North Carolina Fishery Management Plan

Amendment 2

River Herring

Blueback Herring (*Alosa aestivalis)*
Alewife (*Alosa pseudoharengus*)

North Carolina Division of Marine Fisheries
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July 2012	Timeline begins
July 2013	Internal review comments
August 2013	Revised with NCDMF recommendations
November 2013	First draft approved by MFC for public comment
February 2014	MFC selects preferred management options
March 2014	Reviewed by DENR Secretary
April 2014	Reviewed by the Joint Legislative Commission on Governmental Operations
August 2014	Draft rules approved for Notice of Text
February 2015	Plan amendment and rules adopted by the MFC
March 2015	Final FMP

1.0 ACKNOWLEDGEMENTS

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3.0 EXECUTIVE SUMMARY

3.1 GOALS AND OBJECTIVES

The goal of the N.C. River Herring Fishery Management Plan (FMP) is to restore the long-term viability of the river herring (blueback herring, *Alosa aestivalis*, and alewife, *Alosa pseudoharengus*) population. The development of the fishery management plan is based on blueback herring as the indicator species for determining stock status. To achieve these goals, it is recommended that the following objectives be met:

1. Identify and describe population attributes necessary to sustain long-term stock viability.

2. Protect, restore and enhance spawning and nursery area habitats.

3. Initiate, enhance, and/or continue programs to collect and analyze biological, social, economic, fishery, and environmental data needed to effectively monitor and manage the river herring fishery.

4. Promote a program of education and public information to help the public understand the causes and nature of problems in the river herring stocks, its habitats and fisheries, and the rationale for management efforts to solve these problems.

3.2 STOCK STATUS

The Atlantic State Marine Fisheries Commission (ASMFC) completed a stock assessment on river herring in 2012 (ASMFC 2012), including data through 2009 (See Section 15, Appendix 15.3). The coast-wide assessment found river herring to be depleted throughout their range. The North Carolina stock assessment found that, although the stock was not experiencing overfishing, it remained overfished. The spawning stock biomass was less than 5 percent of the amount necessary for replacement and due to the biology of the species, significant improvements would not be likely within such a short time frame.

3.2.1 Stock Status Indicators

Amendment 1 to the 2000 River Herring FMP implemented four stock recovery indicators to evaluate stock status (for reference, see section 16.7 in Appendix 15.3, the 2012 Stock Assessment). Harvest restrictions would not be lifted until all the indicators were met. The Plan Development Team (PDT), in developing Amendment 2, determined that only three of the stock recovery indicators were necessary and decided that the term “stock status indicator” was more appropriate.

The stock status indicators are based on blueback herring data and are:

1. Catch per unit effort (CPUE) of 60 young-of-the-year in the Albemarle Sound juvenile abundance survey
2. 10% repeat spawners observed in Chowan River Pound Net Survey

3. Spawning stock biomass (SSB) of 30% un-fished SSB, estimated in stock assessment model

Collectively, these indices represent *minimal* stock rebuilding goals for the recovery of river herring stocks in the Albemarle Sound and Chowan River. The ASMFC in the 2012 stock assessment recommended a ten-year interval between stock assessments (ASMFC 2012). The PDT recommended using the first two stock status indicators (juvenile abundance and repeat spawners) as a trigger for doing a stock assessment earlier than ten years. If a three-year moving average of each of the indicators was above the threshold, it would trigger the need for a new stock assessment, which would determine the third stock status indicator.

3.2.2 Monitoring Programs and Recommendations

The North Carolina Division of Marine Fisheries (NCDMF) and the North Carolina Wildlife Resource Commission (NCWRC) currently monitor river herring populations, primarily in the rivers and tributaries of Albemarle Sound, with some sampling occurring in other areas of the state. Amendment 1 recommended a monitoring program in the Albemarle Sound area that included a juvenile abundance survey, a spawning area survey, a pound net survey and an independent gill net survey. In addition, NCWRC conducts electrofishing surveys of adult river herring.

3.2.2.1 NCDMF Juvenile Sampling

The NCDMF currently monitors juvenile river herring production through its Program 100 Anadromous Juvenile Survey. Program 100 was established in 1972 and currently consists of a total of 62 trawl and 29 seine stations throughout Albemarle Sound and is used to assess juvenile abundance of all anadromous species. The juvenile abundance index (JAI), used as a stock status indicator for blueback herring, is calculated from the 11 core seine stations, sampled once a month June through October. The JAI was determined to be a valid indicator of cohort strength and to have value as a management tool and stock status indicator.

3.2.2.2 NCDMF River Herring Spawning Area Survey

The NCDMF anadromous spawning area surveys are conducted through the Program 150 Adult Anadromous Spawning Area Survey and Program 160 Anadromous Egg and Larval Survey. Surveys have been conducted annually in the Chowan River system in conjunction with one other system in the Albemarle Sound area on a rotating basis since 2008. Prior to 2008, spawning area surveys were conducted sporadically in various systems since 1972 with no consistency. These surveys are necessary to determine which areas are currently functioning as productive spawning areas. These surveys will provide data to determine which areas should be considered for habitat restoration and protection through the Coastal Habitat Protection Plan (CHPP) and stock restoration efforts.

3.2.2.3 NCWRC Adult River Herring Survey

The NCWRC conducts weekly boat-electrofishing surveys for adult river herring February through April at various sample sites in various systems throughout North

Carolina at locations that have a prior history of spawning adults. Sampling began in 2006 and location sites per system may vary across years. At the present time, sampling occurs in the following mainstem tributaries. In the Chowan River Basin, sampling is conducted in Indian and Bennett's creeks. In the Tar River Basin, sampling is conducted in Chicod and Bear creeks. In the Neuse River Basin, sampling is conducted in Village Creek. In the Cape Fear River Basin, sampling is conducted in Town and Rice's creeks.

3.2.2.4 NCDMF Chowan River Pound Net Survey

The Chowan River pound net survey was implemented in 2008 to provide estimates of catch-per-unit of effort (CPUE), percent of repeat spawners, as well as size, age and sex data for alewife and blueback herring. These data are necessary to monitor stock status indicators and the overall stock status of river herring in the Albemarle Sound area.

The NCDMF contracts with four commercial pound net fishermen in the Chowan River system to collect river herring samples from their pound nets. An unculled subsample of adult river herring is obtained weekly from each fisherman's pound nets. The total sample is approximately 20 lb.

3.2.2.5 NCDMF Independent Gill Net Survey

The NCDMF Independent Gill Net Survey (IGNS), while primarily targeted at striped bass, does collect data on a number of other species, including both species of river herring

NCDMF personnel record sex, weight, fork length and total length, as well as spawning condition, and obtain otoliths and scales to determine age and spawning frequency.

3.2.2.6 Monitoring Recommendations

- Continue juvenile abundance seine and trawl survey in all tributaries of the Albemarle Sound area. Expand these surveys to other areas of the state.

- Continue spawning area surveys in the Chowan River annually and in one system in the Albemarle Sound area on a rotating basis. Expand these surveys to other areas of the state.

- Continue Chowan River pound net survey. Expand this survey to other tributaries in the Albemarle and other areas of the state if spawning area surveys identify significant spawning runs in these other systems.

- Continue NCWRC adult river herring surveys and expand to other tributaries in the Albemarle Sound area and other systems of the state as opportunities arise.

3.3 ENVIRONMENTAL FACTORS AND HABITAT

The most recent stock assessment revealed that, despite a moratorium on harvest of river herring in North Carolina, populations continue to be depleted. Problems exist in the areas of physical habitat and water quality. Considerable habitat area has been lost through wetland drainage, stream channelization and conversion to other uses. Some streams are blocked by dams or storm debris, and other physical barriers. Migration and spawning may be affected by replacement of small road bridges with culverts. Oxygen-consuming wastes are discharged into a number of streams and practices to control non-point discharges are inadequate causing nuisance algal blooms, fish kills and fish diseases over the years. There are also questions concerning the status of the forage base for river herring.

Amendment 1 to the River Herring FMP made a recommendation to investigate and identify man-made barriers to river herring migration and to create a list of impediments for removal or replacement. Following those recommendations, NCDMF initiated a survey of culverts and obstructions. The priority list has resulted in the replacement of failing culverts and prioritized others for replacement or repair. In 2009, NCDMF also began a water quality monitoring program that consists of datasondes deployed in the tributaries of Albemarle Sound to monitor conditions in areas used by river herring during spawning and juvenile development.

3.4 PRINCIPAL ISSUES AND MANAGEMENT OPTIONS

NCDMF and the Fishery Management Plan Development Team (PDT) developed a list of issues for river herring to be addressed in Amendment 2 to the FMP, along with management options for each of those issues.

3.4.1 Discretionary Harvest Season

In 2007, Amendment 1 to the North Carolina River Herring FMP implemented a no-harvest provision for commercial and recreational fisheries of river herring in coastal waters of the state. It also included a 7,500 pound limited research set-aside harvest to be used for data collection and to provide product to local herring festivals. The Director allocated a maximum of 4,000 pounds to be used for this season, which occurs in the Chowan River Herring Management Area around Easter week each year.

3.4.1.1 Issue

The discretionary river herring harvest season is currently not serving the intended purposes of providing biological data for stock analysis and local product for area festivals and events. In addition, the North Carolina river herring stocks are depleted and remain well below recovery goals outlined in Amendment 1 to the North Carolina River Herring FMP.

3.4.1.2 Recommendation

NCMFC- Option 2- Eliminate the Discretionary Harvest Season and the Discretionary Harvest Permit.

NCWRC- **Option 2**

Advisory Committee- **Revised Option 1**- Remove the collection of biological sampling/data as an intent of the Discretionary Harvest Season/Permit and require permit holders to report the pounds and disposition of their catches in logbooks daily.

3.4.2 Possession of River Herring in Coastal Waters

3.4.2.1 Issue

The NCWRC passed a rule in November 2012 that prohibits the possession of river herring greater than six inches while fishing or boating in inland waters. This rule became effective August 1, 2013, creating a discrepancy with North Carolina Marine Fisheries Commission Rules (NCMFC) regarding possession of river herring in joint and coastal waters of the state.

3.4.2.2 Recommendation

NCMFC- **Option 3**- Prohibit possession of river herring (alewife and blueback herring) greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier and remove alewife and blueback herring from exceptions in the Mutilated Finfish Rule 15A NCAC 03M .0101.

NCWRC- Option 3

Advisory Committee- **Option 3**

3.5 RESEARCH RECOMMENDATIONS

The following are research recommendations developed by the River Herring Plan Development Team to guide researchers in developing projects. The PDT ranked these recommendations as Low, Medium, or High. A High ranking indicates a large gap in information that might be critical for management decisions. A Low ranking does not imply lack of importance but may indicate an issue that has been partially addressed or is less time-sensitive in nature.

3.5.1 Life History

- Conduct studies of river herring egg and larval survival and development in North Carolina river systems. **High priority**
- Conduct research on predation of all life stages of river herring in the Albemarle Sound and other systems in North Carolina (including invasive species such as blue catfish and other predators). **Medium priority**
- Conduct studies on energetics of feeding and spawning migrations of river herring in North Carolina. **Medium priority**

3.5.2 Stock Status

- Estimate bycatch and discard mortality of river herring captured incidentally in Atlantic Ocean fisheries coastwide. **High priority**
- Estimate bycatch and discard mortality of river herring captured incidentally in inside fisheries. **Medium priority**

3.5.3 Environmental Factors

3.5.3.1 Water Quality Recommendations

- Evaluate effects of existing and future water withdrawals on water quality, quantity and fisheries habitat in coastal watersheds. NCDCM and NCWRC review and comment on water withdrawals and their effect on fisheries and habitat. **High priority**
- Determine if contaminants are present and identify those that are potentially detrimental to various life history stages of river herring. Long term water quality monitoring devices have been maintained and deployed to identify shifts or swings in water quality in multiple tributaries in the Albemarle Sound area. **High priority**
- Evaluate the impacts/effects of reverse osmosis (RO) plants on receiving waters and aquatic resources. NCDCM and NCWRC provide comments on permit applications for RO plants; some work by universities to evaluate effects of RO plants in local river systems. **Low priority**

3.5.3.2 Obstruction Recommendations

- Identify all man-made physical obstructions to river herring migrations (update Collier and Odom project) and prioritize impediments for removal /replacement after identification. The NCDMF has surveyed culverts in the Chowan River area and developed a priority list for replacement or repair. This information will be used by a paid graduate student to investigate fish friendly culverts. **High priority**
- Identify research needs regarding impediments to river herring migration**. High priority**

3.5.3.3 Impingement and Entrainment Recommendations

- Research is needed to determine the fate of river herring eggs, larvae and juveniles that are impinged, and then released through screen cleaning operations. **Low priority**

3.5.3.4 Climate change

- The specific effects of climate change, including warming water, increased drought severity, and loss of flood plain spawning habitat should be further investigated. **Low priority**

4.0 INTRODUCTION

4.1 AUTHORITY FOR MANAGEMENT

Fisheries management includes all activities associated with maintenance, improvement, and utilization of the fisheries resources of the coastal area, including research, development, regulation, enhancement, and enforcement.

Many different state laws (General Statutes – G.S.) provide the necessary authority for fisheries management in North Carolina. General authority for stewardship of the marine and estuarine resources by the North Carolina Department of Environment and Natural Resources (NCDENR) is provided in G.S. 113-131. The Division of Marine Fisheries (NCDMF) is the arm of the Department that carries out this responsibility. G.S. 113-136 provides enforcement authority for NCDMF enforcement officers. General Statute 113-170.3 authorizes research and statistical programs. The North Carolina Marine Fisheries Commission (NCMFC) is charged to "manage, restore, develop, cultivate, conserve, protect, and regulate the marine and estuarine resources of the State of North Carolina" (G.S. 143B-289.51). The NCMFC can regulate fishing times, areas, fishing gear, seasons, size limits, and quantities of fish harvested and possessed (G.S. 113-182 and 143B-289.52). General Statutes 113-221.1 and 143B-289.52 allows the MFC to delegate authority to implement its regulations for fisheries "which may be affected by variable conditions" to the Director of NCDMF by issuing public notices called "proclamations". Thus, North Carolina has a very powerful and flexible legal basis for coastal fisheries management. The General Assembly has retained for itself the authority to establish commercial fishing licenses, but has delegated to the NCMFC authority to establish permits for various commercial fishing gears and activities.

The Fisheries Reform Act of 1997 (FRA) and as ratified in 2004 establishes a process for preparation of coastal fisheries management plans for North Carolina. The FRA states: "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:

a. Contain necessary information pertaining to the fishery or fisheries, including management goals and objectives, status of the relevant fish stocks, stock assessments for multi-year 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.

b. Recommend management actions pertaining to the fishery and fisheries.

c. 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.

d. Specify a time period, not to exceed two years from the date of the adoption of the plan, for ending overfishing. This subdivision shall only apply to a plan for a fishery that is not producing a sustainable harvest.

e. 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.

f. 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.

Sustainable harvest is defined in the FRA 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."

Overfished is defined as "the condition of a fishery that occurs when the spawning stock biomass of the fishery is below the level that is adequate for the recruitment class of a fishery to replace the spawning class of the fishery". Overfishing is defined as "fishing that causes a level of mortality that prevents a fishery from producing a sustainable harvest."

4.2 RECOMMENDED MANAGEMENT PROGRAM

4.2.1 Goals and Objectives

The goal of Amendment 2 to the N.C. River Herring Fishery Management Plan (FMP) is to restore the long-term viability of the river herring (blueback herring, *Alosa aestivalis*, and alewife, *Alosa pseudoharengus*) population. The development of the fishery management plan is based on blueback herring as the indicator species for determining stock status. To achieve these goals, it is recommended that the following objectives be met:

1. Identify and describe population attributes necessary to sustain long-term stock viability.

2. Protect, restore and enhance spawning and nursery area habitats.

3. Initiate, enhance, and/or continue programs to collect and analyze biological, social, economic, fishery, and environmental data needed to effectively monitor and manage the river herring fishery.

4. Promote a program of education and public information to help the public understand the causes and nature of problems in the river herring stocks, its habitats and fisheries, and the rationale for management efforts to solve these problems.

4.2.2 Management Measures

Several management measures were recommended in Amendment 1 to the N.C. River Herring Fishery Management Plan, including a no-harvest provision and gear restrictions. The no-harvest provision allowed up to 7,500 pounds of river herring set aside for research at the Division Director's discretion.

The gear restrictions for the Albemarle Sound and Chowan River Herring Management Areas for January 1-May 1 remain in effect and include the following:

- Eliminate the use of gill nets less than 3 ¼ inch stretched mesh (ISM),
- Restrict the use of 3 ¼ ISM to 800 yards of net,
- Eliminate the use of drift gill nets.

In addition a cap on the number of pound net participants in the river herring fishery was also recommended. This restriction would only be implemented in the event of an open commercial fishery.

In other areas of the state the following restrictions apply from January 1 to May 1:

- Eliminate the use of gill nets less than 3¼ ISM in canals and areas adjacent to canals leading to Lake Mattamuskeet,
- Restrict drift gill nets to greater than or equal to 3¼ ISM.

4.3 DEFINITION OF MANAGEMENT UNIT

The management unit includes the two species of river herring (blueback herring, *Alosa aestivalis*, and alewife, *A. pseudoharengus*) and their fisheries throughout coastal North Carolina.

There are two management areas specified for river herring and they are defined as follows:

> The Albemarle Sound River Herring Management Area (ASRHMA) - Albemarle Sound and all its Coastal, Joint and Inland water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their Coastal, Joint and Inland water tributaries, including Oregon Inlet, north of a line from Roanoke Marshes Point 35° 48.5015'N - 75° 44.1228' W across to the north point of Eagles Nest Bay 35° 44.1710' N - 75° 31.0520' W (Figure 4.1).
>
> The Chowan River Herring Management Area (CRHMA) - Northwest of a line from Black Walnut Point 35° 59.9267' N - 76° 41.0313' W to Reedy Point 36° 02.2140' N - 76° 39.3240' W, to the North Carolina/Virginia state line; including the Meherrin River (Figure 4.1).

River herring are distributed throughout the coastal waters of North Carolina, ascending many streams to their headwaters or until blocked by dams or other obstructions. As shown in Table 4.1, they have been harvested historically from virtually all coastal streams. Over the last 30 – 35 years, however, the fisheries were overwhelmingly concentrated in the Albemarle Sound area. In addition, historical landings data indicate

that the river herring fisheries have always been concentrated in the Albemarle Sound area, with minor fisheries in other coastal streams (NCDMF 2000).

Amendment 1 to the River Herring Fishery Management Plan (NCDMF 2007) instituted a no harvest restriction on river herring for commercial and recreational fisheries in the joint and coastal waters of North Carolina. The FMP also established a 7,500 pound discretionary harvest allowance of river herring to be allocated at the discretion of the Division of Marine Fisheries Director. This discretionary harvest allowance was implemented to provide river herring for biological research as well as local product for area festivals and events.

New funds and personnel gave NCDMF the opportunity to collect data that assesses many of the management recommendations and research needs outlined in the original FMP. Although Amendment 1 also called for these programs to be expanded statewide, the lack of funds and personnel have prevented that from occurring. For the reasons provided above, this FMP will primarily focus on the Albemarle Sound area and secondarily on the other areas of the state.

4.4 GENERAL PROBLEM(S) STATEMENT

The Atlantic State Marine Fisheries Commission completed a stock assessment on river herring in 2012, utilizing data through 2009 (ASMFC 2012). The coastwide assessment found river herring to be depleted throughout their range. The North Carolina stock assessment found that river herring populations, although overfishing was no longer occurring, were still overfished.

4.4.1 Stock Problems

A fish stock exhibiting low abundance or biomass is considered overfished. If the exploitation rate on a stock exceeds sustainable or target levels, then overfishing is also occurring. The May 2005 River Herring Stock Assessment (Grist 2005) indicated that the Chowan River blueback herring and alewife stocks were overfished and that overfishing was occurring. This determination was based on an overall evaluation of the stocks and review of several available stock status indicators. The overfished status of the Chowan River blueback herring stock agreed with that reported by Carmichael (1999). Crecco and Gibson (1990) conducted a stock assessment analysis in 1988 and found that the Chowan River blueback herring stock was over exploited and alewife were overfished. The most recent stock assessment (ASMFC 2012) revealed little change, despite a 5-year no harvest provision imposed in Amendment 1 of the River Herring FMP (2007).

Recruitment through much of the 1970s and early 1980s sustained the Chowan River stock of river herring in spite of very high fishing mortality. A succession of poor year-classes during the mid-1980s could not support the high fishing mortality at that time, so subsequently the stock declined to historically low levels. Spawning stock biomass and recruitment of blueback herring and alewife declined dramatically during the mid to late 1980's and have never recovered. Sustained high exploitation over the last 25 years reduced the Spawning Stock Biomass (SSB) to the extent that current levels were insufficient to produce even moderate recruitment for either blueback herring or alewife. The stock is comprised of an inadequate number of spawners and too few repeat spawners. Landings in the commercial fisheries were depressed beginning in the late

1980's, even considering the harvest limits imposed after 1995. Amendment 1 to the River Herring Fishery Management Plan prohibited most fishing on river herring in North Carolina, with the exception of a 7,500 pound research set-aside season that takes place for a few days in the spring.

The most recent stock assessment based on blueback herring as the indicator species and completed by the ASMFC in 2012, showed populations to be depleted throughout their range. Because of the fishing moratorium, overfishing is no longer occurring, but the stock continues to be overfished because the SSB, though increasing slightly in the last decade (Section 5, Figure 5.19), is less than 5% of the amount necessary for replacement in the absence of fishing. The three-year running average of juvenile abundance continues to be well below the 60 fish per haul target (Section 5, Figure 5.22). Finally, the percentage of repeat spawners continues to be below the 10% target.

Table 4.1 Landings and value of river herring in North Carolina 1962-2006.

	Albemarle Sound (excluding tribs.)		Croatan Sound		Currituck Sound		Chowan River		Roanoke River		Tribs. to Albemarle S.		Pamlico Sound	
Year	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)
1962	3,262,600	32,626	20,000	200	25,000	250	10,786,000	107,860	122,000	1,220	6,600	66	16,200	162
1963	2,366,100	23,661	25,000	250	40,400	404	12,288,400	122,884	300,000	3,000	23,100	231	16,900	169
1964	1,920,500	19,205	35,000	350	22,300	223	4,948,900	50,760	565,000	5,650	26,800	268		
1965	1,827,700	19,976	15,000	150	10,000	100	10,944,200	112,080			12,000	120	3,200	33
1966	1,274,200	13,916			1,000	20	10,911,300	116,597	256,300	2,566	41,400	498	18,700	391
1967	322,100	5,427	5,000	50	11,700	121	18,016,100	309,992	38,000	746	27,700	475	33,900	467
1968	1,067,200	16,824	3,300	35	10,000	150	12,950,100	194,881	1,306,300	19,771	34,000	593	75,600	933
1969	769,000	13,415	19,300	193	12,000	180	17,536,100	266,614	1,286,100	19,293	10,200	181	2,000	20
1970	217,600	3,263			1,000	20	10,701,300	173,541	469,400	14,270	65,100	1,118		
1971	553,500	9,088					10,426,000	166,339	1,670,500	26,062	61,700	1,396	1,000	25
1972	297,551	6,480	2,670	53			10,594,117	182,052	335,488	7,393	7,317	167		
1973	472,153	13,327	4,590	137			7,350,578	196,212	92,056	3,571	5,132	216	149	7
1974	150,490	5,748			7,554	288	5,736,905	224,074	256,110	13,588	53,838	2,682		
1975	597,440	28,659					5,031,756	168,847	230,433	14,485	89,850	3,374		
1976	356,123	21,304			4,150	415	5,734,776	286,830	300,100	27,775	6,211	426		
1977	828,679	38,247					7,418,218	360,962	252,700	21,232	20,746	895	490	29
1978	491,372	24,688			3,950	208	5,615,113	239,227	383,199	15,328	76,418	5,454	30,697	1,465
1979	466,389	32,741	3,000	120	2,900	128	4,303,663	260,229	209,950	12,258	45,392	2,695	2,894	216
1980	680,476	51,882	*	*	4,850	420	5,382,954	379,206	71,773	6,911	20,323	1,615	5,263	527
1981	1,050,871	87,524	*	*	2,585	225	3,314,447	202,814	155,860	13,118	17,432	1,416	39,774	3,627
1982	1,558,873	144,751	*	*	22,787	2,597	7,459,968	515,545	240,540	25,725	49,956	4,629	4,565	429
1983	1,190,909	118,887	110,576	10,732	39,255	3,614	4,405,915	313,747	92,200	14,415	20,093	1,812	5,471	639
1984	1,791,289	193,857	*	*	9,100	1,258	4,561,503	382,919	65,672	8,495	49,815	5,315	*	*
1985	2,296,010	177,908	*	*	*	*	8,871,391	635,190	204,750	20,826	*	*	4,190	499
1986	689,297	94,764	*	*			5,767,874	517,945	244,994	26,519	14,860	1,937	3,780	424
1987	705,585	85,153	*	*			2,334,719	265,640	*	*	*	*		
1988	1,490,413	178,848	*	*			2,259,888	271,186	*	*	20,250	2,430	*	*
1989	554,878	69,157					908,145	110,795	*	*	*	*	*	*
1990	365,881	56,047	*	*			710,849	106,635	*	*	60,037	9,065	1,505	166
1991	352,458	28,361	*	*			1,202,535	87,799	*	*	*	*		
1992	217,918	22,161	*	*			1,135,340	113,655	255,772	25,578	*	*		
1993	111,749	10,308			117	15	801,115	56,806			*	*	25	3
1994	180,271	33,348	729	73	1,357	136	390,852	44,017	*	*	29,015	18,428	1,000	245
1995	97,137	34,277	1,723	344	640	160	280,681	73,482	2,858	715	47,723	20,111	3,923	1,022
1996	104,166	34,311	4,708	2,139	114	28	404,884	82,129	2,176	1,675	12,562	12,039	625	155
1997	109,876	46,927	9,436	5,321	159	59	201,928	67,454	*	*	4,766	5,075	518	302
1998	115,436	46,814	16,831	13,815	157	62	377,311	135,901	*	*	10,338	6,555	601	399
1999	85,086	33,928	21,101	22,884	98	35	332,466	119,247	*	*	3,305	3,167	280	100
2000	88,903	28,646	36,539	23,261	893	262	184,741	57,272	337	450	11,945	4,144	8,120	12,906
2001	49,678	21,081	24,085	9,159	1,485	632	201,717	76,707	*	*	14,162	6,244	15,172	5,992
2002	39,251	14,681	16,569	6,099	136	51	93,048	34,587	*	*	19,650	7,486	4,676	1,683
2003	67,175	29,631	6,552	4,039	1,535	675	84,591	37,220			23,178	10,203	15,100	6,865
2004	73,092	31,651	15,248	6,566	1,297	558	77,177	33,186	*	*	13,698	5,890	3,529	1,517
2005	63,350	32,515	17,495	8,944	*	*	157,087	81,196	*	*	11,844	6,055	*	*
2006	22,573	17,318	9,633		288	221	67,404	51,713	*	*	5,670	4,350	*	*

Table 4.1 continued.

	Pamlico River		Neuse River		Cape Fear River		Atlantic Ocean		Other Areas		State Total	
Year	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)

1962	61,100	611	2,000	20	100	1			800	8	14,302,400	143,024
1963	27,700	277	4,000	40	4,500	45			3,500	35	15,099,600	150,996
1964	33,500	335	8,200	82	700	7					7,560,900	76,880
1965	13,400	139			300	3					12,825,800	132,601
1966	15,500	262	500	5	400	6					12,519,300	134,261
1967	30,300	425			300	4			900	9	18,486,000	317,716
1968	4,500	55	200	9	200	8			73,500	1,410	15,524,900	234,669
1969	1,500	56							125,500	3,765	19,761,700	303,717
1970	200	11			1,100	23			65,700	1,510	11,521,400	193,756
1971	100	2	400	10	1,200	50			7,500	150	12,721,900	203,122
1972											11,237,143	196,145
1973			1,240	49							7,925,898	213,519
1974	3,995	340	650	33							6,209,542	246,753
1975	250	15					2,338	121			5,952,067	215,501
1976											6,401,360	336,750
1977	2,980	238									8,523,813	421,603
1978	5,200	260			704	50			500	25	6,607,153	286,705
1979	64,444	3,397	1,130	56			19,388	1,939			5,119,150	313,779
1980	32,609	2,110					*	*	20,275	1,656	6,218,523	444,327
1981	10,049	1,482	*	*			143,232	5,252	*	*	4,753,723	316,850
1982	12,556	1,864	*	*			7,679	726	80,779	8,333	9,437,703	704,599
1983	3,813	528							*	*	5,868,332	464,389
1984	11,137	1,280					9,497	843	18,096	2,461	6,516,109	596,428
1985	7,308	731					*	*	164,629	10,752	11,548,278	845,906
1986	3,306	496					*	*	90,212	5,208	6,814,323	647,293
1987	2,288	297					19,279	1,000	133,104	15,972	3,194,975	368,062
1988	1,593	195					*	*	419,067	49,507	4,191,211	502,166
1989	934	105							27,120	3,785	1,491,077	183,842
1990	307	43					*	*	19,046	2,303	1,157,625	174,259
1991									20,385	2,112	1,575,378	118,272
1992							110,794	10,773	3,354	286	1,723,178	172,453
1993	*	*							3,229	362	916,235	67,494
1994	14	1	1,668	167			38,834	3,883	*	*	644,309	100,996
1995	*	*	64	15			19,174	4,793	62	16	453,984	134,934
1996	*	*	103	59			*	*	165	38	529,503	132,573
1997			185	278			5,568	1,949	2,374	1,317	334,809	128,682
1998	56	20	539	189					*	*	521,930	204,706
1999	*	*	*	*					1,158	1,514	443,494	180,874
2000	44	13	*	*			*	*	815	252	332,336	127,206
2001	*	*	45	81			45	17	373	142	306,761	120,053
2002	*	*	*	*			39	15	1,493	1,121	174,860	65,723
2003	*	*	773	464			*	*	814	358	199,716	89,456
2004	*	*	302	226			*	*	4,199	1,805	188,542	81,399
2005	*	*	*	*					245	125	250,021	128,834
2006									1,249	958	109,243	83,812

* denotes confidential information. It is included in “Other Areas.”

Table 4.2 River herring research and monitoring work by the NCDMF in the rivers and sounds of eastern North Carolina

		Type of work				
System	Years	Spawning areas	Juvenile abundance	Adult aging	Migration	Stock assessment
Albemarle Sound area	1971 – present	1972-80 1982-83 1987-88 1993 2001 2007-13	1972 – present	1972 – present	1974 – 76	1996, 1998, 1999, 2005, 2012
Tar-Pamlico	1974-81	1975-76 1980	1974-81	1974-81	1975-76	
Neuse	1976-81	1977-79	1976-81	1976-81	1977-79	
White Oak	1973-75	1974-75	1974-75	1974-75		
New	1973-75	1974-75	1974-75	1974-75		
Cape Fear	1975-81	1976-81	1975-81	1976-81		

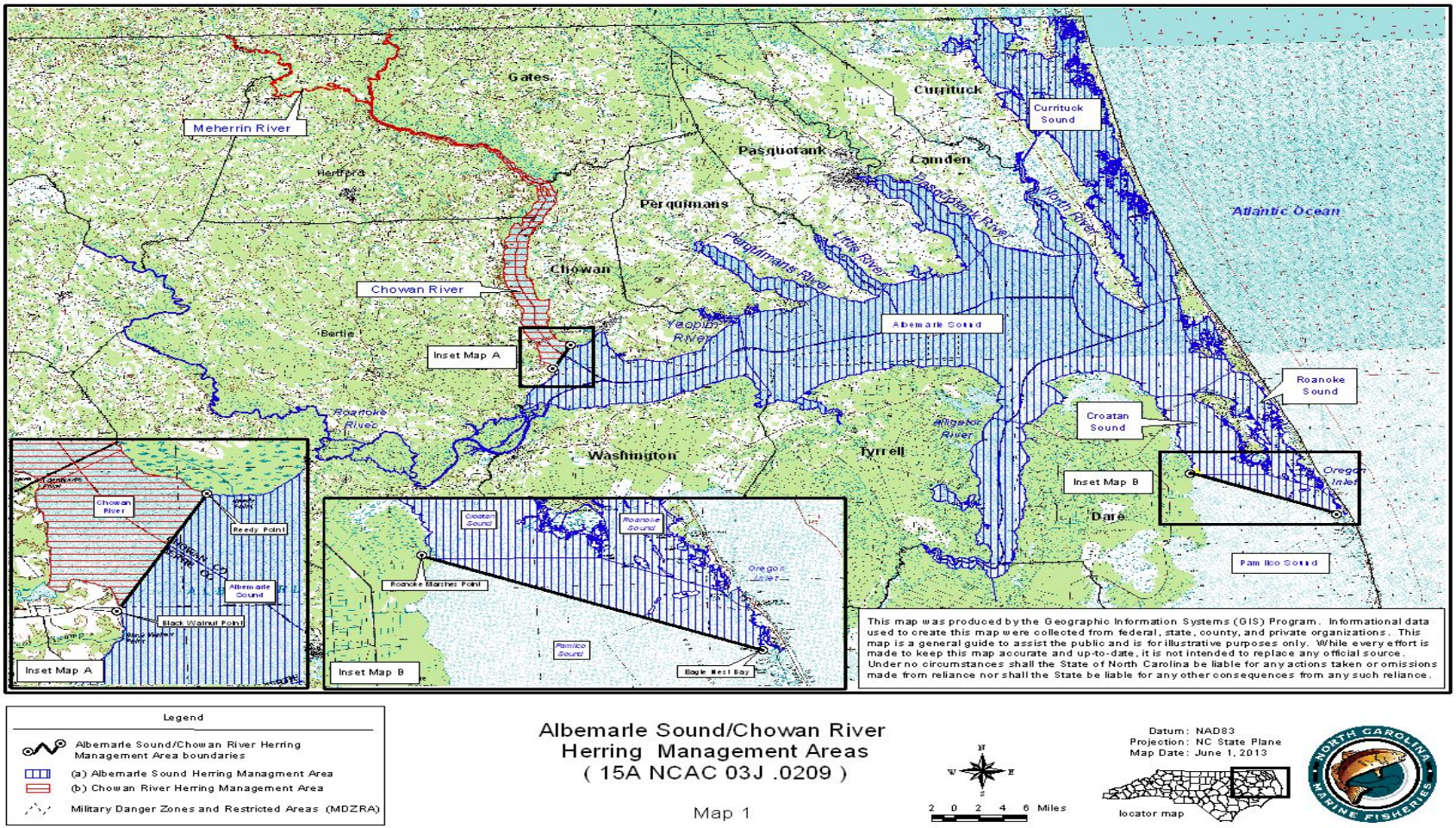


Figure 4.1 Albemarle Sound/Chowan River Herring Management Areas. ASHMA is in blue and CHRHMA is in red.

4.4.2 Environmental Issues

Problems exist in the areas of physical habitat and water quality. Considerable habitat area has been lost through wetland drainage, stream channelization and conversion to other uses. Some streams are blocked by dams, storm debris, and other physical barriers. Migration and spawning may be affected by replacement of small road bridges with culverts. Oxygen-consuming wastes are discharged into a number of streams and practices to control non-point discharges are inadequate causing nuisance algal blooms, fish kills and fish diseases over the years. There are also questions concerning the status of the forage base for river herring.

Amendment 1 to the River Herring Management Plan made a recommendation to investigate and identify man-made barriers to river herring migration and to create a list of impediments for removal or replacement. Following those recommendations, NCDMF initiated a survey of culverts and obstructions. The priority list has resulted in the replacement of failing culverts and prioritized others for replacement or repair.

4.4.3 Insufficient Assessment Data

Data concerning the stocks were lacking in many areas. Amendment 1 made several recommendations to improve data collection efforts, with a variety of monitoring programs. First, spawning area surveys have been conducted each year since 2007 in the Chowan River watershed and in the other river systems in Albemarle Sound on a rotating basis (Programs 150 and 160-Table 4.2). Secondly, the Chowan River Contracted Pound Net Survey (Program 410) was implemented in 2008 to provide data that were lost when the no-harvest provision began. Local pound net fishermen are contracted to set and fish pound nets in the Chowan River and visually estimate the number of pounds of herring caught during the spring spawning run. Samples of herring are collected for age composition and spawning condition. Third, the long-term juvenile monitoring program continues, with 11 core seines stations and 5 additional stations sampled monthly from June through October (Program 100). Finally, adult river herring data are collected in the Independent Gill Net Survey each year as recommended. Data are still lacking in areas of the state other than Albemarle Sound.

4.4.4 Inadequate Environmental Data

All fish stocks are basically dependent on environmental conditions for their survival. The key environmental conditions which control river herring behavior, survival, health and spawning success are unknown beyond a few measures, such as water temperature. In 2009, NCDMF began a water quality monitoring program, involving the installation of datasondes in most of the tributaries of Albemarle Sound. These datasondes collect hourly data on a variety of water quality parameters, such as dissolved oxygen, water temperature, conductivity and pH. The instruments remain in the water year-round and can be moved to various locations as the need arises. Water quality and other environmental data are also taken each time a sample is collected in Program 100 (Juvenile Anadromous Independent Fishery), Program 135 (Striped Bass Independent Gill Net Survey), Program 150 (Adult Anadromous Spawning Area Survey) and Program 160 (Anadromous Egg and Larval Survey). River herring are collected as part of all of these programs.

4.4.5 Socioeconomic Data

Because no fishery for river herring has existed since 2006, socioeconomic data to assess the cumulative effects of reduced stock availability and harvest restrictions on fishermen who have traditionally relied on the fishery for economic opportunity are lacking.

4.5 EXISTING PLANS, STATUTES, AND RULES

4.5.1 Plans

In May 2009, the Atlantic States Marine Fisheries Commission adopted Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring. Amendment 2 refers specifically to river herring management. This amendment required all states to close commercial and recreational fisheries for river herring by January 1, 2012, unless they developed and submitted for approval a sustainable fisheries plan. Currently only five of thirteen member states with river herring fisheries allow fishing. North Carolina adopted a moratorium in 2007 prior to this requirement and in response to the 2005 stock assessment. The discretionary harvest of 7,500 pounds was accepted as North Carolina's sustainable fisheries plan. This season occurs around the Easter holiday each year and typically brings in less than 1,000 pounds each year. Plans of the regional fishery management councils under the federal Magnuson-Stevens Act do not directly affect the river herring fisheries. However, river herring may be taken as bycatch in the mid-Atlantic and New England area fisheries for Atlantic mackerel and Atlantic herring. There are Magnuson-Stevens Act FMPs for these fisheries, so there are indirect federal management effects on North Carolina's river herring fisheries. The Mid-Atlantic Fishery Management Council is currently developing two amendments to the Mackerel, Squid and Butterfish Fishery Management Plan that deal with river herring. The goal of Amendment 14 is to implement effective catch monitoring so that the extent of river herring bycatch in these fisheries can be accurately estimated and subsequently reduced. Amendment 15 will consider adding river herring and shad as stocks in the fishery. The New England Fishery Management Council developed Amendment 5 to the Atlantic Herring Fishery Management Plan to improve catch accounting and address river herring bycatch in that fishery. In addition, the South Atlantic Fishery Management Council's Habitat Plan for the South Atlantic Region (SAFMC 1998) specifically considers habitat needs for anadromous fishes, including both species of river herrings. The Mid-Atlantic Fishery Management Council recommended a cap of 236 metric tons on the incidental catch of river herring and shad in the Atlantic mackerel fishery for 2014. Reaching this cap would result in early closure of that fishery.

In February 2000, the North Carolina Albemarle Sound Area River Herring FMP was approved by the MFC. Amendment 1 was approved in 2007. The plan is reviewed and updated at least every five years.

4.5.2 Statutes (North Carolina General Statutes)

All management authority for North Carolina's river herring fishery is vested in the State of North Carolina. Since the stocks depend greatly on habitats found in both coastal and inland waters and river herring fisheries occur in both areas, the North Carolina Marine Fisheries Commission and the North Carolina Wildlife Resources Commission will implement management actions in their respective jurisdictions pursuant to the recommendations contained in this plan. General authorities noted in Section 4.1 provide the NCMFC and NCWRC with regulatory powers to manage the fisheries.

Other statutes that affect herring fishing practices, rulemaking, agency jurisdiction and habitat protection and provide authority for the recommendations contained in this plan include:

G.S. 113-129.	Definitions relating to resources*
G.S. 113-131.	Resources belong to public; stewardship of conservation agencies; grant and delegation of powers; injunctive relief
G.S. 113-132.	Jurisdiction of fisheries agencies*
G.S. 113-134.	Rules*
G.S. 113-181.	Duties and powers of Department
G.S. 113-182.	Regulation of fishing and fisheries*
G.S. 113-182.1	Fishery Management Plans*
G.S. 113-221.1	Proclamations; emergency review*
G.S. 113-224.	Cooperative agreements by Department*
G.S. 113-268.	Injuring, destroying, stealing, or stealing from nets, seines, buoys, pots, etc.*
G.S. 143B-279.8.	Coastal Habitat Protection Plans*

Statutes marked with an asterisk are printed in North Carolina Fisheries Rules for Coastal Waters 2011. Text of all North Carolina statutes are available at www.ncga.state.nc.us/gascripts/Statutes/Statutes.asp.

4.5.3 North Carolina Marine Fisheries Commission Rules

15A NCAC 03I .0101 (4) (a) (b) (h) DEFINITIONS

All definitions set out in G.S. 113, Subchapter IV and the following additional terms apply to this Chapter:

(4) Fish habitat areas. The estuarine and marine areas that support juvenile and adult populations of fish species, as well as forage species utilized in the food chain. Fish habitats as used in this definition, are vital for portions of the entire life cycle, including the early growth and development of fish species. Fish habitats in all coastal fishing waters, as determined through marine and estuarine survey sampling, include:

(a) Anadromous fish nursery areas. Those areas in the riverine and estuarine systems utilized by post-larval and later juvenile anadromous fish.

(b) Anadromous fish spawning areas. Those areas where evidence of spawning of anadromous fish has been documented in Division sampling records through direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae.

(h) Strategic Habitat Areas. Locations of individual fish habitats or systems of habitats that provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity.

15A NCAC 03J .0101 FIXED OR STATIONARY NETS

It is unlawful to use or set fixed or stationary nets:

(1) In the channel of the Intracoastal Waterway or in any other location where it may constitute a hazard to navigation;

(2) So as to block more than two-thirds of any natural or manmade waterway, sound, bay, creek, inlet or any other body of water;

(3) In the middle third of any marked navigation channel;

(4) In the channel third of the following rivers: Roanoke, Cashie, Middle, Eastmost, Chowan, Little, Perquimans, Pasquotank, North, Alligator, Pungo, Pamlico, and Yeopim.

15A NCAC 03J .0102 NETS OR NET STAKES

It is unlawful to use nets or net stakes:

(1) Within 150 yards of railroad or highway bridge crossing the Northeast Cape Fear River, New River, White Oak River, Trent River, Neuse River, Pamlico River, Roanoke River, and Alligator River;
(2) Within 300 yards of any highway bridge crossing Albemarle Sound, Chowan River, Croatan Sound, Currituck Sound and Roanoke Sound;
(3) If such net stakes are of metallic material.

15A NCAC 03J .0103 GILL NETS, SEINES, IDENTIFICATION, RESTRICTIONS

(a) It is unlawful to use gill nets:
(1) With a mesh length less than 2 ½ inches.
(2) In internal waters from April 15 through December 15, with a mesh length 5 inches or greater and less than 5 ½ inches.

(b) The Fisheries Director may, by proclamation, limit or prohibit the use of gill nets or seines in coastal waters, or any portion thereof, or impose any or all of the following restrictions on gill net or seine fishing operations:
(1) Specify area.
(2) Specify season.
(3) Specify gill net mesh length.
(4) Specify means/methods.
(5) Specify net number and length.

(c) It is unlawful to use fixed or stationary gill nets in the Atlantic Ocean, drift gill nets in the Atlantic Ocean for recreational purposes, or any gill nets in internal waters unless nets are marked by attaching to them at each end two separate yellow buoys 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. Gill nets, which are not connected together at the top line, are considered as individual nets, requiring two buoys at each end of each individual net. Gill nets connected together at the top line are considered as a continuous net requiring two buoys at each end of the continuous net. Any other marking buoys on gill nets used for recreational purposes shall be yellow except one additional buoy, any shade of hot pink in color, constructed as specified in this Paragraph, shall be added at each end of each individual net. Any other marking buoys on gill nets used in commercial fishing operations shall be yellow except that one additional identification buoy of any color or any combination of colors, except any shade of hot pink, may be used at either or both ends. The owner shall be identified on a buoy on each end either by using engraved buoys or by attaching engraved metal or plastic tags to the buoys. Such identification shall include owner's last name and initials and if a vessel is used, one of the following:
(1) Owner's N.C. motor boat registration number, or
(2) Owner's U.S. vessel documentation name.

(d) It is unlawful to use gill nets:
(1) Within 200 yards of any flounder or other finfish pound net set with lead and either pound or heart in use, except from August 15 through December 31 in all coastal fishing waters of the Albemarle Sound, including its tributaries to the boundaries between coastal and joint fishing waters, west of a line beginning at a point 36° 04.5184' N - 75° 47.9095' W on Powell Point; running southerly to a point 35° 57.2681' N - 75° 48.3999' W on Caroon Point, it is unlawful to use gill nets within 500 yards of any pound net set with lead and either pound or heart in use;
(2) From March 1 through October 31 in the Intracoastal Waterway within 150 yards of any railroad or highway bridge.

(e) It is unlawful to use gill nets within 100 feet either side of the center line of the Intracoastal Waterway Channel south of the entrance to the Alligator-Pungo River Canal near Beacon "54" in Alligator River to the South Carolina line, unless such net is used in accordance with the following conditions:
(1) No more than two gill nets per vessel may be used at any one time;
(2) Any net used must be attended by the fisherman from a vessel who shall at no time be more than 100 yards from either net; and
(3) Any individual setting such nets shall remove them, when necessary, in sufficient time to permit unrestricted boat navigation.

(f) It is unlawful to use drift gill nets in violation of 15A NCAC 03J .0101(2) and Paragraph (e) of this Rule.

(g) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation in the gill net attended areas designated in 15A NCAC 03R .0112(a).
(h) It is unlawful to use unattended gill nets with a mesh length less than five inches in a commercial fishing operation from May 1 through November 30 in the internal coastal and joint waters of the state designated in 15A NCAC 03R .0112(b).
(i) For gill nets with a mesh length five inches or greater, it is unlawful:

(1) To use more than 3,000 yards of gill net per vessel in internal waters regardless of the number of individuals involved.
(2) From June through October, for any portion of the net to be within 10 feet of any point on the shoreline while set or deployed, unless the net is attended.

(j) For the purpose of this Rule and 15A NCAC 03R .0112, shoreline is defined as the mean high water line or marsh line, whichever is more seaward.

15A NCAC 03J .0203 CHOWAN RIVER AND ITS TRIBUTARIES

In the Chowan River and its tributaries:

(1) It is unlawful to anchor the lead line of any net closer than 50 feet from shore except in the Meherrin River.
(2) It is unlawful to use pound nets in any tributary creek or within 150 yards of the mouth of any such tributary creek of the Chowan River.
(3) It is unlawful to set a pound net within 200 yards parallel to any other pound net in the Chowan River.
(4) It is unlawful to use a seine within 1,000 yards of the mouth of any creek tributary to the Chowan River.
(5) It is unlawful to set a trotline within 100 yards of a pound net from February 1 through May 31.

15A NCAC 03J .0209 ALBEMARLE SOUND/CHOWAN RIVER HERRING MANAGEMENT AREAS

(a) The Albemarle Sound Herring Management Area is defined as Albemarle Sound and all its joint water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their joint water tributaries, including Oregon Inlet, north of a line beginning on the west shore at a point 35° 48.3693' N – 75° 43.7232' W on Roanoke Marshes Point; running southeasterly to the east shore to a point 35° 44.1710' N – 75° 31.0520' W on the north point of Eagles Nest Bay.
(b) The Chowan River Herring Management Area is defined as that area northwest of a line beginning on the west shore at a point 35° 59.9267' N – 76° 41.0313' W on Black Walnut Point; running northeasterly to the east shore to a point 36° 02.2140' N – 76° 39.3240' W on Reedy Point, to the North Carolina/Virginia state line; including the Meherrin River.
(c) Effective January 1, 2001, it is unlawful to use drift gill nets in the Albemarle Sound and Chowan River river herring management areas with a mesh length less than three inches from January 1 through May 15.

15A NCAC 03J .0501 DEFINITIONS AND STANDARDS FOR POUND NETS AND POUND NET SETS

(a) For the purpose of this Section the following terms are hereby defined:

(1) Pound Net Set Permit. A Division authorization to set and fish a pound net set in a commercial fishing operation in a specified location in a specified fishery.
(2) Permit period. One year from the date of issuance of a new or renewal pound net set permit.
(3) Deployed pound net. Setting of any part of a pound net, except for a location identification stake or for a pound net used in the Atlantic Ocean a location identification buoy placed at each end of a proposed new location.
(4) Operational pound net set. A pound net set as defined in 15A NCAC 03I .0101 and deployed according to rules and permit conditions with net attached to stakes or anchors for the lead and pound, including only a single pound in a multi-pound set, and a non-restricted opening leading into the pound such that the set is able to catch and hold fish.

(5) Flounder pound net. A pound net set that produces a catch consisting of 50 percent or more flounder by weight of the entire landed catch, excluding blue crabs or a pound net set with all pounds (holding pen) constructed of four inch stretch mesh or greater.

(6) Shrimp pound net. A pound net set with all pounds (holding pen) constructed of stretch mesh equal to or greater than one and one-fourth inches and less than or equal to two inches.

(b) It is unlawful for a pound net used in a commercial fishing operation to:

(1) Be deployed on a site without first obtaining a Pound Net Set Permit from the Fisheries Director.

(2) Fail to be operational for a minimum of 30 consecutive days during the pound net set permit period unless a season for the fishery for which the pound net set is permitted is ended earlier due to a quota being met.

(c) It is unlawful for a pound net set in a commercial fishing operation in coastal fishing waters to fail to:

(1) Have the permittee's identification legibly printed on a sign no less than six inches square, securely attached to a stake at the permitted ends of each set at all times. For pound net sets in the Atlantic Ocean using anchors instead of stakes, the set shall be identified with a yellow buoy, which shall be of solid foam or other solid buoyant material no less than five inches in diameter and no less than 11 inches in length. The permittee's identification shall be legibly printed on the buoy. The identification on signs or buoys shall include the Pound Net Set Permit number and the permittee's last name and initials.

(2) Have yellow light reflective tape or yellow light reflective devices on each pound. The yellow light reflective tape or yellow light reflective devices shall be affixed to a stake of at least three inches in diameter on any outside corner of each pound, shall cover a vertical distance of not less than 12 inches, and shall be visible from all directions.

(3) Have a marked navigational opening at least 25 feet wide at the end of every third pound. The opening shall be marked with yellow light reflective tape or yellow light reflective devices on each side of the opening. The yellow light reflective tape or yellow light reflective devices shall be affixed to a stake of at least three inches in diameter, shall cover a vertical distance of not less than 12 inches, and shall be visible from all directions.

If a permittee notified of a violation under this Paragraph fails or refuses to take corrective action sufficient to remedy the violation within 10 days of receiving notice of the violation, the Fisheries Director shall revoke the permit.

(d) It is unlawful to use a Recreational Commercial Gear License (RCGL) shrimp pound net as defined in 15A NCAC 03O .0302 (a)(8) in coastal fishing waters unless the shrimp pound net is:

(1) Marked by attaching to the offshore lead, one floating buoy, any shade of hot pink in color, which is 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. The identification shall include owner's last name and initials and if a vessel is used, one of the following:

(A) Gear owner's current motor boat registration number; or

(B) Owner's U.S. vessel documentation name.

(2) Set a minimum of 100 yards from a RCGL shrimp pound net set or 300 yards from an operational permitted shrimp pound net set.

(e) Escape Panels:

(1) The Fisheries Director may, by proclamation, require escape panels in pound net sets and may impose any or all of the following requirements or restrictions on the use of escape panels:

(A) Specify size, number, and location.

(B) Specify mesh length, but not more than six inches.

(C) Specify time or season.

(D) Specify areas.

(2) It is unlawful to use flounder pound net sets without four unobstructed escape panels in each pound. The escape panels shall be fastened to the bottom and corner ropes on each wall on the side and back of the pound opposite the heart. The escape panels shall

be a minimum mesh size of five and one-half inches, hung on the diamond, and shall be at least six meshes high and eight meshes long.

(f) During 1 December through 1 February the Director shall by proclamation establish time periods and areas where it is unlawful to fail to remove all nets from pound net sets in commercial fishing operations in internal coastal waters.

(g) It is unlawful within 30 days of abandonment of a permitted pound net set to fail to remove all stakes and associated gear from coastal fishing waters. The responsible party for abandoned pound net gear may be charged the costs incurred by the Division when the Division undertakes removal of the abandoned pound net gear.

15A NCAC 03J .0502 POUND NET SET PERMIT APPLICATION AND PROCESSING

(a) All initial, renewal or transfer applications for Pound Net Set Permits, and the operation of such pound net sets, shall comply with the rules governing all permits as provided in 15A NCAC 03O .0502. The procedures and requirements for obtaining permits are set forth in 15A NCAC 03O .0501.

(b) Applicants for Pound Net Set permits shall meet the following eligibility requirements as determined by the Fisheries Director:

(1) Applicant is an individual and not a corporation, partnership, organization or other entity;

(2) Applicant has in the past complied with fisheries rules and laws and does not have any licenses or privileges under suspension or revocation. In addition, a history of habitual fisheries violations evidenced by eight or more convictions in 10 years shall make an individual ineligible.

(3) Applicant has in the past complied with all permit conditions, rules and laws related to pound nets.

(4) Applicant holds proper valid license(s) and permit(s) necessary to fish the type of net indicated in the application.

(c) Applications for Pound Net Set permits shall include the following:

(1) A base map provided by the Division indicating the proposed set location including an inset vicinity map showing the location of the proposed set with detail sufficient to permit on-site identification and location.

(2) Declaration of the type of pound net that will be deployed at the site. One of the following pound net fisheries shall be specified:

(A) Flounder pound net set;

(B) Bait pound net set;

(C) Shrimp pound net set;

(D) Blue crab pound net set;

(E) Other finfish pound net set.

(d) For proposed new location(s), the Fisheries Director shall issue a public notice of intent to consider issuance of a Pound Net Set Permit allowing for public comment for 20 days, and after the comment period, may hold public meetings to take comments on the proposed pound net set. If the Director does not approve or deny the application within 90 days of receipt of a complete and verified application, the application is deemed denied. The applicant shall be notified of denial in writing. Approval is conditional based upon the applicant's continuing compliance with eligibility requirements set out in Paragraph (e) of this Rule and specific conditions contained on the Pound Net Set Permit. The final decision to approve or deny the Pound Net Set Permit application may be appealed by the applicant by filing a petition for a contested case hearing, in writing, within 60 days from the date of mailing notice of such final decision to the applicant, with the Office of Administrative Hearings.

(e) In order for a site to be deemed suitable for a pound net set, the proposed set location shall meet the following criteria as determined by the Fisheries Director:

(1) The proposed pound net set, either alone or when considered cumulatively with other existing pound net sets in the area, will not interfere with public navigation or with existing, traditional uses of the area other than navigation, and will not violate 15A NCAC 03J .0101 and .0102;

(2) The proposed pound net set will not interfere with the rights of any riparian or littoral landowner, including the construction or use of piers;

(3) The proposed pound net set will not, by its proximate location, interfere with existing pound net sets in the area. Flounder or other finfish pound net sets will be a minimum of

1,000 yards, as measured in a perpendicular direction, from any point on a line following the permitted location of existing pound net sets; except

(A) in Chowan River as referenced in 15A NCAC 03J .0203; and

(B) for renewal of pound net sets permitted prior to January 1, 2003;

(4) The proposed shrimp or blue crab pound net set will be a minimum of 300 yards, as measured in a perpendicular direction, from any point on a line following the permitted location of existing pound net sets;

(5) The proposed pound net set is not located in Core Sound in areas designated in 15A NCAC 03R .0113 except that only those Pound Net Set Permits valid within the specified area as of March 1, 1994, may be renewed or transferred subject to the requirements of this Rule; and

(6) Issuance of the proposed Pound Net Set Permit is in compliance with management measures adopted in fishery management plans.

15A NCAC 03J .0503 POUND NET SET PERMIT RENEWAL

An application for renewal of an existing Pound Net Set Permit shall be filed not less than 30 days prior to the date of expiration of the existing permit, and shall not be processed unless filed by the permittee. The Fisheries Director shall review the renewal application under the criteria for issuance of a new Pound Net Set Permit. The Fisheries Director may hold public meetings and may conduct such investigations necessary to determine if the permit should be renewed.

15A NCAC 03J .0504 POUND NET SET PERMIT TRANSFER

It is unlawful to transfer a Pound Net Set Permit without a completed application for transfer being submitted to the Division not less than 45 days before the date of the transfer. The application shall be made by the proposed new permittee in writing and shall be accompanied by a copy of the current permittee's permit and an application for a Pound Net Set Permit in the new permittee's name. The Fisheries Director may hold a public meeting and conduct such investigations necessary to determine if the permit should be transferred. The transferred permit expires on the same date as the initial permit. Upon death of the permittee, the permit may be transferred to the Administrator/Executor of the estate of the permittee if transferred within six months of the Administrator/Executor's qualification in accordance with Chapter 28A of the North Carolina General Statutes. The Administrator/Executor shall provide a copy of the deceased permittee's death certificate, a copy of letters of administration/letters testamentary and a list of eligible immediate family members as defined in G.S. 113-168 to the Morehead City Office of the Division. Once transferred to the Administrator/Executor, the Administrator/Executor may transfer the permit(s) to eligible immediate family members of the deceased permittee. No transfer is effective until approved and processed by the Division.

15A NCAC 03J .0505 POUND NET SET PERMIT CONDITIONS

(a) It is unlawful for a permittee:

(1) To fail to notify the Marine Patrol Communications Center within 72 hours by phone:

(A) Of an operational pound net set. Notification shall include the name of permittee, type of net, Pound Net Set Permit number, county where located, a specific location site, and how many pounds are in the set; and

(B) Of a change to the type of net being set at the permitted site.

(2) To make false notifications.

(3) To fail to render the pound net set inoperable during any closed season for the type of fishery for which the pound net is permitted.

Failure to comply with this Paragraph is grounds for the Fisheries Director to revoke any Pound Net Set Permits held by the permittee and for denial of any future applications for Pound Net Set Permits.

(b) Pound net sets are subject to inspection at all times.

(c) Daily reporting may be a condition of the permit for a pound net set for fisheries under a quota.

(d) It is unlawful to fail to remove all pound net stakes and associated gear within 30 days after expiration of the permit or notice by the Fisheries Director that an existing Pound Net Set Permit has been revoked or denied.

15A NCAC 03M .0101 MUTILATED FINFISH

It is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish that is subject to a size or harvest restriction without having head and tail attached, except:

(1) mullet when used for bait;

(2) blueback herring, hickory shad and alewife when used for bait provided that not more than two fish per boat or fishing operation may be cut for bait at any one time; and

(3) tuna possessed in a commercial fishing operation as provided in 15A NCAC 03M .0520.

15A NCAC 03M .0513 RIVER HERRING

It is unlawful to possess river herring taken from coastal fishing waters unless the river herring season is open.

15A NCAC 03R .0115 ANADROMOUS FISH SPAWNING AREAS

The anadromous fish spawning areas as defined in 15A NCAC 03I .0101 and referenced in 15A NCAC 03 N .0106 are delineated in the following coastal waters:

(1) Currituck Sound Area:

(a) Northwest River- all waters of the Northwest River and its tributaries east of a line beginning on the north shore at a point 36º 30.8374' N – 76º 04.8770' W; running southerly to the south shore to a point 36º 30.7061' N – 76º 04.8916' W.

(b) Tull Bay/Tull Creek- all waters of Tull Bay and its tributaries northeast of a line beginning on the north shore at a point 36º 30.0991' N – 76º 04.8587' W; running southeasterly to the south shore to a point 36º 29.9599' N – 76º 04.7126' W; and south of a line beginning on the west shore at a point 36º30.9867' N – 76º 02.5868' W; running easterly to the east shore to a point 36º31.0045' N – 76º 02.3780' W; and west of a line beginning on the north shore at a point 36º 30.8291' N – 76º 02.1329' W; running southwesterly to the south shore to a point 36º 30.1512' N – 76º 02.4982' W.

(2) Albemarle Sound Area:

(a) Big Flatty Creek- all waters of Big Flatty Creek and its tributaries east of a line beginning on the north shore at a point 36º 09.3267'N – 76º 08.2562'W; running southerly to the south shore to a point 36º 08.9730'N – 76º 08.3175'W and north of a line beginning on the west shore at a point 36º 07.9621'N – 76º 07.1818'W; running easterly to the east shore to a point 36º 08.2706'N – 76º 06.2525'W.

(b) Batchelor Bay- west of a line beginning on the north shore at a point 35º 58.2070' N – 76º 42.7267' W; running southeasterly to the south shore to a point 35º 56.5622' N – 76º 41.5506' W.

(c) Bull Bay- southwest of a line beginning on the northwest shore at a point 35º 58.9002' N – 76º 23.9965' W; running southeasterly to the southeast shore at a point 35º 56.7198' N – 76º 18.8964' W.

(3) North River- all waters of the North River and its tributaries east of a line beginning on the north shore at a point 36º 18.7703' N – 75º 58.7384' W; running southerly to the south shore to a point 36º 18.4130' N – 75º 58.7228' W; and north of a line beginning on the west shore at a point 36º 16.9952' N – 75º 57.0758' W; running easterly to the east shore to a point 36º 16.9801' N – 75º 56.6820' W.

(4) Pasquotank River- all waters of the Pasquotank River and its tributaries south of a line beginning on the west shore at a point 36º 18.0768' N – 76º 13.0979' W; running easterly to the east shore along the south side of the Highway 158 Bridge to a point 36º 18.0594' N – 76º 12.9620' W; and northwest of a line beginning on the northeast shore at a point 36º 14.3294' N– 76º 04.7866' W; running southwesterly to the southwest shore to a point 36º 12.8147' N- 76º 07.0465' W.

(5) Pasquotank River Area:

(a) Charles Creek- north of a line beginning on the west shore at a point 36º 17.8090' N – 76º 13.0732' W; running easterly to the east shore to a point 36º 17.8024' N – 76º 13.0407' W.

(b) New Begun Creek- east of a line beginning on the north shore at a point 36º 13.3298' N – 76º 08.2878' W; running southerly to the south shore to a point 36º 13.0286' N – 76º 08.1820' W.

(6) Little River- all waters of the Little River and its tributaries southeast of a line beginning on the west shore at a point 36º 12.5237' N – 76º 16.9418' W; running southeasterly to the east shore to a point 36º 12.2950' N – 76º 17.1405' W; and north of a line beginning on the west shore at a point 36º 09.6537' N – 76º 15.0689' W; running northeast to the east shore to a point 36º 10.2112' N – 76º 14.0287' W.

(7) Perquimans River- all waters of the Perquimans River and its tributaries northeast of a line beginning on the west shore at a point 36º 11.6569' N – 76º 28.0055' W; running southeasterly to the east shore to a point 36º 11.6123' N – 76º 27.9382' W; and northwest of a line beginning on the southwest shore at a point 36º 11.1512' N – 76º 27.4424' W; running northeasterly to the northeast shore to a point 36º 11.5124' N – 76º 26.7298' W.

(8) Perquimans River Area:

(a) Walter's Creek- northeast of a line beginning on the north shore at a point 36º 11.1305' N – 76º 27.9185' W; running southeasterly to the south shore to a point 36º 11.0224' N – 76º 27.6626' W.

(b) Mill Creek- south of a line beginning on the west shore at a point 36º 11.9766' N – 76º 27.2511' W; running easterly to the east shore to a point 36º 11.9757' N – 76º27.5752' W.

(9) Yeopim River- all waters of the Yeopim River and its tributaries east of a line beginning on the north shore at a point 36º 05.4526'N – 76º27.7651'W; running southerly to the south shore to a point on Norcum Point 36º 05.1029'N – 76º27.7120' W; and west of a line beginning on the north shore at a point 36º 04.7426' N – 76º 24.2537' W; running southwesterly to the south shore to a point 36º 04.1137' N – 76º 24.5366' W.

(10) Yeopim River Area, Yeopim Creek- south of a line beginning on the west shore at a point 36º 04.7206' N – 76º 24.8396' W; running easterly to the east shore to a point 36º 04.7426' N – 76º 24.2536' W.

(11) Edenton Bay- all waters of Edenton Bay and its tributaries west of a line beginning on the north shore at a point 36º 03.3757' N – 76º 36.3629' W; running southerly to the south shore to a point 36º 03.3551' N – 76º 36.3574' W; and north of a line beginning on the west shore at a point 36º 02.1767' N – 76º 38.4058' W; running easterly to the east shore to a point 36º 02.0299' N – 76º 36.0445' W; and east of a line beginning on the west shore at a point 36º 03.2819' N – 76º 37.0138' W; running northeasterly to the east shore to a point 36º 03.4185' N – 76º 36.6783' W.

(12) Chowan River- all waters of the Chowan River and tributaries northwest of a line beginning on the west shore at a point 36º 02.3162' N – 76º 42.4896' W; running northeasterly to the east shore to a point 36º 03.1013' N – 76º40.8732' W; and south of a line beginning on the west shore at a point 36º 32.6293' N – 76º 55.3564' W; and running to the east shore to a point 36º 32.6284' N – 76º 55.1757' W.

(13) Chowan River Area, Meherrin River- all waters of the Meherrin River and tributaries west of a line beginning on the north shore at a point 36º 25.9937' N – 76º 56.8884' W; running southerly to the south shore to a point 36º 25.7926' N – 76º 56.8966' W; and south of a line beginning on the west shore at a point 36º 32.7867' N – 77º 09.8885' W; running easterly to the east shore to a point 36º 32.7807' N – 77º 09.8565' W.

(14) Cashie River- all waters of the Cashie River and tributaries east of a line beginning on the north shore at a point 35º 54.7865' N – 76º 49.0521' W; running southerly to the south shore at a point 35º 54.6691' N – 76º 49.0553' W; west of a line beginning on the north shore at a point 35º 56.4598' N – 76º 43.8093' W; running southerly to the north shore to a point on the north shore of an island in the mouth of the river 35º 56.2250' N – 76º 43.9265' W; west of a line beginning on the south shore at a point of an island in the mouth of the river 35º 56.1254' N – 76º 43.9846' W; running southerly to the south shore to a point 35º 56.0650' N – 76º 43.9599' W.

(15) Middle River- all waters of the Middle River southwest of a line beginning on the west shore at a point 35º 55.4000' N – 76º 43.8259' W; running southeasterly to the east shore to a point 35º 55.3977' N – 76º43.6797' W.

(16) Eastmost River- all waters of the Eastmost River and its tributaries south of a line beginning on the west shore at a point 35º 56.5024' N – 76º 42.4877' W; running westerly to the east shore to a point 35º 56.4070' N – 76º 42.7647' W.

(17) Roanoke River - all waters of the Roanoke River and tributaries south of a line beginning on the west shore at a point 35º 56.5068' N – 76º 41.8858' W; running easterly to the east shore to a point 35º 56.5324' N – 76º 41.5896' W; and southeast of a line beginning on the west shore at a point 36º 12.5264' N – 77º 23.0223' W; running northeasterly to the east shore along the south side of the Highway 258 Bridge to a point 36º 12.5674' N – 77º 22.9724' W.

(18) Roanoke River Area:

(a) Warren Neck Creek- all waters of Warren Neck Creek and its tributaries west of a line beginning on the northwest shore at a point 35º 52.1820' N – 76º 47.4855' W; running southerly to the southeast shore to a point 35º 52.1448' N – 76º 47.4237' W.

(b) Thoroughfare- all waters of the Thoroughfare south of a line beginning on the west shore at a point 35º 54.0510' N – 76º 48.1206' W; running easterly to the east shore to a point 35º 54.0684' N – 76º 48.0613' W; and north of a line beginning on the west shore at a point 35º 53.2842'N – 76º 48.8650' W; running easterly to the east shore to a point 35º 55.2800' N – 76º 48.8077' W.

(c) Devils Gut- all waters of Devils Gut and its tributaries northwest of a line beginning on the west shore at a point 35º 49.5300' N – 76º 54.2209' W; running easterly to the east shore to a point 35º 49.5486' N – 76º 54.1703' W.

(d) Conine Creek- all waters of Conine Creek and its tributaries west of a line beginning on the north shore at a point 35º 52.9752' N – 76º 58.0474' W; running southwesterly to the south shore to a point 35º 52.9776' N – 76º 57.9958' W.

(19) Scuppernong River- all waters of the Scuppernong River and tributaries southeast of a line beginning on the northeast shore at a point 35º 56.7196' N – 76º 18.8964' W; running southwesterly to the southwest shore to a point 35º 56.3351' N – 76º 19.6609' W; and north of a line beginning on the west shore at a point 35º 54.0158' N – 76º 15.4605' W; running easterly to the east shore to a point 35º 54.0406' N – 76º 15.3007' W.

(20) Alligator River- all waters of the Alligator River and tributaries east of a line beginning on the north shore at Cherry Ridge Landing at a point 35º 42.2172' N – 76º 08.4686' W; running southerly to the south shore to a point 35º 42.1327' N – 76º 08.5002' W; and south of a line beginning on the west shore at a point 35º 57.4252' N – 76º 00.8704' W; running easterly to the east shore to a point 35º 57.5494' N – 75º 56.8268' W.

(21) Alligator River Area, the Frying Pan- all waters of the Frying Pan and its tributaries west of a line beginning on the north shore at a point 35º 46.0777' N – 76º 03.3439' W; running southerly to the south shore to a point 35º 45.6011' N – 76º 03.3692' W.

(22) Neuse River- all waters of the Neuse River and its tributaries northwest of a line beginning on the west shore at a point 35° 08.8723'N - 77° 04.6700' W; running northeasterly to the east shore to a point 35° 09.1032' N - 77° 04.3355' W and southeast of a line at Pitch Kettle Creek beginning on the north shore at a point 35° 16.9793'N - 77° 15.5529'W; running south to the south shore to a point 35°16.9237'N - 77° 15.5461' W.

(23) Neuse River Area:

(a) Smith Creek- north of a line beginning on the west shore at a point 35° 02.2439'N - 76° 42.3035' W; running easterly to the east shore to a point 35° 02.2392' N - 76° 42.1910' W.

(b) Kershaw Creek- north of a line beginning on the west shore at a point 35° 02.4197'N - 76° 43.7886' W; running easterly to the east shore to a point 35° 02.4218'N - 76° 43.7367' W.

(24) White Oak River- all waters north of a line beginning at a point on the west shore 34° 46.0728' N - 77° 08.9657' W; running easterly to a point on the east shore 34° 46.1431' N

- 77° 08.8907' W; running north to the Coastal – Inland waters boundary line beginning at a point on the west shore 34° 48.1466' N - 77° 11.4711' W; running northeasterly to a point on the east shore 34° 48.1620' N - 77° 11.4244' W.

(25) Cape Fear River- all waters north of a line beginning at a point on the west shore 34° 07.7034' N – 77° 57.3431' W; running easterly to a point on the east shore 34° 08.0518' N – 77° 55.7626' W; running north to the Joint - Inland waters boundary on the following rivers:

(a) Cape Fear River- at a line beginning at a point on the west shore 34° 24.2628' N - 78° 17.6390' W; running northeasterly along the Lock and Dam # 1 to a point on the east shore 34° 24.2958' N - 78° 17.5634' W.

(b) Black River- at a line beginning at a point on the north shore 34° 22.0783' N - 78° 04.4123' W; running southeasterly to a point on the south shore 34° 21.9950' N - 78° 04.2864' W.

(c) Northeast Cape Fear River- at a line beginning at a point on the west side 34° 26.5658' N - 77° 50.0871' W; running northeasterly along the southern side of the NC 210 Bridge to a point on the east side 34° 26.6065' N - 77° 49.9955' W.

4.5.4 North Carolina Wildlife Resources Commission Rules

Under NCWRC rules (15A NCAC 10C .401), "While boating on or fishing in the following inland fishing waters, no person shall take river herring (alewife and blueback) that are greater than six inches in total length or possess such herring regardless of origin in:
(A) Roanoke River downstream of Roanoke Rapids Dam,
(B) Tar River downstream of Rocky Mount Mill Dam,
(C) Neuse River downstream of Milburnie Dam,
(D) Cape Fear River downstream of Buckhorn Dam,
(E) Pee Dee River downstream of Blewett Falls Dam,
(F) Lumber River including Drowning Creek,
(G) all the tributaries to the rivers listed above,
(H) all other inland fishing waters east of Interstate 95."

This rule took effect August 1, 2013.

15A NCAC 10C .0602 ANADROMOUS FISH SPAWNING AREAS DEFINED

Anadromous fish spawning areas are those areas where evidence of spawning of anadromous fishes has been documented by direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae.

History Note: Authority G.S. 113-132; 113-134;
Eff. May 1, 2008.

15A NCAC 10C .0603 DESCRIPTIVE BOUNDARIES

The following waters have been designated as anadromous spawning areas:

(1) Currituck Sound Area:

(a) Northwest River including designated tributaries - main stem waters west of a line beginning on the north shore at a point 36° 30.8374' N – 76° 04.8770' W; running southerly to the south shore to a point 36° 30.7061' N – 76° 04.8916' W; and south of a line beginning on the west shore at a point 36° 33.0259' N – 76° 09.1609' W; running easterly to the east shore to a point 36° 33.0292' N – 76° 08.9488' W; including the following tributary from the confluence with Northwest River in the direction indicated to the specified boundary: Moyock Run (Shingle Landing Creek) - upstream (southwest) to a line beginning on the west shore at a

point 36° 31.5252' N – 76° 10.7385' W; running easterly along US 168 (Caratoke Highway) to the east shore to a point 36° 31.5140' N – 76° 10.7239 W.

(b) Tull Creek - southwest of a line beginning on the north shore at a point 36° 30.0991' N – 76° 04.8587' W; running southeasterly to the south shore to a point 36° 29.9599' N – 76° 04.7126' W; including the following tributaries from their confluence with Tull Creek to the specified boundary:

(i) Roland Creek - upstream (northwest) to a line beginning on the north shore at a point 36° 29.8274' N – 76° 08.1294' W; running southerly to the south shore to a point 36° 29.8120' N – 76° 08.1308' W; and east of a line beginning on the northwest shore of Guinea Mill Run Canal at a point 36° 28.9227' N – 76° 07.9126' W; running southerly along US 168 bridge (Caratoke Highway) to the southeast shore at a point 36° 28.9045' N – 76° 07.8956' W.

(ii) New Bridge Creek - upstream (south) to a line beginning on the northwest shore at a point 36° 28.0046' N – 76° 06.3312' W; running southeasterly along US 168 bridge (Caratoke Highway) to the southeast shore to a point 36° 27.9970' N – 76° 06.3243' W.

(iii) Cowells Creek - upstream (south) to a line beginning on the west shore at a point 36° 27.1571' N – 76° 04.5391' W; running easterly along US 168 bridge (Caratoke Highway) to the east shore to a point 36° 27.1542' N – 76° 04.5128' W.

(iv) Buckskin Creek - upstream (southeast) to a line beginning on the west shore at a point 36° 27.1925' N – 76° 04.1671' W; running easterly along US 168 bridge (Caratoke Highway) to the east shore to a point 36° 27.1989' N – 76° 04.1400' W.

(c) West Landing - north of a line beginning on the west shore at a point 36° 30.9867' N – 76° 02.5868' W; running easterly to the east shore to a point 36° 31.0045' N – 76° 02.3780' W; and west of a line beginning on the north shore at a point 36° 31.5828' N – 76° 02.2977' W; running southerly to the south shore to a point 36° 31.5618' N – 76° 02.2870' W.

(2) Albemarle Sound Area:

(a) Big Flatty Creek - west of a line beginning on the north shore at a point 36° 09.3267' N – 76° 08.2562' W; running southerly to the south shore to a point 36° 08.9730' N – 76° 08.3175' W; including the following tributaries from the confluence with Big Flatty Creek in the direction indicated to the specified boundary:

(i) Chapel Creek - upstream (northwest) to a line beginning on the north shore at a point 36° 09.6689' N – 76° 09.9595' W; running southerly along SSR 1103 (Esclip Road) to the south shore to a point 36° 09.6522' N – 76° 09.9612' W.

(ii) Mill Dam Creek - upstream (southwest) to a line beginning on the north shore at a point 36° 09.0094' N – 76° 10.1667' W; running southerly along SSR 1103 (Esclip Road) to the south shore to a point 36° 08.9931' N – 76° 10.1611'W.

(b) Salmon Creek - southwest of a line beginning on the north shore at a point 36° 00.4648' N – 76° 42.3513' W; running southeasterly to the south shore to a point 36° 00.3373' N – 76° 42.1499' W; and south of a line beginning on the west shore at a point 36° 02.4783' N – 76° 45.8164' W; running easterly to the east shore to a point 36° 02.4807' N – 76° 45.7906' W.

(c) Mackeys (Kendrick) Creek - southeast of a line beginning on the north shore at a point 35° 56.3806' N – 76° 36.4356' W; running southwesterly to the south shore to a point 35° 56.3122' N – 76° 36.4613' W; and northwest of a line beginning on the southwest shore at a point 35° 52.5564' N – 76° 37.0968' W; running northeasterly along SSR 1122 bridge (Buncombe Avenue) to the northeast shore to a point 35° 52.5470' N – 76° 37.1113' W; including the following tributary from its confluence with Mackeys Creek in the direction indicated to the specified

boundary: Main Canal - upstream (southeast) to a line beginning on the southwest shore at a point 35° 52.8229' N – 76° 36.6916' W; running northeasterly along SSR 1122 (Buncombe Avenue) to the northeast shore to a point 35° 52.8390' N – 76° 36.6708' W.

(d) Deep Creek (Washington County) - west of a line beginning on the north shore at a point 35° 56.1291' N – 76° 23.1179' W; running southerly to the south shore to a point 35° 56.0744' N – 76° 23.1230' W; and east of a line beginning on the north shore at a point 35° 55.4610' N – 76° 25.3996' W; running southerly along SSR 1302 bridge (Pea Ridge Road) to the south shore to a point 35° 55.4323' N – 76° 25.3974' W; and east of line beginning on the north shore at a point 35° 55.7173' N – 76° 25.3848' W; running southerly along SSR 1302 bridge (Pea Ridge Road) to the south shore to a point 35° 55.6863' N – 76° 25.3957' W.

(e) Banton (Bunton or Maybell) Creek - south of a line beginning on the west shore at a point 35° 56.0552' N – 76° 22.0664' W; running northeasterly to the east shore to a point 35° 56.1151' N – 76° 21.8760' W; and northeast of a line beginning on the west shore at a point 35° 55.6117' N – 76° 22.2463' W; running easterly to the east shore to a point 35° 55.6128' N – 76° 22.2126' W.

(f) Tom Mann Creek - south of a line beginning on the west shore at a point 35° 58.5296' N – 75° 52.8982' W; running easterly to the east shore to a point 35° 58.5175' N – 75° 53.6851' W.

(g) Peter Mashoes Creek - west of a line beginning on the north shore at a point 35° 57.2344' N – 75° 48.3087' W; running southerly to the south shore to a point 35° 56.7805' N – 75° 48.3563' W.

(3) North River, including Indiantown Creek and other designated tributaries - main stem waters west of a line beginning on the north shore at a point 36° 18.7703' N – 75° 58.7384' W; running southerly to the south shore to a point 36° 18.4130' N – 75° 58.7228' W; and south of a line beginning on the west shore at a point 36° 21.7982' N – 76° 07.0726' W; running easterly along US 158 bridge to the east shore to a point 36° 21.8030' N – 76° 07.0612' W; including the following tributary from the confluence with North River in the direction indicated to the specified boundary: Crooked Creek - upstream (west) to a line beginning on the north shore at a point 36° 18.7171' N – 76° 01.4361' W; running southerly to the south shore to a point 36° 18.7002' N – 76° 01.4296' W.

(4) North River Area: Bump Landing Creek - east of a line beginning on the north shore at a point 36° 19.3757' N – 75° 57.9057' W; running southerly to the south shore to a point 36° 19.2496' N – 75° 57.9107' W; and west of a line beginning on the north shore at a point 36° 19.4049' N – 75° 57.4963' W; running southeasterly to the south shore to a point 36° 19.3830' N – 75° 57.5098' W.

(a) Narrow Ridges Creek - east of a line beginning on the north shore at a point 36° 18.3249' N – 75° 57.8910' W; running southerly to the south shore to a point 36° 18.1388' N – 75° 57.9029' W; and west of a line beginning on the north shore at a point 36° 18.1566' N – 75° 57.4879' W; running southeasterly to the south shore to a point 36° 18.1221' N – 75° 57.5095' W.

(b) Great Creek - west of a line beginning on the north shore at a point 36° 18.1045' N – 75° 58.4289' W; running southerly to the south shore to a point 36° 17.9882' N – 75° 58.4458' W; and northeast of a line beginning on the north shore at a point 36° 17.1310' N – 76° 00.3414'W; running southeasterly to the south shore to a point 36° 17.1163' N – 76° 00.3310' W. On the north shore of Great Creek within the fourth tributary: south of a line beginning on the west shore at a point 36° 18.1729' N – 75° 58.9137' W; running southeasterly to the south shore to a point 36° 18.1640' N – 75° 58.9022' W.

(c) Deep Creek - east of a line beginning on the north shore at a point 36° 17.1576' N – 75° 56.7594' W; running southerly to the south shore to a point 36° 16.9846' N – 75° 56.6802' W; and south of a line beginning on the west shore at a point 36° 17.9515' N – 75° 56.5174' W; running easterly to the east shore to a point 36° 17.9523' N – 75° 56.5042' W.

(d) Public Creek - west of a line beginning on the north shore at a point 36° 17.2462' N – 75° 58.2774' W; running southerly to the south shore to a point 36° 17.2121' N – 75° 58.2788' W; and northeast of a line beginning on the north shore at a point 36° 17.1661' N – 75° 58.6059' W; running southeasterly to the south shore to a point 36° 17.1574' N – 75° 58.6003' W.

(5) Pasquotank River including designated tributaries - main stem waters north of a line beginning on the west shore at a point 36° 18.0769' N – 76° 13.0979' W; running easterly along the south side of the US 158 bridge to the east shore to a point 36° 18.0594' N – 76° 12.9620' W and south of a line at South Mills beginning on the west shore at a point 36° 26.7432' N – 76° 19.6666' W; running easterly along US 17 business (Main Street) to the east shore to a point 36° 26.7642' N – 76° 19.5932' W; and southeast of a line beginning on the northeast shore at a point 36° 26.1777' N – 76° 22.1079' W; running southwesterly to the southwest shore to a point 36° 26.1693' N – 76° 22.1257' W; including the following tributaries from their confluence with the Pasquotank River in the direction indicated to the specified boundary:

(a) Joyce Creek - upstream (northeast) to a line beginning on the north shore at a point 36° 26.8329' N – 76° 17.6174' W; running southwesterly along SSR 1224 bridge (Old Swamp Road) to the south shore to a point 36° 26.8103' N – 76° 17.6193' W.

(b) Sawyers Creek - upstream (northeast) to a line beginning on the northeast shore at a point 36° 21.7237' N – 76° 10.2841' W; running southwesterly along SSR 1203 bridge (Scotland Road) to the southwestern shore to a point 36° 21.7115' N – 76° 10.3041' W.

(c) Knobbs Creek - upstream (northwest) to a line beginning on the northwest shore at a point 36° 18.5172' N – 76° 14.5920' W; running southeasterly along SSR 1309 bridge (Main Street Extended) to the southeast shore to a point 36° 18.4973' N – 76° 14.5729' W.

(6) Pasquotank River Area:

(a) Charles Creek - south of a line beginning on the west shore at a point 36° 17.8090' N – 76° 13.0732' W; running easterly to the east shore to a point 36° 17.8024' N – 76° 13.0407' W; and northeast of a line beginning on the northwest shore at a point 36° 17.4713' N – 76° 13.2227' W; running southeasterly along NC 34 (Road Street) to the southeast shore to a point 36° 17.4565' N – 76° 13.2140' W.

(b) Areneuse Creek and Mill Dam Creek - north of a line beginning on the west shore at a point 36° 17.3133' N – 76° 08.1655' W; running southeasterly along NC 343 bridge to the east shore to a point 36° 17.1328' N – 76° 07.6269' W; and southwest of a line beginning on the west shore of Mill Dam Creek at a point 36° 18.5994' N – 76° 07.8672' W; running southeasterly to the east shore to a point 36° 18.5991' N – 76° 07.8379' W; and southwest of a line beginning on the northwest shore of Areneuse Creek at a point 36° 18.0342' N – 76° 06.9433' W, running southeasterly along NC 343 bridge to the southeast shore to a point 36° 18.0196' N – 76° 06.9245' W.

(c) Portohonk Creek - northeast of a line beginning on the west shore at a point 36° 15.0519' N – 76° 05.2793' W; running southeasterly to the east shore to a point 36° 15.0391' N – 76° 05.2532' W; and south of a line beginning on the west shore at a point 36° 16.2809' N – 76° 04.8223' W; running easterly along NC 343 bridge to the east shore to a point 36° 16.2794' N – 76° 04.8051' W.

(d) New Begun Creek - west of a line beginning on the north shore at a point 36° 13.3298' N – 76° 08.2878' W; running southerly to the south shore to a point 36° 13.0286' N – 76° 08.1820' W; and southeast of a line beginning on the northeast shore at a point 36° 12.5577' N – 76° 10.3998' W; running southwesterly along NC 34 bridge (Weeksville Road) to the southwest shore to a point 36° 12.5467' N – 76° 10.4186' W; and northeast of a line beginning on the northeast shore at a point 36° 12.3280' N – 76° 10.4934' W; running northwesterly to the northwest shore to a point 36° 12.3067' N – 76° 10.5438' W.

(7) Little River including designated tributaries - main stem wasters northwest of a line beginning on the west shore at a point 36° 12.2950' N – 76° 17.1405' W; running southeasterly to the east shore to a point 36° 12.5237' N – 76° 16.9418' W; and south of a line beginning on the west shore at a point 36° 16.9826' N – 76° 23.1763' W; running easterly along SSR 1223 (Five Bridges Road, Perquimans County) and SSR 1303 (Cherry Glade Road, Pasquotank County) bridge to the east shore to a point 36° 16.9840' N – 76° 23.1570' W; including the following tributary from the confluence with Little River in the direction indicated to the specified boundary: Halls Creek - upstream (northeast) to a line beginning on the northwest shore at a point 36°13.2067' N – 76° 16.5769' W; running southeasterly along SSR 1140 (Halls Creek Road) to the southeast shore to a point 36° 13.1944' N – 76° 16.5523' W.

(8) Little River Area:

(a) Deep Creek - southwest of a line beginning on the north shore at a point 36° 11.0945' N – 76° 16.6717' W; running southeasterly to the south shore to a point 36° 10.7510' N – 76° 16.2258' W; and south of a line beginning on the west shore at a point 36° 10.2553' N – 76° 18.7639' W; running easterly to the east shore to a point 36° 10.2633' N – 76° 18.7267' W.

(b) Symonds Creek - northeast of a line beginning on the north shore at a point 36° 10.2898' N – 76° 14.1801' W; running southeasterly to the south shore to a point 36° 10.2042' N – 76° 14.0368' W; and south of a line beginning on the west shore at a point 36° 11.4843' N – 76° 13.7218' W; running easterly along SSR 1100 bridge (Nixonton Road) to the east shore to a point 36° 11.4839' N – 76° 13.7028' W.

(9) Perquimans River including designated tributaries - main stem waters southwest of a line beginning on the west shore at a point 36° 11.6569' N – 76° 28.0055' W; running southeasterly along the US 17 business bridge (Church Street) to the east shore to a point 36° 11.6123' N – 76° 27.9382' W; and west of a line beginning on the north shore at a point 36° 18.8942' N – 76° 31.1905' W; running southeasterly to the south shore to a point 36° 18.8723' N – 76° 31.1734' W; and south of a line beginning on the west shore at a point 36° 18.9514' N – 76° 32.6510' W; running easterly along SSR 1202 bridge (Perry Bridge Road) to the east shore to a point 36° 18.9361' N – 76° 32.6584' W; including the following tributary from the confluence with the Perquimans River in the direction indicated to the specified boundary: Goodwin Creek - upstream (west) to a line beginning on the northwest shore at a point 36° 11.2807' N – 76° 33.6243' W; running southerly along SSR 1110 bridge (Center Hill Highway) to the southeast shore to a point 36° 11.2585' N – 76° 33.5755' W; and north to a line beginning on the west shore at a point 36° 11.0494' N – 76° 32.3409' W; running easterly along SSR 1110 bridge (Center Hill Highway) to the east shore to a point 36° 11.0383' N – 76° 32.2780' W.

(10) Perquimans River Area:

(a) Mill Creek - north of a line beginning on the west shore at a point 36° 11.9757' N – 76° 27.5752' W; running easterly to the east shore to a point 36° 11.9766' N – 76° 27.2511' W; and southwest of a line beginning on the northwest shore at a point 36° 13.2910' N – 76° 26.6778' W; running southeasterly along SSR 1214 bridge (Lake Road) to the southeast shore to a point 36° 13.2762' N – 76° 26.6580' W.

(b) Walter's Creek - southwest of a line beginning on the north shore at a point 36° 11.1305' N – 76° 27.9185' W; running southeasterly to the south shore to a point 36° 11.0224' N – 76° 27.6626' W; and northeast of a line beginning on the northeast shore at a point 36° 10.0498' N – 76° 28.4208' W; running southwesterly along US 17 to the southwest shore to a point 36° 10.0408' N – 76° 28.4354' W.

(c) Suttons Creek - north of a line beginning on the west shore at a point 36° 10.0394' N – 76° 23.7945' W; running southeasterly to the east shore to a point 36° 09.9325' N – 76° 23.5263' W; and south of a line beginning on the west shore at a point 36° 11.5101' N – 76° 23.6253' W; running easterly along SSR

1300 bridge (New Hope Road) to the east shore to a point 36° 11.5081' N – 76° 23.6060' W.

(d) Jackson (Cove) Creek - northeast of a line beginning on the north shore at a point 36° 08.4642' N – 76° 20.3324' W; running southeasterly to the east shore to a point 36° 08.4159' N – 76° 20.2890' W; and southwest of a line beginning on the northwest shore at a point 36° 08.6083' N – 76° 20.1512' W; running southeasterly to the southeast shore to a point 36° 08.6007' N – 76° 20.1312' W.

(e) Muddy Creek - northwest of a line beginning on the north shore at a point 36° 07.0381' N – 76° 17.1350' W; running southeasterly to the east shore to a point 36° 07.0218' N – 76° 17.1226' W; and south of a line beginning on the west shore at a point 36° 07.5922' N – 76° 16.8153' W; running easterly to the east shore to a point 36° 07.5933' N – 76° 16.7757' W.

(11) Yeopim River including designated tributaries - main stem waters west of a line beginning on the north shore at a point 36° 05.4526' N – 76° 27.7651' W; running southerly to the south shore to Norcum Point 36° 05.1029' N – 76° 27.7120' W; and southeast of a line beginning on the north shore at a point 36° 05.1202' N – 76° 29.5050' W; running southwesterly to a point 36° 05.0644' N – 76° 29.5586' W; and running easterly to the east shore to a point 36° 05.0571' N – 76° 29.4657' W; including the following tributaries from the confluence with Yeopim River in the direction indicated to the specified boundary:

(a) Yeopim Creek - upstream (north) to a line beginning on the west shore at a point 36° 07.4416' N – 76° 26.4833' W; running easterly along SSR 1347 (Holiday Island Road) to the east shore to a point 36° 07.4409' N – 76° 26.4667' W.

(b) Bethel Creek - upstream (north) to a line beginning on the southwest shore at a point 36° 07.1208' N – 76° 29.3581' W; running northeasterly to the northeast shore to a point 36° 07.1724' N – 76° 29.2818' W.

(c) Burnt Mill Creek - upstream (northwest) to a line beginning on the northeast shore at a point 36° 05.7727' N – 76° 32.6234' W; running southwesterly along US 17 to the southwest shore to a point 36° 05.7663' N – 76° 32.6374' W.

(d) Middleton Creek - upstream (southeast) to a line beginning on the northwest shore at a point 36° 04.2913' N – 76° 30.2613' W; running southeasterly along SSR 1100 bridge (Drummond Point Road) to the southeast shore to a point 36° 04.2813' N – 76° 30.2460' W; and northeast of a line beginning on the northwest shore at a point 36° 04.0714' N – 76° 29.5779' W; running southeasterly along SSR 1100 (Drummond Point Road) to the southeast shore to a point 36° 04.0639' N – 76° 29.5583' W.

(12) Edenton Bay Area:

(a) Pembroke Creek (Pollock Swamp) - northwest of a line beginning on the west shore at a point 36° 03.2819' N – 76° 37.0138' W; running northeasterly to the east shore to a point 36° 03.4185' N – 76° 36.6783' W; and west of a line beginning on the north shore at a point 36° 08.1216' N – 76° 37.7846' W; running southerly along SSR 1316 bridge (Greenhall Road) to the south shore to a point 36° 08.1035' N – 76° 37.7818' W.

(b) Queen Anne Creek - east of a line beginning on the north shore at a point 36° 03.3757' N – 76° 36.3629' W; running southerly to the south shore to a point 36° 03.3551' N – 76° 36.3574' W; and southwest of a line beginning on the northwest shore at a point 36° 03.5719' N – 76° 35.0968' W; running southeasterly along NC 32 bridge (Yeopim Road) to the southeast shore to a point 36° 03.5659' N – 76° 35.0796' W.

(13) Chowan River Area:

(a) Buckhorn Creek (Hertford County) - north of a line beginning on the west shore at a point 36° 31.9519' N – 76° 55.2580' W; running easterly to the east shore to a point 36° 31.9628' N – 76° 55.2429' W; and east of a line beginning on the north shore at a point 36° 31.9443' N – 76° 55.8902' W; running southerly to the south shore to a point 36° 31.9099' N – 76° 55.8904' W.

(b) Somerton Creek - north of a line beginning on the west shore at a point 36° 31.7177' N – 76° 54.8327' W; running easterly to the east shore to a point 36° 31.7143' N – 76° 54.7810' W; and south of the NC/VA state line.

(c) Meherrin River Area:

(i) Vaughan's Creek (Kirby's Creek) - west of a line beginning on the north shore at a point 36° 28.3541' N – 77° 05.6259' W; running southerly to the south shore to a point 36° 28.3307' N – 77° 05.6369' W; and east of a line beginning on the north shore at a point 36° 28.7019' N – 77° 08.7566' W; running southerly along SSR 1362 bridge (Watson Mill Road) to the south shore to a point 36° 28.6834' N – 77° 08.7593' W; and northeast of a line beginning on the northwest shore at a point 36° 28.0921' N – 77° 08.5719' W; running southeasterly along SSR 1362 bridge (Watson Mill Road) to the southeast shore to a point 36° 28.0787' N – 77° 08.5557' W. Turkey Creek - from the confluence with Vaughan's Creek upstream; and northeast of a line beginning on the northwest shore at a point 36° 27.8047' N – 77° 07.7316' W; running southeasterly along SSR 1363 (Turkey Branch Road, Northampton County) and SSR 1300 bridge (Wise Store Road, Hertford County) to the southeast shore to a point 36° 27.7957' N – 77° 07.7170' W.

(ii) Potecasi Creek - southwest of a line beginning on the west shore at a point 36° 26.1234' N – 76° 57.5262' W; running southeasterly to the east shore to a point 36° 26.1005' N – 76° 57.4960' W; and east of a line beginning on the north shore at a point 36° 22.1250' N – 77° 05.3109' W; running southerly along SSR 1160 bridge (Spring Avenue) to the south shore to a point 36° 22.1035' N – 77° 05.3220' W.

(A) Old Tree Swamp - from the confluence with Potecasi Creek upstream to a line beginning on the west shore at a point 36° 22.5909' N – 77° 04.0382' W; running easterly along SSR 1167 bridge (Beaver Dam Road) to the east shore to a point 36° 22.5895' N – 77° 04.0192' W.

(B) Cutawhiskie Creek - from the confluence with Potecasi Creek upstream to a line beginning on the northwest shore at a point 36° 21.2751' N – 77° 04.3761' W; running southeasterly along SSR 1137 bridge (Liverman Mill Road) to the southeast shore to a point 36° 21.2583' N - 77° 04.3461' W.

(d) Mud Creek - north of a line beginning on the west shore at a point 36° 23.5134' N – 76° 53.9131' W; running easterly to the east shore to a point 36° 23.5132' N – 76° 53.8815' W; and east of a line beginning on the north shore at a point 36° 23.6287' N – 76° 53.8782' W; running southerly to the south shore to a point 36° 23.5943' N – 76° 53.8784' W.

(e) Catherine Creek (Hertford County) - south of a line beginning on the west shore at a point 36° 22.9579' N – 76° 53.1994' W; running southeasterly to the east shore to a point 36° 22.9456' N – 76° 53.1742' W; and north of a line beginning on the west shore at a point 36° 22.7142' N – 76° 53.1872' W; running easterly to the east shore to a point 36° 22.7209' N – 76° 53.1631' W.

(f) Buckhorn Creek (Run Off Swamp) (Gates County) - north of a line beginning on the west shore at a point 36° 22.9682' N – 76° 51.9172' W; running easterly to the east shore to a point 36° 22.9614' N – 76° 51.8870' W; and east of a line beginning on the north shore at a point 36° 23.3321' N – 76° 52.0233' W; running southerly to the south shore to a point 36° 23.3101' N – 76° 52.0244' W.

(g) Spikes Creek - northwest of a line beginning on the west shore at a point 36° 22.6515' N – 76° 50.8882' W; running northeasterly to the east shore to a point 36° 22.6684' N – 76° 50.8493' W; and east of a line beginning on the north shore at a point 36° 22.9574' N – 76°51.4953' W; running southerly to the south shore to a point 36° 22.9419' N – 76° 51.4959' W.

(h) Barnes Creek - north of a line beginning on the west shore at a point 36° 21.8820' N – 76° 48.6419' W; running easterly to the east shore to a point 36° 21.8978' N – 76° 48.5902' W; and east of a line beginning on the north shore at a point 36° 22.8208' N – 76° 50.0931' W; running southerly to the south shore to a point 36° 22.7839' N – 76° 50.0941' W.

(i) Shingle (Island) Creek - north of a line beginning on the north shore of the western most entrance into Chowan River at a point 36° 21.8449' N – 76° 48.0940' W; running southeasterly to the south shore to a point 36° 21.7831' N – 76° 48.0427' W. At the eastern most entrance to the creek: north of a line beginning of the west shore at a point 36° 21.8469' N – 76° 47.2668' W; running northeasterly to the east shore to a point 36° 21.9062' N – 76° 47.1862' W.

(j) Sarem Creek - east of a line beginning on the north shore at a point 36° 21.7259' N – 76° 46.4085' W; running southerly to the south shore to a point 36° 21.6748' N – 76° 46.4392' W; and southeast of a line beginning on the southwest shore at a point 36° 25.0514' N – 76° 49.4791' W; running northeasterly along SSR 1118 bridge (Taylors Road) to the northeast shore to a point 36° 25.0710' N – 76° 49.4657' W; including the following tributary from the confluence with Sarem Creek in the direction indicated to the specified boundary: Cole Creek - upstream (northeast) to a line beginning on the west shore at a point 36° 24.5075' N – 76° 47.0641' W; running easterly along NC 37 bridge to the east shore to a point 36° 24.5048' N – 76° 47.0397' W.

(k) Hodges Creek - west of a line beginning on the north shore at a point 36° 21.2459' N – 76° 46.3421' W; running southerly to the south shore to a point 36° 21.1823' N – 76° 46.3243' W; and east of a line beginning on the north shore at a point 36° 21.1597' N – 76° 46.6073' W; running southerly to the south shore to a point 36° 21.1309' N – 76° 46.6084' W.

(l) Wiccacon River including designated tributaries - west of a line beginning on the north shore at a point 36° 20.5439' N – 76° 45.4550' W; running southeasterly to the south shore to a point 36° 20.4684' N – 76° 45.3392' W; and east of a line beginning on the northeast shore at a point 36° 19.0196' N – 76° 53.5596' W; running southwesterly to the southwest shore to a point 36° 18.9936' N – 76° 53.5751' W; including the following tributaries from their confluence with Wiccacon River in the direction indicated to the specified boundary:

(i) Ahoskie Creek - upstream (south) to a line beginning on the west shore at a point 36° 16.4860' N – 76° 54.1172' W; running easterly along NC 561 to the east shore to a point 36° 16.4796' N – 76° 54.0933' W.

(ii) Chinkapin Creek - upstream (southwest) to a line beginning on the northwest shore at a point 36° 15.1763' N – 76° 50.9758' W; running southeasterly along SSR 1432 bridge (Big Mill Road) to the southeast shore to a point 36° 15.1671' N – 76° 50.9567' W.

(m) Beef Creek - north of a line beginning on the west shore at a point 36° 20.3235' N – 76° 44.6401' W; running easterly to the east shore to a point 36° 20.3070' N – 76° 44.5797' W; and east of a line beginning on the north shore at a point 36° 20.9720' N – 76° 44.7930' W; running southerly to the south shore to a point 36° 21.0058' N – 76° 44.7931' W.

(n) Goose Creek - west of a line beginning on the north shore at a point 36° 19.5838' N – 76° 44.5971' W; running southerly to the south shore to a point 36° 19.5375' N – 76° 44.5925' W; and northeast of a line beginning on the west shore at a point 36° 19.9806' N – 76° 45.2656' W; running easterly to the east shore to a point 36° 19.9799' N – 76° 45.2356' W.

(o) Swain Mill (Taylor Pond) Creek - west of a line beginning on the north shore at a point 36° 18.5808' N – 76° 43.4729' W; running southerly to the south shore to a point 36° 18.5616' N – 76° 43.4706' W; and northeast of a line beginning on the northwest shore at a point 36° 18.5029' N – 76° 43.5882' W; running southeasterly along SSR 1441 bridge (Swain Mill Road) to the southeast shore to a point 36° 18.4906' N – 76° 43.5694' W.

(p) Bennetts Creek - north of a line beginning on the west shore at a point 36° 18.3499' N – 76° 42.0286' W; running northeasterly to the east shore to a point 36° 18.4057' N – 76° 41.6986' W; and southwest of a line beginning on the northwest shore at a point 36° 25.9349' N – 76° 41.9859' W; running southeasterly along the Merchants Mill Pond Dam to the southeast shore to a point 36° 25.9154' N – 76° 41.9530' W.

(q) Catherine Creek including designated tributaries -main stem waters northeast of a line beginning on the west shore at a point 36° 18.1011' N – 76° 41.1286' W; running southeasterly to the east shore to a point 36° 17.9413' N – 76° 40.8627' W; including the following tributaries from the confluence with Catherine Creek in the direction indicated to the specified boundary:

(i) Trotman Creek - upstream (northwest) to a line beginning on the north shore at a point 36° 20.8213' N – 76° 38.1714' W; running southerly along NC 32 bridge to the south shore to a point 36° 20.7989' N – 76° 38.1646' W.

(ii) Warwick Creek - upstream (northeast) to a line beginning on the north shore at a point 36° 19.8212' N – 76° 38.0409' W; running southerly along NC 32 bridge to the south shore to a point 36° 19.7833' N – 76° 38.0235' W.

(r) Stumpy Creek - east of a line beginning on the north shore at a point 36° 16.6440' N – 76° 40.4251' W; running southerly to the south shore to a point 36° 16.6255' N – 76° 40.4196' W; and west of a line beginning on the north shore at a point 36° 16.7331' N – 76° 39.9154' W; running southerly along SSR 1232 bridge (Cannon Ferry Road) to the south shore to a point 36° 16.7220' N – 76° 39.9220' W.

(s) Dillard (Indian) Creek - east of a line beginning on the north shore at a point 36° 14.2234' N – 76° 41.5901' W; running southerly to the south shore to a point 36° 14.2023' N – 76° 41.5855' W; and west of a line beginning on the north shore at a point 36° 13.7727' N – 76° 40.3878' W; running southerly along SSR 1226 (Dillards Mill Road) to the south shore to a point 36° 13.7592' N – 76° 40.3875' W.

(t) Keel (Currituck) Creek - north of a line beginning on the west shore at a point 36° 14.1245' N – 76° 44.1961' W; running easterly to the east shore to a point 36° 14.0899' N – 76° 43.8533' W; and south of a line beginning on the west shore at a point 36° 15.2755' N – 76° 43.5077' W; running easterly to the east shore to a point 36° 15.2746' N – 76° 43.4750' W.

(u) Rocky Hock Creek - east of a line beginning on the west shore at a point 36° 06.5662' N – 76° 41.3108' W; running southeasterly to the east shore to a point 36° 06.6406' N – 76° 41.4512' W; and southwest of a line beginning on the northwest shore at a point 36° 08.3485' N – 76° 39.9790' W; running southeasterly along the face of Bennett Mill Pond Dam to the southeast shore to a point 36° 08.3353' N – 76° 39.9603' W.

(14) Cashie River including designated tributaries - main stem waters west of a line beginning on the north shore at a point 35° 54.7865' N – 76° 49.0521' W; running southerly to the south shore to a point 35° 54.6691' N – 76° 49.0553' W; and east of a line beginning on the north shore at a point 36° 05.7521' N – 77° 04.0494' W; running southerly along SSR 1260 bridge (Republican Road) to the south shore to a point 36° 05.7171' N – 77° 04.0344' W; including the following tributaries from their confluence with Cashie River in the direction indicated to the specified boundary:

(a) Connarista Swamp - upstream (north) to a line beginning on the west shore at a point 36° 06.4489' N – 77° 02.4658' W; running easterly along SSR 1221 bridge (Charles Taylor Road) to the east shore to a point 36° 06.4501' N – 77° 02.4236' W.

(b) Whiteoak Swamp - upstream (northeast) to a line beginning on the northwest shore at a point 36° 04.6654' N – 76° 58.5841' W; running southeasterly along US 13 to the southeast shore to a point 36° 04.6480' N – 76° 58.5676' W.

(c) Chiska Creek - upstream (west) to a line beginning on the north shore at a point 36° 02.5659' N – 77° 02.3636' W; running southerly along SSR 1112 bridge (Roquist Pocosin Road) to the south shore to a point 36° 02.5463' N – 77° 02.3730' W.

(d) Hoggard Mill Creek - upstream (north) to a line beginning on the northwest shore at a point 36° 01.5828' N – 76° 56.9799' W; running southeasterly along the Hoggard Mill Pond Dam to the southeast shore to a point 36° 01.5479' N – 76° 56.9556' W.

(e) Roquist Creek - upstream (west) to a line beginning on the northeast shore at a point 36° 00.6453' N – 77° 02.8441' W; running southwesterly along SSR 1112 bridge (Roquist Pocosin Road) to the southwest shore to a point 36° 00.6119' N – 77° 02.8719' W.

(f) Wading Place Creek - upstream (east) to a line beginning on the west shore at a point 35° 58.1755' N – 76° 53.0010' W; running easterly along NC 308 bridge (Cooper Hill Road) to the east shore to a point 35° 58.1631' N – 76° 52.9542' W.

(15) Cashie River Area:

(a) Broad Creek - south of a line beginning on the west shore at a point 35° 55.0568' N – 76° 45.2632' W; running easterly to the east shore to a point 35° 55.0543' N – 76° 45.1309' W.

(b) Grennel Creek - east of a line beginning on the north shore at a point 35°55.3147' N – 76° 44.5010' W; running southerly to the south shore to a point 35° 55.2262' N – 76° 44.5495' W.

(c) Cashoke Creek - west of a line beginning on the north shore at a point 35° 56.2934' N – 76° 44.1769' W; running southwesterly to the south shore to a point 35° 56.2623' N – 76° 44.1993' W; and east of a line beginning on the north shore at a point 35° 56.3383' N – 76° 44.5958' W; running southerly along NC 45 bridge to the south shore to a point 35° 56.2839' N – 76° 44.5836' W.

(16) Roanoke River including designated tributaries - main stem waters northwest of a line beginning on the west shore at a point 36° 12.5264' N – 77° 23.0223' W; running northeasterly along the south side of the US 258 bridge to the east shore to a point 36° 12.5674' N – 77° 22.9724' W; to the base of the Roanoke Rapids Dam; including the following tributary from the confluence with Roanoke River in the direction indicated to the specified boundary: Bridgers Creek - upstream (northeast) to a line beginning on the west shore at a point 36° 15.0786' N – 77° 22.3766' W; running easterly to the east shore to a point 36° 15.0846' N – 77° 22.3083' W.

(17) Roanoke River Area:

(a) Kehukee Swamp - west of a line beginning on the north shore at a point 36° 05.1942' N – 77° 18.9596' W; running southwesterly to the south shore to a point 36° 05.1670' N – 77° 18.9761' W; and south of a line beginning on the northeast shore at a point 36° 05.7019' N – 77° 19.3686' W; running southwesterly to the southwest shore to a point 36° 05.6909' N – 77° 19.3902' W.

(b) Wire Gut - north of a line beginning on the west shore at a point 36° 00.9580' N – 77° 13.0755' W; running easterly to the east shore to a point 36° 00.9542' N – 77° 13.0320' W; and east of a line beginning on the north shore at a point 36° 01.4294' N – 77° 13.6239' W; running southerly to the south shore to a point 36° 01.3873' N – 77° 13.6270' W.

(c) Apple Tree Creek - east of a line beginning on the north shore at a point 36° 00.4174' N – 77° 12.3252' W; running southeasterly to the south shore to a point 36° 00.3987' N – 77° 12.3088' W; and south of a line beginning on the west shore at a point 36° 02.3508' N – 77° 13.6900' W; running easterly to the east shore to a point 36° 02.3497' N – 77° 13.6055' W; and east of a line beginning on the north shore at a point 36° 01.9425' N – 77° 12.4225' W; running southerly to the south shore to a point 36° 01.9066' N – 77° 12.4222' W.

(d) Indian Creek - east of a line beginning on the north shore at a point 35° 59.0794' N – 77° 11.4926' W; running southerly to the south shore to a point 35° 59.0597' N – 77° 11.4967' W; and southwest of a line beginning on the northwest shore at

a point 36° 03.5103' N – 77° 10.6537' W; running southeasterly along SSR 1108 bridge (Indian Woods Road) to the southeast shore to a point 36° 03.4917' N – 77° 10.6402' W; and west of a line beginning on the north shore at a point 36° 02.3940' N – 77° 09.3722' W; running southerly along SSR 1108 bridge (Indian Woods Road) to the south shore to a point 36° 02.3787' N – 77° 09.3711' W.

(e) Prices Gut - west of a line beginning on the north shore at a point 35° 57.3701' N – 77° 11.9815' W; running southerly to the south shore to a point 35° 57.3552' N – 77° 11.9796' W; and east of a line beginning on the north shore at a point 35° 57.4077' N – 77° 12.0401' W; running southerly to the south shore to a point 35° 57.3763' N – 77° 12.0135' W.

(f) Rainbow Gut - south of a line beginning on the west shore at a point 35° 55.9334' N – 77° 11.3246' W; running easterly to the east shore to a point 35° 55.9275' N – 77° 11.3136' W.

(g) Coniott Creek including designated tributaries - main stem waters west of a line beginning on the north shore at a point 35° 56.6562' N – 77° 04.2860' W; running southwesterly to the south shore to a point 35° 56.6397' N – 77° 04.3066' W; and southeast of a line beginning on the northeast shore at a point 35° 59.4139' N – 77° 08.2158' W; running southwesterly along SSR 1122 bridge (Broad Neck Road) to the southwest shore to a point 35° 59.3976' N – 77° 08.2491' W; including the following tributary from the confluence with Coniott Creek in the direction indicated to the specified boundary: Frog Level Swamp - upstream to a line beginning on the north shore at a point 35° 58.0087' N – 77° 06.3447' W; running southerly to the south shore to a point 35° 57.9223' N – 77° 06.3483' W.

(h) Conoho Creek - north of a line beginning on the west shore at a point 35° 52.5439' N – 77° 02.6673' W; running easterly to the east shore to a point 35° 52.5407' N – 77° 02.6280' W; and southeast of a line beginning on the northeast shore at a point 35° 58.3271' N – 77° 17.6825' W; running southwesterly along NC 11 bridge to the southwest shore to a point 35° 58.3096' N – 77° 17.7006' W.

(i) Sweetwater Creek including designated tributaries - main stem east of a line beginning on the west shore at a point 35° 51.6464' N – 77° 00.5090' W; running southeasterly to the east shore to a point 35° 51.6252' N – 77° 00.4879' W; and northwest of a line beginning on the northeast shore at a point 35° 48.6186' N – 77° 02.0173' W; running southwesterly along SSR 1501 bridge (Big Mill Road) to the southwest shore to a point 35° 48.5968' N – 77° 02.0311' W; including the following tributary from the confluence with Sweetwater Creek in the direction indicated to the specified boundary: Peter Swamp - upstream (southeast) to a line beginning on the west shore at a point 35° 49.0798' N – 77° 00.2510' W; running easterly to the east shore to a point 35° 49.0705' N – 77° 00.2118' W.

(j) Unnamed Tributary (upstream of Old Mill Creek) - northwest of a line beginning on the northeast shore at a point 35° 53.9775' N – 76° 56.6431' W; running southwesterly to the southwest shore to a point 35° 53.9913' N – 76° 56.6238' W; and southeast of a line beginning on the northeast shore at a point 35° 54.1143' N – 76° 56.8761' W; running southwesterly along SSR 1542 bridge (Bertie County) to the southwest shore to a point 35° 54.0927' N – 76° 56.8956' W.

(k) Old Mill Creek - north of a line beginning on the west shore at a point 35° 53.9483' N – 76° 55.3921' W; running southeasterly to the east shore to a point 35° 53.9378' N – 76° 55.3710' W; and south of a line beginning on the west shore at a point 35° 54.3010' N – 76° 55.0492' W; running easterly along SSR 1518 bridge (Bertie County) to the east shore to a point 35° 54.3085' N – 76° 55.0164' W.

(l) Gardner Creek - south of a line beginning on the west shore at a point 35°50.1599' N – 76° 56.0211' W; running easterly to the east shore to a point 35° 50.1633' N – 76° 55.9899' W; and north of a line beginning on the west shore at a point 35° 48.4791' N – 76° 55.9768' W; running easterly to the east shore to a point 35° 48.4834' N – 76° 55.9378' W.

(m) Cut Cypress Creek - northeast of a line beginning on the north shore at a point 35° 51.9465' N – 76° 53.5762' W; running southeasterly to the south shore to a point 35° 51.9229' N – 76° 53.5556' W.

(n) Roses Creek - southeast of a line beginning on the north shore at a point 35° 50.1683' N – 76° 50.9664' W; running southwesterly to the south shore to a point 35° 50.1363' N – 76° 56.9907' W; and north of a line beginning on the west shore at a point 35° 49.5501' N – 76° 50.7358' W; running easterly to the east shore to a point 35° 49.5649' N – 76° 50.6674' W.

(o) Broad Creek - west of a line beginning on the north shore at a point 35° 52.5191' N – 76° 50.4235' W; running southerly to the south shore to a point 35° 52.4262' N – 76° 50.3791' W.

(p) Welch Creek - south of a line beginning on the west shore at a point 35° 51.8458' N – 76° 45.8381' W; running easterly along the shoreline and across the mouths of the three creek entrances to the east shore to a point 35° 51.8840' N – 76° 45.6207' W; and north of a line beginning on the west shore at a point 35° 49.7473' N – 76° 47.1058' W; running easterly to the east shore to a point 35° 49.7506' N – 76° 47.0778' W.

(q) Conaby Creek - south of a line beginning on the west shore at a point 35° 55.3779' N – 76° 42.4401' W; and running easterly to the east shore to a point 35° 55.3752' N – 76° 42.3408' W; north of a line beginning on the southwest shore at a point 35° 51.6443' N – 76° 44.5188' W; running northeasterly to the northeast shore to a point 35° 51.6538' N – 76° 44.4926' W.

(18) Scuppernong River including designated tributaries - main stem waters south of a line beginning on the west shore at a point 35° 54.0158' N – 76° 15.4605' W; running easterly to the east shore to a point 35° 54.0406' N – 76° 15.3007' W; and east of a line beginning on the north shore at a point 35° 51.6231' N – 76° 26.1210' W; running southerly to the south shore to a point 35° 51.5952' N – 76° 26.1178' W; including the following tributaries from their confluence with Scuppernong River in the direction indicated to the specified boundary:

(a) First Creek (Rider's Creek) - upstream (south) to a line beginning on the north shore at a point 35° 53.5116' N – 76° 14.0222' W; running southerly along NC 94 bridge to the south shore to a point 35° 53.4948' N – 76° 14.0125' W.

(b) Second Creek - upstream (south) to a line beginning on the north shore at a point 35° 53.0541' N – 76° 15.1132' W; running southerly along SSR 1105 (Bodwell Road) to the south shore to a point 35° 53.0286' N – 76° 15.1211' W.

(c) Lake Phelps - all waters of Lake Phelps and the following main canals connecting to Scuppernong River:

(i) Moccasin Canal;

(ii) Western (Enoch) Canal;

(iii) Mountain Canal;

(iv) Thirty-foot Canal;

(v) Somerset (Old) Canal;

(vi) Batava (Minerva, Magnolia, Bonarva) Canal; and

(vii) Bee Tree Canal.

(19) Alligator River Area:

(a) Little Alligator River - west of a line beginning on the north shore at a point 35° 56.7640' N – 76° 01.0299' W; running southerly to the south shore to a point 35° 55.9362' N – 76° 01.2492' W; and north of a line beginning on the west shore at a point 35° 56.4784' N – 76° 07.5433' W; running easterly to the east shore to a point 35° 56.4771' N – 76° 07.5076' W.

(b) East Lake - east of a line beginning on the north shore at a point 35° 56.1676' N – 75° 55.2603' W; running southerly to the south shore to a point 35° 55.4727' N – 75° 55.5043' W; and south of a line beginning on the west shore at a point 35° 58.6402' N – 75° 52.1855' W; running easterly to the east shore to a point 35° 58.5887' N – 75° 51.7080' W.

(c) Second Creek - west of a line beginning on the north shore at a point 35° 51.7616' N – 76° 03.5105' W; running southerly to the south shore to a point 35° 51.1317' N – 76° 03.8003' W.

(d) Milltail Creek - east of a line beginning on the north shore at a point 35° 50.5192' N – 75° 58.6134' W; running southerly to the south shore to a point 35° 50.4956' N – 75° 58.6158' W; and northwest of a line beginning on the northeast shore at a point 35° 47.7377' N – 75° 53.1295' W; running southwesterly to the southwest shore to a point 35° 47.7180' N – 75° 53.1295' W.

(e) Whipping Creek and Lake - east of a line beginning on the north shore at a point 35° 41.3930' N – 76° 00.2481' W; running southerly to the south shore to a point 35° 41.3717' N – 76° 00.2554' W; and west of a line beginning on the north shore at a point 35° 42.1737' N – 75° 57.6728' W; running southerly to the south shore to a point 35° 42.1570' N – 75° 57.6732' W.

(f) Swan Creek and Lake - east of a line beginning on the north shore at a point 35° 40.2674' N – 76° 00.7360' W; running southerly to the south shore to a point 35° 40.2420' N – 76° 00.7548' W.

(20) Alligator River including designated tributary - main stem waters west of a line beginning on the north shore at Cherry Ridge Landing at a point 35° 42.2172' N – 76° 08.4686' W; running southerly to the south shore to a point 35° 42.1327' N – 76° 08.5002' W; and east of a line beginning on the north shore at a point 35° 36.0502' N – 76° 13.9734' W; running southerly along NC 94 to the south shore to a point 35° 36.0300' N – 76° 13.9779' W; including the following tributary from the confluence with Alligator River in the direction indicated to the specified boundary: Northwest Fork - upstream (north) to a line beginning on the north shore at a point 35° 43.6826' N – 76° 11.9538' W; running southerly to the south shore to a point 35° 43.6495' N – 76° 11.9692' W.

(21) Croatan Sound Area:

(a) Spencer Creek - west of a line beginning on the north shore at a point 35° 51.4205' N – 75° 45.0645' W; running southerly to the south shore to a point 35° 51.3876' N – 75° 45.0640' W; and west of a line beginning on the north shore 35° 51.5597' N – 75° 45.0141' W; running southerly to the south shore to a point 35° 51.4624' N – 75° 45.0498' W; and west of a line beginning on the north shore at a point 35° 51.6783' N – 75° 44.9125' W; running southerly to the south shore to a point 35° 51.5693' N – 75° 45.0109' W; and east of a line beginning on the north shore at a point 35° 52.5133' N – 75° 46.3070' W; running southerly to the south shore to a point 35° 52.4635' N – 75° 46.3110' W.

(b) Callaghan Creek - west of a line beginning on the north shore at a point 35° 51.1312' N – 75° 45.1327' W; running southwesterly to the south shore to a point 35° 51.0953' N – 75° 45.1629' W; and east of a line beginning on the north shore at a point 35° 50.0643' N – 75° 46.6041' W; running southerly to the south shore to a point 35° 50.0306' N – 75° 46.6034' W.

(22) Pamlico River Area:

(a) Chocowinity Creek - south of a line beginning on the west shore at a point 35° 30.4778' N – 77° 04.4049' W; running southerly to the east shore at a point 35° 30.4692' N – 77° 04.3862' W; and north of a line beginning on the west shore at a point 35° 28.3423' N – 77° 05.0615' W; running easterly to the east shore at a point 35° 28.3413' N – 77° 05.0334' W.

(b) Blounts Creek - south of a line beginning on the west shore at a point 35° 23.9524' N – 76° 58.0357' W; running easterly to the east shore at a point 35° 23.9565' N – 76° 57.9576' W; and north of a line beginning on the west shore at a point 35° 22.3210' N – 76° 57.7210' W; running easterly along NC 33 to the east shore at a point 35° 22.3080' N – 76° 57.6706' W; on Nancy Run, north of a line beginning on the west shore at a point 35° 22.7132' N – 76° 59.0317' W; running easterly along NC 33 to the east shore at a point 35° 22.7064' N – 76° 59.0191' W; on Herring Run, north and west of a line beginning on the north shore at a point 35° 22.5435' N – 76° 56.9969' W; running southerly along SSR

1100 (Core Point Road) to the south shore at a point 35° 22.5168' N – 76° 57.0063' W.

(c) Durham Creek - south of a line beginning on the west shore at a point 35° 21.5669' N – 76° 51.9166' W; running easterly along the SSR 1955 bridge (Durham Creek Lane) to the east shore at a point 35° 21.5721' N – 76° 51.8621' W and north of a line beginning on the west shore at a point 35° 19.1959' N – 76° 52.3278' W; running southeasterly along NC 33 to the east shore at a point 35° 19.1802' N – 76° 52.2947' W.

(d) Little Goose Creek - north and east of a line beginning on the north shore at a point 35° 28.7258' N – 76° 55.8667' W; running southeasterly to the south shore at a point 35° 28.5986' N – 76° 55.7922' W and west of a line beginning on the north shore at a point 35° 29.0329' N – 76° 54.2344' W; running southeasterly along SSR 1334 (Camp Leach Road) to the south shore at a point 35° 29.0283' N – 76° 54.2228' W; and the unnamed northwest branch, south of a line beginning on the north shore at a point 35° 29.4589' N – 76° 55.0263' W; running southwesterly to the south shore at a point 35° 29.4492' N – 76° 55.0322' W.

(e) Broad Creek - north of a line beginning on the west shore at a point 35° 30.0451' N – 76° 57.6152' W; running easterly to the east shore at a point 35° 30.0459' N – 76° 57.5318' W and south of a line beginning on the west shore at a point 35° 32.1646' N – 76° 58.5193' W; running easterly along US 264 to the east shore at a point 35° 32.1588' N – 76° 58.5048' W.

(f) Runyon Creek - north of a line beginning on the west shore at a point 35° 32.1615' N – 77° 02.3606' W; running easterly along the NC 32 bridge (Park Drive) to the east shore at a point 35° 32.1340' N – 77° 02.3438' W and south of a line beginning on the north shore at a point 35° 33.0407' N – 77° 01.1497' W; running southeasterly to the south shore at a point 35° 33.0260' N – 77° 01.1449' W.

(23) Tar River including designated tributaries - main stem waters west of a line beginning on the north shore at a point 35° 33.1993' N – 77° 05.3977' W; running southerly to the south shore at a point 35° 32.9978' N – 77° 05.1529' W and east of a line beginning on the north shore at a point 35° 57.6505' N – 77° 48.2537' W; running southeasterly along the Rocky Mount Mill Pond Dam to the south shore at a point 35° 57.5997' N – 77° 48.1412' W; including the following tributaries from their confluence with Tar River in the direction indicated to the specified boundary:

(a) Swift Creek - upstream (northwest) to a line beginning on the north shore at a point 36° 00.5829' N – 77° 39.9482' W; running southerly to the south shore at a point 36° 00.5413' N – 77° 39.9616' W.

(b) Fishing Creek - upstream (northwest) to a line beginning on the north shore at a point 36° 08.0430' N – 77° 43.2829' W; running southerly to the south shore at a point 36° 08.0173' N – 77° 43.2921' W; on Deep Creek, upstream (northeast) to a line beginning on the north shore at a point 35° 57.8688' N – 77° 27.2298' W; running southeasterly to the south shore at a point 35° 57.8403' N – 77° 27.1890' W.

(c) Town Creek - upstream (west) to a line beginning on the north shore at a point 35° 48.4135' N – 77° 36.7687' W; running southwesterly to the south shore at a point 35° 48.3728' N – 77° 36.7686' W.

(d) Otter Creek - upstream (west) to a line beginning on the west shore at a point 35° 43.2448' N – 77° 31.9013' W; running easterly to the east shore at a point 35° 43.2385' N – 77° 31.8735' W.

(e) Tyson Creek - upstream (southwest) to a line beginning on the west shore at a point 35° 40.4470' N – 77° 30.7015' W; running easterly to the east shore at a point 35° 40.4107' N – 77° 30.6075' W.

(f) Conetoe Creek - upstream (north and east) to a line beginning on the north shore at a point 35° 44.5315' N – 77° 29.1676' W; running southerly to the south shore at a point 35° 44.5071' N – 77° 29.1894' W.

(g) Hardee Creek - upstream (southwest) to a line beginning on the west shore at a point 35° 35.6842' N – 77° 19.3857' W; running easterly to the east shore at a point 35° 35.6781' N – 77° 19.3680' W.

(h) Chicod Creek - upstream (west) to a line beginning on the west shore at a point 35° 34.6186' N – 77° 14.0233' W; running southerly to the east shore at a point 35° 34.5985' N – 77° 14.0169' W.

(i) Old Grindle Creek - upstream (north) to a line beginning on the north shore at a point 35° 35.3098' N – 77° 09.9461' W; running southerly along SSR 1565 (Grimesland Bridge Road) to the south shore at a point 35° 35.2891' N – 77° 09.9511' W.

(j) Bear Creek - upstream (southwest) to a line beginning on the west shore at a point 35° 32.4699' N – 77° 07.4185' W; running easterly to the east shore at a point 35° 32.4697' N – 77° 07.3758' W.

(24) Tranters Creek including designated tributaries - main stem waters north and west of a line beginning on the west shore at a point 35° 33.1993' N – 77° 05.3978' W; running easterly to the east shore at a point 35° 33.2408' N – 77° 05.0872' W and south of a line beginning on the west shore at a point 35° 45.7848' N – 77° 15.2294' W; running easterly to the east shore at a point 35° 45.7905' N – 77° 15.1931' W; including the following tributaries from their confluence with Tranters Creek in the direction indicated to the specified boundary:

(a) Aggie Run - upstream (east) to a line beginning on the north shore at a point 35° 38.3433' N – 77° 05.5003' W; running southeasterly to the south shore at a point 35° 38.2633' N – 77° 05.4097' W.

(b) Cherry Run - upstream (northeast) to a line beginning on the north shore at a point 35° 35.1560' N – 77° 04.0436' W; running southerly along US 17 to the south shore at a point 35° 35.1404' N – 77° 04.0437' W.

(25) Lake Mattamuskeet - all waters and all inland manmade tributaries of Lake Mattamuskeet.

(26) Bay River Area: Trent Creek - south of a line beginning on the west shore at a point 35° 06.2738' N – 76° 43.1071' W; running easterly along the NC 55 bridge (Pamlico County) to the east shore to a point 35° 06.2603' N – 76° 43.0741' W; and north of a line beginning on the southwest shore at a point 35° 04.3545' N – 76° 42.8282' W; running northeasterly to the northeast shore to a point 35° 04.3686' N – 76° 42.8117' W.

(27) Neuse River including designated tributaries - main stem waters south of a line beginning on the east shore at a point 35° 47.9955' N – 78° 32.2902' W; running westerly along Milburnie Dam (Bridges Lake Dam) to the west shore to a point 35° 48.0280' N – 78° 32.3989' W; and northwest of a line near Pitch Kettle Creek beginning on the north shore at a point 35° 16.9793' N – 77° 15.5529' W; running south to the south shore to a point 35° 16.9237' N – 77° 15.5461' W; including the following tributaries from their confluence with Neuse River in the direction indicated to the specified boundary:

(a) Middle Creek - upstream (west) to a line beginning on the southwest shore at a point 35° 30.4489' N – 78° 24.1072' W; running northeasterly along the NC 210 bridge (Johnston County) to the northeast shore to a point 35° 30.4767' N – 78° 24.0676' W.

(b) Mill Creek - upstream (west) to a line beginning on the north shore at a point 35° 20.7619' N – 78° 20.0813' W; running southerly along the SSR 1185 bridge (Joyner Bridge Road) to the south shore to a point 35° 20.7262' N – 78° 20.0938' W.

(c) Little River - upstream (northwest) to a line beginning on the southwest shore at a point 35° 40.0035' N – 78° 15.5262' W; running northeasterly along the NC 42 bridge (Johnston County) to the northeast shore to a point 35° 40.0142' N – 78° 15.5060' W.

(d) Walnut Creek - upstream (north) to a line beginning on the west shore at a point 35° 15.5439' N – 77° 52.5703' W; running easterly to the east shore to a point 35° 15.5407' N – 77° 52.5574' W.

(e) Bear Creek - upstream (north) to a line beginning on the northeast shore at a point 35° 21.1265' N – 77° 49.1500' W; running southwesterly to the southwest shore to a point 35° 21.1125' N – 77° 49.1605' W.

(f) Falling Creek - upstream (northwest) to a line beginning on the west shore at a point 35° 15.6635' N – 77° 41.5862' W; running easterly along the US 70 bridge (Banks School Road) to the east shore to a point 35° 15.6687' N – 77° 41.5540' W.

(g) Contentnea Creek - upstream (northwest) to a line beginning on the west shore at a point 35° 34.1707' N – 77° 47.5396' W; running easterly to the east shore to a point 35° 34.1704' N – 77° 47.4966' W.

(h) Halfmoon Creek - upstream (southwest) to a line beginning on the north shore at a point 35° 19.1578' N – 77° 20.2050' W; running southerly to the south shore to a point 35° 19.1335' N – 77° 20.2036' W.

(i) Village Creek - upstream (southwest) to a line beginning on the northeast shore at a point 35° 18.4795' N – 77° 18.1037' W; running southwesterly to the southwest shore to a point 35° 18.4603' N – 77° 18.1121' W.

(j) Kitten Creek - upstream (northwest) to include all waters.

(k) Core Creek - upstream (west) to a line beginning on the north shore at a point 35° 10.7941' N – 77° 18.9102' W; running southerly to the south shore to a point 35° 10.7715' N – 77° 18.9012' W.

(l) Pitchkettle Creek - upstream (northwest) to include all waters.

(28) Neuse River Area:

(a) Turkey Quarter and Greens creeks - southeast of a line beginning on the west shore of Turkey Quarter Creek at a point 35° 15.6738' N – 77° 14.6823' W; running southeasterly to the southeast shore of Turkey Quarter Creek to a point 35° 15.6534' N – 77° 14.6470' W; and northwest of a line beginning on the north shore of Greens Creek at a point 35° 14.1883' N – 77° 11.8862' W; running southwesterly to the southwest shore of Greens Creek to a point 35° 14.1389' N – 77° 11.7535' W.

(b) Taylor Creek - northwest of a line beginning on the north shore at a point 35° 14.3719' N – 77° 10.8050' W; running southwesterly to the south shore to a point 35° 14.3300' N – 77° 10.8352' W.

(c) Pine Tree Creek - west of a line beginning on the north shore at a point 35° 12.6663' N – 77° 07.4285' W; running southwesterly to the south shore to a point 35° 12.7033' N – 77° 07.3594' W and north of a line beginning on the west shore at a point 35° 12.8553' N – 77° 07.8300' W; running easterly to the east shore to a point 35° 12.8372' N – 77° 07.7934' W and north of a line beginning on the west shore at a point 35° 13.2012' N – 77° 08.7753' W; running southeasterly to the east shore to a point 35° 13.1714' N – 77° 08.7071' W.

(d) Swift and Little Swift creeks - north of a line beginning on the west shore at a point 35° 11.5972' N – 77° 06.0562' W; running easterly to the east shore to a point 35° 11.5816' N – 77° 05.9861' W for both creeks and south of a line beginning on the northeast shore at a point 35° 17.8175' N – 77° 08.9421' W; running southwesterly along the SSR 1440 bridge (Streets Ferry Road) to the southwest shore to a point 35° 17.8027' N – 77° 08.9529' W for Swift Creek; and southwest of two lines, one beginning on the northwest shore of Fisher Swamp at a point 35° 14.6533' N – 77° 03.9072' W; running southeasterly to the southeast shore to a point 35° 14.6322' N – 77° 03.8983' W; and the other beginning on the northwest shore of Little Swift Creek at a point 35° 14.1315' N – 77° 03.6823' W; running southeasterly along the SR 1627 bridge (Craven County) to the southeast shore to a point 35° 14.1179' N – 77° 03.6676' W for Little Swift Creek.

(e) Bachelor Creek - west of a line beginning on the north shore at a point 35°09.0099' N – 77° 04.5858' W; running southerly to the south shore to a point 35° 08.9085' N – 77° 04.7172' W and east of a line at Rollover Creek beginning

on the north shore at a point 35° 07.9194' N – 77° 11.9438' W; running southerly to the south shore to a point 35° 07.8931' N – 77° 11.9445' W.

(f) Trent River Area:

(i) Brice Creek - south of a line beginning on the west shore at a point 35° 02.1261' N – 77° 02.1243' W; running easterly to the east shore to a point 35° 02.1268' N – 77° 02.1015' W and north of a line beginning on the west shore at a point 34° 59.7828' N - 77° 00.0710' W; running easterly along the SSR 1101 bridge (County Line Road) to the east shore to a point 34° 59.7789' N - 77° 00.0534' W.

(ii) Mill Creek - south of a line beginning on the west shore at a point 35° 00.4595' N – 77° 12.8427' W; running easterly to the east shore to a point 35° 00.4593' N – 77° 12.8160' W; and north of a line beginning on the west shore at a point 34° 59.8881' N – 77° 12.8536' W; running easterly to the east shore to a point 34° 59.8878' N – 77° 12.8368' W.

(iii) Mill Run - southwest of a line beginning on the northwest shore at a point 35° 00.3766' N – 77° 16.8680' W; running southeasterly along the NC 58 bridge (Jones County) to the southeast shore to a point 35° 00.3654' N – 77° 16.8487' W; and northeast of a line beginning on the northwest shore at a point 35° 00.0929' N – 77° 17.3282' W; running southeasterly to the southeast shore to a point 35° 00.0740' N – 77° 17.3024' W.

(g) Trent River including all the waters of Jumping Creek - main stem waters southwest of a line beginning on the west shore at a point 35° 01.9478' N – 77° 15.6377' W; running easterly along the SSR 1121 bridge (Oak Grove Road) to the east shore to a point 35° 01.9506' N – 77° 15.6095' W; and northeast of a line beginning on the northeast shore at a point 35° 04.0759' N – 77° 35.3891' W; running southwesterly along the SSR 1153 bridge (Vine Swamp Road) to the southwest shore to a point 35° 04.0624' N – 77° 35.4063' W; including all the waters of Jumping Creek.

(h) Upper Broad Creek - northwest of a line beginning on the north shore at a point 35° 06.8922' N – 76° 56.3911' W, running southerly to the south shore to a point 35° 06.8623' N – 76° 56.3916' W and southeast of a line beginning on the west shore at a point 35° 08.3197' N – 76° 58.7314' W; running easterly along the NC 55 bridge at the Craven and Pamlico county line to the east shore to a point 35° 08.3209' N – 76° 58.6753' W.

(i) Beard Creek - northwest of a line beginning on the north shore at a point 35° 02.6853' N – 76° 52.3346' W; running southerly to the south shore to a point 35° 02.6663' N – 76° 52.3351' W and southeast of line beginning on the southwest shore at a point 35° 03.7198' N – 76° 52.6024' W; running northeasterly along the SSR 1115 bridge (Pamlico County) to the northeast shore to a point 35° 03.7258' N – 76° 52.5942' W.

(j) Dawson Creek - northwest of a line beginning on the southwest shore at a point 35° 01.8352' N – 76° 47.4672' W; running northeasterly to the northeast shore to a point 35° 01.8475' N – 76° 47.4283' W; and southeast of a line beginning on the southwest shore of Fork Run at a point 35° 02.1112' N – 76° 48.3083' W; running northeasterly along the SSR 1005 bridge (Pamlico County) to the northeast shore of Fork Run to a point 35° 02.1206' N – 76° 48.2922' W.

(k) Slocum Creek:

(i) Southwest Prong - southwest of a line beginning on the northwest shore at a point 34° 53.1520' N – 76° 55.8540' W; running southeasterly along the SSR 1746 bridge (Greenfield Heights Boulevard) to the southeast shore to a point 34° 53.1369' N – 76° 55.8460' W; and northeast of a line beginning on the west shore at a point 34° 51.5981' N – 76° 57.1687' W; running easterly to the east shore to a point 34° 51.5935' N – 76° 57.1229' W.

(ii) East Prong - south of a line beginning on the west shore at a point 34° 52.9687' N – 76° 54.5195' W; running easterly along the NC 101 bridge (Fontana Boulevard) to the east shore to a point 34° 52.9680' N – 76° 54.5020' W.

(l) Hancock Creek - south of a line beginning on the west shore at a point 34° 52.1403' N – 76° 50.8518' W; running easterly along the NC 101 bridge (Craven County) to the east shore to a point 34° 52.1412' N – 76° 50.8382' W.

(29) White Oak River - main stem waters north and west of a line beginning on the west shore at a point 34° 48.1466' N – 77° 11.4711' W; running easterly to a point on the west shore 34° 48.1620' N – 77° 11.4244' W; and south and east of a line beginning on the west shore at a point 34.° 53.5120' N – 77° 51.4013' W; running easterly to a point on the east shore 34° 53.5009' N – 77° 14.0194' W; including the following tributaries from their confluence with White Oak River in the direction indicated to the specified boundary:

(a) Holston Creek - east to a line beginning on the north shore at a point 34°49.6284' N – 77° 09.3783' W; running southerly to shore at a point 34° 49.6177' N – 77° 09.3670' W.

(b) Grant's Creek - west to a line beginning on the north shore at a point 34°47.9302' N – 77° 12.8060' W; running southerly along SSR 1434 bridge (Belgrade-Swansboro Road) to a point on the south shore 34° 47.9185' N – 77° 12.7954' W.

(30) New River - main stem waters north of a line beginning on the west shore at a point 34° 45.1654' N – 77° 26.1222' W; running easterly along the US Highway 17 bridge to a point on the east shore 34° 45.2007' N – 77° 25.9790' W; and south of a line beginning at a point on the west shore 34° 50.5818' N – 77° 30.1735' W running easterly along the SSR 1316 bridge (Rhodestown Road) to a point on the east shore 34° 50.5951' N – 77° 30.1534' W.

(31) Northeast and Little Northeast Creeks - north and east of a line beginning on the west shore at a point 34° 44.0778' N – 77° 21.2640' W; running southeasterly along the railroad bridge to a point on the east shore 34° 44.0446' N – 77° 21.2126' W; and west of a line beginning on the north shore 34° 44.9055' N – 77° 19.7541' W; running southerly along SSR 1406 bridge (Piney Green Road) to a point on the south shore 34° 44.8881' N – 77° 19.7649' W.

(32) Northeast Cape Fear River - main stem waters north of a line beginning at a point on the west shore 34° 26.5658' N – 77° 50.0871' W; running northeasterly along the NC 210 bridge to a point on the east shore 34° 26.6065' N – 77° 49.9955' W and south of a line beginning on the west shore 34° 38.7667' N – 77° 52.3417' W running easterly along SSR 1318 bridge (Croomsbridge Road) to a point on the east shore 34° 38.7744' N – 77° 52.3093' W; including the following tributaries from their confluence with the Northeast Cape Fear River in the direction indicated to the specified boundary:

(a) Burgaw Creek - west to a line beginning on the north shore at a point 34° 32.4670' N – 77° 51.1705' W; running southerly along SSR 1411 bridge (Stag Park Road) to a point on the south shore 34° 32.4567' N – 77° 51.1711' W.

(b) Pike Creek - west to a line beginning on the north shore at a point 34° 28.7928' N – 77° 52.5148' W; running southerly along SSR 1411 bridge (Ashton Lake Road) to a point on the south shore 34° 28.7882' N – 77° 52.5261' W.

(c) Merrick Creek - north and east to a line beginning on the north shore at a point 34° 26.8264' N – 77° 48.1948' W; running southerly along NC 210 bridge to a point on the south shore 34° 26.8028' N – 77° 48.1797' W.

(d) Island Creek - south and east to a line beginning on the west shore at a point 34° 22.0359' N – 77° 48.9107' W; running easterly along SSR 1002 bridge (Holly Shelter Road) to a point on the east shore 34° 22.0213' N – 77° 48.8854' W.

(e) Prince George Creek - south and east to a line beginning on the north shore at a point 34° 20.6773' N – 77° 54.2113' W; running southerly along NC 133 bridge to a point on the south shore 34° 20.6659' N – 77° 54.2170' W.

(f) Turkey Creek - north and east to a line beginning on the north shore at a point 34° 23.8546' N – 77° 54.7872' W; running southerly along NC 133 bridge to a point on the south shore 34° 23.8429' N – 77° 54.7772' W.

(g) Long Creek - north and west to a line beginning on the west shore at a point 34° 26.3494' N – 78° 01.5716' W; running easterly along NC 210 bridge to a point on the east shore 34° 26.3500' N – 78° 01.5396' W.

(33) Black River - north and west of a line beginning on the west shore at a point 34° 22.0783' N – 78° 04.4123' W; running easterly to a point on the east shore 34° 21.9950' N – 78 ° 04.2864' W and south and east of a line beginning at a point on the north shore 34° 42.5285' N – 78° 15.8178' W; running southerly to a point on the south shore 34° 42.5008' N – 78° 15.7972' W. South River - south and east of a line beginning at a point on the west shore 34° 38.4120' N – 78° 18.7075' W; running easterly along SSR 1007 bridge (Ennis Bridge Road) to a point on the east shore 34° 38.4080' N – 78° 18.6727' W.

(34) Cape Fear River - main stem waters north and west of a line at Lock and Dam #1 beginning on the west shore at a point 34° 24.2628' N – 78° 17.6390' W; running easterly to a point on the east shore 34° 24.2958' N – 78° 17.5634' W and south and east of a line beginning at a point on the west shore 35° 24.8404' N – 78° 49.4267' W; running easterly to a point on the east shore 35° 24.8833' N – 78° 49.3288' W; including the following tributaries from their confluence with the Cape Fear River in the direction indicated to the specified boundary:

(a) Brown's Creek - south and west to a line beginning on the north shore at a point 34° 36.8641' N – 78° 35.0917' W; running southerly along NC 87 bridge to a point on the south shore 34° 36.8477' N – 78° 35.0731' W.

(b) Hammond Creek - south and west to a line beginning on the north shore at a point 34° 34.032' N – 78° 30.3542' W; running southerly along NC 87 bridge to a point on the south shore 34° 34.0142' N – 78° 30.3397' W.

(c) Steep Run - south and west to a line beginning on the north shore at a point 34° 25.5019' N – 78° 20.9934' W; running southerly along NC 87 bridge to a point on the south shore 34° 25.4742' N – 78° 20.9549' W.

(d) Wayman's Creek - south and west to a line beginning on the north shore at a point 34° 22.4396' N – 78° 16.3904' W; running southerly along NC 87 bridge to a point on the south shore 34° 22.4287' N – 78° 16.3723' W.

(e) Livingston Creek - south to a line beginning on the north shore at a point 34° 19.5405' N – 78° 12.9889' W; running southerly along NC 87 bridge to a point on the south shore 34° 19.5128' N – 78° 12.9727' W.

(f) Hood Creek - south and west to a line beginning on the north shore at a point 34° 18.6658' N – 78° 07.1988' W; running southerly along NC 87 bridge to a point on the south shore 34° 18.6612' N – 78° 07.1741' W.

(g) Indian Creek - west to a line beginning on the north shore at a point 34° 17.7383' N – 78° 02.6706' W; running southerly along SSR 1453 bridge (Brunswick County) to a point on the south shore 34° 17.7210' N – 78° 02.6697' W.

(h) Sturgeon Creek - west to a line beginning on the north shore at a point 34° 14.6391' N – 78° 01.8154' W; running southerly to a point on the south shore 34° 14.5918' N – 78° 01.7941' W.

(i) Mill Creek - north and west of Sturgeon Creek to a line beginning on the north shore at a point 34° 15.2342' N – 78° 01.6370' W; running southerly to a point on the south shore 34° 15.2024' N – 78° 01.6525' W.

(j) Alligator Creek - north of the Brunswick River to the origin of the Creek excluding the dredged portions of the Creek.

(k) Jackeys Creek - west of the Brunswick River to a line beginning on the north shore at a point 34° 11.9672' N – 77° 58.8303' W; running southerly along the NC 133 bridge to a point on the south shore 34° 11.9544' N – 77° 58.8307' W.

(l) Mallory Creek - west of the Brunswick River to a line beginning on the north shore at a point 34° 10.0530' N – 77° 58.5927' W; running southerly along the NC Highway 133 bridge to a point on the south shore 34° 10.0351' N – 77° 58.5942' W.

(m) Town Creek - west to a line beginning on the north shore at a point 34° 09.4084' N – 78° 05.5059' W; running southerly along US 17 bridge to a point on the south shore 34° 09.3731' N – 78° 05.5147' W.

(n) Lilliput Creek - west to a line beginning on the north shore at a point 34° 04.5292' N – 77° 57.3187' W; running southerly along NC 133 bridge to a point on the south shore 34° 04.5137' N – 77° 57.3108' W.

History Note: *Authority G.S. 113-132; 113-134;*
Eff. May 1, 2008.

4.5.5 Other States River Herring Rules and Regulations

See Section 15, Appendix 3 for a list of rules and regulations for blueback herring and alewife in other East Coast states.

5.0 GENERAL LIFE HISTORY

5.1 INTRODUCTION

Alewife and blueback herring, collectively known as river herring, are anadromous members of the family Clupeidae (herrings and shads). Anadromous means they migrate from the ocean, enter coastal bays and sounds through inlets, and ascend into freshwater rivers and streams to spawn, traveling further upstream during wet years and remaining downstream during dry years. Surviving adults then return to the ocean after spawning. The young-of-the-year fish use rivers and estuaries as nursery grounds as they migrate downstream after hatching. After the juveniles leave the rivers and estuaries in the fall or early winter, they complete their development in the Atlantic Ocean, over the continental shelf off New England (Loesch 1987; Jenkins and Burkhead 1994). Historically, the two species have occurred geographically together from New Brunswick and Nova Scotia in Canada south to the northern coastal area of South Carolina. Blueback herring occur further south, to northern Florida. Spawning in both species usually occurs from March through July, with populations in lower latitudes spawning sooner and northern latitudes spawning later (Tyus 1974; Loesch and Lund 1977; Pardue 1983).

There are important life history differences between the two species (Loesch 1987). Alewife tend to spawn in slow-moving waters, such as deep pools or oxbows (Jones et al. 1978), while blueback herring tend to select fast-moving waters, such as main-stream areas of large rivers and tributaries, for spawning (Loesch and Lund 1977). Blueback herring were found farther upstream relative to alewife in the Cape Fear River (Davis and Cheek 1966). In areas where both species occur, alewife generally spawn 3 to 4 weeks earlier than blueback herring (Jones et al. 1978; Loesch 1987). However, some research in North Carolina indicates otherwise. Research on the lower Roanoke River showed little difference in the spawning times of alewife and blueback herring (Walsh et al. 2005); while research on the Tar-Pamlico indicated that blueback herring may spawn earlier than alewife (Overton et al. 2012). Although herring are thought to return to the streams of their birth for spawning, both species readily colonize new streams or ponds and will reoccupy systems from which they have been extirpated (Loesch 1987). Both juveniles and adults respond negatively to light, in riverine and offshore habitats, with alewife remaining deeper in the water column in both habitats (Klauda et al. 1991). Both species are important prey during all life stages for many other species of commercial and recreational importance. Both species have also been widely stocked in inland freshwater lakes and reservoirs where they live and reproduce entirely in freshwater and serve as prey for freshwater game fish. Freshwater residency has also been documented in populations of both alewife (Palkovacs et al. 2008) and blueback herring (Limburg et al. 2001) that are landlocked and separated from anadromous populations by river dams.

In the collective population of river herring, the percentage of alewife and blueback herring present in major Albemarle Sound tributaries has varied based on sampling of the commercial catch (Johnson et al. 1981). For example, percent composition of alewife ranged from 4% in 1977 to 49% in 1979, with alewife dominating the early catches in each year. From 1989 through 1992, the percentage of alewife ranged from 14.2 to 31.2% (Winslow and Rawls 1992). The same pattern of early dominance by alewife, with subsequent later dominance by blueback herring, is evident in weekly species composition samples taken during the 1980-92 spawning runs on the Chowan and Scuppernong rivers (Winslow et al. 1983; Winslow and Rawls 1992). The fraction of alewife in the commercial catch for those years ranged from 27 to 37%.

Beginning in 2008, the NCDMF implemented a contracted pound net survey in the Chowan River in order to collect biological and abundance data necessary for stock analysis. Between 2008 and 2012, alewife have tended to dominate the unculled samples taken from those nets, which is the opposite of commercial catch from previous years. Since the beginning of the contracted pound net survey, the percentage of alewife has ranged from 26.3 to 60.0%. This difference between the pound net survey samples and prior fish house samples may be due to changes in species abundance or may be because the nets were set in different locations than in previous years.

5.1.1 Alewife

The alewife has a gray to gray-green back and silvery sides, 12 to 19 dorsal fin rays, 15 to 21 anal fin rays, and the eye diameter is usually greater than the snout length (Bozeman et al. 1989; Jones et al. 1978). They range in size as adults from about 230 mm (9 in) to over 330 mm (13 in). Alewife have a pink peritoneum lining of the body cavity. Catches of adult alewife from offshore National Marine Fisheries Service (NMFS) Atlantic Coast trawl surveys were confined to areas north of 40^{o} north latitude in the summer and fall (Fay et al. 1983; Loesch 1987). Winter catches were made between 40° and 43° north latitude, with spring catches distributed over the entire continental shelf. Alewife were more abundant than blueback herring when all samples were combined. The majority of catches occurred at depths less than 100 m (328 ft). Alewife were most abundant at depths between 56 and 110 m (184 and 361 ft), deeper than blueback herring. Neves (1981) suggested that the greenish dorsal coloration of the alewife is associated with the deeper vertical distribution of the species relative to blueback herring, given that a greenish coloration would provide better camouflage at those depths, since green wavelengths penetrate deeper than blue. Adult alewife destined for spawning in Albemarle Sound tributaries migrate from the northwest Atlantic Ocean, through Oregon Inlet and perhaps Hatteras Inlet, in late winter and early spring. Spawning surveys conducted by NCDMF since the mid-1970s during March through May have documented spawning in many tributary streams of Albemarle Sound's major Rivers such as the North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator rivers (Street et al. 1975; Johnson et al. 1977; Johnson et al. 1981; Winslow et al. 1983; Winslow et al. 1985; Winslow and Rawls 1992; Rawls 2001). Alewife are iteroparous spawners, meaning that they can spawn multiple years through the course of their lives (Kissil 1974). Known historical anadromous fish spawning areas are depicted in Figures 5.1-5.3, which also delineates Essential Fish Habitat (EFH) for anadromous species. Table 5.1 summarizes the amount of documented anadromous fish spawning and use areas (by type of water body) relative to potential habitat. Potential habitat includes all streams in the coastal plain shown on 1:100,000 scale hydrologic maps downstream of major impediments.

Table 5.1 Amount of documented anadromous fish habitat relative to potential habitat in coastal North Carolina. See Figures 5.1-5.3 for reference.

		ANADROMOUS FISH SPAWNING AND USE AREAS (miles)					
		Potential			Documented		
MU	**Hydrographic feature**	**NC**	**VA**	**Total**	**NC**	**VA**	**Total**
Albemarle	Major rivers	8	48	56	8	0	8
	Lake shorelines	34	4	39	10	0	10
	Tributaries	3,150	995	4,145	247	0	247
	Coastal shorelines	1,241	76	1,317	516	0	516
Chowan	Major rivers	95	44	139	141	48	189
	Lake shorelines	0	0	0	0	0	0
	Tributaries	1,272	2,084	3,356	267	117	384
	Coastal shorelines	88	0	88	88	0	88
Roanoke	Major rivers	181	0	181	181	0	181
	Lake shorelines	0	0	0	0	0	0
	Tributaries	1,382	0	1,470	427	0	427
	Coastal shorelines	6	0	6	4	0	4
Albemarle watershed		7,459	3,251	10,797	1,889	165	2,054
Pamlico	Major rivers	0	0	0	0	0	0
	Lake shorelines	79	0	79	37	0	37
	Tributaries	852	0	852	42	0	42
	Coastal shorelines	664	0	664	14	0	14
Tar/Pamlico	Major rivers	83	0	83	86	0	86
	Lake shorelines	8	0	8	0	0	0
	Tributaries	3,936	0	3,936	188	0	188
	Coastal shorelines	550	0	550	79	0	79
Neuse	Major rivers	220	0	220	188	0	188
	Lake shorelines	14	0	14	0	0	0
	Tributaries	4,469	0	4,469	302	0	302
	Coastal shorelines	369	0	369	11	0	11
Core/Bogue	Major rivers	0	0	0	0	0	0
	Lake shorelines	0	0	0	0	0	0
	Tributaries	226	0	226	9	0	9
	Coastal shorelines	674	0	674	0	0	0
New/White Oak	Major rivers	0	0	0	0	0	0
	Lake shorelines	14	0	14	0	0	0
	Tributaries	793	0	793	64	0	64
	Coastal shorelines	347	0	347	82	0	82
Cape Fear	Major rivers	237	0	237	231	0	231
	Lake shorelines	10	0	10	0	0	0
	Tributaries	4,690	0	4,690	246	0	246
	Coastal shorelines	212	0	212	19	0	19
Pamlico and southern watersheds		18,446	0	18,446	1,598	0	1,598
TOTALS	Major rivers	824	91	916	835	48	883
	Lake shorelines	158	4	163	47	0	47
	Tributaries	20,771	3,079	23,937	1,793	117	1,909
	Coastal shorelines	4,151	76	4,227	813	0	813
	All waterbodies	25,905	3,251	29,242	3,487	165	3,652

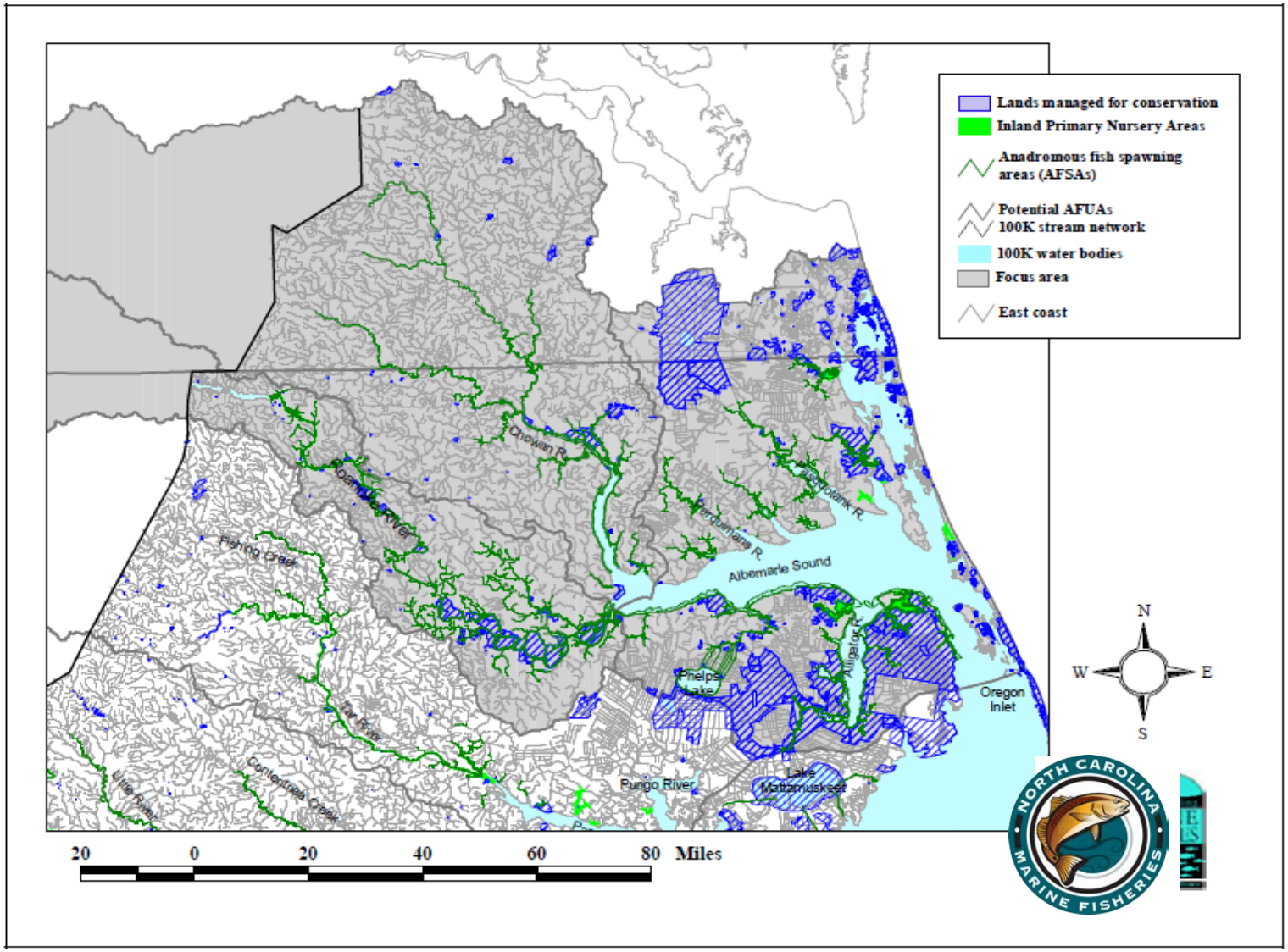


Figure 5.1. Anadromous fish spawning areas (as delineated by NCDMF, 2/20/06), lands managed for conservation (CGIA, 2002), and Primary Nursery Areas in Inland Fishing Waters (designated by NCWRC, 8/03) in the northern coastal plain of North Carolina.

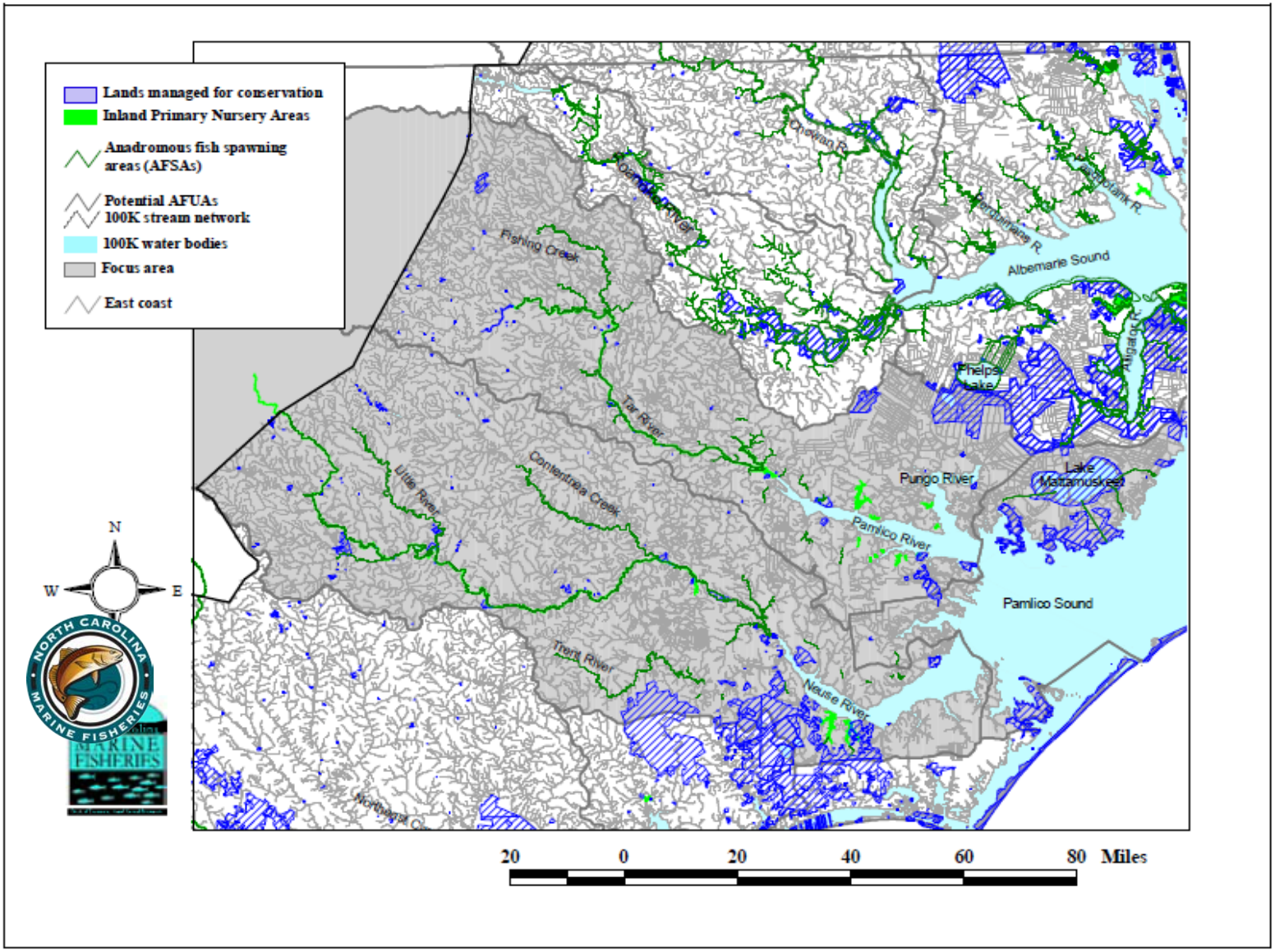


Figure 5.2 Anadromous fish spawning areas (as delineated by NCDMF, 2/20/06), lands managed for conservation (CGIA, 2002), and Primary Nursery Areas in Inland Fishing Waters (designated by NCWRC, 8/03) in the central coastal plain of North Carolina.

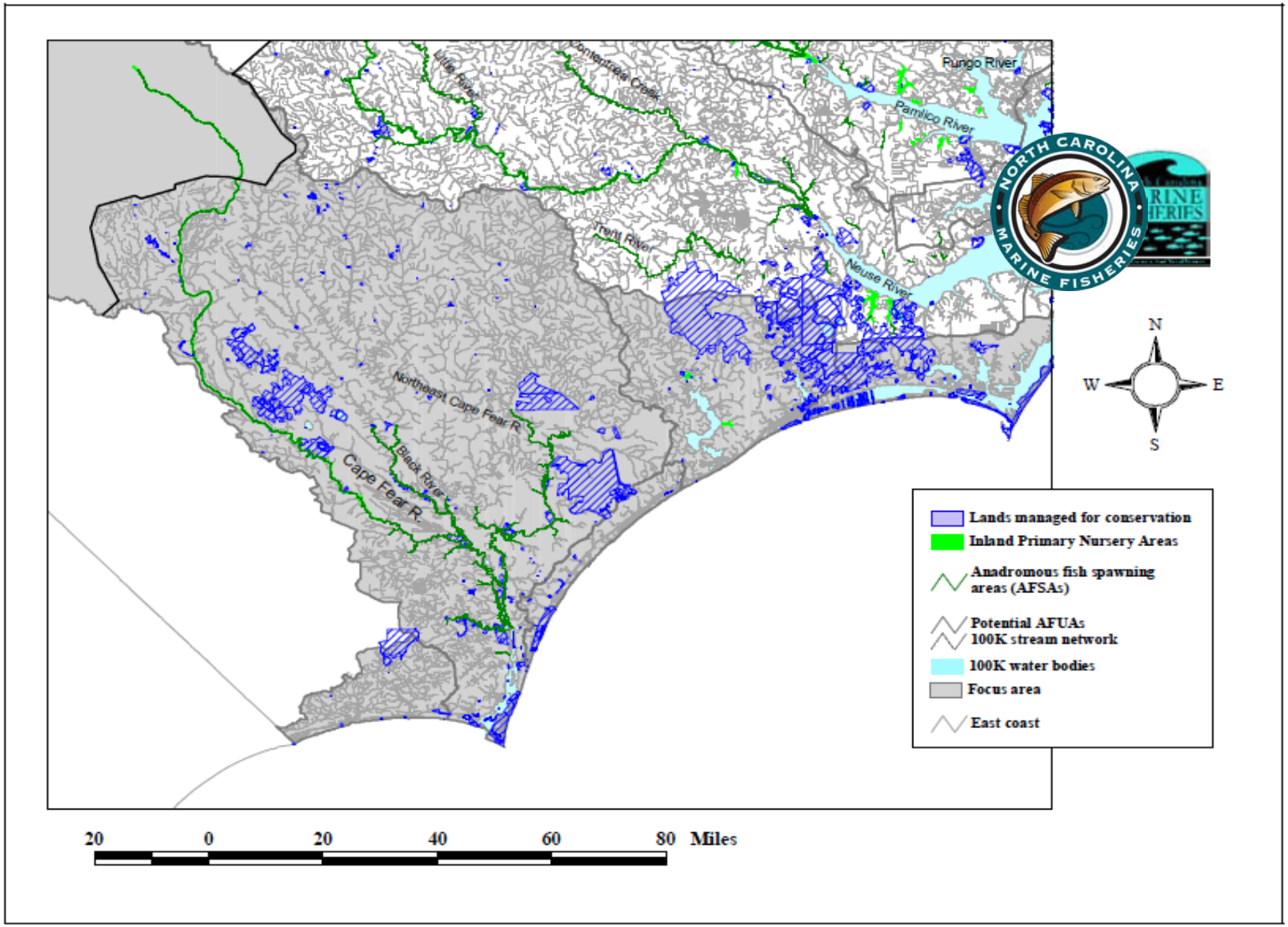


Figure 5.3 Anadromous fish spawning areas (as delineated by NCDMF, 2/20/06), lands managed for conservation (CGIA, 2002), and Primary Nursery Areas in Inland Fishing Waters (designated by NCWRC, 8/03) in the southern coastal plain of North Carolina.

Although the alewife has been reported as ranging from Newfoundland south to South Carolina (Loesch 1987), surveys reported by Rulifson (1994) in 1980 and repeated 12 years later (Rulifson 1994) indicated that the species now occurs in south Atlantic coastal rivers only in North Carolina. In North Carolina, populations were reported in the North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator rivers (all tributaries of Albemarle Sound); Lake Mattamuskeet and canals to the lake, Tar-Pamlico, Pungo, Neuse, and Trent rivers (tributaries to Pamlico Sound); New River; White Oak River; and Cape Fear, Northeast Cape Fear and Brunswick rivers. The status of these populations is presented in Table 4 of Rulifson (1994). All populations were listed as either "declining" or "status unknown" as of 1992.

Anadromous alewife may begin spawning as early as age 3, with the majority reaching sexual maturity at age 4 or 5. Fecundity in females ranged from 60,000 to 100,000 eggs (Fay et al. 1983). Moser and Patrick (2000) reported a mean alewife fecundity estimate of 118,670 eggs for the Albemarle area. Spawning populations are generally younger in the south. Females sampled from Albemarle Sound tributaries were primarily (94-97%) ages 4 through 6, with fish present up to ages 7 or 8 (Johnson et al. 1981). The historical average repeat spawning from 1972 through 1981 was 9.4% for alewife (see Section 5.3). Spawning occurs in the spring, earlier in the south and later in the north (Pardue 1983; Tyus 1974; Loesch and Lund 1977). Alewife in North Carolina spawn at water temperatures of 12.9 to 16° C (55-61° F) (Tyus 1974; Winslow et al. 1983; Winslow 1989). Alewife use a wide variety of spawning sites including lotic (flowing water) and lentic (standing water) habitats. However, alewife spawning is most common in lentic habitats like flooded backwaters and swamps (Walsh et al. 2005; Overton et al. 2012).

Alewife are sexually dimorphic with females growing larger than males. Female alewife collected from the Chowan River pound net fishery were on average 10 mm longer than males (Figure 5.4). The mean lengths at age and length frequency distributions for alewife have decreased among males and females since 1972 (Figure 5.4). During 1972 through 1976, modal peaks for males ranged from 240 mm to 250 mm, while during 2008 through 2011, they ranged from 220 mm to 240 mm. For females, modal peaks ranged from 260 mm to 270 mm in 1972 through 1976, and ranged from 230 mm to 260 mm in 2008 through 2011 (Figure 5.5).

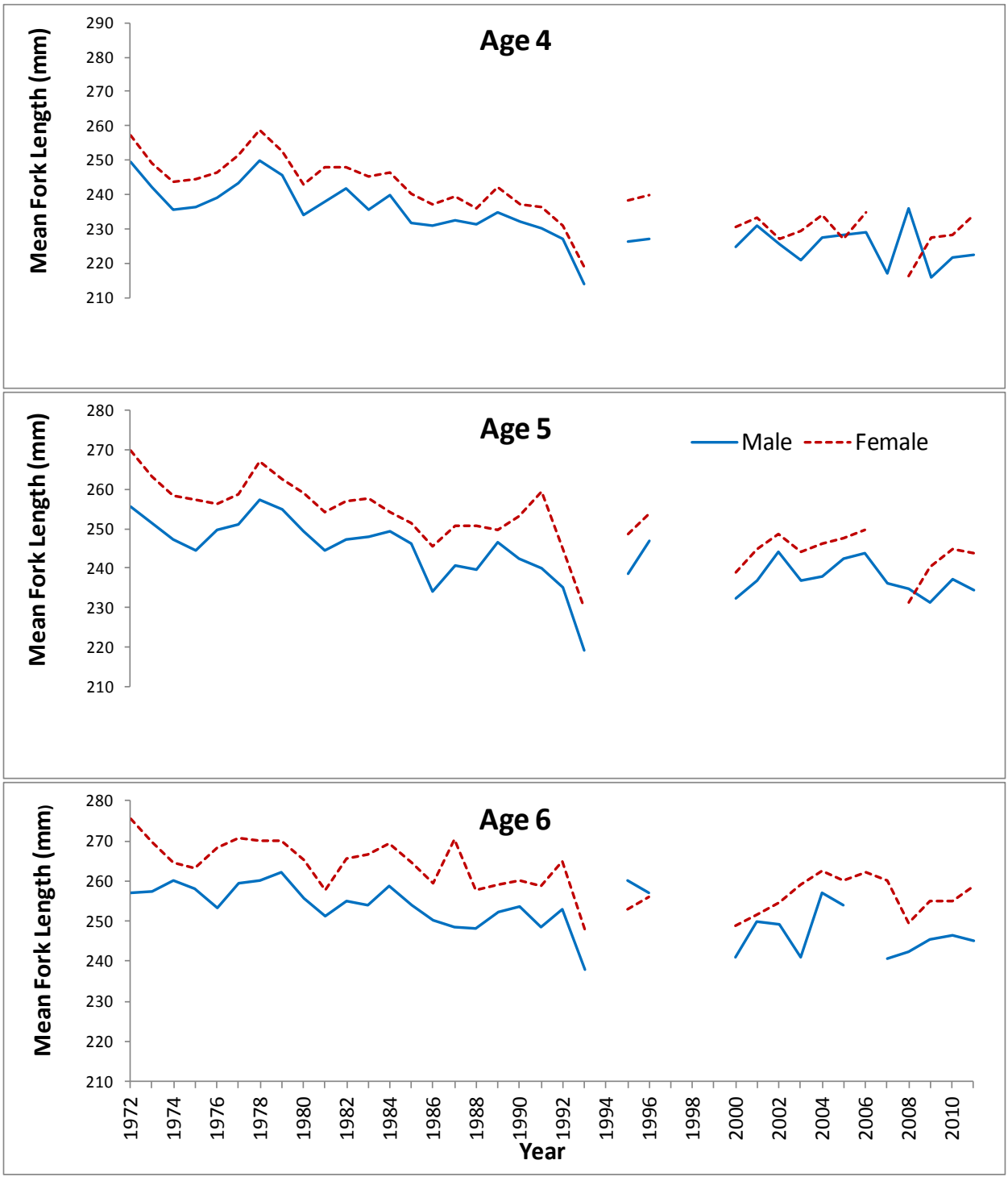


Figure 5.4 Mean length at age of alewife from the Chowan River pound net fishery, 1972-2011.

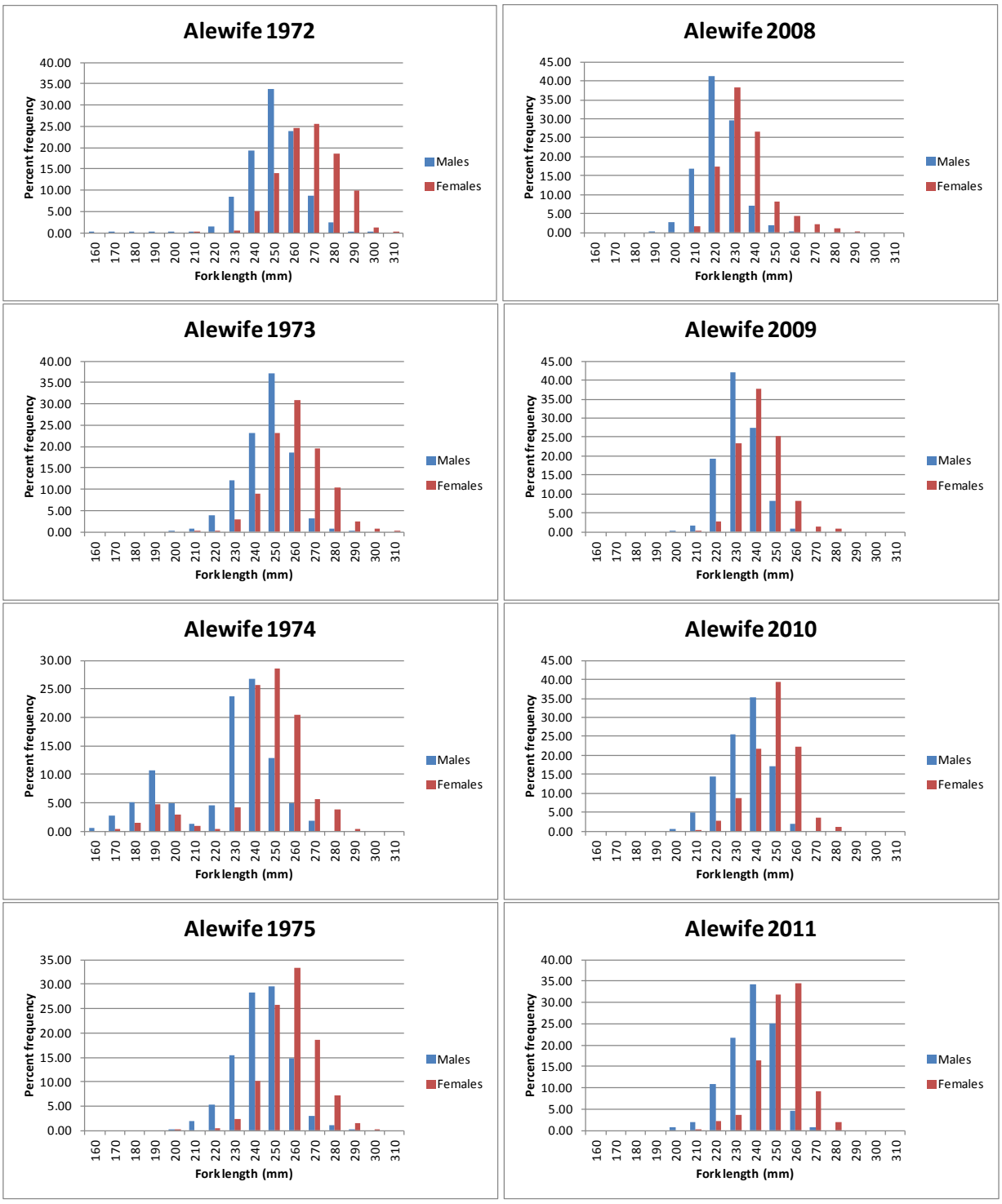


Figure 5.5 Length frequency distributions of male and female alewife collected from the Chowan River pound net fishery from 1972-1976, and 2008-2011.

Alewife eggs are at first adhesive and demersal until they become water-hardened after 24 hours, at which time they lose their adhesive properties and become pelagic (Loesch and Lund 1977; Jones at al. 1978). Eggs hatch in approximately 50 to 360 hours, depending upon temperature (Fay et al. 1983). The alewife yolk-sac stage lasts from 2 to 5 days, with larval alewife ranging in size from 4.3 to 19.9 mm (0.2 to 0.8 in). Transformation to the juvenile stage occurs at about 20 mm (0.8 in). Juvenile alewife may initially exhibit upstream movement during periods of decreased flows and encroachment of saline waters (Greene et al. 2009), later moving downstream as fall approaches. Emigration of juveniles from Albemarle Sound occurs from September through mid-November of the first year of life, and may be stimulated by heavy rainfall, high water, and/or sharp declines in water temperatures. Researchers on other watersheds have found that water temperature, previous day rainfall, discharge, and available forage can be important factors that trigger emigration (Gahagan et al. 2010). High abundance of juveniles may trigger an early migration (e.g. summer) (Richkus 1975), although an early migration has not been documented in North Carolina (Sara Winslow/NCDMF, personal communication 2005). Habitat requirements for critical early life history stages of the alewife as determined by Klauda et al. (1991) and Greene et al. (2009) are presented in Table 5.2.

Table 5.2 Habitat requirements for the critical early life history stages of alewife, *Alosa pseudoharengus* (Klauda et al. 1991; Greene et al. 2009).

Life Stage	**Zone**	**Temperature °C**	**Salinity %**	**Dissolved Oxygen mgL^{-1}**	**pH**	**Suspended Solids mgL^{-1}**
Egg	substrate and water column	10.6-26.7 (suitable) 17.2-21.1 (optimum)	NIF (suitable) 0-2 (optimum)	≥5.0 (suitable) NIF (optimum)	5.0-8.5 (suitable) NIF (optimum)	<1000 (suitable) NIF (optimum)
Prolarva (have yolk sac)	water column	8-31 (suitable) 15-24 (optimum)	NIF (suitable) 0-3 (optimum)	≥5.0 (suitable) NIF (optimum)	5.5-8.5 (suitable) NIF (optimum)	NIF
Postlarva (4.3-19.9 mm)	water column	14-28 (suitable) 20-26 (optimum)	NIF (suitable) 0-5 (optimum)	≥5.0 (suitable) NIF (optimum)	NIF	NIF
Early juvenile (≥20 mm)	water column and near substrate	10-28 (suitable) 15-20 (optimum)	NIF (suitable) 0-5 (optimum)	≥3.6 (suitable) NIF (optimum)	NIF	NIF

NIF indicates no information found.

Larval alewife primarily consume zooplankton (Binion et al. 2012), while juveniles tend to consume crustacean eggs, insects and insect eggs (Davis and Cheek 1966). Shrimp, squid, and small fishes may be eaten in some areas or by larger individuals (Jenkins and Burkhead 1994). Alewife are important prey for other species jointly managed by federal and state governments and the ASMFC, including bluefish, American eel, striped bass, and weakfish. Age-1 striped bass, in particular, can feed heavily on Alosines during their fall emigration (Tuomikoski 2004; Rudershausen et al. 2005). State managed freshwater species such as largemouth bass, pumpkinseed, redfin pickerel, shiners, walleye, white bass, white perch, and yellow perch also consume alewife (Loesch 1987).

5.1.2 Blueback Herring

Blueback herring have a blue to blue-green back and silver sides with a prominent dark spot on the shoulder, 15 to 20 dorsal fin rays, 15 to 21 anal fin rays, and the eye diameter is usually less than or equal to the snout length (Jones et al. 1978: Bozeman et al. 1989). In contrast to the alewife, blueback herring have a black peritoneum lining the body cavity. They range in size from around 230 mm (9 in) at age 3 to around 313 mm (12.3 in) at age 8 or 9. Catch data from NMFS ocean trawl surveys (Neves 1981) indicate that blueback herring spend most of their time offshore in water depths of less than 328 ft (100 m). North of Cape Hatteras, blueback herring were most abundant at depths between 89 and 180 ft (27 and 55 m). Catches of blueback herring in summer and fall were confined to the areas north of 40°− north latitude. Winter catches were made between 40° and 43° north latitude. Spring catches were distributed over the entire Continental Shelf portion of the study area (Fay et al. 1983).

Blueback herring have a broader range in the south Atlantic than alewife, occurring as far south as coastal rivers in Florida. Rulifson (1994) indicated that the species occurs in the following North Carolina river systems: North, Pasquotank, Little, Perquimans, Yeopim, Chowan, Meherrin, Roanoke, Cashie, Scuppernong and Alligator rivers (all tributaries of Albemarle Sound); Tar-Pamlico, Pungo, Neuse, and Trent rivers (tributaries to Pamlico Sound); New River; White Oak River; and Cape Fear, North East Cape Fear and Brunswick rivers. Known historical anadromous spawning areas are depicted in Figures 5.1- 5.3, which also delineates Essential Fish Habitats for the species. Table 5.1 summarizes the amount of documented anadromous fish spawning and use areas (by type of water body) relative to potential habitat.

Blueback herring have been reported to spawn in the lower portions of the tributary rivers of estuaries along the east coast from Nova Scotia to the St. Johns River in Florida (Fay et al. 1983). Loesch (1987) noted that both species have the ability to ascend rivers far upstream although earlier studies suggested that alewife will ascend further upstream than blueback herring (Hildebrand 1963; Scott and Crossman 1973), while other research suggest that blueback herring will ascend farther upstream in the southern range (Davis and Cheek 1966). Blueback herring are iteroparous, heterochronal spawners, meaning that they spawn multiple seasons (iteroparous) and release multiple batches of eggs (heterochronal) through the course of the spawning season (McBride et al. 2010).

Blueback herring vary more than alewife in age of first spawning, although, their maturation rates are similar (Fay et al. 1983). Spawning populations in Albemarle Sound tributaries were dominated by ages 4-6 during the late 1970s and early 1980s (Johnson et al. 1981, Winslow et al. 1983). Fecundity of blueback herring ranged from 45,800 eggs in a 238 mm (9.4 in) individual to 349,700 in a 310 mm (12.2 in) fish (Fay et al. 1983). Moser and Patrick (2000) reported a mean fecundity estimate of 150,901eggs/female for blueback herring from the Albemarle area.

Blueback herring are sexually dimorphic with females growing larger than males. Female blueback herring collected from the Chowan River pound net fishery were on average 10 mm longer than males (Figure 5.6). The mean lengths at age for blueback herring have decreased by on average 20 mm among males and females since 1972. The length frequency distributions for blueback herring have also decreased (Figure 5.7). During 1972 through 1976, modal peaks for males ranged from 240 mm to 250 mm, while from 2008 and 2011, they ranged from 220 mm to 230 mm. For females, modal peaks ranged from 250 mm to 260 mm during 1972 through 1976, and ranged from 230 mm to 240 mm from 2008 to 2011.

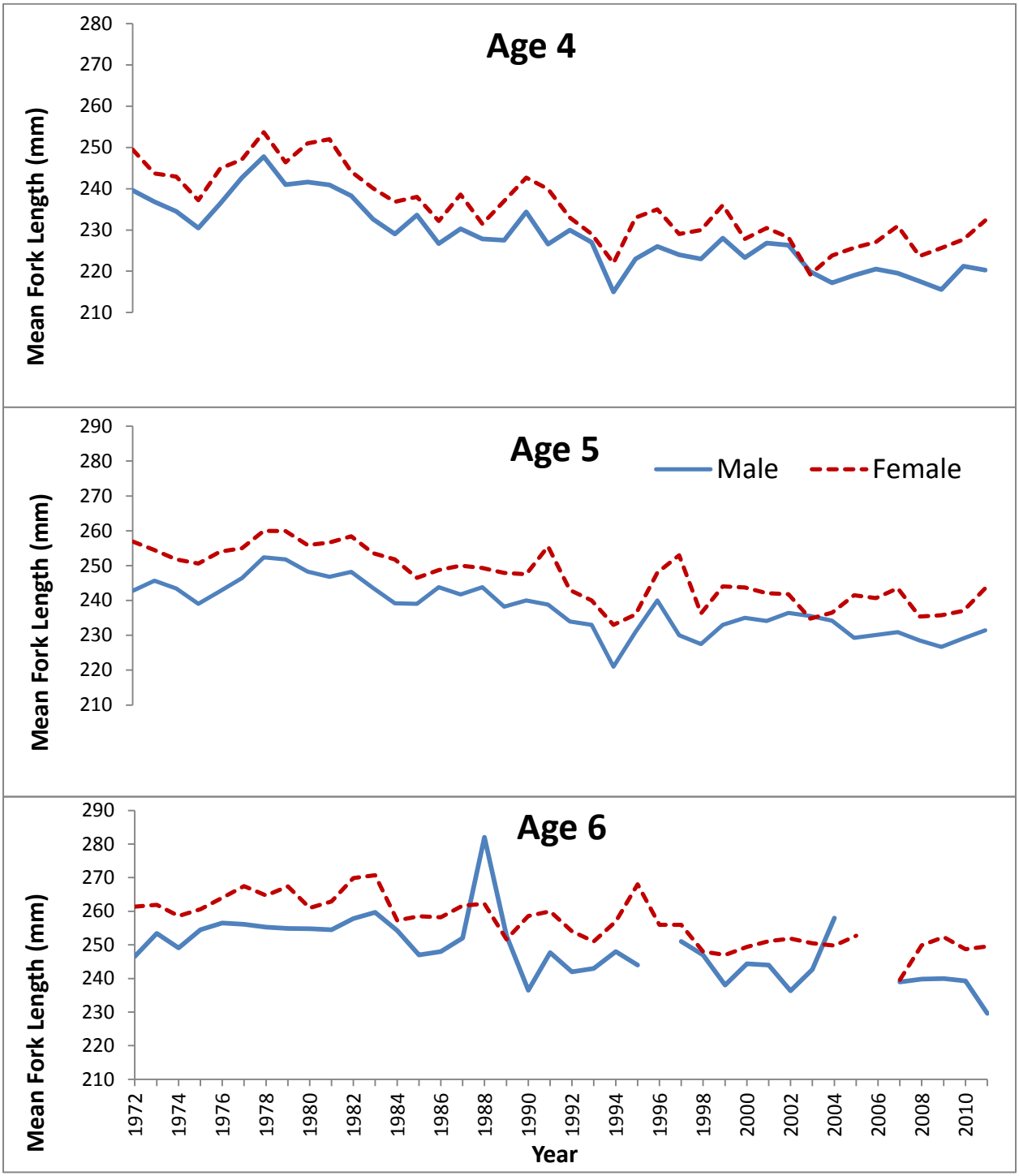


Figure 5.6 Mean length at age of blueback herring from the Chowan River pound net fishery, 1972-2011.

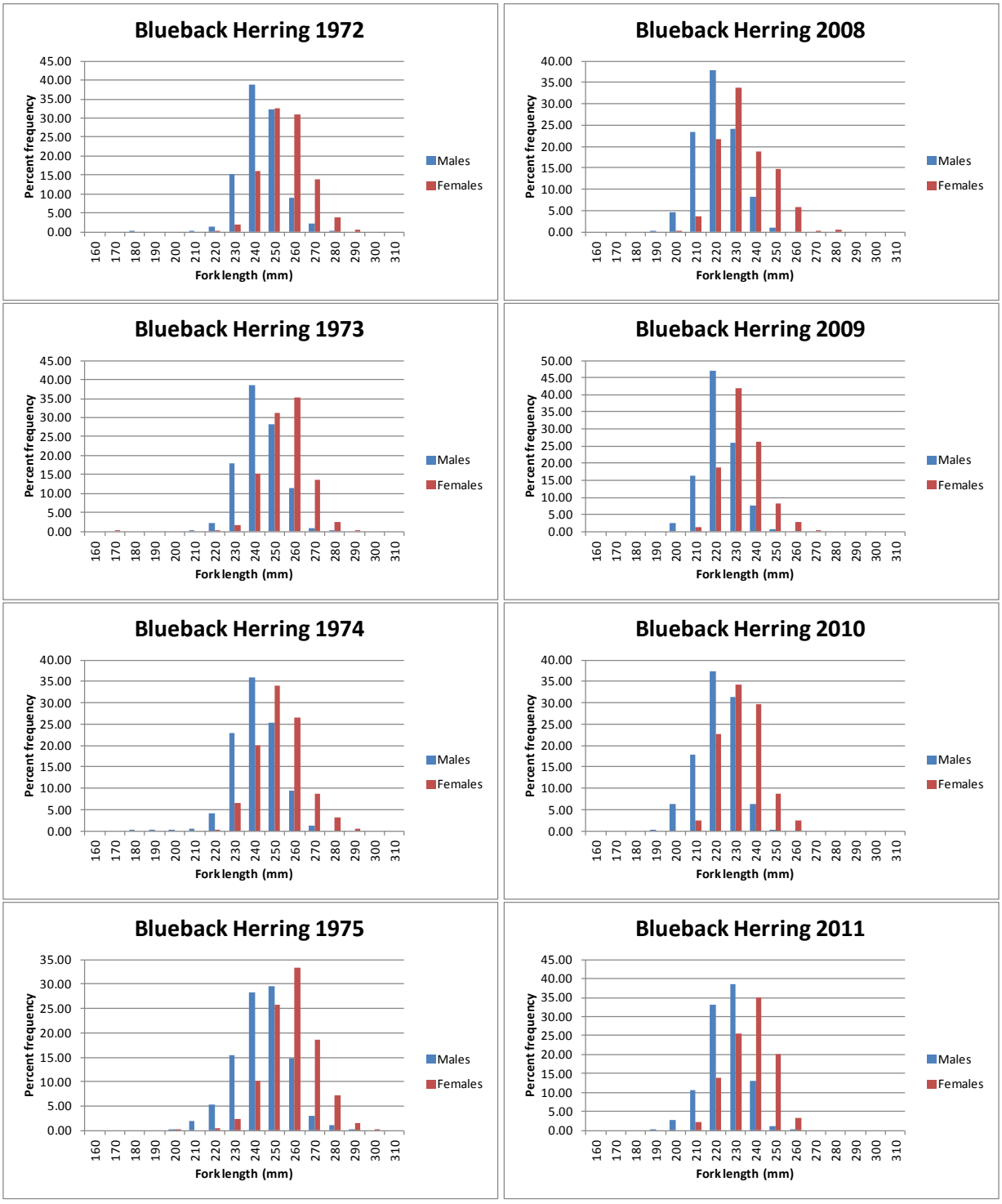


Figure 5.7 Length frequency distributions of male and female blueback herring collected from the Chowan River pound net fishery from 1972-1976, and 2008-2011.

In North Carolina, blueback herring begin spawning at warmer temperatures than alewife, with recorded spawning temperatures of 14.4-17° C (58-63° F) (Winslow 1989; Winslow et al. 1983). Blueback herring use a wide variety of spawning sites including lotic and lentic habitats (Loesch and Lund 1977; Walsh et al. 2005; Overton et al. 2012). Blueback herring often spawn in flooded back swamps, oxbows and along stream edges. Both species spawn in groups, scatter their eggs, and cease spawning when water temperatures rise above 27° C (81^{o} F).

Blueback herring eggs, like those of alewife, are at first adhesive and demersal until they become water-hardened after 24 hours, at which time they lose their adhesive properties and become buoyant (Loesch and Lund 1977; Jones at al. 1978). Eggs hatch in approximately 55 to 94 hours, depending upon the temperature. Yolk-sac larvae average 5.1 mm (0.2 in) at absorption and remain in that stage for 2 to 3 days. Larval blueback herring range from 4 to 15.9 mm (0.2-0.4 in) in length. Transformation to the juvenile stage is completed at about 20 mm (0.8 in). Like juvenile alewife, juvenile blueback herring may initially exhibit upstream movement during the summer, followed by downstream movement beginning in October. Juveniles exhibit diel movement, moving toward the bottom during the day and toward the surface at night. Emigration of juveniles from estuarine nursery areas in North Carolina occurs from September to November. Little information is available once emigration to sea has occurred. Habitat requirements for critical early life stages of blueback herring as documented by Klauda et al. (1991) and Greene et al. (2009) are presented in Table 5.3.

Table 5.3 Habitat requirements for the critical early life history stages of blueback herring, *A. aestivalis* (Klauda et al. 1991; Greene et al. 2009).

Life Stage	**Zone**	**Temperature °C**	**Salinity %**	**Dissolved Oxygen mgL^{-1}**	**pH**	**Suspended Solids mgL^{-1}**
Egg	substrate and water column	7-26 (suitable) 20-24 (optimum)	0-22 (suitable) 0-2 (optimum)	NIF (suitable) NIF (optimum)	5.7-8.5 (suitable) 6.0-8.0 (optimum)	<1000 (suitable) NIF (optimum)
Prolarva (~5.1 mm)	water column	13-26 (suitable) NIF (optimum)	0-22 (suitable) NIF (optimum)	≥5.0 (suitable) NIF (optimum)	6.2-8.5 (suitable) 6.5-8.0 (optimum)	<500 (suitable) NIF (optimum)
Postlarva (4-15.9 mm)	water column	13-28 (suitable) NIF (optimum)	0-22 (suitable) NIF (optimum)	≥5.0 (suitable) NIF (optimum)	NIF	NIF
Early juvenile (≥20 mm)	water column and near substrate	11-32 (suitable) 20-30 (optimum)	0-28 (suitable) 0-5 (optimum)	≥4.0 (suitable) NIF (optimum)	NIF	NIF

NIF indicates no information found.

Larval blueback herring, like alewife, are primarily zooplankton feeders (Binion et al. 2012). Young-of-the year Blueback herring consume various species of copepods and cladocerans (Jenkins and Burkhead 1994). In the ocean, the species' diet consists of copepods, other plankton, pelagic shrimps, small fishes and fish fry. The food of adults is similar to that of juveniles and includes insects during the spawning migration (Jenkins and Burkhead 1994). The blueback herring is a small species, and as such, is important forage for other species. It is preyed upon by the same species that prey on alewife and other clupeid fishes, and constitutes an important link in estuarine and marine food webs between zooplankton and top predators (Rudershausen et al. 2005).

5.2 HISTORICAL ABUNDANCE

In North Carolina, there are no long-term data available on river herring abundance. Historical abundance of river herring in Albemarle Sound based on landings and fishing effort data was investigated by Hightower et al. (1996). Fisheries in Albemarle Sound once harvested large numbers of river herring, but landings in recent years are substantially lower. Average landings during the 90-year period of 1880-1970 were 11.9 million pounds (5.4 million kg). Landings in 1998, in contrast, were only 4.2 % of the historical average (519,289 lbs; 235,548 kg; see Section 7). This comparison does not take into account the change in effort since the fishing season was implemented in 1995. Hightower et al. (1996) noted that the estimate of maximum sustainable yield derived from their modeling of the period 1845-1993 was 5.7 million kg (12.6 million lbs), similar to the long-term average reported landings. They stated that the only remaining question was whether habitat has been lost or degraded to such a degree that historical levels of harvest are no longer possible.

5.3 RESEARCH RECOMMENDATIONS

The River Herring Fishery Management Plan Development Team made the following recommendations for research into the life history of river herring:

- Conduct studies of river herring egg and larval survival and development in North Carolina river systems. **High priority**
- Conduct studies on energetics of feeding and spawning migrations of river herring in North Carolina. **Medium priority**
- Conduct research on predation of all life stages of river herring in the Albemarle Sound and other systems in North Carolina (including invasive species such as blue catfish and other predators). **Medium priority**

5.4 NCDMF SAMPLING PROGRAMS

The following section describes the NCDMF sampling programs that collect data on river herring. Juvenile sampling provides data for the juvenile abundance index (JAI), which is one of the required stock status indicators identified in Amendment 1. The Independent Gill Net Survey and Chowan River Pound Net Survey provide some estimates of relative abundance of adult herring as well as provide material used for aging and repeat spawning estimates.

5.4.1 Juvenile Sampling

The NCDMF began nursery area sampling for juvenile blueback herring and alewife in the Albemarle Sound area in 1972. Program 100 was established to index annual relative abundance of juvenile anadromous species, including all alosines. Thirty-four stations were established in the western Albemarle Sound area and sampled with trawls and seines. The Carolina wing trawl was adopted as the standard trawl in place of the Cobb trawls in June 1974 (Johnson et al. 1977), and the seine sampling continued. The 34 stations (23 trawls and 11 seines) were sampled monthly during June-October. During September, an additional 43 stations (28 trawls and 15 seines) were sampled throughout the Albemarle Sound area to determine distribution and nursery areas of anadromous species.

Seine stations were sampled with a 60 ft bag seine with ¼ inch mesh bag, with a single haul considered one unit of effort. The Carolina wing trawl had a headrope length of 26 ft, containing webbing which ranged from 4 inch stretched mesh in the wings to 1/8 inch mesh tail bag. The trawl was pulled for 10 minutes, and was considered one unit of effort for determining CPUE. Samples were sorted to species, and up to 30 individuals of each alosine species present were measured to the nearest millimeter fork length (mm, FL), and all others were counted.

Based on catch consistency the seine proved to be the best sampling gear for blueback herring, and the wing trawl was the best for alewife. Due to a further reduction in federal aid funds, trawl sampling was dropped at the end of June 1984. Sampling with seines at the 11 cores stations has continued during June-October each year (Figure 5.8). During September, an additional 13 seine stations are sampled throughout the Albemarle Sound area (Figure 5.8) to determine distribution and migration.

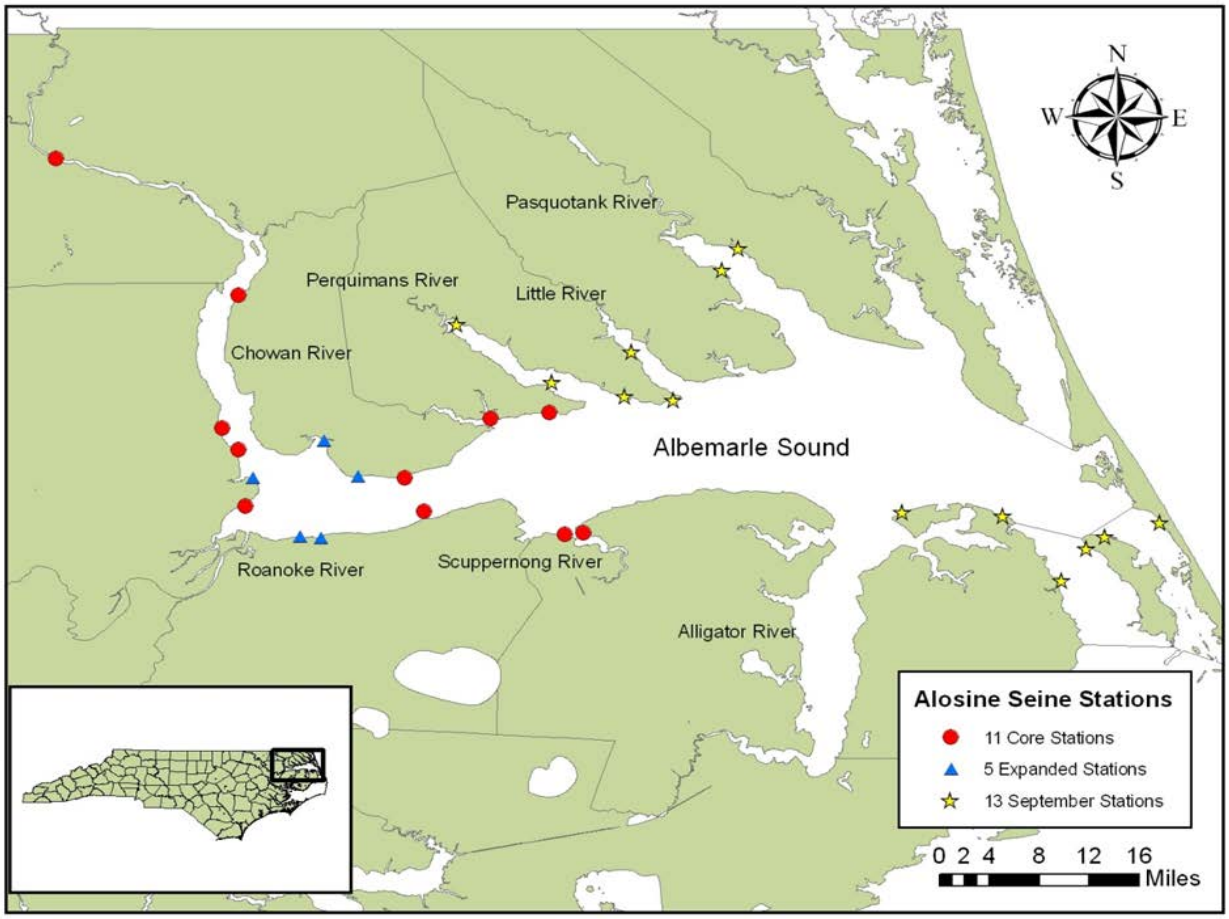


Figure 5.8 All alosine seines station sampled June-October each year.

A recommendation of the 2000 River Herring FMP was to expand the seine survey in the western Albemarle Sound area to determine if the core nursery areas were no longer being utilized and/or if juvenile production was being overlooked. Five additional seine stations were added in 1999 and have been sampled monthly during June-October (Figure 5.8).

Annual sampling to determine the relative abundance of young-of-the-year (YOY) striped bass has been conducted at seven sampling locations (Hassler stations), in the western Albemarle Sound area since 1955. Dr. W.W. Hassler (North Carolina State University) conducted the sampling program from 1955 through 1987, through various funding sources (Hassler et al. 1981, 1982; Hassler and Taylor 1986). The NCDMF has conducted the sampling since 1988 (Henry et al. 1992; Taylor and Hardy 1993, 1994; Trowell and Winslow 1997, 1998; Dilday and Winslow 2002; Winslow 2005). These sampling efforts also provide long-term data for blueback herring and alewife juvenile abundance.

An 18 foot semi-balloon trawl, constructed of 1.5 inch stretched mesh webbing in the body and 0.5 inch stretched mesh in the cod end is utilized. Sampling occurs annually during mid-July through October. Each trawl sample is pulled for 15 minutes, and considered one unit of effort for calculating CPUE. Samples are sorted to species, counted and measured to the nearest millimeter fork length (mm, FL). Central sound trawls have been conducted since 1984 in the

central portion of Albemarle Sound. These 12 stations are completed every other week opposite the Hassler trawl stations.

Historical trawl and seine stations were reactivated in 2004 to help fill data needs for a perch and catfish fishery management plans. These stations are conducted on a monthly basis from June-October each year. These 43 stations and the 12 Central Sound stations use the same gear as the Hassler trawls, but the tow time is reduced to 10 minutes. The seines utilize the same gear as the other seines. All of these sampling stations can potentially catch river herring (Figure 5.9).

Since 2004, juvenile sampling for anadromous fish in the Albemarle Sound has consisted of 62 trawl stations and 29 seines stations, all of which have the potential to capture juvenile river herring. The juvenile abundance index (JAI), used as a stock status indicator, is calculated from the 11 core seine stations, sampled once a month. Blueback herring is the indicator species for the purposes of determining stock status, but a JAI is also calculated for alewife.

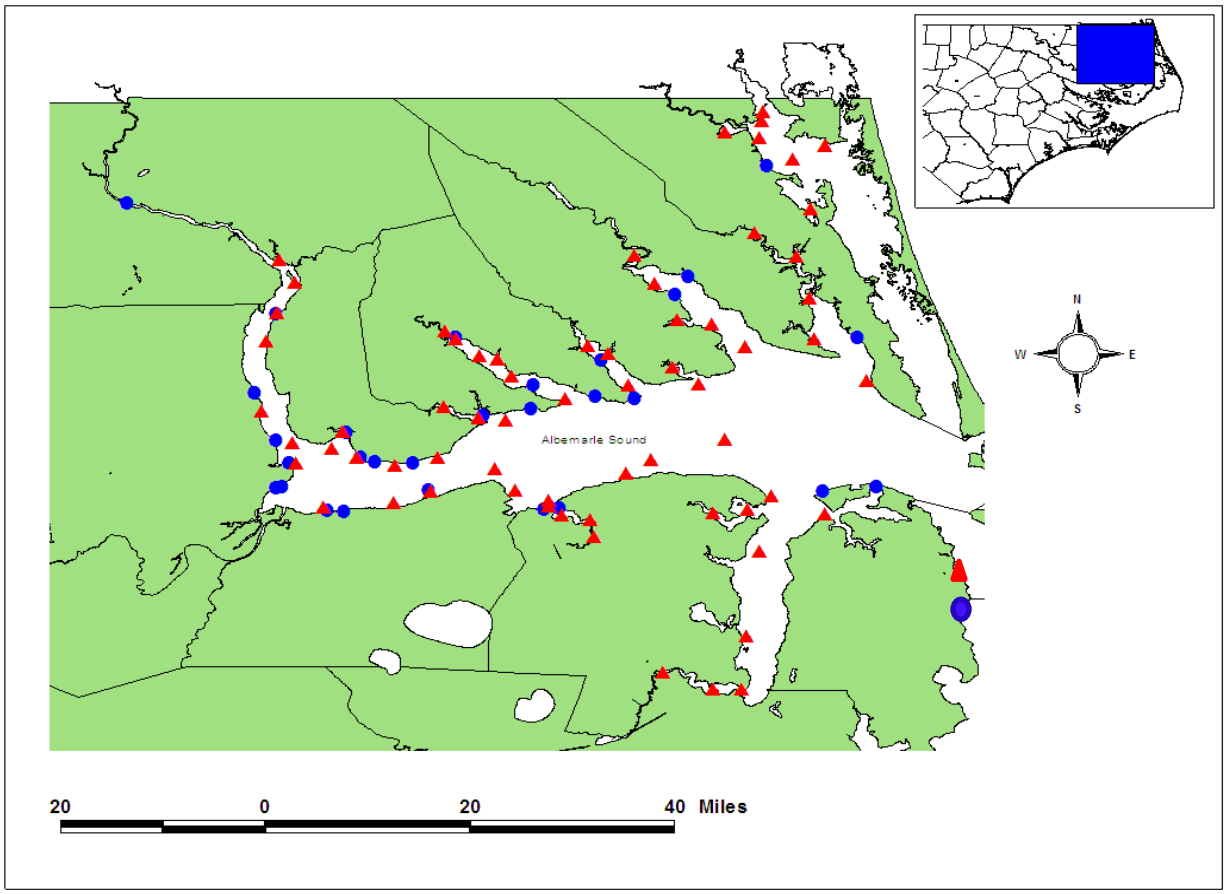
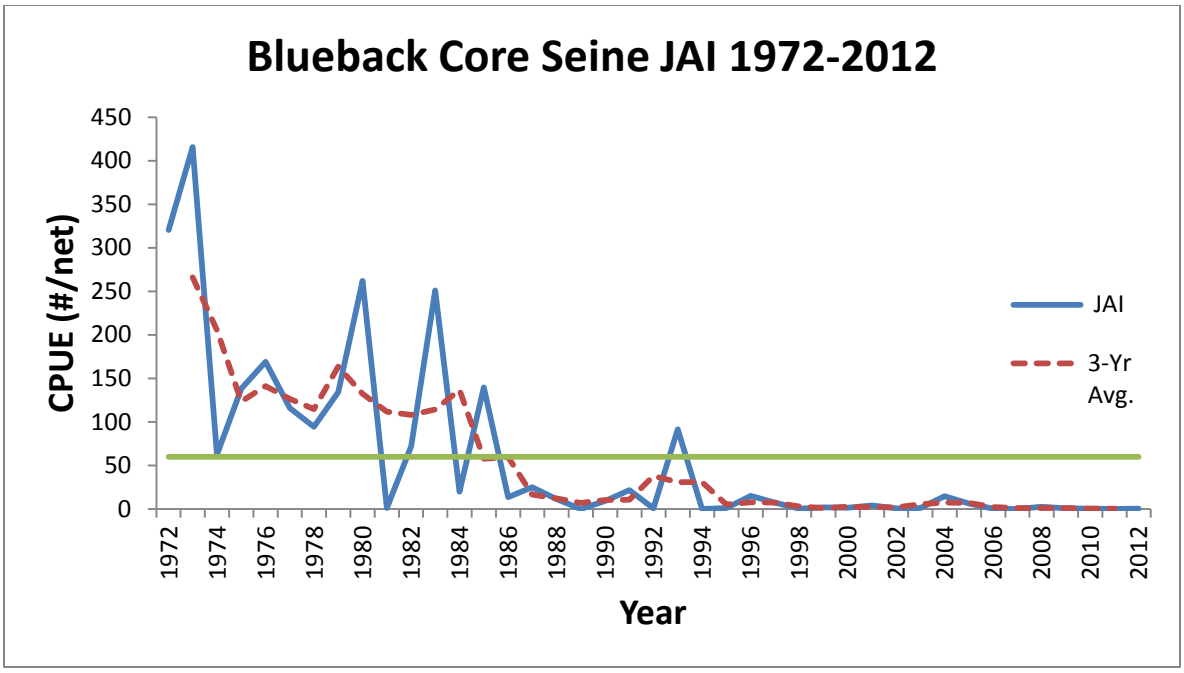


Figure 5.9 Program 100 sampling stations in the Albemarle Sound area.

Juvenile abundance for blueback herring has dropped dramatically since the mid-1980s and has not exceeded the target of 60 per seine haul since 1993 (Figure 5.10). The highest CPUE recorded for blueback herring was 415 fish per haul in 1973. The mean abundance from 1972-1986 was 132 fish per haul. From 1987-2001, the mean was 11.5 fish per haul, whereas mean CPUE was 2.6 fish per haul from 2002-2012. The number of samples collected has varied from 13 in 1972 to 55 in 2012. For alewife, the results have been similar, with the highest abundances occurring in 1980 (Figure 5.10). The mean abundance from 1972-1986 was 5 fish per haul. From 1987-2001, the mean CPUE was 0.85 fish per haul and, since 2002, the mean is 0.93.

Indices of juvenile river herring exhibit similar patterns in the western sound Hassler trawls (Figures 5.11). For blueback herring and alewife, catch rates are variable from year to year, with blueback herring CPUE peaking around 1997 and alewife in 2003. Since 2004, catch rates have been close to zero for most years.



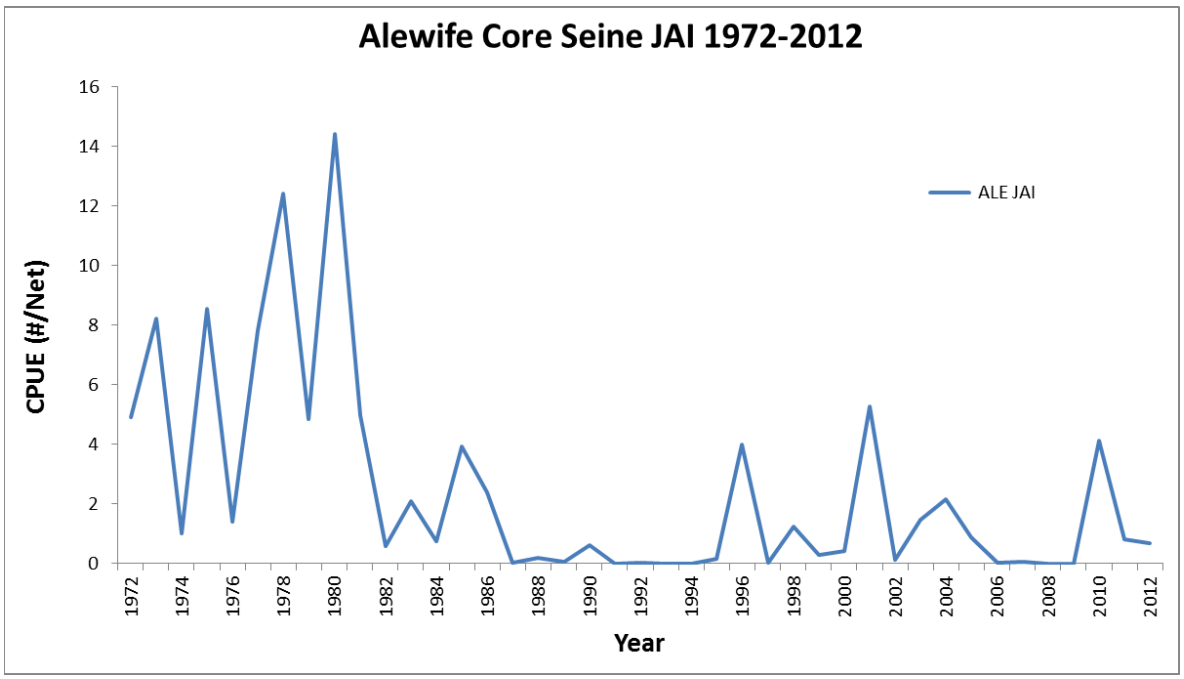


Figure 5.10 Blueback herring and alewife juvenile abundance, 11 core stations sampled monthly. The JAI target of 60 fish per haul and a three-year moving average are also shown for blueback herring.

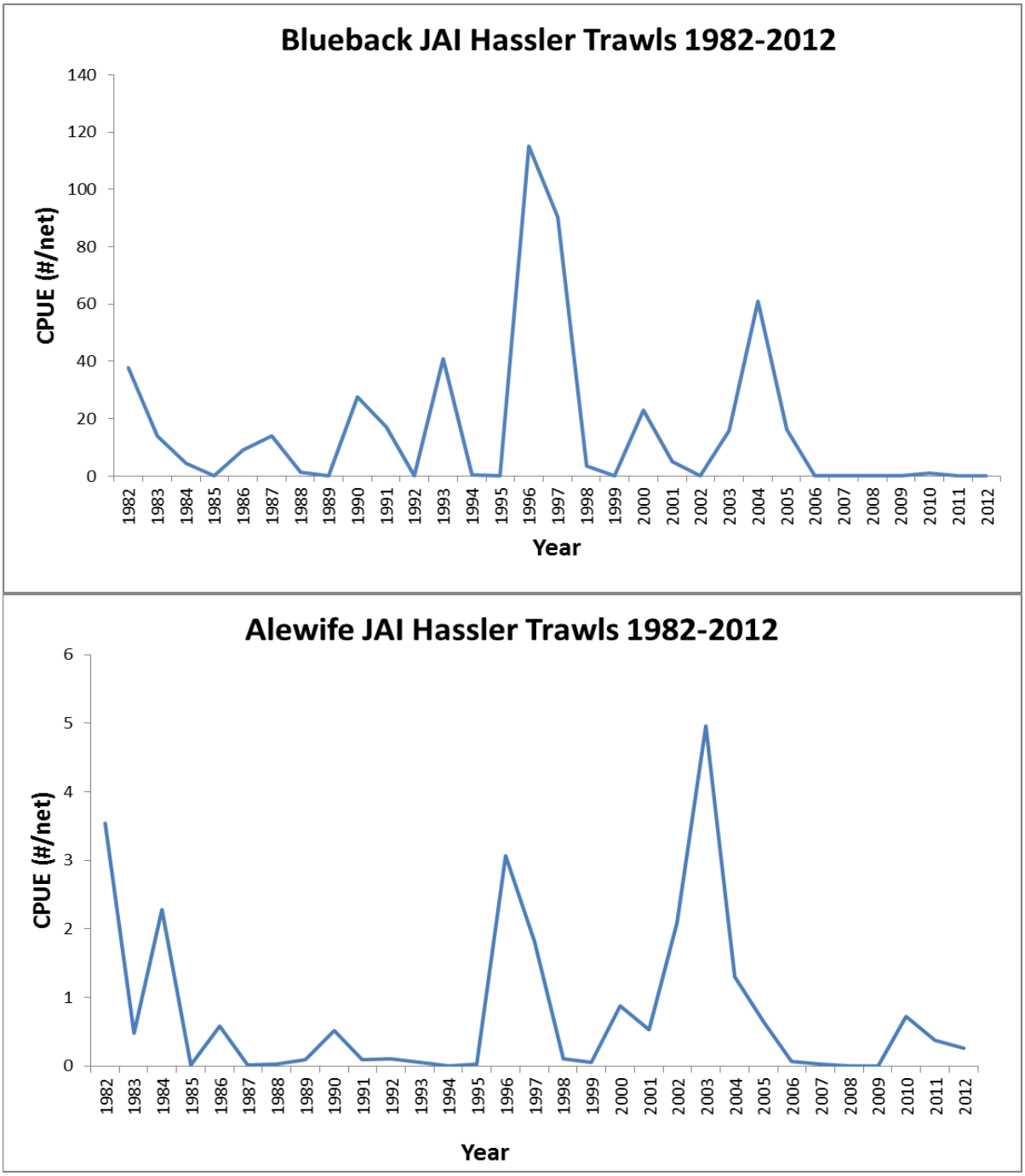


Figure 5.11 Blueback herring and alewife JAI in Western Albemarle Sound Hassler trawls, 1982-2012.

5.4.2 Independent Gill Net Sampling

The NCDMF has been conducting an Independent Gill Net Survey (Program 135) throughout the Albemarle Sound area since October 1990 (Figure 5.12). In 1991, Zone I in the Chowan River area was dropped and Zone VII in Croatan Sound was added. All zones are sampled in the fall and winter. Effort shifts entirely to Zone II in the spring. While the survey is intended to sample the striped bass population, blueback herring and alewife have also been collected annually, primarily, in 2.5 and 3.0 inch stretched mesh (ISM) gill nets. NCDMF personnel record sex, weight, fork length and total length and collect scales to obtain age and spawning condition. The CPUE by species, mesh size and year are shown in Figure 5.13. The blueback herring catch rate has declined in the 2.5 ISM since 2000. Alewife showed a substantial increase in 2007 in the 2.5 ISM, followed by a decline since then. Catch rates are much lower in the 3.0 ISM, but also more variable. Alewife have shown a slight increase in catch rates in the 3.0 ISM since 2005, while blueback herring have shown a decrease in catch rates since 2007. Catch rates are much lower in the 3.0 ISM because the larger mesh size is less likely to catch river herring. Alewife are larger than blueback herring and have higher catch rates in the larger mesh. A negligible amount of river herring are caught in 3.5 ISM, but the data are excluded from analysis. For both species in the IGNS, females are larger than males and are also more frequently caught (Figure 5.14). Prior to 1995, herring were not sexed in this survey. The average size for blueback herring has declined since the beginning of this survey, while the average weight has not shown a similar trend (Figure 5.15). Blueback herring had an overall mean length of 240.9 mm, while alewife averaged 242.3 mm. The mean weight for bluebacks was 0.21 kg, while the mean weight for alewife was 0.23 kg.

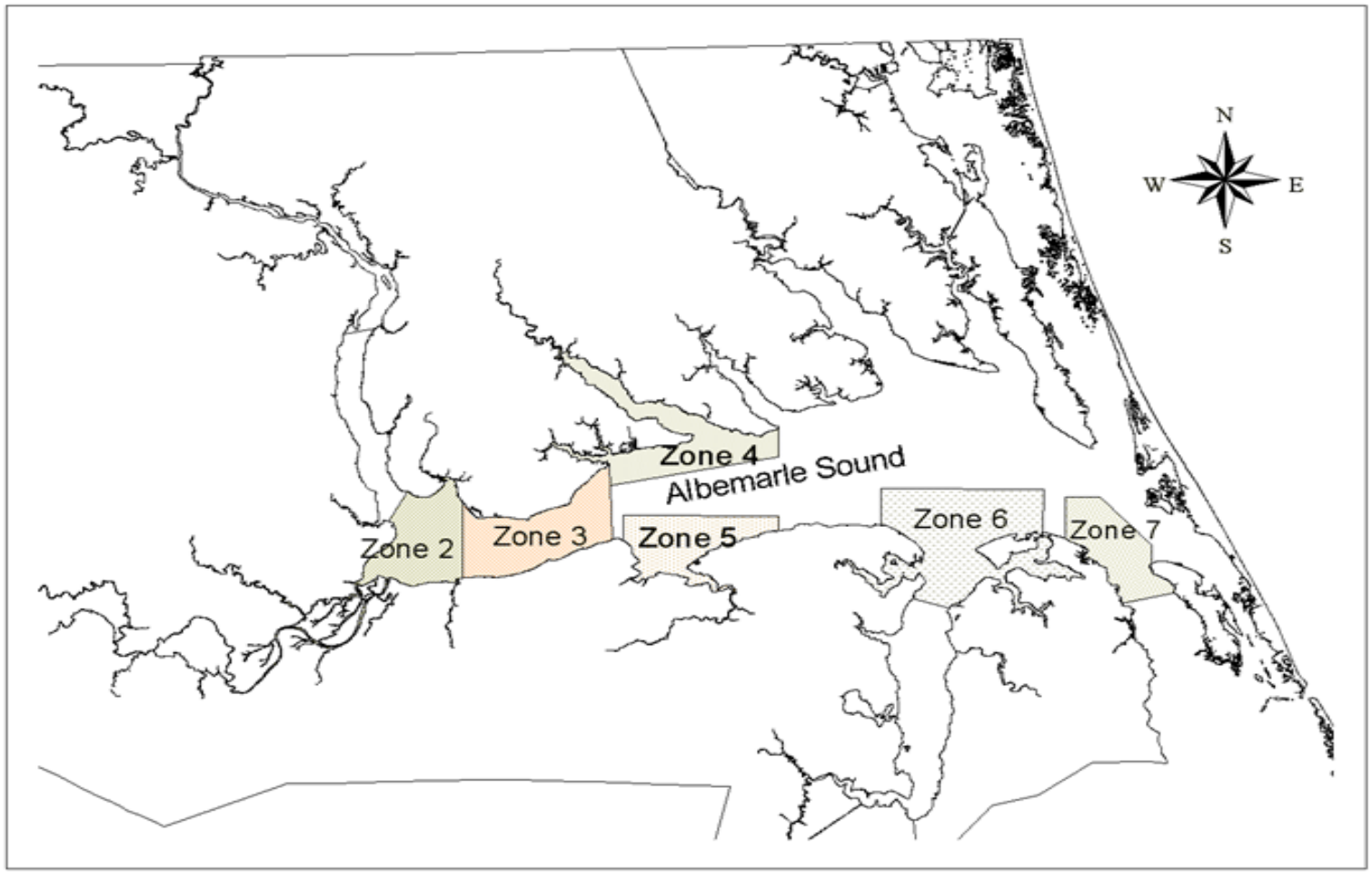


Figure 5.12 Location of sampling zones for NCDMF independent gill net survey, Albemarle Sound area, 1991–2012.

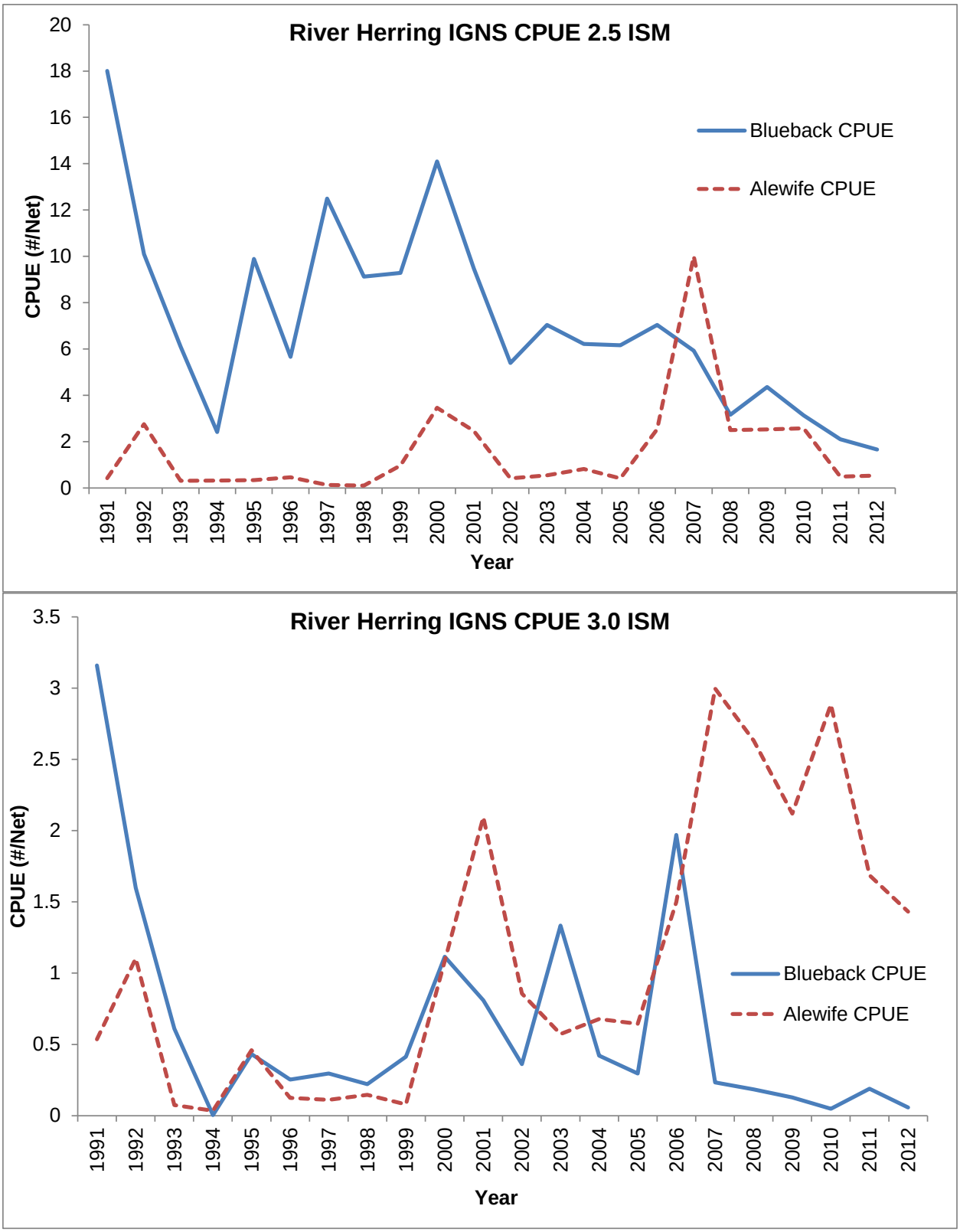


Figure 5.13 Blueback herring and alewife catch rates in the 2.5 and 3.0 inch stretched mesh from the NCDMF independent gill net survey, January - March, Albemarle Sound area, 1991 – 2012.

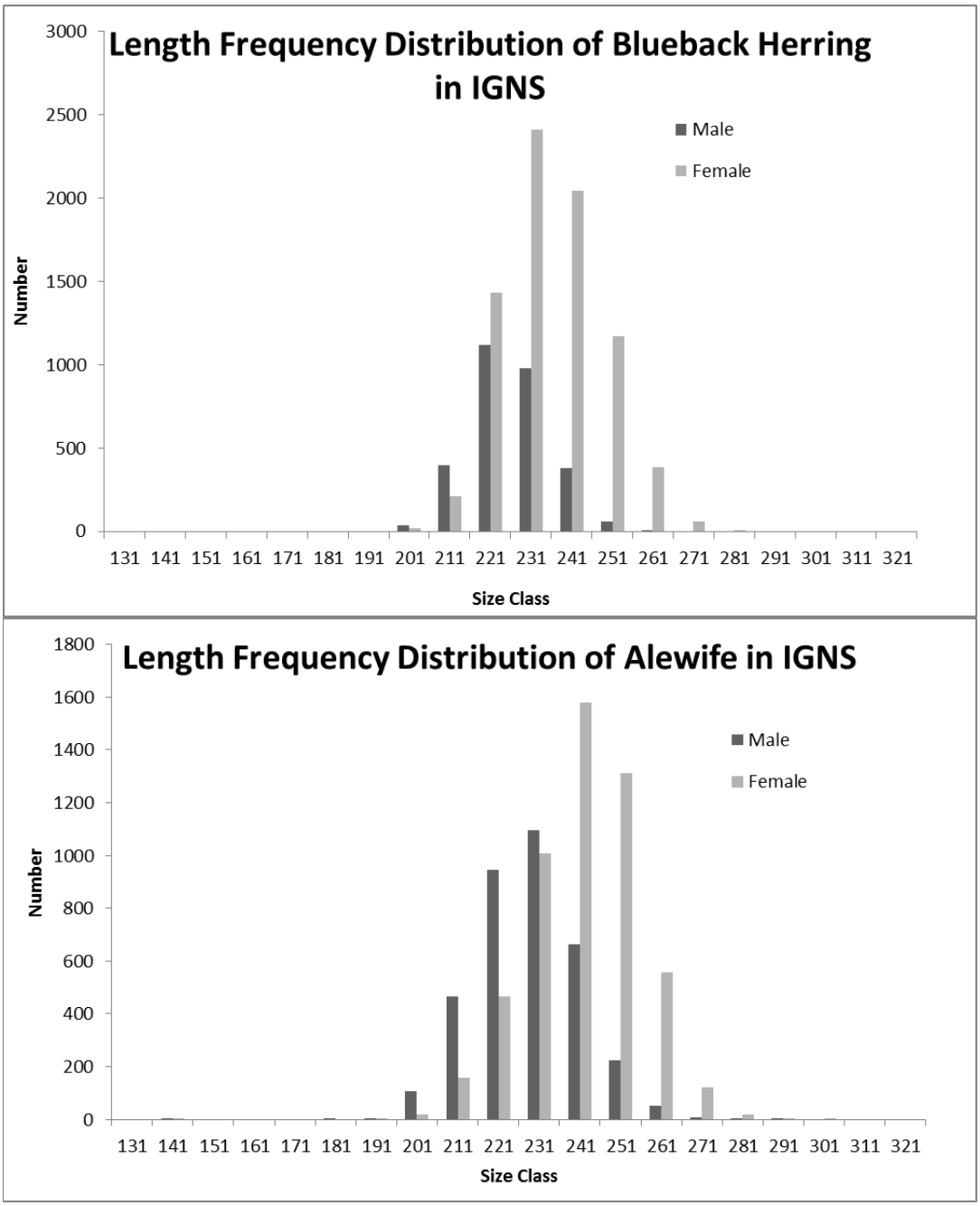


Figure 5.14 Length frequency distribution of blueback herring and alewife in the Independent Gill Net Survey, 1995-2012.

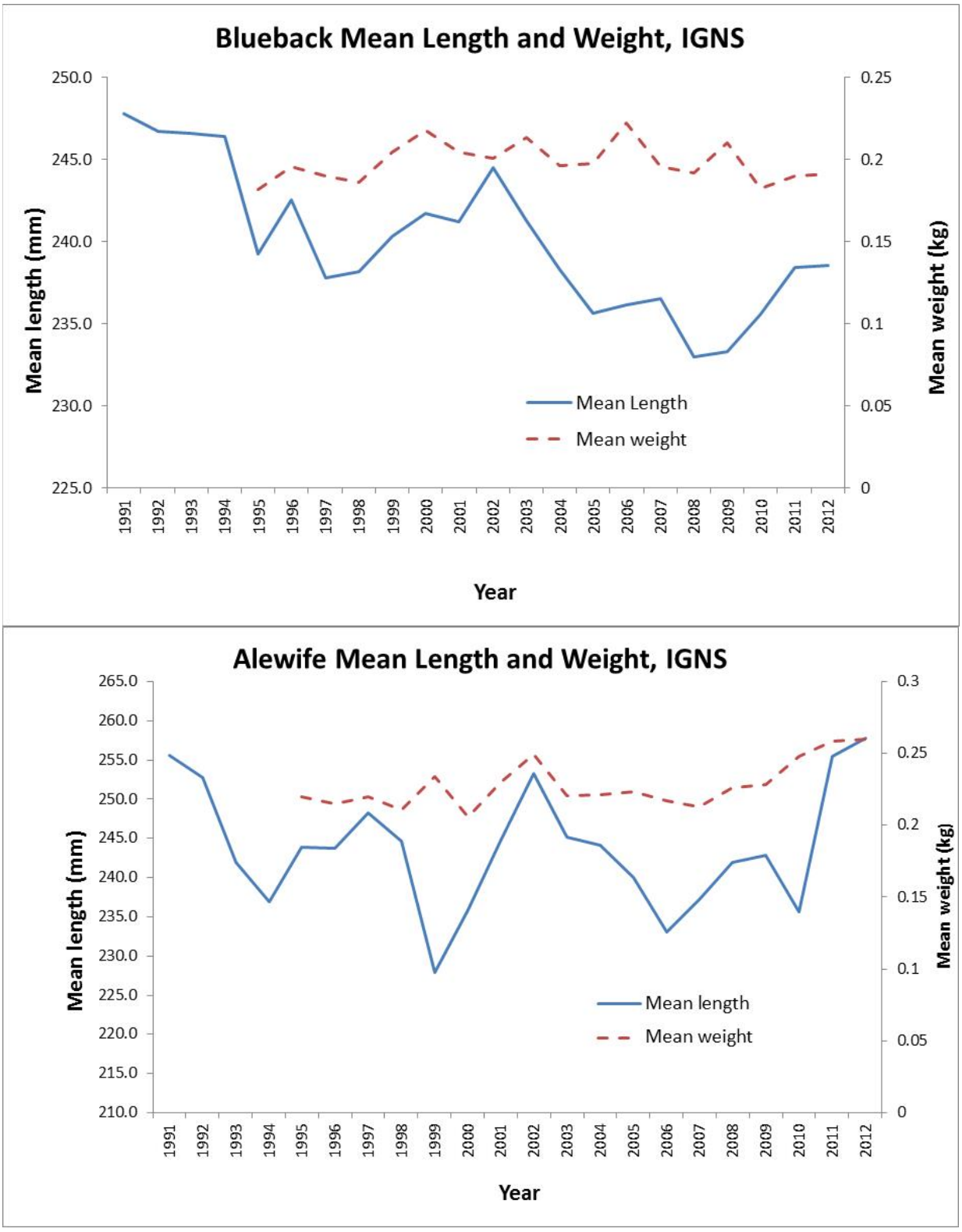


Figure 5.15 Mean length and weight for blueback herring and alewife in the Independent Gill Net Survey 1991-2012. Weights were not collected prior to 1995.

5.4.3 Pound Net Survey

The NCDMF has monitored size, age, sex, spawning frequency, and year class abundance for river herring from commercial fisheries since 1972. In response to stock declines, Amendment 1 to the River Herring Fishery Management Plan instituted a no-harvest provision that began with the 2007 season. To replace data lost with the no-harvest provision, the NCDMF developed an alternative pound net survey to continue sampling the Chowan River herring population. NCDMF contracts with commercial fishermen to set and fish pound nets at several locations in the Chowan River (Figure 5.16). The survey is designed to replicate the type of data normally collected from commercial harvests. The data from this survey are also used to update the Atlantic States Marine Fisheries Commission Interstate Fishery Management Plan for Shad and River Herring, in stock assessments, and in updating the North Carolina River Herring Fishery Management Plan.

Three commercial fishermen were contracted to fish commercial pound net sets in the Chowan River, NC during the 2008 river herring spawning season. An additional commercial fisherman was contracted in 2009 for a total of four fishermen. This additional contract was necessary to obtain samples from the middle Chowan River from Tunis Landing to the mouth of the Meherrin River (Figure 5.16). A weekly, unculled subsample of adult river herring is obtained from each fishermen's contracted pound nets; the total sample is approximately 20 lb. In 2008, contracted fishermen were required to estimate the total daily catch in pounds from their two contracted pound nets. Beginning in 2009, sampling was expanded to include an estimate of the total daily catch in pounds from all of the pound nets set regardless of whether it was a designated contracted net or not. Total daily catch is estimated visually from a total of all pound nets set and recorded in a logbook. Alewife and blueback herring are counted and sampled to determine length, weight, sex, and spawning condition. Scales are also collected for ageing and repeat spawning determination.

Figure 5.17 shows the estimated total catch in the pound net survey. It ranged from a low of 18,000 pounds in 2012 to 89,000 pounds in 2009, but varied considerably among the three locations. Catch per-unit-effort (CPUE) is calculated by dividing the total number or weight of fish caught by the number of net days each pound net fished. A net day is equal to one unit of effort and is equal to a 24-hour period in which a net was set (Table 5.4). The contribution for each species in the total catch is proportional to the percentage of each species in the samples. The total CPUE of river herring has fallen each year of this survey, but the proportion of each species is similar across all years, with the exception of 2009 (Figure 5.18).

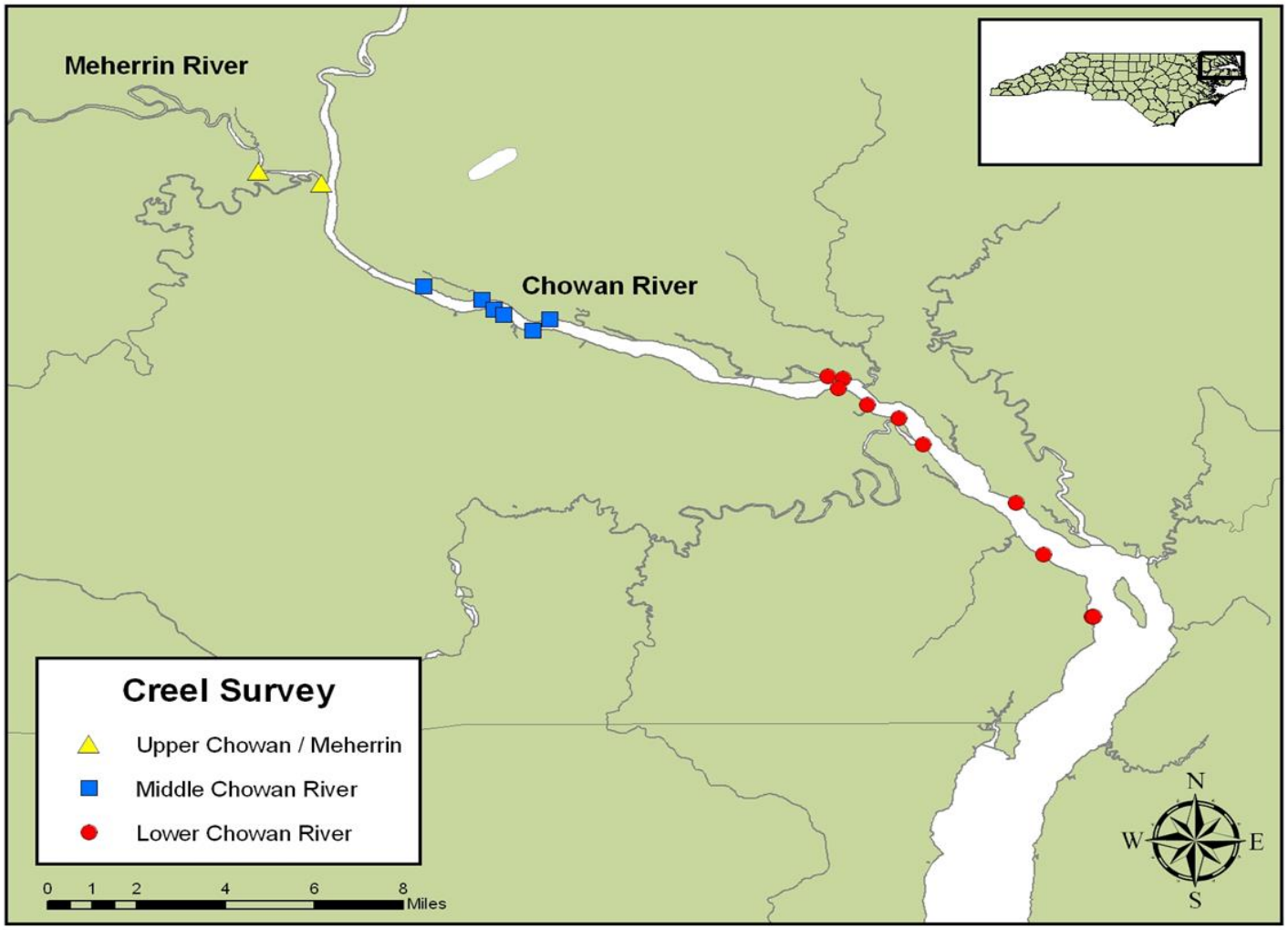


Figure 5.16 Locations of contracted pound net sets in the Chowan River 2009-2012.

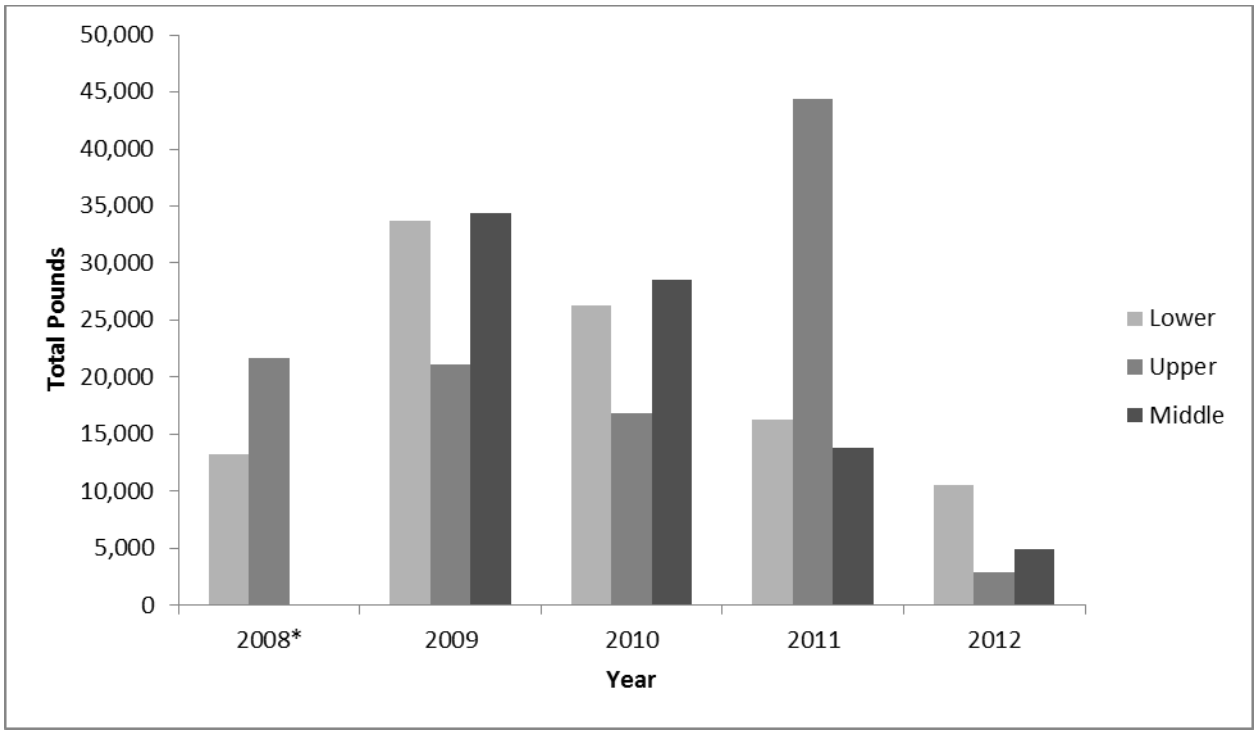


Figure 5.17 Estimated pounds by year and location in the Chowan River pound net survey, 2008-2012.

*Middle Chowan River was not sampled in 2008.

Table 5.4 Total pound net effort, catch rates and total catch by species, and total river herring catch and CPUE for the Chowan River Pound Net Survey 2009-2012.

Year	Total Effort (PN Weeks)	BB Catch (lbs)	BB CPUE	ALE Catch (lbs)	ALE CPUE	Total RH (lbs)	Total CPUE
2009	217	65,763	303.06	23,482	108.21	89,245	411.27
2010	260	36,004	138.48	35,528	136.65	71,532	275.12
2011	286	31,278	109.36	43,207	151.07	74,485	260.44
2012	315	7,181	22.80	11,234	35.66	18,415	58.46
Total	**1,078**	**140,226**	**130.08**	**113,451**	**105.24**	**253,677**	**235.32**

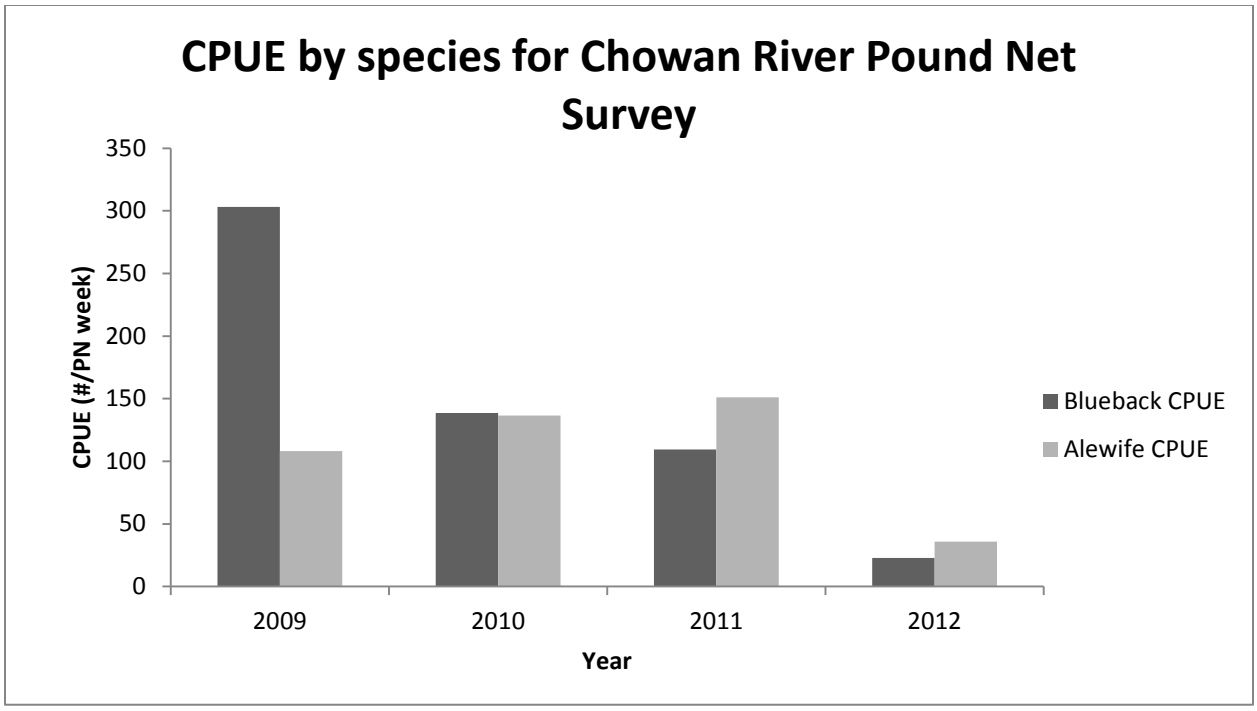


Figure 5.18 CPUE by species for the Chowan River Pound Net Survey 2009-2012. 2008 is not included because the Middle Chowan was not sampled that year.

A total of 2,738 blueback herring have been aged since this program began in 2008, 67% males and 33% females. Males ranged from ages 3 to 6, with 84.5% at ages 4 or 5. Females ranged from ages 3 to 8, with 93% ages 4-6. The maximum number of spawning marks for blueback herring was 2 and the average percentage of repeat spawners was 3%, with a range of 1.3 to 5.8%. For alewife, a total of 4,330 were aged, 51.4% females and 49.6% males. Males ranged in age from 3 to 8, with 97% between age 4 and 6. Females also ranged from age 3 to 8, with 91% between 4 and 6. The maximum number of spawning marks for alewife was 3 and the average percentage of repeat spawners was 20.7%.

5.5 STATUS OF THE STOCK

5.5.1 Unit stock and distribution

River herring (blueback herring *Alosa aestivalis* and alewife *Alosa pseudoharengus)* are each anadromous members of the Clupeidae family. Spawning occurs in coastal rivers and backwaters, and after a period of estuarine development, juveniles move into offshore waters (Loesch 1987; Jenkins and Burkhead 1994). Anadromous species occupy marine waters until sexual maturation, when they begin long-distance spring migrations to coastal rivers for spawning (Myers 1949). Both river herring species are thought to return to natal rivers after maturation. Although some mixing of populations may occur in marine habitats, adults resegregate into distinct riverine populations (Palkovacs et al. 2012). Thus each major system (e.g. Albemarle Sound) is treated as a separate stock unit for the purposes of fisheries management and stock assessment.

Historically, river herring supported commercial and recreational fisheries in most of North Carolina's coastal rivers, and major concentrations of river herring were found in the Albemarle Sound and its tributaries. The Albemarle Sound, including its tributaries, is currently the only system with a substantial river herring population that has supported commercial or recreational fisheries in the recent past. Fishery data are generally unavailable or inadequate to assess the status of North Carolina river herring populations outside of the Albemarle Sound and its tributaries. Historically, the NCDMF conducted spawning and nursery area surveys and some age composition work for most of the coastal streams outside the Albemarle Sound area, but this work ended 15–23 years ago, as federal aid funds were reduced. Therefore, only data from the Albemarle Sound and primarily the Chowan River were used to determine the stock status of alewife and blueback herring in North Carolina. Blueback herring was selected as the indicator species for the NC river herring stock assessment and the overall development of the NC River Herring FMP.

5.5.2 Assessment data and methods

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Chowan River blueback herring stock was constructed and used to estimate the population sex-specific numbers-at-age, exploitation rates, and annual recruitment of age-3 fish during 1972–2009 using four data sources: total in-river catches, age and length compositions, a fisheries-independent YOY index, and assumed rates of age- and sex-specific natural mortality. Biological samples for sex, age, and length data were collected from fishery landings, and natural mortality values were estimated using average weight at age and the Lorenzen (1996) method. Only ages 3 through 8+ were represented in the model because these are the only ages caught by the fishery and therefore the ages with the best data.

The cohort dynamics of the SCA model are a hybrid of the Margaree River model in Gibson and Myers (2003). The model incorporates the immature and mature phases by sex of blueback herring and assumes the year begins at the start of spawning. Mature individuals of each age move into the Chowan River where they are intercepted and removed for harvest, assuming that harvest occurs before reaching the spawning grounds. The SCA model was fit using statistical software, AD Model Builder (Fournier et al. 2012).

5.5.3 Abundance and biomass

Previous river herring fishery management plans have elected to assess the stock using three-year moving averages of female spawning stock biomass (SSB) in order to address year-to-year variability in stock size. Thus, only three-year moving averages of SSB are presented here. Over the assessment period from 1972–2009, blueback herring female SSB ranged from greater than 6 million pounds in the 1970s to a low of 52,000 pounds in 2003 (Figure 5.19). High levels of SSB persisted through the mid-1980s but declined to 213,000 pounds (approximately 1/30th of SSB during the 1970s) by the mid-1990s. Since the drastic stock decline from the 1980s through early 2000s and the SSB low in 2003, SSB has stabilized and begun to increase however, SSB remained below 200,000 pounds at the end of the assessment time series.

Blueback herring abundance trends have mirrored those of SSB. Abundance declined from greater than 100 million fish in the 1970s to a low of 1.1 million fish in 2002 (Figure 5.20). Abundance levels declined by 95% from the 1970s and early 1980s through the mid-1990s. Abundance has begun to increase since the low of 2002 and is currently approximately 2 million fish.

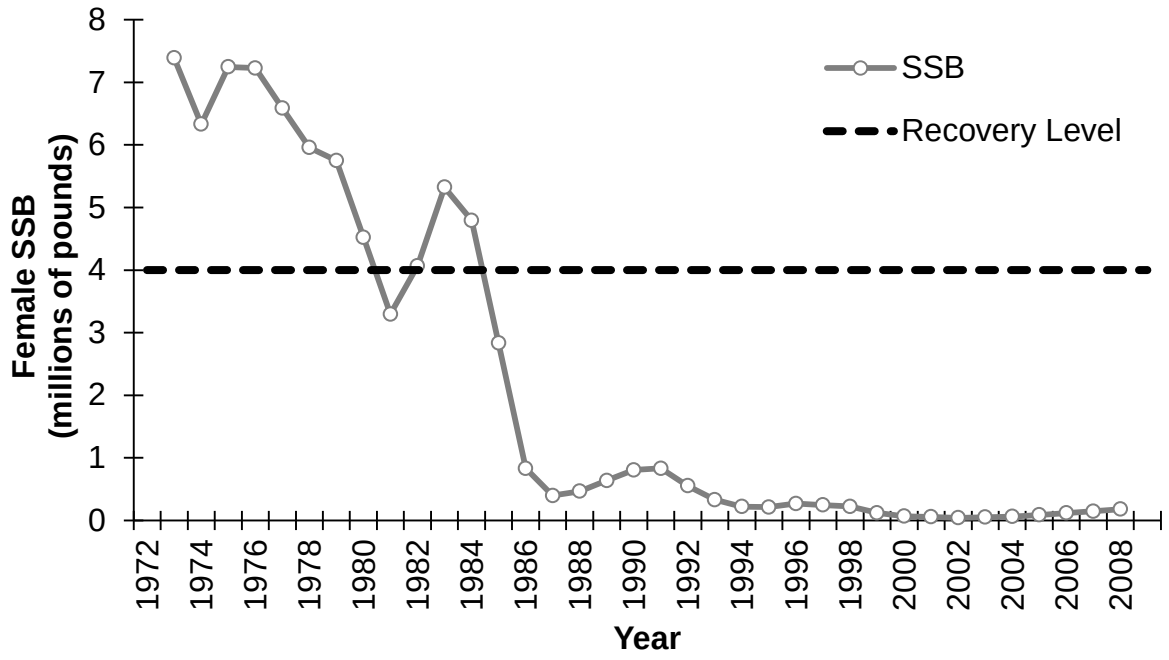


Figure 5.19 Three year moving average of female blueback herring spawning stock biomass estimated by the statistical catch-at-age model. Recovery level = stock status indicator of 30% unfished spawning stock biomass (SSB).

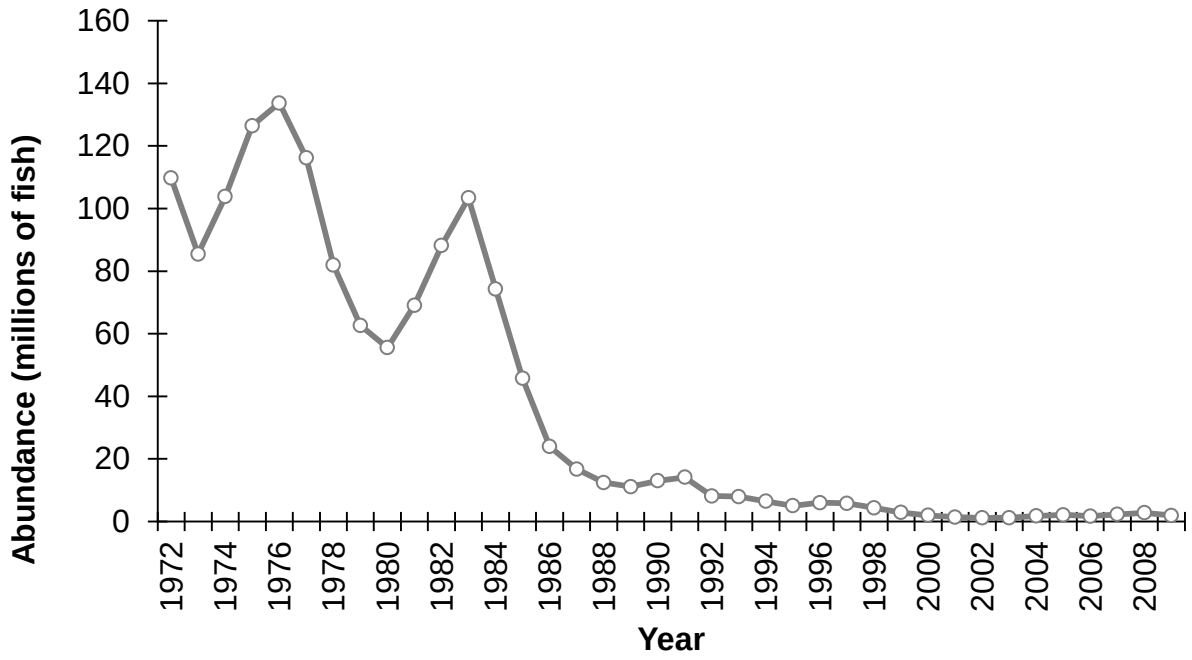


Figure 5.20 Blueback herring abundance estimated by the statistical catch-at-age model.

5.5.4 Fishing mortality

SCA estimates of the instantaneous rate of annual fishing mortality (*F*) varied over three distinct time periods. The period from 1972 through 1984 was characterized by relatively low *F* estimates, averaging 0.34 (Figure 5.21). Beginning in the mid-1980s, *F* began to fluctuate dramatically as river herring populations collapsed. For example, fishing mortality peaked in 1986 then declined to the second lowest value in the 38-year assessment period in 1990. Erratic patterns in fishing mortality persisted through 1999, when the second highest estimate of *F* occurred (F_{1999} = 1.14). Subsequent to 1999 *F* has declined steadily, and since the establishment of the no harvest provision in 2007, *F* has been minimal.

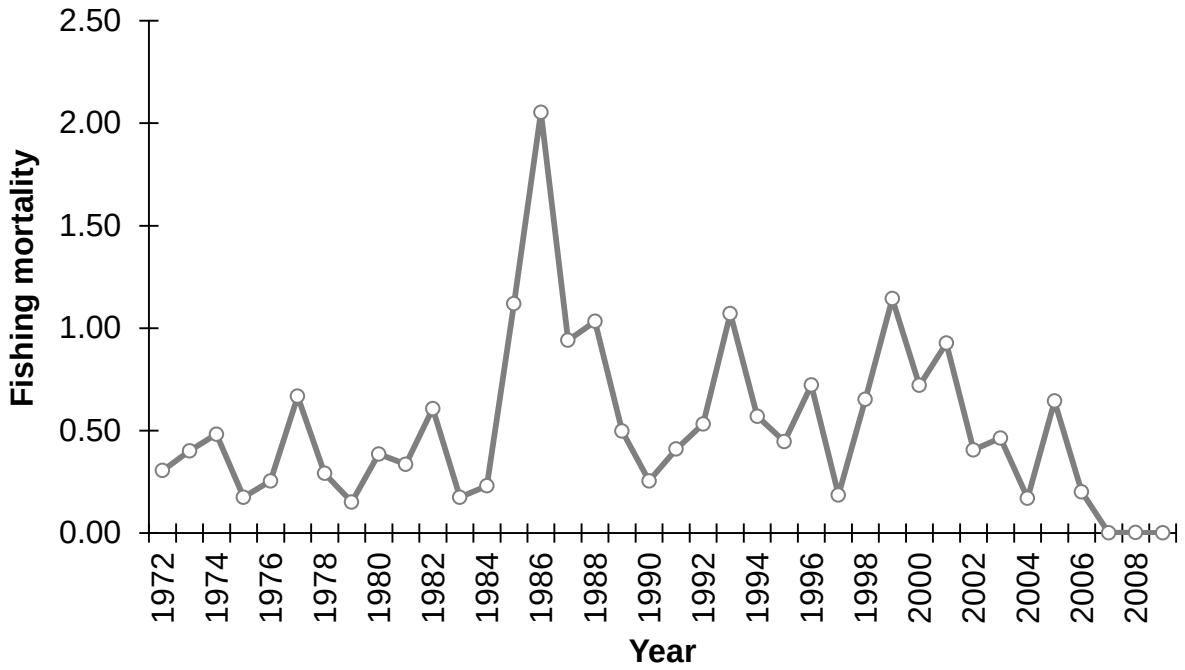


Figure 5.21 Fishing mortality estimated by the statistical catch-at-age model for blueback herring.

5.5.5 Stock status determination criteria

Three stock status indicators were adopted by the FMP plan development team, each based on a three-year moving average:

1. Catch per unit effort (CPUE) of 60 young-of-the-year per haul in the Albemarle Sound juvenile abundance survey
2. 10% repeat spawners observed in fishery-dependent pound net samples
3. SSB of 30% unfished SSB, estimated in stock assessment model.

Collectively, these indices represent minimal stock rebuilding goals for the recovery of river herring stocks in the Albemarle Sound and Chowan River.

Data and SCA estimates up to 2009 indicate that none of the three stock status indicators has been reached, and the river herring stock has been below these levels since the mid-1980s. Data from the Albemarle Sound juvenile abundance index and Chowan River pound nets indicate that poor recruitment has been observed in every year since 1987 (Figure 5.22) and low numbers of repeat spawners have been observed in every year since 1983 (Figure 5.23). Terminal year (2009) three-year moving averages are CPUE of 1.4 for the juvenile abundance survey and 1.7% repeat spawners. SSB has been below the stock status indicator in every year since 1984 (Figure 5.19). The three-year moving average of SSB was 180,000 pounds for the terminal year (5% of stock status indicator).

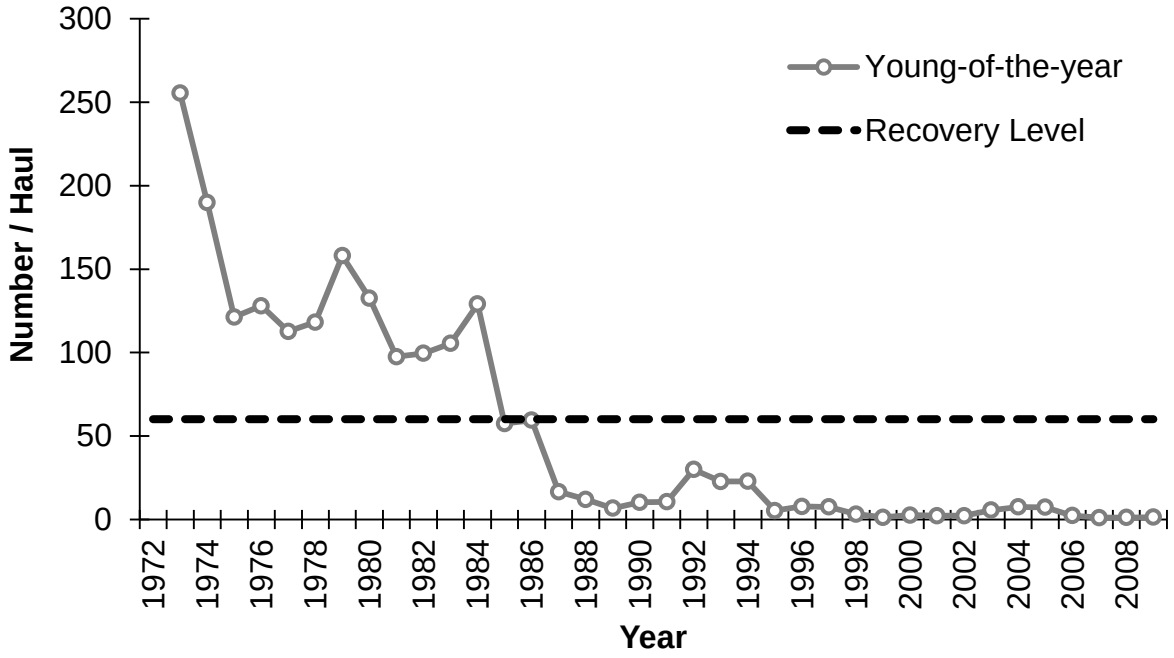


Figure 5.22 Three-year moving average of mean number of young of the year captured in the Albemarle Sound juvenile abundance survey. Recovery level = stock status indicator of 60 young-of-the-year / haul.

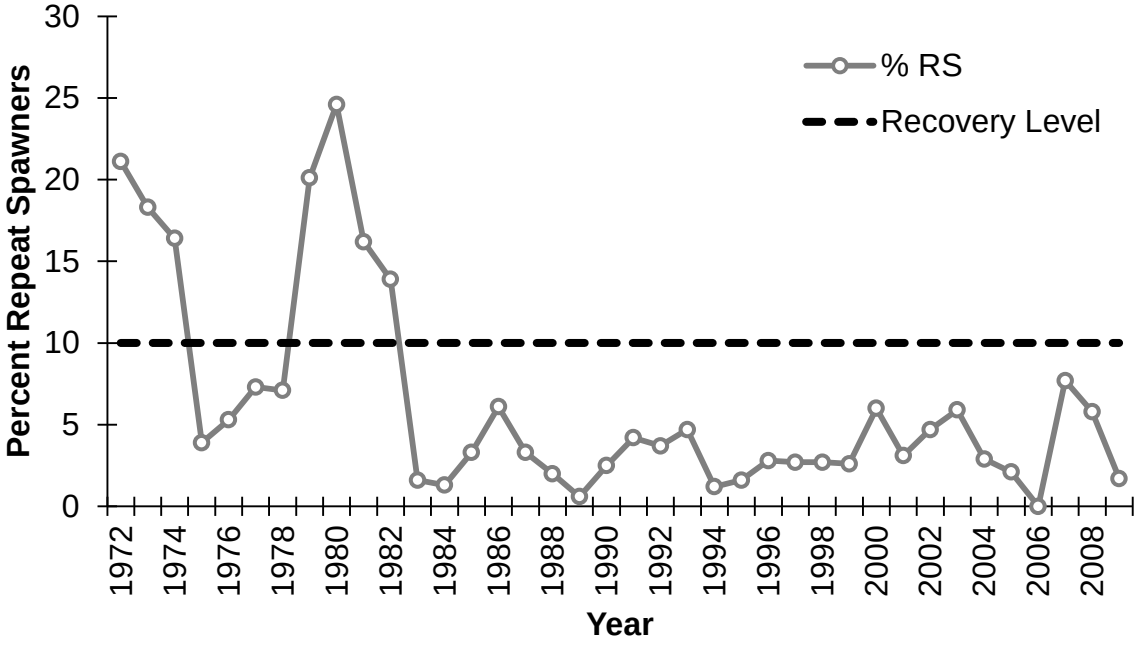


Figure 5.23 Three-year moving average of repeat spawner blueback herring captured in fishery-dependent pound net samples. Recovery level = stock status indicator of 10% repeat spawners.

5.5.6 Projections

No stock projection was completed at the time of the current stock assessment due to the extremely depleted nature of river herring stocks. Very slow rates of rebuilding since the establishment of the no-harvest provision in 2007 suggest that at this time, no level of fishing mortality is viable; thus, predicting future stock size would yield very little information regarding sustainable levels of fishing. At the time of the previous assessment, stock projections suggested that recovery of river herring stocks would be accomplished at the scale of decades, and stock rebuilding was unlikely in the near future (NCDMF 2007). The ASMFC in the 2012 stock assessment recommended a ten-year interval between stock assessments (ASMFC 2012). The River Herring Fishery Management Plan Development Team agreed to use the three stock status indicators as a trigger for doing a stock assessment earlier. If a three-year moving average of each of the indicators was above the threshold that would trigger the need for a new stock assessment.

5.5.7 Endangered Species Act Listing

On August 5, 2011 the National Marine Fisheries Service (NMFS) received a petition from the Natural Resources Defense Council (NRDC), requesting that they list alewife and blueback herring under the Endangered Species Act (ESA) as threatened throughout all of their ranges. In the alternative, they requested that NMFS designate distinct population segments (DPS) of alewife and blueback herring as specified in the petition (Central New England, Long Island Sound, Chesapeake Bay, and North Carolina for alewife, and Central New England, Long Island Sound and Chesapeake Bay for blueback herring). The NMFS reviewed the petition and determined that, based on the information in the petition and the information they had at the time that the petitioned action may be warranted. They issued a positive 90-day finding on November 2, 2011, and as a result were required to review the status of the species (e.g., anadromous alewife and blueback herring) to determine if listing under the ESA was warranted.

The NMFS utilized the information in the May 2012 ASMFC River Herring Stock Assessment in review of the petition. They also worked with ASMFC to identify any data gaps or otherwise missing elements. They held workshops/working group meetings focused on addressing information on stock structure, extinction risk analysis and climate change. NMFS determined, after reviewing the information, that listing alewife or blueback as threatened or endangered was not warranted at this time (78 CFR 48944). The NMFS issued a news release on August 8, 2013 announcing the decision (NMFS 2013). The finding was filed on August 9, 2013 and became effective August 12, 2013. The NMFS also indicated that they had provided funding to the ASMFC to work with them as well as other partners to implement a coordinated coast-wide effort to continue to address data gaps and proactively conserve river herring and their habitat. NMFS will work with the ASMFC to establish a technical working group to develop the plan for river herring throughout both species' range from Canada to Florida. This group will attempt to quantify the impact of ongoing restoration and conservation efforts and new fisheries management measures that are being developed such as catch caps in two federal fisheries; review any new information produced from ongoing scientific studies such as genetic analyses, ocean migration patterns, and climate change impacts; and assess available data to determine whether recent reports of higher river counts in many areas along the coast in the last two years represent sustained trends. NMFS is also committed to continuing to work with partners and tribal governments to implement important conservation efforts and fund needed research for river herring. They intend to revisit the status of river herring within the next five years.

5.5.8 Stock Status Research Recommendations

The River Herring Fishery Management Plan Development Team made the following recommendations for research into the stock status of river herring:

- Estimate bycatch and discard mortality of river herring captured incidentally in Atlantic ocean fisheries coastwide. **High priority**
- Estimate bycatch and discard mortality of river herring captured incidentally in inshore fisheries. **Medium priority**

6.0 CURRENT RIVER HERRING MONITORING PROGRAMS

Amendment 1 to the N.C. River Herring FMP outlined a river herring monitoring program that consisted of a juvenile sampling survey, spawning area survey, Chowan River pound net survey and continued collection of river herring data from an ongoing Albemarle Sound Striped Bass Independent Gill Net Survey (IGNS). A water quality sampling program, consisting of the deployment of datasondes for continuous water quality monitoring was also implemented.

The following surveys are currently being conducted in the Albemarle Sound area specifically for the collection of river herring data and should continue. Maintenance of an intensive monitoring program is essential to evaluate stock status indicators and the overall status of North Carolina river herring stocks.

6.1 NCDMF JUVENILE SAMPLING

The NCDMF currently monitors juvenile river herring production through its Program 100 Anadromous Juvenile Survey. Program 100 was established in 1972 and currently consists of a total of 62 trawl and 29 seine stations throughout Albemarle Sound and is used to assess juvenile production of all anadromous species. The juvenile abundance index (JAI), used as a stock status indicator for blueback herring, is calculated from the 11 core seine stations, sampled once a month June-October. The JAI was determined to be a valid indicator of cohort strength and to have value as a management tool and stock status indicator. Seine stations are sampled with a 60 ft bag seine with 0.25 inch mesh bag, with a single haul considered one unit of effort.

Trawl stations are sampled with an 18 foot semi-balloon trawl, constructed of 1.5 inch stretched mesh webbing in the body and 0.5 inch stretched mesh in the cod end is utilized. Sampling occurs monthly from June through October. Each trawl sample is pulled for 10 minutes (15 minutes for Hassler stations; see section 5.3.7), and considered one unit of effort for calculating CPUE.

Juvenile alosines are sorted by species, counted, and a maximum subsample of 30 individuals is measured to the nearest millimeter for fork length (FL) and total length (TL) to determine growth. All other species are enumerated by species and in some cases a subsample (maximum of 30 per station) is measured for FL and/or TL. Surface and bottom water temperature (°C), dissolved oxygen (mg/L), conductivity (mS), salinity (ppt) and pH are collected using a Yellow Springs Instruments (YSI) meter. Any submerged aquatic vegetation (SAV) collected in the sample is identified to species and/or genus.

6.2 NCDMF SPAWNING AREA SURVEY

The NCDMF anadromous spawning area surveys are conducted through the Program 150 Adult Anadromous Spawning Area Survey and Program 160 Anadromous Egg and Larval Survey. Surveys have been conducted annually in the Chowan River system in conjunction with one other system in the Albemarle Sound area on a rotating basis since 2008. Prior to 2008, spawning area surveys were conducted sporadically in various systems since 1972 with no consistency. These surveys are necessary to determine which areas are currently functioning as productive spawning areas. These surveys will provide data to determine which areas should be considered for habitat restoration and protection through the Coastal Habitat Protection Plan and stock restoration efforts.

Sampling begins at stations closest to the mouth of each tributary. One or more of the following criteria are used to determine an Anadromous Fish Spawning Area (AFSA): (1) the presence of running ripe adult females, (2) the presence of eggs or larval fish, or (3) the visual observance of spawning. To designate a station as a spawning area, a minimum of one of the previous criteria needed to be met. If one of the criteria is met, sampling is continued upstream of the current station to further track river herring migration into tributaries.

Sampling in Program 150 is conducted with short shots (usually 5-10 yards) of monofilament gill net of various sizes (2.5-4.0 inch stretch mesh) and 1.5 inch mesh fish pots at selected stations in each system, usually at bridge crossings. In certain systems gill nets or pots may be set in areas that can only be reached by boat.

Adult samples are sorted to species and all individuals of each alosine species present are measured (mm, FL, TL), weighed (kg), sexed, spawning condition is determined, and an ageing sample is taken. All other species are enumerated by species and in some cases a subsample (maximum of 30 per station) is measured for FL and/or TL.

Ichthyoplankton net tows are conducted from March through mid-May, following evidence of spawning, or used exclusively in areas where adult samples are not conducted. Each plankton net consists of 500 micron mesh encircling a 50 cm wide mouth to a conical length of 150 cm. A collection jar with a 500 micron mesh is attached to the cod end. Surface and mid water tows are conducted if the water depth is greater than 2.0 m. Gear restriction allows the mid water net to be fished to a maximum depth of 2.5 m. The net is deployed and pushed in an upstream direction for five minutes at 1.4 knots. Tributary access points that are too small to sample with a boat mounted larval net are fished from bridge crossings. The net is lowered into the tributary from the bridge and water is allowed to flow through the net for ten minutes. Larval fish and eggs are sorted by species, counted, and a maximum subsample of 10 individuals is measured to the nearest millimeter TL. All other species are enumerated by species.

Surface and bottom water temperature (°C), dissolved oxygen (mg/L), conductivity (mS), salinity (ppt) and pH are collected using a Yellow Springs Instruments (YSI) meter. Additional habitat and environmental data are collected at each sampling site.

6.3 NCWRC ADULT RIVER HERRING SURVEY

The NCWRC conducts weekly boat-electrofishing surveys for adult river herring February through April at various sample sites in various systems throughout North Carolina at locations that have a prior history of spawning adults. Sampling began in 2006 and location sites per system may vary across years. In the Chowan River Basin, sampling is conducted in Indian and Bennett's creek but also has occurred in Catherine's Creek. In the Tar River Basin, sampling is conducted in Chicod and Bear creeks. In the Neuse River Basin, sampling is conducted in Village Creek. In the Cape Fear River Basin, sampling is conducted in Town and Rice's creeks. A boat–mounted electrofishing unit (Smith–Root 7.5 GPP) with one dip netter is used to capture fish during daylight hours and electrofishing effort (in seconds) is recorded.

Species are identified and total length, total weight and sex are taken and fish are released at the site. Relative abundance of each year class is indexed by catch-per-unit-effort (CPUE) and expressed as number of fish captured per hour of electrofishing.

6.4 NCDMF CHOWAN RIVER POUND NET SURVEY

The Chowan River pound net survey was implemented in 2008 to provide estimates of CPUE, percent of repeat spawners, as well as size, age and sex data for alewife and blueback herring. These data are necessary to monitor stock status indicators and the overall stock status of river herring in the Albemarle Sound area.

The NCDMF contracts with four commercial pound net fishermen in the Chowan River system to collect river herring samples from their pound nets. A weekly, unculled subsample of adult river herring is obtained from each fishermen's contracted pound nets; the total sample is approximately 20 lb. Sampling includes an estimate of the total daily catch in pounds from all of the pound nets set regardless of whether it was a designated contracted net or not. Total daily catch is estimated from a total of all pound nets set and recorded in a logbook. Alewife and blueback herring are counted and sampled to determine length, weight, sex, and spawning condition. Scales and otoliths are taken for ageing. Total pounds and catch rates are estimated for alewife and blueback herring.

6.5 WATER QUALITY MONITORING PROGRAM

The water quality of coastal areas has been sampled frequently through various programs, but none have adequate long term data to document the effect of water quality on river herring. Long term water quality data is necessary to effectively evaluate the effects of water treatment plants, water withdrawals, and potential water contaminant sources throughout tributaries during critical life stages of river herring.

This program monitors water quality at set stations throughout the Albemarle Sound area. Stations are selected based on seasonal spawning habits and critical life stages of river herring. These data are representative of water conditions, changes, and shifts during critical life stages of river herring and other various finfish. To obtain the data the program utilizes YSI 600 XLM V2 multi parameter sondes with a YSI 6150 ROX optical dissolved oxygen probe, a YSI 6561 pH probe, and a YSI 6560 conductivity and temperature probe. Sondes are cleaned and calibrated every 60 days or as needed. Sondes may be deployed to record water quality at any desired intervals and can be moved to monitor water quality in areas during seasonal spawning. The interval and time period in which sondes can be deployed is based on available battery life as well as bio-fouling of probes that requires cleaning and calibration of the sonde. Water quality measuring devices monitor a range of parameters including time, temperature (°C), salinity (ppt), conductivity (mS), dissolved oxygen (mg/L), and pH.

A YSI 650 multi-parameter display unit is used to download the data from the sondes to transfer to the computer. YSI Ecowatch software is used to upload the data to the computer and export it to a CDF file for uploading to the database.

6.6 RECOMMENDATIONS

The management recommendations:

- Continue juvenile abundance seine and trawl survey in all tributaries of the Albemarle Sound area. Expand these surveys to other areas of the state.
- Continue spawning area surveys in the Chowan River annually and in one system in the Albemarle Sound area on a rotating basis. Expand these surveys to other areas of the

state. NCMFC and the Northern District Advisory Committee support this recommendation as funding is available.

- Continue Chowan River pound net survey. Expand this survey to other tributaries in the Albemarle and other areas of the state if spawning area surveys identify significant spawning runs in these other systems.
- Continue NCWRC adult river herring surveys and expand to other tributaries in the Albemarle Sound area and other systems of the state as opportunities arise.

7.0 STATUS OF THE FISHERIES

7.1 INTRODUCTION

Anadromous species such as river herring are managed and regulated by two state agencies because they spend time in both fresh and saltwater. Fisheries in coastal fishing waters are under the jurisdiction of the NCMFC, while herring fisheries in designated inland fishing waters are under the NCWRC. The different jurisdictional areas are described in NCMFC Rules, 2011, Subchapter 3Q – Jurisdiction of Agencies: Classification of Waters. River herring, during the pelagic part of their lifecycle, occur in offshore fisheries as bycatch and may be managed by federal fishery management councils. Under the authority of the Atlantic States Coastal Fisheries Cooperative Management Act, the Atlantic States Marine Fisheries Commission coordinates the interstate management of river herring and shad. In 2009, the ASMFC approved Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring that deals specifically with river herring (ASMFC 2009).

River herring were fished intensively throughout the 1970s and 1980s. Fishing pressure, in combination with a variety of environmental issues, such as habitat loss and poor water quality, has resulted in a precipitous decline in the populations. Because previous management actions failed to recover the river herring fishery, Amendment 1 to the River Herring Fishery Management Plan instituted a commercial and recreational no-harvest provision for river herring beginning in 2007. The sole exception to the no-harvest provision is a discretionary harvest season (small research set-aside season) in the spring, limited to a maximum of 7,500 pounds, and set by proclamation at the discretion of the NCDMF Director.

7.2 COMMERCIAL FISHERY

7.2.1 North Carolina

River herring have been subjected to intensive exploitation since colonial times along the Atlantic coast. The Albemarle Sound area has always been the center of the North Carolina fishery. In North Carolina, river herring were among the first fish to be exploited commercially because their oily flesh allowed them to be salt-preserved, without ice or refrigeration.

In colonial times, fishing for river herring served largely subsistence, rather than commercial, purposes. During the late colonial and antebellum periods, planters in the Edenton area developed major fisheries for spawning American shad (*Alosa sapidissima*) and river herring in the Chowan River and Albemarle Sound. Only during the post-bellum period, with improved transportation and the availability of ice were markets created for fresh fish and shellfish, allowing independent watermen to emerge (Taylor 1992). A more detailed description of the historical fisheries in the Albemarle Sound area is found in the 2000 River Herring FMP (Section 6.2.1).

The use of pound nets revolutionized fishing in North Carolina, especially in the Albemarle Sound (Taylor 1992). Chestnut and Davis (1975) reported that 2,767 pound nets were set in North Carolina in 1927. Since the 1960s, the majority of the river herring pound nets have been set in the rivers, and the leads seldom exceeded 200 yards in length (Walburg and Nichols 1967). The Chowan River has been the center of the river herring pound net fishery, and from the late 1970s through the late 1980s the number of river herring pound nets ranged from 421 to 615 nets annually, with the amount of pound nets declining from 348 in 1989 to 30

in 2005 (Figure 7.1). Table 7.1 shows river herring harvest totals by gear for North Carolina and Table 7.2 shows the totals for the Albemarle Sound area. In most years, upwards of 90% of the catch came from Albemarle Sound and its tributaries, most of which is accounted for by the Chowan River (Table 7.3).

Anchored and drift gill nets were historically used in the river herring fishery. The amount of gill net effort in the fishery prior to 1994 is unknown. During the 1970s, the gill net harvest of river herring accounted for up to approximately 15% of the total harvest. However, from 1987 to 1994, the proportion of gill net landings increased to 24-40% of the total river herring harvest from North Carolina. This increase may have been due to a directed fishery for roe fish. Pound nets have harvested the majority of river herring through the years, accounting for approximately 90% of the total harvest overall (Table 7.2).

Several other types of commercial gears have been used in the river herring fishery, including fyke nets, fish wheels, and dip nets. These gears have contributed very little to the total harvest in the Albemarle area. From 1915 through 1965, various regulations were enacted for the Albemarle Sound river herring fishery (seasons, area closures, gear restrictions).

From the late 1800s until the no-harvest provision in 2007, the areas fished and gears used to harvest river herring remained essentially unchanged. The extent of the river herring fisheries in both the amount of gear and harvest, however, declined significantly (Table 7.1).

Because of declines in river herring catches beginning in the mid-1980's (Figure 7.2), a fishing season was implemented by MFC rule (NCDEHNR 1997, 15A NCAC 3M.0513) in 1995 that prohibited taking blueback herring, alewife, American shad and hickory shad (*Alosa mediocris*) by any method from April 15 through January 1. This rule was adopted to allow more fish to escape fishing mortality and spawn. The rule was in effect in 1995 and 1997. In 1996, the rule was suspended only for the Chowan River pound net fishery, extending the season for ten days. Once the season was extended, the fishery operated on a 250,000 pound total allowable catch (TAC). During 1998, the rule was again suspended, and the season was extended for an additional 15 days for the Chowan River pound net fishery, which operated on a 400,000 pound TAC for the entire season.

The MFC amended the river herring rule (15A NCAC 3M.0513) in a temporary action for the 1999 harvest season. The temporary rule gave the Fisheries Director proclamation authority, based on variability in environmental and local stock conditions, to take various actions and impose an annual quota for river herring in the Albemarle Sound River Herring Management Area of 450,000 pounds.

The 2000 River Herring Fishery Management Plan established a 300,000 pound TAC for the Albemarle Sound and Chowan River Herring Management Areas. Of that total the Chowan River pound net fishery was allocated 200,000 pounds, the Albemarle area gill net fishery received 67,000 pounds and 33,000 pounds was left to the discretion of the Fisheries Director to be used for pound nets outside the Chowan River management area, fyke nets, and haul seines.

In response to continued decline, the MFC implemented interim management measures for the ASRHMA for the 2006 harvest season, reducing the TAC to 100,000 pounds. The 2006 Chowan River pound net fishery was allocated 65,000 pounds, the Albemarle Sound gill net fishery 30,000 pounds and 5,000 pounds was allocated at the Director's discretion.

During 1995-1998, North Carolina accounted for 29-52% of the total river herring landings from the Atlantic coast. From 1999 to 2004, the State contributed 9-33% of the Atlantic coast river herring harvest. Landings from the Albemarle Sound area accounted for 92 to ~100% of the state's total river herring landings during 1995-2004 and 97% overall for those years (Table 7.2). The Chowan River pound net fishery contributed 60-77% of North Carolina's annual river herring harvest during 1995-1999. Since 2000, the Chowan River pound net fishery contributed 41-66% of the state's total river herring harvest. Regulations enacted for striped bass conservation in 1988 (gill net mesh size restrictions, yardage restrictions, area closures) impacted river herring harvest in the Albemarle Sound area. Even with these regulations, the river herring gill net fishery accounted for approximately 24-38% of the overall harvest from 1995 to 1999 (Table 7.1). Since the 67,000 pound TAC was implemented in 2000, gill nets accounted for 24-40% of the annual river herring landings in the Albemarle area (Table 7.2).

During 1995-1999, the number of pound nets set in the Chowan River ranged from 68 to 102. The number of pound nets set in the Chowan River from 2000 to 2005 ranged from 36 to 63. In 1999, just 14 Chowan River pound net fishermen participated in the fishery while only nine participated in 2005. Since the 200,000 pound TAC was implemented in 2000, the Chowan pound net fishery only reached the TAC once in 2001.

For all finfish, the total number of participants in the Albemarle Sound area fisheries during the January to May season from 1994 to 2004, remained fairly constant, while the total number of trips for the same period increased since 1994 (Table 7.4). The number of participants harvesting river herring in the Albemarle area declined from 239 in 1996 to 117 in 2004 (Table 7.4). The total number of trips harvesting river herring in the ASMA declined after 1994 (Table 7.4). The pound net fishery saw the greatest drop in the number of participants from 1995 to 2004, but the number of trips increased (Table 7.4). The no-harvest provision began with the 2007 fishing season and no commercial harvest outside of the discretionary harvest season has been allowed in the years since then.

River herring were historically used for human consumption. The fillets were generally processed and salted, while the roe was used either fresh or canned. During 1995-1999, the percentage of the river herring harvest used for bait ranged from 6 to 39%. From 2000 to the implementation of the no-harvest provision, 2% or less of the total river herring harvest has been sold as bait.

Table 7.1 River herring landings and percentage by gear from North Carolina, 1962-2006.

	Pound Nets		Float and Sink Gill Nets		Drift Gill Nets		Haul Seine		Trawl		Other Gears		
Year	*Pounds*	*% Total Landings*	*Pounds*	*% Total Landings*	*Pounds*	*% Total Landings*	*Pounds*	*% Total Landings*	*Pounds*	*% Total Landings*	*Pounds*	*% Total Landings*	*Total Pounds*
1962	12,443,100	87.0	1,682,300	11.8	151,500	0.2	151,500	1.1			800	0.0	14,302,400
1963	12,941,200	85.7	1,798,900	11.9	43,000	0.3	301,200	2.0			15,300	0.1	15,099,600
1964	5,883,300	77.8	1,069,100	14.1	76,500	1.0	532,000	7.0					7,560,900
1965	9,077,200	70.8	3,229,700	25.2	1,700	0.0	514,000	4.0			3,200	0.0	12,825,800
1966	12,414,000	99.2	103,000	0.8	200	0.0	1,000	0.0			1,100	0.0	12,519,300
1967	18,395,100	99.5	46,200	0.2	6,100	0.0	36,000	0.2			2,600	0.0	18,486,000
1968	13,597,600	87.6	914,100	5.9	85,000	0.5	854,700	5.5			73,500	0.5	15,524,900
1969	17,905,100	90.6	717,600	3.6	55,100	0.3	1,003,400	5.1			80,500	0.4	19,761,700
1970	10,873,100	94.4	13,200	0.1	18,600	0.2	581,800	5.0			34,700	0.3	11,521,400
1971	11,657,400	91.6	38,700	0.3	39,300	0.3	979,000	7.7			7,500	0.1	12,721,900
1972	10,868,387	96.7	1,863	0.0	46,248	0.4	320,645	2.9					11,237,143
1973	7,741,724	97.7	1,389	0.0	17,740	0.2	165,045	2.1					7,925,898
1974	5,866,038	94.5	31,277	0.5	49,000	0.8	263,227	4.2					6,209,542
1975	5,480,095	92.1	116,828	2.0	227,674	3.8	127,470	2.1					5,952,067
1976	6,106,419	95.4	122,553	1.9	111,900	1.7	60,488	0.9					6,401,360
1977	8,112,192	95.2	97,570	1.1	181,700	2.1	132,351	1.6					8,523,813
1978	5,487,100	83.0	876,009	13.3	146,669	2.2	96,875	1.5			500	0.0	6,607,153
1979	4,256,323	83.1	574,227	11.2	173,950	3.4	95,198	1.9	19,452	0.4			5,119,150
1980	5,354,430	86.1	757,576	12.2	56,898	0.9	46,513	0.7	*	*	3,106	0	6,218,523
1981	3,452,189	72.6	1,053,593	22.2	63,820	1.3	35,389	0.7	141,232	3.0	*	*	4,753,723
1982	7,720,694	81.8	1,649,488	17.5	37,000	0.4	20,721	0.2	7,679	0.1	*	*	9,437,703
1983	4,491,831	76.5	1,313,731	22.4	29,000	0.5	30,970	0.5			2,800	0.0	5,868,332
1984	4,591,016	70.5	1,866,635	28.6	36,632	0.6	6,452	0.1	9,497	0.1	5,877	0.1	6,516,109
1985	10,658,014	92.3	815,364	7.1	73,500	0.6	*	*			*	*	11,548,278
1986	5,895,596	86.5	822,377	12.1	56,100	0.8			*	*	*	*	6,814,323
1987	2,411,710	75.5	764,602	23.9			*	*	*	*	*	*	3,194,975
1988	2,307,436	55.1	1,864,258	44.5					*	*	*	*	4,191,211
1989	928,759	62.3	562,308	37.7					*	*	10	0.0	1,491,077
1990	782,356	67.6	364,196	31.5					*	*	*	*	1,157,625
1991	1,042,110	66.1	533,268	33.9									1,575,378
1992	1,392,104	80.8	225,794	13.1					*	*	*	*	1,723,178
1993	804,380	87.8	111,628	12.2			101	0.0			*	*	916,235
1994	423,644	65.8	173,568	26.9	4,130	0.6	181	0.0	*	*	42,785	6.6	644,309
1995	274,191	60.4	156,137	34.4	*	*	21	0.0	*	*	23,635	5	453,984
1996	406,411	76.8	119,305	22.5	1,278	0.2	10	0.0			2,499	0.5	529,503
1997	201,793	60.3	123,333	36.8	2,781	0.8	4	0.0	*	*	6,897	2.1	334,809
1998	374,700	71.8	143,267	27.4	2,284	0.4			*	*	1,680	0.3	521,930
1999	336,934	76.0	102,065	23.0	2,165	0.5	*	*			2,331	0.5	443,494
2000	230,890	69.5	91,768	27.6	376	0.1	*	*			9,302	2.8	332,336
2001	210,283	68.5	86,209	28.1	*	*	*	*			10,269	3	306,761
2002	92,668	53.0	71,644	41.0	322	0.2	*	*	*	*	10,226	6	174,860
2003	97,603	48.9	82,127	41.1	*	*	3,846	1.9			16,140	8.1	199,716
2004	90,154	47.8	75,928	40.0	*	*	5,395	2.9			17,064	9.0	188,541
2005	159,386	63.7	74,727	29.9	*	*	*	*			15,908	6.4	250,021
2006	66,071	60.6	36,520	33.5	*	*	*	*			6,451	5.9	109,042

*Denotes confidential landings; these are incorporated into “Other Gears.”

Table 7.2 Total harvest of river herring by gear type for the Albemarle Sound Area, 1962-2006.

	Pound Nets		Gill Nets		Seines		Other		Total
Year	*Pounds*	*% Annual Total*	*Pounds*	*% Annual Total*	*Pounds*	*% Annual Total*	*Pounds*	*% Annual Total*	
1962	12,427,700	87.38%	1,647,500	11.58%	147,000	1.03%	0	0.00%	14,222,200
1963	12,926,000	85.93%	1,804,000	11.99%	301,200	2.00%	11,800	0.08%	15,043,000
1964	5,879,300	78.20%	1,116,400	14.85%	522,800	6.95%	0	0.00%	7,518,500
1965	9,077,200	70.87%	3,221,700	25.15%	510,000	3.98%	0	0.00%	12,808,900
1966	12,405,200	99.37%	76,900	0.62%	1,000	0.01%	1,100	0.01%	12,484,200
1967	18,373,600	99.74%	34,700	0.19%	9,700	0.05%	2,600	0.01%	18,420,600
1968	13,570,800	88.29%	980,900	6.38%	819,200	5.33%	0	0.00%	15,370,900
1969	17,903,100	91.19%	771,200	3.93%	958,400	4.88%	0	0.00%	19,632,700
1970	10,873,100	94.93%	29,000	0.25%	551,800	4.82%	500	0.00%	11,454,400
1971	11,656,300	91.70%	76,400	0.60%	979,000	7.70%	0	0.00%	12,711,700
1972	10,868,387	96.72%	48,111	0.43%	320,645	2.85%	0	0.00%	11,237,143
1973	7,741,724	97.69%	17,740	0.22%	165,045	2.08%	0	0.00%	7,924,509
1974	5,866,038	94.54%	75,632	1.22%	263,227	4.24%	0	0.00%	6,204,897
1975	5,480,095	92.11%	343,834	5.78%	125,550	2.11%	0	0.00%	5,949,479
1976	6,106,419	95.39%	234,453	3.66%	60,488	0.94%	0	0.00%	6,401,360
1977	8,112,192	95.21%	275,800	3.24%	132,351	1.55%	0	0.00%	8,520,343
1978	5,487,100	83.52%	997,577	15.18%	85,375	1.30%	0	0.00%	6,570,052
1979	4,256,323	84.60%	679,773	13.51%	95,198	1.89%	0	0.00%	5,031,294
1980	5,354,430	86.65%	776,748	12.57%	46,513	0.75%	1,500	0.02%	6,179,191
1981	3,452,189	75.71%	1,065,035	23.36%	35,124	0.77%	7,500	0.16%	4,559,848
1982	7,720,694	82.07%	1,668,276	17.73%	18,800	0.20%	0	0.00%	9,407,770
1983	4,491,831	76.67%	1,333,447	22.76%	30,970	0.53%	2,700	0.05%	5,858,948
1984	4,590,766	70.70%	1,891,977	29.14%	6,452	0.10%	3,800	0.06%	6,492,995
1985	10,658,014	92.38%	877,311	7.60%	1,400	0.01%	0	0.00%	11,536,725
1986	5,895,596	87.12%	871,371	12.88%	0	0.00%	0	0.00%	6,766,967
1987	2,411,710	76.00%	761,598	24.00%	100	0.00%	0	0.00%	3,173,408
1988	2,307,436	60.24%	1,523,240	39.76%	0	0.00%	0	0.00%	3,830,676
1989	928,759	62.35%	560,872	37.65%	0	0.00%	0	0.00%	1,489,631
1990	782,356	68.34%	362,384	31.66%	0	0.00%	0	0.00%	1,144,740
1991	1,042,110	66.15%	533,268	33.85%	0	0.00%	0	0.00%	1,575,378
1992	1,391,814	86.34%	220,175	13.66%	0	0.00%	0	0.00%	1,611,989
1993	804,380	87.80%	111,580	12.18%	101	0.01%	126	0.01%	916,187
1994	423,644	70.28%	174,869	29.01%	157	0.03%	4,148	0.69%	602,818
1995	274,191	63.65%	155,154	36.02%	21	0.00%	1,396	0.32%	430,762
1996	406,411	76.88%	119,697	22.64%	10	0.00%	2,491	0.47%	528,609
1997	201,792	61.45%	125,397	38.19%	*	0.00%	1,188	0.36%	328,377
1998	374,700	71.96%	144,358	27.72%	0	0.00%	1,676	0.32%	520,734
1999	336,934	76.04%	103,856	23.44%	*	0.00%	2,323	0.52%	443,113
2000	230,701	71.77%	83,358	25.93%	*	0.00%	7,394	2.30%	321,453
2001	210,283	72.15%	71,078	24.39%	*	0.00%	10,095	3.46%	291,456
2002	92,668	57.08%	65,920	40.61%	*	0.00%	3,748	2.31%	162,336
2003	97,603	53.33%	65,764	35.93%	3,846	2.10%	15,817	8.64%	183,030
2004	90,154	48.84%	72,349	39.19%	5,395	2.92%	16,710	9.05%	184,608
2005	159,386	63.81%	77,135	30.88%	1,278	0.51%	11,978	4.80%	249,777
2006	66,071	61.95%	35,753	33.52%	0	0.00%	4,828	4.53%	106,652
Grand Totals	**233,807,201**	**87.76%**	**26,283,590**	**9.87%**	**6,198,146**	**2.33%**	**115,418**	**0.04%**	**266,404,355**

Table 7.3 River herring landings and value by waterbody in North Carolina, 1962-2006.

	Albemarle Sound (Not including tributaries)		Croatan Sound		Currituck Sound		Chowan River		Roanoke River		Tribs. To Albemarle Sound		Pamlico Sound	
Year	*Pounds*	*Value ($)*	*Pounds*	*Value ($)*	*Pounds*	*Value*	*Pounds*	*Value ($)*	*Pounds*	*Value ($)*	*Pounds*	*Value ($)*	*Pounds*	*Value ($)*
1962	3,262,600	32,626	20,000	200	25,000	250	10,786,000	107,860	122,000	1,220	6,600	66	16,200	162
1963	2,366,100	23,661	25,000	250	40,400	404	12,288,400	122,884	300,000	3,000	23,100	231	16,900	169
1964	1,920,500	19,205	35,000	350	22,300	223	4,948,900	50,760	565,000	5,650	26,800	268		
1965	1,827,700	19,976	15,000	150	10,000	100	10,944,200	112,080			12,000	120	3,200	33
1966	1,274,200	13,916			1,000	20	10,911,300	116,597	256,300	2,566	41,400	498	18,700	391
1967	322,100	5,427	5,000	50	11,700	121	18,016,100	309,992	38,000	746	27,700	475	33,900	467
1968	1,067,200	16,824	3,300	35	10,000	150	12,950,100	194,881	1,306,300	19,771	34,000	593	75,600	933
1969	769,000	13,415	19,300	193	12,000	180	17,536,100	266,614	1,286,100	19,293	10,200	181	2,000	20
1970	217,600	3,263			1,000	20	10,701,300	173,541	469,400	14,270	65,100	1,118		
1971	553,500	9,088					10,426,000	166,339	1,670,500	26,062	61,700	1,396	1,000	25
1972	297,551	6,480	2,670	53			10,594,117	182,052	335,488	7,393	7,317	167		
1973	472,153	13,327	4,590	137			7,350,578	196,212	92,056	3,571	5,132	216	149	7
1974	150,490	5,748			7,554	288	5,736,905	224,074	256,110	13,588	53,838	2,682		
1975	597,440	28,659					5,031,756	168,847	230,433	14,485	89,850	3,374		
1976	356,123	21,304			4,150	415	5,734,776	286,830	300,100	27,775	6,211	426		
1977	828,679	38,247					7,418,218	360,962	252,700	21,232	20,746	895	490	29
1978	491,372	24,688			3,950	208	5,615,113	239,227	383,199	15,328	76,418	5,454	30,697	1,465
1979	466,389	32,741	3,000	120	2,900	128	4,303,663	260,229	209,950	12,258	45,392	2,695	2,894	216
1980	680,476	51,882	*	*	4,850	420	5,382,954	379,206	71,773	6,911	20,323	1,615	5,263	527
1981	1,050,871	87,524	*	*	2,585	225	3,314,447	202,814	155,860	13,118	17,432	1,416	39,774	3,627
1982	1,558,873	144,751	*	*	22,787	2,597	7,459,968	515,545	240,540	25,725	49,956	4,629	4,565	429
1983	1,190,909	118,887	110,576	10,732	39,255	3,614	4,405,915	313,747	92,200	14,415	20,093	1,812	5,471	639
1984	1,791,289	193,857	*	*	9,100	1,258	4,561,503	382,919	65,672	8,495	49,815	5,315	*	*
1985	2,296,010	177,908	*	*	*	*	8,871,391	635,190	204,750	20,826	*	*	4,190	499
1986	689,297	94,764	*	*			5,767,874	517,945	244,994	26,519	14,860	1,937	3,780	424
1987	705,585	85,153	*	*			2,334,719	265,640	*	*	*	*		
1988	1,490,413	178,848	*	*			2,259,888	271,186	*	*	20,250	2,430	*	*
1989	554,878	69,157					908,145	110,795	*	*	*	*	*	*
1990	365,881	56,047	*	*			710,849	106,635	*	*	60,037	9,065	1,505	166
1991	352,458	28,361	*	*			1,202,535	87,799	*	*	*	*		
1992	217,918	22,161	*	*			1,135,340	113,655	255,772	25,578	*	*		
1993	111,749	10,308			117	15	801,115	56,806			*	*	25	3
1994	180,271	33,348	729	73	1,357	136	390,852	44,017	*	*	29,015	18,428	1,000	245
1995	97,137	34,277	1,723	344	640	160	280,681	73,482	2,858	715	47,723	20,111	3,923	1,022
1996	104,166	34,311	4,708	2,139	114	28	404,884	82,129	2,176	1,675	12,562	12,039	625	155
1997	109,876	46,927	9,436	5,321	159	59	201,928	67,454	*	*	4,766	5,075	518	302
1998	115,436	46,814	16,831	13,815	157	62	377,311	135,901	*	*	10,338	6,555	601	399
1999	85,086	33,928	21,101	22,884	98	35	332,466	119,247	*	*	3,305	3,167	280	100
2000	88,903	28,646	36,539	23,261	893	262	184,741	57,272	337	450	11,945	4,144	8,120	12,906
2001	49,678	21,081	24,085	9,159	1,485	632	201,717	76,707	*	*	14,162	6,244	15,172	5,992
2002	39,251	14,681	16,569	6,099	136	51	93,048	34,587	*	*	19,650	7,486	4,676	1,683
2003	67,175	29,631	6,552	4,039	1,535	675	84,591	37,220			23,178	10,203	15,100	6,865
2004	73,092	31,651	15,248	6,566	1,297	558	77,177	33,186	*	*	13,698	5,890	3,529	1,517
2005	63,350	32,515	17,495	8,944	*	*	157,087	81,196	*	*	11,844	6,055	*	*
2006	22,573	17,318	9,633	7,390	288	221	67,404	57,712	*	*	5,670	4,350	*	*

Table 7.3- River herring landings, cont'd.

	Pamlico River		Neuse River		Cape Fear River		Atlantic Ocean		Other Areas		State Total	
Year	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)	Pounds	Value ($)
1962	61,100	611	2,000	20	100	1			800	8	14,302,400	143,024
1963	27,700	277	4,000	40	4,500	45			3,500	35	15,099,600	150,996
1964	33,500	335	8,200	82	700	7					7,560,900	76,880
1965	13,400	139			300	3					12,825,800	132,601
1966	15,500	262	500	5	400	6					12,519,300	134,261
1967	30,300	425			300	4			900	9	18,486,000	317,716
1968	4,500	55	200	9	200	8			73,500	1,410	15,524,900	234,669
1969	1,500	56							125,500	3,765	19,761,700	303,717
1970	200	11			1,100	23			65,700	1,510	11,521,400	193,756
1971	100	2	400	10	1,200	50			7,500	150	12,721,900	203,122
1972											11,237,143	196,145
1973			1,240	49							7,925,898	213,519
1974	3,995	340	650	33							6,209,542	246,753
1975	250	15					2,338	121			5,952,067	215,501
1976											6,401,360	336,750
1977	2,980	238									8,523,813	421,603
1978	5,200	260			704	50			500	25	6,607,153	286,705
1979	64,444	3,397	1,130	56			19,388	1,939			5,119,150	313,779
1980	32,609	2,110					*	*	20,275	1,656	6,218,523	444,327
1981	10,049	1,482	*	*			143,232	5,252	*	*	4,753,723	316,850
1982	12,556	1,864	*	*			7,679	726	80,779	8,333	9,437,703	704,599
1983	3,813	528							*	*	5,868,332	464,389
1984	11,137	1,280					9,497	843	18,096	2,461	6,516,109	596,428
1985	7,308	731					*	*	164,629	10,752	11,548,278	845,906
1986	3,306	496					*	*	90,212	5,208	6,814,323	647,293
1987	2,288	297					19,279	1,000	133,104	15,972	3,194,975	368,062
1988	1,593	195					*	*	419,067	49,507	4,191,211	502,166
1989	934	105							27,120	3,785	1,491,077	183,842
1990	307	43					*	*	19,046	2,303	1,157,625	174,259
1991									20,385	2,112	1,575,378	118,272
1992							110,794	10,773	3,354	286	1,723,178	172,453
1993	*	*							3,229	362	916,235	67,494
1994	14	1	1,668	167			38,834	3,883	*	*	644,309	100,996
1995	*	*	64	15			19,174	4,793	62	16	453,984	134,934
1996	*	*	103	59			*	*	165	38	529,503	132,573
1997			185	278			5,568	1,949	2,374	1,317	334,809	128,682
1998	56	20	539	189					*	*	521,930	204,706
1999	*	*	*	*					1,158	1,514	443,494	180,874
2000	44	13	*	*			*	*	815	252	332,336	127,206
2001	*	*	45	81			45	17	373	142	306,761	120,053
2002	*	*	*	*			39	15	1,493	1,121	174,860	65,723
2003	*	*	773	464			*	*	814	358	199,716	89,456
2004	*	*	302	226			*	*	4,199	1,805	188,542	81,399
2005	*	*	*	*					245	125	250,021	128,834
2006									1,249	958	109,243	83,812

* Denotes confidential landings, incorporated in "Other Areas."

Table 7.4 Participants, trips, landings, and value for all finfish and river herring in the Albemarle Sound Management Area, 1994-2006.

		All Finfish Species				River Herring			
Year	Gear	Number of Participants**	Number of Trips	Pounds	Value ($)	Number of Participants**	Number of Trips	Pounds	Value ($)
1994	Gill Net (Drift)	15	76	5,143	4,535	5	62	2,790	3,625
	Gill Net (Float & Sink)	354	5,847	1,089,946	529,865	166	2,358	171,639	47,999
	Gill Net (Runaround)	9	16	7,476	2,021	*	*	*	*
	Pound Net	56	1,343	780,519	137,887	40	929	423,627	44,328
	Other Gears	224	1,509	265,196	83,909	21	148	4,305	568
	Total:	**480**	**8,791**	**2,148,280**	**758,217**	**202**	**3,497**	**602,361**	**$96,520**
1995	Gill Net (Drift)	3	33	3133	784	3	33	3126	782
	Gill Net (Float & Sink)	479	7,387	832,921	468,856	181	2,291	152,027	56,484
	Gill Net (Runaround)	4	19	1,458	980				
	Pound Net	39	726	578,160	140,481	32	376	274,189	71,459
	Other Gears	246	1672	298,166	107,781	17	94	1,417	363
	Total:	**593**	**9,837**	**1,713,838**	**718,882**	**204**	**2,794**	**430,759**	**$129,087**
1996	Gill Net (Drift)	5	13	1,332	1,548	4	12	1,268	1,515
	Gill Net (Float & Sink)	422	6,749	1,056,348	519,090	211	2,621	118,425	49,672
	Gill Net (Runaround)	*	*	*	*				
	Pound Net	43	831	746,045	141,638	35	365	406,396	78,605
	Other Gears	285	1599	270,385	145,419	19	105	2,501	2,525
	Total:	**572**	**9,192**	**2,074,110**	**807,695**	**239**	**3,103**	**528,590**	**$132,317**
1997	Gill Net (Drift)	11	64	3,142	3,249	7	59	2,598	2,965
	Gill Net (Float & Sink)	394	7,245	1,023,127	627,206	184	2,046	122,798	56,418
	Gill Net (Runaround)	5	8	3,087	1,513				
	Pound Net	34	836	479,181	141,436	25	388	201,792	66,172
	Other Gears	231	1703	268,767	174,977	18	108	1,191	540
	Total:	**527**	**9,856**	**1,777,304**	**948,381**	**213**	**2,601**	**328,379**	**$126,096**
1998	Gill Net (Drift)	3	17	2,743	1,236	3	17	2,284	1,131
	Gill Net (Float & Sink)	366	6,709	1,150,800	693,890	190	2,220	142,066	67,828
	Gill Net (Runaround)	7	13	980	525	*	*	*	*
	Pound Net	27	684	588,357	194,080	22	417	374,700	134,488
	Other Gears	212	1555	233,210	133,068	19	97	1,679	642
	Total:	**482**	**8,978**	**1,976,090**	**1,022,799**	**206**	**2,751**	**520,728**	**$204,089**

Table 7.4. Cont'd.

		All Finfish Species				River Herring			
Year	Gear	Number of Participants**	Number of Trips	Pounds	Value ($)	Number of Participants**	Number of Trips	Pounds	Value ($)
1999	Gill Net (Drift)	7	33	2,391	2,001	7	33	2,165	1,917
	Gill Net (Float & Sink)	407	8,836	1,392,511	798,703	164	2,083	101,677	56,963
	Gill Net (Runaround)	7	12	3,396	1,808				
	Pound Net	30	844	597,141	211,159	24	527	336,934	120,873
	Other Gears	244	1955	303,248	158,352	17	137	2,331	987
	Total:	**524**	**11,680**	**2,298,687**	**1,172,023**	**190**	**2,780**	**443,106**	**$180,740**
2000	Gill Net (Drift)	*	*	*	*	*	*	*	*
	Gill Net (Float & Sink)	385	9,227	1,317,009	690,848	164	1,563	83,038	32,446
	Gill Net (Runaround)	13	49	16,804	7,180	*	*	*	*
	Pound Net	36	925	546,539	165,430	30	559	230,701	78,299
	Other Gears	169	1329	371,393	208,594	23	205	9,614	3,288
	Total:	**469**	**11,530**	**2,251,745**	**1,072,052**	**189**	**2,327**	**323,353**	**$114,033**
2001	Gill Net (Drift)								
	Gill Net (Float & Sink)	405	10,284	1,268,732	702,184	115	790	70,957	29,206
	Gill Net (Runaround)	15	75	14,002	6,416	5	7	115	157
	Pound Net	31	742	521,368	156,145	23	421	210,283	80,422
	Other Gears	201	1384	253,738	156,529	25	136	10,127	4,173
	Total:	**502**	**12,485**	**2,057,840**	**1,021,274**	**143**	**1,354**	**291,483**	**$113,957**
2002	Gill Net (Drift)	5	11	687	185	*	*	*	*
	Gill Net (Float & Sink)	391	8,747	1,213,274	681,883	109	1,139	65,789	24,547
	Gill Net (Runaround)	13	41	10,788	4,860	*	*	*	*
	Pound Net	37	960	465,811	130,648	24	580	92,668	34,503
	Other Gears	201	1469	179,181	100,278	18	117	10,324	3,913
	Total:	**474**	**11,228**	**1,869,741**	**917,854**	**132**	**1,836**	**168,781**	**$62,964**
2003	Gill Net (Drift)	3	3	684	312				
	Gill Net (Float & Sink)	396	9,008	1,943,532	1,051,071	135	1,175	65,757	30,172
	Gill Net (Runaround)	8	15	8,376	3,623	*	*	*	*
	Pound Net	29	706	388,500	143,678	19	468	97,603	42,950
	Other Gears	226	1556	297,776	170,953	37	252	19,670	8,647
	Total:	**487**	**11,288**	**2,638,868**	**1,369,637**	**156**	**1,895**	**183,030**	**$81,769**

Table 7.4. Cont'd.

		All Finfish Species				River Herring			
Year	Gear	Number of Participants**	Number of Trips	Pounds	Value ($)	Number of Participants**	Number of Trips	Pounds	Value ($)
2004	Gill Net (Drift)	*	*	*	*	*	*	*	*
	Gill Net (Float & Sink)	359	8,180	1,339,116	781,307	98	716	72,321	31,113
	Gill Net (Runaround)	9	20	5,756	2,253				
	Pound Net	26	590	257,027	71,850	15	416	90,154	38,766
	Other Gears	188	1327	213,398	150,835	35	297	22,130	9,732
	Total:	**440**	**10,117**	**1,815,297**	**1,006,245**	**117**	**1,429**	**184,605**	**79,611**
2005	Gill Net (Drift)	19	210	171,544	31,956	9	91	2,526	1,291
	Gill Net (Float & Sink)	359	7,294	1,238,714	832,667	119	1,1134	74,532	38,127
	Gill Net (Runaround)	15	33	16,257	5,762	*	*	*	*
	Pound Net	22	525	288,021	117,600	15	393	159,386	82,371
	Other Gears	115	841	201,427	123,502	23	149	13,255	6,880
	Total:	**411**	**8,902**	**1,915,963**	**1,111,487**	**137**	**1,770**	**249,776**	**128,709**
2006	Gill Net (Drift)	12	57	7,655	6,701	4	13	324	166
	Gill Net (Float & Sink)	281	6,465	915,604	723,846	73	533	35,599	18,024
	Gill Net (Runaround)	9	17	5,319	2,181	*	*	*	*
	Pound Net	18	534	216,117	91,203	13	317	66,071	33,776
	Other Gears	92	815	188,739	100,148	5	83	6,123	3,130
	Total:	**325**	**7,886**	**1,333,433**	**924,079**	**85**	**947**	**108,117**	**55,096**

* Denotes confidential landings. These are incorporated into "Other Gears."

** Number of participants is not additive across gears because an individual participant can use more than one gear type.

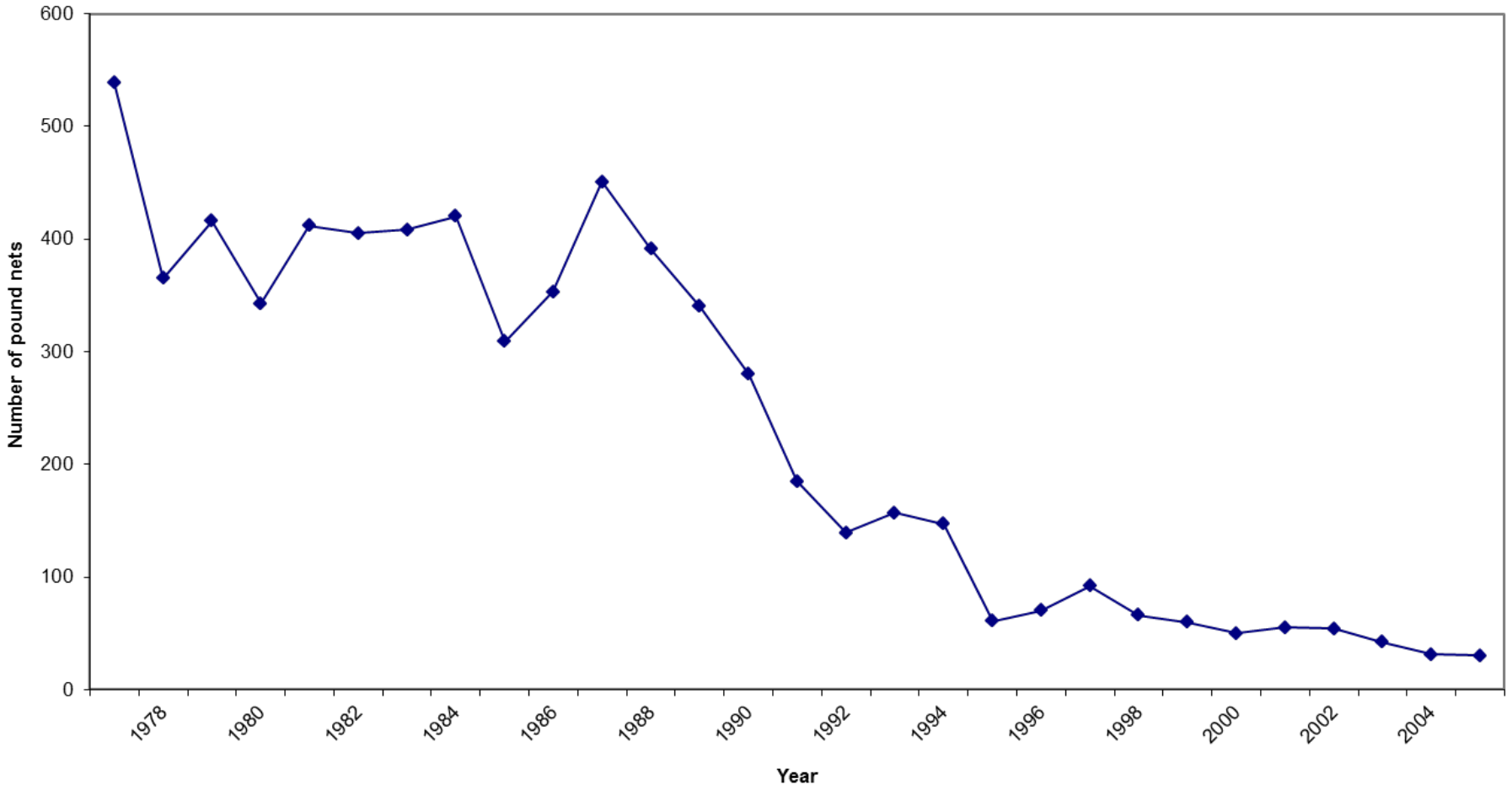


Figure 7.1 Mean number of pound nets set in the Chowan River, 1977-2005.

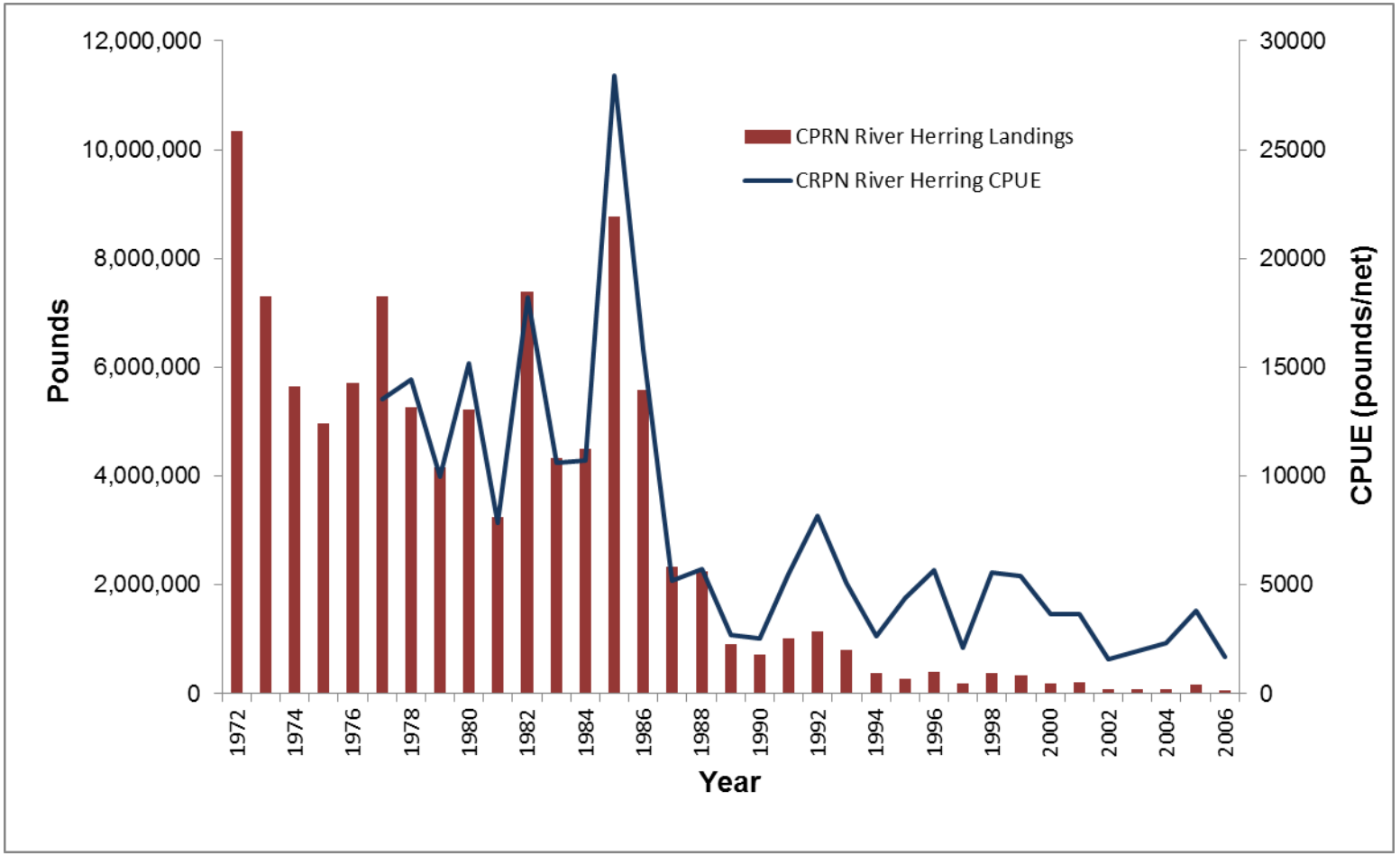


Figure 7.2 River herring pound net landings and catch-per-unit-of effort in the Chowan River pound net fishery (CRPN) Chowan River, NC, 1972-2006.

7.2.2 Ocean Fishery

Substantial oceanic landings of river herring were reported by foreign fishing fleets operating in United States territorial waters between 1967 and 1972. In 1969, the peak year, total reported landings of river herring in the foreign fishery were 10,950 metric tons (24 million pounds). Foreign fleets harvested primarily fish that were less than 7.5 inches long and mostly immature (Street and Davis 1976). This level of fishing pressure on sub-adult river herring was probably a major factor contributing to the declines in commercial landings of river herring along the Atlantic coast seen in the mid-1970s.

Since 1977, the foreign fishery for river herring within the U.S. Exclusive Economic Zone (200 mile limit) has been restricted by federal rules under the authority of the Magnuson-Stevens Act. No directed foreign fishing for river herring has been allowed since the passage of the Magnuson-Stevens Act. The annual allocation of river herring landings to the foreign fisheries between 1977 and 1980 was 1.1 million pounds. After 1981, the total annual allocation was limited to 100 metric tons (220,460 pounds), less than 2% of the total US river herring harvest in a typical year prior to that period. Even though foreign fishing pressure on river herring stocks in offshore waters has been reduced for 35 years, the population has not recovered anywhere along the Atlantic Coast. River herring landings from the Atlantic Ocean (usually listed simply as alewife) ranged from over 5 million pounds in 1987 to slightly over 200,000 in 2006 (ASMFC 2009).

River herring are no longer targeted in the ocean fisheries but are often found in mixed schools with fish that are targeted, including Atlantic herring, squid, mackerel, and butterfish. This bycatch includes both juveniles and adults. The National Marine Fisheries Service observer program estimated the incidental catch of river herring in 2005 as 41,458 pounds and 121,246 pounds in 2007 (ASMFC 2009). More recently (2009-2010), the amount of bycatch of herring in these fisheries was estimated to be several million fish in the various small-mesh mid-water and bottom trawl fisheries (MAFMC 2012). In 2012, the Mid Atlantic Fishery Management Council approved Amendment 14 to the Mackerel, Squid, and Butterfish Fishery Management Plan. Specifically, there are three problem areas to be addressed with this amendment:

1. There is a high degree of uncertainty in river herring bycatch numbers due to low levels of catch monitoring.
2. Catch of river herring in these fisheries may be impacting the species' recovery.
3. The overall current management framework may be insufficient to conserve river herring stocks.

The options approved for management included measures designed to improve river herring catch monitoring and to implement catch caps on river herring in the mackerel fishery. These measures take effect in 2014. The amendment also considered adding river herring as a managed stock in the Mackerel, Squid, and Butterfish FMP, but the Council at its October, 2013, meeting decided against this. Instead, they opted to establish an interagency working group that would address issues with both shad and river herring.

The New England Fishery Management Council is addressing bycatch and incidental catch of river herring in the Atlantic herring fishery with Amendment 5 to the Atlantic Herring Fishery Management Plan (NEFMC 2013). The preferred options for managing river herring bycatch in this fishery include establishing River Herring Monitoring/Avoidance areas with options for implementing additional catch monitoring provisions in those areas, and 100% observer

coverage in the limited access Atlantic herring fishery, which would increase precision in estimates of all bycatch, including river herring.

7.2.3 Discretionary Harvest

In 2007, Amendment 1 to the North Carolina River Herring Fishery Management Plan implemented a no-harvest provision for commercial and recreational fisheries of river herring in coastal waters of the state. It also included a 7,500 pound limited research set-aside harvest to be used for data collection and to provide product to local herring festivals. The Director allocated a maximum of 4,000 pounds to be used for this season, which occurs around Easter week each year and only in the Chowan River Herring Management Area. The season and the permits are managed by proclamation. Interested parties call NCDMF offices to receive the applications for the permits. To participate in the fishery, individuals must have a permit and hold a valid commercial license. They must also participate in statistical data collection efforts. Permit holders are allocated between 125 and 250 pounds and can harvest river herring with pound nets or gill nets, but are restricted to 100 yards of 3 inch mesh (Table 7.5). Harvested herring, if sold, must be sold to a licensed and permitted river herring dealer, who must report landings daily to NCDMF. Although this program was originally designed to provide product for local herring festivals during the spring run, it is rarely, if ever used for that purpose (K. Rawls, personal communication). NCDMF used data collected from the discretionary harvest period, but since 2008 has contracted with pound net fishermen to provide those samples. Table 7.6 summarizes the totals for the last six years of this discretionary harvest season. Of the permits issued, over 40% were either not used, or the permit-holders did not sell the fish. Fish that are given away or used for personal consumption are not enumerated on trip tickets.

Table 7.5 Discretionary harvest season dates and limits.

Year	Dates	Limits (lbs)
2007	April 4-7	200
2008	March 19-22	250
2009	April 8-11	125
2010	April 1-4	125
2011	April 18-21	150
2012	April 2-5	150

Table 7.6 Total pounds, value, number of participants, and number of permits issued for the Discretionary Harvest season, by year.

Year	Pounds	Value ($)	Trips	# Participants	# Permits
2007	1,103	856	22	10	15
2008	1,292	775	25	9	13
2009	643	836	27	14	27
2010	1,765	1,765	41	16	30
2011	1,611	1,611	30	16	23
2012	678	678	18	10	32

7.3 RECREATIONAL FISHERY

There is currently no recreational fishery for river herring. Formerly, most river herring caught recreationally were likely used for personal consumption or for bait. The 2007 no-harvest provision also applied to the recreational fishery. Several variations of dip nets (called “special fishing devices” when used in inland waters) were the primary gears used to harvest river herring although gill nets have also been used. River herring have also been harvested by hook and line. They take a variety of baits and artificial lures and were occasionally caught incidentally in the shad fishery on spoons, jigs or small darts (B. Long, personal communication). River herring have been harvested with a “Sabiki” rig to use as bait in the striped bass recreational fishery. While it is legal to catch them by this method, it is illegal to keep them.

Historically, river herring have been taken for personal consumption in every major North Carolina coastal river system. An analysis of river herring harvest by Baker (1968) indicated the majority of herring harvested by special device licensees in 1967-1968 occurred in the Chowan and Roanoke River basins. River herring were also harvested in other river basins, but American shad and hickory shad were of more importance to fishermen in those areas. Baker (1968) estimated that special device licensees harvested 2.9 million pounds of river herring coastwide, some of which were sold. The recreational component of this total, however, is unknown. Although these fish were taken by fishermen licensed by NCWRC at that time, changes in designations of coastal/joint/inland fishing waters, changes in jurisdictional responsibilities between NCDMF and NCWRC, and the unknown proportion of these fish which were harvested with the intent of sale precludes an estimate of the historical level of river herring harvest for personal consumption.

The NCWRC, however, implemented a moratorium in all inland waters of coastal rivers and their tributaries on possession of river herring larger than six inches, effective July 1, 2006. The NCMFC also implemented a no-harvest provision in 2007 that applied to both commercial and recreational fishing in coastal and joint fishing waters. Both agencies allowed possession of river herring purchased from bait dealers with proper documentation (i.e. receipt for purchase including the dealer’s name and amount purchased). The main source for this bait was South Carolina, currently one of the few states that allow a small harvest of river herring. In 2013, the NCWRC implemented a rule that prohibits possession of river herring greater than six inches while boating or fishing in inland waters. This rule took effect August 1, 2013 and was created in response to abuse by anglers of the receipt policy, which was by mutual agreement between NCWRC and NCMFC. The problems occurred when anglers falsify receipts or they replace river herring legally bought for bait with illegally caught river herring. Law enforcement has no way to tell the difference. The six-inch provision exists to allow anglers to use stunted reservoir river herring for bait. There is a substantial industry around the use of these fish for bait. Guides or anglers travel to the reservoirs to cast-net for these fish, then either sell them or use them for bait in the striped bass fishery. The NCMFC will consider adopting this rule, or a very similar one, in 2014.

A recreational drift net river herring fishery existed on the Roanoke River for many years. This fishery has never been fully assessed by NCDMF or NCWRC. The NCDMF initiated a pilot drift net creel survey in 1999 to characterize this fishery for development of future monitoring strategies and to provide managers with weekly reports of recreational drift net activity including participation, catch rates, species composition, net sizes, etc. Sampling was conducted in the lower river area including Williamston, Jamesville, and Plymouth. Interviews were conducted three days per week, for a total of 21 sampling days in 1999. Catches of river herring ranged

from 20 to 300 fish per vessel with a mean of 106. Drift duration ranged from 1 to 5 hours with a mean of 2.2 hours. A total of 2,764 river herring were observed in the survey. Because there was no estimate of total effort, total catch cannot be estimated. Through the survey, the county of residence of the participant was determined. Martin, Edgecombe, Greene, and Pitt counties accounted for the majority of the participants.

In 2004, Vogelsong et al. (2004) conducted a Recreational Commercial Gear License (RCGL) - Herring Drift Netters Survey in the Roanoke River. The survey was conducted from February 1 through April 11, 2004 with 45 drift netters being sampled and a catch estimate for the season of 5,386 pounds. The number of herring caught per day for the season ranged from 0 to 20+, with a mean of 14.4 fish. The number of drifts per day ranged from one to nine, with a mean of 3.4. Based on the survey, 46% were catching fish for personal consumption and 54% for bait for striped bass fishing.

The NCDMF established a monthly RCGL survey but due to the low response rates during the river herring season the estimates of pounds and trips are unreliable. Very few RCGL holders participated in the herring fishery and the survey was discontinued due to budget cuts.

8.0 SOCIO-ECONOMIC CHARACTERISTICS OF THE FISHERY

8.1 FISHERY ECONOMICS

8.1.1 Commercial Fishery

The commercial fishery for river herring was largely closed after 2006. For this reason, landings in this section are updated through 2006. There is a small discretionary commercial harvest fishery that remains. For more information on this harvest, refer to the Status of the Fisheries Section of this document.

8.1.1.1 Ex-vessel Value and Price

River herring was the most economically important commercial finfish harvested in North Carolina in the late 1800's (Chestnut and Davis 1975). It was not until 1918 that menhaden became more economically viable than river herring. Figure 8.1 shows the nominal ex-vessel value (the actual amount paid dockside to the fishermen) and the inflation adjusted ex-vessel value of the landings for all years to the value of a dollar in 1972. Deflated values are calculated using the U.S. Consumer Price Index and provide a dollar value that is comparable across all years. Data prior to 1950 are presented in Table 8.1, however are not included in the figure below as these data are not available on a consecutive annual basis. There are no comparable deflated figures prior to 1918, therefore inflation adjusted values and prices start this year.

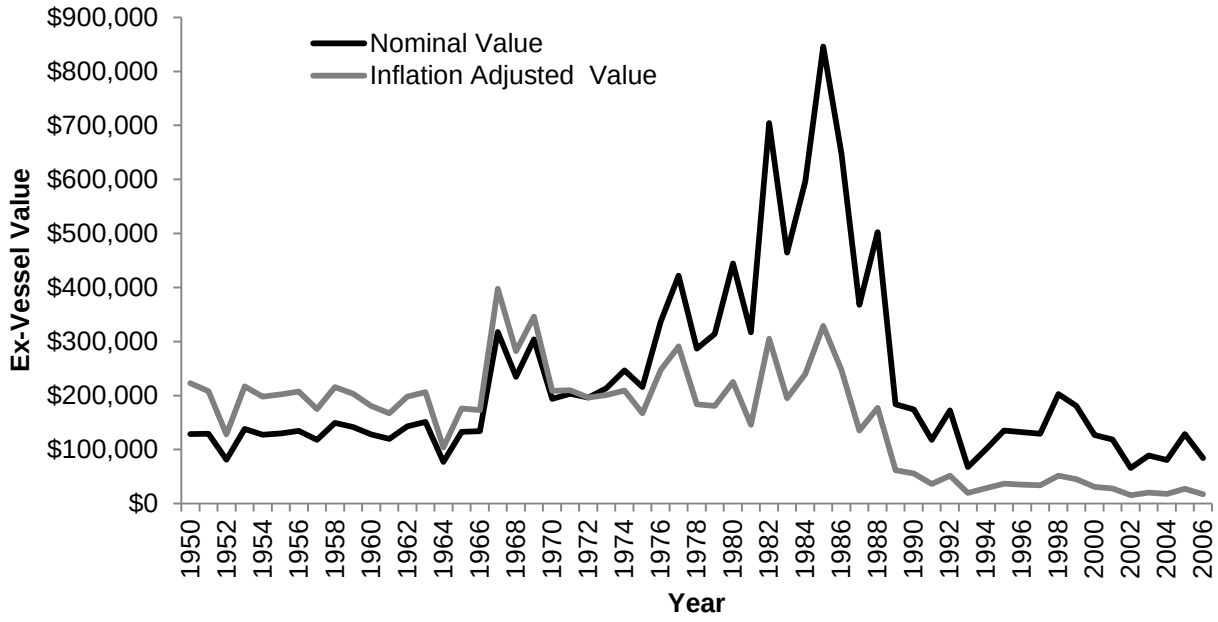


Figure 8.1 Commercial ex-vessel value of river herring landings, North Carolina, 1950 – 2006 (Chestnut and Davis 1975; NCDMF Trip Ticket Program).

Prior to 1952, the annual inflation adjusted ex-vessel value of river herring fluctuated from a high of $1,110,659 in 1918 to a low of $127,823 in 1932. Inflation adjusted landings values remained fairly constant from 1953 until about 1963 ranging in value from $216,695 to $167,076. Average annual landings values began to increase significantly in 1967 and declined sharply beginning in

1989 when the inflation adjusted value of landings was $61,973. Since then, the trend has been toward decreasing annual value with the inflation adjusted value of landings in 2006 at $17,474. Nominal values (the actual ex-vessel price paid to the fisherman) have shown a similar trend over time. In 1988, the ex-vessel value was $502,166, but by 2006 the total ex-vessel value paid for river herring landed in North Carolina had dropped to $84,276.

A survey is conducted periodically by the NCDMF to obtain price estimates from dealers for fish they have purchased from fishermen. The data from the survey are used to determine an average annual price for each market grade. During the peak of the nominal value of the fishery in 1985, the nominal price per pound was $0.07. The peak price per pound on a nominal and inflation adjusted basis was seen in 2006 when prices were $0.77 and $0.16 per pound respectively. Table 8.1 includes the nominal and inflation adjusted annual values and price per pound for river herring over the entire available time series from 1887 to 2006.

Table 8.1 Inflated and deflated ex-vessel and price per pound of river herring landings, North Carolina, 1887 – 2006 (Chestnut and Davis 1975; NCDMF Trip Ticket Program).

Year	Nominal Value	Inflation Adjusted Value	Nominal Price Per Pound	Inflation Adjusted Price Per Pound	Year	Nominal Value	Inflation Adjusted Value	Nominal Price Per Pound	Inflation Adjusted Price Per Pound
1887	$173,219		$0.01		1968	$234,669	$281,873	$0.02	$0.02
1888	$161,673		$0.01		1969	$303,717	$345,923	$0.02	$0.02
1889	$145,383		$0.01		1970	$193,756	$208,737	$0.02	$0.02
1890	$164,636		$0.01		1971	$203,122	$209,642	$0.02	$0.02
1897	$125,655		$0.01		1972	$196,145	$196,145	$0.02	$0.02
1902	$114,680		$0.01		1973	$213,519	$201,016	$0.03	$0.03
1908	$141,629		$0.01		1974	$246,753	$209,215	$0.04	$0.03
1918	$401,219	$1,110,659	$0.03	$0.08	1975	$215,501	$167,434	$0.04	$0.03
1923	$119,404	$291,876	$0.02	$0.04	1976	$336,750	$247,384	$0.05	$0.04
1927	$148,831	$357,537	$0.01	$0.03	1977	$421,603	$290,809	$0.05	$0.03
1928	$107,928	$263,824	$0.01	$0.03	1978	$286,705	$183,808	$0.04	$0.03
1929	$102,223	$249,878	$0.01	$0.02	1979	$313,779	$180,661	$0.06	$0.04
1930	$68,533	$171,538	$0.01	$0.02	1980	$444,327	$225,399	$0.07	$0.04
1931	$90,723	$249,488	$0.01	$0.03	1981	$316,850	$145,702	$0.07	$0.03
1932	$41,894	$127,823	$0.01	$0.02	1982	$704,599	$305,205	$0.07	$0.03
1934	$90,901	$283,557	$0.01	$0.02	1983	$464,389	$194,894	$0.08	$0.03
1936	$129,675	$389,958	$0.01	$0.03	1984	$596,428	$239,949	$0.09	$0.04
1937	$58,461	$169,699	$0.01	$0.03	1985	$845,906	$328,614	$0.07	$0.03
1938	$112,211	$332,654	$0.01	$0.03	1986	$647,293	$246,869	$0.09	$0.04
1939	$77,183	$232,104	$0.01	$0.03	1987	$368,062	$135,431	$0.12	$0.04
1940	$108,856	$325,013	$0.01	$0.04	1988	$502,166	$177,435	$0.12	$0.04
1945	$176,783	$410,529	$0.02	$0.05	1989	$183,842	$61,973	$0.12	$0.04
1950	$128,459	$222,804	$0.02	$0.03	1990	$174,259	$55,731	$0.15	$0.05
1951	$129,267	$207,822	$0.01	$0.02	1991	$118,272	$36,298	$0.08	$0.02
1952	$81,221	$128,115	$0.01	$0.02	1992	$172,453	$51,379	$0.10	$0.03
1953	$138,415	$216,695	$0.01	$0.02	1993	$67,494	$19,524	$0.07	$0.02
1954	$127,580	$198,247	$0.01	$0.02	1994	$100,999	$28,487	$0.16	$0.04
1955	$129,670	$202,246	$0.01	$0.02	1995	$134,934	$37,009	$0.30	$0.08
1956	$134,810	$207,171	$0.01	$0.02	1996	$132,389	$35,270	$0.25	$0.07
1957	$117,734	$175,135	$0.01	$0.01	1997	$128,988	$33,593	$0.39	$0.10
1958	$149,143	$215,715	$0.01	$0.01	1998	$202,437	$51,913	$0.39	$0.10
1959	$141,537	$203,307	$0.01	$0.01	1999	$180,874	$45,381	$0.41	$0.10
1960	$128,150	$180,969	$0.01	$0.01	2000	$126,685	$30,752	$0.38	$0.09
1961	$119,511	$167,076	$0.01	$0.01	2001	$118,546	$27,980	$0.39	$0.09
1962	$143,024	$197,960	$0.01	$0.01	2002	$65,712	$15,268	$0.38	$0.09
1963	$150,996	$206,263	$0.01	$0.01	2003	$88,862	$20,187	$0.44	$0.10
1964	$76,880	$103,664	$0.01	$0.01	2004	$80,694	$17,856	$0.43	$0.09
1965	$132,601	$175,959	$0.01	$0.01	2005	$128,834	$27,574	$0.52	$0.11
1966	$134,261	$173,213	$0.01	$0.01	2006	$84,276	$17,474	$0.77	$0.16
1967	$317,716	$397,621	$0.02	$0.02					

Fishermen sell river herring to the dealers primarily as whole fish by the pound. They are occasionally sold individually, or only the roe (fish eggs) may be sold. The price per pound of river herring roe is customarily much higher than the whole fish price per pound. Relatively few pounds of river herring roe are sold each year; however, prior the closure of the commercial fishery in 2007, the harvesting of herring for roe was becoming a much larger component of the commercial river herring fishery. Figure 8.2 shows the average annual price per pound paid to fishermen. The numbers reflect both the nominal price per pound and the inflation adjusted price per pound.

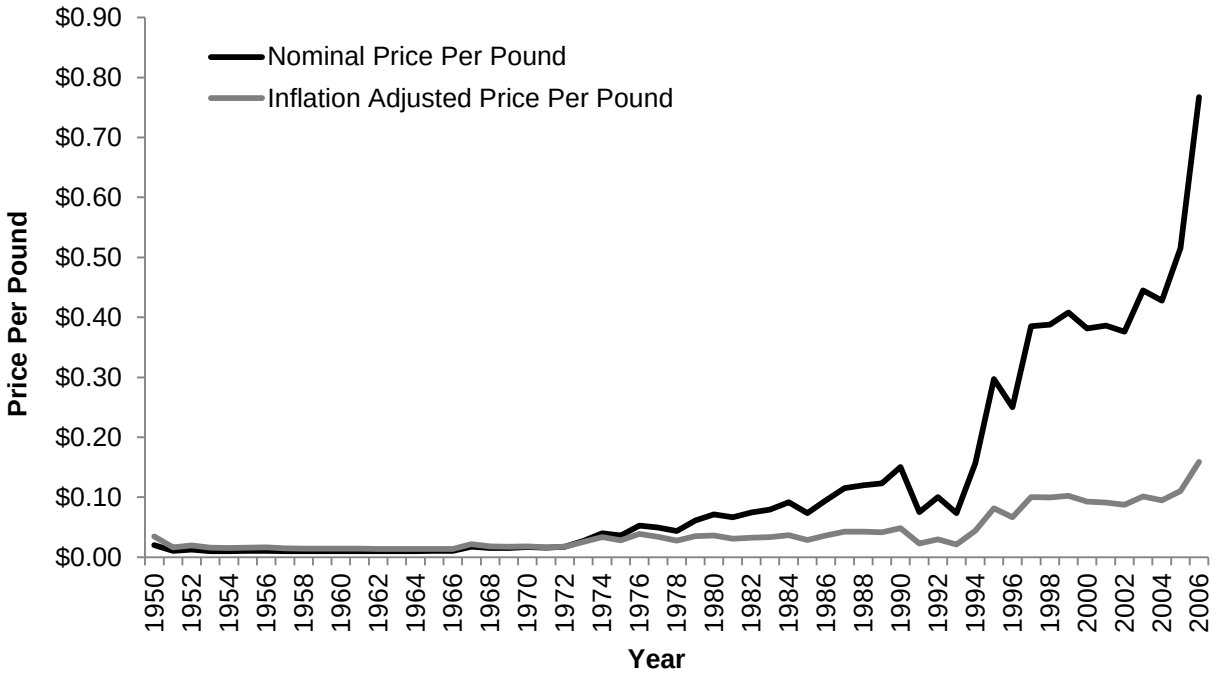


Figure 8.2 Commercial ex-vessel price per pound for river herring landings, North Carolina, 1950 – 2006 (Chestnut and Davis 1975; NCDMF Trip Ticket Program).

8.1.1.2 Gear

The advent of the North Carolina Trip Ticket system in 1994 allowed the NCDMF to track landings by individual trips taken by fishermen. Price estimates derived from the surveyed dealers in Table 8.2 do not take gear type or time of year into account. However, since the river herring fishery is highly seasonal, it is likely that prices fluctuate greatly based on supply and demand. As river herring return from the ocean to spawn, higher prices may be received early in the season from gill nets fished in the eastern part of the Albemarle Sound Management Area. Pound net fishermen in the Chowan River may receive lower prices per pound as river herring are landed upstream later in the season. Table 8.2 shows the ex-vessel value (unadjusted for inflation) and average price per pound paid to fishermen who landed river herring either using gill nets or pound nets. More gill net trips landed river herring in each year compared to pound nets. This is due primarily to how the two gears are fished.

Gill net-harvested river herring tend to bring a higher price per pound for two main reasons: 1) individual gill net trips usually bring in fewer pounds per trip; and 2) the river herring gill net season starts earlier than the pound net fishery. With lower amounts of river herring typically

available during the gill net season, demand for the product drives the price up. In each year other than 1994, the total annual ex-vessel value from pound nets is higher than from gill nets partially due to management measures that went into place beginning in 1995. Total Allowable Catches (TACs) implemented in 2000 further solidified the discrepancy in landings by gear by allocating a larger amount of the quota to the pound net fishery.

Table 8.2 Ex-vessel value and average price per pound for gill net, pound net, and other gear trips for river herring, North Carolina, 1994 – 2006 (NCDMF Trip Ticket Program).

	Gill Nets		Pound Nets		Other	
Year	Ex-Vessel Value	Price Per Pound	Ex-Vessel Value	Price Per Pound	Ex-Vessel Value	Price Per Pound
1994	$52,282	$0.29	$44,330	$0.10	$4,387	$0.10
1995	$58,335	$0.37	$71,459	$0.26	$5,140	$0.25
1996	$51,468	$0.43	$78,388	$0.19	$2,533	$1.01
1997	$59,944	$0.48	$66,484	$0.33	$2,559	$0.37
1998	$68,951	$0.47	$132,851	$0.35	$635	$0.38
1999	$59,015	$0.57	$120,873	$0.36	$987	$0.42
2000	$45,552	$0.49	$78,301	$0.34	$2,831	$0.30
2001	$35,036	$0.41	$79,372	$0.38	$4,138	$0.41
2002	$27,356	$0.38	$34,503	$0.37	$3,853	$0.38
2003	$37,530	$0.46	$42,653	$0.44	$8,678	$0.44
2004	$32,627	$0.43	$38,428	$0.43	$9,639	$0.44
2005	$39,583	$0.51	$82,371	$0.52	$6,880	$0.52
2006	$28,838	$0.77	$50,700	$0.77	$4,737	$0.77

8.1.1.3 Water Bodies

Traditionally, pound nets in the Chowan River landed the greatest portion of the river herring catch each year. Gill nets landed more river herring primarily from the eastern parts of the Albemarle Sound Management Area. Figure 8.3 shows the annual ex-vessel value of river herring from the Albemarle Sound, Chowan River, and all other state water bodies. From 1962 to 1986, the ex-vessel value for landings from the Chowan River showed variability from one year to the next; however, in those years there was an overall increasing trend in the values of landings. Since 1991, only three years have seen total annual ex-vessel landings values greater than $100,000. The years of 2002 to 2004 showed the lowest annual ex-vessel values with the total value of landings from the Chowan River in each year being less than $40,000. Landings values rebounded slightly in 2005 and 2006.

The ex-vessel value of river herring landed from the Albemarle Sound remained fairly constant from 1962 to 1979, with most years' value at less than $30,000. The Albemarle Sound fishery saw increased landings value throughout most years in the 1980's with landings values at or near $100,000 per year from 1982 to 1988. In 1990, the ex-vessel value of landings began to drop and remained roughly in the range of $20,000 to $40,000 each year. This decrease in landings value corresponded with the observed decrease in overall harvest.

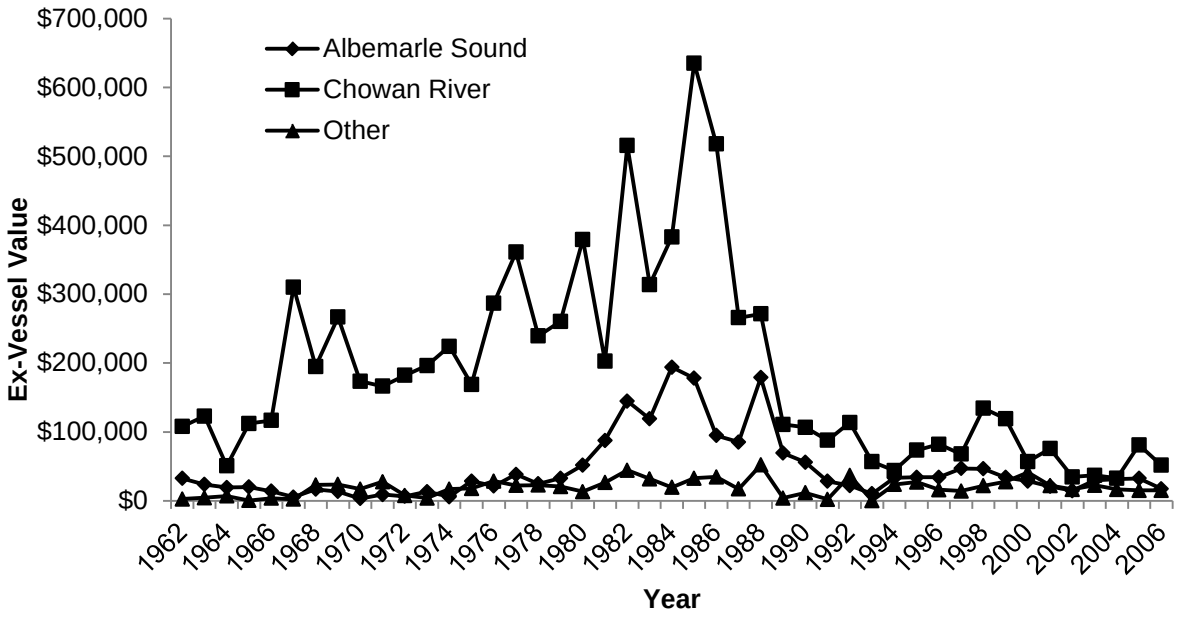


Figure 8.3 Annual ex-vessel landings value (inflated) for river herring from selected water bodies, North Carolina, 1962 – 2006 (NCDMF Trip Ticket Program).

The average price per pound received by fishermen for river herring showed an increasing trend from 1962 to 1990, going from $0.01 per pound in 1962 to $0.15 per pound in 1990 (Figure 8.4). In 1990 as the pounds of river herring landed decreased, the price per pound showed a decrease as well. However, by 1995 the price began to increase dramatically and reached at least $0.40 per pound in all water bodies by 2003. Prices were $0.77 per pound for all water bodies in 2006.

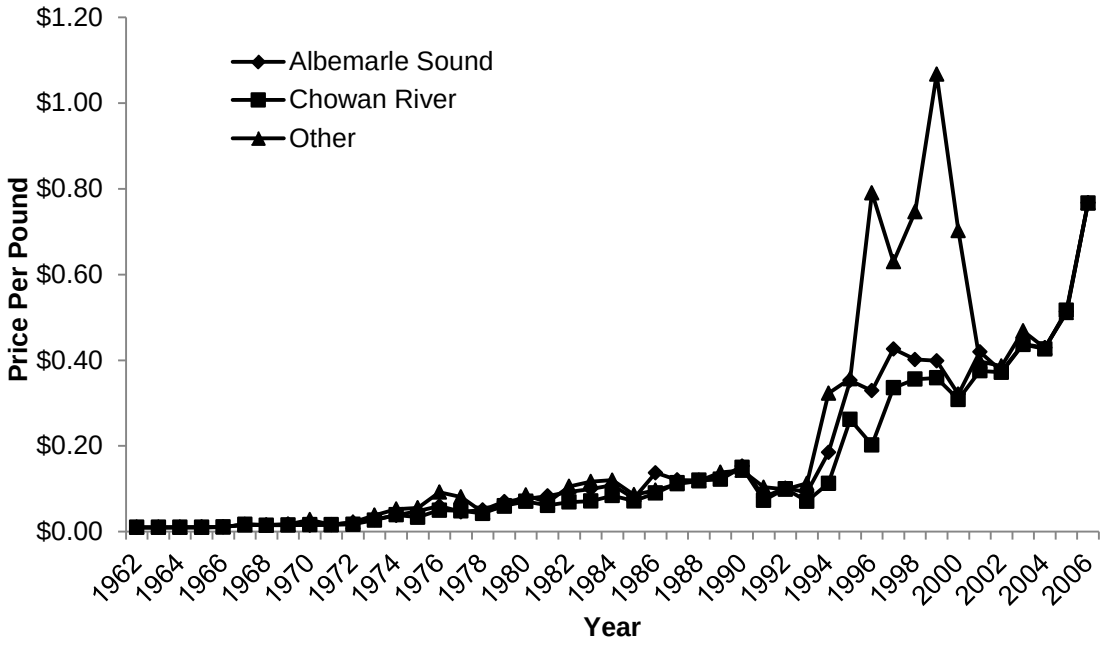


Figure 8.4 Annual average price per pound (inflated) for river herring from selected water bodies, North Carolina, 1962 – 2006 (NCDMF Trip Ticket Program).

8.1.1.4 Participants

The NCDMF trip ticket program enables managers to monitor fishing activity at the trip level, including providing a count of how many people are participating in the fishery. By 1994 the amount of fishing activity for river herring had already been greatly reduced from its historic highs in landings and likely in participation. Table 8.3 shows a decreasing trend in participation with a high in 1996 of 265 fishermen to 99 participants in 2006. The majority of river herring participants in each year have total annual ex-vessel landings values of less than $500 each. Few fishermen in any year have annual ex-vessel landings values of more than $5,000. Two years, 1998 and 1999, saw the greatest number of fishermen landing more than $5,000, those being 14 and 10, respectively.

Table 8.3 Number of participants and annual ex-vessel landings value for river herring, North Carolina, 1994 – 2006 (NCDMF Trip Ticket Program).

Annual Ex-Vessel Value	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
<$25	121	125	144	114	107	100	91	45	54	55	43	45	33
$25 - $100	17	28	41	41	39	37	30	34	31	37	22	29	17
$100.01 - $500	44	32	40	31	33	30	42	37	29	48	36	38	24
$500.01 - $1,000	22	18	12	10	16	7	27	13	16	16	14	11	9
$1,000.01 - $5,000	26	24	22	31	14	20	13	13	14	20	19	14	11
>$5,000	*	5	6	4	14	10	7	9	*	4	*	7	5
Total	*	232	265	231	223	204	210	151	*	180	*	144	99

* Denotes confidential data

Fishermen, especially gill net fishermen, typically catch and sell multiple species from a single trip. River herring accounted for less than 50% of the catch by value for the majority of these fishermen. Most fishermen with river herring landings did not rely on these fish for a major portion of their fishing income during the herring season; approximately 50% of the fishermen derived 20% or less of their total fishing income from river herring. However, the importance of river herring to many of these fishermen was that the fishery occurred primarily in the winter and early spring, a time of year when there are few other opportunities to derive income as a commercial fisherman.

The primary gears used for catching river herring were gill nets and pound nets. Species most typically landed from gill nets along with river herring include catfishes (*Ameiurus* spp. *& Ictalurus* spp.*)*, southern flounder (*Paralichthys lethostigma*), mullet (*Mugil spp.*), white perch (*Morone americana),* and yellow perch (*Perca flavescens)*. Species landed with river herring from pound nets include catfishes, shad (*Alosa* spp.), perches, and striped bass (*Morone saxatilis*).

Figure 8.5 shows the number of participants for each year from 1994 to 2006 who fished for river herring using different gear types. The majority of fishermen who land river herring in each of the years used gill nets. While fewer fishermen used pound nets to land river herring, the numbers of fish they landed resulted in higher overall ex-vessel values than river herring landed in gill nets.

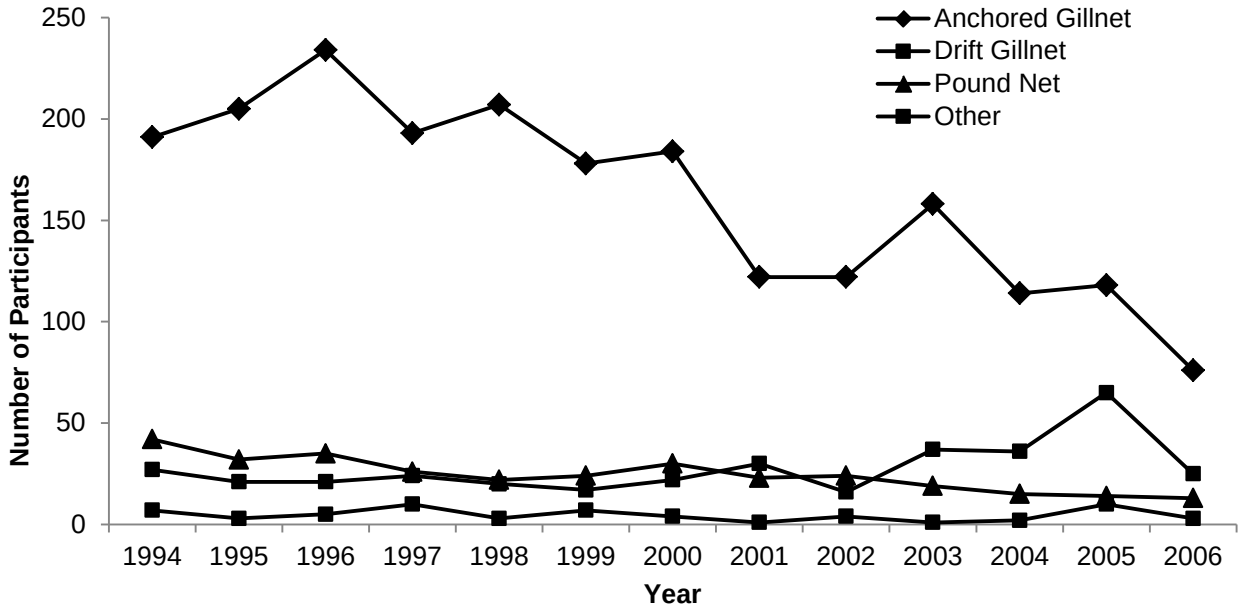


Figure 8.5 Participants in the river herring fishery by gear usage, North Carolina, 1994 – 2006 (North Carolina Trip Ticket Program).

Table 8.4 shows the number of dealers statewide who reported landings of river herring on trip tickets between 1994 and 2006. In 1996, 55 dealers reported landings of river herring. By 2005 the number had declined to 27 dealers. Between 1994 and 1999 about half of all dealers

reported annual river herring landings values of less than $1,000 per year. In most years about 10% of dealers reported river herring landings valued at more than $10,000. Fewer than 6 dealers each year reported landings of more than $10,000.

Table 8.4 Number of dealers and annual ex-vessel landings value for river herring, North Carolina, 1994 – 2006 (NCDMF Trip Ticket Program).

Annual Ex-Vessel Value	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
<$100	25	24	27	24	18	18	19	15	12	12	12	4	7
$100.01 - $500	9	6	11	9	8	6	9	6	7	9	5	5	8
$500.01 - $1,000	5	*	4	*	6	4	4	3	*	5	*	*	*
$1,000.01 - $5,000	10	8	7	12	7	9	10	9	13	11	8	11	4
$5,000.01 - $10,000	*	*	3	*	*	0	*	*	*	*	5	*	3
>$10,000	4	5	3	*	3	4	3	3	*	3	*	4	3
Total	*	46	55	51	*	41	*	*	*	*	34	27	*

* Denotes confidential data

Dare County consistently had the greatest number of dealers reporting landings of river herring on trip tickets, although the trend was towards fewer dealers (Table 8.5). Chowan and Pasquotank were the only two other counties consistently reporting landings of river herring from 1994 to 2006, but many other counties had dealers reporting river herring on trip tickets. The location of the dealer's county is not necessarily an indication of where the fish were caught; rather it is an indication of where the fish were landed. Other counties where dealers reported river herring landings at least one year between 1994 and 2006 included: Beaufort, Bertie, Brunswick, Camden, Carteret, Craven, Currituck, Hertford, Martin, Onslow, Pamlico, Perquimans, Pitt, Tyrrell, and Washington. Many of these additional counties had only one or two dealers reporting river herring landings and many had no dealers reporting landings in some years.

Table 8.5 Number of dealers reporting river herring purchases by county, North Carolina, 1994 – 2006 (NCDMF Trip Ticket Program).

County	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dare	11	12	14	13	11	9	9	9	10	7	7	7	4
Chowan	9	4	3	3	3	3	3	3	3	3	3	3	4
Pasquotank	3	3	5	4	4	3	3	3	3	3	3	3	*
Other	32	27	33	31	26	26	31	23	19	29	21	14	17
Total	55	46	55	51	44	41	46	38	35	42	34	27	*

* Denotes confidential data

8.1.1.5 Processing

Processed river herring products historically have included fresh whole fish, frozen bait, salt herring fillets, salt headless dressed fish, and canned or fresh roe. Unprocessed river herring also are used as bait.

There has been an overall decline in river herring processing activities in North Carolina since 1970 (Table 8.6). The number of processing plants fluctuated between three and seven plants between 1970 and 1982. Since 1982, the trend has been towards a decreasing number of plants processing river herring. Processing activities fell during these years in relation to a sharp decline in landings and due to a lower demand for the product. As of 1998, there has only been one plant in North Carolina processing river herring. As of 2004, NOAA Fisheries reports that the one current operation processes extremely small amounts; however, it is unclear if the herring are caught within the state or imported (Peter Fricke, NOAA Fisheries, personal communication).

The value of river herring processed products increased steadily from $341,384 in 1970 to a peak of almost $1.5 million in 1984 and has decreased ever since. Within a decade, processed product value declined more than 95% from about $1 million in 1985 to less than $55,000 in 1994.

Table 8.6 Employment and processed value for river herring processors, North Carolina, 1970 – 2004 (NOAA Fisheries).

Year	No. Plants	Seasonal Employment	Yearly Employment	Processed Value
1970	5	134	130	$341,384
1971	5	137	137	$825,858
1972	4	137	137	$535,186
1973	5	98	98	$687,066
1974	5	91	91	$1,331,862
1975	5	126	113	$1,299,315
1976	5	105	92	$1,029,151
1977	6	112	104	$601,511
1978	5	110	101	$361,706
1979	4	93	75	$419,177
1980	3	92	75	$515,186
1981	3	69	44	$481,133
1982	7	142	118	$1,044,529
1983	5	99	71	$1,427,178
1984	4	88	60	$1,461,946
1985	6	118	98	$1,027,221
1986	5	120	97	$758,536
1987	5	120	95	$257,207
1988	5	103	85	$428,742
1989	5	86	73	$145,336
1990	3	62	59	$85,526
1991	3	60	56	$103,496
1992	3	61	58	$102,189
1993	3	62	60	$121,600
1994	3	69	66	$54,750
1995	2	76	76	*
1996	2	76	76	*
1997	2	72	72	*
1998	1	*	*	*
1999	1	*	*	*
2000	1	*	*	*
2001	1	*	*	*
2002	1	*	*	*
2003	1	*	*	*
2004	1	*	*	*

* Denotes confidential data

From 1970 to 1997, the processing sector provided full-time and seasonal employment in several communities; however, employment by the river herring processors declined greatly during these years. The decline was primarily related to the decreased availability of raw product. River herring processing employment and processed value data are confidential after 1997 because there was only one processor left in North Carolina (see Table 8.6). According to NOAA Fisheries, the one remaining processor was speculated to have a “special connection to the fishery because the processor is obviously not making any money on the venture” (Peter Fricke, personal communication).

8.1.1.6 Economic Impact of Commercial Fishing

The expenditures and income within the commercial fishing industry in North Carolina produce ripple effects in the state's economy. Each dollar earned and spent within the industry generates a more vigorous economy by stimulating additional activity in other industries that fosters jobs, income, and economic output. These impacts are calculated using IMPLAN, an economic modeling software. This software uses an input-output model to estimate economic impacts as dollars are spent and re-spent in the state economy. In 2006, the commercial river herring industry in North Carolina contributed, directly and indirectly, approximately $137,000 to the state's economy (Table 7.8). These estimates are limited and must be viewed as conservatively low, as they do not include wholesale (seafood dealers), retail, and foodservice sectors due to lack of river herring specific economic data for those sectors.

Table 8.7 Economic impact of the commercial river herring fishery in North Carolina in 2006.

Economic inputs	$84,276
Additional economic activity	$52,547
Total economic impact	$136,823

8.2 SOCIAL IMPORTANCE OF THE FISHERY

8.2.1 Commercial Fishery

8.2.1.1 Historical Importance

Fishing for river herring each spring has been a long-standing tradition in northeastern North Carolina. For most participants, the primary importance of the fishery is more social and cultural than it is economic. Generations of local residents have pulled seines, set small gill nets, and drifted gill nets on the Chowan, Roanoke, Tar, Neuse, and other rivers to catch river herring for fish fry events. These events often served to raise money for a church or civic organization.

8.2.1.2 Community Reliance on the Commercial Fishery

In the past when landings of river herring were at or near their historical highs, many northeastern North Carolina communities relied on the annual runs of river herring for a significant source of economic activity. In 2004, only 35 out of 136 (roughly 26%) fishermen with recorded landings of river herring had an ex-vessel value greater than $500. Since 2007, the commercial harvest of river herring has declined further with the implementation of the discretionary harvest. At current levels, no single community in North Carolina is greatly impacted economically by the value of landings of river herring.

8.2.1.3 Perceived Conflicts, Perception of Important Issues, etc.

The Socioeconomics Program of the North Carolina Division of Marine Fisheries surveys commercial fishermen from various parts of the state. At the time of the writing of this management plan, there are little to no current data for river herring fishermen due to the small number of fishermen that still remain in the fishery. Therefore, it is not possible to address perceived conflicts and other important social issues at this time.

8.2.2 Recreational Fishery

The North Carolina Fisheries Reform Act of 1997 made a distinction between commercial and recreational fishermen in coastal and joint waters. Persons who previously fished with commercial gear, but did not sell their catch were required, starting in 1999, to purchase a Recreational Commercial Gear License (RCGL) license. This license allowed those who previously fished for river herring using a gill net to continue to do so, but with a 100-yard limit on the amount of net that can be used by a single fisherman or up to 200-yards if there are at least two fishermen in the boat, each with an active license. RCGL fishermen are prohibited from fishing using a pound net. River herring are no longer legally harvested by recreational fishermen.

8.2.3 Demographic Characteristics

8.2.3.1 Commercial Fishermen

A specific survey of river herring fishermen was conducted by the NCDMF in 1998 to obtain demographic information on the participants in the Albemarle Sound fishery which was reported in the first North Carolina river herring management plan. That survey indicated the average age of river herring fishermen at the time was 53, with a range of 44 to 59 years. The average fisherman had fished for 20 years and the majority had fished for between 4 and 40 years. The majority of those fishermen had a high school education. As previously mentioned, there are little to no current data for river herring fishermen due to the small number of fishermen that still remain in the fishery.

8.2.3.2 Recreational Fishermen

Demographic information for RCGL river herring fishermen was captured on the 2001 annual survey. The average RCGL fisherman who lands river herring was a little over 49 years old and had been fishing commercial gear for nearly 20 years. Over 88% were born in North Carolina and they had lived in North Carolina an average of nearly 43 years. The majority of RCGL river herring fishermen were married white males. Most had a high school diploma or some college as their highest level of education. The total average household income was between $30,000 and $75,000 dollars.

8.3 Research Recommendations

A socioeconomic analysis on the cumulative effects of a recovery in the river herring stock and fishery could be completed to assess and estimate the possible overall impacts to fishermen and communities who have traditionally relied on the fishery for economic opportunity.

8.4 Definitions

Commercial Fishing – Fishing in which fish harvested, either in whole or in part, are intended to enter commerce through sale, barter or trade. Since 1999, a commercial fisherman in North Carolina is required to have a license issued by the NCDMF and is allowed only to sell to a licensed dealer.

Inflation-adjusted price and value – Inflation is a general upward price movement of goods and services in an economy, usually as measured by the Consumer Price Index (CPI). Ex-vessel prices and values can be adjusted (deflated) according to the CPI to remove the effects of inflation so that the value of a dollar remains the same across years. Inflation adjusted values allow for easier understanding and analysis of changes in values. Some products allow for a Producer Price Index (PPI). The PPI measures inflation in wholesale goods. It is considered a more reliable indicator than CPI because it is related to a specific product or group of products. The PPI is related to the CPI in that PPI is considered a precursor to CPI because fluctuations in production costs are usually associated with general measures of inflation.

Fishing Trip – A period of time over which fishing occurs. The time spent fishing includes configuring, deploying, and retrieving gear, clearing animals from the gear, and storing, releasing or discarding catch. When watercraft are used, a fishing trip also includes the time

spent traveling to and from fishing areas or locales and ends when the vessel offloads product at sea or returns to the shore. When fishing from shore or man-made structures, a fishing trip may include travel between different fishing sites within a 24-hour period.

Nominal (Ex-vessel) Price and Value - The total landed dollar amount of a given species (or species landing condition and market category). Example: 100 lbs. of river herring at a PRICE of $0.43 per pound will have a VALUE of $43. These values represent the amounts paid to a fisherman by a seafood dealer.

Recreational Fishing – A recreational fishing trip is any trip for the purpose of recreation from which none of the catch is sold or bartered. This includes trips with effort but no catch. Fishermen who wish to use limited amounts of commercial fishing gear in joint and coastal waters under North Carolina Division of Marine Fisheries jurisdiction are required to have a Recreational Commercial Gear License (RCGL).

9.0 ENVIRONMENTAL FACTORS

9.1 Habitat

River herring utilize a variety of habitats as described in the life history section with variations in habitat preference due to location, season, and ontogenetic stage. Anadromous river herring use several habitats over the course of their life cycle varying from fresh inland water to estuaries and the coastal ocean. River herring are found in most habitats identified by the North Carolina Coastal Habitat Protection Plan (CHPP) including: water column, wetlands, submerged aquatic vegetation (SAV), soft bottom, hard bottom, and shell bottom (Deaton et al. 2010). Each habitat is part of a larger habitat mosaic, which plays a vital role in the overall productivity and health of the coastal ecosystem. Although river herring are found in all of these habitats, the usage varies by habitat. Additionally, these habitats provide the appropriate physicochemical and biological conditions necessary to maintain and enhance the river herring population. Limburg and Waldman (2009) have shown that the loss of habitat contributes to the decline in anadromous fish stocks throughout the world. Therefore the protection of each habitat type is critical to the recovery and sustainability of the river herring stock. Information on the ecological value of each of these habitats to river herring and their current condition is provided below.

Successful restoration, recovery, and maintenance of river herring populations in all coastal river systems cannot occur unless the extent and quality of all the required habitats are maintained or restored. Parameters which are important for defining the quality of habitats used by river herring and their prey include dissolved oxygen (DO), temperature, salinity, current velocity, flow delivery pattern and timing (for spawning reaches), and prey abundance. In-stream DO concentrations greater than 5 milligrams per liter (mg/l) are recommended for all life stages of river herring (Funderburk et al. 1991).

Coastal basins with historical or potential river herring spawning, nursery, and adult/subadult habitats which are situated wholly or primarily in North Carolina are: Albemarle Sound and its tributaries, the major ones being the Chowan and Roanoke rivers; Pamlico Sound and its tributaries, with the Neuse and Tar/Pamlico rivers the largest; the Newport River; the White Oak River; the New River; the Cape Fear and Northeast Cape Fear rivers; and the Shallotte River. Additional North Carolina rivers which enter the Atlantic Ocean in South Carolina also host river herring populations. These include the Pee Dee River and its tributaries, the Waccamaw and Lumber rivers.

9.1.1 Water Column

Water column habitat is defined as “the water covering a submerged surface and its physical, chemical, and biological characteristics” (Deaton et al. 2010). River herring migrate from the ocean, enter coastal bays and sounds through inlets, and ascend into freshwater rivers and streams to spawn, traveling further upstream in wet years and remaining downstream in dry years. Surviving adults then return to the ocean after spawning. The young-of-the-year fish use rivers and estuaries as nursery grounds as they migrate downstream after hatching. After the juveniles leave the rivers and estuaries in the fall or early winter, they complete their development in the Atlantic Ocean, over the continental shelf off New England (Loesch 1987; Jenkins and Burkhead 1994). The two species occur geographically together from New Brunswick and Nova Scotia in Canada south to the northern coastal area of South Carolina. Blueback herring occur further south, to northern Florida. There are important life history

differences between the two species (Loesch 1987). Alewife select slower-flowing areas for spawning, with blueback herring reported to select faster-flowing sites in areas where both species occur; however such areas generally do not exist in the FMP management area. Smith (2006) found alewife eggs only on one of the high water velocity creeks (Town Creek) in the Tar River basin, but found very few river herring eggs overall. River herring are known to use the water column for spawning, forage, and development. Some species of anadromous fish (e.g. Pacific salmon and sea lamprey) are known to use olfactory cues to home to their natal spawning grounds (Dittman and Quinn 1996; Vrieze et al. 2010). Other anadromous fish experts suggest that these findings are also true for river herring (Rulifson et al 2012; Zapf 2012). Ross and Biagi (1990) state that it appears olfactory cues are the primary means for homing behavior in alewife. Several tagging and otolith microchemistry studies have shown evidence that river herring will return to natal waterbodies to spawn and then return to spawn in subsequent years (Jessop 1994; Messieh 1977; Rulifson et al. 2012, Zapf 2012). Any alterations (i.e. water quality degradation) to these cues could erase river herring's ability to find their natal spawning grounds. For more information regarding water quality requirements refer to Section 5: Life History.

9.1.2 Soft Bottom

Soft bottom habitat is defined as "unconsolidated, unvegetated sediment that occurs in freshwater, estuarine, and marine systems" (Deaton et al. 2010). The soft bottom habitat is separated into freshwater, estuarine, and marine habitats due to differing geomorphology, sediment type, water depth, hydrography, and/or salinity regimes (Deaton et al. 2010). Underlying geology, basin morphology, and physical processes influence the physical and chemical makeup of the soft bottom habitat, which may influence river herring distribution. In general, coarse sands are concentrated along high-energy and eroding shorelines, while fine muds are concentrated along low-energy shorelines and deepwater basins (Riggs et al. 1996; Wells 1989).

Soft bottom plays an important role in the functionality of estuarine systems, acting as both a source and sink for nutrients, chemicals, and microbes. Natural and human-induced nutrients and toxins are trapped and reprocessed in soft bottom areas through intense biogeochemical processes. The fate of these materials depends strongly on freshwater discharge, density stratification, and salt wedge formation (Matson and Brinson 1985; Matson and Brinson 1990; Paerl et al. 1998). In North Carolina, an abundance of nutrients and organic matter are stored in soft bottoms. These materials are processed both within the sediments and from the sediments into the overlying water column through microbial processes. Increased nutrient and organic inputs exacerbate microbial activity, often leading to declining dissolved oxygen concentration, potentially affecting the distribution of river herring within this habitat. Pardue (1983) suggested that substrates with 75% silt that contained detritus and vegetation were optimal for egg and larval habitat for both alewife and blueback herring (Greene et al. 2009).

9.1.3 Submerged Aquatic Vegetation

Submerged aquatic vegetation (SAV) habitat is "bottom that is recurrently vegetated by living structures of submerged, rooted vascular plants (i.e. roots, rhizomes, leaves, stems, propagules), as well as temporarily unvegetated areas between vegetated patches" (Deaton et al. 2010). SAV occurs in both subtidal and intertidal zones, and is generally separated into two types of communities: high salinity estuarine communities including species such as eelgrass (*Zostera marina*) and shoalgrass (*Halodule wrightii*), and low salinity/freshwater communities

including species such as wild celery (*Vallisneria americana*) and sago pondweed (*Potamogeton pectinatus*). Eurasian water milfoil (*Myriophyllum spicatum*), although non-native, is also an important component of the low salinity/freshwater SAV community, especially in the northeastern waters of North Carolina. River herring have been known to use SAV for refuge, as a nursery area, and for foraging (Olney and Boehlert 1988; Boger 2002; Greene et al. 2009; Deaton et al. 2010).

The spatial structure of SAV habitat can be quite variable, ranging from small isolated patches of plants less than a meter in diameter to continuous meadows covering several acres (Street et al. 2005). By nature, the extent of SAV coverage tends to fluctuate on the scale of days to decades, depending on species and physical conditions (Fonseca et al. 1998). In addition, SAV abundance, biomass, and species composition in North Carolina waters varies seasonally with changes in temperature and light conditions (Dawes et al. 1995; SAFMC 1998). The MFC and the North Carolina Coastal Resources Commission (NCCRC) redefined the definition of SAV to encompass both the seasonal and spatial complexity of this habitat. This rule defines SAV habitat as areas that have had one or more species of high or low salinity present over the past 10 growing seasons (15A NCAC 03I .0101). Under current NCMFC rule, SAV habitat is designated as a Fish Habitat Area [NCMFC rule 15A NCAC 03I .0101 (b)(20)].

The ecological services SAV provides maintain and enhance the overall functionality of estuaries and coastal rivers. The above- and below-ground structures of SAV modify wave energy regimes, stabilize sediments and adjacent shorelines, and cycle nutrients within the system (SAFMC 1998; Thayer et al. 1984). These processes generally increase water clarity, decrease the frequency of nuisance algal blooms, and promote conditions favorable for growth and expansion of SAV (Thayer et al. 1984). Furthermore, because of their high rate of primary production, SAV is an important source of organic matter. The large quantities of organic material produced by SAV support the base of a complex food web necessary for the maintenance of fish and invertebrate populations (Thayer et al. 1984; Hurley 1990; Laney et al. 2007; SAFMC 1998).

In addition to their importance to ecosystem function, SAV also provides crucial structural habitat for fishes and invertebrates. The three dimensional structure of SAV affords a surface for epiphytic algae and animals to attach to, as well as a safe area for refuge and foraging for a number of species of fishes and invertebrates (SAFMC 1998). Additionally, SAV coverage provides a safe corridor for movement of fishes and invertebrates between adjacent foraging habitats (Irlandi and Crawford 1997; Micheli and Peterson 1999). SAV has also been shown to harbor higher or equivalent densities, growth, and survival of nekton compared to adjacent salt marshes, and higher densities, growth, and survival of nekton as compared to macroalgae, oyster reefs, or soft bottom habitats.

9.1.4 Shell Bottom

Shell bottom is defined in the CHPP as “estuarine intertidal or subtidal bottom composed of surface shell concentrations of living or dead oysters (*Crassostrea virginica*), hard clams (*Merceneria merceneria*), and other shellfish” (Deaton et al. 2010). There are no documented articles showing river herring utilization of shell bottom. Although river herring are not documented using shell bottom, they can benefit from the improved water quality that is provided by live oysters and clams.

9.1.5 Hard bottom

Hard bottom habitat is defined in the CHPP as “exposed areas of rock or consolidated sediments, usually colonized by a thin veneer of live or dead biota, and generally located in the ocean rather than in the estuarine system” (Deaton et al. 2010). However riverine hard bottom also occurs near the fall lines of coastal rivers. Some reports have stated that alewife spawning habitat can include gravel or coarse stone habitats in (Mansueti and Hardy 1967; Edsall 1970; Jones et al. 1978; Jones and Thompson 1978). In the Rappahannock River, Virginia, Boger (2002) identified spawning areas for alewife that consisted of primarily sand, pebbles, and cobbles.

9.1.6 Wetlands

Wetlands are defined as “areas that are inundated or saturated by an accumulation of surface or groundwater at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (federal regulations [40 CFR 230.3(t)]; Environmental Management Commission (EMC) rules [15A NCAC 2B .0202(71)]; Deaton et al. 2010). Wetlands are considered one of the most biologically productive ecosystems on Earth (Teal 1962). The primary productivity associated with wetlands is converted into secondary production of fishes, and invertebrates through detrital and microalgal pathways (Peterson and Howarth 1987). In coastal regions, wetlands typically are found in both estuarine and freshwater areas. Estuarine wetlands are tidal in nature and generally occur in low energy environments of bays, sounds, and rivers in polyhaline and mesohaline waters. Freshwater wetlands, including freshwater marshes, bottomlands hardwood forest, and swamp forests, generally occur in low-salinity to freshwater areas of creeks, streams, and rivers. River herring will utilize wetland habitat for nursery habitat, foraging, refuge, and spawning (Deaton et al. 2010).

9.2 HABITAT DESIGNATIONS AND STRATEGIC HABITAT AREAS

All of the above habitats play critical roles at various life states of river herring for their survival. Maintaining high habitat quality for managed fish species is of so much concern to the U.S. Congress, that they mandated the appropriate federal management agencies to define habitats vital to fish, with a view towards facilitating their increased protection. The North Carolina General Assembly also recognizes the importance of habitat quality, as illustrated through the creation of the Clean Water Management Trust Fund (CWTF) to conserve land, the Fisheries Reform Act to restore and enhance fish habitat, and other actions. In the past the CWTF had a budget of up to $100,000,000, but in the past two years (2011 and 2012), the budget has been dramatically reduced to less than $50,000,000. Some habitat areas have been designated by state agencies due to their exceptional condition and/or importance for aquatic life. The North Carolina Environmental Management Commission (NCEMC) has designated various waters of the state as Outstanding Resource Waters (ORW); the NCMFC has designated coastal waters and wetlands as Primary (PNA) and Secondary Nursery Areas (SNA) and Anadromous Fish Spawning Areas (AFSA); and the NCWRC has designated Primary Nursery Areas in inland waters (PNA) and AFSAs.

Anadromous fish spawning areas are defined as “those areas where evidence of spawning of anadromous fish has been documented by direct observation of spawning, capture of running ripe females, or capture of eggs or early larvae” (NCAC 3I.0101 (20) MFC 2005). These areas were geographically designated in rule in 2008. Anadromous nursery areas are defined as

“those areas in the riverine and estuarine systems utilized by post-larval and late juvenile anadromous fish” (NCAC 3I.0101 (20) (D) MFC 2005).

Strategic Habitat Areas (SHAs) are defined in the CHPP as “Specific locations of individual fish habitats or systems of fish habitats that have been identified to provide exceptional habitat functions or that are particularly at risk due to imminent threats, vulnerability, or rarity. These may include areas previously delineated by other state or federal agencies (Areas of Environmental Concern (AEC), Habitat Areas of Particular Concern (HAPCs), Outstanding Resource Waters (ORWs), for example), or others as deemed necessary in an approved CHPP. Strategic Habitat Areas allow for site-specific management measures to be recommended.” While all fish habitats are necessary for sustaining viable fish populations, some areas may be especially important to fish viability and productivity. Protection of these areas would therefore be a high priority (Street et al. 2005). During the SHA identification process, key species for a region are taken into account. In 2009, the MFC nominated and approved SHAs for the sounds and tributaries of Albemarle, Currituck, Roanoke, and Croatan sounds and the nearshore Atlantic Ocean (Figure 9.1). The SHA Advisory Committee identified anadromous fish as one of the key species in Region 1 leading to approximately 75 % of the AFSA in Region 1 being approved as SHAs (NCDMF 2009). The SHAs for the Pamlico Sound, Tar and Neuse rivers and the associated tributaries were approved in 2011. In development of Region 2 (Figure 9.2), the SHA Advisory Committee did not identify river herring as a key species, but AFSA and river herring were discussed during the expert corroboration (NCDMF 2011). SHAs covering the rest of the state are expected to be completed within the next two years.

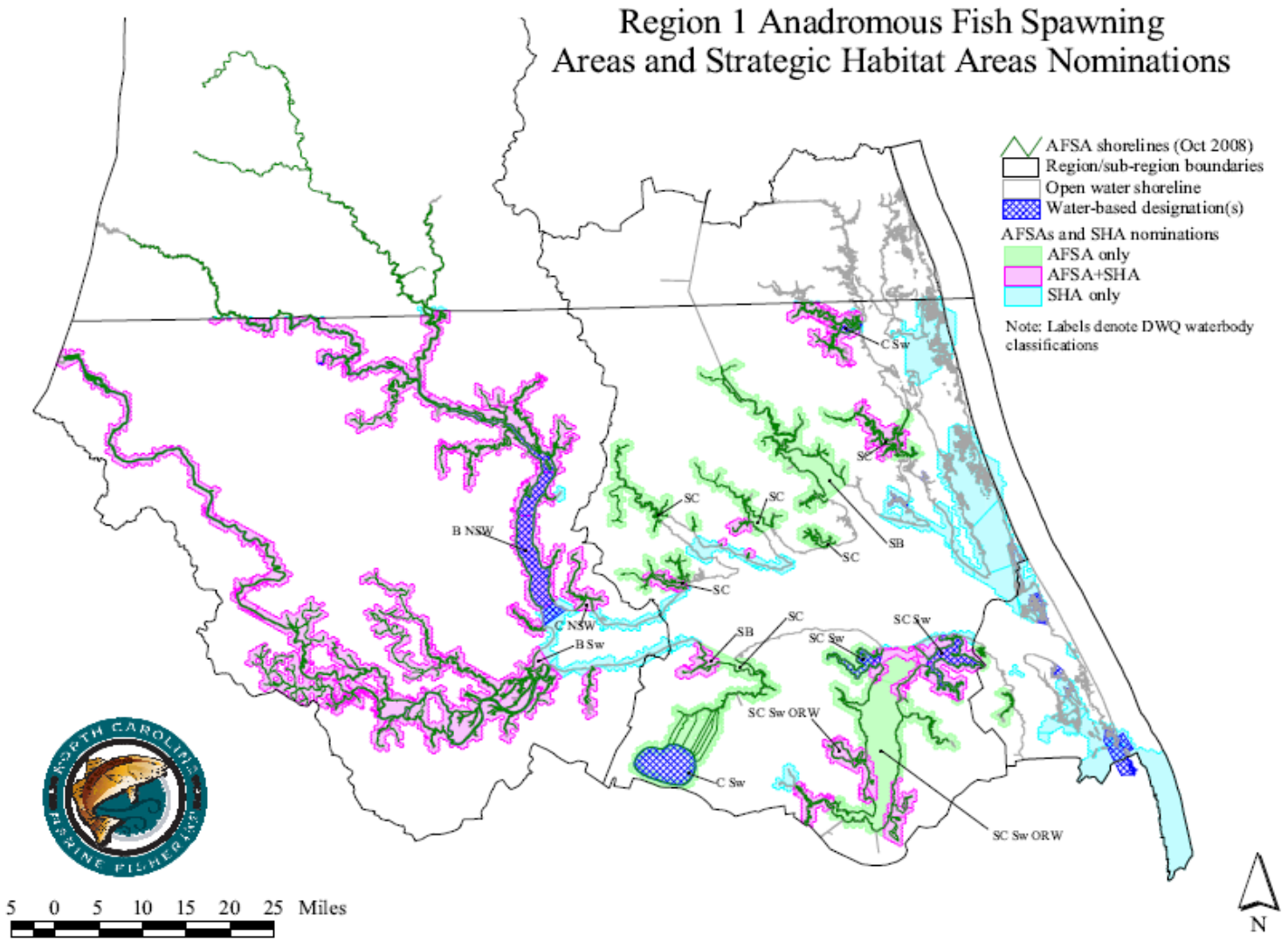


Figure 9.1 North Carolina Region 1 (Albemarle Sound and tributaries) Strategic Habitat Areas and Anadromous Fish Spawning Areas.

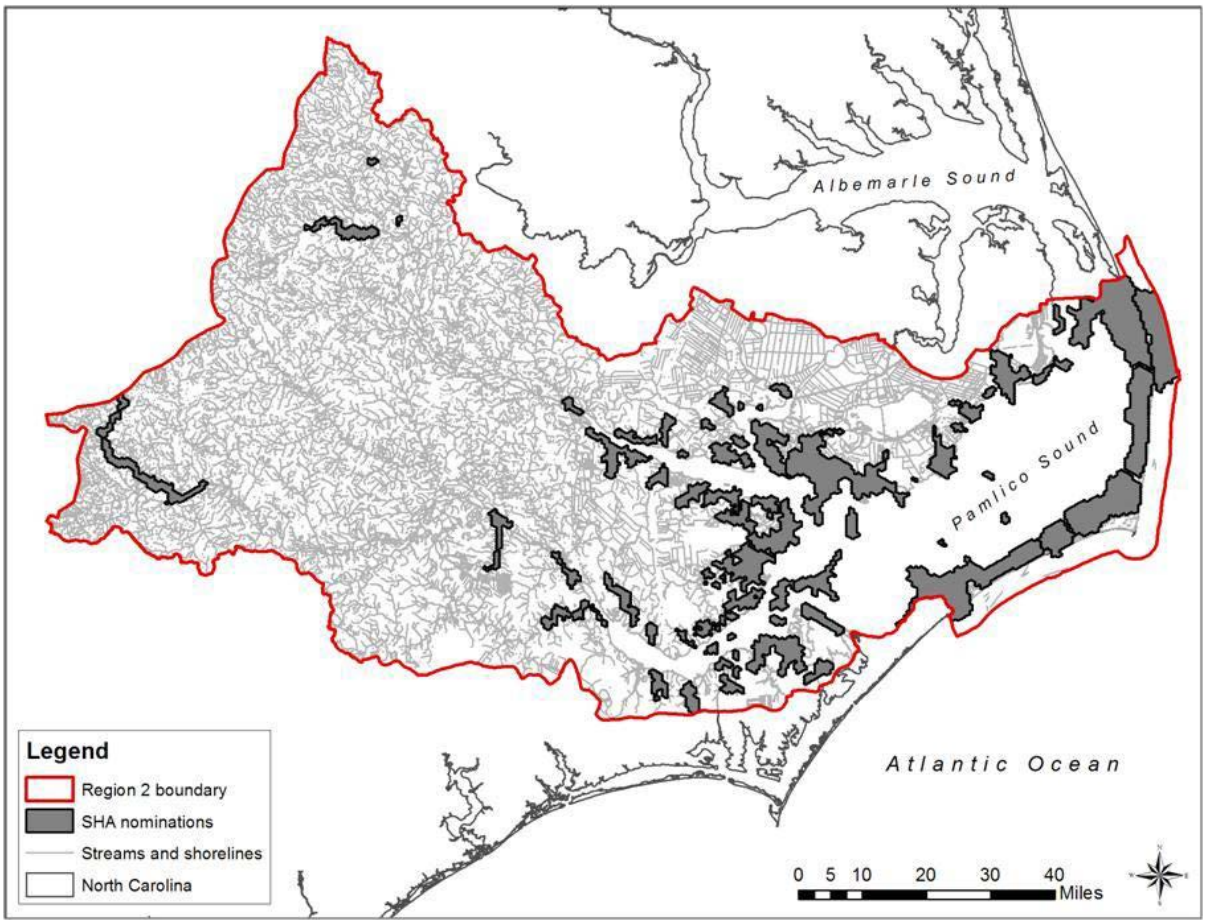


Figure 9.2 Region 2 Strategic Habitat Area nominations.

9.3 FEDERAL ESSENTIAL FISH HABITAT

Within the 1996 amendment to the Magnuson-Stevens Fishery Conservation and Management Act (also known as the Sustainable Fisheries Act), Congress defined Essential Fish Habitat (EFH) for species managed by the NMFS and the federal Regional Fishery Management Councils as follows (USDOC 1996): “The term “essential fish habitat” means those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity.” [16 U.S.C. 1802, Section 3, 104-297] The U.S. Secretary of Commerce was instructed to: “...within 6 months of the date of enactment of the Sustainable Fisheries Act, establish by regulation guidelines to assist the Councils in the description and identification of essential fish habitat in fishery management plans (including adverse impacts on such habitats) and in the consideration of actions to ensure the conservation and enhancement of such habitats.” [16 U.S.C. 1855, Section 305, 104-297(b)(1)(A)]. Congress further mandated that the federal Fishery Management Councils**:** “...shall comment on and make recommendations to the Secretary [of Commerce] and any Federal or State agency concerning any such activity that, in the view of the Council, is likely to substantially affect the habitat, including essential fish habitat, of an anadromous fishery resource under its authority.” [16 U.S.C. 1855, Section 305, 104-297(b)(3)(B)]. The Atlantic States Marine Fisheries Commission has an interstate fisheries management plan for river herring (ASMFC 2009). This document describes Essential Fish

Habitat for river herring in terms of habitats used for spawning, nursery, and as a migration corridor. These areas will be covered by delineation of anadromous fish spawning and nursery habitats, as a step in the SHA location process.

9.4 HABITAT PROTECTION STATUS

Habitats may receive various levels of protection as a result of 1) placement in some form of permanent private (conservation easement) or public (national fish hatchery, national wildlife refuge, national park, state game land, state park) ownership; 2) receiving special designation which highlights their value and may require a higher level of scrutiny of any proposed uses (PNAs, AFSA, ORW, EFH); or 3) requiring a federal or state permit for certain types of development (CAMA permit in coastal counties, Clean Water Act Section 404 permit in wetlands, Clean Water Act Section 401 Water Quality Certification in all waters, Clean Water Act Section 402 NPDES permit for all wastewater discharges).

Some habitats which are in public ownership and completely protected from future development provide spawning and nursery habitats for river herring. These habitats include spawning and nursery areas located in federal national wildlife refuges and within the boundary of Edenton National Fish Hatchery. River herring are documented to use portions of Roanoke River National Wildlife Refuge, Alligator River National Wildlife Refuge, Mattamuskeet National Wildlife Refuge, Pocosin Lakes National Wildlife Refuge, and Cape Hatteras National Seashore. Many kilometers of shoreline habitat are protected by NCWRC Gamelands, specifically Chowan Swamp Gamelands, Bertie Gamelands, and Lower Roanoke River Wetlands Gamelands. The USFWS is currently creating an inventory of all the refuges where river herring can be found. Habitats located within the boundaries of state parks also should remain protected from future impacts. The Pocosin Lakes National Wildlife Refuge is in the process of exploring expansion of the Refuge by almost 11,000 acres. The private sector can also purchase land through grants such as the Clean Water Trust Fund, which has not funded a land conservation project since prior to 2009 in an area that would protect historical river herring habitat.

The Center for Geographic Information in North Carolina has created GIS coverage of protected lands in North Carolina. The coverage includes lands owned and managed by federal, state, county, and municipal governments, as well as conservation organizations, other nonprofit organizations, and land trust properties. However, it does not include lands with restoration cost-share agreements in the State's Wetland Reserve Program. Figures 5.1– 5.3 in the life history section show these protected areas relative to Anadromous Fish Spawning Areas.

Following an initial request by the NCDMF the NCWRC has designated PNAs in inland waters in coastal North Carolina which may serve as spawning and/or nursery habitats for river herring. These areas were established through extensive survey sampling conducted by NCDMF personnel. These areas need to be maintained, as much as possible, 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 (NCAC T15A:10C.0501). The inland waters designated include: Broad Creek, Deep Creek and Lutz Creek- tributaries to North River; East Lake and Little Alligator River-tributaries to Alligator River; Martin Point Creek (Jean Guite Creek), Tull Creek and Tull Bay- tributaries to Currituck Sound (NCAC T15A:10C.0503); Duck Creek, Bath Creek, Mixon Creek, Porter Creek, Jordan Creek, right prong of South Creek, Strawhorn Creek, Muddy Creek, Bond Creek, Tooley Creek, Jacobs Creek, Jacks Creek – tributaries of the Tar-Pamlico; Slocum Creek, Hancock Creek – tributaries of the lower Neuse River; French Creek, Upper New River – New River estuary (Figures 5.1 – 5.3). In addition, the NCWRC has later

designated mainstem segments of the Roanoke, Tar, Neuse, and Cape Fear rivers as Primary Nursery Areas.

The degree to which remaining habitats not in public ownership or without special designations may be protected during federal or state permit review programs is totally dependent on the degree to which the regulatory agencies are willing to incorporate the recommendations of fishery management agencies, the commitment of permit applicants to effectively implement such recommendations, and the ability and will of management agencies to conduct follow-up studies and request regulatory agencies to enforce compliance when violations are documented.

Further protection for river herring spawning and nursery habitats may be achieved through implementation of nonregulatory management measures which result in the restoration of function to habitats historically used by the species. One such example is the Edenton Bay Watershed Restoration Plan, a plan spearheaded by the North Carolina Office of the Environmental Defense Fund (EDF). Partners in the plan include Chowan County, the Town of Edenton, Albemarle RC & D Council, North Carolina Division of Soil and Water Conservation, North Carolina Division of Marine Fisheries, North Carolina State University, the University of North Carolina at Wilmington, and the U.S. Fish and Wildlife Service. The purpose of the plan is to initiate a multi-phase, multi-funded, integrated watershed restoration program focused on the restoration of water quality and watershed integrity necessary to restore the historic river herring fishery of Edenton Bay (Rader 1998). Portions of the plan included the restoration of riparian forests, reducing non-point discharges, and protection of the existing riparian forested wetlands. Groups should look to reports such as McNaught et al. (2010) Chowan Basin Restoration plan for areas that should be restored or conserved. Additional regulatory or nonregulatory management actions should be taken to enhance habitat and water quality conditions in and downstream of spawning areas.

9.5 WATER QUALITY

The water quality of coastal rivers in North Carolina has been monitored for many years, but few studies have attempted to document the effects of water quality on river herring. NCDMF collects water quality data with every sample that is collected. Parameters measured include dissolved oxygen, temperature, salinity and conductivity. They also collect pH in some programs. In 2009, NCDMF began a water quality monitoring program, deploying up to 14 datasondes in the creeks and rivers around Albemarle Sound. The datasondes remain in place for up to two months and run continuously, collecting measurements once an hour of dissolved oxygen, temperature, conductivity and pH (see Section 6.0 for more details). The purpose of this program is to monitor water conditions in the river herring spawning areas, but the data can also be used in the event of a fish kill or other unusual occurrence. Rulifson (1994) listed poor water quality, including chemical pollution, turbidity, and low dissolved oxygen as a concern in relation to the decline in river herring stocks. The few studies that have investigated this relationship have focused on the Chowan River basin. The Chowan River has experienced serious water quality problems which resulted in nuisance algal blooms and fish kills throughout the 1970s and early 1980s (Stanley 1992). During this time period, there were only three major industrial discharges within the basin: United Piece Dye Works (UPDW) textile plant at Arrowhead Beach, Farmer's Chemical fertilizer plant at Tunis, and Union Camp Corporation paper mill at Franklin, Virginia (NCDWQ 1997a). Otherwise, the basin had little urban development and was dominated by forest and agriculture, which combined to make up 89% of the land cover (McMahon and Lloyd 1995). The Chowan River-Dismal Swamp Basin in Virginia

is mostly rural with approximately 64% of its land covered by forest (source: **http://www.deq.state.va.us/wqa/ir2004.html**, November 2005). Cropland and pasture make up another 28%, while only about 6% is classified as urban. The extensive ditching for agricultural and forestry through uplands and wetlands leads to altered hydrology and greater runoff.

Due in part to nutrient inputs from these discharges, as well as non-point sources, the Chowan River was the first coastal river in North Carolina to experience major eutrophication problems. This situation ultimately led to the designation of the Chowan River as Nutrient Sensitive Waters by the North Carolina Environmental Management Commission (NCEMC) in 1979, providing a legal basis for limiting nutrient inputs into the system (NCDWQ 1997a). As a result of this designation, a number of multi-disciplinary studies and water quality management programs were initiated within the basin. Water quality management plans including the Chowan/Albemarle Action Plan (NCDEM 1982a) and the Chowan River Water Quality Management Plan (NCDEM 1982b) were implemented, targeting nutrient reductions. In 1982, the goals of the Chowan River Water Quality Management Plan included a 30 to 40% reduction in phosphorus and a 15 to 25% reduction in nitrogen (NCDWQ 1997a). The fertilizer plant at Tunis has since closed, although seepage from waste ponds still located on the property is of concern. Both the paper mill and textile mill have implemented technological and process changes to improve the quality of their discharges. All of the municipal wastewater treatment facilities located in the basin have converted to land application operations in order to reduce the input of nutrients directly into surface waters. In addition, to combat non-point source inputs, agricultural best management practices (BMPs) are now used to reduce nutrient, sediment, and pesticide runoff from many of the farms in the basin.

Nitrogen inputs into the Chowan River from point sources declined 92% between 1982 and 1997, with only one discharger, UPDW, still discharging a significant amount of nitrogen during that time. Most of the nitrogen from UPDW was tightly bound in the inorganic dyes in a form which is not biologically available. The DWQ renewed the UPDW discharge permit in 1998, continuing to allow a nitrogen discharge of 20 mg/l until 2003, at which time the nitrogen limit was lowered to 5.5 mg/l. As of 2005, UPDW is the only major permitted discharger in the North Carolina portion of the Albemarle watershed. However, there are numerous minor permitted discharges in the Albemarle watershed. Both types of dischargers are prevalent elsewhere in coastal North Carolina (Figure 9.3).

Between 50 and 75% of the nitrogen and 64 to 84% of the phosphorus flowing into the Chowan River in North Carolina comes from agricultural sources. In the lower river, an additional 30 to 37% of the nitrogen and 20 to 25% of the phosphorus comes from atmospheric deposition (NCDWQ 1997a). Estimates of nutrient sources and loads in Virginia, comprising 76% of the Chowan watershed, were unavailable at the time of this writing.

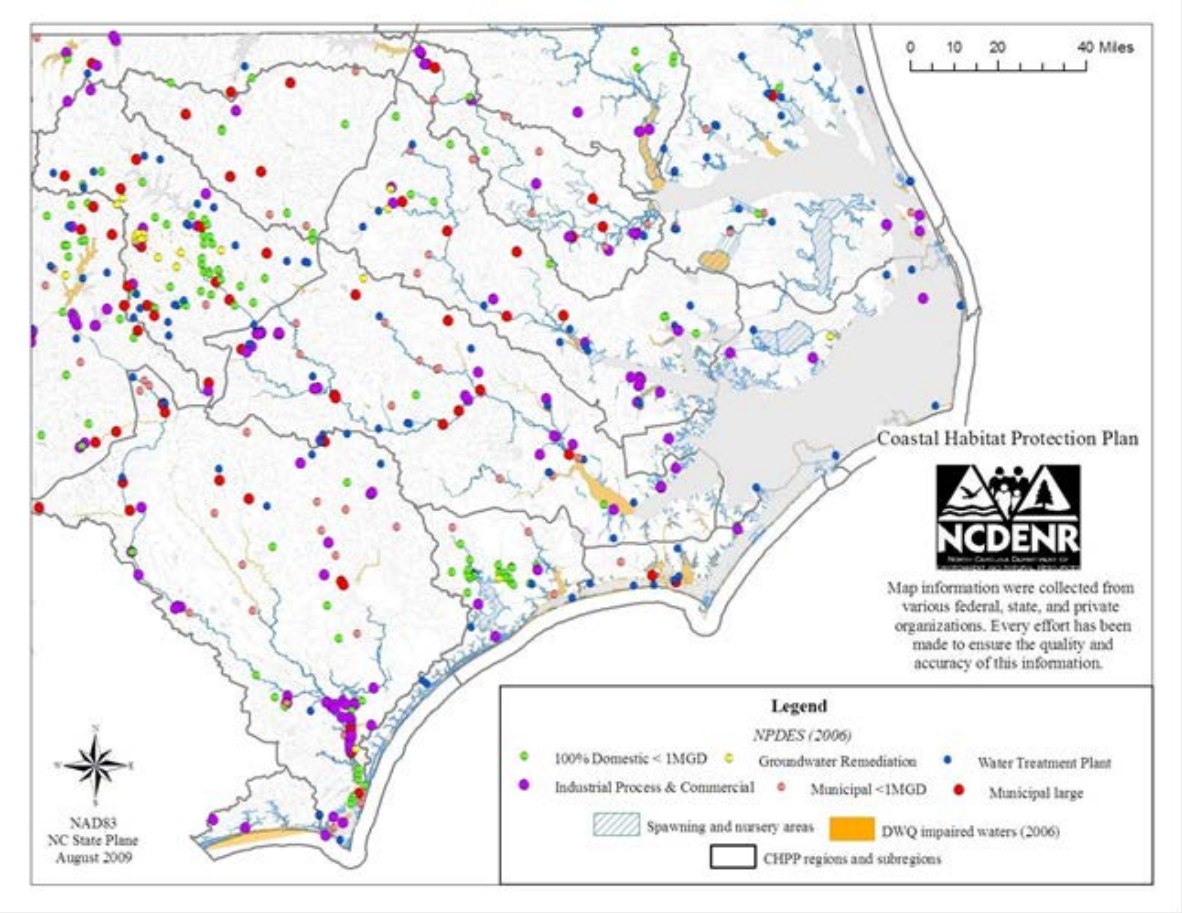


Figure 9.3 Location of NPDES permits (NCDWQ data) relative to fish spawning and nursery areas.

Use estimates for the Virginia portion of the Chowan watershed indicate, however, that there is less agricultural land and more forested land than in the North Carolina portion (source: **http://www.deq.state.va.us/wqa/ir2004.html**, November 2005). There are also fewer NPDES discharges in the Virginia portion of the Chowan watershed (Source: **http://gisweb.deq.virginia.gov/deqims/2004irgis.zip**, November 2005).

Water quality assessment results for the Albemarle watershed are conducted annually by the North Carolina Division of Water Quality (NCDWQ) and Virginia Department of Environmental Quality. They use a variety of data, including ambient water quality monitoring data collected monthly and biological community data. These data are used to determine if the monitored water bodies are supporting their basic uses – the most basic being aquatic life. Use support ratings identify water bodies in the Albemarle Sound area as impaired. These areas include Albemarle Sound, Alligator River (copper and dioxin) and Roanoke River (low dissolved oxygen) (**http://portal.ncdenr.org/c/document_library/get_file?uuid=9d45b3b4-d066-4619-82e6-ea8ea0e01930&groupId=38364**, accessed June 2013) (Figure 9.4). The next update of impaired waters will be in 2014. In 2012 the United States Geological Society (USGS) partnered with Albemarle Pamlico National Estuary Partnership (APNEP) to catalogue monitoring and research programs relevant to the Albemarle Sound and its tributaries and how they compare to national standards. Once gaps have been identified the partnership will strive to fill these voids by augmenting state water quality monitoring programs. The report was under

review in June 2013 but it found gaps in some of the larger water bodies and the USGS will perform two years of one time sampling to add information to these gaps (M. Moorman, USGS personal communication, 2013).

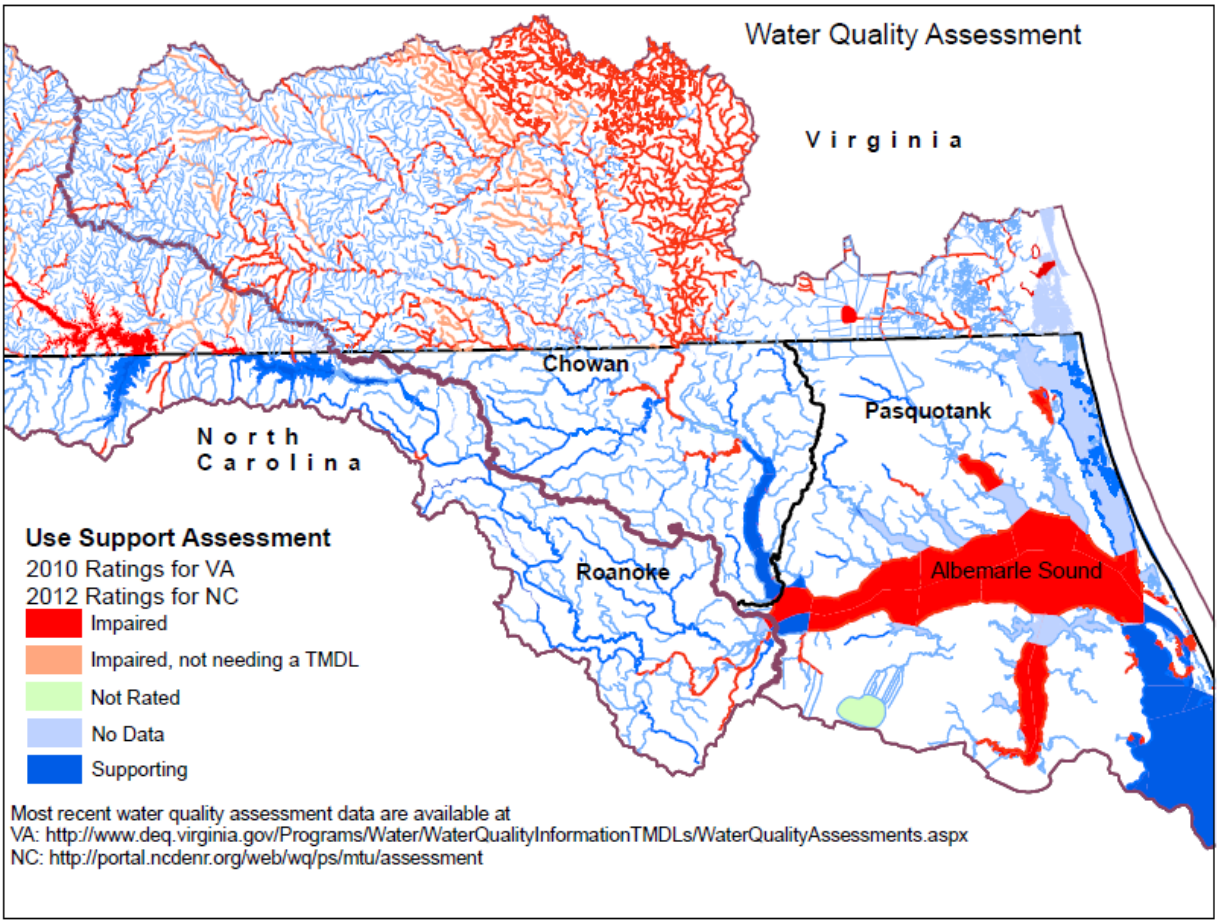


Figure 9.4 Water quality use support assessment for Albemarle Sound area including Virginia (2010) and North Carolina (2012).

The role and impact of atmospheric nitrogen deposition in coastal estuaries in general and North Carolina in particular (Paerl 1995; Paerl et al. 1999) had been a concern since the 1990s. Increases in deposition of atmospheric nitrogen to sensitive estuarine and coastal waters appear to have contributed to accelerating algal production (eutrophication) and water quality declines (hypoxia, toxicity, and fish kills) (Paerl et al. 1999). Although atmospheric nitrogen is derived from a variety of sources, including urbanization as well as agricultural and industrial growth, recent increases in the North Carolina Coastal Plain are a direct result of the substantial increase in livestock operations and their associated nitrogen-rich (ammonia) wastes. The number of hogs has remained above 9,000 head since 2001 (**http://www.ncagr.gov/stats/facts/Hogs.pdf accessed August 2012**). Both the increase in, and changes in proportions of, nitrogen sources play roles in the structuring of estuarine and coastal algal communities, and may promote major biotic changes, including the proliferation of nuisance blooms (Paerl et al. 1999). The impacts from large-scale livestock operations on water quality in downstream tributaries needs to be evaluated in the southern coastal region where hog farms are growing (source: **http://www.ncagr.com/stats/cnty_est/ctyhogyr.htm**,

November 2005). While these problems have been identified and must be addressed, their extent and impacts in relation to river herring spawning and nursery habitat within each basin have yet to be determined.

Although in 2011, Chowan River river herring larvae concentrations were three times higher than in 1983 (Butler 2012) with increased water quality, Butler (2012) went on to state that stakeholders should continue to improve water quality. There is some question as to why these larvae are not transitioning into adults, but further improvement in water quality may help river herring recovery (A. Overton, ECU, personal communication, 2013).

9.5.1 Point Source Discharges

The North Carolina Division of Water Quality (NCDWQ) has the responsibility of ensuring that the waste limits in the National Pollutant Discharge Elimination System (NPDES) permits are established to protect water quality standards in receiving waters. NPDES permits contain effluent limitations that establish the theoretical safe level of various pollutants that may be discharged into surface waters. In some instances the pollutants may be high pH water being discharged to low pH water or when a discharge will increase the flows above normal conditions. Maintaining adequate levels of DO on a year-round basis is a major issue in all of coastal NC. For most of the State's waters the dissolved oxygen standard is 5.0 mg/L. Streams classified, as "swamp waters" by NCDWQ do not retain this level of protection, and are instead assigned acceptable DO levels on a case-by-case basis. Because many of the rivers and tributaries in coastal river basins receive drainage from swampland, low DO and low pH characteristics can be naturally occurring. This further reduces the ability of these waters to buffer negative impacts arising from seemingly low levels of point and non-point source pollution. Although these waters have pH levels that are low, river herring larvae have been observed (see Life History section). The cumulative effects of multiple discharges in coastal North Carolina are of concern and NCDWQ has concluded that the past approach of assigning acceptable DO levels may have resulted in the over allocation of waste assimilative capacity of receiving waters. The NCDWQ has identified the need to develop a better method of assessing the ability of swamp waters to assimilate oxygen-consuming waste.

The largest permitted outfall (approximately 80 MGD) in the Albemarle management area is from the Domtar (formerly Weyerhaeuser Paper Company), which operates a paper mill near Plymouth. The outfall originally discharged into Welch Creek until 1988 when it was relocated to the mainstem Roanoke River. In the 1980s, dioxin, a carcinogen byproduct of the chlorine paper bleaching process and a discharge in Weyerhaeuser's effluent was found to be accumulating in the tissues of fish living in the lower Roanoke River. It was not until 1994 that a complete modernization of the paper mill was instituted, rendering the use of chlorine in the bleaching process obsolete. Although dioxin levels in fish tissues are gradually decreasing, fish consumption advisories remained in effect in the Albemarle/Roanoke management area as a result, and Welch Creek and the lower Roanoke River retained an *impaired-waters* listing until 2012 when it was lifted. Other large paper mills discharge effluents into the upper reaches of Roanoke River near Roanoke Rapids and to the Blackwater River in Virginia, a major tributary to the Chowan River.

The Chowan River was the first coastal river in North Carolina to experience major eutrophication problems in part due to nutrient inputs from point source dischargers, which resulted in the classification of Nutrient Sensitive Waters by the NCEMC in 1979. Since that time best management practices have been implemented in agriculture, municipal wastewater treatment facilities in the basin have converted to land application, the fertilizer plant at Tunis

closed, and paper and textile mills have implemented processes to improve the quality of their discharges. Nitrogen inputs into the Chowan River from point sources have declined 92% between 1982 and 1997.

Point discharges are also a special concern in the other coastal systems, as these areas receive effluent from numerous municipal wastewater treatment plants. Some of the largest of these are permitted to the cities of Raleigh, Smithfield, and Kinston on the Neuse River; Rocky Mount, Tarboro, and Greenville on the Tar River; and Fayetteville and Wilmington on the Cape Fear River. Major industrial discharges are also present near the mouths of the Neuse and Cape Fear rivers.

Currently, Martin Marietta Mine has submitted and received a NPDES permit to discharge up to 12 MGD of fresh water into the headwaters of Blounts Creek (Tar-Pamlico River Basin). This discharge may increase the flows, pH, and decrease salinity in portions of Blounts Creek. The NCDMF objected to the mine's discharge stating concerns to the negative impacts on flow and pH in an area known to have spawning river herring. These alterations may impact migration in one of the areas of the Pamlico River that has seen recent evidence of spawning river herring.

9.5.2 Non-point Discharges

Sedimentation resulting from erodible agricultural fields, construction and development sites, unstable shorelines, woody debris removal, and road construction adjacent to waters in coastal North Carolina degrades water quality and threatens fisheries resources. In addition, increasing urbanization has intensified stormwater run-off pollution within each river basin. This is especially true in Dare and Currituck counties in the Albemarle area, which have experienced population growth in excess of 100% between 1970 and 1980, and again from 1980 to 1990. Similar increases have been observed in Brunswick (43%), Pender (42%), and New Hanover (33%) counties in the southern portion of the state between 1990 and 2000. The losses of wetlands and riparian buffer zones, which help to filter pollutants and settle out sediments, have an adverse impact on water quality and fisheries resources in adjacent water bodies.

Maintenance of good water quality in spawning and nursery habitats is essential to the well-being of river herring stocks. High concentrations of suspended solids (500-1000 mg/l) significantly reduce hatching and survival of river herring eggs. When impacts on reproductive processes are severe, year-class strength, and ultimately recruitment of individuals to the fishery, is significantly reduced. Management strategies focused on the protection and maintenance of the water quality functions of wetlands, specifically for non-point source pollutant abatement, need to be strengthened and enforced in coastal North Carolina. The NCDWQ has identified the need for more widespread monitoring data to better assess the impacts of non-point sources of pollution on water quality.

9.5.3 Dissolved Oxygen

Dissolved oxygen levels drop below the 4 mg/l state standard (swamp water standard) for significant periods of time in the lower Roanoke River and Albemarle Sound (Manooch and Rulifson 1989; Mulligan 1991; NCDEM 1992; Mulligan et al. 1993; Bales et al. 1993; Fromm and Lebo 1997; Lebo 1998). This level of DO is tolerated by adult river herring, but is lower than the requirement for eggs and larvae (Funderburk et al. 1991). Hypoxic events occur most frequently in late spring, summer, and early fall (Mulligan 1991) and are most frequent in the portion of the Roanoke River near Plymouth, in the Cashie River downstream of Sans Souci, and in western Albemarle Sound. Reviews state that the biological oxygen demand (BOD) assimilative capacity

in the lower Roanoke River (Jamesville to the Sound) gets exhausted (Briggs 1991; Mulligan 1991; Mulligan et al. 1993). Hypoxic events are also common in the tributaries during the spring river herring spawning runs. Figures 9.5 and 9.6 show NCDMF datasonde data collected at Catherine's Creek, off the Chowan River, from March through May in 2009 and 2010. For both years, dissolved oxygen collapsed to less than 1 mg/l early in March and did not begin recovering until late May. Many of these low-oxygen events correspond with lack of rainfall and are especially evident in the tributaries. No such low-oxygen event occurred in 2010 in the Chowan River (Figure 9.7). The level of DO fluctuates normally and also decreases in the warmer months. DO crashes often occur when the area is impacted by a hurricane storm surge. Continuous DO monitoring data are available from USGS stations; those stations at Plymouth and Jamesville documented low DO events, as reported in the earlier studies referenced above. The USGS data at Plymouth show 21 consecutive days when daily average DO was below 5 mg/l (range between 1.0 and 4.9 mg/l) in late August and early September 1998. Ambient water quality monitoring by DWQ on a monthly basis has not recorded the low DO levels, as indicated through the USGS continuous monitoring stations. Such infrequent sampling rarely measures acute events, such as low DO. In 2013, the USGS budget was reduced resulting in the removal of several monitoring gauges.

Concentrations of DO in the Roanoke River between Roanoke Rapids and Hamilton were higher, predominantly above the 5 mg/l standard. Concentrations are generally highest near the Roanoke Rapids Dam and decline downstream. Low flow water quality modeling (NCDEM 1996) and ambient data collection efforts document DO sags downstream of Weldon and downstream of Scotland Neck. Variations in DO concentrations through the lower river have been attributed to a combination of reservoir operations, swamp water drainage, and over 30 permitted dischargers (totaling approximately 100 million gallons per day) of oxygen-consuming municipal and industrial wastes (Rulifson et al. 1990; Mulligan et al. 1993; Fromm and Lebo 1997; Lebo 1998).

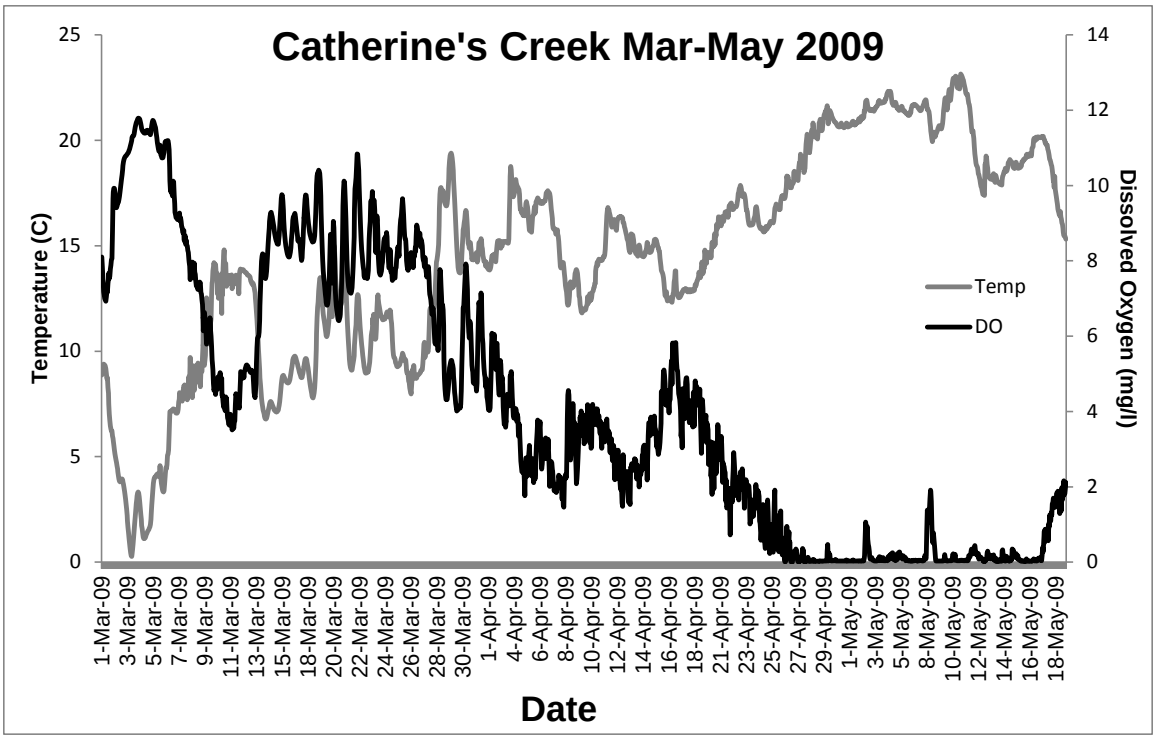


Figure 9.5 Catherine's Creek temperature and dissolved oxygen data from March through May, 2009.

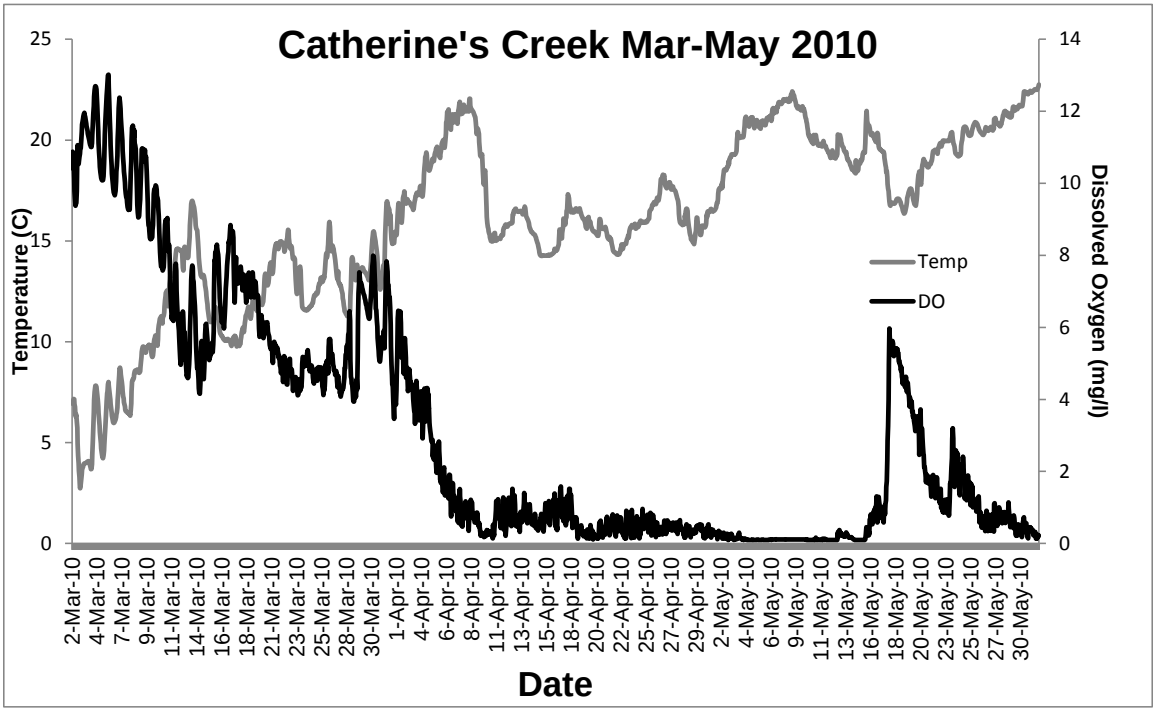


Figure 9.6 Catherine's Creek temperature and dissolved oxygen data from March through May, 2010.

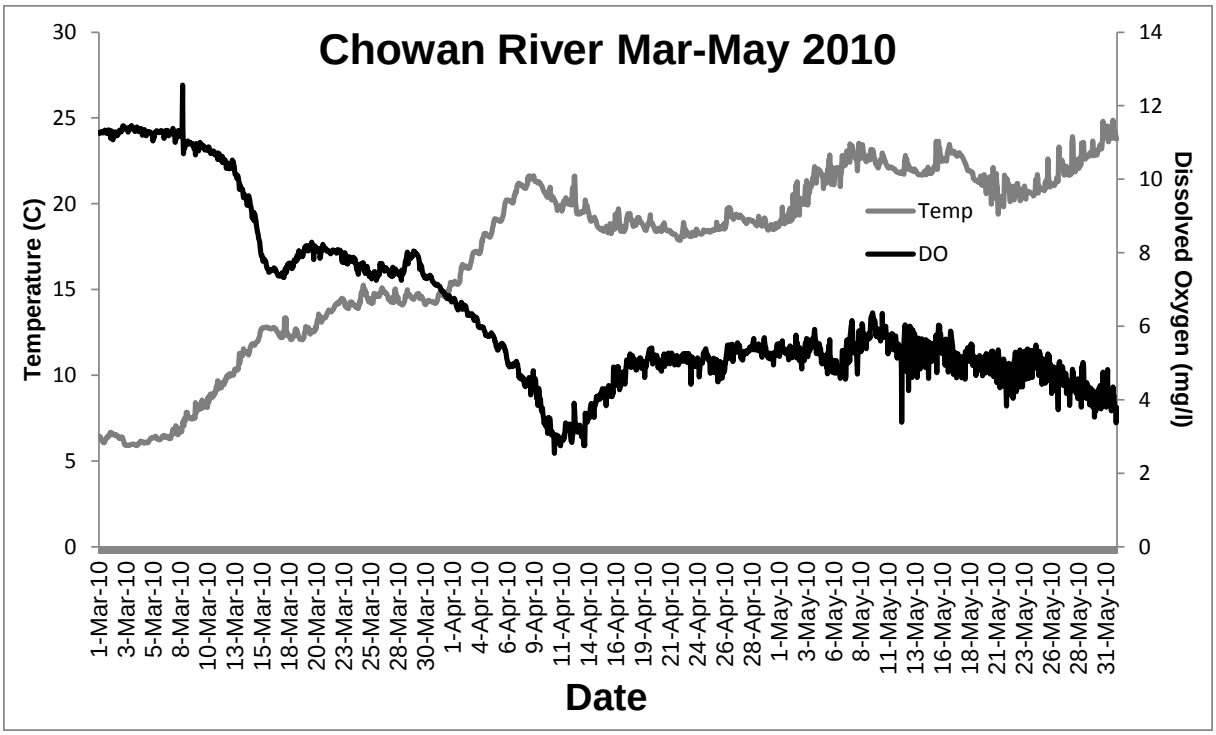


Figure 9.7 Chowan River (at the Highway 13 bridge near Winton) temperature and dissolved oxygen for March through May, 2010.

9.5.4 Endocrine-Disrupting Chemicals and Toxins

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 (DeFur and Foersom 2000; Weis and Weis 1989; Wilbur and Pentony 1999; Deaton et al. 2010). EDCs may include some, but not necessarily all industrial chemicals, pesticides, metals, flame retardants, plasticizers, disinfectants, prescription medications such as antibiotics and hormones, and some pharmaceuticals and personal care products. While the public may realize that pesticides and heavy metals from industrial and car emissions may be dangerous, it is less known that seemingly benign products such as caffeine, ibuprofen, antibacterial soap, and byproducts from plastic bottles and upholstery materials are entering coastal waters and may be adversely affecting the growth and reproduction of aquatic organisms. Some examples of the effects that have been documented as a result of exposure to these contaminants include: decreases in reproduction, altered sexual development or “gender bending”, environmental antibiotic resistance to one or more antibiotics, and changes in population structure or localized extinction of some species. Despite many years of sampling by NCDMF, only one herring was found possessing both male and female gonads (C. Rountree, personal communication, 2013). In 2008, the NCMFC established an Endocrine Disrupting Chemical workgroup to discuss what was known regarding the effects of EDCs on coastal fishery species, and status of these chemicals in estuarine waters. The workgroup recommended that to assess potential impact of endocrine disruptors in North Carolina’s estuaries, a site-specific, compound specific monitoring program is needed. The program should include:

- *Estuarine monitoring of the concentration and prevalence of priority chemicals of concern with possible focus on the Neuse River system,*
- *Specific research on the effects of chemicals on fishery species, particularly blue crab, oysters, and fish,*
- *Education and outreach regarding proper disposal of pharmaceuticals, pesticides and antibiotics, including what existing waste management and recycling programs are available,*
- *Expand the NC Pesticide Disposal Assistance Program to include unused and outdated pharmaceuticals, and*
- *A plan for removal of chemicals from wastewater and runoff.*

The National Oceanic and Atmospheric Administration (NOAA) conducted sediment sampling in North Carolina estuarine waters from 1994 through 1997 as part of their Estuarine Monitoring and Assessment Protocol (EMAP) (Balthius et al. 1998; Hackney et al. 1998; Hyland et al. 1996; Hyland et al. 1998). Of the 39 sites sampled by EMAP north of Oregon Inlet, 12 had more than two contaminants above a level where biological degradation occurs 10% of the time (Hackney et al. 1998). Nickel, chromium, and DDT were the most frequent contaminants, although lead and mercury contamination in the Albemarle region accounted for 100% of the ER-L (effective range – low) exceeding among all North Carolina sites (Hackney et al. 1998). While there was no geographical clustering of these sites, the sediments at all 12 sites containing multiple (3 or more) elevated contaminants were very muddy (silt/clay fraction >90%). All sites with less silt had lower chemical levels. Repeatability of contaminant levels was moderate; only 12 of 23 chemicals found to be elevated during one year, were elevated when sampled in another year. It was also noted that in the Albemarle Sound, sediment contamination levels were likely mobilized and dispersed by hurricane associated flooding and wind throughout the estuary, thus contaminating large areas rather than getting transported out of Albemarle Sound (Hackney et al. 1998). The implications of this information for river herring are unknown.

A study by USGS found the concentration of herbicides in the Albemarle-Pamlico system highest from late May to early June, decreasing gradually until September (Source: **http://nc.water.usgs.gov/albe/pubs/ALBEetroabs.htm**) - which is during the latter half of the spawning period for river herring. This application of pesticides during the spawning period could result in fresh herbicides being washed into the tributary creeks where sensitive river herring eggs and larvae are beginning their downstream migration. The USGS monitoring and research catalog program report also found a gap in pesticide monitoring, but due to costs additional sampling was not included (M. Moorman, USGS, pers. com. 2013). The NCDWQ has developed a new NPDES general permit to regulate the use of pesticides based on the area and amount of pesticides that will be used each calendar year (NCG560000). Permit conditions include minimizing discharges to state waters by applying pesticides at or below the highest rate allowed by the pesticide label, perform regular maintenance to reduce leaks or spills, and reporting requirements if federal threatened or endangered species or federally designated critical habitats are adversely impacted. Applicators will be considered permitted if they do not exceed certain thresholds. These thresholds vary by pesticide use and location (mosquitoes and other flying insects 15,000 acres, aquatic weeds in water 1,000 acres, at water's edge 200 linear miles, aquatic nuisance animal control in water 200 acres, aquatic nuisance animal control at water's edge 200 linear miles, forest canopy pest control 10,000 acres, and intrusive vegetation control 500 linear miles).

In 1990, the NCDEHNR issued a consumption advisory for Chowan River fish due to elevated levels of dioxin in fish tissue. As a result of improved discharges, dioxin levels in fish in the

Chowan River have dropped to the point that the fish consumption advisory was lifted in 1998 for all fish but carp and catfish. The fish consumption advisory for carp and catfish is still in effect for western Albemarle Sound, eastern portions of the Roanoke River, and Welch Creek (Source**: http://epi.publichealth.nc.gov/fish/current.html** accessed August 2012). Welch Creek has high levels of dioxin as it has historically been a discharge site for Weyerhauser/Domtar plant in Plymouth. In February 2012, Welch Creek was capped with 8 to 10 cm of sand to allow natural degradation of the dioxin. In addition to the cap, Domtar was responsible for mitigation of the consumption advisories by putting land into easements to protect riparian wetlands.

Despite the improvements in water quality indicators, degraded water quality has been suggested repeatedly as a cause of the decline in the Chowan River herring fishery by fishermen as well as in the scientific literature (Winslow 1989; Stanley 1992; Rulifson 1994). As a result, several studies to evaluate the impact of water quality on various life stages of river herring have been completed. Most of those studies were carried out prior to recent water quality improvements.

Two of the studies investigated the impact of pulp mill effluent on river herring. The Union Camp Corporation pulp mill stores its waste in settling ponds for much of the year, and in late fall to early winter, the waste is released into the Chowan River through a discharge canal located just north of the North Carolina-Virginia border. It had been hypothesized that this discharge caused river herring to alter their migratory route, and possibly avoid the Chowan River entirely. Kearson (1971) conducted a study to evaluate the impacts of the effluent on game fish, as designated by the NCWRC. Over a three-year period, 43,593 fishes were captured representing 15 game and 15 nongame species. A total of 8,436 fishes were tagged. Based on these collections and tag returns, it was determined that a mass avoidance of the pulp mill waste by game fish did not occur. Furthermore, the study indicated that concentrations of the effluent were not high enough to discourage river herring spawning.

Everett (1983) further assessed the impact of pulp mill effluent by comparing weekly river herring catches of three commercial fishermen within the Chowan River to weekly river concentrations of pulp mill effluent during the 1979 to1982 seasons. During high flow years (1979, 1980, and 1982), the effluent made up a very low percentage (<5%) of river flow and did not appear to result in herring avoidance. However, during 1981, a low flow year, pulp mill waste comprised a large percentage (26%) of the flow, and based on catches, river herring did avoid the effluent. Everett (1983) further determined, based on historical flow data, that avoidance of pulp mill waste by river herring could not account for their decline. However, it was recommended that the effect of pulp mill waste on the food chain, in particular algal assemblages, and the subsequent impact on river herring be investigated. The study was conducted in a mesocosm, using sulfite pulp mill effluent. Culp et al. (2003) compared toxic concentrations with algal biomass, taxonomic composition, benthic invertebrate abundance and composition, and insect emergence. They found that low concentrations of effluent (5% v/v) increased periphyton biomass and caused changes in community structure within the diatom-dominated community. The study results suggested that effluent has little effect on the abundance of benthic invertebrates, but significantly changes species composition. However, the main impact of pulp mill effluent was nutrient enrichment rather than harmful toxic contamination. Several studies have linked kraft pulp effluent to reduced gonad size, masculinization of females, and reduced fecundity (Hewitt et al. 2008).

To evaluate the impacts of water quality on river herring larvae, O'Rear (1981) conducted larval sampling in conjunction with water quality monitoring during the early 1980s at stations throughout the basin. In addition, larvae were collected, returned to the laboratory, and observed for several days. This study suggested that water quality within the basin did not have a direct effect on river herring larvae, but it did recommend further study of the larval food chain.

In 1982 and 1983, the zooplankton populations and the diet of juvenile blueback herring were studied in the Chowan River (Winslow et al. 1984). The study indicated that for a very productive system, zooplankton densities were low compared to James River, Virginia (the only comparable data available), suggesting that the forage base for juvenile river herring was poor. Therefore, it was hypothesized that juvenile blueback herring were selecting alternative, less suitable prey within the Chowan River resulting in poorer growth compared to herring populations in other river systems. However, the study was unable to link reduced densities of zooplankton to the excessive algal blooms and poor water quality. Zooplankton populations were limited in part by the flushing effects of high flows. In addition, a shift in the zooplankton community to strong-swimming copepods and small-bodied nauplii and rotifers suggested that filter-feeding predators, such as juvenile blueback herring, were controlling the zooplankton populations in the Chowan River (Winslow et al. 1984). Rulifson et al. (1993) and Coggins (2005) suggested that low numbers of zooplankton may have been causing lower numbers of river herring. Using different sampling techniques, Binion et al. (2012) observed overlap between Alosine and zooplankton abundance, leading to the conclusion that the failure of river herring stock recovery was not a result of food limitation during early life stages.

In 1996 and 1997, the effects of water quality on the hatching success of blueback herring eggs were investigated within the Chowan River and several of its tributaries (Waters and Hightower. 1997). This study used 11 sites from the mouth of the river to its headwaters, including mainstem river sites and smaller streams. Factors such as temperature, pH, DO, nutrients, and contaminants (PCBs and pesticides) were considered. The results indicated that hatching success differed significantly among sites, but was generally good (exceeding 50%) within the basin. Excluding the Dillards Creek data, the hatching success was 75% or greater. Dissolved oxygen was the only water quality parameter with values outside the reported range for normal development of blueback herring eggs. Based on correlation and regression analyses, DO appeared to be the primary factor related to differences in hatch rate among sites. The lowest DO values and lowest hatch success occurred in a few small tributaries (Dillard, Deep Swamp, and Catherine creeks). The proportion of total spawning and nursery habitat with low DO throughout coastal North Carolina is currently unknown. Depending on the actual portions involved, the severity of water quality impacts on successful spawning of river herring could be significant. Also, water quality in the myriad of tributary creeks could be significantly different than mainstem rivers. With river herring at such low population levels, improving and/or protecting water quality and associated hatching success in every creek could benefit toward stock recovery.

Although some work has been aimed at determining the relationship between water quality conditions and river herring abundance for the Chowan River, the impacts of water quality on river herring reproduction in other coastal river systems have not even been investigated. However, the DWQ has identified water quality concerns for each coastal river in a series of basin-wide water quality management plans (NCDWQ 1994, 1996a, 1996b, 1997a, 1997b, 1997c, 1998a, 1998b, 2001, 2005). For all river systems, these concerns include oxygen-consuming wastes, nutrient levels, toxic substances (heavy metals, chlorine, ammonia, etc.), pH, sedimentation, urban stormwater runoff, and fecal coliform bacteria levels. In addition, the

plans identify concerns specific to each basin. For example, development along the North Carolina coast, particularly in the Albemarle Sound region, and the subsequent environmental impacts should be addressed. On the Roanoke and Tar rivers, the impact of reservoirs used for power generation and flood control needs to be evaluated. In these systems, downstream flows are highly regulated, and their management can affect both water quality and habitat.

9.5.5 Flow Alterations

Besides degrading water quality, modifications to normal flow conditions (e.g., stream blockages, water withdrawals, droughts, or discharges) can negatively impact river herring migrations. Both high and low discharges have been found to decrease larval alewife survival (Sismour 1994; O'Connell and Angermeier 1997). The Roanoke River Water Flow Committee was established in 1988 specifically to address the issue of flows in the lower Roanoke River (NCDMF 2004). As a result, operation of the Roanoke Rapids Dam has changed to meet the flow requirements of striped bass during their spawning period from April to June (NCDMF 2004). However, the consistent application of flows targeting striped bass spawning may not be as beneficial to river herring spawning in the Roanoke system considering their differing spawning habitats (striped bass – mainstem, river herring – tributaries). Riley (2012) examined the relationship between flows in the Roanoke River and larval abundances from 1984 to 2009 and observed larval fish abundance was negatively affected by spring river flow ($r2 = 0.62$). When flows were >300m^3/s larvae were pushed out of the Roanoke River while the best recruitment of juveniles occurred in years when flows were between 141 and 311 m^3/s. Butler (2012) found lower flows and higher river herring larval abundances in the Chowan supporting the results of Riley (2012). Riley (2012) suggests that modifying the flow guidelines during the year for river herring as well as striped bass would support the recovery of river herring in the Roanoke River. Specifically returning the flows to pre-impoundment in February will aid in cueing spawning migrations and in March to aid in larval development. In 2010, the North Carolina General Assembly directed the NCDENR to develop hydrologic models for each river basin in North Carolina. An important part of this bill requires the department to determine the flows needed to maintain ecological integrity in surface waters. The bill further authorized the creation of a Science Advisory Board (SAB) to assist the department in assessing these ecological flows. Members of the SAB include staff from the NCDMF, NCWRC, USGS, and NMFS as well as several other government agencies and non-government organizations. The SAB is expected to make their recommendations by the end of 2013.

9.6 OTHER HABITAT CONCERNS

The degradation and loss of critical freshwater spawning and nursery habitats are believed to have contributed to the decline in river herring stocks along the east coast of the United States, including North Carolina (Rulifson 1994). Rulifson (1994) indicated that within North Carolina, physical impacts such as channelization, dredge and fill activities, dams, industrial water intakes, industrial waste discharges, and road construction all had the potential to impact river herring reproduction. The extent of these impacts varies among river systems, and their link to river herring adult populations has not been fully investigated.

In North Carolina, anadromous fish spawning areas have been delineated for all river systems (Figure 5.1 – 5.3). From the late 1960s to the early 1980s, several surveys were initiated for this purpose, including Baker (1968), Sholar (1975), Fischer (1980), Hawkins (1980a, 1980b), and Winslow et al. (1983). These studies demonstrated that river herring use a wide range of habitat types for spawning, such as small, densely vegetated streams; fresh and brackish marshes;

hardwood swamps; and flooded low-lying areas adjacent to both mainstem rivers and tributaries. Baker (1968) indicated that herring used nearly all accessible rivers and streams in eastern North Carolina. The work by Baker was conducted when river herring populations were much higher than they are currently. However, much of these data are now outdated, and the current status of spawning and nursery habitat is unknown for most areas. The NCDMF has been performing spawning area surveys on the Chowan annually and the other Albemarle Sound river systems on a rotating basis (see Monitoring section for more detail). This data will be used by a fellow (NCDMF, Sea Grant, and N.C. State) to look at spawning areas and obstructions. Furthermore, the overall quality of these habitats in general has never been well-documented, and the impacts of habitat degradation as a whole cannot be measured. Nevertheless, because spawning and nursery areas are so diverse and widespread, any activities that alter aquatic habitat in eastern North Carolina have the potential to adversely impact river herring in some manner.

9.6.1 Wetland Fill

Dredging, draining, and filling activities have altered or destroyed habitat used by river herring during various life stages. In eastern North Carolina, these activities are most often associated with agriculture, residential development, and commercial forestry (Stanley 1992). A variety of studies have estimated losses to wetlands. Although these estimates include losses of wetland areas that are isolated and not accessible to river herring, they do indicate the overall magnitude of habitat loss, which is thought to be significant in some areas. Hefner et al. (1994) reported that in North Carolina, the net loss of wetlands from the mid-1970s to the mid-1980s was 1.2 million acres (485,640 ha), the highest net loss among states in the southeastern United States. A majority of these losses were swamps and bottom land hardwood forests. In the North Carolina portion of the Chowan River basin, Craig and Kuenzler (1983) documented a 30% reduction in oak-gum-cypress forested wetlands from 1964 to 1974. Over that same period, it was also noted that 31% of the total land within the North Carolina portion of the basin had been artificially drained for agriculture (Craig and Kuenzler 1983). Many of these projects occurred in the lower Chowan River basin and impacted bottomland hardwood forests, brackish marshes, headwater forests, swamp forests, and wet flats. The amount of fill in Section 401 wetlands in the Chowan and Pasquotank River Basins has been dramatically reduced in recent years (Table 9.1, 9.2, and 9.3).

Currently, only small areas of wetland (mostly non-riparian) can be filled without a permit and require mitigation. Land developers must also leave a 50-foot buffer (including some natural vegetation) along the Nutrient Sensitive Waters of the Chowan River basin (with numerous exemptions). Even forestry operations cannot alter riparian wetlands without a 404 permit from the United States Army Corps of Engineers (USACE) or 401 water quality certification from the NC Division of Water Quality. However, the conversion of non-riparian wetland to residential communities in many areas undoubtedly has an impact on the hydrology and water quality of adjacent riparian wetlands.

Table 9.1 Chowan River Basin impacted wetlands, streams, and mitigation for 2005 to 2010 (NCDWQ unpublished data).

Year	Wetland Acres Impacted	Stream Feet Impacted	Wetland Mitigation acres	Stream Mitigation feet
2005	19.2	165	0	123
2006	2.3	201	3.13	0
2007	0.08	82	0	0
2008	0.03	42	0.03	0
2009	0.62	40	0.21	0
2010	0.032	42	0	0

Table 9.2 Pasquotank River Basin impacted wetlands, streams, and mitigation for 2005 to 2010 (NCDWQ unpublished data).

Year	Wetland Acres Impacted	Stream Feet Impacted	Wetland Mitigation acres	Stream Mitigation feet
2005	7.20	230	1.8	14
2006	5.03	112	5.31	255
2007	6.40	259	4.1	420
2008	6.70	1394	0.65	0
2009	0.92	1820	0.06	0
2010	1.07	33	0.12	0

Table 9.3 Fill activities Chowan River and Pasquotank River basins (Albemarle Sound and its tributaries excluding the Chowan and Roanoke rivers) from 1994 to 1996 and 2005 to 2010.

1994-1996 Acres of wetlands permitted to be filled in the Chowan River basin (DWQ1997a)	2005- 2010 Acres of wetlands permitted to be filled in the Chowan River Basin[1]	1994-1996 Acres of wetlands permitted to be filled in the Pasquotank River basin (DWQ1997b)	2005- 2010 Acres of wetlands permitted to be filled in the Pasquotank River Basin[1]
48.19	**21**	**131.43**	**14.01**

[1]Unpublished data provided by H. Patt NCDWQ.

9.6.2 Channelization

Stream channelization, most often associated with flood control projects, has also resulted in the loss of essential habitat. To evaluate this issue, Frankensteen (1976) compared a channelized creek (Grindle Creek) to a natural creek (Chicod Creek) within the Tar River basin. This work determined that high water velocities occurring in channelized sections of the stream prevented the entrance of both adult and juvenile herring into these areas. Channelization also removed in-creek vegetation and woody debris which served as a substrate for fertilized eggs. In addition, this loss of vegetation and debris reduced habitat for invertebrates resulting in a reduction in the diversity and quantity of prey for juvenile river herring. Disposal of spoil along the shoreline created spoil banks which prevented access for both adults and juveniles to

sloughs, pools, adjacent vegetated areas, and backwater swamps. Problems associated with channelization have also been observed in other systems. Sholar (1975) stated that a channelized section of the New River did not provide suitable spawning habitat, contributing to reduced recruitment within the system. Hawkins (1980b) also noted that channelization had reduced habitat in Swift, Little Swift, and Bear creeks within the Neuse River basin. In the Albemarle Sound area, channelization projects have taken place on numerous tributaries, including the Cashie River, Ahoskie Creek, Joyce Creek, Pollock Swamp, Bear Swamp, and Burnt Mill Creek. The channelization projects through 2005 are presented in Table 9.4, by county and miles affected. In the Albemarle Sound area, 281.1 miles of streams have been channelized. Some of these streams have since re-naturalized and the river herring have returned (Sara Winslow NCDMF, personal communication 2005). However, these re-naturalized streams are being considered for re-channelization by the NC Division of Soil and Water Conservation. One such proposal involved the re-channelization of Ahoskie Creek in 2005 which was recommended for denial by the NCDMF. The towns of Cherry and Creswell have currently been exploring options to channelize the Scuppernong River to alleviate flooding. At this time no permit applications have been submitted for this project and no permits for other channelization projects have been issued. Granting the permit to channelize or re-channelize would effectively condone degradation of anadromous fish spawning habitat by the state of North Carolina.

Table 9.4 Channelization projects in the Albemarle Sound area, by system, county and miles affected up to 2005.

Project name	Counties	Miles affected
Ahoskie Creek	Bertie, Hertford, Northampton	65.7
Cutawhiskie Creek	Hertford, Northampton	53.9
Pollock Swamp	Chowan	25.0
Horse/Flat Swamp	Hertford	26.1
Hobbsville/Sunbury	Chowan, Gates, Perquimans	60.0
Gum Neck	Tyrrell	16.9
Folley Ditch	Gates	7.4
Burnt Mill Creek	Chowan, Perquimans	9.0
Bear Swamp	Perquimans, Chowan	17.1
Total		**281.1**

9.6.3 River Blockages

A blockage is defined as any man-made or natural obstruction that impedes river herring trying to reach historical spawning areas. Dams, culverts, and log jams all act as blockages to river herring migration. Mainstem dams occur in most coastal rivers in North Carolina (excluding the New, White Oak, Shallotte, Lockwood Folly, and Northeast Cape Fear rivers) (Figure 9.8). The lowermost dams are often located near the fall line as in the Meherrin, Roanoke, Nottoway, Tar and Neuse rivers (Bowman and Hightower 2001). The impacts from dams have been suggested to decimate river herring stocks. Using historical harvest documents in nine Maine watersheds, researchers estimated that river herring productivity was reduced to 0 to16% of virgin stocks from 1750 to 1900 (Hall and Frisk 2012). If restoration goals are set, there needs to be an acknowledgement between historical stocks and the actual potential productivity post-dam construction (Hall and Frisk 2012).

In the Coastal Plain of North Carolina, there are 512 documented dams. Of these dams, 125 are in the Albemarle Sound and its tributaries and the remaining 387 are found in the Tar/Pamlico, Neuse, and Cape Fear rivers and their tributaries (Deaton et al. 2010). These blockages have had detrimental impacts to river herring populations in the Roanoke, Tar, Neuse, and Cape Fear rivers and contributed to the decline of river herring populations. In the following sections the dams that impede river herring migration on the main portions are described, with the understanding that there are many other dams on the tributaries.

Although there has been some progress in working with dam operators on flow releases and with the removal of some dams in North Carolina, there are still numerous blockages that do not allow river herring to reach historical spawning grounds. Neither NCDMF nor NCWRC has authority covering existing dams unless a hydroelectric facility comes up for relicensing. At that point both agencies would have certain rights and privileges to comment on settlement agreements submitted to the Federal Energy Relicensing Commission. The Clean Water Trust Fund (CWTF) has monies available to buy existing dams or have them opened for fish passage. The CWTF receives input from both agencies on where fisheries priorities exist in the state. In 2010, American Rivers, initiated a dam removal program in North Carolina. This organization has been working with state and federal agencies to prioritize which dams should and can be removed. While creating this list, American Rivers has been actively trying to obtain funding to remove dams. The Southeast Aquatic Resources Partnership is partnering with the Nature Conservancy to perform a GIS assessment that will prioritize barriers to aquatic resources movement for removal. This assessment, the Southeast Aquatic Connectivity Assessment Project will prioritize on both the regional and state scales. Researchers at East Carolina University (R. Rulifson and J.P. Walsh) are in the process of estimating the acreage of habitat gained by the removal of the first and second obstructions on North Carolina Coastal Rivers.

9.6.4 Chowan Watershed

In the Chowan watershed, there is one hydropower dam on the Meherrin River, and one on the Nottaway River (Baskerville Mill dam), both in Virginia. In addition to dams found on mainstem rivers, numerous smaller mill dams are found on creeks throughout eastern North Carolina. For example, Collier and Odom (1989) reported three such dams within the Chowan River basin on Bennetts, Indian, and Rockyhock creeks (Figure 9.8). The dams on mainstem and tributary portions of the Chowan drainage basin form the upstream boundaries of some documented anadromous fish spawning habitat in North Carolina and Virginia. Although there is a fish passage structure, the upstream boundaries include the Emporia Dam on the Meherrin River in Virginia (Collier and Odom 1989). The structure at the dam does not effectively pass fish

upstream. Removing or bypassing these dams would open access to many miles of potential spawning habitat. Recent fish passage in the Chowan watershed includes only the Bennett's Creek dam creating Merchant's Mill Pond (Mike Wicker USFWS, personal communication, 2005) and Dillard's Mill Pond rock weir. The effectiveness of dam removal/bypassing in river herring recovery will depend on whether the runs have been extirpated from the entire stream reach impounded.

9.6.4.1 Roanoke River

Currently, numerous large and small dams are present in the Roanoke River Basin. Roanoke Rapids Dam at river mile 137 is the lowermost dam on the mainstem of the river. Roanoke Rapids Dam impounds the river to Gaston Dam at river mile 145. Gaston Dam impounds the river to river mile 170, below Kerr Dam at river mile 179. Kerr Dam impounds the river up the Dan River to river mile 206, and up the Staunton River to river mile 212 (Laney et al. 2001). Currently the Mid-East Resource Conservation and Development Council are working with Albemarle-Pamlico National Estuary Partnership (APNEP) and the NCWRC to restore river herring passage and habitat at the Hoggard Mill Pond in the headwaters of the Cashie River (J. Hawhee, APNEP, personal communication 2013).

9.6.4.2 Tar/Pamlico River

The Rocky Mount Mills Dam is the lowermost dam on the Tar River that obstructs migration of striped bass, American shad, Atlantic sturgeon, hickory shad, and blueback herring (Collier and Odom 1989). The Rocky Mount Mills Dam is a small hydro-dam that conducts peaking operations to produce electricity. Removal of the dam is unlikely due to the fact that the City of Rocky Mount has a water supply intake just above the dam and the dam is listed as a state historical site. However, discussions with the current owner, Capitol Broadcasting, Inc., are ongoing regarding the possibility of improving water flows downstream, and providing upstream passage for American shad. If water flows can be improved, this would be beneficial for all species using the Tar River, including river herring. Two other Tar River dams further upstream are considered to be within the range of anadromous fish migration, but are not currently accessible (Collier and Odom 1989).

9.6.4.3 Neuse River

The first blockage in the Neuse River is Milburnie Dam at river mile 183. The next obstruction is Falls of Neuse Dam at river mile 195. A substantial amount of mainstem habitat was restored in 1998 with the removal of the Quaker Neck Dam near Goldsboro (Bowman and Hightower 2001).

Removal of Milburnie Dam would allow the United States Army Corps of Engineers (USACE) some latitude to provide a stable flow regime for the Neuse and provide access to another 10-20 miles of riverine habitat for spawning. The owner of the dam has expressed an interest in removing the dam. The DWQ has expressed concern over removal of Milburnie Dam, due to possible loss of wetlands associated with the dam. In March 2010, the USACE received a prospectus to utilize the 29,000 linear feet of the Neuse River above the Milburnie Dam as a mitigation bank for state and federal permits. The applicant hopes to begin a phased removal of the dam in the fall 2013.

Little River, a Neuse River tributary, has had three low-head dams removed since 1998. Cherry Hospital Dam, Rain Mills Dam, and Lowell Mill Dam have been removed and have reconnected

51 river miles of Little River to the Neuse River and 147 river miles including Little River tributaries. Near Goldsboro there is the water withdrawal and treatment structure but it has been breached. This structure may still impede striped bass migrations during low flow years (W. Laney, USFWS, personal communication 2010). Full removal of this dam is not an option since it is the city of Goldsboro back up water intake structure so American Rivers has been working with the city to develop fish passage at this location.

9.6.4.4 Cape Fear River

In the Cape Fear River, the lowermost obstructions to migration are the three locks and dams located within the Coastal Plain operated by the USACE. The Cape Fear River may provide the best opportunity for remediation of obstructions. The Corps constructed a rock ramp fish passage for the lower most lock and dam, and is in discussions with resource agencies to design and construct fish passages on the other two locks and dams. There are water supply intakes above all three dams which prevents them from being removed.

9.6.5 Other Obstructions

Water control structures located on drainage canals to Lake Phelps (16,600 ac, 6718 ha) and Lake Mattamuskeet (40,015 ac, 16,194 ha) limit river herring migrations into these areas (Godwin and Rulifson 2002). Collier and Odom (1989) listed storm gates located on Western Canal, Thirtyfoot Canal, Old Canal, and Batava Canal at Lake Phelps as confirmed impediments to migration. In addition, Bee Tree Canal connecting Lake Phelps to the Scuppernong River has historically supported a significant spawning run of river herring and in the mid-1970s, a fish ladder was proposed for this canal (Kornegay and Dineen 1979). The water control structure located on Bee Tree Canal, along with those located on other canals, have been opened on an irregular basis, allowing river herring to enter the lake and apparently spawn. In the past when access was provided, large numbers of juvenile herring were collected in the lake. The operation of these structures is done according to a 1980 Lake Phelps Management Plan. Due to the agreements in the plan the gates that release water to the Scuppernong River have not been opened since 2007 (M. Wicker, USFWS, personal communication 2013). The USFWS, USGS, and NC State Parks are working together to obtain funding to update the management plan to bring back the historical spawning runs.

At Lake Mattamuskeet, the wooden flap gates of the water control structures located on each of four drainage canals were replaced in 1989 with stainless steel gates. The new gates are heavy and open only slightly. These narrow openings create high water velocities which prevent herring from entering. This action subsequently reduced the herring run (Roger Rulifson, ECU, personal communication 2013), which had formerly supported a substantial dipnet fishery (Tyus 1974). The installation of fish weirs and the replacement of the original wooden flap gates have restored some river herring and estuarine species, such as blue crabs, to Lake Mattamuskeet (Rulifson and Wall 1998).

9.6.5.1 Culverts

Although dams are the most obvious obstructions, road culverts may have more overall effect on river herring. Culverts are popular, low-cost alternatives to bridges when roads must cross small streams and creeks. The effect of reduced light from culverts and bridges on river herring migratory behavior was examined in a study conducted in tributaries of Albemarle Sound and in the Neuse, Pamlico, and Cape Fear rivers in 1999 (Moser and Terra 1999). Results showed that river herring preferred to migrate through areas with some ambient lighting during the day, but required only a low amount of light – at least 1.4% of ambient light. Where lighting was less than 1.4% ambient conditions, avoidance was observed. Light measurements in the center of the structures were below this threshold in 6 ft. diameter corrugated metal pipes and 6 ft by 6 ft box culverts. Sufficient light was available in 12 ft diameter pipes and bridges more than one meter above the water surface. Light was marginally adequate in bridges less than one meter above the water surface. Light penetrated approximately 10 ft inside the 6 ft diameter culverts. Since the average length of the 6 ft diameter pipes was 54 ft, approximately 30 ft in the center of the pipes was dark. Although culverts may reduce the number of herring passing upstream of the structures, some fish did successfully pass through culverts at night and, in some cases, under low light conditions (<1%) during the day. The locations of the documented culverts in the Albemarle Sound watershed are shown in Figure 9.8. Culvert upgrades in other states have shown dramatic increases in the number of river herring migrating upstream. In Bride Brook Creek, Connecticut a tidal culvert was replaced tripling the number of alewives passing through from 2009 and almost double from 2012 (S. Gephard, CTDEP, personal. communication 2013),

Although the amount of habitat affected by an individual culvert may seem small, the cumulative impact of culverts within a watershed can be substantial (Collier and Odom 1989). Collier and Odom (1989) documented two culverts in Perquimans County that were confirmed impediments, with another 18 culverts suspected of blocking herring migration throughout the Albemarle Sound region. An analysis of current obstructions to river herring spawning areas was conducted by NCDMF staff in 2005 using data from Collier and Odum (1989), Moser and Terra (1998), and NCDOT data on culvert and bridge locations (current as of 2003). The analysis revealed very few spawning areas that have not been obstructed by culverts since the spawning area surveys were conducted (Figure 9.8). The NCDMF has documented most of the culverts in the Albemarle, Chowan, and Roanoke River basins. As a result of this river herring habitat threat, the NCDMF has surveyed over 500 culverts to determine the ability of herring to move above these structures. In addition, the NCDMF has conducted spawning area surveys annually in the Chowan River system since 2008. NCDMF staff set small sections of gill nets from the bridges or use baskets to collect running ripe river herring. If running ripe river herring were encountered, the gill nets/baskets were moved to an upstream location. This process was repeated until herring were not encountered in the system. During sampling, the presence of running ripe females was recorded in order to identify river herring spawning areas. The number of herring that were encountered at each bridge was recorded. While surveying these structures NCDMF staff identified 44 structures that impede river herring migration. This list was then prioritized to the top six structures that if replaced would restore river herring habitat (Table 9.5). These culverts were prioritized based on historical evidence or presence of large numbers of river herring in other nearby tributaries. Although these culverts have been identified as priorities, all culverts that impede migrations should be made passable as the opportunities become available. In developing the priority list, NCDMF staff kayaked stretches of the rivers to determine if there were other blockages impeding migration. NCSU, Seagrant, and NCDMF will begin a project in 2013 to further analyze the culvert and spawning ground survey data to determine criteria for fish-friendly culverts. In addition to the NCDMF work, the Environmental Defense Fund (EDF) created a habitat restoration plan for the Chowan River Basin (McNaught

et al.2010). As part of this plan EDF identified structures by sub-basins that are preventing river herring migration. These recommended structures were generally suggested along with additional habitat restoration or conservation measures including the purchase of land for spawning habitat conservation.

Table 9.5 List of priority culverts as identified by NCDMF.

SYSTEM	WATERBODY	ROAD NAME
Chowan River	Pembroke Creek	Hickory Fork Rd.
Chowan River	Bennett's Creek	Nixon's Ditch @ SR 1100 (Carter Road)
Chowan River	Queen Anne's Creek	Soundside Road
Chowan River	Brook's Creek	Bazemore Rd.
Chowan River	Stumpy Creek	SR 1332 (Cannon Ferry Road)
Chowan River	Queen Anne's Creek	Paxton Road

In the past the NCDOT has followed anadromous fish stream crossing guidelines that were developed as part of a multi-agency group in 1988 (Appendix 16.4). These guidelines have not been updated since they were first developed. In 2012, NCDMF and NCWRC have initiated discussions with NCDOT to update these guidelines to include new information. This group includes both permitting (USACE, NCDCM, and NCDWQ) as well as resource agencies (NCDMF, NCWRC, NMFS, and USFWS) and Federal Highways.

Efforts to document natural obstructions, such as beaver dams and vegetation blockages have rarely been undertaken relative to anthropogenic blockages. Collier and Odom (1989) noted two vegetation blockages on Pollock Swamp Creek, Chowan County and Suttons Creek, Perquimans County, as well as one beaver dam on Eastmost Swamp, Bertie County. Odom et al. (1986) indicated that log and driftwood jams on the Meherrin River created barriers that prevented the upstream migration of anadromous species. However, due to aquatic weed control programs, snagging operations, and natural events such as hurricanes Bertha (1996), Fran (1996), Bonnie (1998), Floyd (1999), Isabel (2003), and Irene (2012) these types of blockages can be temporary in nature. Nevertheless, such barriers most often occur on small streams and creeks, and therefore, can have an impact on river herring habitat (Collier and Odom 1989). Although blockages to the upstream migration of river herring can occur, the in-stream woody debris and vegetation often provide needed spawning and nursery habitat in many streams. Fertilized river herring eggs are initially adhesive and attach to vegetation and woody debris as a substrate. In addition, both juveniles and adults use this habitat as protective cover and as feeding sites. Invertebrates that also use this habitat provide an important food source for river herring. Future projects involving log salvage and de-snagging could result in the unnecessary elimination of habitat by removing woody debris and vegetation. Local governments have requested and performed clearing and snagging removal on Rutman Creek (Hyde County) and the Scuppernong to minimize flooding of residential areas, farmland, and to improve navigability for small vessels.

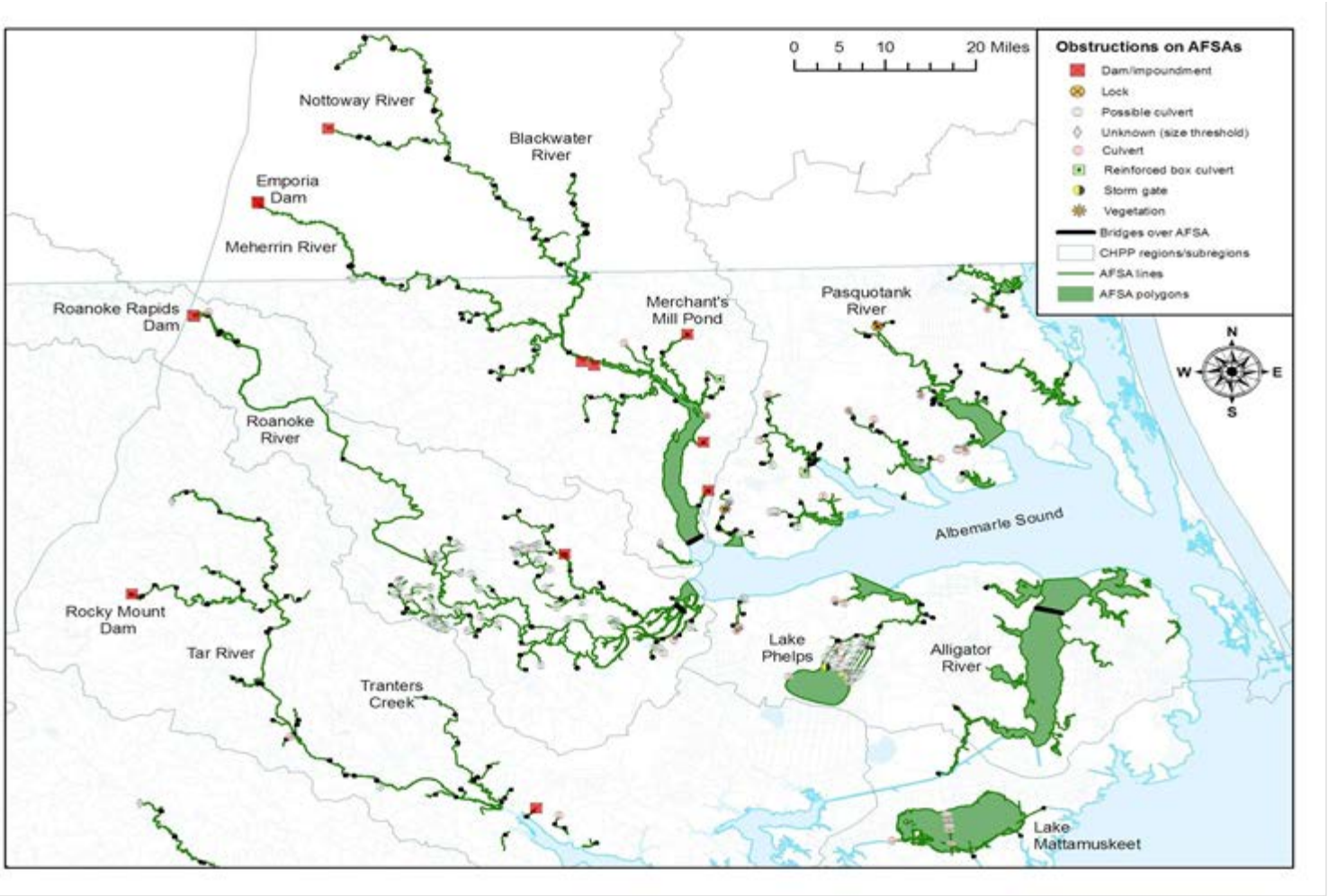


Figure 9.8 Documented water control structures in the North Carolina Coastal Plain (northern regions) relative to Anadromous Fish Spawning areas (AFSAs). Data from Virginia Game and Inland Fisheries (1983 data), Collier and Odum (1989), Moser and Terra (1999), Department of Transportation (2003 data), Division of Water Resources (2003 data), and USACE obstructions inventory (2009 data).

When reviewing these projects, the NCDMF and NCWRC will request the following conditions that the NCWRC developed. 1) Woody debris removal would not be allowed between February 15 and September 30 in any year. 2) As much work as possible should be performed by hand labor (chain saws, winches, etc.) from floating vessels to minimize impacts to stream banks, riparian vegetation, and aquatic resources. We strongly encourage contractors to work from vessels no larger than needed to navigate the site. When hand labor is not practical and stream size can accommodate, heavy equipment should be operated from barges or platforms on the water to minimize bank disturbance. 3) Root wads from cut trees should be left in place and on their original alignment. 4) Bushes, limbs, and other materials hanging in or over the water that do not obstruct flow should not be removed. 5) Dead, hollow trees located along stream banks should not be removed or disturbed. 6) Leaning trees located along stream banks should not be cut or removed with the exception of those with obviously unstable root structure and in imminent danger of falling.

9.6.5.2 Entrainment and Impingement

Each day in North Carolina, millions of gallons of water are pumped from coastal rivers by industrial, municipal, and agricultural water users. During the river herring spawning season, eggs and fry drifting downstream with river currents are subject to being suctioned out of the rivers through various water pumping systems. Juvenile river herring that have not fully developed their swimming abilities are also susceptible to be removed via water intakes. Removal of these eggs, fry, and juveniles represents a direct loss in river herring reproductive success.

Alewife eggs are approximately 0.80 to 1.27 mm and blueback herring 0.87 to 1.11 mm in diameter. Once hatched, river herring larvae are approximately 4.0 to 19.9 mm in length. Transformation to the juvenile stage is completed in both species at ~20 mm total length. River herring eggs, fry, and juveniles are unable to avoid being entrained into most water withdrawal systems. Once entrained, eggs, fry, and juveniles may be considered completely lost from the river. Even if the withdrawn water is returned to the river (such as is the case with industrial cooling water), river herring are killed by high water pressure, turbulence, abrasion, and exposure to excessive temperatures. Some intake structures are equipped with fine-mesh screens to exclude fish eggs and larvae; however, the screens require constant cleaning with air and water jets to remove debris. In many instances, fish eggs and fry may not be completely entrained into the system but might be impinged on screens by water pressure. Larval herring, striped bass, and perch are entrainable with a mesh side of 2 mm and are impinged on smaller screens (Rulifson 1993). Little is known about the survival rates of eggs and fry that are impinged, and then released by screen cleaning operations, but damage from pressure and abrasion seems likely. The importance of egg, fry, and juvenile losses through water intakes is unknown; however, for those populations in which spawners are few, these losses could theoretically be significant. In the lower Cape Fear River, a study at the Brunswick Steam Electric Plant found that the combined use of fish diversion structures, fine mesh screens, a fish return system, and flow minimization reduced the number of impinged or entrained larvae and fish by 40 to 70% (Thompson 2000). Although the overall impact is currently unknown, these losses could theoretically be significant for the river herring population in which spawners are few. In order to reduce the number of eggs and fry that are affected by intake structures the NCDMF and the NCWRC have adopted the standard of water flow less than 0.25 ft/s with 1 mm slotted screens. In addition to these standards, NCDMF and NCWRC will request that applicants perform a larval fish study to determine the location in the water column that will minimize impingement and entrainment. These standards are similar to those that are required in Virginia (Gowan et al. 1999). Devices including electrical screens, air bubble curtains, lights,

high-frequency sound, and chemicals have been developed as a “warning” system to deter fish from intake systems (Martin et al. 1994; Greene et al. 2009). Cage experiments in Georgia showed that high frequency sound worked as an inexpensive method to minimize entrainment of blueback herring (Nestler et al. 1992). The primary concern with cooling water intake structures is the cumulative impact of multiple facilities on fish populations (ASMFC 2002a; ASMFC 2002b). For example, in the Delaware Bay estuary, which has four power plant facilities, it was estimated that an average of 14.3 million fish/year were impinged and more than 616 million fish/year were entrained (EPA 2002). Data regarding water withdrawals is needed to understand the magnitude of water withdrawals on entrainment and impingement and potential ecological effects on ecological flows. Although the North Carolina Division of Water Resources (NCDWR) requires registration of major water withdrawals, compliance with registration requirements is not monitored therefore the full extent of withdrawals is unknown. The EPA has proposed rules (EPA 316) that would require water cooling structures to perform studies that limit impingement by setting limits on fish that can be killed, perform studies to limit fish mortality. These rules were proposed but legal challenges have delayed implementation. A ruling should be completed in November 2013.

Prior to 2008 when NC legislation SL2008-0143 required the North Carolina Department of Agricultural to collect annual information from farmers who withdraw 10,000 gallons or more, the magnitude and seasonal timing of agricultural water withdrawals from coastal rivers was unknown. The only reporting that was done prior to this requirement was by farmers who withdrew over 1,000,000 gallon in any one day to report to the NCDWR. Total withdrawals were highest in the Cape Fear CHPP region followed by the Roanoke, Neuse, and Tar/Pamlico sub-regions (Table 9.6). These withdrawals totaled almost 5,200 million gallons per day. Many of these withdrawals have been permitted without the suggested NCDMF and NCWRC intake recommendations. In 2002, NCDWR published new rules to reduce groundwater withdrawals in 15 coastal counties of North Carolina in order to protect the aquifer. The Central Coastal Plains Cooperative Use Area (15A NCAC 2E) required reductions in groundwater withdrawal of up to 69% by 2018 in those counties and required permits for withdrawals over 10,000 gallons. Reducing groundwater withdrawals may mean increasing surface water withdrawals from rivers and streams, which may impact river herring.

Table 9.6 Surface water withdrawals and relevant capacities derived from 2008 data reported to NCDENR-Division of Water Resources and Department of Agriculture and Consumer Services Agricultural Statistics for CHPP sub-regions. (Source: D. Rayno/NCDWR, unpublished data, 2009, Deaton et al. 2010).

	Community Water Systems*		Thermoelectric Generation		Other Uses**		
CHPP sub-region	**No. of systems**	**treatment capacity (MGD)**	**No. of facilities**	**withdrawal capacity (MGD)**	**No. of systems**	**withdrawal capacity (MGD)**	**Total withdrawal capacity (MGD)**
Cape Fear	2	337.6	4	2334.4	21	122.8	2794.8
Roanoke (NC portion)	8	68.7	3	1763.1	7	32.3	1864.1
Neuse	11	219.1	1	31.7	11	91.7	342.5
Tar-Pamlico	7	84.5	0	0	6	13.8	98.3
TOTALS	*48*	*709.776*	*8*	*4129.23*	*45*	*260.613*	5099.619

*Data submitted to DWR in Local Water Supply Plans for water systems supplying residential, commercial, institutional and industrial users

**Includes agricultural operations, golf courses, quarries, and non-electric generating industrial operations

9.6.6 Climate Change/Sea Level Rise

Rising sea level is a major threat to coastal and riparian wetlands in North Carolina. Analyses of data from tide gauge stations in Hampton, Virginia, and Charleston, South Carolina, from 1921 to 2000 (Riggs 2001), show sea level rising along the Atlantic coast by about 3.35 mm per year (1.1 ft per 100 years). Gauge data specific to North Carolina are available only for 20 years, but suggest a slightly greater rate of approximately 4.57 mm per year (1.5 ft per 100 years). Initially, sea level rise can potentially provide more river herring habitat spawning and nursery areas. Using predictive models for Salmon Creek, Weaver 2009 showed that the flooding of riparian wetlands provided productive spawning and nursery habitat for river herring. Eventually with continued rising water levels these habitats may degrade. Climate change may cause more years in which drought conditions occur. During the last few years drought conditions have been observed, with less water in the creeks river herring have not had access to historical spawning grounds. In 2013, there has been a higher number of river herring observed, possibly due to the higher levels of rainfall, cooler spring, or earlier summer. In 2012, NMFS held a workshop with river herring experts to discuss the impacts of climate change/sea level rise on river herring. These experts hypothesized:

- that there will be changes in freshwater flows and floods that could negatively impact river herring migrations and food availability,
- the distribution of alewife and blueback herring in the marine environment has shifted from south of Cape Cod north into the Gulf of Maine which may be a result of climate change,
- climate change could be a contributing factor to a range contraction of alewives and blueback herring,
- climate change could contribute to river herring hybridization (NMFS 2012).

The specific effects of climate change, including warming water, increased drought severity, and loss of flood plain spawning habitat should be further investigated.

9.6.7 Sedimentation

Griffin et al. (2009) experimentally examined the effects of sedimentation on Pacific herring (*Clupea pallasi).* Griffin et al. (2009) observed the lethal and sublethal effects depending on the timing of the elevated sediment loads. Within the first 2 hours of exposure to elevated sediment levels, there was a clustering of eggs which led to precocious larval hatches and higher percentages of abnormal larvae and increased larval mortality. Alewife eggs had higher rates of egg infections from fungi when there were elevated levels of suspended solids (Schubel and Wang 1973). Klauda et al. (1991) hypothesized that this would also occur in blueback herring eggs as well. Messieh et al. (1992) states that larval herring can be inhibited by re-suspension of dredged materials and larval herring will avoid areas with concentrations of re-suspended material as low as a few milligrams per liter (Wilber et al. 2005). In order to minimize the impacts to anadromous fish from sedimentation, both the NCWRC and NCDMF request that all in-water work in anadromous fish spawning and nursery areas follow a seasonal work moratorium. These moratoriums vary depending on the area, but generally range from February through September, but may extend into October. NCWRC and NCDMF request these moratoriums in order to eliminate or minimize impacts due to elevated turbidity and noise levels during peak anadromous fish spawning periods.

9.6.8 Acoustic Impacts

Construction methods such as pile driving may increase noise levels in the water column. River herring are hearing “specialists” and are able to detect sounds at frequencies greater than 120 kHz. The key issue is whether exposure to anthropogenic sounds will alter behavior in such a manner that it impacts the ability of a fish to forage, avoid predators, navigate, or find a mate. Studies point out that there are very few well-controlled studies that have examined changes in the behavior of fishes in general, let alone marine species, from human-produced sound, but some studies have shown that high frequency sounds (124.6 and 130.9 kHz) have caused river herring to avoid certain areas for up to an hour (Nestler et al. 1992). Ultimately, high frequency acts as a barrier to these fishes, preventing utilization of a specific area, whether it is for foraging or spawning migrations. Acoustic impacts to river herring can be caused from construction projects (pile driving) or from military sonar.

9.6.9 Invasive Species

9.6.9.1 Aquatic Plants

The most troublesome species in low salinity, estuarine waters are Eurasian water milfoil (*Myriophyllum spicatum*) and hydrilla (*Hydrilla verticillata*). It is possible for water milfoil and hydrilla to become thick dense beds that will out compete native SAV species. The presence of these two species may remove critical habitat by “choking” out native species or fish kills may arise due to low DO levels. Weed control activities in coastal waters are primarily focused on these species. Control activities target areas where native species are not the dominant species based on site assessments (R. Emens NCDWR, personal communication 2009). A recent consultation involved the area of Kitty Hawk Bay where treatments of dense Eurasian milfoil stands resulted in a significant reduction of milfoil coverage (Deaton et al. 2010). The North Carolina Aquatic Weed Control Panel, in cooperation with the Town of Kill Devil Hills, intends to continue monitoring the milfoil infestation and conduct spot treatments on an as needed basis. Long-term management and restoration of SAV habitat should include replacement of Eurasian water milfoil and hydrilla with native species throughout the estuary. The AWCP staff agreed to

consult with regional NCDMF staff prior to chemical applications in public trust waters to ensure that fish habitat impacts are minimized, and should continue to do so.

To spray submerged or emergent vegetation in public trust waters, one must be licensed for herbicide spraying and have a special certification for public water spraying (B. Bruss NC Dept of Agriculture, personal communication 2009). The spraying must be done according to the label and overspray to unintentional areas would be a violation of the label. Only state agencies or local government are allowed to have the public water certification. Possible violations are investigated by the NC Department of Agriculture on request. In 2008 property owners in a private subdivision treated a large area of public trust waters independently, without having proper certification or consulting with NCDWR or NCDMF staff. As a result, a large area of native and non-native SAV species was obliterated. G.S. 113-300.1 states that NCWRC has authority to regulate, prohibit, or restrict use of poisons or pesticides severely affecting wildlife resources (includes SAV as a resource), as long as the rules do not conflict with the Pesticide Law of 1971 or Structural Pest Control Act of 1955. Furthermore, an Attorney General review in 1995 found that MFC had authority under 143B-289.3(b) to regulate use of pesticides on SAV. EPA is in the process of requiring a NPDES permit for any spraying of aquatic pesticides and herbicides over or near public trust waters. DWQ is in the process of developing the permit. However, the exemption thresholds will be fairly high and the permit will not address the spraying of native vegetation.

9.6.9.2 Catfish

Both the blue catfish (*Ictalurus furcatus*) and flathead catfish (*Pylodictis olivaris*) are nonnative catfish species in coastal North Carolina that are known to prey on native fishes including river herring. In North Carolina, flathead catfish do not target native species, but they are opportunistic feeders eating whatever becomes available (Pine 2005). Both species have been documented to consume river herring (Schloesser et al. 2011). At the current time, the blue catfish population is expanding in the Albemarle Sound and its tributaries but the extent of its effect on river herring is unknown. Flathead catfish do not appear to be an issue in the Albemarle Sound region, but they have been collected by NCDMF throughout coastal waters (NCDMF unpublished data). The NCDMF has no regulations for the taking of invasive catfish in NC, which should help to keep these catfish populations low.

9.7 RECOMMENDATIONS

Although there are many habitat recommendations that may aid in the recovery of river herring, flow modifications and removal of obstructions are two of the most promising options. These two threats not only affect the direct access to spawning grounds, but they will also affect water quality conditions that are necessary for river herring. Many of these were also components of the CHPP implementation plan. In reviewing the past river herring habitat and water quality management recommendations, many have been implemented or are substantially underway. They include:

- *Update spawning and nursery area surveys conducted previously in all areas of the state.* Spawning Area Surveys Conducted in Yeopim River (2007), Meherrin River (2008) Scuppernong River (2009), Mackey's Creek (2009), Perquimans River (2010), Little River (2010), Chowan River (2008-2012), Edenton Bay (2008-2012), and Roanoke River (2012).

- *Work with other agencies to identify potential incentives for landowners for protection of riparian buffers in the management area.* Ongoing through CHPP and Strategic Habitat Area (SHA) development.
- *Develop, identify and clarify what critical habitat actions are needed to protect, enhance and restore habitats and water quality affecting river herring.* SHA Advisory Committee completed identifying SHAs in Region 1 (Albemarle Sound) and Region 2 (Pamlico Sound, Tar/Pamlico River and Neuse River). The rest of coastal North Carolina should be completed by the end of 2014.
- *Advocate adoption of NCDMF identified anadromous spawning and nursery areas for river herring into rule.* NCDMF and NCWRC spawning areas have been identified and are currently in rule.
- *Advocate implementation and stronger enforcement of regulations protecting critical habitat in the management areas.* Ongoing.
- *Advocate purchase of land adjacent to critical habitat areas to ensure protections.* Ongoing. NCMFC and the River Herring Advisory Committee support this recommendation as funding is available.
- *Advocate that coastal counties undertake the preparation and aggressive funding of open space preservation and conservation plans.* Ongoing.
- *Continue to make recommendations on all state, federal and local permits where applicable.* Ongoing.
- *Support implementation of habitat recommendations of the CHPP and APES and the ESPSR.* In 2010 Environmental Defense Fund published *River Herring Habitats, searching the Chowan River Basin,* which evaluated current river herring habitat.
- *Maintain, restore and improve habitat to increase growth, survival and reproduction of river herring.* Ongoing.

River Obstructions

- *Chowan River – Investigate abundance and spawning contribution on river herring in the Blackwater, Nottoway, and Meherrin Rivers; determine impacts of dams on spawning (requires VA agencies participation).*
- *Tar River – Investigate feasibility of fish passage on Rocky Mount Mill Dam and Tar River Reservoir Dam. Would provide an additional 20-40 miles of spawning habitat but not clear if beneficial to river herring.* Resource agencies are in discussions with the dam owner to construct fish passage at Rocky Mount Mill Dam.
- *Neuse River – Investigate the feasibility of removing Milburnie Dam in Wake County.* Currently under permit review.
- *Cape Fear River-Rock ramp was constructed at Lock and Dam 1 in 2013. Investigate the feasibility of construction of Fish Passage at Lock and Dams 2 and 3.*

Impingement and Entrainment

- *DWQ should require documentation of agricultural water withdrawals from coastal rivers.* In 2008, the North Carolina Department of Agriculture was mandated with collecting information on agricultural water withdrawals greater than 10,000 gallons per day. Implemented in 2008.
- *Develop a comprehensive list of industrial and municipal water withdrawals and their intake specifications by river system coast wide.* Maps have been created but need to be updated as new withdrawals are permitted.
- *Collect data on the density and distribution of river herring eggs, fry and juveniles in coastal rivers so that potential losses can be determined.* Ongoing.

- *Identify effective engineering solutions to prevent entrainment and impingement of river herring eggs, fry and juveniles.* Ongoing. NCDMF currently recommends intakes have a 1mm screen and 0.25 feet per second intake velocities.
- *Continue to give close attention to state and federal permits where water withdrawal is involved; providing estimates of river herring egg, fry and juvenile loss when possible.* Ongoing.
- *Monitor the progress of USEPA's implementation of Section 316(b) rules.* Rule was suspended in 2007. EPA is working to update the rule with an expected date of November 2013 (**http://water.epa.gov/lawsregs/lawsguidance/cwa/316b/index.cfm** accessed February 28, 2013).
- *In the absence of effective exclusion methodology, require water users to curtail withdrawals during periods in which river herring eggs, fry and juveniles may be present.* Ongoing
- *Recommend that NCDWQ and NCDWR be required to interface NPDES discharges and whole watershed management.*

9.7.1 Coastal Habitat Protection Plan Actions

There are many actions that natural resource managers can take to sustain and enhance habitat and water quality conditions for river herring. High priority needs include:

Preserving existing coastal wetlands and restoring wetlands
Protecting AFSAs from dredging and water quality degradation
Protecting and enhancing AFSA habitat
Reducing pollutant loading from point and non-point sources

These management needs are currently being addressed through several existing CHPP recommendations (Deaton et al. 2010) and implementation actions (NCDENR 2011) that were approved by the CHPP Steering Committee. Listed below are those CHPP recommendations and implementation actions that could be beneficial for protecting and improving habitat and water quality issues affecting river herring.

2.2. Identify and designate Strategic Habitat Areas using ecologically based criteria, analyze existing rules and enact measures needed to protect Strategic Habitat Areas, and improve programs for conservation (including voluntary actions) and acquisition of areas supporting Strategic Habitat Areas.

3.1 Expand habitat restoration in accordance with ecosystem restoration plans, including (Street et al. 2005, Deaton et al. 2010-modified):

b) Reestablishment of riparian wetlands and streams.

3.4. Protect estuarine and public trust shorelines and shallow water habitats by revising shoreline stabilization rules to include consideration of erosion rates and prefer alternatives to vertical shoreline stabilization measures that maintain shallow nursery habitat.

3.5 Protect and enhance habitat for anadromous fishes by:

b) Eliminating or modifying obstructions to fish movements, such as dams and culverts, to improve fish passage.

3.7 Protect important fish habitat functions from damage associated with activities such as dredging and filling.

4.5. Improve land-based strategies throughout the river basins to reduce non-point pollution and minimize cumulative losses to wetlands and streams through voluntary actions, assistance, and incentives.

4.6. Work with EMC and other DENR regulatory divisions to implement strategies to reduce runoff and protect riparian habitat adjacent to AFSAs.

9.7.2 Research Recommendations

Along with the recommendations listed above there are certain research questions that should be answered to determine the impacts on river herring. The River Herring PDT discussed these recommendations and assigned a priority ranking of High, Medium, or Low as a way to determine how critical these needs are.

Water Quality

- *Evaluate effects of existing and future water withdrawals on water quality, quantity and fisheries habitat in coastal watersheds.* NCDCM and NCWRC review and comment on water withdrawals and their effect on fisheries and habitat. **High priority**
- *Determine if contaminants are present and identify those that are potentially detrimental to various life history stages of river herring.* Long term water quality monitoring devices have been maintained and deployed to identity shifts or swings in water quality in multiple tributaries in the Albemarle Sound area. **High priority**.
- *Evaluate the impacts/effects of reverse osmosis plants on receiving waters and aquatic resources.* NCDCM and NCWRC provide comments on permit applications re: RO plants; some work by universities to evaluate effects of RO plants in local river systems. **Low priority**

Obstruction

- *Identify all man-made physical obstructions to river herring migrations (update Collier and Odom project) and prioritize impediments for removal /replacement after identification.* The NCDMF has surveyed culverts in the Chowan River area and developed a priority list for replacement or repair. This information will be used by a paid graduate student to investigate fish friendly culverts. **High priority**
- *Identify research needs regarding impediments to river herring migration.* **High priority***.*

Impingement and Entrainment

- *Research is needed to determine the fate of river herring eggs, fry and juveniles that are impinged, and then released through screen cleaning operations.* **Low priority**.

Climate Change

- *The specific effects of climate change, including warming water, increased drought severity, and loss of flood plain spawning habitat should be further investigated.* **Low priority.**

10.0 PROTECTED SPECIES

10.1 BACKGROUND

This section of the FMP is designed to identify protected species that may be encountered in the river herring fishery. Since 2007, commercial and recreational harvest of river herring has been prohibited, with the exception of a commercial Discretionary Harvest Season (DHS). The commercial river herring harvest season is restricted to a 4-day harvest period centered on the Easter holiday, where each individual participant is permitted to harvest river herring only in the Chowan River Herring Management Area. Table 7.5 gives the dates for the years 2007-2012, as well as the individual limits. Gears are restricted to 100 yards of 3.0 inch stretched mesh (ISM) gill nets and pound nets. Landings are not to exceed 4,000 pounds, and landings from 2007-2012 have averaged 1,200 pounds (Table 7.6) A full description of the DHS can be found in the Status of the Fisheries Section of this document.

10.2 STATUTES AND LAWS

10.2.1 Endangered Species Act (ESA)

The Endangered Species Act (ESA) was enacted in 1973, “to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved, (and) to provide a program for the conservation of such endangered species and threatened species.” The ESA is federally-administered by the National Marine Fisheries Service (NMFS) and the United States Fish and Wildlife Service (USFWS). It is unlawful for any person subject to the jurisdiction of the United States to import, export, take within the US or territorial sea of the US, take upon the high seas, possess, sell, deliver, carry, transport, ship, receive, or offer for sale, any endangered species, or to violate any regulation pertaining to such species or to a threatened species under Section 4(d) of the ESA.

The ESA defines a species as threatened when it is likely to become an endangered species within the foreseeable future. An endangered species is defined as any species which is in danger of extinction throughout all or a significant part of its range. A take is to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct (STAC 2006). Candidate species are species that appear to warrant consideration for addition to the federal ESA list. They are sometimes referred to as “species of special concern”. These species receive no substantive or procedural protection under the ESA.

10.2.2 Marine Mammal Protection Act (MMPA)

The Marine Mammal Protection Act (MMPA) of 1972 was enacted in response to increasing concerns by scientists and the public that significant declines in some species of marine mammals were caused by human activities. It established a national policy to prevent marine mammal species and population stocks from declining to a point where they ceased to be significant functioning elements of the ecosystem.

The Department of Commerce through the NMFS is charged with protecting whales, dolphins, porpoises, seals, and sea lions. Walruses, manatees, otters, and polar bears are protected by the Department of the Interior through the USFWS. The MMPA established a moratorium on the taking of marine mammals in U.S. waters. It defines “take” to mean “to hunt, harass, capture, or kill” any marine mammal or attempt to do so. Exceptions to the moratorium can be made

through permitting actions for take incidental to commercial fishing and other nonfishing activities, for scientific research, and for public display at licensed institutions such as aquaria and science centers.

10.2.3 Migratory Bird Treaty Act (MBTA)

The original 1918 statute implemented the 1916 Convention between the U.S. and Great Britain (for Canada) for the protection of migratory birds. Later amendments implemented treaties between the U.S. and Mexico, the U.S. and Japan, and the U.S. and the Soviet Union (now Russia). The statute makes it unlawful, unless permitted by regulations, to pursue, hunt, take, capture, kill or sell any migratory bird. The statute does not discriminate between live or dead birds and also grants full protection to any bird parts including feathers, eggs and nests. Over 800 species are currently on the list.

Migratory birds are managed federally by the USFWS. There are several species of diving ducks and seabirds that are unintentionally caught and drowned in gill nets. The USFWS completed a study to assess bird mortality in nearshore anchored gill nets in the ocean from New Jersey to Virginia and found that an estimated 2,387 birds were killed in the mid-Atlantic gill net fishery from February through April 1998 (Forsell 1999). A few studies have been conducted on seabird bycatch in the American shad gill net fishery (Rose 2000, 2001, 2004). These nets primarily caught diving birds such as loons, cormorants and grebes.

10.2.4 North Carolina Endangered Species Act (Chapter 113 Article 25)

Listing of protected species from a state perspective lies with North Carolina Wildlife Resource Commission (NCWRC) (NC General Statutes - Chapter 113 Article 25). The NCWRC compiled state lists of animals deserving protection over 20 years ago based on guidance from Scientific Councils (the group of scientists identified and assembled by the NCWRC North Carolina Nongame Wildlife Advisory Committee to review the scientific evidence and to evaluate the status of wildlife species that are candidates for inclusion on a protected animal list) on mammals, birds, reptiles, amphibians, freshwater fishes, mollusks, and crustaceans. Endangered, Threatened, and Special Concern species of mammals, birds, reptiles, amphibians, freshwater fishes, freshwater and terrestrial mollusks, and crustaceans are protected by state law. Protection for crustaceans and certain venomous snakes was enacted in 2002. However, state law does not allow for protection of invertebrate groups other than mollusks and crustaceans

10.3 SPECIES

The following protected species could be found in the same waters that are used by NC river herring fisheries. A number of them are listed under the ESA as endangered or threatened, while others are identified as protected under the MMPA or MBTA. Although all of the species listed may be found in the general geographical area where river herring are harvested, it would be a rare occurrence for these species to be affected by the fishery for river herring due to the significant gear and season restrictions. Some species may inhabit areas other than those in which the fishery is prosecuted, or may migrate through the area at times when the fishery is not in operation.

Mammals

West Indian manatee *(Trichechus manatus)*	Endangered
Bottlenose dolphin (*Tursiops truncatus*)	

Fish

Shortnose sturgeon *(Acipenser brevirostrum)*	Endangered
Atlantic sturgeon *(Acipenser oxyrinchus oxyrinchus)*	Endangered

Reptiles

Green sea turtle *(Chelonia mydas)*	Threatened
Kemp's Ridley sea turtle *(Lepidochelys kempii)*	Endangered
Hawksbill sea turtle (*Eretmochelys imbricate*)	Endangered
Leatherback sea turtle *(Dermochelys coriacea*)	Endangered
Loggerhead sea turtle (*Caretta caretta*)	Threatened/Endangered

Birds

Greater scaup (*Aythya marila*)
Lesser scaup (*Aythya affinis*)
Old squaw (*Clangula hyemalis*)
Common loon *(Gavia immer)*
Red-Throated Loon (*Gavia stellata*)
Red-breasted mergansers (*Mergus serrator*)
Ruddy duck (*Oxyura jamaciensis*)
Double-crested cormorant (*Phalacrocorax auritus*)
Horned grebe (*Podiceps aurita*)
Pied-billed grebe (*Podilymbus podiceps*)
Brown pelican *(Pelecanus occidentalis*)

10.3.1 Manatees

Two West Indian manatee sightings have occurred in the Pamlico Sound in the last 22 years. The peak warm season population in North Carolina is typically less than a dozen individuals (Lee and Socci 1989). There have not been any recorded strandings of manatees resulting from interactions with gill nets along the southeastern United States from 1993 through 1999 (Waring et al. 2000). Interactions between oceanic or estuarine gill nets, shrimp trawls, and manatees are unlikely to occur due to their low abundance in North Carolina. One manatee was sighted near Manteo and in the Alligator River in 2008 (**http://hamptonroads.com/2008/11/manteo-nc-alligator-sightings-likely-manatee**).

10.3.2 Bottlenose Dolphins

According to the 2009 U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment, there are nine stocks of bottlenose dolphins on the east coast, two of which are in North Carolina (Waring et. al. 2009). From 2003 to 2007, sixty-four dolphins of the Northern North Carolina Estuarine System Stock (NNCESS) were found stranded or entangled in fishing gear within the area from Beaufort to the North Carolina/ Virginia border. This stock interacts with three fisheries (blue crab trap/pot fishery, long haul seine fishery and inshore gill net fishery). It is unknown how many of these strandings were due to interactions with these fisheries (Waring et. al. 2009). While dolphins are found in Albemarle Sound, especially the eastern-most portion, it is unknown whether they travel as far west as the Chowan River. It is possible, though unlikely, that there may be interactions with the pound net fishery in the Chowan River. Better

observer coverage should provide more information on interactions with these fisheries, especially in the western Albemarle Sound/Chowan River area.

10.3.3 Shortnose Sturgeon

Documented reports of shortnose sturgeon in North Carolina are limited to two areas: western Albemarle Sound (1881 and 1998) and the Cape Fear River [1987 (Ross et al. 1988)]. Although these two areas likely harbor distinct population segments, the Cape Fear population may number less than 50 fish, and there has been only one adult male captured from the Albemarle region. Historical reports from the 19th century indicate that shortnose sturgeon inhabited the Pamlico and Neuse rivers, but obstructions and poor water quality may have eliminated shortnose sturgeon from these rivers since then (SSSRT 2010). Occasional identification of shortnose sturgeon may actually be mis-identified juvenile Atlantic sturgeon. No shortnose sturgeon have been documented from Albemarle Sound since 1998 (SSSRT 2010).

10.3.4 Atlantic Sturgeon

There are anecdotal reports of Atlantic sturgeon collected in the pound net fishery; however the NCDMF has no direct data that describes a level of interactions. The NCDMF is seeking funding to expand its observer program to include pound nets to determine if any interactions are occurring. The NCDMF is also aware of increased NMFS observer coverage in this fishery and is in the process of making a request for available interaction data.

During the four-day discretionary river herring harvest fishermen are allowed to use both gill nets and pound nets, but only in the Chowan River. Gill nets are limited to 100 yards of three-inch mesh. Since the program began in 2007, no known Atlantic sturgeon interactions have occurred in either type of gear. Pound nets set for the Chowan River Pound Net Survey (Section 6) can also be used during the four-day harvest period. No sturgeon interactions have been reported during this survey. Sturgeon occur in the Chowan River and a Vemco-tagged fish has been reported from the Highway 17 bridge (M. Loeffler, NCDMF, personal communication 2013).

10.3.5 Sea Turtles

There are five species of sea turtles that occur in North Carolina waters. Loggerhead, green and leatherback turtles all nest on North Carolina beaches, but most nests are made by loggerheads (STAC 2006). All sea turtle species are listed as either threatened or endangered under the ESA. NCDMF has taken numerous steps to reduce the potential of sea turtle interactions and especially mortalities in the fisheries of the state. These restrictions include areas closed to commercial fishing at times when sea turtles are likely to be present, gear restrictions (i.e. limiting the amount or size of nets used and reduced tow times for trawls), and requiring net attendance by fishermen during certain times of the year.

Satellite tracking studies of sea turtles showed no activity in the western Albemarle Sound and no strandings were reported from the counties surrounding the Chowan River from 1995-2004 (STAC 2006). With warming seas and increasing turtle populations, it is possible that interactions may occur in the future. No interactions with sea turtles have been reported from the four-day discretionary harvest since its inception in 2007. Because this fishery occurs in March or April, it is unlikely that sea turtles would be found in either Albemarle Sound or the Chowan River at that time of year.

10.3.6 Birds

A few studies have documented the interaction of birds with floating and sinking gill nets. Rose (2000, 2001, and 2004) studied bird bycatch in nets designed to catch American shad over three shad seasons (2000-2002). These studies took place over an entire fishing season, generally lasting more than 100 days. These nets had a mesh size of 5.5 ISM, larger than that used to catch river herring. Floating nets caught more birds than sinking nets overall (111 versus 61) and the most common bird caught in these nets was the red-throated loon (42% of the overall total). The nets used in the river herring DHS use 3.0 ISM but, because no studies have been done on the bird bycatch for this size net, it is unknown whether those would be likely to catch more birds or fewer. Because the season is limited to four days, it is likely that the numbers would be limited as well. There are anecdotal reports that birds such as cormorants swimming inside of pound nets, but no studies have been done on the interactions of birds with pound nets. Increasing observer coverage may provide more data on seabird interactions with this fishery as well.

11.0 PRIVATE CULTURE, AQUACULTURE, AND STOCK ENHANCEMENT

11.1 PRIVATE CULTURE

There is currently no North Carolina Division of Marine Fisheries or North Carolina Wildlife Resources Commission program to administer private culture of alewife or blueback herring. There is no provision to allow private use of public trust waters for the culture of finfish in North Carolina limiting any approved river herring aquaculture to private ponds. However, there are no known historical records of private culture being conducted in the State of North Carolina, nor are there any known plans to privately culture river herring in the future. The current no-harvest provision for alewife and blueback herring prevents access to native brood stock until populations recover from depleted status.

11.2 AQUACULTURE

Aquaculture in North Carolina is currently defined under Article 63, Aquaculture Development Act as the propagation and rearing of aquatic species in controlled or selected environments, including but not limited to, ocean ranching (G.S. 106-758). Aquaculture is considered a form of agriculture and the North Carolina Department of Agriculture and Consumer Services is designated as the lead state agency in matters pertaining to aquaculture (G.S. 106-759). The Department of Agriculture and Consumer Services has the authority to regulate the production and sale of commercially raised freshwater fish and freshwater crustacean species. Rules have been developed by the Board of the Department of Agriculture and Consumer Services to register facilities for the production and sale of freshwater aquaculturally raised species, and set standards under which the commercially reared species may be transported, possessed, bought, and sold. The governing body of the Department of Agriculture and Consumer Services is limited to commercially reared fish and does not include authority over the wild fishery resource, which is managed under authority of the Wildlife Resources Commission (G.S. 106-761(a)). The General Assembly gives the Marine Fisheries Commission authority to make rules and take all steps necessary to improve cultivation, harvesting, and marketing of shellfish in North Carolina both from public and private beds (G.S. 113-201). The General Assembly also gives the Marine Fisheries Commission jurisdiction over the conservation of marine and estuarine resources including the regulation of aquaculture facilities as defined in G.S. 106-758 which cultivate or rear marine and estuarine resources (G.S. 113-132).

11.2.1 North Carolina Department of Agriculture and Consumer Services

The Department of Agriculture and Consumer Services has the power and duty to provide aquaculturalists with information and assistance in obtaining permits related to aquaculture activities, and to promote investment in aquaculture facilities in order to expand production and processing capabilities. The Department of Agriculture and Consumer Services also works with the appropriate state and federal agencies to review, develop, and implement policies and procedures to facilitate aquaculture development. The Department of Agriculture and Consumer Services issues the aquaculture licenses. The license is for any person who owns or operates an aquaculture facility for the purpose of possession, production, transportation, sale or commercial catchout. Twenty-two species are approved for propagation and production: (http://www.ncagr.gov/markets/aquaculture/documents/ExplanationoftheAquacultureLicense.pdf) and possession of any species other than those on the list is not allowed except with special written permission from the Wildlife Resources Commission (neither alewife nor blueback

herring are on this list). Three of the 22 species have specific restrictions that also must be approved through the Wildlife Resources Commission.

The Department of Agriculture and Consumer Services has two types of licenses and one permit available to aquaculturists; 1) Aquaculture Propagation and Production Facility License; 2) Commercial Catchout Facility License; and 3) Holding Pond/Tank Permit. The Aquaculture Propagation and Production Facility License is valid for five years for the operation of fish hatcheries and production facilities for the approved species only. The Commercial Catchout Facilities License allows the facility to only be stocked with species from hatcheries and production facilities, approved by the Department of Agriculture and only for the species listed in G.S. 106-761(b) to prevent the introduction of diseases, and is valid for five years. The catchout facility owner or operator is only authorized to sell fish taken by fishermen directly from the pond and must provide receipts of the sales. No fish taken from the catchout facility may be sold by the angler and there are no angler license requirements for anglers fishing in the licensed commercial catchout facilities. The Holding Pond/Tank Permit is for all facilities holding live food or bait species for sale. This permit is valid for two years for the approved species. Possession of either an Aquaculture Propagation and Production Facility License or a Commercial Catchout Facility License will serve in lieu of a Holding Pond/Tank Permit for possession both on and off their facilities premises.

11.3 STOCK ENHANCEMENT

Currently, there is a ten year pilot program to determine effectiveness of enhancement of blueback herring stocks in North Carolina by release of cultured fry. The North Carolina Wildlife Resources Commission and United States Fish and Wildlife Service are conducting fry stocking for a five year period with an overlapping seven year monitoring program for selected waters. Modification or expansion of the program is determined annually during the Inter-jurisdictional Fisheries Cooperative meeting between the Wildlife Resources Commission, Fish and Wildlife Service, and Division of Marine Fisheries. The first year of stocking in the planned 10-year restoration program began in 2012. Blueback herring were cultured at the Edenton National Fish Hatchery in Edenton, North Carolina. Broodstock were collected by electrofishing from Indian and Bennett's Creek, which are tributaries of the Chowan River. Batches of fish were placed into four tanks at that hatchery and each batch was maintained separately during broodstock collection, egg and fry production, and stocking. Each creek was stocked with fry originating from the broodstock taken from that creek. A total of 711,083 fry were stocked in the two creeks.

This project utilized genetic markers to identify stocked cohorts. The broodstock and fry from each batch were genotyped to identify parentage. Beginning in 2015, returning adult blueback herring will be tested to determine the incidence of hatchery origin (NCWRC 2013).

12.0 PRINCIPAL ISSUES AND MANAGEMENT OPTIONS

12.1 DISCRETIONARY RIVER HERRING HARVEST SEASON

I. ISSUE

The discretionary river herring harvest season is currently not serving the intended purposes of providing biological data for stock analysis and local product for area festivals and events. In addition, the North Carolina river herring stocks are depleted and remain well below recovery goals outlined in Amendment 1 to the North Carolina River Herring Fishery Management Plan (FMP). This issue paper will evaluate the utility of the discretionary river herring harvest season.

II. ORIGINATION

The River Herring plan development team.

III. BACKGROUND

The North Carolina Marine Fisheries Commission (MFC) adopted Amendment 1 to the River Herring FMP in February of 2007 (NCDMF 2007). The FMP implemented a commercial and recreational no harvest provision for river herring in the joint and coastal waters of the state. The FMP also put in place a 7,500 lb limited research set aside to be allocated at the discretion of the director of the NCDMF. The purpose of the research set aside is to collect data necessary for stock analysis, and to provide local product for area festivals. The director allocated a maximum harvest of 4,000 lb. during the discretionary season.

In order to implement the harvest of this discretionary amount, a Discretionary Herring Fishing Permit (DHFP) was created. The permit and season are managed by proclamation. Individuals participating in the fishery are required to: (1) hold a DHFP, (2) harvest only from the Chowan River Herring Management Area (CRHMA) during the harvest period, (3) hold a valid North Carolina Standard Commercial Fishing License (SCFL) or a Retired SCFL, and (4) participate in statistical information and data collection programs. Individuals have to contact the NCDMF each season and obtain a DHFP if they are interested in participating.

Each permit holder is allocated 125-250 lbs, depending on the number of permits issued, for the four day season centered around the Easter holiday. The permit holders may harvest river herring with pound nets or gill nets and 3.0 inch stretched mesh gill nets are restricted to 100 yards. If harvested river herring are sold, they must be sold to a licensed and permitted river herring dealer. Permitted river herring dealers are required to report their landings daily to NCDMF via fax or phone through the quota monitoring program. In addition, all dealers are required to fill out a trip ticket for each transaction with a fisherman and to submit these reports to NCDMF monthly.

The North Carolina section of the 2012 Atlantic States Marine Fisheries Commission River Herring Coastwide Benchmark Stock Assessment indicates the North Carolina river herring stocks remain at historically low levels (ASMFC 2012). North Carolina river herring stocks remain below all reference points and no stock recovery goals have been met. Continued harvest from a depleted stock is a concern.

IV. AUTHORITY

North Carolina General Statutes 113-134, 113-182, 113-221.1

113-169.1 Permits for gear, equipment, and other specialized activities authorized

North Carolina Marine Fisheries Commission Rules 2011 (15A NCAC)

03O .0501	Procedures and requirements to obtain permits
03O .0502	Permit conditions; General
03O .0503(b.3.)	Permit condition; Specific: Albemarle Sound Management Area for River Herring Dealer Permit
03O .0506	Special Permit Required for Specific Management Purposes
03M .0512	Compliance with fishery management plans
03M .0513	River Herring

V. DISCUSSION

The discretionary river herring harvest season has been conducted annually since 2007. The permit and season are managed by proclamation. The dates of the season have varied, centered around the Easter holiday when the area festivals and cultural events have traditionally taken place in various counties in the Albemarle Sound area. The poundage limits shown in Table 12.1 are set based on the number of permits issued and are implemented in order to keep the total pounds landed per season below the 4,000 lb. maximum harvest level established at the director's discretion.

Table 12.1 Dates and individual poundage limits for the discretionary river herring harvest season in the Chowan River Herring Management Area, NC, 2007-2012.

Year	Dates	Limits/Permit Holder (lbs)
2007	April 4-7	200
2008	March 19-22	250
2009	April 8-11	125
2010	April 1-4	125
2011	April 18-21	150
2012	April 2-5	150

Table 12.2 shows the total pounds landed, number of trips, number of participants and permits 2007-2012 from the NCDMF Trip Ticket Program (TTP). This program requires dealers to complete a trip ticket for each transaction with a fisherman and to submit these reports to the NCDMF on a monthly basis. Annual landings averaged 1,182 pounds and ranged from 643 pounds to 1,765 pounds. The number of permit holders averaged 23.3 for the time series with

the total number of permits issued each year ranging from 13 to 32. The number of participants represents the fishermen that sold their catch to a licensed and permitted river herring dealer. The number of participants averaged 12.5 for the time series and ranged from 9 to 16. Each year the number of participants is considerably lower than the number of permits issued. Table 12.2 includes the percentage of permits with no sales reported. This could be due to fishermen not participating in the fishery after receiving their permit or not selling their catch, in which case no trip ticket would be required and those landings would not be recorded. Based on anecdotal information, it appears that quite a few fishermen are using their catch for personal consumption. This highlights the concern that not all of the harvest is being recorded for a species of concern.

Table 12.2 Total pounds, trips, participants and permit numbers issued in the discretionary river herring harvest season, Chowan River Herring Management Area, NC, 2007-2012.

Year	Pounds	Trips	# Participants	# Permits	% Permits No Sell
2007	1,103	22	10	15	33
2008	1,292	25	9	13	31
2009	643	27	14	27	48
2010	1,765	41	16	30	47
2011	1,611	30	16	23	31
2012	678	18	10	32	69

In 2007, NCDMF obtained biological samples from the discretionary season including lengths, weights, sex, maturity and aging structures. However, beginning in 2008, NCDMF implemented a contracted pound net survey in the Chowan River and this survey has provided adequate samples for the collection of river herring biological and abundance data, making the discretionary river herring harvest season unnecessary for this purpose.

In addition to the biological data, the intent of the season was to provide fresh, local product for area festivals and events. According to various restaurant owners, dealers and festival coordinators, there are not enough river herring available from the discretionary harvest season to provide the local restaurants and festivals with a consistent supply for their businesses and events. Most, if not all, of the local restaurants and festivals purchase their river herring from other states. South Carolina and Virginia, prior to the moratorium implemented in that state in 2012, have been the main sources of river herring in North Carolina since the no harvest restrictions were implemented in 2007.

Permit holders may harvest river herring from the CRHMA with pound nets or gill nets. Gill nets with 3.0 inch stretched mesh are restricted to 100 yards. Due to the moratorium on the harvest of river herring outside of the discretionary harvest season, very few pound net sets are active in the CRHMA other than those used in the contracted pound net survey. In addition, by mid to late March, alewife begin to migrate out of the system and the spawning run at this time can be comprised mostly of blueback herring. Considering the smaller size of blueback herring it could be problematic for fishermen using gill nets to catch their harvest limit due to the selectivity of the 3.0 inch stretched mesh gill net for capturing larger alewife. Fishermen have indicated that the gill net mesh size regulations coupled with the effects weather may have due to the short

four day season, have restricted their ability to capture their harvest limits during the discretionary season. Furthermore, anecdotal reports suggest that some fishermen may be using their catch for personal consumption. These interacting factors may explain why the landings reported are considerably lower than the totals allocated.

The intent of the discretionary harvest season is currently not being met. The NCDMF fisheries management, license and statistics, and marine patrol staff expend considerable hours issuing proclamations and permits and ensuring adequate enforcement during the season. There is also additional concern that NCDMF is not obtaining data for all of the river herring being removed during the limited season due to fishermen using their catch for personal consumption. There is currently no system in place to quantify those removals.

VII. PROPOSED MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

1. Status quo- Continue the Discretionary Harvest Season
   + Allows limited harvest of a culturally and historically important resource
   + Small economic benefit to fishermen and dealers
   - Season continues without intended purposes being met
   - Unknown amount of harvest of a depleted stock (due to personal consumption)
   - Considerable administrative effort to issue proclamations and permits associated with the season
   - Considerable enforcement effort to monitor the season, permits and harvest limits

2. Eliminate the Discretionary Harvest Season (and the Discretionary Harvest Permit)
   + Reduces additional removals of a depleted stock
   + Eliminates the administrative effort and cost of issuing permits and proclamations associated with the season
   + Eliminates additional enforcement effort necessary to monitor the season
   + Removes reporting burden for dealers
   + Eliminates the concern regarding unknown total harvest numbers (due to personal consumption)
   - Eliminates access to a culturally and historically important resource
   - Loss of income to commercial fishermen and dealers

VIII. RECOMMENDATION

NCMFC- **Option 2-** Eliminate the Discretionary Harvest Season and the Discretionary Harvest Permit.

NCWRC- Option 2

AC- Revised Option 1- Remove the collection of biological sampling/data as an intent of the Discretionary Harvest Season/Permit and require permit holders to report the pounds and disposition of their catches in logbooks daily (vote was 4-1-1).

Prepared by Kathy Rawls, Kathy.Rawls@ncdenr.gov, 252-264-3911
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Revised: April 1, 2013

Revised: April 4, 2013 PDT recommendations
Revised: April 12, 2013
Revised: April 16, 2013 NCDMF recommendations
Revised: June 4, 2013 AC recommendations
Revised: February 26, 2014 NCMFC recommendations
Revised: February 28, 2014 NCWRC recommendations

12.2 POSSESSION OF RIVER HERRING IN COASTAL WATERS

I. ISSUE

The North Carolina Wildlife Resources Commission (NCWRC) passed a rule in November 2012 that prohibits the possession of river herring greater than six inches in inland waters while fishing or boating. This rule becomes effective August 1, 2013, creating a discrepancy with North Carolina Marine Fisheries Commission Rules (MFC) regarding possession of river herring in joint and coastal waters of the state.

II. ORIGINATION

Wildlife Resources Commission staff serving on the North Carolina River Herring Plan Development Team (PDT).

III. BACKGROUND

The NCWRC implemented a harvest moratorium in August 2006 that prohibits the take or possession of herring (alewife and blueback herring) greater than six inches in length from inland fishing waters of coastal rivers and their tributaries up to the first impoundment. This rule became effective just prior to the MFC adoption of Amendment 1 to the North Carolina River Herring FMP in February 2007 which implemented a commercial and recreational no harvest provision in the joint and coastal waters of the state, with a limited 7,500 pound discretionary harvest season.

Both agencies currently allow possession of river herring purchased from bait/tackle dealers as long as the anglers provide a receipt with the name of the dealer and the amount of bait purchased. This agreement is not specified in rule or writing and was entered into by both agencies as a mutual agreement for enforcement. The NCWRC passed a rule in November 2012, prohibiting the possession of river herring greater than six inches while boating on or fishing in inland waters. This rule was created in response to significant illegal activity and abuse of the mutual “receipt” agreement between the NCWRC and the NCDMF. This rule becomes effective August 1, 2013. NCWRC staff serving on the PDT asked that the MFC consider mirroring the new NCWRC river herring possession rule in the amendment of the 2007 River Herring FMP in order to maintain consistency in regulations for river herring in state waters.

The proposed rules included in this issue paper address possession of river herring while boating or fishing in coastal fishing waters and do not affect individuals or businesses that purchase river herring for personal consumption that originate from sources outside of North Carolina.

IV. AUTHORITY

North Carolina General Statutes

113-134	Rules
133-182	Regulation of fishing and fisheries
143B-289.52	Marine Fisheries Commission- powers and duties

North Carolina Marine Fisheries Commission Rules 2011 (15A NCAC)

03M .0513 River Herring

V. DISCUSSION

Since adoption of Amendment 1 to the North Carolina River Herring FMP both the NCDMF and the NCWRC have allowed anglers to possess river herring (from sources outside of NC) for use as bait as long as they have a receipt from the bait/seafood dealer or tackle shop where purchased. Most, if not all of the river herring legally used for bait comes from other states, but some may be legally harvested during the discretionary harvest period and sold by licensed river herring dealers.

The Atlantic States Marine Fisheries Commission (ASMFC) adopted Amendment 2 to the Interstate Fishery Management Plan for Shad and River Herring in May 2009. The amendment required that all states close their commercial and recreational fisheries for river herring beginning January 1, 2012 unless they develop and submit for approval a sustainable fishery management plan. Submitted plans must clearly demonstrate that the state's fisheries are sustainable through targets that are developed and maintained by the state. The sustainable fishery plans are subject to Technical Committee review and Shad and River Herring Board approval. South Carolina and Virginia have been the most widely used resources for obtaining river herring in North Carolina since the no harvest provision was implemented in 2007. In January of 2012, Virginia implemented a moratorium on the harvest of river herring in state waters, as a response to the requirement of Amendment 2, leaving South Carolina as the closest resource. Of the 15 members of the Atlantic States Marine Fisheries Compact with river herring fisheries, only five currently have open or limited fisheries.

Law enforcement from both agencies indicated that possible enforcement loopholes have been created with the allowance of possession for bait. These loopholes may include anglers replacing legally purchased river herring with those taken illegally and falsifying receipts to include names of dealers that do not exist or inaccurate amounts purchased. Marine Patrol indicated that although these loopholes may exist in all waters of the state, the majority of the issues likely occur in areas where river herring are more abundant such as the Roanoke and Chowan Rivers.

In response to suspected abuse of the existing rule and possible enforcement loopholes, the NCWRC passed a restricted possession rule that goes into effect August 1, 2013. The herring regulations in the North Carolina Administrative Code as they apply to Inland waters are as follows:

15A NCAC 10C .0401 MANNER OF TAKING NONGAME FISHES: PURCHASE AND SALE

(a) Except as permitted by the rules in this Section, it is unlawful to take nongame fishes from the inland fishing waters of North Carolina in any manner other than with hook and line or grabbling. Nongame fishes may be taken by hook and line or grabbling at any time without restriction as to size limits or creel limits, with the following exceptions:

(2) While boating on or fishing in the following inland fishing waters, no person shall take river herring (alewife and blueback) that are greater than six inches in total length or possess such herring regardless of origin: coastal rivers and their tributaries including Roanoke River downstream of Roanoke Rapids Dam, Tar River downstream of Rocky Mount Mill Dam, Neuse River downstream of Milburnie Dam, Cape Fear River downstream of Buckhorn Dam, Pee Dee River

downstream of Blewett Falls Dam, the entire Lumber River including Drowning Creek, in all their tributaries, and in all other inland fishing waters east of Interstate 95.

(c) Nongame fishes, except alewife and blueback herring, excluding those less than six inches in length collected from Kerr Reservoir (Granville, Vance, and Warren counties), blue crab, and bowfin, taken by hook and line, grabbling or by licensed special devices may be sold. Eels less than six inches in length may not be taken from inland waters for any purpose.

15A NCAC 10C .0402 TAKING NONGAME FISHES FOR BAIT OR PERSONAL CONSUMPTION

(d) No person shall take or possess during one day more than 200 nongame fish in aggregate for bait or personal consumption subject to the following restrictions:

(2) While boating on or fishing in the following inland fishing waters, no river herring (alewife and blueback) that are greater than six inches in total length shall be taken and no such river herring shall be possessed regardless of origin: coastal rivers and their tributaries including Roanoke River downstream of Roanoke Rapids Dam, Tar River downstream of Rocky Mount Mill Dam, Neuse River downstream of Milburnie Dam, Cape Fear River downstream of Buckhorn Dam, Pee Dee River downstream of Blewett Falls Dam, the entire Lumber River including Drowning Creek, and in all other inland fishing waters east of Interstate 95; and

The NCWRC proposes that the above rule will effectively close the enforcement loopholes in inland waters and provide additional protection for a depleted stock.

The use of live bait to catch striped bass is popular in upper portions of the Roanoke River Management Area and the take of river herring less than six inches was implemented to allow for the use of stunted river herring found in Piedmont reservoirs while protecting anadromous blueback herring and alewife that exceed six inches in length. Stunted, reservoir populations of river herring are present in John H. Kerr, Gaston, and Roanoke Rapids reservoirs. Anglers will often use cast nets to capture threadfin shad, gizzard shad and river herring from these Piedmont lakes prior to their fishing trips to use as live bait. The six-inch provision allows stunted river herring that may be mixed in with other species to be kept and used by anglers. In addition, a current regulation (15A NCAC 10C .0401 (c)) allows for the sale of river herring less than six inches collected from Kerr Reservoir.

River herring are used as cut-bait in the striped bass fishery in the lower Roanoke River and to a lesser extent in some of the other river systems in the state. In inland waters it is unlawful, while fishing, to change the appearance of fish subject to size limits or daily creel limits or remove the head and/or tail from fish that are regulated by a size limit so that they may not be measured and/or identified. In joint and coastal waters, it is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish that is subject to a size or harvest restriction without having head and tail attached; except that blueback herring and alewife when used for bait can be cut as long as no more than two are cut at any one time. If possession of river herring less than six inches was implemented in joint and coastal waters, it may be problematic to allow anglers to cut up river herring, which would make it difficult for enforcement to determine the original length of the fish.

VI. PROPOSED RULE(S)

Option 2

15A NCAC 03M .0513 RIVER HERRING
It is unlawful to take or possess river herring ~~taken~~ from N.C. coastal fishing ~~waters. unless the river herring season is open.~~ waters. Possession of river herring from sources other than N.C. coastal fishing waters shall be limited to fish less than or equal to six inches total length aboard a vessel or while engaged in fishing from the shore or a pier.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. March 1, 1995;
Amended Eff. August 1, 1998;
Temporary Amendment Eff. May 1, 2000; August 1, 1999; July 1, 1999; March 1, 1999;
Amended Eff. April 1, 2015; October 1, 2008; December 1, 2007; April 1, 2001.

Option 3

15A NCAC 03M .0513 RIVER HERRING
It is unlawful to take or possess river herring ~~taken~~ from N.C. coastal fishing ~~waters. unless the river herring season is open.~~ waters. Possession of river herring from sources other than N.C. coastal fishing waters shall be limited to fish less than or equal to six inches total length aboard a vessel or while engaged in fishing from the shore or a pier.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. March 1, 1995;
Amended Eff. August 1, 1998;
Temporary Amendment Eff. May 1, 2000; August 1, 1999; July 1, 1999; March 1, 1999;
Amended Eff. April 1, 2015; October 1, 2008; December 1, 2007; April 1, 2001.

15A NCAC 03M .0101 MUTILATED FINFISH
It is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish that is subject to a size or harvest restriction without having head and tail attached, except:
(1) mullet when used for bait;
(2~~) blueback herring,~~ hickory shad ~~and alewife~~ when used for bait provided that not more than two ~~fish~~ per boat or fishing operation may be cut for bait at any one time; and
(3) tuna possessed in a commercial fishing operation as provided in 15A NCAC 03M .0520.
History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. January 1, 1991;
Temporary Amendment Eff. May 1, 2001;
Amended Eff. April 1, 2011; July 1, 2006; August 1, 2002.
Amended Eff. April 1, 2015

Option 4

15A NCAC 03M .0513 RIVER HERRING
(a) It is unlawful to take or possess river herring ~~taken~~ from coastal fishing waters. ~~unless the river herring season is open.~~
(b) It is unlawful to possess river herring, regardless of origin aboard a vessel or while engaged in fishing from the shore or a pier.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. March 1, 1995;
Amended Eff. August 1, 1998;
Temporary Amendment Eff. May 1, 2000; August 1, 1999; July 1, 1999; March 1, 1999;
Amended Eff. April 1, 2015; October 1, 2008; December 1, 2007; April 1, 2001.

15A NCAC 03M .0101 MUTILATED FINFISH
It is unlawful to possess aboard a vessel or while engaged in fishing from the shore or a pier any species of finfish that is subject to a size or harvest restriction without having head and tail attached, except:
(1) mullet when used for bait;
(2) blueback herring, hickory shad and alewife when used for bait provided that not more than two fish per boat or fishing operation may be cut for bait at any one time; and
(3) tuna possessed in a commercial fishing operation as provided in 15A NCAC 03M .0520.
History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. January 1, 1991;
Amended Eff. January 1, 1991;
Temporary Amendment Eff. May 1, 2001;
Amended Eff. April 1, 2011; July 1, 2006; August 1, 2002.
Amended Eff. April 1, 2015

VII. PROPOSED MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

1. Status quo- Continue to allow possession of river herring (alewife and blueback herring) for use as bait (with appropriate receipt/documentation)
   + No additional burden on anglers
   + Small economic benefit to local bait dealers
   + Allows purchase of bait from out-of-state
   - Conflicts with NCWRC rule (effective August 1, 2013)
   - Continued abuse by anglers replacing legally purchased river herring with those taken illegally
   - Continued abuse by anglers creating receipts that falsify information

2. Prohibit possession of river herring (alewife and blueback herring) greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier
   + Eliminates discrepancies with NCWRC rule on river herring possession in inland waters
   + Eliminates abuse by anglers replacing legally purchased river herring with those taken illegally
   + Eliminates abuse by anglers creating receipts that falsify information
   + Allows opportunity for anglers to use river herring less than six inches as bait
   - Continue to allow river herring to be cut for bait making enforcement of size limit difficult
   - Eliminates the purchase of bait from out-of-state
   - Additional burden on anglers to secure bait
   - Eliminates economic benefit to local bait dealers

3. Prohibit possession of river herring (alewife and blueback herring) greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier and remove alewife and blueback herring from exceptions in the Mutilated Finfish Rule 15A NCAC 03M .0101
   + Eliminates discrepancies with NCWRC rule prohibiting possession in inland waters

+ Eliminates abuse by anglers replacing legally purchased river herring with those taken illegally
+ Eliminates abuse by anglers creating receipts that falsify information
+ Allows opportunity for anglers to use river herring less than six inches as bait with head and tail attached
+ Eliminates allowance of cutting river herring for bait easing enforcement of size limit
- Eliminates the purchase of bait from out-of-state
- Additional burden on anglers to secure bait
- Eliminates economic benefit to local bait dealers
- Eliminates the use of river herring cut bait for anglers

4. Prohibit possession of river herring (alewife and blueback herring) aboard a vessel or while engaged in fishing from the shore or a pier and remove alewife and blueback herring from exceptions in the Mutilated Finfish Rule 15A NCAC 03M .0101
   + Eliminates abuse by anglers replacing legally purchased river herring with those taken illegally
   + Eliminates abuse by anglers creating receipts that falsify information
   + Eliminates possible loopholes created by allowing possession of river herring under six inches
   + Easily enforced
   - Eliminates the purchase of bait from out-of-state
   - Additional burden on anglers to secure bait
   - Eliminates economic benefit to local bait dealers
   - Eliminates the use of river herring for bait
   - Conflicts with NCWRC rule (effective August 1, 2013)

VIII. RECOMMENDATION

NCMFC- Option 3- Prohibit possession of river herring (alewife and blueback herring) greater than six inches aboard a vessel or while engaged in fishing from the shore or a pier and remove alewife and blueback herring from exceptions in the Mutilated Finfish Rule 15A NCAC 03M .0101.

NCWRC- Option 3

AC- Option 3

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Revised: April 16, 2013 MRT edits
Revised: June 4, 2013 AC recommendations
Revised: July 26, 2013 NCDMF/RAT recommendations
Revised: October 11, 2013 to reflect change in AC position.
Revised: February 26, 2014 NCMFC recommendations
Revised: February 28, 2014 NCWRC recommendations

12.3 RIVER HERRING FISHERY MANAGEMENT PLAN RULE REORGANIZATION AND BOUNDARY CHANGE

I. ISSUE

Regulations defining the location of the Albemarle Sound/Chowan River Herring Management Areas need to be moved from Subchapter 03J to Subchapter 03R within Title 15A of the N.C. Administrative Code for improved organization and public clarity.

Additionally, a change to the boundary of the Anadromous Fish Spawning Area of the Cashie River is needed for consistency with boundary changes previously made in a separate fishery management plan.

II. ORIGINATION

Both of these issues originated with N.C. Division of Marine Fisheries (NCDMF) staff.

III. BACKGROUND

The description and boundaries of the Albemarle Sound/Chowan River Herring Management Area were originally placed in 15A NCAC 03J .0209 in 2001. Subchapter 03J of the N.C. Administrative Code contains rules for nets, pots, dredges, and other fishing devices for specific areas. A more appropriate subchapter for this rule is Subchapter 03R, Section .0200, which contains descriptive boundaries for fishery management areas and already includes the Striped Bass Management Areas.

The other issue addressed in this paper pertains to a change that was made in the boundary between the Albemarle Sound Management Area and Roanoke River Management Area for management of striped bass at the Cashie River that became effective June 1, 2013. The change was part of the N.C. Estuarine Striped Bass Fishery Management Plan Amendment 1 and made it easier for the public to identify where the management areas begin. Because this is also a boundary for the Anadromous Fish Spawning Area, it should be changed to maintain consistency (Figure 12.1).

IV. AUTHORITY

G.S. 113-134 RULES
G.S. 113-182 REGULATION OF FISHING AND FISHERIES
G.S. 113-221 RULES
G.S. 143B-289.52 MARINE FISHERIES COMMISSION – POWERS AND DUTIES

IV. DISCUSSION

Relocating the description and boundaries of the Albemarle Sound/Chowan River Herring Management Area to Subchapter 03R will maintain consistency with how fishery management area rules are organized. All of these areas will be listed together, making them easier for the public to find. A cross reference to this rule found in 15A NCAC 03O .0503 also needs to be updated.

Changing the boundary coordinates of the Anadromous Fish Spawning Area to reflect those changes made to the Albemarle Sound and Roanoke River management areas will maintain consistency for management and enforcement purposes.

VI. PROPOSED RULE(S)

15A NCAC 03J .0209 ALBEMARLE SOUND/CHOWAN RIVER RIVER HERRING MANAGEMENT AREAS

(a) ~~The Albemarle Sound Herring Management Area is defined as Albemarle Sound and all its joint water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their joint water tributaries, including Oregon Inlet, north of a line beginning on the west shore at a point 35° 48.5015' N – 75° 44.1228' W on Roanoke Marshes Point; running southeasterly to the east shore to a point 35° 44.1710' N – 75° 31.0520' W on the north point of Eagles Nest Bay.~~

(b) ~~The Chowan River Herring Management Area is defined as that area northwest of a line beginning on the west shore at a point 35° 59.9267' N – 76° 41.0313' W on Black Walnut Point; running northeasterly to the east shore to a point 36° 02.2140' N – 76° 39.3240' W on Reedy Point, to the North Carolina/Virginia state line; including the Meherrin River.~~

~~(c)~~ It is unlawful to use drift gill nets with a mesh length less than three inches from January 1 through May 15 in the Albemarle Sound and Chowan River river herring management areas defined in 15A NCAC 03R .0202.

History Note: *Authority G.S. 113-134; 113-182; 143B-289.52;*
Temporary Adoption Eff. May 1, 2000;
Eff. April 1, 2001;
Amended Eff. April 1, 2015; June 1, 2013; December 1, 2007;

15A NCAC 03O .0503 PERMIT CONDITIONS; SPECIFIC

(a) Horseshoe Crab Biomedical Use Permit:

(1) It is unlawful to use horseshoe crabs for biomedical purposes without first obtaining a permit.

(2) It is unlawful for persons who have been issued a Horseshoe Crab Biomedical Use Permit to fail to submit a report on the use of horseshoe crabs to the Division of Marine Fisheries due on February 1 of each year. Such reports shall be filed on forms provided by the Division and shall include a monthly account of the number of crabs harvested, statement of percent mortality up to the point of release, and a certification that harvested horseshoe crabs are solely used by the biomedical facility and not for other purposes.

(3) It is unlawful for persons who have been issued a Horseshoe Crab Biomedical Use Permit to fail to comply with the Atlantic States Marine Fisheries Commission Horseshoe Crab Fisheries Management Plan monitoring and tagging requirements for horseshoe crabs. Copies of this plan are available from the Atlantic States Marine Fisheries Commission, 1444 Eye Street, NW, 6th Floor, Washington, DC 20005, (202) 289-6400, or the Division of Marine Fisheries' Morehead City Office.

(b) Dealers Permits for Monitoring Fisheries under a Quota/Allocation:

(1) During the commercial season opened by proclamation or rule for the fishery for which a Dealers Permit for Monitoring Fisheries under a Quota/Allocation permit is issued, it is unlawful for fish dealers issued such permit to fail to:

(A) Fax or send via electronic mail by noon daily, on forms provided by the Division, the previous day's landings for the permitted fishery to the dealer contact designated on the permit. Landings for Fridays or Saturdays shall be submitted on the following Monday. If the dealer is unable to fax or electronic mail the required information, the permittee shall call in the previous day's landings to the dealer contact designated on the permit but shall maintain a log furnished by the Division;

(B) Submit the required log to the Division upon request or no later than five days after the close of the season for the fishery permitted;

(C) Maintain faxes and other related documentation in accordance with 15A NCAC 03I .0114;

(D) Contact the dealer contact daily regardless of whether or not a transaction for the fishery for which a dealer is permitted occurred;

(E) Record the permanent dealer identification number on the bill of lading or receipt for each transaction or shipment from the permitted fishery.

(2) Striped Bass Dealer Permit:

(A) It is unlawful for a fish dealer to possess, buy, sell or offer for sale striped bass taken from the following areas without first obtaining a Striped Bass Dealer Permit validated for the applicable harvest area:

(i) Atlantic Ocean;

(ii) Albemarle Sound Management Area as designated in 15A NCAC 03R .0201; and

(iii) The joint and coastal fishing waters of the Central/Southern Management Area as designated in 15A NCAC 03R .0201.

(B) No permittee shall possess, buy, sell or offer for sale striped bass taken from the harvest areas opened by proclamation without having a North Carolina Division of Marine Fisheries issued valid tag for the applicable area affixed through the mouth and gill cover, or, in the case of striped bass imported from other states, a similar tag that is issued for striped bass in the state of origin. North Carolina Division of Marine Fisheries striped bass tags shall not be bought, sold, offered for sale, or transferred. Tags shall be obtained at the North Carolina Division of Marine Fisheries Offices. The Division of Marine Fisheries shall specify the quantity of tags to be issued based on historical striped bass landings. It is unlawful for the permittee to fail to surrender unused tags to the Division upon request.

(3) Albemarle Sound Management Area for River Herring Dealer Permit: It is unlawful to possess, buy, sell or offer for sale river herring taken from the following area without first obtaining an Albemarle Sound Management Area for River Herring Dealer Permit: Albemarle Sound Management Area for River Herring is defined in ~~15A NCAC 03J .0209.~~15A NCAC 03R .0202.

(4) Atlantic Ocean Flounder Dealer Permit:

(A) It is unlawful for a fish dealer to allow vessels holding a valid License to Land Flounder from the Atlantic Ocean to land more than 100 pounds of flounder from a single transaction at their licensed location during the open season without first obtaining an Atlantic Ocean Flounder Dealer Permit. The licensed location shall be specified on the Atlantic Ocean Flounder Dealer Permit and only one location per permit shall be allowed.

(B) It is unlawful for a fish dealer to possess, buy, sell, or offer for sale more than 100 pounds of flounder from a single transaction from the Atlantic Ocean without first obtaining an Atlantic Ocean Flounder Dealer Permit.

(5) Black Sea Bass North of Cape Hatteras Dealer Permit. It is unlawful for a fish dealer to purchase or possess more than 100 pounds of black sea bass taken from the Atlantic Ocean north of Cape Hatteras (35° 15.0321' N) per day per commercial fishing operation during the open season unless the dealer has a Black Sea Bass North of Cape Hatteras Dealer Permit.

(c) Blue Crab Shedding Permit: It is unlawful to possess more than 50 blue crabs in a shedding operation without first obtaining a Blue Crab Shedding Permit from the Division of Marine Fisheries.

(d) Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean:

(1) It is unlawful to trawl for shrimp in the Atlantic Ocean without Turtle Excluder Devices installed in trawls within one nautical mile of the shore from Browns Inlet (34° 35.7000' N latitude) to Rich's Inlet (34° 17.6000' N latitude) without a valid Permit to Waive the Requirement to Use Turtle Excluder Devices in the Atlantic Ocean when allowed by proclamation from April 1 through November 30.

(2) It is unlawful to tow for more than 55 minutes from April 1 through October 31 and 75 minutes from November 1 through November 30 in this area when working under this permit. Tow time begins when the doors enter the water and ends when the doors exit the water.

(3) It is unlawful to fail to empty the contents of each net at the end of each tow.

(4) It is unlawful to refuse to take observers upon request by the Division of Marine Fisheries or the National Marine Fisheries Service.

(5) It is unlawful to fail to report any sea turtle captured. Reports shall be made within 24 hours of the capture to the Marine Patrol Communications Center by phone. All turtles taken incidental to trawling shall be handled and resuscitated in accordance with requirements specified in 50 CFR

223.206, copies of which are available via the Internet at www.nmfs.gov and at the Division of Marine Fisheries, 127 Cardinal Drive Extension, Wilmington, North Carolina 28405.

(e) Pound Net Set Permits. Rules setting forth specific conditions for pound net sets are set forth in 15A NCAC 03J .0505.

(f) Aquaculture Operations/Collection Permits:

(1) It is unlawful to conduct aquaculture operations utilizing marine and estuarine resources without first securing an Aquaculture Operation Permit from the Fisheries Director.

(2) It is unlawful:

(A) To take marine and estuarine resources from coastal fishing waters for aquaculture purposes without first obtaining an Aquaculture Collection Permit from the Fisheries Director.

(B) To sell, or use for any purpose not related to North Carolina aquaculture, marine and estuarine resources taken under an Aquaculture Collection Permit.

(C) To fail to submit to the Fisheries Director an annual report due on December 1 of each year on the form provided by the Division the amount and disposition of marine and estuarine resources collected under authority of this permit.

(3) Lawfully permitted shellfish relaying activities authorized by 15A NCAC 03K .0103 and .0104 are exempt from requirements to have an Aquaculture Operation or Collection Permit issued by the Fisheries Director.

(4) Aquaculture Operations/Collection Permits shall be issued or renewed on a calendar year basis.

(5) It is unlawful to fail to provide the Division of Marine Fisheries with a listing of all designees who will be acting under an Aquaculture Collection Permit at the time of application.

(g) Scientific or Educational Collection Permit:

(1) It is unlawful for individuals or agencies seeking exemptions from license, rule, proclamation or statutory requirements to collect for scientific or educational purposes as approved by the Division of Marine Fisheries any marine and estuarine species without first securing a Scientific or Educational Collection Permit.

(2) It is unlawful for persons who have been issued a Scientific or Educational Collection Permit to fail to submit a report on collections to the Division of Marine Fisheries due on December 1 of each year unless otherwise specified on the permit. The reports shall be filed on forms provided by the Division. Scientific or Educational Collection Permits shall be issued on a calendar year basis.

(3) It is unlawful to sell marine and estuarine species taken under a Scientific or Educational Collection Permit:

(A) without the required license(s) for such sale;

(B) to anyone other than a licensed North Carolina fish dealer; and

(C) without authorization stated on the permit for such sale.

(4) It is unlawful to fail to provide the Division of Marine Fisheries a listing of all designees who will be acting under Scientific or Educational Collection Permits at the time of application.

(5) The permittee or designees utilizing the permit shall call or fax the Division of Marine Fisheries Communications Center not later than 24 hours prior to use of the permit, specifying activities and location.

(h) Under Dock Oyster Culture Permit:

(1) It is unlawful to cultivate oysters in containers under docks for personal consumption without first obtaining an Under Dock Oyster Culture Permit.

(2) An Under Dock Oyster Culture Permit shall be issued only in accordance with provisions set forth in G.S. 113-210(c).

(3) The applicant shall complete and submit an examination, with a minimum of 70 percent correct answers, based on an educational package provided by the Division of Marine Fisheries pursuant to G.S. 113-210(j). The examination demonstrates the applicant's knowledge of:

(A) the application process;

(B) permit criteria;

(C) basic oyster biology and culture techniques;

(D) shellfish harvest area closures due to pollution;

(E) safe handling practices;

(F) permit conditions; and

(G) permit revocation criteria.

(4) Action by an Under Dock Oyster Culture Permit holder to encroach on or usurp the legal rights of the public to access public trust resources in coastal fishing waters shall result in permit revocation.

(i) Atlantic Ocean Striped Bass Commercial Gear Permit:

(1) It is unlawful to take striped bass from the Atlantic Ocean in a commercial fishing operation without first obtaining an Atlantic Ocean Striped Bass Commercial Gear Permit.

(2) It is unlawful to use a single Standard Commercial Fishing License, including assignments, to obtain more than one Atlantic Ocean Striped Bass Commercial Gear Permit during a license year.

(j) Coastal Recreational Fishing License Exemption Permit:

(1) It is unlawful for the responsible party seeking exemption from recreational fishing license requirements for eligible individuals to conduct an organized fishing event held in coastal or joint fishing waters without first obtaining a Coastal Recreational Fishing License Exemption Permit.

(2) The Coastal Recreational Fishing License Exemption Permit shall only be issued for recreational fishing activity conducted solely for the participation and benefit of one of the following groups of eligible individuals:

(A) Individuals with physical or mental limitations;

(B) Members of the United States Armed Forces and their dependents, upon presentation of a valid military identification card, for military appreciation;

(C) Individuals receiving instruction on recreational fishing techniques and conservation practices from employees of state or federal agencies, or instructors affiliated with educational institutions; and

(D) Disadvantaged youths.

(3) The Coastal Recreational Fishing License Exemption Permit is valid for the date(s), time and physical location of the organized fishing event for which the exemption is granted and the time period shall not exceed one year from the date of issuance.

(4) The Coastal Recreational Fishing License Exemption Permit shall only be issued when all of the following, in addition to the information required in 15A NCAC 03O .0501, is submitted to the Fisheries Director in writing a minimum of 30 days prior to the event:

(A) The name, date(s), time and physical location of the event;

(B) Documentation that substantiates local, state or federal involvement in the organized fishing event, if applicable;

(C) The cost or requirements, if any, for an individual to participate in the event; and

(D) An estimate of the number of participants.

(k) For Hire Fishing Permit:

(1) It is unlawful to operate a For Hire Vessel unless the vessel operator possesses either the For Hire Blanket Coastal Recreational Fishing License (CRFL) for the vessel as provided in 15A NCAC 03O .0112 or a Division of Marine Fisheries For Hire Fishing Permit for the vessel.

(2) It is unlawful for a For Hire vessel operator to operate under the For Hire Fishing Permit without:

(A) Holding the USCG certification required in 15A NCAC 03O .0501(g)(1);

(B) Having the For Hire Fishing Permit for the vessel or copy thereof in possession and ready at hand for inspection;

(C) Having current picture identification in possession and ready at hand for inspection.

(3) It is unlawful for the permittee to fail to notify the Division within five days of any changes to information provided on the permit.

(4) It is unlawful to fail to display a current For Hire Fishing Permit decal mounted on an exterior surface of the vessel so as to be visible when viewed from the port side while engaged in for-hire recreational fishing.

(5) The For Hire Fishing Permit is valid for one year from the date of issuance.

History Note: *Authority G.S. 113-134; 113-169.1; 113-169.3; 113-182; 113-210; 143B-289.52;*
Temporary Adoption Eff. September 1, 2000; August 1, 2000; May 1, 2000;
Eff. April 1, 2001;
Amended Eff. April 1, 2015; April 1, 2009; July 1, 2008; January 1, 2008; September 1, 2005; October 1, 2004; August 1, 2004; August 1, 2002.

15A NCAC 03R .0115 ANADROMOUS FISH SPAWNING AREAS

The anadromous fish spawning areas as defined in 15A NCAC 03I .0101 and referenced in 15A NCAC 03N .0106 are delineated in the following coastal waters:

(1) Currituck Sound Area:

(a) Northwest River- all waters of the Northwest River and its tributaries east of a line beginning on the north shore at a point 36º 30.8374' N – 76º 04.8770' W; running southerly to the south shore to a point 36º 30.7061' N – 76º 04.8916' W.

(b) Tull Bay/Tull Creek- all waters of Tull Bay and its tributaries northeast of a line beginning on the north shore at a point 36º 30.0991' N – 76º 04.8587' W; running southeasterly to the south shore to a point 36º 29.9599' N – 76º 04.7126' W; and south of a line beginning on the west shore at a point 36º30.9867' N – 76º 02.5868' W; running easterly to the east shore to a point 36º31.0045' N – 76º 02.3780' W; and west of a line beginning on the north shore at a point 36º 30.8291' N – 76º 02.1329' W; running southwesterly to the south shore to a point 36º 30.1512' N – 76º 02.4982' W.

(2) Albemarle Sound Area:

(a) Big Flatty Creek- all waters of Big Flatty Creek and its tributaries east of a line beginning on the north shore at a point 36º 09.3267'N – 76º 08.2562'W; running southerly to the south shore to a point 36º 08.9730'N – 76º 08.3175'W and north of a line beginning on the west shore at a point 36º 07.9621'N – 76º 07.1818'W; running easterly to the east shore to a point 36º 08.2706'N – 76º 06.2525'W.

(b) Batchelor Bay- west of a line beginning on the north shore at a point 35º 58.2070' N – 76º 42.7267' W; running southeasterly to the south shore to a point 35º 56.5622' N – 76º 41.5506' W.

(c) Bull Bay- southwest of a line beginning on the northwest shore at a point 35º 58.9002' N – 76º 23.9965' W; running southeasterly to the southeast shore at a point 35º 56.7198' N – 76º 18.8964' W.

(3) North River- all waters of the North River and its tributaries east of a line beginning on the north shore at a point 36º 18.7703' N – 75º 58.7384' W; running southerly to the south shore to a point 36º 18.4130' N – 75º 58.7228' W; and north of a line beginning on the west shore at a point 36º 16.9952' N – 75º 57.0758' W; running easterly to the east shore to a point 36º 16.9801' N – 75º 56.6820' W.

(4) Pasquotank River- all waters of the Pasquotank River and its tributaries south of a line beginning on the west shore at a point 36º 18.0768' N – 76º 13.0979' W; running easterly to the east shore along the south side of the Highway 158 Bridge to a point 36º 18.0594' N – 76º 12.9620' W; and northwest of a line beginning on the northeast shore at a point 36º 14.3294' N– 76º 04.7866' W; running southwesterly to the southwest shore to a point 36º 12.8147' N- 76º 07.0465' W.

(5) Pasquotank River Area:

(a) Charles Creek- north of a line beginning on the west shore at a point 36º 17.8090' N – 76º 13.0732' W; running easterly to the east shore to a point 36º 17.8024' N – 76º 13.0407' W.

(b) New Begun Creek- east of a line beginning on the north shore at a point 36º 13.3298' N – 76º 08.2878' W; running southerly to the south shore to a point 36º 13.0286' N – 76º 08.1820' W.

(6) Little River- all waters of the Little River and its tributaries southeast of a line beginning on the west shore at a point 36º 12.5237' N – 76º 16.9418' W; running southeasterly to the east shore to a point 36º 12.2950' N – 76º 17.1405' W; and north of a line beginning on the west shore at a point 36º 09.6537' N – 76º 15.0689' W; running northeast to the east shore to a point 36º 10.2112' N – 76º 14.0287' W.

(7) Perquimans River- all waters of the Perquimans River and its tributaries northeast of a line beginning on the west shore at a point 36º 11.6569' N – 76º 28.0055' W; running southeasterly to the east shore to a point 36º 11.6123' N – 76º 27.9382' W; and northwest of a line beginning on the southwest shore at a point 36º 11.1512' N – 76º 27.4424' W; running northeasterly to the northeast shore to a point 36º 11.5124' N – 76º 26.7298' W.

(8) Perquimans River Area:

(a) Walter's Creek- northeast of a line beginning on the north shore at a point 36º 11.1305' N – 76º 27.9185' W; running southeasterly to the south shore to a point 36º 11.0224' N – 76º 27.6626' W.

(b) Mill Creek- south of a line beginning on the west shore at a point 36º 11.9766' N – 76º 27.2511' W; running easterly to the east shore to a point 36º 11.9757' N – 76º27.5752' W.

(9) Yeopim River- all waters of the Yeopim River and its tributaries east of a line beginning on the north shore at a point 36º 05.4526'N – 76º27.7651'W; running southerly to the south shore to a point on Norcum Point 36º 05.1029'N – 76º27.7120' W; and west of a line beginning on the north shore at a point 36º 04.7426' N – 76º 24.2537' W; running southwesterly to the south shore to a point 36º 04.1137' N – 76º 24.5366' W.

(10) Yeopim River Area, Yeopim Creek- south of a line beginning on the west shore at a point 36º 04.7206' N – 76º 24.8396' W; running easterly to the east shore to a point 36º 04.7426' N – 76º 24.2536' W.

(11) Edenton Bay- all waters of Edenton Bay and its tributaries west of a line beginning on the north shore at a point 36º 03.3757' N – 76º 36.3629' W; running southerly to the south shore to a point 36º 03.3551' N – 76º 36.3574' W; and north of a line beginning on the west shore at a point 36º 02.1767' N – 76º 38.4058' W; running easterly to the east shore to a point 36º 02.0299' N – 76º 36.0445' W; and east of a line beginning on the west shore at a point 36º 03.2819' N – 76º 37.0138' W; running northeasterly to the east shore to a point 36º 03.4185' N – 76º 36.6783' W.

(12) Chowan River- all waters of the Chowan River and tributaries northwest of a line beginning on the west shore at a point 36º 02.3162' N – 76º 42.4896' W; running northeasterly to the east shore to a point 36º 03.1013' N – 76º40.8732' W; and south of a line beginning on the west shore at a point 36º 32.6293' N – 76º 55.3564' W; and running to the east shore to a point 36º 32.6284' N – 76º 55.1757' W.

(13) Chowan River Area, Meherrin River- all waters of the Meherrin River and tributaries west of a line beginning on the north shore at a point 36º 25.9937' N – 76º 56.8884' W; running southerly to the south shore to a point 36º 25.7926' N – 76º 56.8966' W; and south of a line beginning on the west shore at a point 36º 32.7867' N – 77º 09.8885' W; running easterly to the east shore to a point 36º 32.7807' N – 77º 09.8565' W.

(14) Cashie River- all waters of the Cashie River and tributaries east of a line beginning on the north shore at a point 35º 54.7865' N – 76º 49.0521' W; running southerly to the south shore at a point 35º 54.6691' N – 76º 49.0553' W; west of a line beginning on the ~~north~~ west shore at a point ~~35º 56.4598' N – 76º 43.8093' W;~~ 35° 56.2934' N –76° 44.1769' W; running ~~southerly~~ easterly to the north shore to a point on the north shore of an island in the mouth of the river 35º 56.2250' N – 76º 43.9265' W; west of a line beginning on the south shore at a point of an island in the mouth of the river 35º 56.1254' N – 76º 43.9846' W; running southerly to the south shore to a point 35º 56.0650' N – 76º 43.9599' W.

(15) Middle River- all waters of the Middle River southwest of a line beginning on the west shore at a point 35º 55.4000' N – 76º 43.8259' W; running southeasterly to the east shore to a point 35º 55.3977' N – 76º43.6797' W.

(16) Eastmost River- all waters of the Eastmost River and its tributaries south of a line beginning on the west shore at a point 35º 56.5024' N – 76º 42.4877' W; running westerly to the east shore to a point 35º 56.4070' N – 76º 42.7647' W.

(17) Roanoke River - all waters of the Roanoke River and tributaries south of a line beginning on the west shore at a point 35º 56.5068' N – 76º 41.8858' W; running easterly to the east shore to a point 35º 56.5324' N – 76º 41.5896' W; and southeast of a line beginning on the west shore at a point 36º 12.5264' N – 77º 23.0223' W; running northeasterly to the east shore along the south side of the Highway 258 Bridge to a point 36º 12.5674' N – 77º 22.9724' W.

(18) Roanoke River Area:

(a) Warren Neck Creek- all waters of Warren Neck Creek and its tributaries west of a line beginning on the northwest shore at a point 35º 52.1820' N – 76º 47.4855' W; running southerly to the southeast shore to a point 35º 52.1448' N – 76º 47.4237' W.

(b) Thoroughfare- all waters of the Thoroughfare south of a line beginning on the west shore at a point 35º 54.0510' N – 76º 48.1206' W; running easterly to the east shore to a point 35º 54.0684' N – 76º 48.0613' W; and north of a line beginning on the west shore at a

point 35º 53.2842'N – 76º 48.8650' W; running easterly to the east shore to a point 35º 55.2800' N – 76º 48.8077' W.

(c) Devils Gut- all waters of Devils Gut and its tributaries northwest of a line beginning on the west shore at a point 35º 49.5300' N – 76º 54.2209' W; running easterly to the east shore to a point 35º 49.5486' N – 76º 54.1703' W.

(d) Conine Creek- all waters of Conine Creek and its tributaries west of a line beginning on the north shore at a point 35º 52.9752' N – 76º 58.0474' W; running southwesterly to the south shore to a point 35º 52.9776' N – 76º 57.9958' W.

(19) Scuppernong River- all waters of the Scuppernong River and tributaries southeast of a line beginning on the northeast shore at a point 35º 56.7196' N – 76º 18.8964' W; running southwesterly to the southwest shore to a point 35º 56.3351' N – 76º 19.6609' W; and north of a line beginning on the west shore at a point 35º 54.0158' N – 76º 15.4605' W; running easterly to the east shore to a point 35º 54.0406' N – 76º 15.3007' W.

(20) Alligator River- all waters of the Alligator River and tributaries east of a line beginning on the north shore at Cherry Ridge Landing at a point 35º 42.2172' N – 76º 08.4686' W; running southerly to the south shore to a point 35º 42.1327' N – 76º 08.5002' W; and south of a line beginning on the west shore at a point 35º 57.4252' N – 76º 00.8704' W; running easterly to the east shore to a point 35º 57.5494' N – 75º 56.8268' W.

(21) Alligator River Area, the Frying Pan- all waters of the Frying Pan and its tributaries west of a line beginning on the north shore at a point 35º 46.0777' N – 76º 03.3439' W; running southerly to the south shore to a point 35º 45.6011' N – 76º 03.3692' W.

(22) Neuse River- all waters of the Neuse River and its tributaries northwest of a line beginning on the west shore at a point 35° 08.8723'N - 77° 04.6700' W; running northeasterly to the east shore to a point 35° 09.1032' N - 77° 04.3355' W and southeast of a line at Pitch Kettle Creek beginning on the north shore at a point 35° 16.9793'N - 77° 15.5529'W; running south to the south shore to a point 35°16.9237'N - 77° 15.5461' W.

(23) Neuse River Area:

(a) Smith Creek- north of a line beginning on the west shore at a point 35° 02.2439'N - 76° 42.3035' W; running easterly to the east shore to a point 35° 02.2392' N - 76° 42.1910' W.

(b) Kershaw Creek- north of a line beginning on the west shore at a point 35° 02.4197'N - 76° 43.7886' W; running easterly to the east shore to a point 35° 02.4218'N - 76° 43.7367' W.

(24) White Oak River- all waters north of a line beginning at a point on the west shore 34° 46.0728' N - 77° 08.9657' W; running easterly to a point on the east shore 34° 46.1431' N - 77° 08.8907' W; running north to the Coastal – Inland waters boundary line beginning at a point on the west shore 34° 48.1466' N - 77° 11.4711' W; running northeasterly to a point on the east shore 34° 48.1620' N - 77° 11.4244' W.

(25) Cape Fear River- all waters north of a line beginning at a point on the west shore 34° 07.7034' N – 77° 57.3431' W; running easterly to a point on the east shore 34° 08.0518' N – 77° 55.7626' W; running north to the Joint - Inland waters boundary on the following rivers:

(a) Cape Fear River- at a line beginning at a point on the west shore 34° 24.2628' N - 78° 17.6390' W; running northeasterly along the Lock and Dam # 1 to a point on the east shore 34° 24.2958' N - 78° 17.5634' W.

(b) Black River- at a line beginning at a point on the north shore 34° 22.0783' N - 78° 04.4123' W; running southeasterly to a point on the south shore 34° 21.9950' N - 78° 04.2864' W.

(c) Northeast Cape Fear River- at a line beginning at a point on the west side 34° 26.5658' N - 77° 50.0871' W; running northeasterly along the southern side of the NC 210 Bridge to a point on the east side 34° 26.6065' N - 77° 49.9955' W.

History Note: *Authority G.S. 113-134; 113-182; 113-221; 143B-289.52;*
Eff. December 1, 2007;
Amended Eff. April 1, 2015.

15A NCAC 03R .0202 RIVER HERRING MANAGEMENT AREAS

(a) The Albemarle Sound River Herring Management Area referenced in 15A NCAC 03J .0209 is defined as the coastal and joint fishing waters of Albemarle, Currituck. Roanoke, Croatan and Pamlico sounds and all their joint water tributaries north of a line beginning on the west shore at a point 35° 48.5015' N – 75° 44.1228' W on Roanoke Marshes Point; running southeasterly to the east shore to a point 35° 44.1710' N – 75° 31.0520' W on the north point of Eagles Nest Bay.

(b) The Chowan River River Herring Management Area referenced in 15A NCAC 03J .0209 is defined as the area northwest of a line beginning on the west shore at a point 35° 59.9267' N – 76° 41.0313' W on Black Walnut Point; running northeasterly to the east shore to a point 36° 02.2140' N – 76° 39.3240' W on Reedy Point, to the North Carolina/Virginia state line; including the Meherrin River.

History Note: Authority G.S. 113-134; 113-182; 143B-289.52;
Eff. April 1, 2015;

VII. PROPOSED MANAGEMENT OPTIONS

(+ potential positive impact of action)
(- potential negative impact of action)

1. Status Quo- No changes

+ No administrative burden
- Not consistent with how fishery management area rules are organized
- Not consistent with boundary references

2. Move Albemarle Sound/ Chowan River River Herring Management Areas from 15A NCAC 03J .0209 to 15A NCAC 03R .0202, correct reference to Albemarle Sound/ Chowan River River Herring Management Areas in 15A NCAC 03O .0503 (b) (3), and correct boundary to Cashie River Anadromous Fish Spawning Area in 15A NCAC 03R .0115 (14).

+ Maintain consistency in how fishery management areas are organized.
+ Cross-references will be up to date.
+ Boundary coordinates will be consistent.
- Minor administrative burden.

VIII. RECOMMENDATION

NCMFC- Option 2- Move Albemarle Sound/ Chowan River River Herring Management Areas from 15A NCAC 03J .0209 to 15A NCAC 03R .0202, correct reference to Albemarle Sound/ Chowan River River Herring Management Areas in 15A NCAC 03O .0503 (b) (3), and correct boundary to Cashie River Anadromous Fish Spawning Area in 15A NCAC 03R .0115 (14).

NCWRC- Option 2

AC- Option 2

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Revised: August 1, 2013 NCDMF

Revised: February 26, 2014 NCMFC recommendations
Revised: February 28, 2014 NCWRC recommendations

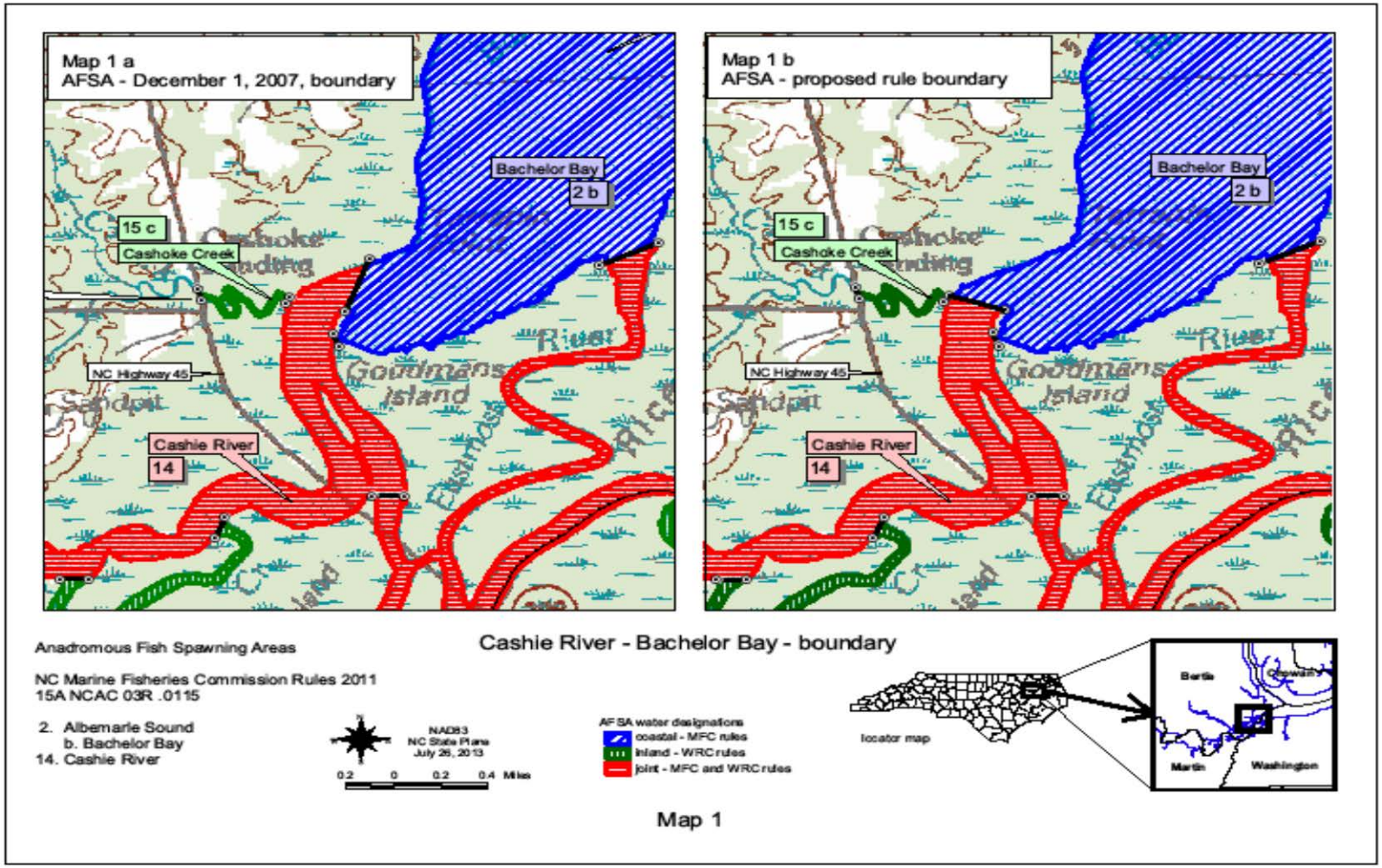

Figure 12.1 Map showing the old boundary (left) and the new boundary (right) for the Anadromous Fish Spawning Area on the Cashie River.

13.0 RESEARCH RECOMMENDATIONS

The following are research recommendations developed by the River Herring Plan Development Team to guide researchers in developing projects. The PDT ranked these recommendations as Low, Medium, or High. A High ranking indicates a large gap in information that might be critical for management decisions. A Low ranking does not imply lack of importance but may indicate an issue that has been partially addressed or is less time-sensitive in nature.

13.1 Life History

- Conduct studies of river herring egg and larval survival and development in North Carolina river systems. **High priority**

- Conduct research on predation of all life stages of river herring in the Albemarle Sound and other systems in North Carolina (including invasive species such as blue catfish and other predators). **Medium priority**

- Conduct studies on energetics of feeding and spawning migrations of river herring in North Carolina. **Medium priority**

13.2 Stock Status

- Estimate bycatch and discard mortality of river herring captured incidentally in Atlantic ocean fisheries coastwide. **High priority**

- Estimate bycatch and discard mortality of river herring captured incidentally in inside fisheries. **Medium priority**

13.3 Environmental Factors

13.3.1 Water Quality Recommendations

- Evaluate effects of existing and future water withdrawals on water quality, quantity and fisheries habitat in coastal watersheds. NCDMF and NCWRC review and comment on water withdrawals and their effect on fisheries and habitat. **High priority**

- Determine if contaminants are present and identify those that are potentially detrimental to various life history stages of river herring. Long term water quality monitoring devices have been maintained and deployed to identify shifts or swings in water quality in multiple tributaries in the Albemarle Sound area. **High priority**

- Evaluate the impacts/effects of reverse osmosis (RO) plants on receiving waters and aquatic resources. NCDCM and NCWRC provide comments on permit applications re: RO plants; some work by universities to evaluate effects of RO plants in local river systems. **Low priority**

13.3.2 Obstruction Recommendations

- Identify all man-made physical obstructions to river herring migrations (update Collier and Odom project) and prioritize impediments for removal /replacement after identification. The NCDMF has surveyed culverts in the Chowan River area and developed a priority list for replacement or repair. This information will be used by a paid graduate student to investigate fish friendly culverts. **High priority**

- Identify research needs regarding impediments to river herring migration. **High priority**.

13.3.3 Impingement and Entrainment Recommendations

- Research is needed to determine the fate of river herring eggs, fry and juveniles that are impinged, and then released through screen cleaning operations. **Low priority**

13.3.4 Climate change

- The specific effects of climate change, including warming water, increased drought severity, and loss of flood plain spawning habitat should be further investigated. **Low priority**

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15.0 APPENDICES

15.1 INTERNAL TIMELINE FOR AMENDMENT 2 OF THE RIVER HERRING FISHERY MANAGEMENT PLAN

DMF INTERNAL TIMELINE FOR THE DEVELOPMENT OF THE N.C. RIVER HERRING FMP AMENDMENT 2

(Revised April 2, 2013)

TASK (RESPONSIBLE PARTY)	TIMELINE
Appoint PDT (DMF Director, WRC Executive Director)	July 2012
Discuss use of ASMFC stock assessment; identify initial issues; develop goal and objectives (PDT)	October 2012
Review FMP (PDT); assign individual PDT members to update FMP sections (PDT Leads)	October 2012
Determine if amendment is needed (PDT, FMP Coordinator)	October 2012
Develop timeline (PDT) and approve it (DMF Director)	October 2012
Solicit and submit FMP AC candidates to MFC Chairman (PDT Leads, 2012 MFC Liaison)	October-November
Appoint FMP AC (DMF Director, MFC Chairman)	December 2012
Conduct first FMP AC meeting for orientation; discuss stock assessment, issues, goal and objectives (PDT, FMP AC)	Early January 2013
Appoint RAT subgroup (RAT Chairman)	January 2013
Present stock assessment, issues, goal and objectives to MRT and DMF Director for approval (PDT Leads)	Mid-January 2013
DMF Director and WRC Executive Director review stock assessment, issues, goal and objectives	Late January 2013
If changes discussed, present stock assessment, issues, goal and objectives to MRT and DMF Director for approval (PDT Leads)	By February 11, 2013
Present timeline to MFC; request approval of goal and objectives from MFC; solicit input on issues from MFC (PDT Leads, MFC)	February 28, 2013
Finalize list of major issues; review management issues; develop issue papers; revise informational sections (PDT, FMP AC, RAT Subgroup)	January-August 2013

Establish PDT, FMP AC, DMF, and WRC positions (PDT, FMP AC, MRT, DMF Director, WRC Executive Director)	September 2013
Complete draft amendment and forward it to FMP AC (PDT)	October 2013
Obtain MFC approval for review of draft amendment by public and regional ACs * (PDT Leads, MFC)	November 14, 2013
Post draft amendment on web site and present it at AC meetings (Public Affairs, PDT Leads)	November-December 2013
Address public comments with FMP AC and revise draft amendment, if necessary (PDT, FMP AC)	January 2014
Present revised draft amendment to MRT and DMF Director for approval and final DMF position (PDT Leads)	February 2014
Incorporate final DMF position in revised draft amendment and forward 2014 updated draft to WRC Executive Director (PDT Leads)	By mid-February
Present updated draft amendment to MFC for selection of preferred management options and approval for review by DENR Secretary and JLCGO (PDT Leads, MFC)	February 2014
Revise draft amendment with MFC comments, if necessary (PDT)	March 2014
Submit final draft amendment to DMF Director and WRC Executive Director (PDT Leads, MFC Liaison, DMF Director, WRC Executive Director)	March 2014
Submit final draft amendment to DENR Secretary (DMF Director)	March 2014
Forward final draft amendment to JLCGO (DENR Secretary)	March 2014
Incorporate DENR Secretary and JLCGO comments (PDT)	April 2014
Present final draft amendment and proposed rules to MFC and WRC; request approval for Notice of Text for Rulemaking (PDT Leads, FMP Coordinator, MFC and WRC)	May 2014
Publish proposed rules in *N.C. Register*	August 2014
Conduct public hearings on proposed rules	September 2014
Submit final draft amendment and permanent rules to MFC for final approval	November 2014
Rules reviewed by Office of Administrative Hearings Rules Review Commission	January 2015
Earliest effective date of rules	February 1, 2015

Forward new rules to vendor for publication	February 2015
MFC Proposed effective date of new rules	April 1, 2015
WRC Proposed effective date of new rules	August 1, 2015

*Public meetings for the FMP will be held in each of the regional districts (northern and southern)

AC	Advisory Committee
DMF	Division of Marine Fisheries
FMP	Fishery Management Plan
MFC	Marine Fisheries Commission
PDT	Plan Development Team (DMF staff)
Secretary	Secretary of the Department of Environment and Natural Resources
JLCGO	Joint Legislative Commission on Governmental Operations
MRT	DMF Management Review Team
RAT	DMF Rules Advisory Team
WRC	Wildlife Resources Commission

15.2 RIVER HERRING REGULATIONS BY STATE

15.2.1 Commercial

State	Season	Comments
Maine	Closed	Exceptions are municipalities with existing river herring fishing rights
New Hampshire	Closed on Wednesdays only	Regulations vary by river
Massachussetts	Closed	
Rhode Island	Closed	
Connecticut	Closed	
New Jersey	Closed	
New York	March 15-June 15	Hudson River only; various area and gear restrictions; recreational anglers are allowed to sell their catch.
Pennsylvania	Closed	
Delaware	Closed	
Maryland	Closed	
Virginia	Closed	
South Carolina	February-May (but varies)	Regulations vary by river system

15.2.2 Recreational

State	Season	Comments
Maine	None	Hook and line, dip net, 25 per day.
New Hampshire	Closed on Wednesdays only	Regulations vary by river
Massachussetts	Closed	
Rhode Island	Closed	
Connecticut	Closed	
New Jersey	Closed	
New York	March 15-June 15	Hudson River only; various area and gear restrictions; recreational anglers are allowed to sell their catch.
Pennsylvania	Closed	
Delaware	Closed	
Maryland	Closed	
Virginia	Closed	
South Carolina	February-May (but varies)	Regulations vary by river system

15.3 2012 ASMFC STOCK ASSESSMENT

16. Status of River Herring Stocks in North Carolina Rivers

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Executive Summary
River herring fisheries in North Carolina's coastal sounds and rivers were once among the largest freshwater fisheries in the world. Significant declines in commercial landings and overall stock abundance began in the mid to late 1980s and continues on an overall declining trend. In 2007 the NC Marine Fisheries Commission adopted the NC River Herring Fishery Management Plan (NCRHFMP) that implemented a no harvest provision for commercial and recreational river herring fisheries in the Coastal and Joint waters of the state.

A forward- projecting age structured statistical catch -at -age (SCA) model for Chowan River blueback herring (*Alosa aestivalis)* was applied to the total in-river catches, age compositions, length compositions, and a fisheries independent young-of-year (YOY) index to estimate age-3 abundance and mortality rates. The assessment time period was 1972-2009. Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.14 in 1979 to as high as 0.87 in 1986. Exploitation averaged about 0.28 prior to 1985, increased to an average of 0.70 during 1985–1988, and averaged about 0.40 between 1989 and 2006. Since the moratorium, exploitation rates have been close to zero. Fishing mortality averaged about 0.34 prior to 1985, increased to an average of 1.3 during 1985–1988, and averaged about 0.56 between 1989 and 2006. Since the moratorium, fishing mortality has been close to zero. Blueback herring total abundance (3+) declined steadily from 133 million fish in 1979 to 55 million fish in 1980. Total abundance increased through 1983 to 103 million fish and then declined precipitously to its lowest value of 1.1 million fish in 2002. Since 2002 total abundance has averaged 1.9 million fish. Age- 3 abundance peaked at 81 million fish in 1975, and has declined precipitously since 1983 to 0.62 million fish in 2001. Since 2002, total abundance of age-3 fish has averaged 1.0 million fish. Female SSB fluctuated but declined steadily from the peak of 5.2 million kilograms in 1972 to a low of 0.14 million kilograms in 1986. Female SSB increased slightly to 0.46 million through 1990, but then it declined slowly to its lowest level of 15,000 kilograms in 2003. Since 2004, female SSB has averaged about 81,000 kilograms. From the spawner-recruit data and production model, F_{MED} was estimated to be 0.59. The fishing mortality rate that produces maximum sustainable yield, F_{MSY}, was 0.39 and corresponding spawning stock bass, SSB_{MSY}, was 1,955,333 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,195,873 kilograms). Current female spawning stock biomass is only 5% of SSB_{MSY}. The fishing mortality rate that drives the population to extinction, F_{COL}, was 0.91. The estimates of F_{MSY} and F_{COL} are considerably lower than those estimated for

alewife (F_{MSY} > 1.0; F_{COL} >1.82) in three Canadian rivers by Gibson and Myers (2003b). When comparing fishing mortality rate estimates to the derived reference points the fishing mortality exceeded all reference points several times over the time series, particularly after 1985.

Excessive exploitation and poor recruitment have led to depletion of the Chowan River blueback herring stock. Despite a fishing pressure that is almost negligibly low since implementation of the 2007 no- harvest provision, the stock remains overfished as the spawning stock biomass remains less than 5% of the amount necessary to replace itself in the complete absence of fishing.

16.1 INTRODUCTION

Historically, river herring (blueback herring, *Alosa aestivalis* and, alewife *Alosa pseudoharengus)* supported commercial and recreational fisheries in most of North Carolina's coastal rivers. The major concentrations of river herring historically and currently are found in the Albemarle Sound and its tributaries (Figure). Due to overfishing, habitat loss and water quality degradation, river herring landings in North Carolina began to decline in the mid to late 1980's. The 2005 North Carolina River Herring Stock Assessment indicated that river herring were overfished and that overfishing was occurring (Grist 2005). In 2006 the NC Wildlife Resources Commission (NCWRC) adopted a rule that prohibits possession of river herring six inches and greater in all inland waters of the state. In 2007 the NC Marine Fisheries Commission (NCMFC) adopted Amendment 1 to the NC River Herring Fishery Management Plan (NCRHFMP), which prohibited commercial and recreational harvest in all coastal and joint waters of the state and set aside a 7,500 pound annual research harvest with area, season and gear restrictions. A maximum 4,000 pounds (of the 7,500 pounds) are allocated for commercial harvest and data collection in a limited fishery with quota, time and area restrictions. This fishery was approved by the ASMFC Shad & River Herring Management Board in 2011. The NCRHFMP also identified stock recovery indicators which are currently being monitored by the NC Division of Marine Fisheries (NCDMF). Revision of the 2007 NCRHFMP will begin in July of 2012. River herring data available from 2007-2011 will be analyzed and presented in the update of the 2007 FMP.

Although the 2007 NCRHFMP was a statewide plan, river herring data from systems outside of the Albemarle Sound area are not available. The NCDMF has conducted spawning and nursery area surveys and some age composition work for most of the coastal streams outside the Albemarle Sound area, but this work ended 15 – 23 years ago, varying with area, as federal aid funds were decreased. Current data, other than landings data, simply do not exist for river herring outside the Albemarle Sound area. Data from the Albemarle Sound and particularly Chowan River were used to determine the 2005 stock status of alewife and blueback herring in NC. Blueback herring was selected as the indicator species for the 2005 NC River Herring Stock Assessment and the overall development of the NCRHFMP. One of the key research recommendations in the 2007 NCRHFMP was to expand data collection programs to other river systems in the state. Currently, no expansion of those data collection programs has occurred.

16.2 DESCRIPTION OF MANAGEMENT UNIT

The management of river herring in North Carolina is conducted in joint and coastal waters by the NCDMF and in inland waters by the NCWRC. The management units established in the 2000 Albemarle Sound River Herring Fishery Management Plan (ASFHRMP) include the two species of river herring (blueback and alewife) and their fisheries throughout coastal North Carolina.

The management areas are defined as follows:

The Albemarle Sound River Herring Management Area (ASRHMA)- Albemarle Sound and all its Coastal, Joint and Inland water tributaries; Currituck Sound; Roanoke and Croatan sounds and all their Coastal, Joint and Inland water tributaries, including Oregon Inlet, north of a line from Roanoke Marshes Point 35° 48.3693' N -75° 43.7232' W across to the north point of Eagles Nest Bay 35° 44.1710' N - 75° 31.0520' W.

The Chowan River Herring Management Area (CRHMA)- Northwest of a line from Black Walnut Point 35° 59.9267' N - 76° 41.0313' W to Reedy Point 36°02.2140' N - 76° 39.3240' W, to the North Carolina/Virginia state line; including the Meherrin River.

16.3 REGULATORY HISTORY

From 1915-1965 various regulations including season and area closures as well as gear restrictions were implemented in the N.C. river herring fisheries. Beginning in 1995 various restrictions including season closures and total allowable catch limits were implemented.

The two management areas (ASRHMA and CRHMA) were established in the 2000 ASRHFMP and defined in North Carolina Fisheries Rules for Coastal Waters 2003 rule 15A NCAC 3J. 0209. An annual quota, or total allowable catch (TAC) of 300,000 pounds was established in 2000 for the ASRHMA and was allocated as follows: 200,000 pounds to the pound net fishery for the CRHMA; 67,000 pounds to the ASRHMA gill net fishery; 33,000 pounds to be allocated at the discretion of the NCDMF Director (15A NCAC 3M.0513). The same rule also granted the Director proclamation authority as it applies to blueback herring, alewife, American and hickory shad fisheries, and also established a 25 fish per person per day (blueback herring and alewife combined) recreational creel limit.

The commercial TAC was further reduced in 2006 for the ASRHMA with 65,000 pounds allocated to CRHMA pound net fishery; 35,000 pounds to the ASRHMA gill net fishery; 5,000 pounds to be allocated at the NCDMF Director discretion.

Rule 15A NCAC 3O.0503 outlines the requirements for the Albemarle Sound Management Area River Herring Dealer Permit. To purchase river herring a dealer must obtain an Albemarle Sound Management Area River Herring Dealer Permit. The permit conditions require the dealer to report landings daily to the NCDMF, and allow biological sampling of catches by NCDMF personnel.

The NCMFC through the development and approval of Amendment 1 to the NCRHFMP approved a no harvest provision for river herring, commercial and recreational, in waters under their jurisdiction in 2007. The NCMFC approved a 7,500 pound limited research set aside to be allocated at the NCDMF Director's discretion to collect data necessary for stock analysis, and to provide availability of local product for local festivals. To implement the harvest of this discretionary amount, a Discretionary Herring Fishing Permit (DHFP) was created. Individuals interested in participating had to meet the following requirements: (1) obtain a DHFP, (2) harvest only from the Joint Fishing Waters of Chowan River during the harvest period, (3) must hold a valid North Carolina Standard Commercial Fishing License (SCFL) or a Retired SCFL, and (4) participate in statistical information and data collection programs. If harvested river herring were sold they had to be sold to a licensed and permitted River Herring Dealer. The Director allocated a maximum of 4,000 lbs of the 7,500 lb set aside for harvest in the limited fishery. Each permit holder was allocated 125-250 lbs for the four day season during Easter weekend from 2007-2010. This limited fishery has also met the requirements of Amendment 2 to the ASMFC Shad & River Herring Fisheries Management Plan and was approved by the ASMFC Shad & River Herring Management Board in 2011.

Anadromous Fish Spawning Areas (AFSA) have been adopted by NCWRC and NCMFC into NC rule 15NCAC 03R.0115 through the implementation of Amendment 1 of the NCRHFMP. These areas are designated using spawning area surveys conducted in North Carolina as well as current and future surveys that will continue to re-evaluate spawning habitat.

The NCWRC has authority over the Inland Waters of the state. Since July 1, 2006 harvest of river herring, greater than 6 inches has been prohibited in the inland waters of North Carolina's coastal systems.

16.4 ASSESSMENTS HISTORY

In 2005, an updated stock assessment was conducted examining both blueback herring and alewife in NC. Although blueback herring and alewife are landed in other areas of the Albemarle Sound by a variety of gears, the largest fishery, both in the present and historically, is that of the Chowan River pound nets. Catch-at-age data from the Chowan River pound net fishery were used to estimate exploitation rates and abundance from 1972 to 2003. Cohort and annual catch curves provided initial estimates of mortality, while a spreadsheet- based catch at age model incorporating a multinomial error distribution provided estimates of annual recruitment, abundance at age, and fishing mortality. Bootstrapping and log-likelihood profiling were used to evaluate the precision of model estimates.
Estimated fishing mortality for 1972 to 1994 is 0.90 for blueback herring and, except for 1995 and 1997, fishing mortality has ranged from a low of 0.98 in 1998 to a high of 1.91 in 2003, with a corresponding exploitation ranging from 63% to 85%. Estimated fishing mortality for 1972 to 1994 is 0.98 for alewife and, except for 1995 and 1997, fishing mortality has ranged from a low of 1.01 in 1998 to a high of 1.86 in 2002, with corresponding exploitations ranging from 64% to 85%. Chowan River blueback herring recruitment averaged 28.9 million age-3 fish per year between 1972 and 1985. However, since 1986 it has only averaged around 3.6 million fish, and in the last five-years, only 552,000 fish. Chowan River alewife recruitment averaged

7.5 million age-3 fish a year between 1972 and 1986. However, since 1987 it has only averaged around 587,000 fish and in the last five-years, only 317,000 fish.

Blueback herring declines in recruitment through the 1990's dramatically reduced SSB to a record low of 89,678 pounds in 2003. Similarly, alewife spawning stock biomass declined rapidly during the early 1990's. From 1994 to 1999, alewife SSB averaged 22,953 pounds, with a record low of 10,862 pounds in 1995. Excessive exploitation combined with poor recruitment has significantly reduced abundance of both river herring species over the last 20 years and has led too much lower catches than were supported historically. Utilizing blueback herring as an indicator species, a Beverton-Holt stock-recruitment model and a stochastic recruitment model were fit and estimated model parameters were used to project population conditions under various management strategies (Grist 2005).

The 2010 Chowan River blueback herring stock assessment report results can be found in section 16.11 of this document.

16.5 STOCK SPECIFIC LIFE HISTORY

The alewife and the blueback herring, collectively known as river herring, are anadromous members of the family Clupeidae (herrings and shads). "Anadromous" means they migrate from the ocean, enter coastal bays and sounds through inlets, and ascend into freshwater rivers and streams to spawn, traveling further upstream in wet years and remaining downstream in dry years. Surviving adults then return to the ocean after spawning. The young-of-the-year fish use rivers and estuaries as nursery grounds as they migrate downstream after hatching. After the juveniles leave the rivers and estuaries in the fall or early winter, they complete their development in the Atlantic Ocean, over the continental shelf off New England (Loesch 1987; Jenkins and Burkhead 1993). The two species occur geographically together from New Brunswick and Nova Scotia in Canada south to the northern coastal area of South Carolina. Blueback herring occur further south, to northern Florida. There are important life history differences between the two species (Loesch 1987). Alewives select slower-flowing areas for spawning, with blueback herring reported to select faster-flowing sites in areas where both species occur. In areas where both species occur, alewives generally spawn earlier. While fish are believed to return to the streams of their birth for spawning, both species readily colonize new streams or ponds and will reoccupy systems from which they have been extirpated (Loesch 1987). Both juveniles and adults respond negatively to light, in both riverine and offshore habitats, with alewives remaining deeper in the water column in both habitats (Klauda et al. 1991). Both species are important prey during all life stages for many other species of commercial and recreational importance. Both species have also been widely stocked in inland freshwater lakes and reservoirs where they live and reproduce entirely in freshwater and serve as prey for freshwater game fish.

In the collective population of river herring, the percentage of alewife and blueback herring present in major Albemarle Sound tributaries has varied based on sampling of the commercial catch (Johnson et al. 1981). For example, percent composition of alewife ranged from 4 % in 1977 to 49 % in 1979, with alewife dominating the early catches in each year. From 1989 through 1992, the percentage of alewife ranged from 14.2 to 31.2% (Winslow and Rawls 1992). The same pattern of early dominance by alewife, with subsequent later dominance by blueback

herring, is evident in weekly species composition samples taken during the 1980-92 spawning runs on the Chowan and Scuppernong rivers (Winslow et al. 1983; Winslow and Rawls 1992). The fraction of alewife in the commercial catch for those years ranged from 27 to 37%.

16.6 HABITAT DESCRIPTION

River herring have historically been found in all N.C. coastal rivers and streams. The main populations of river herring are found in the Albemarle Sound and its tributaries, with smaller runs historically in the Tar, Pamlico, Neuse and Cape Fear River systems.

The Albemarle Sound system includes Albemarle, Croatan, Roanoke and Currituck Sounds and all of their tributaries. The Albemarle Sound, located in the northeastern portion of North Carolina, is a shallow estuary extending 55 miles in an east-west direction averaging 7 miles wide and 13-20 ft deep. Ten rivers drain into the Albemarle Sound which joins Pamlico Sound through Croatan and Roanoke Sounds and empties into the Atlantic Ocean via Oregon Inlet. The majority of tributaries that empty into the sound originate in extensive coastal swamps.

The Chowan River flows approximately 50 miles and is formed with the merging of Virginia's Blackwater and Nottoway rivers. It is a major tributary to the Albemarle Sound and it is the primary spawning area for river herring in North Carolina. The Chowan River empties into western Albemarle Sound. This area as well as most of the Albemarle Sound and all of its tributaries serves as a major anadromous fishery nursery area for river herring.

Anadromous spawning area surveys conducted by the NCDMF demonstrated that river herring use a wide range of habitat types for spawning, such as small, densely vegetated streams; fresh and brackish marshes; hardwood swamps; and flooded low-lying areas adjacent to both mainstem rivers and tributaries. In North Carolina, anadromous fish spawning areas are designated in NCMFC rule 15A NCAC 03R.0115 and NCWRC rule 15A NCAC 10C .0603 and include areas in most river systems.

River herring spawn in the upper reaches of North Carolinas coastal rivers and streams in the early spring. The juveniles spend most of their first year in the nearshore waters of the coastal rivers and sounds and emigrate to the ocean when water temperatures begin to cool in the fall.

16.7 RESTORATION PROGRAMS

The 2007 NCRHFMP identified various restoration targets for the river herring stocks. The 2007 NCRHFMP utilized the Chowan River blueback herring stock as the indicator species to establish stock recovery indicators. The plan identified stock recovery indicators that would be used to evaluate and determine recovery status of the river herring stock. The stock recovery indicators for the 2007 NCRHFMP are as follows:

Juvenile abundance – The restoration target for juvenile abundance of blueback herring is to achieve a three year moving average catch per unit of effort of at least 60.

Percent Repeat Spawners – The Chowan River blueback herring spawning stock should contain at least 10% repeat spawners (percent of the spawning stock that have spawned more than once).

Spawning Stock Biomass (SSB) – The restoration target to restore Chowan River blueback herring SSB to a minimum stock size threshold (MMST) of 4 million pounds.

Recruitment – Recruitment of age three blueback herring should be restored to a three-year moving average of at least 8 million fish.

In addition to the above stock recovery indicators the 2007 NCRHFMP recommended a variety of research needs and management options that address various issues such as habitat availability and degradation, predation, bycatch, critical habitat and water quality and that would contribute to the recovery of river herring stocks in North Carolina. A full description of these recommendations can be found in the 2007 NCRHFMP.

16.8 AGE

Age samples of the blueback herring and alewife catch from the Chowan River commercial pound net fishery are available from fish house sampling conducted from 1972-2006. The target sampling frequency is to collect unculled samples of at least 30 fish weekly, from at least 3 area commercial fishhouses during the fishing season.

Following the closure of the commercial river herring fisheries in N.C. a commercial pound net survey was implemented to collect aging samples of river herring from the Chowan River. Depending on the year 3- 4 commercial fishermen were contracted to fish commercial pound net sets in the Chowan River, NC during the traditional river herring commercial harvest season. All fishermen were required to obtain a weekly unculled adult sub-sample of approximately 20 pounds of river herring from their contracted pound nets. In 2009 sampling was expanded to include a visual estimate of the total daily catch of river herring in pounds from all of the pound nets set regardless of whether it was a designated contracted net or not. Adult samples were sorted to species and all individuals of each alosine species present were measured (mm, FL,TL), weighed (kg), sexed, spawning maturity was determined, and an ageing sample was taken. A complete analysis of the Chowan River Pound Net Survey data will be included in the update of the 2007 NC River Herring FMP which will begin in July 2012.

Scale samples collected for ageing were mounted between two microscope slides and read under an Eyecom 3000 microfiche reader and aged by methods similar to that in Street et al. (1975). Stratified sub-sampling, based on techniques developed by Ketchen (1950), was used to compile individuals for ageing. Samples were sorted by species, and sex, then placed in 10 mm size groups. If 15 or less samples were present in a size group, all of the samples were aged. If more than 15 samples were present in a size group, half of the fish in the group were aged. Proportions within each sex and size group were calculated and expanded to the remaining sample.

16.9 FISHERY DESCRIPTIONS

Since 2007 the commercial and recreational harvest of river herring is prohibited in all coastal and joint waters of the state. There is a 7,500 pound research set-aside harvest, with 4,000 pounds allocated to be taken over a four day period with area and gear restrictions (see section 13.3 for a complete description). The possession of river herring greater than 6 inches in the inland waters of North Carolina has been prohibited since 2006.

16.9.1 Commercial Fishery

Commercial Landings

River herring have been subjected to intensive exploitation since colonial times along the Atlantic coast. The Albemarle Sound area has always been the center of the North Carolina fishery. In North Carolina, river herring were among the first fish to be exploited commercially because their oily flesh allowed them to be salt-preserved, without ice or refrigeration.

NCDMF has monitored commercial landings of river herring since 1972. Prior to 1994, commercial landings in North Carolina were acquired via a NCDMF and National Marine Fisheries Service (NMFS) Cooperative statistics program on a monthly basis from licensed seafood dealers; however, reporting at the time was not mandatory. In 1994 NCDMF implemented a mandatory commercial harvest data collection system known as the Trip Ticket Program (TTP). The Trip Ticket Program is a dealer-based reporting program that obtains a trip-level census of commercial landings in North Carolina.

The annual commercial harvest of river herring for the Albemarle Sound as well as other areas of the state is presented in Table 16.1. As mentioned previously, the Chowan River is the historical mainstay of the North Carolina river herring fishery and continued to serve in that capacity until the close of the commercial fishery statewide in 2007.

The use of pound nets revolutionized fishing in North Carolina, especially in the Albemarle Sound (Taylor 1992). Chestnut and Davis (1975) reported that 2,767 pound nets were set in North Carolina in 1927. Since the 1960s, the majority of the river herring pound nets have been set in the rivers, and the leads seldom exceeded 200 yards in length (Walburg and Nichols 1967). The Chowan River has been the center of the river herring pound net fishery, and from the late 1970s to the late 1980s the number of river herring pound nets ranged from 421 to 615 nets annually, with the amount of pound nets declining from 348 in 1989 to 175 in 1994.

Gill nets, anchor and drift, have historically been utilized in the river herring fishery. The amount of gill net effort in the fishery prior to 1994 is unknown. During the 1970s, the gill net harvest of river herring accounted for approximately 15% of the total Albemarle Sound area harvest. However, from 1987 to 1994, the proportion of gill net landings increased to 24-40% of the total river herring harvest from the Albemarle Sound area. This increase may have been due to a directed fishery for roe fish. In 1986, approximately 6 million pounds were harvested in pound nets and 900,000 pounds from gill nets. During 1988, pound nets landed 2.3 million pounds and gill nets 1.5 million pounds. In contrast, 1994 totals of 425,000 pounds from pound nets and 175,000 pounds from gill nets was harvested.

Several other types of commercial gears have been used in the river herring fishery: fyke nets, fish wheels and dip nets. These gears have contributed very little to the total harvest in the Albemarle area. From 1915 through 1965, various regulations were enacted for the Albemarle Sound river herring fishery (seasons, area closures, gear restrictions).

The Albemarle Sound area accounted for 66-100% of the state's river herring harvest from 1889 to 1994. Between 1962 and 1994, the Chowan River pound net fishery contributed 43-97% of the state's total river herring landings. From 1950 to 1994, North Carolina accounted for 13.6-84.5% of the river herring landings of the Atlantic coast states.

Since the late 1800s, the areas fished and gears used to harvest river herring have remained essentially unchanged. The extent of the river herring fisheries in both the amount of gear and harvest, however, has declined significantly. The fisheries in the Albemarle Sound area are now pursued as multi-species fisheries, which are not totally dependent on river herring.

During 1995-1998, North Carolina accounted for 29-52% of the total river herring landings from the Atlantic coast. From 1999-2004, the State contributed 9-33% of the Atlantic coast river herring harvest. Landings from the Albemarle Sound area accounted for 91.6-99.8% of the state's total river herring landings during 1995-2004. The Chowan River pound net fishery contributed 60.3-76.5% of North Carolina's annual river herring harvest during 1995-1999.

Since 2000, the Chowan River pound net fishery contributed 41-66% of the state's total river herring harvest. Since 1988, regulations enacted for striped bass conservation (gill net mesh size restrictions, yardage restrictions, area closures) have impacted river herring harvest in the Albemarle Sound area. Even with these regulations, the river herring gill net fishery has accounted for a greater proportion of the overall harvest from 1995 - 1999 (21.2-38.1%). Since the 67,000 pound TAC was implemented in 2000, gill nets have accounted for 24.4-39.5% of the annual river herring landings in the Albemarle area.

Currently, the commercial harvest is restricted to a 7,500 pound research set aside, with a 4,000 pound maximum allocation to be harvested over a four day period during the Easter holiday weekend in the Chowan River. Participation is limited to permitted fishermen. Landings for the research set aside season have ranged from 643 pounds in 2009 to 1,765 pounds in 2010 (Table 16.2). The number of permits issued to participate in the fishery has ranged from 30 in 2010 to 13 in 2008.

Commercial Catch Rates

Catch per unit effort (CPUE) for the Chowan river pound net fishery has been calculated since 1977 (Table 16.3; Figure 16.2). Catch effort was calculated by dividing the total weight (kg) by the total effort in pound net weeks (calculated as the number of pound nets fished each week summed over the entire season). Weeks were considered Sunday to Saturday and begin the first full week in January. Pound net effort was determined by an aerial survey, conducted with the assistance of the NCDMF marine patrol as well as pound net permit application data.

While the maximum number of pound nets set in any given week decreased drastically from a high of 624 in 1977 to only 36 in 2004, the total weeks fished has differed little over the years with the exception of 1997 when nets were only set for 5 weeks. Therefore, the overall decrease in total effort is due more to fewer nets set than to a reduction in the length of the fishing season. Since 2001, the number of weeks fished has increased slightly as a result of the TAC not being met, and the season remaining open longer, or nets being set earlier in the fishing season. Effort

has decreased considerably since the implementation of a harvest quota in 1995 and has varied without trend since that time.

Catch per unit effort for blueback herring and alewife from the Chowan River commercial pound net fishery declined considerably since the mid-1980s. Blueback herring CPUE increased slightly during the 1995-2005 seasons, but declined significantly in 2000. Alewife CPUE decreased considerably in 1993-1999, with slight increases in 2001. Both CPUE's remained well below the historical levels until the close of the fishery in 2006.

Repeat Spawners

The NCDMF has monitored repeat spawning for the Chowan River blueback herring and alewife since 1972 (Table 16.4). Percent repeat spawners for blueback herring from the Chowan River spawning stock is one of the stock recovery indicators identified in the 2007 NCRHFMP. The Chowan River blueback herring spawning stock should contain at least 10% repeat spawners (percent of the spawning stock that have spawned more than once). The percent of blueback herring repeat spawners in the pound net harvest averaged 14.8% during 1972-1982. From 1983 through 1989, the percentage of repeat spawners declined significantly, ranging from 0.6% to 6.1%. During the 1990s, blueback herring spawning repetition remained low, ranging from 1.2% (1994) to 4.7% (1993). During 2000 through 2003, a slight increase in the percentage was observed but declined again in 2004 (2.9%). Percentages increased again in 2007 and 2008 but declined again in 2009 and remain well below the historical average.

The percentage of alewife repeat spawners has also decreased since the 1970s, with a mean of 9.4% from 1972 through 1981. From 1988-1999, no or very small samples of alewife were obtained from the Chowan River pound net fishery, due to scarcity in the harvest. During 2001-2004, alewife samples were obtained from the pound net fishery and an increase in the percentage of repeat spawners was observed. Percent repeat spawners averaged 9.1 from 2004-2009.

Age Composition/Mean Size at Age

The age structure of blueback herring taken in the Chowan River pound net fishery has been characterized since 1972. From the 1970s to the early 1990s, sampling was conducted at up to six fish houses on a weekly basis. From 2000 through 2006, samples were obtained weekly from up to three fish houses until the season closed in 2006. Throughout the years, unculled pound net samples of at least 30 individuals each of blueback herring and alewife were obtained at least weekly during the spring. Size, age and sex composition of the harvest was determined from these samples. Samples of up to 30 fish from each fishhouse were obtained, up to three times per week during the season, and after the season, into the second week of May. Samples in 2007 were obtained from Chowan River pound nets during the research set aside season. Samples since 2008 have been collected from the Chowan River Pound Net Survey.

The aged pound net samples have been dominated by fish ages 4-6 throughout the entire time period (Appendix Table 16.3.) From 1972-1981, seven year olds comprise 4.1 % of the aged sample annually. In recent years, age seven fish comprise less than 1% of the aged sample.

Data from pound net samples for both blueback herring and alewife shows a decline in mean length at age since 1972 (Figures 16.3 and 16.4).

16.9.1 Recreational Fishery

Historically, river herring have been taken for personal consumption in every major North Carolina coastal river system. An analysis of river herring harvest by Baker (1968) indicated the majority of herring harvested by special device licensees in 1967-1968 occurred in the Chowan and Roanoke River basins. River herring were also harvested in other river basins, but American shad and hickory shad (*Alosa mediocris*) were of more importance to fishermen in those areas. Coastwide, Baker (1968) estimated that special device licensees harvested 2.9 million pounds of river herring some of which were sold. The recreational component of this total, however, is unknown. Although these fish were taken by fishermen licensed by NCWRC at that time, changes in designations of Coastal/Joint/Inland Waters, changes in jurisdictional responsibilities between NCDMF and NCWRC, and the unknown proportion of these fish which were harvested with the intent of sale precludes an estimate of the historical level of river herring harvest for personal consumption. The recreational fishery for river herring closed in 2007. It is now illegal to possess recreationally caught river herring in the coastal and joint waters of the state. It is also illegal to possess river herring greater than 6 inches from the inland waters of the state.

For the years leading up to the 2007 harvest closure, the extent of river herring harvest for personal consumption in coastal North Carolina is unknown. According to NCWRC Enforcement Officers who patrolled the inland waters of the Cape Fear, Neuse, and Tar-Pamlico river basins at that time, very few (usually none) special device licensees specifically targeting river herring were encountered in these areas, principally due to the low numbers or absence of these species. Special device licensees targeting river herring are still encountered in small tributaries of the Roanoke and Chowan rivers during the spring months of years prior to the closure, and an active recreational herring fishery persisted in tributaries to the Meherrin River. Recreational river herring fishermen are still found at small bridge crossings over tributaries to other Albemarle Sound river systems such as the Pasquotank, Perquimans, Yeopim and Scuppernong rivers. Low effort directed at river herring harvest in these areas is likely indicative of low river herring abundance.

A recreational drift net river herring fishery existed on the Roanoke River for many years. This fishery has never been fully assessed by NCDMF or NCWRC. The NCDMF initiated a pilot drift net creel survey in 1999 to characterize this fishery for development of future monitoring strategies and to provide managers with weekly reports of recreational drift net activity (participation, catch rates, species composition, net sizes, etc). Sampling was conducted in the lower river area including Williamston, Jamesville, and Plymouth. Interviews were conducted three days per week, for a total of 21 sampling days in 1999. Catches of river herring ranged from 20 to 300 fish per vessel with a mean of 106. Drift duration ranged from 1 to 5 hours with a mean of 2.2 hours. A total of 2,764 river herring were observed in the survey. Because there was no estimate of total effort, total catch cannot be estimated.

The recreational fishery for river herring closed in 2007. It is illegal to possess recreationally caught river herring in the coastal and joint waters of the state. It is also illegal to possess river herring greater than 6 inches from the inland waters of the state.

16.10 Fisheries Independent Surveys

16.10.1 Juvenile abundance

The NCDMF began nursery area sampling for juvenile blueback herring and alewife in the Albemarle Sound area in 1972, with eleven core stations being established and sampled throughout the time period (Figure 16.5). This survey was designed to index annual relative abundance of juvenile blueback herring and alewife. Thirty-four stations were established in the western Albemarle Sound area and sampled with trawls and seines. The Carolina wing trawl was adopted as the standard trawl in place of the Cobb trawls in June 1974 (Johnson et al. 1977), and the seines continued. The 34 stations (23 trawls and 11 seines) were sampled monthly during June-October. During September, an additional 43 stations (28 trawls and 15 seines) were sampled throughout the Albemarle Sound area to determine distribution and nursery areas of anadromous species.

Seine stations were sampled with a 60 ft bag seine with ¼ inch mesh bag, with a single haul considered one catch-per-unit-of-effort (CPUE). The Carolina wing trawl had a headrope length of 26 ft, containing webbing which ranged from 4 inch stretched mesh in the wings to 1/8 inch mesh tail bag. The trawl was pulled for 10 minutes, and was considered one CPUE. Samples were sorted to species, and up to 30 individuals of each alosine species present were measured to the nearest millimeter fork length (mm, FL), and all others were counted.

Based on catch consistency the seine proved to be the best sampling gear for blueback herring, and the wing trawl was the best for alewife. Due to a further reduction in federal aid funds, trawl sampling was dropped at the end of June 1984. Sampling with seines at the 11 cores stations has continued during June-October each year from 1972-2011. During September, an additional 13 seine stations are sampled throughout the Albemarle Sound area to determine distribution and migration.

Juvenile abundance indices (JAI) are established for alewife and blueback herring using data from the 11 core stations sampled once per month, June-October, 1972-2010 (Figures 16.6 and 16.7). The JAI for blueback herring and alewife fluctuated over the years in the Albemarle Sound area. The highest CPUE recorded for blueback herring was in 1973 (362.9 fish/seine); the lowest was in 1994 (0 fish/seine), part of a very low CPUE trend during 1986-2005. The thirty-nine year average CPUE for blueback herring is 50.6, dropping from 70.4 long-term average as reported in the 2000 River Herring FMP. The stock recovery indicator for juvenile abundance of blueback herring is to achieve a three year moving average catch per unit of effort of at least 60. The current 3 year average based on the 2008-2010 data is 1.39.

The average CPUE for alewife during the 1972-2010 period is 2.0 fish/seine compared to the 2.5 fish/seine reported in 2000. Alewife JAI increased slightly in 2003 and dropped again in 2006. However, numbers increased dramatically in 2010 with a JAI of 4.13.

16.10.1.1 Independent Gill Net Survey

Since 1990, NCDMF has been conducting an independent gill net survey (IGNS) throughout the Albemarle Sound area (Figure 16.8). The survey was designed for striped bass data collection. However, river herring are captured during the survey and size, age, and sex data are collected. Gill nets are set in sizes from 2.5 through 7.0 inch stretched mesh (ISM), in half-inch increments and 8.0, and 10.0 ISM are utilized.

River herring CPUE has been calculated from the IGNS throughout the Albemarle Sound area since 1991. Blueback herring and alewife CPUE from the 2.5 ISM and 3.0 ISM (combined) January-May, 1991-2010 are shown in Figure 16.9. The CPUE of blueback herring has continued a general decline since 2000. Alewife CPUE has been low for most of the time series with a general increase since 2005. CPUE has been steady from 2008-2010.

16.11 ASSESSMENT APROACHES AND RESULTS

16.11.1 Statistical catch-at-age model for the Chowan River

A forward-projecting age-structured statistical catch-at-age (SCA) model for the Chowan River blueback herring stock was applied to total in-river catches, age compositions, length compositions, and a fisheries-independent young-of-year (YOY) index to estimate age-3 abundance and mortality rates. The assessment time period was 1972 to 2009.

16.11.1.1 Model Structure

The population model is aged-based and projects the population numbers-at-age by sex *s* forward through time given model estimates of age-3 numbers and mortality rates, assumed known values of natural mortality for immature and mature fish by age, and proportion mature-at-age. The population numbers-at-age ($N_{s,d,y,a}$) matrix has dimensions *s* x *d* x *y* x *A-2*, where *s* is number of sexes, *d* is the number of maturity phases, *y* is the number of years, and *A* is the oldest age group (age 8+). There were six year-classes in the model, representing ages 3 through 8+.

The cohort dynamics of the model is a hybrid of the Margaree River model in Gibson and Myers (2003a). The model incorporates the immature and mature phases by sex and assumes the year begins at the start of spawning. Mature individuals of each age move into the Chowan River where they are intercepted and removed for harvest. The model assumes harvest occurs before the fish reach the spawning grounds. Biological samples for sex, and age and repeat-spawning data are collected from fishery landings. The model allows different natural mortality values for each year, age, sex, and maturity phase.

Given the above dynamics, population numbers-at-age by sex and maturity phases are calculated through time by using the cohort survival models shown in Figure 16.10. The number of age-3 bluebacks at the beginning of spawning season (R_y) are directly estimated in the model, and these estimates are partitioned into sex- (1=female; 2=male) and maturity phase- (1=immature*;* 2=mature) specific estimates of age-3 abundance using sex ratio and mature proportions-at-age (derived outside of the model):

Female

Immature: $\hat{N}_{1,1,y,3} = \hat{R}_y \cdot f \cdot (1 - p_{1,y,3})$

Mature: $\hat{N}_{1,2,y,3} = \hat{R}_y \cdot f \cdot p_{1,y,3}$

Male

Immature: $\hat{N}_{2,1,y,3} = \hat{R}_y \cdot (1 - f) \cdot (1 - p_{2,y,3})$

Mature: $\hat{N}_{2,2,y,3} = \hat{R}_y \cdot (1 - f) \cdot p_{2,y,3}$

where f is the female sex ratio (proportion) and p is the proportion mature by sex s, year y, and age a. Recruitment of age-3 bluebacks (R_y) is modeled as a log-normal deviation from average recruitment:

where $\overline{R}$ is the average recruitment parameter and e_y are independent and identically distributed normal random errors with mean zero and constant variance and are constrained to sum to zero over all years. This formulation differs from the original Gibson and Meyers model, which linked recruitment via a Beverton-Holt equation to log-normal deviations.

The initial population abundance-at-age for ages 4 to 8+ in 1972 for each sex and maturity phase is calculated by assuming a static stock:

Immature: $\hat{N}_{s,1,1972,a} = \hat{N}_{s,1,1972,a-1} \cdot \exp^{-M_{s,1,1972,a-1}} \cdot (1 - p_{s,1972,a})$

Mature: $\hat{N}_{s,2,1972,a} = \hat{N}_{s,2,1972,a-1} \cdot (1 - \hat{u}_{1972}) \cdot \exp^{-M_{s,2,1972,a-1}} + \hat{N}_{s,1,1972,a-1} \cdot \exp^{-M_{s,1,1972,a-1}} \cdot p_{s,1972,a}$

where M is the sex-, maturity phase-, year-, and age-specific instantaneous natural mortality rate, and u is the year-specific exploitation rate. Population abundance-at-age for ages 4 through 7 in the remaining years is calculated by:

Immature: $\hat{N}_{s,1,y,a} = \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot (1 - p_{s,y,a})$

Mature: $\hat{N}_{s,2,y,a} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} + \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a}$

The population abundance of the plus group (8+) is calculated as:

Mature: $\hat{N}_{s,2,y,8+} = \hat{N}_{s,2,y-1,a-1} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,a-1}} + \hat{N}_{s,1,y-1,a-1} \cdot \exp^{-M_{s,1,y-1,a-1}} \cdot p_{s,y,a} + \hat{N}_{s,2,y-1,8+} \cdot (1 - \hat{u}_{y-1}) \cdot \exp^{-M_{s,2,y-1,8+}}$

Exploitation rates for each year (u_y) are estimated as individual parameters in the model.

Input values for age- and sex-specific M were calculated using the Lorenzen (1996) equation that relates body weight (in grams) to natural mortality. The grand mean of average weight-at-age of blueback herring from the pound net fishery during 1972 through 1980 was used to derive M.

Natural mortality rate was assumed constant with time and among maturity phases for the base model runs. The *M* estimates for each sex and age were:

	Age					
	3	4	5	6	7	8
Female	0.71	0.66	0.64	0.62	0.60	0.59
Male	0.72	0.70	0.67	0.64	0.62	0.61

The annual proportions of fish mature at each age and sex were calculated from repeat-spawner frequency data provided by the NCDMF. When data were missing in some years and ages, averaged values from surrounding cells were used to fill in missing data (Appendix Table 16.1).

Total removals of blueback herring are one set of data from which age-3 abundances and exploitation rates are estimated. Total catch in numbers was provided by NCDMF (Appendix Table 16.2). Total catch for 2007 to 2009 was estimated by using pound net catch proportions provided in 2008, average blueback landings to alewife landings ratio from years prior to 2007, and annual mean weight by species. Given estimates of annual numbers of mature for fish at each sex and age, predicted removals-at-age is computed by:

$$\hat{C}_{y,s,a} = \hat{N}_{y,s,m,a}\hat{u}_y$$

where $C_{y,s,a}$ is the predicted in-river removals of sex (*s)* of age (*a)* during year (*y)*. All predictions are stored in an array of dimensions *s* x *y* x *A-2*. Predicted catch-at-age data are then compared to the observed total catch and observed proportions of catch numbers-at-age data (sample numbers at age are provided in Appendix Table 16.3) through the equations:

Predicted Total Catch: $$\hat{C}_y = \sum_s \sum_a \hat{C}_{y,s,a}$$

Predicted Proportions of Catch Numbers-At-Age: $$\hat{P}_{y,s,a} = \frac{\hat{C}_{y,s,a}}{\sum_a \hat{C}_{y,s,a}}$$

The North Carolina YOY seine survey index for blueback herring was incorporated into the model by linking it to the recruitment estimates:

$$\hat{I}_y = \hat{q} \cdot \hat{R}_{y+3}$$

where $\hat{I}_y$ is the predicted index of survey in year *y*, and *q* is the catchability coefficient. Based on the lagged year comparison, YOY indices from 1972 to 2006 (Appendix Table 16.4) were used to tune recruitment estimates for 1975 to 2009.

Female spawning stock biomass (SSB) in year *y* was calculated as:

$$SSB_y = \sum_a \hat{N}_{1,2,y,a} \cdot (1 - \hat{u}_y) \cdot w_{1,2,y,a}$$

where $w_{1,2,y,a}$ is the mean weight-at-age for mature females in year *y* and age *a*. Calculated mean weights-at-age are provided in Appendix Table 16.5.

Fishing mortality rates were calculated from the estimated exploitation rates assuming a Type I fishery:

$$\hat{F}_y = -\log_e(1-\hat{u}_y)$$

Standard errors of fishing mortality rates were derived using the delta method provided in AD Model Builder.

Lognormal errors were assumed for the total catch data and YOY index. The concentrated likelihood was weighted for variation in each observation. The generalized concentrated negative log-likelihood ($-L_l$; Parma 2002; Deriso et al. 2007) is:

$$-L_l = 0.5 * \sum_i n_i \; * \ln\left(\frac{\sum_i RSS_i}{\sum_i n_i}\right)$$

where n_i is the total number of observations and RSS_i is the weighted residual sum-of-squares from dataset i. Equations for the weighted residual sum-of-squares of total removals (C) and escapement numbers (E) are:

$$RSS_C = \lambda_C \sum_y \left(\frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{CV_y}\right)^2$$

$$RSS_I = \lambda_E \sum_y \left(\frac{\log_e(I_y + 1e^{-5}) - \log_e(\hat{I}_y + 1e5)}{CV_y}\right)^2$$

where CV_y is the coefficient of variation for the observed catch or index estimate in year y, and λ_C and λ_E are the relative weights (Parma 2002; Deriso et al. 2007). The CVs for the YOY index were high; therefore, the lambda value for total catch was set to 10 to force the model to fit the pattern in total catch since the catch values are likely more accurate.

For catch age composition data, a multinomial error distribution is assumed and the negative log-likelihood is calculated using the general equation:

$$-L_p = \lambda_p \sum_y \sum_s -n_{y,s} \sum_a (P_{y,s,a} + 1e^{-5}) \cdot \ln(\hat{P}_{y,s,a} + 1e^{-5})$$

where $n_{y.s}$ is the effective number of fish of sex s aged in year y, and $P_{y,s,a}$ is the observed proportions of catch-at-age.

Effective sample size is estimated using the iterative procedures of McAllister and Ianelli (1997). In essence, the average effective sample size for catch age (or length) composition data of each sex is calculated using the following formula:

$$\hat{\bar{n}}_s = \frac{\sum_y \hat{n}_{y,s}}{d_{y,s}}$$

and $\hat{n}_y$ is defined as:

$$\hat{n}_{y,s} = \frac{\sum_a \hat{P}_{y,s,a}(1-\hat{P}_{y,s,a})}{\sum_a (P_{y,s,a}-\hat{P}_{y,s,a})^2}$$

where $\hat{P}_{y,s,a}$ is the predicted proportion-at-age a (or l for length data) in year y from the escapement numbers, $P_{y,s,a}$ is the observed proportion-at-age, and d_y is the number of years of data for escapement series. The average effective sample size is applied, re-calculated, and re-substituted until the average effective sample size stabilizes under equal weighting of all likelihood components.

The total log-likelihood of the model is:

$$f = -L_l - L_p$$

The total log-likelihood was estimated by the auto-differentiation routine in AD Model Builder to search for the "best" age-3 abundance estimates that minimize the total log-likelihood. AD Model Builder allows the minimization process to occur in phases. During each phase, a subset of parameters is held fixed and minimization is done over another subset of parameters until eventually all parameters have been included. In this model, the following parameters were solved over two phases:

Phase	
1	average recruitment (log scale) and exploitation rates
2	catchability coefficient(s) (log scale)
3	recruitment deviations

Model fit for all components was checked by using standardized residual plots and root mean square errors. Standardized residuals (r) for lognormal (total catch and YOY index) were calculated as:

Total Catch:
$$r_{C,y} = \frac{\log_e(C_y + 1e^{-5}) - \log_e(\hat{C}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$$

YOY Index:
$$r_{I,y} = \frac{\log_e(I_y + 1e^{-5}) - \log_e(\hat{I}_y + 1e^{-5})}{\sqrt{\log_e(CV_y^2 + 1)}}$$

The root mean square error for total catch and the YOY index was calculated as:

YOY Index

$$RMSE_C = \sqrt{\frac{\sum_y r_{C,y}^2}{n}}$$

Total Catch

$$RMSE_I = \sqrt{\frac{\sum_y r_{I,y}^2}{n}}$$

where n is the total for Total Catch or YOY index values.
For catch age composition data, standardized residuals were derived as:

$$r_{y,s,a} = \frac{P_{y,s,a} - \hat{P}_{y,s,a}}{\sqrt{\frac{\hat{P}_{y,s,a}(1-\hat{P}_{y,s,a})}{\hat{\bar{n}}_s}}}$$

where n_s is the average effective sample size for sex s and type of data.

16.11.1.2 Reference Point Derivation

Reference points for management were derived using three analytical approaches. First, yield-per-recruit (YPR) analyses were conducted to derive $F_{0.10}$ (F where slope between two adjacent YPR values is 10% of the slope at the origin) and F_{MAX} (F at maximum yield) reference values. Second, spawning biomass-per-recruit (SPR) analysis was conducted to derive the $F_{40\%}$ and $F_{20\%}$ reference points (fishing mortality rates that reduce the spawning biomass to 40% and 20% of the maximum unfished biomass, respectively). Third, recruitment and spawning stock biomass estimates in conjunction with SPR and YPR (production model method in Gibson and Myers 2003b) were used to derive values for F_{MED} (level of fishing mortality where recruitment has been sufficient to balance losses to fishing mortality in half the observed years), F_{COL} (the fishing mortality that drives the population to extinction), F_{MSY} (the fishing rates that produces maximum sustainable yield), SSB_{MSY} (the spawning stock biomass at MSY), and $SSB_{20\%}$ (minimum threshold population size).

The YPR and SPR analyses follow the model adapted by Gibson and Myers (2003c) for alewife. For a given F, YPR is calculated as:

$$YPR_F = \sum_{a=3}^{\max a} SS_a w_a (1 - e^{-F})$$

where SS_a is given by:

$$SS_3 = p_3$$
$$SS_4 = SS_3 e^{-M_{m,3}-F} + (1-p_3)e^{-M_{i,3}} p_4$$
$$SS_5 = SS_4 e^{-M_{m,4}-F} + (1-p_3)(1-p_4)e^{-M_{i,3}-M_{i,4}} p_5$$
$$SS_6 = SS_5 e^{-M_{m,5}-F} + (1-p_3)(1-p_4)(1-p_5)e^{-M_{i,3}-M_{i,4}-M_{i,5}} p_6$$
$$SS_7 = SS_6 e^{-M_{m,6}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}} p_7$$
$$SS_8 = SS_7 e^{-M_{m,7}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}} p_8$$

Where a is the age of the fish, p_a is the proportion mature at that age, $M_{m,a}$ and $M_{i,a}$ are the instantaneous natural mortality rates for mature and immature fish of age a, and w_a is the female weight at age.

Since a plus group was used in the model, one additional SS_a was calculated to match the maximum observed age (9) for female blueback:

$$SS_9 = SS_8 e^{-M_{m,8}-F} + (1-p_3)(1-p_4)(1-p_5)(1-p_6)(1-p_7)(1-p_8)e^{-M_{i,3}-M_{i,4}-M_{i,5}-M_{i,6}-M_{i,7}-M_{i,8}} p_8$$

Similarly, SPR is calculated as:

$$SPR_F = \sum_{a=3}^{\max a} SS_a w_a e^{-F}$$

YPR and SPR were calculated for a set of Fs that ranged from 0 to 5 with an increment of 0.01. F_{MAX} was found by selecting the fishing mortality where YPR_F takes its largest value, and $F_{0.10}$ was found by selecting the fishing mortality where the marginal gain in yield was 10% that at $F = 0$. The $SPR_{x\%}$ reference points were found by selecting the fishing mortality rate where SPR_F was x% that of $SPR_{F=0}$. Data from 1976 were used to calculate SPR and YPR values to develop historical estimates of population quantities before the decline in abundance and changes in age structure.

F_{MED} was calculated by finding the fishing mortality rate that produced a SPR replacement line with a slope that equals the median survival ratio (median of R_y/SSB_{y-3}) from the spawner-recruitment (S-R) biomass estimates. The remaining quantities were produced using a production model based on the Beverton-Holt spawner-recruit model. A Beverton-Holt spawner-recruit model was fit externally to the age-3 recruitment numbers (R_y) and corresponding spawning stocking biomass (SSB_{y-3}). The model is:

$$R_y = \frac{aSSB_{y-3}}{1+(aSSB_{y-3}/R_0)} e^{\epsilon}$$

Here, a is the slope at the origin of the spawner-recruit relationship (the maximum rate at which spawners can produce recruits at low population sizes) and R_0 is the asymptotic recruitment level which is the carrying capacity expressed as the number of fish that survive to age-3 (Gibson and Myers 2003b, 2003c). The linearized form of the model:

$$\log_e(R_y) = \log_e(a) + \log_e(SSB_{y-3}) - \log_e(1 + aSSB_{y-3}/R_0) + \varepsilon$$

was fitted to the spawner-recruitment data using non-linear least-squares regression. Only estimates of recruitment from 1978–2005 and SSB from 1975–2002 were used to estimate the S-R relationship to eliminate the influence and possible bias of the static stock abundance estimates during the first year (1972) and the retrospective bias near the terminal (see below). For a given level of *F*, the equilibrium spawning biomass (SSB*) is calculated using the relationship:

$$SSB^* = \frac{(\hat{a}SPR_F - 1)\hat{R}_0}{\hat{a}}$$

The corresponding equilibrium number of recruits (R*) is found by substituting SSB* in the spawner-recruit model:

$$R^* = \frac{\hat{a}SSB^*}{1 + (\hat{a}SSB^*/\hat{R}_0)}$$

The equilibrium catch (C*) is R* multiplied by the yield-per-recruit for the given value of *F*:

$$C^* = R^* \cdot YPR_F$$

F_{MSY} is found by finding the fishing mortality rate that produces the maximum C*, and SSB_{MSY} is the value of SSB* corresponding to this fishing mortality rate. F_{COL} is the value of *F* where $1/SPR_{F=0} = a$. The minimum threshold population size ($SSB_{20\%}$) was calculated as 20% of the equilibrium spawner abundance in the absence of fishing:

$$SSB_{20\%} = 0.2\frac{(\hat{a}SPR_{F=0} - 1)\hat{R}_0}{\hat{a}}$$

16.11.1.3 Base Model Results

The female sex ratio (*f*) used in the base model run was 0.5. Initial CVs used for the total catch were 0.30, and for the YOY index, the CVs estimated for the arithmetic mean were used as a proxy since the standard error for the geometric mean was not provided. As noted above, a lambda for the total catch was set of 10 to force the model to match the total catch patterns. The root mean square error (RMSE) for the YOY index was 1.96. Based on examination of estimated effective sample sizes, a constant effective sample size for female and male catch age composition was set at 35.

Resulting contributions to total likelihood are listed in Table 16.5. The converged total likelihood was 3,567.7. A total of 78 parameters were estimated in the model. The resulting estimates of recruitment, exploitation rates, and catchability coefficients are given in Table 16.6. The model fit the observed total catch YOY index (Figure 16.11), as well as catch age composition of each sex fairly well (Figures 16.12 and 16.13). Based on coefficients of variation, most parameter estimates, except those near the terminal year, were precise (<0.20; Table 16.6).

16.11.1.4 Exploitation and Fishing Mortality Rates

Exploitation rates for blueback herring in the Chowan River before the 2007 moratorium ranged as low as 0.14 in 1979 to as high as 0.87 in 1986 (Table 16.6; Figure 16.14). Exploitation averaged about 0.28 prior to 1985, increased to an average of 0.70 during 1985–1988, and averaged about 0.40 between 1989 and 2006. Since the moratorium, exploitation rates have been close to zero. Corresponding fishing mortality rates are listed in Table 16.7 and are plotted in Figure 16.14. Fishing mortality averaged about 0.34 prior to 1985, increased to an average of 1.3 during 1985–1988, and averaged about 0.56 between 1989 and 2006. Since the moratorium, fishing mortality has been close to zero.

16.11.1.5 Population Abundance

The abundance estimates of the Chowan River blueback herring stock by sex, maturity phase, year, and age are given in Table 16.8, and total abundance by maturity state and year is given in Table 16.9. Blueback herring total abundance (3+) declined steadily from 134 million fish in 1976 to 55 million fish in 1980 (Table 16.9; Figure 16.14). Total abundance increased through 1983 to 103 million fish but then declined precipitously to its lowest value of 1.1 million fish in 2002 (Figure 16.15). Since 2003, total abundance has averaged 1.9 million fish. Age-3 abundance peaked at 81 million fish in 1975,, and declined precipitously since 1983 to .62 million fish in 2001. Since 2002, total abundance of age-3 fish has averaged 1.0 million fish.

16.11.1.6 Spawning Stock Biomass

Estimates of female spawning stock biomass for blueback herring are provided in Table 16.10. Female SSB fluctuated but declined steadily from the peak of 5.2 million kilograms in 1972 to a low of 0.14 million kilograms in 1986 (Figure 16.14). Female SSB increased slightly to 0.46 million through 1990, but then it declined slowly to its lowest level of 15,000 kilograms in 2003. Since 2004, female SSB has averaged about 61,000 kilograms.

16.11.1.7 Retrospective Analysis

Small to moderate retrospective bias was evident in estimates of age-3 abundance, exploitation rate, female SSB, and total population abundance (Figure 16.16). For age-3 abundance and total population abundance, the terminal year estimate was consistently under-estimated. For exploitation rates and female SSB, the retrospective patterns were over- and under-estimation of the value, respectively.

16.12 BENCHMARKS

The fit of the Beverton-Holt stock-recruitment equation to the age-3 abundance and female SSB is shown in Figure 16.17. A plot of the residuals indicated reasonable model fit (Figure 16.17). The estimates of a and R_0 are 22.529 (SE = 4.698) and 39,930,375 fish (SE = 17,869,407), respectively. The estimate of a was precise (CV=0.21), but the estimate of R_0 was only moderately precise (CV=0.45). Reference points generated from YPR, SPR, and the production model are shown in Table 16.11. For YPR analysis, the fishing mortality rate that maximized the

yield-per-recruit, F_{max}, was greater than 5, and $F_{0.1}$ was 1.03 (Figure 16.18). The fishing mortality that reduced the female spawning biomass to 40% and 20% of the level without fishing was 0.53 and 1.01, respectively.

From the spawner-recruit data and production model, F_{MED} was estimated to be 0.59. The fishing mortality rate that produces maximum sustainable yield, F_{MSY}, was 0.39 and corresponding spawning stock bass, SSB_{MSY}, was 1,955,333 kilograms. SSB_{MSY} was higher than the 20% of the equilibrium spawner biomass, $SSB_{20\%}$ (1,195,873 kilograms). Current female spawning stock biomass is only 5% of SSB_{MSY}. The fishing mortality rate that drives the population to extinction, F_{COL}, was 0.91. The relationships between the reference points from the production model are shown with the S-R data in Figure 16.19. The estimates of F_{MSY} and F_{COL} are considerably lower than those estimated for alewife ($F_{MSY} > 1.0$; $F_{COL} > 1.82$) in three Canadian rivers by Gibson and Myers (2003b). Fishing mortality rate estimates are compared to the derived reference points in Figure 16.20 and show that fishing mortality exceeded all reference points several times over the time series, particularly after 1985.

16.12.1 Sensitivity Analyses

Sensitivity analyses were conducted to determine the influence of assumed-known input values on the resulting estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance. The sensitivity of the base model to the female sex ratio, proportion mature-at-age, and natural mortality rate inputs were examined. The following changes in input parameters were made:

Female sex ratio:	±20% change
Sex-specific proportions-at-age:	Used average for entire time series
Natural mortality:	±20% change in all age-specific values; Linear increase of mature fish base rates to 20% over time from 1990 to 2009

In addition, changes to the total catch were made to determine potential effects of missing recreational catch and by-catch. In this scenario, total catch was increased by 10% and 30% from 1990 to 2006. The time period of increase for this exercise and the linear increase in natural mortality was selected to mirror the increasing striped bass harvest and potential interest in river herring as bait to catch striped bass.
Changing the female sex ratio by ± 20% had little impact (< ± 4%) on the estimates of age-3 abundance, exploitation rates, and total population abundance (). The ± 20% change had about an equivalent impact (± 20% change) on the female SSB estimates (Figure 16.20).

Use of the time-series average proportion mature-at-age for each sex had a profound effect on the model output. In a few years, estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance changed by as much as 100% (Figure 16.21). These changes were the result of the worsening agreement between predicted and observed catch age composition.

Increases in the sex- and age-specific natural mortality rates by 20% had large impacts (changes up to ± 20%) on the estimates of age-3 abundance, female SSB, exploitation rates, and total population abundance (Figure 16.22). Decreasing the sex- and age-specific natural mortality

rates by 20% had only a moderate impact (some changes up to ± 50%) on the estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance (Figure 16.22).

Linear increases in the sex- and age-specific natural mortality rates of the mature male and female bluebacks from 0% in 1990 to 20% in 2009 had moderate impacts (< ± 40% change) on the estimates of age-3 abundance, exploitation rates, female SSB, and total population abundance (Figure 16.23).

Increases in total catch by 10% and 30% from 1990 to 2006 produced larger estimates of age-3 abundance, female SSB, and total population abundance, and smaller estimates of exploitation rates (Figure 16.24).

16.12.1.1 Alternate Natural Mortality Rates

The impact of alternate estimates of age- and sex-specific natural mortality on model results was evaluated. The Lorenzen (1996) values derived earlier were scaled such that cumulative survival from age 1 to maximum age (9 females; 8 males) was equal to 1.5%. This cumulative survival value comes from the method of Hoenig (1983) as described in Hewitt and Hoenig (2005). The resulting values were:

	Age						
	3	4	5	6	7	8	
Female:		0.50	0.47	0.45	0.44	0.42	0.41
Male:	0.55	0.52	0.50	0.48	0.46	0.45	

Lower natural mortality rates produced lower estimates of age-3 number, spawning stock biomass, and total population size but higher estimates of exploitation rates (Figure 16.25).

16.13 Conclusions and recommendations

The previous NCRHFMP (NCDMF 2007) concluded that the ASMA river herring stock was undergoing overfishing and was overfished, despite the low TAC. No model used in the assessment (Grist, 2005) was estimated to rebuild the stock within the legal time frame of 10 years. Based on these results, the 2007 FMP recommended a no harvest provision, coupled with various gear restrictions The 2007 NCRHFMP identified four stock recovery indicators for the Chowan River blueback herring stock: a three-year running average juvenile abundance index of greater than 60 fish per haul, a spawning population comprised of greater than 10% repeat spawners, a spawning stock biomass of greater than 4 million pounds (1.8 million kg) and a three-year running average of greater than 8 million age three fish. The factors leading to this recommendation remain largely unchanged since 2007, despite a fishing pressure that is almost negligibly low. Therefore, although the stock is not currently experiencing overfishing, it remains overfished since the spawning stock biomass remains less than 5% of the amount necessary to replace itself in the complete absence of fishing (Figure 16.10).

Estimates of fishing mortality are well below all estimated thresholds for the final three years (Table 16.7, Figure 16.11). The forward-projecting statistical catch-at-age model estimates

juvenile abundance as well below the target of 60 fish per haul (Figure 16.26), with no increasing pattern evident. After an abrupt increase to 8.8% in 2007, the percentage of repeat spawners declined to below its average for the previous decade (Figure 16.4). A Mann-Kendall trend analysis shows that the spawning stock biomass has increased significantly ($p=0.002$) during the past decade, but remains at approximately 5% of the target of 1.8 million kg (Table 16.10, Figure 16.5). The recruitment target continues at less than 1million fish, well below the 8-million fish target, with no increasing pattern evident.

While current research programs are recommended to continue, assessing progress towards recovery goals would be improved with additional research and surveys. Many recommendations made in the previous assessment (Grist, 2005) and the 2007 NCRHFMP are echoed here. A complete assessment of all river herring spawning and nursery areas in NC are identified in the 2007 NCRHFMP as needed research. In addition, the NCRHFMP identified four stock recovery indicators as restoration targets. Data collected through a Chowan River Pound Net Survey and a juvenile abundance survey to monitor these indicators are essential in determining stock status of Chowan River blueback herring.

Although the Chowan River is the dominant system for river herring in North Carolina, the 2007 NCRHFMP identified a research need to expand data collection to all areas of the Albemarle Sound as well as other systems in the state.

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Table 16.1 Commercial landings of river herring in North Carolina, 1972-2006.

Year	Atlantic Ocean	Albemarle Sound Area (excluding Chowan River)	Chowan River	Other Areas	Lb
1972	--	643,026	10,594,117	0	11,237,143
1973	--	573,931	7,350,578	1,389	7,925,898
1974	--	467,992	5,736,905	4,645	6,209,542
1975	2,338	917,723	5,031,756	250	5,952,067
1976	--	666,584	5,734,776	0	6,401,360
1977	--	1,102,125	7,418,218	3,470	8,523,813
1978	--	954,939	5,615,113	37,101	6,607,153
1979	19,388	796,099	4,303,663	0	5,119,150
1980	*	796,237	5,382,954	39,332	6,218,523
1981	143,232	1,245,401	3,314,447	50,643	4,753,723
1982	7,679	1,872,156	7,459,968	97,900	9,437,703
1983	--	1,453,033	4,405,915	9,384	5,868,332
1984	9,497	1,931,492	4,561,503	13,617	6,516,109
1985	*	2,665,334	8,871,391	11,553	11,548,278
1986	40,270	999,093	5,767,874	7,086	6,814,323
1987	19,279	838,689	2,334,719	2,288	3,194,975
1988	19,517	1,570,788	2,259,888	341,018	4,191,211
1989	--	581,486	908,145	1,446	1,491,077
1990	11,073	433,891	710,849	1,812	1,157,625
1991	--	372,843	1,202,535	0	1,575,378
1992	110,794	476,649	1,135,340	395	1,723,178
1993	--	115,072	801,115	*	916,235
1994	38,834	211,372	390,852	3,251	644,309
1995**	19,174	150,082	280,681	4,049	453,984
1996**	*	123,725	404,884	894	529,503
1997**	5,568	126,453	201,929	861	334,809
1998**	--	143,424	377,312	1,197	521,930
1999**	--	110,657	332,464	373	443,494
2000**	599	140,696	182,658	8,378	332,336
2001**	*	89,767	201,717	15,277	306,761
2002**	*	75,736	92,979	6,145	174,860
2003**	*	98,440	84,591	16,685	199,716
2004**	*	107,430	77,177	3,934	188,542
2005**	--	92,688	157,088	245	250,021
2006**	--	40,590	67,404	1,249	109,243

**Denotes confidential data*

***Season or TAC in ASMA*

Table 16.2 Commercial landings and value of research set-aside river herring harvest in North Carolina, 2007-2010.

Year	# of Permits Issued	Quota (lbs/permit/period)	Harvest (lbs)
2007	15	200	1,103
2008	13	250	1,292
2009	27	125	643
2010	30	125	1,765
Average	21	175	1,201
Total	85		4,803

Table 16.3 Catch-per-unit effort of blueback herring and alewife in the commercial pound net fishery, Chowan River, NC.

Year	Total PN fished	Weeks fished	Effort in PN weeks	PN BB Catch	BB CPUE	PN ALE.Catch	ALE. CPUE
1977	624	9	4,854	7,001,059	1,442	291,711	60
1978	383	10	3,645	4,050,767	1,111	1,209,970	332
1979	502	12	4,996	2,118,907	424	2,035,813	407
1980	500	9	3,090	3,388,983	1,096	1,824,837	590
1981	525	10	4,120	2,041,319	495	1,198,870	291
1982	480	11	4,461	5,388,115	1,207	1,992,865	446
1983	486	12	4,895	2,380,261	486	1,947,488	398
1984	480	12	5,040	3,196,416	634	1,305,578	259
1985	421	12	3,708	6,845,568	1,846	1,930,802	520
1986	451	12	4,241	4,244,280	1,000	1,340,299	316
1987	501	11	4,969	1,353,601	272	980,194	197
1988	506	12	4,689	1,430,114	305	804,440	171
1989	348	9	3,063	626,222	204	281,347	92
1990	360	11	3,077	610,931	198	99,455	32
1991	226	11	2,037	720,218	353	294,174	144
1992	180	12	1,669	806,091	483	329,249	197
1993	197	11	1,729	640,092	370	160,023	92
1994	175	8	1,173	377,728	322	7,709	6
1995	73	8	484	263,163	543	5,371	11
1996	95	10	555	394,491	711	3,985	7
1997	102	5	461	190,071	412	1,920	4
1998	75	11	463	361,285	780	7,373	16
1999	68	8	471	318,495	676	6,500	14
2000	51	9	445	146,126	328	36,532	82
2001	63	7	385	136,998	356	64,470	167
2002	62	12	648	47,235	73	38,648	60
2003	50	10	419	45,326	108	35,614	85
2004	36	12	376	29,595	79	42,589	113
2005	41	15	447	148,552	332	7,424	16
2006	39	13	355	45,578	128	20,224	57

Table 16.4 Percentage of blueback herring and alewife repeat spawners (spawned more than once) from the Chowan River pound net fishery, 1972-2009.

Year	Percent BB	Percent Alewife
1972	21.1	15.9
1973	18.3	13.2
1974	16.4	4.6
1975	3.9	9.3
1976	5.3	14.4
1977	7.3	4.1
1978	7.1	4.9
1979	20.1	3.3
1980	24.6	13.7
1981	16.2	9.7
1982	13.9	0.5
1983	1.6	2.5
1984	1.3	10.2
1985	3.3	0.0
1986	6.1	0.0
1987	3.3	0.7
1988	2.0	2.5
1989	0.6	0.0
1990	2.5	No Samples
1991	4.2	5.7
1992	3.7	12.5
1993	4.7	No Samples
1994	1.2	No Samples
1995	1.6	No Samples
1996	2.8	No Samples
1997	2.7	No Samples
1998	2.7	No Samples
1999	2.6	No Samples
2000	6.0	1.1
2001	3.1	5.0
2002	4.7	14.8
2003	5.9	5.4
2004	2.9	10.4
2005	2.1	12.6
2006	0.0	3.1
2007^	7.7	10.0
2008*	5.8	8.0
2009*	1.7	10.5

^ Based on research set aside data

*Based on samples obtained from contracted pound net sets

Table 16.5 Likelihood components with respective contributions in base model run.

Likelihood Components

	Weight	RSS
YOY Index	1	104.056
Total Catch	10	14.4095
Catch Age Comps	1	3549.76
Total Likelihood		3567.68
Number of Estimates		78
AIC		7291.37

Catch RMSE	0.199002
Index RMSE	1.95584

Table 16.6 Parameter estimates and associated standard deviations of base model configuration.

Year	Age-3 Numbers	SD	CV
1972	64,476,000	5.93E+06	0.09
1973	39,926,000	6.55E+06	0.16
1974	68,271,400	1.00E+07	0.15
1975	81,223,300	1.01E+07	0.12
1976	74,589,600	9.53E+06	0.13
1977	55,735,400	7.67E+06	0.14
1978	33,063,000	5.01E+06	0.15
1979	26,287,600	4.46E+06	0.17
1980	26,402,600	4.64E+06	0.18
1981	44,989,000	6.12E+06	0.14
1982	55,936,600	7.12E+06	0.13
1983	66,017,800	7.00E+06	0.11
1984	25,929,900	3.66E+06	0.14
1985	12,777,100	1.91E+06	0.15
1986	9,536,740	1.30E+06	0.14
1987	9,844,720	1.19E+06	0.12
1988	6,089,410	9.18E+05	0.15
1989	6,987,980	9.84E+05	0.14
1990	8,391,700	9.66E+05	0.12
1991	8,479,400	8.71E+05	0.10
1992	2,375,930	4.21E+05	0.18
1993	4,934,790	5.93E+05	0.12
1994	3,443,090	4.58E+05	0.13
1995	2,497,120	3.87E+05	0.15
1996	3,856,640	4.66E+05	0.12
1997	3,344,890	3.69E+05	0.11
1998	1,721,320	2.22E+05	0.13
1999	1,217,790	1.52E+05	0.13
2000	1,019,300	1.44E+05	0.14
2001	623,960	1.22E+05	0.20
2002	631,886	1.47E+05	0.23
2003	708,111	1.74E+05	0.25
2004	1,231,180	2.93E+05	0.24
2005	1,308,180	4.39E+05	0.34
2006	879,986	3.70E+05	0.42
2007	1,487,230	6.40E+05	0.43
2008	1,649,470	7.40E+05	0.45
2009	504,497	437682	0.87

Year	u	SD	CV
1972	0.263	0.031	0.12
1973	0.330	0.047	0.14
1974	0.383	0.059	0.15
1975	0.160	0.026	0.16
1976	0.224	0.032	0.14
1977	0.487	0.066	0.13
1978	0.252	0.037	0.15
1979	0.140	0.022	0.16
1980	0.320	0.048	0.15
1981	0.285	0.050	0.17
1982	0.455	0.061	0.13
1983	0.160	0.023	0.14
1984	0.206	0.025	0.12
1985	0.674	0.048	0.07
1986	0.872	0.040	0.05
1987	0.610	0.070	0.11
1988	0.644	0.065	0.10
1989	0.392	0.058	0.15
1990	0.224	0.031	0.14
1991	0.336	0.039	0.12
1992	0.413	0.044	0.11
1993	0.657	0.067	0.10
1994	0.434	0.052	0.12
1995	0.360	0.049	0.14
1996	0.514	0.061	0.12
1997	0.169	0.023	0.13
1998	0.479	0.048	0.10
1999	0.681	0.053	0.08
2000	0.513	0.054	0.10
2001	0.604	0.068	0.11
2002	0.333	0.063	0.19
2003	0.371	0.082	0.22
2004	0.156	0.040	0.26
2005	0.475	0.132	0.28
2006	0.182	0.070	0.39
2007	0.001	0.001	0.44
2008	0.002	0.001	0.44
2009	0.001	0.000	0.44

q	Estimate	SD	CV
1	2.44E-07	3.10E-08	0.13

Table 16.7 Derived fishing mortality values for Chowan River blueback herring.

Mature Fish			
Year	F	SD	CV
1972	0.305	0.042	0.14
1973	0.401	0.070	0.18
1974	0.483	0.096	0.20
1975	0.175	0.031	0.18
1976	0.254	0.041	0.16
1977	0.667	0.128	0.19
1978	0.291	0.049	0.17
1979	0.151	0.026	0.17
1980	0.386	0.071	0.18
1981	0.336	0.069	0.21
1982	0.607	0.113	0.19
1983	0.175	0.028	0.16
1984	0.230	0.032	0.14
1985	1.120	0.146	0.13
1986	2.053	0.309	0.15
1987	0.941	0.179	0.19
1988	1.033	0.182	0.18
1989	0.497	0.095	0.19
1990	0.254	0.040	0.16
1991	0.410	0.059	0.14
1992	0.532	0.075	0.14
1993	1.071	0.196	0.18
1994	0.570	0.092	0.16
1995	0.446	0.076	0.17
1996	0.722	0.126	0.17
1997	0.185	0.027	0.15
1998	0.652	0.092	0.14
1999	1.143	0.166	0.15
2000	0.720	0.111	0.15
2001	0.926	0.173	0.19
2002	0.406	0.095	0.23
2003	0.464	0.131	0.28
2004	0.170	0.047	0.28
2005	0.644	0.251	0.39
2006	0.201	0.086	0.43
2007	0.001	0.001	0.44
2008	0.002	0.001	0.44
2009	0.001	0.000	0.44

Table 16.8 Estimates of population abundance by sex, maturity state, year, and age.

Female Immature Age

Year	Total	3	4	5	6	7	8+
1972	19,766,980	18,053,300	1,695,280	18,400	0	0	0
1973	22,826,950	19,723,500	3,071,030	32,420	0	0	0
1974	36,466,683	34,135,700	2,269,080	61,903	0	0	0
1975	40,976,900	39,718,200	1,258,700	0	0	0	0
1976	41,618,960	36,698,100	4,920,860	0	0	0	0
1977	40,136,304	27,867,700	12,250,800	17,804	0	0	0
1978	22,937,488	16,366,200	6,507,970	63,318	0	0	0
1979	14,481,139	12,539,200	1,915,030	26,909	0	0	0
1980	16,639,840	13,082,500	3,507,780	49,489	71	0	0
1981	27,717,575	22,494,500	4,978,320	244,755	0	0	0
1982	31,515,120	27,688,600	3,826,520	0	0	0	0
1983	35,547,740	32,348,700	3,199,040	0	0	0	0
1984	17,446,080	12,420,400	5,025,680	0	0	0	0
1985	11,243,150	6,388,540	4,854,610	0	0	0	0
1986	6,953,091	4,768,370	2,129,520	55,201	0	0	0
1987	5,505,510	4,681,160	811,142	13,208	0	0	0
1988	3,578,650	3,044,710	533,940	0	0	0	0
1989	3,692,056	3,413,630	278,426	0	0	0	0
1990	3,545,486	3,394,440	151,046	0	0	0	0
1991	3,794,990	3,561,350	233,640	0	0	0	0
1992	1,629,206	1,121,440	507,766	0	0	0	0
1993	2,716,618	2,408,180	302,139	6,299	0	0	0
1994	2,124,655	1,666,460	458,195	0	0	0	0
1995	1,507,889	1,223,590	284,299	0	0	0	0
1996	2,352,359	1,928,320	421,100	2,939	0	0	0
1997	1,956,022	1,628,960	324,233	2,829	0	0	0
1998	1,231,369	860,660	369,201	1,508	0	0	0
1999	818,688	608,895	209,030	763	0	0	0
2000	627,019	509,648	113,158	4,213	0	0	0
2001	459,551	310,732	148,585	234	0	0	0
2002	422,118	315,943	106,175	0	0	0	0
2003	482,443	354,056	127,838	549	0	0	0
2004	653,796	589,738	64,058	0	0	0	0
2005	622,532	588,029	34,503	0	0	0	0
2006	481,913	439,993	41,920	0	0	0	0
2007	739,596	649,174	90,422	0	0	0	0
2008	930,308	824735	104685	888	0	0	0
2009	364,159	252248	111911	0	0	0	0

Female Mature Age

Year	Total	3	4	5	6	7	8+
1972	35,432,718	14,184,700	12,321,100	5,551,980	2,167,660	859,551	347,727
1973	20,239,939	239,556	10,945,400	5,537,960	2,167,660	859,551	489,812
1974	16,070,182	0	7,506,700	5,312,950	1,972,190	780,719	497,623
1975	22,836,069	893,457	15,523,900	3,567,450	1,761,740	654,814	434,708
1976	25,837,012	596,716	14,975,100	7,386,400	1,579,190	795,616	503,990
1977	18,782,957	0	6,019,150	8,528,720	3,020,840	658,895	555,352
1978	18,716,349	165,315	7,193,020	7,864,480	2,316,440	833,659	343,435
1979	17,462,720	604,614	6,192,070	6,116,250	3,133,750	931,644	484,392
1980	11,632,484	118,812	2,912,680	3,692,730	2,787,770	1,449,830	670,662
1981	7,249,182	0	1,493,340	2,591,950	1,350,180	1,019,830	793,882
1982	12,976,973	279,683	7,232,780	3,124,750	1,105,970	519,168	714,622
1983	16,756,929	660,178	10,488,800	4,014,790	897,839	324,200	371,122
1984	20,406,776	544,528	11,150,900	6,205,860	1,777,730	405,589	322,169
1985	12,318,412	0	1,464,490	7,175,990	2,599,530	759,704	318,698
1986	5,597,709	0	1,011,370	2,700,990	1,235,120	456,467	193,762
1987	3,272,027	241,196	1,533,200	1,154,530	211,892	85,273	45,936
1988	2,859,557	0	1,813,810	728,507	244,552	44,486	28,202
1989	2,106,438	80,362	1,218,490	609,729	136,762	46,837	14,258
1990	3,140,580	801,407	1,551,280	527,073	195,610	44,762	20,448
1991	3,444,351	678,352	1,740,870	700,051	215,598	81,630	27,850
1992	2,611,186	66,526	1,464,550	718,076	245,051	76,994	39,989
1993	1,366,106	59,218	268,422	700,779	222,412	77,434	37,842
1994	1,187,267	55,090	735,749	203,708	129,962	41,005	21,754
1995	1,146,990	24,971	550,322	451,870	60,744	39,537	19,546
1996	708,541	0	188,327	326,015	152,470	20,911	20,818
1997	1,065,453	43,484	623,816	262,093	85,044	39,838	11,179
1998	1,060,979	0	449,429	433,928	116,304	38,007	23,311
1999	695,265	0	214,108	311,029	119,953	32,583	17,592
2000	407,346	0	186,202	139,095	52,675	20,567	8,808
2001	267,861	1,248	101,980	105,075	37,905	13,786	7,867
2002	179,367	0	46,838	97,669	22,063	8,075	4,723
2003	144,896	0	27,494	70,464	34,328	7,911	4,699
2004	250,528	25,855	110,012	75,012	23,662	11,617	4,370
2005	464,866	66,063	266,165	81,092	33,379	10,742	7,424
2006	391,462	0	264,239	90,080	22,456	9,430	5,257
2007	409,065	94,439	125,898	133,378	38,852	9,881	6,617
2008	471,848	0	260842	110826	70231	20871	9078
2009	595,218	0	293565	188682	58801	37713	16457

Table 16.8 Continued.

Male Immature Age

Year	Total	3	4	5	6	7	8+
1972	19,927,002	18,730,300	1,194,330	2,372	0	0	0
1973	19,054,260	17,787,000	1,267,260	0	0	0	0
1974	34,378,862	33,487,100	891,762	0	0	0	0
1975	39,554,890	37,403,300	2,151,590	0	0	0	0
1976	37,082,090	34,460,400	2,621,690	0	0	0	0
1977	38,703,500	27,867,700	10,835,800	0	0	0	0
1978	20,635,714	15,490,000	5,059,620	86,094	0	0	0
1979	13,122,458	12,315,700	806,758	0	0	0	0
1980	15,124,954	12,897,700	2,218,040	9,214	0	0	0
1981	26,030,584	22,292,100	3,697,730	40,754	0	0	0
1982	28,543,270	25,982,500	2,560,770	0	0	0	0
1983	30,708,020	29,278,900	1,429,120	0	0	0	0
1984	13,687,760	10,851,700	2,836,060	0	0	0	0
1985	9,007,560	6,139,390	2,868,170	0	0	0	0
1986	5,419,508	4,549,030	857,659	12,819	0	0	0
1987	4,852,357	4,577,790	274,567	0	0	0	0
1988	2,421,304	2,298,750	122,554	0	0	0	0
1989	2,785,455	2,718,320	67,135	0	0	0	0
1990	2,272,787	2,248,970	23,817	0	0	0	0
1991	2,792,311	2,713,410	78,818	83	0	0	0
1992	1,115,190	1,072,730	42,264	196	0	0	0
1993	2,478,836	2,351,430	127,406	0	0	0	0
1994	1,246,731	1,158,600	88,131	0	0	0	0
1995	1,318,864	1,199,870	118,994	0	0	0	0
1996	1,612,167	1,561,940	50,227	0	0	0	0
1997	1,084,963	1,021,860	63,103	0	0	0	0
1998	872,435	771,151	100,971	313	0	0	0
1999	662,164	573,579	88,585	0	0	0	0
2000	509,932	497,927	12,005	0	0	0	0
2001	328,695	305,428	23,267	0	0	0	0
2002	318,804	308,992	9,812	0	0	0	0
2003	337,127	327,501	9,626	0	0	0	0
2004	437,109	431,530	5,579	0	0	0	0
2005	513,553	510,192	3,361	0	0	0	0
2006	381,088	365,194	15,894	0	0	0	0
2007	576,006	569,607	6,399	0	0	0	0
2008	835,872	757,931	77,909	32	0	0	0
2009	363,494	245,438	118,056	0	0	0	0

Male Mature Age

Year	Total	3	4	5	6	7	8+
1972	34,607,460	13,507,700	12,769,200	5,264,860	1,987,090	772,348	306,262
1973	23,327,864	2,175,970	12,696,300	5,267,230	1,987,090	772,348	428,926
1974	16,914,643	648,578	8,475,260	4,850,520	1,804,560	701,513	434,212
1975	23,089,760	3,208,320	14,343,200	3,040,470	1,531,940	587,293	378,537
1976	29,200,015	2,834,400	16,895,500	7,047,940	1,306,140	678,140	437,895
1977	18,616,152	0	7,007,950	7,809,310	2,797,230	534,176	467,486
1978	19,711,018	1,041,480	8,505,050	7,080,080	2,050,020	756,664	277,724
1979	17,588,286	828,059	7,112,050	5,670,170	2,752,700	808,166	417,141
1980	12,168,268	303,630	4,123,310	3,428,820	2,495,360	1,248,320	568,828
1981	8,095,685	202,451	2,680,750	2,453,070	1,197,840	894,753	666,821
1982	15,106,506	1,985,750	8,360,380	2,787,780	918,099	451,469	603,028
1983	20,360,589	3,730,010	11,744,600	3,533,950	777,343	263,799	310,887
1984	22,784,463	2,113,290	12,940,100	5,607,290	1,518,560	344,203	261,020
1985	13,168,564	249,153	3,231,070	6,513,100	2,279,380	636,101	259,760
1986	5,962,838	219,345	2,170,290	1,935,210	1,087,900	392,325	157,768
1987	3,107,525	344,565	1,953,380	564,219	133,651	73,622	38,088
1988	3,595,738	745,953	2,171,150	514,920	112,678	27,504	23,533
1989	2,526,217	775,666	1,181,060	444,710	93,808	21,153	9,820
1990	4,044,813	1,946,870	1,529,050	390,175	138,453	30,095	10,170
1991	4,106,436	1,526,290	1,751,010	600,773	154,883	56,634	16,846
1992	2,787,751	115,232	1,771,690	616,185	204,126	54,216	26,301
1993	1,355,510	115,968	427,696	537,782	185,313	63,225	25,526
1994	1,918,994	562,946	1,075,780	136,057	94,313	33,489	16,410
1995	1,077,211	48,694	599,918	345,873	39,372	28,123	15,230
1996	1,306,604	366,381	548,978	249,727	113,256	13,285	14,977
1997	1,690,221	650,581	783,793	157,351	62,067	29,006	7,424
1998	1,213,783	89,509	659,505	354,375	66,892	27,189	16,314
1999	690,674	35,316	309,464	220,696	94,596	18,369	12,233
2000	434,517	11,722	272,665	92,970	35,994	15,898	5,268
2001	338,199	6,552	221,876	71,838	23,146	9,234	5,554
2002	224,806	6,951	140,119	55,185	14,557	4,833	3,162
2003	247,656	26,554	143,032	51,253	18,823	5,116	2,878
2004	420,944	184,062	161,964	49,461	16,498	6,244	2,715
2005	529,619	143,900	282,295	70,645	21,359	7,341	4,079
2006	447,455	74,799	269,229	75,289	18,985	5,915	3,238
2007	536,140	174,005	201,141	117,251	31,513	8,188	4,042
2008	536,720	66,804	283,927	102,890	59,914	16,593	6,592
2009	566,160	6,811	283,327	179,430	52,571	31,536	12,486

Table 16.9 Total population abundance (number of fish 3+) estimate for the Chowan River blueback herring stock by maturity state.

Year	Immature	Mature	Total
1972	39,693,983	70,040,178	109,734,161
1973	41,881,210	43,567,803	85,449,013
1974	70,845,545	32,984,825	103,830,370
1975	80,531,790	45,925,829	126,457,619
1976	78,701,050	55,037,027	133,738,077
1977	78,839,804	37,399,109	116,238,913
1978	43,573,203	38,427,367	82,000,570
1979	27,603,597	35,051,006	62,654,603
1980	31,764,795	23,800,752	55,565,547
1981	53,748,159	15,344,867	69,093,026
1982	60,058,390	28,083,479	88,141,869
1983	66,255,760	37,117,518	103,373,278
1984	31,133,840	43,191,239	74,325,079
1985	20,250,710	25,486,976	45,737,686
1986	12,372,598	11,560,547	23,933,145
1987	10,357,867	6,379,552	16,737,419
1988	5,999,954	6,455,295	12,455,249
1989	6,477,511	4,632,655	11,110,166
1990	5,818,273	7,185,392	13,003,665
1991	6,587,301	7,550,787	14,138,087
1992	2,744,396	5,398,937	8,143,332
1993	5,195,454	2,721,616	7,917,069
1994	3,371,386	3,106,261	6,477,647
1995	2,826,753	2,224,201	5,050,954
1996	3,964,526	2,015,144	5,979,670
1997	3,040,986	2,755,674	5,796,659
1998	2,103,805	2,274,762	4,378,567
1999	1,480,852	1,385,939	2,866,791
2000	1,136,952	841,863	1,978,815
2001	788,246	606,060	1,394,307
2002	740,922	404,173	1,145,095
2003	819,570	392,552	1,212,121
2004	1,090,905	671,472	1,762,377
2005	1,136,085	994,486	2,130,570
2006	863,000	838,917	1,701,917
2007	1,315,602	945,206	2,260,808
2008	1,766,180	1,008,568	2,774,748
2009	727,653	1,161,378	1,889,031

Table 16.10 Estimates of female spawning stock biomass (kilograms) for the Chowan River blueback herring stock.

		Female SSB (kg)					
		Age					
Year	Total	3	4	5	6	7	8+
1972	5225143	1944810	1861860	855338	354721	133056	75358
1973	2768179	23417	1370370	778638	343958	155382	96415
1974	2063930	0	866408	688631	288489	130104	90298
1975	3781748	109509	2437070	628930	350521	148425	107293
1976	4014457	67572	2171980	1203080	290286	166614	114925
1977	2038547	0	577430	918810	367282	91265	83760
1978	2912659	18045	1005640	1234750	410451	168284	75489
1979	3153966	75918	995848	1104640	638746	216336	122478
1980	1759074	11796	370384	527332	449287	266194	134081
1981	1241358	0	213485	420563	248030	192447	166833
1982	1483053	19813	756725	379710	146448	76384	103973
1983	2812416	74842	1620670	748456	196030	72690	99728
1984	2948732	57533	1497060	916973	314928	86995	75244
1985	761371	0	80311	416944	176496	57036	30585
1986	144928	0	21028	68290	34240	14060	7311
1987	226036	11955	97534	85160	17697	8420	5271
1988	170264	0	98155	46945	18806	3405	2952
1989	238725	6845	123806	78275	19554	7694	2550
1990	457807	101336	229851	75642	37633	8681	4664
1991	400196	60794	181443	100847	34064	17612	5436
1992	272198	5471	138505	78877	30228	12211	6906
1993	79332	2030	13799	40589	13263	5838	3813
1994	98670	3738	53258	16243	17639	4174	3617
1995	121908	1918	54232	46844	7774	7464	3677
1996	69715	0	17197	30719	16440	2387	2973
1997	173968	3974	84992	53782	17734	10756	2730
1998	91596	0	34406	37061	11750	4810	3569
1999	38579	0	10714	17547	6614	2056	1648
2000	33737	0	13679	11911	4715	2171	1260
2001	20160	59	6300	7947	3452	1485	916
2002	22390	0	4870	12174	3235	1184	926
2003	15460	0	2145	7491	4060	896	869
2004	32303	2618	12998	9495	3794	2314	1084
2005	36781	4163	19570	7240	3331	1331	1146
2006	51024	0	32421	11789	3729	1820	1264
2007	73233	12920	22127	25573	8342	2329	1943
2008	75164	0	35932	17700	13951	4917	2664
2009	95432	0	39899	30169	11635	8894	4835

Table 16.11 Reference points derived from YPR, SPR and production model methods.

	Basis	Estimate
Yield Per Recruit	F0.1	1.03
	Fmax	5
Spawner Per Recruit	F40%	0.51
	F20%	1.01
Production Model	Fmed	0.59
	Fcol	0.91
	Fmsy	0.39
	SSBmsy	1955333
	SSB20%	1195873

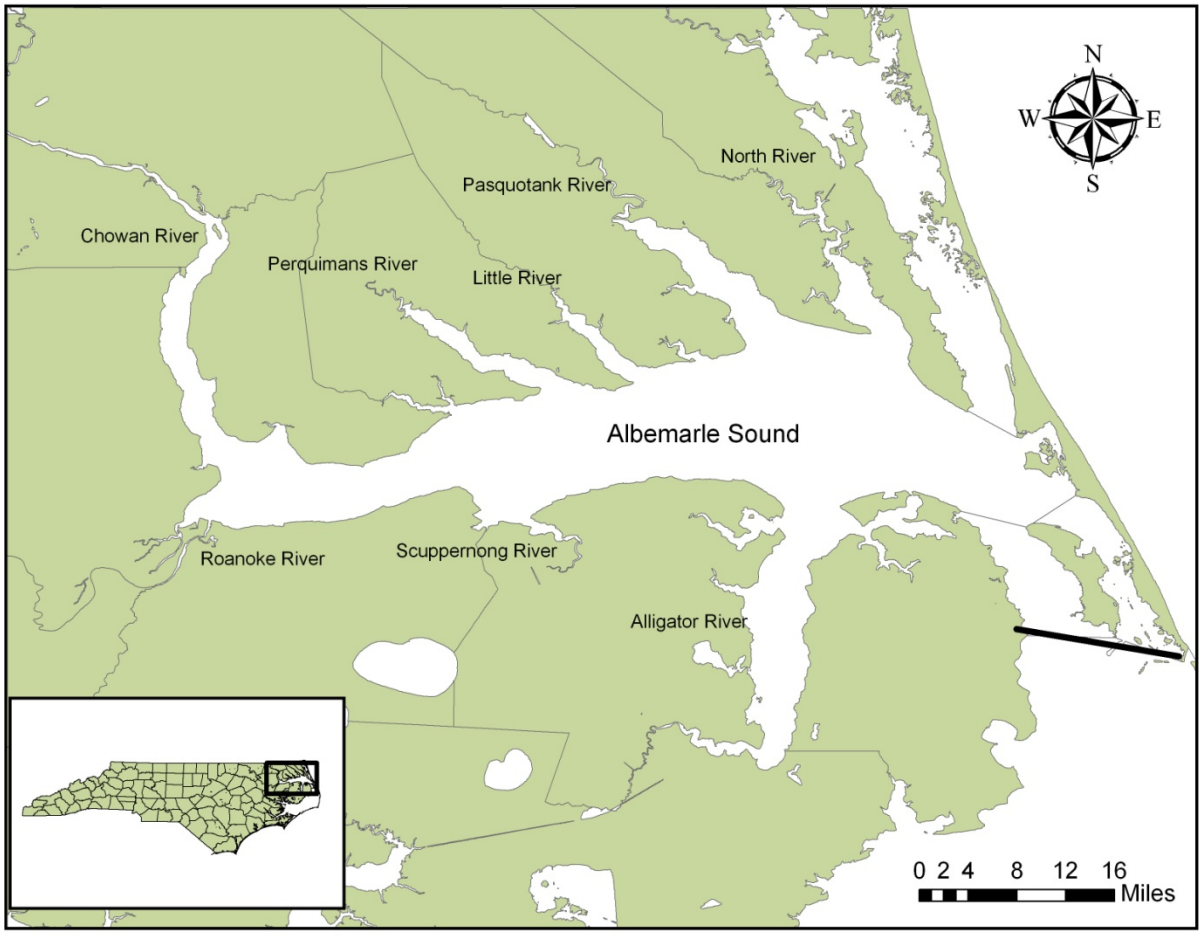


Figure 16.1 Albemarle Sound and tributaries, NC.

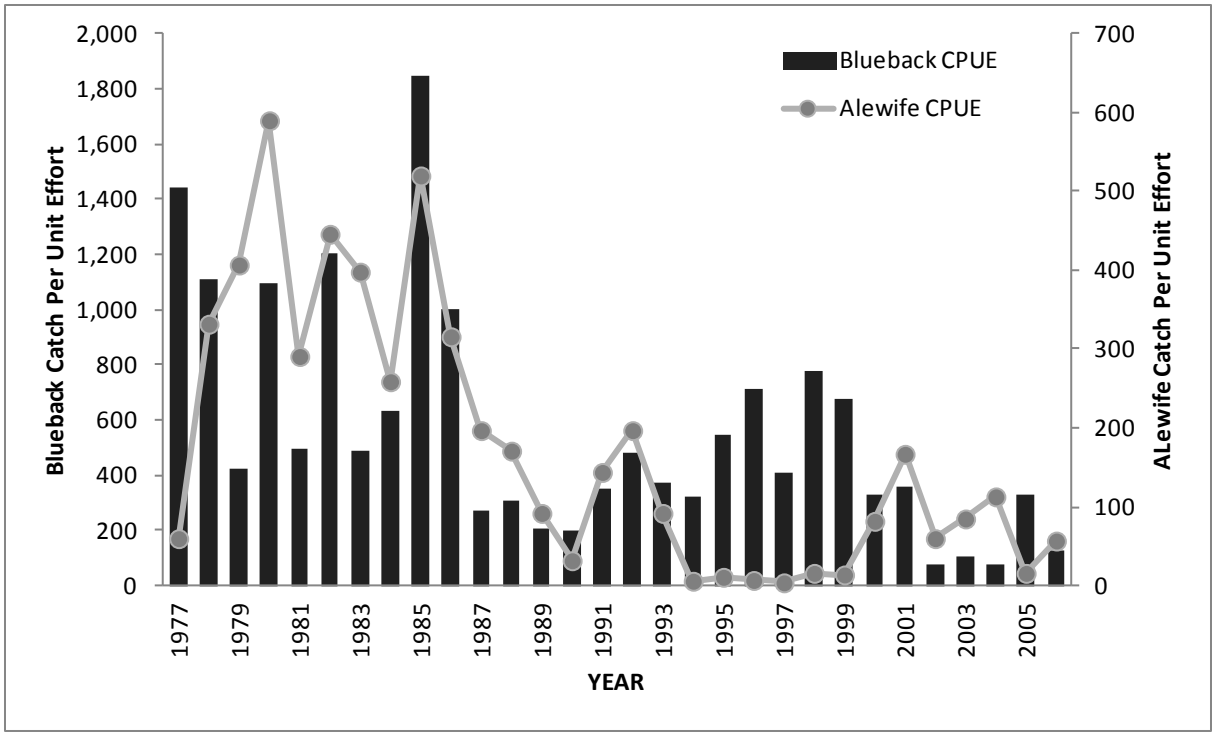
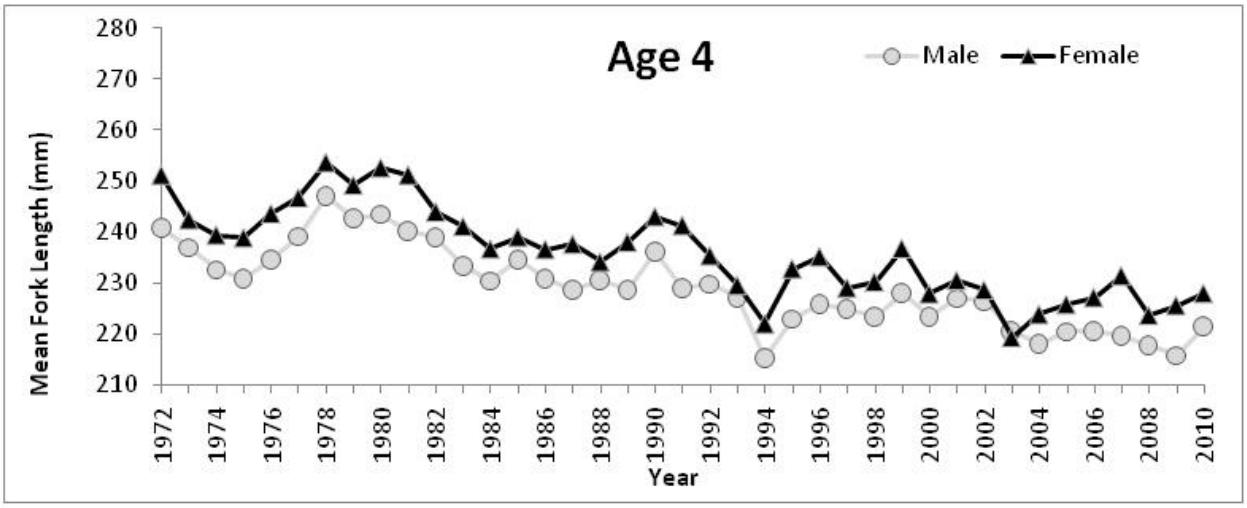
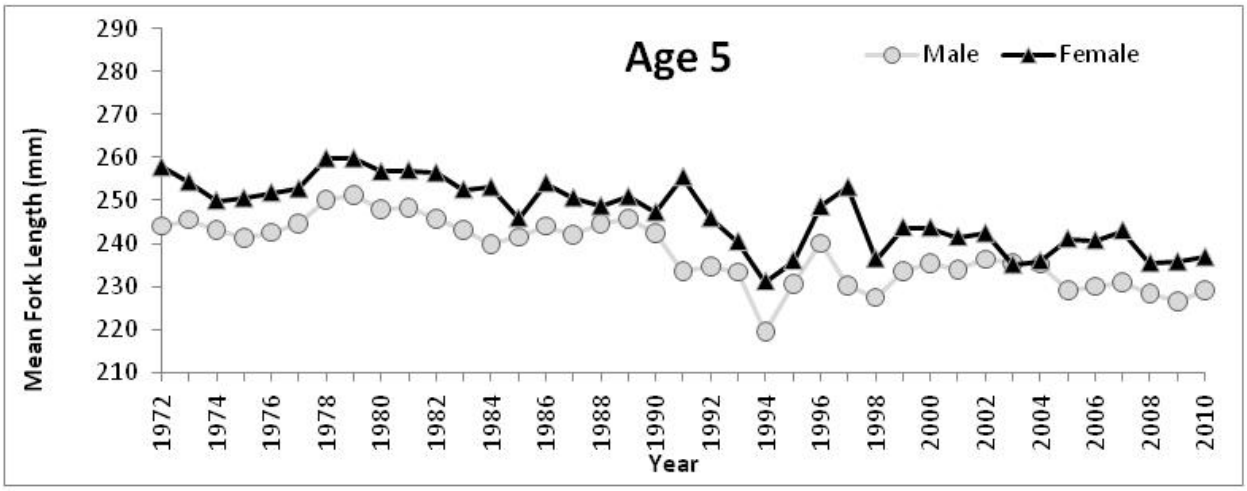
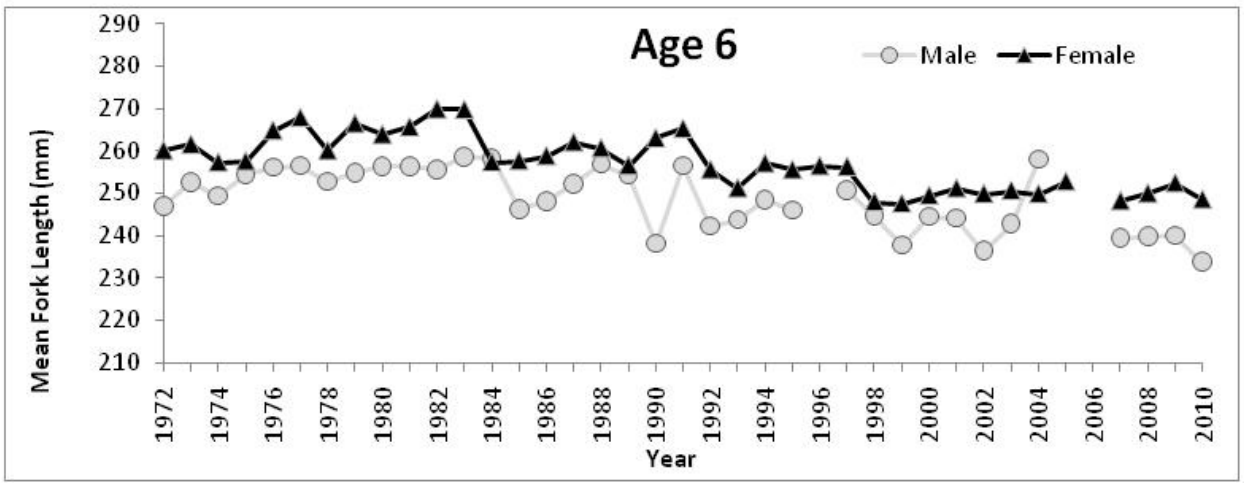


Figure 16.2 Catch per unit effort for blueback herring and alewife from the Chowan River commercial pound net fishery 1977-2006.



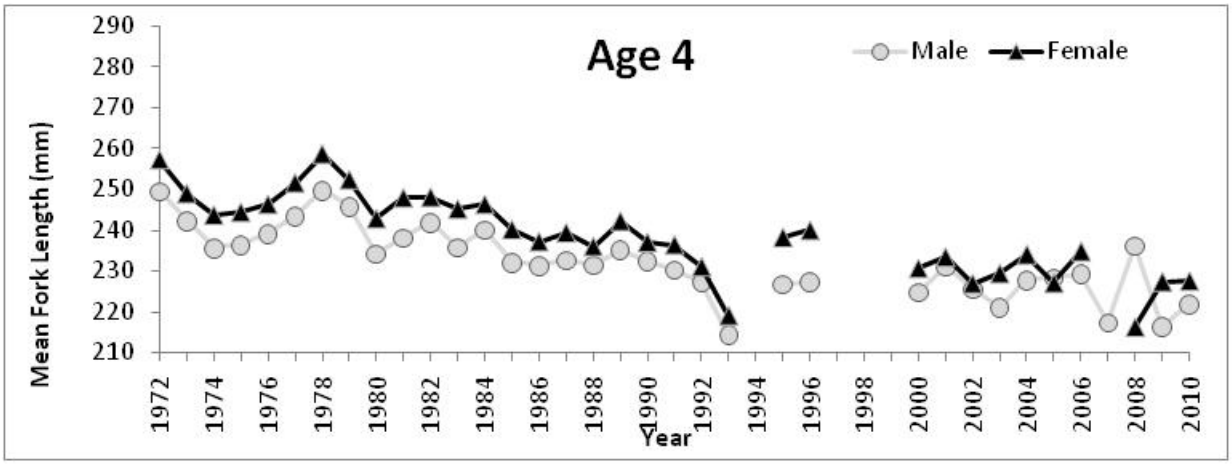


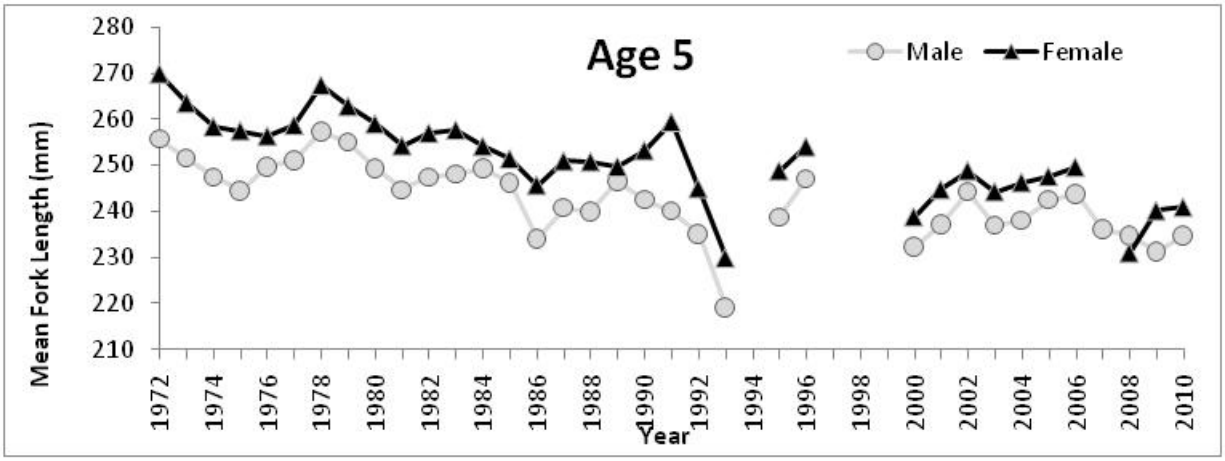


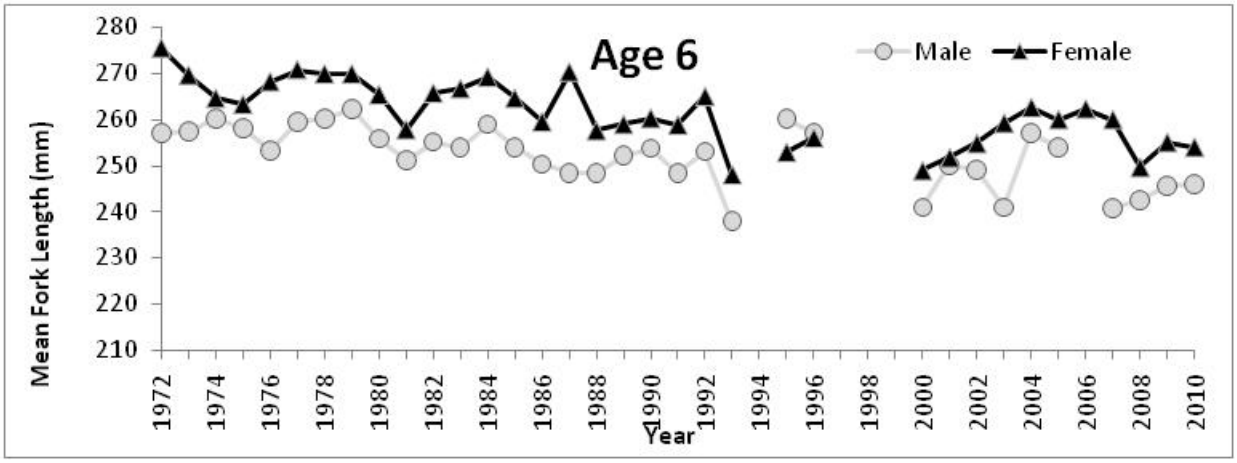
**2007 results based on samples collected from the research set aside harvest, April 4-7*

***2008-2010 results based on samples obtained from contracted pound net sets*

Figure 16.3 Mean length at age of blueback herring from the Chowan River pound net fishery, NC, 1972-2010.







**2007 results based on samples collected from the research set aside harvest, April 4-7*
***2008-2010 results based on samples obtained from contracted pound net sets*

Figure 16.4 Mean length at age of alewife from the Chowan River pound net fishery, NC, 1972-2010.

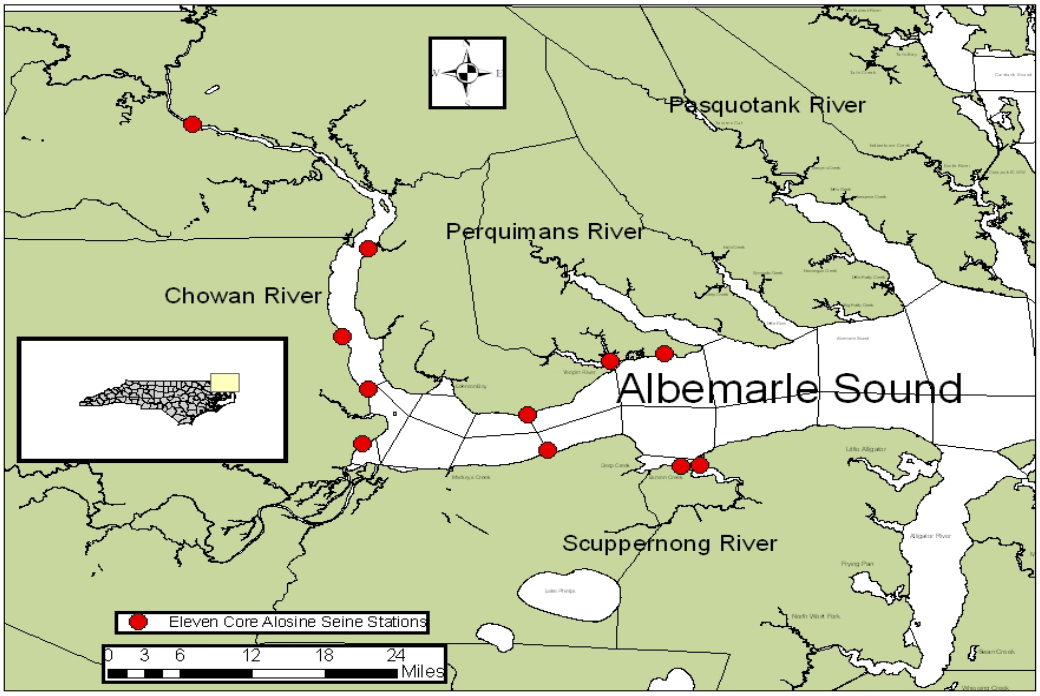


Figure 16.5 Alosine nursery area sampling sites in the Albemarle Sound area, NC 1972-2010.

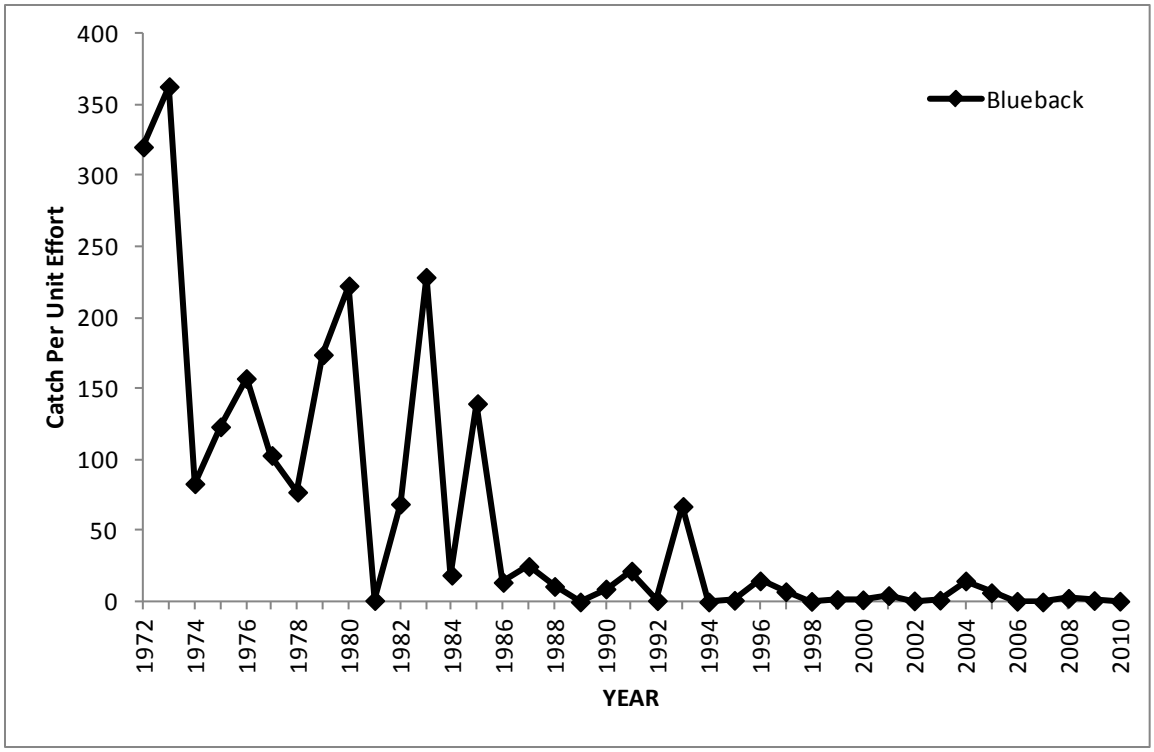


Figure 16.6 Juvenile blueback herring catch per unit effort from core seine stations, Albemarle Sound area, NC, 1972-2010.

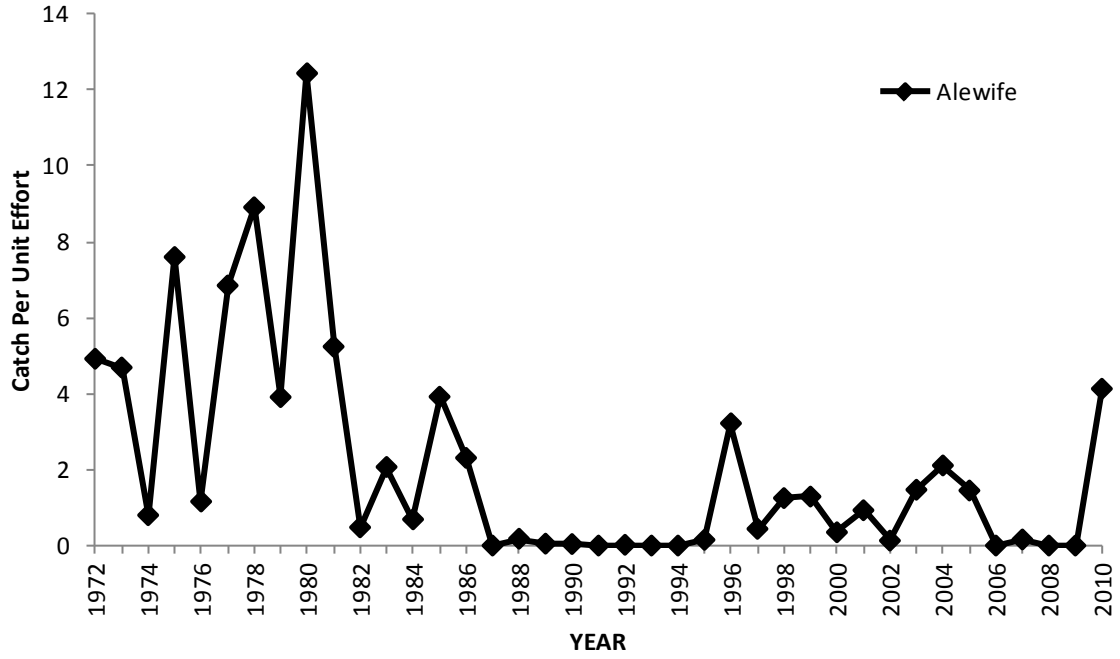


Figure 16.7 Juvenile alewife catch per unit effort from core seine stations, Albemarle Sound area, NC, 1972-2010.

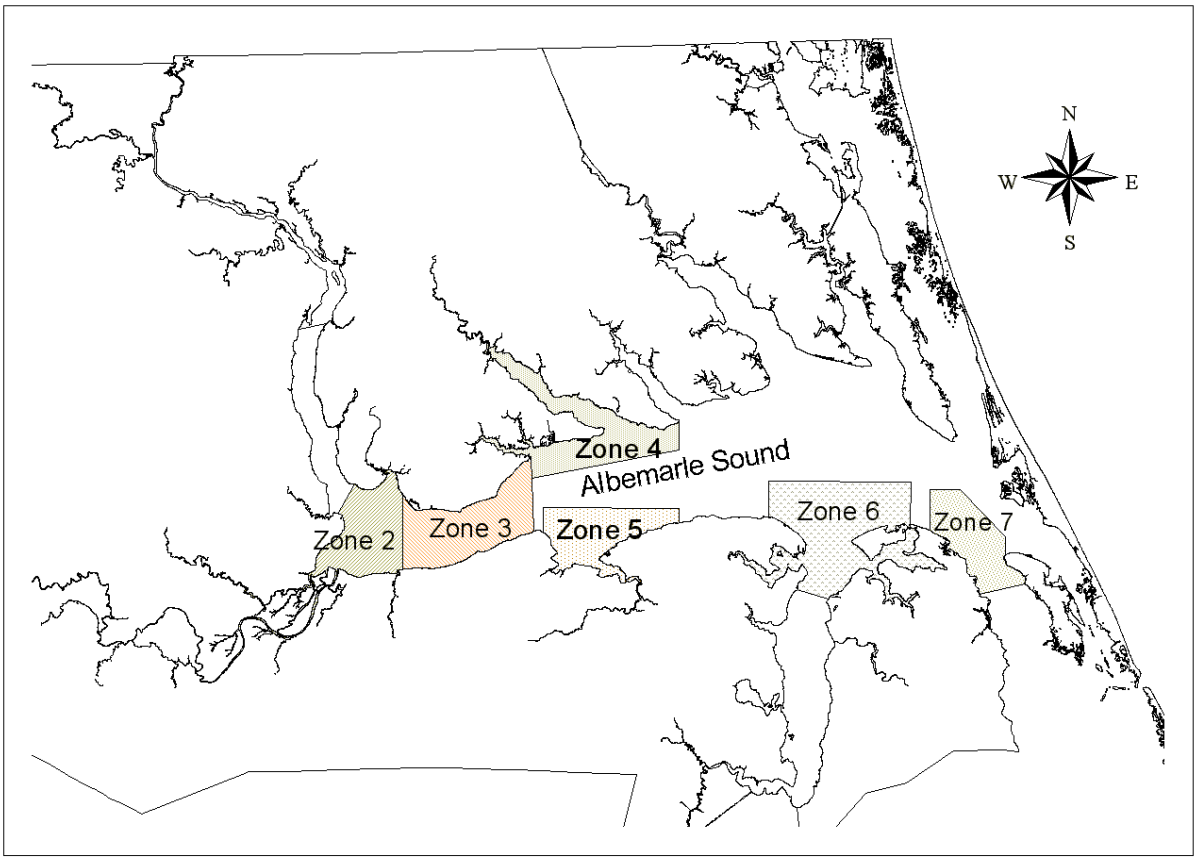


Figure 16.8 Location of sample zones for NCDMF independent gill net survey, Albemarle Sound area, 1990 – 2010.

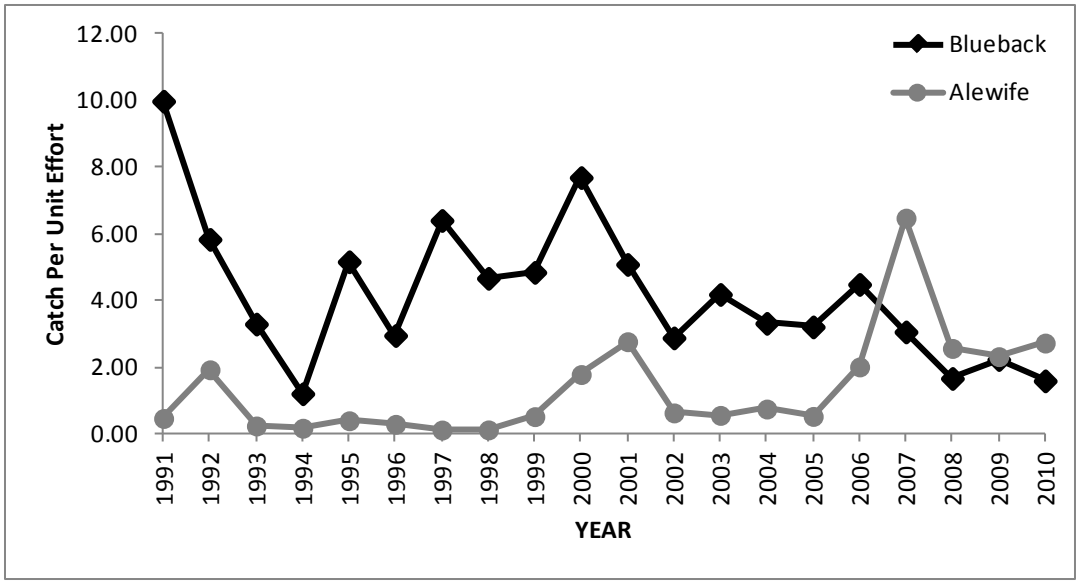


Figure 16.9 Catch per unit effort for alewife and blueback herring from the Albemarle Sound Independent Gill Net Survey, 2.5 and 3.0 ISM gill net, January-May, 1991-2010.

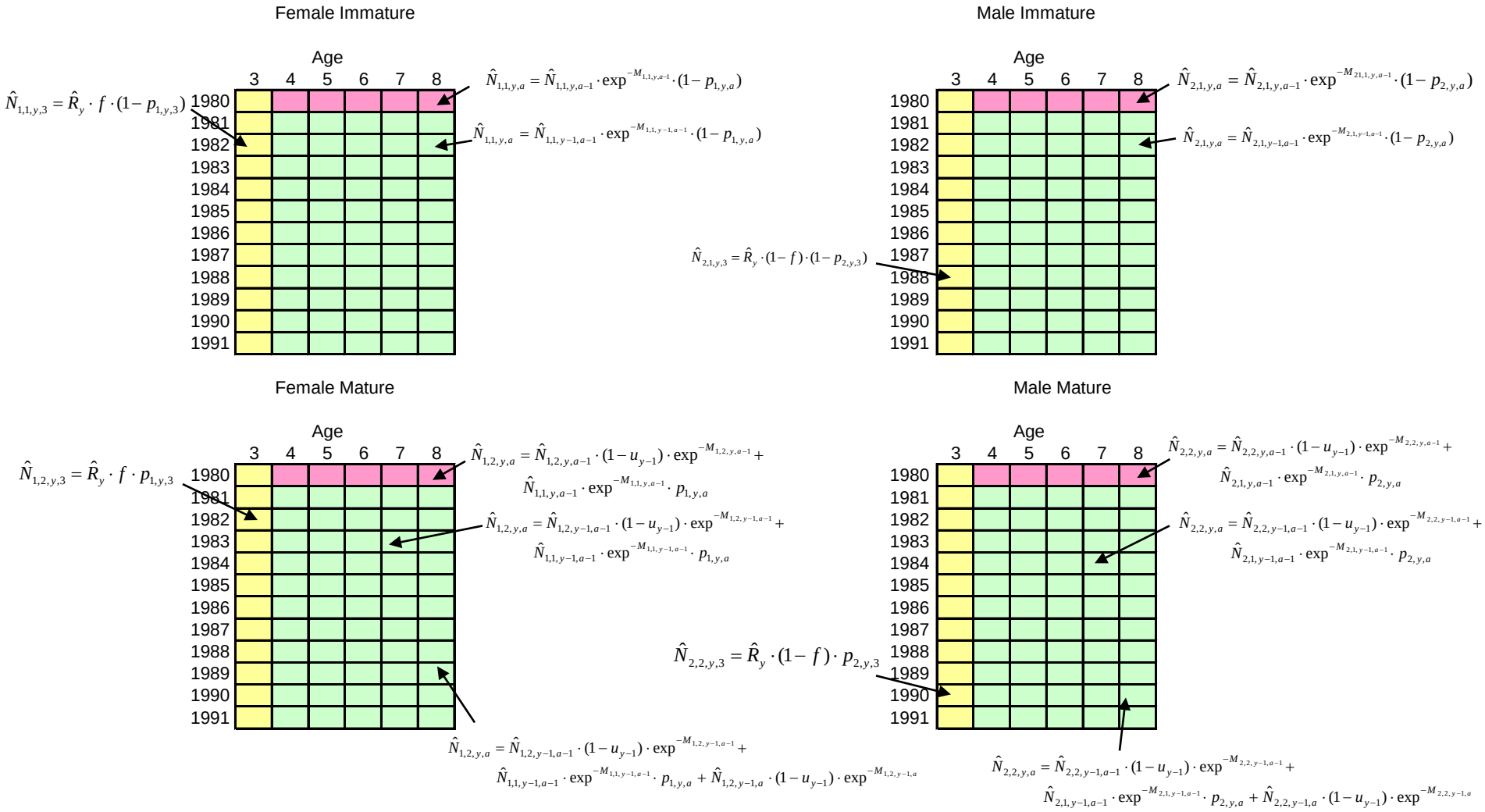


Figure 16.10 Diagram of blueback herring cohort population dynamics .

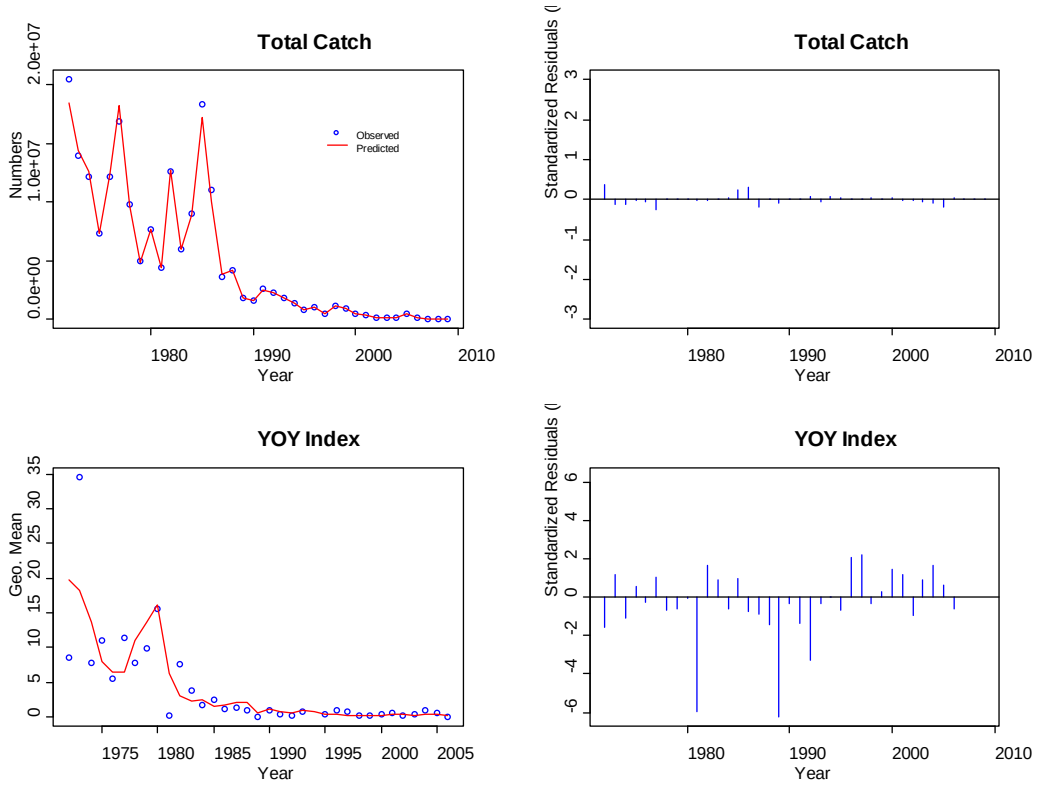


Figure 16.11 Comparison of total catch and YOY index observed and predicted values and standardized residuals for Chowan River blueback herring.

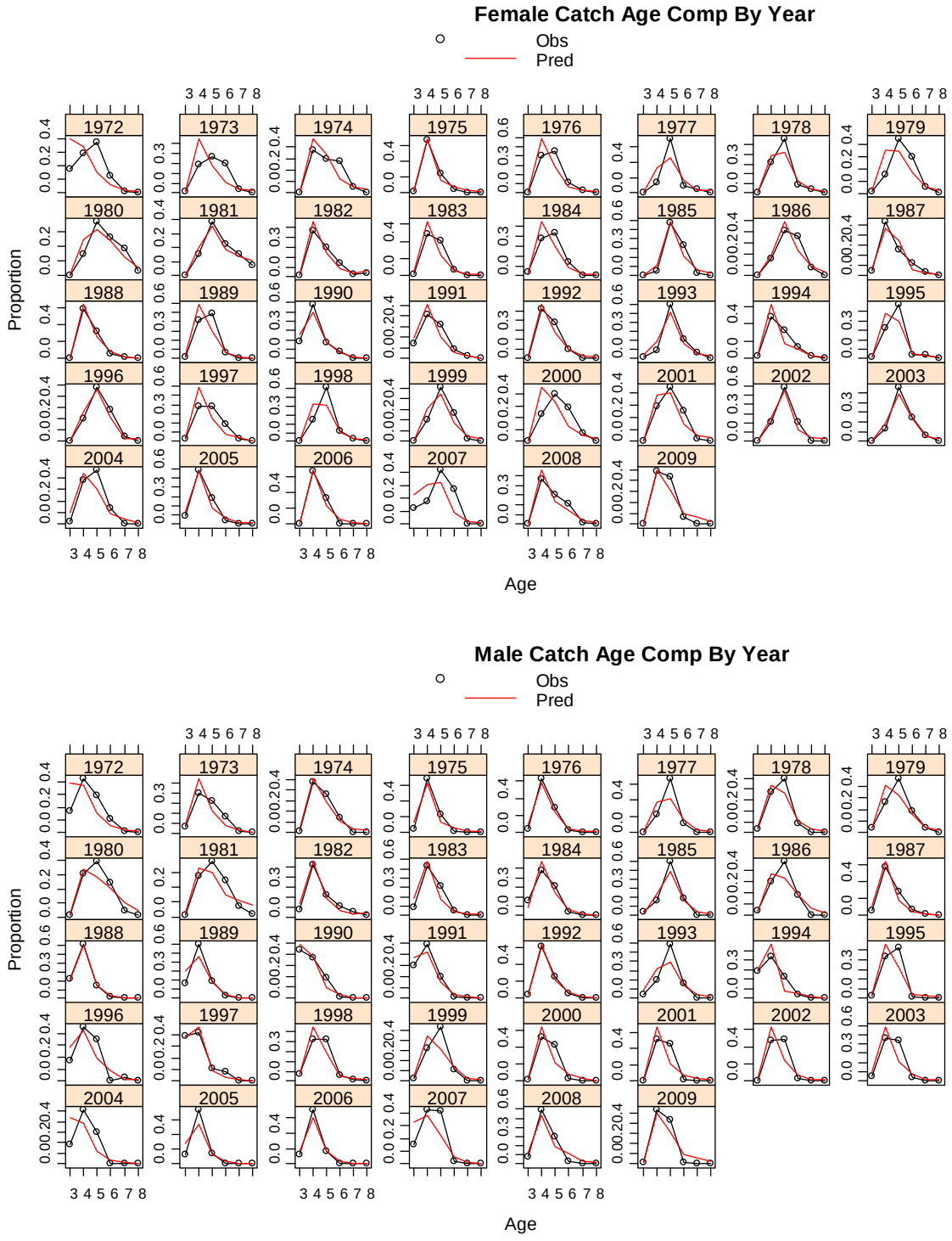


Figure 16.12 Observed and predicted catch age composition (proportions) for Chowan River blueback herring by sex, age, and year.

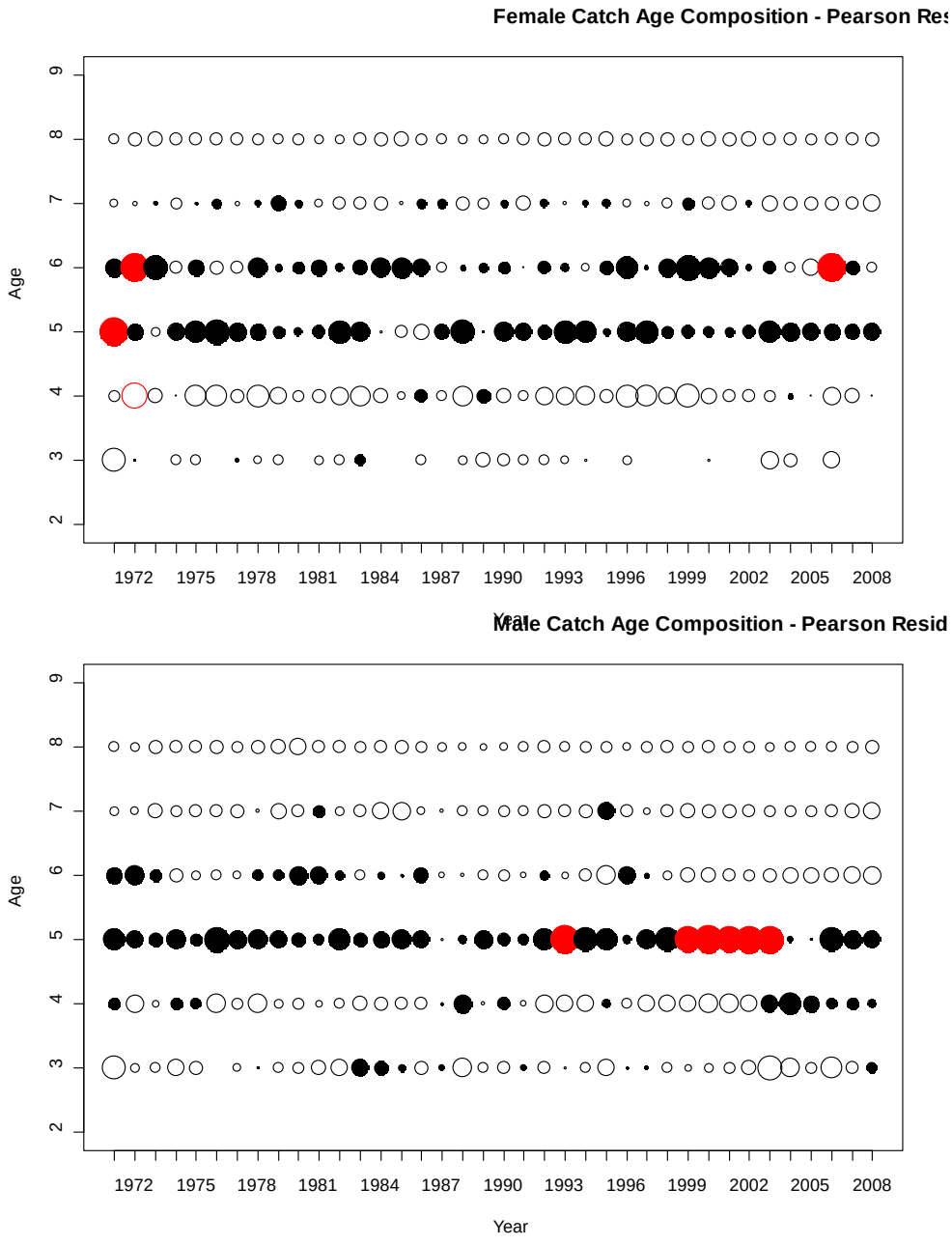


Figure 16.13 Bubble plots of standardized residuals of catch age composition by sex, year, age.

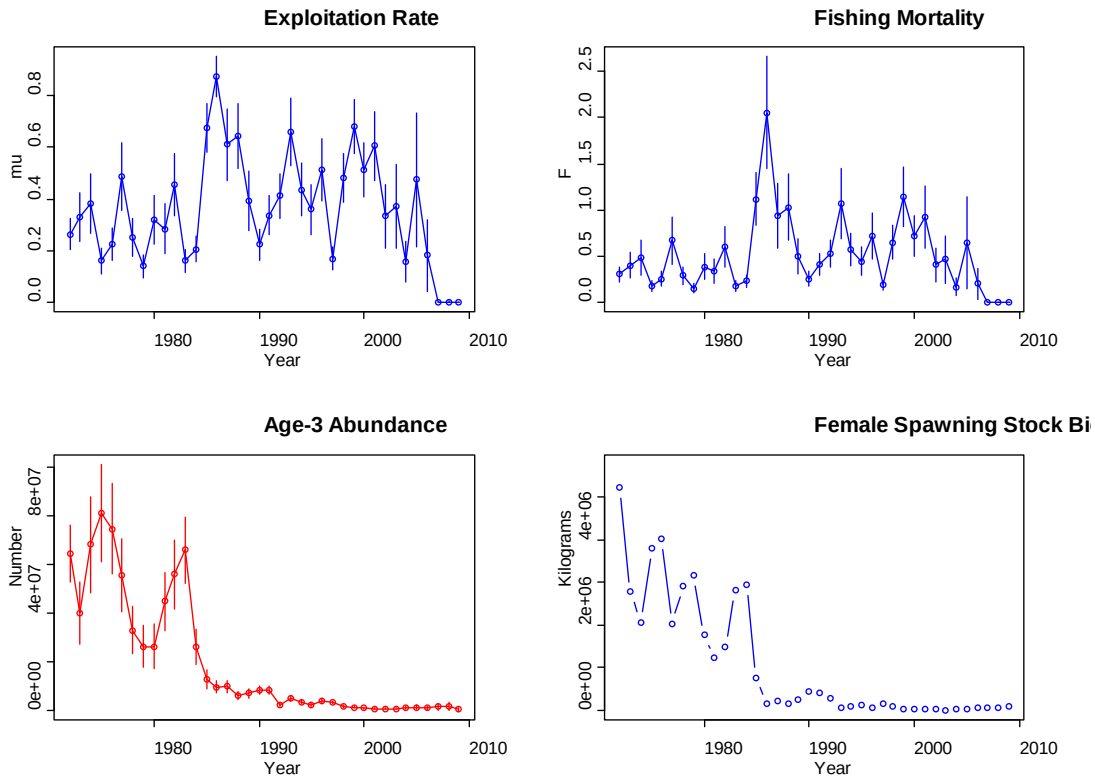


Figure 16.14 Estimates of exploitation rates, derived fishing mortality rates, recruitment (age-3 numbers), and estimates of female spawning stock biomass (in kilograms) for Chowan River blueback herring. Vertical lines, where present, represent 95% confidence intervals.

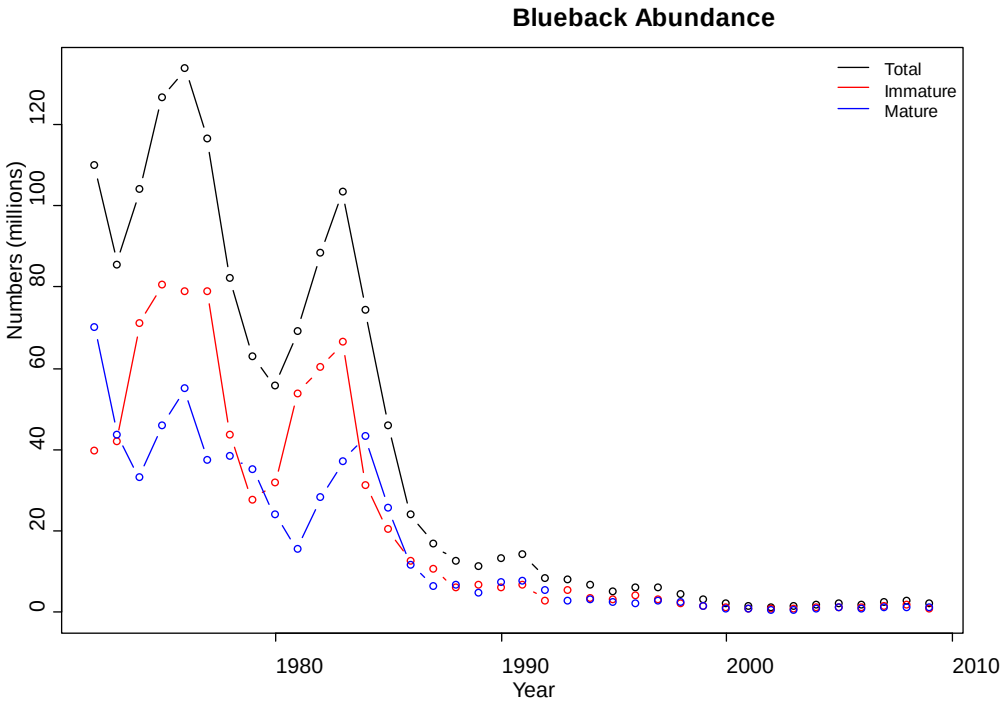


Figure 16.15 Population abundance (3+) estimates of the Chowan River blueback stock. Abundances are shown for immature and mature fish (sexes combined) and the total population.

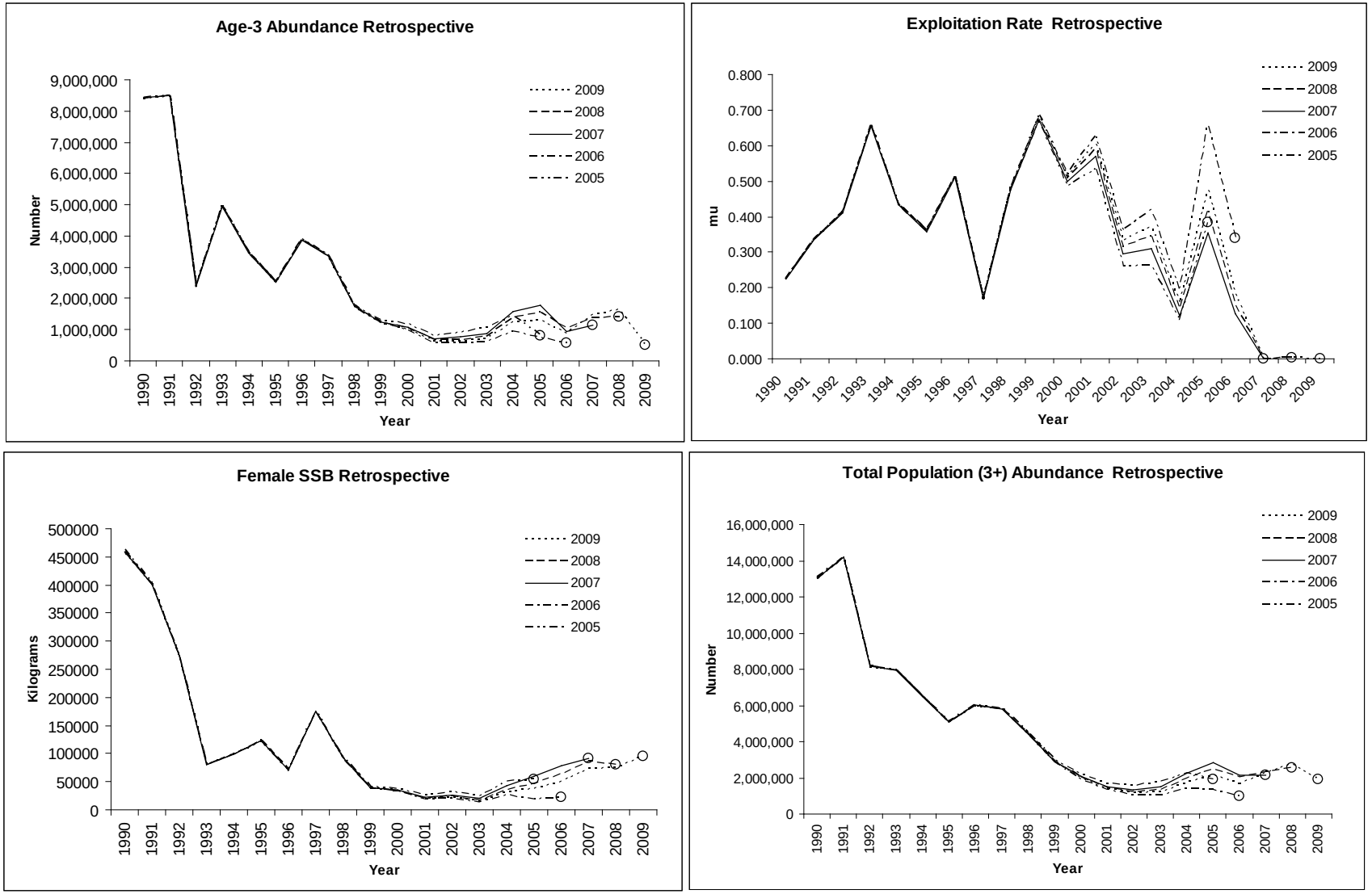


Figure 16.16 Retrospective analyses for age-3 abundance, exploitation rate, female spawning stock biomass, and total population abundance.

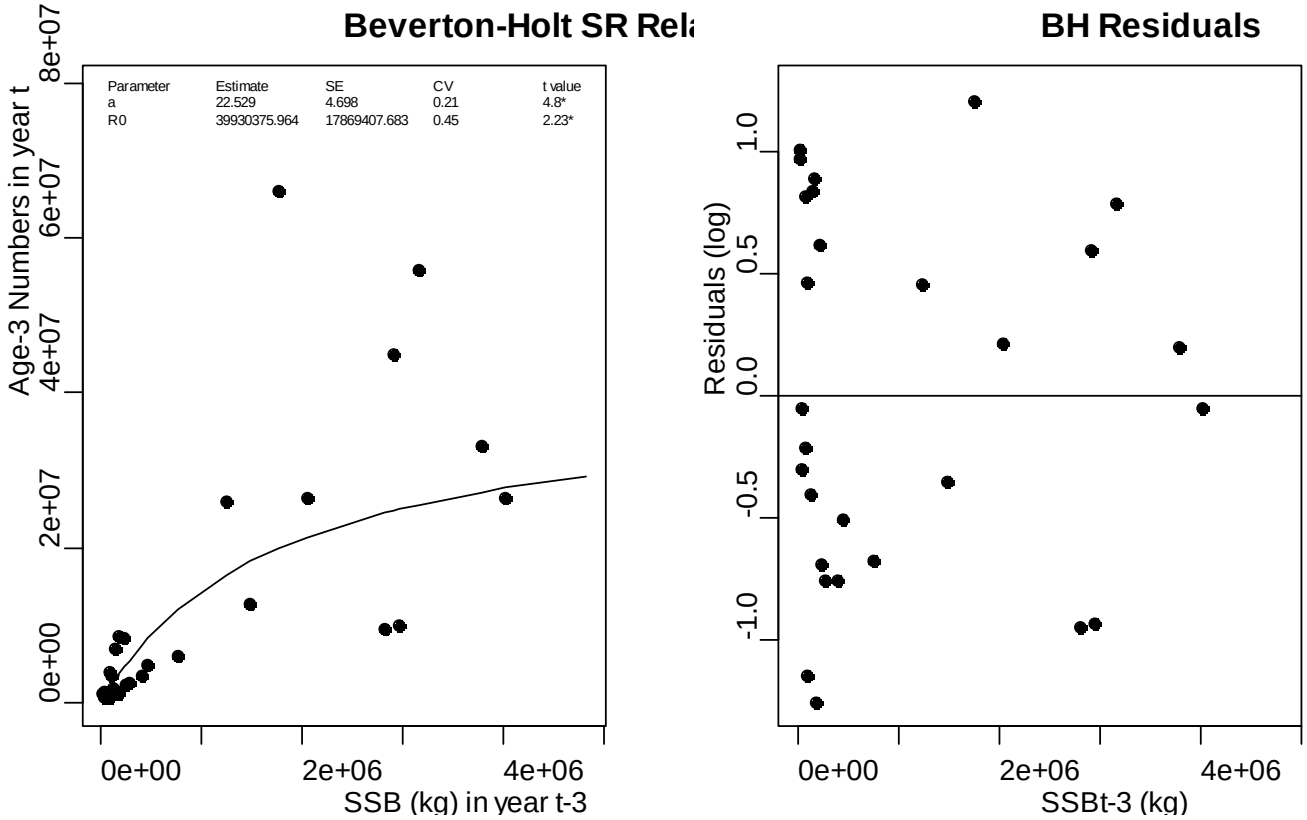


Figure 16.17 Fit of the Beverton-Holt stock-recruitment relationship to the age-3 abundance and female spawning stock biomass. Estimates of parameters a and R_0 from the Beverton-Holt equation are provided in the first graph, and residuals for the model fit are shown in the second graph.

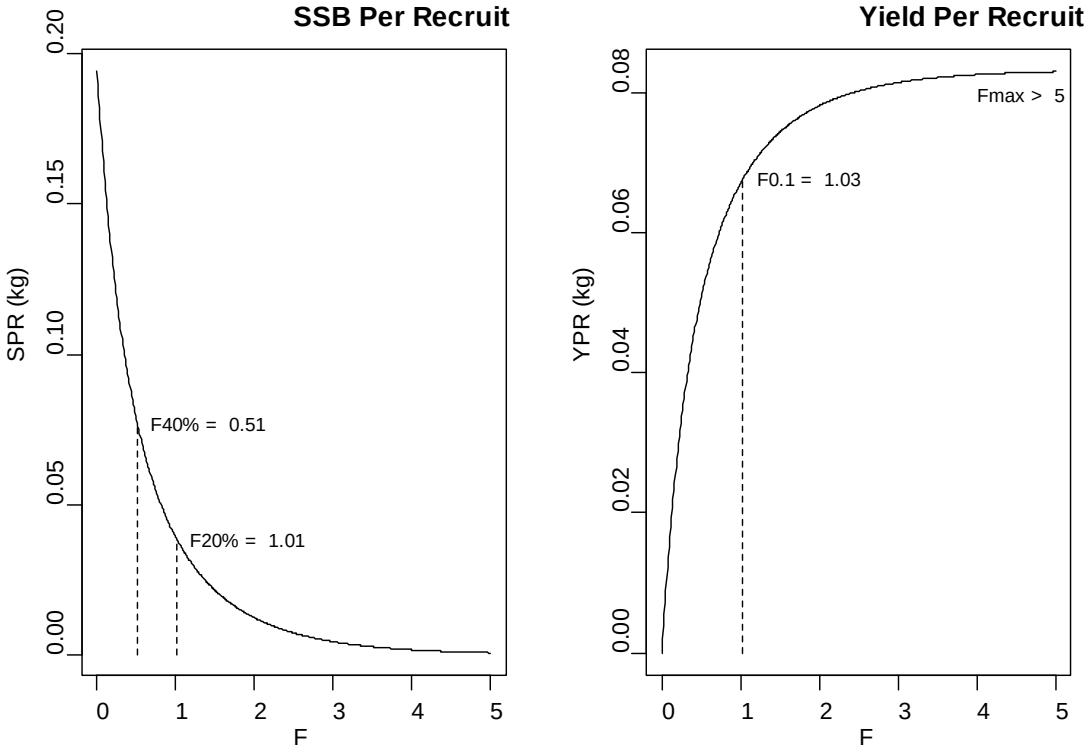


Figure 16.18 Results of spawning biomass per recruit and yield-per-recruit and analyses for the Chowan River blueback herring stock.

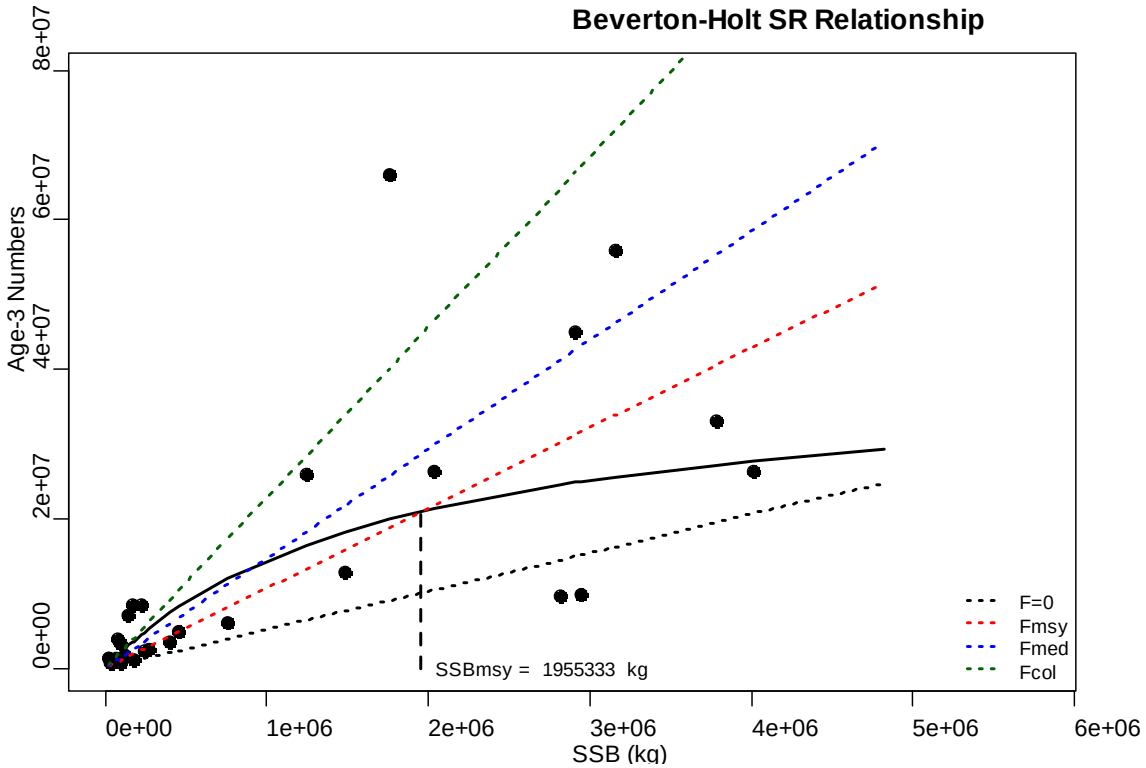


Figure 16.19 Beverton-Holt spawner-recruit model and production model reference points (see text) for the Chowan River blueback herring stock. Also shown is the replacement line in absence of fishing mortality (F=0).

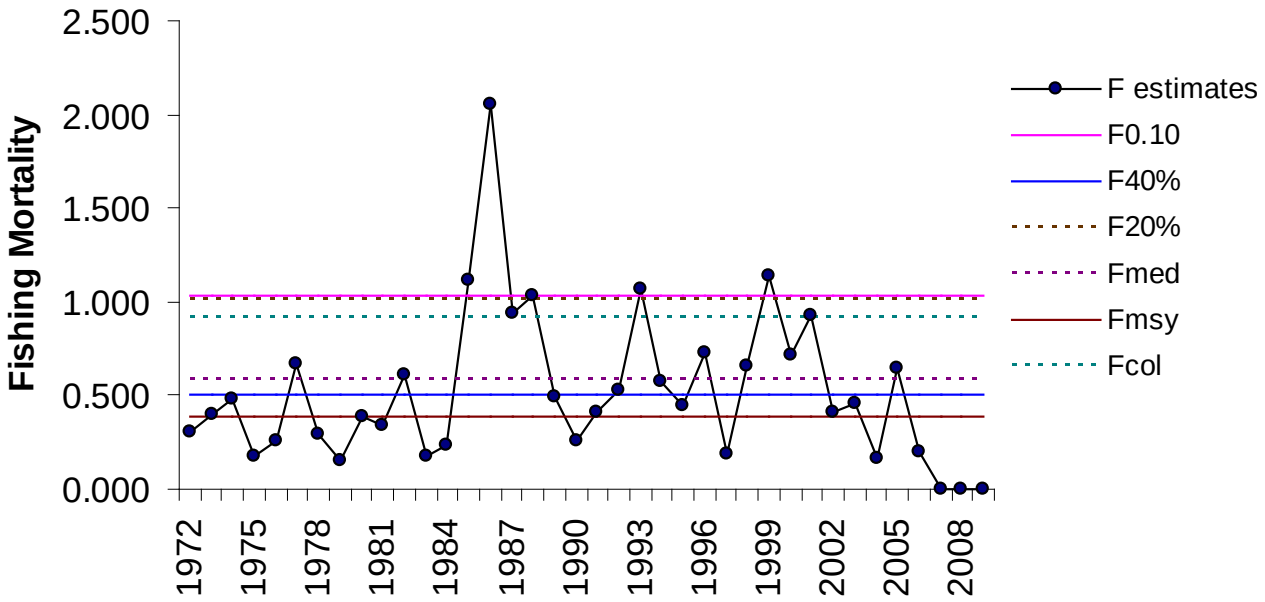


Figure 16.20 Comparison of fishing mortality rates to reference points.

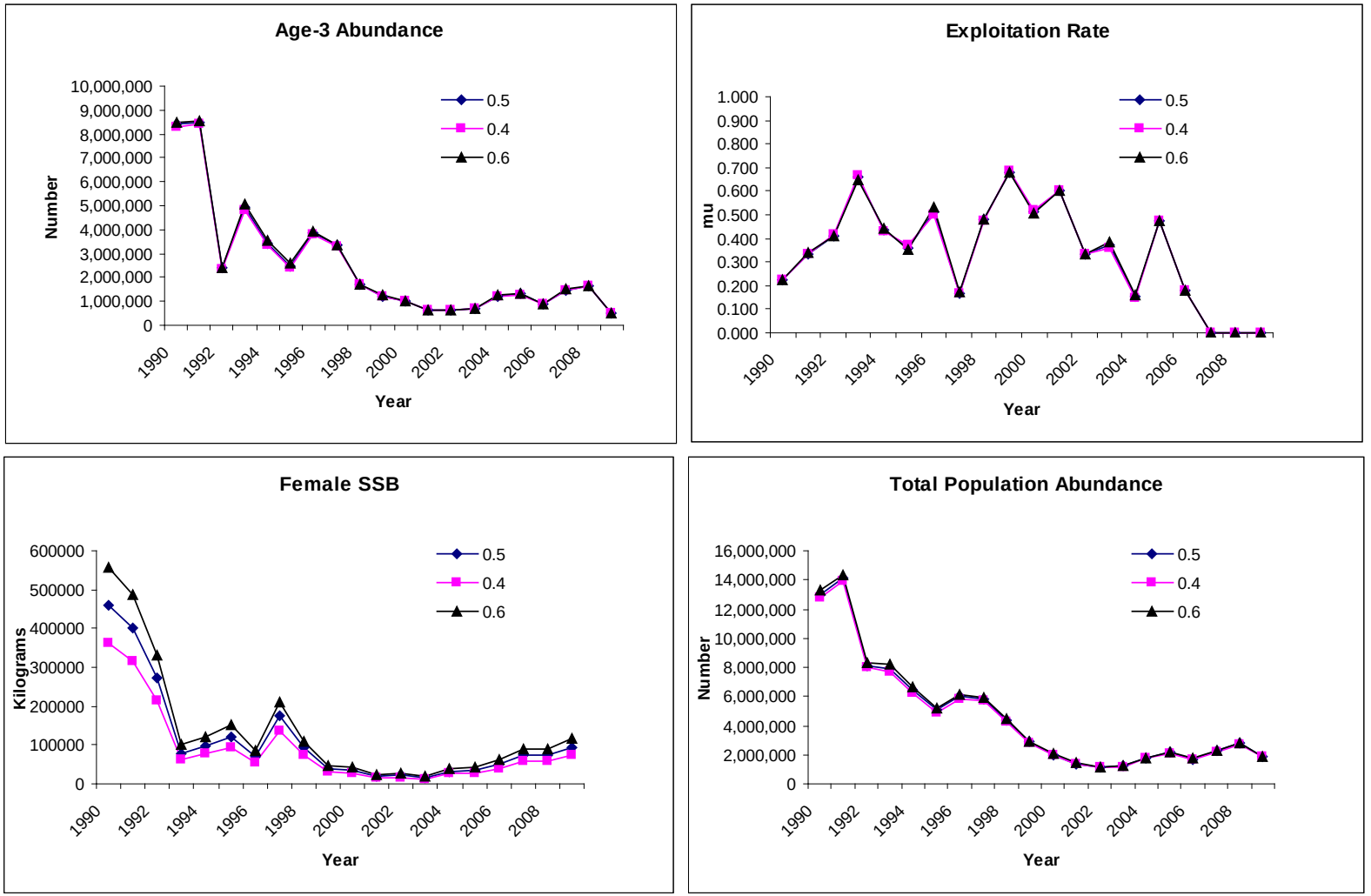


Figure 16.21 Results of sensitivity analysis of input female sex ratio. Base model ratio =0.5.

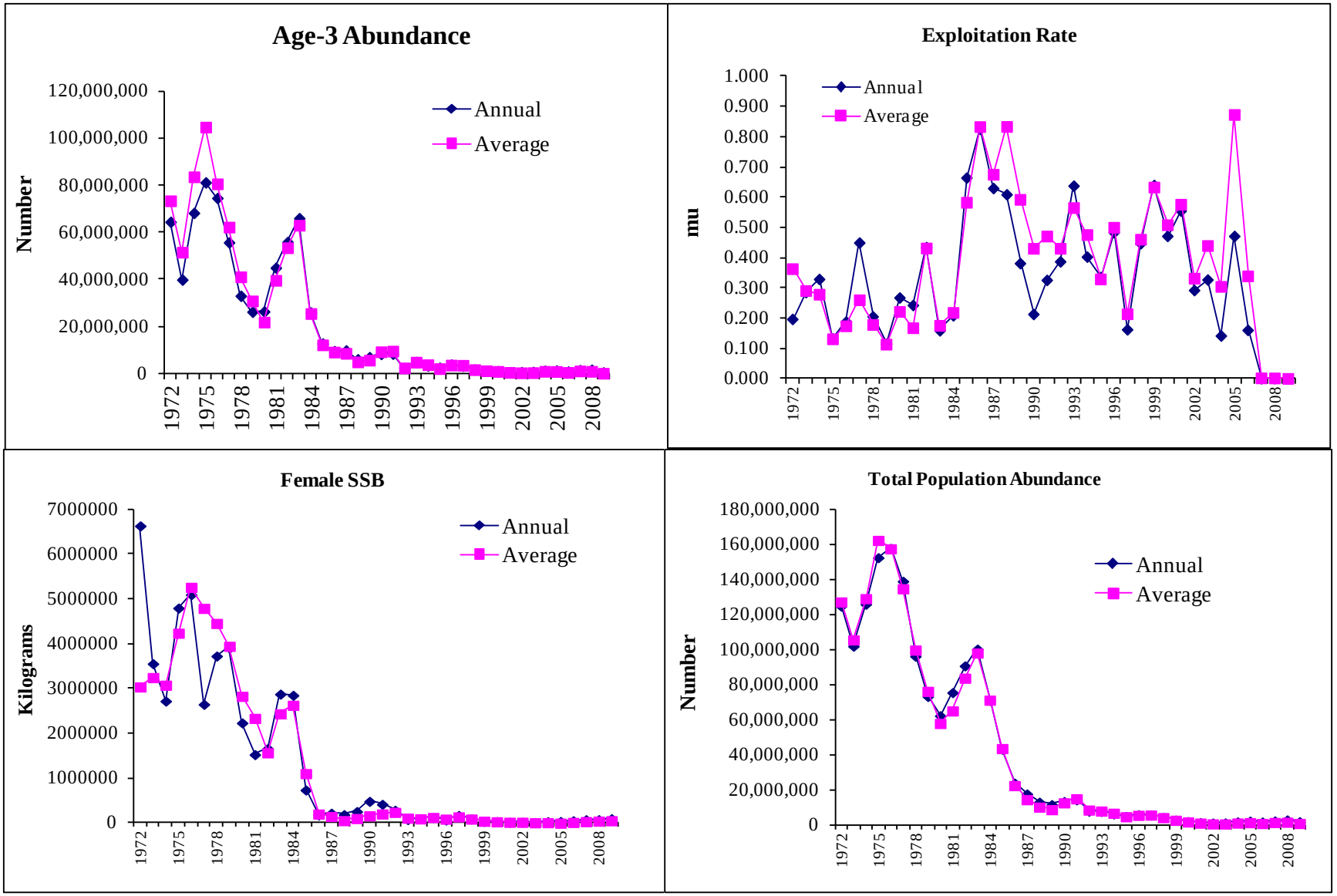


Figure 16.22 Results of sensitivity analysis of proportion mature-at age using annual estimates (base model) or time series averages.

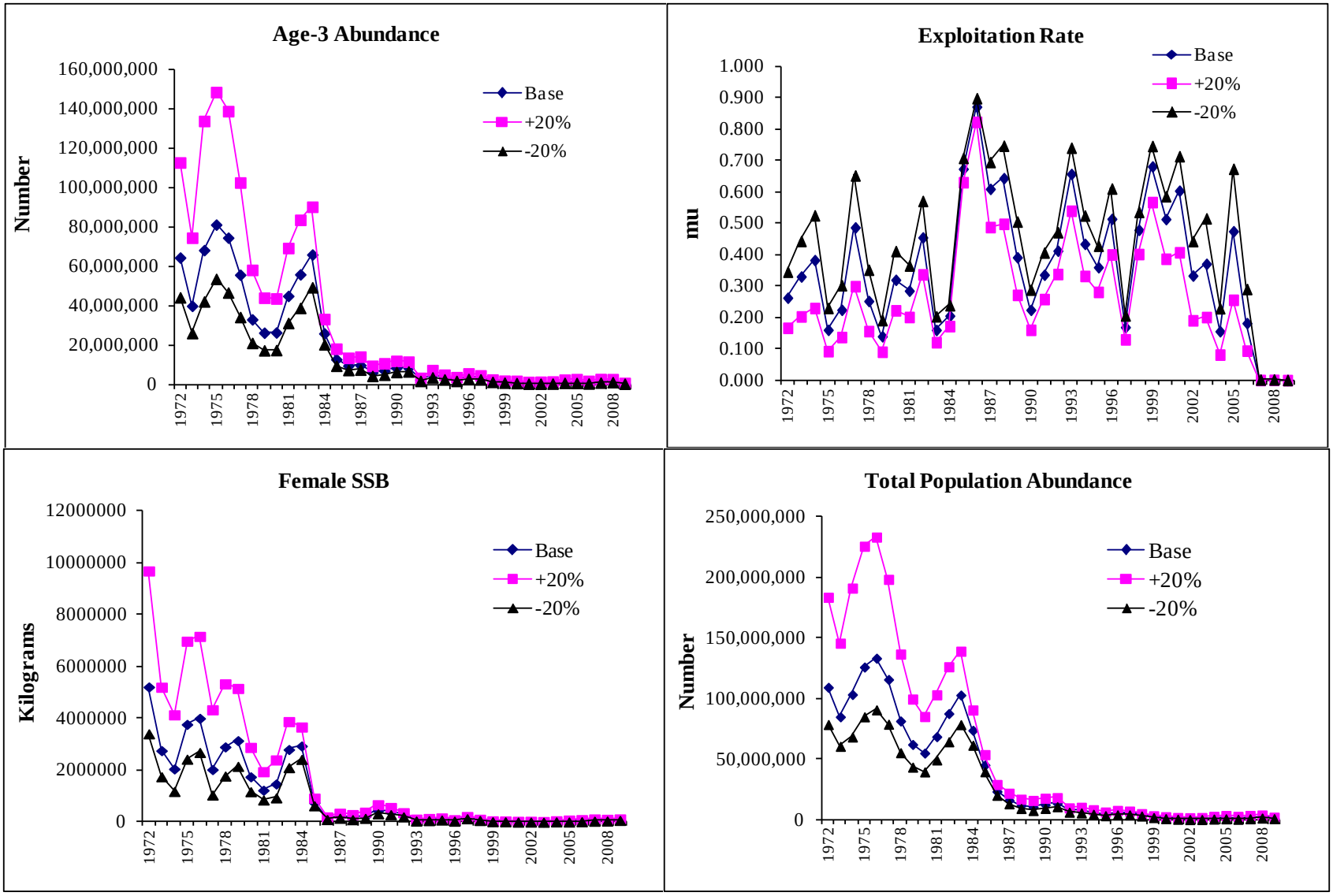


Figure 16.23 Results of sensitivity analysis of changing input sex- and age-specific natural mortality rates by ±20%.

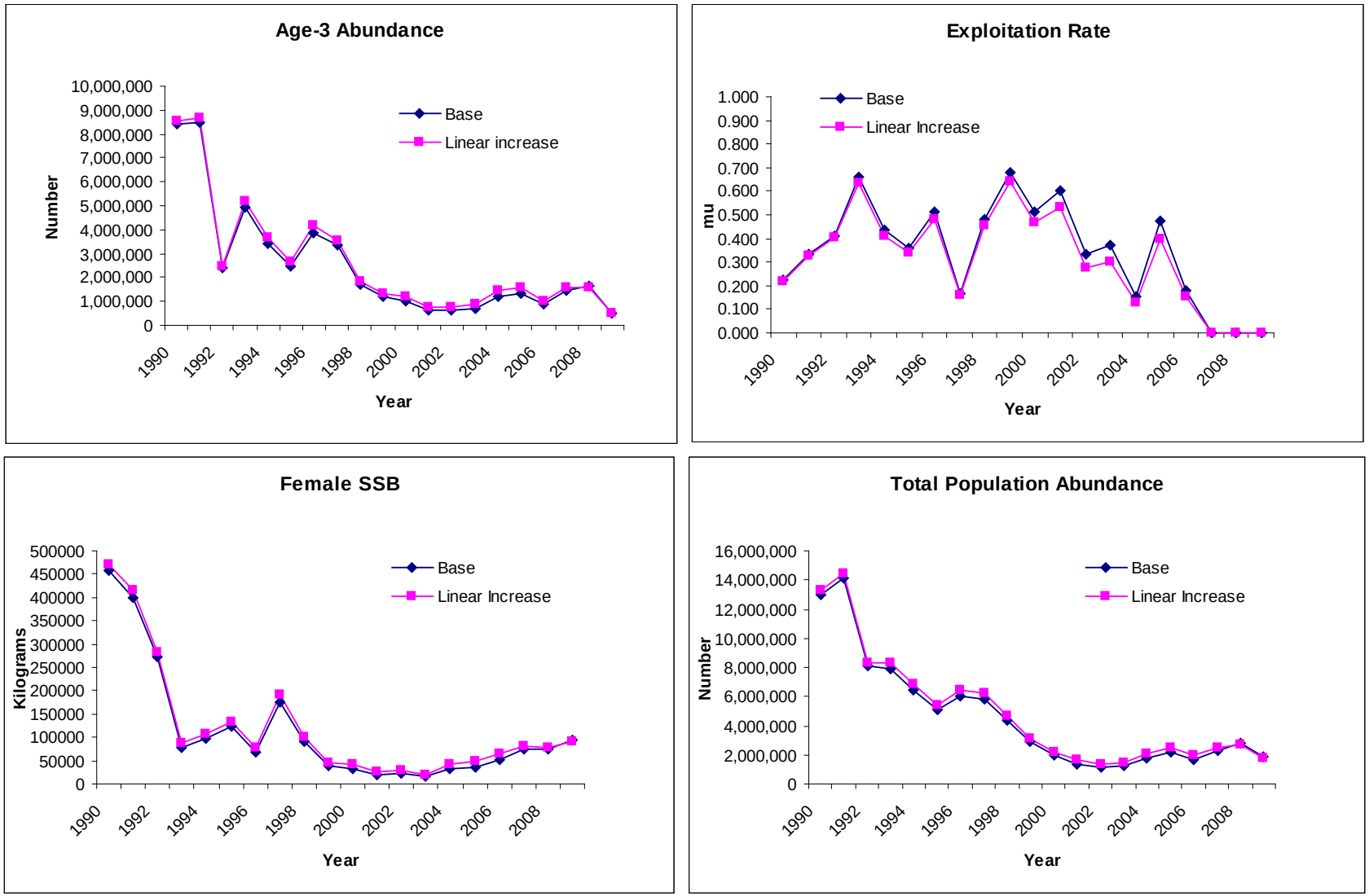


Figure 16.24 Results of sensitivity analysis of input sex- and age-specific natural mortality rates for mature fish (linear increase to 20% of base from 1990-2009).

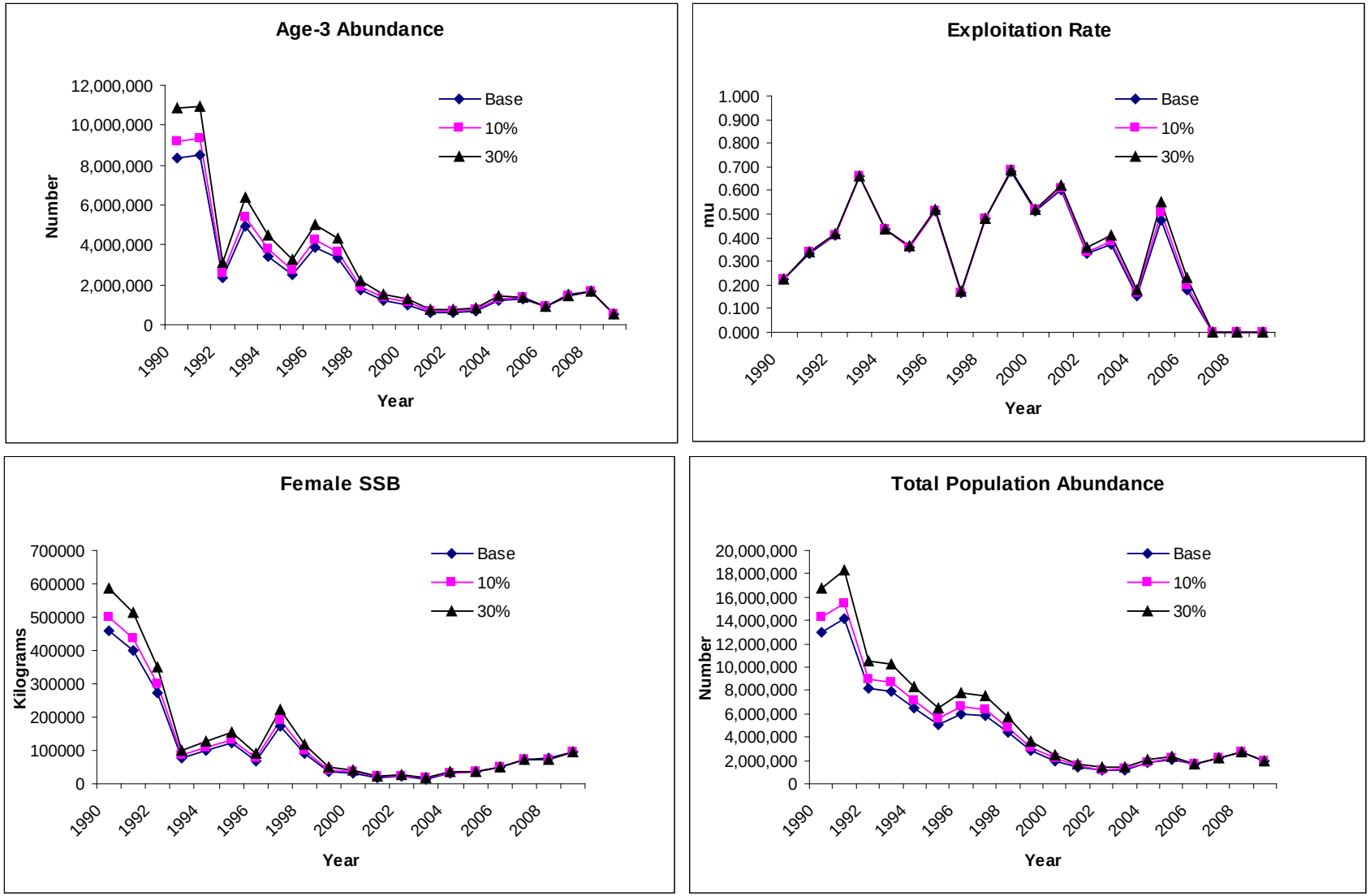


Figure 16.25 Results of sensitivity analysis of total catch. Total catch from 1990-2006 was increased by 10% and 30%.

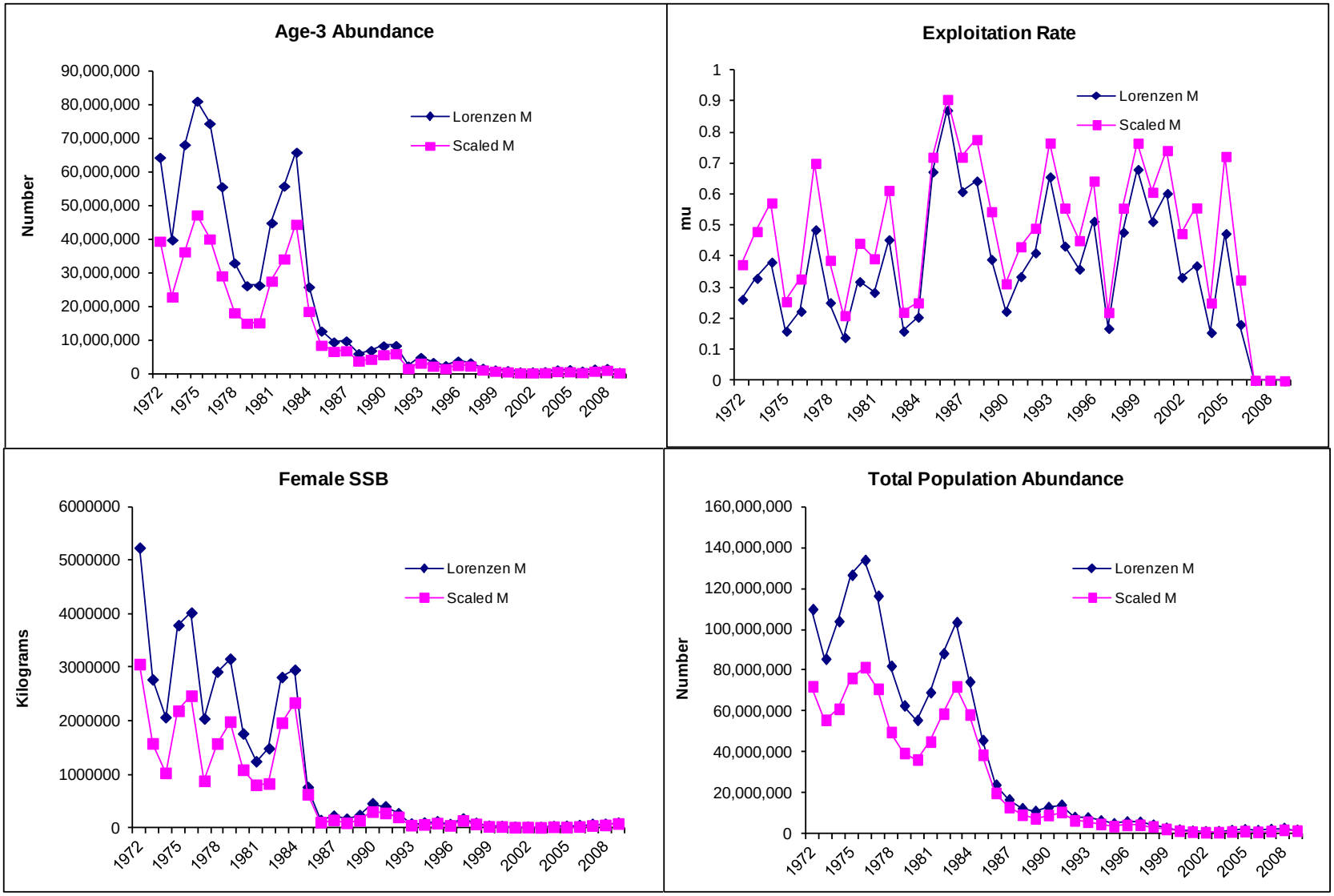


Figure 16.26 Comparison of Age-3, exploitation rates, spawning stock biomass, and total population estimates resulting from use of age-specific Lorenzen (1996) natural mortality estimates and Lorenzen (1996) values scaled to Hoenig (1983) estimate of natural mortality.

Appendix Table 16.1. Estimates of proportion mature-at-age for female and male blueback herring in the Chowan River by year.

Female

Year	3	4	5	6	7	8
1972	0.440	0.809	0.979	1.000	1.000	1.000
1973	0.012	0.654	0.963	1.000	1.000	1.000
1974	0.000	0.766	0.961	1.000	1.000	1.000
1975	0.022	0.925	1.000	1.000	1.000	1.000
1976	0.016	0.748	1.000	1.000	1.000	1.000
1977	0.000	0.321	0.993	1.000	1.000	1.000
1978	0.010	0.525	0.990	1.000	1.000	1.000
1979	0.046	0.762	0.992	1.000	1.000	1.000
1980	0.009	0.431	0.950	0.995	1.000	1.000
1981	0.000	0.226	0.865	1.000	1.000	1.000
1982	0.010	0.654	1.000	1.000	1.000	1.000
1983	0.020	0.765	1.000	1.000	1.000	1.000
1984	0.042	0.684	1.000	1.000	1.000	1.000
1985	0.000	0.205	1.000	1.000	1.000	1.000
1986	0.000	0.322	0.978	1.000	1.000	1.000
1987	0.049	0.654	0.988	1.000	1.000	1.000
1988	0.000	0.768	1.000	1.000	1.000	1.000
1989	0.023	0.814	1.000	1.000	1.000	1.000
1990	0.191	0.910	1.000	1.000	1.000	1.000
1991	0.160	0.860	1.000	1.000	1.000	1.000
1992	0.056	0.710	1.000	1.000	1.000	1.000
1993	0.024	0.452	0.976	1.000	1.000	1.000
1994	0.032	0.613	1.000	1.000	1.000	1.000
1995	0.020	0.653	1.000	1.000	1.000	1.000
1996	0.000	0.300	0.980	1.000	1.000	1.000
1997	0.026	0.658	0.987	1.000	1.000	1.000
1998	0.000	0.539	0.991	1.000	1.000	1.000
1999	0.000	0.506	0.996	1.000	1.000	1.000
2000	0.000	0.622	0.961	1.000	1.000	1.000
2001	0.004	0.407	0.996	1.000	1.000	1.000
2002	0.000	0.305	1.000	1.000	1.000	1.000
2003	0.000	0.177	0.990	1.000	1.000	1.000
2004	0.042	0.632	1.000	1.000	1.000	1.000
2005	0.101	0.881	1.000	1.000	1.000	1.000
2006	0.000	0.855	1.000	1.000	1.000	1.000
2007	0.127	0.582	1.000	1.000	1.000	1.000
2008	0.000	0.672	0.981	1.000	1.000	1.000
2009	0.000	0.724	1.000	1.000	1.000	1.000

Male

Year	3	4	5	6	7	8
1972	0.419	0.869	0.996	1.000	1.000	1.000
1973	0.109	0.861	1.000	1.000	1.000	1.000
1974	0.019	0.897	1.000	1.000	1.000	1.000
1975	0.079	0.868	1.000	1.000	1.000	1.000
1976	0.076	0.856	1.000	1.000	1.000	1.000
1977	0.000	0.354	1.000	1.000	1.000	1.000
1978	0.063	0.627	0.984	1.000	1.000	1.000
1979	0.063	0.893	1.000	1.000	1.000	1.000
1980	0.023	0.630	0.977	1.000	1.000	1.000
1981	0.009	0.411	0.963	1.000	1.000	1.000
1982	0.071	0.764	1.000	1.000	1.000	1.000
1983	0.113	0.887	1.000	1.000	1.000	1.000
1984	0.163	0.801	1.000	1.000	1.000	1.000
1985	0.039	0.457	1.000	1.000	1.000	1.000
1986	0.046	0.713	0.991	1.000	1.000	1.000
1987	0.070	0.876	1.000	1.000	1.000	1.000
1988	0.245	0.945	1.000	1.000	1.000	1.000
1989	0.222	0.940	1.000	1.000	1.000	1.000
1990	0.464	0.982	1.000	1.000	1.000	1.000
1991	0.360	0.928	0.993	1.000	1.000	1.000
1992	0.097	0.968	0.995	1.000	1.000	1.000
1993	0.047	0.756	1.000	1.000	1.000	1.000
1994	0.327	0.923	1.000	1.000	1.000	1.000
1995	0.039	0.789	1.000	1.000	1.000	1.000
1996	0.190	0.914	1.000	1.000	1.000	1.000
1997	0.389	0.917	1.000	1.000	1.000	1.000
1998	0.104	0.797	0.990	1.000	1.000	1.000
1999	0.058	0.764	1.000	1.000	1.000	1.000
2000	0.023	0.957	1.000	1.000	1.000	1.000
2001	0.021	0.904	1.000	1.000	1.000	1.000
2002	0.022	0.934	1.000	1.000	1.000	1.000
2003	0.075	0.936	1.000	1.000	1.000	1.000
2004	0.299	0.965	1.000	1.000	1.000	1.000
2005	0.220	0.984	1.000	1.000	1.000	1.000
2006	0.170	0.936	1.000	1.000	1.000	1.000
2007	0.234	0.964	1.000	1.000	1.000	1.000
2008	0.081	0.719	0.990	1.000	1.000	1.000
2009	0.027	0.680	1.000	1.000	1.000	1.000

Appendix Table 16.2. Estimates of total catch (in numbers) of pound nets for blueback herring in the Chowan River used in the base model run.

Year	Numbers
1972	20,443,867
1973	13,918,880
1974	12,141,597
1975	7,286,423
1976	12,121,822
1977	16,831,692
1978	9,762,107
1979	4,921,229
1980	7,617,940
1981	4,360,204
1982	12,658,422
1983	5,955,402
1984	9,023,870
1985	18,364,344
1986	10,997,451
1987	3,664,782
1988	4,162,095
1989	1,772,115
1990	1,612,157
1991	2,545,614
1992	2,281,605
1993	1,763,114
1994	1,380,804
1995	814,048
1996	1,043,026
1997	468,830
1998	1,105,760
1999	948,791
2000	436,067
2001	363,260
2002	133,659
2003	143,201
2004	102,534
2005	447,376
2006	153,862
2007	1,325
2008	1,808
2009	763

Appendix Table 16.3. Number of Chowan River blueback samples from pound nets aged by sex, year, and age.

Female

Year	3	4	5	6	7	8
1972	25	42	54	18	2	0
1973	1	23	30	24	3	0
1974	0	29	23	21	4	0
1975	2	63	23	4	1	0
1976	1	49	55	14	4	0
1977	0	20	98	14	7	1
1978	1	31	55	8	4	0
1979	3	21	58	39	8	1
1980	0	32	80	57	41	8
1981	0	50	122	73	50	23
1982	1	49	31	15	3	4
1983	2	50	42	7	0	1
1984	4	36	42	13	0	0
1985	0	5	48	28	2	0
1986	0	14	37	32	7	0
1987	4	43	21	10	3	0
1988	0	48	27	5	2	0
1989	1	18	21	3	0	0
1990	16	51	15	7	0	0
1991	14	42	32	9	3	0
1992	1	55	41	10	0	0
1993	1	4	25	9	3	0
1994	1	15	10	4	1	0
1995	1	16	28	2	2	0
1996	0	10	24	14	2	0
1997	2	29	29	14	2	0
1998	0	131	321	60	17	0
1999	0	50	125	67	7	0
2000	0	58	102	74	19	1
2001	1	72	111	64	5	0
2002	0	29	82	29	1	0
2003	0	13	53	24	6	0
2004	2	36	44	13	0	0
2005	15	98	47	8	0	0
2006	0	37	18	0	0	0
2007	7	10	23	15	0	0
2008	0	148	98	66	5	0
2009	0	105	93	15	1	0

Male

Year	3	4	5	6	7	8
1972	46	112	78	28	3	0
1973	16	93	76	38	5	2
1974	3	74	55	22	1	0
1975	6	77	27	3	1	0
1976	12	147	69	7	1	0
1977	0	39	115	20	1	0
1978	5	47	62	11	1	0
1979	12	66	116	48	11	0
1980	2	66	85	53	9	2
1981	3	97	131	87	25	7
1982	10	74	31	16	7	2
1983	19	108	65	11	1	0
1984	23	68	44	6	0	0
1985	5	22	76	24	0	0
1986	5	32	51	20	0	0
1987	8	73	36	10	2	0
1988	36	99	23	4	1	0
1989	20	70	23	4	0	0
1990	48	41	20	2	0	0
1991	42	68	27	2	0	0
1992	9	116	49	12	1	0
1993	4	17	50	14	1	0
1994	15	23	12	2	0	0
1995	2	33	40	1	0	0
1996	10	26	20	0	2	0
1997	14	15	4	3	0	0
1998	30	163	163	23	6	0
1999	9	101	167	35	1	0
2000	15	383	316	24	1	0
2001	3	170	155	7	0	0
2002	2	86	87	6	0	0
2003	9	80	76	8	0	0
2004	27	73	43	1	0	0
2005	16	89	18	0	0	0
2006	12	66	16	0	0	0
2007	25	70	69	3	0	0
2008	49	358	181	20	0	0
2009	7	174	142	5	0	0

Appendix Table 16.4. Young-of-the-year blueback herring seine index by year. -1 = not used. The 1994 value was not used because the model could not reconcile zero YOY fish.

Year	Geo Mean
1972	8.63
1973	34.52
1974	7.70
1975	11.08
1976	5.52
1977	11.32
1978	7.76
1979	9.90
1980	15.57
1981	0.25
1982	7.58
1983	3.80
1984	1.75
1985	2.47
1986	1.16
1987	1.25
1988	0.95
1989	0.02
1990	0.99
1991	0.40
1992	0.10
1993	0.79
1994	-1.00
1995	0.29
1996	0.90
1997	0.81
1998	0.13
1999	0.18
2000	0.38
2001	0.58
2002	0.19
2003	0.36
2004	0.90
2005	0.56
2006	0.09
2007	0.06
2008	0.17
2009	0.10

Appendix Table 16.5. Female weights-at-age (kg). Color indicates that values were estimated from observed values from other years.

Year	3	4	5	6	7	8
1972	0.19	0.20	0.21	0.22	0.21	0.29
1973	0.15	0.19	0.21	0.24	0.27	0.29
1974	0.15	0.19	0.21	0.24	0.27	0.29
1975	0.15	0.19	0.21	0.24	0.27	0.29
1976	0.15	0.19	0.21	0.24	0.27	0.29
1977	0.15	0.19	0.21	0.24	0.27	0.29
1978	0.15	0.19	0.21	0.24	0.27	0.29
1979	0.15	0.19	0.21	0.24	0.27	0.29
1980	0.15	0.19	0.21	0.24	0.27	0.29
1981	0.15	0.20	0.23	0.26	0.26	0.29
1982	0.13	0.19	0.22	0.24	0.27	0.27
1983	0.14	0.18	0.22	0.26	0.27	0.32
1984	0.13	0.17	0.19	0.22	0.27	0.29
1985	0.13	0.17	0.18	0.21	0.23	0.29
1986	0.13	0.16	0.20	0.22	0.24	0.29
1987	0.13	0.16	0.19	0.21	0.25	0.29
1988	0.13	0.15	0.18	0.22	0.22	0.29
1989	0.14	0.17	0.21	0.24	0.27	0.29
1990	0.16	0.19	0.18	0.25	0.25	0.29
1991	0.13	0.16	0.22	0.24	0.33	0.29
1992	0.14	0.16	0.19	0.21	0.27	0.29
1993	0.10	0.15	0.17	0.17	0.22	0.29
1994	0.12	0.13	0.14	0.24	0.18	0.29
1995	0.12	0.15	0.16	0.20	0.30	0.29
1996	0.13	0.19	0.19	0.22	0.24	0.29
1997	0.11	0.16	0.25	0.25	0.33	0.29
1998	0.12	0.15	0.16	0.19	0.24	0.29
1999	0.13	0.16	0.18	0.17	0.20	0.29
2000	0.13	0.15	0.18	0.18	0.22	0.29
2001	0.12	0.16	0.19	0.23	0.27	0.29
2002	0.13	0.16	0.19	0.22	0.22	0.29
2003	0.13	0.12	0.17	0.19	0.18	0.29
2004	0.12	0.14	0.15	0.19	0.24	0.29
2005	0.12	0.14	0.17	0.19	0.24	0.29
2006	0.13	0.15	0.16	0.20	0.24	0.29
2007	0.14	0.18	0.19	0.22	0.24	0.29
2008	0.13	0.14	0.16	0.20	0.24	0.29
2009	0.13	0.14	0.16	0.20	0.24	0.29

15.4 1997 DOT ANADROMOUS FISH STREAM CROSSING GUIDELINES

Anadromous Fish are a valuable resource and their migration must not be adversely impacted. The purpose of this document is to provide guidance to the North Carolina Department of Transportation to ensure that replacement of existing and new highway stream crossing structures will not impede the movement of anadromous fish.

Applicable when:

- Project is in the coastal plain defined by the “fall line” as the approximate western limit.
- For perennial and intermittent streams delineated on most recent USGS 7.5 minure quadrangle maps.

General guidelines:

- Design and scheduling of projects should avoid the necessity of instream activities during the spawning migration period. For the purpose of these guidelines, “Spring” is considered to fall between February 15 and June 15. (In areas where the shortnose sturgeon may be present, the Cape Fear, Brunswick and Waccamaw rivers, spring shall be defined as February 1 to June 15).
- Bridges and other channel spanning structures are preferred where practical.

Technical guidelines:

- In all cases, the width, height, and gradient of the proposed opening shall be such as to pass the average historical spring flow without adversely altering flow velocity. Spring flow should be determined from gauge data if available. In the absence of the data, bankfull flow can be used as a comparative level. (Reference, “Fisheries Handbook of Engineering Requirements and Biological Criteria”, Bell 1973, for fish swimming limitations.
- The invert of culverts shall be set at least as foot below the natural stream bed.
- Crossings of perennial streams serving watersheds greater than one square mile shall provide a minimum of four (4) feet of additional opening width (measured at spring flow elevation) to allow for terrestrial wildlife passage.
- In stream footings for bridges will be set one foot below the natural stream bed when practical.

For crossing sites which require permit review, the following information will be provided as a minimum to facilitate resource agency review.

- Plan and profile views showing the existing and proposed crossing structures in relation to the stream bank and bed.
- Average historical spring flow (or bankfull flow) for the site.
- How the proposed structure will affect the velocity and stage of the spring flow (bankfull).
- Justification for a variance from the guideline recommendations.