal of the stock.
Target – The level of fishing mortality or of the biomass, which permit a long-term sustainable exploitation of the stock, with the best possible catch.

A POWERPOINT PRESENTATION WILL BE PROVIDED AT THE MEETING.

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Jason E. Rock and Corrin L. Flora, Blue Crab Fishery Management Plan Co-Leads

SUBJECT: Draft N.C. Blue Crab Fishery Management Plan Amendment 3

Issue

The draft N.C. Blue Crab Fishery Management Plan (FMP) Amendment 3 containing the N.C. Division of Marine Fisheries' (NCDMF) and the Blue Crab FMP advisory committee's (AC) initial positions on the issues is ready to be presented to the N.C. Marine Fisheries Commission's (NCMFC) standing ACs for their comment and recommendations. The division and Blue Crab FMP AC have developed management measures for the commission's consideration to meet statutory requirements to achieve sustainable harvest* in the blue crab fishery, end overfishing* by 2022, rebuild the spawning stock biomass* (SSB) by 2030, and implement additional blue crab stock* and habitat protection measures.

Findings

- The most recent stock assessment determined the blue crab stock is overfished* and overfishing is occurring.
- Reductions in harvest are necessary to end overfishing within two years and recover the stock from an overfished status within a 10-year period.
- To reach the fishing mortality* (*F*) threshold* and end overfishing within two years, a 0.4% reduction in harvest is necessary, while a 5.9% reduction is necessary to reach the fishing mortality target*. A reduction to the *F* threshold will not recover the stock from an overfished status by 2030.
- For the SSB to reach the threshold by 2030 and end the overfished status with a 50% probability of success, a 2.2% reduction in harvest is required. To reach the SSB target by 2030, a 19.8% reduction in total removals is required.
- Issue papers were developed to achieve sustainable harvest as well as to explore management measures beyond those required for sustainable harvest to implement additional stock and habitat protection measures. Issue papers developed for Amendment 3 include:
    1. Achieving sustainable harvest in the North Carolina blue crab fishery
    2. Management measures beyond quantifiable harvest reductions
    3. Addressing water quality concerns impacting the North Carolina blue crab stock
    4. Expand crab spawning sanctuaries to improve spawning stock biomass
    5. Establish a framework to implement the use of terrapin excluder devices in crab pots
    6. Bottom disturbing gear in the blue crab fishery

Action Needed

At their August 2019 business meeting the commission is scheduled to review the draft of Amendment 3 and vote to send Amendment 3 out for public and standing AC review.

Overview

Blue crab is a commercially and recreationally important fishery currently managed under Amendment 2 and the May 2016 Revision to Amendment 2 of the N.C. Blue Crab FMP.

Stock Assessment

Blue crab is assessed as a single biological unit stock occurring within North Carolina waters. A stock assessment with a **terminal year*** of 2016 determined the North Carolina blue crab stock is overfished and overfishing is occurring (Figure 1).

- The stock assessment estimated biological reference points of 75% of F_{MSY*} (fishing mortality target) as 1.22 and F_{MSY} (fishing mortality threshold) as 1.46. Estimated F in the terminal year of 2016 is 1.48, which is higher than the threshold and indicates overfishing is occurring.
- The stock assessment estimated an SSB target of 73 million mature female blue crabs (approximately 24 million pounds) and a threshold of 64 million mature female blue crabs (approximately 21 million pounds). Estimated SSB in the terminal year of 2016 is 50 million mature female blue crabs (approximately 17 million pounds), which is lower than the threshold and indicates the stock is overfished.

Statutory Requirements

North Carolina General Statute 113-182.1 mandates fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving a sustainable harvest, and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute 113-129 as "the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished."

In accordance with North Carolina General Statute 143B-289.52(e1) a supermajority of the Commission shall be six members. A supermajority shall be necessary to override recommendations from the NCDMF regarding measures needed to end overfishing or to rebuild overfished stocks.

See Table 1 for the division and Blue Crab FMP AC recommendations for each issue paper.

Timeline

<u>September 2019</u>

Draft Amendment 3 will be presented to the Northern Regional, Southern Regional, Shellfish/Crustacean, and Habitat and Water Quality ACs in September 2019. A public comment period will be held during the meetings and the meetings will occur within the comment period for the public to submit comments in writing.

State of North Carolina | Division of Marine Fisheries
3441 Arendell Street | P.O. Box 769 | Morehead City, North Carolina 28557
252-726-7021

October 2019
The Blue Crab FMP AC will meet following the completion of the standing advisory committee meetings and public comment period for final approval of its recommendations based on input by the public and other committees.

November 2019
The division will detail AC and public input and the commission will vote to select its preferred management options and vote to send the draft Amendment 3 to the Department of Environmental Quality secretary, the Joint Legislative Oversight Committee on Agriculture and Natural and Economic Resources, and the Fiscal Research Division for review and comment.

February 2020
The commission will consider departmental and legislative input and vote on final approval of Amendment 3. If approved, management measures will be implemented via the proclamation authority of the division Director following the meeting.

*Definitions

Sustainable Harvest – The amount of blue crab (in numbers) that can be taken from the stock at a given fishing intensity and the stock biomass does not change year to year.
Overfishing – Occurs when the rate that blue crab that are harvested or killed exceeds a specific threshold.
Spawning Stock Biomass – Total number of mature female blue crabs in the stock.
Stock – A group of the same species in a given area. Unlike a population, a stock is defined as much by management concerns (jurisdictional boundaries or harvesting locations) as by biology.
Overfished – State of a stock that occurs when the stock size falls below a specific threshold.
Fishing Mortality (*F*) – Rate at which blue crab are removed from the population due to fishing.
Threshold – The maximum values of fishing mortality or minimum values of the biomass, which must not be exceeded. Otherwise, it is considered that it might endanger the capacity of self-renewal of the stock.
Target – The level of fishing mortality or biomass, which permit a long-term sustainable exploitation of the stock.
Terminal Year – The final year of estimates being used in an analysis.
Maximum Sustainable Yield (MSY) – The largest yield that can be taken from a stock and sustained over time.

State of North Carolina | Division of Marine Fisheries
3441 Arendell Street | P.O. Box 769 | Morehead City, North Carolina 28557
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Table 1. Summary of NCDMF and Blue Crab FMP AC initial management recommendations (as of July 2019). All recommendations below are still drafts and subject to change during the development of and public review of Amendment 3.

Issue Paper	NCDMF Recommendation	Blue Crab FMP AC Recommendation
1. Sustainable Harvest	Option 12.8: 1) 5-inch mature female minimum size limit, 2) prohibit immature female hard crab harvest, and 3) a March 1 through March 31 closure period. Recommended season closure for Option 12.8 will replace current pot closure period and will remain closed for the entire time period Maintain 5% cull tolerance established in 2016 Revision Adopt proposed adaptive management framework	Option 18.3: 1) North of the Highway 58 Bridge: January 1 through January 31 closed season, 6.75" mature female hard crab maximum size limit, and prohibit immature female hard crab harvest and 2) South of the Highway 58 Bridge: March 1 through March 15 closed season and prohibit immature female hard crab harvest Recommended season closure for Option 18.3 will replace current pot closure period and will remain closed for the entire time period Maintain 5% cull tolerance established in 2016 Revision Motion to recommend the proposed adaptive management framework failed in a 3-3 tie
2. Qualitative Management	Option 2a: increase number of cull rings in pots to 3 Option 3b: two cull rings placed within one full mesh of corner and the apron on opposite outside panels in the upper chamber Option 4c: remove cull ring exemptions for Newport River and eastern Pamlico Sound and prohibit designation of exempt areas in future Option 7c: prohibit harvest of sponge crabs year-round Option 8a: establish 3" minimum size limit for peeler and soft crabs	Leave in existing rules put in in 2016 and do not adopt anything else at this time, except with 2 options on cull rings: 1) 2 cull rings in proper corner placement or 2) keeping the 3 cull rings with 1 in proper placement
3. Water Quality	Support all management options presented Recommend Option 4 as the highest priority Division habitat staff shall regularly report back to the Shellfish/Crustacean AC with progress on each management option	Support all management options in this paper Support making the highest priority option four tasking the CHPP steering committee to what is suggested here and follow up with each of the other recommendations as that step is justified Have the habitat staff report back to the Shellfish/Crustacean AC with progress

Issue Paper	NCDMF Recommendation	Blue Crab FMP AC Recommendation
4. Spawning Sanctuaries	Expand boundaries as presented for Oregon, Hatteras, Ocracoke, and Barden inlets Move boundary for Drum Inlet crab spawning sanctuary as presented Concur with AC recommendations for Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Shallotte, Lockwood Folly, and Tubbs inlets Use PDT recommended boundary for Cape Fear River Inlet crab spawning sanctuary Concur with AC recommendation of a March 1 through October 31 closure for Beaufort Inlet through Tubbs Inlet sanctuaries with same restrictions as existing crab spawning sanctuaries Establish a crab spawning sanctuary to serve as a migration corridor on the east side of Croatan Sound, as presented, closed to blue crab harvest from May 16 through July 15 and with the same restrictions as existing sanctuaries	Keep Oregon, Hatteras, and Ocracoke the same and change Drum and Barden to proposed boundaries Add spawning sanctuaries from Beaufort through Tubbs inlets using AC recommended boundaries with a closure period of March 1 through October 31 with same restrictions as existing sanctuaries
5. Diamondback Terrapin Protections	Use the criteria as outlined in this paper for the establishment of Diamondback Terrapin Management Areas (DTMAs)	Use science on locally specific pot funnel design to reduce terrapins and identify individual creeks with terrapin population hot spots that would be closed to potting
6. Bottom Disturbing Gear	Option 1a: prohibit taking of crabs with crab dredges Option 1d: reduce the bycatch limit from oyster dredges to 10% of the total weight of the combined oyster and crab catch or 100 pounds, whichever is less Option 2a: prohibit use of crab trawls in areas where shrimp trawls are already prohibited in the Pamlico, Pungo, and Neuse rivers	Not adopt any of the recommended management options on crab dredge and leave crab trawl lines as is

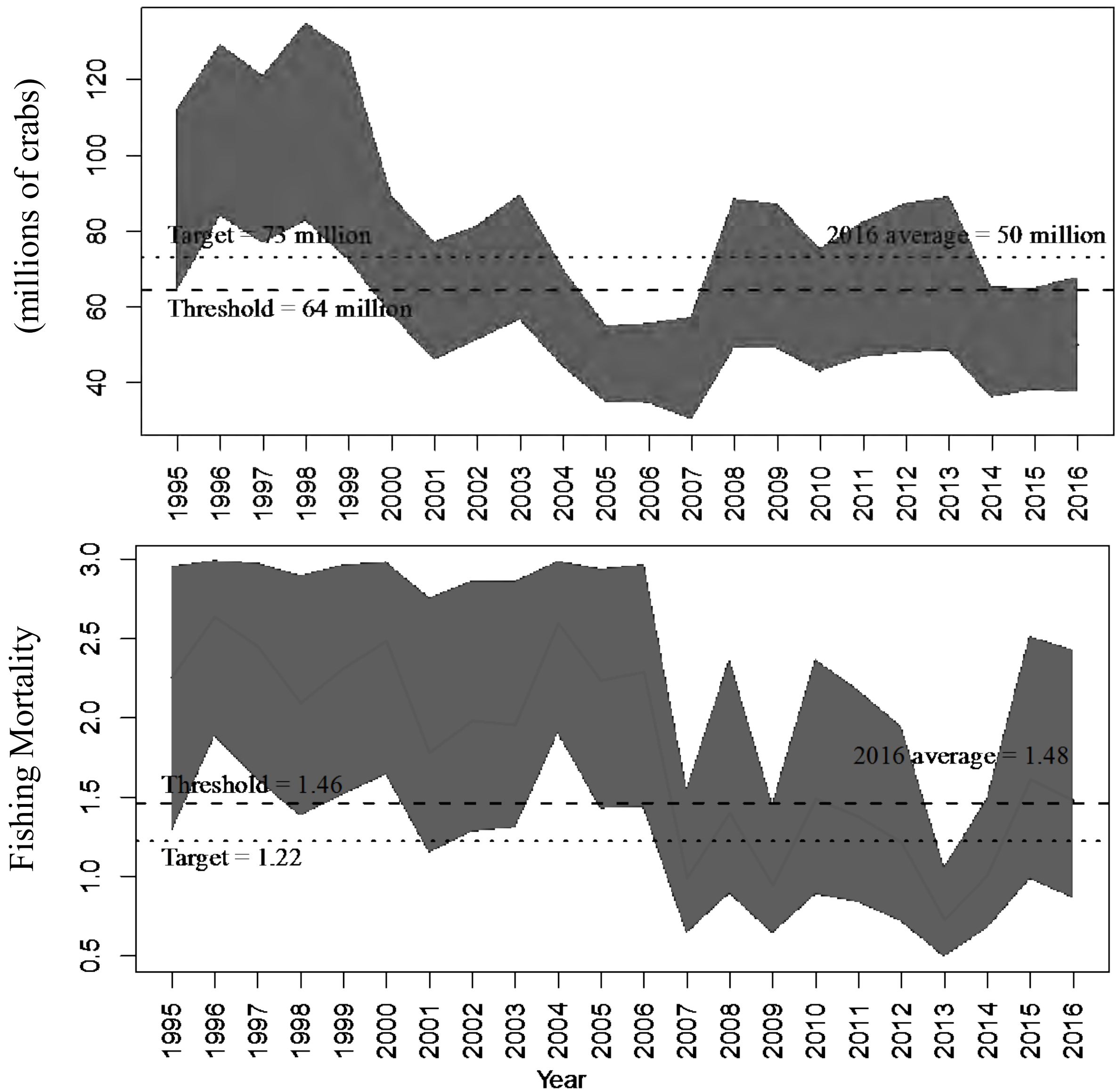

Figure 1. Estimated spawning stock biomass (millions of crabs) and fishing mortality (F) of the North Carolina blue crab stock. The shaded area represents the 95% credible interval. The threshold and target values are shown as dashed lines.

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LIST OF ACRONYMS

ASMFC – Atlantic State Marine Fisheries Commission
CFVR – Commercial Fishing Vessel Registration
CHPP – Coastal Habitat Protection Plan
CRC – Coastal Resources Commission
CRFL – Coastal Recreational Fishing License
CW – Carapace Width
DAPD – Department of Agriculture, Pesticide Division
DCM – Division of Coastal Management
DO – Dissolved oxygen
EDCs – Endocrine disrupting chemicals
EEZ – Exclusive Economic Zone
EFH-HAPC – Essential Fish Habitat – Habitat Areas of Particular Concern
EMC – Environmental Management Commission
ESA – Endangered Species Act
FMP – Fishery Management Plan
FRA – Fisheries Reform Act
HQW – High Quality Water
ITP – Incidental Take Permits
MMPA – Marine Mammal Protection Act
NCDEQ – North Carolina Department of Environmental Quality
NCDMF – North Carolina Division of Marine Fisheries
NCMFC –North Carolina Marine Fisheries Commission
NCWRC – North Carolina Wildlife Resources Commission
NOAA – National Oceanographic and Atmospheric Administration
NSW – Nutrient Sensitive Waters
ORW – Outstanding Resource Waters
RSCFL – Retired Standard Commercial Fishing License
RCGL – Recreational Commercial Gear License
SAFMC – South Atlantic Fishery Management Council
SAV – Submerged aquatic vegetation
SCFL – Standard Commercial Fishing License
SEAMAP – Southeast Area Monitoring and Assessment Program
SHAs – Strategic Habitat Area
USACE – United States Army Corps of Engineers
USEPA – United States Environmental Protection Agency
WS – Water Supply

EXECUTIVE SUMMARY

North Carolina's blue crab resource supports the state's largest and most valuable commercial fishery. Commercially, blue crab has been harvested since the 1800s and is one of the state's most important seafood industries. The blue crab fishery in North Carolina is the fourth largest in the United States. Will be completed prior to final adoption of the plan.

INTRODUCTION

This is Amendment 3 to the N.C. Blue Crab Fishery Management Plan (FMP). The last review of the plan concluded in November 2013 and resulted in Amendment 2 to the plan. There was a revision to Amendment 2 in May 2016 to implement management changes resulting from the adaptive management strategy in Amendment 2. That strategy relied on the Traffic Light Stock Assessment to provide information on the relative condition of the stock. In August 2016, the N.C. Marine Fisheries Commission (NCMFC) directed the next review of the plan to begin immediately instead of in 2018, despite the five-year span statutorily allowed. In Amendment 3, this management strategy is replaced by an adaptive management framework based on a comprehensive stock assessment for blue crab that is updated at least once in between scheduled plan reviews.

DEFINITION OF MANAGEMENT UNIT

The management unit includes the blue crab (*Callinectes sapidus*) and its fisheries in North Carolina coastal waters.

MANAGEMENT AUTHORITY

The Fisheries Reform Act of 1997 (FRA) and its subsequent amendments established the requirement to create FMPs for all of North Carolina's commercially and recreationally significant species or fisheries. The FRA "recognizes the need to protect our coastal fishery resources and to balance the commercial and recreational interests through better management of these resources" and requires the NCMFC "to provide fair regulation of commercial and recreational fishing groups in the interest of the public." Fishery management plans normally take about two years to complete and are required to be reviewed at least once every five years. Upon review, amendment of a plan is required when changes to management strategies are necessary. Through this process, the commission also has authority to implement federal fishery regulations (as minimum North Carolina standards) through the N.C. Fishery Management Plan for Interjurisdictional Fisheries, which selectively adopts management measures contained in approved federal Council or Atlantic States Marine Fisheries Commission (ASMFC) FMPs by reference. The goal of FMPs is to provide direction for the management of a fishery and to ensure long-term viability of North Carolina fisheries. It is a science-based management approach designed to include balanced stakeholder input from all sides, to look at the available data, to recognize the gaps, and to agree to the best possible path to manage the fisheries while acknowledging and minimizing impacts to various groups.

Under § 113-182.1, each FMP shall contain necessary information pertaining to the fishery or fisheries, as well as include conservation and management measures that will provide the greatest overall benefit to the State, particularly with respect to food production, recreational opportunities, the protection of marine ecosystems, and that will produce a sustainable harvest. For these purposes, data are gathered, analyzed, interpreted, and management measures implemented. The division is empowered to collect scientific and statistical information as may be needed to determine conservation (§ 113-131; § 143B-286). FMPs are the ultimate product that bring all the information and considerations into one document for a species.

North Carolina's coastal fishery resources (the "fish") exist within a system of interdependent habitats that provide the basis for long-term fish production available for use by people (the "fisheries"). The FRA law also recognized the importance of having sufficient quantity of quality habitat to support fish species throughout their life history. Because of this relationship between habitat and fish populations, the law contains the directive to protect and enhance habitats supporting coastal fisheries through the creation of Coastal Habitat Protection Plans (CHPP, G.S. 143B-279.8). While much of the concern over declining fish stocks has been directed at overfishing, habitat loss and degradation may make a stock more susceptible to decline. The effect of habitat loss and degradation can be indicated by the lack of recovery of certain stocks after fishing pressure is reduced. The CHPP law specifically requires identification of "existing and potential threats to the habitats" and "actions to protect and restore the habitats" (G.S. 143B-279.8). Under the law the NCMFC shall ensure, to the maximum extent practicable, their actions are consistent with the Coastal Habitat Protection Plan and shall adopt rules to implement Coastal Habitat Protection Plans in accordance with Chapter 150B of the General Statutes. Either the FMP or CHPP statutes may provide the management authority for requiring habitat measures, but generally the FMP authority has only been employed when there is a specific detrimental habitat threat from a fishery.

The N.C. General Assembly enacts fisheries statutes, or laws, and provides the NCMFC authority to adopt rules to implement those statutes. These rules are found in Chapters 03 and 18A of Title 15A of the N.C. Administrative Code. The N.C. Department of Environmental Quality (NCDEQ) is the parent agency of the commission and the N.C. Division of Marine Fisheries (NCDMF). The commission is responsible for managing, protecting, preserving and enhancing the marine and estuarine resources under its jurisdiction. In support of these responsibilities, the division conducts management, enforcement, research, monitoring, statistics and licensing programs to provide information on which to base decisions on rule making. The division presents information to the commission and department in the form of fishery management and coastal habitat protection plans and proposed rules. The division also administers and enforces the commission's adopted rules. Another tool the state uses to manage fisheries is the proclamation. The commission has the authority to delegate to the fisheries director the ability to issue public notices, called proclamations, suspending or implementing particular commission rules that may be affected by variable conditions. The proclamation authority granted to the fisheries director includes the ability to open and close seasons and fishing areas, set harvest and gear limits, and establish conditions governing various fishing activities. Proclamation authority and proclamation measures are codified in rules.

GOAL AND OBJECTIVES

Goal: Manage the blue crab fishery to achieve a self-sustaining population that provides sustainable harvest using science-based decision making processes. The following objectives will be used to achieve this goal.

Objectives:

1. Implement management strategies that maintain/restore the blue crab spawning stock with multiple cohorts and adequate abundance to prevent recruitment overfishing.
2. Restore, enhance, and protect habitat and environmental quality necessary to maintain or increase growth, survival, and reproduction of the blue crab population.

3. Use biological, environmental, habitat, fishery, social, and economic data needed to effectively monitor and manage the blue crab fishery and its ecosystem impacts.
4. Promote stewardship of the resource through increased public awareness regarding the status and management of the blue crab fishery, including practices that minimize bycatch and discard mortality.

FISHERY MANAGEMENT PROGRAM IMPLEMENTED UNDER AMENDMENT 2 (2013)

MANAGEMENT MEASURES IN PLACE UNDER AMENDMENT 2 (2013)

All management authority for the North Carolina blue crab fishery is vested in the State of North Carolina. The NCMFC adopts rules and policies and implements management measures for the blue crab fishery. See Appendix 4 for a list of statues, rules, and regulations under Amendment 2 to the N.C. Blue Crab FMP. This summary does not maintain exact language and should not be relied upon for legal purposes. See North Carolina General Statutes, North Carolina Administrative Code and Proclamations for exact language. There are no federal or interstate FMPs that apply specifically to the blue crab fishery in North Carolina.

Amendment 2 to the N.C. Blue Crab FMP was adopted in November 2013 (for a timeline of plans, amendments, and related documents see Appendix 2). This amendment replaced the spawner index trigger with an adaptive management framework based on an annual Traffic Light Stock Assessment update, provided management recommendations, explored issues affecting the fishery, and listed research recommendations to fill data needs. Rules established in Amendment 2 went into effect April 2014. Management changes included: opening the Pungo River to pots, closing Lower Broad Creek to pots, modifying crab dredging rules to conform with current harvest management, incorporating the Pamlico Sound four-inch crab trawl line into rule, redefining criteria exempting escape rings to unbaited pots and pots baited with a male crab, repealing proclamation authority allowing escape ring requirement, exemption to harvest peeler crabs, adopting no trawl line boundaries in the Pamlico Sound and Newport River for areas where escape ring closures are allowed, modification of trawl nets rule to identify Pamlico, Back, and Core sounds as areas that can open under proclamation for peeler crab trawling, modification to clearly state in rule the intent of the exceptions, culling tolerance, separation requirements for various crab categories, and established proclamation authority to require terrapin excluders (once a framework of criteria and excluder specifications were approved by the NCMFC).

In November 2016, adaptive management measures were implemented under the authority of Amendment 2. These included: reducing the cull tolerance from 10% to 5%, requiring an additional escape ring mounted in the upper chamber within one full mesh of the corner and divider of the pot, eliminating harvest of immature female hard crabs, prohibiting the harvest of dark sponge crabs (brown and black) from April 1 through April 30, and prohibiting harvest of crabs with dredges except incidental to lawful oyster dredging. All adaptive management measures became effective June 6, 2016 except for the additional cull ring which was delayed until January 15, 2017. This delay coincided with the annual pot closure period to allow fishermen time to modify pots.

COMPLIANCE AND ENFORCEMENT

There are two main sources of data necessary for fisheries management and evaluated for each FMP: fishery dependent and fishery independent data. Fishery dependent data are derived from the fishing process itself and are collected through such avenues as self-reporting, fish house surveys, onboard observers, telephone surveys or vessel-monitoring systems. Fishery dependent sampling allows managers to account for sources of removals and the size and age structure of those removals. Fishery-independent data comes from research and monitoring surveys conducted by the state agencies. Scientists take samples throughout the potential range of the target fish(s) based on statistically valid sample designs that are not influenced by changes in fishing activity. Fishery independent sampling allows managers to monitor trends in the relative abundance of a species. Fishery dependent and independent sampling complement one another to provide a more complete picture of the condition of a fish stock. Dependent sampling intended to monitor trends in relative abundance can be biased by changes in: gear specifications, fishing effort, areas fished, level of expertise of fishermen, technology, etc.

The division's License and Statistics Program is another source of fishery dependent information. The number of licenses issued to various types of fishermen such as the Standard Commercial Fishing License (SCFL), Retired Standard Commercial Fishing License (RSCFL), Commercial Fishing Vessel Registration (CFVR), Recreational Commercial Gear License (RCGL), and Coastal Recreational Fishing License (CRFL) may be used to determine the number of fishermen and vessels involved in various fisheries. These licenses are authorized in Chapter 113 of the North Carolina General Statutes.

The North Carolina Marine Patrol has officers working in three distinct law enforcement districts along the coast. In addition to checking commercial and recreational fishermen, officers patrol waterways, piers, and beaches in coastal areas. They also inspect seafood houses, vehicles transporting seafood, and restaurants across the state to ensure compliance with fisheries rules. In addition to the inspections listed above, the Marine Patrol have mandatory patrol responsibilities. The U.S. Food and Drug Administration requires North Carolina to patrol a certain number of hours in polluted waters each year. This is a primary function for the North Carolina Marine Patrol to ensure the health and welfare of consumers of North Carolina shellfish. The Marine Patrol also assists the observer program with gill net observations to ensure the division meets the required observer coverage as required by its federal Incidental Take Permits (ITPs). Failure to follow the requirements of the ITPs through lack of sufficient observer coverage could cause the estuarine gill net fishery to close completely.

DESCRIPTION OF THE STOCK

BIOLOGICAL PROFILE

Physical Description

Blue crabs are one of the most recognizable species of North Carolina. A swimming crustacean sought after for tender, sweet meat. Blue crabs have a carapace (shell) which has nine marginal teeth, the final one forming a distinct point. The carapace varies from blue to dark olive green.

Blue crabs have five pairs of legs: bright blue claws often having red tips, three pairs of walking legs, and specially adapted paddle-shaped rear swimming legs. Male and female blue crabs are easily identified by the shape of the apron on their abdomen (underside). A male crab is easily recognized by the T-shaped apron (Figure 1 A). The immature female apron is triangular-shaped and held tightly against the abdomen (Figure 1 B). The mature female's apron becomes rounded and can be easily pulled away from the body after the final molt (Figure 1 C). When mature females develop an egg mass (sponge) it is visible beneath the apron ranging from bright orange to black (Figure 1 D).

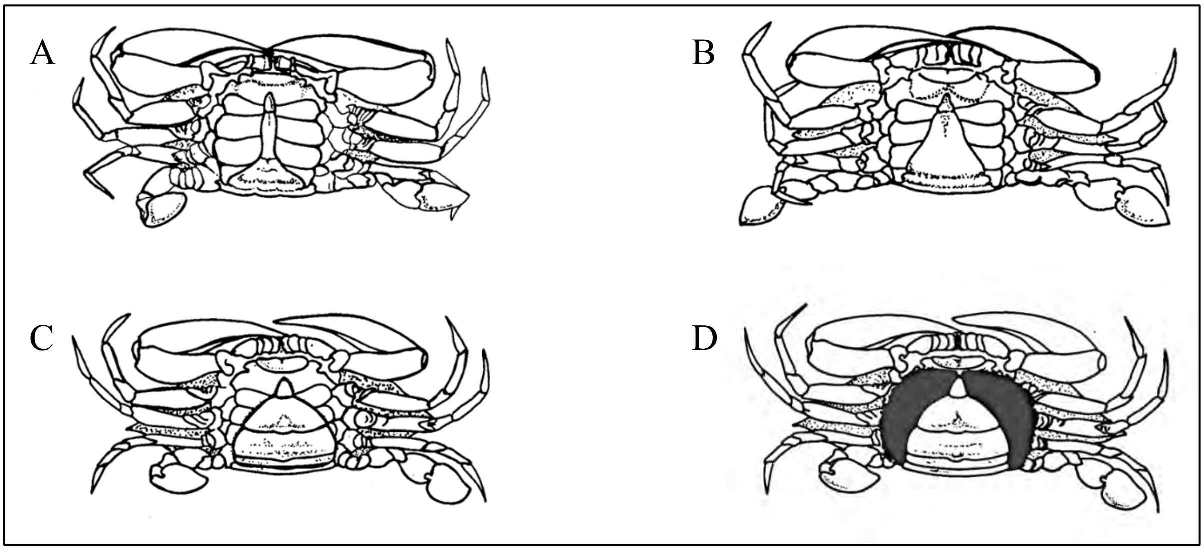

Figure 1 Apron shape differences between male and female blue crabs and immature and mature female blue crabs. A. "Jimmy" – male blue crab. B. "She-crab" – immature female blue crab. C. "Sook" – mature female blue crab. D. "Sponge crab" – Egg bearing mature female blue crab.

Distribution

The first larval stage (zoea) of blue crabs occurs offshore for several weeks where it undergoes several developmental stages before metamorphosing (transforming) into the next stage, called megalopae (1; 2). Because of the lack of inlets in Albemarle Sound, megalopae are transported primarily into Pamlico Sound, North Carolina via onshore wind events and nighttime incoming spring tides (3), which may be overshadowed by tropical storms, depending on frequency and wind direction (4). Megalopae then settle in seagrass beds in the seaward portion of the sounds before exhibiting density-dependent secondary dispersal resulting in juveniles being widely distributed throughout the estuaries of North Carolina (5). This means that as more crabs enter grass beds and crabs grow they will begin to migrate to areas with less crabs. Decreases in salinity and the presence of bottom structure encourage settlement after this secondary migration. Therefore, crabs begin to prefer the fresher waters of the rivers and western portions of the sounds. After growth and maturation, females migrate to spawn in the high-salinity waters near the inlets (6). Other studies have also shown that the migratory behavior of mature female blue crabs continues between clutches (batch of eggs), and spawning females are continually moving seaward through the spawning season (7; 8; 9). Males do not migrate regularly as adults (10).

Habitat

Blue crabs require both inshore brackish waters and high salinity ocean waters during their life cycle (6). The preferred habitat of blue crabs is tidal marsh estuaries characterized by soft mud bottom and waters of moderate salinity (11). Juvenile blue crabs use seagrass beds and areas of high detritus to grow and avoid predators (12). Adult blue crabs have different habitat preferences by sex and salinity. Mature female blue crabs are more commonly found in higher salinity waters (>10 ppt) near inlets and the eastern side of the sounds. While males prefer lower salinities (3 to 15 ppt) predominantly in the rivers and on the western side of the sounds.

Reproduction

Blue crabs mature between one and two years of age in North Carolina (13). Estimates of length at 50% maturity range from 3.9 in (98.8 mm) in 1999 to 4.9 in (125.7 mm) in 2015. Mating occurs during the spring or summer in brackish estuarine waters as females' molt into maturity (14; 6). Spawning typically occurs within two months after mating if mating occurs early in the growing season; however, females can retain sperm through winter for spawning the following spring (15; 14). Spawning is initiated after migration to high-salinity areas near oceanic inlets. In the Chesapeake Bay, Prager et al. (16) found that fecundity (fertility) was significantly related to carapace width and estimated that average fecundity was 3,200,000 eggs per clutch. Females may spawn once or several times a season. In North Carolina, spawning has two peak pulses, April–June and August–September (9).

Age and Growth

Blue Crabs undergo seven to eight developmental stages [Figure 2; (17; 18; 2)]. Molting is a process of growth in blue crabs that requires shedding the hard exoskeleton. Fischler (19) reported an average life span of three years for blue crabs in North Carolina and a maximum size of around 8.5 in (217 mm). Estimates of maximum age have ranged between five and eight years for blue crabs in the Chesapeake Bay (20). Traditional growth models used for finfish are impractical to apply to crustaceans in general because the models assume growth is continuous (21; 22). For blue crabs and other crustaceans, the shell grows in discrete stages via shedding of the exoskeleton (molt). Carapace-width-to-length relationships have been estimated for blue crabs sampled from many estuaries throughout their range in the eastern United States (23; 24).

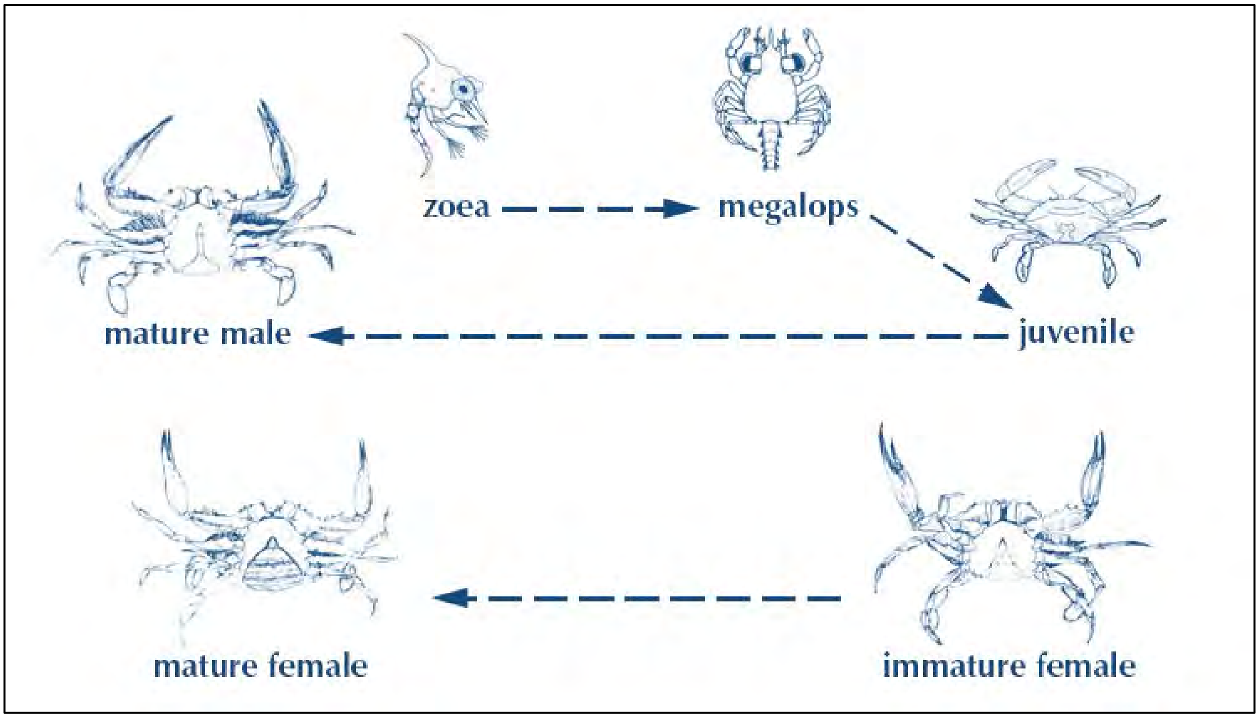

Figure 2 Lifecycle of the blue crab (*Callinectes sapidus*). (6).

Growth in blue crabs is rapid the first summer and is dependent on temperature, molt frequency, food quality and availability, and life stage. Optimum growth of blue crabs occurs at temperatures between 59°F (15°C) to 86°F (30°C), and growth stops when the temperature goes below 50°F (10°C) (25). In temperate regions, where winter temperatures regularly fall below this threshold, blue crabs bury into the sediment. During this dormant period, no growth occurs, thereby extending the time to reach maturity (26). Laboratory observations indicate that growth of blue crabs is 12% to 35% per molt (25). Most blue crabs go through 18 to 20 post-larval molts before becoming sexually mature (1).

Ageing crustaceans is notoriously difficult. Crustaceans do not have persistent hard parts usually used to track and count rapid- and slow-growing periods to determine age. Recent advances in quantifying and calibrating oxidation products (lipofuscins) in nerve tissue have been promising as an alternative to the traditional carapace width estimators used to calibrate carapace width with age estimates. Lipofuscin extraction, however, is a new and costly technique that has not been widely used in ageing laboratories (27). A study in Florida, using two known age cohorts, found that lipofuscin indices were negatively correlated to age (28). These results suggest that more research is needed before this method can be used to age blue crabs.

Recently, another method that has been used to determine age in crustaceans is analyzing growth bands found around the calcified region of the eyestalk or gastric mill in shrimp, crabs, and lobsters (29). While this method has been successful to estimate age in longer-lived, cold water crustaceans like the American lobster (*Homarus americanus*), this method has not been tested in blue crabs.

Predator-Prey Relationships

Blue crabs consume a wide variety of food, fulfilling roles as predators and detritivores (animals that feed on dead organic material). They are large consumers of annelid worms (bristle worms, leeches, and other segmented worms), crustaceans, live or dead fish, vegetation, detritus, and feed heavily on oyster spat and juvenile clams (30). Bivalve mollusks (clams, oysters, mussels, and scallops) are a major portion of blue crab diets (31; 32; 33). They are also cannibalistic, and larger crabs are capable of exhibiting a check on population growth by consuming large amounts of small crabs and juveniles. Blue crabs are a part of the diets many recreationally important species, including striped bass, black drum, red drum, bluefish, southern flounder, and Atlantic croaker (34).

STOCK STATUS

Stock Unit Definition

The unit stock includes all blue crabs in North Carolina coastal fishing waters.

Assessment Methodology

A comprehensive stock assessment approach, the sex-specific two-stage model, was applied to available data to assess the status of North Carolina's blue crab stock during 1995–2016. Data were available from commercial fishery monitoring programs and several fishery-independent surveys. The two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, and thus, provided a comprehensive assessment of blue crab status in North Carolina. The hierarchical Bayesian approach was used to estimate model parameters, which can incorporate uncertainty associated with the data and model assumptions (35). The stock status of North Carolina blue crab in the current assessment (36) was determined based maximum sustainable yield (MSY).

Current Stock Status

Based on the results of the assessment, the North Carolina blue crab stock in 2016 is overfished with a probability of 0.98, given the average spawner abundance in 2016 being estimated at 50 million mature female blue crabs (below the threshold estimate of 64 million). Overfishing is also occurring in 2016 with a probability of 0.52, given the average fishing mortality in 2016 being estimated at 1.48 (above the fishing mortality threshold estimate of 1.46; (35).

DESCRIPTION OF THE FISHERIES

A more in depth analysis and discussion of North Carolina's commercial and recreational blue crab fisheries can be found in earlier versions of the Blue Crab FMP (37; 11; 38); all documents are available on the NCDMF website at: http://portal.ncdenr.org/web/mf/fmps-under-development) or the License and Statistics Annual Report (39) produced by the division which can be found at: http://portal.ncdenr.org/web/mf/marine-fisheries-catch-statistics.

The socio-economic information presented is about the current fishery and is not intended to be used to predict potential impacts from management changes. However, this and other information pertaining to fishery management plans is included to help inform decision-makers regarding the long-term viability of the state's commercially and recreationally significant species or fisheries. For a detailed explanation of the methodology used to estimate the economic impacts please refer to the NCDMF License and Statistics Section Annual Report (39).

COMMERCIAL FISHERY

Blue crab supports the largest and most valuable commercial fishery in North Carolina, accounting for landings of 27.8 million pounds with an ex-vessel value of $26.9 million in 2016 (Table 1). North Carolina has historically accounted for approximately 22% of annual Atlantic coast blue crab landings since 1950 (Figure 3). Landings of blue crab in North Carolina have fluctuated through time but peaked in the late 1990s (Figure 4).

Table 1 Blue crab commercial landings (millions of pounds) and value (millions of dollars) for hard, soft, and peeler crabs combined from major blue crab producing states, 2007-2016. Source: (40)

State \ Year	2007	2008	2009	2010	2011	2012
Alabama	2.6 / $1.7	1.8 / $1.5	1.5 / $1.0	0.9 / $0.7	1.6 / $1.1	1.3 / $1.0
Delaware	3.8 / $5.3	3.5 / $4.6	3.4 / $5.4	4.1 / $6.0	3.5 / $4.8	4.6 / $6.7
Florida East Coast	4.1 / $4.9	3.3 / $4.3	1.6 / $2.4	2.6 / $3.4	3.2 / $4.2	3.4 / $4.7
Florida West Coast	6.1 / $5.8	2.7 / $3.3	3.4 / $4.2	5.8 / $6.7	6.8 / $7.7	4.2 / $5.1
Georgia	4.4 / $3.8	4.2 / $3.9	3.6 / $3.8	2.3 / $2.6	3.4 / $3.3	4.3 / $4.3
Louisiana	45.1 / $35	41.7 / $32.2	53.1 / $37.3	30.8 / $30.3	43.9 / $36.8	46.3 / $43.9
Maryland	30.8 / $41.7	34.9 / $50.1	38.8 / $52	66.3 / $79.1	51.2 / $60.3	43.7 / $60.5
Mississippi	0.7 / $0.7	0.5 / $0.4	0.5 / $0.6	0.4 / $0.4	0.4 / $0.3	0.8 / $0.7
New Jersey	4.6 / $5.5	5.8 / $7.3	0.3 / $0.2	9.5 / $12	9.6 / $9.4	7.4 / $10.0
New York	0.7 / $1.2	0.5 / $0.9	0.9 / $1.2	1.0 / $1.6	0.5 / $0.8	0.1 / $0.2
North Carolina	21.4 / $21.4	32.9 / $27.6	29.7 / $27.4	30.7 / $26.4	30.0 / $21.3	26.8 / $22.8
South Carolina	4.1 / $3.5	4.5 / $4.2	4.0 / $4.1	3.3 / $3.6	5.4 / $5.1	5.9 / $5.8
Texas	3.5 / $2.8	2.6 / $2.3	2.8 / $2.5	3.4 / $3.1	2.9 / $2.8	2.9 / $2.9
Virginia	25.1 / $15.8	23.2 / $18	32.8 / $21.2	38.5 / $29.1	39.7 / $26.3	33.1 / $24.6

State \ Year	2013	2014	2015	2016	Average	Percent of Total Landings
Alabama	1.0 / $1.0	1.2 / $1.3	1.3 / $1.2	1.9 / $1.8	1.5 / $1.2	0.9%
Delaware	2.5 / $4.6	2.0 / $4.4	2.1 / $4.5	3.9 / $7.9	3.3 / $5.4	2.0%
Florida East Coast	2.2 / $3.8	1.5 / $3.1	1.6 / $3.4	1.6 / $3.2	2.5 / $3.7	1.5%
Florida West Coast	4.5 / $6.5	4.5 / $7.4	4.9 / $8.5	3.5 / $6.1	4.6 / $6.1	2.8%
Georgia	3.2 / $4.0	2.7 / $3.8	2.9 / $4.2	3.1 / $3.7	3.4 / $3.7	2.0%
Louisiana	39.2 / $51.6	43.2 / $66.7	41.3 / $58.1	40.1 / $49.4	42.5 / $44.1	25.3%
Maryland	24.2 / $50.0	24.7 / $52.8	28.7 / $52	34.9 / $60.7	37.8 / $55.9	22.5%
Mississippi	0.4 / $0.4	0.6 / $1.0	0.8 / $1.2	0.8 / $0.9	0.6 / $0.7	0.3%
New Jersey	4.4 / $8.1	3.2 / $4.1	7.2 / $8.7	6.9 / $7.7	5.9 / $7.3	3.5%
New York	0.1 / $0.2	0.3 / $0.6	0.2 / $0.4	0.2 / $0.4	0.5 / $0.8	0.3%
North Carolina	22.2 / $30.0	26.2 / $34.0	32.1 / $34.0	25.5 / $24.1	27.8 / $26.9	16.5%
South Carolina	5.1 / $6.4	3.8 / $5.8	3.7 / $4.8	4.4 / $5.5	4.4 / $4.9	2.6%
Texas	1.9 / $2.3	2.2 / $3.1	4.3 / $5.5	5.0 / $6.4	3.2 / $3.4	1.9%
Virginia	24.3 / $24.0	24.2 / $27.0	29.7 / $33.1	28.1 / $40.9	29.9 / $26	17.8%

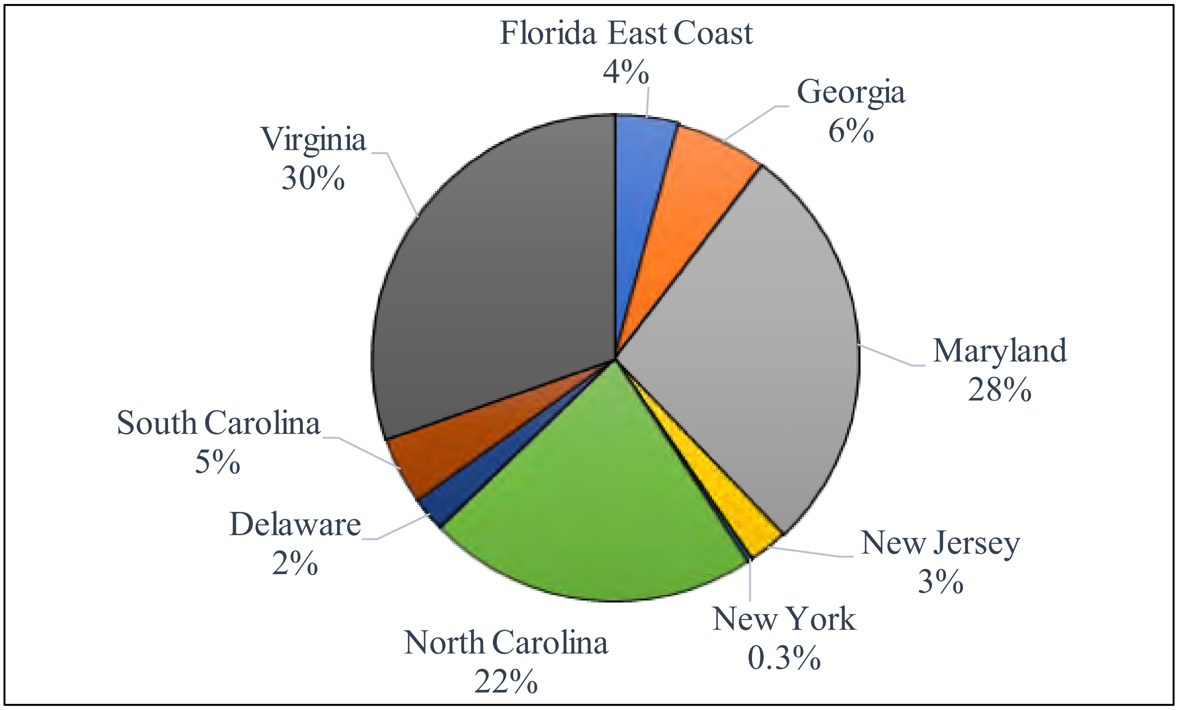

Figure 3 Average contribution to U.S. Atlantic coast blue crab landings by state, 1950-2016. Source: (40)

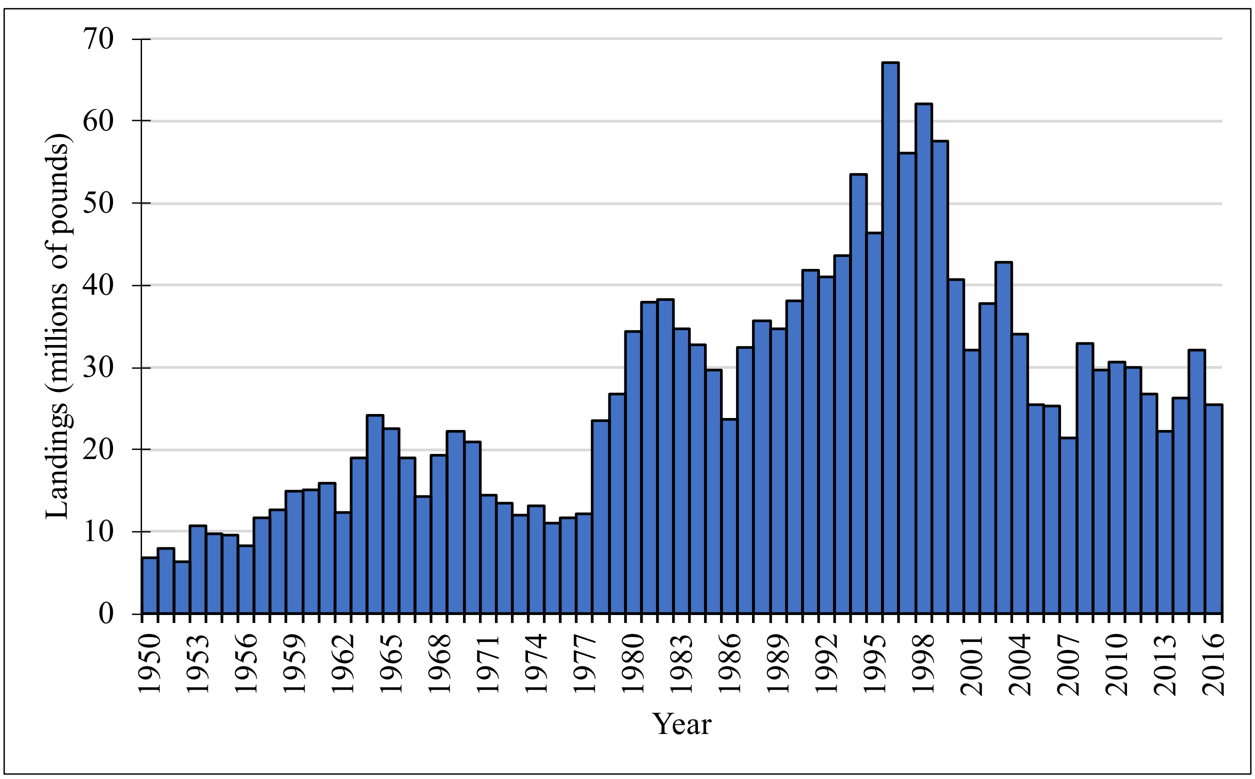

Figure 4 North Carolina annual blue crab commercial landings, 1950-2016. Source: (40)

Commercial Fishery Data Collection

In North Carolina, fishermen have been harvesting blue crabs commercially since the 1800s, with the earliest documented landings reported in 1889 (41). However, landings statistics are patchy prior to 1950. In 1994, the NCDMF implemented a mandatory trip ticket program to monitor commercial landings and fishing effort. Through this program, the NCDMF collects commercial landings data on a trip basis from licensed seafood dealers. The NCDMF requires dealers purchasing blue crabs from commercial fishermen to submit trip tickets that capture information about their catch, such as what was harvested, where it was caught, how it was caught, and how much was harvested. Commercial fishermen who sell their catch directly to consumers are required to possess a dealer's license and submit trip tickets.

The NCDMF's License and Statistics section conducts economic research pertaining to North Carolina and Atlantic coastal fisheries using information from the trip ticket program and surveys. This section publishes results annually in the License and Statistics Annual Report (39; http://portal.ncdenr.org/web/mf/marine-fisheries-catch-statistics) and also provides information to NCDMF and other agencies to support scientific research and resource management.

Unless otherwise noted, all data presented in the following sections are from the NCDMF trip ticket program. Data are presented from 2007-2016. Trends are shown for the ex-vessel value and harvest volume is presented in pounds.

Annual Landings and Value

Average blue crab landings in North Carolina between 2007 and 2016 were 27.8 million pounds (Table 2). The lowest landings during this period was 21.4 million pounds in 2007 and the highest was 32.9 million pounds in 2008.

Annual ex-vessel value of commercial blue crab landings averaged $26.9 million from 2007 to 2016 (Table 2). Annual ex-vessel value reached a low of $21.3 million in 2011 and a high of $33.7 million in 2015.

Ex-vessel price per pound of blue crabs (ex-vessel value divided by annual commercial landings) average $0.97 per pound from 2007 to 2016 (Table 2). Ex-vessel price per pound reached a low of $0.71 per pound in 2011 and a high of $1.35 per pound in 2013.

Table 2 North Carolina commercial blue crab landings and value, 2007-2016.

Year	Harvest	Reported Ex-vessel Value	Reported Ex-vessel Price Per Pound	Inflation Adjusted Ex-vessel Value	Inflation Adjusted Price Per Pound
2007	21,424,960	$21,431,955	$1.00	$26,480,167	$1.24
2008	32,916,691	$27,555,386	$0.84	$30,679,127	$0.93
2009	29,707,232	$27,428,995	$0.92	$30,805,897	$1.04
2010	30,683,011	$26,543,791	$0.87	$28,401,979	$0.93
2011	30,035,392	$21,282,264	$0.71	$21,190,451	$0.71
2012	26,785,669	$22,806,938	$0.85	$22,806,938	$0.85
2013	22,202,623	$30,006,447	$1.35	$30,308,482	$1.37
2014	26,230,965	$34,027,403	$1.30	$32,887,456	$1.25
2015	32,134,501	$33,724,424	$1.05	$33,616,270	$1.05
2016	25,459,475	$24,112,715	$0.95	$24,116,347	$0.95
Average	27,758,052	$26,892,032	$0.97	$28,129,312	$1.01

Landings by Crab Type

In North Carolina, fishermen harvest hard-shell, soft-shell, and peeler blue crabs (Figure 5). Peeler blue crabs still have a hard shell but are in the pre-molt stage (i.e., a white line is present on the swimming leg). Hard-shell blue crabs are typically sold to: 1) wholesale/retail seafood dealers that grade, pack, and ship blue crabs to live markets or crab processors, 2) retail seafood dealers, and 3) consumers directly.

Hard-shell blue crabs sold to live markets are typically graded by size. Grading occurs either onboard the vessel or at the dock. Graded sizes vary based on crab abundance and market demands but generally include:

- Number 1 males: greater than 5.75 inches carapace width (CW)
- Number 2 males: 5.25 to 6 inches CW
- Number 3 females: greater than 5.5 inches CW
- Straights and Culls: smaller crabs destined for processing

Blue crab fishermen also cull and shed peeler blue crabs either in their own facility or sell them to other shedding operations.

Hard-shell blue crab landings accounted for 97.0% of the cumulative landings and 88.2% of the cumulative ex-vessel value of blue crabs harvested in North Carolina from 2007 to 2016. Average hard shell blue crab landings during this period were 26.9 million pounds (Table 3). Landings fluctuated from a low of 20.6 million pounds in 2007 to a high of 32.3 million pounds in 2008. During this period, the ex-vessel price per pound ranged from a low of $0.62 in 2011 to a high of $1.23 in 2013.

The harvest of soft-shell and peeler blue crabs is minor compared to hard-shell blue crabs but they are an economically important sector of the blue crab fishery as they tend to command a higher market price. Soft-shell crabs primarily come from crab shedding operations. In these operations, peeler blue crabs are placed into open or closed recirculating tank systems and sorted according to molt stage. Once a crab sheds it is immediately removed because it is very vulnerable to predation from other crabs and to prevent the shell from hardening to a point the crab becomes unmarketable.

Soft-shell blue crabs comprised 1.2% of the total landings and 6.8% of the total ex-vessel value of blue crab landings from 2007 to 2016. Average soft-shell blue crab landings during this period were 323,080 pounds (Table 3). Landings fluctuated from a low of 198,876 pounds in 2009 to a high of 446,405 pounds in 2011. The ex-vessel price per pound averaged $5.72 from 2007 to 2016, almost six and half times the average ex-vessel price per pound for hard-shell blue crabs during the same period.

Peeler blue crabs accounted for 1.8% of the total landings and 5.0% of the total ex-vessel value of blue crab from 2007 to 2016. During this period, average peeler blue crab landings ranged from a low of 351,995 pounds in 2008 to a high of 706,671 pounds in 2015 (Table 3). From 2007 to 2016, the real ex-vessel price per pound for peeler blue crabs averaged $2.66, roughly three times the average ex-vessel price per pound for hard-shell blue crabs during this period.

Table 3 Landings and real ex-vessel price per pound of North Carolina blue crabs by type, 2007-2016.

Year	Hard-shell	Peeler	Soft-shell
2007	20,562,166 / $0.88	498,917 / $2.38	363,918 / $5.87
2008	32,338,899 / $0.79	351,995 / $2.51	225,822 / $5.51
2009	29,140,483 / $0.86	367,904 / $3.01	198,876 / $6.45
2010	29,794,332 / $0.80	568,228 / $2.11	320,480 / $4.82
2011	28,964,480 / $0.62	624,376 / $1.90	446,405 / $4.66
2012	25,991,391 / $0.78	468,867 / $2.37	325,426 / $4.60
2013	21,438,089 / $1.23	447,135 / $3.24	317,425 / $6.59
2014	25,242,662 / $1.19	621,046 / $3.12	367,284 / $5.82
2015	31,040,019 / $0.95	706,671 / $2.99	380,379 / $5.67
2016	24,732,129 / $0.84	445,843 / $2.95	284,786 / $7.24
Average	26,924,465 / $0.89	510,098 / $2.66	323,080 / $5.72

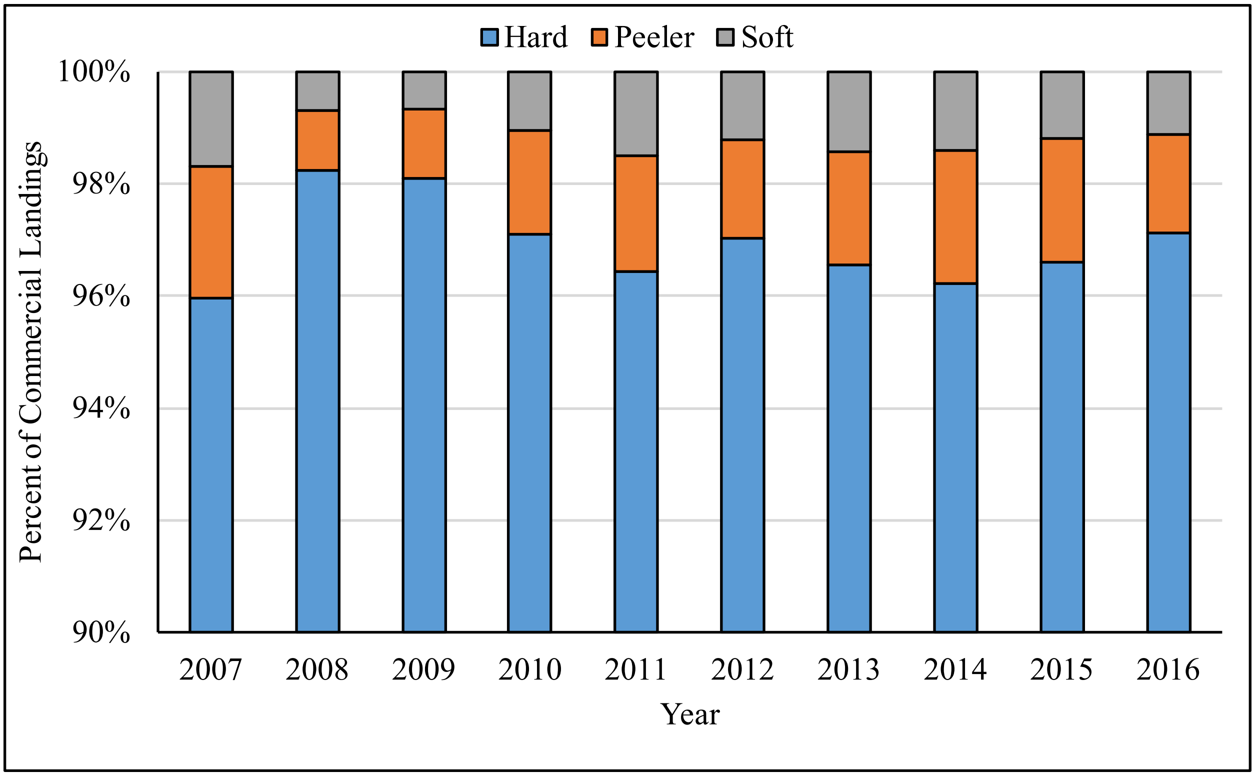

Figure 5 North Carolina blue crab commercial landings percent by type, 2007-2016.

Landings by Season

Commercial blue crab landings in North Carolina vary by season. Landings are lowest in January and February, averaging approximately 89,230 pounds and $78,159 monthly (from 2007 to 2016; Table 4). Average monthly landings are highest in the summer months: 4.2 million pounds and $4.1 million in June, 4.0 million pounds and $3.8 million in July, and 4.3 million pounds and $3.9 million in August.

Average ex-vessel price per pound also fluctuates seasonally (Table 4). From 2007 to 2016, average ex-vessel price per pound ranged from $0.70 per pound in November to $2.31 per pound May.

Table 4 Average monthly blue crab landings (pounds), ex-vessel value, and ex-vessel price per pound, 2007-2016.

Month	Average Landings	Average Ex-vessel Value	Average Ex-vessel Price per Pound
January	84,046	$70,603	$1.16
February	94,413	$85,716	$1.40
March	645,065	$634,210	$1.59
April	967,654	$1,178,043	$2.16
May	3,189,032	$4,596,248	$2.31
June	4,232,447	$4,117,839	$1.58
July	3,989,698	$3,806,953	$1.36
August	4,273,003	$3,916,515	$1.43
September	4,138,995	$3,567,066	$1.26
October	3,705,524	$2,984,561	$0.87
November	1,845,994	$1,462,970	$0.70
December	592,208	$471,308	$0.90

Landings by Gear Type and Vessel Length

Early blue crab fishermen used baited trotlines to harvest hard-shell blue crabs in North Carolina (41). In the mid-1960s crab pots became the most popular gear used in the blue crab fishery due to their efficiency. While several gear types are used to harvest blue crabs, most fishermen use crap pots, generally baited with Atlantic menhaden or other finfish. From 2007 to 2016, approximately 97% of the total blue crab landings have been harvested with crab pots (Table 5; Figure 6). Landings from other blue crab specific gears account for approximately 3% of the total landings and all other commercial gears account for less than 1% of the total landings. Overall, the majority of commercial blue crab landings in North Carolina are from vessels between 15 and 30 feet long. Vessels less than 15 feet long account for less than 1% of the landings on average from 2007 to 2016. Vessels 31 feet long and greater accounted for approximately 12% of the landings on average during this same period.

Table 5 Annual blue crab landings (pounds) by gear type, 2007-2016.

Year	Crab Pot	Peeler Pot	Crab Trawl	Peeler Trawl	Crab Dredge	Other	Total
2007	20,909,150	413,827	28,789	-	2,656	70,538	21,424,960
2008	30,967,910	293,679	1,557,934	-	-	97,169	32,916,691
2009	28,431,358	266,464	913,928	-	7,981	87,501	29,707,232
2010	29,789,952	489,097	286,653	2,746	52,769	61,794	30,683,011
2011	29,095,531	668,414	199,217	2,724	6,843	62,664	30,035,392
2012	26,247,049	457,413	7,608	2,466	2,335	68,798	26,785,669
2013	21,697,292	379,412	54,658	1,813	-	69,448	22,202,623
2014	25,471,904	637,572	38,059	1,843	10	81,577	26,230,965
2015	31,054,531	835,009	185,527	1,580	1,382	56,472	32,134,501
2016	24,754,952	503,728	163,250	1,323	2,958	33,264	25,459,475
Average	26,841,963	494,461	343,562	2,071	9,617	68,922	27,758,052

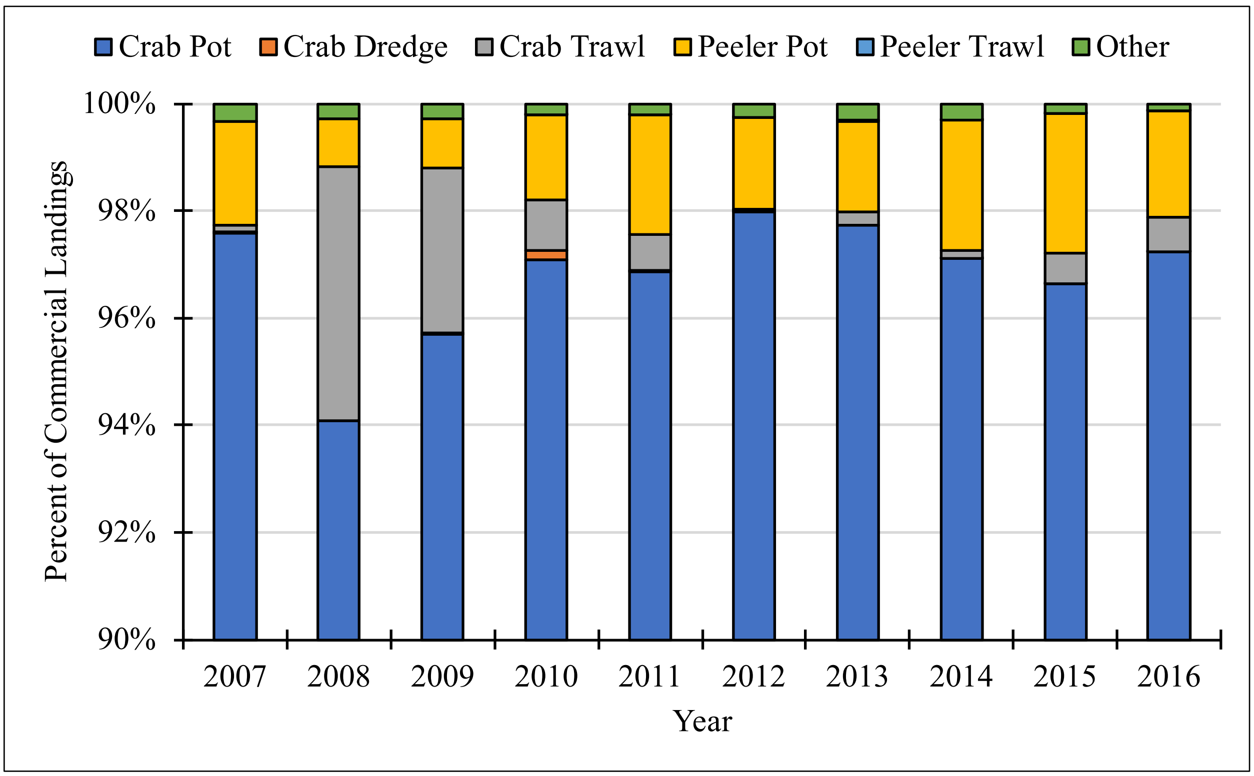

Figure 6 Percent of annual blue crab commercial landings by gear type, 2007-2016.

Landings by Area

Commercial fishermen in North Carolina are asked to identify the area in which they caught the majority of their catch during each trip. The Albemarle Sound (Albemarle Sound, Albemarle Sound Rivers, and Currituck, Roanoke, and Croatan sounds) and Pamlico Sound (Pamlico Sound and Pamlico Sound Rivers) estuary systems accounted for, on average, 93% of the total annual blue crab harvest from 2007 to 2016 (Table 6). During this time period, the average ex-vessel value was highest in the Currituck, Roanoke, and Croatan sounds, followed by Core-Bogue sounds, Albemarle Sound, White Oak River and South, Pamlico Sound Rivers, Pamlico Sound, and Albemarle Sound Rivers.

Table 6 Blue crab landings (millions of pounds) and average ex-vessel price per pound by area, 2007-2016.

Year	Albemarle Sound Rivers	Albemarle Sound	Currituck, Roanoke, and Croatan Sounds	Pamlico Sound	Pamlico Sound Rivers	Core-Bogue Sounds	White Oak River and South	Statewide*
2007	0.8 / $0.70	10.9 / $1.02	3.1 / $1.24	1.7 / $0.96	3.2 / $0.90	0.5 / $0.77	1.3 / $0.87	21.4 / $1.00
2008	1.2 / $0.72	17.9 / $0.86	4.9 / $0.92	4.2 / $0.72	2.9 / $0.84	0.4 / $0.81	1.4 / $0.75	32.9 / $0.84
2009	1.7 / $0.66	15.1 / $0.96	5.6 / $1.03	3.3 / $0.77	2.2 / $0.91	0.4 / $0.88	1.4 / $0.83	29.7 / $0.92
2010	1.2 / $0.71	13.6 / $0.84	4.5 / $0.97	4.6 / $0.86	4.9 / $0.85	0.5 / $0.91	1.3 / $1.99	30.7 / $0.87
2011	1.6 / $0.47	12.3 / $0.71	4.2 / $0.84	5.0 / $0.68	5.0 / $0.70	0.5 / $0.64	1.4 / $0.77	30.0 / $0.71
2012	2.0 / $0.63	12.6 / $0.89	3.5 / $0.96	3.6 / $0.80	2.8 / $0.80	0.8 / $0.71	1.6 / $0.87	26.8 / $0.85
2013	2.5 / $1.16	11.3 / $1.40	2.7 / $1.39	2.5 / $1.25	1.3 / $1.54	0.6 / $1.27	1.3 / $1.26	22.2 / $1.35
2014	3.5 / $1.10	13.1 / $1.26	3.7 / $1.42	2.1 / $1.41	2.1 / $1.44	0.6 / $1.57	1.2 / $1.32	26.2 / $1.30
2015	4.1 / $0.72	13.6 / $1.06	4.5 / $1.20	3.5 / $1.03	4.6 / $1.07	0.7 / $1.32	1.2 / $1.30	32.1 / $1.05
2016	2.8 / $0.57	9.0 / $1.06	3.8 / $1.06	4.2 / $0.83	3.5 / $0.88	0.8 / $1.13	1.3 / $1.08	25.5 / $0.95
Average	2.1 / $0.74	12.9 / $1.00	4.0/ $1.10	3.5 / $0.93	3.3 / $0.99	0.6 / $1.00	1.3 / $1.00	27.8 / $0.98

*Ocean data are not presented, landings in the ocean averaged less than 8,000 pounds per year during this period.

Albemarle Sound

From 2007 to 2016, Albemarle Sound led all areas in blue crab landings, averaging just under 13 million pounds annually. Albemarle Sound is defined as Albemarle Sound proper as defined in the NCDMF Trip Ticket program. Landings peaked at 17.9 million pounds in 2008 and were lowest in 2016 (9.0 million pounds). Seasonal landings follow similar trends as most areas with highest average landings levels from June through October.

Currituck, Roanoke, and Croatan Sounds

Blue crab landings from the Currituck, Roanoke, and Croatan sounds ranked second among all areas, averaging 4 million pounds annually. This area comprises only Currituck, Roanoke, and Croatan sounds. Landings peaked at 5.6 million pounds in 2009 and were lowest in 2013 (2.7 million pounds).

Pamlico Sound

Blue crab landings from Pamlico Sound ranked third during this period averaging 3.5 million pounds annually. Pamlico Sound is defined a Pamlico Sound and its associated bays as defined in the NCDMF Trip Ticket program. Landings peaked at 5.0 million pounds in 2011 and were lowest in 2007 (1.7 million pounds).

Pamlico Sound Rivers

Blue crab landings from Pamlico Sound rivers ranked fourth among all areas, averaging 3.3 million pounds annually. Pamlico Sound rivers include the Pamlico, Pungo, Bay, and Neuse rivers. Landings peaked at 5.0 million pounds in 2011 and were lowest in 2013 (1.3 million pounds).

Albemarle Sound Rivers

Blue crab landings from Albemarle Sound rivers ranked fifth during this period averaging 2.1 million pounds annually. Albemarle Sound rivers include the Alligator, Chowan, Pasquotank, Perquimans, and Roanoke rivers. Landings peaked at 4.1 million pounds in 2015 and were lowest in 2007 (0.8 million pounds).

White Oak River and South

Blue crab landings from the White Oak River and south ranked sixth among all areas, averaging 1.3 million pounds annually. This area includes the White Oak River and all waters south to the South Carolina state line. Landings peaked at 1.6 million pounds in 2012 and were lowest in 2014 and 2015 at 1.2 million pounds.

Core Sound and Bogue Sound

Blue crab landings from Core and Bogue sounds ranked last during this period, averaging 0.6 million pounds annually. The Core Sound and Bogue Sound area includes Core, Back, and Bogue sounds and the North and Newport rivers. Landings peaked at 0.8 million pounds in 2012 and 2016 and were lowest in 2008 and 2009 at 0.4 million pounds.

Demographic Characteristics

The average age of commercial fishermen involved in the blue crab fishery ranged from 45 years old in 2016 to 49 in 2012, 2013, and 2015 (Table 7). Most commercial fishermen are also male and Caucasian (Tables 8 and 9).

Table 7 Average age of commercial fishermen who harvested blue crab from 2007 – 2016.

Year	Average Age
2007	48
2008	48
2009	47
2010	47
2011	48
2012	49
2013	49
2014	48
2015	49
2016	45

Table 8 Number of commercial fishermen by gender who harvested blue crab from 2007 – 2016.

Year	Male	Female	Unknown
2007	888	60	5
2008	850	60	5
2009	926	60	6
2010	912	68	7
2011	861	60	5
2012	830	61	8
2013	801	57	8
2014	856	64	6
2015	847	66	13
2016	813	66	9

Table 9 Number of commercial fishermen by race who harvested blue crab from 2007 – 2016.

Year	African American	American Indian	Asian/Pacific Islands	Caucasian	Hispanic	Unknown
2007	23	1	61	853	4	10
2008	24	2	52	824	5	8
2009	20	3	57	901	2	9
2010	21	4	63	887	2	10
2011	21	4	59	835	1	6
2012	21	3	53	810	1	11
2013	23	3	46	781	1	12
2014	23	2	51	838	1	11
2015	21	2	53	832	1	17
2016	21	1	51	801	1	12

During the sale and renewal of commercial licenses, an economic survey is conducted that asks commercial fishermen if they obtain more than 50 percent of their income from commercial fishing. Most blue crab fishermen indicated they do generate more than 50 percent of their income from commercial fishing, however the difference between the number of those fishermen indicating less than 50 percent of their income from commercial fishing and those indicating making more than 50 percent has been getting smaller in recent years (Table 10)

Table 10 Number of commercial fishermen who indicated they make less or more than 50 percent of their income from commercial fishing as indicated from the economic survey conducted during license sales and renewals from license years 2007 to 2016.

Year	Less than 50%	More than 50%	Unknown
2007	136	702	6
2008	187	774	5
2009	184	813	18
2010	181	846	14
2011	157	841	6
2012	149	771	15
2013	130	750	18
2014	163	748	38
2015	210	755	24
2016	255	697	17

Commercial Crabbers

A fisherman needs to hold a Standard Commercial Fishing License (SCFL) or a Retired Standard Commercial Fishing License (RSCFL) to land blue crabs commercially in North Carolina. Commercial licenses are sold on a fiscal year calendar, which runs from July 1 to June 30. The total number of SCFLs and RSCFLs issued over fiscal year 2007 to fiscal year 2016 ranged from 6,425 in 2016 to 6,906 in 2007 (Table 11). The number of participants with reported landings ranged from 863 in 2013 to 990 in 2009. Most of participants who operate in the blue crab commercial fishery landed hard-shell blue crabs with the number of participants ranging from 815 in 2013 to 944 in 2010. The number of participants reporting landings from peeler and soft-shell crabs is much less. The number of participants reporting peeler crabs ranged from 476 in 2016 to 561 in 2009. For soft-shell crabs, the number of participants ranged from 209 in 2011 to 270 in 2009.

Table 11 Total number of SCFL/RSCFLs issued and participants landing blue crab.

Year	SCFL/RSCFLs Issued[1]	Participants w/Blue Crab Landings	Participants w/ Hard-Shell Crab Landings	Participants w/ Peeler Crab Landings	Participants w/ Soft-Shell Crab Landings
2007	6,906	952	890	548	270
2008	6,861	914	857	526	245
2009	6,827	990	943	561	245
2010	6,815	984	944	551	238
2011	6,819	925	883	511	209
2012	6,794	895	837	506	229
2013	6,699	863	815	502	253
2014	6,685	923	887	534	259
2015	6,635	923	883	534	241
2016	6,465	884	862	476	237
Average	6,751	925	880	525	423

[1] SCFL/RSCFLs are issued on a fiscal year (July 1 to June 30).

Most participants who land blue crabs live in the coastal counties of North Carolina. Over 73% of the participants who landed blue crabs in 2016 were from Dare (20%), Beaufort (14%), Carteret (11%), Hyde (7%), Currituck (6%), Pamlico (5%), Perquimans (5%), and Tyrrell (5%) counties.

Fishery Effort

The number of trips reporting landings of blue crabs averaged over 54,000 over the 2007 to 2016 period. The number of trips ranged from 51,707 in 2016 to 59,313 in 2009 (Table 12). The average landings per trip ranged from 398 pounds per trip in 2007 to 625 pounds per trip in 2008. The real value per trip ranged from $404 in 2011to $585 in 2014.

Looking more specifically at the crab and peeler pot fishery, the average number of pots reported on trip tickets as being fished from 2007 to 2016 was over 13.6 million per year. The number of pots fished ranged from 12,2 million in 2013 to 16.4 million in 2015. The average number of pots fished per trip ranged from 241 pots per trip in 2007 to 293 pots per trip in 2015. The average blue crab catch per pot ranged from 1.70 pounds per pot in 2007 and 2014 to 2.50 pounds in 2008.

Table 12	Annual trips, catch per trip, real value per trip, total number of pots, pots fished per trip, and catch per pot in the blue crab fishery.

Year	Trips[1]	Catch Per Trip[1]	Real Value Per Trip[1]	Total Pots Reported Fished[2]	Pots Per Trip[3]	Catch Per Pot
2007	53,833	398	$492	12,585,097	241	1.70
2008	52,654	625	$583	12,525,056	249	2.50
2009	59,313	501	$519	14,069,873	247	2.04
2010	54,977	558	$517	13,336,039	249	2.27
2011	52,406	573	$404	12,814,114	253	2.32
2012	52,697	508	$433	12,547,175	245	2.13
2013	52,631	422	$576	12,199,083	239	1.81
2014	56,217	467	$585	15,322,181	283	1.70
2015	57,603	558	$579	16,433,869	293	1.94
2016	51,707	492	$466	14,712,005	291	1.72
Average	54,404	510	$515	13,654,449	259	2.01

[1] The number of trips, catch per trip, and real value per trip is from all trips that recorded blue crabs across all gear types including pots, trawls, dredges, and other.
[2] The total number of pots reported fished is the sum of what was reported on trip tickets and duplicates the number of pots fished by an individual each time they fill out a trip ticket. For example, if a fishermen fishes 50 pots each trip and has 100 trips for the year it will calculated as 5,000 pots fished.
[3] The number of pots per trip is the average number of pots reported fished on trip tickets. This is not the same as the number of pots a fisherman may have in the water. For example, a fisherman may have 500 pots in the water but only fish 250 pots on a particular day, so the number of pots fished for the trip would be 250 pots.

The total number of vessels landing blue crabs ranged from 1,077 in 2016 to 1,192 in 2009 (Table 13). Most vessels land 5,000 pounds or less of blue crabs. The number of vessels landing less than 1,000 pounds has remained stable since 2010, except for 2014 when the numbers peaked at 343. The number of vessels landing 1,000 to 5,000 pounds has fluctuated over the years declined from 214 in 2015 to 201 in 2016. The number of vessels landing 5,001 to 10,000 pounds declined overall from 2007 to 2013 and then increased in 2014 and has remained stable since. Fluctuations in the number of vessels landing more than 20,000 pounds occurred over the time period. Looking specifically at the number of vessels landing more than 100,000 pounds, the number of vessels were lowest in 2007 at 33 and then increased to 94 in the following year. Since then, the number of vessels landing more than 100,000 pounds declined and remained in the 70s to 80s until 2013 at which point then declined. In 2015, the number of vessels with landings more than 100,000 pounds peaked at 102 and has declined since then.

Table 13 Annual number of vessels landing blue crab by poundage range, 2007-2016.

Year	< 1,000 Pounds	1,000 - 5,000 Pounds	5,001 - 10,000 Pounds	10,001 - 20,000 Pounds	20,001 - 50,000 Pounds	50,001 - 100,000 Pounds	>100,000 Pounds	Total
2007	317	216	131	124	181	107	33	1,109
2008	325	182	97	108	160	132	94	1,098
2009	337	213	122	122	198	128	72	1,192
2010	299	222	120	134	199	124	79	1,177
2011	306	179	108	136	194	109	82	1,114
2012	300	203	97	137	172	91	77	1,077
2013	309	204	108	136	152	89	57	1,055
2014	343	185	129	122	171	106	68	1,124
2015	307	214	125	142	167	98	102	1,155
2016	295	201	120	119	188	83	71	1,077
Average	314	202	116	128	178	107	74	1,118

Seafood Dealers and Shedders

The number of seafood dealers reporting landings of blue crabs has ranged from 241 in 2008 to 280 in 2010 (Table 14). Most dealers operate in the hard-shell crab fishery with the number of dealers reporting hard-shell crabs ranging from 211 in 2007 to 245 in 2010. The number of dealers reporting landings of peeler crabs ranged from 111 in 2016 to 124 in 2007. Looking at soft-shell crabs, the number of dealers reporting landings has ranged from 77 in 2015 to 102 in 2007.

Table 14 Annual number of seafood dealers reporting landings of blue crab, 2007-2016.

Year	Number of Dealers w/ Blue Crab Landings	Number of Dealers w/ Hard-Shell Crab Landings	Number of Dealers w/ Peeler Crab Landings	Number of Dealers w/ Soft-Shell Crab Landing
2007	247	211	124	102
2008	241	217	118	94
2009	274	243	123	94
2010	280	245	118	98
2011	266	230	120	88
2012	259	227	116	82
2013	243	213	113	86
2014	269	241	119	96
2015	252	223	116	77
2016	268	226	111	84
Average	260	228	118	90

The number of blue crab shedding permits issued by fiscal year ranged from 267 in 2013 to 314 in 2007 (Table 15). Shedding operations used mostly two types of tanks: closed recirculating or flow through tanks. Two other types of tanks may also be used but they are much less common (floating tank and other types). The number of flow through tanks have generally declined from 2007 and ranged from 4,067 in 2013 to 4,067 in 2007. The number of close recirculation tanks have followed the same overall pattern through 2012 but showed an increase in 2013 to 2015 before declining again. The number of closed recirculating tanks ranged from 955 in 2012 to 1,665 in 2007.

Table 15 Annual number of permitted blue crab shedding operations, 2007-2016. Fiscal year runs from July 1 through June 30.

Fiscal Year	Shedding Permits Issued	Closed Recirculating Tanks	Flow Through Tanks	Floating Tanks	Other Tanks
2007	314	1,665	6,642	63	32
2008	304	1,564	6,462	339	31
2009	300	1,166	5,152	543	55
2010	301	1,046	5,941	238	71
2011	292	1,145	5,192	16	1
2012	287	955	5,534	74	13
2013	267	1,261	4,067	40	0
2014	279	1,378	4,224	144	31
2015	268	1,418	4,104	87	82
2016	268	1,312	4,265	146	74
Average	288	1,291	5,158	169	39

Crab Processors

Crab processing is an important component of the blue crab commercial industry. In North Carolina, crab processing facilities may have two types of permits. The first type is for the initial cooking, picking, and packing of crab meat and the second type is for repacking crab meat that has previously been cooked and packaged. An individual facility may have one or both types of permits which must be renewed annually and expire on March 31 each year. The number of permitted processing facilities has remained fairly stable since 2007 (Table 16). However, the number of permitted facilities is roughly half of what it was in the late 1990s (38). Several factors have contributed to the decline in the number of processing facilities including a shift from processed crabs to a live basket market, increased competition from imports, and more stringent federal Hazard Analysis and Critical Control Point (HACCP) requirements.

Table 16 Annual (April 1-March 31) number of permits issued for crustacea processing facilities, 2007-2018. Data from the NCDMF Shellfish Sanitation section.

Year	Total Number of Permitted Facilities	Total Number of Picking Permits	Total Number of Repacking Permits	Total Number of Facilities Permitted for Picking and Repacking
2007-2008	10	7	2	1
2008-2009	9	6	2	1
2009-2010	13	7	2	4
2010-2011	11	5	2	3
2011-2012	14	8	3	3
2012-2013	13	8	2	3
2013-2014	11	7	1	3
2014-2015	11	7	1	3
2015-2016	17	8	2	7
2016-2017	17	6	2	9
2017-2018	14	4	2	8
2018-2019	15	4	2	9

Swimming Crab Imports

The United States imports two types of "swimming crabs" related to blue crab: *Portunidae* (the family that includes blue crabs) and *Callinectes* (the blue crab genus). According to NOAA Fisheries U.S. Foreign Trade database, total U.S. imports of swimming crab have averaged 46.8 million pounds and $384 million per year between 2007 and 2016. Imports bearing the broader Portunidae label averaged 39.8 percent of the total volume and 36.6 percent of the total real value of swimming crab imports during the period. Imports under the Callinectes label averaged 60.2 percent of total volume and 63.4 percent of the total real value of swimming crab imports from 2007to 2016. The United States imports swimming crab in two forms, frozen and in air tight containers. Imports of frozen crab averaged 4.1 million pounds and $23.6 million per year from 2007 to 2016; imports of crab in air tight containers averaged 42.7 million pounds and $360 million per year during the same period.

Between 2007 and 2016, the United States imported swimming crab products from as few as 14 to as many as 21 different countries. The majority of swimming crab products come from a relatively small number of countries with five countries making up an average of 80% of imports from 2007-2016. Indonesia has been the number one source of swimming crab product imports in every year from 2007 to 2016. The total volume of swimming crab product imports from Indonesia comprised almost one-third of the total volume of all swimming crab product imports on average from 2007 to 20116 (42).

Summary of Economic Impact of Commercial Fishing

The economic impact estimates presented represent those of commercial blue crab harvesters, dealers, and processors and are calculated via the NCDMF commercial fishing economic impact model. These estimates are given for four categories: all commercial blue crab harvest, hard blue crab harvest, peeler blue crab harvest, and soft blue crab harvest

Blue crab boasts the highest ex-vessel values in the state and in 2016 resulted in over $150 million in economic impact (Table 17), with hard blue crabs dominating this cash flow. Peeler and soft blue crabs also contribute to this industry, each generally producing greater than $1 million in ex-vessel revenues per year. On top of this, the peeler and soft blue crab fisheries tend to exhibit similar landings values, with soft blue crab values slightly higher overall. Additionally, annual changes in ex-vessel value across segments are generally consistent, in that years with lower hard blue crab revenues tend to exhibit lower soft and peeler blue crab revenues as well (Tables 18, 19, and 20).

Given gear and catch changes are proposed under this amendment, the commercial fishery will likely see a reduction in ex-vessel value due to an expected reduction in landings. However, effort, and therefore supply, are not being controlled for, and because of this, expected changes to marginal prices of crab are unknown. Additionally, as management changes that reduce landings are being implemented across all aspects of the blue crab fishery, economic losses due to these regulations can be expected across the hard, soft, and peeler fisheries. Lastly, these output measures were calculated using annual ex-vessel values and participant counts. While ex-vessel values per blue crab segment are fully independent, some participants may be fishing across multiple segments, possibly even during the same trip. Because of this, output measures on a per-segment scale (Tables 18, 19, and 20) are not additive and may be over-estimating total contributions, but still capture the socioeconomic importance of each blue crab fishery to the state economy.

Table 17 Economic impacts associated with the commercial blue crab fishery for all product categories, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	884	25,459,475	24,112,715	2,313	56,569,819	85,443,052	123,871,511
2008	923	32,134,501	33,724,424	2,782	68,330,127	103,098,756	155,900,595
2009	923	26,230,965	34,027,403	2,807	69,978,824	105,642,579	155,668,594
2010	863	22,202,623	30,006,447	2,656	65,839,269	99,304,559	149,381,907
2011	895	26,785,669	22,806,938	2,069	51,868,420	78,192,850	119,032,842
2012	925	30,035,392	21,282,264	2,217	56,147,717	84,607,194	128,240,957
2013	984	30,683,011	26,543,791	2,882	72,762,337	109,704,172	167,489,172
2014	990	29,707,232	27,428,995	3,255	83,092,013	125,316,017	190,518,399
2015	914	32,916,691	27,555,386	3,329	84,243,536	127,096,494	190,345,529
2016	952	21,424,960	21,431,955	2,302	61,024,899	91,970,507	151,757,244

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

Table 18 Economic impacts associated with the commercial blue crab fishery for hard blue crabs only, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	862	24,728,862	20,734,833	2,142	54,520,426	82,794,003	119,109,877
2008	883	31,047,438	29,457,925	2,674	67,018,157	101,401,623	152,852,403
2009	887	25,242,648	29,954,605	2,689	68,542,255	103,783,999	152,327,477
2010	815	21,438,077	26,465,523	2,520	64,179,463	97,157,235	145,519,395
2011	837	25,991,387	20,198,891	1,908	49,882,882	75,624,156	114,416,771
2012	883	28,964,633	18,016,736	2,087	54,544,208	82,532,792	124,514,063
2013	944	29,794,329	23,801,594	2,704	70,621,095	106,934,054	162,511,562
2014	943	29,140,473	25,039,379	3,051	80,629,140	122,129,805	184,793,115
2015	857	32,338,889	25,429,231	3,115	81,663,530	123,758,747	184,347,951
2016	890	20,562,159	18,109,497	2,142	58,906,380	89,230,343	144,809,891

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

Table 19 Economic impacts associated with the commercial blue crab fishery for peeler blue crabs only, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	476	445,844	1,314,879	1,272	44,081,515	69,300,649	94,855,735
2008	534	706,688	2,111,103	1,430	51,871,181	81,807,854	117,660,362
2009	534	621,040	1,935,462	1,512	54,154,728	85,169,934	118,865,501
2010	502	447,120	1,449,542	1,392	50,497,796	79,456,993	113,680,978
2011	506	468,855	1,112,025	1,075	39,649,466	62,385,167	90,625,651
2012	511	624,362	1,186,286	1,139	42,808,999	67,351,373	97,238,954
2013	551	568,210	1,197,855	1,449	55,493,614	87,363,675	127,345,662
2014	561	367,881	1,106,883	1,646	63,685,607	100,210,007	145,405,556
2015	526	351,986	882,319	1,743	65,126,559	102,364,916	145,905,501
2016	548	498,904	1,186,031	1,224	46,726,694	73,476,730	104,868,510

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

Table 20 Economic impacts associated with the commercial blue crab fishery for soft blue crabs only, 2007-2016.

Year	Participants[1]	Pounds[1]	Ex-Vessel Value ($)[1]	Jobs[2,3]	Income Impacts ($)[3]	Value Added Impacts ($)[3]	Output Impacts ($)[3,4]
2007	237	284,769	2,063,004	1,321	44,667,748	70,058,414	96,217,809
2008	241	380,375	2,155,396	1,449	52,094,259	82,096,423	118,178,657
2009	259	367,277	2,137,335	1,521	54,260,444	85,306,706	119,111,372
2010	253	317,426	2,091,382	1,410	50,707,520	79,728,316	114,169,022
2011	229	325,426	1,496,021	1,119	40,192,410	63,087,575	91,887,913
2012	209	446,397	2,079,242	1,158	43,045,092	67,656,799	97,787,685
2013	238	320,472	1,544,342	1,482	55,881,742	87,865,796	128,247,920
2014	245	198,878	1,282,733	1,656	63,807,683	100,367,936	145,689,337
2015	245	225,816	1,243,836	1,745	65,153,344	102,399,567	145,967,765
2016	270	363,896	2,136,426	1,259	47,195,899	74,083,615	106,407,193

[1] As reported by the North Carolina Trip Ticket Program
[2] Represents both full-time and part-time jobs
[3] Economic impacts calculated using the NCDMF commercial fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.
[4] Represents sales impacts

RECREATIONAL FISHERY

Recreational Harvest Estimates

Recreational fishermen harvest blue crab for personal consumption and for use as bait. Harvest occurs using a variety of gears including crab pots (rigid and collapsible), gill nets, shrimp trawls, trot-lines, hand-lines, and dip nets. Prior to July 1999, no license was required to harvest blue crab recreationally unless a vessel was used. Since July 1, 1999, a RCGL has been required to recreationally harvest blue crab using commercial gear. Gears exempt from this license include collapsible crab pots, cast nets, dip nets, hand-lines, and seines (less than 30 feet). Additionally, one pot per person may be fished from shore along privately-owned land or a privately-owned pier without a RCGL. The recreational harvest limit for blue crab is 50 per person per day, not to exceed 100 per vessel. A Coastal Recreational Fishing License (CRFL) is not required to recreationally harvest blue crabs.

Long-term comprehensive estimates of recreational harvest data are lacking in North Carolina. However, there have been several short-term or targeted surveys meant to estimate recreational blue crab harvest. In 2002, Vogelsong et. al (43) surveyed coastal waterfront landowners to estimate recreational harvest. They found that approximately 30% harvested blue crab from their property and 7% harvest blue crab away from their property. It was estimated that 279,434 pounds of blue crabs were harvested in 2002 by coastal waterfront landowners. From 2002 to 2008, the NCDMF surveyed RCGL holders estimated an average of 587,172 pounds were harvested annually. In the fall of 2010 the NCDMF began surveying CRFL holders that indicated they harvested crabs. From 2011 to 2016, an estimated average of 97,774 blue crabs (approximately 32,591 pounds) was harvested annually.

Summary of Economic Impact of Recreational Fishing

The economic impact estimates presented for blue crab recreational fishing represent the economic activity generated from trip expenditures. It should be noted that not included in these estimates, but often presented in NCDMF overall recreational impacts models, are the durable good impacts from economic activity associated with the consumption of durable goods (e.g., rods and reels, other fishing related equipment, boats, vehicles, and second homes).

Overall, the economic impact of blue crab harvesting is significantly smaller than the commercial impact, with an estimated economic impact of $2.7 million in 2016 (Table 21). Which is reflective of the lack of a sport fishery, as well as its importance to the commercial seafood trade. The majority of recreational blue crab trips occur onshore (not requiring a vessel), and therefore often provide fewer market-level benefits, with the only inputs being gear and bait purchases, travel to site, and permitting. Of those trips that occur in a vessel, these occur near or inshore, and require less gear, fuel, and other related expenditures.

With the proposed management changes, there will be little effect felt on the recreational fishery from an economic standpoint. Moving forward, there may be economic gains in the recreational sector, as the proposed changes may improve abundance over time, leading to better access and interest for recreational blue crab harvest.

Table 21 Economic impacts associated with recreational blue crab fishing, 2010-2016.

Year	Trips[1]	Estimated Expenditures (thousands of dollars)[2]	Jobs[3,4]	Income Impacts (thousands of dollars)[4]	Value-Added Impacts (thousands of dollars)[4]	Output Impacts (thousands of dollars)[4]
2010	5173	719,703	7	204,531	318,772	564,174
2011	24818	3,595,514	33	1,007,600	1,566,718	2,769,964
2012	26863	3,969,593	36	1,109,089	1,724,489	3,052,227
2013	30732	4,698,622	41	1,275,287	1,973,401	3,497,781
2014	23381	3,583,168	31	992,335	1,538,414	2,732,729
2015	27963	4,289,639	37	1,176,955	1,822,986	3,255,294
2016	23325	3,629,892	31	1,001,615	1,550,695	2,748,555

[1] Trip estimates from Coastal Recreational Fishing License (CRFL) surveys
[2] Estimated expenditures include only trip expenditures.
[3] Includes full time and part time jobs
[4] Economic impacts calculated using the NCDMF coastal recreational fishing economic impact model and IMPLAN economic impact modeling software. Economic impact estimates are for the state economy of North Carolina.

FISHERY IMPACT ON THE ECOSYSTEM

HABITAT

Bottom disturbing fishing gear can impact ecosystem function through habitat degradation, bycatch, and derelict gear. The primary gear used in the blue crab fishery is crab pots, although crab trawls and crab dredges are also used making up a small portion of the fishery. Other gears used include trot-lines, hand-lines, and dip nets but ecosystem impacts are considered minimal due to the construction of the gear and fishing methods.

GEAR IMPACTS TO HABITAT

While crab pots are the most abundant gear used in the fishery, their impact on habitat (on an individual pot basis) is relatively low due to their small footprint, light weight, open structure, and location placed. Physical impacts increase if pots are placed directly on structured habitat for prolonged periods. A study conducted in North Carolina found that prolonged deployment or movement of crab pots on marsh vegetation, which can occur when gear is lost or abandoned, significantly reduced stem height and density after being present eight weeks (44). The cumulative loss of wetlands could degrade the ecosystem services they provide, such as nursery habitat, pollutant removal, and shoreline stabilization (45). Fortunately, Uhrin and Schellinger (44) found that when pots were removed, the vegetation recovered after approximately four months. In contrast, damage to submerged aquatic vegetation (SAV) from derelict pots is potentially greater and more permanent due to sedimentation in the pot, scour around the edges, and additional uprooting of grass along a path if dragged across the bottom during storms (46; 47; 48). Submerged aquatic vegetation is an important fish habitat consisting of underwater rooted vascular plants and is defined in rule [NCMFC Rule 15A NCAC 03I .0101 (4)(i)]. The extent that pots are interacting with and damaging SAV beds in NC is not known. Where resources are limited, derelict gear cleanup should prioritize removal of pots on or near SAV (44). Zinc plates used to minimize rusting on crab pots is a habitat concern since these may contribute to heavy metal pollution in estuarine systems (49). Research is needed to validate this potential impact.

With an estimate of over one million crab pots deployed annually in North Carolina (38), crab pots are potentially impeding ecological function of soft bottom habitat as a migratory corridor. Inlets, a type of soft bottom, are a critical bottleneck for mature females as they move through the lower estuary to spawning areas. The five most northerly inlets in North Carolina are designated as Crab Spawning Sanctuaries, with seasonal gear restrictions to aid migration and spawning. The remaining 16 inlets do not have similar protection. The protective effectiveness of the existing sanctuaries and associated rules continues to be a research need. Eggleston et al. (50) found female blue crab abundance to be no different inside the crab spawning sanctuaries than 1 km to 2 km outside the boundaries. Modification of Crab Spawning Sanctuary boundaries or rules could potentially improve their effectiveness.

Crab trawls and crab dredges are mobile bottom-disturbing fishing gear. Reviews of fishing gear impacts have categorized crab dredging and crab/shrimp trawling as having severe and moderate impacts to SAV, respectively (49; 51; 46; 45). Crab dredging is particularly damaging due to the long teeth that are designed to dig deep into the sediment, uprooting and destroying above and below-ground plant structure. Crab trawls can also cause extensive damage to SAV from trawl doors that dig into the sediment and uproot plants. Dragged chain can cut or damage above-ground leaves, but this does not always result in complete mortality (46). Both dredges and trawls can elevate turbidity, reducing water clarity needed for SAV growth and survival. Loss and damage to SAV is detrimental to the estuarine system due to the large diversity of fish and invertebrates that are dependent on it as a nursery and foraging area (45). Over 34 economically important fish species, and 150 other fish and invertebrates have been documented in SAV in North Carolina. Additionally, SAV improves water clarity, cycles nutrients, and sequesters carbon. More information on the ecological value, distribution, and condition of SAV in North Carolina can be found in the Coastal Habitat Protection Plan (45).

Crab trawling and crab dredging can cause structural damage to oyster reefs (52). Dredging reduces the height of subtidal reefs, scatters and removes shell substrate needed for oyster recruitment, and destabilizes the reef structure (53; 54) . Subsequently, available substrate for oyster recruitment and structural habitat complexity for refuge and foraging are reduced. The lower profile of the disturbed shell bottom is more susceptible to sedimentation, disease, and hypoxia. Structurally complex oyster reefs are critical habitat for blue crab, as well as over 40 economically important species, and numerous prey species. Oyster reefs improve water quality, stabilize bottom sediment, and reduce shoreline erosion (45). It is estimated that over 90% of subtidal oyster reefs have been lost since the late 1800s. Historical and more recent losses of oyster reefs in the Pamlico Sound region are summarized in NCDMF (52) and NCDEQ (45). Historical losses are attributed primarily to overharvesting from oyster dredging and have not recovered due to disease, water quality issues, and lack of hard substrate for recruitment. Significant resources are being invested in oyster restoration, so any fishery activity that impacts shell bottom would be counterproductive to those efforts.

Because of the documented impacts to SAV and shell bottom, dredging and trawling are primarily restricted to soft bottom habitat. While soft bottom habitat is more dynamic and adapted to disturbance, productivity can still be impacted. Dragging gear over the bottom reduces small scale habitat complexity of soft bottom structure by removing or damaging scattered epifauna such as sponges, removing benthic invertebrates that produce burrows and pits such as tube worms, and smoothing of features such as sediment ridges and ripples (55; 51) . Reduced structural complexity and increased turbidity from frequent trawling can reduce feeding success of filter feeding invertebrates due to gill clogging or can increase predation by exposing organisms previously buried and reducing cover (55). In a review of gear impacts by Johnson (13), toothed dredging activities in soft bottom habitat appear to have a significant physical impact on the benthic organisms and topography in the dredge path, but there were few long-term impacts. Most studies reported recovery of taxa and topography in three to six months. Impacts from crab trawling are similar or somewhat more severe to those reported for shrimp trawling since crab trawls use heavier chain and doors that can dig deeper into the sediment.

Studies that have examined the effects of crab and shrimp trawling on turbidity and productivity of shallow estuarine soft bottom habitat have shown little sustained negative or positive impacts on primary or secondary productivity. Suspended sediment significantly increased in the water column up to three times greater than pre-trawling conditions but redeposited at varying rates, depending on the substrate and currents (56; 57; 58). Sedimentation in North Carolina studies varied between 15 minutes and 24 hours, occurring faster in areas with sandy sediment, low currents and calm winds. Studies on the effects of trawling on primary production found mixed results, with benthic microalgae reduced in one study but not others (59; 57; 60). One explanation for low impacts from gear disturbance is the bottom in North Carolina's shallow estuarine system is frequently disturbed by wind in and consequently the benthic community is adapted to bottom disturbance.

Habitat impacts from crab dredging and trawling are limited by the relatively low amount of fishing effort with these gears. From 2014 to 2016, the number of crab trawl trips ranged from 180-470 per year, and the number of crab dredge trips ranged from 3-14 per year. In contrast there were 4,598-7,468 shrimp trawl trips during this same period. Crab dredge use is limited to an area of primarily soft bottom habitat in northern Pamlico Sound (approximately 86,900 acres) and is opened by rule from January 1 to March 1 [NCMFC Rule15A NCAC 3L .0203]. Some SAV and subtidal shell bottom may also occur in or near this area. Although the low fishing effort results in a small area of impact due to crab dredging, the destruction potential of the gear to all habitats, combined with spatial preference for harvesting mature female blue crabs, results in a net adverse impact to blue crabs from the use of this gear. Crab trawl use occurs in areas open to trawling predominantly in Pamlico Sound and adjacent estuarine rivers. There is potential for crab trawling to occur over SAV in the western portions of the Pamlico system, although most SAV occurs in water less than 1 m, where it is too shallow for trawl operation. There is also potential for crab trawling to occur over or near low profile oyster bottom, potentially damaging the integrity of the habitat and increasing turbidity.

BYCATCH AND DISCARDS

Undersized and Other Non-Legal Blue Crabs

As of June 2016 through the revision to Amendment 2, hard crabs must measure five inches from point to point on the carapace for males or be in the mature stage for females to be considered legal for harvest. Additionally, mature females possessing a dark sponge (brown and black stages) may not be kept between April 1st and April 30th each year. A culling tolerance allows no more than five percent by number of any combination of undersize males, and immature or dark sponge bearing females to be possessed. Any hard blue crab not considered legal for harvest must be immediately returned to the water from where they were taken. Crab pots may attract and capture blue crabs which are not legal for harvest and their chance of becoming injured and dying increases the longer they are trapped (61).

Cull (escape) rings can be mounted to crab pots to help undersize crabs escape, while retaining legal sized catch. Both the location and size of the cull rings can affect the odds of undersized crabs escaping (62; 63). As of January 2017, implemented by the revision to Amendment 2, both commercial and recreational hard crab pots in North Carolina are required to have three escape rings with an inside diameter no smaller than two and five-sixteenths inches. Two of these escape rings must be mounted on opposite outside panels, and one must be mounted in a corner close to the bottom of the pot, or upper chamber if present. These requirements apply statewide, except NCMFC rule 15A NCAC 03J .0301(g) allows for specific areas in Pamlico Sound and the Newport River as exceptions in NCMFC rule (15A NCAC 03R .0118) and are intended to reduce the capture and mortality of undersized hard crabs.

Other Species

Crab pots are the predominant gear in the blue crab fishery, with crab trawls and crab dredges making up a very small percentage of the total gear used. Both finfish and shellfish species may be caught as bycatch in crab pots. This bycatch may be retained and landed as incidental catch or discarded as a result of economic, legal, or personal considerations.

Statewide annual landings of the marketable portion of the incidental bycatch from hard crab and peeler pots, as recorded by the NCDMF Trip Ticket Program single gear trips, has averaged 57,343 pounds since 2007 and represents .02% of the total landings from this gear. Seven species or species groups comprise over 90% of all incidental catch landed from hard crab and peeler pots: catfish 36% (Ictaluridae), oyster toadfish 19% (*Opsanus tau*), whelks 18% (*Busycon spp., Busycotypus spp.*), Florida stone crabs 10% (*Menippe mercenaria*), southern flounder 5% (*Paralichthys lethostigma*), northern puffer 2% (*Sphoeroides maculatus*), and spotted seatrout 2% (*Cynoscion nebulosus*) (Figure 7).

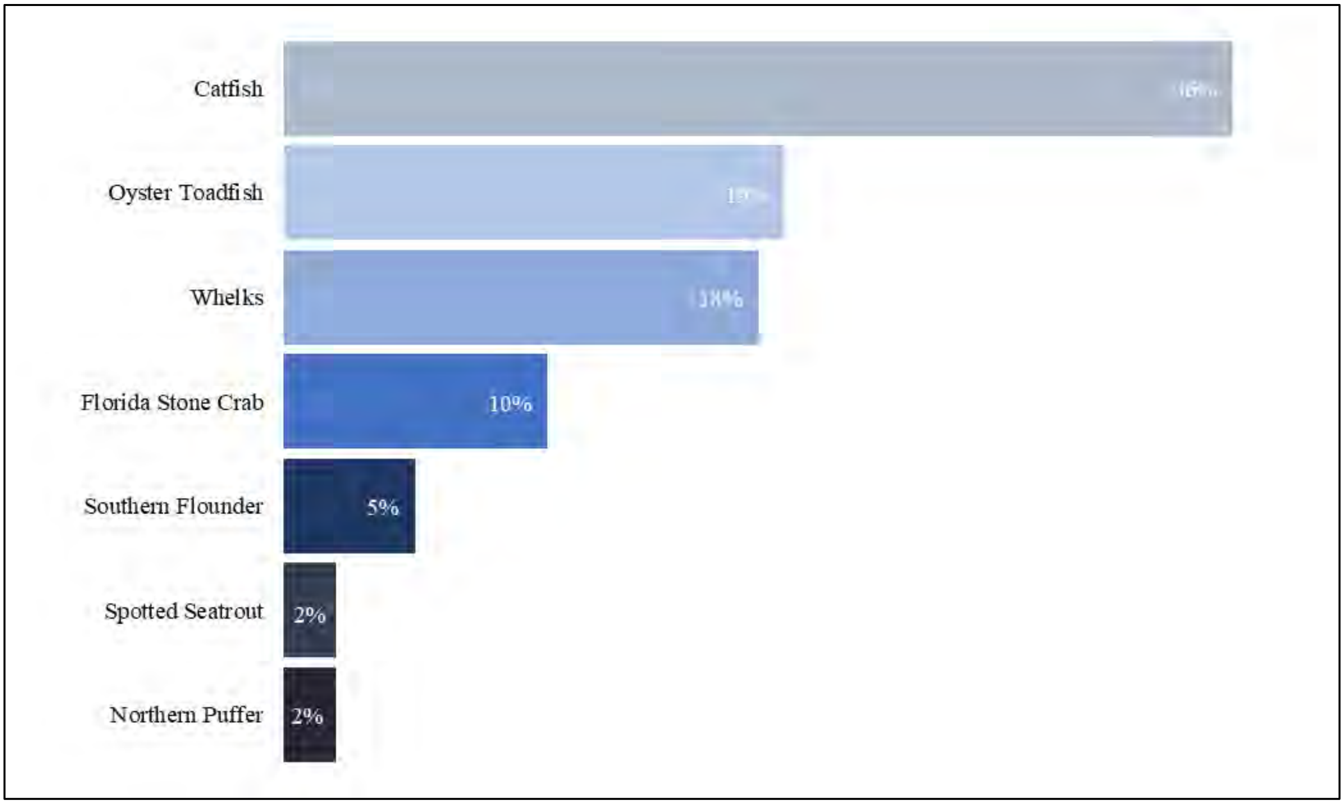

Figure 7 The percentage each of the top seven species (or species groups) contributes to all incidental catch landed from hard crab and peeler pots between 2007 and 2016.

Bycatch and discards have been examined in the North Carolina blue crab pot fishery. Doxey (64) examined bycatch in both hard crab and peeler pots in the Neuse River. Flounder (*Paralichthys* spp.) accounted for 34% of the total hard crab pot bycatch, and other important species reported captured in this this study include spot (*Leiostomus xanthurus*), spotted seatrout, gray trout (*Cynoscion regalis*), red drum (*Sciaenops ocellatus*), and diamondback terrapin (*Malaclemys terrapin*). The catch-per-unit-effort of all bycatch species averaged 0.007 organisms per hard crab pot, and of the captured bycatch in hard crab pots, 70% were released alive, 22% were either dead or injured, and 8% was used for bait. Thorpe et al. (65), investigated bycatch in hard crab pots in locations in Brunswick and Carteret Counties. Sub legal southern flounder were the most commercially and recreationally important fish species caught as bycatch in this study, with other finfish bycatch including, spadefish (*Chaetodipterus faber*), oyster toadfish, and pinfish (*Lagodon rhomboids*). Other species captured included diamondback terrapins, as well as channeled whelk (*Busycotypus canaliculatus*) and Florida stone crabs, which are two important shellfish species caught as bycatch and landed as incidental catch during this research.

NCDMF (10) evaluated the ability of multiple finfish species to escape both control crab pots (without escapement "cull" openings) and crab pots with escapement openings, over a 24-hour period. White catfish (*Ameiurus catus*), black drum (*Pogonias cromis*), and white perch (*Morone Americana*) had the highest escapement rates, and southern flounder had the lowest rate. Overall escapement from the control pots was very good and increasing the size of the escapement openings appeared to enhance escapement efficiency for finfish species.

Protected Species

Protected species is a broad term that encompasses a range of organisms that are identified by federal or state protective statutes, such as the Endangered Species Act (ESA), Marine Mammal Protection Act (MMPA), and Migratory Bird Treaty Act. Of the many federal and state protected species, whales, bottlenose dolphins, sea turtles, and diamondback terrapins are considered to have the greatest potential to interact with the North Carolina blue crab fishery. Baited crab pots may attract protected species which can possibly get entangled in the buoy lines or entrapped. Although crab trawls are an active gear that focus on the estuarine bottom and are restricted to areas without submerged aquatic vegetation, interactions with protected species are possible. Crab dredges are an active bottom gear restricted to a small, specific area of Pamlico Sound and therefore are less likely to interact with protected species than the other two gears mentioned.

Since the 1970s, the NCDMF has been proactive in developing ways to minimize impacts to threatened and endangered marine species. The NCDMF works closely with the National Oceanic and Atmospheric Administration (NOAA) Fisheries and other state and federal agencies to develop regulations that minimize impacts to protected species and still allow for economically important fisheries.

Marine Mammals

North Carolina has two species of baleen whales that traverse the state during their annual migration. These are the North Atlantic right whale (*Eubalaena glacialis*) and the humpback whale (*Megaptera novaeangliae*), both of which are protected under the MMPA and have been designated endangered under the ESA. Ship strikes pose a threat to many baleen whales, particularly the critically endangered North Atlantic right whale. Entanglement in various types of fishing gear is an additional threat to many species of whales. The humpback is one of the most abundant whale species off the North Carolina coast and one of the most often affected in entanglements in this state (38).

Bottlenose dolphin (*Tursiops truncatus*) are occasionally captured or entangled in various kinds of fishing gear. Bottlenose dolphin carcasses that displayed evidence of possible interaction with a trap/pot fishery (i.e., rope and/or pots attached, or rope marks) have been recovered by the Marine Mammal Stranding Network between North Carolina and the Atlantic coast of Florida (38).

The North Carolina blue crab fishery has been categorized as a level II commercial fishery by the federal government in regard to the MMPA, or as only having occasional interactions with marine mammals (66). Most of the crab pot effort in the North Carolina blue crab fishery is located within the sounds, rivers, and estuaries of the state, with a very small portion occurring in the nearshore coastal ocean. As a protection for marine mammals in North Carolina ocean waters, fishermen setting any type of pots in nearshore waters (inside the 100-foot contour) are required to use sinking lines and break-away devices known as “weak links”. Weak links in this nearshore area off North Carolina must have a breaking strength of no greater than 600 lbs., while beyond the 100-foot contour to the eastern edge of the Exclusive Economic Zone (EEZ), a breaking strength of no greater than 1,500 lbs. is required (67). In state inshore waters, NCMFC Rule 15A NCAC 03J .0301 (k) makes it unlawful to use pots to take crabs unless the line connecting the pot to the buoy is non-floating to reduce interactions with boaters, which also reduces the potential for marine mammal entanglements in this gear.

Sea Turtles

Five species of sea turtles occur in North Carolina, Kemp's ridley sea turtle (*Lepidochelys kempii*), hawksbill sea turtle (*Eretmochelys imbricate*), leatherback sea turtle (*Dermochelys coriacea),* green sea turtle (*Chelonia mydas*), and the loggerhead sea turtle (*Caretta caretta*). Loggerhead and green sea turtles are federally listed as threatened, while the others are listed as endangered.

Sea turtles may be attracted to baited crab pots as a source of food. Sea turtle entrapment in a pot or trap is not likely, but entanglement in the buoy lines of pots has been documented (68). There have been documented cases of loggerhead sea turtles entangled in crab pot gear in North Carolina, which lead to the death of the turtle (38). As sea turtles attempt to obtain either bait or crabs from crab pots, significant damage to the gear can occur. Sea turtles reportedly overturn the pot and bite the bottoms and sides, resulting in torn mesh and crushed pots. This damage also results in higher operating costs and decreased catches for crab fisherman. Plastic bait well covers have been shown to significantly reduce pot damage from loggerhead turtles and result in higher average blue crab catch when used on typical crab pots (69).

Diamondback Terrapins

Diamondback terrapins are a relatively small turtle species found throughout North Carolina's estuarine coastal waters. This species is listed by the North Carolina Wildlife Resources Commission (NCWRC) as a North Carolina species of "Special Concern" statewide, and as a Federal "Species of Concern" in Dare, Pamlico and Carteret counties in NC. However, these designations do not specifically provide any special state or federal protection.

Populations of diamondback terrapins have declined throughout their range and their incidental capture in crab pots may account for more adult diamondback terrapin mortalities than any other single factor (70). Diamondback terrapins are long-lived, late to mature, and display relatively low fecundity (71). Delayed sexual maturity and low reproductive rates, coupled with long life spans and strong site fidelity, are characteristics that make this species especially susceptible to substantial population declines or even local extinction from incidental bycatch and death of a relatively low number of individuals from the population annually (72; 73).

Several factors have been identified in determining the likelihood of diamondback terrapin bycatch in crab pots where crab fishing activities and diamondback terrapin occurrence overlap, and taking these factors into consideration, diamondback terrapin mortality from incidental bycatch in crab pots can be mitigated in North Carolina. Each of these limiting factors and its relationship to diamondback terrapin catchability in crab pots, as well as establishing a framework to employ terrapin excluder devices in the blue crab fishery is discussed in the issue paper: Appendix 4.5: Establish a Framework to Implement the Use of Terrapin Excluder Devices in Crab Pots.

Derelict Gear

Derelict gear or “ghost pots” are crab pots that either through abandonment or loss (buoy lines cut by boats, storm events, etc.) continue to catch crabs and finfish. The long life of vinyl coated crab pots, and their ability to continue to capture blue crabs and finfish, raises concern about their impact to the ecosystem if they are lost or abandoned.

The number of crab pots used in the North Carolina commercial blue crab fishery is considered to be over one million, with an annual hard crab pot loss estimate of 17% (38). A ghost pot study conducted by NCDMF estimated the average yearly catch of legal blue crabs in a single ghost pot to be 40.4 individuals, with an average mortality rate of 45% (10). Voss et al. (74) conducted a study examining derelict crab pots in North Carolina and found that 41% of retrieved pots contained bycatch, 37% were capable of trapping organisms, and the pots retrieved were estimated to have been in the water for an average of approximately 2 years. In that study, a total of 18 species were identified as unable to leave the pot, and likely to suffer mortality. The most abundant of these species which are also of management interest to NCDMF included: blue crab, Florida stone crab, sheepshead (*Archosargus probatocephalus*), black sea bass (*Centropristis striata*), and diamondback terrapin.

Since 2003, the NCDMF Marine Patrol has been actively removing derelict crab pots from state waters during the winter clean up period. Between January 15 and February 7 each year, all pots are required to be removed from the water. Any crab pots found during this time are considered lost or abandoned and removed from our waterways. The NC Coastal Federation began a pilot study in 2013 to employ commercial fisherman to collect derelict crab pots in the northern region of the state. In 2017 this cooperative cleanup effort was expanded statewide, resulting in over 35,000 ghost pots being removed from North Carolina waters by the NCDMF Marine Patrol and commercial waterman over the last fourteen years (Table 22).

Table 22 Number of derelict crab pots removed each year during the crab pot cleanup period between January 15 and February 7. The northern area is approximately from the Virginia state line to Ocracoke, the central area is from the Pungo River to Emerald Isle, and the southern area is from Cape Carteret to the South Carolina State line.

Year	Northern Area	Central Area	Southern Area	Total
2003	4,047	900	127	5,074
2004	7,708	527	108	8,343
2005	2,168	N/A	N/A	2,168
2006	1,117	391	24	1,532
2007	896	135	24	1,055
2008	757	190	110	1,057
2009	589	257	60	906
2010	570	154	24	748
2011	656	183	141	980
2012	684	160	295	1,139
2013	451	445	545	1,441
2014	364	64	226	654
2015	1,004	149	155	1,308
2016	753	80	70	903
2017	2,836	1,219	249	4,304
2018	2,245	1,004	247	3,496

ECOSYSTEM IMPACTS ON THE FISHERY

As previously described in the biological profile section, blue crabs migrate throughout the estuary and nearshore ocean, utilizing a variety of habitats along the way. Submerged aquatic vegetation (SAV), wetlands, and shell bottom are particularly important for refuge and foraging. Inlets are a critical area of soft bottom for life cycle completion since planktonic megalopae must pass through the inlets to settle into estuarine nursery habitat, and conversely, sponge crabs must move to the inlet system and nearshore ocean to spawn. Since blue crabs depend on multiple habitats throughout the coastal system, degradation of any single habitat, as well as disruption of migratory connectivity, could negatively affect growth and survival of blue crabs. However, the high mobility of blue crabs within the system provides overall resilience to degradation in any one localized area.

WATER QUALITY DEGRADATION

Growth and survival of blue crabs is maximized when water quality parameters, such as temperature, salinity, and oxygen, are within optimal ranges. These parameters have been identified by life stage in the biological profile and other documents [Table 23; (75; 76; 45)]. When conditions are outside the suitable range for extended periods, blue crabs can be adversely impacted. Rapid change in environmental parameters typically associated with large freshwater influx from rain events or hurricanes, triggers blue crab movement and can temporarily alter the spatial distribution of blue crabs on a large scale (77; 78).

Table 23 Water quality parameters required by and habitats associated with different life stages of blue crab. No documented data where blank (75; 79; 76; 80).

Life Stage	Salinity (ppt)	Temperature (C)	DO (mg/L)	Associated Habitats
Adult	0-30	5-39	>3	Entire estuary
Spawning Female	23-28	19-29		Inlet and Ocean
Larvae	>20	16-30		Inlet and Ocean
Juveniles	2-21	16-30		Wetlands, SAV, Shell Bottom, Soft Bottom

Hypoxia

Low dissolved oxygen (hypoxia) can cause sublethal stress or mortality in blue crabs. Sublethal stress may alter feeding and growth rates, behavior, and vulnerability to predators (76). Where blue crabs could not escape hypoxic waters, mortality occurred when oxygen levels were below 3.0 mg/L for one to three days; mortality occurred within three hours when less than 0.5 mg/L (75). While adults require 3-5 mg/L DO, juvenile blue crabs may be less tolerant of hypoxia than adults (81) and may require more than 5 mg/L. Blue crab tolerance to hypoxia decreases with increasing temperature (82). A study showed blue crabs collected from the Neuse River Estuary, where frequent hypoxia occurs, had a hypoxia-tolerant structure and survived longer exposures to hypoxia than those collected from waters without this issue (Bogue and Back Sounds; (83).

Hypoxic events have resulted in locally elevated mortality among crabs constrained by capture in pots in the Chowan, Neuse, and Pamlico river systems ((84); T. Pratt, personal communications). Neuse River crab fishermen indicated they would move pots and alter fishing frequency during low oxygen events to avoid blue crabs dying in pots. Adjustments in fishing activity were based on changing environmental observations and catch rates (85). Low oxygen events occur naturally when the water column becomes stratified for a long period, particularly during summer in deeper areas. High nutrient levels and low flushing increase a waterbody's susceptibility to hypoxia and subsequent fish kills (45). Most nutrient pollution in the Albemarle-Pamlico system has been linked to agriculture (86; 87; 88). Other sources of nutrients are stormwater runoff from developed land and point source discharges of treated wastewater. Runoff transports nutrients, sediment, toxins, and pathogens into surface waters, and can lead to rapid changes in salinity and temperature (89; 45).

Toxins

Chemical contaminants in the water and soft bottom can adversely impact blue crabs directly by causing mortality, or indirectly by altering endocrine related growth and reproductive processes. Acute toxicity of a variety of pesticides to blue crab were determined by the US Environmental Protection Agency (USEPA) and summarized in Funderburk et al. (75) and Osterberg et al. (90).

These studies stated the presence of any pesticide had a detrimental effect and increased mortality rates on larval and juvenile blue crabs, particularly after molting. Many factors affect a chemical's toxicity to marine organisms. Eggs and larvae are generally more sensitive to toxins than adult and juvenile life stages as they have more permeable membranes and less developed detoxifying systems (75; 91; 92).

Endocrine disrupting chemicals (EDCs) are hormonally active chemicals that alter growth, development, reproductive, or metabolic processes adversely affecting the organism, its progeny, and/or stock viability (93; 92; 94). Endocrine disrupting chemicals include some industrial chemicals, pesticides, metals, flame retardants, plasticizers, disinfectants, prescription medications, pharmaceuticals, and personal care products. These contaminants have been found in North Carolina waters (95; 96) . Endocrine disrupting chemicals can cause mortality or sub-lethal stress on shellfish and crustaceans, depending on the concentration and extent of exposure. Flame retardants (polybrominated diphenyl ethers), which have widespread occurrence in surface waters, have been linked to inhibiting molting in blue crabs (97).

Many insecticides function by being endocrine disrupters, targeting disruption of larval development to adult (e.g. flea medication, fire ant treatment). Successful metamorphosis of larval mud crab, *Rhithropanopeus harrisii*, was shown to be negatively impacted by this type of insecticide (98). The study suggested species with more complex metamorphic processes, such as crabs, are more sensitive to compounds acting as endocrine disruptors. In coastal NC, insecticides are often used in agriculture operations. Osterberg et al. (90) conducted research on the toxicity of four commonly used insecticides to blue crab at different life stages. Results found that while all were toxic to megalopae and juveniles, lamda-cyhalothrin and Karate (the commercial product name) were the most acutely toxic compounds. They calculated that pesticide overspray into shallow ditches and creeks approximately 0.2-0.4 m deep or less would have concentrations sufficient to kill more than 50% of juvenile blue crabs within the affected waters. Acephate and Orthene, other common insecticides, had significantly lower toxicity, suggesting the use of certain insecticides could potentially be less detrimental to blue crabs.

Mass mortality of peeler blue crabs has been reported in the Pamlico estuary. The Department of Agriculture, Pesticide Division (DAPD) investigated a 2012 event reported to the Division of Water Resources and Marine Fisheries. The cause of the kill was found to be the pesticide bifenthrin which is commonly used with cotton and considered highly toxic to invertebrates. Rain following the spraying of adjacent cotton fields, carried runoff from the fields to the canal where the raceway intake occurred. The DAPD rules prohibit aerial application of pesticides under conditions likely to result in drift to non-target areas. However, drift of chemicals into surface waters does occur at times. Deposition of pesticides labeled toxic or harmful to aquatic life is not permitted in or near waterbodies. However, chemicals applied on land can be carried by stormwater runoff across land and ditches into surface waters. In the 2012 incident, the pesticide application did not violate label application directions, but there were some best management practices that could have been followed to minimize impacts. After the kill, the NCMFC's Crustacean Advisory Committee requested the division look into this. The topic was discussed by the NCMFC's Habitat and Water Quality Advisory Committee and DAPD staff spoke about the process and the specific incident. As a result of the meeting, the DAPD staff offered to increase outreach and technical assistance to farmers and additional training to pesticide applicators. Information was included on the NCDMF website and in dealer newsletters regarding what to do if a blue crab kill occurs.

Microplastics in the water column are a growing concern for aquatic organisms, including crustaceans (99). Of the numerous species documented to have ingested microplastics (pieces < 5 mm in size), bivalves and crabs are especially vulnerable (100). Microplastics enter crabs through the gills or gut, negatively impacting oxygen consumption and ion exchange. The properties of the plastics allow for adsorption of organic pollutants, toxins, and heavy metals. Analysis of microplastics in Atlantic mud crab (*Panopeus herbstii)* and eastern oyster (*Crassostrea virginica)* in Florida found crabs had two orders of magnitude more pieces of microplastics per individual, primarily fibers than oysters (101). On average, the crabs had 4.2 pieces per individual and a mean of 20 additional pieces per individual temporarily entangled on exterior surfaces. In addition to blue crabs directly ingesting microplastics, they may accumulate them by forage on Atlantic mud crab or other species that previously ingested these plastics.

HABITAT DEGRADATION AND LOSS

As blue crabs migrate through the coastal ecosystem over their life cycle, they utilize many different habitats, including SAV, wetlands, shell bottom, and soft bottom. These habitats are described in detail in the NC Coastal Habitat Protection Plan (45) and shown in Figures 8 and 9. Portions of these habitats have been degraded or lost over time by a variety of anthropogenic sources (45), potentially impacting blue crab populations.

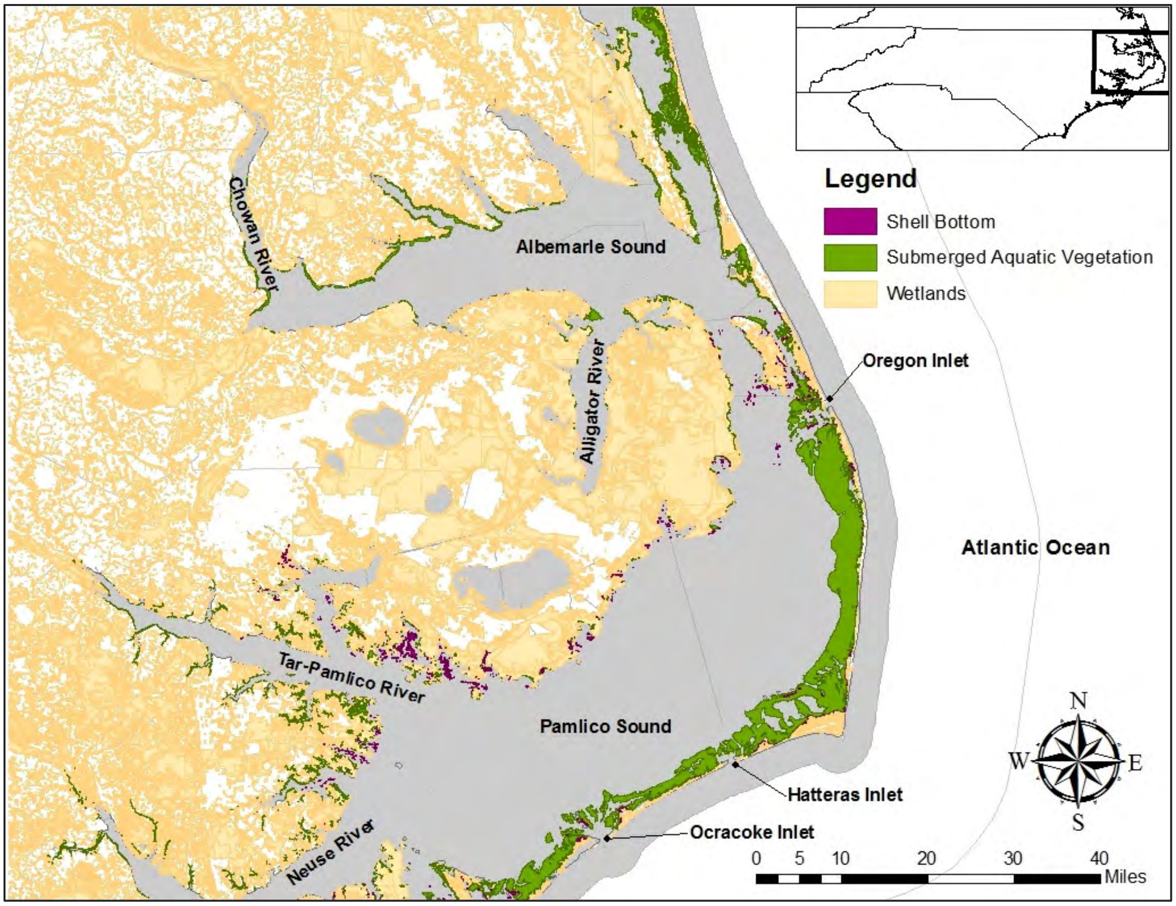

Figure 8 Location of mapped shell bottom, submerged aquatic vegetation, and wetlands – northern coast.

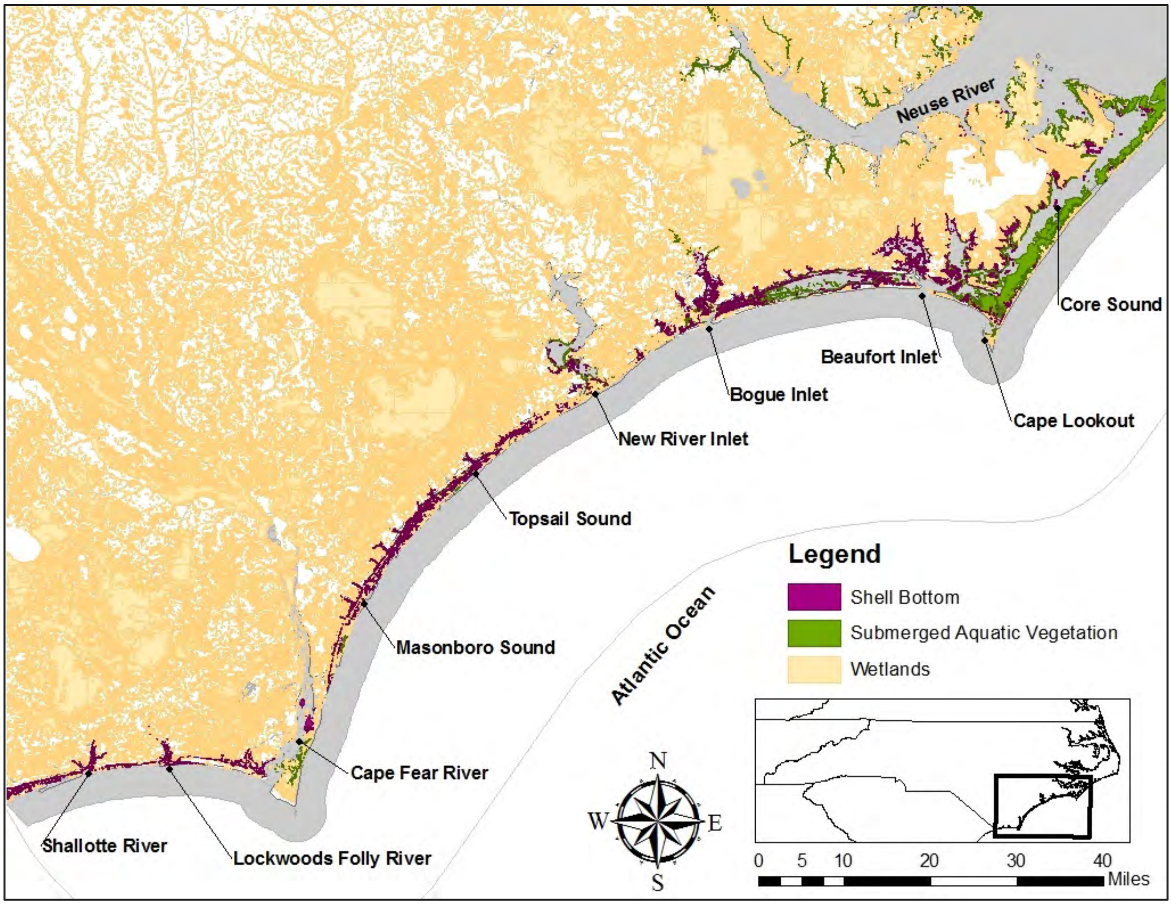

Figure 9 Location of mapped shell bottom, submerged aquatic vegetation, and wetlands – southern coast.

Submerged aquatic vegetation

The structural complexity of submerged aquatic vegetation (SAV) is critical habitat not only for blue crabs but over 150 species of fauna, including prey for blue crabs. Post-larval and early juvenile blue crabs (< 12 mm carapace width) use SAV for initial settlement and protection while they forage and grow. Adult blue crabs also use SAV for protection while molting and overwintering. In the Albemarle-Pamlico estuarine system, most initial recruitment of juvenile blue crabs occurs in SAV beds around inlets behind the Outer Banks. However, in years with large storm events, blue crabs disperse into lower salinity habitats where they recruit into marsh habitat (5). When SAV is lacking blue crabs are forced to recruit into other habitat structure, such as marsh (5), shell bottom (102; 103), detrital matter and woody debris (104).

Blue crabs have been shown to be more abundant in SAV than in shallow unvegetated estuarine bottoms in North Carolina and elsewhere (105; 106). Within SAV, juvenile crab density was documented to be greater where beds are large, continuous, and vegetated with dense, tall grass shoots (106; 107; 105; 108; 109; 5; 110). Using a habitat-specific demographic model to quantify the effects of habitat on population fitness, Ralph and Lipcius (111) found increased survival of age-0 blue crabs when vegetated habitats were present, which resulted in increased population growth rates.

As a primary producer, SAV takes up carbon dioxide and releases oxygen into surface waters. The plants stabilize sediment, and improve water clarity, which in turn enhances conditions for other habitats and organisms. Due to the important ecological functions provided by SAV to the ecosystem and multiple life stages of blue crab, reduced abundance or change in the distribution of SAV could negatively impact blue crab population. The 2016 CHPP summarizes known distribution, temporal change, and threats (e.g. reduced water clarity from stormwater runoff, wastewater discharges, dredging, bottom disturbing gear, etc.) for navigation and fishing) to SAV. In 2016, there were estimated to be at least 150,000 acres of SAV in NC. Historical change in extent has not been quantified but qualitatively known to have declined in some areas.

Wetlands

Like SAV, postlarvae and juvenile blue crabs use wetlands for foraging, refuge, and migration through the estuary (45). This includes detrital matter and woody debris from adjacent wetland vegetation, particularly in the Albemarle and Pamlico systems. Blue crabs utilize marsh edge and woody debris more than unvegetated bottom and occur more regularly in marshes with longer inundation periods (112; 113). They also use wetlands to a greater extent when SAV and oyster reefs are not present, such as in the lower salinity regions of river-dominated estuaries (12). Blue crabs in these lower salinity areas also have higher growth rates and lower predation than in the more saline waters (12). The NCDMF estuarine trawl survey data show blue crab is one of the dominant juvenile species in marshes and shallow tidal creeks (34, 114).

North Carolina's extensive estuary is rich in wetlands, with an estimated 3,759,700 acres within the coastal region (45). However, this is approximately half of what existed pre-1800s (115). While federal and state laws have greatly reduced dredge and fill impacts to wetlands, losses still occur on a smaller scale due development, navigational dredging, and erosion associated with wave energy and rising sea level (45).

Wetland loss lowers the habitat's capacity to support blue crabs, to trap and filter upland pollutants, and buffer storm events. Wetland losses associated with development and shoreline hardening reduce nursery habitat and food resources available for blue crab. Looking at the effect of land use change on fish abundance, Meyer (116) found a negative correlation between abundance of juvenile blue crabs and conversion of wetlands/undeveloped forest to agriculture/development (where the development change was greater than or equal to 12%). When assessing the effect of bulkheads and living shorelines on fish and invertebrates, Scyphers et al. (117) found living shorelines supported a greater abundance and diversity of aquatic life, with blue crabs being the most clearly enhanced (300% more abundant). Predation related mortality was significantly less at vegetated shorelines than at bulkheads or riprap (118).

Shell Bottom

Oyster reefs are used as nursery habitat for early juveniles and foraging grounds for adults (12; 109). In Pamlico Sound after initial settlement, juveniles undergo a secondary migration to shallow, less-saline waters in the upper estuaries and rivers of western Pamlico Sound (5) inhabiting oyster and wetland habitat. Blue crabs forage heavily on invertebrates and oyster spat in shell bottom (119; 120; 121). Shell bottom enhances conditions for other habitats used by blue crabs. Filter feeding shellfish improve water clarity conditions, benefiting SAV, and buffer wave energy along the shoreline reducing erosion of wetlands (122; 123; 45). For subtidal oyster reefs, the vertical height of the reef elevates oysters off the bottom, avoiding anoxic water and sedimentation and provides refuge for blue crabs during hypoxic events (121; 54; 124).

In North Carolina, shell bottom occurs on intertidal and subtidal bottom and both are used by blue crabs (122). Based on NCDMF's Bottom Mapping Program, there are approximately 21,220 acres of shell bottom habitat in coastal waters, excluding subtidal oysters in waters greater than 15' water depth (45). It is estimated that over 90% of the subtidal oyster habitat, primarily in the Pamlico Sound system has been lost (36). Loss was initially due to mechanical harvest of oysters in the early 1900s, followed by lack of recovery due to disease, continued harvest, and sedimentation. Current factors threatening subtidal oyster habitat are sedimentation and low DO (54; 125). Abundance of both intertidal and subtidal shell bottom habitat is limited by harvest and lack of hard substrate.

Inlets and Ocean Bottom

Adult female blue crabs migrate from brackish areas to high-salinity waters near ocean inlets to spawn from late spring to early fall (6). Connectivity between shell bottom, wetlands, and SAV throughout the estuary enhances the ability of blue crabs to forage and move through the system, particularly adult females migrating to their spawning grounds near inlets (126; 112).

Females rely on high-salinity cues to ensure eggs are released for development on the continental shelf. Ogburn and Habegger (127) used Southeast Area Monitoring and Assessment Program (SEAMAP) data from 1990-2011 to assess spawning habitat in the South Atlantic Bight. Using reproductive condition of mature females as an indicator of spawning, they found blue crabs spawned throughout the South Atlantic Bight and as far as 13 km offshore. In North Carolina, mature females were most abundant in the ocean in the summer, where approximately 84% had spawned and had only remnant eggs. Results of Ramach et al. (128) suggest inlets serve as migration corridors to the ocean where eggs are released and dispersed. Fishing effort on sponge crabs while migrating to and through inlet corridors for spawning could negatively impact the blue crab population.

HABITAT AND WATER QUALITY PROTECTION

Coastal Habitat Protection Plan

As noted earlier in the Introduction, the FRA statutes mandates the Department to prepare and periodically update the CHPP (G.S. 143B 279.8). The legislative goal for the CHPP is long-term enhancement of the coastal fisheries associated with coastal habitats. The plan provides a framework for management actions to protect and restore habitats critical to North Carolina's coastal fishery resources. There are three commissions that have regulatory jurisdiction over the coastal resources, water, and marine fishery resources including: Marine Fisheries Commission (NCMFC), Coastal Resources Commission (CRC), and the Environmental Management Commission (EMC). Habitat recommendations related to fishery management can be addressed directly by the NCMFC. Other habitat recommendations not under NCMFC authority (e.g. water quality management) can be addressed through the CHPP implementation process. The CHPP helps to ensure consistent actions among these three commissions as well as their supporting DEQ agencies.

The CHPP describes and documents the use of habitats by species supporting coastal fisheries, status of these habitats, and the impacts of human activities and natural events on those habitats. Fish habitat is defined as freshwater, estuarine, and marine areas that support juvenile and adult populations of economically important fish, shellfish, and crustacean species (commercial and recreational), as well as forage species important in the food chain (45).

The CHPP recommends that some areas of fish habitat be designated as "Strategic Habitat Areas" (SHAs). SHAs are defined as specific locations of individual fish habitat or systems of habitat that have been identified to provide critical habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity. Additionally, the CHPP focuses on the fish habitat and threats to the habitat. The process of identifying and designating SHAs was completed in 2018 with the approval of nominated SHAs by the NCMFC and field verification is underway. The NCMFC also has several rules in place that provide protection for blue crab habitat. Some rules prohibit bottom disturbing gear in specific areas, others designate sensitive fish habitat such as nursery areas and SAV beds, and with applicable gear restrictions (see Appendix 4.6). Descriptive boundaries are included under the 15A NCAC 03R rules. Figures 10 and 11 provide a visual representation of several rule categories of these habitat gear related rules.

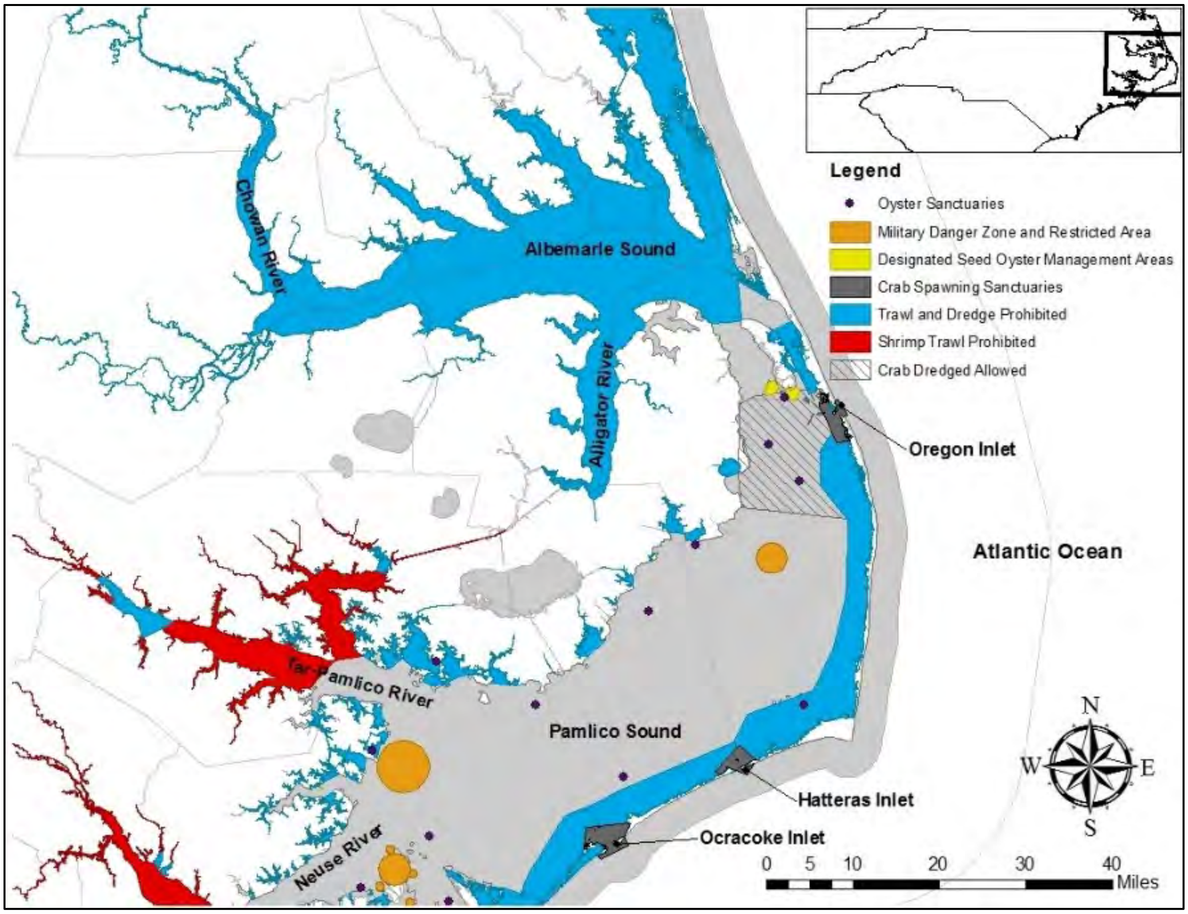

Figure 10 Estuarine areas where bottom disturbing gear is prohibited year-round or seasonally – northern coast.

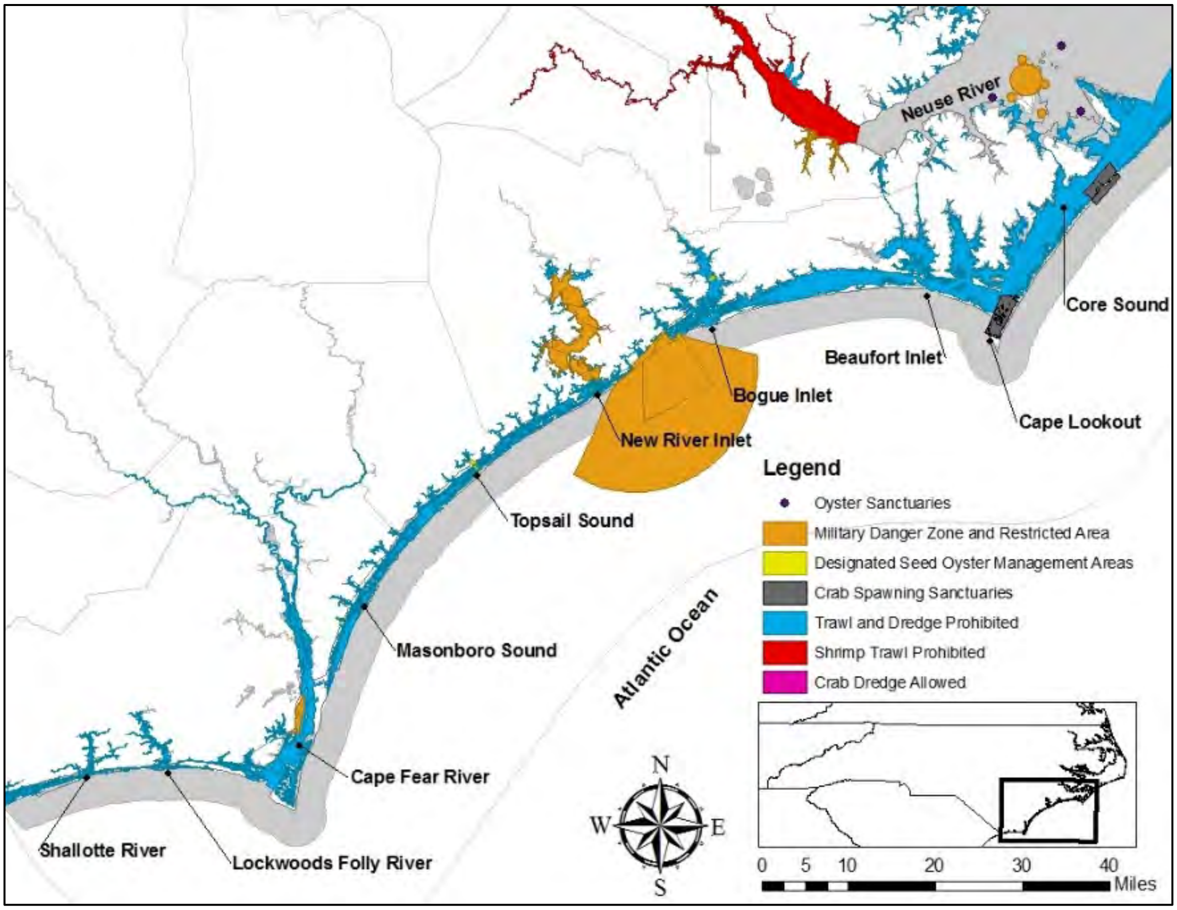

Figure 11 Estuarine areas where bottom disturbing gear is prohibited year-round or seasonally – southern coast.

Authority of Other Agencies

The North Carolina Department of Environmental Quality (NCDEQ) has several divisions responsible for rulemaking, permitting, certification, technical and financial assistance, planning, and monitoring activities which impact the coastal water quality or habitat. The Division of Coastal Management (DCM) is responsible for development permits along the estuarine shoreline in 20 coastal counties. Wetland development activity throughout North Carolina is primarily permitted through the US Army Corps of Engineers (USACE) and Division of Water Resources (DWR 401 certification program). The DWR has established a water quality classification and standards program for "best usage" to promote protection of unique and special pristine waters with outstanding resource values. Water quality standards and required management strategies for point and nonpoint sources differ by water quality classification such as High Quality Waters (HQW), Outstanding Resource Waters (ORW), Nutrient Sensitive Waters (NSW), and Water Supply (WS). Various federal and state environmental and resource agencies evaluate projects proposed for permitting and provide comments and recommendations to the DCM, DWQ, and USACE on potential habitat and resource impacts. The South Atlantic Fishery Management Council (SAFMC) has designated Essential Fish Habitat – Habitat Areas of Particular Concern (EFH-HAPC), for federally managed species, which can provide additional protection from development projects. Several habitat areas used by blue crab are designated as EFH-HAPC, including SAV and inlets. Habitat protection relies on enforcement, the efforts of commenting agencies to evaluate impacts, and the incorporation of recommendations into permitting decisions. Habitats are also protected through the acquisition and management of natural areas as parks, refuges, reserves, or protected lands by public agencies and/or private groups.

SIGNIFICANT WEATHER EVENTS

Significant weather events such as droughts and hurricanes can alter physio-chemical parameters and consequently influence the occurrence and distribution of fish and habitat in coastal North Carolina waters. Predominant winds, currents, and rainfall at a certain time of year highly affect annual recruitment success of larvae into nursery habitat. Although indirect, blue crabs are affected by natural disturbances of their environment. In particular, hurricanes can affect blue crab harvest in the short term by concentrating blue crabs in areas where they are vulnerable to fishing gear (129). Significantly lower statewide blue crab landings in 2000 compared to landings in the late 1990's were attributed to prolonged water quality degradation in the Pamlico estuarine system following the 1999 hurricanes (130). In 1989, 2000, and 2003, lower catch per unity effort of blue crabs from NCDMF's estuarine trawl survey coincides with hurricanes and the three highest years of rainfall from 1980 to 2016 (Figure 12).

If storms are too extreme, above normal freshwater input can lower salinity to the point that megalopae and juvenile blue crab mortality occurs, negating the benefits of increased settlement. However, not all the effects of hurricanes are detrimental. For example, peaks in post-larval blue crab settlement coincided with hurricane tracks coming from a southwesterly direction (4). A large ingress of post-larval blue crabs could make a significant contribution to the blue crab population.

Hurricanes can cause flooding, flush pollutants from the upper estuarine bottom, cause sedimentation over oyster reefs, and erode wetland shorelines. While these extreme weather events have always occurred, there is evidence that the frequency and severity of minor (non-storm event) nuisance flooding and hurricanes on the east and Gulf coasts are increasing (131; 132; 133).

Major droughts occurred in North Carolina during 2000-2002 and 2007-2008 (45). The drought of 2007-2008 was the worst in North Carolina since recordkeeping began on the subject in 1895. The cycle of flood and drought years has a significant impact on the water quality and SAV by reducing freshwater input and could be a factor in blue crab recruitment success (Figure 12).

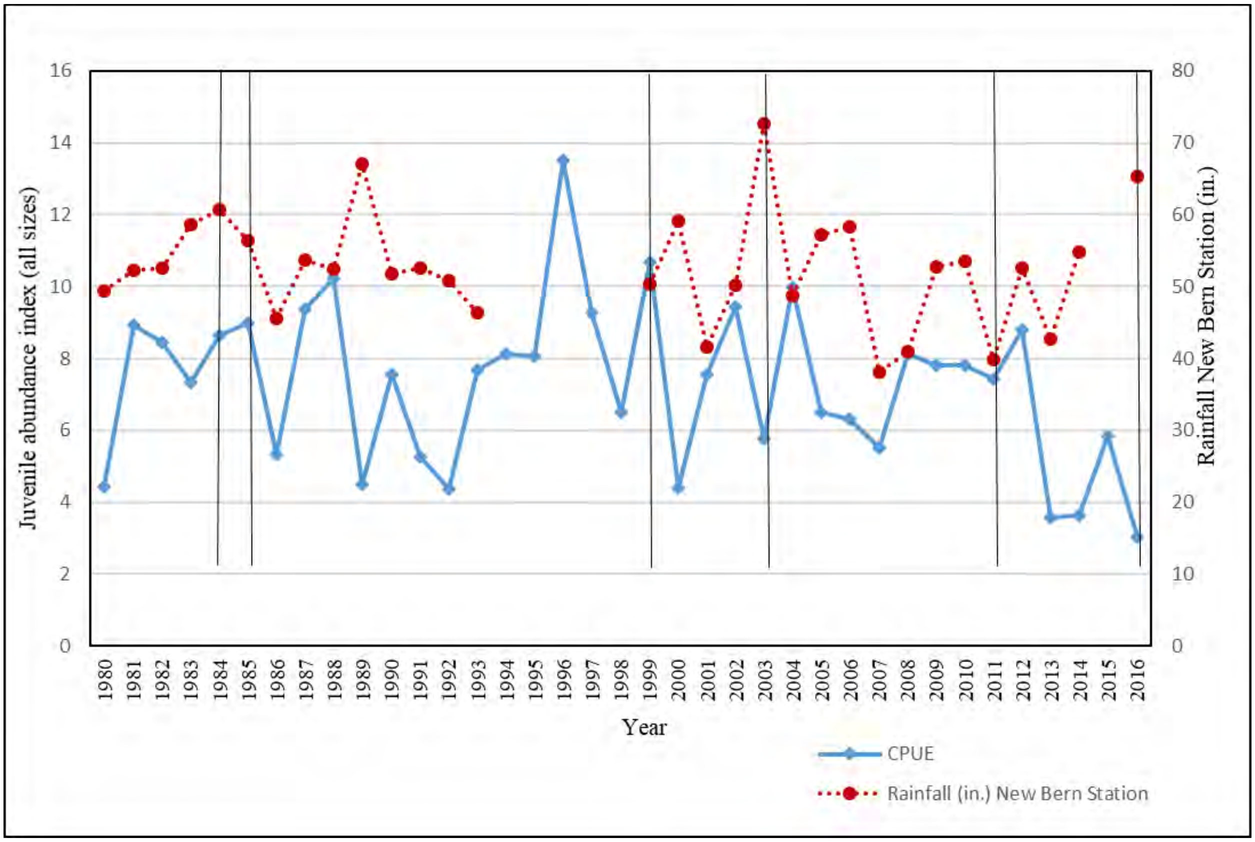

Figure 12 Annual rainfall from the New Bern station and juvenile abundance index (CPUE, all crab sizes) in New Bern, NC, 1980-2016. Source – National Weather Service and NCDMF data. Black vertical lines are years with major hurricane landfall events in NC.

A warming trend in air temperature is the primary driver of climate change that can alter the distribution and health of fish and their habitat. The 2014 National Climate Assessment summarizes observed and expected climate change and impacts regionally and overall in the U.S. (132). Of the potential changing oceanographic conditions under warming temperatures and rising sea level has large implications to North Carolina's estuarine system, including accelerated wetland loss, degraded water quality, loss of SAV, degradation of oyster reefs, and a more open estuary due to barrier island breaching (45). Crustaceans and mollusks are at risk due to increasing acidification of waters associated with increasing carbon dioxide levels. In Puget Sound, Washington, oyster hatcheries have observed high mortality of larvae and spat due to the inability to form their calcareous shells (134). Crustaceans with good osmoregulation tend to be less vulnerable and calcification of carapaces may not change but could be more energetically costly.

DISEASE AND PARASITES

Diseases and parasites observed in blue crabs from North Carolina include bacterial infections (shell disease), a dinoflagellate parasite *Hematodinium* sp., an amoeba parasite *Paramoeba perniciosa* (gray crab disease), and a microsporidian parasite Ameson michaelis (cotton crab disease). Infection rates of the parasitic dinoflagellate *Hematodinium perezi* in blue crabs along the Atlantic and Gulf coasts can exceed 50% and is usually lethal (135). A Gulf coast study found shell disease present in blue crabs at a rate of 55%, and Vibrio spp. present in the hemolymph of 22% of blue crabs (136). The prevalence of these in North Carolina is unknown. In 1987, an extreme outbreak of shell disease was observed in the Pamlico River (137). The chronic presence of shell disease was suggested as a possible factor contributing to a significant, progressive decline in blue crab landings in the Pamlico River during 1985 to1989 (138). Weinstein et al. (139) found elevated levels of arsenic, aluminum, manganese, and other metals from blue crabs in contaminated waters of Pamlico River, compared to those in a relatively uncontaminated area of Albemarle Sound. Gray crab disease has not been a major problem, though there have been periodic outbreaks causing localized mortalities (140). Cotton crab disease was identified as the suspected cause of excessive mortality and weakened peelers and soft crabs in northern Outer Banks, NC shedding operations during 1999. Prevalence and lethality of diseases and parasites in blue crabs can increase under stressful conditions such as poor water quality (141). A listing of potential parasites, diseases, symbionts, and other associated organisms reported from blue crabs is presented in Guillory et al. (61).

INVASIVE SPECIES

Invasive species are plants, animals, and other organisms not native to an ecosystem and may cause economic or environmental harm by affecting the health of organisms, displacing native species, or altering natural habitat conditions. Non-native species introductions are a growing and imminent threat to living aquatic resources throughout the United States. Pathways of entry to North Carolina waters include release from aquaria and mariculture facilities, boat movement, discharge of ballast water, attachment to fishing gear, and through association with other non-native species (142; 143). Often fish species are introduced deliberately for sport-fishing purposes.

Blue catfish (*Ictalurus furcatus*) was introduced as a sport fish into Virginia waterways and has entered into the waters of North Carolina. Blue catfish have been found to regularly consume blue crabs in the Chesapeake Bay, VA during the fall and winter months with blue crab occurrence estimated at 30% of blue catfish diet during this time (144). Another non-native species known to consume blue crabs is the Asian tiger shrimp (*Penaeus monodon*). Tiger shrimp were first reported to the NCDMF in 2008. The population is believed to be small in North Carolina waters. However, in a mesocosm experiment, blue crabs less than 25mm carapace width were often located, attacked, and successfully consumed by Asian tiger shrimp (145). Preying on blue crabs, Asian tiger shrimp and blue catfish have the potential to negatively impact the blue crab population.

The invasive Rhizocephalan parasitic barnacle (*Loxothylacus panopaei*) has been reported in Xanthid crabs (*Eurypanopeus depressus*) in the Masonboro and Rachel Carson National Estuarine Research Reserves (146). The parasite impacts the host by impeding reproduction, halting growth, and reducing feeding. These barnacles, which originated from the Gulf of Mexico, are known to also infect blue crabs (147), although their presence in blue crabs in North Carolina has not been investigated. Infected blue crabs in Texas were found to rarely burrow below the sediment (148), which would increase vulnerability to predation and environmental conditions.

Juvenile blue crabs use submerged aquatic vegetation beds as a source of refuge. Non-native aquatic plants can cause severe environmental impacts, outcompeting and displacing native plants. Large expanses of coastal rivers and streams in North Carolina were previously blocked by mats of alligatorweed (*Alternanthera philoxeroides*) and Eurasian watermilfoil (*Myriophyllum spicatum*; 149). These plants were successfully cleared through chemical treatment and waterways remain open with limited maintenance control. However, studies in the Chesapeake Bay found as non-native plant density increased so did native plant density (150) and function as nursery areas for juvenile blue crabs (151). Similarly, NCDMF sampling data has found juvenile blue crabs and other species in Eurasian watermilfoil in low salinity waters such as Kitty Hawk Bay and Currituck Sound. When non-native spread is assessed on a local scale, habitats may be altered to promote native plant spread by reduced water velocity, increased sedimentation, sediment stabilization, and increased water clarity. Control, research, and education are the three key elements of a successful aquatic weed control program. For more information on invasive species see the North Carolina Coastal Habitat Protection Plan 2016 (45)and the North Carolina Aquatic Nuisance Species Management Plan (152).

BYCATCH IN OTHER FISHERIES

Due to the broad environmental and habitat tolerances of blue crabs, they are found in the same areas as many of North Carolinas commercially important finfish and shellfish species. This habitat sharing, in part, causes blue crabs to be caught incidentally as bycatch in fisheries targeting other species.

Crab pots are the primary gear used to harvest blue crabs. These, along with other gears that target blue crab, make up over 99% of blue crab harvest; however, they are caught as bycatch with other types of gear (38). Blue crabs harvested as bycatch make up less than 0.5% of the total landings, ranging from 32,567 (2016) to 79,993 pounds (2014) in the past ten years (Figure 13).

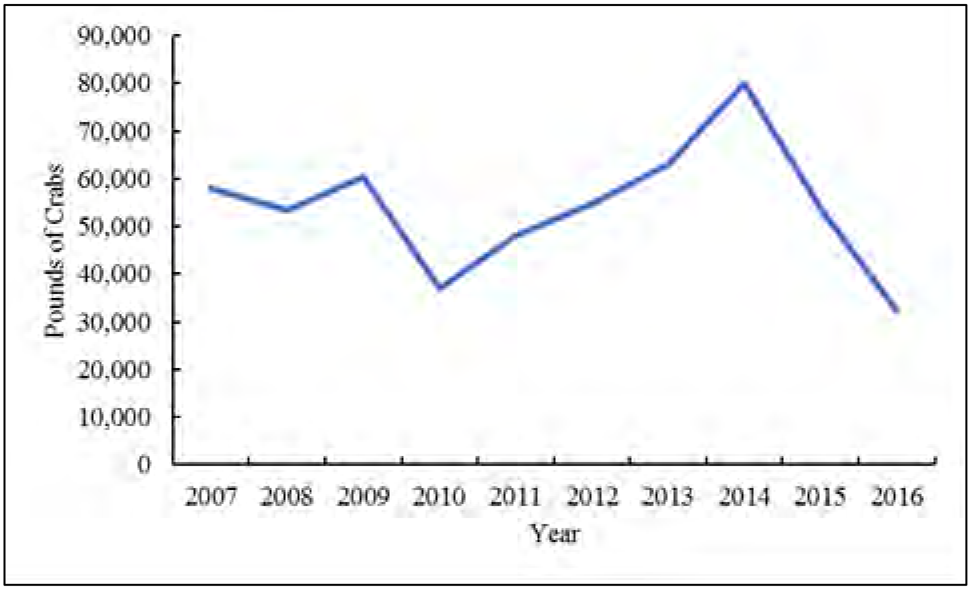

Figure 13 Pounds of blue crabs harvested as bycatch from all fisheries, 2007-2016.

Studies have found blue crabs make up between 6% and 30% of total catch by number in the estuarine gill net fishery, typically accounting for the majority of non-finfish catch (153; 154; 155; 156; 157; 158). Hassel (157) found blue crab bycatch increased as gill net mesh size decreased. Shrimp trawls are also a significant source of blue crab bycatch. Blue crabs make up 0.14% of catch by weight in otter trawls (159), and 2.03% by weight in skimmer trawls (160).

Blue crabs are also discarded as bycatch in many fisheries. They can be discarded for a variety of reasons, such as; limited quantity, sublegal size, or difficult to remove from gear causing crabs to be unmarketable after removal (e.g. gill nets). Gill nets are the only gear with reliable discard estimates of blue crab from commercial catches in North Carolina. This discard data is collected as part of the estuarine gill net observer program in which observers sample the catch of fishermen when they fish their gear. Over the past five years, 80% of the nearly 24 thousand observed crabs caught in gill nets were discarded (Table 24). There is high mortality associated with removal from this gear because when crabs become entangled in the webbing it is very difficult and time consuming to remove them without harming the crab. Due to current data limitations it is not feasible to estimate the total discard mortality of blue crabs in all fisheries in North Carolina. However, from the estimates available, these discards may represent a significant source of fishing mortality.

Table 24 Number of observed blue crabs kept and discarded from the estuarine gill net observer program, 2013-2017.

Year	Kept Crabs	Discarded Crabs	Total	Discard Percentage	Observed Trips with Number of Crabs Recorded	Total Observed Trips (Onboard)	Total Estuarine Gill Net Trips
2013	741	4,751	5,492	87%	451	661	29,128
2014	1,883	5,613	7,496	75%	540	827	21,048
2015	1,076	2,997	4,073	74%	413	784	17,385
2016	681	2,706	3,387	80%	353	656	16,859
2017	284	2,940	3,224	91%	315	740	20,459
Total	4,665	19,007	23,672	80%	2,072	3,668	104,879

PROPOSED MANAGEMENT STRATEGIES UNDER BLUE CRAB AMENDMENT 3

See Appendix 4: Issue Papers and Appendix 5: Proposed Rules

RESEARCH RECOMMENDATIONS

BIOLOGICAL PROFILE

High
Research mature female migration routes and seasonal habitat use (e.g., inlets, staging areas).

Medium
Research the impact of increased predator abundance on the blue crab stock.

COMMERCIAL FISHERY

Low
Research and identify key market forces and their effects on the blue crab industry.

BYCATCH AND DISCARDS

High
Research gear modifications to minimize interactions with non-target species (e.g., diamondback terrapin) in the blue crab fishery.

Research interaction rates of non-target species in the blue crab fishery and identify factors that may lead to interactions (e.g., migration patterns, habitat utilization).

Medium
Characterize the harvest and discard of blue crabs from crab shedding operations.

WATER QUALITY DEGRADATION

High

Research the impact of endocrine disrupting chemicals on the various life stages of blue crabs and ways to reduce their introduction into estuarine waters, including discharge from wastewater treatment plants.

Research the impacts of land use activities and shoreline clearing on water quality and the blue crab stock.

Medium

Research the extent, causes, and impacts of hypoxia and anoxia on blue crab behavior and population abundance in estuarine waters.

HABITAT DEGRADATION AND LOSS

High

Identify biological characteristics of submerged aquatic vegetation beds of ecological value to blue crab and implement restoration and conservation measures.

Medium

Assess the impact of inlet dredging activities on mature female blue crabs.

Identify, map, and protect shallow detrital habitat of ecological value to blue crab and implement restoration and conservation measures.

INVASIVE SPECIES

Medium

Research the impact of invasive species (e.g., blue catfish) on the blue crab stock.

BYCATCH IN OTHER FISHERIES

High

Implement long-term monitoring of blue crab discards in other fisheries (e.g., gill net, trawl).

2018 BLUE CRAB STOCK ASSESSMENT

High

Develop statewide fishery-independent survey(s) to monitor the abundance of all blue crab life stages.

Expand time and area coverage of existing fishery-independent surveys.

Better characterize the magnitude of recreational harvest.

Develop better estimates of life-history parameters, especially growth and natural mortality.

Explore alternative biological reference points.

Medium
Identify key environmental factors that significantly impact North Carolina's blue crab stock and investigate assessment methods that can account for these environmental factors.

Implement monitoring of hazardous events (e.g., hurricane, extreme hot or cold weather) affecting blue crab population dynamics and harvest.

Explore alternative model types.

Low
Investigate and support research on promising methods to age blue crabs.

Evaluate the genetic stock structure of blue crabs within North Carolina and the magnitude of mixing between populations.

Identify programs outside the NCDMF that collect data of potential use to the stock assessment of North Carolina's blue crabs.

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APPENDICES

APPENDIX 1. GLOSSARY OF BIOLOGICAL TERMS

Abundance Index
A relative measure of the weight or number of fish in a stock, a segment of the stock (e.g. the spawners), or an area. Often available in time series, the information is collected through scientific surveys or inferred from fishery data.

Age
The number of years of life completed, here indicated by an Arabic numeral, followed by a plus sign if there is any possibility of ambiguity (age 1, age 1+).

Assessment
A judgment made by a scientist or scientific body on the state of a resource, such as a fish stock (e.g. size of the stock, potential yield, on whether it is over- or underexploited), usually for the purpose of passing advice to a management authority.

Barrier Island
A sedimentary island, generally elongate and low, that is built by longshore transport or wave action parallel to the coast.

Benthic
1. Defining a habitat or organism found on the sea bottom10;
2. Of or pertaining to the seafloor (or bottom) of a water body.

Bloom
A sudden increase in the abundance of alga or phytoplankton resulting in a contiguous mass of highly concentrated phytoplankton in the water column.

Buffer Zone
The area that separates the core from areas in which human activities that threaten it occur.

Bycatch
Fish other than the primary target species that are caught incidental to the harvest of the primary species. Bycatch may be retained or discarded. Discards may occur for regulatory or economic reasons.

Bycatch Reduction Device (Excluder)
A device inserted in a fishing gear (usually trawl nets, close to the codend) to allow escapement, alive, of unwanted (non-target and prohibited) species (e.g. jellyfish), smaller fish (juveniles), and threatened or endangered species (e.g. sea turtles, marine mammals).

Catchability
In general, the extent to which a stock is susceptible to fishing.

Carapace
The hard upper shell of a turtle, crustacean, or arachnid.

Catch Per Unit (of) Effort (CPUE)
The quantity of fish caught (in number or in weight) with one standard unit of fishing effort; e.g. number of fish taken per 1,000 hooks per day or weight of fish, in tons, taken per hour of trawling. CPUE is often considered an index of fish biomass (or abundance). Sometimes referred to as catch rate. CPUE may be used as a measure of economic efficiency of fishing as well as an index of fish abundance. Also called: catch per effort, fishing success, availability.

Cohort
1. In a stock, a group of fish generated during the same spawning season and born during the same time period;
2. In cold and temperate areas, where fish are long-lived, a cohort corresponds usually to fish born during the same year (a year class). For instance, the 1987 cohort would refer to fish that are age 0 in 1987, age 1 in 1988, and so on. In the tropics, where fish tend to be short lived, cohorts may refer to shorter time intervals (e.g. spring cohort, autumn cohort, monthly cohorts).

Commercial Fishery
A term related to the whole process of catching and marketing fish and shellfish for sale. It refers to and includes fisheries resources, fishermen, and related businesses.

Crustaceans
A group of freshwater and saltwater invertebrates with jointed legs and a hard shell of chitin. Includes shrimps, crabs, lobsters, and crayfish.

Current
A horizontal movement of water.

Decline
A decline is a reduction in the number of individuals, or a decrease of the area of distribution, the causes of which are either not known or not adequately controlled. It need not necessarily still be continuing. Natural fluctuations will not normally count as part of a decline, but an observed decline should not be considered part of a natural fluctuation unless there is evidence for this. A decline that is the result of harvesting that reduces the population to a planned level, not detrimental to the survival of the species, is not covered by the term.

Density-Dependence
The dependence of a factor influencing population dynamics (such as survival rate or reproductive success) on population density. The effect is usually in the direction that contributes to the regulative capacity of a stock.

Detritus
Dead organic matter and the decomposers that live on it; when broken up by decomposers, detritus provides energy to many coastal ecosystems.

Discard
To release or return fish to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Ecosystem
A geographically specified system of organisms, the environment, and the processes that control its dynamics. Humans are an integral part of an ecosystem.

Effort
The amount of time and fishing power used to harvest fish; includes gear size, boat size, and horsepower.

Epifauna
Benthic fauna living on the substrate but not burrowing into it (as on a hard seafloor) or living on other organisms.

Escapement
The number or proportion of fish surviving (escaping from) a given fishery at the end of the fishing season and reaching the spawning grounds. The term is generally used for salmon management.

Essential Fish Habitat (EFH)
Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity" (16 U.S.C. 1802(10)). The EFH guidelines under 50 CFR 600.10 further interpret the EFH definition as follows: Waters include aquatic areas and their associated physical, chemical, and biological properties that are used by fish and may include aquatic areas historically used by fish where appropriate; substrate includes sediment, hard bottom, structures underlying the waters, and associated biological communities; necessary means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem; and "spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

Estimated Discard Mortality
Estimates of discards can be made in a variety of ways, including samples from observers and logbook records.

Estuarine
1. Relating to or formed in an estuary (e.g. estuarine currents; estuarine animals);
2. Belonging to an estuary (river mouth), an area in which sea water is appreciably diluted by fresh water from rivers.

Estuary
A coastal ecological ecosystem that is partially enclosed, receives freshwater input from land, and has a horizontal fresh-salt salinity gradient; the average salinity of estuarine waters is defined as being 30 practical salinity units (PSU) for at least 1 month per year.

Exclusive Economic Zone (EEZ)
The EEZ is the area that extends from the seaward boundaries of the coastal states (3 nautical miles (n.mi.) in most cases, the exceptions are Texas, Puerto Rico and the Gulf coast of Florida at 9 n.mi.) to 200 n.mi. off the U.S. coast. Within this area the United States claims and exercises sovereign rights and exclusive fishery management authority over all fish and all continental shelf fishery resources.

Exoskeleton
A rigid external covering for the body in some invertebrate animals, especially arthropods, providing both support and protection.

Ex-Vessel
Refers to activities that occur when a commercial fishing boat lands or unloads a catch. For example, the price received by a captain (at the point of landing) for the catch is an ex-vessel price.

Fecundity
The potential reproductive capacity of an organism or population expressed in the number of eggs (or offspring) produced during each reproductive cycle. Fecundity usually increases with age and size. The information is used to compute spawning potential.

Finfish
Vertebrate and cartilaginous fishery species, not including crustaceans, cephalopods, or other mollusks.

Fish
Used as a collective term, includes mollusks, crustaceans and any aquatic animal which is harvested.

Fish Stock
The living resources in the community or population from which catches are taken in a fishery. Use of the term fish stock usually implies that the particular population is more or less isolated from other stocks of the same species and hence self-sustaining. In a particular fishery, the fish stock may be one or several species of fish but here is also intended to include commercial invertebrates and plants.

Fisheries Management
The integrated process of information gathering, analysis, planning, decision making, allocation of resources, and formulation and enforcement of fishery regulations by which the fisheries management authority controls the present and future behaviors of the interested parties in the fishery in order to ensure the continued productivity of the living resources.

Fishery
1. Generally, a fishery is an activity leading to harvesting of fish. It may involve capture of wild fish or raising of fish through aquaculture;

2. A unit determined by an authority or other entity that is engaged in raising or harvesting fi sh. Typically, the unit is defined in terms of some or all of the following: people involved, species or type of fish, area of water or seabed, method of fishing, class of boats, and purpose of the activities;
3. The combination of fish and fishers in a region, the latter fishing for similar or the same species with similar or the same gear types.

Fishery-Dependent
Data collected directly on a fish or fishery from commercial or sport fishermen and seafood dealers. Common methods include logbooks, trip tickets, port sampling, fishery observers, and phone surveys.

Fishery-Independent
Characteristic of information (e.g. stock abundance index) or an activity (e.g. research vessel survey) obtained or undertaken independently of the activity of the fishing sector. Intended to avoid the biases inherent to fishery-related data.

Fishery Management Plan (FMP)
1. A document prepared under supervision of the appropriate fishery management council for management of stocks of fish judged to be in need of management. The plan must generally be formally approved. An FMP includes data, analyses, and management measures;
2. A plan containing conservation and management measures for fishery resources, and other provisions required by the Magnuson-Stevens Act, developed by fishery management councils or the Secretary of Commerce.

Fishery Management Unit
A fishery or a portion of a fishery identified in a fishery management plan (FMP) relevant to the FMP's management objectives. The choice of stocks or species in an FMU depends upon the focus of FMP objectives, and may be organized around biological, geographic, economic, technical, social, or ecological perspectives.

Fishery Models
Simplified representations of the fisheries complex reality. May or may not be a mathematical representation.

Fishing
Any activity, other than scientific research conducted by a scientific research vessel, that involves the catching, taking, or harvesting of fish; or any attempt to do so; or any activity that can reasonably be expected to result in the catching, taking, or harvesting of fish and any operations at sea in support of it.

Fishing Effort
The amount of fishing gear of a specific type used on the fishing grounds over a given unit of time (e.g. hours trawled per day, number of hooks set per day, or number of hauls of a beach seine per day). When two or more kinds of gear are used, the respective efforts must be adjusted to some standard type before being added. Sometimes referred to as effective fishing effort.

Fishing Gear
The equipment used for fishing (e.g. gill net, hand line, harpoon, haul seine, long line, bottom and midwater trawls, purse seine, rod-and-reel, pots and traps). Each of these gears can have multiple configurations.

Fishing Mortality (F)
1. F stands for the fishing mortality rate in a particular stock. It is roughly the proportion of the fishable stock that is caught in a year;
2. A measurement of the rate of removal from a population by fishing. Fishing mortality can be reported as either annual or instantaneous. Annual mortality is the percentage of fish dying in one year. Instantaneous mortality is that percentage of fish dying at any one time.

Food Chain
The transfer of energy from the source in plants through a series of organisms with repeated eating and being eaten. At each transfer, a large proportion of the potential energy is lost as heat. The shorter the food chain (or the nearest the organism is from the beginning of the food chain), the greater the available energy which can be converted in biomass.

Forage Species
Species used as prey by a larger predator for its food. Includes small schooling fishes such as anchovies, sardines, herrings, capelin, smelts, and menhaden, and invertebrates such as squid.

Gear
A fishing gear is a tool used to catch fish, such as hook-and-line, trawl net, gill net, pot, trap, spear, etc.

Gear Restriction
1. A type of input control used as a management tool whereby the amount and/or type of fishing gear used by fishers in a particular fishery is restricted by law5;
2. Limits placed on the type, amount, number, or techniques allowed for a given type of fishing gear.

Growth
Usually an individual fish's increase in length or weight with time. Also may refer to the increase in numbers of fish in a population with time.

Habitat
1. The environment in which the fish live, including everything that surrounds and affects its life, e.g. water quality, bottom, vegetation, associated species (including food supplies);
2. The locality, site and particular type of local environment occupied by an organism.

Harvest
The total number or weight of fish caught and kept from an area over a period of time. Note that landings, catch, and harvest are different.

Health
The condition of the marine environment from the perspective of adverse effects caused by anthropogenic (human) activities, in particular habitat destruction, changed sedimentation rates and the mobilization of contaminants. Such condition refers to the contemporary state of the ocean, prevailing trends, and the prognosis for improvement or deterioration of its quality.

Incidental Take
The "take" of protected species (such as listed salmon, marine mammals, sea turtles, or sea birds) during fishing. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct.

Indicators
1. A variable, pointer, or index. Its fluctuation reveals the variations in key elements of a system. The position and trend of the indicator in relation to reference points or values indicate the present state and dynamics of the system. Indicators provide a bridge between objectives and action;
2. Signals of processes, inputs, outputs, effects, results, outcomes, impacts, etc., that enable such phenomena to be judged or measured. Both qualitative and quantitative indicators are needed for management learning, policy review, monitoring, and evaluation;
3. In biology, an organism, species, or community whose characteristics show the presence of specific environmental conditions, good or bad.

Invasive species
An introduced species that out-competes native species for space and resources.

Invertebrate
Animals without a backbone. In fishery management terms, refers to shellfish, including lobsters, clams, shrimps, oysters, crabs, and sea urchins.

Juvenile
A young fish or animal that has not reached sexual Maturity.

Landings
1. The number or poundage of fish unloaded by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the locations at which fish are brought to shore2;
2. The part of the catch that is selected and kept during the sorting procedures on board vessels and successively discharged at dockside.

Landings Data
Information on the amount of fish caught and landed per Year.

Life Cycle
Successive series of changes through which an organism passes in the course of its development.

Lipofuscin
Brown-yellow pigmented granules that accumulate with age in certain tissues.

Management Authority
The legal entity that has been assigned by a state or states with a mandate to perform certain specified management functions in relation to a fishery, or an area (e.g. a coastal zone). Generally used to refer to a state authority, the term may also refer to an international management organization.

Management Strategy
The strategy adopted by the management authority to reach established management goals. In addition to the objectives, it includes choices regarding all or some of the following: access rights and allocation of resources to stakeholders, controls on inputs (e.g. fishing capacity, gear regulations), outputs (e.g. quotas, minimum size at landing), and fishing operations (e.g. calendar, closed areas, and seasons).

Marine
Waters that receive no freshwater input from the land and are substantially of full oceanic salinity (>30 practical salinity units (PSU) throughout the year).

Mature Individuals
The number of individuals known, estimated, or inferred to be capable of reproduction.

Maturity
Refers to the ability, on average, of fish of a given age or size to reproduce. Maturity information, in the form of percent mature by age or size, is often used to compute spawning potential.

Megalopae
The final larval stage found in decapod crustaceans.

Mesh Size
The size of holes in a fishing net. Minimum mesh sizes are often prescribed by regulations in order to avoid the capture of the young of valuable species before they have reached their optimal size for capture.

Migration
1. Systematic (as opposed to random) movement
of individuals of a stock from one place to another, often related to season. A knowledge of the migration patterns helps in targeting high concentrations of fish and managing shared stocks;
2. The movements of fish from feeding ground to spawning ground and back again, from nursery ground to feeding ground, and from spawning ground to nursery ground.

Model
In fisheries science, a description of something that cannot be observed. Often a set of equations and data used to make estimates.

Monitoring
1. To observe and record changes;
2. The collection of information for the purpose of assessment of the progress and success of a plan. Monitoring is used for the purpose of assessing performance of a management plan or compliance scheme and revising them, or to gather experience for future plans.

Mortality
Measures the rate of death of fi sh. Mortality occurs at all life stages of the population and tends to decrease with age. Death can be due to several factors such as pollution, starvation, and disease but the main source of death is predation (in unexploited stocks) and fishing (in exploited ones).

Mortality Rate
The rate at which the numbers in a population decrease with time due to various causes. Mortality rates are critical parameters in determining the effects of harvesting strategies on stocks, yields, revenues, etc. The proportion of the total stock (in numbers) dying each year is called the “annual mortality rate.

Native Species
A local species that has not been introduced.

Nearshore
Shallow waters at a small distance from the shore.

Non-Point Sources
Sources of sediment, nutrients, or contaminants that originate from many locations.

Nursery
That part of a fish’s or animal’s habitat where the young develop and grow.

Objective
Expresses the object of an action or what is intended to be achieved. Any objective will include explicit statements against which progress can be measured, and identify which things are truly important and the way they interrelate; quantified objectives are referred to as targets.

Overfished
1. An overfished stock or stock complex “whose size is sufficiently small that a change in management practices is required to achieve an appropriate level and rate of rebuilding.” A stock or stock complex is considered overfished when its population size falls below the minimum stock size threshold (MSST). A rebuilding plan is required for stocks that are deemed overfished
2. A stock is considered “overfished” when exploited beyond an explicit limit beyond which its abundance is considered ‘too low’ to ensure safe reproduction. In many fisheries fora the term is used when biomass has been estimated to be below a limit biological reference point that is used as the signpost defining an “overfished condition.” This signpost is often taken as being FMSY, but the usage of the term may not always be consistent

Overfishing
1. According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce maximum sustainable yield (MSY) on a continuing basis." Overfishing is occurring if the maximum fishing mortality threshold (MFMT) is exceeded for 1 year or more;
2. In general, the action of exerting fishing pressure (fishing intensity) beyond the agreed optimum level. A reduction of fishing pressure would, in the medium term, lead to an increase in the total catch.

Parameter
A "constant" or numerical description of some property of a population (which may be real or imaginary).

Peeler
A hard shell crab in pre-molt stages.

Plankton
Floating organisms whose movements are more or less dependent on currents. While some zooplankton exhibit active swimming movements that aid in maintaining vertical position, plankton as a whole are unable to move against appreciable currents.

Pollution
1. The introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life; hazards to human health; hindrance to marine activities, including fishing and other legitimate uses of the sea; impairment of quality of sea water; and reduction of amenities;
2. Presence of substances and heat in environmental media (air, water, land) whose nature, location, or quantity produces undesirable environmental effects;
3. Activity that generates pollutants.

Population
The number of individuals of a particular species that live within a defined area.

Pots
Traps, designed to catch fish or crustaceans, in the form of cages or baskets of various materials (wood, wicker, metal rods, wire netting, etc.) and having one or more openings or entrances. Usually set on the bottom, with or without bait, singly or in rows, connected by ropes (buoy-lines) to buoys on the surface showing their position.

Predation
Relationship between two species of animals in which one (the predator) actively hunts and lives off the meat and other body parts of the other (the prey).

Primary Production
Assimilation (gross) or accumulation (net) of energy and nutrients by green plants and by organisms that use inorganic compounds as food.

Processing
The preparation or packaging of fish to render it suitable for human consumption, retail sale, industrial uses, or long-term storage, including but not limited to cooking, canning, smoking, salting, drying, filleting, freezing, or rendering into meal or oil, but not heading and gutting unless additional preparation is done.

Production
1. The total output especially of a commodity or an industry;
2. The total living matter (biomass) produced by a stock through growth and recruitment in a given unit of time (e.g. daily, annual production). The "net production" is the net amount of living matter added to the stock during the time period, after deduction of biomass losses through mortality;
3. The total elaboration of new body substance in a stock in a unit of time, irrespective of whether or not it survives to the end of that time.

Recruit
1. A young fish entering the exploitable stage of its life cycle;
2. A member of "the youngest age group which is considered to belong to the exploitable stock."

Recruitment (R)
1. The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area. For example, the number of fish that grow to become vulnerable to the fishing gear in one year would be the recruitment to the fishable population that year;
2. This term is also used in referring to the number of fish from a year class reaching a certain age. For example, all fish reaching their second year would be age 2 recruits.

Relative Abundance
Relative abundance is an estimate of actual or absolute abundance; usually stated as some kind of index; for example, as bottom trawl survey stratified mean catch per tow.

Removals
All of the fish "removed" from a stock by fishing, including the catch and any fish killed but not caught.

Resources
1. A natural source of wealth and revenue. Biological resources include genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use of value for humanity. Fishery resources are those resources of value to fisheries;
2. Anything that has value; living and nonliving components of nature such as fish, oil, water, and air.

Rulemaking
The process of developing Federal regulations which occurs in several steps, including publishing proposed rules in the Federal Register, accepting comments on the proposed rule, and publishing the final rule. An "advanced notice of proposed rulemaking" is published when dealing with especially important or controversial rules.

Salinity
The total mass of salts dissolved in seawater per unit mass of water; generally expressed in parts per thousands (ppt).

Sample
A proportion or a segment of a fish stock that is removed for study, and is assumed to be representative of the whole. The greater the effort, in terms of both numbers and magnitude of the samples, the greater the confidence that the information obtained is a true reflection of the status of a stock (level of abundance in terms of numbers or weight, age composition, etc.).

Seagrass
Rooted, grass-like flowering plants, such as eelgrass, that are adapted to live at sea, submersed, and can tolerate a saline environment.

Secondary Dispersal
A mechanism driving movement following initial settlement to benthic habitats often triggered by environmental or biological factors.

Shellfish
Shellfish include both mollusks, such as clams, and crustaceans, such as lobsters.

Spawning
Release of ova, fertilized or to be fertilized.

Spawning Stock
1. Mature part of a stock responsible for reproduction;
2. Strictly speaking, the part of an overall stock having reached sexual maturity and able to spawn. Often conventionally defined as the number or biomass of all individuals beyond "age at first maturity" or "size at first maturity"; that is, beyond the age or size class in which 50 percent of the individuals are mature.

Species
Group of animals or plants having common characteristics, able to breed together to produce fertile (capable of reproducing) offspring, and maintaining their "separateness" from other groups.

Stakeholder
1. A large group of individuals and groups of individuals (including governmental and non-governmental institutions, traditional communities, universities, research institutions, development agencies and banks, donors, etc.) with an interest or claim (whether stated or implied) that has the potential of being impacted by or having an impact on a given project and its objectives. Stakeholder groups that have a direct or indirect "stake" can be at the household, community, local, regional, national, or international level;
2. An actor having a stake or interest in a physical resource, ecosystem service, institution, or social system, or someone who is or may be affected by a public policy.

Stock
A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. A fish stock may be treated as a total or a spawning stock. Total stock refers to both juveniles and adults, either in numbers or by weight, while spawning stock refers to the numbers or weight of individuals that are old enough to reproduce.

Stock Assessment
The process of collecting and analyzing biological and statistical information to determine the changes in the abundance of fishery stocks in response to fishing, and, to the extent possible, to predict future trends of stock abundance. Stock assessments are based on resource surveys; knowledge of the habitat requirements, life history, and behavior of the species; the use of environmental indices to determine impacts on stocks; and catch statistics. Stock assessments are used as a basis to assess and specify the present and probable future condition of a fishery.

Subtidal
Permanently below the level of low tide, an underwater environment.

Sustainability
1. Ability to persist in the long-term. Often used as "short hand" for sustainable development;
2. Characteristic of resources that are managed so that the natural capital stock is non-declining through time, while production opportunities are maintained for the future.

Thresholds
1. Levels of environmental indicators beyond which a system undergoes significant changes; points at which stimuli provoke significant response;
2. A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, and then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Tidal Marsh
Low, flat marshland traversed by channels and tidal hollows and subject to tidal inundation. Normally, the only vegetation present are salt-tolerant bushes and grasses.

Total Catch
Total catch (optimum yield, OY). The landed catch plus discard mortality.

Trawl Net
Towed net consisting of a cone-shaped body closed by a bag or codend and extended at the opening by wings. It can be towed by one or two boats and, according to the type, used on the bottom or in midwater (pelagic). In certain cases, as in trawling for shrimp or flatfish, the trawler can be specially rigged with outriggers to tow up to four trawls at the same time (double rigging)

Trawling
Fishing technique in which a net is dragged behind the vessel and retrieved when full of fi sh. This technique is used extensively in the harvest of pollock, cod, and other flatfish in North Pacific and New England fisheries. It includes bottom and midwater fishing activities.

Trotline
A heavy fishing line with baited hooks attached at intervals by means of branch lines.

Turbidity
The condition resulting from the presence of suspended particles in the water column which attenuate or reduce light penetration.

Undersized
Fish (caught) at a size smaller than the minimum size limit established by regulation.

Value
1. Market and nonmarket values, gross and net values, and net benefits to consumers or goods and services;
2. The contribution of an action or object to user-specified goals, objectives, or conditions.

Water Column
The vertical column of seawater that extends from the surface to the bottom.

Water Quality
The chemical, physical, and biological characteristics of water in respect to its suitability for a particular purpose.

Water Resources
Water usable as inputs for economic production and livelihoods. A distinction is made between renewable and nonrenewable water resources. Nonrenewable water resources are not replenished at all or for a very long time by nature. This includes the so-called fossil waters. Renewable water resources are rechargeable due to the hydrological cycle unless they are overexploited, comprising groundwater aquifers and surface water like rivers and lakes.

APPENDIX 2. TABLE OF AMENDMENTS TO STATE PLAN

Amendments, revisions, information updates, and supplements to the Blue Crab FMP

Original FMP Adoption:	December 1998
Amendments:	Amendment 1 – December 2004 Amendment 2 – November 2013
Revisions:	May 2016
Supplements:	None
Information Updates:	None

APPENDIX 3. EXISTING PLANS, STATUTES, AND RULES

Existing Plans, Statutes, and Rules. This summary does not maintain exact language and should not be relied upon for legal purposes. See North Carolina General Statutes, North Carolina Administrative Code and Proclamations for exact language. The commission has the authority to delegate to the fisheries director the ability to issue public notices, called proclamations, suspending or implementing particular commission rules that may be affected by variable conditions. The proclamation authority granted to the fisheries director includes the ability to open and close seasons and fishing areas, set harvest and gear limits, and establish conditions governing various fishing activities. Proclamations are not included in this document because they change frequently.

Major General Statutes that apply to the blue crab fishery include but are not limited to:

- G.S.113-129. Definitions relating to resources.
  - Definitions in statute include fishing access areas, coastal fisheries, coastal fishing waters, crustaceans, fisheries resources, joint fishing waters, overfished, and overfishing.
- G.S.113-130. Definitions relating to activities of public.
  - Definitions in statute include resident, to buy, to fish, to sell, to take, and vessel.
- G.S.113-132. Jurisdiction of fisheries agencies.
  - Marine Fisheries Commission has jurisdiction over the conservation of marine and estuarine resources.
- G.S. 113-268 Injuring, destroying, stealing, or stealing from nets, seines, buoys, pots, etc
  - It is unlawful without authority of the owner to take fish from fishing gear; willfully, wantonly, and unnecessarily destroy gear; and willfully steal, destroy, or injure fishing gear.

Major rules that apply to the blue crab fishery include but are not limited to:

- 15A NCAC 03I .0101 DEFINITIONS
  - Definitions in rule of what constitutes a blue crab shedding process and operation, peeler crab, and commercial fishing equipment or gear.
- 15A NCAC 03I .0105 LEAVING DEVICES UNATTENDED
  - It is unlawful to leave pots in coastal fishing waters for more than five consecutive days.
- 15A NCAC 03J .0104 TRAWL NETS
  - Proclamation authority is granted to the Fisheries Director to open areas described in 15A NCAC 03R .0106 to peeler crab trawling, defines mesh sizes for crab trawls, defines when it is permissible to take and possess blue crabs incidental to shrimp trawling, and sets forth limitations of incidental blue crab catch while shrimp trawling.
- 15A NCAC 03J .0301 POTS
  - The statewide pot cleanup period, closure periods, and the time and waterways restricted to pot usage are set in rule. Additionally, this rule sets forth gear identification criteria. The Fisheries Director is granted proclamation authority over escape ring requirements including time, area, means and methods, season, and quantity.

- 15A NCAC 03J .0302 RECREATIONAL USE OF POTS
    - o Recreational pots must be marked with a hot pink buoy and identifying information. Licensing requirements for recreational pots are included in this rule.
- 15A NCAC 03J .0303 DREDGES AND MECHANICAL METHODS PROHIBITED
    - o The maximum weight of dredges, number of dredges, and time of day dredging and mechanical methods are allowed is set in rule.15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS
    - o Cull tolerances, hard crab size limits, and peeler stage allowance are set under rule. The Fisheries Director is given proclamation authority to establish further restrictions upon the harvest of blue crabs.
- 15A NCAC 03L .0202 CRAB TRAWLING
    - o By Fisheries Director proclamation areas and times may be specified to take or possess crabs by trawl. Mesh size of trawl gear is set in rule.
- 15A NCAC 03L .0203 CRAB DREDGING
    - o The time and areas allowed for crab dredging are set in rule. The Fisheries Director, by proclamation authority, may further restrict the use of dredges to take blue crabs.
- 15A NCAC 03L .0204 CRAB POTS
    - o The Fisheries Director, by proclamation authority, may require the use of terrapin excluder devices in crab pots while additionally imposing restrictions which specify areas, time periods, and means and methods.
- 15A NCAC 03L .0201 CRAB SPAWNING SANCTUARIES
    - o The time period in which certain gears may not be set or used in crab spawning sanctuaries is set. The Fisheries Director may, by proclamation authority, designate additional areas and impose restrictions based on area, time, means and methods, and harvest limits.
- 15A NCAC 03R .0106 TRAWL NETS PROHIBITED
    - o Trawl net prohibited areas referenced in 15A NCAC 03J .0104 are delineated.
- 15A NCAC 03R .0107 DESIGNATED POT AREAS
    - o Pot areas referenced in 15A NCAC 03J .0301 are delineated.
- 15A NCAC 03R .0109 TAKING CRABS WITH DREDGES
    - o The area referenced in 15A NCAC 03L .0203 is delineated.
- 15A NCAC 03R .0110 CRAB SPAWNING SANCTUARIES
    - o The crab spawning sanctuaries within which the taking of crabs may be restricted or prohibited are described.

Major General Statute that apply to habitat protection include but are not limited to:

- G.S. 143B-279.8 Coastal Habitat Protection Plans
    - o Lays out the process and purpose of creating the Coastal Habitat Protection Plans.

Major rules that apply to habitat protection include but are not limited to:

- 15A NCAC 03K .0204 Mechanical Methods Prohibited Areas
    - o Prohibits the use of mechanical methods in mechanical methods prohibited areas to take oysters

- 15A NCAC 03K .0103 Shellfish Management Areas
    - The Fisheries Director may designate areas which the use of trawl nets, long haul seines, or swipe nets are prohibited.
- 15A NCAC 03N .0101 Fish Habitat Areas Scope and Purpose
    - Fish habitat areas are to establish and protect fragile estuarine and marine areas which support economically important populations.
- 15A NCAC 03N .0104 Prohibited Gear, Primary Nursery Areas
    - Prohibits use of trawl net, long haul seine, swipe net, dredge, or mechanical methods for clam or oysters in primary nursery areas
- 15A NCAC 03N .0105 Prohibited Gear, Secondary Nursery Areas
    - Prohibits use of trawl nets in permanent secondary nursery areas except select areas open by proclamation for shrimp or crab trawling.
- 15A NCAC 03R .0103 Primary Nursery Areas
    - Delineates boundaries of primary nursery areas.
- 15A NCAC 03R .0104 Permanent Secondary Nursery Areas
    - Delineates boundaries of permanent secondary Nursery Areas
- 15A NCAC 03K .0108 Dredges and Mechanical Methods Prohibited
    - Prohibits gears in areas of SAV, salt marsh, shellfish leases, Primary Nursery Areas, and designated Mechanical Methods Prohibited Areas

Table 4.3.1. East coast and Gulf of Mexico blue crab effort regulations by state as of May 2019.

	Harvest restrictions			
State	Season	Catch Limit	Time	Days
New Jersey	Delaware Bay Apr. 6 – Dec 4 Other Waters Mar. 15 – Nov. 30	None	Delaware Bay 4am-9pm Other Waters 24-hrs	None
Delaware	Mar. 1-Nov 30	None	1 hr. before sunrise-sunset	Sunday
Maryland	Males Apr. 1-Nov 16 Mature Female Apr. 1-Nov 10	Mature female	½ hr. before sunrise – 7 ½ hrs. after sunrise	Prohibited either Sun. or Mon.
Virginia	Mar. 17-Nov 30 Mature females prohibited Nov. 21-30	47 bushels Mar.17-Apr. 30 27 bushels May-Aug.	6am-2pm Mar.17-Apr. 30 5am-1pm May-Aug.	Mon.-Sat. except peeler pots
North Carolina	No pots Jan. 15-Feb. 7 May open areas cleared of pots	None	1 hr. before sunrise-1hr. after sunset	None
South Carolina	None	None	5am-9pm Apr. 1-Sept 15 6am-7pm Sept 15-Mar.31	None
Georgia	None	None	None	None
Florida	10 day closure for derelict trap removal	None	1 hr. before sunrise-1hr. after sunset	None
Alabama	Periodic derelict trap removal with no set closure period	None	1 hr. before sunrise-sunset	None
Mississippi	Possible 10-30 day closure for abandoned trap removal	None	½ hr. before sunrise – ½ hr. after sunset	None
Louisiana	Possible 14 day closure for abandoned trap removal	None	½ hr. before sunrise – ½ hr. after sunset	None
Texas	No pots 10-30 days in Feb.-Mar.	None	½ hr. before sunrise – ½ hr. after sunset	None

Table 4.3.2. East coast and Gulf of Mexico blue crab pot gear regulations by state as of May 2019.

State	Gear restrictions				
	Pots (max)	Escape Rings	Degradable Panels	Terrapin Excluders	Buoys
New Jersey	Delaware Bay 600 Other Waters 400	None	Yes	Some areas	Reflective I.D. Sink line
Delaware	200/vessel 500/vessel	None	None	None	I.D. Color coded
Maryland	50 up to 900/vessel w/ 2 crew	1 (2-3/16") 1 (2-5/16") May close for peelers	None	None But limited pot area	I.D.
Virginia	Chesapeake Bay 425 Tributaries and Potomac Tribs. in VA 255 Peeler 210	Seaside Eastern Shore 1 (2-3/16") 1 (2-5/16") Bay & Tribs. 2 (2-3/8")	None	None	I.D.
North Carolina	None Newport River only 150	3 (2-5/16")* May be closed in some areas	None	None	I.D. Sink line
South Carolina	None	2 (2-3/8")	None	None	I.D. With colors
Georgia	200 including peeler pots	2 (2-3/8")*	None	None	I.D. No green
Florida	Inshore 600 Offshore 400 Non-transfer 100 Peeler 400	3 (2-3/8")	Yes	None	I.D. Sink line
Alabama	None	2 (2-5/16") May be closed for peelers	None	None	I.D. ½ white Sink line
Mississippi	None	2 (2-3/8") Can be closed Apr.-Jun. Sept.-Oct.	None	None	I.D. or Color code
Louisiana	None	2 (2-5/16")* Can be closed Apr.-Jun. Sept.-Oct.	None	None	I.D. on metal trap tag/plastic bait cover Sink line
Texas	None	2 (2-3/8")	Yes	None	I.D. White gear tag

*Special placement required

Table 4.3.3. East coast and Gulf of Mexico blue crab life stage regulations by state as of May 2019.

	Size limits (inches)				
State	Hard	Soft	Peeler	Culling Tolerance	Sponge Crab Protection
New Jersey	4.75” 4.5” mature female	3.5”	3”	Zero	Prohibited
Delaware	5”	3.5”	3”	5% by number	Prohibited
Maryland	5” Apr. 1- July 14 5.25” July 15- Dec 15	3.5”	3.25” Apr. 1- July 14 3.5” July 15- Dec 15 Separated from catch	5 hard crabs/ bushel or 13/barrel 10 peelers	Prohibited to take but may sell from another state
Virginia	5”	3.5”	3.25” Mar. 17-Jul. 15 3.5” Jul. 16-Nov. 30	10 hard crabs/ bushel or 35/barrel 10 peelers/bushel or 5% in other containers	Prohibit brown/black sponge Bay wide Sanctuary at 35 ft. contour May 1-Sept. 15
North Carolina	5” Prohibit immature female	None	None Separated. White-lines no sale	5% by number/container	Prohibit brown/black sponge Spawning sanctuaries
South Carolina	5” Includes mature female	5” Includes mature female	None with peeler permit	Zero	Prohibited to take but may sell from another state
Georgia	5”	5”	3”	Zero	Prohibited to take but may sell from another state
Florida	5” Includes mature female	5”	None Separated from catch	5% by number/ container except bait	Prohibited
Alabama	5” Includes mature female Bait Dealer exempt	None Separate from catch	None Separated from catch	Zero except bait and work box	Prohibited May 26-Jan 14
Mississippi	5” Includes mature female	None	None	Zero	Prohibited Crab sanctuaries
Louisiana	5” Includes mature female Prohibit immature female	None	None Separated from catch	2% by number in 50 crab random sample	Prohibited Crab sanctuaries
Texas	5” Includes mature female	5”	5”	5% by number in separate container for bait only	Prohibited to take but may sell from another state

APPENDIX 4. ISSUE PAPERS

APPENDIX 4.1: ACHIEVING SUSTAINABLE HARVEST IN THE NORTH CAROLINA BLUE CRAB FISHERY

I. ISSUE

Implement management measures to achieve sustainable harvest in the North Carolina blue crab fishery.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF).

III. BACKGROUND

In North Carolina, fishermen have been harvesting blue crabs commercially since the 1800s, with the earliest documented landings reported in 1889 (1). Blue crab (*Callinectes sapidus*) is the most economically important species for commercial fisheries in North Carolina accounting for landings of 27.8 million pounds with an ex-vessel value of $26.9 million in 2016. North Carolina typically ranks within the top three blue crab producing states on the east coast both in pounds harvested and in value. North Carolina has historically accounted for approximately 22% of annual Atlantic coast blue crab landings since 1950.

The management strategy established in Amendment 1 to the Blue Crab FMP, adopted in 2004, used a single point estimate management trigger for stock status based on September data for mature female blue crabs from the Pamlico Sound Survey (P195; (2)). If the trigger was reached, then a seasonal 6.75-inch maximum size limit for mature females and a 5.25-inch minimum size limit for peeler crabs was enacted annually. Compliance and enforcement of the seasonal mature female maximum size limit and minimum size limit for peeler crabs was limited, hence they were largely ineffective at protecting large mature females. Even when crabbers complied with the management measure by releasing large females or undersize peelers, they may have been captured multiple times and injured, or ultimately harvested by another crabber during their migration to the lower estuaries and into the sounds.

Amendment 2 to the Blue Crab FMP adopted by the Marine Fisheries Commission in November 2013 incorporated the use of the traffic light stock assessment method and adaptive management measures for management of the blue crab stock (3). The Traffic Light method provided a more robust indicator of the overall blue crab stock condition because the data inputs were from multiple surveys encompassing all aspects of the blue crab’s life history and distribution rather than a single point index. The 2016 revision to Amendment 2 implemented additional management measures due to exceeding a management threshold established in Amendment 2 (4). Those measures were:

- prohibit harvest of immature female hard crabs;
- prohibit harvest of dark sponge crabs from April 1 to April 30;

- prohibit targeted crab dredging;
- reduce the cull tolerance from 10% to 5%;
- require three cull rings in each crab pot; and
- require one cull ring to be placed within one full mesh of the corner and one full mesh of the bottom of the divider in the upper chamber of the pot.

As part of Amendment 3 a new stock assessment was conducted. A comprehensive stock assessment approach, the sex-specific two-stage model, was applied to available data to assess the status of North Carolina's blue crab stock during 1995–2016 (5). Data were available from commercial fishery monitoring programs and several fishery-independent surveys. The two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, and thus, provided a comprehensive assessment of blue crab status in North Carolina. The model estimated an overall declining trend in catch, relative abundance indices, population size of both male and female recruits and fully recruited crabs, with a rebound starting in 2007. The estimated fishing mortality remained high before 2007, and decreased by approximately 50% afterwards. The stock assessment only included hard blue crab harvest from the commercial fishery. Recreational harvest data was not included due to data limitations and commercial peeler and soft blue crab harvest data was not included due to them accounting for a small portion of the overall commercial landings and modelling limitations.

The stock status of North Carolina blue crab in the current stock assessment was determined based on maximum sustainable yield (MSY). Based on the results of this stock assessment, the North Carolina blue crab resource in 2016 was overfished with a 98%probability, given the average spawner abundance in 2016 was estimated at 50 million crabs (below the threshold estimate of 64 million crabs). Overfishing was also occurring in 2016 with a 52% probability, given the average fishing mortality in 2016 was estimated at 1.48 (above the fishing mortality threshold estimate of 1.46).

North Carolina General Statute 113-182.1 mandates that fishery management plans shall: 1) specify a time period not to exceed two years from the date of adoption of the plan to end overfishing, 2) specify a time period not to exceed 10 years from the date of adoption of the plan for achieving a sustainable harvest and 3) must also include a standard of at least 50% probability of achieving sustainable harvest for the fishery. Sustainable harvest is defined in North Carolina General Statute 113-129 as *"the amount of fish that can be taken from a fishery on a continuing basis without reducing the stock biomass of the fishery or causing the fishery to become overfished"*.

In order to recover the blue crab stock, management options were developed to reduce fishing mortality (F) to end overfishing and rebuild the spawning stock and achieve sustainable harvest in the blue crab fishery (Table 4.1.1). A harvest reduction of 0.4% (in numbers of crabs) is projected to end overfishing within two years and a harvest reduction of 2.2% is projected to achieve sustainable harvest and rebuild the blue crab spawning stock within 10 years of the date of adoption of the plan with a 50% probability of success. This level of reduction is projected to bring spawning stock abundance to the threshold value of 64 million mature females.

Table 4.1.1. Catch reduction projections for varying levels of fishing mortality (*F*), based on 2016 data from the stock assessment, and the probability of achieving sustainable harvest within the 10-year rebuilding period defined in statute. The bolded row indicates the minimum requirement defined in statute.

F (yr -1)	Catch reduction (%)	Probability of achieving sustainable harvest within 10 years (%)	Comments
1.48	0	31	2016 average *F* from stock assessment
1.46	0.4	45	Catch reduction to meet *F* threshold and end overfishing
1.40	1.7	46	Catch reduction to meet spawner abundance threshold and end overfished status
1.38	**2.2**	**50**	**Catch reduction to meet minimum statutory requirement for achieving sustainable harvest**
1.30	3.8	67	
1.22	5.9	90	Catch reduction to meet *F* target
1.10	9.3	96	
1.00	12.3	100	
0.90	15.7	100	
0.80	19.8	100	Catch reduction to meet spawner abundance target
0.70	24.3	100	

There is also a need to update the adaptive management framework in the Blue Crab FMP. Amendment 2 established an adaptive management framework for blue crab management based on the annual update of the blue crab traffic light analysis (3). This framework requires annual updates of the blue crab traffic light analysis to be presented to the Marine Fisheries Commission as part of the annual Stock Overview report. If either the adult abundance or production characteristics of the traffic light are above 50% red for three consecutive years, then moderate management action (as defined in the framework; Table 4.1.2) is required. Additionally, if either the adult abundance or production characteristics is above 75% red for two years in a three-year period then elevated management action is required. The three-year period was chosen to prevent taking management action due to annual variability and to instead base any management response on a short but continued declining trend in the population. This framework was adopted in part due to the lack of a quantitative assessment of the blue crab stock. Now that a quantitative assessment has been completed and approved for management use (5) the adaptive management framework should be adjusted accordingly.

Table 4.1.2. Management measures under the adaptive management framework for the blue crab Traffic Light in the North Carolina Blue Crab Fishery Management Plan Amendment 2.

Characteristic	Moderate management level	Elevated management level
Adult abundance	A1. Increase in minimum size limit for male and immature female crabs A2. Reduction in tolerance of sublegal size blue crabs (to a minimum of 5%) and/or implement gear modifications to reduce sublegal catch A3. Eliminate harvest of v-apron immature hard crab females	A4. Closure of the fishery (season and/or gear) A5. Reduction in tolerance of sublegal size blue crabs (to a minimum of 1%) and/or implement gear modifications to reduce sublegal catch A6. Time restrictions
Recruit abundance	R1. Establish a seasonal size limit on peeler crabs R2. Restrict trip level harvest of sponge crabs (tolerance, quantity, sponge color) R3. Close the crab spawning sanctuaries from September 1 to February 28 and may impose further restrictions	R4. Prohibit harvest of sponge crabs (all) and/or require sponge crab excluders in pots in specific areas R5. Expand existing and/or designate new crab spawning sanctuaries R6. Closure of the fishery (season and/or gear) R7. Gear modifications in the crab trawl fishery
Production	P1. Restrict trip level harvest of sponge crabs (tolerance, quantity, sponge color) P2. Minimum and/or maximum size limit for mature female crabs P3. Close the crab spawning sanctuaries from September 1 to February 28 and may impose further restrictions	P4. Prohibit harvest of sponge crabs (all) and/or require sponge crab excluders in pots for specific areas P5. Reduce peeler harvest (no white line peelers and/or peeler size limit) P6. Expand existing and/or designate new crab spawning sanctuaries P7. Closure of the fishery (season and/or gear)

IV. AUTHORITY

North Carolina General Statutes
G.S. 113-134 RULES
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 113-182.1 FISHERY MANAGEMENT PLANS
G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Commission Rules
15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS

V. DISCUSSION

Management measures specific to recreational harvest and commercial peeler and soft blue crab harvest were not included here because the harvest reductions needed relate specifically to the stock assessment and the commercial hard blue crab fishery. However, any approved management changes will affect all applicable sectors of the blue crab fishery. The discussion below includes specific management measures that were both quantifiable and projected to meet the harvest reduction for hard blue crabs, based on the terminal year of the stock assessment (2016), needed to end overfishing within two years and achieve sustainable harvest within 10 years with at least a 50% probability of success as outlined in North Carolina General Statute 113-182.1. Several management tools were explored to achieve sustainable harvest in the hard blue crab fishery. These include size limits, season and life stage closures, and reducing the cull tolerance of prohibited blue crabs, or some combination of these measures. Where possible, management impacts are presented by region (Figure 4.1.1). Data from the ocean were not included in this analysis as landings are minimal and often confidential.

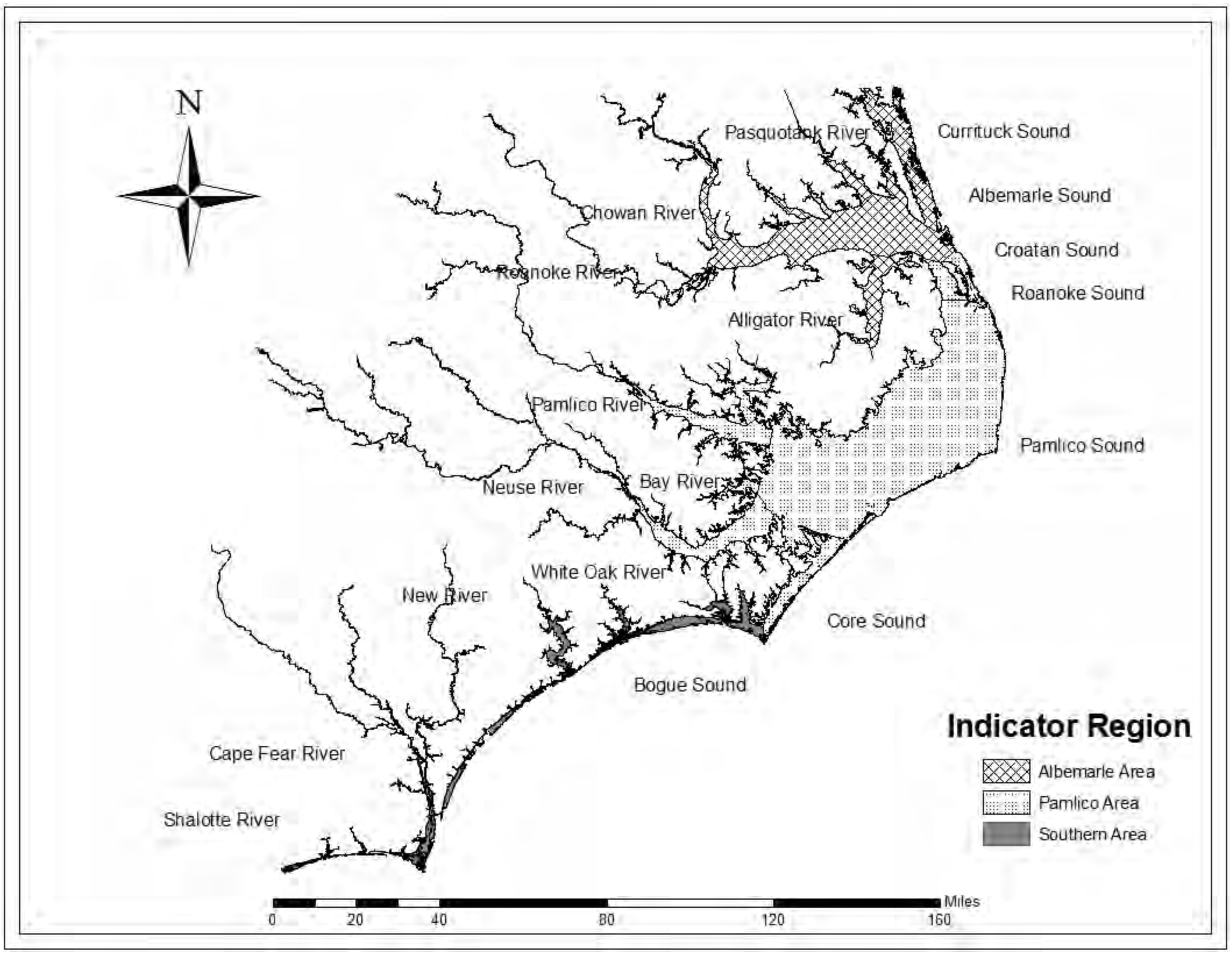

Figure 4.1.1. Map defining the spatial regions used in evaluating potential management impacts.

North Carolina General Statute 113-182.1 states the North Carolina Marine Fisheries Commission (NCMFC) can only recommend the General Assembly limit participation in a fishery if the commission determines sustainable harvest in the fishery cannot otherwise be achieved. Sustainable harvest can be achieved without the use of limited entry therefore limited entry is not considered an option at this time. The management options presented in this paper are a starting point for discussion on achieving sustainable harvest. Public input could provide additional options.

Trip limits, gear closures, and effort controls were not considered viable options for achieving sustainable harvest because they all allow for the possibility of recoupment by the fishery which prevents the accurate calculation of potential harvest reductions. While a trip limit could reduce the daily harvest of blue crabs it would be unlikely to reduce overall harvest unless trip limits were sufficiently low to make recoupment unlikely. Gear closures present the same issue of recoupment by the fishery where harvest from a closed gear may just be transferred to an open gear thereby providing little to no real harvest reduction. Effort controls, such as pot limits and fishing time restrictions, were not considered as recoupment is a concern with both approaches. A pot limit may not provide a real harvest reduction as blue crabs may potentially be caught in remaining pots in higher numbers, unless the limit was low enough to make gear saturation an issue which may be offset by simply fishing pots more frequently. Fishing time restrictions typically aim to limit the amount of gear that can reasonably be fished in a particular day but may be offset by increasing the number of crew aboard a vessel or fishing fewer pots more frequently. Some of these management options are explored in other issue papers such as the “Management Measures Beyond Quantifiable Harvest Reductions” issue paper, as they may provide some additional protections but their impact cannot be reasonably quantified.

Mature Female Size Limit

Size limits are a common management tool used to rebuild or protect the spawning stock of several species (e.g., striped bass, southern flounder, spotted seatrout). Mature females, peeler, and soft crabs are exempt from the 5-inch minimum size limit for hard crabs (NCMFC Rule 15A NCAC 03L .0201). The short-term effects of establishing a size limit for mature females would be reducing the pool of mature females available for harvest, which in turn would decrease the overall harvest. Decreasing the harvest of mature females should have an immediate effect on reducing the fishing mortality on mature female blue crabs. The benefit to the fishery of establishing a size limit for mature females would not be realized until the recruits produced survive to contribute to the population and the fishery. One of the major benefits to establishing a size limit for mature females is it would protect a portion of the spawning stock from harvest allowing them to remain in the population and the opportunity to release more clutches of eggs. Establishing a size limit for mature females could have a negative impact on the market by reducing the number of blue crabs available for purchase.

Establish a Maximum Size Limit for Mature Female Blue Crabs

Assuming no cull tolerance for mature female blue crabs, maximum size limit options were explored that fell within the range needed to attain sustainable harvest. From the analysis, most mature female blue crabs harvested are less than 6 inches’ carapace width (CW). There were two maximum size limit options falling within the range needed for sustainable harvest, a 6.75-inch and 6.5-inch maximum size limit. The 6.75-inch CW maximum size limit would have an estimated 1.5% overall harvest reduction on average for 2016 which represents approximately 1.4% of the hard crab value (Table 4.1.3). The 6.5-inch CW maximum size limit would have an estimated 4.3% overall harvest reduction on average for 2016 which represents approximately

3.8% of the hard crab value (Table 4.1.4). Recoupment from either maximum size limit should not occur since once mature females reach either size they would be permanently protected from legal harvest.

Table 4.1.3. Harvest percentage (by number) and value of mature female blue crabs 6.75 inches CW and greater by area and overall, 2011-2017.

	Mature Female Harvest Percent >6.75" Carapace Width					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	0.6	0.9	0.1	1.6	244,793	1.4
2012	0.6	1.7	0.1	2.5	375,392	1.9
2013	2.1	0.5	<0.1	2.7	558,381	2.1
2014	1.8	1.3	0.1	3.2	901,165	3.0
2015	0.8	1.5	<0.1	2.4	587,445	2.0
2016	0.2	1.2	0.1	1.5	296,399	1.4
2017*	0.8	1.0	0.1	1.9	272,161	1.5
2011-2016 Average	1.0	1.2	0.1	2.3	493,929	2.0

*2017 shown for informational purposes only, not used in stock assessment.

Table 4.1.4. Harvest percentage (by number) and value of mature female blue crabs 6.5 inches CW and greater by area and overall, 2011-2017.

	Mature Female Harvest Percent >6.5" Carapace Width					Percent of
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Total Value
2011	1.6	2.3	0.3	4.2	627,286	3.5
2012	1.9	3.8	0.3	6.0	950,835	4.7
2013	4.7	1.5	0.2	6.4	1,355,304	5.1
2014	4.2	2.3	0.2	6.7	1,885,193	6.3
2015	1.9	3.3	0.1	5.4	1,334,084	4.5
2016	1.1	3.0	0.2	4.3	788,728	3.8
2017*	1.5	2.2	0.2	3.8	554,013	3.1
2011-2016 Average	2.5	2.7	0.2	5.4	1,156,905	4.8

*2017 shown for informational purposes only, not used in stock assessment.

Establish a Minimum Size Limit for Mature Female Blue Crabs

Assuming no cull tolerance for mature female blue crabs, minimum size limit options were explored that fell within the range needed to attain sustainable harvest. From the analysis, most mature female blue crabs harvested are less than 6 inches' CW. There were two minimum size limit options falling within the range needed for sustainable harvest, a 5-inch and 5.25-inch minimum size limit. The 5-inch CW minimum size limit would have an estimated 0.9% overall harvest reduction for 2016 which represents approximately 0.8% of the hard crab value (Table 4.1.5). The 5.25-inch CW minimum size limit would have an estimated 4.1% overall harvest reduction for 2016 which represents approximately 3.5% of the hard crab value over this same period (Table 4.1.6). Recoupment from either minimum size limit should not occur since once mature, females do not get any larger thus they would be permanently protected from legal harvest.

Table 4.1.5. Harvest percentage (by number) and value of mature female blue crabs less than 5 inches CW by area and overall, 2011-2017.

	Mature Female Harvest Percent <5" Carapace Width					Percent of Total
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Value
2011	0.0	1.2	0.0	1.2	155,675	0.9
2012	0.2	0.6	0.1	0.9	135,483	0.7
2013	0.2	0.9	0.3	1.4	328,168	1.2
2014	0.2	0.2	0.3	0.7	169,988	0.6
2015	0.1	0.1	0.1	0.3	72,376	0.2
2016	0.3	0.5	0.1	0.9	165,365	0.8
2017*	0.8	0.4	0.4	1.6	254,034	1.4
2011-2016 Average	0.2	0.6	0.1	0.9	171,176	0.7

*2017 shown for informational purposes only, not used in stock assessment.

Table 4.1.6. Harvest percentage (by number) and value of mature female blue crabs less than 5.25 inches CW by area and overall, 2011-2017.

	Mature Female Harvest Percent <5.25" Carapace Width					Percent of Total
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Value
2011	0.8	3.0	0.2	3.9	558,223	3.1
2012	0.9	1.7	0.3	2.9	451,630	2.2
2013	0.9	2.2	0.7	3.8	782,678	3.0
2014	0.5	0.6	0.8	1.8	468,715	1.6
2015	1.0	0.5	0.2	1.6	453,072	1.5
2016	1.4	2.2	0.4	4.1	726,198	3.5
2017*	1.9	1.4	0.9	4.2	639,781	3.6
2011-2016 Average	0.9	1.7	0.4	3.0	573,419	2.4

*2017 shown for informational purposes only, not used in stock assessment.

Life Stage and Season Closures

Closures to the blue crab fishery could include season, area, gear, or life stage. The premise behind this management tool is to restrict harvest, whether by time, location, fishery, or life stage to provide protection to blue crabs that are vulnerable to harvest in a particular place and time.

Prohibit Harvest of Immature Female Hard Crabs

Prohibiting the harvest of immature female hard crabs is an example of a life stage closure. In June 2016 the harvest of immature (v-apron) female blue crabs was prohibited under the conditions of the adaptive management framework in Amendment 2 (4; 5). The intent of this measure was to allow immature females the opportunity to mature before being subject to harvest. Data from 2016 was not used in calculating the average value because the prohibition occurred mid-way through the fishing year and would deflate the average reduction if it were included with years when the prohibition was not in effect. Data from 2017 (post-regulation change) was compared to 2011 through 2015 (pre-regulation change) to gauge the impact this regulation change had on commercial hard blue crab harvest after it was implemented. Some low level of harvest was expected in 2017 as immature females are included in the 5% cull tolerance for prohibited crabs in the blue crab catch. The calculations below assume the cull tolerance remains in place.

From 2011 to 2015, immature female crabs made up 1.2% of the total commercial hard blue crab harvest, this fell to 0.5% in 2016, and in 2017 immature female crabs accounted for 0.1% of the total commercial hard blue crab harvest (Table 4.1.7). Even with immature female hard crabs included in the 5% cull tolerance, prohibiting the harvest of immature female hard crabs appears to have increased the opportunity for more females to become spawning adults prior to being eligible for harvest when comparing 2017 harvest to previous years.

Table 4.1.7. Harvest percentage (percent by number) of immature female hard blue crabs by area and overall and annual value of the harvest, 2011 – 2017.

	Immature Female Harvest Percent					Percent
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	of Total Value
2011	0.7	0.5	0.0	1.2	132,871	0.7
2012	1.0	0.2	0.0	1.2	173,246	0.9
2013	1.2	0.1	0.0	1.3	245,834	0.9
2014	1.5	0.2	0.0	1.7	375,154	1.3
2015	0.6	0.3	0.0	0.9	203,234	0.7
2011-2015 Average	1.0	0.3	0.0	1.2	226,068	0.9
2016*	0.4	0.1	0.0	0.5	62,658	0.3
2017**	0.1	0.1	0.0	0.1	11,650	0.1

*2016 not used in average because prohibition on immature female harvest began in June 2016
**2017 shown for informational purposes only, not used in stock assessment

Season Closure

A season closure can be used to restrict harvest during certain times of the year to reduce removals from the stock. Since effort can be increased during the open periods of the fishery to offset losses during the closed season, it is best to have seasonal closures that are a minimum of two weeks, but preferably longer. The timing of harvest from the different blue crab fisheries should also be considered with any season closure.

Late season closures tend to be more effective in achieving harvest reductions because there is less opportunity for recoupment by the fisheries. However, a possible result of season closures would be an increase in discards, particularly in fisheries that land, but do not target blue crabs. Table 4.1.8 shows the monthly harvest percent by month, looking at this table shows, for example, a December closure has the potential to reduce commercial hard blue crab harvest by 2.9% for 2016 which represents approximately 2.8% of the hard blue crab value and a March closure has the potential to reduce commercial hard blue crab harvest by 5.0% and 6.6% of the annual value (Table 4.1.8).

At the request of the Blue Crab FMP AC, additional season closure options were explored for management options 12 and 18 in Table 4.1.13. These include various options for early season closures (portions or all of January, February, or March) as well as different early season closures based on area. If an early season closure is adopted, it would replace the annual pot closure period (Jan. 15 – Feb. 7 which may reopen after Jan. 19) and would remain closed for the entire closure period in order for the estimated harvest reduction to be achieved. Table 4.1.9 shows the estimated 2016 harvest reductions and value for the different early season closure periods explored. For example, one of the options explored is a March 1 through March 24 closure (examined because it is the same number of days as the current pot closure period) which would result in a 4.1% harvest reduction and accounts for 5.5% of the value of the 2016 hard blue crab harvest.

Table 4.1.8. Hard blue crab commercial harvest (percent weight) by region and month and December value by region, 2011 – 2017.

		Monthly Harvest Percent											
Year	Region	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2011	Albemarle	0.0	0.0	2.1	1.4	12.5	18.1	13.8	13.3	18.1	13.5	6.5	0.7
	Pamlico	0.2	0.7	6.7	8.9	13.4	15.4	15.3	10.9	12.9	8.7	5.1	1.8
	Southern	0.2	4.1	10.2	3.4	10.6	10.2	9.6	10.5	11.3	6.8	11.8	11.4
	Overall	0.1	0.6	4.5	4.7	12.8	16.5	14.2	12.1	15.6	11.1	6.2	1.7
2012	Albemarle	0.0	0.2	1.6	0.9	14.7	21.0	18.9	16.2	11.6	10.0	4.4	0.6
	Pamlico	0.3	1.1	5.4	9.7	19.7	19.4	16.0	11.6	6.5	5.9	3.3	1.3
	Southern	2.4	4.9	5.4	8.7	13.5	10.0	10.0	11.3	8.4	7.1	9.4	8.8
	Overall	0.3	0.8	3.0	4.1	16.1	19.7	17.4	14.4	9.9	8.5	4.5	1.4
2013	Albemarle	0.0	0.0	0.3	1.2	5.3	15.0	15.8	19.3	20.5	18.3	4.1	0.3
	Pamlico	0.1	0.1	1.5	8.6	14.5	17.0	14.6	12.6	10.2	11.4	7.7	1.7
	Southern	1.5	3.5	4.3	3.9	13.6	14.0	14.3	12.0	8.4	9.0	8.8	6.7
	Overall	0.2	0.3	0.9	3.1	8.0	15.4	15.4	17.2	17.3	16.0	5.3	1.1
2014	Albemarle	0.0	0.0	0.2	1.3	8.8	15.0	12.7	19.6	22.7	16.3	3.2	0.2
	Pamlico	0.2	0.4	0.9	7.0	11.0	13.3	15.8	16.3	15.4	13.2	5.1	1.4
	Southern	1.1	1.8	2.8	2.9	13.4	14.1	14.5	11.9	10.2	9.3	11.3	6.7
	Overall	0.1	0.2	0.5	2.6	9.6	14.6	13.5	18.4	20.4	15.2	4.0	0.9
2015	Albemarle	0.0	0.0	0.2	1.6	8.1	12.4	10.3	18.4	18.9	19.4	9.0	1.7
	Pamlico	0.2	0.1	1.2	4.2	7.2	13.1	16.8	15.3	12.9	11.7	11.4	5.9
	Southern	1.2	0.8	7.9	4.7	15.3	14.8	9.7	9.5	8.3	8.7	9.6	9.6
	Overall	0.1	0.1	0.9	2.6	8.2	12.7	12.4	17.0	16.4	16.4	9.8	3.4
2016	Albemarle	0.4	0.1	3.3	0.9	8.5	19.7	14.8	13.0	14.2	15.5	8.2	1.4
	Pamlico	1.5	0.4	6.8	3.7	9.0	11.2	13.7	13.3	11.7	13.2	11.0	4.4
	Southern	2.1	2.8	6.2	7.1	16.7	12.4	11.4	9.5	9.0	7.6	8.8	6.5
	Overall	1.0	0.4	5.0	2.4	9.2	15.8	14.1	12.9	12.9	14.0	9.4	2.9
2017*	Albemarle	0.2	0.6	0.9	0.8	16.6	22.5	11.7	13.6	13.3	14.8	4.9	0.2
	Pamlico	1.2	4.0	3.4	6.3	15.9	19.3	14.9	14.0	9.6	7.2	3.7	0.5
	Southern	3.0	7.3	3.6	5.2	13.7	11.3	10.2	10.4	8.6	9.2	10.1	7.2
	Overall	0.8	2.3	2.0	3.1	16.1	20.4	12.7	13.5	11.6	11.7	4.9	0.9
2011-2016 Average	Albemarle	**0.1**	**0.1**	**1.2**	**1.2**	**9.6**	**16.6**	**14.2**	**16.9**	**17.9**	**15.6**	**5.9**	**0.8**
	Pamlico	**0.5**	**0.5**	**4.3**	**6.8**	**12.1**	**14.6**	**15.4**	**13.1**	**11.7**	**10.5**	**7.5**	**3.0**
	Southern	**1.4**	**3.1**	**6.2**	**5.3**	**13.8**	**12.4**	**11.5**	**10.8**	**9.2**	**8.0**	**9.9**	**8.3**
	Overall	**0.3**	**0.4**	**2.5**	**3.3**	**10.7**	**15.7**	**14.4**	**15.3**	**15.4**	**13.5**	**6.7**	**2.0**

*2017 shown for informational purposes only, not used in stock assessment

Table 4.1.9. Additional season closure options explored at the request of the Blue Crab FMP AC.

Closure Period	2016 Harvest Reduction (%)	2016 Value (%)
January 15 - February 7 Closure	0.1	0.2
January 1 - January 31 Closure	1.0	1.0
January 1 - February 28/29 Closure	1.3	1.6
March 1 - March 15 Closure	2.6	3.6
March 16 - March 31 Closure	2.4	3.1
March 1 - March 24 Closure	4.1	5.5
March 8 - March 31 Closure	4.3	5.7
March 1 - March 31 Closure	5.0	6.6
January 1 - January 31 Harvest Closure North of 58 Bridge	0.9	0.2
March 1 - March 15 Closure South of 58 Bridge	0.1	0.1
February 20 - March 15 Closure South of 58 Bridge	0.2	0.2

Adjust the Cull Tolerance of Prohibited Hard Blue Crabs

The current cull tolerance of 5% was implemented in June 2016 under the adaptive management plan in Amendment 2 through the May 2016 Revision (4), prior to this action the cull tolerance was 10%. If Amendment 3 is adopted without either maintaining the cull tolerance at 5% or adopting a different tolerance, then the cull tolerance will revert back to 10%. The harvest reductions for 2011-2015 are in relation to the 10% cull tolerance in place prior to 2016. The 2011-2015 period is included here for reference because if the adopted management strategy does not maintain the current 5% cull tolerance or set another cull tolerance value it will revert back to the 10% cull tolerance in place prior to the adoption of the 2016 Revision. Due to data limitations, low sample size, and fishermen behavior harvest reductions could only be calculated for lowering the cull tolerance to zero.

In order to avoid double counting crabs for the harvest reduction calculations and to properly calculate the harvest reduction from reducing the cull tolerance to zero, two different sets of calculations were produced. This was necessary because the cull tolerance (made up of immature females and sublegal males) and immature female harvest are intrinsically linked. Immature females less than five inches CW were previously included in the 10% cull tolerance and when immature female harvest was prohibited in 2016 they were included in the reduced 5% cull tolerance. As a result, the first set of calculations assumes the prohibition on immature female harvest is no longer in effect and immature females are once again subject to the 5-inch minimum size limit. The second set of calculations assumes the prohibition on immature female harvest remains in place and that reduction is accounted for with that management option.

Reducing the cull tolerance of prohibited hard blue crabs to zero (i.e., sublegal males and immature females) would allow individual crabs a greater chance to mature and spawn prior to being harvested. Assuming the prohibition on immature female harvest is removed and the 5-inch minimum size limit restored, the total harvest reduction from reducing the cull tolerance to zero would be 3.7% (combined for sublegal males and sublegal immature females) for 2016 which represents approximately 2.2% of the hard crab value (Table 4.1.10). Assuming the prohibition on immature female harvest remains in place, the total harvest reduction from reducing the cull tolerance to zero would be 3.6% for 2016 which represents approximately 2.2% of the hard crab value over this same period (Table 4.1.11). Recoupment would likely occur as males or immature females grow to the legal minimum size or as immature females mature.

Table 4.1.10. Harvest percentage (by number) and value of sublegal male and sublegal immature female hard blue crabs by area and overall, 2011-2017.

	Sublegal Male and Sublegal Immature Female Harvest Percent					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	3.7	1.1	0.1	4.9	502,626	2.8
2012	3.8	1.7	0.2	5.7	703,557	3.5
2013	2.1	0.4	0.1	2.7	470,373	1.8
2014	2.3	0.6	0.2	3.1	637,362	2.1
2015	2.7	1.2	0.1	4.0	728,081	2.5
2011-2015 Average	3.0	1.0	0.1	4.1	608,400	2.5
2016*	2.5	0.9	0.2	3.7	464,655	2.2
2017**	3.1	0.5	0.1	3.8	467,038	2.6

*2016 not used in average because prohibition on immature female harvest and reduction in cull tolerance began half way through the year

**2017 shown for informational purposes only, not used in stock assessment

Table 4.1.11. Harvest percentage (by number) and value of sublegal male and immature female (2017 only) hard blue crabs by area and overall, 2011-2017.

	Sublegal Male Harvest Percent					
Year	Albemarle	Pamlico	Southern	Overall	Value ($)	Percent of Total Value
2011	3.5	0.9	0.1	4.5	465,443	2.6
2012	3.5	1.6	0.2	5.3	639,218	3.2
2013	1.8	0.4	0.1	2.3	401,069	1.5
2014	2.2	0.5	0.2	2.8	564,363	1.9
2015	2.5	1.1	0.1	3.8	686,496	2.3
2016*	2.5	0.9	0.2	3.6	452,896	2.2
2017**	3.1	0.5	0.1	3.7	462,804	2.6
2011-2015 Average	2.8	0.9	0.1	3.8	534,914	2.2
2017 Immature Female Harvest	0.1	0.1	0.0	0.1	11,650	0.1

*2016 not used in average because prohibition on immature female harvest and reduction in cull tolerance began half way through the year

**2017 shown for informational purposes only, not used in stock assessment

Harvest Reduction Scenarios

The individual estimated 2016 harvest reduction for each management measure examined are presented in Table 4.1.12. They range from 0.5% (prohibit immature female harvest) to 5.0% (March 1 through March 31 closure). Cumulative reductions for combinations of management measures were calculated using the 2016 reduction from each separate measure as inputs into the appropriate formula for the number of options being combined (Table 4.1.13). Potential management scenario combinations are presented in Tables 4.1.14-4.1.15. They range from implementing one to four of the above management measures and cover all possible combinations of measures explored in this paper. The projected 2016 reductions range from 0.5% to 10.9% depending on the combination of management options. The minimum harvest reduction required to satisfy statutory requirements is 2.2% and can be achieved by implementing a 5.0-inch mature female minimum size limit, prohibiting immature female hard crab harvest, and January 1 through January 31 closure (2.3% reduction). Table 4.1.15 expands on possible closure dates for management scenarios 12 and 18 from Table 4.1.14. Due to the low likelihood they would be selected together, management measure combinations with both a minimum and maximum size limit for mature female blue crabs or multiple closure periods are not presented in Table 4.1.13 but can be produced upon request.

Table 4.1.12. Estimated individual 2016 harvest and value reduction for each management measure.

Management Measure	Estimated 2016 Harvest Reduction (%)	Estimated 2016 Value Reduction (%)
6.75" Mature Female Maximum Size	1.5	1.4
6.5" Mature Female Maximum Size	4.3	3.8
5.0" Mature Female Minimum Size	0.9	0.8
5.25" Mature Female Minimum Size	4.1	3.5
Prohibit Immature Female Harvest	0.5	0.3
December 1 - December 31 Closure	2.9	2.8
Reducing Cull Tolerance to Zero	3.7	2.2
January 15 - February 7 Closure	0.1	0.2
January 1 - January 31 Closure	1.0	1.0
January 1 - February 28/29 Closure	1.3	1.6
March 1 - March 15 Closure	2.6	3.6
March 16 - March 31 Closure	2.4	3.1
March 1 - March 24 Closure	4.1	5.5
March 8 - March 31 Closure	4.3	5.7
March 1 - March 31 Closure	5.0	6.6

Table 4.1.13. Cumulative harvest reduction equations for each number of management options considered.

Number of Options	Harvest Reduction Equation	Variable Definition
1	Z=X	Z=cumulative harvest reduction
2	Z=X+((1-X)*Y)	X=reduction from option 1
3	Z=X+((1-X)*Y)+(1-(X+((1-X)*Y)))*W	Y=reduction from option 2
4	Z=X+((1-X)*Y)+((1-(X+((1-X)*Y)))*W)+((1-(X+((1-X)*Y)+(1-(X+((1-X)*Y)))*W))*U)	W=reduction from option 3
		U=reduction from option 4

Table 4.1.14. Estimated harvest reductions for all management scenario combinations. Gray boxes indicate the harvest reduction needed for varying probabilities of achieving sustainable harvest. Options 1 through 5 do not meet statutory requirements for achieving sustainable harvest. Beginning with option 6, all remaining options meet or exceed the minimum statutory requirement for achieving sustainable harvest. *Examples of different season closures for options 12 and 18 can be found in Table 4.1.15.

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
Options 1-5: Do not meet required 50% probability of ending overfished			
1	Prohibit Immature Female Harvest	1.1	0.5
2	5" Mature Female Minimum Size	0.9	0.9
3	5" Mature Female Minimum Size Prohibit Immature Female Harvest	2.0	1.4
4	6.75" Mature Female Maximum Size	2.3	1.5
5	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest	3.4	2.0
Reduction with a 50% probability of ending overfished			2.2
6	December Closure	2.0	2.9
7	Prohibit Immature Female Harvest December Closure	3.1	3.4
8	Reducing Cull Tolerance to Zero	4.1	3.7
Reduction with a 67% probability of ending overfished			3.8
9	5" Mature Female Minimum Size December Closure	2.9	3.8
10	Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	5.1	4.1
11	5.25" Mature Female Minimum Size	3.0	4.1
12*	5" Mature Female Minimum Size Prohibit Immature Female Harvest December Closure	4.0	4.3
13	6.5" Mature Female Maximum Size	5.4	4.3
14	6.75" Mature Female Maximum Size December Closure	4.3	4.4
15	5" Mature Female Minimum Size Reducing Cull Tolerance to Zero	5.0	4.6
16	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest	4.1	4.6
17	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest	6.4	4.8
18*	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest December Closure	5.3	4.8
19	5" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	5.9	4.9
20	6.75" Mature Female Maximum Size Reducing Cull Tolerance to Zero	6.3	5.1
21	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	7.2	5.5
Reduction with a 90% probability of ending overfished			5.9
22	Reducing Cull Tolerance to Zero December Closure	6.0	6.5

Table 4.1.14. continued…

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
23	Prohibit Immature Female Harvest December Closure Reducing Cull Tolerance to Zero	7.0	6.9
24	5.25" Mature Female Minimum Size December Closure	4.9	6.9
25	6.5" Mature Female Maximum Size December Closure	7.3	7.1
26	5" Mature Female Minimum Size December Closure Reducing Cull Tolerance to Zero	6.9	7.3
27	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest December Closure	6.0	7.3
28	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest December Closure	8.3	7.5
29	5.25" Mature Female Minimum Size Reducing Cull Tolerance to Zero	7.0	7.6
30	5" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	7.8	7.7
31	6.5" Mature Female Maximum Size Reducing Cull Tolerance to Zero	9.3	7.8
32	6.75" Mature Female Maximum Size December Closure Reducing Cull Tolerance to Zero	8.2	7.9
33	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	7.9	8.0
34	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero	10.2	8.2
35	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	9.1	8.3
Reduction with a 96% probability of ending overfished			9.3
36	5.25" Mature Female Minimum Size December Closure Reducing Cull Tolerance to Zero	8.8	10.3
37	6.5" Mature Female Maximum Size December Closure Reducing Cull Tolerance to Zero	11.1	10.5
38	5.25" Mature Female Minimum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	9.7	10.7
39	6.5" Mature Female Maximum Size Prohibit Immature Female Harvest Reducing Cull Tolerance to Zero December Closure	12.0	10.9

Table 4.1.15. Estimated harvest reductions for management options 12 and 18 from Table 4.1.14 with various closure periods requested by the Blue Crab FMP AC.

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2016 Harvest Reduction (%)
Option 12.1: Does not meet required 50% probability of ending overfished			
12.1	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 15 - February 7 Closure	2.2	1.5
Reduction with a 50% probability of ending overfished			2.2
12.2	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 1 - January 31 Closure	2.4	2.3
12.3	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 1 - February 28/29 Closure	2.9	2.7
12.4	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 16 - March 31 Closure	3.4	3.7
Reduction with a 67% probability of ending overfished			3.8
12.5	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 15 Closure	3.2	4.0
12.6	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 24 Closure	4.1	5.4
12.7	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 8 - March 31 Closure	4.2	5.6
Reduction with a 90% probability of ending overfished			5.9
12.8 (PDT)	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 31 Closure	4.6	6.3

Management Option	Management Measure	2011-2016 Average Harvest Reduction (%)	2 Ha Red (
Option 18.1: Does not meet required 50% probability of ending overfished			
18.1	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 15 - February 7 Closure	3.5	
Reduction with a 50% probability of ending overfished			
18.2	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 1 - January 31 Closure	3.7	
18.3 (AC)	Prohibit Immature Female Harvest Jan. 1 - Jan. 31 Closure North of Hwy 58 Bridge March 1 - March 15 Closure South of Hwy 58 Bridge 6.75" Mature Female Max. Size North of Hwy 58 Bridge	3.7	
18.4	Prohibit Immature Female Harvest Jan. 1 - Jan. 31 Closure North of Hwy 58 Bridge Feb. 20 - March 15 Closure South of Hwy 58 Bridge 6.75" Mature Female Max. Size North of Hwy 58 Bridge	3.8	
18.5	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 1 - February 28/29 Closure	4.2	
Reduction with a 67% probability of ending overfished			
18.6	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 16 - March 31 Closure	4.7	
18.7	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 15 Closure	4.6	
Reduction with a 90% probability of ending overfished			
18.8	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 24 Closure	5.4	
18.9	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 8 - March 31 Closure	5.5	
18.10	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 31 Closure	5.9	

Management Option	Management Measure	2011-2016 Average Harvest	2016 Harvest Reductio n (%)	Manageme nt Option	Management Measure	2011-2016 Average Harvest	2016 Harvest Reductio n (%)

		Reductio n (%)	
Option 12.1: Does not meet required 50% probability of ending overfished			
12.1	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 15 - February 7 Closure	2.2	1.5
Reduction with a 50% probability of ending overfished			2.2
12.2	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 1 - January 31 Closure	2.4	2.3
12.3	5" Mature Female Minimum Size Prohibit Immature Female Harvest January 1 - February 28/29 Closure	2.9	2.7
12.4	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 16 - March 31 Closure	3.4	3.7
Reduction with a 67% probability of ending overfished			3.8
12.5	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 15 Closure	3.2	4.0
12.6	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 24 Closure	4.1	5.4
12.7	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 8 - March 31 Closure	4.2	5.6
Reduction with a 90% probability of ending overfished			5.9
12.8 (NCDMF)	5" Mature Female Minimum Size Prohibit Immature Female Harvest March 1 - March 31 Closure	4.6	6.3

		Reductio n (%)	
Option 18.1: Does not meet required 50% probability of ending overfished			
18.1	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 15 - February 7 Closure	3.5	2.1
Reduction with a 50% probability of ending overfished			2.2
18.2	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 1 - January 31 Closure	3.7	2.9
18.3 (AC)	Prohibit Immature Female Harvest Jan. 1 - Jan. 31 Closure North of Hwy 58 Bridge March 1 - March 15 Closure South of Hwy 58 Bridge 6.75" Mature Female Max. Size North of Hwy 58 Bridge	3.7	3.2
18.4	Prohibit Immature Female Harvest Jan. 1 - Jan. 31 Closure North of Hwy 58 Bridge Feb. 20 - March 15 Closure South of Hwy 58 Bridge 6.75" Mature Female Max. Size North of Hwy 58 Bridge	3.8	3.2
18.5	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest January 1 - February 28/29 Closure	4.2	3.3
Reduction with a 67% probability of ending overfished			3.8
18.6	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 16 - March 31 Closure	4.7	4.3
18.7	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 15 Closure	4.6	4.5
Reduction with a 90% probability of ending overfished			5.9
18.8	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 24 Closure	5.4	6.0
18.9	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 8 - March 31 Closure	5.5	6.2
18.10	6.75" Mature Female Maximum Size Prohibit Immature Female Harvest March 1 - March 31 Closure	5.9	6.9

Adaptive Management of the North Carolina Blue Crab Stock

Adaptive management is a structured, iterative process of decision-making when uncertainty is present, with the objective of reducing uncertainty through time with monitoring. Adaptive management uses a learning process to improve management outcomes (6). The challenge with using adaptive management is to find a balance between gaining knowledge to improve management and achieving the best outcome based on current knowledge (7). As more is learned about a fishery, adaptive management provides flexibility to incorporate new data and information to accommodate alternative and/or additional actions. In the context of North Carolina FMPs, adaptive management is an optional management framework contained which allows for specific management changes to be taken between FMP reviews under specified circumstances to accomplish the goals and objectives of the plan. Proposed actions are evaluated, adopted, and documented through a revision document. The revision document and process is comparable to the federal "addendum" process.

Amendment 2 established an adaptive management framework for blue crab management based on the annual update of the blue crab traffic light analysis (3). Amendment 3 will replace this framework with one based on the peer-reviewed and approved stock assessment model developed by division staff for the North Carolina blue crab stock. The stock assessment was able to establish biological reference points necessary for managing and ensuring the sustainable harvest of the blue crab stock. A harvest reduction of 0.4% (in numbers of crabs) is projected to end overfishing within two years and a harvest reduction of 2.2% (in numbers of crabs) is projected to achieve sustainable harvest and rebuild the blue crab spawning stock within 10 years of the date of adoption of the plan with a 50% probability of success. This level of reduction is projected to bring spawning stock abundance to the threshold value of 64 million mature females.

The adaptive management framework upon approval of Amendment 3 shall consist of the following:

1. Update the stock assessment at least once in between full reviews of the FMP, timing at the discretion of the division
2. If the stock is overfished and/or overfishing is occurring, then management measures shall be adjusted using the director's proclamation authority
3. Any quantifiable management measure, including those not explored in this paper, with the ability to achieve sustainable harvest (as defined in the stock assessment), either on its own or in combination, may be considered
4. Use of the director's proclamation authority for adaptive management is contingent on:
    a. consultation with the Northern, Southern, and Shellfish/Crustacean advisory committees
    b. approval by the Marine Fisheries Commission
5. If the stock is not overfished and overfishing is not occurring, then current management measures shall remain in place until a new benchmark stock assessment and the next scheduled review of the FMP is completed

Upon evaluation by the division, if a management measure adopted to achieve sustainable harvest (either through Amendment 3 or a subsequent Revision) is not working as intended, then it may be revisited and either: 1) revised or 2) removed and replaced as needed provided it conforms to steps 3 and 4 above.

VI. MANAGEMENT OPTIONS

(+ Potential positive impact of action)
(- Potential negative impact of action)

Below are overarching positive and negative impacts for all options, specific impacts from an option may be found below that option.

- \+ May increase abundance of mature females helping to rebuild the spawning stock
- \+ Will affect both commercial and recreational blue crab fisheries
- \+ No rule changes required
- − Decreased harvest with economic loss to the fishery

1. Implement a size limit for the harvest of mature female blue crabs
    - \+ May increase juvenile recruitment
    - − Some regions may be impacted more than others
    - − Increased catch processing time for fishermen
        - a. 6.75-inch maximum size limit for mature female blue crabs
        - b. 6.5-inch maximum size limit for mature female blue crabs
        - c. 5.0-inch minimum size limit for mature female blue crabs
        - d. 5.25-inch minimum size limit for mature female blue crabs

2. Limit the harvest of immature female hard blue crabs
    - − Some regions may be impacted more than others
    - − Predicted reduction may be less than expected due to recoupment once immature female crabs mature or they may be legally harvested as peeler or soft crabs
    - − Increased catch processing time for fishermen
        - a. Maintain current prohibition on immature female hard blue crab harvest (in effect through 2016 Revision to Amendment 2)
        - b. Allow harvest of immature female hard blue crabs with a 5-inch minimum size limit

3. Seasonal closure of the blue crab fishery
    - +/- Depending on the timing, the predicted reduction may be less than expected due to recoupment once the fishery reopens

4. Adjust the cull tolerance for prohibited blue crabs
    - \+ Increases escapement of prohibited crabs
    - − Predicted reduction may be less than expected due to recoupment once crabs reach legal size or stage

- − Increased catch processing time for fishermen
  a. Maintain the current cull tolerance of 5% (in effect through 2016 Revision to Amendment 2)
  b. Reduce the cull tolerance to zero

5. Adopt the adaptive management framework based on the peer-reviewed and approved stock assessment model
   - + Management is based on biological reference points
   - + Provides for the protection and future sustainability of the blue crab stock
   - − Potential uncertainty in regulations for public

VII. RECOMMENDATIONS

NCDMF Recommendation
Option 12.8: 1) 5-inch mature female minimum size limit, 2) prohibit immature female hard crab harvest, and 3) a March 1 through March 31 closure period.

Recommended season closure for Option 12.8 will replace current pot closure period and will remain closed for the entire time period

Maintain 5% cull tolerance established in 2016 Revision

Adopt proposed adaptive management framework

Blue Crab FMP Advisory Committee
Option 18.3: 1) North of the Highway 58 Bridge: January 1 through January 31 closed season, 6.75" mature female hard crab maximum size limit, and prohibit immature female hard crab harvest and 2) South of the Highway 58 Bridge: March 1 through March 15 closed season and prohibit immature female hard crab harvest

Recommended season closure for Option 12.8 will replace current pot closure period and will remain closed for the entire time period

Maintain 5% cull tolerance established in 2016 Revision

Motion to recommend the proposed adaptive management framework failed in a 3-3 tie

Northern Advisory Committee

Southern Advisory Committee

Shellfish and Crustacean Advisory Committee

Habitat and Water Quality Advisory Committee

NCMFC Selected Management Strategy

VIII. LITERATURE CITED

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APPENDIX 4.2: MANAGEMENT OPTIONS BEYOND QUANTIFIABLE HARVEST REDUCTIONS

I. ISSUE

Results of qualitative management on the North Carolina blue crab stock cannot be quantified. However, implementing these management measures may serve to improve the overall blue crab stock and reduce bycatch.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF).

III. BACKGROUND

As part of Amendment 3, a comprehensive stock assessment was completed. A sex-specific two-stage model was applied to available data to assess the status of North Carolina's blue crab stock during 1995–2016 (1). Data were available from commercial fishery monitoring programs and several fishery-independent surveys. The two-stage model was developed based on the catch-survey analysis designed for species lacking information on the age structure of the population. The model synthesized information from multiple sources, tracked population dynamics of male and female recruits and fully recruited animals, estimated critical demographic and fishery parameters such as natural and fishing mortality, providing a comprehensive assessment of blue crab status in North Carolina. The model estimated an overall declining trend in catch, relative abundance, population size of both male and female recruits and fully recruited crabs, with a rebound starting in 2007. The estimated fishing mortality remained high before 2007 and decreased by approximately 50% afterwards.

The stock status of North Carolina blue crab in the current stock assessment was determined based on maximum sustainable yield (MSY). Results of this stock assessment indicate the North Carolina blue crab resource in 2016 was overfished with a probability of 0.98, with the average spawner abundance in 2016 estimated at 50 million crabs (below the threshold estimate of 64 million crabs). Overfishing was also occurring in 2016 with a probability of 0.52. The average fishing mortality in 2016 was estimated at 1.48, above the fishing mortality threshold estimate of 1.46.

To increase blue crab spawners and recruitment, qualitative management options were developed. Impact of these measures on recruitment and overfishing cannot always be directly measured from the results of the stock assessment. These qualitative management measures may impact these metrics, however, the magnitude of these management measures as well as the possible response of the stock is unknown.

As previously noted, the 2016 stock assessment set quantifiable values for blue crab fishing mortality (overfishing) and spawning stock biomass (overfished). Projections were performed to demonstrate how changes in fishing mortality would impact spawning stock biomass. The earlier traffic light was not a modeling approach that produces these important biological reference points and therefore all management measures considered at that time were not required to be quantitatively assessed in the same manner as required now via the 2016 stock assessment. Currently there are two categories of management measures: quantifiable and beyond quantifiable. “Quantifiable” are those used as direct data inputs for the stock assessment model and produce weighable impact on blue crab recruitment or mortality. “Beyond Quantifiable” are those that aren’t directly part of the stock assessment model and there is no way to measure the impact to the modelled fishing mortality. This does not mean that beyond quantifiable measures are not important to consider in management, they merely are not able to be included in the percent reduction needed to end overfishing/overfished status as statutorily required. If beyond quantifiable measures are implemented, future stock assessments will indirectly reflect their effect on the fishery status. Various beyond quantifiable management options under consideration include gear modifications, life stage closures, and means to control effort in the fishery. Since specific impacts on recruitment and overfishing cannot be calculated, relevant empirical data for the various option are presented herein.

IV. AUTHORITY

North Carolina General Statutes
113-134 RULES
113-182 REGULATION OF FISHING AND FISHERIES
113-182.1 FISHERY MANAGEMENT PLANS
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

North Carolina Marine Fisheries Rules
15A NCAC 03J .0301 POTS
15A NCAC 03J .0302 RECREATIONAL USE OF POTS
15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS
15A NCAC 03L .0202 CRAB TRAWLING
15A NCAC 03L .0204 CRAB POTS
15A NCAC 03R .0118 EXEMPTED CRAB POT ESCAPE RING AREAS

V. DISCUSSION

Gear Modifications

Modification to harvest gear can be used to reduce catch and mortality of sublegal bycatch of target and non-target species. Several studies have examined the effects of the number, placement, and size of cull rings in crab pots. Sampling is also conducted year-round and statewide at commercial crab houses by NCDMF to characterize the gears and harvest of the commercial trip. This sampling is opportunistic and may not characterize the variations in the gear used in the fishery precisely, and sampling intensity can vary by area and year.

Cull ring size

Cull (escape) rings are a device used in crab pots to reduce bycatch, reduce sublegal harvest, and reduce cull time for fishermen. Current rules require three cull rings per pot of 2 5/16-inches minimum inside diameter, one of which must be placed within one full mesh of the corner and one full mesh of the bottom of the divider in the upper chamber of the pot. Size of cull rings required vary among other states (Appendix 3).

Rudershausen and Turano (2) tested three different size cull rings: 2 5/16-inches, 2 3/8-inches, and 2 7/16-inches. The study indicated catch rates of sublegal males were reduced by increasing cull ring size and not by the number of rings (Table 4.2.1). They also found the catch rates of legal males and mature females were generally maintained with larger cull rings and estimated the body length of minimally legal male crabs was not less than the current minimum cull ring diameter. Rudershausen and Hightower (3) tested three different size cull rings: 2 5/16-inches, 2 3/8-inches, and 2 7/16-inches from May through September 2010 in the Pamlico River. Parameters estimated included the carapace width at which half the individuals are retained pots and the carapace width at initial retention. They found the mean number of legal male crabs was not significantly different among cull ring sizes, but the mean number of sublegal male crabs was significantly less in pots using the two largest cull ring sizes (Table 4.2.2). The credible limits in Table 2 indicate the range of values within which an unobserved parameter of a predictive distribution falls. For instance, a 2 5/16-inch cull ring initial retention would fall in the carapace width range of 4.59 inches to 4.73 inches with a median carapace width of 4.67 inches.

Table 4.2.1. Effects of cull ring size, number of cull rings, and their interactions on the CPUE of blue crabs. An asterisk next to the *F*-value indicates data transformation (2).

			Legal male		Sublegal male		Mature female		Sponge	
Estuary	Effect	df	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Currituck Sound	Ring Size	2	10.62	<0.001	523*	<0.001	3.52*	0.030		
	Ring number	2	8.25	<0.001	11.1*	<0.001	1.28*	0.277		
	Interaction	4	0.87	0.482	0.39*	0.816	0.66*	0.623		
Core Sound	Ring Size	2	1.08	0.340	195*	<0.001	10.2*	<0.001		
	Ring number	2	1.39	0.250	2.41*	0.090	0.42*	0.657		
	Interaction	4	0.30	0.878	0.22*	0.928	0.93*	0.449		
Albemarle Sound	Ring Size	1	0.03*	0.864	83.8*	<0.001	0.82*	0.365		
	Ring number	2	0.34*	0.712	3.27*	0.038	0.004*	0.996		
	Interaction	2	0.27*	0.762	0.41*	0.661	0.07*	0.929		
Bogue Sound	Ring Size	1	0.46	0.498	272*	<0.001	2.47*	0.116		
	Ring number	2	1.14	0.319	1.79*	0.168	0.90*	0.406		
	Interaction	2	0.02	0.983	0.01*	0.990	1.17*	0.310		
Eastern Pamlico Sound	Ring Size	1	1.11	0.292	0.61*	0.433	3.16*	0.076	0.04*	0.849
	Ring number	2	0.76	0.469	1.59*	0.204	1.08*	0.341	0.08*	0.920
	Interaction	2	0.46	0.630	0.16*	0.851	0.03*	0.972	0.12*	0.884
Cape Fear River	Ring Size	1	0.02	0.894	15.7*	<0.001	0.002*	0.962		
	Ring number	2	0.19	0.826	2.91*	0.055	0.005*	0.995		
	Interaction	2	2.82	0.060	0.56*	0.572	0.523*	0.593		
Pamlico River	Ring Size	1	2.99	0.084	29.0*	<0.001	3.44*	0.064		
	Ring number	2	0.95	0.388	1.47*	0.230	0.74*	0.479		
	Interaction	2	0.25	0.782	1.62*	0.197	0.37*	0.688		

Table 4.2.2. Median and credible limits (CLs) of logistic retention model parameter estimates of the carapace width (inches) retention size (at which half the individuals are retained pots) and initial retention size (3).

Cull ring size (mm)	Parameter or variable	2.5 CL	Median	97.5 CL
58.7 (2 5/16-inch)	retention size	4.83	4.91	5.00
	initial retention size	4.59	4.67	4.73
60.3 (2 3/8-inch)	retention size	4.97	5.07	5.17
	initial retention size	4.53	4.65	4.73
61.9 (2 7/16-inch)	retention size	5.05	5.13	5.22
	initial retention size	4.70	4.79	4.87

The percent composition of sampled commercial trips cull ring size usage is presented to characterize the size of cull rings used in the fishery and illustrate the degree of impact if cull ring size requirements were to change (Table 4.2.3). For example, if the minimum cull ring size was increased to 2 3/8-inches, approximately 18% of commercial trips from 2011-2016 sampled were at or above this limit and 15% of commercial trips sampled in 2017. The cost and effort to change the cull ring must also be considered; cull rings can be purchased for around $0.25 each.

Table 4.2.3. Percent of sampled (2011-2017) commercial crab pot trips with various cull ring sizes.

	Percent of Sampled Trips by Cull Ring Size	
Cull Ring Size	2011-2016	2017
2 5/16-inch (minimum legal size)	82%	85%
2 3/8-inch	8%	12%
2 7/16-inch	8%	3%
2 1/2-inch	1%	
>2 1/2-inch	1%	

Number of Cull Rings

Research regarding the number of cull rings in crab pots and the associated reduction in retained sublegal crabs by Rudershausen and Turano (2) determined that increasing the number of cull rings did not significantly reduce catch of sublegal males (Table 4.2.1). Two cull rings have been mandatory in hard crab pots in North Carolina since February 1, 1989, except in exempt areas. In January 2017, the number of cull rings required in hard crab pots was increased to three cull rings as part of the revision to Amendment 2, when the traffic light threshold was met to initiate management restrictions. The number of cull rings required to a pot vary among other states (Appendix 3).

The percent composition of sampled commercial trips is shown to characterize the number of cull rings used in the fishery and illustrate the degree of impact on the fishery if the minimum number of cull rings per pot were to change (Table 4.2.4). For example, if the number of required cull rings was increased to four, approximately 9% of commercial trips sampled were at or above this limit. The cost and effort to change the number of cull rings must also be considered. A new cull ring can be purchased for around $0.25 and effort is required to cut an opening in pot mesh and mount the cull ring. In 2017 the minimum number of cull rings was increased from two to three. Yet 5% of commercial trips sampled in 2017 had less than the minimum three cull rings.

Table 4.2.4. Percent of sampled (2011-2017) commercial crab pot trips with varying sizes of cull rings.

	Percent of Sampled Trips	
Number of Cull Rings	2011-2016	2017
2	87%	5%
3	8%	86%
4	3%	7%
5	1%	1%
>5	1%	1%

Placement of Cull Rings

Research has been done regarding the placement of cull rings in crab pots related to reductions in sublegal crabs. Havens et al. (4) tested pots with modified cull ring placement (Figure 4.2.1). Modified pots had cull rings placed in the corner of the pots and flush with the floor of the upper chamber. Approximately 60% of sublegal crabs escaped modified pots within one hour compared to 4% in unmodified pots. The odds of escapement of sublegal crabs in modified pots in a 24-hour period was eighteen times greater than in unmodified pots. Specific crab reductions from modifying the placement of cull rings in crab pots cannot be calculated and the impact on the fishery is unknown.

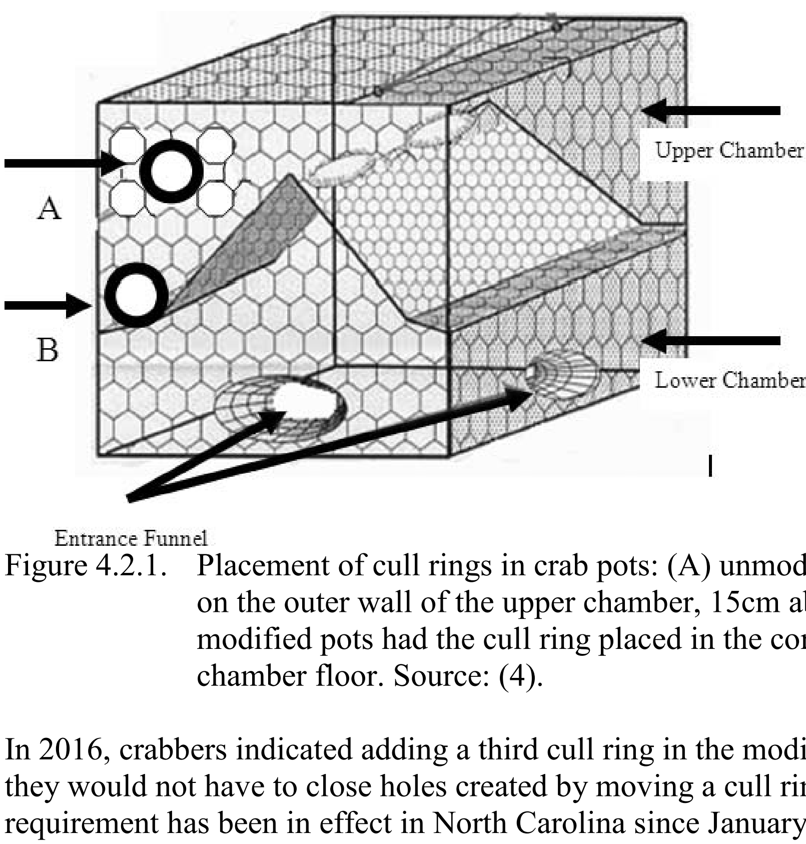

Figure 4.2.1. Placement of cull rings in crab pots: (A) unmodified pots had the cull ring placed on the outer wall of the upper chamber, 15cm above the chamber floor; and (B) modified pots had the cull ring placed in the corner and flush with the upper chamber floor. Source: (4).

In 2016, crabbers indicated adding a third cull ring in the modified position was preferable, as they would not have to close holes created by moving a cull ring. This modified position requirement has been in effect in North Carolina since January 2017. Industry feedback has been positive regarding cull ring placement. Two states besides North Carolina have placement requirements of cull rings (Appendix 3).

Removing Cull Ring Exemptions

Mature female crabs are exempt from the five-inch minimum size limit (NCMFC Rule 15A NCAC 03L .0201 (a)). Some females mature prior to reaching five inches in size and would be unavailable for harvest because once mature they will not grow any larger. Particularly in high salinity areas, such as those with the current escape ring exemption, a portion of the available mature females may be of such a small size they may leave the pot through the 2 5/16-inch escape rings (minimum legal size). Therefore, during the development of Amendment 2, the long-standing proclamation allowing pots to be set without escape rings or with closed escape rings to prevent the loss of small mature female blue crabs in Pamlico Sound and the Newport River were put into rule (Figure 4.2.2). However, the exemption area in Pamlico Sound was reduced by moving the boundary line from six miles from shore to the existing no trawl line behind the Outer Banks.

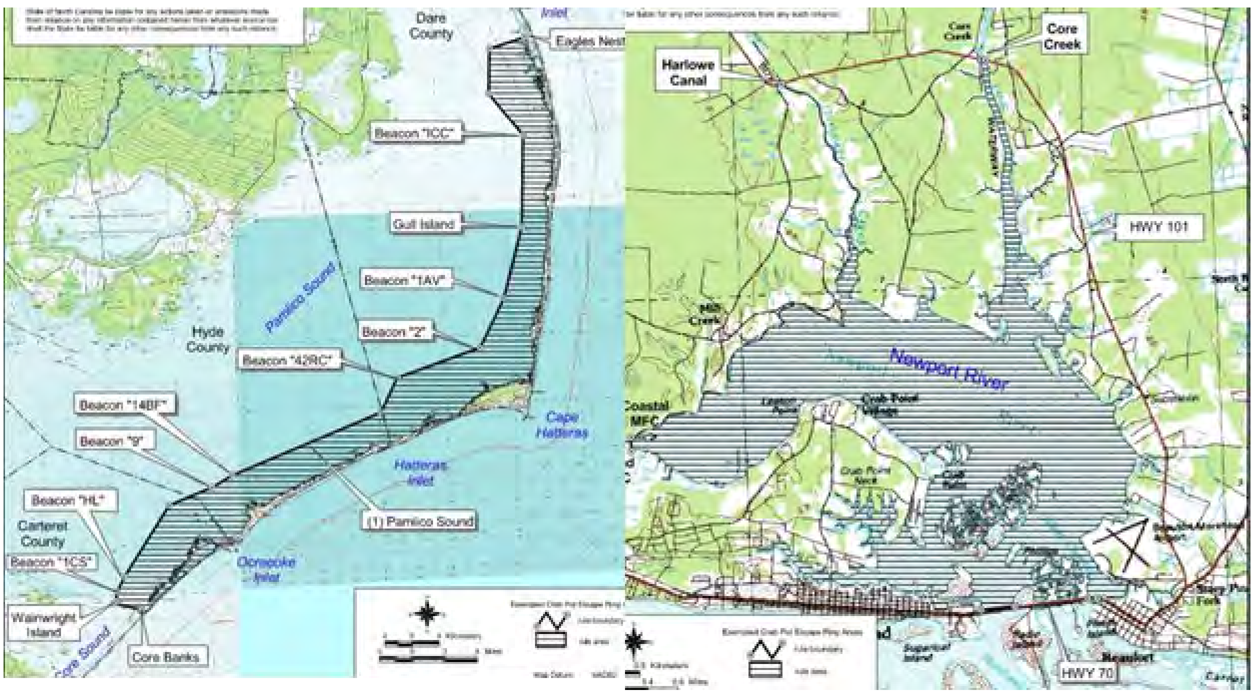

Figure 4.2.2. Escape ring exempted areas in Pamlico Sound, NC (left) and Newport River, NC (right).

Based on NCDMF crab fishery sampling, the escape ring exemption is used in 15% of sampled trips in the allowed areas from 2011-2016 (Table 4.2.5). However, zero trips sampled in 2017 utilized the exemption. Of trips utilizing the exemption, none were from the Newport River. Perhaps in the past when the southern Outer Banks fishery was robust with more crabs and crabbers, the practice of closing the escape rings was more prevalent. Another possibility is there is no market to make it worthwhile for crabbers to retain small mature females.

Table 4.2.5. Percent of sampled (2011-2017) commercial crab pot trips with varying sizes of cull rings in escape ring exempted areas. 2011-2016 n=64, 17 from the Newport River. 2017 n=9, 2 from the Newport River.

	Percent of Sampled Trips	
Number of Cull Rings	2011-2016 (n = 64)	2017 (n = 9)
0	15%	
1	0%	
2	76%	
3	7%	100%
4	2%	

Assuming no cull tolerance for sublegal crabs and a 5-inch minimum size limit, the harvest reduction for eastern Pamlico Sound is approximately 13%. There was not enough commercial crab sampling data specific to the Newport River to estimate harvest reductions for this area. Some measure of recoupment would be likely for both male and immature females. Recoupment for male crabs would likely occur as they grow to the legal minimum size. Recoupment for immature females would likely occur after they undergo their terminal molt and become mature females, which are exempt from the minimum size limit. The recoupment of small mature female crabs would likely be low as some would be able to escape through the existing cull rings.

During development of Amendment 2, NCDMF staff contacted and discussed the Outer Banks escape ring exemption and potential options to modify the boundary with area crabbers. Overall opinions were mixed; but several crabbers indicated they would like to maintain the flexibility to set pots with closed escape rings. If the exemption for these two areas is not removed completely, one alternative would be to reestablish proclamation authority in rule but with specific criteria for the use of that authority. The criteria and resulting rule change could be developed after the adoption of Amendment 3 in conjunction with the Shellfish/Crustacean Advisory Committee. The NCMFC will have the opportunity to weigh in during the rule development process as all rule changes are approved by the commission.

Degradable Panels

An estimated 17% crab pots are lost annually in North Carolina waters (Table 16; 5). Degradable panels disarm gear once lost. This allows organisms which enter derelict pots the ability to leave the trap. Many escape mechanisms rely on hinges or degradable attachments which may fail due to biofouling of the points which hold the panel in place.

During 2002-2005, three different tests were conducted by NCDMF simultaneously in four areas of coastal North Carolina with varying salinities to determine the static degradation of several natural twines and non-coated steel wire (6). Overall, there was a significant amount of variability in the time it took the different materials to degrade within, and between areas and tests. Although, none of the degradable materials had average break times within the critical four-week period when one-third of the annual ghost pot mortality occurred, based on static evaluations, several potentially promising degradable materials were identified for continued testing by commercial crabbers. Additional testing was suggested due to failure rates during deployment and retrieval activities. Table 4.2.6 is an overview of the five test crab pot arrays with varying minimum, maximum, and average break times for each degradable material. Throughout the study, panels functioned better than lid straps. Other states require degradable panels (Appendix 3), which were instituted in part based on the NCDMF 2008 study. This was a complex study with both fishery-independent and fishery-dependent components to the testing, occurring in a variety of environments and salinity regimes.

Table 4.2.6. Minimum, maximum, and average days to break for each degradable material/escapement device, material/device repair time, and percentage of lost catch for functional escapement devices for the commercial crab pot field evaluation in North Carolina, 2005 (6).

		Material – days to break					Percent loss of catch (when device functioned properly)			
Degradable material/escapement device	Total Pots	Number of Pots with Breaks*	Avg.	Min.	Max.	Repair Time (minutes)	Number of Pots with Breaks*	Avg.	Min.	Max.
Lid straps										
Sisal (light)-Lehigh #390/Lid strap	15	11	28	4	58	1.25-10	2	80	80	80
Sisal (heavy) 5/64-inch Cordemex/Lid strap	20	4	76	10	130	1-3	2	67	33	100
Jute (light)-Lehigh #530/Lid Strap	20	11	30	9	72	1-5	5	50	0	100
Jute (heavy) 9/64-inch Winne/Lid strap	15	5	41	25	73	2.25-10	0			
Cotton .062-inch/Lid strap	105	23	37	2	87	1-10	4	79	50	100
Escape panels										
Sisal (light)-Lehigh #390/Panel	30	13	41	5	106	1.25-10	2	100	100	100
Sisal (heavy) 5/64-inch Cordemex/Panel	40	12	50	2	117	1-5	11	97	67	100
Jute (light)-Lehigh #530/Panel	40	21	35	9	165	2-4	15	83	0	100
Jute (heavy) 9/64-inch Winne/Panel	30	14	46	22	107	2.25-10	7	100	100	100
Cotton .062-inch/Panel	35	2	73	72	73	No data	1	100	100	100
Hog Ring 14ga./Panel	35	None								

*Material – days to break, number of pots with breaks is the number of total pots where the material broke. Percent loss of catch, number of pots with breaks is the number of material – days to break, number of pots with breaks where the escape device performed properly (e.g., of 15 pots where light sisal was use, 11 pots had the sisal break and 2 of those 11 pots had the escape device open).

A newer technology has been tested recently in the Chesapeake Bay. Researchers from the Center for Coastal Resources Management, Virginia Institute of Marine Science, College of William & Mary tested polyhydroxyalkanoate (PHA) as a material of choice for biodegradable escape panels. Polyhydroxyalkanoates, unlike plastics or metals, are completely biodegradable by microbes as they are naturally occurring biopolyesters produced by bacteria and used to store energy (7). The PHA break down completely to biomass, water, carbon dioxide, and natural monomers. Panels constructed with PHA have a high certainty of degrading, thus providing an opening the size of the funnel mouth for escapement. To reduce cost, the panel is fabricated to include a cull ring opening as part of the panel (Figure 4.2.3). A blue crab biopanel costs $1.50 each, replacing the $0.25 cull ring. With regular fishing, PHA panel life is extended as UV light inhibits or delays microbe growth, reaching 20 percent loss threshold at about 330 days (8). Although, PHA panels do not degrade within the critical four-week period when one-third of the annual ghost pot mortality occurred, a single panel will degrade 20% within 90 days and reach 40% degraded material (point at which failure is considered) in 180 days (8).

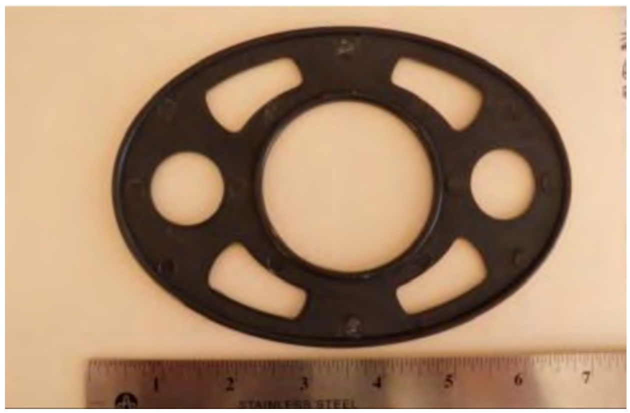

Figure 4.2.3. Polyhydroxyalkanoate biodegradable panel with cull ring and attachment points.

Crab Trawl Tailbag Mesh Size

Existing NCMFC rule requires a minimum stretched mesh of 3-inches for crab trawls for taking hard crabs, except that the Director may, by proclamation, increase the minimum mesh length to no more than 4-inches [15A NCAC 03L .0202 (b)]. Increasing the minimum mesh length of crab trawls in areas not currently under proclamation authority would further reduce catch and mortality of sublegal crab bycatch. In 1992, the NCDMF conducted a study to examine the culling ability of larger tail bag sizes in crab trawls, the number of sublegal blue crabs was reduced by 13% in the 4-inch tail bag and the number of legal crabs was reduced by 7%, as compared to catches in a 3-inch tail bag (Table 4.2.7; 9). Overall survival rates were documented for trawl-caught crabs at 64%, while 93% of the crab pot caught crabs survived (Figure 4.2.4; 10). During a trip in June, a large number of paper shell and soft crabs were killed in the trawling process. Given the high percentage of sublegal blue crabs being captured by the crab trawl fishery, it was recommended that an increase in the minimum tail bag mesh size should be implemented to reduce fishing mortality on this species (9). A reduction of fishing mortality on sublegal crabs should allow more individuals to be available to spawn at a future date. Figure 4.2.5 shows the current boundary for 3-inch and 4-inch crab trawls. Selecting this option would extend the 4-inch minimum mesh size for crab trawls statewide. Increasing the mesh size stateside, based on NCDMF commercial fish house sampling, would impact 84% of fishermen landing crabs from trawl gear.

Table 4.2.7. Total and mean catch weights (kg) of blue crabs for control (3-inch) and experimental (4-inch) tailbags tested in the rivers of western Pamlico Sound, North Carolina, 1991-1992. Table from 9.

	Total			Mean		
Common name	3-inch	4-inch	Percent Difference	3-inch	4-inch	|t| value
Total	305.71	268.36	-12.22	9.86	8.66	1.12
Male	74.00	76	2.70	2.39	2.45	0.51
Immature female	45.00	38.55	-14.33	1.45	1.24	0.57
Female	92.00	86.75	-5.71	2.97	2.80	0.27

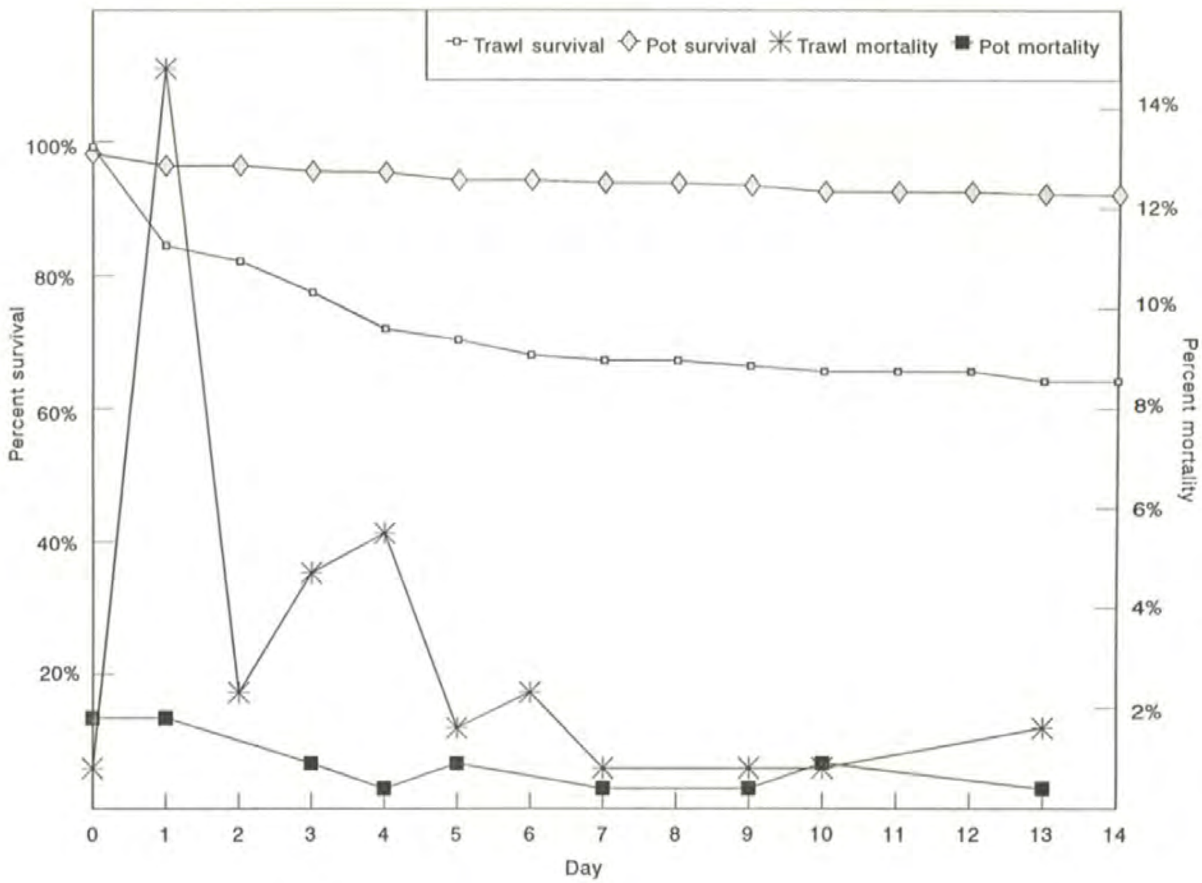

Figure 4.2.4. Cumulative survival rates and daily mortality rates for pot and trawl caught crabs from the Pamlico and Pungo rivers, November 1990-November 1991. High trawl mortality in day 1 is believed to be due to a fish kill in the area a few days before the study began.

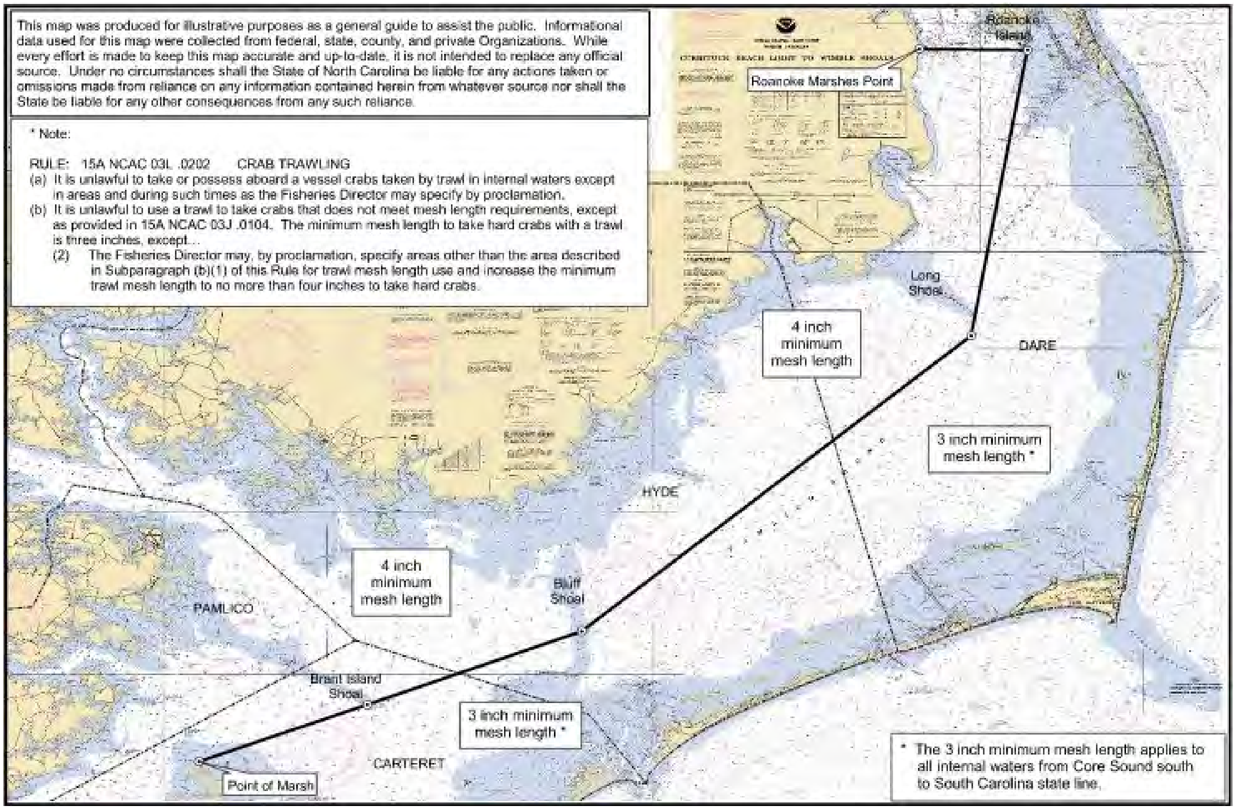

Figure 4.2.5. Current 3-inch and 4-inch crab trawl minimum mesh size boundary in Pamlico Sound.

Limit the Harvest of Sponge Crabs

Sponge crabs are present year-round, however, they begin to appear in significant numbers in March, peaking in May, and persist in lower levels through the summer (Figure 4.2.6). In 2014, the May peak in sponge crabs sampled was greatly evident with 60% of annual sampling occurring in that month. Based on NCDMF fish house sampling, 82% of sponge crabs sampled were from Pamlico Sound 2011-2016 (Table 4.2.8). Often these sponge crab sampling peaks can occur earlier or later in the year than the average May peak. The peak sampling in 2017 was earlier in the season, occurring in March. While in 2011, sampling was evenly distributed wholly between April and July. Prohibition of sponge crab harvest would give mature females the opportunity to spawn and possibly spawn more than once prior to being harvested.

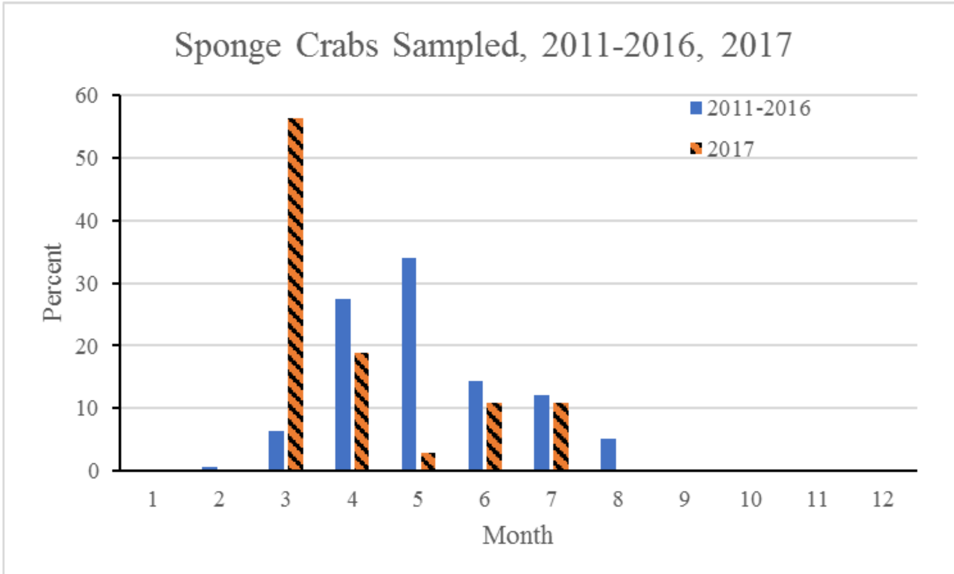

Figure 4.2.6. Average monthly sponge crab frequency in commercial crab sampling, 2011 – 2016, 2017 (2011-2016 n=2,963, 2017 n=571).

A sponge crab closure may be used to restrict harvest during certain times of the year and to reduce removals from the stock and possibly increase recruitment. Since effort can be increased during the open periods of the fishery to offset losses during the closed season, it is best to have seasonal closures that are a minimum of two weeks, but preferably longer. Timing of harvest from the different crab fisheries should also be considered. Since June 6, 2016, dark sponge crabs (brown and black) were prohibited from harvest April 1-April 30. This prohibition has had minimal effect due to the limited duration and specification of sponge color. Additionally, limiting to only dark sponge crabs leads to enforcement complications.

Table 4.2.8. Percent of sampled (2011-2017) sponge crabs by area from NCDMF commercial fish house sampling.

	Year	
Area	2011-2016	2017
Albemarle	< 0.5%	0%
Pamlico	82.0%	62%
Southern	17.5%	38%

Fishing gear interactions may negatively affect blue crab spawning potential. Dickinson et al. (11) reported the majority of sponge crabs caught in pots in the Newport and North rivers of North Carolina had damage to 30-50% of the egg mass. A significantly greater proportion of egg mass damage has been observed of sponge crabs in areas where pots were set as opposed to hand fishing regions of North Carolina (12). Damage may have been from the gear, capture stress, or interactions with other crabs while in pots. Survival of sponge crabs after pot interactions was not affected by sponge damage, however, the likelihood of crabs producing a second clutch was significantly related to previous sponge damage levels (12). Fewer high-damage crabs survived to produce a second clutch (6% reduction). Therefore, an early season closure of the fishery may increase spawning potential of mature females by reducing stress on mature females and reducing damage to egg masses. Removing pots from the water would not only ensure spawning but may also increase future spawning potential of mature females likely to produce multiple clutches.

Seasonal Size Limit for Peeler Crabs

Increased effort and harvest in the peeler/soft blue crab fishery and reduced adult harvest has prompted concern about the impacts of peeler/soft crab harvest on the overall health of the fishery. Mature females, peeler, and soft crabs are exempt from the 5-inch minimum size limit for hard crabs [NCMFC Rule 15A NCAC 03L .0201]. Establishing a minimum size limit for peeler crabs would reduce fishing mortality on the smallest crabs allowed for harvest. Short-term effects of establishing a size limit would be reducing the blue crabs available for harvest, which in turn would decrease the overall harvest. Decreasing harvest should have an effect on reducing fishing mortality. In addition, current peeler fishing practice is to employ live male crabs as an attractant or bit to target immature female peelers. Therefore, the majority of peelers harvested are immature females approaching their terminal molt. Reducing fishing mortality on this segment of the population would contribute to efforts to protect the female spawning stock. Establishing a size limit could have a negative impact on the market by reducing the number of blue crabs available for purchase. However, this may be temporary protection as recoupment may occur in the fishery as crabs grow.

Natural mortality of sublegal crabs (less than five inches) is in the range of 26 - 32% per year in the Chesapeake Bay (13). Eggleston (14) estimated an annual mortality rate of 50% for sub-adult and adult blue crabs in North Carolina. Several other states have minimum size limit restrictions for peeler and/or soft crab harvest (Appendix 4.3). A Maryland report noted that raising the peeler size limit would potentially provide an increase in spawning stock biomass by allowing more females to enter the spawning population (15). Raising the size limit should also increase yield to the fishery. Peeler size limits could possibly improve recruit abundance by allowing some immature female crabs to mature and spawn prior to being subject to harvest.

As the time between sheds increases with increasing size, the probability of capture of larger crabs at the peeler stage decreases. The time interval between sheds of 3.0 or 3.5-inch crabs will generally be one to three months (16). The increased yield from a peeler size limit would not be totally lost to natural mortality. The overall value of the peeler/soft crab fishery might be enhanced by a minimum size limit as larger soft crabs generally bring a higher price. A potential adverse impact on the soft crab fishery would be a decrease in market flexibility, particularly during the early spring when product availability is low and small peeler/soft crabs are in demand, bringing very high prices to fishermen. A peeler size limit may increase handling mortality and waste in the fishery. A peeler/soft crab size limit could allow more effective and efficient enforcement of size limits, both in state and out of state as crabs are shipped to states with existing size limits. Therefore, adopting a peeler minimum size limit of 3 inches would address regulatory consistency among the Atlantic Coast states and potentially foster interstate trade.

NCDMF collects size, sex, and maturity (female) information on peeler crabs harvested for commercial shedding operations (Figure 4.2.7). Sample sizes decline considerably when summarized at a waterbody level and thus, only regional and statewide estimates are provided. Assuming no cull tolerance for sublegal peeler crabs, several minimum size limit options were examined in ¼-inch increments of peelers sampled from 2011 to 2017 (Table 4.2.9). For example, if a 3 ¼-inch minimum size limit was imposed on peeler crab harvest, 4.8% of peeler crabs statewide fell into the size classes below this minimum size. The Pamlico region would be the most impacted by the minimum 3 ¼-inch size limit at 7.3% followed by the Albemarle region at 3.2% and the Southern region at 2.1%.

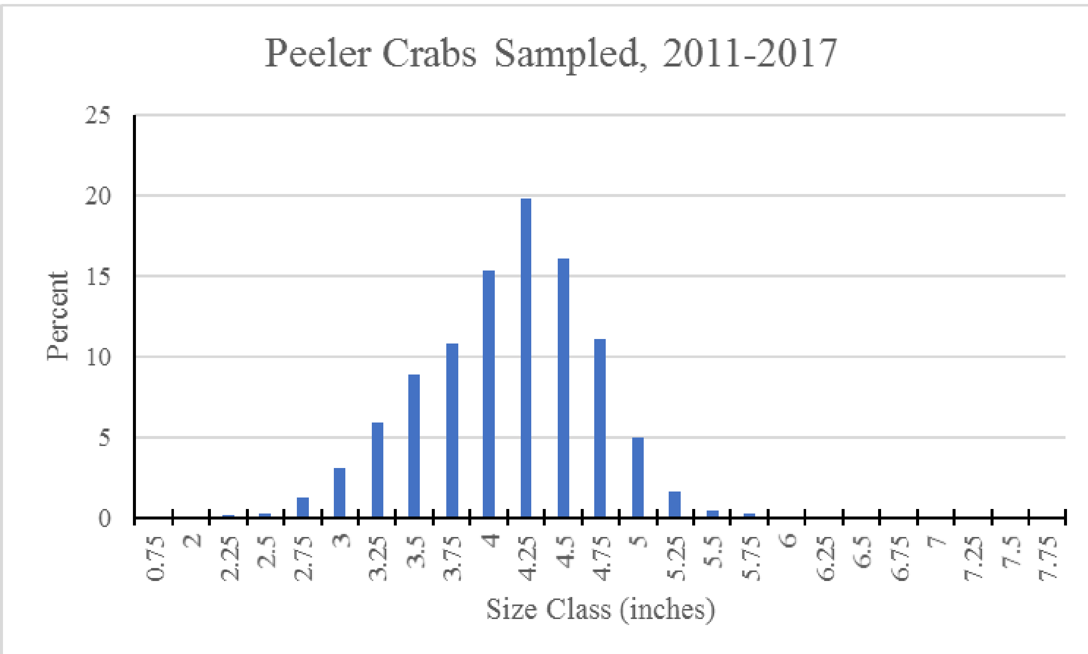

Figure 4.2.7. Average peeler/soft crab size frequency in commercial crab sampling, 2005 – 2017. n=17,708

Table 4.2.9. Estimated harvest reduction percentage (pounds) for various minimum size limits for peeler crabs.

	Peeler Size Limit Reduction Percent			
Minimum Size Limit	Albemarle	Pamlico	Southern	Statewide
3-inch	1.1%	2.8%	0%	1.8%
3 ¼-inch	3.2%	7.3%	2.1%	4.8%
3 ½-inch	6.9%	15.3%	4.1%	10.2%
3 ¾-inch	13.4%	28.2%	10.3%	19.2%

Effort Control

Limiting pots have been discussed since the 1950s. Pot limits are a method of managing effort and improving economic efficiency in the crab pot fishery. The only existing crab pot limit in

North Carolina is a 150 pot per vessel limit in Newport River. This limit was requested by the Newport River crab potters due to gear conflict and has been in existence since 1985.
In 1998 after the Blue Crab FMP was adopted, the NCMFC convened a Regional Stakeholder Advisory Committee to draft an open access plan for the crab pot fishery with discussions including pot limits (17). A considerable amount of time and effort was spent in developing a permit, regional pot limit criteria, and a pot tagging system for enforcement. Consensus could not be reached on an appropriate effort management plan for the blue crab fishery. The NCMFC in 2000 did not implement any aspect of the proposed regional effort management strategy for the crab pot fishery.

The Regional Stakeholder Advisory Committee did not expect effort to increase significantly in the future. While participation has been consistent over time, a marked increase in crab pots occurred in the North Carolina hard crab fishery from 2007 – 2016 (Table 12 Description of the Fishery section). Additionally, the CPUE has remained constant over this time.

Instead of imposing pot limits, restricting to a daily pot fishing time period (e.g., 6 a.m. until 2 p.m.) could potentially reduce the overall amount of gear used and harvest. However, time limits would significantly impact or eliminate fishermen who work other jobs and fish pots after work. Also, problems would develop when full-time fishermen work in tidal areas, generally in the southern region of the state. Such problems as the latter could potentially be addressed through regional management. Many fish houses already restrict fishing times of their crabbers to ensure product is ready for transportation.

<u>Summary of Management Options</u>

Several different management measures are presented in Table 4.2.10. Since projected reductions are not possible for these measures, general effects on landings and economic impacts are presented.

Table 4.2.10. Possible effects to hard crab landings and financial effects on crabbers for each type of management measure.

Management Measure	Effects on Landings	Economic Impact
Increase Cull Ring Size	Neutral	Cost to purchase for all pots Less cull time requires less time on the water and fuel usage
Number of Cull Rings	Neutral	Cost to purchase for all pots Less cull time requires less time on the water and fuel usage
Specify Placement of Cull Rings	Neutral	Cost to add or move cull ring
Remove Cull Ring Exemption	Neutral	Cost to add cull rings
Require Degradable Panel	Neutral	Cost to purchase for all pots Annual cost Replaces need for one cull ring
Increase Tailbag Mesh Size	Minimal reduction in landings	Cost to purchase new tailbag
Limit the Harvest of Sponge Crabs	Reduced landings for limited time Recoupment of catch after eggs shed	Loss of profits
Peeler/Soft Crab Minimum Size Limit	Reduced landings for limited time Recoupment of catch	Loss of profits
Impose Crab Pot Limit	Reduced landings for limited time Recoupment of catch	Loss of profits
Impose Fishing Time Restrictions	Reduced landings for limited time Recoupment of catch	Loss of profits Reduced fuel and gear usage Unfairly impacted crabbers with secondary job

VI. MANAGEMENT OPTIONS

(+ Potential positive impact of action)
(- Potential negative impact of action)

1. Increase cull ring size in pots
    a. Increase cull ring size to 2 3/8 inches
    b. Increase cull ring size to 2 7/16 inches

+Increase escapement of juvenile crabs
+May increase juvenile recruitment
-Decrease harvest with economic loss to the fishery
-Some regions may be impacted more than others
-Additional cost to fishermen to make gear modifications

2. Number of cull rings in pots
    a. Increase the number of cull rings in pots to 3 (in effect through 2016 Revision to Amendment 2)
    b. Increase the number of cull rings in pots to 4
    c. Decrease the number of cull rings in pots to 2 (in effect prior to 2016 Revision to Amendment 2)

+Increase escapement of juvenile crabs
+May increase juvenile recruitment

-Decrease harvest with economic loss to the fishery
-Some regions may be impacted more than others
-Additional cost to fishermen to make gear modifications

3. Specify placement of individual cull rings in pots
    a. Require one cull ring to be placed within one full mesh of the corner and the apron in the upper chamber of the pot (in effect through 2016 Revision to Amendment 2)
    b. Require two cull rings to be placed within one full mesh of the corner and the apron of the pot located on opposite outside panels of the upper chamber of the pot

+Increase escapement of juvenile crabs
+May increase juvenile recruitment
-Decrease harvest with economic loss to the fishery
-Some regions may be impacted more than others
-Additional cost to fishermen to make gear modifications

4. Remove cull ring exemptions to reduce sublegal crabs retained in pots
    a. Remove the cull ring exemption in the Newport River
    b. Remove the cull ring exemption in eastern Pamlico Sound
    c. Remove the cull ring exemptions in the Newport River and eastern Pamlico Sound
    d. Remove the permanent cull ring exemption in rule and replace with proclamation authority to allow the exemption for the Newport River and eastern Pamlico Sound areas (as defined in rule) based on certain criteria. Specific criteria and resultant rule change will be developed in conjunction with the Shellfish/Crustacean AC after the adoption of Amendment 3.

+Increase escapement of juvenile crabs
+May increase juvenile recruitment
-Decrease harvest with economic loss to the fishery
-Some regions may be impacted more than others
-Additional cost to fishermen to make gear modifications

5. Require degradable panels in crab pots to disarm derelict gear

+Increase escapement of juvenile crabs
+Increase escapement of bycatch species
+Disarm abandoned or derelict gear
+Reduce waste from abandoned or derelict gear
-Additional cost to fishermen to install and replace panels
-Possible loss of legal catch due to premature failure of panels

6. Increase crab trawl tailbag mesh size to 4-inches statewide

+Increase escapement of juvenile crabs
+Increase escapement of bycatch species
-Some regions may be impacted more than others
-Additional cost to fishermen to make gear modifications

7. Limit the harvest of sponge crabs

a. Prohibit harvest of dark sponge crabs from April 1 through April 30 (in effect through 2016 Revision to Amendment 2)
b. Prohibit harvest of all sponge crabs from January 1 through May 31
c. Prohibit harvest of all sponge crabs year-round

+Increase spawning potential
+May increase juvenile recruitment
-Some regions may be impacted more than others
-Decrease harvest with economic loss to the fishery
-Increase pressure on other harvest segments (males, immature females, peelers)
-Increase discards where sponge crabs may still be incidentally caught

8. Peeler/soft crab minimum size limit
   a. Establish 3-inch minimum size limit for peeler and soft crabs
   b. Establish a 3 1/4-inch minimum size limit for peeler and soft crabs

+May increase spawning potential
+May increase juvenile recruitment
-Decrease harvest with economic loss to the fishery
-Some regions may be impacted more than others
-Increase discards in the peeler/soft crab fishery
-May increase discard mortality in the peeler/soft crab fishery

9. Impose a limit on the number of crab pots used

+Reduce gear in the water
+May reduce derelict gear
+Decrease cost to fishermen
+Possible increase in CPUE with economic benefit to the fishery
-Increases marine patrol duties
-Some regions may be impacted more than others
-Possible decreased harvest with economic loss to the fishery
-Difficulty implementing a monitoring system
-Administration would be cumbersome and costly
-Previous efforts to establish pot limits were unsuccessful

10. Impose a fishing time restriction

+May decrease the amount of gear fished
+Aid marine patrol
-Unfairly impact part-time crabbers
-Increase number of unattended pots
-Unfairly impact crabbers in tidal waters

VII. RECOMMENDATIONS

<u>NCDMF Recommendation</u>

Option 2a: increase number of cull rings in pots to 3
Option 3b: two cull rings placed within one full mesh of corner and the apron on opposite outside panels in the upper chamber

Option 4c: remove cull ring exemptions for Newport River and eastern Pamlico Sound and prohibit designation of exempt areas in future
Option 7c: prohibit harvest of sponge crabs year-round
Option 8a: establish 3” minimum size limit for peeler and soft crabs

Blue Crab FMP Advisory Committee
Leave in existing rules put in in 2016 and do not adopt anything else at this time. Except with 2 options on cull rings: 1) 2 cull rings in proper corner placement or 2) keeping the 3 cull rings with 1 in proper placement.

Northern Advisory Committee

Southern Advisory Committee

Shellfish and Crustacean Advisory Committee

Habitat and Water Quality Advisory Committee

NCMFC Selected Management Strategy

VIII. LITERATURE CITED

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APPENDIX 4.3: ADDRESSING WATER QUALITY CONCERNS IMPACTING THE NORTH CAROLINA BLUE CRAB STOCK

I. ISSUE

Water quality plays an important role in blue crab life history. Improving water quality by addressing pollution sources, especially agricultural runoff, may positively impact the North Carolina blue crab stock.

II. ORIGINATION

North Carolina Division of Marine Fisheries (NCDMF).

III. BACKGROUND

Growth and survival of blue crabs is maximized when water quality parameters, such as temperature, salinity, and oxygen, are within optimal ranges. These parameters have been identified by life stage in the biological profile and ecosystem impact on the fishery sections (Ecosystem Impact on the Fishery section). When conditions are outside the suitable range for extended periods or environmental parameters rapidly change, blue crabs can be adversely impacted. North Carolina contains the largest estuarine system of any single Atlantic coast state, with numerous estuarine rivers, creeks, sounds, inlets, and ocean bays creating a diverse system of over 2.3 million acres in size. The Albemarle-Pamlico system is the third largest estuarine complex in North America and the second largest in area in the United States (1). The estuarine water sheds' land area is divided between the Coastal Plain and Piedmont physiographic regions, with the majority of land in the Coastal Plain. Large freshwater influx from rain events or hurricanes and long flushing times of the Albemarle-Pamlico system are related to the major environmental stresses facing benthic communities in these areas (2; 3; 1).

Mortality of blue crabs has been observed from exposure to toxins such as the mosquito abatement chemical piperonyl butoxide (4) and industrial biproduct dioxin (5). Bell et al (6) reported adult blue crab survival declined with increased exposure to hypoxia (low dissolved oxygen). After 30 hours, survival markedly declined with 84.4 percent, 54.8 percent, and 3.1 percent surviving low dissolved oxygen (DO) treatments of 1.5 mg L^{-1}, 1.0 mg L^{-1}, and 0.5 mg L^{-1}, respectively. Additionally, movement and burial diminished, however, crabs in chronically hypoxic waterbodies were able to sustain activity longer than those from other waterbodies. Crabbing productivity is reduced in tributaries with average DO concentration less than 5 mg L^{-1} (7). One cause of hypoxia is blue-green algae blooms. Garcia et al (8) confirmed mycrocystins, toxic blue-green algae which may be harmful to humans, may occur in blue crab tissue samples.

As land use changed ≥ 12.8 percent in North Carolina catchments, blue crab catch per trawl declined on average 0.4 crabs per trawl (9). This is opposed to a 0.8 crabs per trawl increase in unaltered catchments. All altered lands can contribute to water quality degradation. Much of the land around the Albemarle-Pamlico Estuarine System, which accounts for the largest amount of blue crab harvest, has been drained to accommodate agriculture and silviculture (Figure 1).

Agricultural lands include cropland, pastureland, animal operations, and land-based aquaculture. Sowing fields, spraying to protect from pests, preparing crops for harvest, and harvesting activities can all impact water quality in ways that may be harmful to blue crabs. This issue paper will focus on water quality impacts from agriculture and potential management measures. Protecting the waters from impacts of agriculture is promoted through natural resource management with assistance from the Department of Agriculture and Consumer Services' Division of Soil & Water Conservation (NCDA&CS S&WC). It is estimated that over two million acres have been drained and developed for agriculture and silviculture along the North Carolina coast. Within each square mile of agricultural land in coastal North Carolina, there are estimated to be more than 20 miles of ditches and canals leading to downstream systems (10; 11).

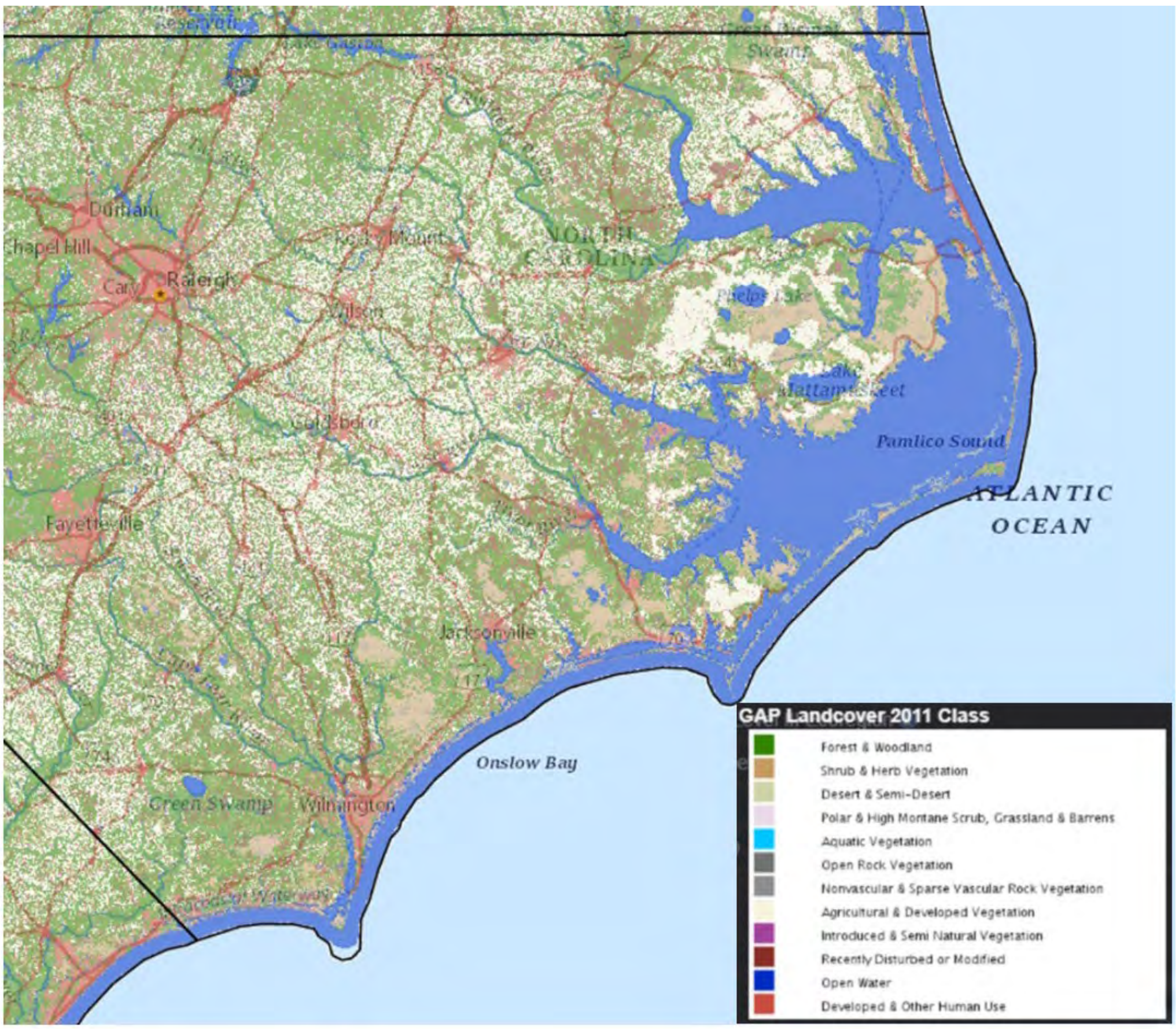


Figure 4.3.1: Land cover types within eastern North Carolina based on USGS GAP land cover data.

Negative environmental impacts due to agriculture include pollution from nutrients, eroded soils, and pesticides. Nationally, northern North Carolina coastal watersheds have ranked in the top 10 percent for nitrogen loading from commercial fertilizer applications and rank near the top as measured by potential threats to human drinking water supplies, fish, and aquatic life due to pesticide leaching and runoff (12; 13). Agricultural land in the Neuse River Basin contributed 55 percent of the total annual nonpoint source nitrogen loading post rain event (14). Toxic chemical contamination is not evaluated by Division of Water Resources (DWR) in estuarine and nearshore ocean waters. Current standards do not eliminate the risk from toxins since: (1) safe levels are not established for many toxic chemicals; (2) mixtures and breakdown products are not considered; (3) effects of seasonal exposure to high concentrations have not been evaluated; and (4) some potential effects, such as endocrine disruption and unique responses of sensitive species, have not yet been assessed.

Nutrient rich environments, poor flushing, abundant fish communities, and brackish salinities are known to promote toxic algal growth (15;16). Outbreaks of the toxic dinoflagellate Pfiesteria occurred in the 1990s in the Neuse, Pamlico, and New River estuaries, which are characterized as shallow, poorly flushed systems (17; 18; 15; 19). Nuisance algal blooms began to occur more often post 1970 and continue to occur regularly in the lower reaches of the Chowan and Neuse rivers (20; 21; 22; 3). Algal blooms are often associated with periods of low DO.

Hypoxia, low DO, is often due to eutrophication (excessive nutrients). Hypoxic events can influence distribution and abundance of blue crabs. In NOAA's 2013 2nd National Habitat Assessment Workshop, it was stated that habitat compression due to low DO may be associated with a 10-50 percent worldwide decline of pelagic predator diversity (23). In North Carolina in 2018, low DO was the cause of 15 of 21 reported fish kills statewide, resulting in mortality of 117,790 individuals (24). Other reported causes include spills and other/unknown causes.

Negative environmental factors affecting blue crab will likely be exacerbated by climate change. Climate change is likely to impact our coastal systems through episodes of extreme weather events which may increase runoff, flooding, and irrigation needs. These impacts can reduce water quality and damage infrastructure in place to transport water on and off the land (25). Warmer temperatures, wetter climates, and increased CO_2 will allow many weeds and pests to thrive, increasing the need for herbicides and pesticides over crops. Bottom temperatures above 25°C are directly correlated to declines on average of 0.6 crabs per trawl catch of blue crabs (9). Heavy episodic rains can increase runoff into receiving surface waters introducing sediment, nutrients, pollutants, animal waste, and other materials making water unusable and in need of water treatment. Conversely, rising sea level and drought can cause coastal waters to become more saline. Higher salinity and water temperature can facilitate the spread of disease through the blue crab stock and alter the life cycle.

On August 14, 1997, Governor James B. Hunt, Jr., signed the Fisheries Reform Act (FRA) into law. The legislation's foremost goal was to ensure healthy fish stocks, the recovery of depleted stocks, and the wise use of fisheries resources. The FRA (G.S. 143B-279.8) requires preparation of Fishery Management Plans (FMPs) by the NCDMF and Coastal Habitat Protection Plans (CHPPs) by DEQ. The legislative goal of the CHPP is "…the long-term enhancement of coastal fisheries associated with coastal habitats." The law specifies the CHPP identify threats and recommend management actions to protect and restore habitats (and water quality) critical to North Carolina's coastal fishery resources. The plans must be adopted by the Coastal Resources (CRC), the Environmental Management (EMC), and the Marine Fisheries (NCMFC) commissions, to ensure consistency among commissions, as well as their supporting DEQ agencies (26).

While the NCMFC manages fishing practices in coastal waters through rules implemented by the NCDMF, several agencies manage activities affecting coastal fisheries and fish habitats. The EMC has authority over activities affecting water quality, such as point and nonpoint discharges (i.e., agricultural runoff, wastewater, and stormwater) and alteration of wetlands. The EMC's rules are implemented by different DEQ agencies, including the Division of Water Resources (DWR), the Division of Air Quality (DAQ), and the Division of Energy, Mineral, and Land Resources (DEMLR). The DEMLR administers rules adopted by multiple regulatory commissions, including the EMC, Sedimentation Control Commission (SCC), and the Mining and Energy Commission. The CRC enacts rules to manage development within and adjacent to public trust and estuarine waters, coastal marshes, and the ocean hazard area. The Division of Coastal Management (DCM) implements rules adopted by the CRC. The Wildlife Resources Commission (WRC), while not a principle participant in the CHPP process, has a direct role in the management of fisheries and habitat through the designation of Primary Nursery Areas (PNAs) and Anadromous Fish Spawning Areas (AFSAs) in Inland Waters, the review of development permits, monitoring and management of habitat, and the regulation of fishing in inland waters. There is a myriad of other state, federal, and interstate programs that directly or indirectly influence coastal fisheries habitat in North Carolina.

Surface waters of North Carolina are assessed regularly by DWR. These data are used to develop use support ratings biennially and reported to the U.S. EPA. The Integrated Report (IR) to Congress regarding the quality of our nation's waters is a compilation of reports of Sections 303d, 305b, and 314 of the Clean Water Act for the 50 states, 5 inhabited territories, and the District of Columbia. Impaired waters are reported on the 303(d) list. A map of the 2018 impaired waters is available from the DWR website as 2018 impaired waters map. DWR monitoring stations within the overall CHPP management unit include approximately 256 ambient stations, 76 fish community sample sites, and 245 benthic macroinvertebrate sample sites. Other water quality monitoring in the CHPP region includes: 22 Albemarle-Pamlico National Estuary Program (APNEP) Citizen's Monitoring Stations, USGS special study investigations, and NCDMF fish sampling programs.

IV. AUTHORITY

North Carolina General Statutes
113-134 RULES
113-182 REGULATION OF FISHING AND FISHERIES
113-182.1 FISHERY MANAGEMENT PLANS
143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES
143B-279.8 COASTAL HABITAT PROTECTION PLANS

V. DISCUSSION

Pollutants can enter surface waters from point sources, such as waste-water treatment plants or industrial discharge, and nonpoint sources, including runoff from agricultural and developed land. Most pollutants in surface waters are the result of nonpoint source activities (27). Most nutrient pollution in the Albemarle and Pamlico systems has been linked to agriculture activities (28; 29; 30). Runoff can introduce sediments, nutrients, bacteria, organic wastes, toxins, and metals into surface waters. Due to the difficulty in controlling, measuring, and monitoring nonpoint sources, a combination of practices known as Best Management Practices are required or recommended to limit negative effects to the waterways. Best Management Practices on agricultural lands may include riparian buffers, erosion and sediment control, conservation tillage, nutrient management, and pest management plans.

High nutrient levels and low flushing rates increase a waterbody's susceptibility to hypoxia and subsequent fish kills (26). Several North Carolina estuarine environments are characterized by slow moving, poorly flushed waters with high levels of nutrients, offering ideal conditions for algae, fungi, and bacteria to thrive. Algal blooms produce large amounts of oxygen during photosynthesis and raise the pH by increasing hydroxide levels. When the water column becomes supersaturated with DO and has a high pH, this may mean a bloom is in progress. The DWR records algal blooms by measuring DO and pH, assuming a bloom is in progress when DO > 110 percent saturation or > 9.0 mg/L, and/or pH > 8.0 s.u. There were nine blooms in the Albemarle Sound during 2010-2014, usually comprised of blue-green algae. In that same period, the Neuse River had 32 blooms and Pamlico River had 76 blooms of a mixture of algae. The 33 blooms investigated in Calico Creek were mostly comprised of bottom-dwelling diatoms, while the 88 blooms in the New River were a mixture of algae types. Of the 27 blooms investigated in the Cape Fear River, 19 were the blue-green alga Microcystis. Microcystis is almost always toxic and can remain on shorelines in high concentrations for several months after blooms.

When algae begin to die and decay, DO levels can drop suddenly. Low DO (hypoxia) can cause sublethal stress or mortality in blue crabs. Sublethal stress may alter feeding and growth rates, behavior, and vulnerability to predators (31). Where blue crabs could not escape hypoxic waters, mortality occurred when oxygen levels were below 3.0 mg/L for one to three days; mortality occurred within three hours when DO was less than 0.5 mg/L (32). Hypoxic events have resulted in locally elevated mortality among crabs constrained by capture in pots in the Chowan, Neuse, and Pamlico river systems (33; T. Pratt, personal communications). Crab fishermen have indicated they move pots and alter fishing frequency during low oxygen events to avoid blue crabs dying in pots. Adjustments in fishing activity were based on changing environmental observations and catch rates (34).

DEQ has regulatory authority over waste management of swine and cattle feedlots that use dry systems and applications of a wastewater or liquid manure; these permitted facilities are inspected by DWR on an annual basis. Hog and cattle concentrated animal feeding operations discharging waste have NPDES permits, but there are no associated water quality monitoring requirements. The DWR Animal Feeding Operations Unit is responsible for permitting and compliance activities of the ~1,980 permitted animal facilities located in the lower Cape Fear and Neuse River basins. Rothenberger et al. (30), modeling land use in the Neuse River, found that areas with high concentrations of confined swine feed operations were the greatest contributors of nitrogen and phosphorus to the lower Neuse. In 1995, a swine operation lagoon failure led to a spill of raw, concentrated effluent into a second-order segment of the New River, North Carolina. In 1996, Hurricane Fran led to ruptures, excessive overflows, and floodplain inundations of 22 animal-waste lagoons in North Carolina. Elevated chlorophyll-a levels were evident 2-weeks after the 1995 spill with a 100-fold higher blue-green algae community than 1994 densities (17). Chlorophyll-a averaged 110 µg/L by July 5, 1995; substantially higher than the 1996 state acceptable water quality standard of ≤40 µg chla/L. Synechococcus and other blue-green algae densities of 10^6 cells/mL and 10^8 cells/mL, respectively, were observed in July 1994 and July 1995. This included a bloom of Phaeocystis flobosa, a harmful blue-green species, with colony densities >10^6 cells/mL. Increases in algal levels can be a major contributor to low oxygen events.

Along with nutrients, pesticides and herbicides may be present in runoff waters. Toxicity of pesticides to blue crab vary greatly due to many factors including application practices, chemical persistence, dilution level, and developmental stage of the blue crab. Eggs and larvae are generally more sensitive to toxins than adult and juvenile life stages as they have more permeable membranes and less developed detoxifying systems (32; 35; 36). Chemical contaminants in the water and soft bottom can adversely impact blue crabs directly by causing mortality, or indirectly by altering endocrine related growth and reproductive processes. Acute toxicity of a variety of herbicides and pesticides to blue crab were determined by the U.S. EPA. These studies stated the presence of chemicals had a detrimental effect and increased mortality rates on larval and juvenile blue crabs, particularly after molting.

Many insecticides function as endocrine disrupters, affecting larval crab development to adult. Fipronil, introduced in 1996, is a commonly used pesticide to control fire ants, cockroaches, beetles, and termites as well as an active ingredient in pet flea and tick treatments. (37). Successful metamorphosis of larval mud crab, Rhithropanopeus harrisii, was shown to be negatively impacted by this type of insecticide (38).

Effects of the pesticide methoprene, a juvenile hormone analog often used for mosquito and flea control, was analyzed in juvenile and adult blue crabs (39). Treatment of megalopae with methoprene delayed successful molting to the first crab stage. After 10 days, 80 percent of treated larvae died as opposed to 25 percent of total larvae in control tanks.

Carbaryl (commercially sold as Sevin) and malathion, are commonly used in agriculture, poultry production, and mosquito abatement. Schroeder-Spain et al. (40) found all treatments of malathion and carbaryl significantly increase righting time (the time it took a crab to flip after being placed upside down) and eyestalk response in both juvenile and adult blue crabs, with malathion additionally decreasing survival time of adult blue crabs. Significant mortality was observed in adult blue crabs; however, reduced righting time and response rate to stimuli make all stages of crabs more susceptible to predation.

Osterberg et al. (41) conducted research on the toxicity of four commonly used insecticides to blue crab at different life stages (Table 1). Researchers calculated that pesticide overspray into shallow ditches and creeks approximately 0.2-0.4 m deep or less would have concentrations sufficient to kill more than 50 percent of juvenile blue crabs within the affected waters.

Table 4.3.1. Pesticide properties and blue crab lethal concentration required to kill 50% listed in order of decreasing toxicity. Commercial products and their active ingredients common use in North Carolina. (data from *41*)

Compound	Use	Class	24 h LC_{50} (95% confidence interval) (µg/L)	
			Megalopae	Juveniles
Karate®	cotton, peanut, tobacco, soybean, termite abatement	Pyrethroid	0.5260 (0.351–0.789)	3.565 (1.721–7.385)
λ-Cyhalothrin	Karate® active ingredient	Pyrethroid	0.2233 (0.1833–0.2720)	2.701 (2.215–3.294)
Trimax™	fruits & vegetables, tobacco	Chloro-nicatinyl	312.7 (222.4–439.9)	816.7 (692.9–962.6)
Imidacloprid	Trimax™ active ingredient	Chloro-nicatinyl	10.04 (6.381–15.79)	1112 (841.9–1,468)
Aldicarb[a]	potatoes, cotton, peanuts, soybean	N-methyl carbamate	311.6 (281.6–344.8)	291.1 (227.7–372.3)
Orthene®	fruits & vegetables, golf courses	Organophosphate	61,210 (48,500–77,260)	191,300 (141,100–259,000)
Acephate	Orthene® active ingredient	Organophosphate	50,380 (44,300–57,300)	137,300 (132,800–141,900)
Roundup® Pro[b]	weed and brush control	Phosphonoglycine	6,279 (5,937–6,640)	316,000 (167,000–595,200)

The herbicide S,S,S-tri-n-butyl phosphorotrithioate (DEF) is widely used as a cotton defoliant. Rainfall simulations indicated on average 14.5 percent of applied DEF becomes runoff from conventional tillage (42). Habig et al. (43) studied the acute neurotoxic effects of short term exposure to DEF on adult blue crabs. Nerve enzyme activity was reduced more than 90 percent at both concentrations. Recovery of exposed crabs was slow and incomplete, 10 days after transfer to toxin-free water nerves regained less than 40 percent of their normal function.
The Department of Agriculture and Consumer Services administers the NC Pesticide Law of 1971 and the North Carolina Pesticide Board adopts regulations, including crop spraying practices. Policies on drift from aerial applications affect the potential for toxin contamination in coastal waters and associated chronic and acute effects on fish populations. Rules prohibit aerial application of pesticides under conditions that will potentially result in drift and adverse effects to non-target areas. Deposition of pesticides labeled toxic or harmful to aquatic life is not permitted in or near waterways.

The Department of Agriculture, Pesticide Division (DAPD) investigated a 2012 mass mortality event of peeler blue crabs reported to the Division of Water Resources and Division of Marine Fisheries. The cause of the kill was found to be the pesticide bifenthrin which is commonly used with cotton and considered highly toxic to invertebrates. Rain following spraying of adjacent cotton fields, carried runoff from the fields to the canal where the peeler raceway intake was located. DAPD rules prohibit aerial application of pesticides under conditions likely to result in drift to non-target areas. However, drift of chemicals into surface waters does occur at times and chemicals applied on land can be carried by stormwater runoff through ditches into surface waters. In the 2012 incident, the pesticide application did not violate label application directions, but there were some Best Management Practices that could have been followed to minimize impacts. After the kill, the NCMFC Shellfish/Crustacean Advisory Committee requested the division look into the mass mortality event. The topic was discussed by the NCMFC Habitat and Water Quality Advisory Committee and DAPD staff spoke about the process and the specific incident. As a result of the meeting, the DAPD staff offered to increase outreach and technical assistance to farmers and additional training to pesticide applicators. Information was included on the NCDMF website and in dealer newsletters regarding what to do if a blue crab kill occurs.

North Carolina has several agricultural non-point source programs throughout the state (Table 2). The North Carolina Department of the Agriculture and Consumer Services (NCDA&CS) is the lead agency for voluntary agricultural non-point source pollution control programs. The Nonpoint Source Section of the Division of Soil and Water Conservation (DSWC) along with NC Cooperative Extension Service (NCCES), NC Agricultural Research Service (NCARS), Basin Oversight Committee (BOC), and the USDA Natural Resources Conservation Service (NRCS) is responsible for managing several programs related to nonpoint source pollution particularly from agricultural lands and providing technical assistance to Soil and Water Conservation Districts (SWCD) and Local Advisory Committees (LACs). The NC Division of Water Resources (DWR) is the lead agency for regulatory agricultural Nonpoint Source (NPS) Pollution control programs.

Table 4.3.2. Agricultural NPS Programs in NC (45).

Category/Program	Local	State	Federal
Agricultural Cost-Share Program	SWCD	DSWC	
NC Pesticide Law of 1971		NCDA&CS	
NCDA&CS Pesticide Disposal Assistance Program		NCDA&CS	
Federal Insecticide, Fungicide, and Rodenticide Act			EPA
Animal Waste Management Regulations	SWCD	DWR, DSWC, NCCES	NRCS
NC Coop. Ext. Service and Ag Research Service		NCARS, NCCES	
Laboratory Testing Services		NCDA&CS	
Watershed Protections (PL-566)			NRCS
Farm Bills Programs			NRCS
Ag Nutrient Regulations in Neuse and Tar-Pam River Basins and the Jordan and Falls Lake Watersheds	LACs	DWR, DSWC, NCDA&CS, BOCs	
Soil, Plant Tissue, and Animal Waste Testing Program		NCDA&CS	

North Carolina water management strategies are developed based on individual watersheds (Figure 2). Agricultural contributions to nonpoint source water pollution are addressed primarily through encouragement of voluntary participation. This is supported through financial incentives, technical and educational assistance, research, and regulatory programs. A variety of cost share programs are available through DSWC. The Neuse River Basin is the focus of a large-scale, long-term watershed restoration projects underway in the state. The DWR initially established 53 rules, enacted in August 1998, with the goal of reducing the average annual load of nitrogen from point and nonpoint sources by a minimum of 30 percent below the average annual load from 1991 – 1995 and then maintain that level. These rules focused on protection and maintenance of riparian areas, wastewater discharge, urban stormwater management, agricultural nitrogen reduction, nutrient management, nitrogen offset fees, and stormwater. As of June 2017, the 30 percent reduction has not been achieved (45). The fifth edition to the Neuse River basin plan is scheduled to be completed in 2019.

Figure 4.3.2. Watershed River basins of North Carolina

Existing state plans recommend water monitoring activities across the state. The CHPP recommends improving strategies throughout river basins to reduce nonpoint pollution and minimize cumulative losses of fish habitat through voluntary actions, assistance, and incentives. This includes improved methods to reduce pollutants from agriculture, increasing use of reclaimed water, increasing use of riparian buffers, and increased funding for strategic land acquisition and conservation. The WRC Action Plan (46) states "Monitoring of aquatic taxa is critical to assessing species and ecosystem health and gauging the resilience of organisms to a changing climate. These monitoring efforts will inform future decisions on how to manage aquatic species. Long-term monitoring is needed to identify population trends and to assess performance of conservation actions. Monitoring plans should be coordinated with other existing monitoring programs where feasible." The APNEP Comprehensive Plan (47) recommends the use of Best Management Practices on agricultural and silvicultural land, establishing contaminant management strategies for those waters not meeting water quality standards, and development and implementation of coordinated landscape-scale hydrological restoration strategies as well as wetland restoration strategies. Additionally, APNEP Engagement Strategy (48) prioritizes outreach at partner events throughout the Albemarle-Pamlico region. The above plans all encourage citizen science projects to educate and engage the public. These programs create a sense of ownership and accomplishment among participants and connect citizens to natural resources and water quality conservation.

There are many management alternatives that may contribute to success of state plan recommendations. Riparian buffer zones, vegetated ditches, and tailwater recovery systems are Best Management Practices which can reduce containments in nonpoint source runoff. Grass and forest buffers can be effective sediment traps. In North Carolina, Cooper et al. (49) estimated 84 to 90 percent of sediment from agricultural fields was trapped in adjoining deciduous hardwood riparian areas. Silt and clay were deposited into the forest while sand deposited along the edge of the riparian zone. Vegetated ditches may also serve not only to remove suspended solids from runoff but also reduce nutrient loads by reducing flow velocity and adding retention time to allow for precipitation and breakdown before reaching receiving waters (50; 51). Tailwater recovery systems also have the potential to reduce nutrient loading to receiving waters and minimize fertilizer application through recycling captured nutrients in irrigation water (52; 53). The addition of water control structures can increase residence time allowing for nutrient degradation and precipitation out of the water column.

Water quality standards should be based on the assimilative capacity of, and impact to, systems as a whole. The NCMFC should urge the Division of Water Quality and Department of Agriculture and Consumer Services to expand regulations and outreach aimed at minimizing agricultural impacts on waterways through Best Management Practices. Amendment 1 to the Blue Crab FMP outlines actions for water quality management strategies and recommends existing and future water quality plans are addressed in a timely manner. Additionally, positions are needed for compliance with DEQ stormwater and surface water programs. The NCMFC should partner with other state organizations to strategize and implement water quality improvements across basins and plan for coastal resilience to climate change. Working with these organizations, farmers and other citizens of North Carolina must be engaged to instill ownership in natural resources and doing their part to reduce their pollution footprint and improve water quality. Protections and restoration of water quality are essential to a sustainable blue crab stock.

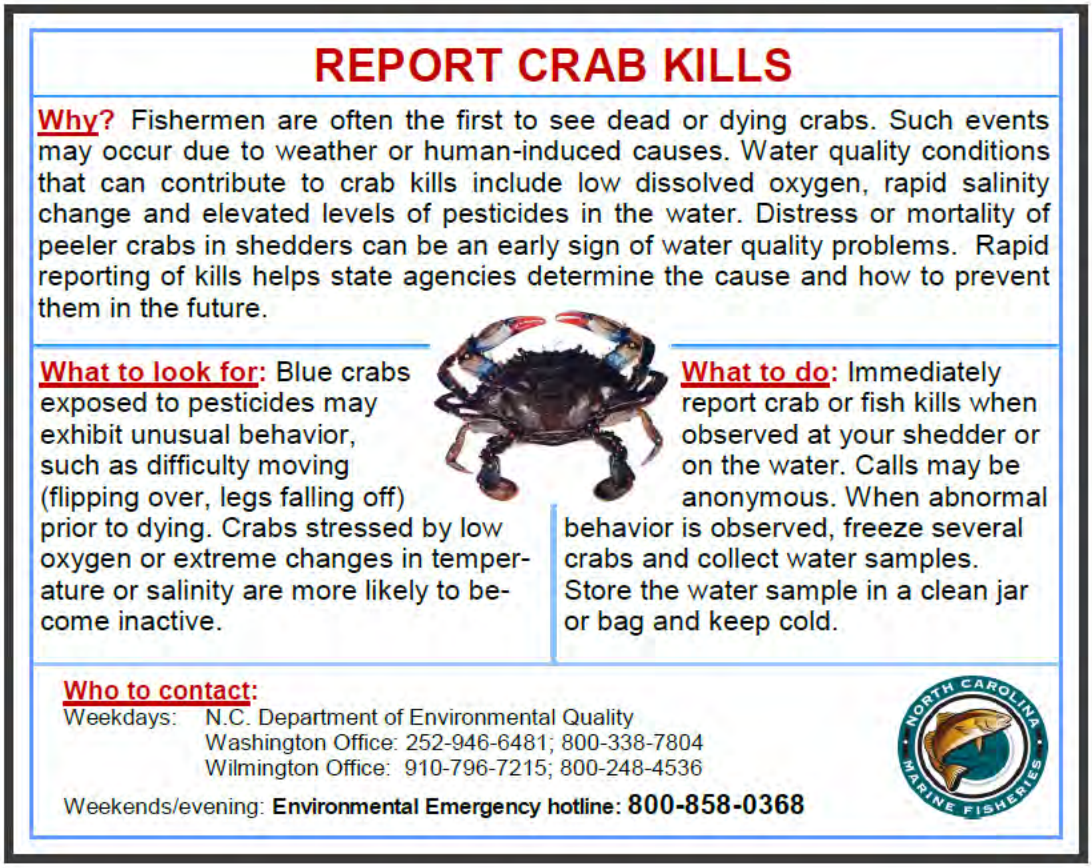
VI. MANAGEMENT OPTIONS

The NCMFC has no regulatory authority over land use and other practices that impact water quality. The NCMFC could:

1. Highlight problem areas and advise other regulatory agencies (Coastal Resources Commission, Environmental Management Commission, DEQ Division of Water Quality, Department of Agriculture and Consumer Services, DEQ Division of Energy, Mineral and Land Resources, US Army Corps of Engineers, and local and state governments) on preferred options and potential solutions.
2. Push to create a joint interagency working group to facilitate cooperation and efforts in monitoring and restoring water quality. This should include coastal monitoring which is currently limited; including increased USGS sampling downstream from wastewater treatment plants.
3. Work with state agencies and interest groups to support maintaining the Clean Water Act at a national level and striving to meet or exceed recommendations
4. Task the CHPP steering committee to prioritize blue crab water quality impacts. These should include hypoxia and toxins, while researching specific sources of water quality degradation and their effects on blue crabs.
5. Send letters to the NCDA&CS Division of Forest Resources, Division of Environmental Programs, Division of Soil and Water Conservation, and Department of Transportation to share their concerns about water quality and the importance of Best Management Practices, especially buffer zones abutting coastal waters.
6. Invite these agencies to future NCMFC meetings in order to present mitigation efforts on water quality impacts, monitoring, and rehabilitation. These may include pesticide and herbicide policies, Best Management Practices reviews, and enforcement.
7. Public outreach is recommended to encourage the public to report crab and fish kills. One possible source of outreach may include a handout when licenses and permits are purchased and/or renewed (recreational and commercial licenses, and shedding permits)

which informs and directs the public how and what to report for these events (Figure 4.3.2).

Figure 4.3.2. Report crab kills post card distributed previously to commercial license holders.



VII. RECOMMENDATIONS

<u>NCDMF Recommendation</u>

- Support all management options presented
- Recommend Option 4 as the highest priority
- Division habitat staff shall regularly report back to the Shellfish/Crustacean AC with progress on each management option

<u>Blue Crab FMP Advisory Committee</u>

- Support all management options in this paper
- Support making the highest priority Option 4, tasking the CHPP steering committee to what is suggested here and follow up with each of the other recommendations as that step is justified
- Have the habitat staff report back to the Shellfish/Crustacean AC with progress

<u>Northern Advisory Committee</u>

Southern Advisory Committee

Shellfish and Crustacean Advisory Committee

Habitat and Water Quality Advisory Committee

NCMFC Selected Management Strategy

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APPENDIX 4.4: EXPAND CRAB SPAWNING SANCTUARIES TO IMPROVE SPAWNING STOCK BIOMASS[1]

I. ISSUE

Consider expansion of existing Crab Spawning Sanctuaries and designation of new Crab Spawning Sanctuaries to protect mature females prior to spawning.

II. ORIGINATION

The 2016 Revision to Amendment 2 to Blue Crab Fishery Management Plan (1) included expansion of existing and/or designation of new Crab Spawning Sanctuaries (CSS) and imposing further fishing restrictions within existing CSS as potential management measures to address low recruitment. Neither the expansion of existing CSS, designation of new CSS, or implementing additional fishing restrictions in the CSS were adopted by the N.C. Marine Fisheries Commission (NCMFC). Expansion of existing and designation of new CSS as well as potential migration corridors are explored in this issue paper.

III. BACKGROUND

Existing Crab Spawning Sanctuaries

In 1965, the law prohibiting the harvest of sponge crabs was repealed and replaced with the designation of five CSS north of Cape Lookout (Table 4.4.1; Figures 4.4.1, 4.4.2, and 4.4.3). The CSS are closed to the use of trawls, pots, and mechanical methods for oysters or clams and to the taking of crabs with any commercial fishing equipment from March 1 through August 31(NCMFC Rule15A NCAC 03L .0205). Existing proclamation authority in NCMFC Rule 03L .0205 allows additional areas to be designated as CSS and allows for further fishing restrictions to be enacted within the CSS. The purpose of these sanctuaries is to protect mature females inhabiting these areas prior to and during the spawning season and to allow them access to ocean waters to release their eggs.

Table 4.4.1. Location and approximate size (in acres) of the five current Crab Spawning Sanctuaries.

Location	Acres
Oregon Inlet	5,788
Hatteras Inlet	4,444
Ocracoke Inlet	8,745
Drum Inlet	5,388
Barden Inlet	4,610

[1] Presented to AC on 4/25/19; Presented to PDT on 3/1/19, 3/26/19, and 5/2/19

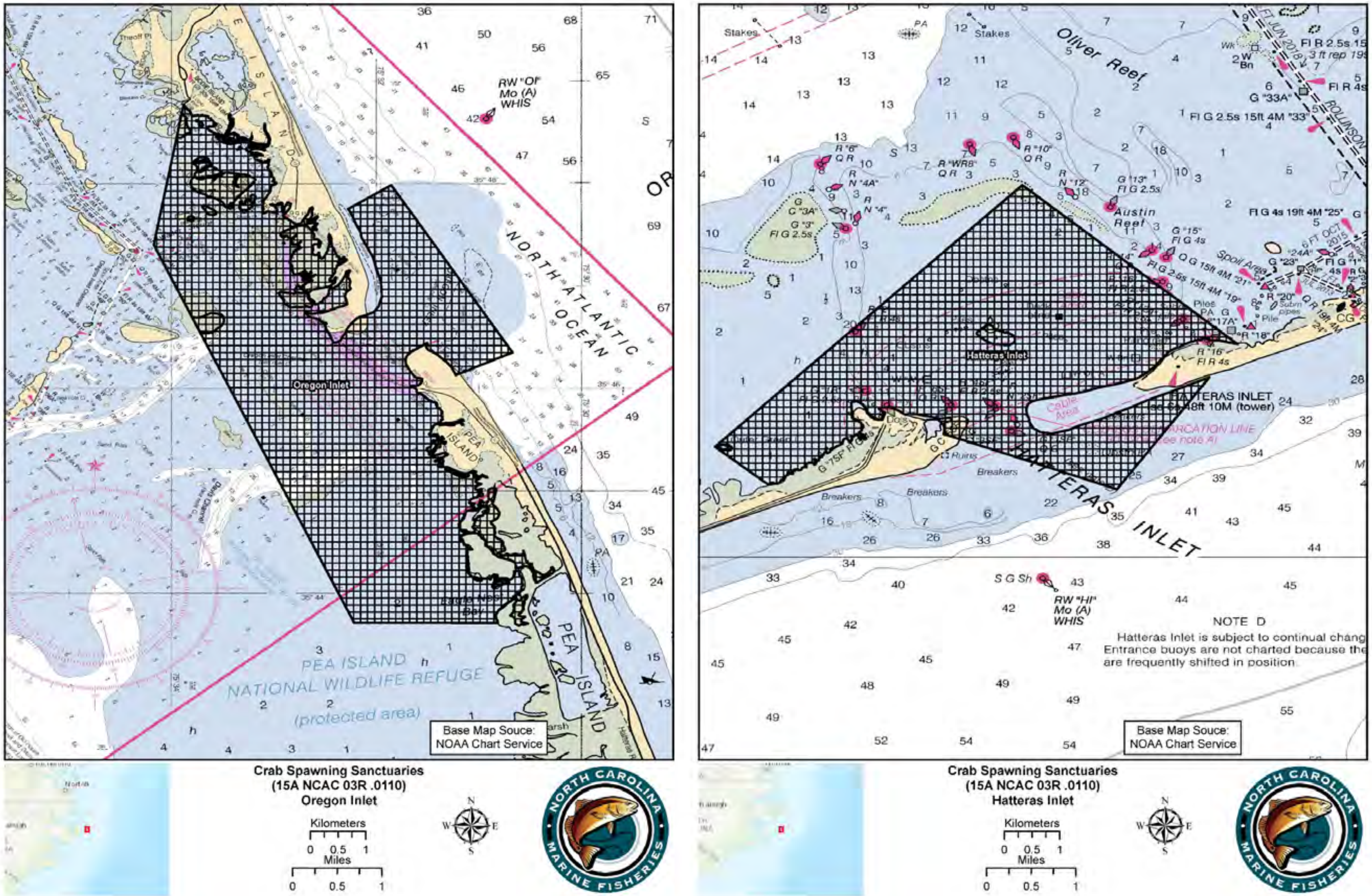
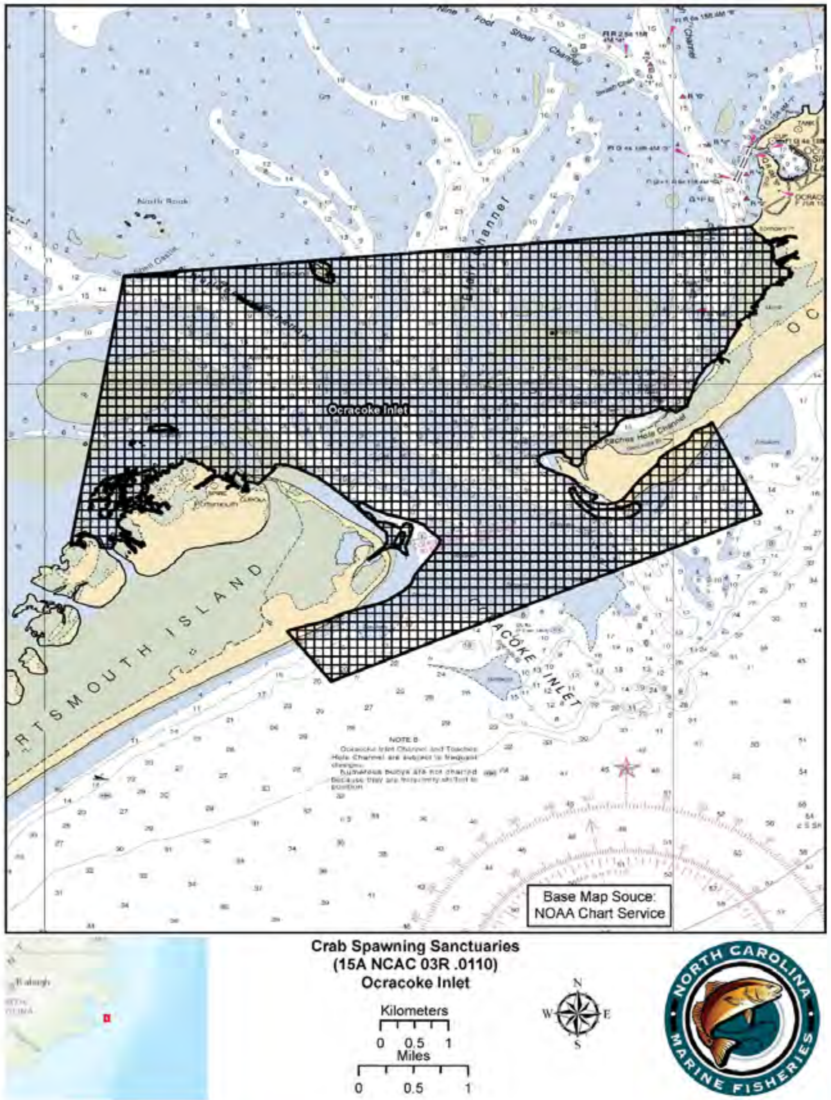


Figure 4.4.1. Current Crab Spawning Sanctuary boundaries for Oregon and Hatteras inlets.



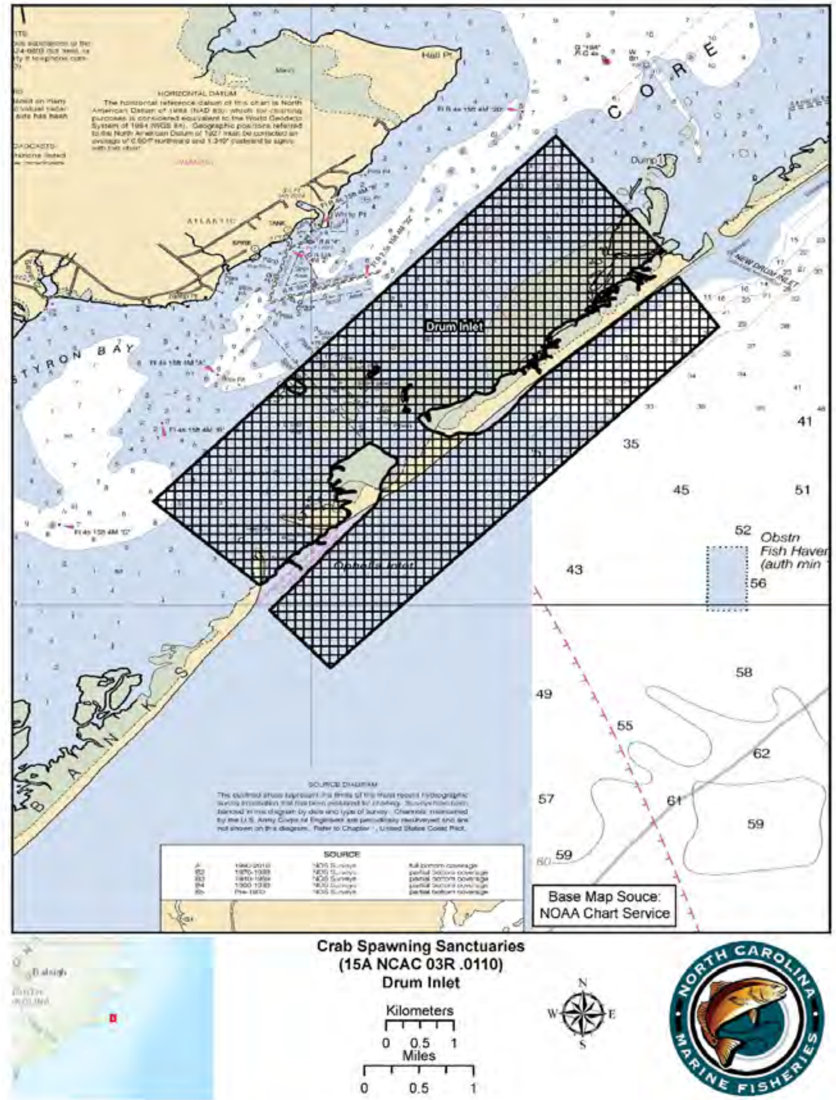


Figure 4.4.2. Current Crab Spawning Sanctuary boundaries for Ocracoke and Drum inlets.

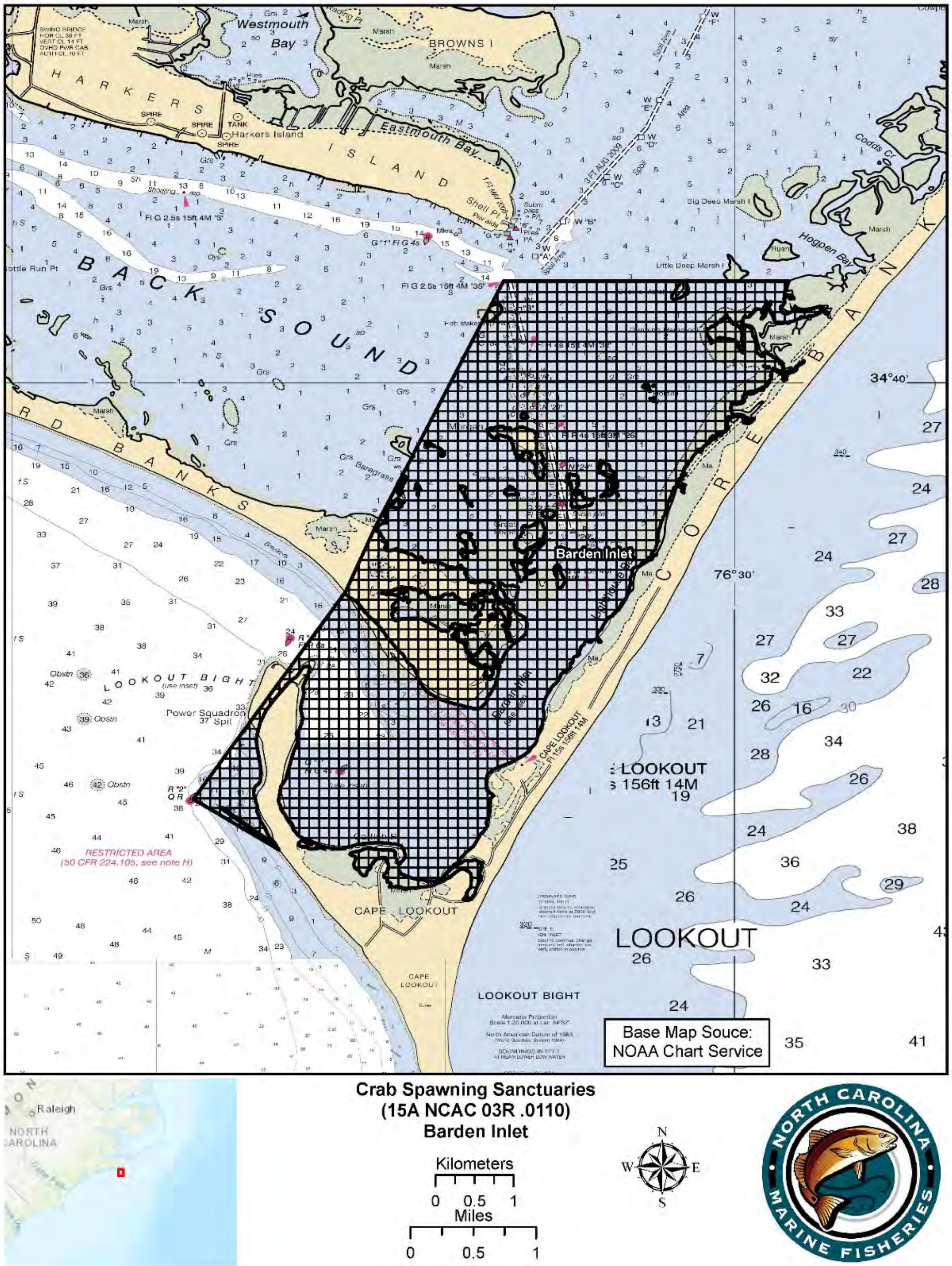


Figure 4.4.3. Current Crab Spawning Sanctuary boundary for Bardens Inlet.

In N.C., blue crab mating peaks in April-June and August-September (2). In the Albemarle-Pamlico system, migration towards the closest inlet starts late September-October for females that mated later in the summer, with spawning the following spring (3). These crabs overwinter in the mud along their migration route or near the inlet system. When mating occurs in early spring, mature female crabs migrate sooner, rather than waiting for fall (2). Commercial crab sampling indicates sponge crabs are most abundant March through May, but are typically present from March through August (see Appendix 4.2, Table 4.2.6).

Several studies have looked at the effectiveness of the five existing CSS in North Carolina. Migration distance, tidal regime, harvest effort along the migration route, and the proportion of post-mating mature female blue crabs protected in the sanctuaries influence the ability of mature female blue crabs to successfully reach the protected spawning grounds and thus the overall success of the sanctuaries.

Researchers (4; 5; 6) sampled blue crabs using crab pots in all five sanctuaries during different years. Mature female crabs were present year-round at all of the CSS, with abundance greatest from June to August at all sanctuaries except Hatteras, where abundance was greatest in April. Most brown sponge crabs were caught in inlet channels. The abundance of mature females was correlated with salinity (5) and temperature (6). Ballance and Ballance (4) concluded that in wet years mature female crabs are more concentrated and abundant within the sanctuaries than in dry years because they are seeking the higher salinity needed for egg development and spawning. In dry years, the salinity is high in a larger portion of Pamlico Sound west of the inlets so many female crabs are located west of the sanctuary boundaries. The difference in salinity could also explain differences in relative abundance among sanctuaries. Tag return data found that females tagged within the sanctuaries in Pamlico Sound were consistently caught within four kilometers of estuarine sanctuary boundaries (4; 7). Crab dredgers have noted that when temperatures drop early in the fall crabs are more abundant in the designated crab dredge area (J. Midgett, personal communication), suggesting they overwinter before reaching the sanctuary boundaries. The Ballance studies concluded the existing CSS are protecting a portion of egg bearing females, varying with environmental conditions, and that designation of migration corridors or expanded sanctuary boundaries could protect more of the spawning stock.

The effectiveness of the spawning sanctuaries was also assessed by trawling in June, August, and September 2002 inside and up to 2 km outside (sound-side and ocean-side) of the CSS boundaries (8). Results found that relative abundance of mature female blue crabs inside the five sanctuaries combined was not significantly higher than outside the sanctuaries (46.8% inside, 41.9% outside sound-side, 11.3% outside ocean-side). The study estimated that total mature female abundance within sanctuary boundaries only accounted for 0.7% of all mature female blue crabs within the Pamlico and Croatan sounds. Comparing the five CSS, Hatteras and Barden inlets had more mature female blue crabs inside sanctuary boundaries (53.9-64.3%) than outside. In contrast, the opposite was true at the other inlets (37.7-40.0%). The relative abundance of female blue crabs at the inlets (inside and outside of sanctuary boundaries) was highest at the northernmost (Oregon) and southernmost (Drum and Barden) inlets and lowest at Ocracoke and Hatteras inlets. This was attributed to blue crabs migrating to the closest inlet, with Oregon Inlet receiving crabs from Albemarle and northern Pamlico sounds, and Drum and Barden inlets receiving crabs from the Neuse and Tar-Pamlico rivers.

New Crab Spawning Sanctuaries

Crab spawning sanctuaries have not been designated south of Bardens Inlet (14 inlets total). In the southern area of the state, inlets tend to be smaller and occur in closer proximity to each other than in the Pamlico Sound system. Since mature females migrate toward the closest inlet, and there are multiple inlets, mature females are likely to be less concentrated at any one inlet (although the Cape Fear River Inlet may be an exception).

While the density of mature females per inlet may be less than at northern inlets, the closer proximity to the inlets and semi-diurnal tides could facilitate a greater proportion of mature female blue crabs reaching the spawning grounds. The mechanism for migrating long distances varies by tidal regime. In waters with semi-diurnal tides, ovigerous female blue crabs (sponge crabs) have a circa-tidal rhythm, swimming in the water column toward the closest inlet on ebb tides (12.4 hr cycles), or circa-lunar rhythm, swimming once daily during the night ebb tide (24.8 hr cycles) (9). There is rapid seaward movement with ebb tide transport (ETT) following oviposition of the first clutch of eggs (10). Peak swimming speed is around one hour after the tide starts falling. In non-tidal systems, such as most of Pamlico Sound, ovigerous females follow circadian rhythm, swimming seaward at night or walking along the bottom (9). Migration slows once reaching waters where salinity is approximately 22 ppt, the salinity necessary for egg development (2).

A crab tagging and modelling study near Beaufort Inlet, where average tidal currents are relatively strong (1 m/s), found most blue crabs were able to migrate approximately 5 km/day using ETT (11). Crab movement was greater during night ebb tides than day ebb tides or flood tides and increased with current speeds. Ramach et al. (12) found that males and mature females in a high salinity embayment near Beaufort Inlet were partitioned with egg bearing females concentrating closer to the opening of the embayment in slightly deeper water than the males. The female crabs use the embayment to forage until egg release is imminent. In this staging area crabs were able to swim to the inlet within one tidal cycle. Migration speed among individual crabs varied, with some being more active than others (13). Down-estuary walking and swimming in the upper estuary and micro-tidal waters, where currents are slower, helps to successfully move the crabs down to areas with stronger currents. In the Beaufort Inlet system, including North and Newport rivers, Back Sound, and Bogue Sound, all crabs were able to migrate to the inlet within four days (13). The migration patterns noted in the Beaufort Inlet system are thought to be comparable to those in other diurnal systems south of Beaufort Inlet. An acoustic tagging study conducted in the White Oak River found that blue crabs began migrating within days of mating (14). The tagged crabs travelled an average of 0.9 km/day, and travelled in the deeper channels (4-5 m water depth), where currents are stronger.

Studies were conducted in the New River in 2006-2007 and in the Cape Fear River in 2005-2006 to assess spatial distribution through the spawning season in these tidal rivers of the southern coast (15; 16). In the Cape Fear River estuary, data indicated that crabs were concentrated in a lower portion of the river from Snow's Cut to the mouth of the river. Ovigerous females had the greatest abundance in the lower river in July. In the New River, female abundance was highest in July, gradually decreasing through November. The decline was attributed to mature female crabs moving into the shallower creeks and bays. No trend between upper, mid, and lower river sections were detected except the upper zone had significantly less female crabs in September than the lower river. Mature females were found predominantly in the lower river (Stones Bay and south). These findings are consistent with studies from inlets to the north, with mature females being most abundant in the lower system during the summer.

IV. AUTHORITY

North Carolina General Statute 113-134 – Rules
North Carolina General Statute 113-182 – Regulation of fishing and fisheries
North Carolina General Statute 113-221.1 – Proclamations; emergency review
North Carolina General Statute 143B-289.52 – Marine Fisheries Commission – powers and duties
NCMFC Rule 15A NCAC 03H .0103 – Proclamations, General
NCMFC Rule 15A NCAC 03L .0205 Crab Spawning Sanctuaries

V. DISCUSSION

Expand Boundaries of Existing Crab Spawning Sanctuaries

A crab spawning sanctuary system is also used in Virginia as a blue crab management tool. The sanctuary boundaries in the Chesapeake Bay were initially found to be ineffective in improving stock size due to the relatively small proportion (16%) of mature female blue crabs that were protected (17). Subsequently, the spawning sanctuary was expanded in 2002 to include a migration corridor, protecting 70% of the mature females. Because post-mating mature females have a lengthy migration and their precise distribution varies seasonally and annually due to weather conditions, the expansion of the historical spawning sanctuary was found to adequately protect mature females (19; 20). This change resulted in a resurgence of the spawning stock (14). Eggleston et al. (8) estimated that <1% of mature female blue crabs in Pamlico and Croatan sounds were protected from harvest (within the spawning sanctuary). Consequently, the protection provided by the CSS in North Carolina is likely insufficient.

Delineating spawning sanctuary boundaries in North Carolina is somewhat more challenging than in the Chesapeake Bay. Unlike North Carolina, the Chesapeake Bay only has one major exit to the ocean so all female crabs inevitably have to concentrate and pass through the migratory corridor and spawning sanctuary. Also, blue crabs were noted to migrate in the deeper channels of the Chesapeake Bay, where depths were 10-14 ft. deep. In contrast, North Carolina has multiple inlets that blue crabs could migrate toward and the bottom is relatively uniform in depth, lacking discrete channels except near inlets.

In addition to the overall small proportion of mature female crabs within the existing CSS, release of eggs prior to reaching the spawning grounds (19) or being caught (14) are other factors that can reduce the effectiveness of the CSS in protecting the spawning stock. Egg release may be more likely to occur in Pamlico Sound where the distance to travel to the inlets is greater, migration is dependent on daily (light) rather than semi-daily cues, and wind-driven currents are slower than tidal flows (10). This supports the need to increase the size of the CSS in Pamlico Sound to better protect the spawning stock.

Ballance and Ballance (4) and Eggleston et al. (8) noted high concentrations of mature females within 4 and 2 km of the CSS boundaries, respectively. Of the five sanctuaries, Oregon, Bardens and Drum inlets had the greatest abundance of mature female blue crabs, likely due to closer proximity to mating grounds. Therefore, inward expansion of the five existing sanctuaries, or the three with the relatively higher abundance, could substantially increase the percent of mature females that would be protected by the sanctuaries.

To help guide any proposed expansion of the existing CSS the blue crab plan and development team reviewed available NCDMF mature female blue crab tagging data (7) and included them on maps showing potential expanded boundary areas. The maps also show the location of oyster cultch planting sites, oyster trigger sampling locations, mechanical clam harvest areas, shellfish leases, and diamondback terrapin interactions where appropriate. Additionally, the current CSS boundaries were examined to ensure they adequately account for movement of the inlets. For example, the existing CSS around Drum Inlet is no longer functional. Ophelia Inlet opened through Core Banks just south of Drum Inlet in 2006 and Drum Inlet closed in 2008-2009. The current boundary for the Drum Inlet CSS does not include all of Ophelia Inlet.

The expanded boundary area of the Oregon Inlet CSS does include some cultch planting and oyster sampling sites but also contains a large number of mature female tag returns (Figure 4.4.4). The expansion areas around Hatteras Inlet (Figure 4.4.4) and Ocracoke Inlet (Figure 4.4.5) contain a few cultch planting sites as well as a significant number of mature female tag returns. The boundary for the Drum Inlet CSS was shifted south to completely cover Ophelia Inlet (Figure 4.4.5). The expansion area around Bardens Inlet covers more deep water area as well as shallow foraging habitat (Figure 4.4.6). Table 4.4.2 shows the acreage of the existing CSS boundaries and the expanded boundaries shown in each map.

Table 4.4.2. Acreage of existing Crab Spawning Sanctuaries and NCDMF recommended boundaries in Amendment 3. * indicates also recommended by Blue Crab AC.

Crab Spawning Sanctuary	Current Acreage	NCDMF Recommended Acreage
Oregon Inlet	5,804	23,332
Hatteras Inlet	4,662	12,282
Ocracoke Inlet	7,914	30,759
Drum/Ophelia Inlet	5,165	5,503*
Barden Inlet	4,637	8,606*

Due to the current regulations in the CSS prohibiting the use of trawls and mechanical methods for harvesting oysters or clams, there could be some impacts to the mechanical oyster, clam and shrimp fisheries if the closure period is extended. For example, expanding the current CSS boundary around Oregon Inlet could potentially impact the mechanical oyster fishery in the area as indicated by the number of cultch planting and sampling sites within the expanded boundary (Figure 4.4.4). The mechanical oyster harvest season occurs from November through the end of March, unless closed earlier due to reaching the management trigger for legal size oysters.

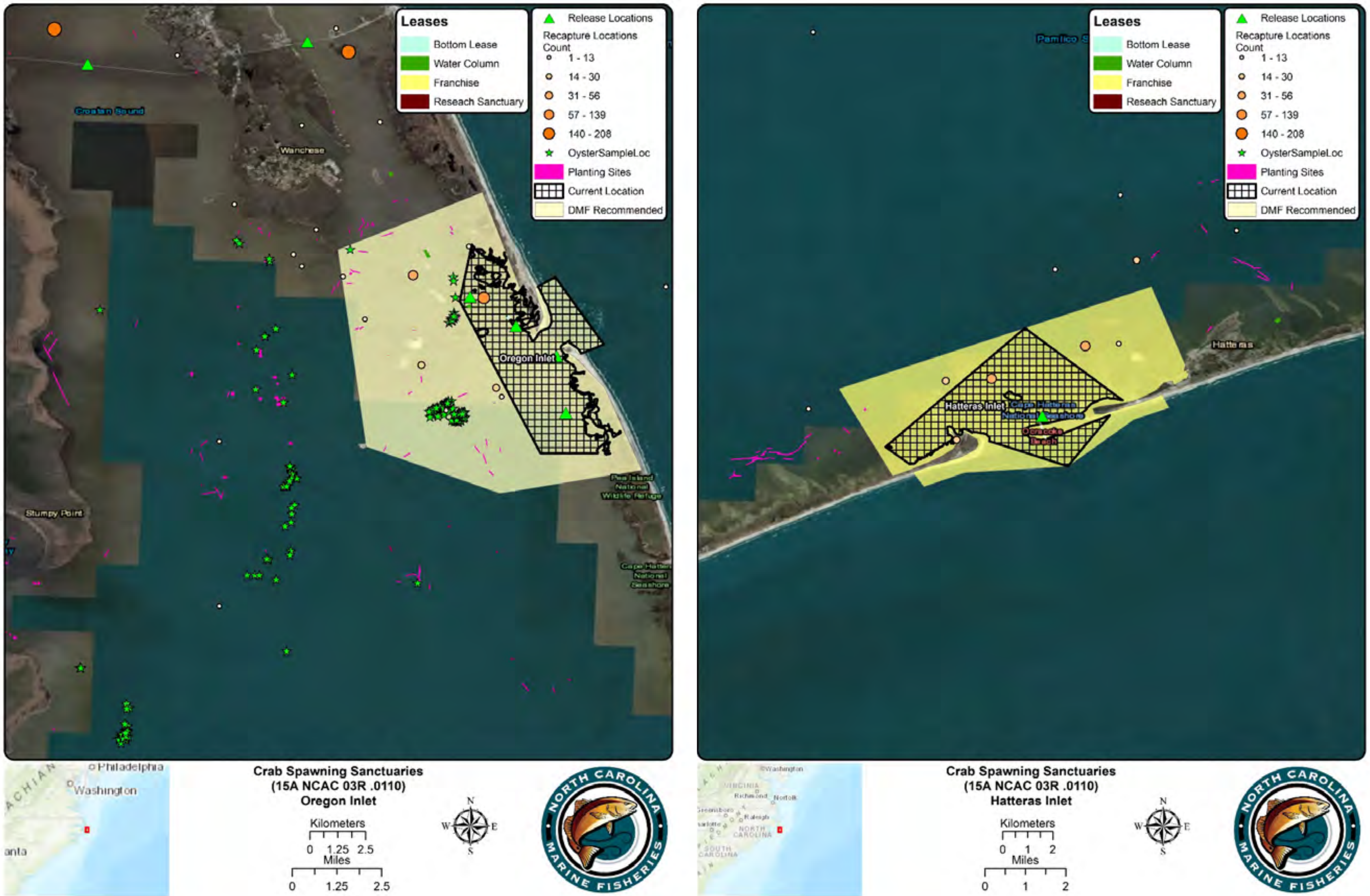


Figure 4.4.4. Proposed locations of new Crab Spawning Sanctuary boundaries for Oregon and Hatteras inlets.

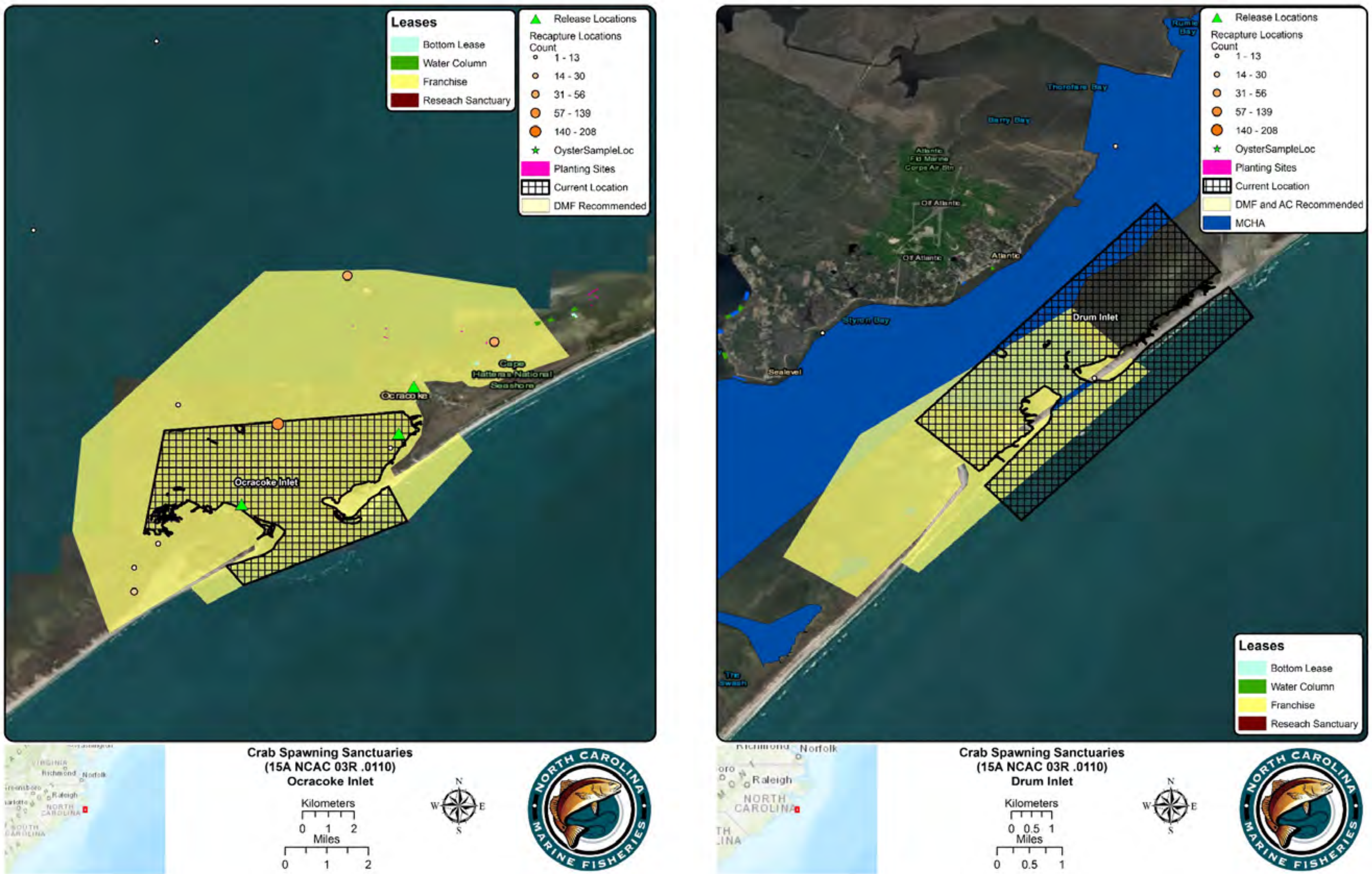


Figure 4.4.5. Proposed locations of new Crab Spawning Sanctuary boundaries for Ocracoke and Drum/Ophelia inlets.

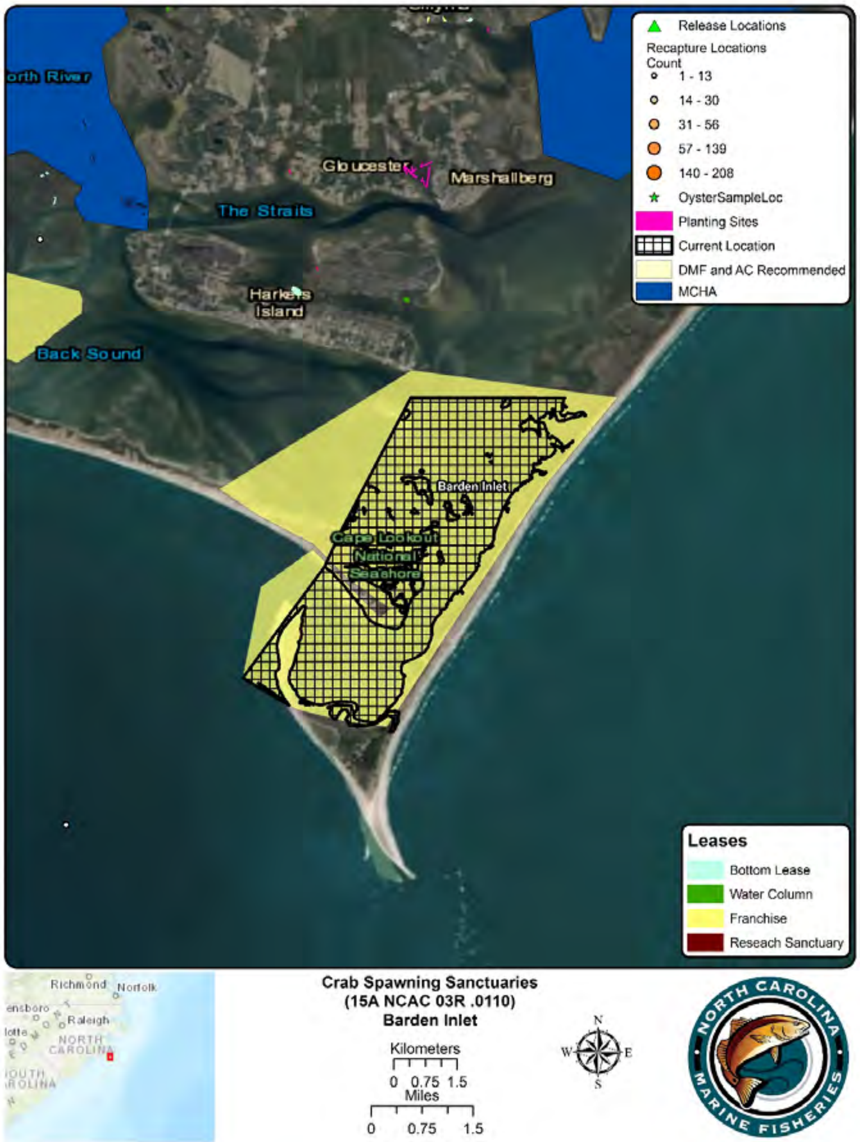


Figure 4.4.6. Proposed location of new Crab Spawning Sanctuary boundary for Bardens Inlet.

Designate New Crab Spawning Sanctuaries

There are 14 inlets that are not designated as crab spawning sanctuaries (Table 4.4.3). These inlets are all south of Barden Inlet. Designating additional crab spawning sanctuaries at some or all of the 14 inlet systems would protect mature females in those areas and enhance local larval recruitment. Average commercial blue crab landings in Core-Bogue sounds and waters south of and including White Oak River account for only 7% of the total average landings from 2007-2016 (Figure 4.4.7). However, crab spawning sanctuaries in these smaller systems could be more effective if a greater percent of mature females are able to reach the protected spawning sanctuaries due to the shorter distance to travel and semi-diurnal tides accelerating migration rates.

Table 4.4.3. Inlets without designated Crab Spawning Sanctuaries south of Barden Inlet, listed north to south.

Inlet Name	
Beaufort	Mason
Bogue	Masonboro
Bear	Carolina Beach
Browns	Cape Fear
New River	Lockwoods Folly
New Topsail	Shallotte
Rich	Tubbs

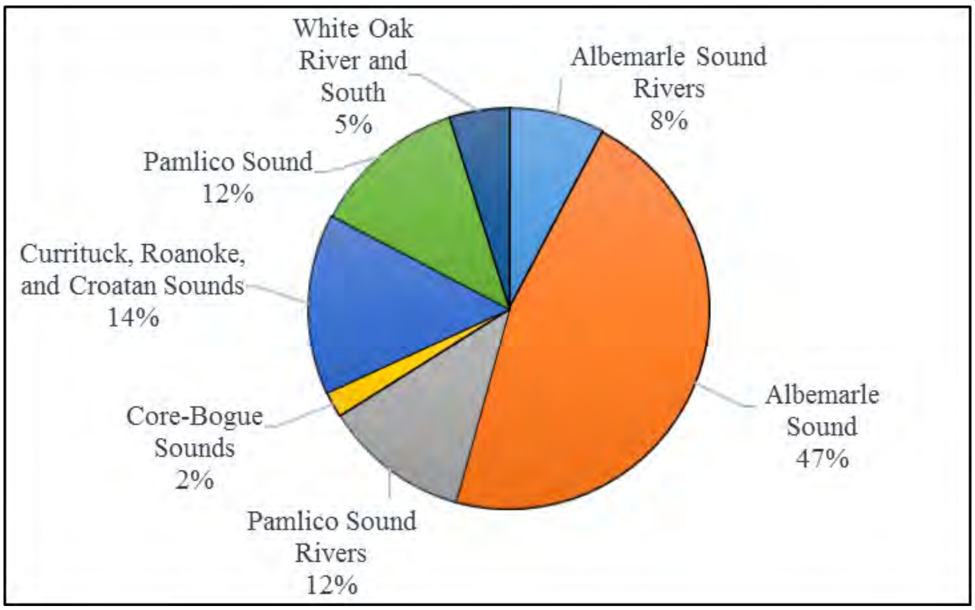


Figure 4.4.7. Percent of commercial crab landings by waterbody, 2007-2016.

Without designated CSS south of Cape Lookout, none of the spawning stock is protected in the southern region of the state. Designating additional CSS would further protect mature females as they migrate to spawning grounds. Designations could be limited to the largest and most stable inlets, or to those that contribute the most in terms of use by spawning females. Of the 14 inlets, the largest are Beaufort, Bogue, and Cape Fear River. Unfortunately, research has not been done to assess abundance of mature female blue crabs at most of the inlets in this region.

Spawning sanctuaries around the southern inlets would prohibit crab pots, trawls, and mechanical methods for harvesting clams and oysters for a portion or all of the year, depending on the management strategy chosen. Creating sanctuaries in the southern inlets could have a short-term impact on blue crab landings, but could lead to a long-term increase in the population and future harvest. Local crabbers have suggested the deep fast flowing waters of the lower Cape Fear River ship channel provide a natural barrier to some crab harvesting practices in that area. Thus, this area serves as an unofficial sanctuary for all blue crabs (1).

Inlets are critical corridors that all estuarine dependent migratory species must pass through to complete their life cycle. Ogburn and Habegger (20) suggested the primary spawning habitat of blue crabs may actually be in coastal ocean waters in the South Atlantic, with inlet systems functioning more as spawning migration corridors. Regardless, mature female blue crabs are concentrated in the vicinity of inlets seasonally and must reach or pass through them to spawn. Other species could also benefit from seasonal restrictions on trawls, including shrimp and associated bycatch species. The extent of trawling effort that occurs within the inlet systems is unknown since the inlet systems are smaller than the commercial trip ticket waterbodies used to track commercial landings. Therefore, the impact of designating CSS in these areas on the shrimp trawl fishery is unquantifiable. Examples of potential sanctuary boundaries are shown in Figures 4.4.8-4.4.14. These figures show the proposed CSS boundaries from the 2016 Revision to Amendment 2 to the N.C. Blue Crab FMP as well as alternative boundaries based on the research discussed above. Table 4.4.4 shows the estimated acreage of the proposed CSS boundaries from the 2016 Revision and the alternative boundaries.

As above, maps for the potential new CSS include NCDMF mature female blue crab tagging data (7) and the location of oyster cultch planting sites, oyster trigger sampling locations, mechanical clam harvest areas, shellfish leases, and diamondback terrapin interactions where appropriate.

Table 4.4.4. Proposed Crab Spawning Sanctuary acreages by inlet from Beaufort Inlet south. *Recommendations differ for NCDMF and AC, value in parentheses is for AC recommendation.

Crab Spawning Sanctuary	NCDMF and AC Recommended Acreage
Beaufort Inlet	4,250
Bogue Inlet	1,427
Bear Inlet	439
Browns Inlet	286
New River Inlet	803
Topsail Inlet	930
Rich Inlet	420
Mason Inlet	334
Masonboro Inlet	519
Carolina Beach Inlet	276
Cape Fear River Inlet*	3,846 (3,695)
Lockwoods Folly Inlet	264
Shallotte Inlet	411
Tubbs Inlet	141

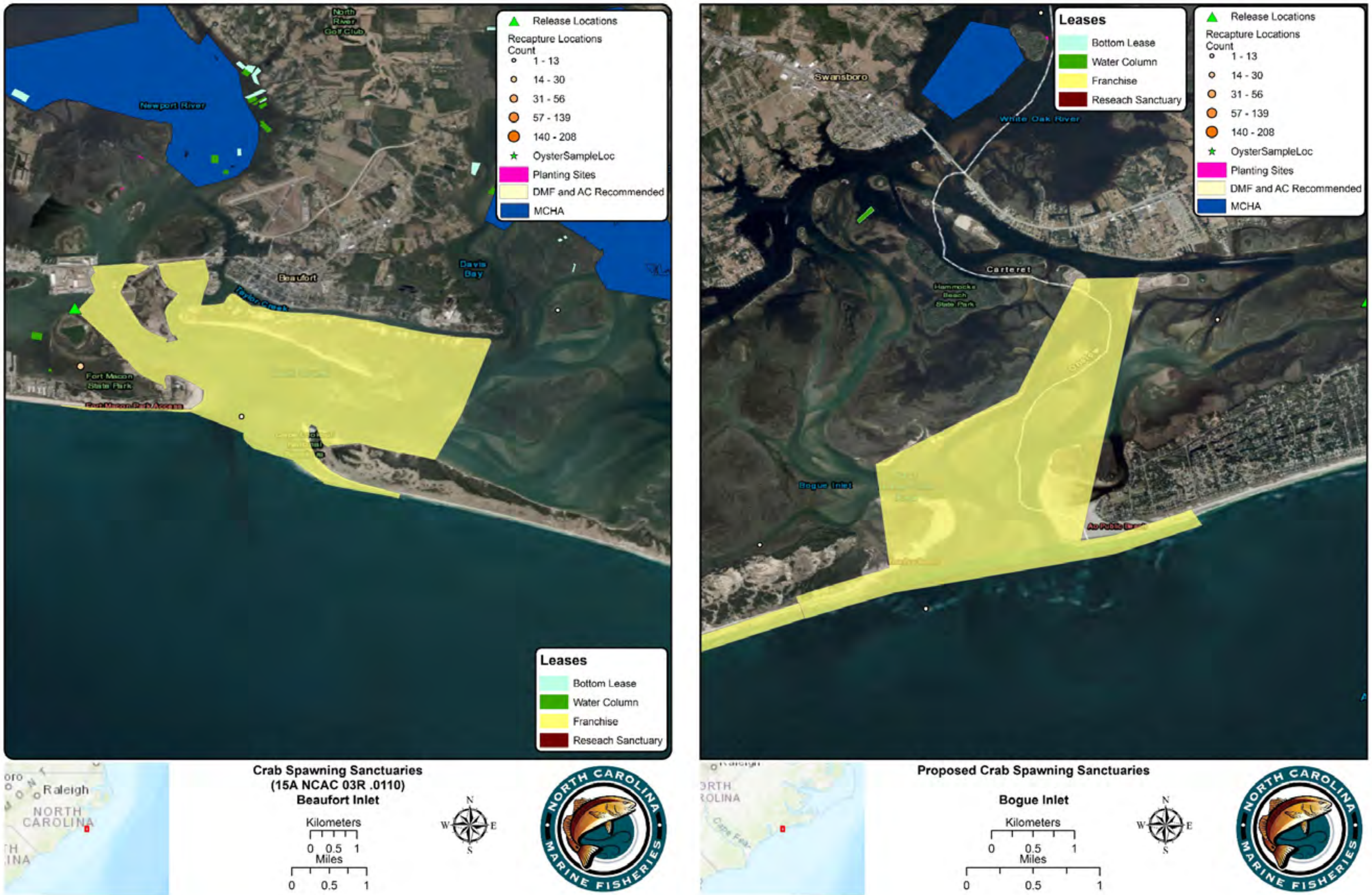


Figure 4.4.8. Proposed locations of new Crab Spawning Sanctuary boundaries for Beaufort and Bogue inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

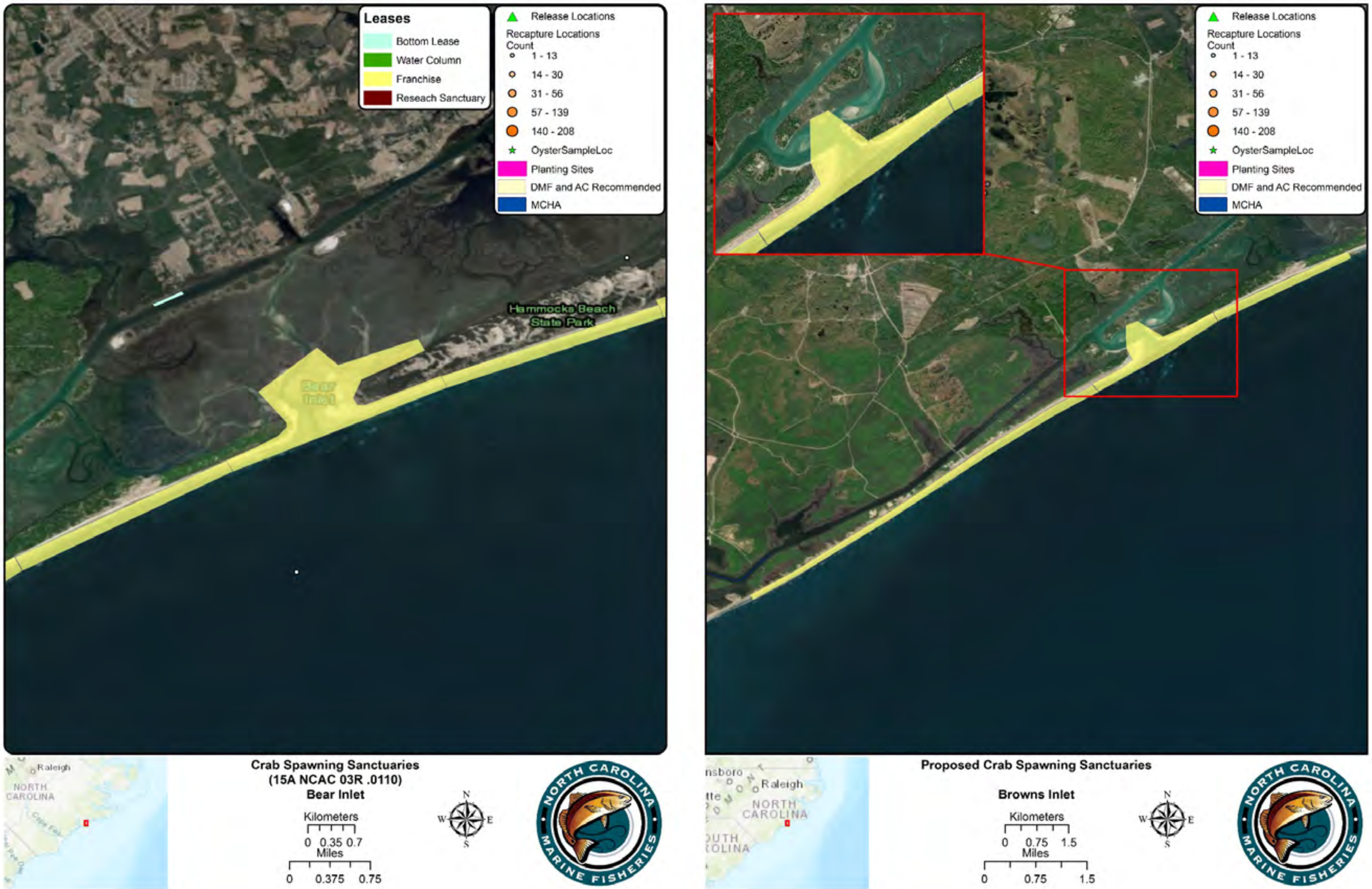


Figure 4.4.9. Proposed locations of new Crab Spawning Sanctuary boundaries for Bear and Browns inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

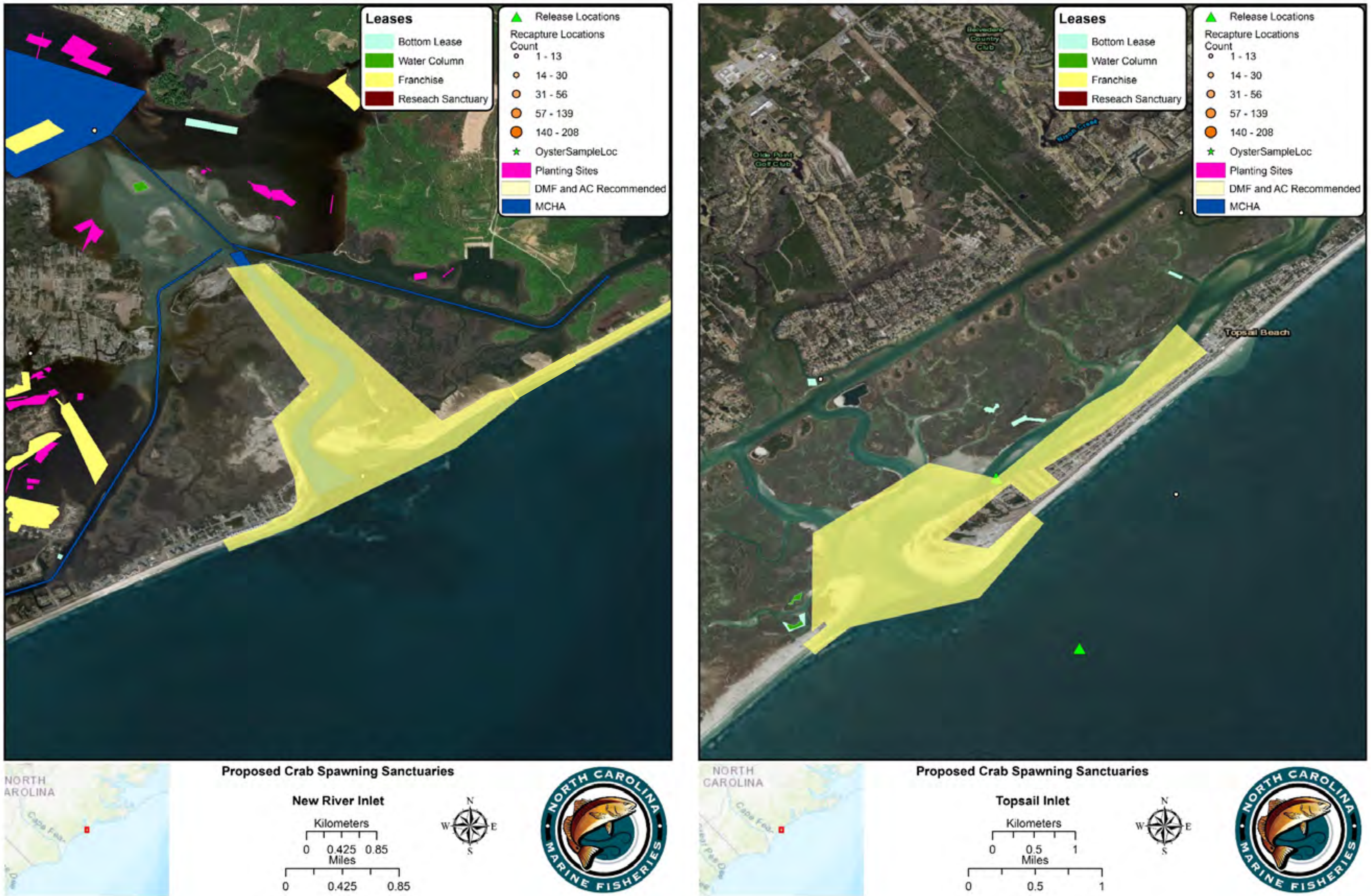


Figure 4.4.10. Proposed locations of new Crab Spawning Sanctuary boundaries for New River and Topsail inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

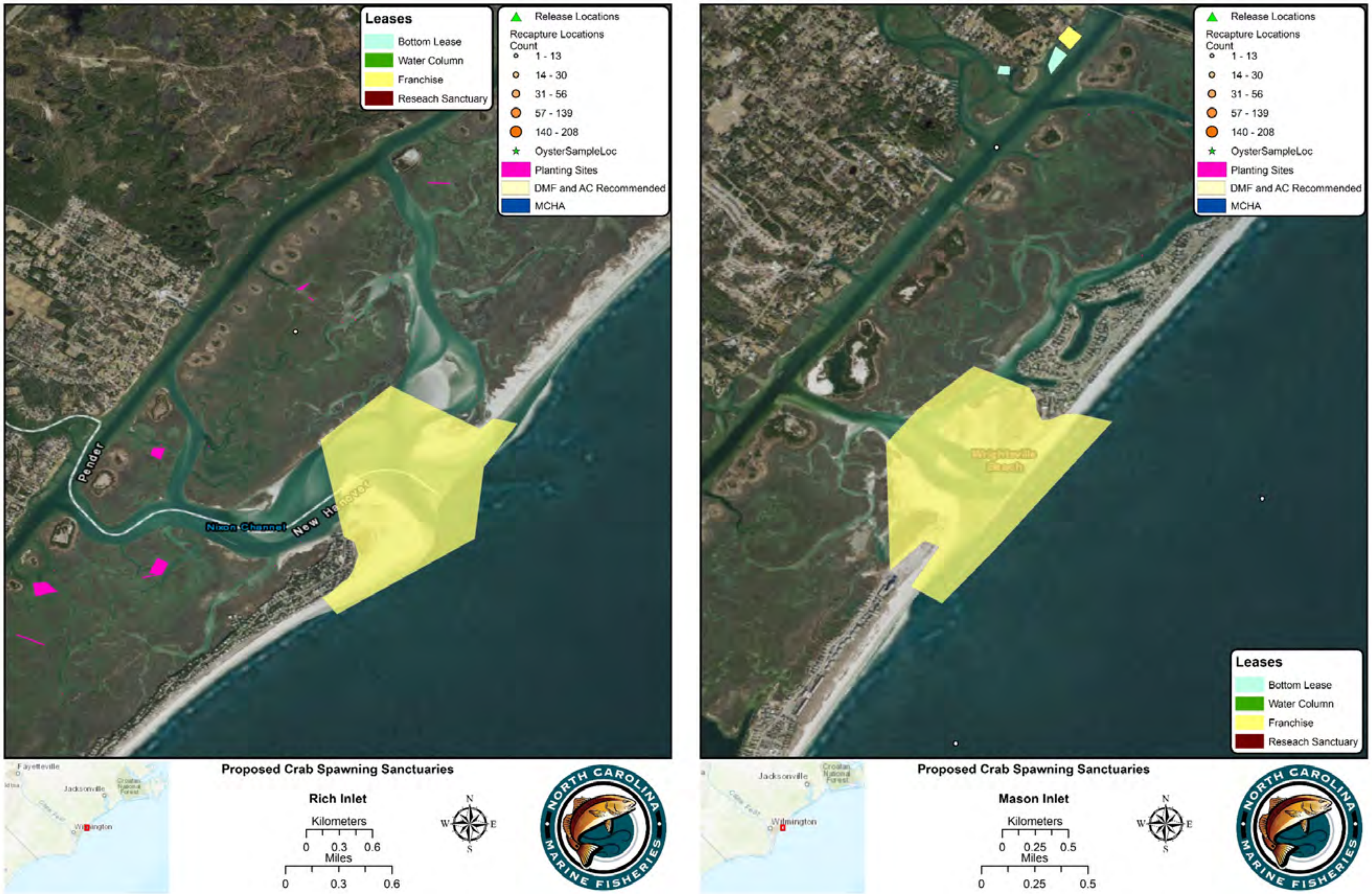


Figure 4.4.11. Proposed locations of new Crab Spawning Sanctuary boundaries for Rich and Mason inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

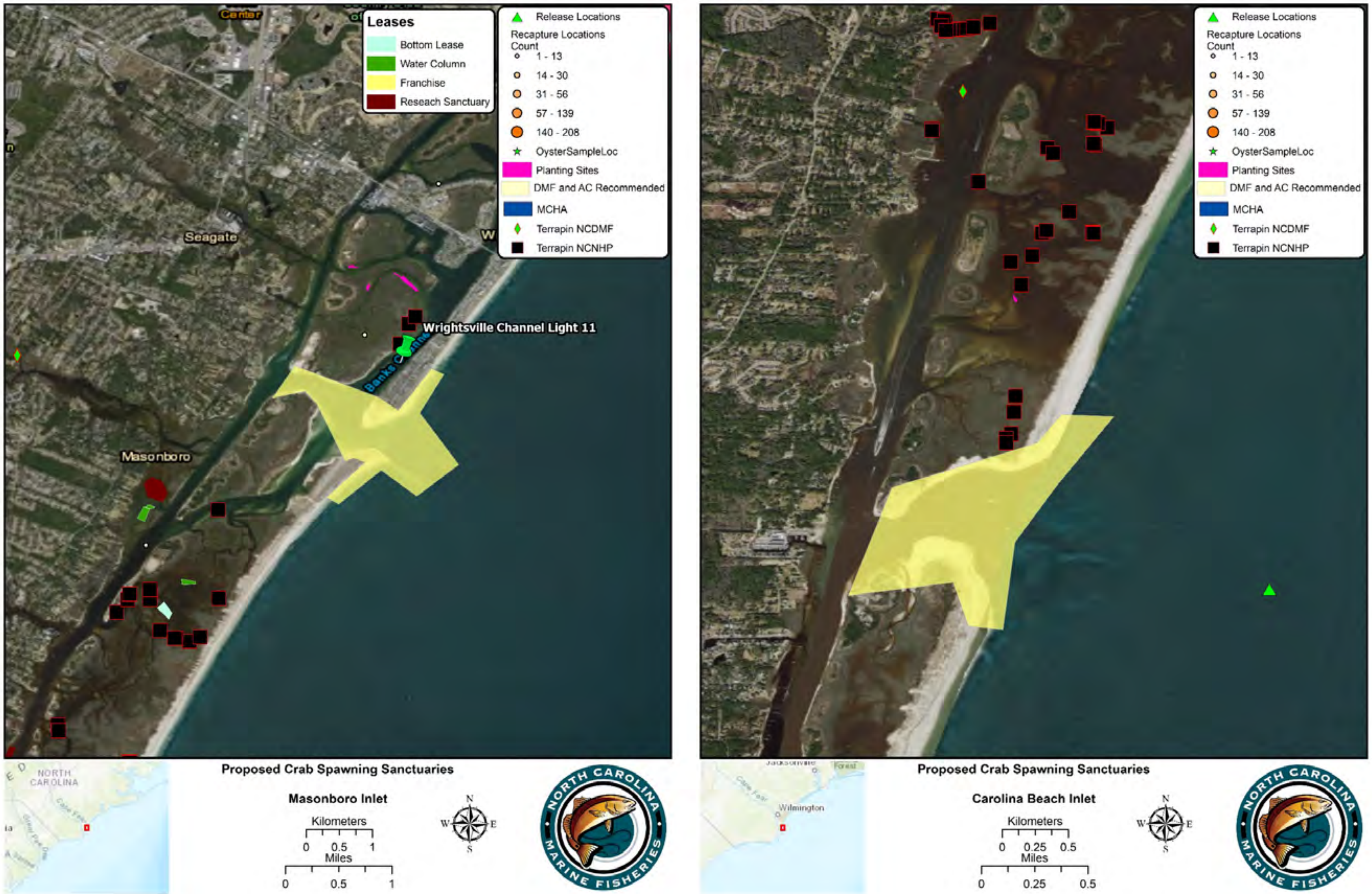


Figure 4.4.12. Proposed locations of new Crab Spawning Sanctuary boundaries for Masonboro and Carolina Beach inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

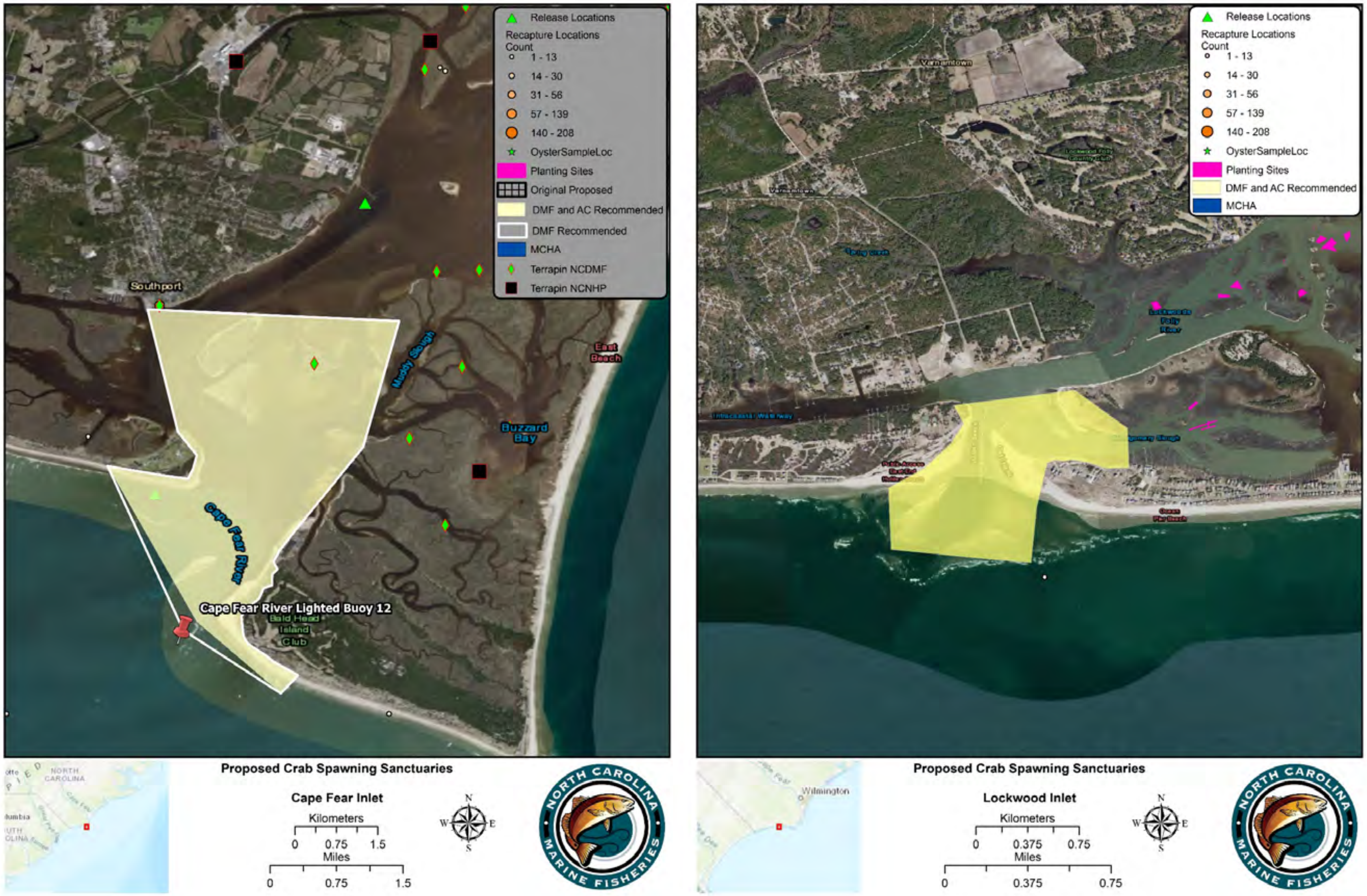


Figure 4.4.13. Proposed locations of new Crab Spawning Sanctuary boundaries for Cape Fear River and Lockwoods Folly inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

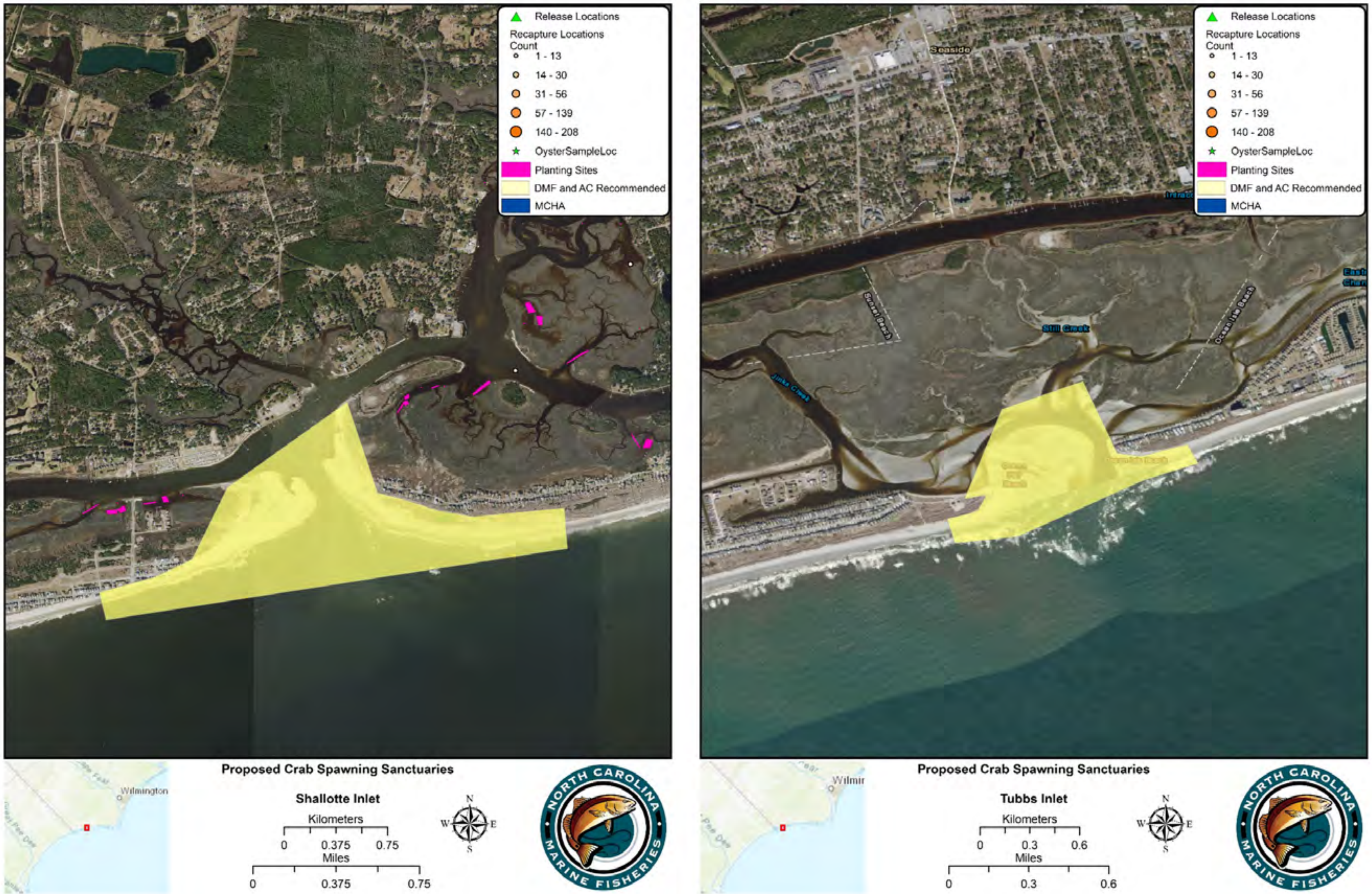


Figure 4.4.14. Proposed locations of new Crab Spawning Sanctuary boundaries for Shallotte and Tubbs inlets. MCHA = Mechanical clam harvest area, fishery open from December through the end of March.

Designation of a Crab Spawning Sanctuary to Serve as a Migration Corridor

Another option to consider is the designation of crab spawning sanctuaries that act as migration corridors leading to inlets but are not themselves associated with an inlet. These would be areas that serve as migration pathways for mature female blue crabs during their migration to coastal inlets. A similar management strategy has been adopted in the Virginia waters of the Chesapeake Bay and was highly effective (Figure 4.4.15).

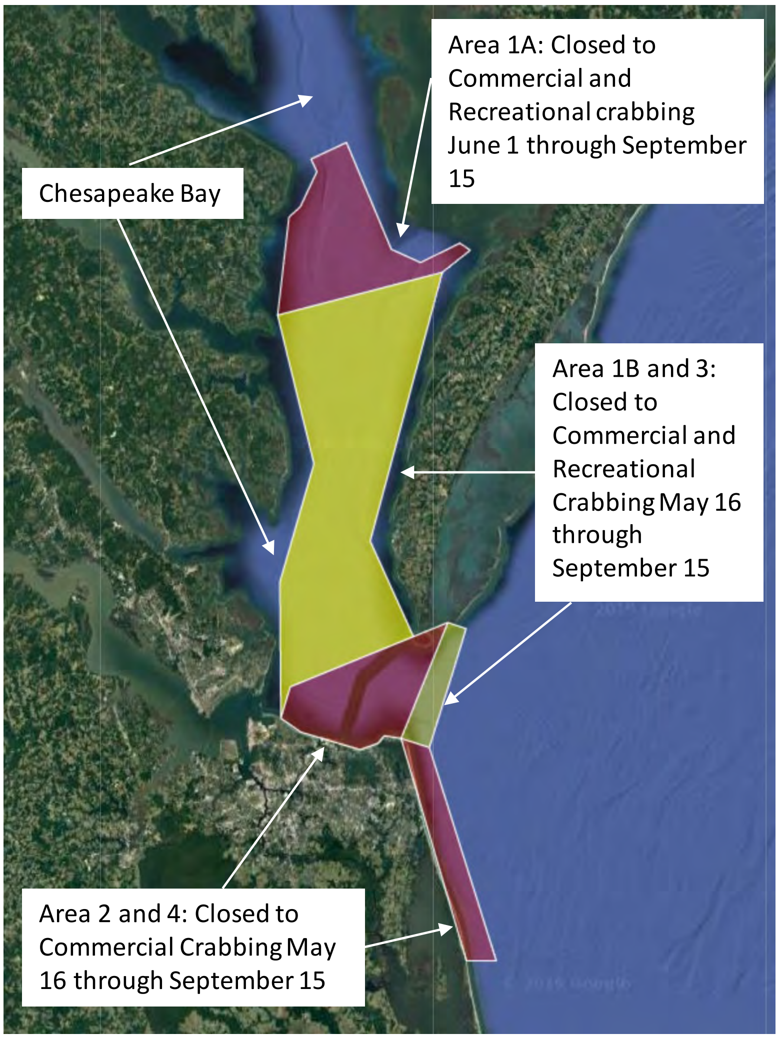


Figure 4.4.15. Virginia's Blue Crab Sanctuaries in the Chesapeake Bay including closure dates (https://webapps.mrc.virginia.gov/public/maps/crab_sanctuaries.php).

Although a distinct migratory corridor from mating sites in the Albemarle-Pamlico system to the spawning grounds was not detected by Eggleston et al. (8), there are several areas where mature female blue crabs are consistently more abundant. In 2002, results from the NCDMF Pamlico Sound Survey, supplemented by additional sampling in August, indicated that mature females were concentrated in northwest Pamlico Sound between Croatan Sound and Pamlico River in June. Mature female blue crabs were more than 50% less abundant in August and September but there was no clear migratory pattern of movement toward the inlets. The crabs might have moved into shallower areas and grass beds that could not be trawled. Mature female blue crabs are known to commonly occur in the seagrass beds behind the Outer Banks during the summer (G. Allen, NCDMF personal communications) which could account for part of their migratory path.

Looking at the entire time series for the Pamlico Sound Survey (1987- 2017), mature female blue crabs are most concentrated in June north of Wysocking Bay and Buxton, across the entire sound (Figures 4.4.16 and 4.4.17). They are also concentrated to a lesser extent in Pungo and lower Pamlico rivers, and Croatan Sound. Additionally, mature female blue crabs occurred throughout the entire area in low numbers (1-50 crabs/trawl). In June, prevailing southwest winds in northern Pamlico Sound would help to push crabs toward Oregon Inlet. Females in the southern Pamlico Sound are closer to Ocracoke, Drum, and Barden inlets. In September, there was overall lower crab abundance and they were concentrated further north in Pamlico and Croatan sounds. In the southern portion of the sound, mature females were concentrated at the mouth of the Pamlico River.

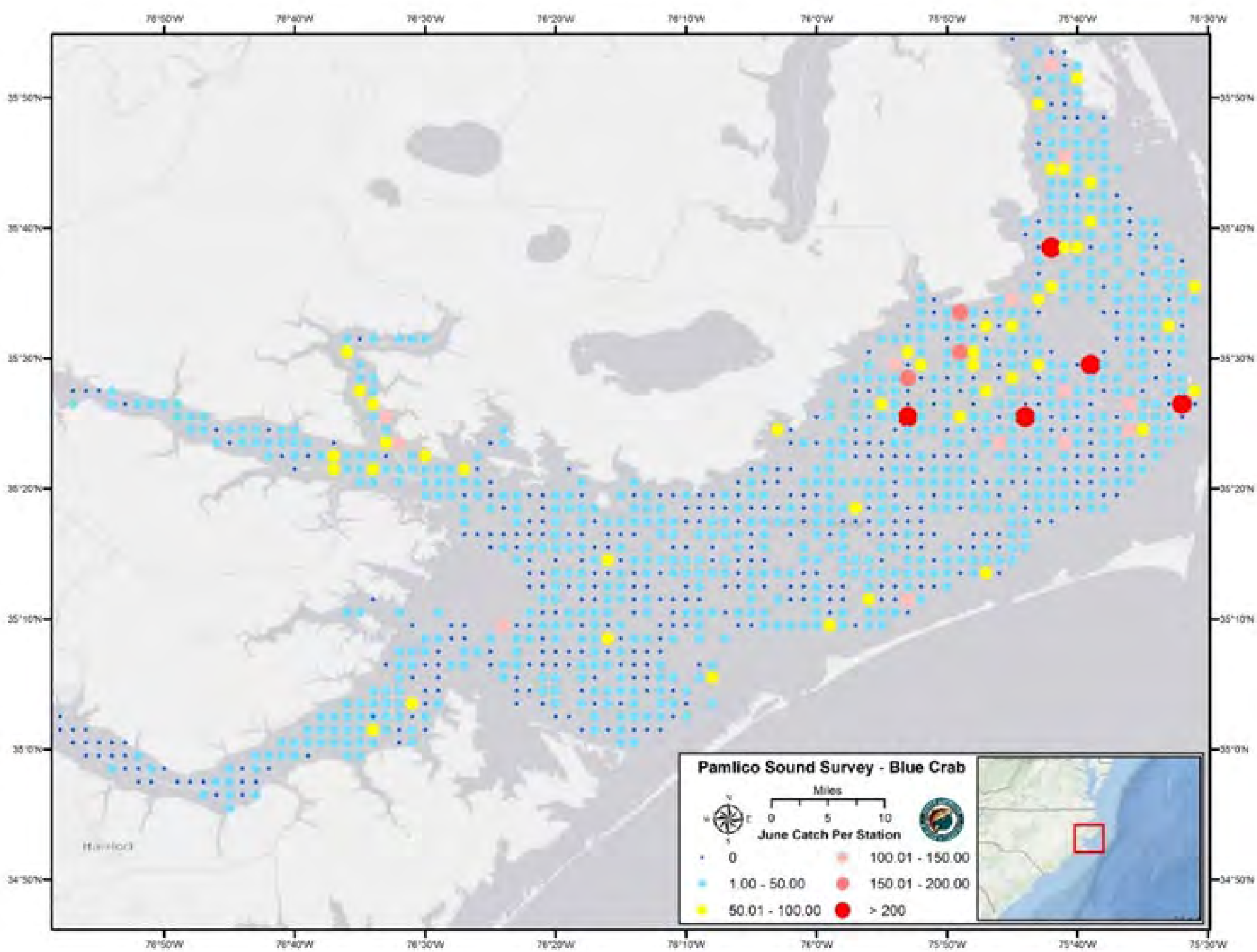


Figure 4.4.16. Total number of mature female blue crabs from Pamlico Sound Survey in June, 1987-2017.

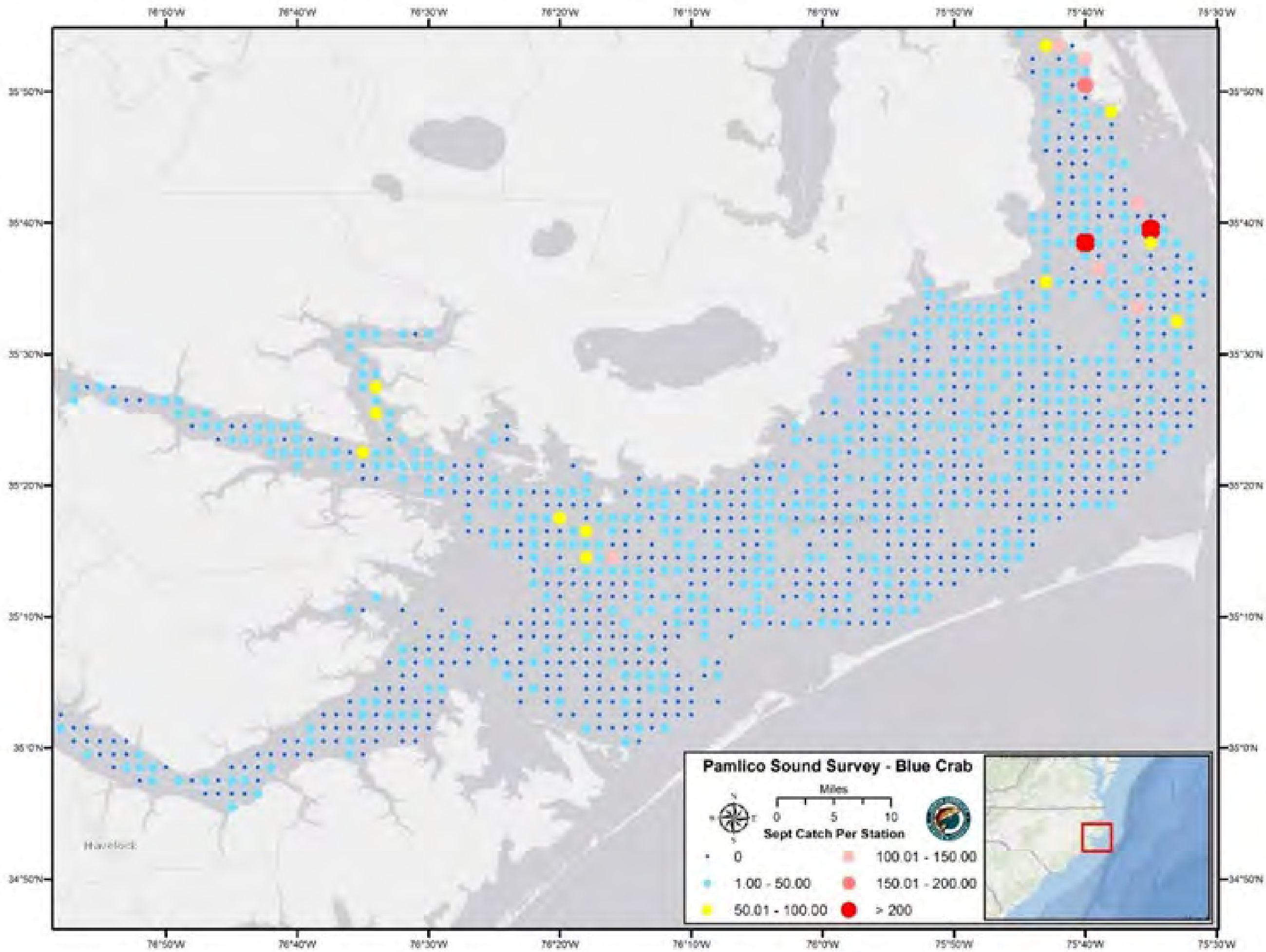


Figure 4.4.17. Total number of mature female blue crabs from Pamlico Sound Survey in September, 1987-2017.

To further evaluate where concentrations of mature females occur seasonally, a GIS tool, Optimal Hot Spot Analysis, was used. This GIS tool identifies statistically significant spatial clusters of high values (hot spots) and low values (cold spots). This tool works by analyzing each feature (sampling grid) within the context of neighboring features. A feature with a high value is interesting but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum and when that difference is too large to be the result of random chance a statistically significant score results.

An Optimal Hot Spot Analysis was conducted by T. Udouj, SEAMAP, using mature female blue crab abundance data from the Pamlico Sound Survey. Figures 4.4.18 and 4.4.19 show the resulting maps for mature females in summer and fall months using the same Pamlico Sound Survey dataset as shown in Figures 4.4.16 and 4.4.17 of actual abundance data. Maps are symbolized based on the confidence level.

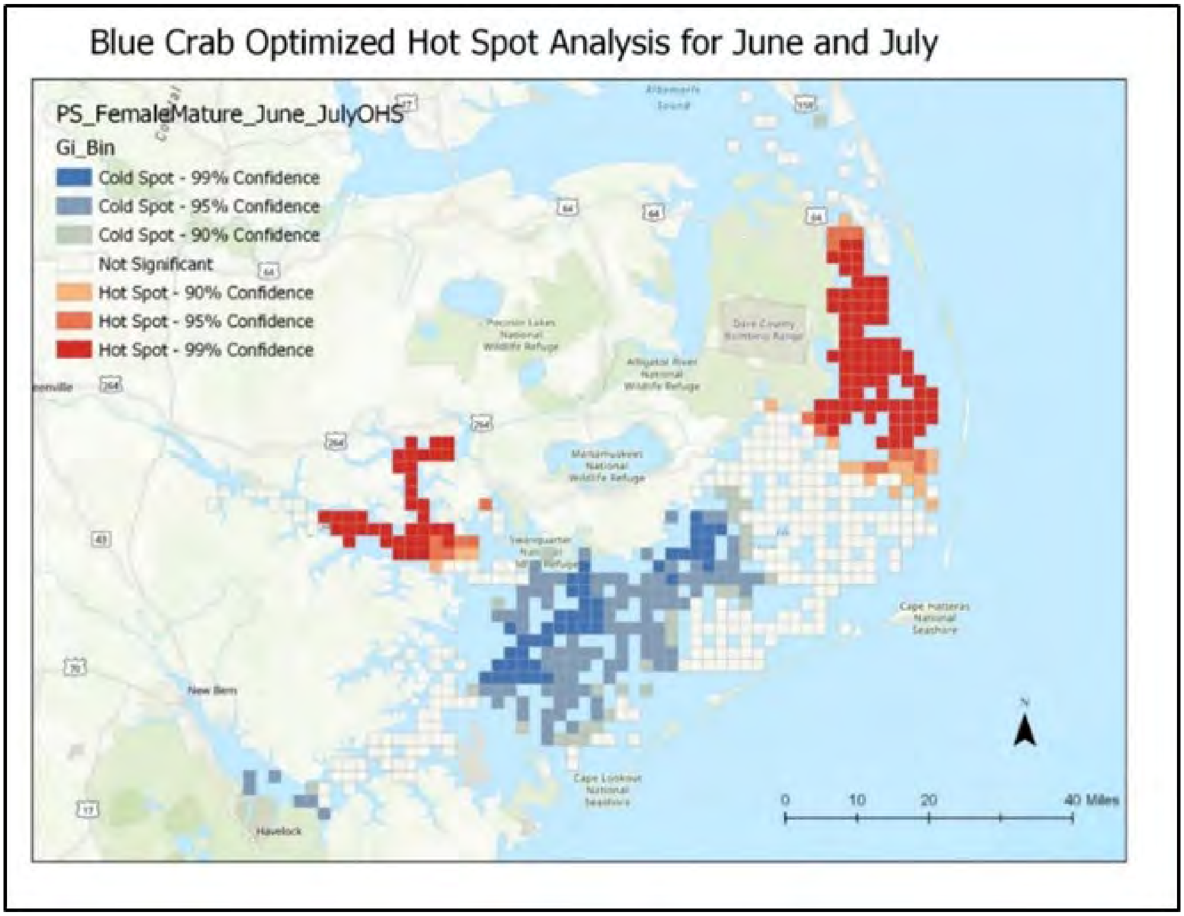


Figure 4.4.18. Areas with high confidence of having exceptionally high (red) or low (blue) numbers of mature female blue crabs from Pamlico Sound Survey in June and July, 1987-2017.

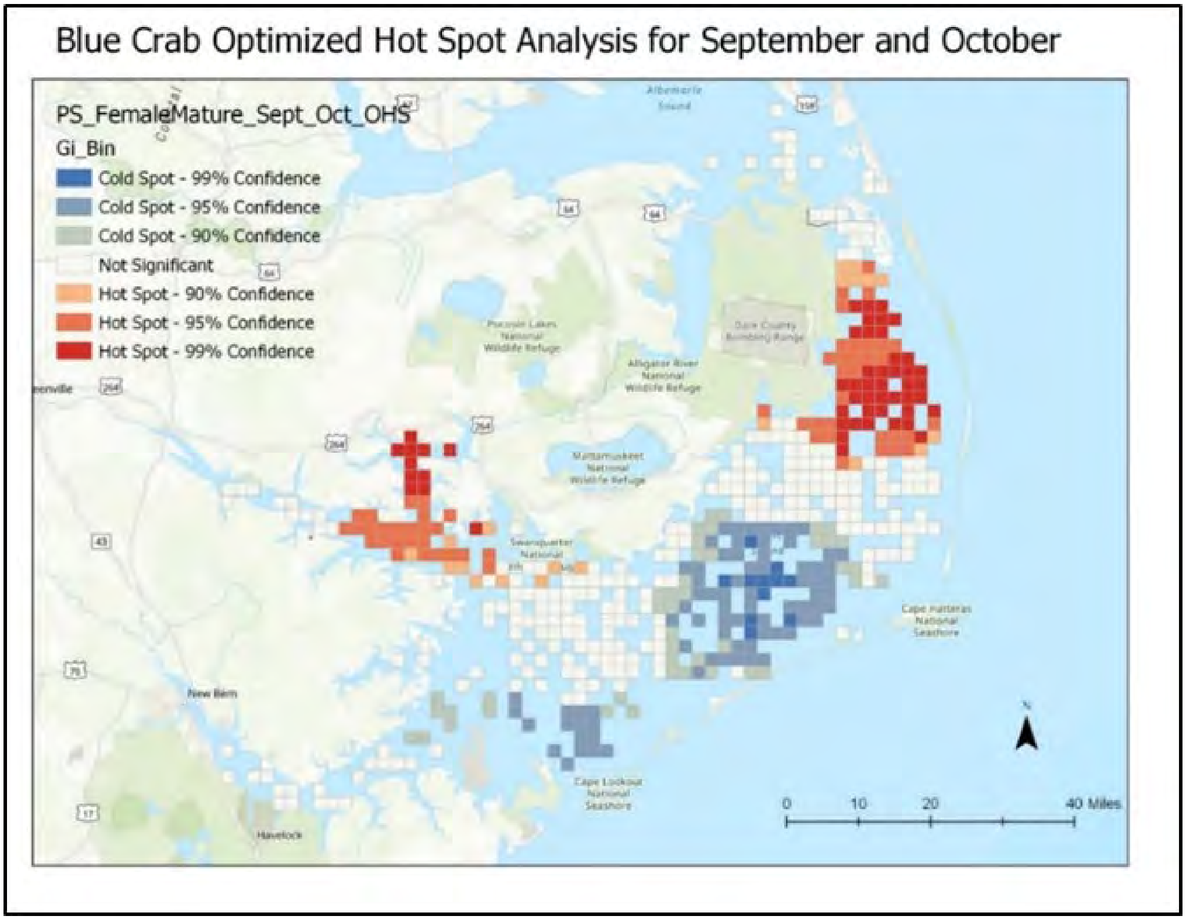


Figure 4.4.19. Areas with high confidence of having exceptionally high (red) or low (blue) numbers of mature female blue crabs from Pamlico Sound Survey in September-October, 1987-2017.

The results for June indicate there is a high probability (95-99%) of high concentrations of mature female blue crabs in Croatan and northern Pamlico sounds and in the Pungo River and lower Pamlico River (red areas; Figure 4.4.18). The results for September are similar, with the confidence values slightly lower (90%; Figure 4.4.19). Creation of a designated migration corridor in Croatan and northern Pamlico sounds, coinciding with the hot spots shown in Figures 4.4.18 and 4.4.19 is a management option to consider that is strongly supported by the data.

Advantages of an expanded sanctuary system and migration corridor include minimizing mortality and increasing protection of mature female blue crabs migrating to the spawning grounds. The economic impact to fishermen can be minimized by limiting the temporal and spatial extent of the protected area. Similarly, a migration corridor could be designated from the Pungo River to the nearest inlet spawning grounds. However, more information on mature female migration routes between the Pungo River, lower Pamlico River, and the inlets is needed to further define those migration corridors.

Data indicates Croatan Sound is a migration corridor for mature female blue crabs as they migrate out of Albemarle and Currituck sounds toward Oregon Inlet to spawn. In the Chesapeake Bay, Virginia opted for a summer closure in the deeper waters of the bay to help mature females migrate to the spawning grounds. A similar strategy could be adopted for the deeper waters of Croatan Sound to help protect mature females once they have mated and begin to migrate toward the spawning grounds. Figure 4.4.20 shows an area that could be designated as a migration corridor and how this area overlaps with the previously identified hot spots. The size of the example migration corridor is approximately 19,948 acres. The timing of landings peaks of hard, soft, and peeler blue crabs throughout the year may help indicate migration timing and indicate a seasonal closure period that would enhance the protection of mature female blue crabs in the waters of Croatan Sound (Tables 4.4.5 and 4.4.6).

Table 4.4.5. Commercial hard blue crab landings trends by Trip Ticket waterbody, 2012-2016.

Waterbody	Landings Peak	Largest Landings Increase	Landings Increase Percent*	Largest Landings Decrease	Landings Decrease Percent*
Chowan River	August	July-August	29	September-October	35.7
Perquimans River	August	July-August	11.2	September-October	12.1
Pasquotank River	August	May-June	9	October-November	11.3
Alligator River	October	April-May	7.9	October-November	10.8
Albemarle Sound	September	May-June	8	October-November	10.4
Currituck Sound	June	April-May	10.3	October-November	8.3
Croatan Sound	October	September-October	11	November-December	11.6
Roanoke Sound	October	September-October	11.2	November-December	12.0
Pamlico Sound	June	March-April	5.2	November-December	6.6

*The landings difference between months is the month to month difference in the percent of annual landings. For example, if January is 5% of the annual landings and February is 20% then the month to month difference in annual landings percent is 15%.

Table 4.4.6. Commercial soft and peeler blue crab landings trends by Trip Ticket waterbody, 2012-2016.

Waterbody	Landings Peak	Largest Landings Increase	Landings Increase Percent*	Largest Landings Decrease	Landings Decrease Percent*
Chowan River	September	July-August	36.1	September-October	60.3
Perquimans River	May/August	April-May	23.2	May-June	14.0
Pasquotank River	May	April-May	84.9	May-June	83.9
Alligator River	May	April-May	52.3	May-June	45.1
Albemarle Sound	May	May-June	58.6	May-June	55.0
Currituck Sound	May	April-May	64.3	May-June	72.9
Croatan Sound	May	April-May	61.2	May-June	68.9
Roanoke Sound	May	April-May	64.6	May-June	74.4
Pamlico Sound	May	April-May	44.8	May-June	58.9

*The landings difference between months is the month to month difference in the percent of annual landings. For example, if January is 5% of the annual landings and February is 20% then the month to month difference in annual landings is 15%.

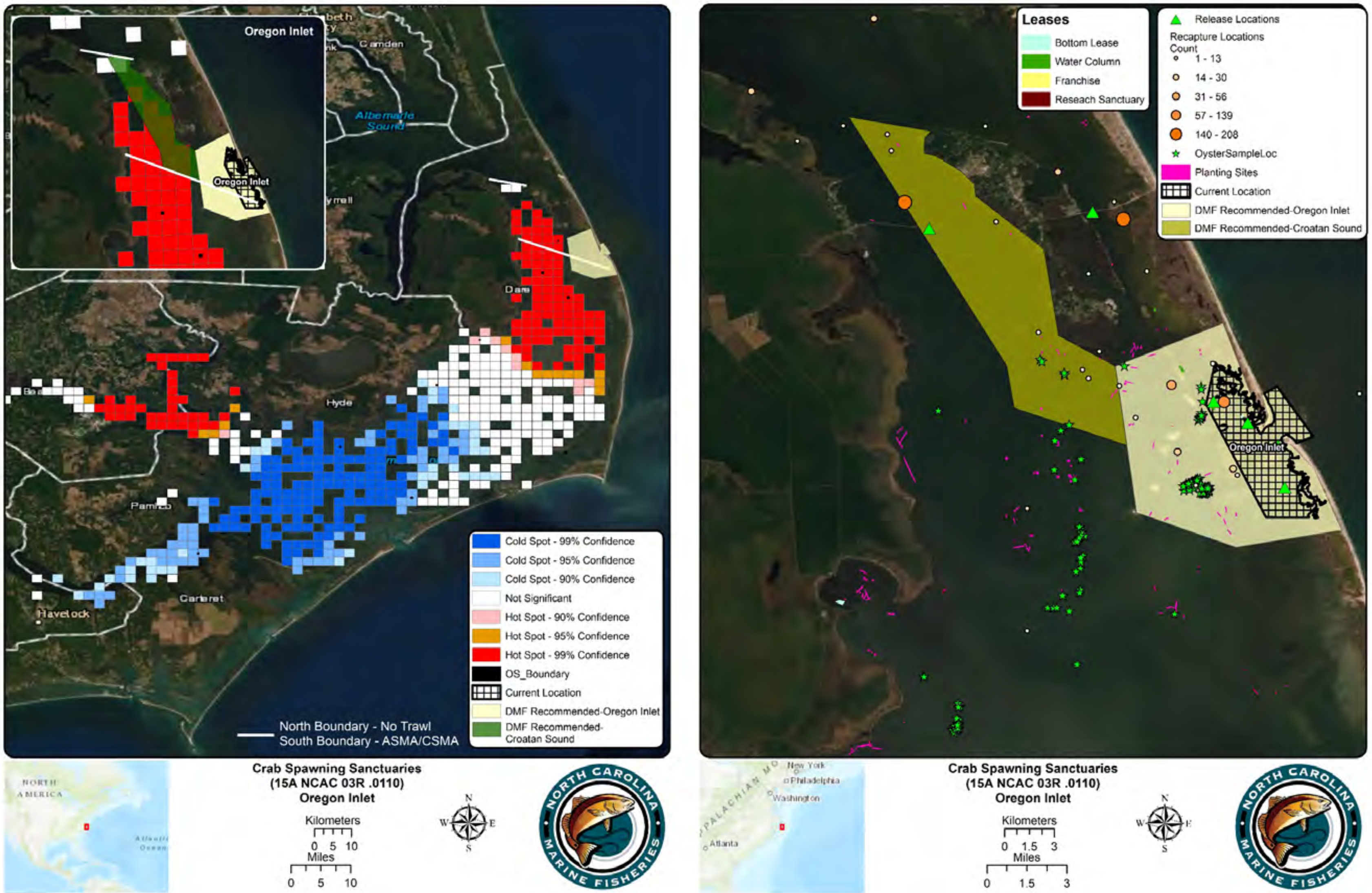


Figure 4.4.20. Location of proposed migration corridor through Croatan Sound in relation to the hot spot analysis results (left) and in relation to the NCDMF recommended Oregon Inlet crab spawning sanctuary expansion (right).

VI. PROPOSED RULES(S)

N/A

VII. MANAGEMENT OPTIONS AND IMPACTS

(+ Potential positive impact of action)
(- Potential negative impact of action)

Below are overarching positive and negative impacts for all options, specific impacts from an option may be found below that option.

+ Will protect additional mature female blue crabs from harvest to allow spawning to occur, potentially leading to increased population size
+ Will reduce some bycatch of finfish where new sanctuaries are established
+ Reduces damage or mortality of sponge crabs from incidental harvest
- Potential for decreased harvest of blue crabs with economic loss to the fishery
- Potential negative impact to the shrimp, oyster, and clam fisheries (depending on management strategy chosen)

1. Expand the boundaries of the five existing crab spawning sanctuaries

2. Establish new crab spawning sanctuaries at all inlets without a crab spawning sanctuary

3. Establish a crab spawning sanctuary to serve as a migration corridor in Croatan Sound

4. Close crab spawning sanctuaries around inlets from March 1 through October 31 to the use of trawls, pots, and mechanical methods for oysters or clams and to the taking of crabs with any commercial fishing equipment

5. Close crab spawning sanctuaries around inlets year round to the use of trawls, pots, and mechanical methods for oysters or clams and to the taking of crabs with any commercial fishing equipment

VIII. RECOMMENDATION

<u>NCDMF Recommendation</u>

- Expand boundaries as presented for Oregon, Hatteras, Ocracoke, and Barden inlets
- Move boundary for Drum Inlet CSS as presented
- Concur with AC recommendations for Beaufort, Bogue, Bear, Browns, New River, Topsail, Rich, Mason, Masonboro, Carolina Beach, Shallotte, Lockwood Folly, and Tubbs inlets
- Use PDT recommended boundary for Cape Fear River Inlet CSS
- Concur with AC recommendation of a March 1 through October 31 closure for Beaufort Inlet through Tubbs Inlet sanctuaries with same restrictions as existing sanctuaries

- Establish a seasonal crab spawning sanctuary to serve as a migration corridor on the east side of Croatan Sound, as presented, closed to blue crab harvest from May 16 through July 15

Blue Crab FMP Advisory Committee
Keep Oregon, Hatteras, and Ocracoke the same and change Drum and Barden to proposed boundaries

Add spawning sanctuaries from Beaufort through Tubbs inlets using AC recommended boundaries with a closure period of March 1 through October 31 with same restrictions as existing sanctuaries

Northern Advisory Committee

Southern Advisory Committee

Shellfish and Crustacean Advisory Committee

Habitat and Water Quality Advisory Committee

NCMFC Selected Management Strategy

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APPENDIX 4.5: ESTABLISH A FRAMEWORK TO IMPLEMENT THE USE OF TERRAPIN EXCLUDER DEVICES IN CRAB POTS

I. ISSUE

Establish a framework for developing proclamation use criteria and terrapin excluder specifications to reduce interactions of diamondback terrapins (*Malaclemys terrapin*) with crab pots.

II. ORIGINATION

North Carolina Marine Fisheries Commission (NCMFC) selected management strategy in Amendment 2 of the Blue Crab Fishery Management Plan.

III. BACKGROUND

The NCMFC adopted Amendment 2 of the North Carolina Blue Crab Fishery Management Plan (FMP) in November 2013 (1). In this plan, the NCMFC recognized diamondback terrapins as a wildlife resource in need of protection from crab pot fishing activities under its jurisdiction and sought to proactively implement conservation measures to prevent localized diamondback terrapin depletions or extirpations through incidental bycatch from current or future activity in the blue crab fishery. To implement this selected management strategy, the NCMFC granted proclamation authority for the director of the North Carolina Division of Marine Fisheries (NCDMF) to require terrapin excluder devices to be used in crab pots. This proclamation authority was placed in NCMFC Rule 15A NCAC 03L .0204(b), which became effective April 1, 2014. This rule states the Fisheries Director may, by proclamation, require the use of terrapin excluder devices in each funnel entrance in crab pots and impose the following restrictions concerning terrapin excluder devices: specify areas; specify time periods; and specify means and methods.

This issue paper develops proclamation issuance criteria necessary to implement the NCMFC management strategy and proposes a framework by which the NCDMF would determine discrete "diamondback terrapin management areas" (DTMAs) where all crab pots fished within would be required to use NCDMF approved terrapin excluder devices or modified pot designs. Once accepted by the NCMFC, this framework would be used to determine appropriate locations of DTMAs across coastal North Carolina. The issue of incidental capture of diamondback terrapins and use of excluders to prevent terrapin bycatch in crab pots in the North Carolina blue crab fishery is thoroughly reviewed in the issue paper "Diamondback Terrapin Interactions with the Blue Crab Pot Fishery" in sections 11.12 and 12.1.5.2 of the 2013 Blue Crab FMP Amendment 2

Diamondback terrapins were moved from "Near Threatened" to the greater risk category "Vulnerable" on the Red List of Threatened Species by the International Union for Conservation of Nature (IUCN) after their most recent assessment in 2018. Ongoing range-wide population declines due to accidental mortality as bycatch in commercial Blue Crab fisheries, and coastal habitat impacts due to development were cited as primary justifications for moving this species into the increased risk category. The North Carolina Wildlife Resources Commission (NCWRC) lists diamondback terrapin as a North Carolina species of “Special Concern” statewide and as a Federal “Species of Concern” in Dare, Pamlico and Carteret counties in NC. The status of “Special Concern” or “Species of Concern” does not specifically provide any special protection under the federal Endangered Species Act, however the federal status may be upgraded to “Threatened” or “Endangered” if natural or human-made factors are affecting its continued existence, or there is an inadequacy of existing regulatory mechanisms in place (e.g. unmitigated mortality from bycatch in crab pots). In February 2011, the NCWRC Nongame Wildlife Advisory Committee received a report from the Scientific Council on Amphibians and Reptiles which recommended the diamondback terrapin be listed as “Threatened” (2). This report, citing a large body of evidence from numerous studies, concluded incidental bycatch in crab pots is the most serious threat to diamondback terrapins in North Carolina (3; 4; 5; 6). Seafood Watch, one of the best-known seafood consumer awareness programs, gives the North Carolina blue crab fishery their lowest rating of “Avoid”, stating that serious concerns about the lack of implementation of any regulations to protect diamondback terrapins from bycatch in crab pots are the primary reason for this poor rating (7).

Diamondback terrapins are found throughout North Carolina’s high salinity coastal marshes however; all coastal areas do not contain suitable terrapin habitat (8). Diamondback terrapins are long-lived, late to mature, and display relatively low fecundity (9). Delayed sexual maturity and low reproductive rates, coupled with long life spans and strong site fidelity, make this species susceptible to substantial population declines or even localized extirpations through the incidental bycatch and removal of a relatively low number of individuals from the population annually ([3; 6).

Genetic analysis (10) of diamondback terrapins sampled from Massachusetts to Texas suggests at least four major regional population groupings across this range, with North Carolina diamondback terrapins belonging to the Coastal Mid-Atlantic grouping. Although diamondback terrapins display high site fidelity, there is enough movement of individuals to maintain long term gene flow within these larger regional scales (10).

Several factors have been identified in determining the likelihood of diamondback terrapin bycatch in crab pots where crab fishing activities and diamondback terrapin occurrence overlap, such as: water depth and distance from shore (11; 12; 13; 14; 15), presence or dimensions of the excluder device (16; 17; 12; 15; 18; 19; 20; 21; 22), and the season which fishing occurs (11; 12; 13; 15; 23). Taking these factors into consideration, diamondback terrapin mortality from incidental bycatch in crab pots can be mitigated, reducing population impacts from localized and regional extinctions within North Carolina, and maintaining genetic connectivity across the Coastal Mid-Atlantic population.

Using the known factors affecting diamondback terrapin bycatch in crab pots, a highly targeted approach to reducing bycatch mortality with the least potential impact to the statewide blue crab fishery can be developed through the establishment of discrete regional DTMAs. This approach would be employed in lieu of either a statewide requirement for terrapin excluder devices to be used on all crab pots, or the prohibition of crab pots from specific areas. This issue is being addressed as part of Amendment 3 instead of being implemented in between FMP amendments due to the scheduled review of the blue crab FMP moved to 2016/2017 on the schedule by the NCMFC in August 2016.

The NCDMF used the following framework to develop criteria for using terrapin excluder devices:

Determine NCDMF approved terrapin excluder device types and sizes to be required.
Determine dates when terrapin excluder devices will be required in crab pots.
Identify the zone of potential diamondback terrapin interaction with crab pots.
Validate diamondback terrapin presence and overlap with potential crab pot interaction zone.
Determine appropriate management area boundaries.
Produce an information paper, present to appropriate regional advisory committee, and receive public comment concerning the proposed DTMA.
Draft proclamation for issuance by NCDMF.

IV. AUTHORITY

North Carolina General Statute 113-134 – Rules
North Carolina General Statute 113-182 – Regulation of fishing and fisheries
North Carolina General Statute 113-182.1. Fishery Management Plans
North Carolina General Statute 113-221.1 – Proclamations; emergency review
North Carolina General Statute 143B-289.52 – Marine Fisheries Commission – powers and duties
NCMFC Rule 15A NCAC 03H .0103 – Proclamations, General
NCMFC Rule 15A NCAC 03J .0301 – Pots
NCMFC Rule 15A NCAC 03L .0201 – Crab Harvest Restrictions
NCMFC Rule 15A NCAC 03L .0204 – Crab Pots

V. DISCUSSION

Step 1 Determine NCDMF approved terrapin excluder device types and sizes

Multiple researchers across the range of diamondback terrapins have examined the effectiveness of terrapin excluder devices, also known as a bycatch reduction device, and their impact on the catch of blue crabs in the pot fishery. Table 4.5.1 provides a summary of these field studies by state. Across all studies the largest reduction in diamondback terrapin bycatch or the largest percent of potential diamondback terrapin exclusion typically occurred using terrapin excluder devices with the smallest vertical opening dimensions (Table 4.5.1). Impacts of terrapin excluder devices to crab catch ranged from 25.7% increased catch rates (24), to a 29% reduction in crab catch rates (25), as well as reduction in the average carapace width of crabs captured (20; 21). Numerous studies have also concluded that specific dimensions of terrapin excluder devices result in no significant reduction in size or catch rate of blue crabs when compared to control pots without terrapin excluder devices. However, some studies that did not find statistically significant differences in crab catch or sizes between control pots and pots with terrapin excluders did acknowledge a trend towards a reduced blue crab catch when terrapin excluders are in place (18; 19). Longer blue crab retention times in pots which employed excluder devices has been shown to mitigate catch rate impacts from lower numbers of crabs entering pots with excluders, resulting in no net loss in overall catch (20). However, from a theoretical modeling approach, which analyzed over 8,000 possible terrapin excluder dimensions (between 3.2 x 5.1 cm and 16 x 16 cm) compared to field collected morphometric dimension of terrapins, the overall excluder opening area followed by the diagonal excluder opening dimension were found to have the greatest predictive relationship with the exclusion of terrapins (22).

Shell height has often been concluded to be the determining dimension in the exclusion of diamondback terrapins from crab pots (16), and across multiple studies rectangular excluders with a vertical opening of 4 cm (1.6 in) or less have been the most effective (Table 4.5.1). In one Virginia study, excluders which prevent terrapins from entering based on shell height were shown to allow the same number of terrapins to be captured in pots when compared to those which prevent entry based on shell width, however based on terrapin measurements simultaneously captured in pots without excluders, the devices which limited by shell width had greater potential exclusion (21). Requiring the use of a terrapin excluder device which restricts entry based on shell height, with a horizontal width less than 16 cm (6.3 in.), the typical width of a crab pot throat, may not result in any additional reduction in diamondback terrapin bycatch if the horizontal opening of the device is no larger than 4 cm (1.6 in.). In North Carolina a 4 x 16 cm (1.6 x 6.3 in.) excluder was shown to offer 100% reduction in potential terrapin capture (15). In South Carolina a relatively square shaped "SC design" excluder with a slightly curved top and bottom 5.1-6.4 x 7.3 cm (2-2.5 x 2.9 in.) which restricts entry based on shell width, would exclude 33% more terrapins than two other commonly tested excluder devices, 5 x 10 cm (2 x 3.9 in.) and 4.5 x 12 cm (1.8 x 4.7 in.), and by increasing the width of this device of 0.4 cm (0.2 in.) 99% of legal-size blue crab would be captured (22). Excluder devices made of 11-gague wire have been tested and have been recommended as an option in Virginia. However, crab pots with 11-gauge wire excluders do allow in large terrapins and wire excluders must be constructed of a gauge heavy enough to maintain rigidity (20). Pre-made plastic terrapin excluder devices may be purchased for approximately $0.50 from manufacturers such as Top-Me Products or made even more inexpensively with at least 10-gauge (or thicker) wire and hog rings (Figure 4.5.1).

The effect of excluder orientation has also been examined. In a controlled aquarium setting, McKee et al. (26) tested the effect of a 5 x 15.2 cm (2 x 6 in.) excluder device mounted both horizontally and vertically on diamondback terrapin entry to crab pots. They found that although there was a 17.5% reduction in diamondback terrapin entries into pots with a horizontally mounted excluder when compared to control pots without an excluder, this difference was not statistically significant. However, the vertically mounted excluder did result in significantly lower amount of diamondback terrapin pot entries and significantly longer entry times when compared to both control and pots with horizontally mounted excluders.

Diamondback terrapins display sexual dimorphism in size, with males not growing as large in shell height and length as females. Small diamondback terrapins of either sex are vulnerable to capture. However, females grow to a shell height which prevents them from entering typical crab pots by the time they reach eight years of age, with mature males possibly remaining vulnerable to pot entrapment throughout their life (4). This difference in growth rate and ultimate size difference between the sexes leaves young individuals (both sexes) and males more vulnerable to capture in crab pots when using some terrapin excluder devices. The selective removal of juveniles and males can lead to localized alterations in both population age structure and sex ratios, which can threaten the survival of the population (6). Due to geographic variation in diamondback terrapin body size, local evaluation of effective terrapin excluder device size may be required (27).

Hart and Crowder (15) in Jarrett Bay, off Core Sound, North Carolina, found using a 4 x 16 cm (1.6 x 6.3 in.) terrapin excluder device would have excluded 100% of all diamondback terrapins encountered during their research, however this would result in a 26.6% reduction in all legal sized male blue crabs captured, a 4.5 x 16 cm (1.8 x 6.3 in.) terrapin excluder device would have potentially excluded 77% of the total diamondback terrapins (100% female, 70% male) while reducing the legal male blue crab catch by 21.2%, and a 5 x 16 cm (2 x 6.3 in.) terrapin excluder device would have potentially excluded 28% of the total diamondback terrapins (50% female, 10% male). Based on pooled shell height data from diamondback terrapins captured by Southwood et al. (28) in Masonboro and Middle Sounds, North Carolina, a terrapin excluder device with a height of 4 cm (1.6 in.) would have excluded 91% of all diamondback terrapins (100% female, 80% male), a terrapin excluder device with a height of 4.5 cm (1.8 in.) would have excluded 51% of all diamondback terrapins (93% female, 0% male), and a terrapin excluder device with a height of 5 cm (2 cm) would have excluded 40% of the all diamondback terrapins (73% female, 0% male). Hart and Crowder (15) recommend the statewide adoption of a 4.5 cm (1.8 in.) height terrapin excluder device, as it offered high diamondback terrapin protection at a lower loss of blue crab catches. This size terrapin excluder device would have prevented the bycatch of 93% of female diamondback terrapins, but 0% of male diamondback terrapins sampled by Southwood et al (28). Chavez and Southwood Williard (19) examined the effects of "large" 5 x 15 cm (2 x 6 in.) and "small" 3.8 x 15 cm (1.5 x 6 in.) terrapin excluder devices on the catch of blue crab and diamondback terrapins at multiple sites around Beaufort, NC. They concluded that neither size resulted in a significant reduction in the number nor carapace width of blue crabs caught when compared to pots without terrapin excluder devices and resulted in a potential 86% (100% female, 0% male) to 100% reduction in diamondback terrapins captured, respectively. Chavez and Southwood Williard (19) did comment that although there was no statistically significant reduction in blue crab catch numbers, there is a trend toward catch reduction in pots fitted with the smaller terrapin excluder device.

As terrapin excluder devices have been demonstrated to reduce the efficiency of crab pots, crab fisherman may respond by increasing the total number of pots fished in an area to offset reductions in crab catch, resulting in an increase in the potential for diamondback terrapin interactions within the DTMAs. The possibility for increased localized crab pot effort as a response to the requirement to the use of terrapin excluder devices highlights the need to employ the most effective terrapin excluder devices.

The best current available data from diamondback terrapin and blue crab research should be used when considering the dimensions and type of excluder devices to be approved by NCDMF, and to be required for use in DTMAs. Arendt et al. (22), when modelling diamondback terrapin exclusion probabilities for the range of device dimensions tested and published in the literature since 1994, determined the 4 x 8 cm (1.6 x 3 in.) shell height limiting excluder followed by the "SC design" 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.) shell width limiting excluder to be the most effective at reducing the probability of diamondback terrapin entry into crab pots. These exclusion probabilities were calculated using dimensions from blue crabs and diamondback terrapins captured in South Carolina. As regional variation in morphometric length x width relationships as well as size distributions may exist for both blue crabs and diamondback terrapins, the exact reductions in diamondback terrapin capture and impacts to blue crab catch may likely be site specific for each excluder dimension. In North Carolina field studies, excluders which limit based on shell height, with an opening no more than 4 cm vertical height and no more than 16 cm horizontal width (1.6 x 6.3 in.) have been shown to offer the greatest protection to both male and female diamondback terrapins, however this size excluder device is shown to impact the blue crab catch in pots where they are employed (see Table 4.5.1). When examining the size distribution of diamondback terrapins captured in North Carolina by researchers at the University of North Carolina Wilmington, both a height limiting excluder with a vertical opening of no greater than 4 cm (1.6 in.) and the "SC design" 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.) shell width limiting excluder would appear to prevent the bycatch of the majority and most frequent size ranges of terrapins captured in North Carolina (Figure 4.5.2) and should be approved for use as bycatch reduction methods in any proposed DTMAs.

To allow for collaboration between stakeholders, NCDMF a diamondback terrapin bycatch reduction workgroup consisting of North Carolina fisherman, academic researchers, and fishery managers should be formed. This workgroup may review and test existing excluder devices or work in partnership to examine novel bycatch reduction designs to minimize the impact to blue crab catch while reducing terrapin bycatch. Recommendations on additional excluder devices or modified pot designs by the workgroup will be considered for approved use in DTMAs by the NCDMF in consultation with the Shellfish/Crustacean Advisory Committee. To be considered for approval by the NCDMF, the other devices or modified pot designs must be shown to reduce impacts to blue crab catch or cost to fisherman and maintain a level of diamondback terrapin protection offered by existing approved excluder devices.

Step 1 Summary:
The following terrapin excluder devices shall be considered approved for use in DTMAs: the pre-made plastic shell width limiting "SC design" measuring 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.); any pre-made plastic shell height limiting excluder devices with an internal opening no larger than 4 x 16 cm (1.6 x 6.3 in.) height by width; or any shell height limiting excluders made from at least 10-gauge galvanized wire and hog rings with an internal opening no larger than 4 x 16 cm (1.6 x 6.3 in.) height by width. A diamondback terrapin bycatch reduction workgroup of fisherman, academic researchers, and managers will be created. Additional or alternative terrapin excluder devices or modified pot designs recommended through the workgroup may be approved by NCDMF, in consultation with the Shellfish/Crustacean Advisory Committee, provided they have been shown to reduce impacts to blue crab catch or cost to fisherman and maintain the level of diamondback terrapin protection offered by the terrapin excluder devices initially approved and listed above.

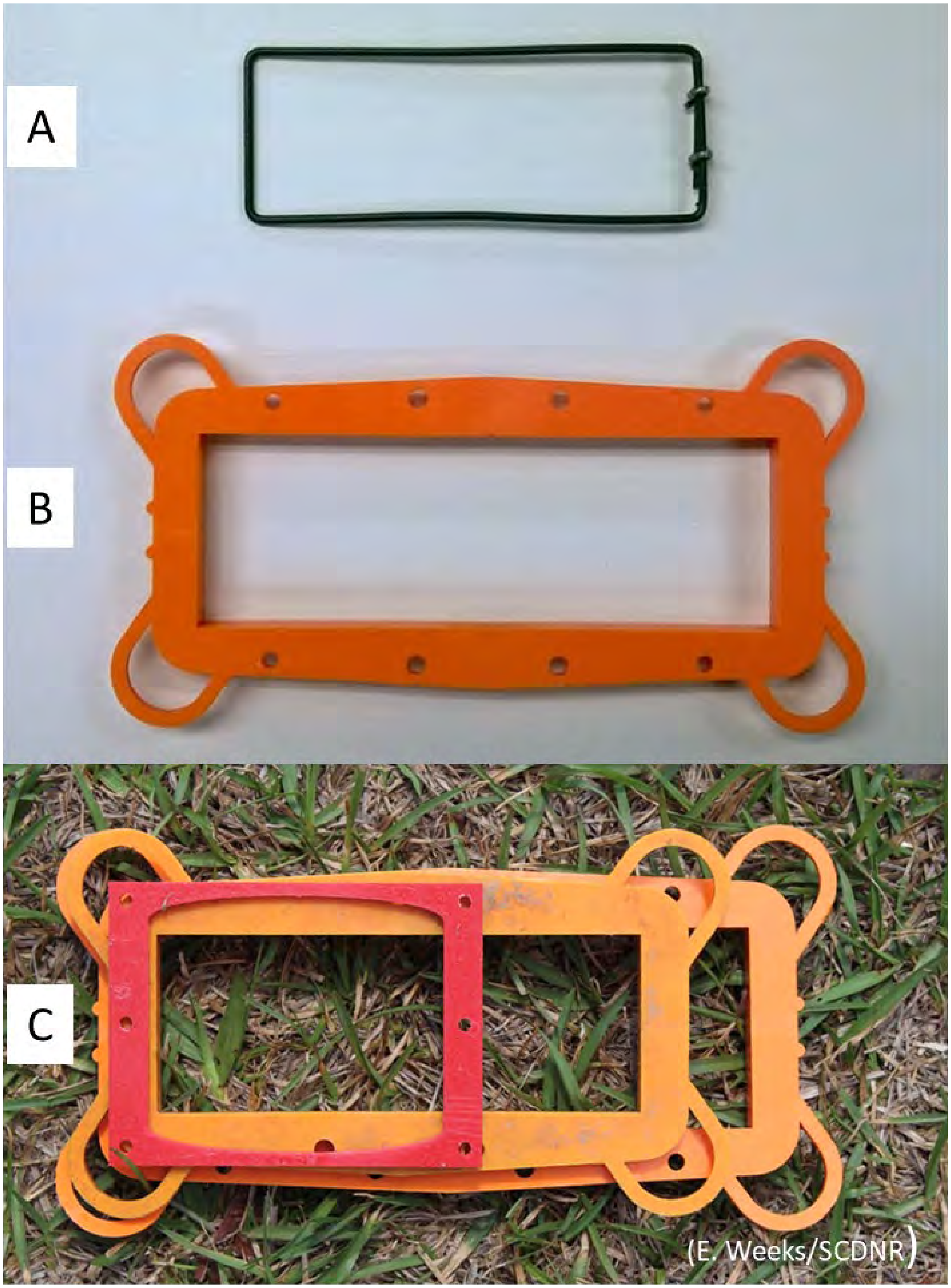

Figure 4.5.1. Examples of terrapin excluder devices for use in crab pots include: (A) wire and hog ring excluder made by a crab pot manufacturer, (B) premade plastic excluder made by Top-Me Products, (C) plastic "SC design" excluder, a shell width limiting device (red) shown on top of two premade plastic shell height limiting devices (photo credit: E. Weeks/SCDNR).

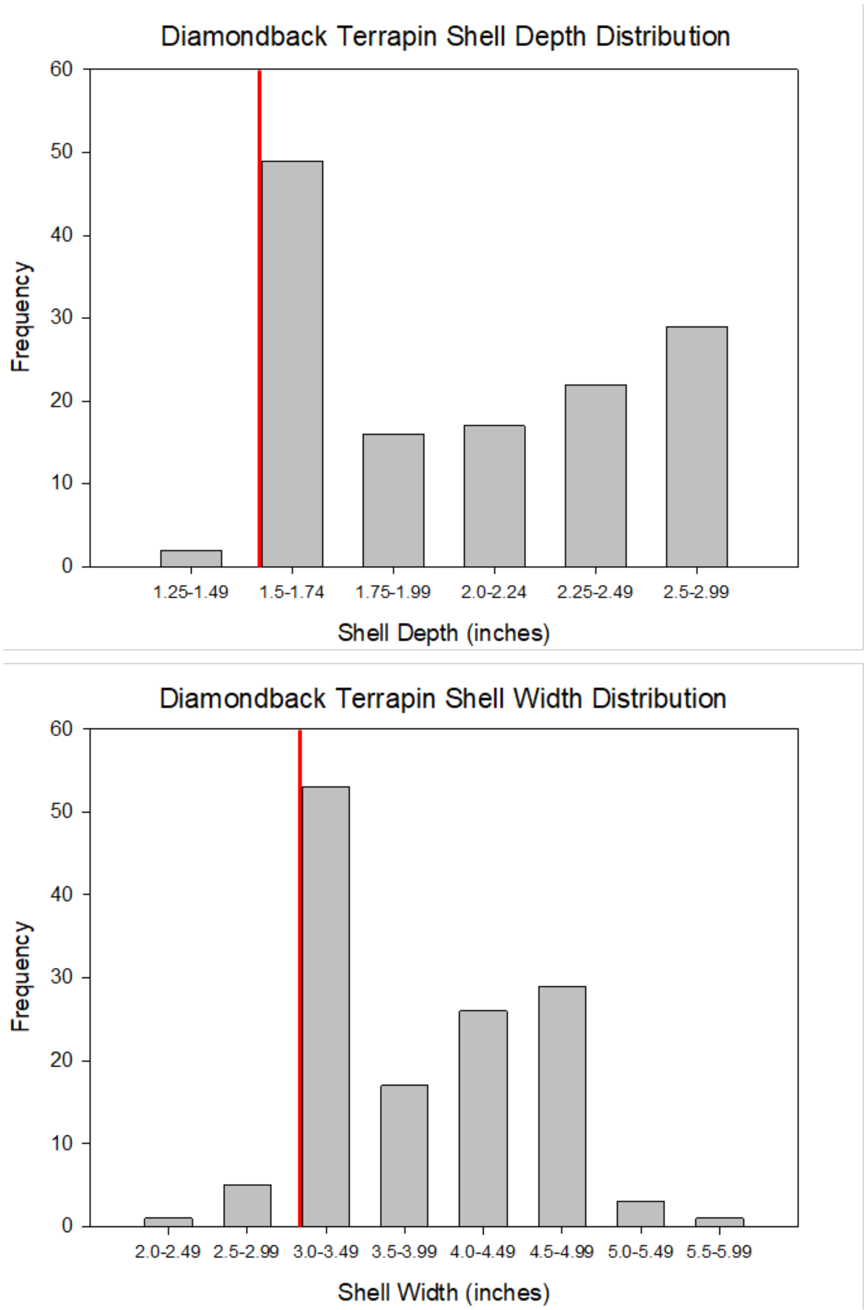

Figure 4.5.2. Distribution of shell depth and height for diamondback terrapins (N=135) in coastal North Carolina. Data compiled by Dr. Amanda Williard (Department of Biology and Marine Biology, University of North Carolina Wilmington). These data represent field records for terrapins captured by seine at multiple sites (Figure 8 Island, Masonboro Island, Bald Head Island, and Beaufort) 2008 to 2018. Vertical red lines approximate potential exclusion of individuals in the size frequency bins to the right of the line; in the upper panel by a height limiting excluder design with a vertical opening of no greater than 4 cm (1.6 in.) and by a shell width limiting “SC design” 5.1-6.4 x 7.5 cm (2-2.5 x 3.1 in.) in the lower panel.

Table 4.5.1. Summary results of field studies examining effectiveness of different terrapin excluder device dimensions and impacts to blue crab catch. A * signifies no diamondback terrapins were caught in the study.

Location	Reference	Excluder Dimensions (cm; height x width)	Impact to Diamondback Terrapin Bycatch	Impact to Blue Crab Catch
NJ	Mazarella 1994 (29)	5 x 10	93% reduction	No significant difference
NJ	Wood 1997 (30)	5 x 10	90% reduction	11% increase in catch rates
		4.5 x 10	100% reduction	9% increase in catch rates
DE	Cole and Helser 2001 (17)	5 x 10	59% reduction	No significant change in number
		4.5 x 12	66% reduction	12% reduction in legal crabs
		3.8 x 12	100% reduction	26% reduction in legal crabs
MD	Roosenburg and Green 2000 (16)	5 x 10	47% reduction	No significant effect on size or number
		4.5 x 12	82% reduction	No significant effect on size or number
		4 x 10	100% reduction	Significant reduction in size and number
VA	Rook et al. 2010 (31)	4.5 x 12	96% reduction	No significant effect on size or number
VA	Upperman et al. 2014 (18)	5 x 15.2	75% potential exclusion	No significant effect on size or number
		4.5 x 12	96% potential exclusion	Significant reduction in size and number
VA	Corso et al. 2017 (20)	5.1 x 15.2	83% reduction	No significant effect on number
				Significant reduction in size (1mm)
VA	Grubbs et al. 2017 (21)	5.1 x 15.3	87% reduction	No significant reduction in catch rate
				Significant reduction in size (2mm)
		6.4 x 7.3	87% reduction	No significant reduction in catch rate
				Significant reduction in size (2mm)
NC	Grant 1997 (25)	5 x 10	75% reduction	19% reduction
		4 x 12	100% reduction	29% reduction
NC	Thorpe and Likos 2008 (32)	5 x 12	*	5.7% reduction
		5 x 10	*	18.2% reduction
NC	Hart and Crowder 2011 (15)	5 x 16	28% potential exclusion	5.7% reduction in legal male crabs
		4.5 x 16	77% potential exclusion	21.2% reduction in legal male crabs
		4 x 16	100% potential exclusion	26.6% reduction in legal male crabs
NC	Chavez and Southwood Williard 2017	5 x 15	86% potential exclusion	No significant reduction in size or number

Location	Reference	Excluder Dimensions (cm; height x width)	Impact to Diamondback Terrapin Bycatch	Impact to Blue Crab Catch
	(19)	3.8 x 15	100% potential exclusion	No significant reduction in size or number
SC	Grubbs et al. 2017 (21)	5.1 x 15.3	*	No significant reduction in catch rate
				Significant reduction in size (1mm)
		6.4 x 7.3	*	Significant reduction in catch rate
				Significant reduction in size (2mm)
GA	Belcher and Sheirling 2007 (33)	5 x 16	98% reduction	7% reduction in number
FL	Butler and Heinrich 2007 (34)	4.5 x 12	73.2% reduction	No significant effect on size or number
LA	Guillory and Prejean 1998 (24)	5 x 10	*	25.7% increase in overall catch rate

Step 2 Determine dates when terrapin excluder devices will be required

Diamondback terrapins display seasonal differences in habitat use and are known to enter a state of torpor during the winter months. Hardin and Southwood Williard (23) observed radio tagged diamondback terrapins begin exiting the water column and burrow into the marsh mud once water temperatures drop below 20 degrees Celsius (68 °F) during October in Masonboro Sound, North Carolina. They then observed diamondback terrapins resuming activity in April as water temperatures rose. The peak catch of diamondback terrapins in crab pots was seasonal in South Carolina, with the majority of captures occurring during April and May (11). These elevated catches were probably associated with post hibernation feeding and reproductive activity (11). In Jarrett Bay, North Carolina, Hart and Crowder (15) observed all diamondback terrapin interactions with blue crab pots during April and May. In Masonboro Sound, North Carolina, Alford and Southwood Williard (35) sampled modified "tall" crab pots from May to late October. These modified pots are greater in height than standard commercial crab pots, which allows entrapped diamondback terrapins access to air during all tidal phases to prevent drowning mortality. During those months, 27 diamondback terrapins were captured with May having the highest capture rate with 12 diamondback terrapins, followed by June and July with five and four, respectively. There were no captures in August, four in September, and two in October. In southeastern North Carolina, the diamondback terrapin "active season", was determined to be between April 1 and October 31 by observing the movement and activity patterns of radio tagged diamondback terrapins (23). NCDMF has recently encountered active diamondback terrapins in sampling programs in March, during higher than average spring temperatures. Allowing fisherman to use crab pots without terrapin excluder devices during the dormant season (November 1 – February 28) in DTMAs should not result in significant bycatch of diamondback terrapins, however, this may result in crab pots without terrapin excluder devices being lost and becoming "ghost pots" within DTMAs. Though not baited, these "ghost pots" may continue to cause bycatch mortality (36).

Step 2 Summary:
As peak captures of diamondback terrapins in crab pots occur in early spring as individuals emerge and become active, it is important to account for annual variably in spring temperature and have terrapin excluder devices employed before diamondback terrapins become active. Based on NCDMF interactions and research conducted in North Carolina, terrapin excluder devices shall be used in designated DTMAs from March 1 through October 31 to cover the entirety of the potential diamondback terrapin active season to limit diamondback terrapin bycatch. Both commercial and recreational crab pots would be required to use terrapin excluder devices when fishing in DTMA's during the diamondback terrapin active season.

Step 3 Identify the zone of potential diamondback terrapin interaction with crab pots

Crab pots are one of the most widely distributed fishing gears in the state, occurring throughout all coastal and joint fishing waters. Diamondback terrapins typically spend most of their lives in shallow water adjacent to tidal wetlands, resulting in only a small portion of the area used in the crab pot fishery spatially intersecting with diamondback terrapin habitat (27). The water depths in these nearshore diamondback terrapin habitat areas generally range from < 1 m to 3 m (< 3.3 to 9.8 ft.). In a cooperative research study between crab fishermen and the management agency in South Carolina, 1,913 crab pots set between 0 and 9 m (0 and 29.5 ft.) in depth were sampled. All captured diamondback terrapins were from pots set at depths < 5 m (16.4 ft.), and 97% were captured in pots at depths < 3 m (9.8 ft.; 14).

Thorpe et al. (13) notes that at a study site in Carteret County, North Carolina, all pots sampled were set greater than 91 m (298.6 ft.) from shore and no diamondback terrapins were caught. However, at sites in Brunswick County, North Carolina, all pots were set within 4.5 m to 91 m (14.8 to 298.6 ft.) from shore, resulting in nine diamondback terrapins being caught (all of which were captured < 13 m (42.7 ft.) from shore). Grant (25), at three estuarine sites in North Carolina, showed significant reductions in diamondback terrapin captures as distance from shore increased. The majority of diamondback terrapins (84.5%) were captured less than 25 m (82 ft.) from shore and 15.5% were taken between 26 and 50 m (85.3 and 164 ft.) offshore. None were captured in pots more than 50 m (164 ft.) from shore. In Jarrett Bay (Core Sound), North Carolina, all diamondback terrapin captures occurred within 321 m (1,053.1 ft.) of the shoreline, with 90% occurring 250 m (820.2 ft.) or less from the shore and 76% occurring 150 m (492.1 ft.) or less from the shore (15).

From these studies, it can be inferred the potential zone of most diamondback terrapin interactions with crab pots in North Carolina are areas that are both less than 250 m (820.2 ft.) from any shoreline and less than 3 m (9.8 ft.) deep at low tide. However, using a specific depth and distance from shore as a metric for requiring a terrapin excluder device may be problematic to effectively enforce, due to changing tides and currents. The designation of discrete DTMAs, which primarily contain habitats less than this depth and distance from shore, are easier to enforce as a way to implement a terrapin excluder device requirement in the crab pots.

Using these parameters (less than 250 m (820.2 ft.) from any shoreline, and less than 3 m (9.8 ft.) deep at low tide), a GIS layer was created for the state and mapped to identify regions that meet both criteria (Figure 4.5.3). A narrow band of potential interaction zone lies immediately behind nearly all of the outer banks and other barrier islands. The southern shoreline of Albemarle Sound, as well as locations in the Alligator and Pasquotank rivers also contain areas of potential interaction zone. Broader regions of potential interaction zones occur within Currituck Sound, as well as the lower Newport River and areas around Fort Macon and Beaufort. The widest and most continuous area identified as a potential interaction zone occurs primarily in New Hanover and Brunswick counties in the coastal areas spanning from Figure 8 Island to Bald Head Island.

Step 3 Summary:
Based on currently available data, areas both less than 250 m from any shoreline and less than 3 m deep at low tide shall be generally identified as areas of potential overlap between diamondback terrapins and the crab pot fishery. These criteria may be revised as additional research is completed.

<u>Step 4 Validate diamondback terrapin presence and overlap with potential crab pot interaction zone</u>

Several sampling programs conducted by the NCDMF encounter diamondback terrapins. These programs include several fishery-independent trawl surveys, a commercial gill net observer program, and fishery-independent gill net survey. These sampling programs are all conducted in brackish marsh areas across the state which contain possible suitable diamondback terrapin habitat. From 1970 to 2017, a total of 649 individual diamondback terrapin interactions were documented. Due to multiple captures at one site, or fixed station designs in sampling programs, these 649 individual diamondback terrapins have been recorded from 173 unique locations throughout coastal North Carolina.

The North Carolina Natural Heritage Program (NCNHP), maintains a database of natural resource information which also contains diamondback terrapin distribution information. This database is used by government agencies, industry, the military, and conservation groups to make economic development, infrastructure, and land conservation decisions. NCNHP diamondback terrapin distribution data comes from reported sightings as well as compiled data from published research, such as the Southwood Williard and Harden (28) postcard survey. Plotting both the NCDMF sampling program diamondback terrapin interactions and the NCNHP data over the potential interaction zone, visually illustrates the areas statewide where diamondback terrapin populations are likely to occur as bycatch in the crab pot fishery (Figure 4.5.4).

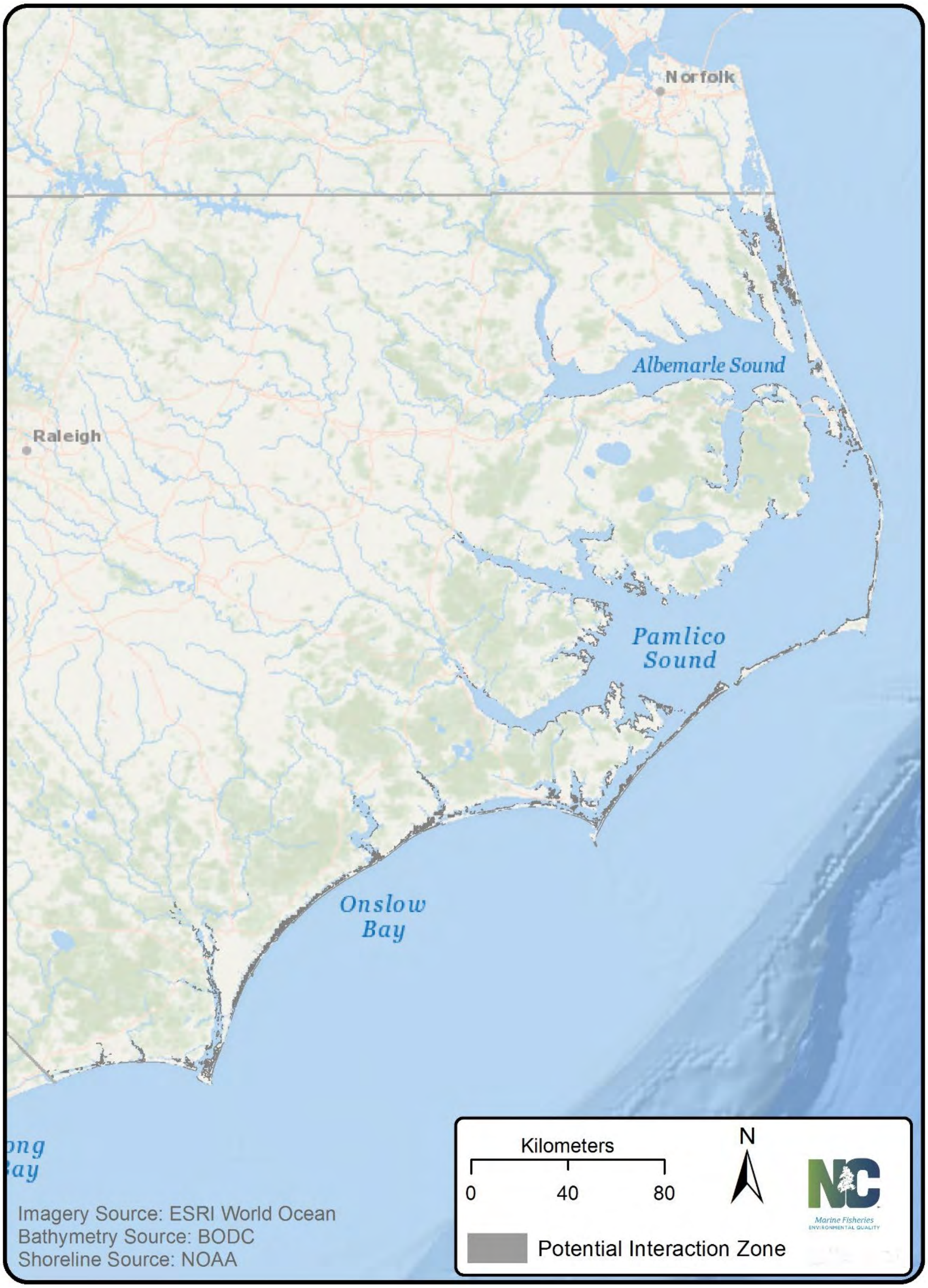

Figure 4.5.3. A map of coastal North Carolina showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots.

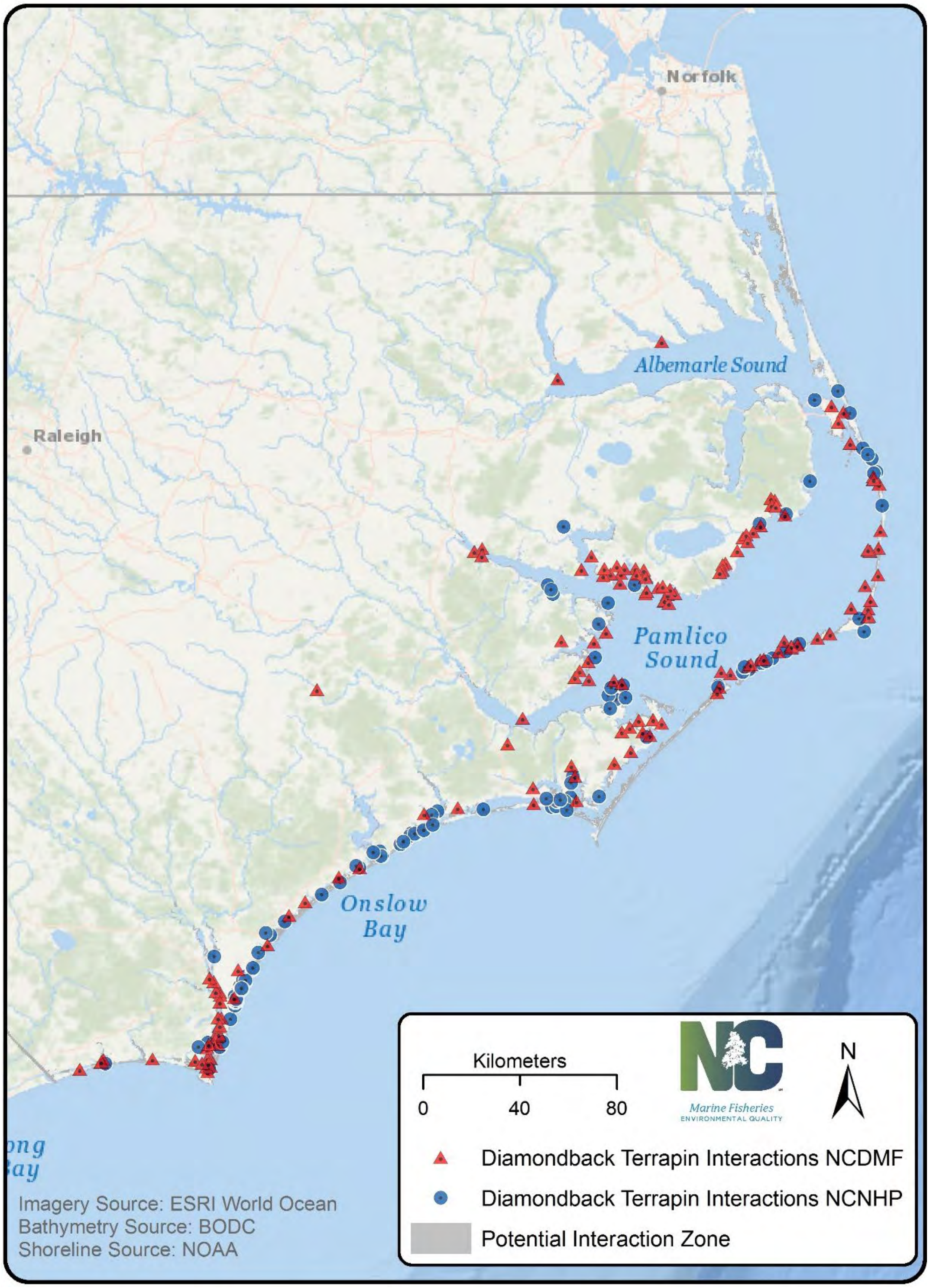

Figure 4.5.4. A map of coastal North Carolina showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

Diamondback terrapin distribution is observed primarily from Roanoke Island to the South Carolina line. There are two NCDMF interactions recorded in Albemarle Sound, however the rest of the region north of Roanoke Island does not have any diamondback terrapin occurrences documented in either the NCDMF or NCNHP datasets. The area in Currituck Sound which is highlighted as a potential interaction zone, also does not have documented diamondback terrapin occurrences. Some areas which have been identified as potential interaction zones with overlapping diamondback terrapin occurrences include: the areas immediately behind the Outer Banks from Roanoke Island to Portsmouth Island, portions of western Pamlico Sound, the lower Newport River, areas around Fort Macon and Beaufort, as well as the areas from Figure 8 Island to Bald Head Island. Detailed regional maps highlight the potential interaction zone and known terrapin occurrences for these areas (Figures 4.5.5 – 4.5.9). The region spanning from Wrightsville Beach to the lower Cape Fear River shows one of the relatively wide areas of potential interaction zone which also has numerous documented diamondback terrapin occurrences in the state (Figure 4.5.9).

Step 4 Summary:
Diamondback terrapin presence and overlap with the crab pot interaction zone shall be verified using any of the following: data from the NCDMF, NCNHP, other agencies, universities, and peer-reviewed published literature.

<u>Step 5 Determine appropriate Diamondback Terrapin Management Area boundaries</u>

The creation of DTMAs would focus the use of terrapin excluder devices or approved modified pot designs to essentially create sanctuary areas where diamondback terrapins would otherwise suffer mortality due to incidental catch in crab pots. Crab pots will not be banned in these areas, however to successfully ensure the maintenance of diamondback terrapin populations within these areas and to have them possibly serve as long-term regional source populations, bycatch should be reduced to low levels within the DTMA's.

Diamondback terrapins have been observed to have relatively small home ranges in North Carolina. In Core Sound, average radio tagged terrapin home range size was calculated to be 3.05 km2 (1.18 mi.2), with a maximum observed home range of 7.41 km2 (2.86 mi.2) (37). In coastal New Hanover County, NC, the maximum straight-line travel distance of radio tagged terrapins observed was 1.20 km (0.75 mi.) for individuals captured in Masonboro Sound, and 1.05 km (0.65 mi.) for Figure 8 Island marshes (23). The size of a DTMA should at a minimum allow for the protection of the entire possible home range size of the target local terrapin population and may include adjacent unoccupied suitable terrapin habitat to allow for population recovery. The smallest size to likely be an effective DTMA should encompass the largest known home range of diamondback terrapin in NC, or cover 7.41 km2 (2.86 mi.2, 1830 acres) of suitable terrapin habitat.

For an area to be considered for designation as a DTMA, a diamondback terrapin population must be documented (e.g., NCDMF, NCNHP, or other agency or university data), as well as being identified as a potential area for diamondback terrapin interactions with crab pots (via the GIS depth and distance layer). The boundaries should incorporate a significant portion of the selected region identified as a potential interaction zone. Natural boundaries for ease of marking and enforcement should be considered, however the design should minimize including any waterbody area not designated as potential interaction zone. Boundaries of other existing natural or conservation areas may be used to identify DTMAs to simplify enforcement and marking, provided they are comprised primarily of the potential interaction zone.

Examples of possible types of natural or conservation areas in NC include State Natural Areas, National Estuarine Research Reserves, National Wildlife Refuges, and National Seashores. State Natural Areas have been designated by the North Carolina Division of Parks and Recreation to protect areas sensitive to human activities and preserve and protect areas of scientific, aesthetic, or ecological value. The National Estuarine Research Reserve System (NERR) is a network of protected areas across the United States which protects coastal and estuarine habitats for long-term research, education, and coastal conservation. The National Wildlife Refuge system (NWRS), and National Seashores are networks of federally managed lands and waters within the United States recognized and protected for their natural value. Considering these types of management areas when delineating DTMAs allows NCDMF to use boundaries that have been previously established and marked and serves as additional justification for requiring terrapin excluder devices in areas which have been independently determined as environmentally sensitive or important habitats for the protection of wildlife. An increase in crab pot density of one pot per creek is associated with a 74.6% decline in terrapin count, when estimating the impact of unmodified crab pots on a refuge wide scale (38). The use of terrapin excluder devices or modified pot designs for the reduction of diamondback terrapin mortality in crab pots would align with the wildlife protection and conservation goals of the various managing agencies for these existing designated areas. Negative impacts from crab pot mortality and low potential rates of recolonization may prevent maintaining ongoing populations of diamondback terrapins in refuges or reserves unless diamondback terrapin loss through bycatch is minimized (38).

Step 5 Summary:
Boundaries of DTMAs shall be drawn to incorporate a significant portion of the potential interaction zone containing verified population(s) of diamondback terrapins and to minimize the inclusion of areas not identified in the potential interaction zone. Boundaries of preexisting natural or conservation areas may be used as DTMA boundaries to simplify enforcement and support the conservation goals of these areas.

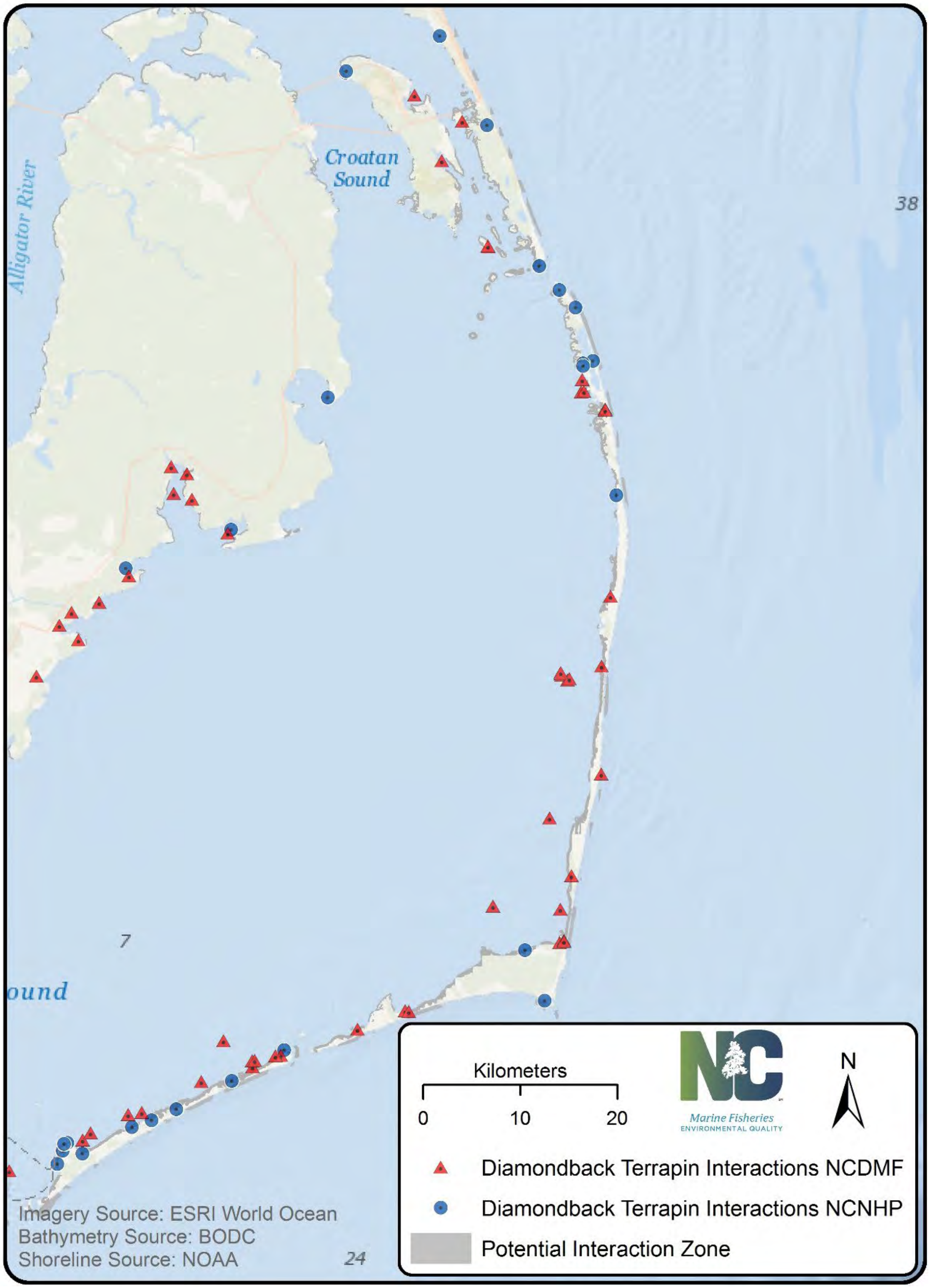

Figure 4.5.5. A map of eastern Pamlico Sound showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

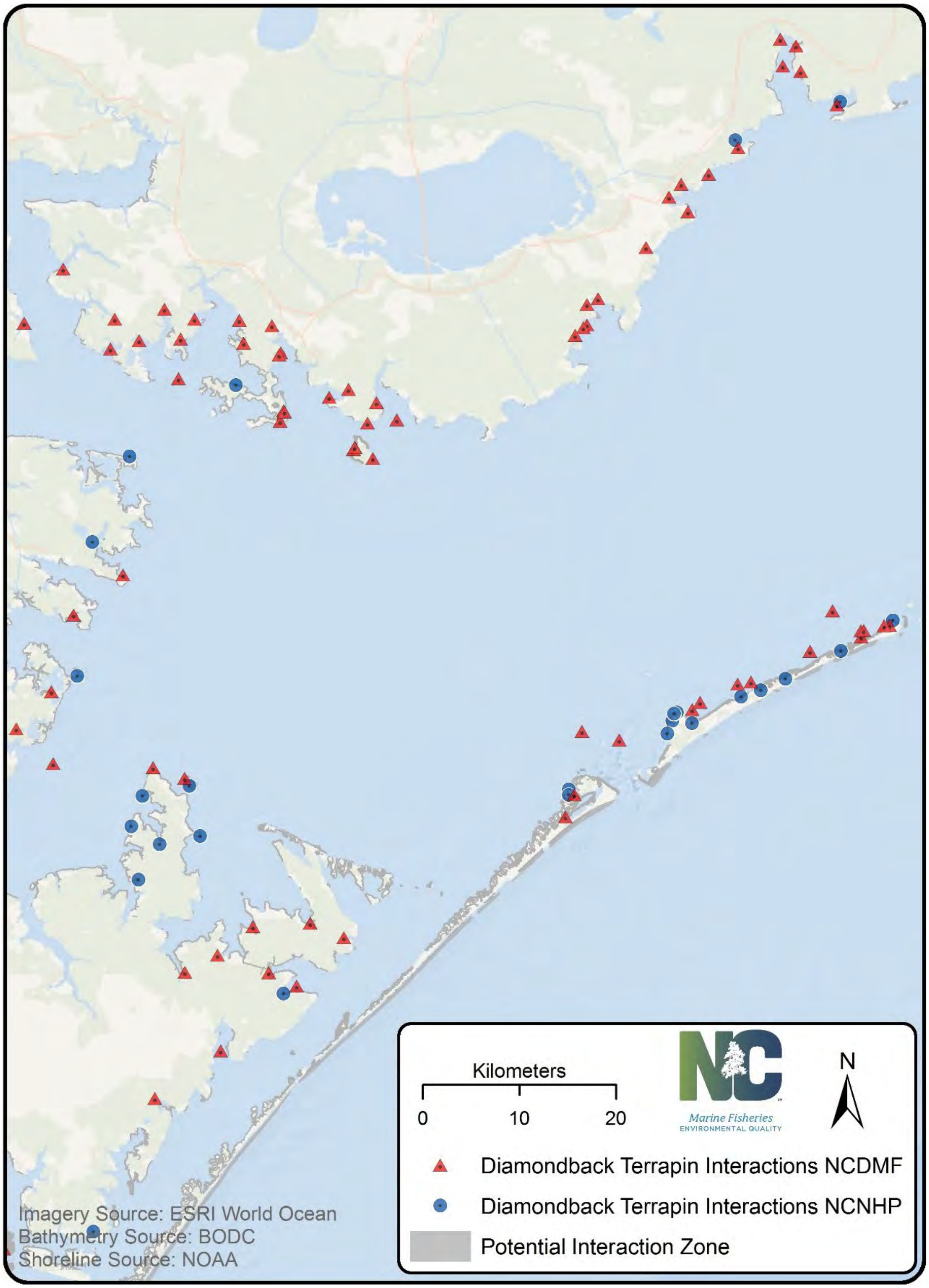

Figure 4.5.6. A map of western Pamlico Sound showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

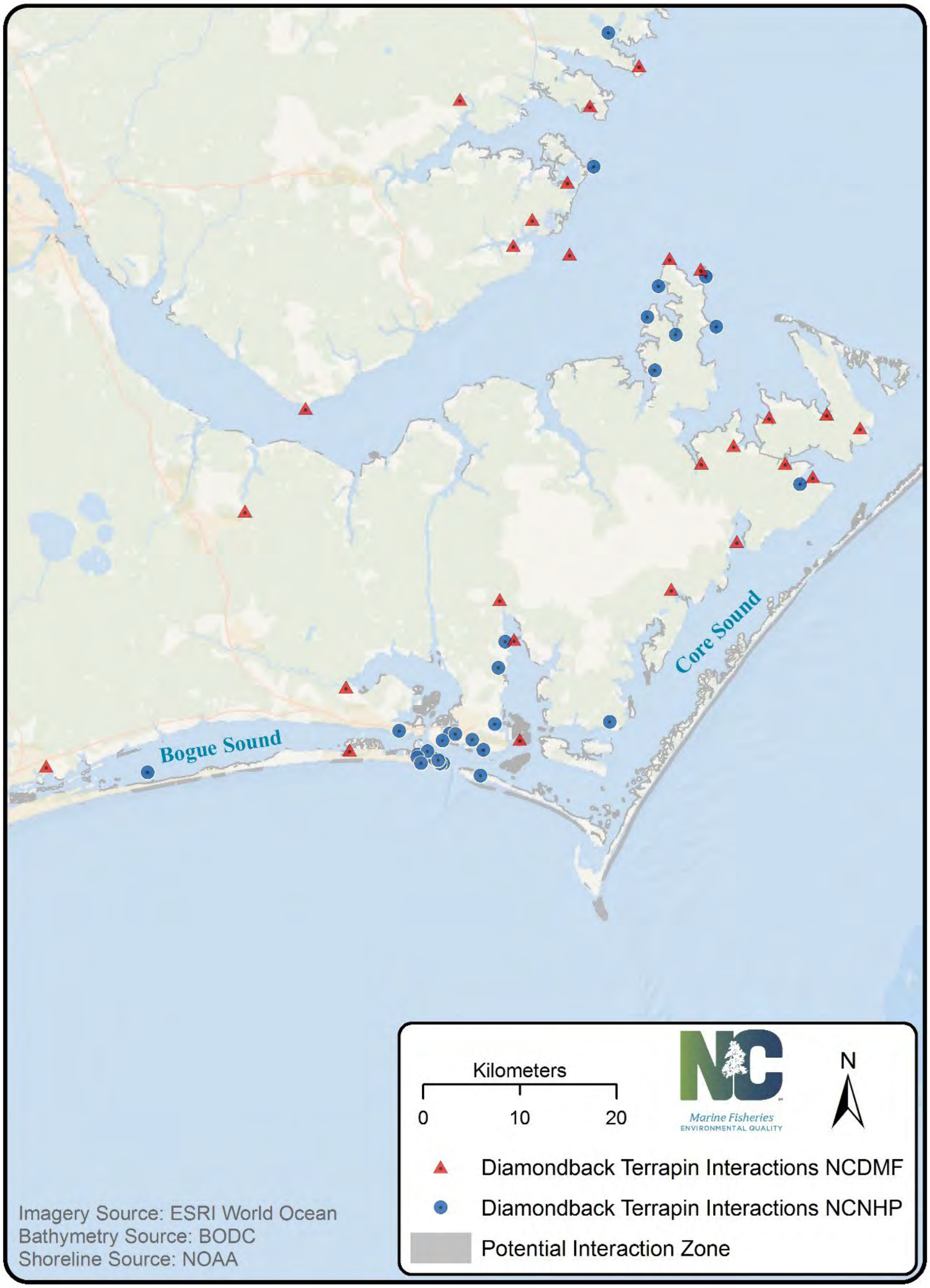

Figure 4.5.7. A map of Core and Bogue sounds showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

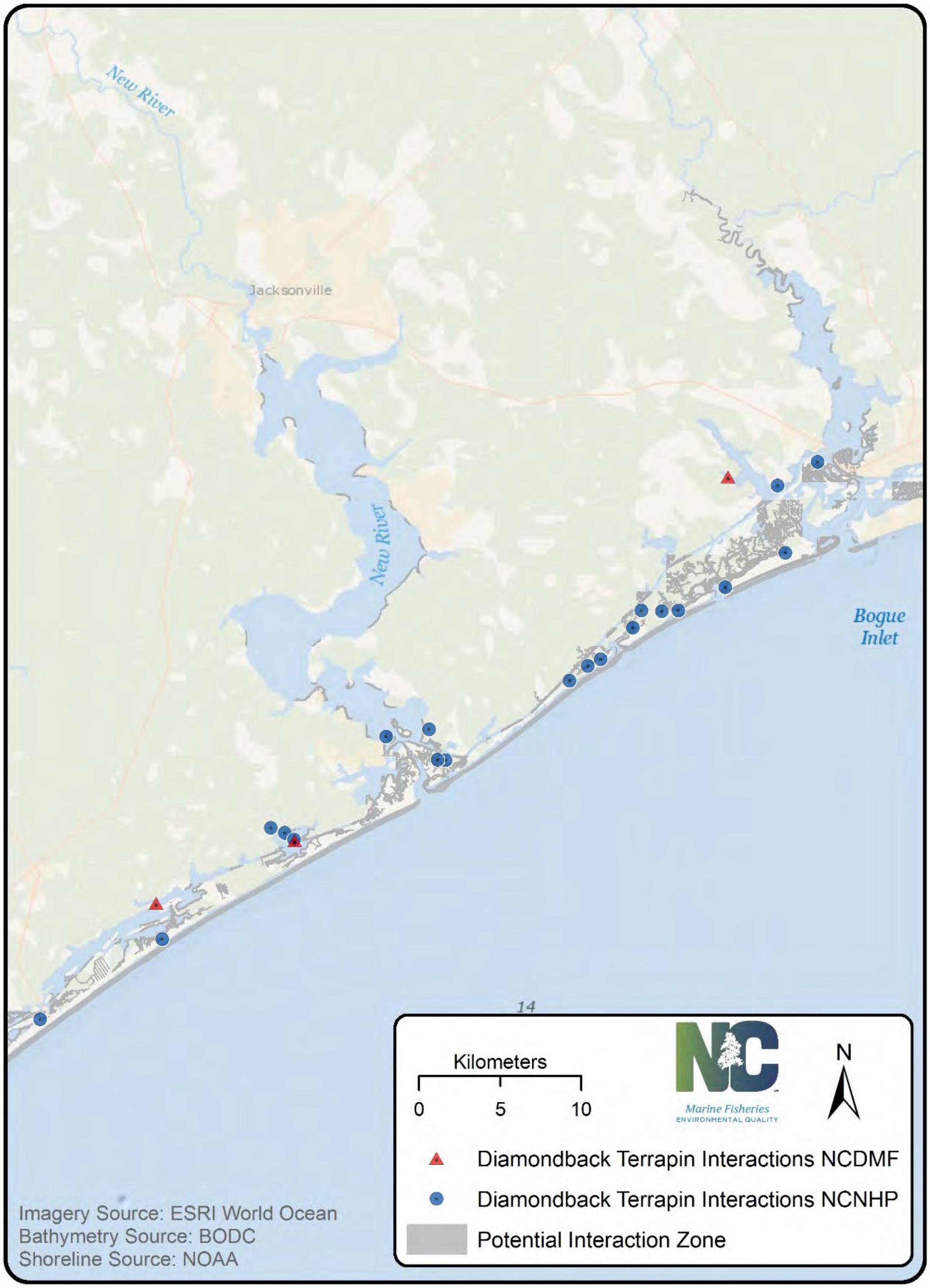

Figure 4.5.8. A map of coastal Onslow and Pender counties showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

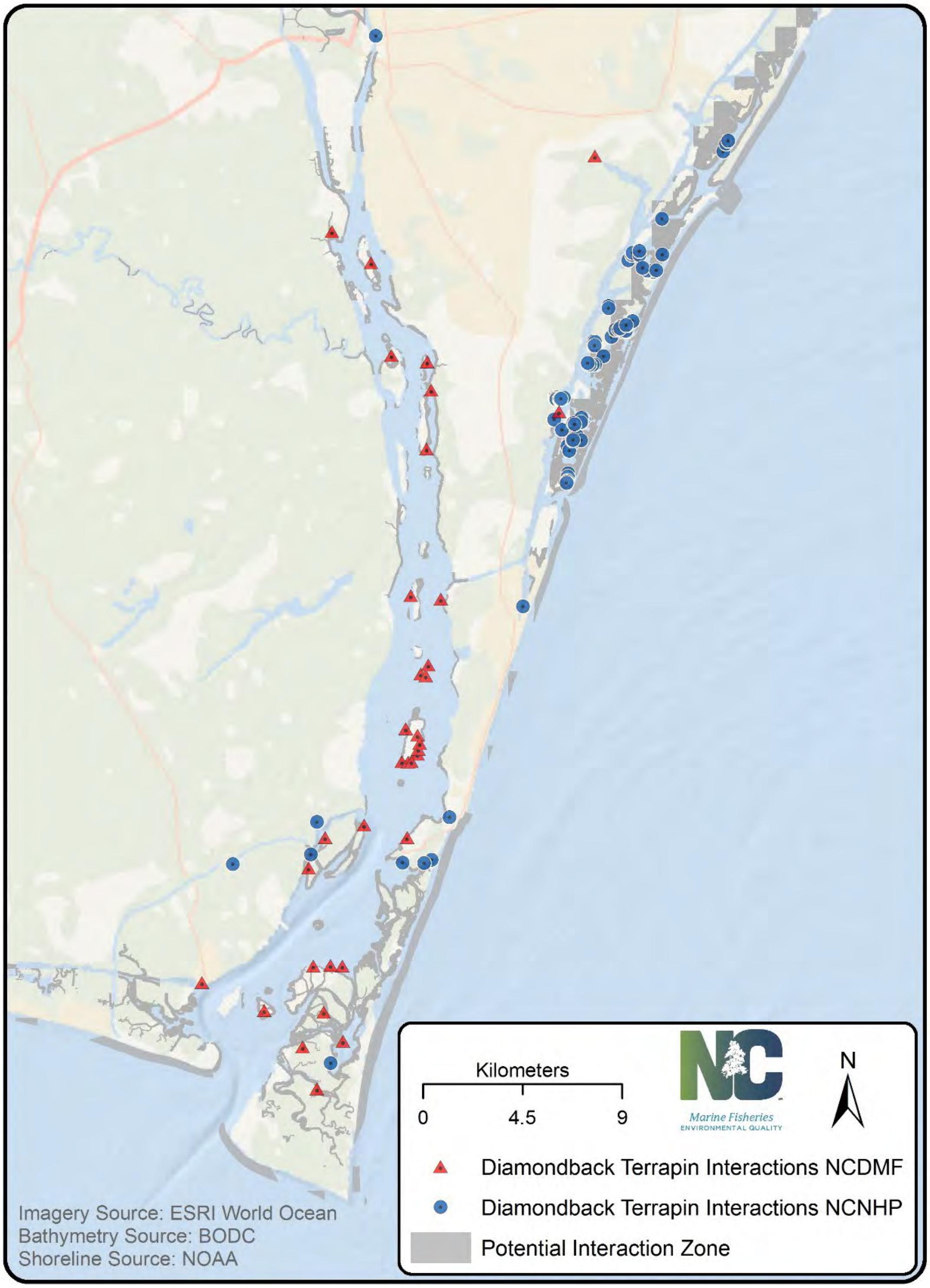

Figure 4.5.9. A map of coastal New Hanover and Brunswick counties showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

Step 6 Public notice of the proposed DTMA

Once an area has been identified by NCDMF as an area where establishing a DTMA would be appropriate, an information paper containing the following details of the proposed DTMA will be produced:

1) Map and coordinates of the proposed DTMA boundaries.
2) Cited sources and summary of diamondback terrapin presence data within the proposed DTMA.
3) Information on any existing natural or conservation areas overlapping with the proposed DTMA.
4) Data on the local blue crab fishery within the proposed DTMA.

Maps of the proposed DTMA shall illustrate the proposed DTMA boundaries as well as display the GIS layer illustrating the zone of potential diamondback terrapin interaction with crab pots based on the established depth and distance from shore criteria. Maps will also overlay known locations where diamondback terrapins have been documented to occur. Source data for diamondback terrapin occurrences from publications will be summarized and cited as references. Data sources such as NCDMF biological database records or NCNHP will also be listed and referenced. If the proposed location is within an existing natural or conservation areas (e.g. NERR, NWRS), supporting information about or from the managing agency will be provided. Participation and landings (pounds and value) data from the local blue crab fishery to be impacted by the proposed DTMA will also be presented. However, under certain situations limited data may be available to the public due to data confidentiality issues with landings data involving small numbers (less than three individuals) of fishery participants.

The resultant information paper will be presented to the appropriate regional advisory committee for their input and to receive public comment. Public notice will be made via a press release and the issue paper describing the proposed DTMA will be made available with a 30-day public comment period open prior to the regional advisory committee meeting. The division will contact local crab fishermen in the area to be impacted as well as any diamondback terrapin researchers working in the region for their comment. The division will take into consideration advisory committee and public comments and may work with fishermen and researchers to modify the proposed DTMA boundaries to maintain protections for diamondback terrapins while minimizing impacts to the local blue crab fishery.

Step 6 Summary:
The division shall produce an information paper (with the information outlined above), present the information to the appropriate regional advisory committee for their input, inform the public of the proposed DTMA via a press release, hold a 30-day public comment period, and contact local crab fishermen and diamondback terrapin researchers for their comment.

Step 7 Issuance of DTMA proclamation

Once the previous steps have been completed, the division shall issue a proclamation designating the DTMA without any NCMFC action as outlined in this issue paper and by NCMFC rule 15A

NCAC 03L .0204. The proclamation will contain GPS coordinates, a description of the boundaries, and a map illustrating the DTMA. All commercial and recreational hard or peeler crab pots fished within the DTMA shall be required to properly use any of the NCDMF approved terrapin excluder types, from March 1 through October 31. Terrapin excluders will be securely affixed by at least each of the four corners of the device in each funnel opening of the crab pot, in a manner that restricts the maximum dimensions of any opening in the funnel to that of the internal opening dimensions of the approve excluder device employed (Figure 4.5.10). Excluder devices would not be required to be used if the maximum inner opening dimensions of all funnel entrances did not exceed those of an approved excluder device. NCDMF will issue DTMA proclamations at least one month prior to their effective date, with a goal of designating DTMAs prior to the annual pot closure period to allow impacted fishermen time to make modifications to their gear for compliance to the proclamation.

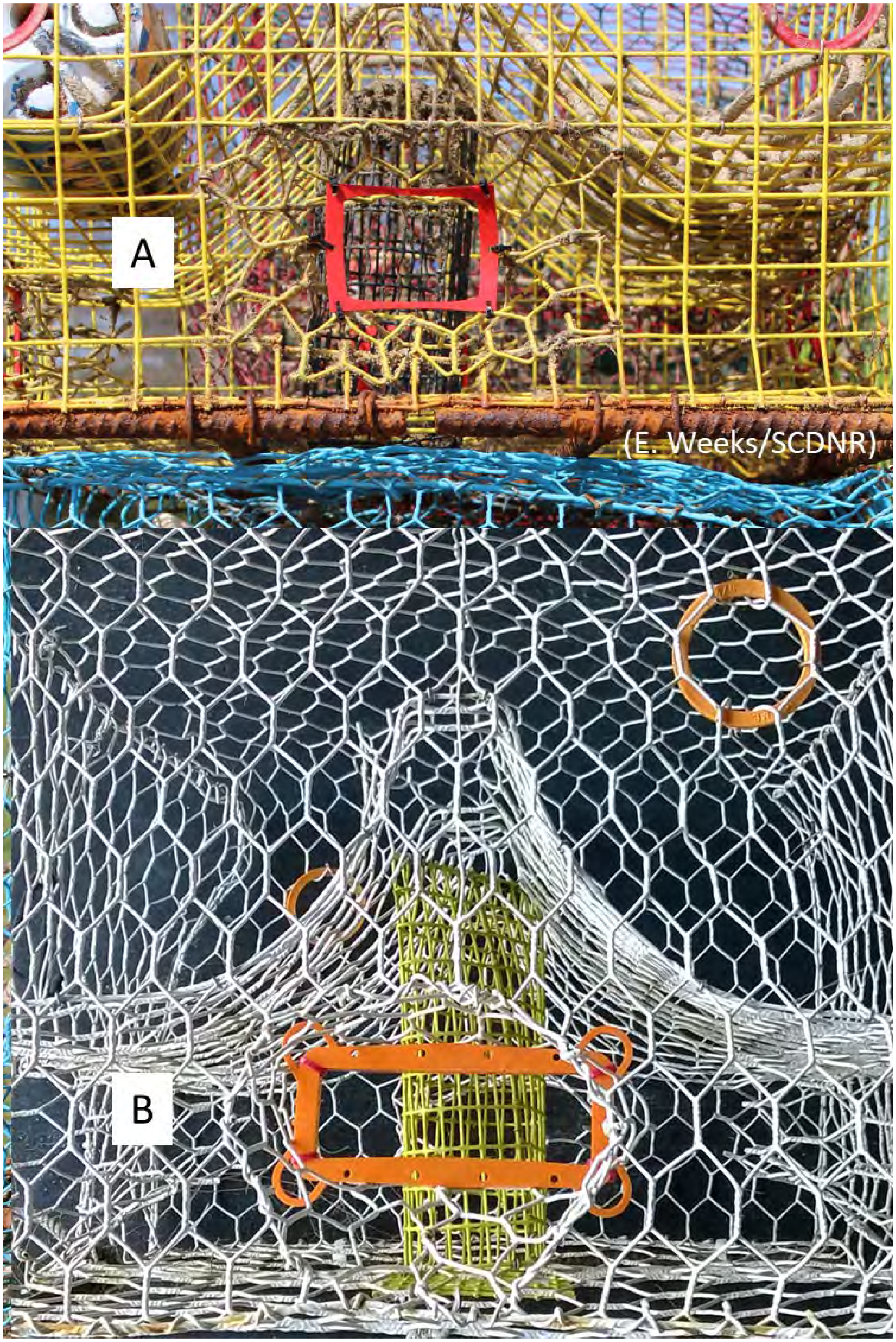

Figure 4.5.10. Premade plastic diamondback terrapin excluder devices shown inside one entrance funnel opening of crab pots. (A) The “SC design” shell width limiting excluder. (B) A shell height limiting excluder.

NCDMF will mark boundaries of any proclaimed DTMA's and post informational signs similar to those marking other existing management areas. Posted signs will indicate all crab pots fished within the marked area will require the use of an approved terrapin excluder device from March 1 through October 31.

Step 7 Summary:
The division will issue a proclamation and mark the boundaries of the DTMA at least one month prior to its effective date.

Additional Discussion

The framework outlined in this issue paper is the next step necessary in implementing the NCMFC selected management strategy adopted in the 2013 Blue Crab FMP Amendment 2, which granted proclamation authority for the director of the North Carolina Division of Marine Fisheries (NCDMF) to require the use of terrapin excluder devices in crab pots. This framework defines the proclamation use criteria, and creates a stepwise process involving public comment, Advisory Committee consultation, and the most current scientific data, to develop Diamondback Terrapin Management Areas.

The targeted DTMA approach offers improved localized protection of diamondback terrapins and minimizes the impacts to the statewide crab fishery (commercial and recreational). As crabbers typically fish their pots within one specific region, terrapin excluder device requirements for DTMAs will disproportionally affect those fishermen who set pots within the DTMA. While this may be viewed as unfair to these impacted fishermen, these areas will be determined using the best available data to have significant overlap with diamondback terrapins and the highest probability of diamondback terrapin interactions occurring with crab pots. A broader seasonal application of a less restrictive 5 x 16 cm (2 x 6.3 in.) terrapin excluder device across all pots fished in less than 3 m (9.8 ft.) of water and less than 250 m (820.2 ft.) from shore, may be viewed as more equitable. However, using pot set depth or distance from shore as criteria for requiring terrapin excluder devices is not realistically enforceable, and the use of less restrictive terrapin excluder devices may not be effective at preventing size selective mortality and localized extirpations. Broader regional requirements for the use of terrapin excluder devices would result in a greater reduction of diamondback terrapin bycatch overall but would also have a significant impact on blue crab commercial harvest and place an undue restriction on crab pots fished too deep or far from shore to incidentally capture diamondback terrapins.

The goal of this management strategy is to reduce diamondback terrapin capture and mortality in crab pots. Areas designated as DTMAs will minimize the inclusion of areas too deep or far from shore and help prevent the capture of diamondback terrapins in crab pots during the active season. However, not all areas within the zone of potential interaction will be designated as DTMAs. Smaller management areas within the overall zone of potential interaction will be created to protect specific areas documented to contain populations of diamondback terrapins and focus on including areas such as reserves or refuges designated as environmentally sensitive or important habitats for the protection of wildlife. This targeted DTMA approach is the most focused way to offer diamondback terrapin populations the greatest protection from bycatch mortality while having the least overall impact to the statewide blue crab fishery. Proactively taking these steps to address diamondback terrapin bycatch in crab pots may help mitigate the need to seek further state or federal protection (Threatened or Endangered listing) of diamondback terrapins. Additionally, addressing this issue may help improve future ratings the blue crab pot fishery receives from groups like Seafood Watch and the ability for the fishery to achieve sustainable harvest certifications from groups like the Marine Stewardship Council.

If the NCMFC does not agree with a particular DTMA established through this process, N.C. General Statute § 113-221.1 allows the NCMFC to call an emergency meeting, at the request of five or more members, to review a proclamation issued under the authority delegated to the Fisheries Director. At that meeting the NCMFC may approve, cancel, or modify the proclamation.

VI. PROPOSED RULE(S)

No rule change required. Proclamation authority is contained in existing rule (NCMFC Rule 15A NCAC 03L .0204(b)).

VII. RECOMMENDATIONS

NCDMF Recommendation
Use the criteria as outlined in this paper for the establishment of DTMAs

Blue Crab FMP Advisory Committee
Use science on locally specific pot funnel design to reduce terrapins and identify individual creeks with terrapin population hot spots that would be closed to potting.

Northern Advisory Committee

Southern Advisory Committee

Shellfish and Crustacean Advisory Committee

Habitat and Water Quality Advisory Committee

NCMFC Selected Management Strategy

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ATTACHMENT 1: INFORMATION PAPER ON PROPOSED DIAMONDBACK TERRAPIN MANAGEMENT AREAS IN MASONBORO SOUND AND THE LOWER CAPE FEAR RIVER

Diamondback terrapins are listed by the North Carolina Wildlife Resources Commission (NCWRC) as a North Carolina species of "Special Concern" statewide and as a Federal "Species of Concern" in Dare, Pamlico and Carteret counties in NC. Numerous studies have concluded that incidental bycatch in crab pots is the most serious threat to diamondback terrapins in North Carolina and throughout their range (1). Diamondback terrapins are susceptible to substantial population declines or even localized extirpations through incidental bycatch in crab pots and removal of a relatively low number of individuals from the population annually (2).

Diamondback Terrapin Management Areas (DTMAs) are discrete areas within the estuarine and coastal waters of North Carolina which have been designated by the North Carolina Division of Marine Fisheries (NCDMF) to reduce bycatch of diamondback terrapins in the blue crab pot fishery though the use of terrapin excluder devices. These areas have been documented to contain populations of diamondback terrapins through capture in NCDMF sampling programs, and/or through academic research, as well as contain significant waterbody area in which diamondback terrapins are susceptible to incidental capture in crab pots (water less than 3 m (9.8 ft.) deep as well as less than 250 m (820.2 ft.) from shore). The criteria and framework which identifies and creates a DTMA is described and established in the issue paper: Establish a Framework to Implement the Use of Terrapin Excluder Devices in Crab Pots, in Amendment 3 of the Blue Crab Fishery Management Plan. In an area designated as a DTMA, all crab pots (including peeler pots) fished between February 28 and October 31 are required to have approved terrapin excluder devices and constructed out of heavy plastic or wire no smaller than 10-gauge) properly secured in each funnel opening. Excluder devices would not be required to be used if the maximum inner opening dimensions of all funnel entrances did not exceed those of an approved excluder device.

The areas behind Masonboro Island and in the lower Cape Fear River behind Bald Head Island have been identified as containing populations of diamondback terrapins using NCDMF and North Carolina Natural Heritage Program (NCNHP) data sets, as well as being a potential area for diamondback terrapin interactions with crab pots (Figure A1). Both areas have also served as study sites for academic diamondback terrapin research on abundance as well as documenting and verifying interactions and bycatch in crab pots (3; 4; 5; 6; 7; 8; 9; 10; 11).

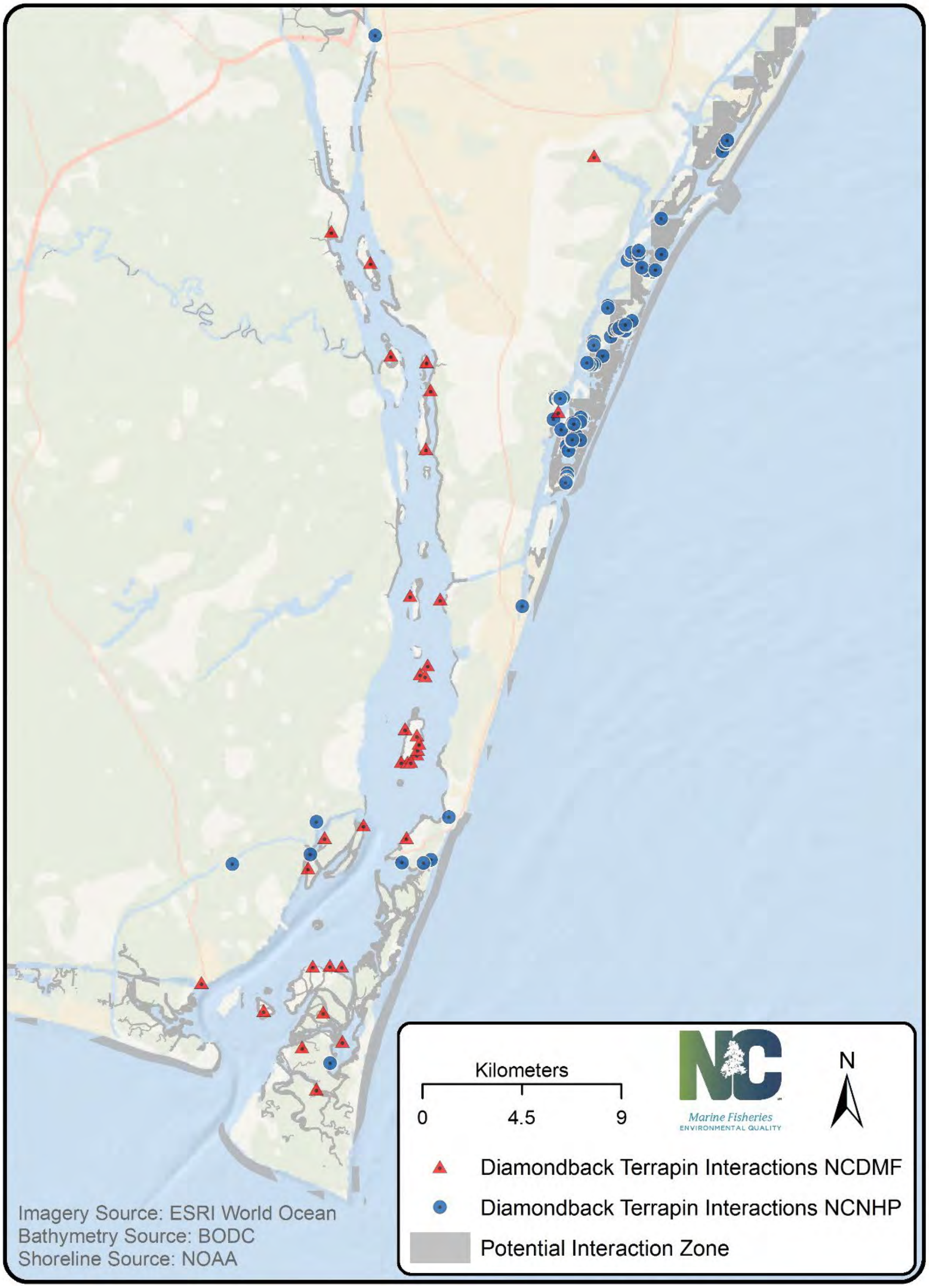

Figure A1. A map of coastal New Hanover and Brunswick counties showing the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.) from any shoreline) of diamondback terrapins and crab pots, overlaid with NCDMF (1971 – 2017) and NCNHP diamondback terrapin observations.

Summary of Diamondback Terrapin Research Documenting Presence and Interaction with Crab Pots

Grant (3) identified the marshes behind Masonboro Island as an area with both a population of diamondback terrapins and an active commercial blue crab pot fishery. Diamondback terrapins were documented and captured in crab pots. Terrapin excluder devices were tested and opening heights of 4 cm (1.6 in.) resulted in 100% exclusion of diamondback terrapins compared to 5 cm (2 in.) height terrapin excluder devices which still allowed diamondback terrapin capture in crab pots. Both terrapin excluder device dimensions resulted in reductions in blue crab catch.

Thorpe et al. (4) captured terrapins in crab pots fished in a typical manner by a commercial fisherman set in a location in the lower Cape Fear River near Bald Head Island, NC during a crab pot bycatch study. It was commented that the rate of diamondback terrapin capture suggests a high potential for bycatch.

Thorpe and Likos (5) evaluated terrapin excluder devices in commercial blue crab pots in the lower Cape Fear River near Bald Head Island, NC. One diamondback terrapin was captured in a crab pot using a 5 x 12 cm (2 x 4.7 inches) excluder, and recommended further assessment based on terrapin size and range in NC. Additionally, recreational and recreational commercial gear license crab pots were observed tied to piers and set close to shore in creeks in areas which would likely have diamondback terrapins.

Southwood et al. (6) used radio telemetry to document diamondback terrapin distribution and habitat use in the lower Cape Fear River and near Masonboro Island. Diamondback terrapins were documented in these areas, and when found swimming they were typically in shallow water less than 3 m (9.8 ft.). Both alive and dead diamondback terrapins were observed entrapped in a crab pot which was exposed during low tide. It was suggested that placing crab pots in deeper water and further from the marsh edge would help reduce diamondback terrapin bycatch.

Alford (7) used tall crab pots (which prevented bycatch mortality) to capture diamondback terrapins and monitor their population between May and October in the areas behind Masonboro Island. Diamondback terrapins were captured at the highest frequency in May, and 65% of all captured diamondback terrapins were male. As males were more likely to be captured in crab pots it was suggested there was the potential to cause a skewed sex ratio due to bycatch mortality.

Southwood Williard and Harden (8) used a postcard survey to investigate potential interactions between blue crab fisheries and diamondback terrapins. Results of this survey were incorporated into the NCNHP dataset, which include occurrences near Bald Head Island and behind Masonboro Island.

Harden and Southwood Williard (9) evaluated the seasonal bycatch risk of diamondback terrapins in crab pots. Diamondback terrapins were captured and monitored by radio telemetry behind Masonboro and Figure Eight Islands, New Hanover Co., NC. Diamondback terrapins were observed to be active and out of dormancy between April 1 and September 30. Crab pots were documented in these areas during the diamondback terrapin active season and were found to typically be located between 15 and 30 m (49 and 98 ft.) from the marsh edge and in water ranging from 0 to 2.8 m (0 to 9.8 ft.) deep at low tide. Between June 2008 and May 2009, four of the 29 monitored diamondback terrapins were captured as bycatch in crab pots. Results indicate crab pots and diamondback terrapins co-occur with a patchy distribution, resulting in a greater than expected potential for interaction than if both were uniformly distributed.

Chavez and Southwood Williard (10) assessed the impact of two terrapin excluder device sizes, 5.1 x 15.2 cm, and 3.8 x 15.2 cm (2 x 6 in. and 1.5 x 6 in.), in crab pots on blue crab catch at sites in Masonboro and Bogue sounds, NC. Areas behind Masonboro Island had the highest rates of capture in crab pots. It was concluded the larger size terrapin excluder device allowed male diamondback terrapins to enter traps, while the smaller size would have prevented their capture. Nether terrapin excluder device has a statistically significant impact on blue crab size or catch. However, the smaller excluder did show a non-significant downward trend.

Munden (11) examined the population change of diamondback terrapins around Masonboro Island between 2009 and 2017, along with the number of crab pots. Diamondback terrapin head count and crab pot survey data collected as part of a fixed kayak route citizen science project during this period was analyzed. Mean number of diamondback terrapins observed per kilometer in 2017 decreased to a low of 0.016 from a high of 0.938 in 2014, while the mean number of crab pots observed per kilometer in increased to 2.435 in 2107 from 0.804 in 2014.

<u>Existing Ecological Areas</u>

Both Masonboro Island and the region in the lower Cape Fear River north of Bald Head Island are comprised of lands designated as North Carolina Natural Heritage Natural Areas (hereinafter referred to as Natural Areas) as well as designated National Estuarine Research Reserves (NERRs; Figure A2). Natural Areas are designated by the North Carolina Division of Parks and Recreation to protect areas sensitive to human activities and preserve and protect areas of scientific, aesthetic, or ecological value. The NERR system is a network of protected areas across the United States which protects costal and estuarine habitats for long-term research, education, and coastal conservation. The overarching goal of the national NERR system is to provide a foundation for effective coastal management through site research. Masonboro Island Reserve contains the largest undisturbed barrier island in the southern part of the North Carolina coast, and is considered an intact barrier island and estuarine ecosystem. Zeke’s Island Reserve contains a complex of salt marshes, tidal flats, and barrier islands.

The site manager for both reserve locations has expressed concern for declining diamondback terrapin head count numbers coinciding with increased crab pot numbers observed in the annual citizen science fixed route kayak survey and has provided example results (Figures A3-A5). Negative impacts from crab pot mortality and low rates of recolonization may prevent maintaining existing populations of diamondback terrapins in refuges or reserves unless their loss through bycatch is minimized (12). The areas encompassing both Masonboro Island and the lower Cape Fear River north of Bald Head Island have also been nominated as Strategic Habitat Areas (SHAs) by the NCMFC (Figure A6). SHAs represent priority locations for protection or restoration due to their exceptional ecological functions or areas particularly at-risk due to imminent threats to their ability to support coastal fisheries. The large areas in Masonboro Sound and the Cape Fear River were selected due to their biodiversity and high quality of habitats and fishery species. These SHAs also overlap with lands already managed for conservation, and were corroborated with biological data, ecological designations, and specific knowledge of the area.

Figure A2. A map of coastal New Hanover and Brunswick counties showing North Carolina Natural Heritage Natural Areas and National Estuarine Research Reserves (NERRs)

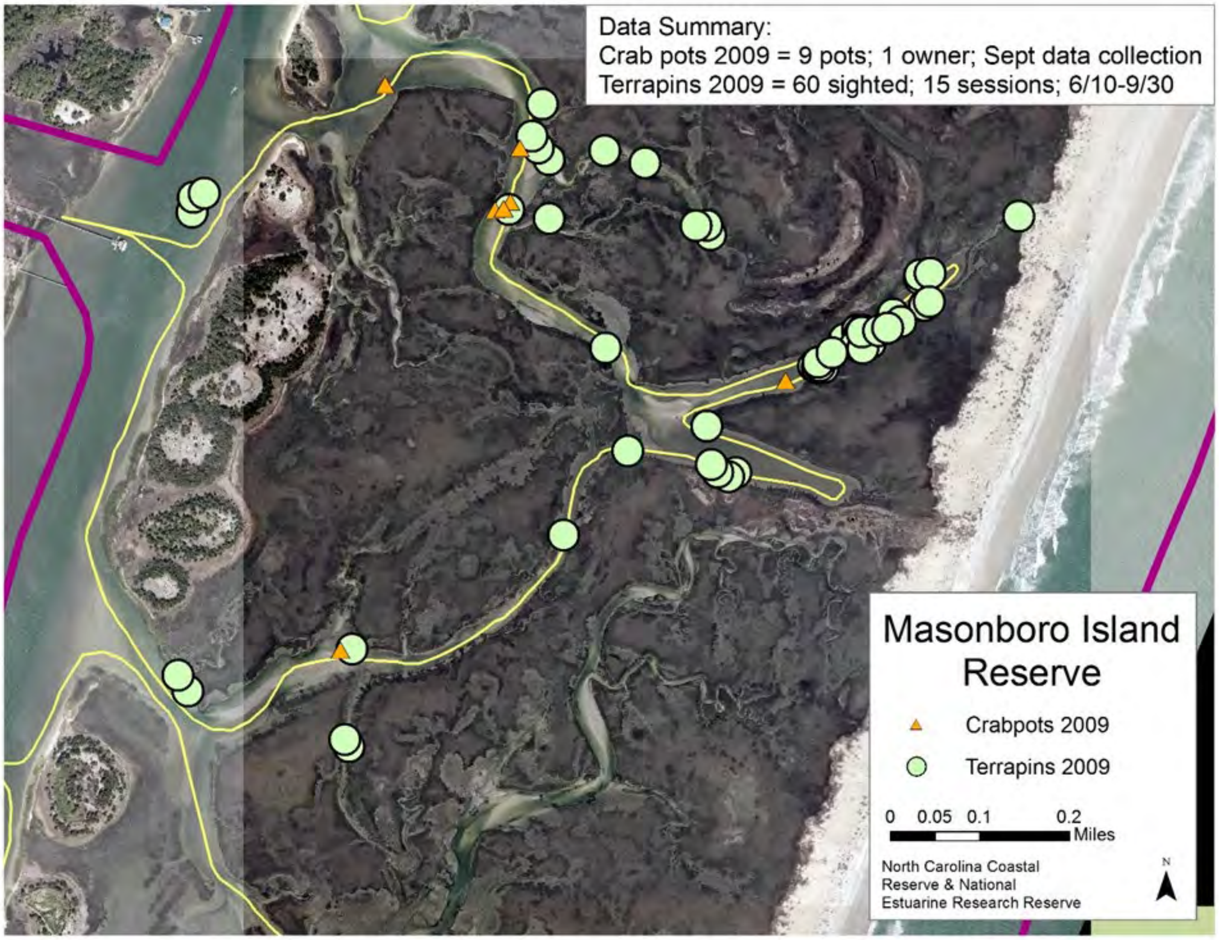

Figure A3. A map showing diamondback terrapin and crab pot locations and counts from a fixed route kayak survey conducted in the Masonboro Island NERR in 2009. Example results of diamondback terrapin and crab pot count data from fixed route kayak surveys in Masonboro Island National Estuarine Research Reserve.

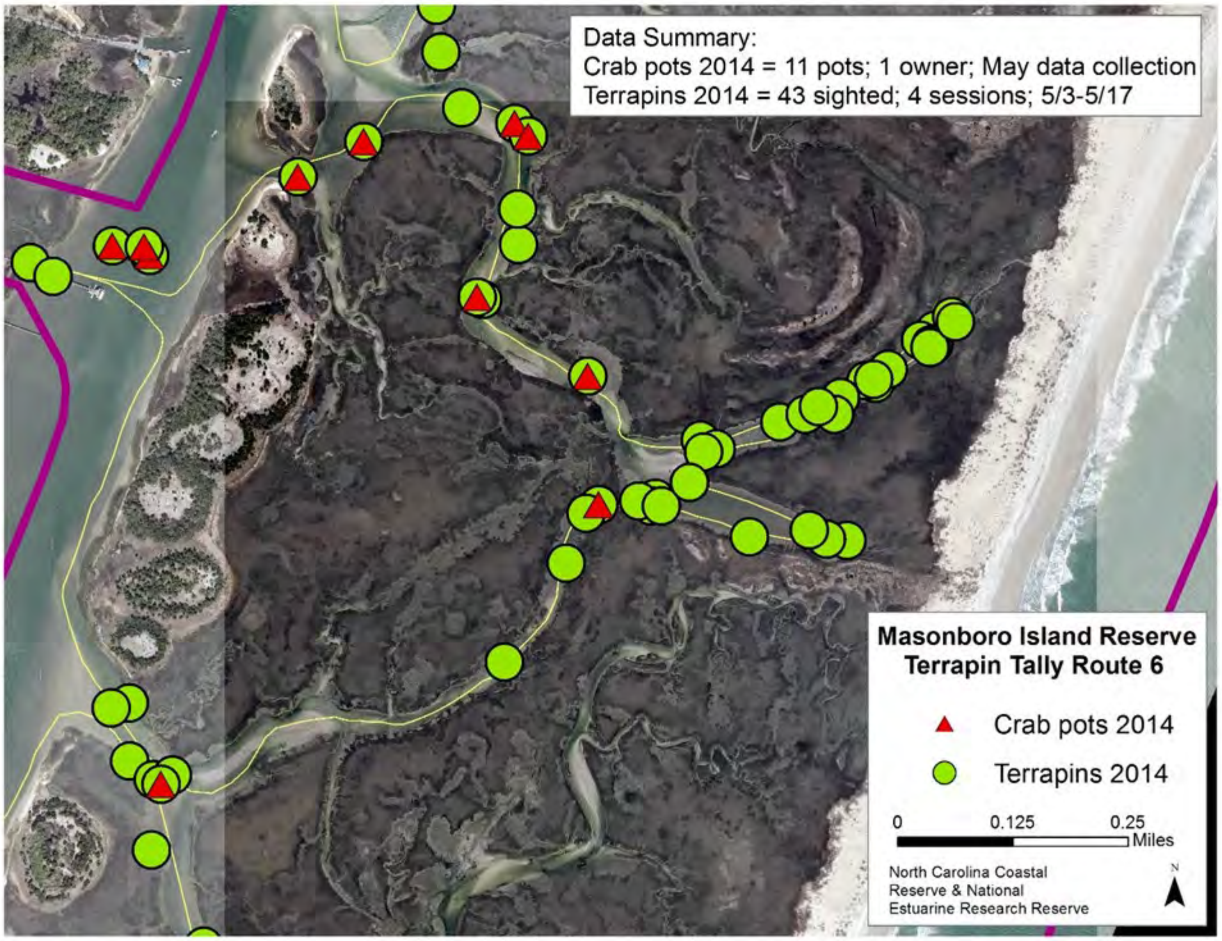

Figure A4. A map showing diamondback terrapin and crab pot locations and counts from a fixed route kayak survey conducted in the Masonboro Island NERR in 2014. Example results of diamondback terrapin and crab pot count data from fixed route kayak surveys in Masonboro Island National Estuarine Research Reserve.

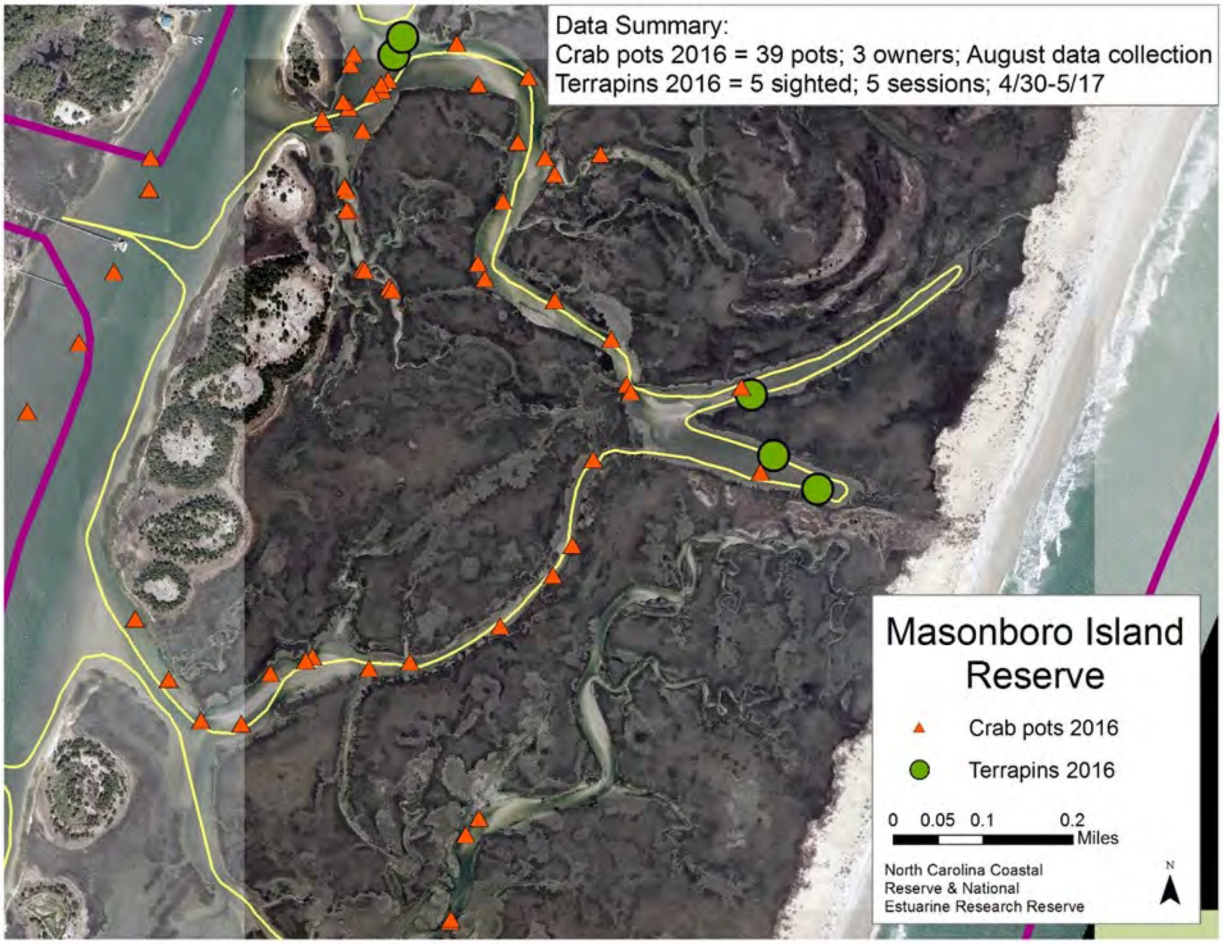

Figure A5. A map showing diamondback terrapin and crab pot locations and counts from a fixed route kayak survey conducted in the Masonboro Island NERR in 2016. Example results of diamondback terrapin and crab pot count data from fixed route kayak surveys in Masonboro Island National Estuarine Research Reserve.

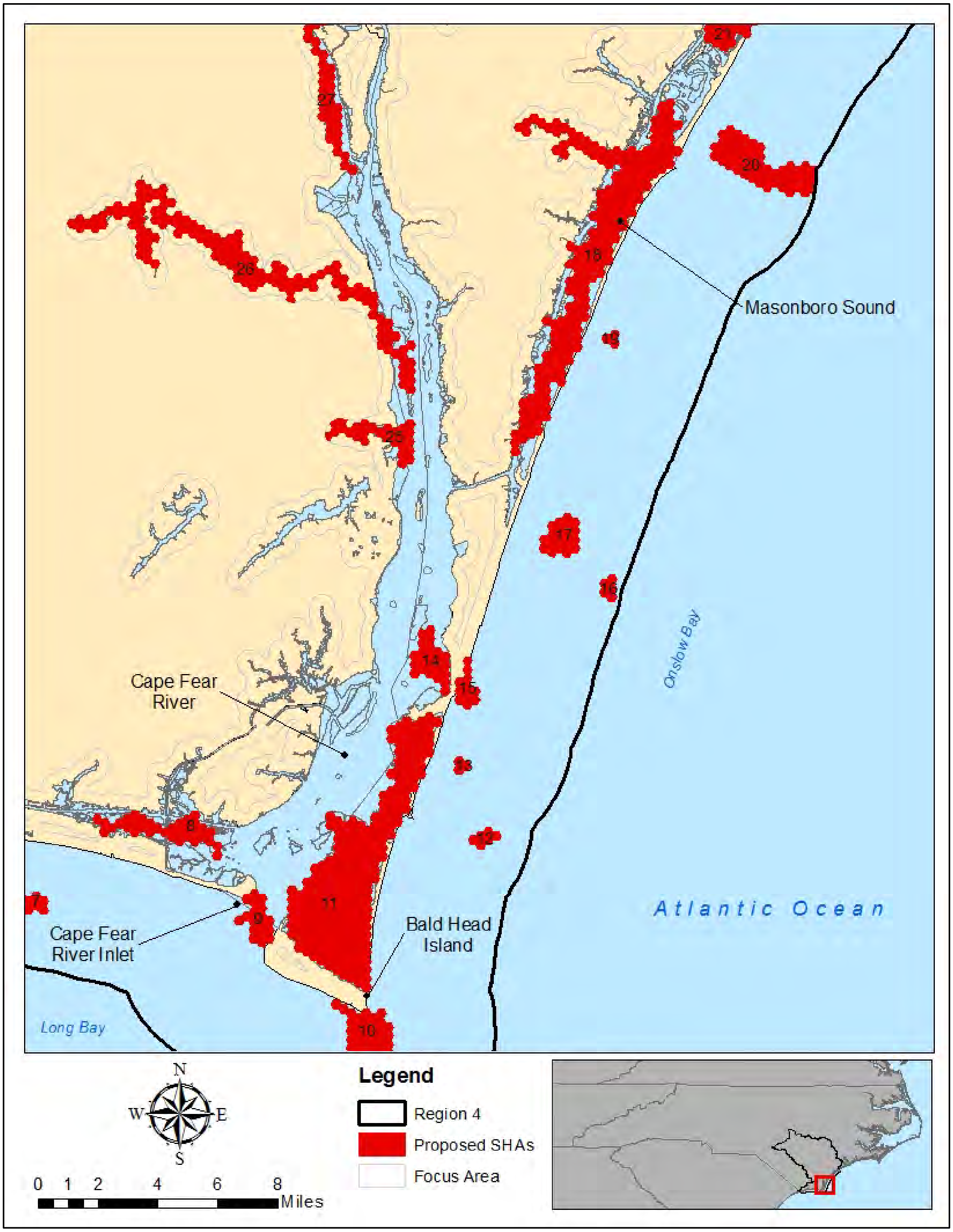

Figure A6. A map of coastal New Hanover and Brunswick counties showing nominated Strategic Habitat Areas in Region 4 of the North Carolina Coastal Habitat Protection Plan.

Proposed Management Areas

Two Diamondback Terrapin Management Areas (DTMAs) are proposed, the Masonboro Island DTMA and the Bald Head Island DTMA (Figure A7). The proposed Masonboro Island DTMA lies entirely within, and shares nearly the entire boundary with, the Masonboro Island Estuarine Research Reserve and Natural Area. This area is also naturally bounded on the east by Masonboro Island, and on the west by the Intracoastal Waterway (IWW). The proposed Bald Head Island DTMA is comprised of Zeke's Island Estuarine Research Reserve in the northern portion of the management area and the Bald Head Island State Natural Area as the southern portion. This area is also naturally bounded by a barrier island to the east, and Bald Head island to the south. The western boundary of this management area follows the "Wall", a rock structure that separates the Cape Fear River from Buzzard Bay, and also serves as the boundary for the Zeke's Island Estuarine Research Reserve. At the end of the wall, a line is drawn southwesterly to the northern tip of Bald Head Island. These two areas use boundaries such as the IWW, landmarks, or existing reserve borders to maximize ease of marking these areas and enforcement.

Each DTMA has been selected to minimize the inclusion of areas outside the zone of potential diamondback terrapin interaction with crab pots, without creating overly complex and unenforceable borders (Table A1). Of the area that is water in the Masonboro Island DTMA, 85% meets the depth and distance criteria considered within the interaction zone, and 61% of the water area in the Bald Head Island DTMA is considered within the interaction zone. The area in the Masonboro Island DTMA that does not fall within this zone is primarily in Dick Bay, which is mostly less than 3 m (9.9 ft.) deep at low tide, but is a large open area which contains area greater than 250 m (820.2 ft.) from any shoreline. Dick Bay is included within the proposed DTMA to reduce complexity in marking and enforcement, as the IWW forms a natural western boundary for this management area. In the Bald Head Island DTMA, the amount of water area that is not considered in the interaction zone is primarily caused by the larger open areas of water to the east of the Wall in the Basin, Second Bay, and Buzzard Bay. These areas are mostly less than 3 m (9.8 ft.) deep at low tide but have area that is greater than 250 m (820.2 Ft.) from any shoreline. These areas were also included in the proposed DTMA to reduce complexity in marking and enforcement, as the Wall forms a well-defined boundary for this management area.

Figure A7. A map of coastal New Hanover and Brunswick counties showing proposed Diamondback Terrapin Management Areas.

Table A1. Total area in acres of proposed Masonboro and Bald Head Island DTMAs, including percent of DTMA that is water, percent of water area that is in the potential interaction zone (< 3 m (9.8 ft.) deep, < 250 m (820.2 ft.)), and percent of the total Trip Ticket reporting area (Masonboro Sound, Cape Fear River) the DTMA encompasses.

Acreage Category	Masonboro	Bald Head
Total land and water area of DTMA (acres)	5,739	9,945
Percent of DTMA area that is water	59%	39%
Percent of DTMA water area in interaction zone	85%	61%
Percent DTMA is of total Trip Ticket reporting area	64%	29%

Regional Commercial Blue Crab Fishery Information

Landings and participation data for the blue crab fishery does not exist at a fine enough scale relative to specific waterbodies to directly assess the number of participants which could be impacted by the creation of the proposed DTMAs. Trip ticket reporting areas for this region include Masonboro Sound, which encompasses the proposed Masonboro Island DTMA and the Cape Fear River, which encompasses the proposed Bald Head Island DTMA. The proposed Masonboro Island DTMA comprises 64% of the Masonboro Sound trip ticket reporting area, while the proposed Bald Head Island DTMA comprises 29% of the Cape Fear River trip ticket reporting area (Table A1). From 2007 and 2016, between 12 and 19 (average of 15) participants reported landings of blue crabs from hard crab and peeler pots from Masonboro Sound, and between 9 and 22 (average 15) participants reported landings of blue crabs from hard crab and peeler pots from the Cape Fear River (Figure A8). Participants reporting landings are generally declining in the Cape Fear River and increasing in Masonboro Sound. Although the proposed Masonboro Island DTMA occupies a smaller footprint, it may likely impact more individual participants than the proposed Bald Head Island DTMA as there are more participants and the proposed Masonboro Island DTMA occupies a greater percentage of the trip ticket reporting area.

Additional species which are landed from crab pots in these two trip ticket reporting areas include whelks "conch" (*Busycon and Busycotypus spp*.), and Florida stone crabs (*Menippe mercenaria*). Landings and participation data for whelk examined by trip ticket reporting area are considered confidential (having a small number of participants) when examined on an annual scale, and are presented as ten-year averages (Table A2). From 2007 and 2016, between 4 and 10 (average of 7) participants reported landings of stone crab from hard crab and peeler pots from Masonboro Sound, and between 3 and 8 (average 5 participants reported landings of stone crab from hard crab and peeler pots from the Cape Fear River (Figure A9). Landings of stone crabs show fluctuations in number between years and area, and average a very small percentage (less than .5%) of the overall landings from crab pots in these two reporting areas. Ten-year average (from 2007 to 2016) landings values for these three species from the Masonboro Sound and Cape Fear River trip ticket reporting areas show Blue Crab as the highest average landings values, followed by stone crab then whelk (Table A3).

Table A2. Average landings of whelk (conch) meats from hard crab and peeler pots, and average number of participants reporting landings between 2007 and 2016 from Trip Ticket reporting areas Masonboro Sound, and Cape Fear River.

Trip Ticket Area	Average Landings	Average Number of Participants
Masonboro Sound	43	2
Cape Fear River	76	3

Table A3. Average value of reported landings of blue crab, whelk (conch), and stone crab from hard crab and peeler pots, between 2007 and 2016 from Trip Ticket reporting areas Masonboro Sound, Cape Fear River, and statewide total. Numbers in parenthesis represent the percentage of each area to the statewide average for each species.

Species	Masonboro Sound	Cape Fear River	Statewide
Blue Crab	$ 116,809 (0.46%)	$ 580,185 (2.32%)	$24,954,534
Whelk	$ 87 (0.11%)	$ 150 (0.19%)	$80,890
Stone Crab	$ 1,407 (7.52%)	$ 970 (5.18%)	$18,717

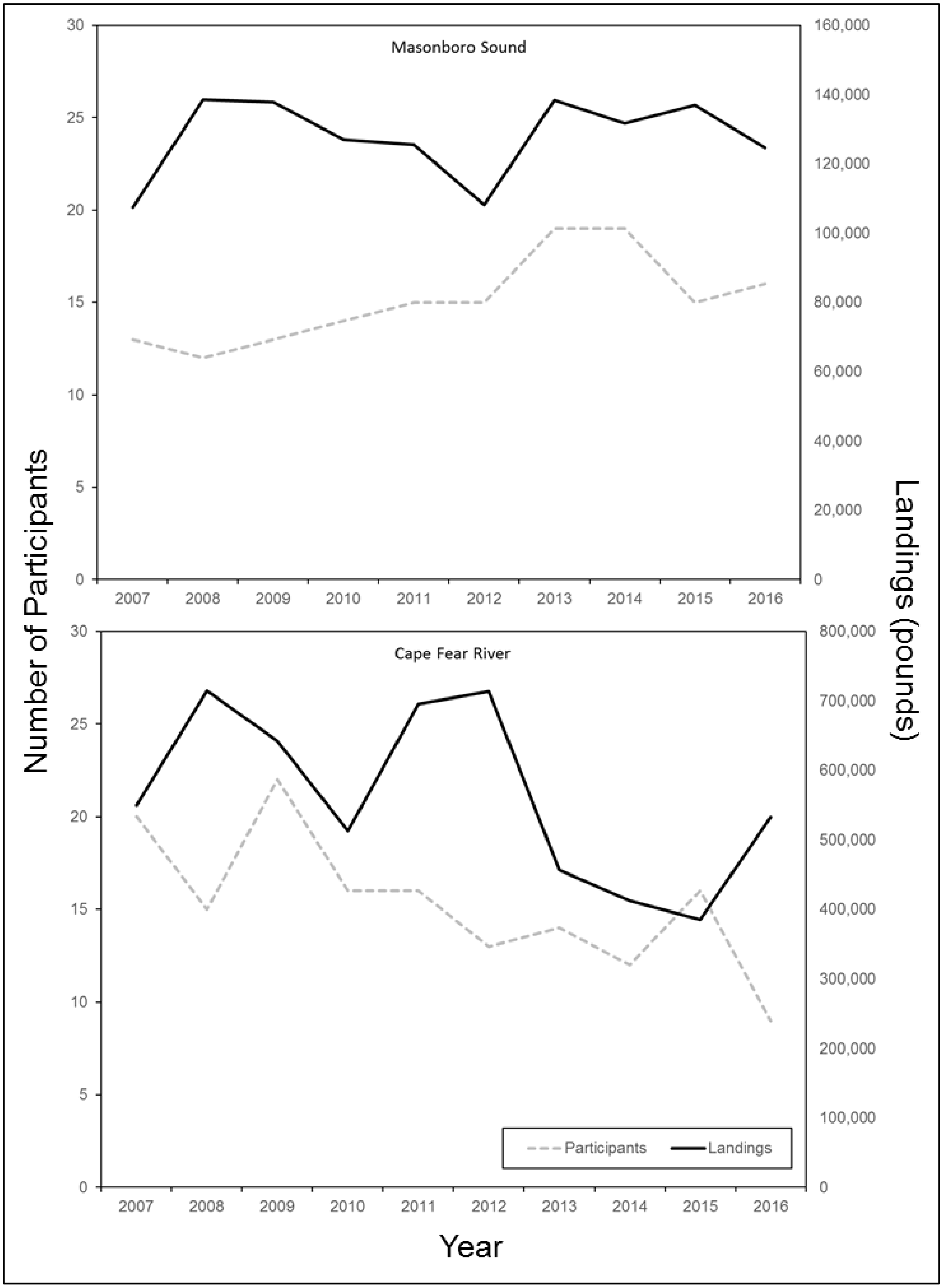

Figure A8. A graph showing number of participants (left axis, dashed line) and landings in pounds (right axis, solid line) of blue crabs in both, hard crab and peeler pots for the Masonboro Sound (upper panel) and Cape Fear River (lower panel) trip ticket reporting areas.

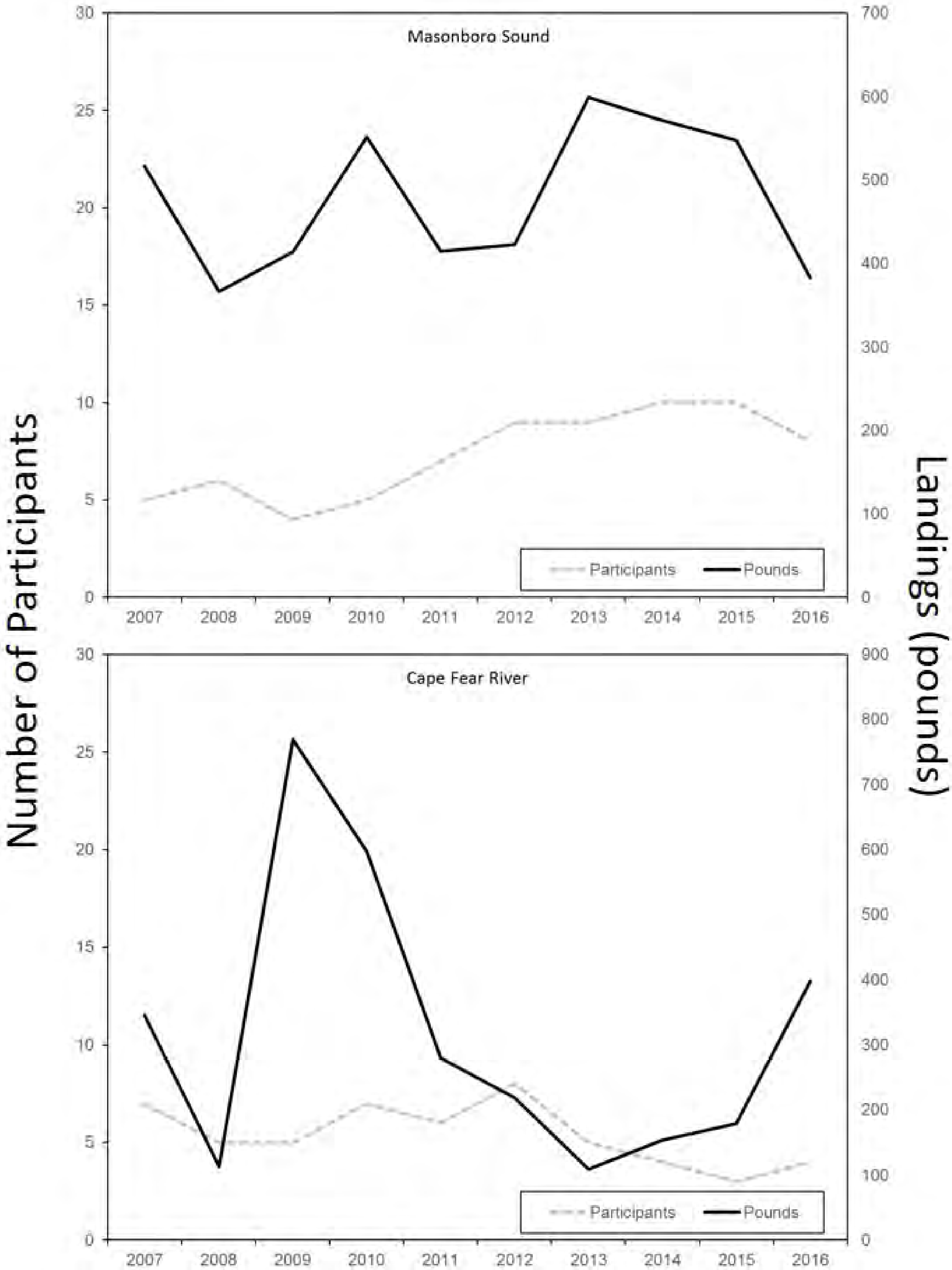

Figure A9. A graph showing number of participants (left axis, dashed line) and landings in pounds (right axis, solid line) of stone crabs in both, hard crab and peeler pots for the Masonboro Sound (upper panel) and Cape Fear River (lower panel) trip ticket reporting areas.

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APPENDIX 4.6: BOTTOM DISTURBING GEAR IN THE BLUE CRAB FISHERY

I. ISSUE

Limit the use of bottom disturbing fishing gear in the blue crab fishery (dredges and trawls), to reduce habitat impacts and improve spawning potential by mature females.

II. ORIGINATION

The "Fishery Impacts to the Ecosystem" section of this plan described habitat impacts associated with dredging and trawling. The NC Coastal Habitat Protection Plan requires that habitat is protected from adverse fishing gear effects. This issue paper will evaluate the need for regulatory changes associated with crab dredging and crab trawling.

III. BACKGROUND

The crab trawl and dredge fisheries have important historical and cultural significance to North Carolina's commercial fishing past. Since the turn of the twentieth century, and the advent of the motor boat, these gears have provided a way for fishermen to harvest crabs in the winter when other gears are ineffective. Due to market demands and the predominance of crab pots for the better part of the last century, crab trawl and dredge landings have waned; making up less than one percent of all crab landings in 2017. Despite their historical significance, these gears present both fishery and habitat level concerns. As discussed in the issue paper "Management Options Beyond Quantifiable", these fisheries predominately catch mature female crabs bedded down in the mud, overwintering. Crab trawl and dredge fisheries utilize bottom disturbing gear that can damage fragile habitats critical to a wide variety of North Carolina's important fish and invertebrate species.

The taking of blue crabs with dredges on public bottom is restricted to one designated area in northern Pamlico Sound, during certain times of year when opened by proclamation (15A NCAC 03L .0203 (a)(1)); or when taken as incidental catch during lawful oyster dredging (15A NCAC 03L .0203 (a)(2)). The taking of blue crabs with crab trawls on public bottom is permitted in large areas of coastal and joint waters south of the Albemarle Sound. Areas and times in which crab trawls may be used to harvest crabs is specified by proclamation (15A NCAC 03L .0202).

In 2013, as part of the adaptive management framework approved in Amendment 2 to the Blue Crab Fishery Management Plan, NCMFC Rule 15A NCAC 03L .0201 CRAB HARVEST RESTRICTIONS was modified, adding:

15A NCAC 03L .0201
(f) In order to comply with management measures adopted in the N.C. Blue Crab Fishery Management Plan, the Fisheries Director may, by proclamation, close the harvest of blue crabs and take the following actions for commercial and recreational blue crab harvest:

(1) specify areas;
(2) specify seasons;

(3) specify time periods;
(4) specify means and methods;
(5) specify culling tolerance; and
(6) specify limits on harvest based on size, quantity, sex, reproductive stage, or peeler stage.

A similar statement allowing proclamation authority to restrict the use of dredges to take crabs was also added (15A NCAC 03L .0203 (a)(3). Additionally, to reduce fishing mortality of sub-legal crabs in crab trawls, 15A NCAC 03L .0202 was modified, increasing the crab trawl minimum mesh length to take hard crabs to four inches in designated areas.

In Amendment 2, blue crabs were not overfished, but there were concerns due to declining indicators (1). A habitat recommendation to consider prohibiting crab dredging was included based on severe habitat damage that can result from dredging. Additionally, gear closure was a potential management strategy included in the blue crab adaptive management framework.

In the 2016 revision to Amendment 2, the NCMFC adopted a partial gear closure implemented through Proclamation M-11-2016. The designated crab dredge area in northern Pamlico Sound was closed; however, incidental harvest of crabs during lawful oyster dredging continued to be allowed as outlined in rule 15A NCAC 03L .0203(a)(2). Once Amendment 3 to the Blue Crab FMP goes into effect, adaptive management measures will be discontinued unless re-adopted (2). This includes the management measures associated with crab dredge and crab trawl fisheries discussed in this issue paper.

Because the 2018 stock assessment indicated blue crabs were overfished and overfishing was occurring (3), a dredge gear closure, trawl gear modification, and area restriction are being revisited. Although not contributing substantially to the fishery, bottom disturbing gears can substantially degrade SAV, shell bottom, soft bottom, and water quality due to high sediment disturbance (2). Further limiting the use of these gears would pose minimal economic impact to fishermen, while reducing habitat impacts and fishing mortality of primarily adult females.

IV. AUTHORITY

North Carolina General Statute 113-134 – Rules
North Carolina General Statute 113-182 – Regulation of fishing and fisheries
North Carolina General Statute 113-221.1 – Proclamations; emergency review
North Carolina General Statute 143B-289.52 – Marine Fisheries Commission – powers and duties
NCMFC Rule 15A NCAC 03H .0103 – Proclamations, General
15A NCAC 03J .0104 Trawl nets
15A NCAC 03L .0202 Crab trawling
15A NCAC 03L .0203 Crab dredging
15A NCAC 03R .0109 Taking crabs with dredges
15A NCAC 03R .0110 Crab Spawning Sanctuaries

V. DISCUSSION

Taking crabs with dredges

The dredge fishery had minimal crab landings in recent years (Table 4.6.1), with most dredge landings coming from oyster dredges in January and February (Table 4.6.2). Since 1995, landings from crab dredging were less than 10,000 lb/yr, with the exception of 2010 when 52,769 lb were landed. Blue crab landings from oyster dredging were minimal (less than 1000 lb) from 1995 to 2003. From 2004 to 2016, landings increased slightly, with the exception of a sharp increase in landings in 2010 and 2011 (Table 4.6.1, Figure 4.6.1). This increase is reflective of a high abundance of crabs in the crab dredge area during the open season due to cooler than normal temperatures and the ease of entering the oyster dredge fishery with a shellfish license that had been intended for hand harvest only. Beginning with the 2012-13 oyster season, management changes were made to the means and methods for Mechanical Harvest of oysters to encourage culled material be returned on a reef. Also, a statutory change in 2013 limited shellfish harvest using the shellfish license to hand harvest only. These changes, along with lower abundance of adult oysters in the Pamlico system, led to lower effort and crab landings after 2011.

The crab dredge fishery is only allowed by NCMFC rule in a designated crab dredge area in northern Pamlico Sound (Figure 4.6.2) in January and February. However, it has remained closed by proclamation since June 2016. The total designated dredge area is 86,899 acres. A Seed Oyster Management Area (SOMA) and three oyster sanctuaries (Crab Hole, Croatan, and Pea Island) occur within the crab dredge area. Dredging is not permitted within oyster sanctuary boundaries. The estuarine portion of the Oregon Inlet Crab Spawning Sanctuary is also within the designated crab dredge area (see Figure 4.4.4).

There are 8,071 acres of SAV and 308 acres of shell bottom mapped within the crab dredging area. Areas greater than 15-ft have not been mapped for shell bottom, therefore the total acreage of shell bottom is likely underestimated. These sensitive habitats are critical to various life stages of blue crabs along with numerous other fish and invertebrates. Because of the diversity of habitat in this area, the critical location as a migratory corridor to the ocean, and good quality of the habitats and water quality, and the ecosystem services provided by these habitats several Strategic Habitat Areas were designated within the dredge area as part of CHPP Regions 1 and 2. Ecosystem services provided by SAV and shell bottom include stabilizing sediment, improving water clarity, reducing shoreline erosion, and stabilizing marsh edge habitat (2). Additionally, SAV releases oxygen into the water, while subtidal oyster rocks with vertical relief provide refuge for crabs and other invertebrates during anoxic events. Maintaining these habitat complexes will not only enhance conditions needed for blue crab as well as numerous other fishery and non-fishery species, but benefit the entire coastal ecosystem. It is well recognized that crab dredging, which is designed to dig up overwintering crabs from the mud, causes more severe damage to benthic habitat than any other gear actively used in NC, particularly to SAV and oysters (4; 5; 6; 2). Since there are less habitat damaging methods available to harvest crabs, the CHPP recommended in 2010 that crab dredging be prohibited.

Table 4.6.1. Annual blue crab landings (pounds) and value ($) from dredges, trawls, and overall, 1995 – 2017. Confidential data is given as less-than a rounded value.

	Crab Dredge		Oyster Dredge		Crab Trawl		Shrimp Trawl		Other Gears		Total	
Year	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)
1995	7,403	4,220	541	308	1,065,578	736,465	225,228	137,832	45,144,790	35,360,461	46,443,541	36,239,286
1996	9,590	4,569	<250	<150	3,090,591	1,733,261	304,450	161,274	63,675,568	41,143,330	67,080,200	43,042,434
1997	2,567	1,328	<250	<150	3,291,288	2,019,161	312,823	189,607	52,483,431	35,475,942	56,090,109	37,686,039
1998	0	0	171	95	3,086,044	1,985,076	554,043	311,755	58,435,913	42,662,715	62,076,170	44,959,640
1999	0	0	213	110	1,817,726	1,149,536	281,370	159,002	55,447,368	36,503,552	57,546,676	37,812,199
2000	0	0	591	390	941,824	759,561	209,247	154,819	39,486,723	36,522,957	40,638,384	37,437,728
2001	7,101	5,524	358	226	997,763	778,549	186,053	122,757	30,989,115	31,324,540	32,180,390	32,231,596
2002	328	239	129	72	1,119,239	657,628	160,664	96,679	36,455,959	32,393,815	37,736,319	33,148,432
2003	8,704	5,016	<1,500	<1,000	1,259,721	850,996	305,582	193,035	41,195,791	36,059,046	42,769,797	37,108,093
2004	4,838	3,357	2,113	1,343	896,554	539,501	163,715	74,368	33,063,388	23,847,274	34,130,608	24,465,843
2005	<1,500	<1,000	6,007	3,030	388,996	365,568	61,807	31,144	24,973,309	19,874,171	25,430,119	20,273,913
2006	<100	<75	2,643	1,185	138,708	90,925	37,027	14,754	25,164,781	16,980,531	25,343,158	17,087,395
2007	2,656	2,742	572	402	28,789	30,811	31,772	15,613	21,361,171	21,382,387	21,424,960	21,431,955
2008	0	0	225	113	1,557,934	863,662	4,244	3,380	31,354,288	26,688,232	32,916,691	27,555,386
2009	7,981	7,166	<100	<75	913,928	556,676	17,298	11,484	28,768,025	26,853,669	29,707,232	27,428,995
2010	52,769	46,163	18,567	15,426	289,399	248,343	11,575	10,395	30,310,701	26,223,464	30,683,011	26,543,791
2011	6,843	4,348	31,861	19,584	201,940	112,871	5,785	4,902	29,788,963	21,140,558	30,035,392	21,282,264
2012	2,335	1,854	2,756	2,108	10,075	11,964	24,146	11,303	26,746,357	22,779,708	26,785,669	22,806,938
2013	0	0	1,305	1,412	56,470	59,638	41,609	31,125	22,103,238	29,914,273	22,202,623	30,006,447
2014	<50	<50	7,372	8,908	39,902	45,390	48,482	36,271	26,135,209	33,936,824	26,230,965	34,027,403
2015	<2,000	<1,500	5,216	5,395	187,107	212,337	12,551	14,187	31,928,245	33,492,505	32,134,501	33,724,424
2016	2,958	2,299	1,404	1,576	164,573	134,863	17,051	14,555	25,274,871	23,959,423	25,459,475	24,112,715
2017	<1,500	<1,000	1,302	1,413	119,312	122,351	17,771	22,045	19,134,770	22,072,006	19,273,156	22,217,815
Average 1995-2017	<5,271	<4,020	<3,715	<2,803	941,890	611,528	131,926	79,230	34,757,477	29,417,017	35,839,963	30,114,380
Average 2013-2017	<1,302	<970	3,320	3,741	113,473	114,916	27,493	23,637	24,915,267	28,675,006	25,060,144	28,817,761

Table 4.6.2. Average monthly blue crab landings (pounds) and value from crab and oyster dredges in the past ten years (2008-2017).

	Crab Dredge		Oyster Dredge		Total	
Month	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)	Weight (lb.)	Value ($)
January	4,016	3,316	1,851	1,344	5,867	4,660
February	3,395	2,993	2,041	1,547	5,436	4,540
March	100	77	656	562	756	639
April	0	0	25	16	25	16
October	0	0	5	3	5	3
November	0	0	1,303	1,060	1,303	1,060
December	0	0	1,126	1,065	1,126	1,065

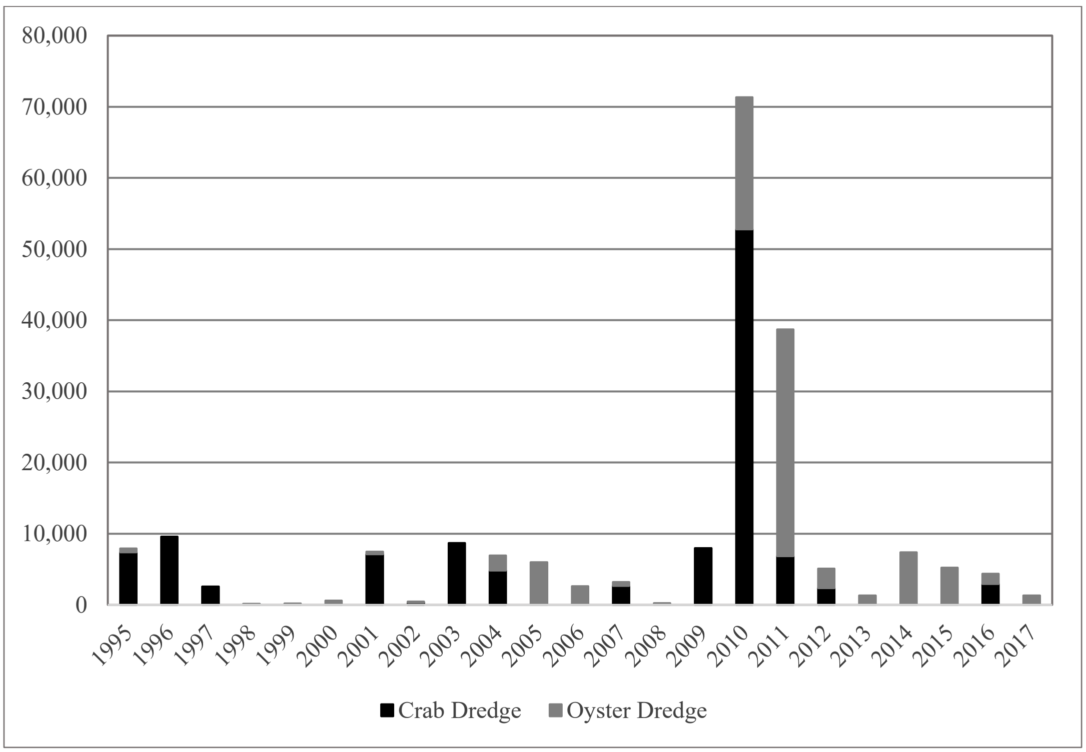

Figure 4.6.1. Blue crab landings from crab and oyster dredges, 1995-2017.

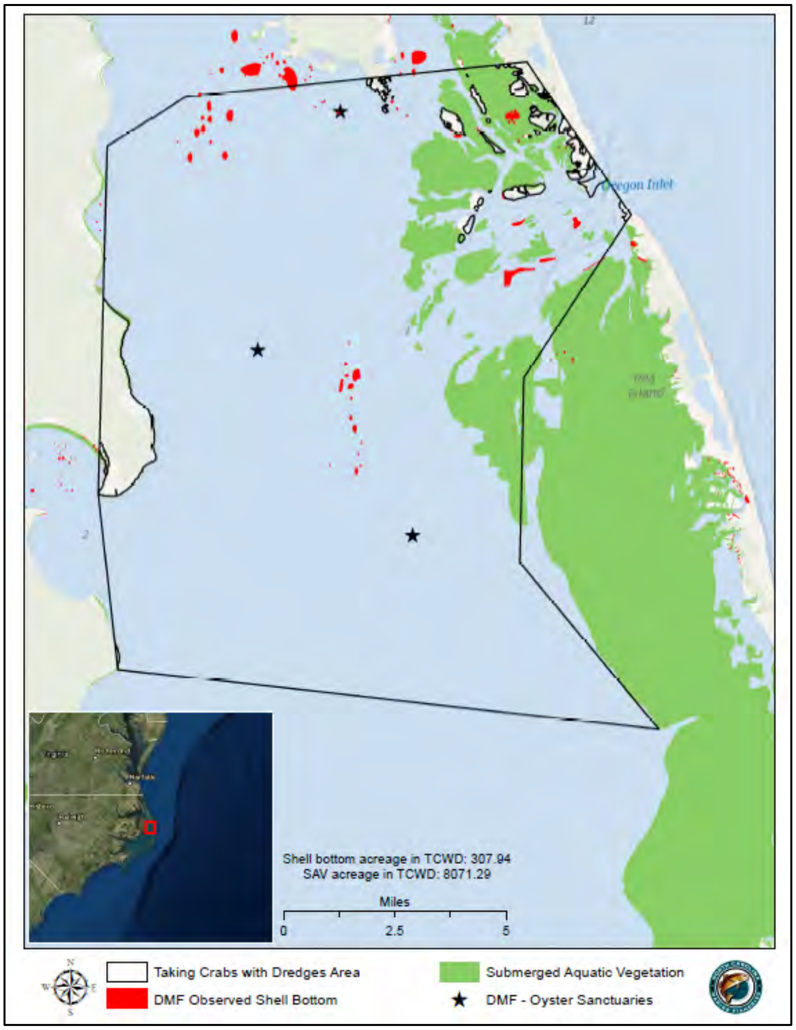

Figure 4.6.2. Location of SAV, shell bottom, and oyster sanctuaries within the designated crab dredge area in northern Pamlico Sound.

Allowing crab bycatch in the oyster fishery has enforcement issues. Rule 15A NCAC 03L .0203 (a)(2) states that the weight of the crabs shall not exceed 50% of the total weight of the combined oyster and crab catch, or 500 pounds, whichever is less. However, Marine Patrol measures by volume (bushels), not weight so enforcement of the weight criteria is difficult. The weight of a bushel can be highly variable, making conversion from bushels to weight inaccurate. Additionally, allowing bycatch of crabs could entice fishermen to dredge in soft bottom adjacent to the oyster rock once they have caught their oysters until they reach their bycatch allowance. Oyster dredging rules have many requirements (e.g., deploying dredge from the side of the vessel, culling on site) to keep dredging activity on the rock rather than digging along the edges and dispersing culled shell material onto soft sediment. Targeting crabs in the bottom adjacent to the oyster rock was not the intent of this rule and could lead to unlawful oyster dredging operations, suspended sediments in the water column, siltation, and damage to shell bottom on the growing edge of the structure. Since the majority of crabs harvested as bycatch in the oyster dredge fishery are mature females (7), allowing blue crab bycatch can lead to additional impact on spawning output needed to increase the blue crab population.

Blue crab landings taken with oyster and crab dredges, as well as effort, are not a significant contributor to the overall blue crab fishery. Landings accounted for only 0.02% of the total blue crab landings over the past five years (2013-2017) (average annual value $4,711). Landings from trawls were similarly low. In contrast, while remaining gears, primarily pots, accounted for 99.42%. The number of participants in the crab dredge fishery in the past five years has ranged from 0-6, and in the oyster dredge fishery ranged from 119-268 (Table 4.6.3).

Due to the location and season of the crab and oyster dredge fisheries, crab landings are primarily mature females. Converting pounds to numbers of individual crabs and using the average over the last five years, this equates to approximately 19,524 crabs/yr taken with crab dredge and 49,797 crabs/yr taken with oyster dredge. While these gears account for a small portion of the overall landings, closing the harvest of blue crabs from these gears would allow roughly 69,300 more females to reproduce the following season. Considering management changes to prohibit the taking of blue crabs with crab and oyster dredges makes ecological sense with relatively minor economic impact (Table 4.6.1).

Table 4.6.3. Participation in the crab dredge, oyster dredge, and crab trawl fisheries

	Crab Dredge		Oyster dredge		Crab and Peeler Trawls	
Year	Participants	Trips	Participants	Trips	Participants	Trips
1995	9	36	15	88	225	2,133
1996	5	27	2	3	297	4,198
1997	3	11	6	31	309	4,916
1998	0	0	68	671	270	5,543
1999	0	0	80	940	208	3,447
2000	0	0	50	392	179	2,186
2001	8	26	58	822	200	2,517
2002	3	5	48	621	135	1,027
2003	3	14	56	892	137	1,672
2004	7	19	123	1,750	172	1,744
2005	2	7	167	2,333	99	1,092
2006	1	1	151	2,486	40	296
2007	3	18	150	1,729	32	157
2008	0	0	159	2,688	44	312
2009	9	44	258	4,481	59	473
2010	20	146	506	10,655	55	295
2011	12	69	355	7,400	41	253
2012	3	4	184	2,264	16	45
2013	0	0	220	3,763	18	104
2014	1	1	268	5,705	32	129
2015	2	14	212	4,028	50	384
2016	6	6	177	2,684	44	402
2017	1	1	119	1,540	32	316
Average 1995-2017	4	20	149	2,520	117	1,463
Average 2013-2017	2	4	199	3,544	35	267

Trawling

Another example of a potential gear closure would be to limit crab trawling in the Pamlico, Pungo, and Neuse rivers to the current shrimp trawl lines in each river, or completely prohibit their use statewide.

Over the past five years there have been minimal landings of blue crabs from crab and shrimp trawls in the Pamlico, Pungo, and Neuse rivers (Table 4.6.4). Figures 4.6.3 and 4.6.4 show the current crab trawl boundary lines and the current shrimp trawl boundary lines for the Pamlico and Neuse river systems. Prohibiting crab trawling in the upper areas of the rivers would eliminate all bottom disturbing fishing gear in these areas.

Mobile disturbing bottom gear such as trawls and dredges can adversely impact fish habitat by resuspending sediments and any associated pollutants into the water column. Suspended sediments can clog gills of juvenile and larval fish, reduce primary production in the water column or benthic community, and release toxins where they can be taken up by estuarine organisms. Dragged gear can cause structural damage or loss to benthic habitats such as SAV and shell bottom. Reviews of fishing gear impacts have categorized crab dredges and crab/shrimp trawls as having more severe impacts than other fishing gear, although the extent varies by the gear configuration, proximity of benthic habitats, and life stages of fish present (*4*; *2*). Refer to the section "Fishery Impacts to the Ecosystem" for more details.

Limiting bottom disturbance could improve habitat conditions not only for blue crab but many other estuarine fishery species and provide additional protection to significant portions of NCMFC approved Strategic Habitat Areas (SHA). Strategic Habitat Areas are complexes of high quality, diverse habitats that provide exceptional ecological functions to important fishery species. These areas have been identified through a comprehensive spatial analysis and represent priority areas for protection and enhancement. Strategic Habitat Areas located within the Pamlico and Neuse systems, as well as other areas open to trawling are shown in Figures 4.6.5 and 4.6.6.

Statewide blue crab landing from crab trawls and shrimp trawls have accounted for only 0.05% and 0.1%, respectively, of the total blue crab harvest over the past five years (Table 4.6.1). The prohibition of blue crab harvest by use of crab and shrimp trawl, as well as crab dredge would have minimal economic effects on the fishery, while addressing fishery and habitat level concerns of these gears.

Table 4.6.4. Annual crab landings (pounds) from crab and shrimp trawls in the Pamlico, Pungo, and Neuse rivers, 1995 – 2017. Confidential data is given as less-than a rounded value.

	Crab Trawl			Shrimp Trawl		
Year	Neuse River	Pamlico River	Pungo River	Neuse River	Pamlico River	Pungo River
1995	35,618	154,056	267,400	34,019	7,452	0
1996	212,979	486,829	298,657	50,710	0	1,412
1997	411,998	400,922	401,605	57,808	11,144	2,883
1998	306,178	559,477	203,993	40,883	1,526	0
1999	243,473	457,575	208,396	31,644	4,264	1,123
2000	47,674	104,043	78,764	11,144	1,472	714
2001	41,030	43,164	17,625	5,390	2,284	462
2002	2,877	4,506	142,682	11,985	1,532	1,027
2003	41,411	139,386	81,037	6,410	<500	<3,000
2004	35,363	76,990	63,604	12,444	0	0
2005	18,982	159,327	8,857	4,992	<500	<500
2006	6,057	19,512	<5,000	1,195	76	<500
2007	1,283	<500	<500	<1,000	<500	0
2008	<500	<500	<500	900	0	0
2009	<500	<500	<500	105	<2,000	0
2010	<500	<500	0	<500	0	0
2011	0	<500	0	<500	<500	0
2012	<500	0	0	0	<500	0
2013	0	0	0	904	0	0
2014	<500	0	0	2,561	0	0
2015	<500	<500	<500	451	<500	0
2016	<1000	<500	<500	<500	<500	0
2017	<500	<500	0	360	0	0

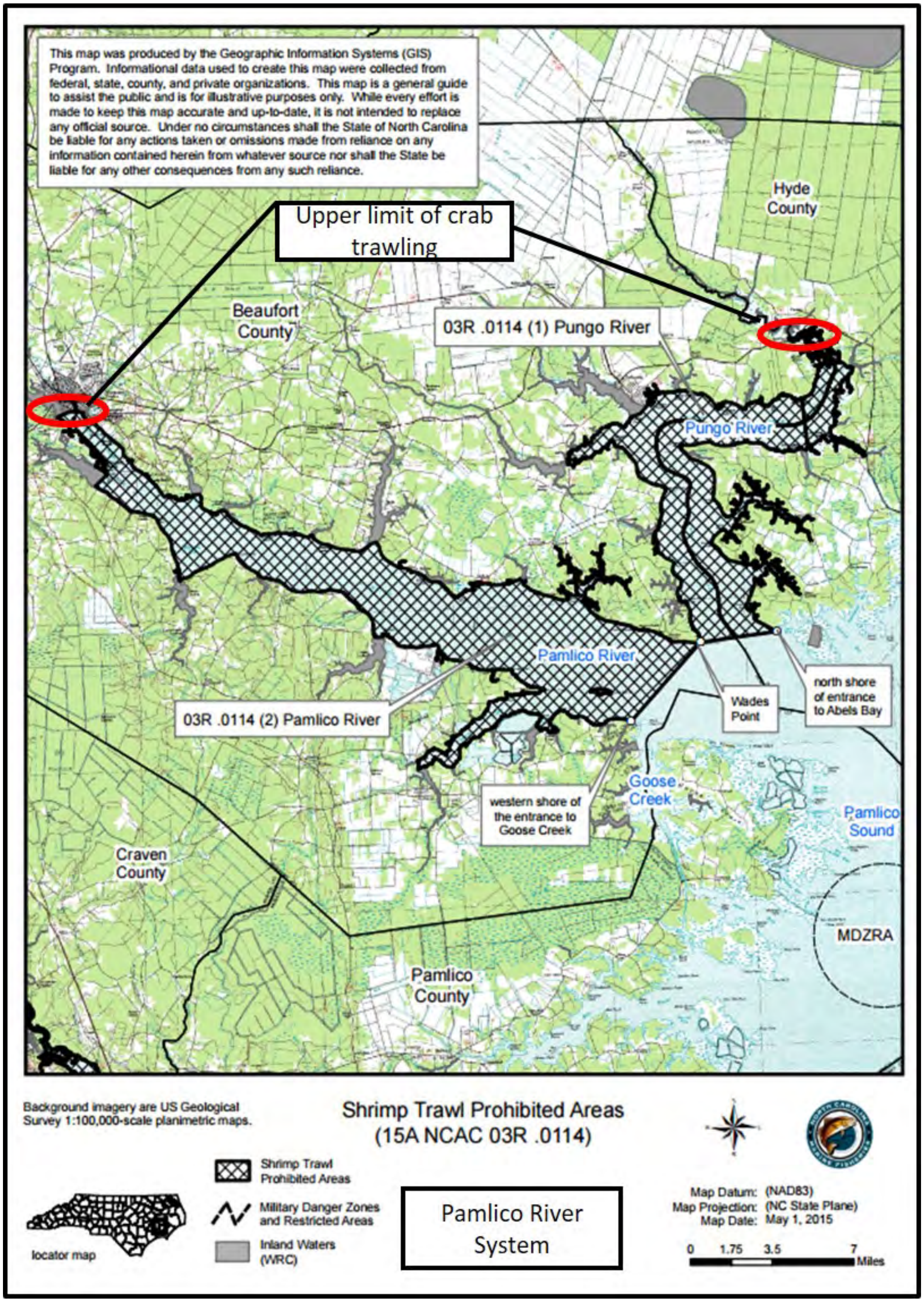

Figure 4.6.3. Areas where crab trawling is allowed within shrimp trawl prohibited areas in the Pamlico and Pungo rivers (hatched area). Red ovals mark the upper limit of trawling.

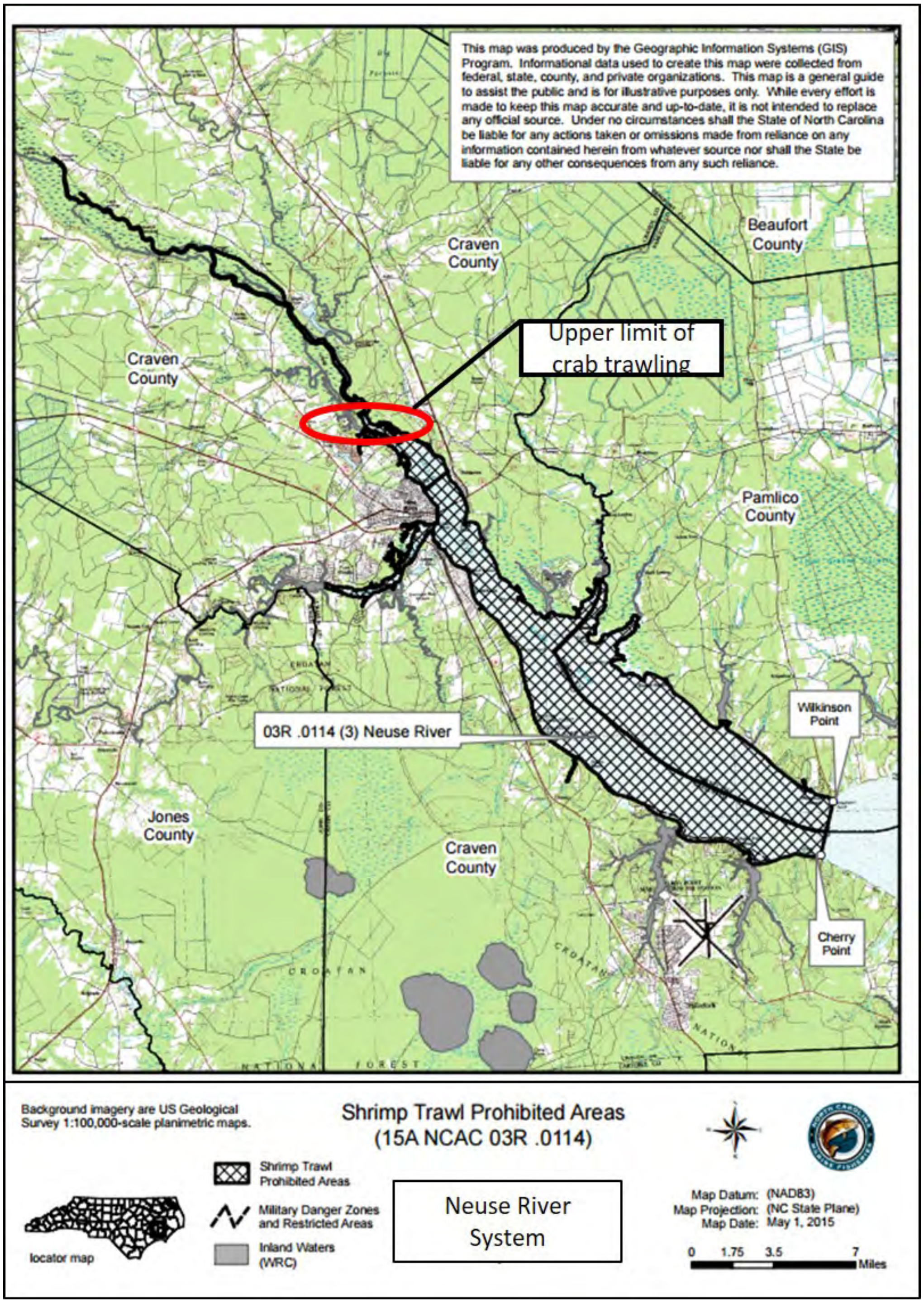

Figure 4.6.4. Area where crab trawling is allowed within the shrimp trawl prohibited area in the Neuse River (hatched area). Red oval marks the upper limit of trawling.

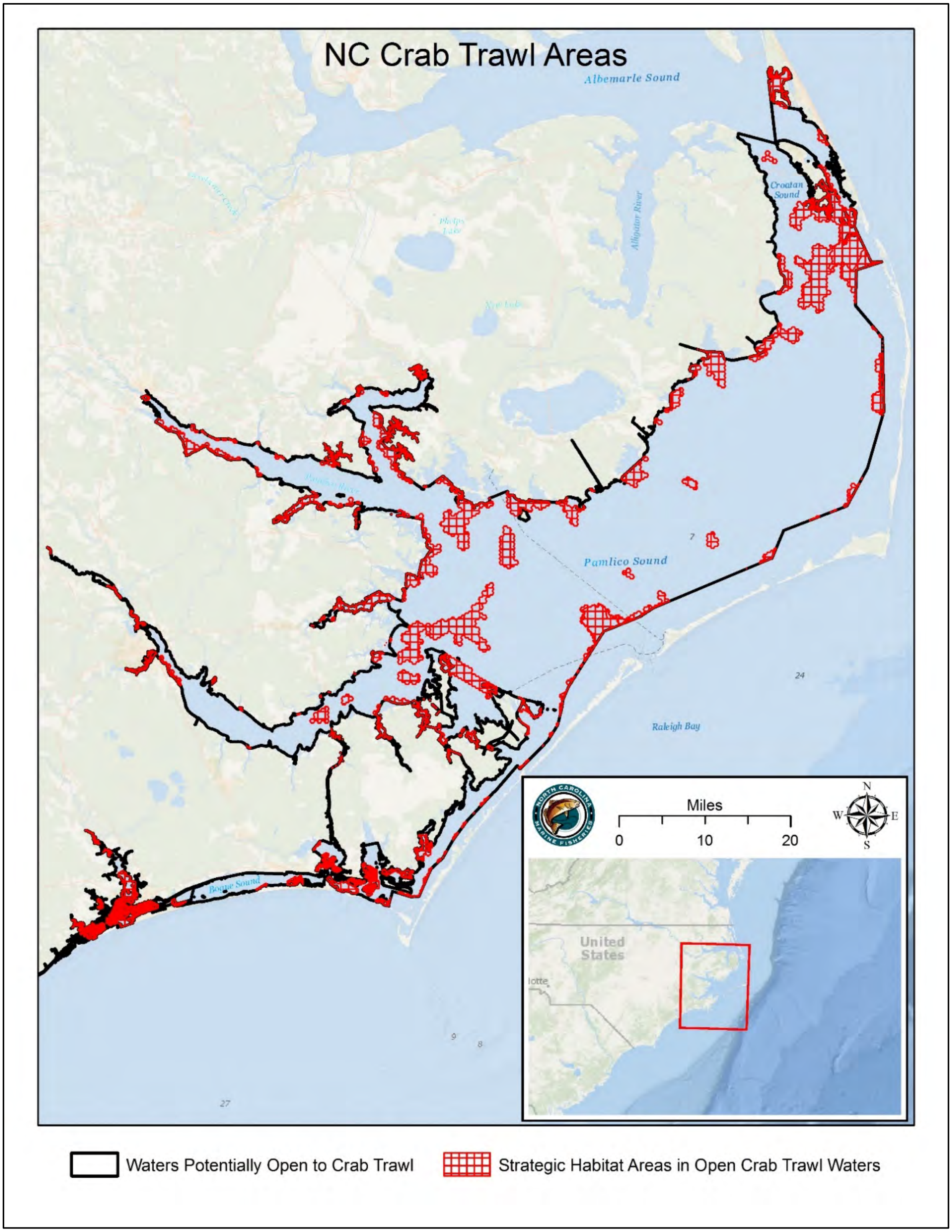

Figure 4.6.5. Current statewide crab trawl boundary lines (Bogue Sound North) with designated strategic habitat areas (SHA) shaded by region.

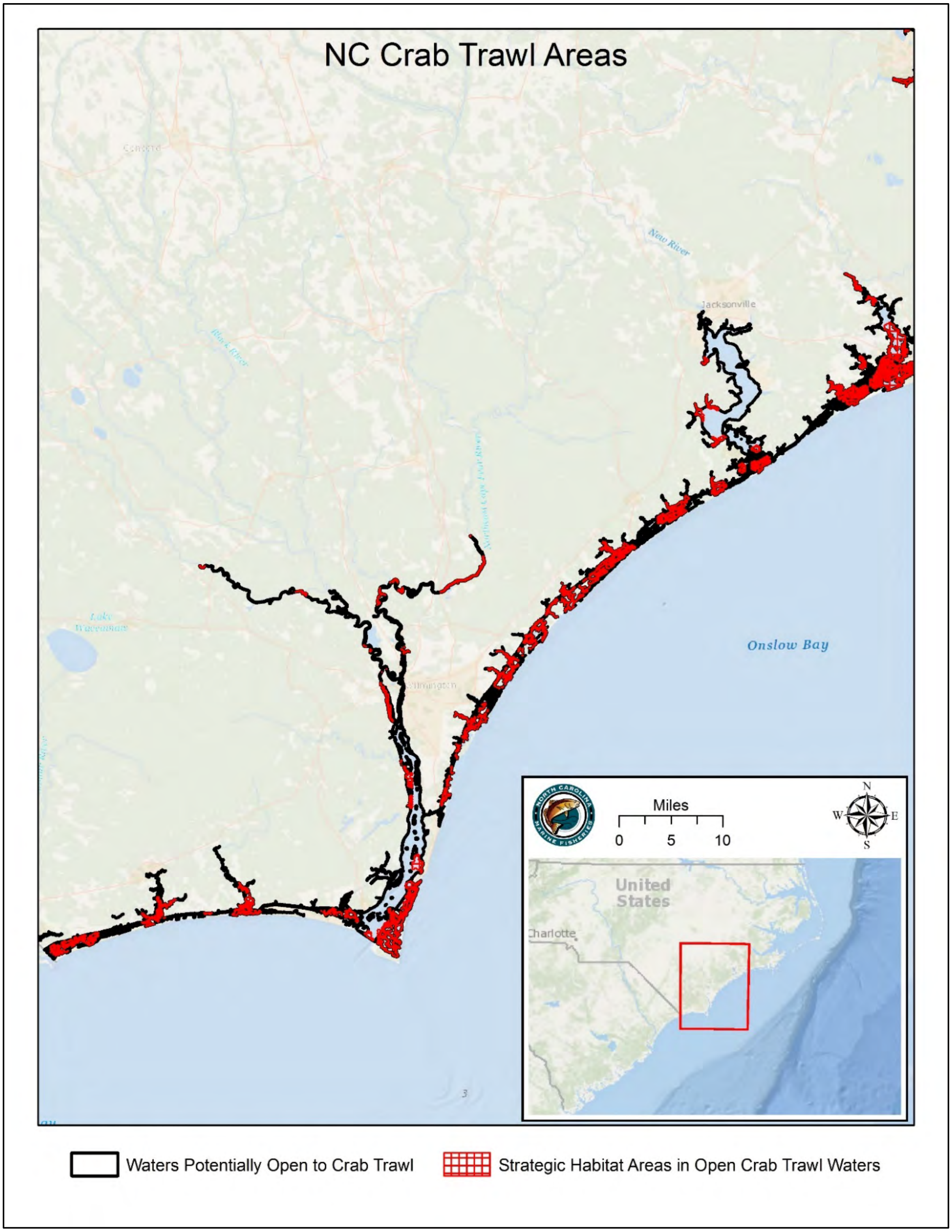

Figure 4.6.6. Current statewide crab trawl boundary lines (South of Bogue Sound) with designated strategic habitat areas (SHA) shaded by region.

VII. MANAGEMENT OPTIONS AND IMPACTS

(+ Potential positive impact of action)
(- Potential negative impact of action)

1. Limit the taking of crabs with dredges
   a. Prohibit the taking of crabs with crab dredges
   b. Prohibit taking of crabs as incidental bycatch during oyster dredging operations
   c. Prohibit the taking of crabs with crab dredges and oyster dredges

   + Will reduce habitat damage to SAV, oyster reefs, and oyster sanctuaries in the crab dredge area
   + May increase abundance of mature females helping to rebuild the spawning stock
   + Will avoid additional impact to oyster rocks and soft bottom
   + Will avoid unlawful targeting of blue crabs in the oyster dredge fishery
   + Easier to enforce
   - Management change required
   - Could lead to some waste of crab bycatch in the oyster fishery
   - Decreased harvest with economic loss to the fishery

2. Limit the use of crab trawls spatially
   a. Prohibit the use of crab trawls in areas where shrimp trawls are already prohibited in the Neuse and Tar-Pamlico rivers (15A NCAC 3R .0114)
   b. Prohibit the use of crab trawls coastwide

   + Will reduce habitat damage to SHAs and other bottom habitat in crab trawl areas
   + May increase abundance of mature females helping to rebuild the spawning stock
   - Decreased harvest with economic loss to the fishery
   - Some regions may be impacted more than others

VIII. RECOMMENDATION

<u>NCDMF Recommendation</u>

Option 1a: prohibit taking of crabs with crab dredges
Option 2a: prohibit use of crab trawls in areas where shrimp trawls are already prohibited in the Pamlico, Pungo, and Neuse rivers

<u>Blue Crab FMP Advisory Committee</u>

Not adopt any of the recommended management options on crab dredge and leave crab trawl lines as is

<u>Northern Advisory Committee</u>

<u>Southern Advisory Committee</u>

Shellfish and Crustacean Advisory Committee

Habitat and Water Quality Advisory Committee

NCMFC selected management strategy

IX. LITERATURE CITED

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APPENDIX 5. PROPOSED RULES

APPENDIX 6. SUGGESTED STATUTORY CHANGES

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

Aug. 7, 2019

MEMORANDUM

TO: N.C. Marine Fisheries Commission

FROM: Catherine Blum, Fishery Management Plan and Rulemaking Coordinator
Fisheries Management Section

SUBJECT: Rulemaking Update

Issue
Update the Marine Fisheries Commission (commission) on the status of rulemaking in support of the Periodic Review and Expiration of Existing Rules per G.S. 150B-21.3A.

Action Needed
The commission is scheduled to vote on approval to begin the rule readoption process for a portion of rules in 15A NCAC 03.

Overview
This memo describes the materials about the rulemaking update for the August 2019 commission meeting. In accordance with requirements of G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules, the commission is scheduled to vote on approval to begin the rule readoption process for two rules: 15A NCAC 03M .0509, Tarpon; and 15A NCAC 03O .0108, License and Commercial Fishing Vessel Registration Transfers. The scheduled action will include approval of the proposed text of the rules, and the fiscal analysis of the rules as approved by the Office of State Budget and Management.

Additional handouts are provided in your briefing book, including a figure showing the steps in the commission's 2019-2020 annual rulemaking cycle. The two approved fiscal analyses are also provided and each of these documents contains an appendix with the text of the corresponding proposed rule. A summary of items for 15A NCAC 03 rule readoption scheduled for the commission to take action on at this meeting is provided, as well as background information on the Periodic Review and Expiration of Existing Rules.

15A NCAC 03 Rule Readoption

2019-2020 Annual Rulemaking Cycle

At its August 2019 meeting, the commission is scheduled to consider approval of Notice of Text for Rulemaking to begin the readoption process for the second group of rules in 15A NCAC 03. The rule package is delayed from the usual start time of May due in part to a compressed workload stemming from the 2018 hurricanes and a vacancy in the division's economist position, which has since been filled. The economist is central to preparing the required fiscal notes for proposed rules. Although G.S. 150B-21.3A(d) exempts an agency from the requirement to prepare a fiscal note for a rule that is readopted without substantive change, the commission's rules remain subject to the requirements of Section 2 of Executive Order 70 under Governor Perdue. These requirements include that an agency "shall quantify the costs and benefits to all parties of a rule to the greatest extent possible. The level of analysis shall be proportional to the significance of the rule." A handout showing the adjusted steps in the commission's 2019-2020 annual rulemaking cycle is included in the briefing materials.

Action Items for August Commission Meeting

For the 2019-2020 rule package, rules proposed for readoption include 15A NCAC 03M .0509, Tarpon. At its February 2018 meeting, the commission voted to have the division begin the process of drafting a rule to make tarpon a no spear, no gaff and no possession fish. At its February 2019 business meeting, the commission selected as its preferred proposed management option to make it unlawful to puncture or harvest tarpon, but to still allow catch and release. The Office of State Budget and Management approved the fiscal analysis of this proposed rule April 1, 2019. The analysis is provided in the briefing materials and includes an appendix with the text of the corresponding proposed rule.

The second proposed rule for the 2019-2020 package is 15A NCAC 03O .0108, License and Commercial Fishing Vessel Registration Transfers. Concern has been raised about third-party transfers (e.g., Craigslist) of Standard Commercial Fishing Licenses (SCFLs) allowing individuals to get a license without going through the eligibility board. At the November 2018 commission meeting, proposed amendments to the SCFL transfer rule were presented that added language to allow transfers of SCFLs or Retired SCFLs under specific circumstances in addition to those defined in statute (G.S. 113-168.2). Concern was raised about several of the proposed amendments to the rule due to potential loopholes in enforcement. In those amendments was language regarding business transfers. After the February 2019 meeting, there was a desire by commercial members of the commission to include language in the rule that would allow for business transfers; therefore, the division looked into this and drafted additional language to add to the transfer rule in an attempt to provide some flexibility for businesses to complete transfers under specific circumstances. The commission agreed by consensus to include the amendments proposed to rule 15A NCAC 03O .0108 as presented in May 2019 in the 2019-2020 package of rules for readoption. The Office of State Budget and Management approved the fiscal analysis of this version of the proposed rule July 3, 2019. The analysis is provided in the briefing materials and includes an appendix with the text of the corresponding proposed rule.

If approved by the commission, the proposed rules in this package will be published in the *N.C. Register* Oct. 1, 2019. A public comment period will be held Oct. 16 to Dec. 2, 2019, within which a public hearing will be held Wednesday, Oct. 23, 2019 at 6 p.m. at the Division of Marine Fisheries Central District Office located at 5285 Highway 70 West in Morehead City. Any public comment received will be forwarded to the commission for its consideration at its February 2020 business meeting when the commission is scheduled to vote on final approval of the rules. The rules in this package are intended to become effective May 1, 2020. Staff recommends the commission approve the following proposed rules and associated fiscal analyses for Notice of Text for Rulemaking to readopt rules per G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules:

- Tarpon, 15A NCAC 03M .0509; and
- License and Commercial Fishing Vessel Registration Transfers, 15A NCAC 03O .0108.

Background on the Periodic Review and Expiration of Existing Rules
Session Law 2013-413, the Regulatory Reform Act of 2013, implemented requirements known as the "Periodic Review and Expiration of Existing Rules." These requirements are codified in a new section of Article 2A of Chapter 150B of the General Statutes in G.S. 150B-21.3A. Under the requirements, each agency is responsible for conducting a review of all its rules at least once every 10 years in accordance with a prescribed process.

The review has two parts. The first is a report phase, which has concluded, followed by the readoption of rules. An evaluation of the rules under the authority of the commission was undertaken in two lots (see Figure 1.) The commission has 211 rules in Chapter 03 (Marine Fisheries), of which 172 are subject to readoption, and 164 rules in Chapter 18A (Shellfish Sanitation.) The commission is the body with the authority for the approval steps prescribed in the process.

Rules	2017	2018	2019	2020	2021	2022
Chapter 03 (172 of 211 rules)	Report	41 Rules Readopted	Rule Readoption (131)			6/30/22 deadline
Chapter 18A (all 164 rules)		Report	Rule Readoption (164)			

Figure 1. Marine Fisheries Commission schedule to comply with G.S. 150B-21.3A, Periodic Review and Expiration of Existing Rules.

N.C. Marine Fisheries Commission
2019-2020 Annual Rulemaking Cycle

August 2019

Time of Year	Action
April-July 2019	Fiscal analysis of rules prepared by DMF staff and approved by Office of State Budget and Management
August 2019	MFC considers approval of Notice of Text for Rulemaking
Oct. 1, 2019	Publication of proposed rules in the *North Carolina Register*
Oct. 16-Dec. 2, 2019	Public comment period held
Wednesday, Oct. 23, 2019	Public hearing held: 6 p.m., Division of Marine Fisheries, 5285 Highway 70 West, Morehead City, NC 28557
February 2020	MFC considers approval of permanent rules
March-April 2020	Rulebook prepared
April 2020	Rules reviewed by Office of Administrative Hearings Rules Review Commission
April 15, 2020	Commercial license sales begin
May 1, 2020	Effective date of new rules
May 1, 2020	Rulebook available online

Regulatory Impact Analysis of Proposed Tarpon Rule Amendments

Rule Amendments: 15A NCAC 03M .0509

Name of Commission: N.C. Marine Fisheries Commission

Agency Contact:
Adam Stemle, Fisheries Economics Program Manager
N.C. Division of Marine Fisheries
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Impact Summary:

State government:	No
Local government:	No
Federal government:	No
Substantial impact:	No

Authority:

North Carolina Marine Fisheries Commission Rules May 1, 2015 (see Appendix I)
15A NCAC 03M .0509 Tarpon

North Carolina General Statutes

GS § 113-134	Rules
GS § 113-182	Regulation of fishing and fisheries
GS § 143B-289.52	Marine Fisheries Commission – power and duties

Necessity: A motion was introduced and passed by the North Carolina Marine Fisheries Commission asking the Division of Marine Fisheries to draft rules to make tarpon a no gaff, no spear, and no possession fish.

The anticipated effective date of the proposed rule changes is April 1, 2020.

I. Summary

A motion was introduced and passed by the Marine Fisheries Commission on February Feb. 15, 2018 asking the Division of Marine Fisheries to amend rule 15A NCAC 03M .0509 to make tarpon a no possession fish and prohibit gaffing, spearing, or puncturing of the fish. The primary goal of the rule change is to improve the survivability of the fish.

II. Introduction and Purpose of Rule Changes

Tarpon are prized by recreational anglers for their large size and strength in their fight. They are found in warmer waters on both sides of the Atlantic Ocean and in the Gulf of Mexico. Tarpon found in state waters are presumed to have migrated from points south, most likely Florida. They will enter the estuaries and have been found in the brackish or low salinity areas as well during the summer months. The population size of tarpon along the southeastern coast of the United States or in North Carolina is unknown. They are a bony fish and not desirable to eat, so most are released after they are caught. Only two tarpon were observed harvested in the 24 years of the division's recreational sampling program, in 1987 and 2010. Although harvest is legal, they are rarely encountered. Very little information is known about tarpon and there are no directed sampling programs for tarpon in North Carolina.

Anecdotal reports from the public since 2017 expressed concern that tarpon were being used as cut bait to fish for sharks. Rule 15A NCAC 03M .0509 allows for the recreational hook and line harvest of tarpon. An email and a phone conversation with two fishing guides to staff occurred since July 2017 and one public comment was received, on behalf of recreational guides, during the Marine Fisheries Commission meeting on Feb. 14, 2018, asking the Commission to consider tarpon a no kill species and include no gaffing and no spearing, to improve the survival of the fish. The public commenter indicated the recreational guides know that tarpon move into N.C. waters on their migratory run from the south to spawn and they see juveniles, but they are unsure if these juveniles survive the winter. A letter was also given to the commission from the Bonefish and Tarpon Trust Foundation further supporting tarpon as a catch and release only species.

Reports on the harvest of tarpon for use as cut bait are undocumented. If used as cut bait, it is required that the angler, while engaged in fishing activities, must retain the carcass with head and tail intact per the Marine Fisheries Commission's mutilated finfish rule, NCAC 15A NCAC 03M .0101. The size of tarpon would pose challenges to adhere to this rule. Recreational release mortality information on tarpon is limited to studies from Florida in the Boca Grande Pass and Tampa Bay areas. All release mortality studies are on tarpon caught from boats with fishing guides and not from shore or piers, with acoustic tagging following the fish for no more than 12 hours after release (Edwards 1992; Edwards 1998; Guindon 2011). These studies found low immediate post-release mortality of tarpon from catch and release. The most comprehensive and latest study estimated tarpon immediate post-release mortality at five percent and factored the mortality to poor handling and irreparable physiological damage from the angling event (Guindon 2011). Use of a gaff or other puncturing tools to facilitate landing the tarpon increases damage to the fish and could decrease its chance of survival. Pier fishing, due to the higher elevation from the water and distance from shore, makes it more likely that gaffs are used in order to land the fish. Therefore, the survival of tarpon from this mode may be less likely than from other modes of capture (i.e., boats, shore).

There is no interstate or federal fishery management plan in place for tarpon; management of this species rests solely with each coastal state. Rule 15A NCAC 03M .0509 for tarpon has been in effect since Oct. 1, 1992 in North Carolina and has remained unchanged. The current rule limits tarpon to be taken only with hook and line and allows for the harvest of one fish per person per day, with no allowance to sell or offer to sell. The proposed rule would still allow catch and release with hook and line gear to occur and continue to prohibit sale of a tarpon, but would prohibit gaffing, spearing, puncturing, or retaining a tarpon. The purpose of this rule change is to satisfy the Marine Fisheries Commission's motion that was passed on Feb. 15, 2018, in response to public comments it received.

III.Benefits

While there are no immediate quantifiable economic benefits to the proposed rule change, the species will benefit from increased protective measures that may reduce post-release mortality from irreparable physiological damage.

IV.Costs

There are no quantifiable costs associated with the proposed rule changes, as the North Carolina recreational tarpon fishery has long been considered primarily a catch and release fishery. The rule change is not anticipated to reduce the number of directed angler trips for tarpon.

Appendix I Proposed Rule Changes:

15A NCAC 03M .0509 TARPON

(a) It ~~is~~ shall be unlawful to ~~sell~~ possess, sell, or offer for sale tarpon.

~~(b) It is unlawful to possess more than one tarpon per person taken in any one day.~~

~~(c)~~(b) It ~~is~~ shall be unlawful to take tarpon by any method other than ~~hook-and-line.~~hook and line.

(c) It shall be unlawful to gaff, spear, or puncture a tarpon.

History Note: *Authority G.S. 113-134; 113-182; ~~113-221; 143B-289.4;~~143B-289.52;*
Eff. October 1, 1992;
Readopted Eff. April 1, 2020.

Appendix II Literature Cited:

Edwards, R. E. 1992. Tarpon release mortality assessment using acoustic tracking. Final Project Report 6634. Florida Department of Natural Resources. 45 pp. https://dspace.mote.org/bitstream/2075/1290/1/MTR%20259.pdf

Edwards, R. E. 1998. Survival and Movement Patterns of Released Tarpon (Megalops atlanticus). Gulf of Mexico Science 16 (1). Retrieved from https://aquila.usm.edu/goms/vol16/iss1/1

Guindon, K. Y. 2011. Evaluating lethal and sub-lethal effects of catch-and-release angling in Florida's Central Gulf Coast recreational Atlantic tarpon (Megalops atlanticus) fishery. Graduate Theses and Dissertations. http://scholarcommons.usf.edu/etd/313.

Regulatory Impact Analysis of Proposed Rule 15A NCAC 03O. 0108

Modifications to Standard Commercial Fishing License Transfers

Rule Amendments: 15A NCAC 03O .0108

Name of Commission: N.C. Marine Fisheries Commission

Agency Contact:
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Impact Summary:

State government:	Yes
Local government:	No
Federal government:	No
Substantial impact:	No

Authority:

G.S. 113-168	Definitions
G.S. 113-168.2	Standard Commercial Fishing License
15A NCAC 03O. 0400	Standard Commercial License Eligibility

Necessity: Over the past couple of years, concern has been raised by the Marine Fisheries Commission (MFC) about the types of license transfers allowed by statute and MFC rule. The current statute governing Standard Commercial Fishing License (SCFL) license transfers (113-168.2) allows transfers under very specific conditions and does not include transfers for licenses held by businesses. Excluding business entities from participating in a license transfer could ultimately result in those entities being removed from the commercial fishery. As a result, the license transfer rule (15A NCAC 03O .0108; Appendix I) was evaluated and several changes to the rule were requested by the MFC to allow more flexibility to transfer a license while ensuring clarity in the rule to avoid potential loopholes.

The anticipated effective date of the proposed rule changes is May 1, 2020.

I. Summary

Over the past couple of years, concerns have been raised by the MFC regarding the license transfer process. The statute authorizing license transfers (G.S. 113-168.2; Appendix II) only recognizes five circumstances as a legal basis for completion of a SCFL transfer. However, the statute delegates to the MFC the authority to establish in rule additional circumstances under which a transfer is allowed. The five conditions defined in statute that allow for a SCFL transfer do not allow for a transfer of a license owned by a business. Excluding business entities from participating in a license transfer could ultimately result in those entities being removed from the commercial fishery in the event a transfer is needed to facilitate their business needs. As a result, the license transfer rule (15A NCAC 03O .0108; Appendix I) was evaluated and several changes to the rule were requested by the MFC. The primary goal of the rule change is to allow more flexibility to transfer a license to ensure license holders are not unintentionally removed from the commercial fishing industry while ensuring clarity in the rule to avoid potential loopholes.

The proposed amendments to this rule add language that would allow for additional scenarios under which a transfer of a SCFL would be authorized such as those to and/or from a business entity. This rule change would also allow the transfer of a SCFL between individual business owners and their businesses in the event a business is created, sold, or dissolved. Related changes include expanding the requirements of certification forms used by the division to confirm the person being transferred the license is eligible and the addition of family members recognized in the SCFL Eligibility Criteria rule (15A NCAC 03O .0404; Appendix III) that are not part of the "immediate family" definition defined in G.S. 113-168 (Appendix II).

II. Introduction and Purpose of Rule Changes

The SCFL is the main commercial fishing license issued in North Carolina. This license allows fishermen to participate in commercial fishing in state waters and allows them to sell their catch to licensed seafood dealers. This license is available to individuals and businesses. Individuals age 65 or older are eligible for a Retired Standard Commercial Fishing License at a reduced fee. Fees for both types of licenses are set in statute. For the remainder of this document, the term "SCFL" will refer to both Standard and Retired Standard Commercial Fishing Licenses. A SCFL can be transferred to another individual in the event of the death or retirement of a license holder or can be transferred to a member of the license owner's immediate family at any time. There is no limit on the number of times a single license can be transferred, and the license must be active to be eligible for transfer. An active license is one that is not expired and is not suspended or revoked because of fisheries violations. Over the last 10 years, there are on average 6,600 SCFLs issued per year and around 475 transfers of this license type are completed annually.

In 1999, a cap was set on the number of SCFLs that could be issued resulting in only three ways to obtain a SCFL after that date:

1. Renew a SCFL already owned.
2. Apply through the eligibility board for a new license.
3. Receive a license transferred to you from another SCFL holder.

Due to the limited opportunities to obtain a SCFL, many license holders who do not actively use their license continue to renew it every year to avoid losing it, otherwise resulting in the license reverting back to the eligibility pool. The eligibility board was established by the Fisheries Reform Act of 1997 (S.L. 1997-400; 1998-225) to provide a mechanism for new fishermen to obtain a SCFL without having owned one in the past. The process and criteria used by the board to determine if an applicant is eligible for a license is outlined in rule (15A NCAC 03O .0400). Typically, the board meets twice a year to review applications received and grant licenses to qualified applicants. On average, there are about 60 licenses issued from the eligibility pool per fiscal year.

Over time, the complexities of business practices within the commercial fishing industry introduced additional scenarios that would require a transfer and brought to light the broader needs of businesses to transfer licenses and to codify those transactions in rule as authorized by statute. Concerns were brought forward by the MFC regarding the possibility of introducing loopholes in the transfer process and some transfers not meeting the requirements set out in the statute (G.S. 113-168.2; Appendix II).

The statute only recognizes five circumstances as a legal basis for completion of a SCFL transfer. However, the statute delegates to the MFC the authority to establish in rule additional circumstances under which a transfer is allowed. The five conditions defined in statute that would allow for a SCFL transfer have limitations and do not meet the needs of some license holders.

One of those limitations includes not allowing for a transfer of a license owned by a business. Excluding business entities from participating in a license transfer could result in those entities being removed from the commercial fishery in the event a transfer is needed to facilitate their business needs. The most common way to transfer a license is to an immediate family member as defined in G.S. 113-168 (Appendix II). The statute defining immediate family does not include grandparents, grandchildren, and legal guardians but these family members are included in the SCFL Eligibility Criteria rule (15A NCAC 03O .0404; Appendix III), which would allow them to obtain a license through the eligibility pool. Due to these limitations and inconsistencies, members of the MFC requested several amendments to the SCFL transfer rule to define additional circumstances that would allow a SCFL transfer to be processed. The proposed amendments will provide more flexibility to ensure license holders are not unintentionally removed from the commercial fishing industry while ensuring clarity in the rule to avoid potential loopholes. The proposed amendments achieve the following:

1. Additional family members will be added to the immediate family definition to allow grandparents, grandchildren, and legal guardians to be eligible for a SCFL or Retired SCFL transfer since they are recognized in the SCFL eligibility criteria rule.
2. The rule will confirm the presence of a certification statement from the transferee that affirms the information provided to the division is true and accurate, which is already required for any transfer but not explicitly stated in rule.
3. An individual holding a SCFL or Retired SCFL may transfer their license to a business in which the license holder is also an owner.
4. If a business is dissolved, the business may transfer the license or licenses of the business to an individual owner of the dissolved business contingent upon a notarized statement showing agreement of all owners of the business for the transfer.
5. If a business is sold, the business may transfer the license or licenses of the business to the successor business at the time of sale.
6. If an owner leaves a business, a license originally owned by that owner may be transferred back to that owner in an individual capacity at the time the owner leaves the business contingent upon a notarized statement showing agreement of all owners of the business for the transfer.
7. Only corporations and limited liability companies will qualify for these types of transfers. The proposed rule amendments address these types of businesses where assets are shared.
8. The term “owner” will include shareholder of a corporation and member of a limited liability company.

These rule amendments provide additional opportunities to transfer a SCFL. Specific requirements are outlined regarding business transfers to avoid ambiguity. There are nearly 200 businesses that hold SCFLs in North Carolina, the majority of which are corporations or limited liability companies. The assets of these business types are typically shared across multiple owners and allow for a separation of assets and risk from owners as an individual. The proposed amendments provide guidance for transferring between individual business owners and their businesses in the event a business is created, sold, or dissolved. Without these amendments, there is the potential for a business or business owner to be removed from the commercial fishing industry if their business becomes dissolved and they cannot renew the license held under their business name.

III. Benefits

License owners will benefit from the proposed rule amendments by being able to transfer their license under additional circumstances that are not included in the current statute but are authorized by the statute to be added to rule. This extra flexibility will prevent the loss of a license held under a business name and reduce the administrative burden on license holders that, for example, wish to transfer their license to a grandchild in the event their children are not interested in commercial fishing.

In Fiscal Year 2018, there were 179 businesses that held a SCFL. In the event any of these businesses are dissolved, the owner will be able to transfer their license under the proposed rule changes into their individual name and continue fishing under that commercial license. Under the current statute and rule, if a business dissolves, the owner is not able to renew any license held in the inactive business's name or transfer it to their individual name, which would result in the owner losing that commercial fishing license. If a license cannot be renewed, it is returned to the eligibility pool and the owner would have to submit an application to the eligibility board to obtain a new license. Depending on the timing of eligibility board meetings and when the company is dissolved, this could cause the owner to be removed from the commercial fishing industry for months while waiting to be approved for another license. If the owner does not meet the eligibility criteria they may not get another license granted to them, which would remove them from the commercial fishing industry all together. Allowing an individual to transfer their personal SCFL into their business name provides additional benefits to the license holder by allowing them to add their licenses to their business tax deductions as property needed or used to operate the business. The number of businesses that may take advantage of the transfers outlined in the proposed rule changes or how many would be removed from commercial fishing in the event the proposed rule changes do not become effective cannot be predicted; therefore, the benefit to the license holder cannot be quantified.

Each transfer is accompanied by a $10.00 replacement fee. The rule amendments discussed above allow for the potential for an increase in SCFL transfers in the future, resulting in a small increase in revenue collected by the division. It is not possible to anticipate the number of license holders that will opt to transfer their license in the future; therefore, the number of new transfers that may occur per fiscal year cannot be quantified. In Fiscal Year 2018, there were 6,164 SCFLs and Retired SCFLs issued and a total of 460 transfers of this license type occurred. Although highly unlikely, if the number of transfers increased by 50%, this would result in an additional 230 transfers per fiscal year and an additional $2,130 in revenue to the division per year.

IV. Costs

The cost to transfer a license is $10.00, resulting in a nominal cost to the license holder wishing to engage in the additional transfer opportunities outlined in the proposed rule. There are no other anticipated costs associated with the proposed rule changes, as any additional transfers that occur can be accommodated using existing division software, staff, and transfer procedures. Administrative forms may need to be updated, but this does not result in any measurable cost to the agency. This would be absorbed into opportunity costs already included as part of normal job duties. Ensuring license transfers are processed according to statute and rule is handled administratively within the License and Statistics Section and does not impact Marine Patrol staff; therefore, there is no impact on enforcement.

Appendix I Proposed Rule Changes:

15A NCAC 03O .0108 LICENSE <u>AND COMMERCIAL FISHING VESSEL REGISTRATION</u> TRANSFERS

<u>(a) To transfer a license or Commercial Fishing Vessel Registration, the license or registration cannot be expired prior to transfer.</u>

<u>(b) Upon transfer of a license or Commercial Fishing Vessel Registration, the transferee becomes the licensee and assumes the privileges of holding the license or Commercial Fishing Vessel Registration.</u>

<u>(c) A transfer application including a certification statement form shall be provided by the Division of Marine Fisheries. A transfer application shall be completed for each transfer including, but not limited to:</u>

<u>(1) the information required as set forth in Paragraph (a) of Rule .0101 of this Section;</u>

<u>(2) a certified statement from the transferee listing any violations involving marine and estuarine resources in the State of North Carolina during the previous three years; and</u>

<u>(3) a certified statement from the transferee that the information and supporting documentation submitted with the transfer application is true and correct, and that the transferee acknowledges that it is unlawful for a person to accept transfer of a license for which they are ineligible.</u>

<u>(d) A properly completed transfer application shall be returned to an office of the Division by mail or in person, except as set forth in Paragraph (e) of this Rule.</u>

<u>(e) A transfer application submitted to the Division without complete and required information shall be deemed incomplete and shall not be considered further until resubmitted with all required information. Incomplete applications shall be returned to the applicant with deficiency in the application so noted.</u>

~~(a)~~<u>(f)</u> ~~Licenses~~ <u>A License</u> to Land Flounder from the Atlantic Ocean ~~may~~ <u>shall</u> only be transferred:

(1) with the transfer of the ownership of a vessel that the licensee owns that individually met the eligibility requirements of ~~15A NCAC 3O .0101 (b) (1) (A) and (b) (1) (B)~~ <u>Sub-Part (b)(1)(A) and (b)(1)(B) of Rule .0101 of this Section</u> to the new owner of ~~that vessel. Transfer of the License to Land Flounder from the Atlantic Ocean transfers all flounder landings from the Atlantic Ocean associated with~~ that vessel; or

(2) by the owner of a vessel to another vessel under the same ownership.

<u>Transfer of a License to Land Flounder from the Atlantic Ocean transfers with it all flounder landings from the Atlantic Ocean associated with that vessel.</u> Any transfer of license under this Paragraph ~~may~~ <u>shall</u> only be processed through the Division of Marine Fisheries Morehead City <u>Headquarters</u> Office and no transfer is effective until approved and processed by the Division.

~~(b)~~<u>(g)</u> <u>Transfer of a</u> Commercial Fishing Vessel ~~Registration Transfer.~~ <u>Registration:</u> ~~When~~ <u>if</u> transferring ownership of a vessel bearing a current ~~commercial fishing vessel registration,~~ <u>Commercial Fishing Vessel Registration,</u> the new ~~owner~~ <u>owner;</u>

<u>(1)</u> shall follow the requirements in ~~15A NCAC 03O .0101~~<u>Rule .0101 of this Section</u> and pay a replacement fee ~~of ten dollars ($10.00)~~ <u>as set forth in Rule .0107 of this Section</u> for a replacement ~~commercial fishing vessel registration.~~ <u>Commercial Fishing Vessel Registration; and</u>

<u>(2)</u> ~~The new owner must~~ <u>shall</u> submit a <u>transfer</u> ~~form~~ <u>application</u> ~~provided by the Division~~ with the signatures of the former ~~licensee~~ <u>owner</u> and ~~the signature of~~ the new ~~licensee~~ <u>owner</u> notarized.

~~(c)~~(h) Transfer of a Standard or Retired Standard Commercial Fishing ~~License transfers:~~License:

(1) It is unlawful for a person to accept transfer of a Standard or Retired Standard Commercial Fishing License for which they are ineligible.

~~(1)~~(2) A Standard or Retired Standard Commercial Fishing License ~~may~~ shall only be transferred if both the transferor and the transferee have no current suspensions or revocations of any Marine Fisheries license privileges. In the event of the death of the transferor, this requirement shall only apply to the transferee.

(3) For purposes of effecting transfers under this Paragraph:

(A) in addition to those family members defined in 113-168(3a), "immediate family" shall mean grandparents, grandchildren, and legal guardians of an individual;

(B) “business” shall mean corporations and limited liability companies that have been registered with the Secretary of State; and

(C) “owner” shall mean owner, shareholder, or manager of a business.

~~(2)~~(4) At the time of the transfer of a Standard or Retired Standard Commercial Fishing License, the transferor ~~must~~ shall indicate the retainment or transfer of the landings history associated with that Standard or Retired Standard Commercial Fishing License. The transferor may retain a landings history only if the transferor holds an additional Standard or Retired Standard Commercial Fishing License. Transfer of a landings history is all or none.

~~(3)~~(5) To transfer a Standard or Retired Standard Commercial Fishing License, the following information is required:

(A) information on the transferee as set ~~out~~ forth in ~~15A NCAC 03O .0101;~~Rule .0101 of this Section;

(B) notarization of the ~~current license holder's~~ transferor’s and the transferee's signatures on ~~a~~ the transfer ~~form provided by the Division;~~application; and

~~(C) when the transferee is a non-resident, a written certified statement from the applicant listing any violations involving marine and estuarine resources during the previous three years;~~

~~(D)~~(C) ~~when~~ if the transferor is retiring from commercial fishing, ~~the transferor must submit~~ evidence showing that such retirement has in fact occurred, ~~for example,~~ which may include, but is not limited to, evidence of the transfer of all ~~licensee's~~ the transferor’s Standard Commercial Fishing Licenses, sale of all the ~~licensee's~~ transferor’s registered vessels, or discontinuation of any active involvement in commercial fishing.

~~Properly completed transfer forms must be returned to Division Offices by mail or in person.~~

~~(4)~~(6) The Standard or Retired Standard Commercial Fishing License ~~which~~ that is being transferred ~~must~~ shall be surrendered to the Division at the time of the transfer application.

~~(5)~~(7) Fees:

(A) ~~Transferee~~ The transferee ~~must~~ shall pay a replacement fee ~~of ten dollars ($10.00).~~as set forth in Rule .0107 of this Section.

(B) ~~Transferee~~ The transferee ~~must~~ shall pay the differences in fees as specified in G.S. ~~113-168.2 (e)~~ 113-168.2(e) or G.S. ~~113-168.3 (b)~~ 113-168.3(b) ~~when~~ if the transferee ~~who~~ is a ~~non-resident~~ ~~is being transferred a resident Standard or Retired Standard Commercial Fishing License.~~ non-resident.

(C) ~~Transferee~~ The transferee ~~must~~ shall pay the differences in fees as specified in G.S. ~~113-168.2 (e)~~ 113-168.2(e) ~~when~~ if the license to be transferred is a Retired Standard Commercial Fishing License and the transferee is less than 65 years old.

(8) Transfer of Standard or Retired Standard Commercial Fishing License for a Business:

(A) An individual holding a Standard or Retired Standard Commercial Fishing License may transfer their license to a business in which the license holder is also an owner of the business in accordance with application requirements as set for in Sub-Paragraph (a) of Rule .0101 of this Section.

(B) If a business is dissolved, the business may transfer the license or licenses of the business to an individual owner of the dissolved business. A dissolved business holding multiple licenses may transfer one license or multiple licenses to one owner or multiple owners or any combination thereof. A notarized statement showing agreement for the transfer of all owners of the business is required to complete this transaction.

(C) If a business is sold, the business may transfer the license or licenses of the business to the successor business at the time of sale.

(D) If an owner leaves the business, any license originally owned by that owner may be transferred back to themselves as an individual at the time the owner leaves the corporation. A notarized statement showing agreement for the transfer of all owners of the business is required to complete this transaction.

~~(6)~~(9) Transfer of Standard or Retired Standard Commercial Fishing License for a Deceased ~~Licensees:~~Licensee:

(A) ~~When the deceased licensee's~~ If an immediate surviving family ~~member(s)~~ member of the deceased licensee is eligible to hold the ~~deceased=s~~ deceased licensee's Standard Commercial Fishing ~~Licenses~~ License or Retired Standard Commercial Fishing License, the Administrator/Executor must give written notification within six months after the Administrator/Executor qualifies under ~~G. S.~~G.S. 28A to the ~~Morehead City Office of the~~ Division ~~of Marine Fisheries~~ of the request to transfer the ~~deceased=s~~ deceased's license to the estate Administrator/Executor.

(B) A transfer to the Administrator/Executor shall be made according to the provisions of ~~Subparagraphs (c (2) - (c) (4)~~Sub-Paragraphs (h)(2)-(h)(4) of this Rule. The Administrator/Executor must provide a copy of the deceased licensee's death certificate, a copy of the certificate of ~~administration~~ administration, and a list of eligible immediate family members to the ~~Morehead City Office of the Division of Marine Fisheries.~~Division.

(C) The Administrator/Executor ~~may~~ shall only transfer a license in the Administrator/Executor name on behalf of the estate to ~~a~~ an eligible surviving family member. The surviving family member transferee ~~may~~ shall only transfer the license to a third party purchaser of the deceased licensee's fishing vessel. Transfers shall be made according to the provisions of ~~Subparagraphs (c) 2 - (c) (4)~~ Sub-Paragraphs (h)(2)-(h)(4) of this Rule.

~~(d) Transfer forms submitted without complete and required information shall be deemed incomplete and will not be considered further until resubmitted with all required information.~~

~~(e) It is unlawful for a person to accept transfer of a Standard or Retired Standard Commercial Fishing License for which they are ineligible.~~

History Note: Authority G.S. 113-134; 113-168.1; 113-168.2; 113-168.3; 113-168.6; 113-182; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. March 1, 1994;
Temporary Amendment Eff. August 1, 1999; July 1, 1999;
Amended Eff. August 1, 2000;
Readopted Eff. May 1, 2020.

Appendix II Current General Statutes:

§ 113-168. Definitions.

As used in this Article:

(1) "Commercial fishing operation" means any activity preparatory to, during, or subsequent to the taking of any fish, the taking of which is subject to regulation by the Commission, either with the use of commercial fishing equipment or gear, or by any means if the purpose of the taking is to obtain fish for sale. Commercial fishing operation does not include (i) the taking of fish as part of a recreational fishing tournament, unless commercial fishing equipment or gear is used, (ii) the taking of fish under a RCGL, or (iii) the taking of fish as provided in G.S. 113-261.

(2) "Commission" means the Marine Fisheries Commission.

(3) "Division" means the Division of Marine Fisheries in the Department of Environmental Quality.

(3a) "Immediate family" means the mother, father, brothers, sisters, spouse, children, stepparents, stepbrothers, stepsisters, and stepchildren of a person.

(4) "License year" means the period beginning 1 July of a year and ending on 30 June of the following year.

(5) "North Carolina resident" means a person who is a resident within the meaning of G.S. 113-130(4).

(6) "RCGL" means Recreational Commercial Gear License.

(7) "RSCFL" means Retired Standard Commercial Fishing License.

(8) "SCFL" means Standard Commercial Fishing License. (1997-400, s. 5.1; 1997-443, s. 11A.119(b); 1998-225, s. 4.9; 2001-213, s. 2; 2004-187, s. 6; 2015-241, s. 14.30(u).)

§ 113-168.2. Standard Commercial Fishing License.

(a) Requirement. - Except as otherwise provided in this Article, it is unlawful for any person to engage in a commercial fishing operation in the coastal fishing waters without holding a SCFL issued by the Division. A person who works as a member of the crew of a vessel engaged in a commercial fishing operation under the direction of a person who holds a valid SCFL is not required to hold a SCFL. A person who holds a SCFL is not authorized to take shellfish unless the SCFL is endorsed as provided in G.S. 113-168.5.

(a1) Use of Vessels. - The holder of a SCFL is authorized to use only one vessel in a commercial fishing operation at any given time. The Commission may adopt a rule to exempt from this requirement a person in command of a vessel that is auxiliary to a vessel engaged in a pound net operation, long-haul operation, or beach seine operation. A person who works as a member of the crew of a vessel engaged in a mechanical shellfish operation under the direction of a person who holds a valid SCFL with a shellfish endorsement is not required to hold a shellfish license.

(b) through (d) Repealed by Session Laws 1998-225, s. 4.11, effective July 1, 1999.

(e) Fees. - The annual SCFL fee for a resident of this State shall be four hundred dollars ($400.00). The annual SCFL fee for a person who is not a resident of this State shall be the amount charged to a resident of this State in the nonresident's state. In no event, however, may the fee be less than four hundred dollars ($400.00). For purposes of this subsection, a "resident of this State" is a person who is a resident within the meaning of:

(1) Sub-subdivisions a. through d. of G.S. 113-130(4) and who filed a State income tax return as a resident of North Carolina for the previous calendar or tax year, or

(2) G.S. 113-130(4)e.

(f) Assignment. - The holder of a SCFL may assign the SCFL to any individual who is eligible to hold a SCFL under this Article. It is unlawful for the holder of an SCFL to assign a shellfish endorsement of an SCFL to any individual who is not a resident of this State. The assignment shall be in writing on a form provided by the Division and shall include the name of the licensee, the license number, any endorsements, the assignee's name, mailing address, physical or residence address, and the duration of the assignment. If a notarized copy of an assignment is not filed with the Morehead City office of the Division within five days of the date of the assignment, the assignment shall expire. It is unlawful for the assignee of a SCFL to assign the SCFL. The assignment shall terminate:

(1) Upon written notification by the assignor to the assignee and the Division that the assignment has been terminated.

(2) Upon written notification by the estate of the assignor to the assignee and the Division that the assignment has been terminated.

(3) If the Division determines that the assignee is operating in violation of the terms and conditions applicable to the assignment.

(4) If the assignee becomes ineligible to hold a license under this Article.

(5) Upon the death of the assignee.

(6) If the Division suspends or revokes the assigned SCFL.

(7) At the end of the license year.

(g) Transfer. - A SCFL may be transferred only by the Division. A SCFL may be transferred pursuant to rules adopted by the Commission or upon the request of:

(1) A licensee, from the licensee to a member of the licensee's immediate family who is eligible to hold a SCFL under this Article.

(2) The administrator or executor of the estate of a deceased licensee, to the administrator or executor of the estate if a surviving member of the deceased licensee's immediate family is eligible to hold a SCFL under this Article. The administrator or executor must request a transfer under this subdivision within six months after the administrator or executor qualifies under Chapter 28A of the General Statutes. An administrator or executor who holds a SCFL under this subdivision may, for the benefit of the estate of the deceased licensee:

a. Engage in a commercial fishing operation under the SCFL if the administrator or executor is eligible to hold a SCFL under this Article.

b. Assign the SCFL as provided in subsection (f) of this section.

c. Renew the SCFL as provided in G.S. 113-168.1.

(3) An administrator or executor to whom a SCFL was transferred pursuant to subdivision (2) of this subsection, to a surviving member of the deceased licensee's immediate family who is eligible to hold a SCFL under this Article.

(4) The surviving member of the deceased licensee's immediate family to whom a SCFL was transferred pursuant to subdivision (3) of this subsection, to a third-party purchaser of the deceased licensee's fishing vessel.

(5) A licensee who is retiring from commercial fishing, to a third-party purchaser of the licensee's fishing vessel.

(h) Identification as Commercial Fisherman. - The receipt of a current and valid SCFL or shellfish license issued by the Division shall serve as proper identification of the licensee as a commercial fisherman.

(i) Record-Keeping Requirements. - The fish dealer shall record each transaction at the time and place of landing on a form provided by the Division. The transaction form shall include the information on the SCFL or shellfish license, the quantity of the fish, the identity of the fish dealer, and other information as the Division deems necessary to accomplish the purposes of this Subchapter. The person who records the transaction shall provide a completed copy of the transaction form to the Division and to the other party of the transaction. The Division's copy of each transaction form shall be transmitted to the Division by the fish dealer on or before the tenth day of the month following the transaction. (1997-400, s. 5.1; 1998-225, s. 4.11; 2001-213, s. 2; 2013-360, s. 14.8(b); 2013-384, s. 2(c); 2014-100, s. 14.9(b).)

Appendix III Current Rules:

15A NCAC 03O .0404 ELIGIBILITY CRITERIA

In determining eligibility of an application for the Standard Commercial Fishing License Eligibility Pool, the Eligibility Board shall apply the following criteria:

(1) Involvement in Commercial Fishing:

(a) Significant involvement in the commercial fishing industry for three of the last five years; or

(b) Significant involvement in commercial fishing or in the commercial fishing industry prior to the last five years; or

(c) In the case of an applicant who is under 16 years of age, significant involvement in commercial fishing for two out of the last five years with a parent, legal guardian, grandparent or other adult; or

(d) Significant involvement of the applicant's family in commercial fishing. For the purpose of this Sub-item, family shall include mother, father, brother, sister, spouse, children, grandparents or legal guardian.

For the purposes of this Rule, significant involvement means persons or corporations who are engaged in the actual taking of fish for sale, from the waters of the State, or other states, jurisdictions, or federal waters, or any licensed dealer or the dealer's employees who purchases fish at the point of landing. Significant involvement does not include activities such as those who transport fish from the point of landing; those who sell or make commercial or recreational fishing gear; those who operate bait and tackle shops unless they are engaged in the actual taking of bait for sale; or those who work in fish markets or crab picking operations.

(2) Compliance with Applicable Laws and Regulations:

(a) The applicant shall not have any licenses, endorsements or commercial fishing vessel registrations issued by the Division of Marine Fisheries or the right to hold such under suspension or revocation at the time of application or during the eligibility review; or

(b) If selected for the Standard Commercial Fishing License Eligibility Pool, the applicant shall become ineligible for the Standard Commercial Fishing License Eligibility Pool if any licenses, endorsements or registrations or the right to hold such issued by the Division of Marine Fisheries are suspended or revoked; or

(c) Four convictions within the last three years or the number of convictions which would cause suspension or revocation of license, endorsement, or registration within the last three years shall result in the application being denied; or

(d) A record of habitual violations evidenced by eight or more convictions in the last 10 years shall result in the application being denied.

For purposes of eligibility for the Standard Commercial Fishing License Eligibility Pool, the term convictions shall include but not be limited to any conviction for violation of any provision of Chapter 113 of the North Carolina General Statutes and any rule implementing or authorized by such statutes; any conviction for violation of G.S. 76-40 and any rule implementing or authorized by such statute; any conviction of Chapter 75A of the North Carolina General Statutes and any rule implementing or authorized by such statutes; any conviction for violation of any provision of Article 7 of Chapter 143B of the North Carolina General Statutes and any rule implementing or authorized by such statutes; any conviction of resist, obstruct, or delay involving a Marine Patrol Officer or Wildlife Officer under G.S. 14-223; and any conviction involving assaultive behavior toward a Marine Patrol Officer or other governmental official of the Department of Environment and Natural Resources or the Wildlife Commission.

Applicants for the Standard Commercial Fishing License Eligibility Pool must provide certification that the applicant does not have four or more marine or estuarine resource violations during the previous three years.

(3) The responsible party shall not have transferred a Standard Commercial Fishing License granted by the Eligibility Board.

(4) All applicants for the Standard Commercial Fishing License Eligibility Pool must meet all other statutory eligibility requirements for the Standard Commercial Fishing License.

History Note: Authority G.S. 113-134; 113-168.1; 113-168.2; 143B-289.52; S.L. 1998-225, s. 4.24;
Temporary Adoption Eff. April 1, 1999;
Eff. August 1, 2000;
Amended Eff. October 1, 2008; February 1, 2008.

ROY COOPER
Governor
MICHAEL S. REGAN
Secretary
STEPHEN W. MURPHEY
Director

August 7, 2019

MEMORANDUM

TO: Marine Fisheries Commission

FROM: Kathy Rawls, Fisheries Management Section Chief

SUBJECT: Temporary Rule Suspension

Issue
In accordance with the North Carolina Division of Marine Fisheries Resource Management Policy Number 2014-2, Temporary Rule Suspension, the North Carolina Marine Fisheries Commission will vote on any new rule suspensions that have occurred since the last meeting of the commission.

Findings
The suspension of portions of North Carolina Marine Fisheries Commission Rule 15A NCAC 03L .0103 (a)(1) occurred since the May 2019 meeting, is subject to commission approval and is noted as an action item on the agenda.

Action Needed
The commission is scheduled to vote on approval of the continued suspension of portions of rule 15A NCAC 03L. 0103 (a)(1).

Overview
In accordance with the North Carolina Division of Marine Fisheries Resource Management Policy Number 2014-2, the North Carolina Marine Fisheries Commission will vote on any new rule suspensions that have occurred since the last meeting of the commission. The following rule suspension occurred since the May 2019 meeting, is subject to approval and is noted as an action item on the agenda:

- Suspension of portions of North Carolina Marine Fisheries Commission Rule 15A NCAC 03L .0103 (a)(1) Prohibited Nets, Mesh Lengths and Areas, for an indefinite period of time. Suspension of this rule allows the division to adjust trawl net minimum mesh size requirements in accordance with the May 2018 Revision to Amendment 1 to the North Carolina Shrimp Fishery Management Plan. This suspension was implemented in proclamation SH-3-2019.

State of North Carolina | Division of Marine Fisheries
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In accordance with policy, the division will report current rule suspensions previously approved by the commission as non-action, items. The current rule suspensions previously approved by the commission are as follows:

- Continued suspension of North Carolina Marine Fisheries Commission Rule 15A NCAC 03M .0516 Cobia, for an indefinite period of time. This continued suspension allows the division to manage the commercial and recreational cobia fisheries in accordance with management actions taken by the commission and in accordance with the Atlantic States Marine Fisheries Commission's Interstate Cobia Fishery Management Plan. This suspension was continued in Proclamation FF-10-2019.

- Continued suspension of portions of North Carolina Marine Fisheries Commission Rule 15A NCAC 03J .0301 Pots, for an indefinite period of time. This continued suspension allows the division to implement the crab pot escape ring requirements adopted by the commission in the May 2016 Revision to Amendment 2 of the North Carolina Blue Crab Fishery Management Plan. This suspension was implemented in Proclamation M-11-2016.

- Continued suspension of portions of North Carolina Marine Fisheries Commission Rule 15A NCAC 03L .0201 Crab Harvest Restrictions, and portions of 03L .203 Crab Dredging, for an indefinite period of time. This continued suspension allows the division to implement the blue crab harvest restrictions adopted by the commission in the May 2016 Revision to Amendment 2 of the North Carolina Blue Crab Fishery Management Plan. These suspensions were implemented in Proclamation M-11-2016.

- Continued suspension of portions of North Carolina Marine Fisheries Commission Rule 15A NCAC 03J .0501 Definitions and Standards for Pound Nets and Pound Net Sets, for an indefinite period of time. Continued suspension of portions of this rule allows the division to increase the minimum mesh size of escape panels for flounder pound nets in accordance with Supplement A to Amendment 1 of the North Carolina Southern Flounder Fishery Management Plan. This suspension was implemented in Proclamation M-34-2015.

- Continued suspension of portions of North Carolina Marine Fisheries Commission Rule 15A NCAC 03M .0519 Shad and 03Q .0107 Special Regulations: Joint Waters, for an indefinite period of time. Continued suspension of portions of these rules allows the division to change the season and creel limit for American shad under the management framework of the North Carolina American Shad Sustainable Fishery Plan. These suspensions were continued in Proclamation FF-12-2019.