DRAFT
North Carolina Estuarine Striped Bass Fishery Management Plan Amendment 2

By

North Carolina Division of Marine Fisheries
and
Wildlife Resources Commission

North Carolina Department of Environmental Quality
North Carolina Division of Marine Fisheries
3441 Arendell Street
P. O. Box 769
Morehead City, NC 28557

DRAFT – SUBJECT TO CHANGE

This document may be cited as:

DMF (North Carolina Division of Marine Fisheries). 2022. North Carolina Estuarine Striped Bass Fishery Management Plan, Draft Amendment 2. North Carolina Division of Marine Fisheries, Morehead City, North Carolina. XXX p.

Disclaimer: Data in this Fishery Management Plan may have changed since publication based on updates to source documents.

ACKNOWLEDGEMENTS

Amendment 2 to the North Carolina (NC) Estuarine Striped Bass Fishery Management Plan (FMP) was developed jointly by the NC Department of Environmental Quality (NCDEQ), Division of Marine Fisheries (DMF) and the NC Wildlife Resources Commission (WRC) under the auspices of the NC Marine Fisheries Commission (MFC) with the advice of the Estuarine Striped Bass Advisory Committee (AC). Deserving special recognition are the members of the Estuarine Striped Bass AC and the DMF Plan Development Team (PDT) who contributed their time and knowledge to this effort.

Estuarine Striped Bass Advisory Committee

Bill Blackwell
Stuart Creighton
Gregory Judy
Paul Lane
Jot Owen
Thomas Smith

Estuarine Striped Bass Plan Development Team

David Belkoski
April Boggs
William Boyd
Andrew Cathey
Sean Darsee
David Dietz
Joe Facendola
Charlton Godwin (Co-lead)
Nathaniel Hancock (Co-lead)
James Harrison
Daniel Ipock
Laura Lee
Yan Li
Brian Long
Justin Lott
Todd Mathes (Co-lead)
Jeremy McCargo
Lee Paramore
Jason Peters
Katy Potoka
Kyle Rachels
Ben Ricks
Jason Rock
Kirk Rundle
Christopher Smith
Scott Smith
Chris Stewart
Thomas Teears
Chad Thomas
Amanda Tong
Katy West (Mentor)
Chris Wilson
Todd VanMiddlesworth

The following division staff were also invaluable in assisting with the development of this document: Alan Bianchi, Corrin Flora, Tina Moore, Steve Poland, Kathy Rawls, Dan Zapf and the many reviewers of the multiple drafts of this plan. Also grateful for the administrative support from Deborah Manley, Jennifer Lewis, Dana Gillikin, Jesse Bissette, and Patricia Smith.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

This section to be completed prior to final adoption of the plan.

DRAFT – SUBJECT TO CHANGE

INTRODUCTION

This is Amendment 2 to the Estuarine Striped Bass Fishery Management Plan (FMP). By law, each FMP must be reviewed at least once every five years (G.S. 113-182.1). The NC Division of Marine Fisheries (DMF) reviews each FMP annually and a comprehensive review is undertaken about every five years jointly with the NC Wildlife Resources Commission (WRC). The last comprehensive review of the plan (Amendment 1) was approved by the NC Marine Fisheries Commission (MFC) in 2013. FMPs are the ultimate product that brings all information and management considerations into one document. The DMF prepares FMPs for adoption by the MFC for all commercially and recreationally significant species or fisheries that comprise state marine or estuarine resources. The goal of these plans is to ensure long-term viability of these fisheries.

North Carolina Striped Bass are managed as three separate stocks within four distinct areas: (1) Albemarle Sound Management Area (ASMA), (2) Roanoke River Management Area, (3) Central Southern Management Area (CSMA), and (4) Atlantic Ocean. The MFC adopts rules and policies and implements management measures for the estuarine striped bass fishery in Coastal Fishing Waters in accordance with 113-182.1. Estuarine Striped Bass is one of the two FMPs jointly developed and approved by the DMF and WRC. The migratory Atlantic Ocean stock is managed by the Atlantic States Marine Fisheries Commission (ASMFC). Until Amendment 2 is approved for management, striped bass are managed under Amendment 1, the November 2014 and November 2020 Revisions to Amendment 1, and the February 2019 Supplement A (DMF 2013, 2014, 2019, 2020).

FISHERY MANAGEMENT PLAN HISTORY

Original FMP Adoption:	January 1994 May 2004
Amendments:	Amendment 1 – May 2013
Revisions:	November 2014 November 2020
Supplements:	Supplement A – February 2019
Information Updates:	None
Schedule Changes:	August 2016
Comprehensive Review:	At least five years after Amendment 2 adoption

Past versions of the Estuarine Striped Bass FMP, Revisions, Amendment, and Supplement (DMF 2004, 2013, 2014, 2019, and 2020) are available on the DMF website.

MANAGEMENT UNIT

There are two geographic estuarine management units in North Carolina, the northern (A-R Stock) and the southern (CSMA). The northern management unit is comprised of two harvest management areas: the Roanoke River Management Area (RRMA) and the Albemarle Sound Management Area (ASMA; Figure 1). RRMA commercial regulations are the responsibility of the MFC, while recreational regulations are the responsibility of the WRC. Recreational and commercial striped bass regulations within the ASMA are the responsibility of the MFC. The ASMA is also subject to compliance with the ASMFC Interstate FMP for Atlantic Striped Bass. North Carolina manages the ASMA stock under the North Carolina Fishery Management Plan for Interjurisdictional Fisheries to ensure compliance with the ASMFC Interstate FMP for Atlantic Striped Bass. For more information see the DMF Fishery Management Plans website.

The southern geographic management unit is the Central Southern Management Area (CSMA) that is comprised of the Tar-Pamlico, Neuse, and Cape Fear rivers as well as Pamlico Sound. Management of striped bass within the CSMA is the sole responsibility of the MFC and the WRC.

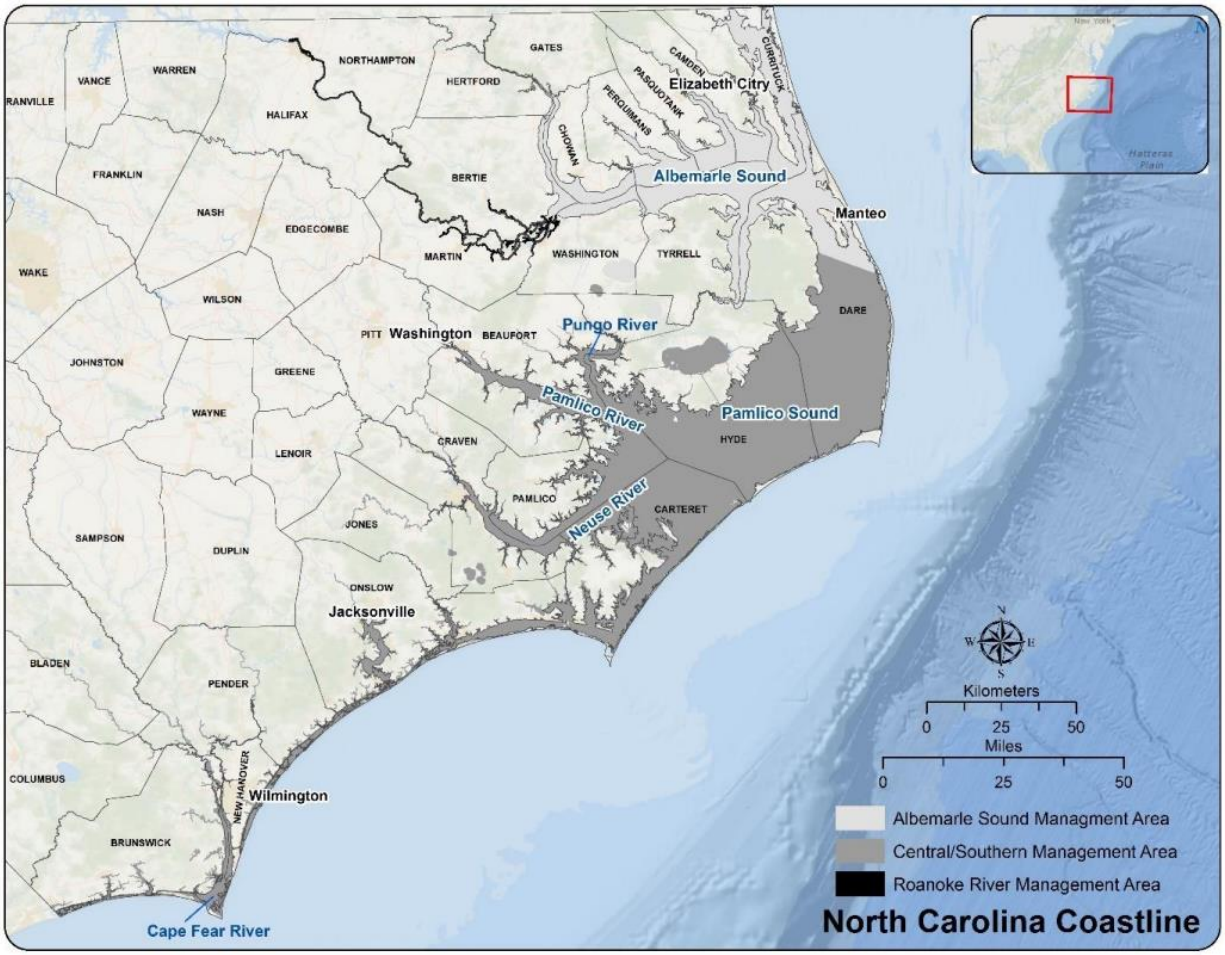

Figure 1. Boundary lines defining the Albemarle Sound Management Area, Central-Southern Management Area, and the Roanoke River Management Area.

GOAL AND OBJECTIVES

The goal of Amendment 2 is to manage the estuarine striped bass fisheries to achieve self-sustaining populations that provide sustainable harvest based on science-based decision-making processes. If biological and/or environmental factors prevent a self-sustaining population, then alternate management strategies will be implemented that provide protection for and access to the resource. The following objectives will be used to achieve this goal.

- Implement management strategies within North Carolina and encourage interjurisdictional management strategies that maintain and/or restore spawning stock with adequate age structure and abundance to maintain recruitment potential and to prevent overfishing.
- Restore, enhance, and protect critical habitat and environmental quality in a manner consistent with the Coastal Habitat Protection Plan, to maintain or increase growth, survival, and reproduction of the striped bass stocks.
- Use biological, social, economic, fishery, habitat, and environmental data to effectively monitor and manage the fisheries and their ecosystem impacts.
- Promote stewardship of the resource through public outreach and interjurisdictional cooperation regarding the status and management of the North Carolina striped bass stocks, including practices that minimize bycatch and discard mortality.

DESCRIPTION OF THE STOCK

BIOLOGICAL PROFILE

Striped bass (*Morone saxatilis*) are an estuarine dependent species found from the lower St. Lawrence River in Canada to the west coast of Florida, through the northern shore of the Gulf of Mexico to Texas. In North Carolina, the species is also known as striper, rockfish, or rock. The stocks from Maine to the Albemarle Sound-Roanoke River in North Carolina are migratory spending most of their adult life in the estuaries and ocean, before moving into fresh water to spawn in the spring. In the ASMA, large Roanoke River striped bass rapidly leave the river system after spawning and migrate north to ocean waters from New Jersey to Massachusetts. In the fall, these fish migrate south to ocean waters off Virginia and North Carolina (Callihan et al. 2015). Southern stocks, including the CSMA, are riverine, spending their entire life in the upper estuary and river systems (Setzler et al. 1980; Rulifson et al. 1982; Callihan 2012).

Striped bass are relatively long-lived and can reach 50 - 60 pounds. Females grow larger than males, with a reported maximum total length of 60 inches in various coastwide sampling programs. The oldest observed striped bass in the ASMA was 31 years, while within the CSMA the maximum suggested age was 17 years. The largest striped bass on record coastwide was caught in the early 1900s in Albemarle Sound weighing 125 pounds.

Striped bass form large schools, feeding on available fishes and invertebrates. Oily fish such as Atlantic menhaden (*Brevoortia tyrannus*), herrings (*Clupea* spp.) and shads (*Alosa* spp.) are common prey, but spot (*Leiostomus xanthurus*), mullet (*Mugil* spp.), Atlantic croaker (*Micropogonias undulatus*), American eel (*Anguilla rostrata*), and blue crabs (*Callinectes sapidus*) are also consumed.

Females in the A-R stock are 29% mature at age-3 and 97% mature at age-4 (Boyd 2011), while females in the Tar-Pamlico and Neuse rivers are 50% mature at 2.7 years and 98% mature by age-3 (Knight 2015). In the Tar-Pamlico and Neuse rivers, fecundity (ability to produce offspring) ranges from 223,110 eggs for an age-3 female to 3,273,206 eggs for an age-10 female (Knight 2015).

Female striped bass produce large quantities of eggs which are broadcast into riverine spawning areas and fertilized by mature males. Fertilized eggs drift with downstream currents hatching in 1.5 - 3 days. Striped bass require flowing, freshwater habitats to spawn successfully, allowing eggs to remain suspended until they hatch, and to transport fry to nursery areas. Environmental conditions including temperature, rainfall, and river flows are important factors influencing the number of juveniles produced annually. Spawning in North Carolina takes place from late March until early June. Peak spawning activity for the A-R stock occurs when water temperature reaches 62 - 67 degrees Fahrenheit in the Roanoke River at Weldon. Spawning grounds in the CSMA are not clearly defined as lock and dam systems block access to historic spawning grounds. This requires river flow changes to allow striped bass over the dams. The CSMA stocks are supported by continuous stocking efforts as evidenced by stocked fish comprising nearly 100% of the striped bass on the spawning grounds (O'Donnell and Farrae 2017). For more information on stocking see Appendix X: Striped Bass Stocking in Coastal North Carolina.

STOCK UNIT

There are four striped bass stocks in North Carolina: Albemarle-Roanoke (A-R), Tar-Pamlico, Neuse, and Cape Fear stocks.

ASSESSMENT METHODOLOGY

The A-R stock was assessed using Stock Synthesis through a forward-projecting statistical catch-at-age model which was applied to data characterizing landings/harvest, discards, fishery-independent indices, and biological data collected from 1991 through 2017 (Lee et. al 2020).

Traditional stock assessment techniques could not be applied to CSMA stocks because of high hatchery contribution and lack of natural recruitment in these systems. A demographic matrix model was developed to evaluate stocking and management measures for striped bass in all three CSMA river systems and a tagging model was developed to estimate striped bass abundance in the Cape Fear River.

STOCK STATUS

A-R Stock

The 2020 A-R striped bass stock assessment indicates the stock is overfished and overfishing is occurring (Lee et. al 2020). The estimate of fishing mortality (F) in the terminal year of the assessment (2017) was 0.27, greater than the $F_{35\%SPR\ Threshold}$ of 0.18 (Figure 2). The estimate of spawning stock biomass (SSB) was 78,576 pounds, less than the $SSB_{35\%SPR\ Threshold}$ of 267,390 pounds (Figure 3). The stock had a period of strong recruitment from 1993 to 2000, then a period

of low recruitment from 2001 - 2017. The complete stock assessment can be reviewed on the division Fishery Management Plans website.

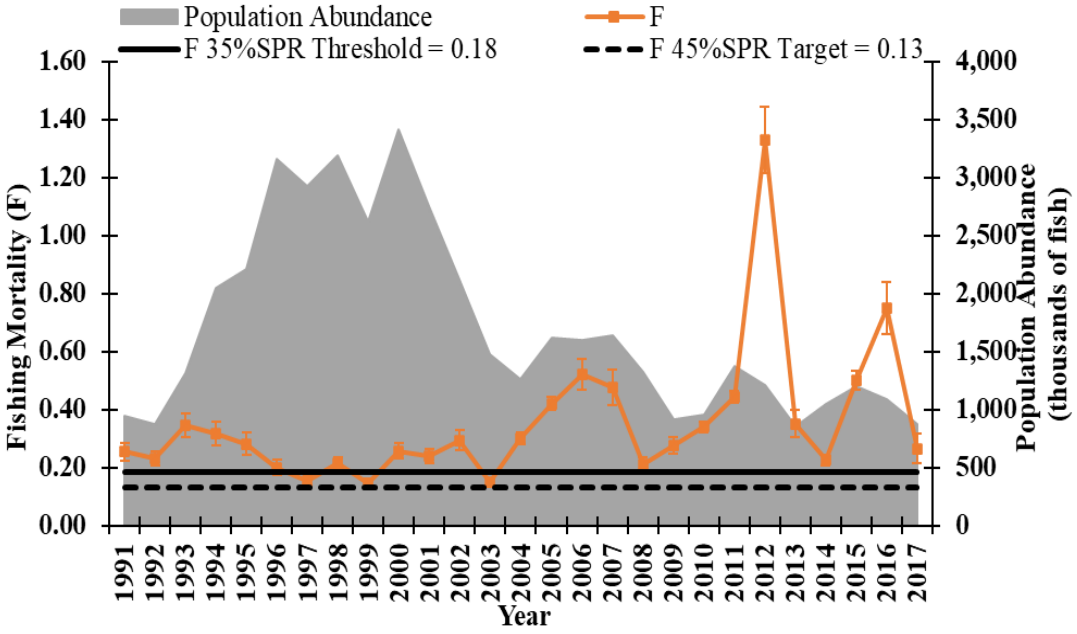

Figure 2. Estimates of fishing mortality (*F*) and population abundance for the Albemarle-Roanoke striped bass stock, 1991–2017. Error bars represent ± two standard errors. Source: Lee et al. 2020.

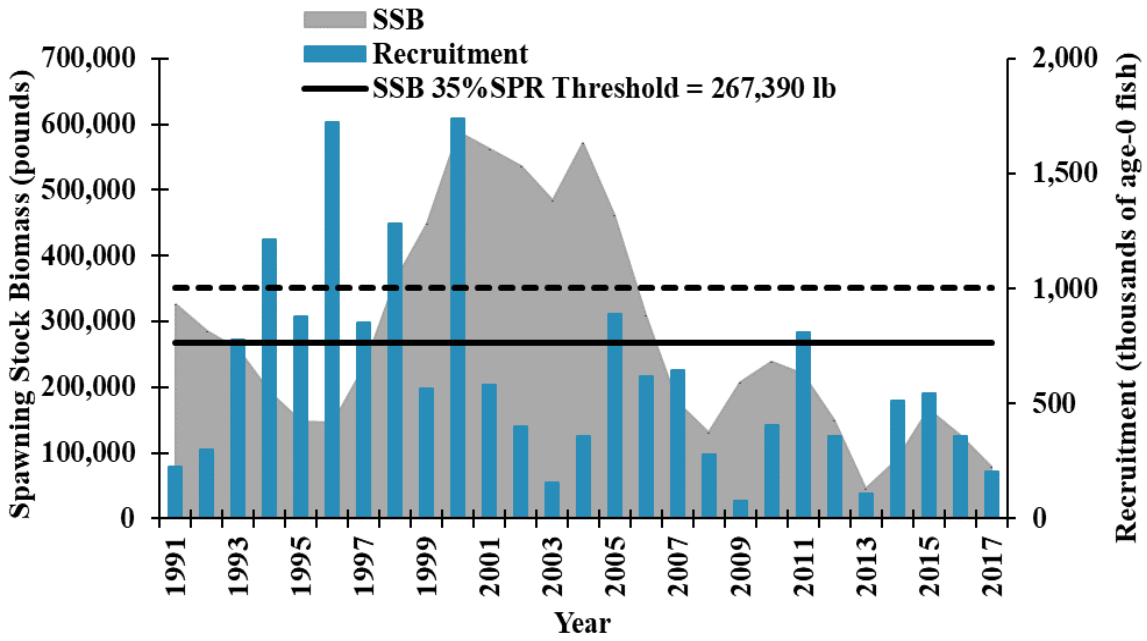

Figure 3. Estimates of spawning stock biomass (SSB) and recruitment of age-0 fish coming into the population each year for the Albemarle-Roanoke striped bass stock, 1991–2017. Source: Lee et al. 2020

CSMA Stocks

The demographic matrix model indicates the striped bass populations in the CSMA are depressed to an extent that sustainability is unlikely at any level of fishing mortality. The model suggests insufficient natural recruitment is the primary factor limiting population abundance of Tar-Pamlico and Neuse stocks and suggests the populations would decline if without stocking (Mathes et al. 2020). Tagging model results show a consistent decline in abundance estimates for striped bass in the Cape Fear River (2012–2018). Even with a no-possession provision for the Cape Fear River since 2008, 2018 abundance was less than 20% of the 2012 abundance. The complete stock assessment report can be reviewed on the division Fishery Management Plans website.

DESCRIPTION OF THE FISHERIES

Additional in-depth analyses and discussion of North Carolina's commercial and recreational striped bass fisheries can be found in earlier versions of the Estuarine Striped Bass FMP, Revisions, Amendment 1, and Supplement A (DMF 2004, 2013, 2014, 2019, and 2020); all FMP documents are available on the DMF Fishery Management Plans website and commercial and recreational landings can be found in the License and Statistics Annual Report (DMF 2020) produced by the DMF which can be found on the DMF Fisheries Statistics page, including a report entitled North Carolina Striped Bass (Marone saxatilis) Commercial Fishery (Gambill and Bianchi 2019).

COMMERCIAL FISHERIES

ASMA

Under Amendment 1, the ASMA commercial striped bass fishery is a bycatch fishery, meaning striped bass harvest occurs while targeting other finfish species. Striped bass cannot be greater than 50% by weight of all other finfish species landed per trip. Daily landing limits of 5–25 striped bass further prevent fishermen from targeting striped bass and aim to ensure striped bass quota remains during times when multispecies gill net fisheries are operating. Most striped bass harvest occurs in conjunction with the American shad (*Alosa sapidissima*) anchored gill net fishery in the spring, followed by the southern flounder (*Paralichthys lethostigma*) anchored gill net fishery in the fall. Since 2015, as a commercial fishery for invasive blue catfish (*Ictalurus furcatus*) has developed, more striped bass landings have occurred in this strike gill net fishery. Strike nets are fished by locating a school of fish, encircling the school with a gill net, then immediately retrieving the net. Harvest from pound nets is the second leading harvest gear with an average of 20% of the total harvest since 2010.

Commercial landings in the ASMA have been limited by annual total allowable landings (TAL) since 1991. Due to gill net mesh size regulations and minimum striped bass size limits since 1993, most harvest consists of fish 4 - 6 years of age. From 1990 through 1997 the TAL was set at 98,000 pounds because the A-R stock was at historically low levels of abundance and was rebuilding. The stock was declared recovered in 1997 and the TAL was gradually increased as stock abundance increased. The TAL reached its maximum level of 275,000 pounds in 2003 as the stock reached record levels of abundance.

As stock abundance declined beginning in 2004, commercial landings no longer reached the annual TAL, even with increases in the number of harvest days and daily possession limits. From 2005 - 2009, landings steadily declined averaging 150,000 pounds (Figure 4).

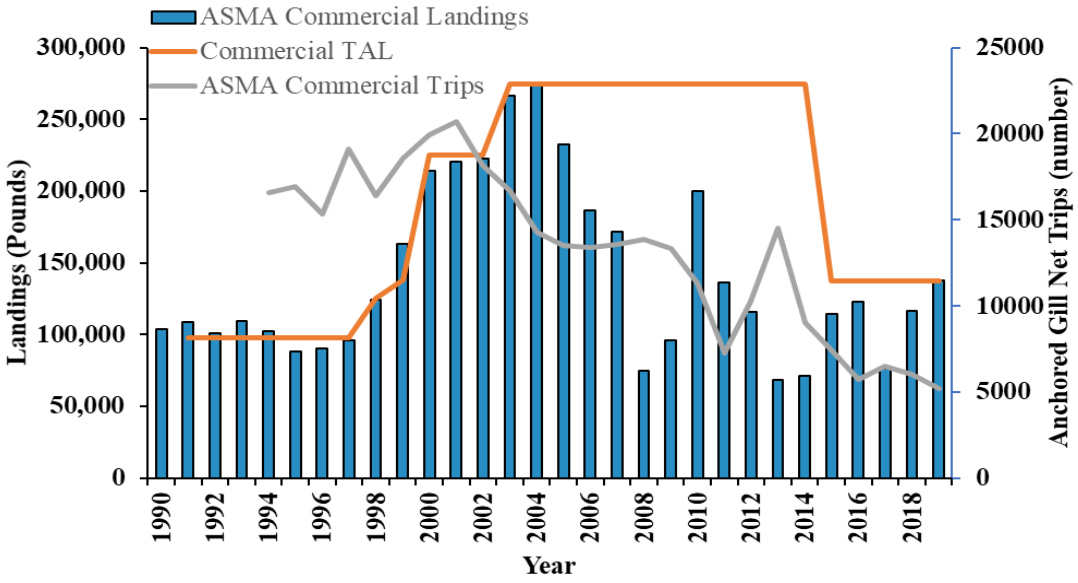

Figure 4. Commercial striped bass landings and the number of all anchored gill net trips in the Albemarle Sound Management Area (ASMA) 1991-2019.

The decline in landings during 2005-2009 was due to poor year classes produced from 2001 - 2004. An increase in landings in 2010 to over 200,000 pounds was due to the strong 2005-year class. Since 2013, landings have declined in part because of a shortened American shad season. In 2021, the commercial TAL was reduced to 25,608 pounds to meet requirements of adaptive management measures in Amendment 1 to the Striped Bass FMP to end overfishing (DMF 2020).

CSMA

Supplement A (2019) closed the CSMA commercial striped bass fishery to protect important year classes of striped bass. From 1994 - 2018 commercial landings in the CSMA were limited by a 25,000 pound annual TAL. From 1994 - 2018 striped bass commercial landings in the CSMA averaged 26,132 (Figure 5). Most commercial landings are from the Tar-Pamlico, Pungo, Neuse, and Bay rivers (Figure 6). From 2004 - 2018, there was only a spring harvest season, opening March 1 and closing when the annual TAL was reached.

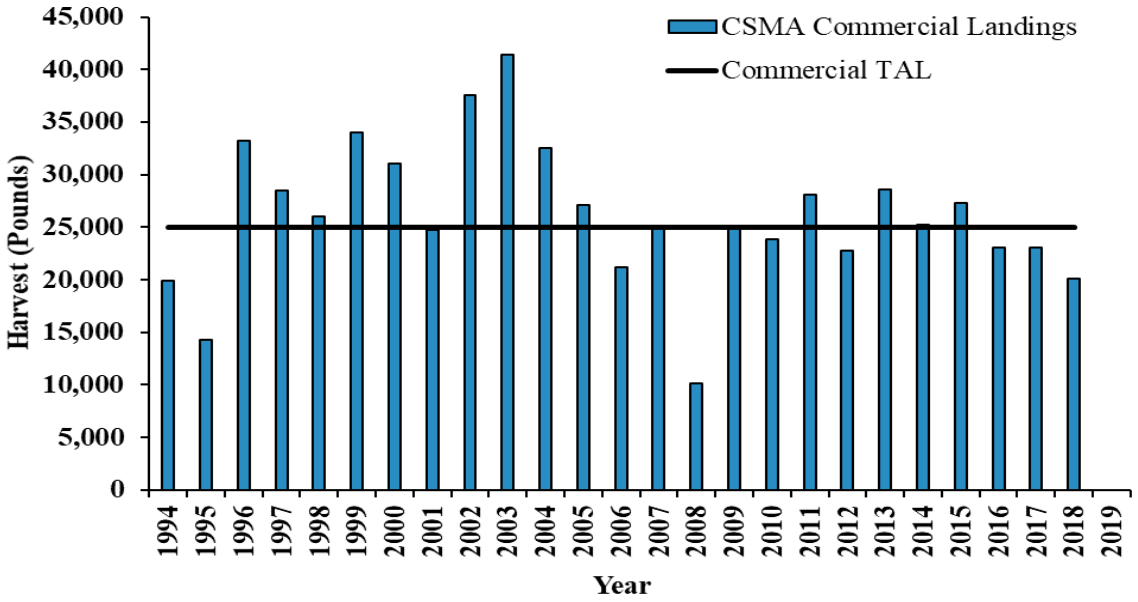

Figure 5. Annual commercial CSMA striped bass harvest and TAL in pounds, 1994-2019. There was no commercial season in 2019.

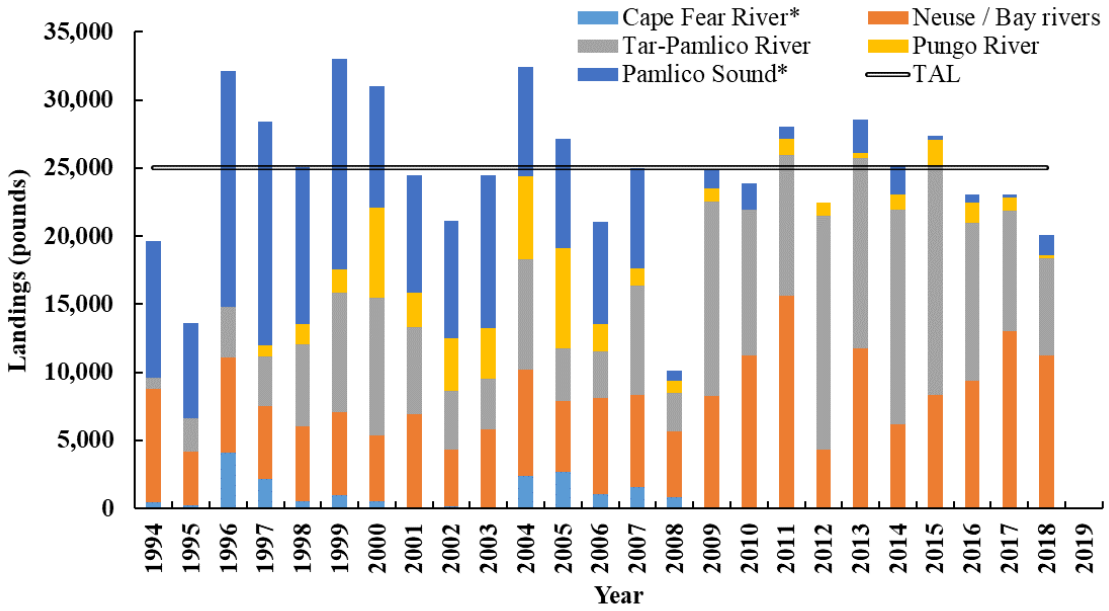

Figure 6. Commercial striped bass harvest by system, and the TAL in the CSMA, 2004-2019. There has been a harvest moratorium in the Cape Fear River since 2009, and a closed season in the CSMA since 2019. *Landings data for the Cape Fear River in 2001 and the Pamlico Sound in 2012 are confidential.

RECREATIONAL FISHERIES

ASMA

In the initial 1994 FMP the MFC voted to split the TAL evenly between commercial and recreational fisheries when the stock recovered. In 1997 the stock was declared recovered and in 1998 the MFC voted to allocate the TAL 50/50 between the commercial and recreational sectors through incremental steps. The recreational TAL from 29,400 pounds in 1997 to 137,500 pounds in 2003. Adaptive management to address the overfished status in 2021 reduced the recreational TAL to 12,804 pounds (DMF 2020). Recreational landings peaked in 2001 at 118,506 pounds (Figure 7). Recreational landings in the ASMA consist of primarily age-3 to age-5 fish.

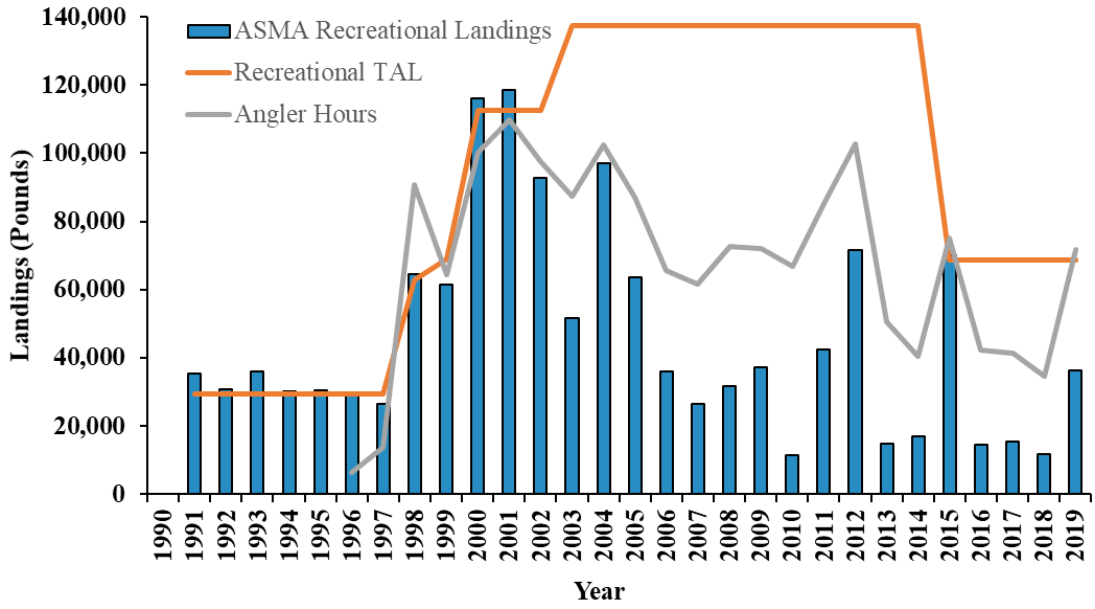

Figure 7. Recreational striped bass landings and the hours of striped bass fishing effort in the Albemarle Sound Management Area (ASMA) 1991-2019.

Beginning in fall 2005, harvest was allowed seven days a week in the ASMA. Additionally, in fall 2006 possession limits were increased from two to three fish. Despite the increases in bag limits and days recreational harvest continued to decline. Several poor year classes produced since 2001 may have contributed to the decline in stock abundance and recreational harvest since 2006. The recreational limit was decreased to two fish per person per day in January 2016. Recreational harvest from 1991–2019 averaged 42,466 pounds in the ASMA. Releases are usually greater than harvest and are dominated by fish less than the 18-inch minimum length limit. Undersized releases during the last 10 years have averaged 24,051 fish (Table 1).

Table 1. Estimates of striped bass angling effort, harvest, and numbers caught and released from the Albemarle Sound Management Area, 1991–2019. Cells with a dash indicate estimates were not generated for that particular metric in that year. Estimates of discards are not available for the post-harvest period.

Year	Striped Bass Trips	Angler Hours	Number of fish harvested	Total pounds harvested	Striped Bass Discard (#over-creel)	Striped Bass Discard (#under-sized)	Striped Bass Discard (#legal-sized)	Total number of fish released	Number of fish caught per trip
1991		-	14,395	35,344	-	-	-	23,540	
1992		-	10,542	30,758	-	-	-	19,981	
1993		-	11,404	36,049	-	-	-	13,241	
1994		-	8,591	30,217	-	-	-	-	
1995		-	7,343	30,564	-	-	-	-	
1996		6,349	7,433	29,186	-	-	-	-	
1997		13,656	6,901	26,724	-	-	-	30,771	
1998		90,820	19,566	64,761	-	-	-	91,888	
1999		64,442	16,967	61,447	-	-	-	40,321	
2000		100,425	38,085	116,414	-	-	-	78,941	
2001		109,687	40,127	118,645	-	-	-	61,418	
2002		97,480	27,896	92,649	-	-	-	51,555	
2003		87,292	15,124	51,794	-	-	-	25,281	
2004		102,505	28,004	97,097	9,877	28,859	2,305	41,041	
2005	13,735	86,943	17,954	63,477	11,333	7,032	2,855	21,220	0.67
2006	10,707	65,757	10,711	35,985	2,490	6,339	626	9,455	0.44
2007	9,629	61,679	7,143	26,633	1,148	12,259	192	13,599	0.81
2008	11,793	72,673	10,048	31,628	391	36,324	260	36,975	1.69
2009	11,326	72,021	12,069	37,313	20	38,683	1,860	40,563	1.73
2010	9,660	66,893	3,504	11,470	569	15,398	233	16,200	1.23
2011	13,114	85,325	13,341	42,536	317	20,114	1,141	21,572	0.82
2012	14,490	102,787	22,345	71,456	1,024	19,977	3,970	24,971	0.68
2013	7,053	50,643	4,299	14,897	31	16,034	316	16,381	1.44
2014	7,264	40,478	5,529	16,867	18	22,558	510	23,086	1.80
2015	11,132	75,009	23,240	70,008	1,573	45,559	2,402	49,534	1.44
2016	7,023	42,276	4,794	14,486	252	8,822	1,278	10,352	0.88
2017	7,658	41,371	4,215	15,480	56	24,004	600	24,660	2.08
2018	9,057	34,764	3,465	11,762	281	21,337	3,970	25,588	2.04
2019	18,833	71,800	10,723	36,351	52	32,020	2,896	34,968	1.18

RRMA

Harvest from 1982 through 2019 averaged 54,103 pounds in the RRMA (Table 2; Figure 8). Discards outnumber landings annually, especially in the RRMA where concentrations of fish on the spawning grounds can be dense. Annual releases from 2005 through 2019 in the RRMA averaged 80,821 fish.

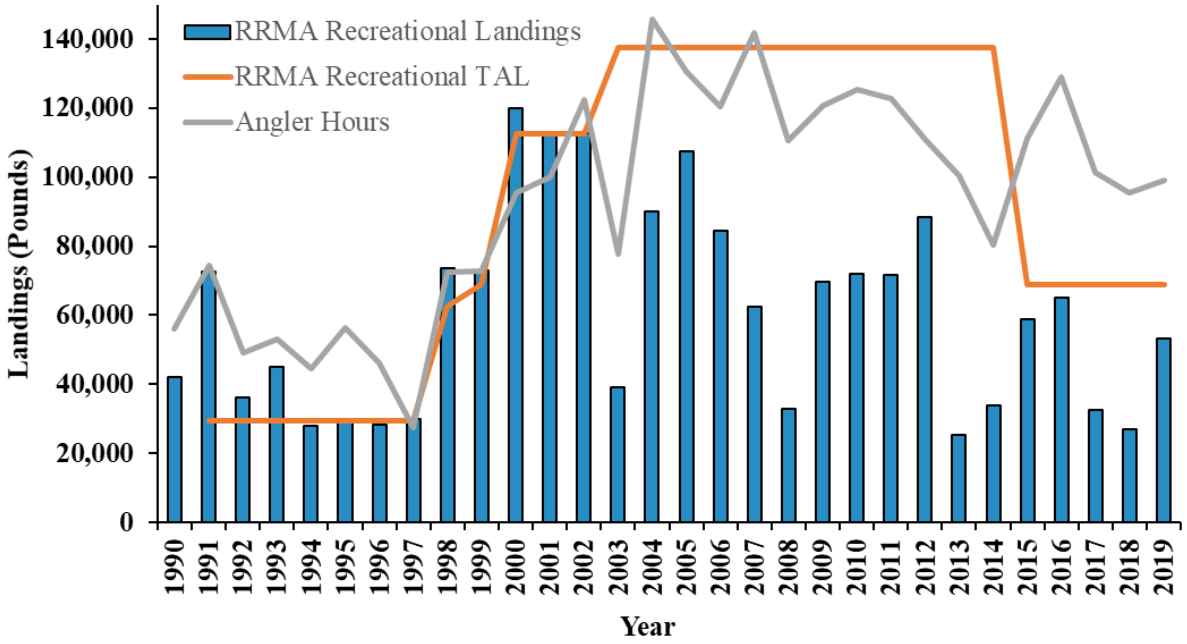

Figure 8. Recreational striped bass landings and the hours of striped bass fishing effort in the Roanoke River Management Area (RRMA) 1991-2019.

From 2003 - 2016, landings averaged 64,389 pounds, with a few noticeably low years (Figure 8). Adaptive management in 2021, reduced the recreational TAL to 12,804 pounds (DMF 2020). During the spring fishery, catches of 100 fish per angler in a day are not uncommon, but catch rates can be heavily impacted by extreme flow conditions. Recreational landings in the RRMA are dominated by age-3 to age-5 fish, primarily due to a no possession rule of fish between 22- and 27-inches total length (TL) and general angling techniques. Few fish over nine years are observed in the creel survey because most anglers do not use the large artificial lures or natural bait needed to effectively target striped bass over 28-inches TL.

CSMA

The DMF began collecting recreational striped bass data in the major rivers of the CSMA in 2004. In 2013, due to low recreational striped bass catch in the Cape Fear River, creel survey methodology was adjusted for American and hickory shad (*Alosa mediocris*) to become the target species. The Supplement A recreational no possession measure approved in February 2019, limited recreational harvest in 2019. Recreational landings fluctuated between 2004 and 2019 (Table 3; Figure 9).

Table 2. Estimates of striped bass angling effort, harvest, and numbers caught and released from the Roanoke River Management Area, 1988–2019. Blank cells indicate data was not collected in that year. **For 1989-2009 number of trips was calculated by dividing the angler hours by 4.75 (assumes each trip was 4.75 hours long). Since 2010, number of trips were estimated based on creel survey data sampling probabilities.

	Open Season (Harvest estimates)					Post-Harvest Period (Catch and Release Only)			
Year	Number Harvested	Weight (lb)	Effort (angler-hours)	Number of trips**	Number released	Number released	Weight (lb)	Effort (angler-hours)	Number of trips**
1988		74,639							
1989	8,753	32,107	46,566	9,803		*	*	*	*
1990	15,694	42,204	56,169	11,825		*	*	*	*
1991	26,934	72,529	74,596	15,704		*	*	*	*
1992	13,372	36,016	49,277	10,374		*	*	*	*
1993	14,325	45,145	52,932	11,144		*	*	*	*
1994	8,284	28,089	44,693	9,409		*	*	*	*
1995	7,471	28,883	56,456	11,885		52,698	*	20,639	4,345
1996	8,367	28,178	46,164	9,719		148,222	*	32,743	6,893
1997	9,364	29,997	23,139	4,871		271,328	*	47,001	9,895
1998	23,109	73,541	72,410	15,244		102,299	*	26,367	5,551
1999	22,479	72,967	72,717	15,309		113,394	*	30,633	6,449
2000	38,206	120,091	95,622	20,131		*	*	*	*
2001	35,231	112,805	100,119	21,078		*	*	*	*
2002	36,422	112,698	122,584	25,807		*	*	*	*
2003	11,157	39,170	77,863	16,392		*	*	*	*
2004	26,506	90,191	145,782	30,691		*	*	*	*
2005	34,122	107,530	130,755	27,527		68,147	*	24,146	5,083
2006	25,355	84,521	120,621	25,394		24,719	*	15,235	3,207
2007‡	19,305	62,492	141,874	29,868		11,622	*	9,254	1,948
2008‡	10,541	32,725	110,608	23,286		47,992	*	17,764	3,740
2009	23,248	69,581	120,675	25,405		*	*	*	*
2010	22,445	72,037	125,495	24,347	77,882	46,028		31,281	5,111
2011	22,102	71,561	122,876	27,311	80,828	26,865		15,110	2,707
2012	28,847	88,539	110,982	27,151	40,772	22,246		8,935	1,881
2013	7,718	25,197	100,391	19,539	49,148	25,074		12,423	2,246
2014	11,058	33,717	80,256	15,960	93,471	72,068		17,542	2,972
2015	20,031	58,962	111,419	22,827	78,401	29,839		12,229	2,207
2016	21,260	65,218	129,132	25,036	34,753	17,891		11,291	2,087
2017	9,899	32,569	101,565	19,688	68,693	9,754		7,446	1,317
2018	8,741	26,797	95,447	18,280	121,969	65,245		14,499	2,462
2019	16,582	53,379	99,259	20,633	117,550	69,642		26,867	5,283

Table 3. Recreational striped bass effort, harvest and discards from the CSMA (2004–2019). The 2019 season was January 1–March 19, 2019.

Year	Fishing Trips	Effort Hours	Number Harvested	Pounds Harvested	Total Discards
2004	12,782	63,791	6,141	22,958	13,557
2005	16,414	69,370	3,832	14,965	16,854
2006	10,611	42,066	2,481	7,352	14,895
2007	10,971	46,655	3,597	10,794	23,527
2008	6,621	28,413	843	2,990	17,966
2009	5,642	26,611	895	3,061	6,965
2010	6,559	25,354	1,757	5,537	7,990
2011	12,606	51,540	2,728	9,474	24,188
2012	18,338	71,964	3,922	15,240	43,313
2013	20,394	86,918	5,467	19,537	32,816
2014	15,682	70,316	3,301	13,368	30,209
2015	18,159	79,398	3,934	14,269	31,353
2016	23,675	110,453	6,697	25,260	75,461
2017	26,125	119,680	7,334	26,973	131,129
2018	16,393	69,917	3371	10,884	49,122
2019	8,820	40,580	959	3,562	37,039
Average	14,362	62,689	3,579	12,889	34,774

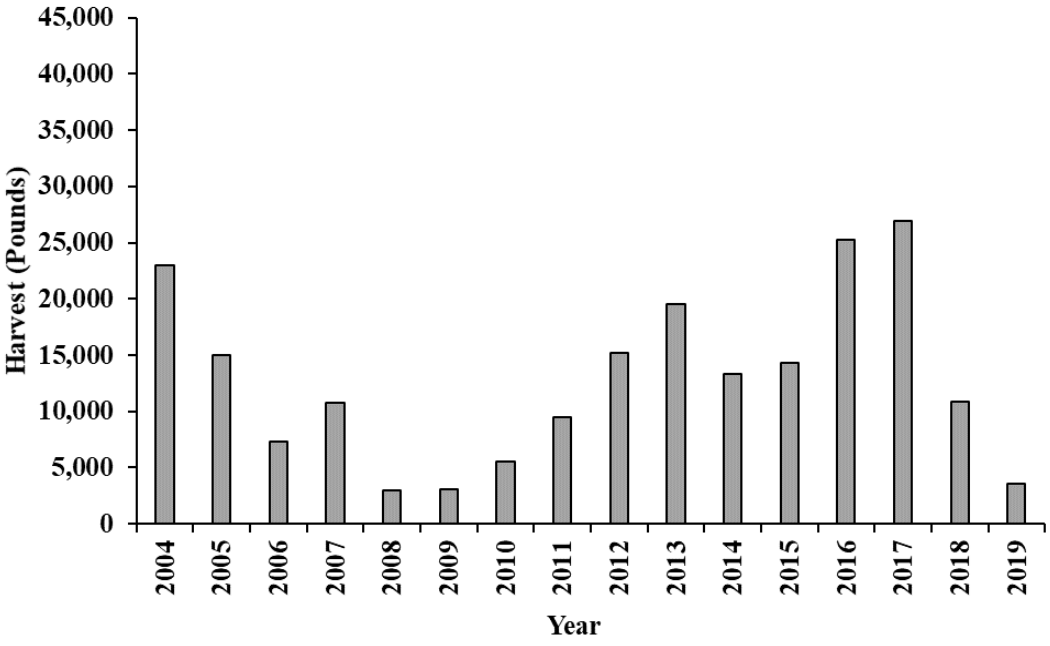

Figure 9. Annual recreational CSMA striped bass harvest in pounds, 2004-2019. The 2019 season was January 1–March 19, 2019.

From 2004 - 2007 most recreational harvest occurred in the Neuse River, but since 2008 harvest has generally been split between the Tar-Pamlico and Neuse rivers (Figure 10). In 2016 and 2017, the number of trips and hours spent targeting striped bass in the CSMA increased substantially compared to other years (Table 3). Within the CSMA there is a significant catch-and-release fishery, averaging 47,309 releases from 2010 - 2019 (Table 3). Undersized discards peaked in 2017 but declined through 2019.

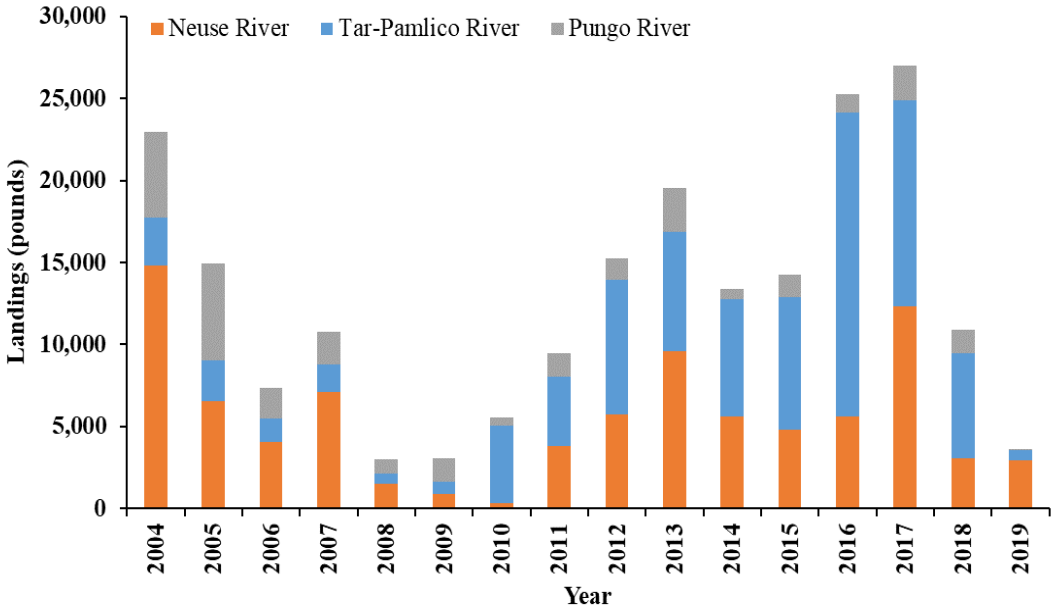

Figure 10. Recreational striped bass harvest in the Tar-Pamlico, Pungo, and Neuse rivers, 2004-2019. The 2019 season was January 1–March 19, 2019.

SUMMARY OF ECONOMIC IMPACT OF STRIPED BASS FISHING

IMPLAN, a modeling software, estimates the economic impacts of an industry to the state at-large, accounting for revenues and participation. For a detailed explanation of the methodology used to estimate the economic impacts please refer to DMF's License and Statistics Section Annual Report on the Fisheries Statistics page. For further information on overall trends, economics, and characteristics of the commercial fishery see the report entitled North Carolina Striped Bass (Marone saxatilis) Commercial Fishery (Gambill and Bianchi 2019). DMF's License and Statistics Section Annual Report. For further details on economics and statistics of the commercial fishery

Commercial

Commercial landings and effort data collected through the DMF trip ticket program is used to estimate the economic impact of the commercial fishing industry. For commercial fishing output, total impacts are derived by incorporating modifiers from NOAA's Fisheries Economics of the United States report (National Marine Fisheries Service 2018), which account for proportional expenditures and spillover impacts from related industries. By assuming striped bass fisheries

contribute to the expenditure categories at a proportion equal to their contribution to total commercial ex-vessel values, we can generate an estimate of the total economic impact of striped bass harvest in the CSMA and ASMA. Additionally, this same indirect impact methodology is applied to the aggregate landings of other species harvested during a striped bass trip. Economic impacts of the striped bass fishery and alternative species cannot be combined. As these landings occurred during the same trips with the same participants, much of the economic impact of striped bass harvest is also reflected in the economic impact of harvest of other species. These two impact categories have been separated to demonstrate how commercial striped bass fishing in the CSMA and ASMA impacts the state economy outside of direct landings, and how that affect could change if commercial striped bass effort were eliminated or reduced.

ASMA

Commercial effort and output in the ASMA are greater than in the CSMA. The number of striped bass commercial fishery participants is roughly two to three times higher than in the CSMA, with total annual trips increased by an even higher factor. Increased effort, and historically higher TAL in the ASMA compared to the CSMA leads to increased harvest of striped bass. Average annual landings of striped bass are roughly 100,000 pounds in the ASMA, with average ex-vessel values of $300,000 (Figure 11). Both values are approximately five times greater than annual values in the CSMA.

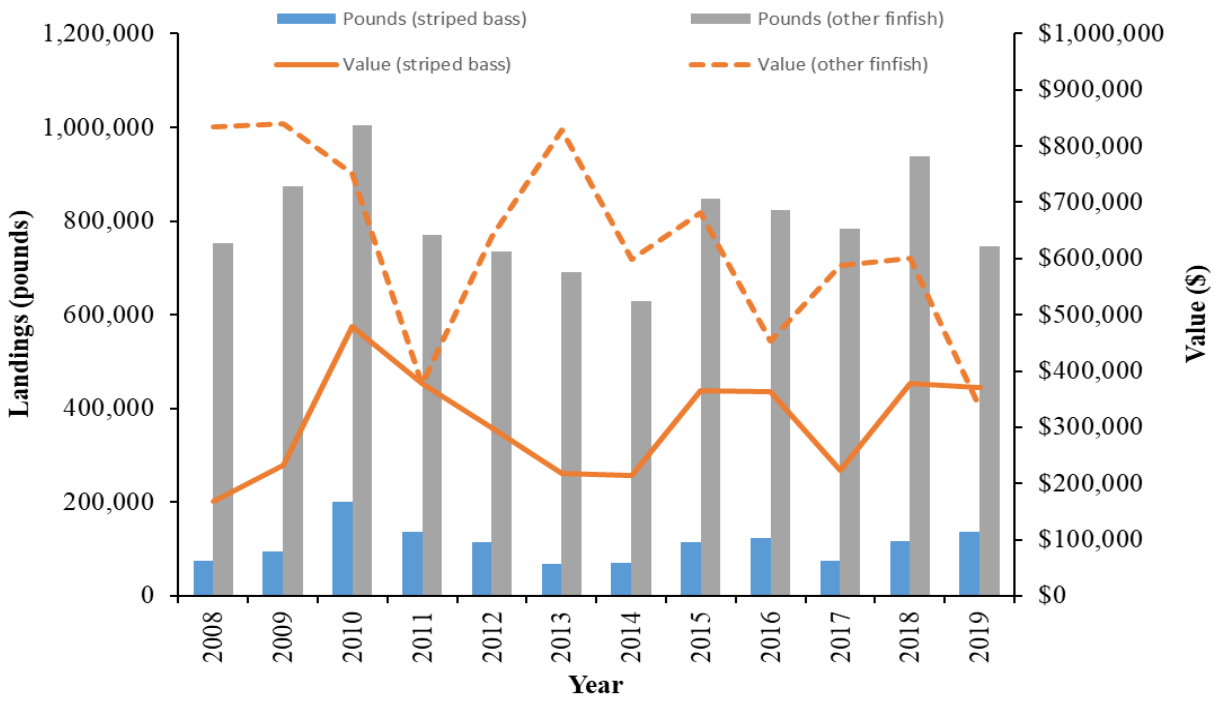

Figure 11. Annual Striped Bass effort and ex-vessel value data for the ASMA, 2008-2019.

Harvest of all other species during striped bass trips in the ASMA is significantly greater than the CSMA and more consistent year-over-year, even when compared as a proportion of striped bass landings (Table 4). While striped bass harvest in the ASMA is roughly five times greater than in

the CSMA, landings of all other species caught during striped bass trips are ten times greater or more annually. This suggests greater overall economic opportunity in the ASMA striped bass commercial fishery, as a larger proportion of additional finfish species are harvested and sold each year. However, per-pound prices of other species are slightly lower in the ASMA compared to the CSMA, suggesting other finfish species landed in the ASMA are slightly less valuable, or that increased harvest leads to decreased prices.

As the total value of striped bass and other products harvested annually in the ASMA is significantly greater, so are the economic impacts to the state (Tables 4 and 5). Annual sales impacts of striped bass harvest average over $1 million annually, with the impacts from the harvest of other species valued between $1 million and nearly $4 million. In general, these estimates demonstrate that the ASMA striped bass commercial fishery produces a greater overall economic impact to the state than in the CSMA.

Table 4. Annual commercial striped bass effort data and estimates of annual economic impact to the state of North Carolina from striped bass harvest for the ASMA, 2008-2019.

Year	Pounds Landed	Ex-Vessel Value	Total Participants	Total Trips	Job Impacts	Income Impacts	Value-added Impacts	Sales Impacts
2008	74,921	$167,750	278	2,857	287	$311,255	$583,523	$756,264
2009	95,794	$231,914	279	3,495	291	$430,176	$813,040	$1,033,704
2010	199,829	$479,648	327	6,116	353	$847,691	$1,586,334	$2,043,151
2011	136,266	$378,577	276	4,212	296	$671,721	$1,256,856	$1,618,695
2012	115,605	$298,162	264	3,612	280	$524,276	$978,808	$1,258,901
2013	68,338	$218,662	268	2,864	280	$372,105	$692,894	$893,139
2014	70,989	$214,143	236	2,834	248	$359,952	$668,554	$864,931
2015	114,488	$365,505	237	4,043	257	$633,013	$1,183,400	$1,515,359
2016	123,111	$362,759	197	4,245	215	$633,119	$1,177,209	$1,477,691
2017	75,991	$222,854	178	2,717	189	$374,107	$696,497	$887,232
2018	116,144	$377,668	193	3,621	215	$683,207	$1,239,287	$1,614,420
2019	136,820	$370,278	192	3,309	212	$636,930	$1,167,901	$1,507,707
Average	110,691	$307,327	244	3,660	260	$539,796	$1,003,692	$1,289,266

Beyond the high-level relationship between commercial striped bass effort and statewide economic impacts, there are also a range of smaller-scale factors in this fishery that could affect its overall contribution to the state economy. A notable example is the difference in management between the CSMA and ASMA. Historically, the CSMA was allocated a smaller striped bass TAL, and operated over a shorter season than the ASMA. Additionally, The ASMA striped bass fishery is regulated under a unique structure, in which striped bass cannot be harvested unless it is in tandem with other finfish species.

Table 5. Annual effort data and estimates of annual economic impact to the state of North Carolina from harvest of all other species caught during trips when striped bass landings occurred in the ASMA, 2008-2019.

Year	Pounds Landed	Ex-Vessel Value	Total Participants	Total Trips	Job Impacts	Income Impacts	Value-added Impacts	Sales Impacts
2008	752,788	$833,879	271	2,826	317	$1,547,237	$2,900,673	$3,759,363
2009	875,110	$838,842	276	3,423	321	$1,555,961	$2,940,795	$3,738,946
2010	1,004,196	$751,024	314	5,896	354	$1,327,298	$2,483,852	$3,199,126
2011	769,786	$376,144	262	4,012	282	$667,404	$1,248,778	$1,608,292
2012	734,894	$639,535	260	3,536	294	$1,124,534	$2,099,472	$2,700,252
2013	690,471	$828,539	265	2,840	310	$1,409,953	$2,625,466	$3,384,216
2014	628,430	$598,214	236	2,818	268	$1,005,535	$1,867,623	$2,416,208
2015	847,805	$682,205	236	3,958	273	$1,181,502	$2,208,785	$2,828,378
2016	823,328	$453,967	194	4,217	217	$792,302	$1,473,192	$1,849,224
2017	784,689	$587,458	177	2,712	207	$986,166	$1,836,006	$2,338,796
2018	937,616	$599,714	193	3,590	228	$1,084,890	$1,967,910	$2,563,599
2019	745,726	$333,321	192	3,295	210	$573,358	$1,051,334	$1,357,223
Average	799,570	$626,904	240	3,594	273	$1,104,678	$2,058,657	$2,645,302

While the exact economic costs and benefits of these differences in regulations cannot be quantified, it is likely the overall economic impact differs greatly between management areas. For example, the ASMA's management structure may lead to increased economic benefit, as the multispecies management could yield higher overall production, and a more robust processing industry.

CSMA

Prior to the 2019 closure, striped bass commercial effort in the CSMA was low. Roughly 100 participants engaged in less than 1,000 striped bass trips annually (Table 6), with the total harvest never exceeding 30,000 pounds or $85,000 (Table 6; Figure 12). Because of the TAL, striped bass harvest was consistent year-over-year except for 2008, which produced notably low striped bass landings. Landings of other species from the striped bass fishery are more variable than striped bass landings. Although landings of other species from striped bass trips generally produced a larger total amount of product, these species generally sold for lower overall prices. As a result, despite higher landings, annual ex-vessel values of other species are comparable to striped bass.

Table 6. Annual commercial striped bass effort data and estimates of annual economic impact to the state of North Carolina from striped bass harvest for the CSMA, 2008-2019. Commercial and recreational harvest of striped bass was closed in the CSMA in March of 2019, with no observed effort for all of 2019.

Year	Pounds Landed	Ex-Vessel Value	Total Participants	Total Trips	Job Impacts	Income Impacts	Value-added Impacts	Sales Impacts
2008	10,115	$20,906	110	706	111	$38,790	$72,722	$94,249
2009	24,847	$56,616	103	915	106	$105,016	$198,482	$252,352
2010	23,888	$55,678	103	680	106	$98,401	$184,143	$237,170
2011	28,054	$72,452	80	661	84	$128,553	$240,536	$309,785
2012	22,725	$51,958	69	571	72	$91,360	$170,567	$219,376
2013	28,597	$84,824	97	784	102	$144,348	$268,790	$346,469
2014	25,245	$69,098	125	826	129	$116,147	$215,725	$279,091
2015	27,336	$84,703	104	809	109	$146,697	$274,246	$351,175
2016	23,041	$69,271	94	685	98	$120,898	$224,795	$201,506
2017	23,018	$66,033	100	808	103	$110,850	$206,376	$237,914
2018	19,903	$61,477	90	776	94	$111,213	$201,732	$233,959
2019	-	-	-	-	-	-	-	-
Average	23,343	$63,001	98	747	101	$110,207	$205,283	$251,186

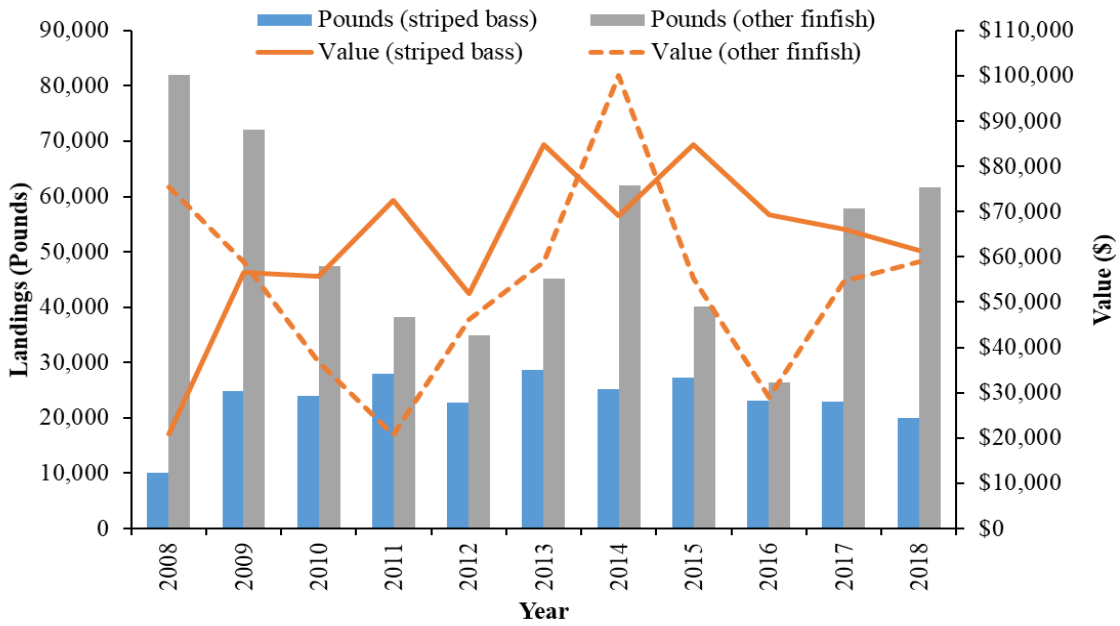

Figure 12. Annual Striped Bass effort and ex-vessel value data for the CSMA, 2008-2019.

When effort data is extended to generate state-wide economic impacts, the same patterns hold. The striped bass fishery produces roughly a quarter of million dollars in sales impacts annually (Table 6). As the annual ex-vessel values and number of participants are comparable with other species harvested during striped bass trips, the economic impact of striped bass and other species is similar, but the economic impact of alternative species varies more year to year (Table 7).

Table 7. Annual effort data and estimates of annual economic impact to the state of North Carolina from harvest of all other species caught during trips when striped bass landings occurred in the CSMA, 2008-2019. Commercial and recreational harvest of striped bass was closed in the CSMA in March of 2019, with no observed effort for all of 2019.

Year	Pounds Landed	Ex- Vessel Value	Total Participants	Total Trips	Job Impacts	Income Impacts	Value-added Impacts	Sales Impacts
2008	81,922	$75,381	109	664	113	$139,867	$262,214	$339,839
2009	72,125	$58,882	90	824	93	$109,221	$206,429	$262,455
2010	47,382	$36,904	97	521	99	$65,220	$122,051	$157,198
2011	38,189	$20,637	71	472	72	$36,617	$68,514	$88,239
2012	34,855	$46,172	60	429	62	$81,186	$151,573	$194,947
2013	45,107	$58,914	91	668	94	$100,255	$186,685	$240,637
2014	62,013	$100,115	114	504	119	$168,283	$312,559	$404,368
2015	40,056	$55,244	89	574	92	$95,677	$178,866	$229,039
2016	26,374	$28,877	85	548	86	$50,398	$93,710	$117,629
2017	57,812	$54,695	105	712	108	$91,817	$170,941	$197,062
2018	61,723	$58,959	97	688	100	$106,658	$193,469	$224,373
2019	-	-	-	-	-	-	-	-
Average	51,596	$54,071	92	600	94	$95,018	$177,001	$223,253

Recreational

Creel surveys provide data on recreational angler effort and expenditures to measure state-wide economic impacts of the fishery. The creel surveys collect information on target species, angler hours, and expenditures across six categories: lodging, food, ice, bait and tackle, vehicle fuel, and boat fuel. Combined, these data allow for an assessment of direct trip expenditures, as well as spillover impacts using IMPLAN statistical software.

ASMA

Annual ASMA effort estimates are combined with per-trip expenditure estimates from the CSMA creel survey, as these values are not tracked in the ASMA. Trip expenditure estimates are only provided using DMF survey data, combined with ASMA effort data. The ASMA maintains the same definition of a striped bass trip as the CSMA, in which striped bass is the angler's primary target, secondary target, or was caught.

In terms of trips and angling hours, the ASMA has the lowest striped bass angling effort among the three management areas (Table 8). Generally, the ASMA produces the lowest overall economic impact to the state of these management areas. As with the RRMA, this analysis

extrapolates impact values from CSMA expenditure estimates, and does not present impact estimates that are fully reflective of the ASMA system.

Table 8. Annual recreational striped bass effort estimates and state-level economic impacts of recreational striped bass angling in the Albemarle Sound Management Area. For this analysis, a striped bass trip is as a primary or secondary directed trip for striped bass, or a trip where striped bass was caught.

Year	Estimated Total ASMA Striped Bass Trips	Estimated Total ASMA Striped Bass Angling Hours	Estimated Sales Impacts	Estimated Income Impacts	Estimated Value Added Impacts	Estimated Job Impacts	Total Expenditures Using DMF Inshore Vessel Trip Costs
2008	11,793	72,673	$378,011	$135,019	$204,838	3.44	$1,834,428
2009	11,326	72,021	$421,153	$152,375	$299,096	3.91	$1,755,517
2010	9,660	66,893	$1,466,355	$551,802	$802,439	11.82	$1,521,849
2011	13,114	85,325	$1,067,875	$377,870	$601,856	9.15	$2,131,210
2012	14,490	102,787	$836,596	$291,843	$477,153	6.99	$2,403,561
2013	7,053	50,643	$494,936	$172,553	$283,706	4.1	$1,187,069
2014	7,264	40,478	$830,858	$288,344	$476,395	6.81	$1,242,414
2015	11,132	75,009	$937,967	$326,264	$535,776	7.72	$1,906,246
2016	7,023	42,276	$312,791	$109,274	$176,394	2.63	$1,217,791
2017	7,658	41,371	$1,098,641	$382,203	$632,422	9	$1,356,190
2018	9,057	34,764	$510,289	$177,879	$289,450	4.22	$1,643,121
2019	18,833	71,800	$1,528,169	$532,055	$873,914	12.63	$3,475,633
Average	10,700	63,003	$823,637	$291,457	$471,120	6.87	$1,806,252

While angler effort, participation, and overall expenditures drive the economic impact of recreational estuarine striped bass angling in the state, the valuation can also be affected by smaller-scale factors specific to the fishery. A number of social, regulatory, or environmental factors could affect the total economic impact of any fishery, though these are often difficult to quantify due to lack of data and clear causality. A notable component that may impact expenditures, and therefore economic impacts to the state, across management areas is variability in slot limits.

Across management areas, each operates under different recreational harvest limits, including both season length and size restrictions. For example, while the ASMA is open for harvest from October to April with an 18-inch minimum TL size limit, the RRMA only allows harvest from March to April, and includes an 18-inch minimum TL size limit and a 22-27-inch TL protective slot. Varying restrictions could affect angler expenditures and total economic impact across management areas. Longer harvest seasons with less restrictive size limits could increase angler effort and expenditures in the ASMA compared to the RRMA, and likely lead to greater economic impacts to the recreational fishing industry.

RRMA

The RRMA creel survey does not collect reliable angler expenditure data, and therefore this analysis incorporates CSMA data instead, using the assumption that angler expenditures would

be comparable across water bodies annually. Additionally, given that on-site expenditure values are not available, the only annual total expenditure estimates are those using RRMA effort data and DMF recreational angler expenditure survey data. In addition, the RRMA creel survey does not include secondary targeting as part of its directed trip definition, as compared to the CSMA which includes that metric.

The state-wide economic impacts of the RRMA recreational fishery are higher than the CSMA because of higher overall effort and less year-to-year variability (Table 9). However, while it is assumed that CSMA expenditure values are a valid proxy for the RRMA, annual variability of the CSMA values impact the RRMA estimates. Therefore, while these are valid estimates of overall impact, they may not be perfectly reflective as they rely on indirect expenditure data.

CSMA

Recreational striped bass effort in the CSMA has generally increased over time, with corresponding increases in state-wide economic impacts. However, striped bass effort in 2019 dropped to its lowest levels in 10 years, with corresponding decreases in economic impact to the state (Table 10). The large increase in value of the fishery in 2017 is most directly attributed to higher lodging estimates from that year's creel survey, which can significantly impact model outputs.

Table 9. Annual recreational striped bass effort estimates and state-level economic impacts of recreational striped bass angling in the Roanoke River Management Area. For this analysis, a striped bass trip is as a directed trip for striped bass or a trip where striped bass was caught.

Year	Estimated Total RRMA Striped Bass Trips	Estimated Total RRMA Striped Bass Angling Hours	Estimated Sales Impacts	Estimated Income Impacts	Estimated Value Added Impacts	Estimated Job Impacts	Total Expenditures Using DMF Inshore Vessel Trip Costs
2008	23,286	110,608	$746,409	$266,604	$404,467	6.79	$3,622,190
2009	25,405	120,675	$944,680	$341,790	$513,880	8.77	$3,937,746
2010	24,347	125,495	$3,695,792	$1,390,759	$2,022,463	29.79	$3,835,657
2011	27,311	122,876	$2,223,940	$786,945	$1,253,414	19.16	$4,438,423
2012	27,151	119,917	$1,567,592	$546,849	$894,076	13.1	$4,503,733
2013	19,539	112,814	$1,371,146	$478,033	$785,967	11.35	$3,288,550
2014	18,932	97,798	$2,165,449	$751,506	$1,241,620	17.74	$3,238,077
2015	25,034	123,648	$2,109,331	$733,712	$1,204,871	17.36	$4,286,828
2016	27,123	140,423	$1,208,006	$422,018	$681,239	10.14	$4,703,140
2017	21,004	109,011	$3,013,303	$1,048,289	$1,740,066	24.67	$3,719,693
2018	20,742	109,947	$1,168,648	$407,372	$662,889	9.67	$3,763,013
2019	20,633	99,259	$1,674,227	$582,907	$957,440	13.84	$3,811,110
Average	23,376	116,039	$1,824,044	$646,399	$1,030,199	15.20	$3,929,013

Table 10. Annual recreational striped bass effort estimates and state-level economic impacts of recreational striped bass angling in the Central-Southern Management Area. For this analysis, a striped bass trip is defined as any trip in which striped bass was an angler's primary target species, secondary target, or was caught.

Year	Estimated Total CSMA Striped Bass Trips	Estimated Total CMSA Striped Bass Angling Hours	Estimated Sales Impacts	Estimated Income Impacts	Estimated Value Added Impacts	Estimated Job Impacts
2008	6,620	28,415	$212,196	$75,793	$114,986	1.93
2009	5,640	26,607	$209,725	$75,879	$114,085	1.95
2010	6,889	25,355	$995,635	$374,666	$544,846	8.03
2011	12,608	51,540	$1,026,671	$363,289	$578,633	8.8
2012	18,338	71,964	$1,058,786	$369,354	$603,879	8.85
2013	20,394	86,918	$1,431,103	$498,937	$820,335	11.85
2014	15,682	70,316	$1,793,659	$622,479	$1,028,444	14.69
2015	18,159	79,398	$1,530,041	$532,211	$873,974	12.59
2016	23,675	110,453	$1,054,420	$368,363	$594,627	8.85
2017	26,125	119,680	$3,748,044	$1,303,895	$2,164,350	30.69
2018	16,394	69,917	$923,651	$321,970	$523,920	7.64
2019	8,820	40,580	$715,654	$249,466	$409,261	5.92
Average	14,945	65,095	$1,224,965	$429,692	$697,612	10.15

ECOSYSTEM PROTECTION AND IMPACTS

As an anadromous species, one that migrates upriver from the ocean or estuary to spawn, habitat requirements for striped bass are specific to life stage. Striped bass are commonly found in habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) as priority habitats. These include the water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, hard bottom, and shell bottom (NCDEQ 2016). These habitats provide appropriate conditions necessary for different life stages of striped bass.

COASTAL HABITAT PROTECTION PLAN

The Fisheries Reform Act statutes require that a CHPP be drafted by the NCDEQ and reviewed every five years (G.S. 143B 279.8). The CHPP is intended as a resource and guide compiled by NCDEQ staff to assist the department, MFC, Environmental Management Comission (EMC), and Coastal Resources Commission (CRC) for the protection and enhancement of fishery habitats of North Carolina. The CHPP ensures consistent actions between commissions as well as their supporting NCDEQ divisions. The three commissions adopt rules to implement the CHPP in accordance with Chapter 150B of the General Statutes. Habitat recommendations related to fishery management can be addressed directly by the MFC. Habitat recommendations not under MFC authority (e.g., water quality management, shoreline development) can be addressed by the EMC and the CRC through the CHPP process.

The CHPP Source Document summarizes the economic and ecological value of coastal habitats to North Carolina, their status, and the potential threats to their sustainability (NCDEQ 2016). The Coastal Habitat Protection Plans and Source Document can be viewed and downloaded from: http://portal.ncdenr.org/web/mf/habitat/chpp/07-2020-chpp.

The CHPP is undergoing a mandated five-year review, with adoption planned in 2021. The review includes two priority issues, "Submerged Aquatic Vegetation (SAV) Protection and Restoration, with Focus on Water Quality Improvements" and "Wetland Protection and Restoration with a Focus on Nature-based Methods", which may have implications for striped bass in North Carolina. The presence of SAV is often used as a bio-indicator of water quality, as it is sensitive to specific conditions. One goal addressed in the CHPP is to modify water quality criteria in an effort to improve light penetration to the seafloor, one of the most important factors affecting SAV growth. Water quality improvements that benefit SAV will also benefit the species that use SAV habitat, like striped bass. As noted below, wetlands provide striped bass with a variety of habitat functions. The wetlands issue paper provides significant justification regarding nature-based methods of restoration and shoreline protection. Therefore, improvements to wetlands through the recommendations of the wetlands paper can have direct benefits to striped bass by increasing available habitat that can be utilized by striped bass.

THREATS AND ALTERATIONS

Nearly all habitat types in the 2016 that are environmentally and economically valuable are used by striped bass during one or more life stages. Each habitat type provides environmental conditions critical to the enhancement and sustainability of striped bass populations in North Carolina. Water quality impacts the habitats required by striped bass at various life stages (i.e., wetlands, submerged aquatic vegetation, shell bottom, and soft bottom). The primary human threats to these habitats include coastal development, industrial/wastewater discharges, and runoff. These threats often alter water chemistry, causing shifts in salinity, temperature, dissolved oxygen (DO), suspended solids, nutrients, pH, velocity, depth, flow, and clarity.

Wetlands, submerged aquatic vegetation, shell bottom, and soft bottom are of particular importance for striped bass as they function as nursery habitat, refuge, foraging grounds, and movement corridors. As anadromous fish, striped bass migrate from one system to another. Therefore, barriers to migration have the potential to significantly affect striped bass populations. Dams across rivers can cause segmentation in waterways and prevent striped bass from accessing historical spawning grounds. Additionally, coastal development that alters or removes migration corridors can further restrict the quantity and quality of habitat. The placement of large structures, such as breakwaters, groins, and jetties, can cause alterations in water flow patterns. For larval striped bass, this can result in altered migration patterns and force larval fish into areas where they are susceptible to predation.

FLOW

Striped bass are broadcast spawners, producing eggs that must remain suspended in the water column to develop and hatch (Bain and Bain 1982). Sufficient river flow is critical before and after the spawning period (Hassler et al. 1981) and is the most important factor influencing year

class strength. Extended periods of high water from May to June negatively impact eggs and fry and recruitment failures in the ASMA since 2001 are thought to be due to spring flooding.

An agreement with the U.S. Army Corp. of Engineers (ACOE) strives to maintain Roanoke River flow rates within optimum levels for striped bass spawning of 6,000 - 8,000 ft^3/s as identified by Hassler (1981) and Rulifson and Manooch (1990). However, recent analysis does not support an optimum flow range but suggests since 1955, strong year classes have not been produced when flows are above 20,000 ft^3/s during the spawning season in May (DMF 2021). Specific flow requirements in the CSMA rivers are unknown. Beginning in 2020, the ACOE modified reservoir release patterns into the Cape Fear River during the peak migratory season to submerge all three locks and dams to enhance upstream passage of anadromous fish to historic spawning grounds. While optimal flow conditions in the Tar-Pamlico and Neuse rivers are unknown, low flow and shallow water may lead to eggs contacting the bottom (Bain and Bain 1982). There are no formal flow agreements for CSMA systems however the ACOE is consulted weekly regarding water releases on the Neuse River.

Egg densities and buoyancy in different systems appear suited for the predominant flow rate of that river (Bergey et al. 2003). Chesapeake Bay striped bass eggs are lighter and maintain their position in the water column of calm waters, whereas Roanoke River striped bass eggs are heavier and maintain their water column position in a high energy system (Bergey et al. 2003). Striped bass from the Tar-Pamlico and Neuse rivers have smaller and heavier eggs compared to other rivers in North Carolina and may require higher flow rates to remain suspended in the water column (Kowalchyk 2020).

RESEARCH NEEDS

The research recommendations listed below (in no particular order) are offered by the division to improve future management strategies of the estuarine striped bass fishery. They are considered high priority as they will help to better understand the stiped bass fishery and meet the goal and objectives of the FMP. A more comprehensive list of research recommendations is provided in the FMP Update and Research Priorities documents reviewed annually and can be found at the Fishery Management Plans website.

- Identify environmental factors (e.g., flow, salinity, predation, dissolved oxygen, algal blooms) affecting survival of striped bass eggs, larvae, and juvenile and investigate methods for incorporating environmental variables into stock assessment models.
- Refine discard mortality estimates for recreational and commercial fisheries by conducting delayed mortality studies to estimate discard losses for recreational and commercial gear during all seasons factoring in relationships between salinity, dissolved oxygen, and water temperature.
- Determine mixing rates between A-R and CSMA striped bass stocks to better inform stock assessments and management.
- Expand, modify, or develop fishery independent sampling programs to fully encompass all striped bass life stages (egg, larval, juvenile, and adult).

- Enhance recreational and commercial data collection to better characterize the magnitude and demographics (e.g., length, weight, age) of discards

STRIPED BASS AMENDMENT 2 MANAGEMENT STRATEGY

This section to be completed when the MFC selects their preferred management strategies that are taken out to review by the DEQ secretary, Gov Ops, AgNEER, and fiscal research division.

LITERATURE CITED

Bain, M.B., and J.L. Bain. 1982. Habitat suitability index models: coastal stocks of striped bass. U.S. Fish and Wildlife Service, Office of Biological Services, Report No. FWS/OBS-82/10.1, Washington, D.C.

Bergey, L. L., R. A. Rulifson, M. L. Gallagher, and A. S. Overton. 2003. Variability of Atlantic coast striped bass egg characteristics. North American Journal of Fisheries Management 23:558-572.

Boyd, J. 2011. Maturation, Fecundity, and Spawning Frequency of the Albemarle/Roanoke Striped Bass Stock. (Under the direction of Dr. Roger Rulifson). Department of Biology, December 2011. 132 pp.

Callihan, J. 2012. Summary maps of North Carolina tagging programs. DMF Marine Fisheries Fellowship, 2011–2012. North Carolina Division of Marine Fisheries, Morehead City, North Carolina.

Callihan, J., J. Harris, and J. Hightower. 2015. Coastal Migration and Homing of Roanoke River Striped Bass. North Carolina Cooperative Fish and Wildlife Research Unit, Department of Applied Ecology, North Carolina State University, Raleigh, NC. 15 pp.

Gambill, M. and A. Bianchi. 2019. The North Carolina Striped Bass (Morone saxatilis) Commercial Fishery. North Carolina Department of Environmental Quality, Division of Marine Fisheries. Morehead City, NC.

Hassler, W.W., N.L. Hill and J.T. Brown. 1981. The status and abundance of striped bass, Morone saxatilis, in the Roanoke River and Albemarle Sound, North Carolina, 1956-1980. Report to the North Carolina Department of Natural Resources and Community Development, Division of Marine Fisheries. Spec. Sci. Rep. 38 pp.

Knight, Evan H. 2015. Maturation and Fecundity of the Neuse and Tar-Pamlico Rivers Striped Bass (Morone saxatilis) Stocks in Coastal North Carolina. Master's Thesis, East Carolina University, Greenville, NC. 59 pp.

Kowalchyk, C. 2020. Influence of Genetic and Environmental Adaptation on Striped bass (Morone saxatilis) Egg Characteristics. Master's Thesis, North Carolina University, Raleigh, NC. 59 pp.

Lee, L.M., T.D. Teears, Y. Li, S. Darsee, and C. Godwin (editors). 2020. Assessment of the Albemarle Sound-Roanoke River striped bass (Morone saxatilis) in North Carolina, 1991–2017. North Carolina Division of Marine Fisheries, DMF SAP-SAR-2020-01, Morehead City, North Carolina. 171 pp.

Mathes, T., Y. Li, T. Teears, and L.M. Lee (editors). 2020. Central Southern Management Area striped bass stocks in North Carolina, 2020. North Carolina Division of Marine Fisheries, DMF SAP-SAR-2020-02, Morehead City, North Carolina. 161 p. + appendices.

NCDEQ (North Carolina Department of Environmental Quality). 2016. North Carolina Coastal Habitat Protection Plan. Morehead City, NC. Division of Marine Fisheries; 33 p.

DMF. 2004. North Carolina Estuarine Striped Bass Fishery Management Plan. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries. Morehead City, NC. 375 pp.

DMF. 2013. Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries. Morehead City, NC. 826 pp.

DMF. 2014. November 2014 Revision to Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan. North Carolina Department of Environment and Natural Resources. North Carolina Division of Marine Fisheries. Morehead City, NC. 15 pp.

DMF. 2019. Supplement A to Amendment 1 to the North Carolina Estuarine Striped Bass Fishery Management Plan. North Carolina Department of Environmental and Natural Resources. North Carolina Division of Marine Fisheries. Morehead City, North Carolina. 40 pp.

DMF. 2020. November 2020 Revision to Amendment 1 to the North Carolina estuarine striped bass fishery management plan. North Carolina Department of Environmental and Natural Resources, Division of Marine Fisheries. Morehead City, North Carolina. 12 pp.

DMF. 2021. Examining the Relationship Between Flow and Year-Class Strength of Striped Bass in the Roanoke River, North Carolina. North Carolina Department of Environmental and Natural Resources, Division of Marine Fisheries. Morehead City, North Carolina. 8 pp.

National Marine Fisheries Service. 2018. Fisheries Economics of the United States, 2016. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS-F/SPO-187a, 243 pp.

O'Donnell T., and D. Farrae. 2017. South Carolina Department of Natural Resources. North Carolina Wildlife Resources Commission 2016 Striped Bass Genotyping and Parentage Analyses 2016 Final Report.

Rulifson, R.A., M.T. Huish, and R.W.W Thoesen. 1982. Status of anadromous fisheries in southeast U.S. estuaries. Pages 413–425 In: V. Kennedy (editor), Estuarine comparisons. Academic Press Inc., New York, NY.

Rulifson, R.A., and C.S. Manooch III. 1990. Recruitment of juvenile striped bass in the Roanoke River, North Carolina, as related to reservoir discharge. North American Journal of Fisheries Management 10(4):397–407.

Setzler, E.M., W.R. Boynton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Mountford, P. Frere, L. Tucker, and J.A. Mihursky. 1980. Synopsis of biological data on striped bass. NOAA Technical Report, NMFS Circular 443: FAO Synopsis No. 121. 69 p.