North Carolina American Shad Sustainable Fishery Plan

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EXECUTIVE SUMMARY

In accordance with the guidelines provided in Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring, North Carolina submits the following American Shad Sustainable Fishery Plan (SFP) for consideration by the Shad and River Herring Management Board (Board) to continue commercial and recreational fisheries in North Carolina. North Carolina's first Sustainable Fishery Plan for American Shad was approved by the Board in May 2012 for 2013 through 2017. The purpose of this plan is to update and modify sustainable management measures for 2018 through 2022 that will allow for maintenance and rebuilding of American Shad populations in North Carolina. The proposed plan includes the same sustainability parameters of relative fishing mortality (relative *F*) and abundance indices, but relative *F* will now be computed by dividing commercial landings by a hind cast 3-year average of a survey index whereas the previous plan used a centered 3-year average. Indices of relative abundance and estimates of relative *F* were calculated for each system using data from the previous plan, updated through 2017. Proposed thresholds (75^{th} and 25^{th} percentiles) for sustainability parameters have now been set using available survey data through 2017 and will remain fixed during the next 5-year management period. North Carolina requests recreational and commercial fisheries in all coastal rivers, and will use the management measures to ensure sustainability of these fisheries.

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1 INTRODUCTION

American Shad (*Alosa sapidissima*) are currently managed under Amendment 3 to the Atlantic States Marine Fisheries Commission (ASMFC) Interstate Fishery Management Plan for Shad and River Herring. The Amendment contains coastwide information on biology, stock status and management of American Shad and can be found on the ASMFC website at www.asmfc.org. Amendment 3 required states and jurisdictions to develop sustainable fishery plans (SFP) by January 2013, which were to be reviewed by the ASMFC Shad and River Herring Technical Committee and approved by their Board, in order to maintain commercial and recreational fisheries (with the exception of catch and release fisheries) for American Shad by (ASMFC 2010). A sustainable fishery is defined in Amendment 3 as "those that demonstrate their stock could support a commercial and/or recreational fishery that will not diminish future stock reproduction and recruitment". North Carolina's first SFP for American Shad was approved by the ASMFC Shad and River Herring Management Board in May 2012 for 2013 through 2017 (NCDMF and NCWRC 2012). The purpose of this plan is to update and modify sustainable management measures for 2018 through 2022 that will allow for the continued maintenance and rebuilding of American Shad populations in North Carolina.

The most recent stock assessment of American Shad stated that populations in the Albemarle Sound and Roanoke River are stable and low, whereas a determination of stock status could not definitively be assigned for the Tar-Pamlico, Neuse and Cape Fear rivers due to limited information (ASMFC 2007a). It should be noted that areas south of Albemarle Sound are in a zone where stocks transition from iteroparity (spawn multiple times over a lifetime) to semelparity (spawn only once followed by death), which can also impact the ability to determine stock status.

Sustainable fishery parameters are being submitted for consideration for the following areas: Albemarle Sound/Roanoke River, Tar-Pamlico River, Neuse River, and Cape Fear River.

2 REQUEST FOR FISHERIES

A sustainable fishery is defined in Amendment 3 as one that demonstrates shad stocks could support a commercial and/or recreational fishery that will not diminish future stock reproduction and recruitment. In the first American Shad SFP for North Carolina, a suite of potential sustainability parameters was considered, and it was decided to develop sustainability parameters for each river system based on relative abundance and relative fishing mortality rate (relative *F*). Relative abundance was calculated using available fisheries-independent survey data that were considered appropriate for measuring the abundance of American Shad and were expressed in terms of catch-per-unit-effort (CPUE). The standard deviations of the annual CPUE index values were also calculated to demonstrate the variability of these values. Environmental conditions on the spawning grounds, especially flow rates, are a major source of the variability associated with these indices. However, sample protocols accommodate variations in stream flow and fish distribution within the survey areas.

Relative *F* is calculated by dividing landings by a fisheries-independent index of relative abundance (Sinclair 1998). Imprecision in the survey index can cause estimates of relative *F* to be noisy. The noise can be dampened by using an average of the survey index over adjacent years in place of point estimates in the denominator. Herein, relative *F* was computed by dividing commercial landings by a hind cast 3-year average of a survey index. Note that in the previous SFP relative *F* was computed by using a centered 3-year average, resulting in the first and last year of

the time series based only on two years of data. The centered average was considered the best option to calculate relative *F* with the short time series of survey data available. However, with an additional five years of data the hind cast 3-year average is determined to be more appropriate, as it ensures the value of the final year in the time series (which can trigger management action) remains unchanged once calculated. In the Albemarle Sound/Roanoke River system, the survey data used in the calculations of relative *F* were subset to reflect the applicable season and gear restrictions for mesh size in the commercial fishery. For the other systems, it is not possible to subset the independent survey data to gear or months of the commercial fishery, due to available survey data for months and the electrofishing survey design. Therefore, relative *F* calculations for the Tar-Pamlico, Neuse, and Cape Fear River were subset to fishery-dependent commercial landings and fishery-independent survey data for March through April.

Indices of relative abundance and estimates of relative *F* were calculated for each system using data from the previous plan, updated through 2017. Thresholds (75^{th} and 25^{th} percentiles) for sustainability parameters will now be computed for set years in all systems. In the previous plan, thresholds were recalculated annually with the addition of another year of data, and there were concerns that the thresholds could slowly decline to extremely low levels without ever being exceeded. The thresholds for this plan will be fixed using the time series for the available survey data through 2017, for all surveys. Thresholds will be reevaluated during the next 5-year review of the plan.

The objective of this SFP update is to refine the calculations of the abundance indices and relative *F* estimates that currently serve as sustainability parameters in each system. Sustainability parameters are based on the female segment of the stock because the commercial fishery targets roe American Shad; roe landings can account for as much as 90% of the total American Shad landings in a year.

While scales have been collected for aging from both fisheries-dependent and fisheries-independent programs since 1972, there was concern regarding the reliability of scales for determining age for the following reasons: first, the scouring that allows for identification of spawning marks could result in loss of annuli and therefore inconsistent scale readings; and second, although increases in average age and percent of older individuals were observed, these were also associated with decreases in average length and weight. Because of these concerns and continued discrepancies between North Carolina Division of Marine Fisheries (DMF) and North Carolina Wildlife Resources Commission (WRC) in the determination of age and spawning marks, age data were not considered for sustainability parameters in any of the systems (See Appendix 1 of the 2012 SFP for additional detail).

The updated sustainability parameters are described below for each system and summarized in Table 1. The selected sustainability parameters will be reported in annual compliance reports and any management actions will be noted. Potential management actions are included in a separate section to eliminate repetition within each of the river system sections, although any action or suite of actions could be specific to and independent of each system.

2.1 Albemarle Sound/Roanoke River

Stock Status

The 2007 ASMFC stock assessment stated American Shad stocks in the Albemarle Sound and Roanoke River were low but stable and suggested a benchmark total mortality rate (Z_{30}) of 1.01

(ASMFC 2007b). Annual estimates of mortality (*Z*) from the assessment indicate that values have fluctuated around the benchmark since 2000.

Commercial Fisheries

The Albemarle Sound area has traditionally accounted for the largest proportion of the state's commercial harvest (Figure 2). Since 2001, American Shad landings from the Albemarle Sound area accounted for over 50% of the total American Shad harvest in North Carolina. Landings from gill nets comprised over 90% of the overall harvest across the same time period.

Recreational Fisheries

Recreational fisheries for Striped Bass (*Morone saxatilis*) and Hickory Shad (*Alosa mediocris*) have existed on the Roanoke River for many years, but little effort, catch or harvest of American Shad have been documented in annual creel surveys. However, creel surveys conducted by the WRC have traditionally focused on Striped Bass effort and harvest; therefore, estimates of American Shad harvest could be underestimated. The spring 2006 Roanoke River creel report estimated a directed harvest of 103 American Shad and release of 541 fish, but the harvest estimate was expanded from only seven observations (McCargo et al. 2007). Annual estimates of American Shad harvest have not been calculated for the Roanoke River fishery since 2006 when the ASMFC suspended the recreational harvest reporting requirements. Additionally, little to no focused recreational effort for American Shad occurs in the Albemarle Sound or tributaries, including the Roanoke River, as most effort is focused on Striped Bass. American Shad are most likely targeted by bank anglers in the Roanoke River, however anecdotal evidence from WRC biologists and enforcement officers indicates American Shad catch and harvest on the Roanoke River is minimal. WRC has not been able to expand the Roanoke River creel survey to include bank anglers due to limited staff availability and funding. The existing creel survey conducted by DMF in the Albemarle Sound and tributaries other than the Roanoke River also targets Striped Bass anglers, but recreational American Shad harvest is rarely documented. Despite the shortcomings of North Carolina creel surveys for estimating American Shad effort and harvest, directed recreational effort for American Shad is minimal because most recreational fisheries occur on the spawning grounds, most of which occur in Virginia portions of Chowan River tributaries. Recreational harvest from these tributaries, including Virginia portions of the Meherrin, Nottaway, and Blackwater rivers, that drain into the Chowan River is unknown. Through recent tagging data (see Section 5.1.2 for additional detail) we know that a large portion of American Shad are ascending the Chowan River, instead of the Roanoke River, to reach spawning grounds located in these Virginia systems. Additional cooperation between both Virginia and North Carolina is needed to properly evaluate the impact of the recreational fishery to the Chowan River spawning stock.

Sustainability Parameters

Data used in the development of sustainability parameters include independent gill net survey (IGNS) data collected by DMF, electrofishing data collected on the Roanoke River spawning grounds by WRC, and commercial landings data collected through the DMF Trip Ticket Program (see Section 5 for complete descriptions of these surveys).

A mortality benchmark of $Z = 1.01$ was calculated for the Albemarle Sound from the 2007 stock assessment, but there was concern that the total mortality estimate for a population in which the age distribution is contracting will not necessarily show an increase if there is no change in the slope that the *Z* estimate is based upon. As noted above, concerns regarding the reliability of scales for

determining age highly influenced the workgroup's decision not to use age data and the *Z* benchmark for sustainability parameters.

The following sustainability parameters and thresholds were evaluated for the Albemarle Sound area:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 3).

- Time series: 2001–2017.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2001-2017.

Female CPUE (IGNS): The female CPUE index based on the DMF IGNS was calculated as the number of fish per haul using data collected during January through May (Figure 4).

- Time series: 2000–2017. Although the IGNS has been conducted since 1991, use of the 2000–2017 time series will allow for more consistent comparison with the female CPUE index from the Roanoke River electrofishing survey, which has been conducted annually since 2000.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2001-2017.

Female Relative F (IGNS): Female relative *F* based on the DMF IGNS was calculated using commercial gill net landings of roe shad in Albemarle Sound (February through April, 2000-2013; March, 2014-2017) and a female index derived from data collected in the 5.0, 5.5 and 6.0-inch mesh sizes of the IGNS (February through April, 2000-2013; March, 2014-2017; Figure 5). The mesh sizes selected most accurately reflect those used by the commercial fleet. In the development of the 2012 SFP, the fishery independent index for the Albemarle Sound/Roanoke River was truncated to represent the commercial season, February through April. When the commercial season was reduced to March 3 through March 24, the IGNS was subset to the month of March for female relative *F* calculation from 2014 to 2017. This has increased the variability in the point estimates for relative *F* and reduced the sample size used in the IGNS index.

- Time series: 2002–2017. See description of time series for female CPUE based on the DMF IGNS.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from the fixed time series 2002-2017.

The sustainability parameters selected for Albemarle Sound/Roanoke River were female CPUE based on the IGNS, female CPUE based on the electrofishing survey and female relative *F* based on the IGNS. Relative *F* based on the IGNS was chosen over relative *F* based on the electrofishing survey because the electrofishing survey is limited to the Roanoke River and so was not considered representative of Albemarle Sound as a whole. The commercial fishery only occurs in Albemarle Sound and its tributaries, except for the Roanoke River. From 1994 to 2017 only 68 pounds of American Shad were landed from the Roanoke River. The IGNS occurs in the same areas of the Albemarle Sound as the commercial fishery, so the calculation of relative *F* based on the IGNS rather than the electrofishing index was determined to be more appropriate. Exceeding the threshold for Female CPUE (IGNS) or Female Relative *F* (IGNS*)* will trigger management action.

Female CPUE (electrofishing survey) will be used in conjunction with a second index for triggering management action (see Section 3 for additional detail).

Results from recent telemetry studies indicate a substantial portion of American Shad tagged in the Albemarle Sound migrate up the Chowan River and into the Meherrin and Nottaway rivers, to date, there have been no tag detections in the Blackwater River. More research into the contribution from these systems is needed, but it appears the Chowan River tributaries are important spawning areas for American Shad entering the Albemarle Sound (See Section 5.1.2 for additional detail). Additionally, electrofishing surveys in the Meherrin, Blackwater and Nottaway rivers are conducted infrequently by the Virginia Department of Game and Inland Fisheries and cannot be used in the development of sustainability parameters.

The IGNS index of female relative abundance for Albemarle Sound has shown slight variation over time (Figure 4) and was below the threshold starting in 2011 for three consecutive years, triggering management action in 2014. The female abundance index derived from the electrofishing survey was above the threshold throughout most of the time series, except for 2006, 2010, and 2016 (Figure 3). This index demonstrated an increase from 2006 to 2008 but decreased in 2009 and dropped below the threshold in 2010. The index increased through 2014 to the highest value of the time series, before declining to below the threshold in 2016, and increasing again in 2017.

Estimates of female relative *F* derived from the IGNS also varied with time. The index exceeded the threshold in 2011 through 2014 and remained below the threshold for the past three years (Figure 5).

Additional Considerations

In 2005, state and federal fisheries management agencies in North Carolina and Virginia reached a Settlement Agreement with Dominion North Carolina Power regarding Federal Energy Regulatory Commission (FERC) relicensing of the Gaston and Roanoke Rapids lakes hydroelectric dams in the Roanoke River basin. Among the mitigation measures required by relicensing was a long-term, well-funded, and coordinated program to restore American Shad in the Roanoke basin. Measures outlined in this effort included improvements in hatchery production of fry, continued intensive monitoring of fry stocking success upstream and downstream of the mainstem reservoirs, development of techniques to estimate American Shad population size, and prescriptions for diadromous fish passage. This restoration effort is coordinated by the Diadromous Fish Restoration Technical Advisory Committee (DFRTAC), which includes representatives from U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Virginia Department of Game and Inland Fisheries (VDGIF), WRC, DMF and Dominion Power. The license states that Dominion is required to design and implement upstream passage for American Shad when population estimates of 20,000 fish have been observed in two years. The target was developed based on a combination of 10% of the projected run size using the 50 shad per acre rule of thumb for riverine habitat between the dam and the river mouth (St. Pierre 1979) and very limited historic landings information. Multiple hydroacoustics research projects have attempted to estimate American Shad populations in the Roanoke River. The average run size estimate during 2006–2011 was 39,000 American Shad, suggesting the American Shad population had reached the target to begin fish passage efforts at Roanoke Rapids Dam (Hightower et al. 2013). Population estimation using the hydroacoustics techniques developed during this research is expensive and labor intensive; the estimates are also imprecise due to the uncertainty involved with assigning species to run count estimates and the difficulty conducting drift gill net studies in the lower Roanoke River. Additionally, evaluations of fry stockings upstream of dams indicate fish spawned upstream would

have little contribution to the population because of low downstream passage rates. Consequently, Dominion Power (with support of state and federal partners) has annually petitioned the FERC for a delay of the design of a fish passage program at Roanoke Rapids Dam. The DFRTAC continues to meet and evaluate the status of the Roanoke Rapids Dam FERC license agreement, including provisions for passage of American Shad.

The previous plan recommended development of creel survey methods to better estimate effort, catch, and harvest of American Shad in the Roanoke River. The existing creel survey conducted each spring on the Roanoke River targets Striped Bass effort and only estimates effort, catch, and harvest for anglers fishing from boats. Few American Shad are encountered each year during the existing Roanoke River creel survey. American Shad are most likely targeted by bank anglers; however, due to inadequate funding and staff availability, WRC has not been able to expand the Roanoke River creel survey to include bank anglers. Anecdotal evidence from WRC biologists and enforcement officers indicates American Shad catch and harvest on the Roanoke River is minimal.

Finally, DMF conducts an annual review of research priorities for all managed species. A top priority has consistently been expansion of existing surveys to meet the need for more accurate JAIs for species of importance. However, lack of funding and staff resources has delayed sufficient expansion of the alosine seine survey.

2.2 Tar-Pamlico River

Stock Status

Stock status could not be determined for the Tar-Pamlico River based on the 2007 ASFMC stock assessment (ASMFC 2007b). There were no definitive trends in abundance, although it was noted that the electrofishing CPUE for the Tar River was higher than in other North Carolina rivers since 2000. A Z_{30} of 1.01 is suggested (ASMFC 2007a).

Commercial Fisheries

Commercial landings of American Shad have declined significantly since the mid-1980s and have remained low and variable without trend since 1994 (Figure 2). Almost all harvest occurs in gill nets.

Recreational Fisheries

A recreational fishery does exist, and estimates of angler effort and catch are calculated using creel surveys. Previously, these surveys rotated among the Tar, Neuse, and Cape Fear rivers. Annual creel surveys coordinated between both DMF and WRC jurisdictions began in 2012 on the Tar-Pamlico and Neuse rivers, and on the Cape Fear River in 2013. Estimates of angler effort and catch are calculated through creel surveys noted in the fishery dependent section of this plan. A confounding factor in the creel survey is that anglers often indicate they targeted "shad" because American and Hickory Shad co-occur in the Tar-Pamlico River. The 2016 Tar-Pamlico creel survey determined recreational anglers caught 4,237 American Shad during 5,115 trips targeting American Shad, Hickory Shad, and non-specific shad species. Of the total catch, 1,417 American Shad were harvested (Table 2). The recreational daily creel limit is 10 American and Hickory Shad in the aggregate.

Sustainability Parameters

Data used in the development of sustainability parameters for the Tar-Pamlico system include electrofishing data collected by WRC and commercial landings data collected through the DMF

Trip Ticket Program (see Section 7 for complete descriptions of these surveys). There is no directed long-term JAI survey for the Tar-Pamlico system. An IGNS has been conducted consistently in the Tar-Pamlico, Pungo, and Neuse river tributaries of Pamlico Sound since 2004, but additional analysis is needed.

The following sustainability parameters and thresholds were evaluated for the Tar-Pamlico River system:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 6).

- Time series: 2000–2017. The electrofishing survey has been conducted annually since 2000 on the Tar River.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2000-2017.

Female Relative F (electrofishing survey): Female relative *F* based on the WRC electrofishing survey was calculated using commercial landings of roes by all gear types from the Pamlico River and the female CPUE index from the Tar River electrofishing survey (Figure 7). Because the electrofishing survey primarily occurs during March through April, only commercial landings from those months were used in the calculations.

- Time series: 2002–2017. The electrofishing survey has been conducted on the Tar River annually during these years.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from the fixed time series 2002-2017.

The sustainability parameters selected for the Tar-Pamlico River were the female CPUE index and female relative *F*, both derived from the WRC electrofishing survey. Exceeding the threshold for any of the selected parameters will trigger management action (see Section 3).

Female relative abundance of American Shad derived from the electrofishing survey in the Tar River has been relatively stable over the time series except for two notably high years in 2003 and 2004 (Figure 6). The index was below the threshold in 2006, 2007 and 2009 but above the threshold in all other years.

Estimates of relative *F* for female American Shad derived from the electrofishing survey were below the threshold during 2003 to 2006 (Figure 7). These estimates of female relative *F* exceeded the threshold in 2002, 2007, 2009, and 2012. The 2017 estimate is well below the threshold.

Additional Considerations

There is potential to improve upstream passage in this system. The WRC, USFWS, Pamlico-Tar River Foundation, and the Albemarle Pamlico National Estuary Partnership have engaged in conversations with the Rocky Mount Mills Dam owner and hydroelectric operator. In addition to interest in providing American Shad access to potential spawning habitat upstream of Rocky Mount Mills Dam, concern exists that hydropeaking operations (periodic spikes in flow) at Rocky Mount Mills Dam compromise the quality of existing spawning habitat. The dam owners agreed to cease hydropeaking during the anadromous spawning season, and the powerhouse has been out of operation for several years. The current owners of the dam have intentions to resume hydroelectric operation, and they are considering fish passage improvements as well.

A cooperative effort between DMF and WRC to improve the frequency and design of recreational creel surveys on the Tar-Pamlico and Neuse rivers began in spring 2012. Creel surveys have occurred annually since that time and include increased coverage on both rivers, which has improved estimates of recreational harvest.

As noted previously, DMF conducts an annual research prioritization exercise for all managed species. One of the top priorities has consistently been expansion of existing surveys to provide accurate juvenile abundance indices (JAI) for all commercially and recreationally important species. Meeting this priority is unlikely, due to the lack of funding available to the DMF to expand current monitoring programs.

2.3 Neuse River

Status of Stocks

Stock status could not be determined for the Neuse River based on the 2007 ASFMC stock assessment (ASMFC 2007b). There were no definitive trends in abundance over the most recent five to ten years of the assessment. A Z_{30} of 1.01 was suggested (ASMFC 2007a).

Commercial Fisheries

Commercial landings of American Shad have declined since 1972. There have been several peaks throughout the time series, but landings have remained low and variable without trend since the early 2000s (Figure 2). Harvest occurs almost entirely from gill nets.

Recreational Fisheries

Estimates of angler effort and catch are calculated through creel surveys noted for previous systems in the fishery-dependent section of this plan. The 2016 Neuse River creel survey determined total recreational catch to be 1,641 American Shad out of a total of 9,574 trips targeting American Shad, Hickory Shad, and non-specific shad species (Table 3). The majority of American Shad catch is released, as harvest was estimated to be only 252 American Shad in 2016. Additionally, as mentioned above a confounding factor in the creel survey is that anglers often indicate they targeted "shad" because American and Hickory Shad co-occur in the Neuse River system. A 1-fish daily limit on American Shad within the aggregate 10-fish recreational creel limit for American and Hickory Shad has been implemented in Coastal, Joint, and Inland Waters of the Neuse River.

Sustainability Parameters

Data used in the development of sustainability parameters for the Neuse River system include electrofishing data collected by WRC and commercial landings data collected through the DMF Trip Ticket Program (see Section 7 for complete descriptions of these surveys). There is no directed JAI survey for the Neuse River. As noted previously, there is an IGNS in the tributaries of Pamlico Sound. While the IGNS for the Neuse River area of the survey has been conducted since 2004, additional time is needed to properly evaluate this survey as an index for American Shad because effort is calculated differently than the Albemarle Sound IGNS. The following sustainability parameters and thresholds were evaluated for the Neuse River system:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 8).

- Time series: 2000–2017. The electrofishing survey has been conducted consistently since 2000 on the Neuse River.

- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from a fixed time series of 2000-2017.

Female Relative F (electrofishing survey): Female relative *F* based on the WRC electrofishing survey was calculated using commercial landings of roes by all gear types from the Neuse River and the female CPUE index from the Neuse River electrofishing survey (Figure 9). Because the electrofishing survey primarily occurs during March through April, only commercial landings from those months were used in the calculations.

- Time series: 2002–2017. This time period reflects the years the electrofishing survey has been conducted on the Neuse River.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from a fixed time series of 2002-2017.

The sustainability parameters selected for the Neuse River were the female CPUE index and female relative *F*, both derived from the WRC electrofishing survey. Exceeding the threshold for any of the selected parameters will trigger management action (see Section 3).

The electrofishing index of relative abundance for female American Shad in the Neuse River has been variable and remained above the threshold for the past seven years. The index was below the threshold in 2000, 2002, 2006, 2007, and 2010 (Figure 8). Relative *F* estimates for female shad derived from the electrofishing survey have been below the threshold since 2008 (Figure 9).

Future Considerations

Access to American Shad spawning habitat is affected by streamflow conditions on the Neuse River, and the variability in timing and strength of streamflow can determine where American Shad spawn. During high flow events, many American Shad migrate upstream to Milburnie Dam (rkm 352), which is the first mainstem dam on the Neuse River. Milburnie Dam is scheduled to be removed in 2017, and the removal will open approximately 25 km of additional spawning habitat to American Shad in the mainstem Neuse River. Future monitoring will determine if American Shad alter their migratory behavior in response to the dam removal. Additionally, further research is needed to determine how spawning success might be related to streamflow. The removal of Milburnie Dam, however, is expected to improve anadromous fish spawning habitat in the Neuse River, especially during high streamflow events.

As noted in the previous section, an annual creel survey rotation prior to 2012 as well as efforts by DMF to expand creel surveys upstream have improved recreational effort and catch/harvest estimates. Annual creel surveys in the Neuse River are anticipated to continue. Expansion of existing surveys to provide accurate JAIs for all commercially and recreationally important species is a DMF priority. Meeting this priority is unlikely, due to the lack of funding available to the DMF to expand current monitoring programs.

Similarly, a representative JAI for American Shad may be a future possibility depending on resources available to expand or reconfigure existing independent surveys.

2.4 Cape Fear River

Stock Status

Similar to the Tar-Pamlico and Neuse rivers, the stock status on the Cape Fear River is unknown, although a Z_{30} of 1.01 was recommended in the latest assessment (ASMFC 2007a, 2007b). Of all

the river systems in North Carolina, the Cape Fear is likely to have the highest proportion of fish that are semelparous (spawn once followed by death).

Commercial Fishery

Commercial landings have displayed several cyclical peaks since 1972, although each successive peak has been slightly lower than the previous. Landings were somewhat low throughout the 2000s (Figure 2). As with the other river systems, the vast majority of landings are from gill nets. There has been very little harvest from other gears.

Recreational Fishery

Like the other systems mentioned, a comprehensive creel survey was initiated in 2013 to identify and estimate recreational American and Hickory Shad effort and catch within the Cape Fear River system. In 2016, the estimate of total recreational catch was 21,011 American Shad from a total of 5,132 trips targeting American Shad, Hickory Shad, and non-specific shad species. Approximately 50% of the American Shad catch was harvested (Table 4). In 2013, the daily creel limit was reduced to a maximum of five American Shad within the 10-fish shad aggregate daily limit. It is important to note that Hickory Shad are encountered infrequently in the Cape Fear River and most of the recreational effort is focused on American Shad.

Sustainability Parameters

Data used in the development of sustainability parameters for the Cape Fear system include electrofishing data collected by WRC and commercial landings data collected through the DMF Trip Ticket Program (see Section 7 for complete descriptions of these surveys). There is no directed JAI survey for the Cape Fear River. While there was an IGNS from 2003–2007, it was a fixed- station survey rather than a stratified random design and was therefore not used in any sustainability parameter calculations.

The following sustainability parameters and thresholds were evaluated for the Cape Fear River system:

Female CPUE (electrofishing survey): The female CPUE index based on the WRC electrofishing survey was calculated as the number of fish per minute using data collected from March through May (Figure 10).

- Time series: 2001–2017. The electrofishing survey has been conducted annually since 2001 on the Cape Fear River.
- Threshold: Three consecutive years of values below the 25th percentile (where 75% of all values are greater) from the fixed time series 2001-2017.

Female Relative F (electrofishing survey): Female relative *F* based on the WRC electrofishing survey was calculated using commercial landings of roes by all gear types from the Cape Fear River and the female index from the Cape Fear River electrofishing survey (Figure 11). Because the electrofishing survey primarily occurs during March through April, only commercial landings from those months were used in the calculations.

- Time series: 2003–2017. This time period reflects the years the electrofishing survey has been conducted on the Cape Fear River.
- Threshold: Three consecutive years of values above the 75th percentile (where 25% of all values are greater) from the fixed time series 2003-2017.

The sustainability parameters selected for the Cape Fear River were the female CPUE index and female relative *F*, both derived from the WRC electrofishing survey. Exceeding the threshold for any of the selected parameters will trigger management action (see "Potential Management Measures").

Relative abundance of female American Shad from the electrofishing survey in the Cape Fear River was low from 2005 through 2011, and values were below the threshold from 2006 to 2011 (Figure 10). Since 2011, relative abundance of female American Shad has been above the threshold and continued to increase through 2015. Estimates of female relative *F* have remained below the threshold since 2012 (Figure 11).

Additional Considerations

Collaborative habitat enhancement projects that focus on fish passage and increasing spawning habitat have been implemented on the Cape Fear River in recent years. Each year, WRC recommends a locking schedule to the USACE to pass anadromous fishes upstream of locks and dams during the spring spawning run. In 2012, a rock arch fishway was constructed below Lock and Dam 1 (LD-1) to facilitate volitional, upstream fish passage. Telemetry studies conducted to evaluate American Shad usage of the rock arch fishway indicate American Shad passage efficiency at the LD-1 fishway ranged 53–65% and was consistent with prior estimates from locking procedures (Raabe et al. 2016). Electrofishing surveys corroborate the telemetry studies, as electrofishing catch rates have increased at the upper two locks and dams and decreased at LD-1 over the last five years. These results indicate American Shad are readily passing LD-1. With presumed historic spawning grounds, upstream of Lock and Dam 3 (LD-3), substrate was strategically placed below Lock and Dam 2 (LD-2) in 2013 to increase the potential spawning habitat for anadromous fish that pass the rock arch fishway but fail to navigate the lockage system. Locking at LD-1 has ceased at this point but continues for LD-2 and LD-3 to facilitate fish passage. American Shad spawning activity has been observed by Commission staff (Bennett Wynne, WRC retired, personal communication), and American Shad eggs have been collected just downstream of LD-2 (Dawn York, Cape Fear River Partnership, personal communication). Therefore, fish that migrated to LD-2 but failed to migrate farther upstream could reproduce and benefit from the habitat enhancement efforts. In recent years, 2016 and 2017, WRC staff have encountered eggs below LD-3 (Clinton Morgeson, WRC, personal communication). The Cape Fear River Partnership, including local, state, and federal agencies, as well as private groups, continues to plan fish passage enhancement projects on the remaining locks and dams on the main stem Cape Fear River.

Based on the construction efforts and changing conditions, DMF and WRC recommended a two-year review of the 75th percentile threshold for female relative *F* in the 2012 SFP as calculation of this parameter was likely to be heavily influenced by drought, floods, and changes in fish passage. There was also concern that restoration efforts might influence electrofishing catch rates due to improvements in fish passage with completion of the rock arch fishway. After review in 2015, no changes were recommended for the Cape Fear system. North Carolina will continue to evaluate American Shad relative abundance and sustainability metrics in the context of improvements in habitat and passage benefiting anadromous fishes in the Cape Fear River.

2.5 Pee-Dee River

The Pee-Dee River originates in North Carolina before flowing into South Carolina and emptying into Winyah Bay. Although approximately 25 km of American Shad spawning habitat is located in

the North Carolina portion of the Pee-Dee River, neither NCWRC nor NCDMF have the resources to conduct monitoring activities in this system. However, South Carolina Department of Natural Resources maintains dependent and independent survey programs in the South Carolina portion of the Pee-Dee River. Commercial and recreational fisheries were approved in the South Carolina SFP issued in 2012. Commercial harvest of American Shad is prohibited in the North Carolina portion of the Pee-Dee River, but recreational harvest is allowed under the statewide recreational creel limit of 10 American and Hickory Shad in combination per day. This recreational creel limit is consistent with the creel limit in South Carolina. We propose maintaining the recreational fishery in the North Carolina portion of the Pee Dee River and defer American Shad management and determination of sustainability to South Carolina. NCWRC will complement management actions in North Carolina waters to maintain consistency with South Carolina when appropriate.

2.6 Other Areas

The areas included in the sustainability parameters submitted for consideration above contain the known American Shad spawning populations in North Carolina, and those systems support the only directed recreational and commercial fisheries in the state. However, American Shad are incidentally encountered in commercial fisheries prosecuted within other non-spawning rivers and coastal sounds. Commercial harvest from these areas is a very small proportion of annual American Shad harvest (Figure 2) and is primarily considered incidental bycatch. For example, commercial harvest from the New and White Oak rivers (two coastal, blackwater rivers) combined averaged only 140 pounds per year between 1994 and 2016. Recreational effort and harvest in areas outside of spawning rivers is most likely non-existent. In the New and White Oak rivers, recreational creel survey intercepts from 2004 to present have not indicated American or Hickory Shad as target species and no American or Hickory Shad have been reported in the catch. While there are currently no independent surveys for American Shad outside of spawning rivers, surveys for other species rarely encounter American Shad. We propose to maintain current harvest seasons (February 15-April 14) to allow commercial harvest of incidental bycatch because these fish will most likely be dead discards and the amount of harvest is minimal. The areas without specified sustainability parameters will fall under default management measures listed in tables 8 and 9. North Carolina will continue to monitor commercial landings through the North Carolina Trip Ticket Program to ensure landings remain low. Dedicated monitoring programs or area closures will be implemented if sudden increases in landings, indicating targeted effort, occur.

3 MANAGEMENT MEASURES

3.1 Potential Management Measures

The environmental circumstances under which a sustainability threshold may be reached can vary among systems. Therefore, different management measures may be used for each system in addressing the triggers. One or more potential management measures presented here and may be used singly or in combination:

- Restrictions on length of season to reduce effort (e.g., March 1–April 14) not to extend beyond the estuarine striped bass quotas being filled (avoids waste of striped bass and shad)
- Trip limits (this may result in discards)
- Reduce allowable number of yards (the 1,000-yard limit in Albemarle Sound could be considered in other areas)
- Area/season closure (e.g., area closure at mouth of Roanoke River from February–mid-November since 1988)

- Only allow fishing certain days of the week (lift days)
- Recreational creel reduction
- Commercial harvest quota (although possible, this could be difficult to implement given existing resources)

If two years of sustainability parameters exceeding thresholds are observed, a suite of management measures could be proactively developed and presented to Finfish and Regional Advisory Committees.

3.2 Management Measures implemented 2013-2017

Changes in management (season lengths, creel limits) since implementation of the SFP in 2013 have been noted in Section 6 and are summarized for convenience in Tables 8 and 9.

Although harvest is an obvious potential contributor to population declines, significant habitat degradation has also occurred in all the river systems. It is unlikely that American Shad populations in North Carolina will recover and expand without considerable resources being dedicated to habitat restoration for this species. Our management goals, however, are intended to sustain population levels as additional habitat is protected or improved through aquatic habitat conservation measures and increased passage opportunities of American Shad beyond impediments that block migration to historic spawning grounds.

Cape Fear River

At the request of the ASMFC Shad and River Herring Technical Committee during development of the 2012 SFP, additional analysis was conducted for the Cape Fear River. This was based on the female relative *F* parameter being over the 75th percentile threshold for two consecutive years, as well as the female CPUE from the electrofishing survey being very close to the threshold for six consecutive years. An 11% percent reduction in commercial harvest was required to bring female relative *F* down to the threshold.

Additional analyses (see Appendix 2 of the 2012 SFP) were conducted to determine the commercial and recreational reductions in harvest that would provide an additional conservation buffer. It was determined that equivalent reductions in harvest for both commercial and recreational sectors would provide the greatest benefit given that commercial and recreational harvest in 2011 were roughly equivalent. Management options that resulted in a 25% reduction in harvest for each sector were calculated, and it was determined that a shortened commercial season and a reduction in the recreational creel limit would best meet the required reductions in harvest. While commercial and recreational harvests have fluctuated somewhat since regulatory changes were implemented, both the electrofishing index and relative *F* index have remained above and below their respective thresholds since 2012. A commercial season from February 20 through April 11 and a recreational creel limit of five fish within the 10-fish aggregate resulted in the necessary 25% reduction.

3.3 Proposed Management Measures for 2018

The following management measures are proposed to be effective January 1, 2018.

Recreational

Albemarle Sound/Roanoke River, Neuse River

- Recreational creel limit of 1-fish for American Shad in Joint and Coastal Waters to complement the WRC 1-fish limit in Inland Waters of these systems (no change to existing DMF and WRC rules).

Tar-Pamlico River

- Recreational creel limit of 10-fish for American Shad in the Joint, Coastal and Inland Waters (no change to existing DMF and WRC rules).

Cape Fear River

- Recreational creel limits of 5-fish for American Shad in the Joint and Coastal Waters of the Cape Fear River to complement the WRC 5-fish limit in the Inland Waters of this river (no change to existing DMF and WRC rules).

Commercial
Albemarle Sound

- Commercial season of March 3-24.

Tar-Pamlico River, Neuse River

- Commercial season of February 15-April 14.

Cape Fear River

- Commercial season of February 20-April 11.

While none of the selected sustainability parameters for any of the river systems have exceeded the triggers for management since 2013, the above measures are considered prudent given the results of the 2007 stock assessment as they pertain to North Carolina. Future changes to creel limits for American Shad in the Inland Waters of the other river systems will also be complemented by DMF for Joint and Coastal Waters.

4 ANCILLARY INFORMATION AND FUTURE CONSIDERATIONS

The focus on female indices for the sustainability parameters in all systems is based on the conclusion that changes in female abundance combined with impacts from various environmental parameters could prove challenging to stock improvement given that the commercial fishery targets roe shad. Major fluctuations in female abundance could potentially impact future recruitment and landings. The use of sex ratios as a sustainability parameter was considered, but it was determined that the sex ratios from both the IGNS (in the Albemarle system and potentially the other systems) and the electrofishing surveys were more suitable for use as long-term trends rather than short-term (i.e., three year) indicators of stock health due to the impact of environmental variability on the data. The intent of the agencies is to monitor the sex ratios from each of the surveys for trends and use this information to help inform future management.

An IGNS has been conducted consistently in the Tar-Pamlico, Pungo, and Neuse Rivers and tributaries of the Pamlico Sound since 2004. Unlike the Albemarle Sound IGNS, American Shad captured in this IGNS program do not have sex assigned in the program data for effort, if age structures are collected sex is assigned and reported in a separate aging program. Only a proportional estimate of sex can be applied to the small sample size. Additionally, effort is calculated differently, by gang of nets, compared to the Albemarle Sound IGNS which calculates effort per individual net. Additional analysis into the data caveats is needed to properly evaluate this survey as a new index of abundance for this plan.

The use of repeat spawning data was also considered as a potential sustainability parameter. However, inconsistencies in determination of repeat spawning marks made it difficult to set a target or threshold. Because repeat spawning continues to be tracked annually as part of the required monitoring program, it will also be used as ancillary information for determining future management. Should greater confidence in repeat spawning data be attained in the future, they may be considered for developing a formal sustainability parameter.

Sustainability parameters have been updated annually in compliance reports, as well as via annual appendices to the SFP detailing changes in management measures. DMF and WRC also jointly review the performance of the plan on an annual basis to determine management measures for the following season.

Finally, during the preparation of this update, both DMF and WRC discussed exploring several additional sustainability parameters, as well as potential future modifications to existing sustainability parameters:

- Consider alternate means of calculating effort from the IGNS and possible incorporation of IGNS from Tar-Pamlico and Neuse as parameters;
- Consider incorporating uncertainty in relative *F* estimates;
- Consider use of alternative modeling approaches that can incorporate environmental parameters as model factors;
- Consider alternative ways to calculate relative *F* including using recreational catch estimates and total catch from the IGNS.

If appropriate, North Carolina would submit a revised SFP for Technical Committee review to allow for inclusions or modifications described above.

5 STOCK MONITORING PROGRAMS

The following descriptions represent the entirety of stock monitoring programs used to assess the health of American Shad in North Carolina. All programs are included in annual compliance reports and as noted in the program descriptions, specific details can be found in past compliance reports.

5.1 Fishery-Independent Monitoring

5.1.1 Juvenile Abundance

A juvenile abundance index is calculated for Albemarle Sound area using data from the alosine seine survey that has been conducted annually since 1972. Eleven core seine stations are sampled monthly in the western Albemarle Sound area during June–October of each year. During September, thirteen additional seine samples are taken to determine distribution and annual variations of alosines in the nursery area. All stations are sampled with an 18.5-m (60-ft) bag seine. Relative abundance data are collected for Blueback Herring, Alewife, American Shad and Hickory Shad from the 11 core stations.

Samples are sorted by species and 30 randomly selected individuals of each alosine species present are measured. Other species present are also noted. Water temperature, salinity, and other environmental characteristics are counted, measured, and recorded. As noted previously, this survey was designed specifically for blueback herring and is not considered a reliable indicator of juvenile American Shad abundance.

No juvenile abundance indices exist for the Tar-Pamlico, Neuse and Cape Fear River systems.

5.1.2 Adult Stock Monitoring

Spawning Area Survey

An annual spawning stock survey and representative sampling for biological data is required from Albemarle Sound and its tributaries, Tar-Pamlico, Neuse, and Cape Fear Rivers for American Shad. Sampling in these areas was initiated in 2000.

WRC personnel collect American Shad from the Roanoke, Tar, Neuse and Cape Fear systems annually during February–June. A boat-mounted electrofishing unit (Smith-Root 7.5 GPP) is used (1 or 2 dip netters) to capture fish during daylight hours, and electrofishing times are recorded in seconds. To minimize size selection during sampling in all river systems, shad are netted as they are encountered regardless of size. Relative abundance of each year-class is indexed by CPUE expressed as the number of fish captured per hour of electrofishing. However, CPUE is converted to fish per minute for sustainability indices described above. American Shad broodstock collections are usually excluded from calculations of CPUE unless collections occur during regular sampling activities. Because broodstock are sacrificed when hatchery spawning is complete, otoliths from broodstock are aged and used to develop age length keys in most years. Total length (mm), weight (g), and sex are recorded for all captured fish. Sampling protocols are unique to each river system and have been refined throughout the survey period. River-specific descriptions of spawning area surveys are provided in the following sections.

Roanoke River

American Shad surveys have been conducted in the Roanoke River from 2001 through 2017. The surveys occur in the mainstem Roanoke River near the Gaston Boating Access Area at river kilometer (rkm) 225. The survey area encompasses the most upstream American Shad spawning habitat in the Roanoke River, and further migration beyond the survey area is blocked by Roanoke Rapids Dam at rkm 227 (approximately 2 km upstream of the survey area). In 2000–2007, sampling was concurrent with Striped Bass surveys in the same sample area and was restricted to April and May. Beginning in 2008, sampling was started earlier in March when water temperatures approach 10^{o}C and continued weekly until low-flow conditions restrict boat navigation or until spawning appears complete (typically end of May or first of June). One dip netter was used 2000–2004 and 2010–2011, whereas two dip netters were used 2005–2009 and 2012–2017. Also in earlier years (2000–2012), two or three shoreline sample sites approximately 1 km each were sampled per week. In 2013–2017, however, samples were conducted at nine sampling sites once per week during the survey period. Electrofishing commenced at the upstream portion of each 500-m site and continued downstream the entire transect. Sites were randomly selected from shoreline and mid-channel habitats along the 3-km stretch downstream of the Hwy 48 bridge. Total electrofishing effort increased from previous years, but the new sample protocol still occurs in the same area as previous years.

Tar River

American Shad spawning area surveys have been conducted on the mainstem Tar River from 2000 through 2017, and survey protocols have changed relatively little throughout the survey period. One dip netter is used to capture fish during daylight hours. Electrofishing samples are conducted weekly during March–May. Sampling begins when water temperatures approach 10^{o}C. Sample sites are located within one of three approximately 15-km segments that encompass most of the American Shad spawning habitat in the Tar River. Segment 1 contains the river stretch from Rocky Mount Mill Dam downstream to the Dunbar Boating Access Area (BAA). Segment 2 includes the

river stretch from Dunbar BAA downstream to the Bell's Bridge BAA. Segment 3 continues from the Bell's Bridge BAA downstream to the Tarboro town ramp. Normally, one sample of approximately 30 minutes of electrofishing time is conducted within a segment during a sample day. Typically, only one 30-minute sample is conducted per week, yet, depending on flows, attempts are made to conduct another 30-minute sample in a different segment, or at least in a different site of the same segment, during that same week. Sample sites within a segment vary from week to week and are selected from areas that appear to have preferred American Shad habitat. Angling activity is avoided. Flows and water temperature determine which segment is sampled on a particular day. Moderate to high flows and warmer water temperatures tend to cause American Shad to move further upstream into segment 1. There are certain minimum river levels required to allow access to the river for electrofishing, yet the majority of American Shad sampling is concentrated in segment 1 when flows are greater than 300 cfs. Flooding often prevents access to the river for sampling, but high water subsides quickly in the Tar River and at least one sample site per week is usually possible.

Neuse River

American Shad electrofishing surveys have been conducted in the Neuse River from 2000 through 2017 and one dip netter is used to capture fish during daylight hours. Electrofishing samples are conducted weekly during March–May. Sampling begins when water temperatures approach 10^{o}C and ends when spawning appears to be complete. Sampling is conducted near known spawning areas at Goldsboro, NC (rkm 240) and Raleigh, NC (rkm 350). Sampling begins at the downstream Goldsboro location in March, and the Raleigh location is added to the weekly sampling regime once 30–40 American Shad are collected in one day at the Goldsboro location. Weekly sampling locations are contingent upon water levels because low flows limit navigability. The Raleigh location is only accessible at moderate to high flows and is dropped from weekly sampling when flows are not adequate for safe and effective sampling. When conditions improve, sampling is resumed at the Raleigh location. Sampling locations have been consistent throughout the survey period, but sampling protocols at each location have varied over time. In early years of the survey, two sample sites were sampled at each location. The sample sites were 2–3 km long and took over one hour of electrofishing time to complete. Since 2015, two or three sample sites are sampled at each location, but the sites have been shortened to around 1 km and electrofishing effort has been reduced. Nevertheless, the same areas have been consistently sampled throughout the survey.

Cape Fear River

Sampling for American Shad has occurred in the Cape Fear River from 2001 through 2017. In most years, one dip netter was used to collect American Shad, but two dip netters have been used 2015–2017 to avoid gear saturation caused by increases in American Shad abundance. In all survey years, sampling occurred at three fixed sample sites adjacent to the base of each of three locks and dams found on the river. Since 2010, sampling efforts have been standardized by electrofishing for 30 minutes downstream of each lock and dam—15 minutes from the middle of each dam down each shoreline. Sampling at each site is attempted weekly when water temperatures approach 10^{o}C and is ended when spawning appears complete. Prior to 2010, however, sampling was more sporadic and did not always occur at each site every week. Other areas in the Cape Fear River upstream of the locks and dams (Buckhorn Dam and Smiley's Falls) are also sampled, but data from sites other than the locks and dams are not included in annual relative abundance analyses. Sampling at the locks and dams is possible under most flow conditions, but flood events can periodically prevent sampling.

Independent Gill Net Survey (IGNS)

Since 1991, DMF has been conducting an independent gill net survey throughout the Albemarle Sound area. The survey was designed for Striped Bass data collection and occurs November through May each year. However, American Shad are captured during the survey and size, age and sex data are collected. Forty-yard segments of gill net from 2.5- through 7.0-inch stretched mesh, in half-inch increments, as well as 8.0, and 10.0-inch stretched mesh are utilized. The sound is divided into zones and grids and random sites are selected within these areas. Lines of float and sink nets are set in both shallow and deep strata if they are present in the grid.

The IGNS in the Pamlico Sound area began 2001, while the rivers (including Pamlico, Pungo and Neuse rivers) began in 2003. The Cape Fear River was added in 2007 and the Core Sound area will begin fully in 2018. The survey runs from February through mid-December and utilizes a different methodology than that conducted in the Albemarle Sound. Thirty-yard segments of gill net are used, ranging from 3.0-inch stretched mesh through 6.5-inch stretched mesh in half-inch increments. The catch from the gang of nets comprises a single sample, unlike the Albemarle where each mesh net is tallied for effort. Each gang of nets is fished in both shallow and deep strata, and sites are preselected at random from within strata-grids.

Albemarle Sound American Shad Movement Study

The Roanoke River and Chowan River tributaries are known spawning rivers for American Shad entering Albemarle Sound. Despite the restoration efforts and research that has occurred in the Roanoke River, the proportion of American Shad migrating up the Chowan River or Roanoke River is largely uncertain. The NMFS and DMF have been conducting an acoustic telemetry study to determine migratory patterns of Albemarle Sound American Shad. The objective of this study was to determine which river basins are used by adult American Shad during the spawning run in 2013, 2014, 2016, and 2017. The study used an existing array of acoustic receivers placed at inlets and throughout Albemarle Sound and the Roanoke River. DMF, WRC, and NCSU maintain and operate these receivers to track movement of Atlantic Sturgeon, Striped Bass, and Largemouth Bass. The study area encompassed the Albemarle Sound, and its associated sounds (Croatan and Currituck) and rivers: North, Pasquotank, Little, Perquimans, Chowan, Roanoke, Scuppernong, and Alligator in northeastern North Carolina and the Meherrin, Nottaway, and Blackwater in southeastern Virginia. Adult American Shad were captured in gill nets with mesh sizes ranging from 4.5 to 6 inches at locations north and south of North Carolina Highway 32 bridge. This area is a funneling point for American Shad that have entered the Albemarle sound to reach spawning grounds on either the Chowan River (north) or the Roanoke River (south). American Shad were implanted with VEMCO V9-2x-A69-1601 coded acoustic transmitter and a PIT tag (only in 2013). Tagged fish were measured and assigned sex if possible. Fish were tagged by inserting the tag through the esophagus into the stomach. Fin clips were taken in 2016 and 2017 to determine hatchery contribution from Roanoke River stocked fish. The acoustic transmitter released a frequency every 90 seconds and tag life was expected to be around two years.

Since 2013, a total of 191 American Shad have been tagged. Table 7 shows the numbers of fish tagged, detected, and that made spawning runs up the Roanoke or Chowan Rivers. The fish that were detected but did not make spawning runs either demonstrated strong fall back behavior and presumably left the sound or are thought to have died.

Shad movement data gathered by this study suggest that a large portion of the spawning stock entering the Albemarle Sound is ascending the Chowan River to spawn. Future studies are needed to

determine potential genetic differences between Chowan River and Roanoke River spawning stocks. Any genetic differentiation between the two rivers can be used to further evaluate spawning stock contribution within the Albemarle Sound population and can allow for more refined management and restoration efforts. Fin clips have been collected from the commercial fishery for future genetic analysis.

5.1.3 Size, Age and Sex Determination

Spawning Area Survey

Sex is determined for each captured fish by applying directional pressure to the abdomen toward the vent and observing the presence of milt or eggs. Each fish is measured for total length in millimeters. Scales are removed from the left side of each fish between the lateral line and the dorsal fin. To estimate age, scales are examined at 33X magnification on a microfiche reader and annuli are counted. Spawning marks are recorded separately. Shad that cannot be aged are assigned ages based on the gender specific age-length key developed for each river and included in CPUE and size-distribution analyses. Beginning in 2011, American Shad have been aged using otoliths, or age distributions have been calculated by applying age-length keys from years when otolith ages were aged up to 10 fish per 10-mm size bin (by sex) are sacrificed for otolith extraction. Broodfish were used to develop age-length keys in addition to spawning area survey fish.

Independent Gill Net Survey

Each fish is measured for fork length and total length. Sex is always determined for fish captured in the Albemarle Sound IGNS. Each fish is sexed by applying directional pressure to the abdomen toward the vent and observing the presence of milt or eggs. Scales are collected from the left side of each fish between the lateral line and the dorsal fin. Scales are prepared and aged according to the Cating (1953) method.

5.1.4 Total Mortality Estimates

Survival estimates are calculated using the Robson and Chapman (1961) method. Robson and Chapman showed that estimates of annual rates of survival can be made from the catch curve of a single season if the population is exposed to unbiased fishing gear beyond the age of recruitment and if year-class strength and survival rate remain constant from year to year. Annual mortality rates are calculated based on observed samples of individuals at age. Only age groups that are fully recruited to the gear are included in the calculations and the resulting estimates only apply to the fully recruited individuals.

5.2 Hatchery Evaluation

5.2.1 Roanoke River American Shad Restoration Project

Since 1998, over 72 million American Shad fry have been stocked in the Roanoke River downstream of Kerr (US Army Corps of Engineers), Gaston (Dominion Power) and Roanoke Rapids (Dominion Power) reservoirs at Weldon, NC. Since 2003, American Shad fry have also been stocked upstream of Kerr Reservoirs at Altavista, Clover Landing, VA; in Gaston Reservoir at Bracey, VA; and Roanoke Rapids Lake near Roanoke Rapids, NC (Table 5). These stocking activities serve as migratory obstruction mitigation required by Federal Energy Regulatory Commission (FERC) relicensing of the Gaston and Roanoke Rapids hydropower dams. The stockings upstream of dams are experimental to evaluate escapement of American Shad and determine the benefits of future fish passage efforts.

In the early years of the restoration project, WRC followed protocols of other states involved in American Shad restoration efforts and obtained broodfish for fry production from nearby rivers having adequate shad stocks. American Shad broodfish were collected by electrofishing from the Tar, Neuse, Cape Fear, and Roanoke rivers from 1998–2010. Hormone injection was used to initiate spawning in the hatchery from 1998 to 2008, but in 2009, for the first time, broodfish were not injected with hormone (LHRHa or sGnRHa pellets) upon arrival at the hatcheries and prior to being transferred to circular spawning tanks. In 2011, only broodfish collected from the Roanoke River were utilized for production. Upon collection, broodfish are placed in circular tanks with oxygen and continuously circulating water onboard the electrofishing boats and are then transferred to large circular, trailer-mounted tanks for transport to the hatcheries.

Annual contribution of hatchery-origin American Shad to the Roanoke River population is evaluated for multiple cohorts of returning adults during the spring spawning run and for out-migrating juveniles during fall of the stocking year. Evaluation of hatchery contribution to the Roanoke River American Shad population was conducted using oxytetracycline (OTC) marks from 1998–2009. Subsequent testing proved OTC marking procedures and analyses were unreliable, and the WRC initiated use of genetic microsatellite markers for parentage-based tagging (PBT) methods in 2010. With the PBT method, each spawning tank contains a genetically discrete batch of broodfish, from which the progeny can be uniquely identified. Fin clips from all American Shad broodfish were stored in numbered vials containing non-denatured, spectrophotometric grade ethanol to later be referenced for determining hatchery origin of at-large fish produced in a given year. All PBT analyses were conducted by the genetics laboratory at the North Carolina Museum of Natural Sciences (NCMNS). Daily OTC marking techniques have not been used since the switch was made to PBT analysis. Fin clips from adult American Shad are collected during spawning stock surveys, and broodfish are also cross-referenced for potential hatchery contribution of stockings from previous years. Broodfish fin clips combined with fin clips collected during weekly samples are collectively referred to as at-large adults

Parentage-based-tagging efforts were initiated in 2010, and the early results (i.e., 2010–2014) cannot capture potential hatchery contribution from year classes before 2010. Thus, percent contribution of hatchery fish is underestimated and should be considered a minimum prior to 2015. Hatchery contribution from these early years should not be used to make inferences regarding the overall hatchery contribution of the spawning stock but can be used to assess hatchery contribution for specific year classes.

In 2012, a total of 289 fin clips was assessed using PBT techniques. Only one fish was determined to be of hatchery origin and was matched with broodfish from the 2010-year class. In 2013, a total of 26 out of 527 at-large adults was found to be of hatchery origin; 25 were matched to the 2010-year class and one to the 2011-year class. In 2014, a total of 708 fin clips was processed, and 90 were determined to be of hatchery origin (12.7%). Of the total, 54 were matched with broodfish from the 2010-year class, 34 from the 2011-year class, and 2 from the 2012-year class. In 2015, 233 of 543 processed fin clips were found to be of hatchery origin (42.9%); 66 were matched with the 2010-year class, 141 with the 2011-year class, 23 with the 2012-year class, and 3 with the 2013-year class. In 2016, 522 fin clips were processed, and 293 were determined to be of hatchery origin (56.1%); 33 were matched with broodfish from 2010, 191 matched with the 2011 broodfish, 38 matched with the 2012 broodfish, and 31 matched with the 2013 broodfish. Between 2010 and 2014, all hatchery-origin fish were stocked at Weldon (below Roanoke Rapids Dam). In 2016, one of the hatchery identified fish was stocked into the Staunton River, upstream of Kerr Reservoir.

This is the first conclusive evidence of a fish being stocked above Kerr Reservoir being captured as an adult on the spawning grounds.

In 2016, a sample of fin clips was obtained from shad intercepted in the Albemarle Sound. A total of 4 out of 117 (3.4%) Albemarle Sound fish was determined to be of hatchery origin; the hatchery fish were from the 2011 and 2012 year classes. In 2017, 5 of 126 (4.0%) fin clips from Albemarle Sound American Shad were determined to be stocked fish. The 2011, 2012 and 2013 year classes were represented in the 2017 stocked fish. In both years, the hatchery contribution in the Albemarle Sound sample was lower when compared with hatchery contribution on the spawning grounds, indicating that Roanoke River spawning fish do not make up the majority of the Albemarle stock. Subsequent years of sampling will continue to investigate this relationship by obtaining fin clips from the Chowan River (when possible), Roanoke River, and Albemarle Sound.

Out-migrating juvenile American Shad are typically collected at night in the lower Roanoke River near Plymouth, NC from September to November using boat-mounted electrofishing gear. Since 2010, hatchery contribution of the out-migration has been assessed using PBT methods and has ranged from 2.7% (2012) to 44.8% (2014); average hatchery contribution was 21% over the survey period. To identify bottlenecks in passage in the Roanoke River, genetically distinct batches of fry were systematically stocked in the Staunton River upstream of Kerr Reservoir, Gaston Reservoir, Roanoke Rapids Lake, and Weldon. Hatchery fish identified in the out-migration can be conclusively matched to their stocking location; from 2010 through 2015 only hatchery-origin juveniles stocked at Weldon were collected. In 2016, however, six hatchery origin juveniles from the out-migrating sample were determined to be stocked in Roanoke Rapids Lake. Results from experimental fry stockings suggest fry spawned upstream of the reservoirs would contribute to the out-migrating juvenile population at a much lower rate than fry spawned downstream of the reservoirs. Thus, it may not be prudent to pass spawning adults upstream of the reservoirs until methods to improve downstream passage are developed.

5.2.2 Neuse River American Shad Restoration Project

The WRC began an American Shad restoration stocking program in the Neuse River in 2012. The goal of the Neuse River American Shad stocking program is to supplement the wild population by stocking fry produced from one spawning tank of approximately 100 broodfish each year. American Shad broodfish are collected from the Neuse River near Goldsboro, NC and are transported to Edenton National Fish Hatchery where they can spawn and fry are reared for approximately 7 days. American Shad fry are stocked in the Neuse River near Goldsboro, NC. Evaluation of hatchery contribution to the Neuse River American Shad population is conducted using the same PBT methods as described for the Roanoke River restoration program. A total of 4,893,186 American Shad fry have been stocked in the Neuse River at the NC Hwy 117 bridge near Goldsboro, NC since 2012, and hatchery contribution to out-migrating juvenile samples has been low (0–13%;Table 6). Hatchery contribution to returning adults has also been low. In 2016, which was the first-year hatchery fish were potentially available as age-4 adults, only 9 of 411 (4%) adults tested with PBT analysis were of hatchery-origin. Contribution of stocked fish may increase slightly in the future as more hatchery cohorts will move into the spawning population, but it appears the stocking program is contributing very little to the overall American Shad population in the Neuse River.

5.3 FISHERY-DEPENDENT MONITORING

5.3.1 Commercial Fishery

Total Catch, Landings and Effort

American Shad landings data are collected through the North Carolina Trip Ticket Program. The number of participants by gear utilized and the total number of positive trips can be determined. For the Albemarle Sound area, the following assumptions are made: (1) trips landing over 100 pounds of shad are considered directed trips, and (2) the maximum yardage used in directed trips is 1,000 yards. The total yardage for each area is determined by multiplying the number of participants by the maximum yardage per area. The catch-per-yard (CPY) is determined by dividing the number of pounds harvested by the total yardage estimate of gill nets fished and multiplied by 1,000 yards. This will result in the pounds landed per 1,000 yards. Catch estimates for other areas are determined similarly.

Size, Age and Sex Composition of Catch

Commercial landings from all four systems (Albemarle Sound, Tar-Pamlico River, Neuse River and Cape Fear River) are sampled to obtain size, age, sex and repeat spawning information. A target of 200 samples from each system has been in place since 1999. For specific information regarding exact number of samples collected per area, please see previous compliance reports.

5.3.2 Recreational Fishery

Total Catch, Landings and Effort

The North Carolina Fisheries Reform Act of 1997 required the MFC to establish limits on recreational use of commercial fishing gear. An individual holding a Recreational Commercial Gear License (RCGL) can use limited amounts of specified commercial gear to catch seafood for personal consumption or recreational purposes. The holder of the RCGL must comply with the recreational size and creel limits, and RCGL catch cannot be sold. During 2002, DMF began a RCGL survey to estimate the harvest by these license holders. The survey was discontinued in 2009 due to budget reductions.

An annual creel survey occurs on the Roanoke River each year. The survey targets Striped Bass catch and effort but also collects information on American Shad and other species, although American Shad catch is low due to the fishing method.

5.3.2.1 Central Southern Management Area Catch, Landings, and Effort

A rotating creel survey occurred on the Tar, Neuse and Cape Fear rivers prior to 2012. A comprehensive creel survey was initiated in 2012 to identify and estimate recreational American and Hickory Shad effort and catch within these systems, which are collectively known as the Central Southern Management Area (CSMA). The CSMA was originally established for purposes of estuarine striped bass management and includes all Internal Coastal, Joint, and contiguous Inland waters of North Carolina south of a line from Roanoke Marshes Point across to Eagle Nest Bay to the South Carolina state line. The areas surveyed in the CSMA include the Neuse, Trent, Tar/Pamlico, Cape Fear and Pungo rivers. The Neuse River basin drains over 6,200 square miles of land with over 3,000 miles of streams and rivers. The mouth of the main channel is six miles across – the widest in the United States. Over 1.3 million residents reside within this river basin. Major tributaries include Crabtree, Swift, and Contentnea creeks, along with the Eno, Little, and Trent rivers. Survey points included 45 boat ramps and fishing access points from Millburnie Park in East Raleigh to Lee's Landing on Broad Creek. The river was divided in three segments, with all

access points in Goldsboro and above classified as the upper zone, sites on Contentnea Creek and downstream from Goldsboro to Core Creek were considered the middle zone, and those downstream from Core Creek, the lower zone. Prior to 2012, the Neuse River was comprised of only two zones with all sites above Contentnea Creek considered the upper.

The Tar/Pamlico River watershed drains over 5,500 square miles with over 2,400 miles of streams and rivers. Major tributaries include Cokey Swamp, Swift, Fishing, and Tranters creeks, and the 30-mile Pungo River near Belhaven, North Carolina – the main tributary in the lower basin. Access points surveyed on the Tar/Pamlico River include 19 boat ramps and access sites from Battle Park in Rocky Mount to the Quarterdeck Marina in Bath, NC. This system was divided into upper and lower zones, with sites upstream of Greenville, North Carolina considered the upper zone. The Pungo River was surveyed at the Leechville ramp (NC-264 bridge), the Belhaven WRC ramp, Wrights Creek WRC ramp, and Cee Bee Marina on Pungo Creek.

The Cape Fear River is the southernmost river within the CSMA and was included to target shad (American and hickory) beginning in 2013.

5.3.2.1.1 Sampling Procedures

Recreational fishing statistics from the CSMA were calculated through a non-uniform stratified access-point creel survey (Pollock et al. 1994). Site probabilities were set in proportion to the likely use of the site according to time of day, day of the week, and season. Probabilities for this survey were assigned based on observed effort from past years and direct observation by creel clerks. Morning and afternoon periods were assigned unequal probabilities of conducting interviews, with each period representing half a fishing day. A fishing day was defined as the period from one hour after sunrise until one hour after sunset. Monthly sampling periods for each river and zone were stratified accordingly, and all weekend and holiday dates along with two randomly selected weekdays were chosen from each week for sampling.

Tar/Pamlico River anglers in the upper zone were interviewed throughout the spring months (January-May), while anglers in the lower zone were interviewed year-round based on the evidence of a year-round fishery and no seasonal closures. Two creel clerks were assigned to this river, with one surveying the upper zone January through May and one clerk surveying the lower zone from January through December. The three zones within the Neuse River were covered with one creel clerk per zone. The lower zone was surveyed from January to December while middle zone surveys were conducted January-May and the upper zone surveys from February-May. The Pungo River was surveyed throughout the year with one creel clerk.

Returning fishing parties were interviewed by a creel clerk at the selected access point to obtain information regarding party size, effort, total number of fish harvested and/or released, primary fishing method, and location. Harvested fish were identified, counted, measured nearest mm fork length (converted to centerline length and total length for appropriate species), and weighed to the nearest 0.1 kg, while information on discarded fish was obtained from the angler to acquire the number and status of discarded individuals. The age structures were given to the Fisheries Management section of DMF for age determination. Creel clerks also obtained socioeconomic information from the angler, including age, state and county of residence, sex, ethnic background, marital status, number of individuals within household, and trip information and expenditures

5.3.2.1.2 Analysis

Effort and Catch Estimations

Samples were reduced to shad species effort and catch only. Results were stratified by river, access point, and time of day. Catch was defined as the sum of harvested fish and discarded fish. Discarded fish equaled the sum of fish caught in excess of creel limits (over-creel), legal-sized fish caught and released, and sub-legal fish returned to the water. Daily effort and catch for each river were calculated by expanding observed numbers by the sample unit probability (time of day probability divided by access area probability). Total catch estimates for the CSMA and catch estimates for each zone and type of day were calculated based on the Horvitz-Thompson estimator for non-uniform probability sampling as such:

$$C = \sum_{i=1}^{n} (c_i / p_i)$$

where a sample of number (n) units is taken, and the probability of the *i*th unit being in the sample is denoted by P_i (Pollock et al. 1994). Total effort over the CSMA and each individual zone and type of day were estimated in the same fashion, as were other extrapolated data. Approximate standard errors (SE) of the catch and effort estimates within zone and type of day were calculated according to:

$$SE = \sqrt{N^2 \left(\frac{s^2}{n} \right)}$$

where s^2 is the variance of the observations, n is the number of days sampled, and N is the number of days of that type available for sampling (Pollock et al. 1994). Estimated catch per unit effort (CPUE) values were obtained by dividing estimated catch by estimated shad spp. trips as well as angler hours (angler-h) in order to identify trends in fishing pressure and angler success. Size structure of shad spp. in harvests was described for each zone using length-frequency distributions of observed samples. Fishing party characteristics and methods used during shad spp. trips reported by anglers were documented by river and day type. The database was created using Access© and statistical analyses were performed with SAS 9.1©. Beginning in 2012, the Wildlife Resources Commission (WRC) Portal Access To Wildlife Systems (PAWS) was used to house these data and estimate effort and catch. DMF and WRC staff have been verifying calculations to ensure consistency with the previous work.

Angler Demographics and Economic Analysis

The CSMA Creel Survey socioeconomic questionnaire included questions to identify characteristics of the shad spp. angling population. Demographics of anglers were reported according to age, residency, gender, ethnic background, marital status, and expressed as a percentage of the total angling population throughout the CSMA. Mean values were calculated. Results were further grouped by river and day type. Anglers were considered to be local, regional, or out-of-state residents. Local anglers resided within the county, while regional anglers resided elsewhere in North Carolina. The socioeconomic questionnaire also included questions regarding trip length, distance traveled, party size, and expenses on lodging, food, ice, bait, equipment rental, and boat fuel and oil. Mean weighted expenditures per trip were reported by river and day type. Lodging and rental expenses were rarely encountered and therefore are not included within this report. The weighted mean of each expenditure was totaled to provide an average trip cost.

For specific information regarding catch and harvest of American Shad, please see previous compliance reports.

5.4 Bycatch and Discards

Bycatch and discard information are not currently collected on commercial trip tickets. The only mechanism that exists to capture commercial bycatch and discards of American Shad in other fisheries is an observer program conducted by DMF to monitor sea turtle and sturgeon interactions in gill nets, as required under the Incidental Take Permits (ITP) for both. The state-wide sea turtle ITP was approved first in September 2013 followed by the Atlantic Surgeon ITP in July 2014. Prior to the approval of the Sturgeon ITP there was little observer coverage in the Western Albemarle Sound and the rivers when the directed American Shad fishing season occurs because there are very few encounters with sea turtles in these areas during that time of year. Observer coverage has increased in recent years, under the Sturgeon ITP because there have been encounters with sturgeon in these areas and times of year where directed American Shad fishing occurs. Even though observer coverage in the area have increased, gear, area, and seasonal restrictions are thought to have kept shad discards relatively low.

Recreational creel surveys capture discard and release information of American Shad and non-target species, but hook-and-line discard mortality is not estimated. Please see previous compliance reports for this information.

6 FISHERY MANAGEMENT PROGRAM

American Shad are jointly managed by the North Carolina Marine Fisheries Commission (MFC) and the North Carolina Wildlife Resources Commission (WRC). The Division of Marine Fisheries (DMF) implements MFC rules for American Shad in the Atlantic Ocean as well as the Coastal and Joint waters of North Carolina, while the WRC Inland Fisheries Division manages American Shad in the state's recreational fishery in Inland Waters. The known extent of American Shad in North Carolina river systems is shown in Figure 1. This Plan is developed by the American Shad Working Group (ASWG) which consists of biologists from both DMF and WRC. The ASWG meets annually to review sustainability parameters and develop associated actions for the management of American Shad in North Carolina's Inland, Joint, and Coastal waters.

6.1 Commercial Seasonal Restrictions (statewide)

From the 1950s to 1965, a January 1 through May 1 commercial season existed in Coastal Waters, while a January 1 through June 1 season existed in Inland Waters throughout the state. From 1966 through 1994, no seasonal restrictions existed for the commercial fishery. Since 1995, a commercial season of January 1 through April 14 has been in place in Coastal and Joint waters although the fishery is rarely opened prior to February 1 each year. Implementation of this seasonal restriction reduced harvest, as a large portion of the commercial American Shad harvest historically occurred after April 14 and into May.

In 2013, under the first year of the North Carolina American Shad SFP, the commercial seasons were restricted to February 15 through April 14 in all systems except for the Cape Fear River (Table 8). In the Cape Fear River, the commercial season was restricted to February 20 through April 11. Following the 2013 season, thresholds in the Albemarle Sound/Roanoke River system were exceeded for three consecutive years (2011,2012, and 2013) triggering further management action; as a result, the commercial season was reduced to March 3 through March 24 to constrain harvest. This season has remained in place for the Albemarle Sound/Roanoke River system since 2013.

6.2 Commercial Gear Restrictions

Albemarle Sound/Roanoke River

Beginning in 1987, western Albemarle Sound (also referred to as Batchelor Bay) has been closed to the use of gill nets from February through mid-November. While the purpose of the closure is Striped Bass conservation, this measure has also afforded protection for American Shad. From 1988 through 1990, limits of 1,000 to 2,000 yards were implemented for 5.25-inch stretched mesh and larger gill nets in Albemarle Sound, and nets could only be set 5 days per week. In April 2016, the MFC adopted a permanent rule implementing yardage restriction for nets with a mesh length of 4.0-inch stretched mesh or greater, the maximum length of gill net shall not exceed 2,000 yards per vessel in all Internal Coastal Waters regardless of the number of individuals involved.

Since 1998, commercial restrictions in Albemarle Sound have been consistent and include a prohibition on the use of gill nets with a mesh size of 3.5–5.0 inches stretched mesh and a limit of 1,000 yards on the use of 5.25-inch and greater (floating) stretched mesh during the open shad season. When the season closes, these nets are removed from the water. The Albemarle Sound is the only system for which mesh size restrictions and yardage limits exist during the shad season.

The Roanoke River has been closed to the use of anchored gill nets since 1991 and drift gill nets since 1993 which greatly reduced harvest of American Shad.

Tar-Pamlico River, Neuse River

Since 2016 a statewide rule limits the amount of large mesh (4.0-inch and greater) gill net set in internal Coastal waters to no more than 2,000 yards per vessel. Prior to 2016 a former rule was suspended in the majority of internal Coastal waters as a result of sea turtle conservation measures to institute no more than 2,000 yards per vessel of 4.0–6.5-inch gill net in the Tar-Pamlico and Neuse systems. Additionally, in certain sections of the Tar-Pamlico and Neuse rivers, gill nets with a mesh size less than five inches must be attended at all times.

Also, it is unlawful to use gill nets of any mesh size in Joint Fishing Waters from midnight on Friday to midnight on Sunday each week (except for portions of Albemarle and Currituck sounds). These existing gill net measures have likely reduced American Shad harvest since they have remained in effect since the spring 2012 fishing season and will remain in effect indefinitely.

Cape Fear River

There are different gill net restrictions then described above for the Tar-Pamlico and Neuse systems (i.e. mesh lengths, spacing, set/retrieval days and times) for the Cape Fear system. Nets can be set in lengths no greater than 100 yards and must have at least a 25-yard space between each individual length of net. Only single overnight sets are allowed; nets can be set one hour prior to sunset and must be retrieved within one hour of sunrise, with no sets allowed Friday, Saturday or Sunday evenings, and the maximum yardage allowed is a 1,000-yard limit per vessel.

It is unlawful to use gill nets of any mesh size on weekends in the Cape Fear system. This measure will remain in effect indefinitely.

6.3 Recreational Restrictions

Prior to 1995, no recreational restrictions existed. Beginning in 1995, it became unlawful to take American Shad and Hickory Shad by any method except hook-and-line from April 15– December 31 in Coastal Waters. Additionally, from 1995 through 1998, there was a recreational season

during January 1 through April 14. Beginning in 1999, it became unlawful to possess more than 10 American Shad and Hickory Shad in the aggregate in both Coastal and Inland Waters.

In 2013, under the first year of the North Carolina American Shad SFP, a 1-fish American Shad limit within the 10-fish aggregate creel limit was implemented in the Joint and Coastal waters of both the Albemarle Sound/Roanoke River and the Neuse River to complement the existing 1-fish limits implemented by the WRC in the Inland Waters of those systems (Table 9). In the Cape Fear system, both the WRC and DMF implemented a 5-fish American Shad limit within the aggregate 10-fish creel limit in their respective jurisdictional waters to meet the requested Technical Committee reductions. All recreational limits have remained unchanged since 2013. The changes noted here have been implemented via rule in Inland Waters by the WRC and via proclamation in Coastal and Joint Waters by DMF.

Albemarle Sound/Roanoke River

In 2010, the WRC implemented a 1-fish American Shad limit within the 10-fish aggregate creel limit for American and Hickory Shad in the Inland Waters of the Roanoke River. DMF complemented the 1-fish limit in Joint and Coastal Waters in 2013. Due to the size of the Albemarle Sound there is no recreational effort for American Shad in the sound itself, and little to no effort is concentrated in the tributaries of the Albemarle Sound. Recreational effort mainly occurs in the Roanoke River where the focus of angler effort is on Striped Bass and American Shad catch is primarily incidental. In Virginia, the Meherrin, Nottaway, and Blackwater Rivers drain into the Chowan River, which a substantial portion of the spawning stock entering the Albemarle Sound ascend to spawn at the head waters of these rivers. Recreational effort in these Virginia systems is not taken into consideration under this plan. While the impact of recreational harvest in Virginia waters is unknown to the spawning stock entering the Albemarle Sound, it is important to note the creel limit in these rivers remains a 10-fish aggregate for American and Hickory Shad.

Neuse River

A WRC rule implementing a 1-fish limit for American Shad in the Inland Waters of the Neuse River became effective in August 2012. DMF complemented the 1-fish limit in Joint and Coastal Waters in 2013.

Tar-Pamlico River

The 10 American and Hickory Shad aggregate creel limit applies throughout the waters of the Tar-Pamlico River and its tributaries.

Cape Fear River

In November 2013, the WRC implemented a 5-fish limit for American Shad within the 10-fish aggregate creel limit in the Inland Waters of the Cape Fear River. DMF complemented the 5-fish limit in Coastal and Joint Waters in 2013.

Atlantic Ocean

Possession of American Shad is prohibited.

All other internal waters

Recreational harvest of American Shad is very rare in internal waters other than those described above. Current regulations, however, allow for a daily harvest of up to 10 American and Hickory Shad, in the aggregate. This regulation includes North Carolina portions of the Pee Dee River.

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7 TABLES

Table 1. North Carolina Sustainable Fishery Plan for American Shad summary of management thresholds and triggers for 2018-2022.

System	Index	Threshold Value	Time Series	Threshold Level	Management Trigger
Albemarle/ Roanoke	Roanoke River Female CPUE	0.131	2001-2017	25th percentile	3 consecutive years below the threshold; does not trigger management by itself
Albemarle/ Roanoke	Albemarle Sound Female CPUE	0.0277	2000-2017	25th percentile	3 consecutive years below the threshold
Albemarle/ Roanoke	Female Relative *F*	1,740,876	2002-2017	75th percentile	3 consecutive years above the threshold
Tar/Pamlico River	Female CPUE	0.384	2000-2017	25th percentile	3 consecutive years below the threshold
Tar/Pamlico River	Female Relative *F*	20,243	2002-2017	75th percentile	3 consecutive years above the threshold
Neuse River	Female CPUE	0.1275	2000-2017	25th percentile	3 consecutive years below the threshold
Neuse River	Female Relative *F*	198,625	2002-2017	75th percentile	3 consecutive years above the threshold
Cape Fear River	Female CPUE	0.112	2001-2017	25th percentile	3 consecutive years below the threshold
Cape Fear River	Female Relative *F*	186,354	2003-2017	75th percentile	3 consecutive years above the threshold

Table 2. Tar-Pamlico River recreational creel survey estimates for trips targeting Shad species (including hickory and American Shad) in numbers and pounds of fish, 2012-2016.

		Effort				Catch					
		Trips (#)	PSE	Hours	PSE	Harvest (#)	PSE	Pounds (lb)	PSE	Discard (#)	PSE
American	2012	490	37.2	1,399	47.6	899	41.9	1,711	41.9	4,257	33.5
	2013	106	78.4	125	85.1	2,484	23.6	6,841	24.1	7,057	41.4
	2014	20	100.0	3	100.0	162	66.6	0	0.0	1,302	74.6
	2015	54	100.0	54	100.0	1,006	47.7	3,262	47.7	2,784	78.7
	2016	1,347	31.1	5,806	51.4	1,417	37.2	807	0.0	2,820	34.0
Hickory	2012	321	47.0	486	46.6	403	61.0	0	0.0	7,286	38.0
	2013	0	0.0	0	0.0	2,250	58.2	2,970	58.3	5,490	55.3
	2014	190	66.2	248	73.1	341	70.1	0	0.0	2,052	56.6
	2015	107	73.7	398	75.3	864	64.4	1,009	65.1	3,848	57.9
	2016	295	52.5	2,086	68.9	1,409	70.9	0	0.0	11,590	67.2
Shad Species	2012	321	47.0	486	46.6	403	61.0	0	0.0	7,286	38.0
	2013	7,314	17.9	16,455	19.9	234	100.0	0	0.0	6,079	34.0
	2014	2,420	22.9	5,701	35.5	0	0.0	0	0.0	17	100.0
	2015	3,521	24.9	9,200	34.5	0	0.0	0	0.0	2,105	88.2
	2016	3,473	27.1	10,160	38.9	0	0.0	0	0.0	0	0.0

Table 3. Neuse River recreational creel survey estimates for trips targeting Shad species (including hickory and American Shad) in numbers and pounds of fish, 2012-2016.

		Effort				Catch					
		Trips (#)	PSE	Hours	PSE	Harvest (#)	PSE	Pounds (lb)	PSE	Discard (#)	PSE
American	2012	8,268	34.7	17,528	29.0	354	104.2	2,141	38.2	511	47.0
	2013	395	28.4	869	27.2	1,384	47.2	3,197	48.7	2,699	62.2
	2014	426	70.1	1,181	82.1	416	51.3	0	0.0	964	61.4
	2015	344	42.5	1,135	43.4	94	76.1	0	0.0	132	46.3
	2016	451	56.2	1,481	35.1	252	47.3	0	0.0	1,389	60.6
Hickory	2012	11,659	28.3	23,157	26.1	10,672	27.4	11,998	28.5	29,041	39.8
	2013	570	39.8	1,517	43.4	12,810	28.4	13,030	26.2	14,138	29.6
	2014	181	65.6	886	60.7	14,557	44.3	16,492	47.0	27,100	39.4
	2015	300	50.7	1,259	48.8	10,418	28.5	10,213	31.5	12,186	42.6
	2016	225	68.7	415	78.4	10,851	36.6	11,140	36.4	29,276	58.0
Shad Species	2012	11,659	28.3	23,157	26.1	10,672	27.4	11,998	28.5	29,041	39.8
	2013	14,840	14.9	31,249	19.1	0	0.0	0	0.0	765	57.7
	2014	12,779	22.0	30,532	30.5	0	0.0	0	0.0	136	100.0
	2015	6,775	21.2	15,393	30.2	0	0.0	0	0.0	136	75.3
	2016	8,898	18.3	25,741	28.1	0	0.0	0	0.0	899	61.8

Table 4. Cape Fear River recreational creel survey estimates for trips targeting Shad species (including hickory and American Shad) in numbers and pounds of fish, 2013-2016.

		Effort				Catch					
		Trips (#)	PSE	Hours	PSE	Harvest (#)	PSE	Pounds (lb)	PSE	Discard (#)	PSE
American	2013	0	0.0	0	0.0	20,243	21.1	46,522	21.0	6,438	73.7
	2014	114	84.5	188	88.0	7,234	25.3	23,027	25.6	0	0.0
	2015	0	0.0	0	0.0	4,136	32.7	11,502	32.2	6,125	39.3
	2016	4,550	15.0	18,820	22.5	10,265	22.1	28,427	22.8	10,746	28.6
Hickory	2013	0	0.0	0	0.0	13	0.0	0	0.0	135	100.0
	2014	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
	2015	0	0.0	0	0.0	12	100.0	0	0.0	0	0.0
	2016	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Shad Species	2013	12,334	22.3	54,807	22.1	2,050	44.8	4,029	44.8	26,457	38.5
	2014	2,820	17.9	11,762	22.2	174	84.0	0	0.0	10,300	56.4
	2015	3,414	22.2	13,933	26.3	0	0.0	0	0.0	264	71.7
	2016	582	60.7	3,681	72.0	0	0.0	0	0.0	648	79.7

Table 5. American Shad fry stocked into the Roanoke River Basin from 1998–2016. Stockings downstream of the lower-most dam occur at Weldon, NC, stockings upstream of John H. Kerr Dam occur at either Altavista or Clover Landing, VA, stockings upstream of Gaston Dam occur at Bracey, VA, and stockings upstream of Roanoke Rapids Dam occur at Roanoke Rapids, NC. Hatchery evaluation techniques have transitioned from Oxytetracyclene (OTC) marks to parentage-based tagging methods using genetic microsatellite markers.

Year	Total Fry Stocked (millions)	Fry Totals (millions) by Stocking Location					Hatchery Evaluation Technique	Age Class at-large
		Weldon, NC	Altavista, VA	Clover Landing, VA	Bracey, VA	Roanoke Rapids, NC		
1998	0.5	0.5	-	-	-	-	OTC	18
1999	0.3	0.3	-	-	-	-	OTC	17
2000	0.8	0.8	-	-	-	-	OTC	16
2001	2.1	2.1	-	-	-	-	OTC	15
2002	0.8	0.8	-	-	-	-	OTC	14
2003	2.3	1.2	1.1	-	-	-	OTC	13
2004	2.3	1.2	1.1	-	-	-	OTC	12
2005	2.5	1.3	1.2	-	-	-	OTC	11
2006	2.4	1.4	1.0	-	-	-	OTC	10
2007	4.3	2.2	2.1	-	-	-	OTC	9
2008	8.2	4.3	3.9	-	-	-	OTC	8
2009	8.6	4.5	4.1	-	-	-	OTC	7
2010	7.8	6.9	0.9	-	-	-	OTC/PBT	6
2011	4.4	4.0	-	0.4	-	-	OTC/PBT	5
2012	4.8	3.8	-	1.0	-	-	OTC/PBT	4
2013	4.5	2.4	-	1.3	0.8	-	PBT	3
2014	7.5	3.5	-	1.4	2.6	-	PBT	2
2015	4.8	2.6	-	0.8	1.5	-	PBT	1
2016	3.8	1.3	-	-	-	2.5	PBT	0
Total	72.7	45.1	15.4	4.9	4.9	2.5		

Table 6. American Shad fry stocked into the Neuse River Basin at NC Highway 117 bridge near Goldsboro and juvenile hatchery contribution based on parentage-based tagging analysis, 2012–2016.

Year	Fry Stocked	Out-migrating Juvenile Hatchery Contribution
2012	573,582	2%
2013	1,184,303	6%
2014	1,377,375	13%
2015	708,045	1%
2016	609,720	0%*
2017	440,161	NA
Total	4,893,196	

*Sample size was only 7 fish

Table 7. American Shad movement study results in numbers of fish tagged in the Albemarle Sound and numbers of tagged fish detected on spawning runs in the Roanoke and Chowan River from 2013-2017.

			Spawning Run	
Year	Tagged	Detected	Roanoke	Chowan
2013	7	5		1
2014	53	35	2	8
2016	56	29		2
2017	75	58	2	22

Table 8. Commercial harvest seasons for American Shad 2012-2017.

System	**2012***	**2013**	**2014**	**2015**	**2016**	**2017**
Albemarle Sound Roanoke River	2/1 - 4/14	2/15 - 4/14	3/3 - 3/24	3/3 - 3/24	3/3 - 3/24	3/3 - 3/24
Tar-Pamlico	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14
Neuse	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14	2/1 - 4/14
Cape Fear	2/1 - 4/14	2/20 - 4/14	2/20 - 4/14	2/20 - 4/14	2/20 - 4/14	2/20 - 4/14
All Other Areas	2/1 – 4/14	2/15 – 4/14	2/15 – 4/14	2/15 – 4/14	2/15 – 4/14	2/1 – 4/14

*last year prior to SFP implementation

Table 9. Recreational creel restrictions for American Shad 2012-2017. All numbers represent limits within an overall 10-fish aggregate creel limit for American and Hickory Shad combined.

System	2012*	2013	2014	2015	2016	2017
Albemarle Sound Roanoke River	1-fish IW 10-fish CJW*	1-fish	1-fish	1-fish	1-fish	1-fish
Tar-Pamlico	10-fish	10-fish	10-fish	10-fish	10-fish	10-fish
Neuse	1-fish IW 10-fish CJW*	1-fish	1-fish	1-fish	1-fish	1-fish
Cape Fear	10-fish	5-fish	5-fish	5-fish	5-fish	5-fish
All Other Areas	10-fish	10-fish	10-fish	10-fish	10-fish	10-fish

*last year prior to SFP implementation; IW=Inland Waters; CJW = Coastal and Joint Waters, blank=all waters

8 FIGURES

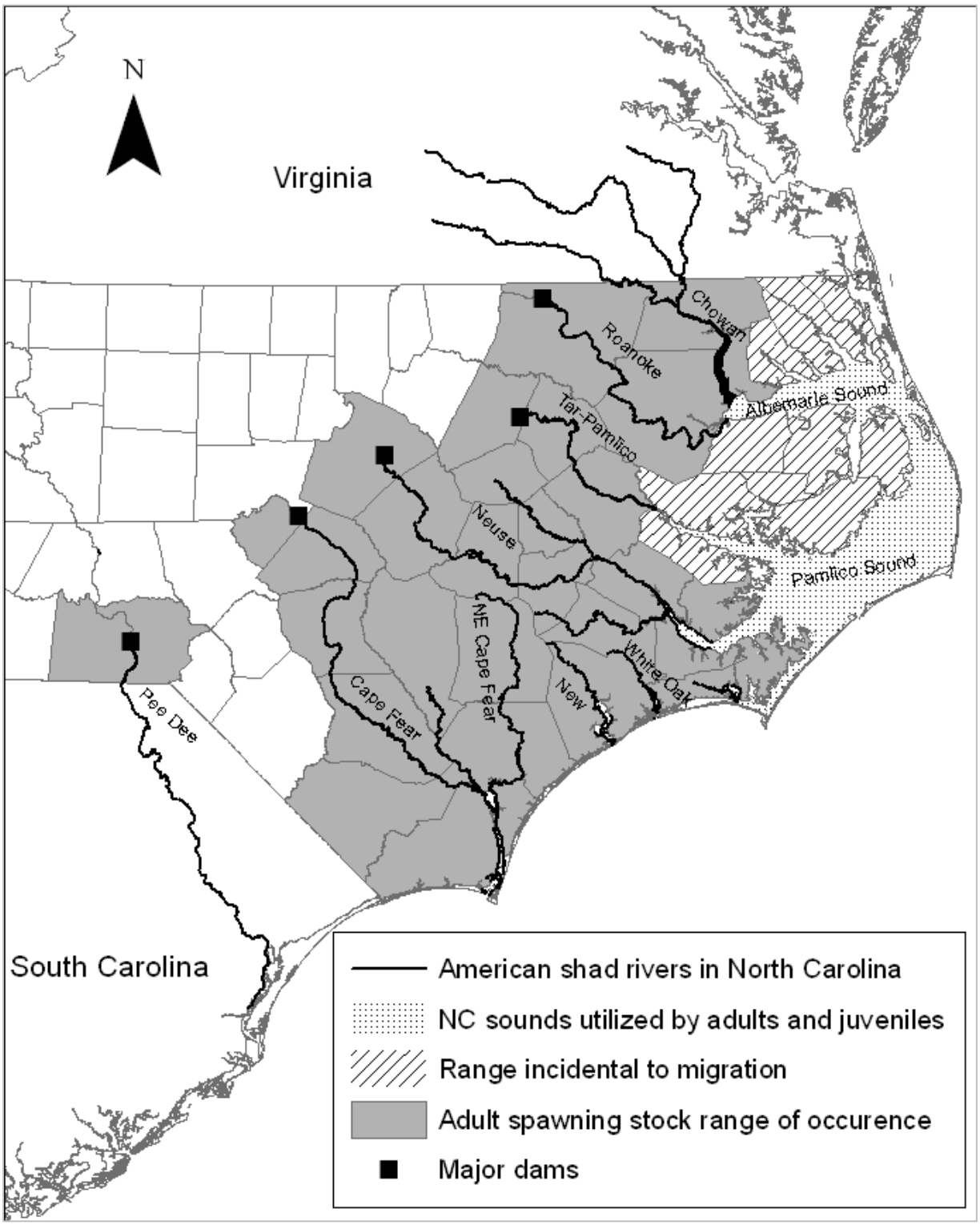


Figure 1. North Carolina river systems depicting the extent of American Shad occurrence and habitat use.

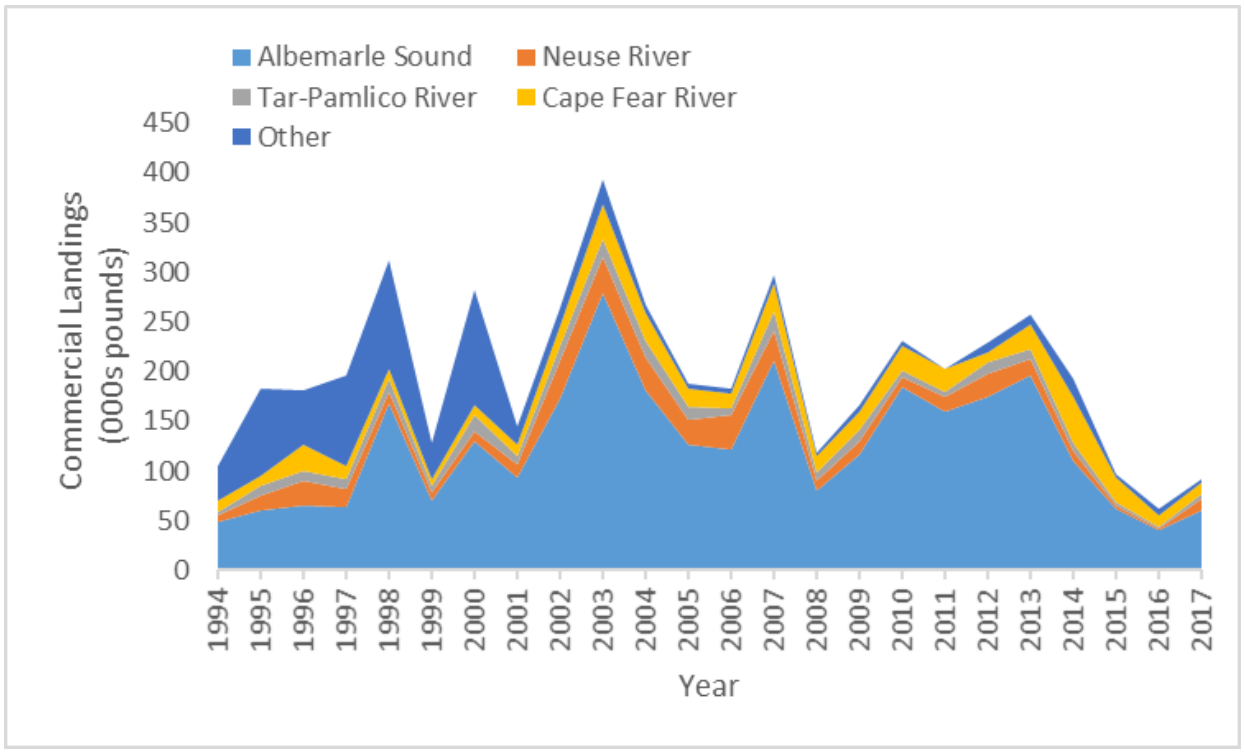


Figure 2. Commercial landings of American Shad in North Carolina by water body, 1994–2017.

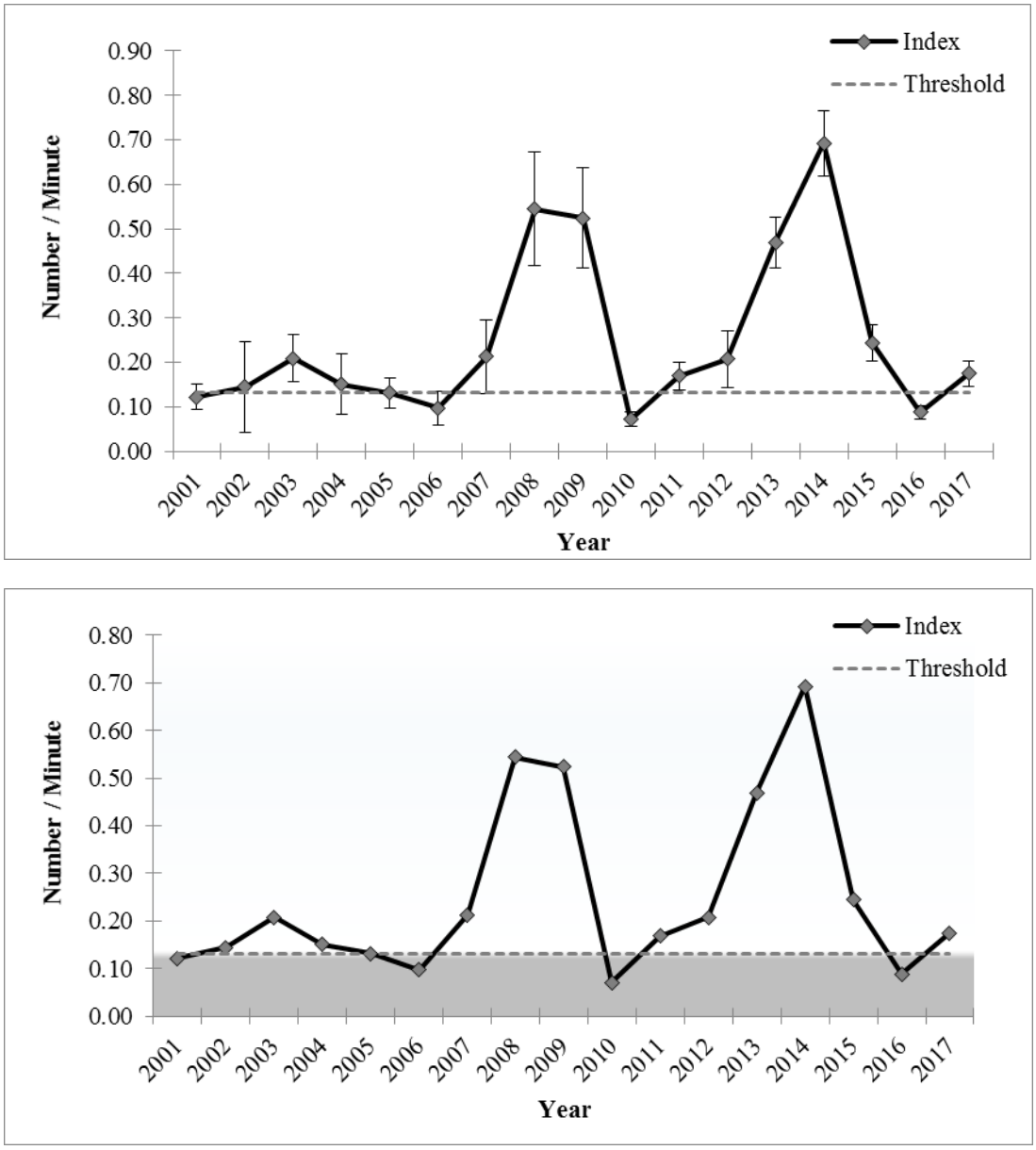


Figure 3. Female index from electrofishing survey (March–May) for Roanoke River, 2001-2017. Threshold represents 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).

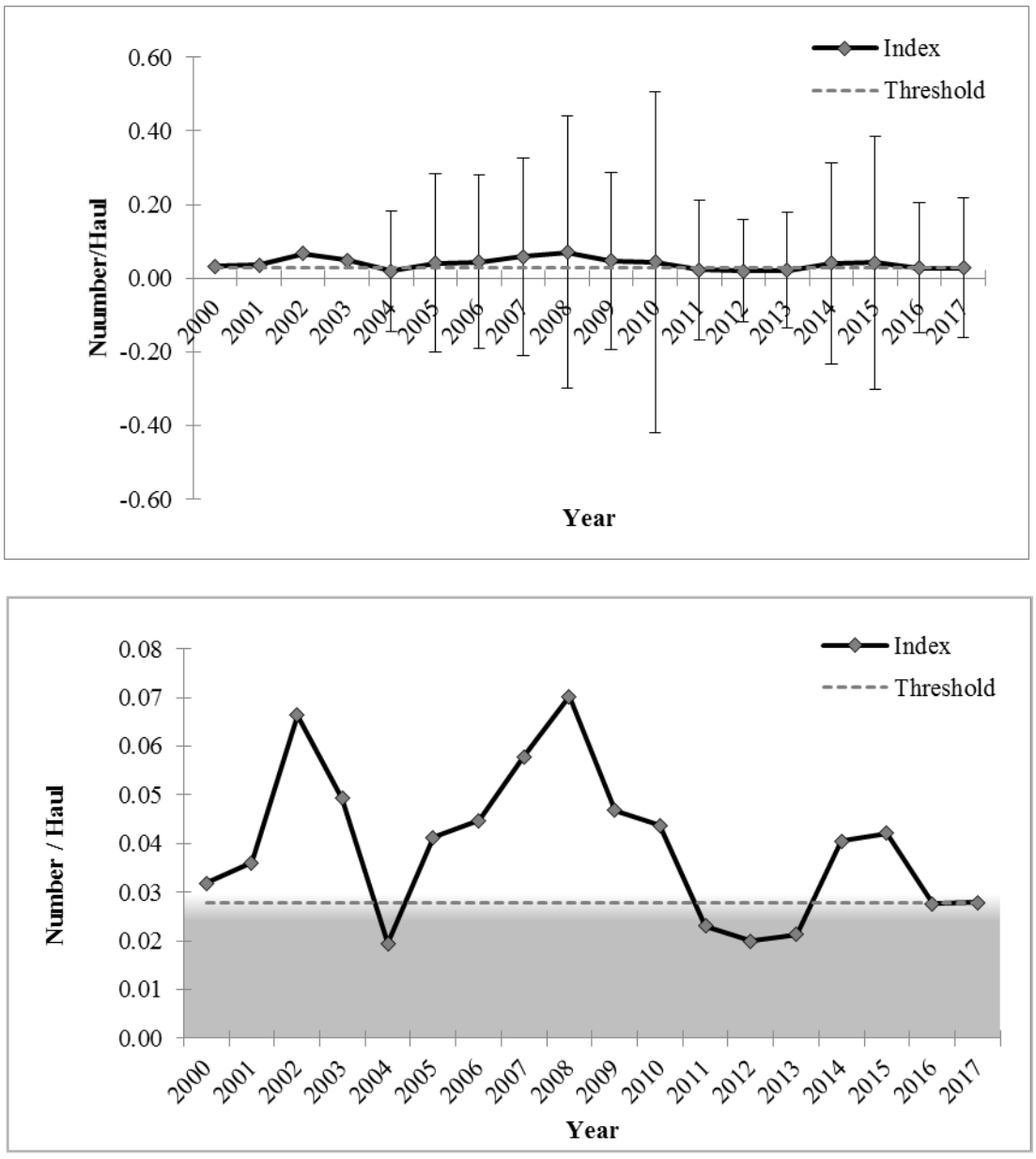
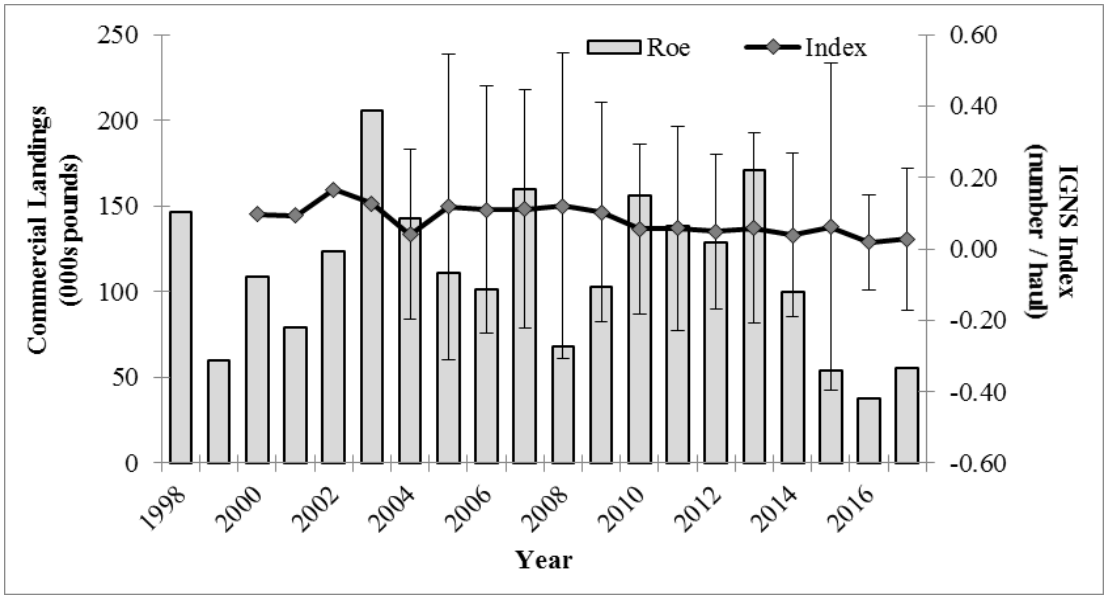


Figure 4. Female index from IGNS (January–May) for Albemarle Sound, 2000–2017. Threshold represents 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).



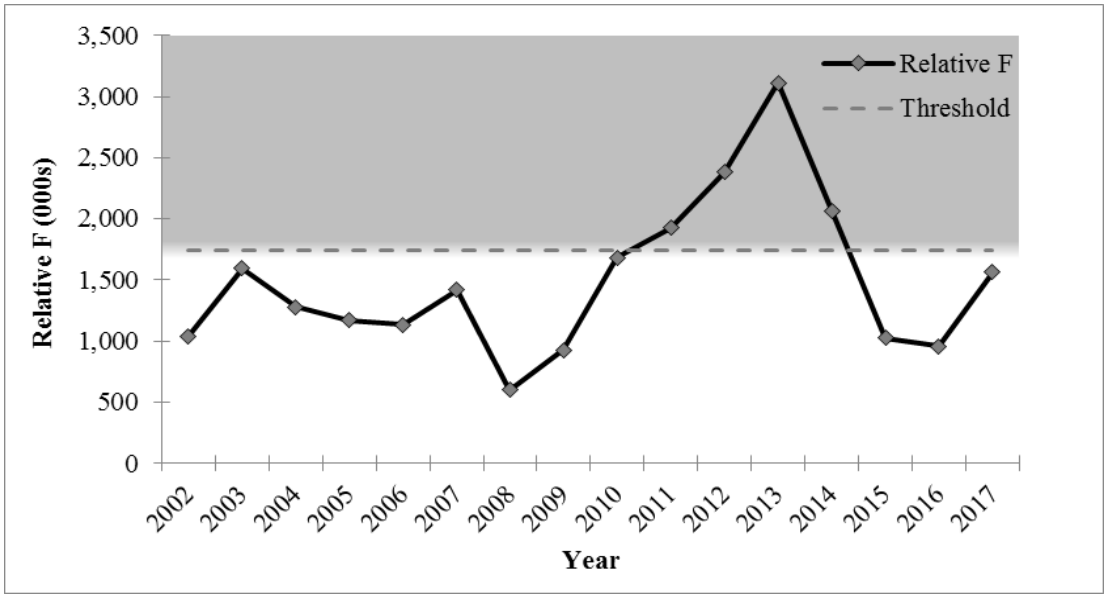


Figure 5**.** Commercial gill net landings of roes (1998-2013 February–April, 2014-2017 March) compared to the female IGNS index (5.0, 5.5 and 6.0-inch mesh sizes, 1998-2013 February–April, 2014-2017 March; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for Albemarle Sound, 2002–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.

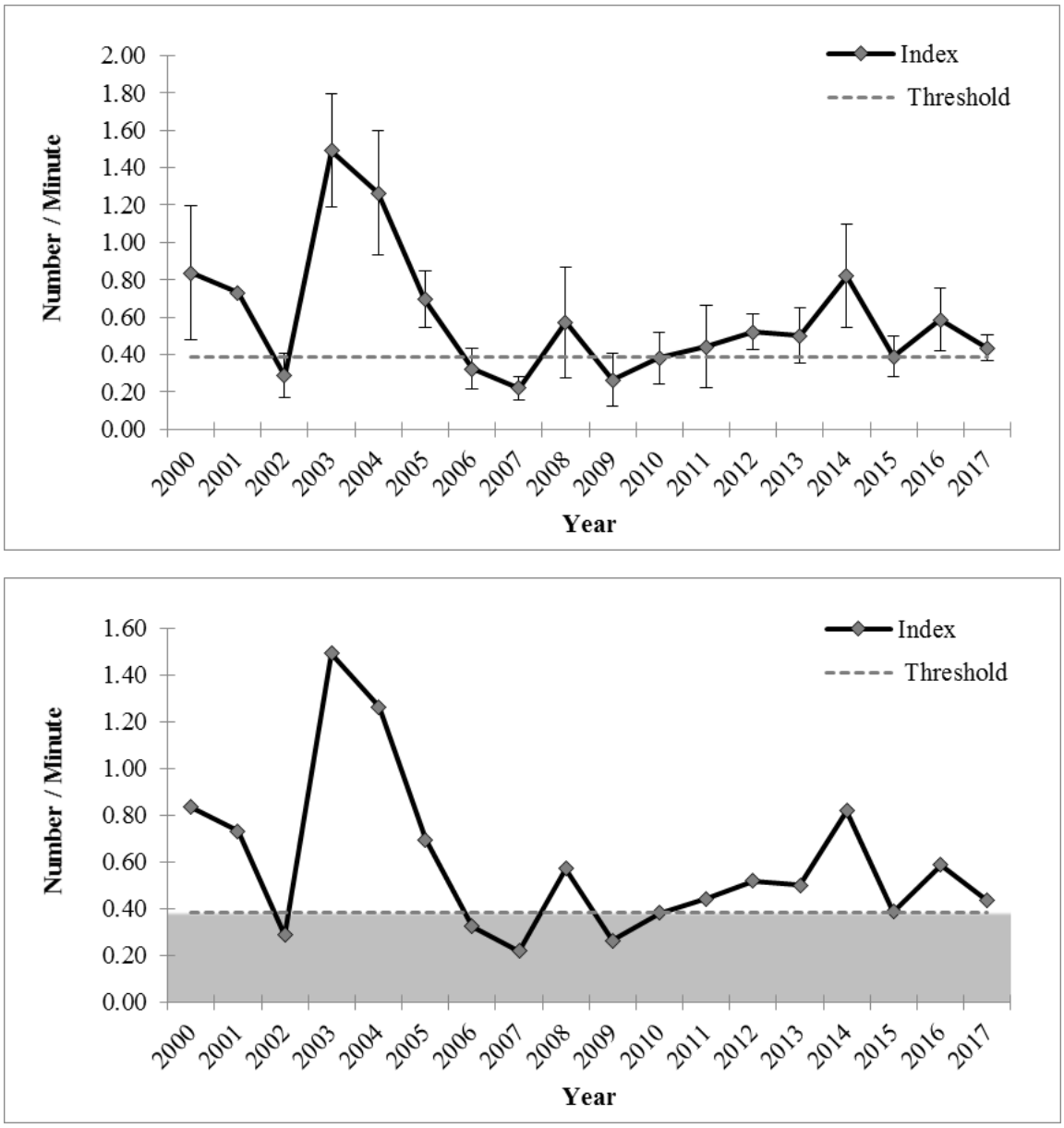


Figure 6. Female electrofishing index (March–May) for the Tar-Pamlico River, 2000–2017. The threshold represents the 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).

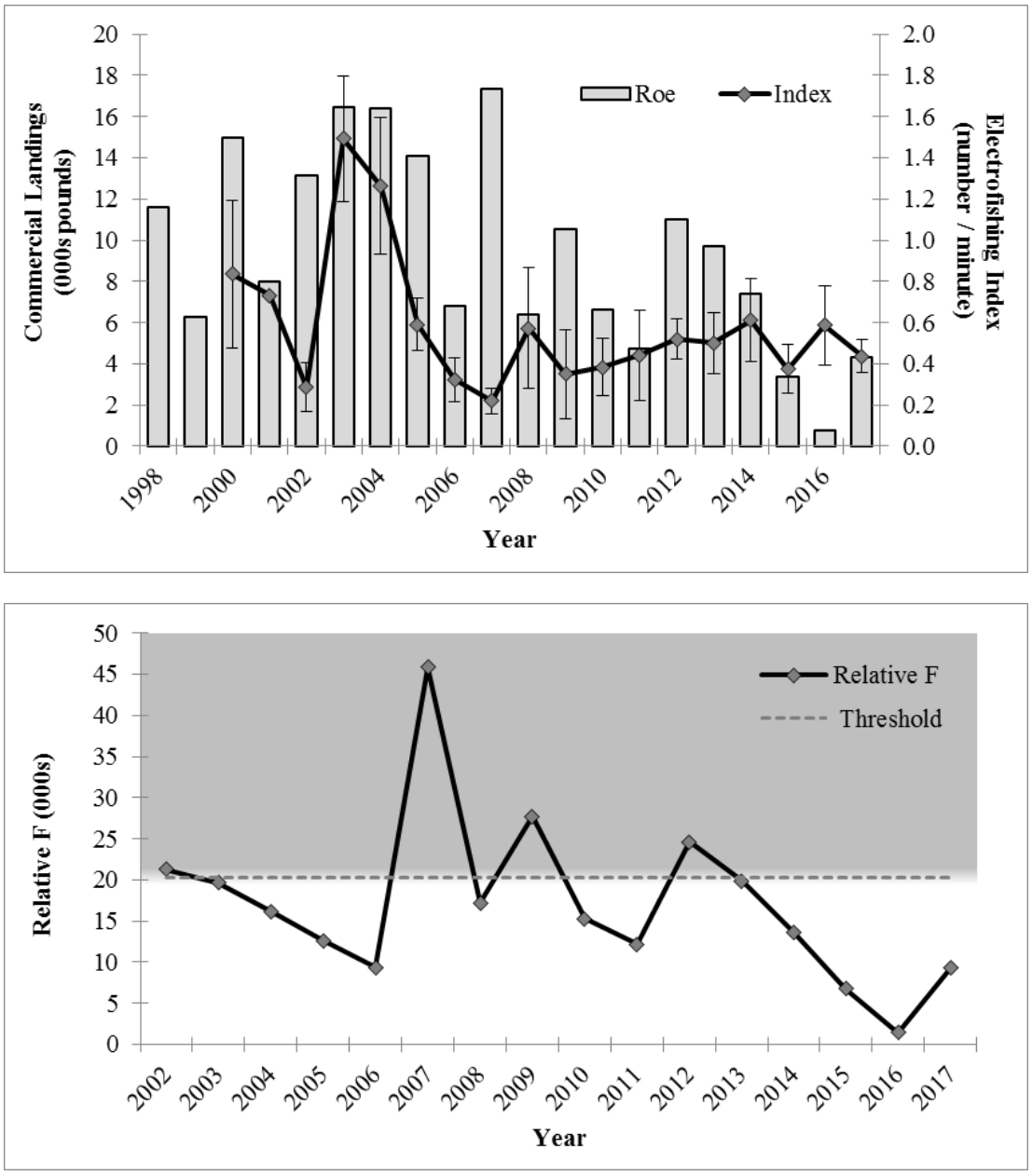


Figure 7. Commercial landings of roes by all gear types (March-April) compared to the female electrofishing index (March–April, 2000-2017; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for the Tar-Pamlico River, 2002–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.

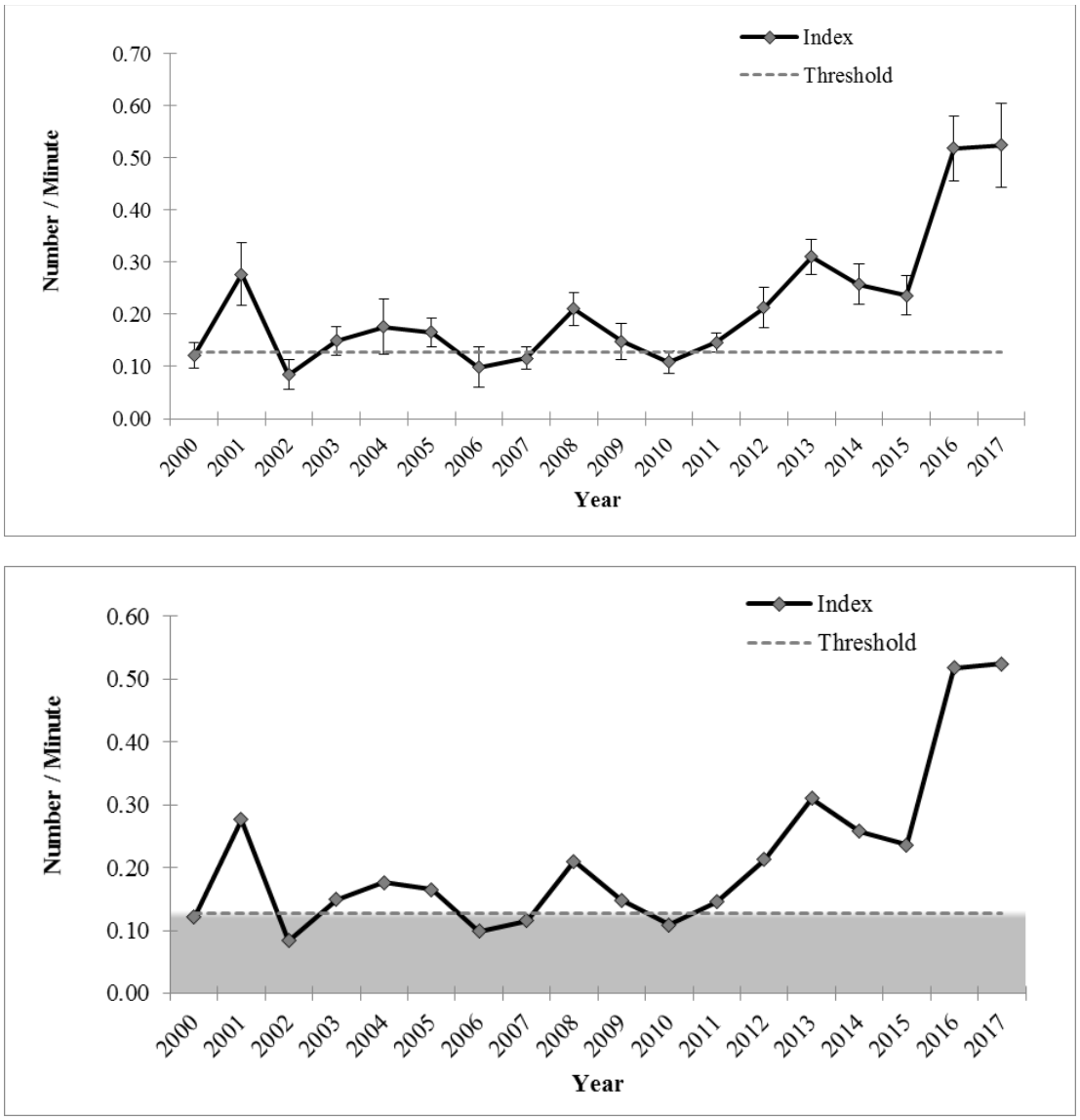


Figure 8. Female electrofishing index (March–May) for the Neuse River, 2000–2017. The threshold represents the 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).

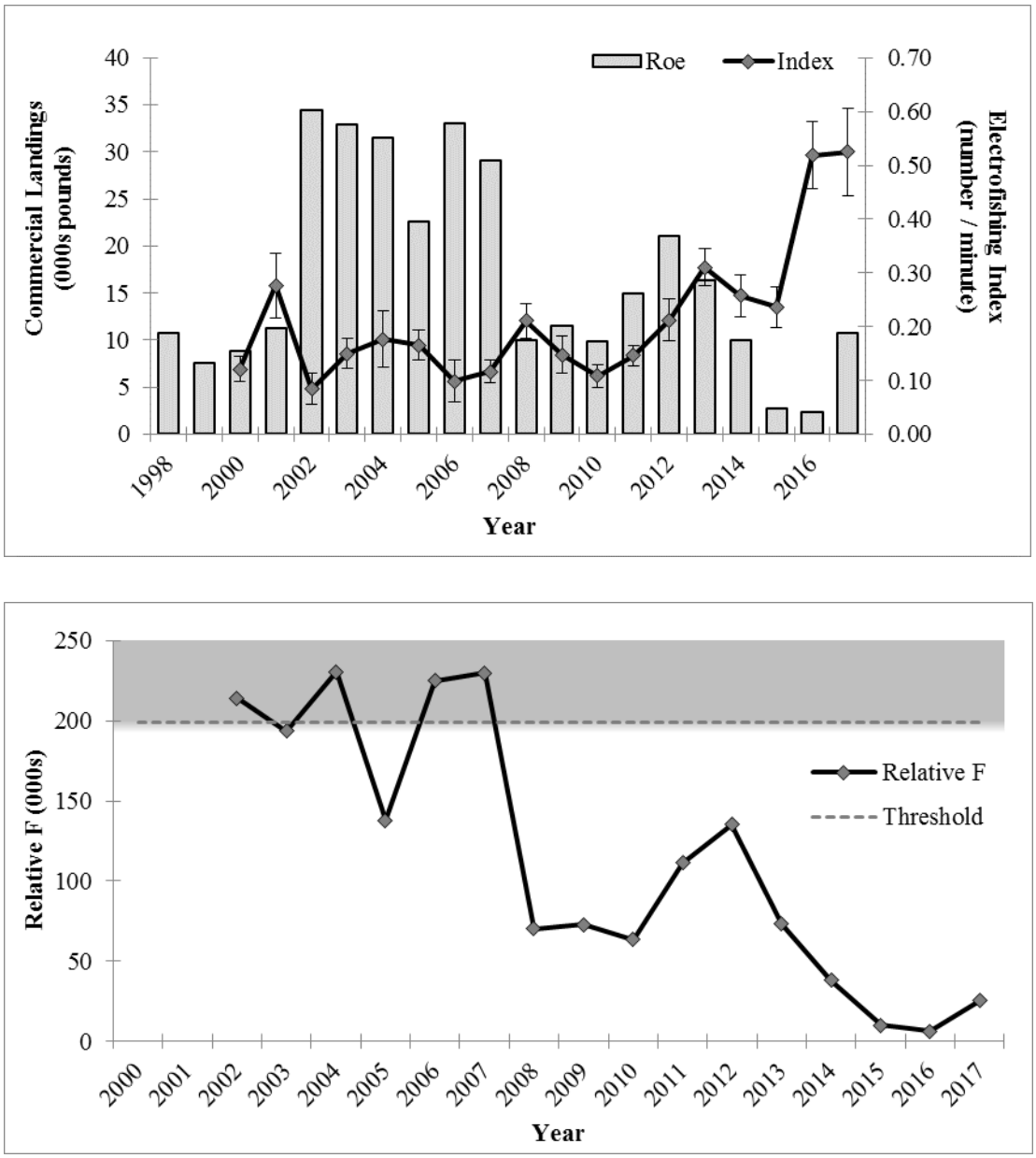


Figure 9. Commercial landings of roes by all gear types (March-April) compared to the female electrofishing index (March-April, 2000-2017; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for the Neuse River, 2002–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.

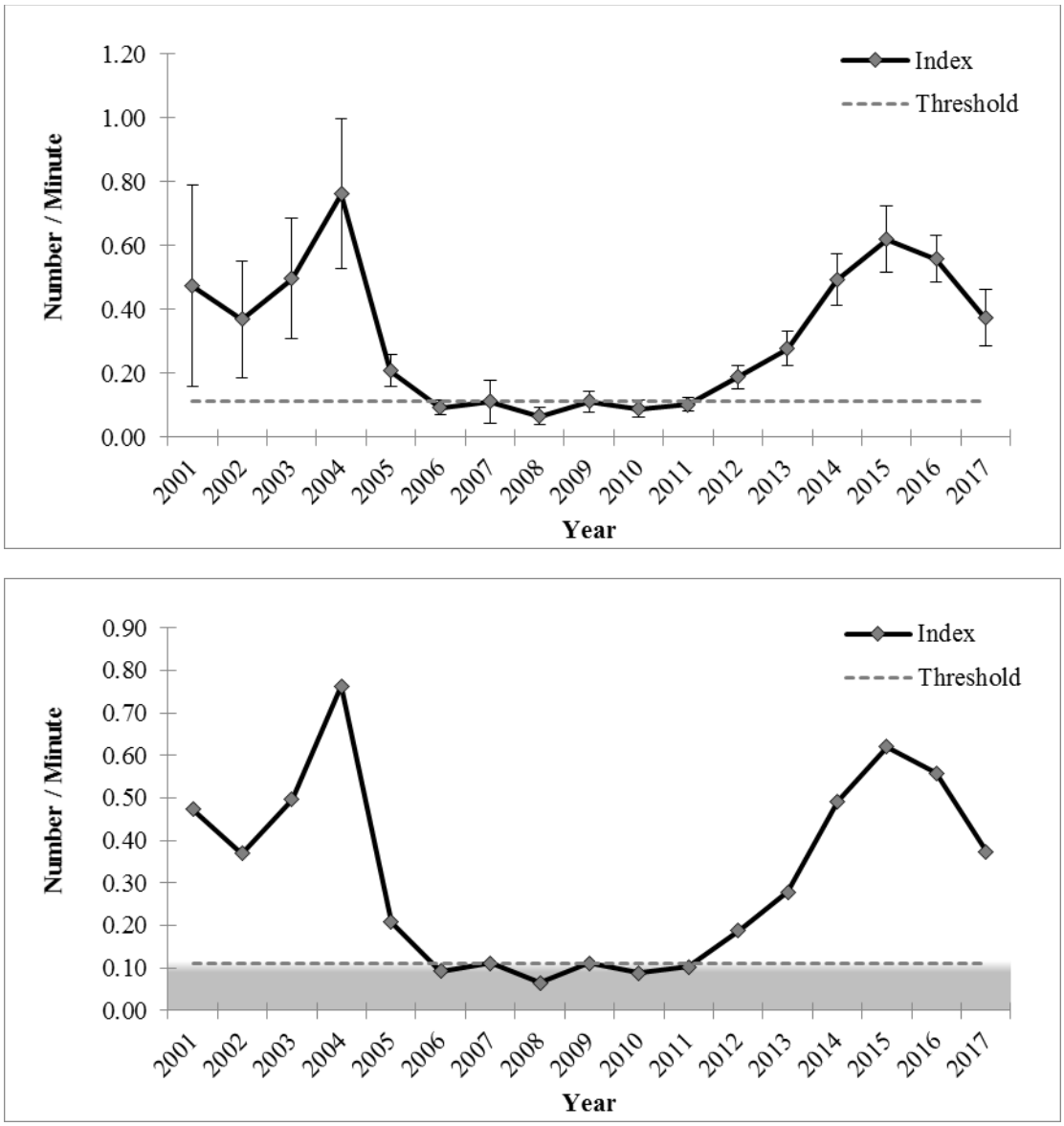


Figure 10. Female electrofishing index (March–May) for the Cape Fear River, 2001–2017. The threshold represents the 25th percentile (where 75% of all values are greater). Error bars represent ±1 standard deviation (top graph). Values in gray are below the threshold (bottom graph).

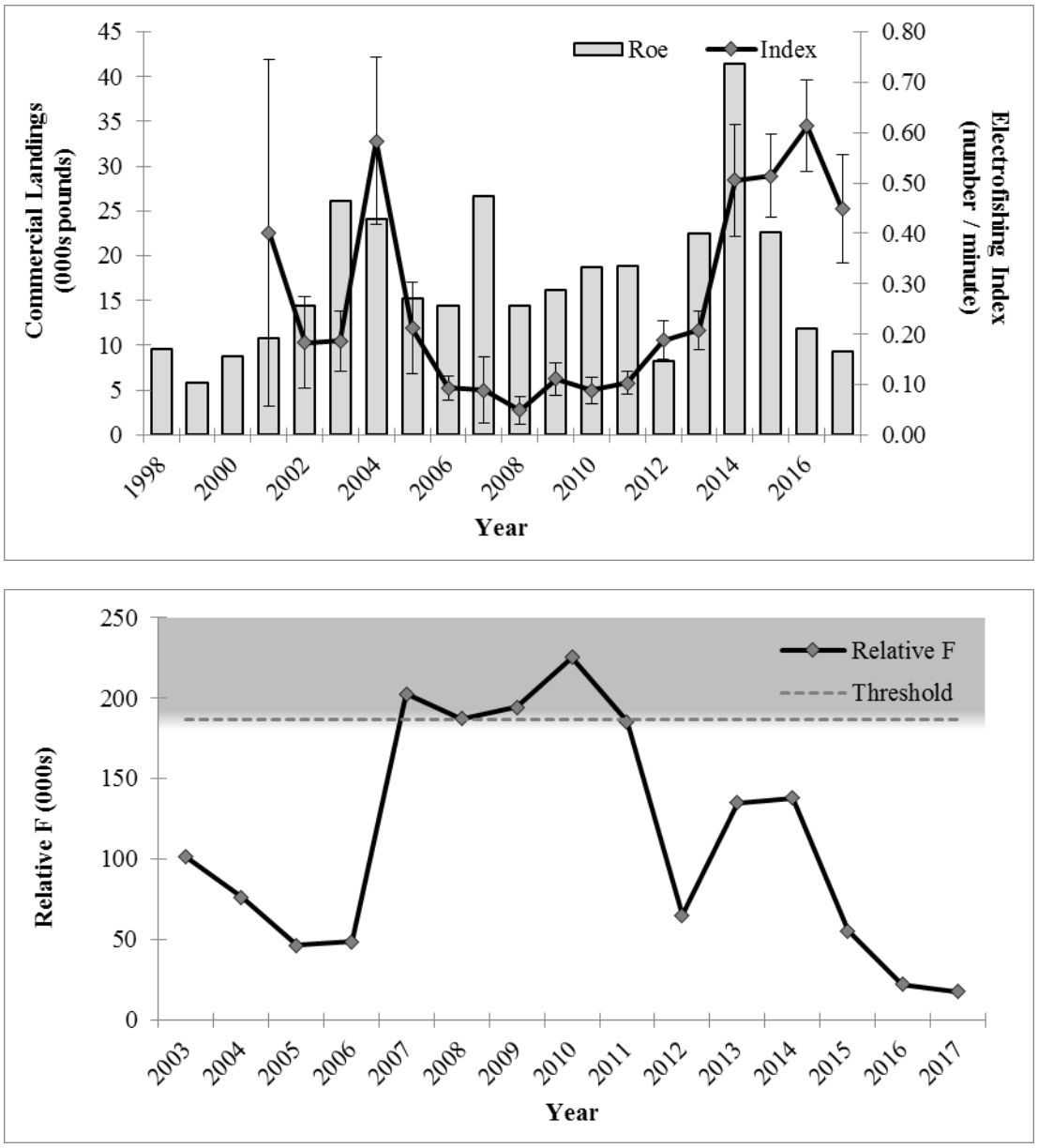


Figure 11. Commercial landings of roes by all gear types (March-April) compared to the female electrofishing index (March-April; top graph) and annual estimates of female relative *F* based on these data (bottom graph) for the Cape Fear River, 2003–2017. The error bars in the top graph represent ±1 standard deviation. The threshold represents the 75th percentile (where 25% of all values are greater), values in gray are exceeding the threshold.