# ASSESSING CRITICAL HABITAT, MOVEMENT PATTERNS, AND SPAWNING GROUNDS OF ANADROMOUS FISHES IN THE TAR/PAMLICO, NEUSE, AND CAPE FEAR RIVERS USING TELEMETRY TAGGING TECHNIQUES

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# COASTAL RECREATIONAL FISHING LICENSE
# FINAL REPORT*

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**Grant Title:** Assessing critical habitat, movement patterns, and spawning grounds of anadromous fishes in the Tar/Pamlico, Neuse, and Cape Fear rivers using telemetry tagging techniques.

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**Final Project Summary:** An acoustic telemetry study was conducted and completed in the Tar/Pamlico, Neuse, and Cape Fear rivers. This study identified and mapped spawning grounds, spawning habitat, and movement patterns of American shad and striped bass in these systems. Important areas of habitat for both residency and spawning which were not previously understood were identified in these river systems and their major tributaries.

## ABSTRACT

An acoustic telemetry study was conducted in the Tar/Pamlico and Neuse rivers, as well as the Cape Fear River basin to identify and map spawning grounds, spawning habitat, and movement patterns of American shad and striped bass. Acoustic receivers (hydrophones) were deployed throughout the inland and coastal portions of the Tar/Pamlico, Pungo, Neuse, Cape Fear, Black, and Northeast Cape Fear rivers in areas suspected or known to be habitat for American shad and striped bass. When possible, attempts were made to deploy receivers, or groups of receivers, at locations that would cover the entire width of the waterway to ensure up or down river migration and movement out of the study area was detected. In 2014, ten American shad were tagged on the Neuse River, nine were tagged in the Tar/Pamlico River, and 19 in the Northeast Cape Fear River. In 2015, 17 American shad were tagged in the Neuse River, 18 were tagged in the Tar/Pamlico River, and 10 in the Black River. In 2016, 21 American shad were tagged in the Northeast Cape Fear River. By 2014, an existing 128 striped bass had been released with acoustic transmitters in the Cape Fear River. In 2014, 20 striped bass were tagged in the Neuse River, 19 were tagged in the Tar/Pamlico River, and 39 in the Cape Fear River. In 2015, 41 striped bass were tagged in the Neuse River, 40 were tagged in the Tar/Pamlico River, and 54 in the Cape Fear River basin. In 2016, 41 striped bass were tagged in the Cape Fear River basin. Attempts were made to download receivers monthly during the project period. A total of 28 American shad and 115 striped bass tagged during this project were detected between March 2014 and August 2017 in the Tar/Pamlico and Neuse rivers. A total of 29 American shad and 249 striped bass were detected between January 2013 and August 2016 in the Cape Fear River. American shad were only detected during the spring season of the year they were tagged, and none were detected in multiple years. No American shad were detected in the lower Neuse River and American shad were only detected in the lower Tar/Pamlico River in 2014. American shad were detected during the spring spawning season at the upper stations of the Black and Northeast Cape Fear rivers. Striped bass in the Tar/Pamlico and Neuse rivers were detected moving up river during the spring and were generally detected in the middle portions of these rivers during the rest of the year. Striped bass in the Cape Fear River were generally detected at a core region near downtown Wilmington during all seasons. Many striped bass in the Cape Fear system showed fidelity to and made repeated spring migrations each year up the Northeast and Cape Fear rivers, suggesting spawning migrations or behavioral contingents. Minimal movements of striped bass between rivers or out of the systems were detected. In the Neuse, Pamlico, and Cape Fear rivers, the percentage of fish detected declined quickly in the season following tagging indicating high mortality or undetected migration out of the system.

## ACKNOWLEDGEMENTS

This project was conducted under the Coastal Recreational Fishing License statute (N.C.G.S. § 113-175) and funded through the North Carolina Marine Resources Fund. We would like to acknowledge the work and thank the many NCDMF and WRC staff that assisted in planning, construction, deployment of tags, and receiver maintenance and downloads during the course of this project.

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# INTRODUCTION

Anadromous fishes have historically supported thriving fisheries in North Carolina. Several river systems in North Carolina were noted to have large migrating populations of anadromous fishes in the 1800s through the early 1900s (Yarrow 1874; Earl 1887; Walburg and Nichols 1967). In the late 1800s, the Neuse River was considered the most important American shad river between the St. John's River in Florida and the James River in Virginia (Walburg and Nichols 1967). The Cape Fear River once supported thriving stocks of anadromous fishes including American shad and striped bass (Yarrow 1874; Earl 1887). Over the years anadromous fish stocks have been significantly impacted by overfishing, loss of habitat, declining water quality, and blockage of upstream spawning migrations (ASMFC 2007; Limburg and Waldman 2009). In a previous attempt to protect critical spawning habitats for anadromous fishes, the North Carolina Division of Marine Fisheries (NCDMF) began a study in 1974 to document Anadromous Fish Spawning Areas (AFSA) throughout North Carolina. The study found AFSA to occur in the Tar/Pamlico, Neuse, and Cape Fear rivers. Areas on the Tar/Pamlico River were identified from Washington, NC to as far upstream as Rocky Mount, NC. On the Neuse River, AFSA were found from New Bern, NC to as far upstream as Raleigh, NC. Cape Fear River AFSA starts below the mouth of Town Creek and continues upstream as far as Lillington, NC (Sholar 1977). Subsequent studies have either collected eggs and larvae (Burdick and Hightower 2006; Smith 2006, 2009) or tagged adult fish (Beasley and Hightower 2000; Bowman and Hightower 2001; Ashley and Rachels 2006) to show evidence of spawning and/or spawning migrations. Specific locations of spawning aggregations and the habitat and environmental characteristics where they occur have not been well documented in these systems. The location of prime spawning areas and habitats should be identified so future stock enhancement efforts can focus on areas that will provide the greatest benefit to protecting and rebuilding the stock (Deaton et al. 2010).

Coast wide, American shad stocks have been in decline for the last century (Freeman et al. 2003; Limburg et al. 2003; Burdick and Hightower 2006) and the 2007 stock assessment accepted by the Atlantic States Marine Fisheries Commission (ASMFC) concluded American shad stocks are at all-time lows and do not appear to be recovering (ASMFC 2010). Research needs specific to North Carolina included: 1) spawning area surveys are needed in all river systems and 2) evaluate the effectiveness of the fishery-independent electrofishing survey used by the North Carolina Wildlife Resources Commission (NCWRC) to monitor relative abundance and describe the spawning stock of American shad (ASMFC 2007). This project will allow NCDMF and NCWRC to map American shad migrations and spawning grounds on a finer scale than previously attempted in the Tar/Pamlico, Neuse, and Cape Fear rivers. Secondarily, this will also allow NCWRC to evaluate the effectiveness of their spawning ground survey.

Historical conditions of the striped bass stock in the Central Southern Management Area (CSMA) are not well documented. Currently, the status of the CSMA striped bass stock is "*unknown*" due to insufficient data for a stock assessment. One of the major concerns about the striped bass stock in the CSMA is the absence of older fish (age 6+) in NCWRC spawning ground surveys and NCDMF fishery-independent surveys (NCDMF and NCWRC 2004, 2011). During development of Amendment 1 to the Estuarine Striped Bass Fishery Management Plan, NCDMF staff assisted with Fishery Resource Grant (FRG) 11-FEG-01 titled "*Exploratory Sampling of Older Striped Bass in the Pamlico River*". This FRG used large mesh (9" and 10" stretch mesh) gill nets to sample for older (age 6+) striped bass from December 2011-February 2012. During 13 sampling trips 17 striped bass were caught with an average length of 45.4 inches (Cuthrell 2012). This FRG

showed older (age 6+) striped bass utilize these waters but are not regularly sampled by existing NCDMF or NCWRC surveys. Tagging studies by Marshall (1977), Hawkins (1980), and Winslow et al. (1983) indicated striped bass in the Tar/Pamlico, Neuse, and Cape Fear rivers are riverine endemic. Understanding the dynamics of these fish in the CSMA is crucial to developing effective management strategies and providing needed data for a stock assessment.

This project will allow NCDMF and NCWRC to map striped bass spawning grounds on a fine scale, determine habitat use during non-spawning periods, determine the residency patterns of older (age 6+) striped bass, and improve fishery-independent surveys in the CSMA.

Preliminary studies in the Cape Fear River were conducted in the winter of 2012 when 20 American shad and 20 striped bass were tagged. Long distance migrations were noted up the Cape Fear, Northeast Cape Fear, and Black rivers for American shad and striped bass, which may be indicative of spawning runs in these systems. The reported upstream migrations were minimal since it appeared some fish went above the current receiver array during a period when spawning was likely to occur. The Northeast Cape Fear and Black rivers do not have migration blockages like the main stem of the Cape Fear River which has low head dams preventing migration. Yet populations of anadromous fishes do not seem to be rebuilding in the Northeast Cape Fear and Black rivers despite past management efforts. Once spawning areas are located in these systems, the spawning and juvenile nursery areas can be analyzed to determine if these areas meet minimal water quality and habitat parameter requirements for sustaining populations. Data collected from this study will be combined with a telemetry study being conducted by the US Geological Survey (USGS) on the main stem of the Cape Fear River tracking the migration and habitat usage of American shad and striped bass above Lock and Dam #1. Combined, the two studies will provide a comprehensive survey of spawning areas in the Cape Fear River system.

This project will improve the current knowledge of American shad and striped bass spawning locations, spawning habitat, and movements in the Tar/Pamlico, Neuse, and Cape Fear river systems. This project will also provide data that can be used to evaluate and improve current NCDMF and NCWRC fishery-independent surveys by providing information on spatial and temporal movement and migration patterns.

## OBJECTIVES

1. Acoustically tag American shad and striped bass in the Tar/Pamlico, Neuse, and Cape Fear rivers prior to and during spring spawning migrations.
2. Maintain an array of acoustic receivers in the Tar/Pamlico, Neuse, and Cape Fear rivers to detect acoustically tagged American shad, striped bass, and other species utilizing these systems.
3. Identify and map spawning grounds, spawning habitat, and movement patterns of American shad and striped bass in the Tar/Pamlico, Neuse, and Cape Fear rivers.
4. Use habitat and movement data to improve current NCDMF and NCWRC fishery-independent surveys to better characterize spawning stock of American shad and striped bass.

# JOB 1: ASSESSING CRITICAL HABITAT, MOVEMENT PATTERNS, AND SPAWNING GROUNDS OF ANADROMOUS FISHES IN THE TAR/PAMLICO, AND NEUSE RIVERS USING TELEMETRY TAGGING TECHNIQUES

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## ABSTRACT

An acoustic telemetry study was conducted in the Tar/Pamlico and Neuse rivers to identify and map spawning grounds, spawning habitat, and movement patterns of American shad and striped bass. Acoustic receivers (hydrophones) were deployed throughout the inland and coastal portions of the Tar/Pamlico, Pungo, and Neuse rivers in areas suspected or known to be habitat for American shad and striped bass. When possible, attempts were made to deploy receivers, or groups of receivers, at locations that would cover the entire width of the waterway to ensure up or down river migration and movement out of the study area was detected. In 2014, ten American shad were tagged on the Neuse River and nine were tagged in the Tar/Pamlico River. In 2015, 17 American shad were tagged in the Neuse River and 18 were tagged in the Tar/Pamlico River. In 2014, 20 striped bass were tagged in the Neuse River and 19 were tagged in the Tar/Pamlico River. In 2015, 41 striped bass were tagged in the Neuse River and 40 were tagged in the Tar/Pamlico River. Attempts were made to download receivers monthly during the project period. A total of 28 American shad and 115 striped bass tagged during this project were detected between March 2014 and August 2017. American shad were only detected during the spring in 2014 and 2015, and none were detected in multiple years. No American shad were detected in the lower Neuse River and American shad were only detected in the lower Tar/Pamlico River in 2014. Striped bass in both rivers were detected moving up river during the spring and were generally detected in the middle portions of both rivers during the rest of the year. Minimal movements of striped bass between rivers or out of the system completely were detected. The percentage of American shad and striped bass detected declined quickly following tagging indicating either high mortality or undetected migration out of the system.

# 1 INTRODUCTION

Historical conditions of the striped bass stock in the Central Southern Management Area (CSMA) are not well documented. Currently, the status of the Central Southern Management Area (CSMA) striped bass stock is "*unknown*" due to insufficient data for a stock assessment. In a previous attempt to protect critical spawning habitats for anadromous fishes, the North Carolina Division of Marine Fisheries (NCDMF) began a study in 1974 to document Anadromous Fish Spawning Areas (AFSA) throughout North Carolina. The study found AFSA to occur in the Tar/Pamlico, and Neuse rivers. AFSA on the Tar/Pamlico River were identified from Washington, NC to as far upstream as Rocky Mount, NC. On the Neuse River, AFSA were found from New Bern, NC to as far upstream as Raleigh, NC. The Pamlico River has been stocked with Phase II striped bass since 1983 and the Neuse River has been stocked with Phase II striped bass since 1982 (NCDMF 2013). Stocking was rotated between the Pamlico, Neuse, and Cape Fear rivers from 1980-2003 and since 2004, stocking has occurred in two systems annually. Since 2010, each system is stocked annually.

This project will allow NCDMF and NCWRC to map American shad and striped bass migrations and spawning grounds on a finer scale than previously attempted in the Tar/Pamlico and Neuse rivers. Secondarily, this will also allow NCDMF and NCWRC to evaluate the effectiveness of fisheries independent sampling for American shad and striped bass by providing data on spatial and temporal movement and migration patterns.

## 1.1 Objective

Conduct a telemetry study in the Tar/Pamlico and Neuse rivers to identify and map spawning grounds, spawning habitat, and movement patterns of American shad and striped bass. This study will also provide key data necessary to evaluate the effectiveness of and improve current NCDMF and NCWRC fishery-independent surveys meant to characterize the spawning stocks.

# 2 METHODS

## 2.1 Receiver Deployment

Acoustic receivers (hydrophones) were deployed throughout the inland and coastal portions of the Tar/Pamlico, Pungo, and Neuse rivers in areas suspected or known to be habitat for American shad and striped bass. Initial receiver deployments occurred in March and April 2014, with attempts made to deploy receivers at inland locations prior to any acoustic tagging of fish. When possible, attempts were made to deploy receivers, or groups of receivers, at locations that would cover the entire width of the waterway to ensure up or down river migration and movement out of the study area was detected. Additional receivers were deployed in deeper water areas or areas with anecdotal reports of larger striped bass. Receivers deployed at inland locations or in shallow water close to shore were strapped to a metal pipe embedded in a concrete base that was attached to shoreline structure by a steel cable (Figure 1). Receivers deployed in deeper water were attached to existing structures (i.e., railroad trestle, channel markers, etc.; Figure 2) or were connected to a high flyer buoy anchored to the bottom (Figure 3).

Initially a gate of six receivers running from a line starting at 35° 26.210' N -76° 35.594' W extending eastward to point at 35° 26.907' N -76° 33.889' W were deployed in the Pungo River. Single receivers were also deployed at the mouths of Pungo and Pantego creeks, at the Pungo River near Leechville and at the entrance of the Intercostal Waterway (ICW) that extends toward the

Alligator River (Figure 4). Three receiver gates were initially deployed in the Pamlico River: at the mouth of Chocowinity Bay (two receivers); Maules Point to Ragged Point (five receivers); and the mouth of South Creek (four receivers). Single receivers were deployed at Core Point, Indian Island, and Goose Creek (ICW entrance heading south towards Neuse River). Additional single receivers were deployed at the mouth of Broad Creek in July 2016; upper Goose Creek in February 2015; the mouth of Blounts Creek in January 2015; the mouth of Durham Creek in January 2015; the mouth of Bath Creek in July 2016; and North Creek in July 2016.

Six inland receivers located in: Rocky Mount (approximately two miles downriver from the dam); just down river of the Dunbar Road boating access site; Princeton, NC; Falkland, NC, Greenville, NC; and Pactolus, NC were initially deployed in the Tar River (Figure 5). An additional inland receiver was deployed in February 2015 near Old Sparta, NC. Single receivers were also deployed at the entrance of the Tar River, the mouth of Tranters Creek, and the Highway 17 Bridge near Washington, NC.

Three receivers were initially deployed in the Bay River area. Single receivers were deployed at the mouth of the river, upriver near Mason Point, and at Gales Creek (ICW entrance heading north towards Pamlico River; Figure 6).

Initially, single receivers were deployed: near Fairfield Harbor, NC; Flanners Beach; the mouth of Slocum Creek; the mouth of Beard Creek; the mouth of Hancock Creek; the mouth of Clubfoot Creek; the mouth of Dawson Creek; the mouth of South River; Adams Creek; near Oriental, NC; Garbacon Shoal; and the mouth of the Neuse River (Figure 6). In fall 2015, NCDMF took over maintenance of receivers located in the Neuse River near New Bern, NC from North Carolina State University (see Bradley 2016). This included a gate of five receivers located near Black Beacon Point; a gate of four receivers located at the railroad trestle crossing the Neuse River in New Bern; one receiver in the lower Trent River near the outlet of Old Towne Lake; one receiver on the Neuse River near Marsh Island; and one receiver on the Neuse River near Shad Cove.

Nine receivers were initially deployed on the inland portion of the Neuse River including five in the Neuse River, and four in Contentnea Creek (Figure 7). One receiver was initially deployed in the Trent River. Inland Neuse River receivers were located at: Milburnie Dam; Smithfield, NC; Richardson Bridge Road; Elroy, NC, and Kinston, NC. Contentnea Creek receivers were located at: Stantonsburg, NC; Snow Hill, NC; Hookerton, NC; and Grifton, NC. An additional Contentnea Creek receiver was deployed in February 2015 at Speights Bridge Road. The Trent River receiver was located near River Bend, NC. An additional Trent River receiver was deployed near Pollocksville, NC in February 2015.

## 2.2 Tagging

Tagging of American shad occurred over three days in March and April 2014 and over three days in March and April 2015. All tagged American shad were captured using a boat mounted electroshocking unit. Tagging of striped bass occurred over nine days in March and April 2014, and over 11 days in March, April, and May 2015. Tagged striped bass were captured using a boat mounted electroshocking unit, gill net, or hook and line. Acoustic tags were deployed in 10 American shad from the Neuse River and nine from the Tar/Pamlico River in 2014. In 2015, acoustic tags were deployed in 17 American shad from the Neuse River and 18 American shad from the Tar/Pamlico River. In 2014, acoustic tags were deployed in 20 striped bass from the Neuse River and 19 striped bass from the Tar/Pamlico River. Acoustic tags were deployed in 41 striped bass from the Neuse River and 40 from the Tar/Pamlico River in 2015.

Captured American shad were held in a holding tank for 10 minutes to determine if they were healthy enough to be tagged. American shad deemed healthy enough to be tagged, were implanted with VEMCO V9 tags. Transponders were implanted into the stomach cavity through the mouth. This method was used by Beasley and Hightower (2000) and experimentally used by NCDMF in the Cape Fear River in 2011 with low mortality rates. Passive Integrated Transponder (PIT) tags were inserted into the back just anterior to the dorsal fin of each fish.

Captured striped bass deemed healthy enough to be tagged were held in a 416-liter holding tank while surgical equipment was prepared. All surgical equipment and materials (i.e., surgical suture, PIT tag, internal anchor tag, acoustic tag, and scalpel) were held in a 22.0 cm metal pan containing 91% isopropyl rubbing alcohol until needed. Once equipment was prepped, fish were removed from the holding tank and placed on a wooden cradle lined with damp sponges. Gills were continuously irrigated with water recirculated from the holding tank. Fish were immobilized by electronarcosis (anesthesia, accompanied by muscle relaxation, through electrical inhibition) using procedures and equipment similar to those described in Hudson et al. (2011). Briefly, metal plates lining the wooden cradle were connected to a 12V 7Ah battery (Enercell Sealed Lead-Acid Battery) using alligator clips allowing electrical current to pass through the fish causing electronarcosis. PIT tags, inserted into the left opercle, and internal anchor tags (type FM-84), inserted into the left side of the abdomen, were implanted in each fish. Individually coded VEMCO V13 or V16 ultrasonic transmitters were inserted into each fish. Scales covering the incision location were removed using a scalpel. The incision location was swabbed with betadine solution and an incision approximately the width of the tag was made posterior to the right pelvic girdle and the tag was inserted. The incision was then closed with 2-4 interrupted sutures (Ethicon Monocryl 2-0 CT-1 27”). After surgery, fish were allowed to recover in the 416-liter holding tank for approximately 30 minutes. Before release, Triple Antibiotic (Ever Ready First Aid and Medical Supply Company) was applied to the incision location. Environmental data including surface and bottom temperature, salinity, and dissolved oxygen were recorded at each tagging location. Temperature, salinity, and dissolved oxygen of water in the holding tank were recorded during tagging events.

### 2.3 Receiver Downloads

Attempts were made to download receivers once per month during the duration of the project. Environmental data, including surface and bottom dissolved oxygen, salinity, temperature, secchi depth, water depth, bottom composition, sediment size, and shoreline characteristics, were recorded at each station during receiver downloads.

### 2.4 Data Analysis

All data was downloaded using VUE 2.2 software and analyses were performed using SAS software. For this analysis, a detection was considered one detection per fish per station per day. For analysis purposes, the spring season included March, April, and May; summer included June, July and August; fall included September, October, and November; winter included January, February, and December.

Number of detections at each station was mapped by year, season, and location (i.e., Tar River, Pamlico River, upper Neuse River, lower Neuse River) using GIS software.

# 3 RESULTS

## 3.1 Tag Deployment

Ten American shad were tagged on the Neuse River in 2014 ranging in length from 374 mm fork length to 490 mm fork length, with an average fork length of 422.8 mm (Table 1). American shad were tagged at two locations on the Neuse River between Goldsboro and Richardson Bridge Road (See maps in Appendix A for American shad tagging locations). Nine American shad were tagged in the Tar/Pamlico River in 2014 ranging in length from 428 mm fork length to 488 mm fork length, with an average fork length of 456.2 mm. American shad on the Tar/Pamlico River were tagged at one location between Tarboro and Dunbar Road and one location at Rocky Mount. Of the 19 American shad tagged in 2014, 53 percent were female and 47 percent were male.

In 2015, 17 American shad were tagged in the Neuse River ranging in length from 336 mm fork length to 480 mm fork length, with an average fork length of 415.6 mm (Table 1). All American shad from the Neuse River were tagged at a single location between Goldsboro and Richardson Bridge Road. In the Tar/Pamlico River, 18 American shad were tagged in 2015 ranging in length from 367 mm fork length to 478 mm fork length, with an average fork length of 422.5 mm (Table 1). American shad on the Tar/Pamlico River were tagged at one location between Tarboro and Dunbar Road and one location at Rocky Mount. Of the 35 American shad tagged in 2015, 46 percent were female and 54 percent were male.

In the Neuse River in 2014, 20 striped bass were tagged ranging in length from 564 mm fork length to 864 mm fork length, with an average fork length of 627.9 mm (Table 2). Neuse River striped bass were tagged at locations at the mouth of Hancock Creek, the mouth of Slocum Creek, the Neuse River around New Bern, and the Neuse River between Goldsboro and Richardson Bridge Road (See maps in Appendix B for striped Neuse River striped bass tagging locations). In the Tar/Pamlico River, 19 striped bass were tagged ranging from 565 mm fork length to 821 mm fork length, with an average fork length of 638.8 mm (Table 2). Tar/Pamlico River striped bass were tagged in the Pamlico River near Washington, the Pungo River near Belhaven, and the Tar River near Dunbar Road (See maps in Appendix C for Tar/Pamlico River striped bass tagging locations). Of the 39 striped bass tagged in 2014, 56 percent were female, 36 percent were male, and eight percent were of unknown sex.

In 2015, 41 striped bass were tagged in the Neuse River ranging in length from 531 mm fork length to 780 mm fork length, with an average fork length of 628.8 mm (Table 2). Neuse River striped bass were tagged at locations near the mouth of Hancock Creek, the mouth of Slocum Creek, the Neuse River between Goldsboro and Richardson Bridge Road, the Neuse River between Smithfield and Clayton, and the Neuse River near Raleigh. In the Tar/Pamlico River, 40 striped bass were tagged ranging in length from 550 mm fork length to 923 mm fork length with an average fork length of 610.9 mm (Table 2). Tar/Pamlico River striped bass were tagged in the Pamlico River near Washington, the Tar River between Tarboro and Dunbar, and the Tar River between Dunbar and Rocky Mount. Of the 81 striped bass tagged in 2015, 31 percent were female, 68 percent were male, and one percent were of unknown sex.

## 3.2 Receiver Downloads and Maintenance

Receiver downloads began in April 2014 and occurred monthly through November 2014 (Table 3). Receiver downloads did not occur in December 2014; April, September, and December 2015; June, September, and December 2016; and January, March, June, July and August 2017. It should

be noted that complete sets of downloads sometimes spanned multiple months. Deviations in receiver download schedules occurred due to bad weather, staff shortages, and other field sampling responsibilities.

While receiver downloads began in April 2014, environmental data were not recorded at each station until June 2015 (Table 4).

From the start of the project problems were incurred with Pungo River receivers going missing or being damaged (Table 5). The receiver at the mouth of the ICW went missing and was then found and redeployed before going missing again in July 2015. A replacement receiver was deployed at this station in April 2016. Due to high boat traffic and wave action, receivers at the Pungo River receiver gate were damaged or went missing as early as July 2014. Despite attempts to replace missing receivers and to strengthen the anchoring mechanism, receivers were lost and upon completion of this project the gate was no longer active.

There were few instances of missing or damaged receivers in the Tar/Pamlico River. The receiver at Battle Park was damaged and replaced in April 2016. The two receivers comprising the Chocowinity Bay gate were either damaged or went missing but were replaced. One receiver in the Maules Point to Ragged Point gate was removed in May 2014 due to damage and one went missing in July 2016, but only one was replaced. The gate of four receivers deployed at South Creek experienced many receiver losses due to high boat traffic and wave action in the area. All four receivers went missing at various times beginning in August 2014. In March 2016, the two active receivers in this gate were moved to markers just inside the mouth of the creek and were active through the end of this project. The receiver in upper Goose Creek went missing in April 2017, but was found and redeployed; the receiver in Bath Creek went missing in April 2017; and the receiver in North Creek went missing in April 2017.

In the Neuse River, the inland receiver at Smithfield was moved in March 2016 due to construction at a nearby boat ramp. The receiver went missing in August 2017, likely due to dredging in the area. The inland receiver at Statonsburg was stolen in June 2014 and was not replaced. The coastal receiver at the mouth of Beard Creek went missing in August 2016 and was replaced. The receiver at the mouth of Clubfoot Creek went missing in January 2016 and was later replaced and then went missing again. The receiver was found and deployed again at the mouth of Clubfoot Creek. The receiver at the mouth of Dawson Creek went missing in September 2014 and was replaced. Two of the receivers at the Black Beacon Point gate went missing and were not replaced. Other receivers in this gate went missing but were replaced.

### 3.3 Detections

A total of 28 American shad and 115 striped bass tagged during this project were detected between March 2014 and August 2017. Maps of American shad detections for the spring of 2014 and 2015 can be found in Appendix A. Maps of striped bass detections from the Neuse River by season for 2014-2017 can be found in Appendix B. Maps of striped bass detections from the Tar/Pamlico River by season for 2014-2017 can be found in Appendix C.

### 3.4 American shad

#### 3.4.1 Neuse River

In 2014, ten American shad were tagged in the Neuse River and 50 percent were detected at least once (Table 6). American shad tagged in 2014 were only detected during the spring and all detections occurred from March 28 through May 18. Detections occurred at all receiver locations

in the upper Neuse River except for the receiver located at Smithfield. There were no detections at the receivers located in Contentnea Creek or receivers located in the lower Neuse River. Two American shad were only detected at the receiver in Goldsboro, and one American shad was only detected at the receiver in Kinston. One fish was initially detected at the receiver in Kinston, indicating fall back from its tagging location (upstream of Goldsboro), and was then detected at the Goldsboro receiver. One fish was initially detected at the receiver located near Kinston, indicating fall back from its tagging location (upstream of Goldsboro), and was then detected at the receiver located in Raleigh. There were generally few detections in 2014 with the number of detections per fish ranging from one to four.

In 2014, nine American shad were tagged in the Tar/Pamlico River and 78 percent were detected at least once (Table 6). American shad tagged in 2014 were only detected during the spring and all detections occurred from April 13 through May 14, 2014. American shad were detected at every Tar River receiver (receiver at Old Sparta was not deployed until 2015). In the Pamlico River, multiple detections occurred at the South Creek gate, the Maules Point to Ragged Point gate, the Chocowinity Bay Gate and the Washington waterfront. American shad detected at upriver locations were subsequently detected moving down the Tar and Pamlico rivers through the Maules Point gate, with one fish being detected at the South Creek gate. One American shad was detected at the Rocky Mount receiver on 24 non-consecutive days during April and May 2015, but was not detected at any other receiver locations. One American shad was initially detected at the Rocky Mount receiver, moved downstream through the Mauls Point to Ragged Point gate and was last detected in the Tar/Pamlico River at the Pactolus receiver on May 7, 2014. The same fish was detected moving through Oregon inlet on May 11, 2014.

In 2015, 17 American shad were tagged in the Neuse River and 47 percent were detected at least once (Table 6). American shad tagged in 2015 were only detected during the spring and all detections occurred after April 1 with a single detection occurring May 20. Detections occurred at all receiver locations in the upper Neuse River except for the receiver located at Kinston. There were no detections at the receivers located in Contentnea Creek or receivers located in the lower Neuse River. Six American shad were only detected at the receiver location in Goldsboro of which four were single detections. One fish had single detections at the Goldsboro and Smithfield receiver locations and one fish was detected moving upstream from Goldsboro to Raleigh.

In 2015, 18 American shad were tagged in the Tar/Pamlico River and 44 percent were detected at least once (Table 6). American shad tagged in 2015 were only detected during the spring and all detections occurred after April 8 with a single detection occurring May 8. Detections occurred at all receiver stations in the Tar River with no detections occurring downriver of the Pactolus receiver. Four American shad were detected on multiple days at the Rocky Mount receiver and were not detected at any other locations. Three fish initially detected at the Rocky Mount receiver were subsequently detected moving downriver as far as the Pactolus receiver. One American shad was detected a single time at the Tarboro receiver and never detected again.

#### 3.4.1.1 River Kilometer and River Discharge

Maximum possible river kilometer for American shad detections in the Neuse River was 339 kilometers (Raleigh receiver) and maximum possible river kilometer for American shad detections in the Tar/Pamlico River was 124 kilometers (Rocky Mount receiver).

#### 3.4.1.2 2014

American shad tagged in the Neuse River in 2014 showed some evidence of upstream migration after tagging with some fish migrating to furthest points upriver (Figure 8). There was no evidence of fish moving downriver. American shad tagged in the Tar/Pamlico River in 2014 showed no sign of moving upriver after tagging with fish being tagged and detected at the furthest points upriver (Figure 8). However, American shad were detected moving down the Tar and Pamlico rivers, as far as South Creek, after being detected upriver.

Neuse River discharge data for the monitoring station near Clayton, NC was downloaded from the USGS website for the period from March 28, 2014 to May 20, 2014. Discharge ranged from 572 $ft^3$/second to 7,750 $ft^3$/second with no clear pattern, though there was a large spike in May (Figure 9). There was no clear relationship between mean river kilometer of American shad detections and mean river discharge.

Tar River discharge data for the monitoring station near Rocky Mount, NC was downloaded from the USGS website for the period from April 1, 2014 to May 15, 2014. Discharge ranged from 295 $ft^3$/second to 4,330 $ft^3$/second, fluctuating widely throughout the time series (Figure 10). There appeared to be little relationship between mean river kilometer of American shad detections and mean river discharge. When discharge was low in April, average river kilometer of detections was high. However, when discharge dropped to its lowest levels in May American shad seemed to move down river.

#### 3.4.1.3 2015

American shad tagged in the Neuse River in 2015 showed some evidence of upstream migration after tagging with some fish migrating to the furthest points upriver, and no indication of downstream migration (Figure 11). American shad tagged in the Tar/Pamlico River in 2015 were tagged and subsequently detected at the furthest points upriver with no indication of American shad moving downstream in 2015 (Figure 11).

Neuse River discharge data for the monitoring station near Clayton, NC was downloaded from the USGS website for the period from April 1, 2015 to May 20, 2015. Discharge ranged from 433 $ft^3$/second to 3,030 $ft^3$/second peaking toward the end of April (Figure 12). Generally, river discharge in 2015 was similar to river discharge in 2014 over a similar time period. There appeared to be some relationship between mean river kilometer of American shad detections and mean river discharge with the furthest upriver detections occurring at peak river discharge.

Tar River discharge data for the monitoring station near Rocky Mount, NC was downloaded from the USGS website for the period from April 1, 2015 to May 15, 2015. Discharge ranged from 379 $ft^3$/second to 2,640 $ft^3$/second, peaking toward the end of April (Figure 13). There was little relationship between mean river kilometer of American shad detections and mean river discharge, with most detections occurring while discharge was relatively low.

## 3.5 Striped Bass

### 3.5.1 Recaptures

Over the course of the project seven acoustic tagged striped bass were harvested and seven were caught and released (Table 7). Of the fish that were caught and released, only two were detected after being released. Of the fish that were harvested, three were detected on the day they were harvested, one was detected the day before harvest, and one was detected two days before harvest. One fish tagged in the Neuse River in March 2014 was caught and released in the Bay River in

December 2014, but was not detected on receivers in the Bay River. One fish tagged in the Tar River in April 2015 was harvested in the Neuse River in April 2017. This fish was detected moving down the Pamlico River, through the Bay River (ICW), and into the Neuse River. One fish tagged in the Tar/Pamlico River in May 2015 was harvested in the Atlantic Ocean between Block Island and Nantucket Sound in September 2015. This fish was detected moving down the Tar and Pamlico Rivers during May 2015, but was not detected after.

### 3.5.2 Neuse River

#### 3.5.2.1 2014

In 2014, 20 striped bass were tagged in the Neuse River. Of the available tags (20 in every season), 75 percent were detected in the spring, 20 percent were detected in the summer, 45 percent were detected in the fall, and 15 percent were detected in the winter (Table 8). Fish tagged in the Neuse River in 2014 were detected from April 11, 2014 through November 7, 2015. It should be noted that while they are not incorporated into this report, striped bass tagged for this project were detected by receivers maintained by North Carolina State University in the upper/middle Neuse River (New Bern) area during 2014 and 2015 (Bradley 2016). Maintenance of those receivers was taken over by NCDMF in fall 2015 and any subsequent detections are included in this report. Of the fish tagged in the Neuse River, the highest percentage of detections occurred in the upper Neuse River during the spring, and the upper/middle Neuse River during the summer, fall, and winter (Figure 14). Of the individual striped bass detected each season in 2014, the highest percentage of individuals were detected in the upper Neuse River during the spring and summer, and upper/middle Neuse during the fall and winter (Figure 15).

One striped bass tagged in the Neuse River in 2014 was initially detected at the Slocum Creek receiver from April 11-14. The fish was then detected at the Mauls Point to Ragged Point receiver gate in the Pamlico River on April 20 and was detected moving up the Pamlico and Tar rivers to the receiver in Tarboro, NC. The fish was detected at Pamlico River receivers until April 2015. Another striped bass tagged in the Neuse River in 2014 moved upriver to the receiver in Raleigh in May 2014, was detected moving down the Neuse River and was detected at the entrance to the ICW heading south toward Bay River from October-December 2014, and was last detected at that receiver in April 2015. One striped bass tagged in the Neuse River in 2014 was initially detected near Beard Creek on April 16, 2014 and at Dawson Creek on April 21-22, 2014. The fish was then detected at Oregon Inlet on May 12, 2014, and never detected again. Another striped bass tagged in the Neuse River in 2014 was initially detected near Beard Creek on April 15, 2014, moved throughout the lower Neuse River, and was last detected at Clubfoot Creek on April 26, 2014. The fish was then detected on May 23, 2014 at a receiver near Shark River, New Jersey; on May 25, 2014 off Jones Beach, New York; on May 29, and June 8, 2014 near Fire Island, New York; and July 3,4, and 9, 2014 near Montauk, New York. On March 13, and March 14, 2015 the same striped bass was detected at two receivers at the mouth of the Chesapeake Bay.

In spring 2014, striped bass were detected at every receiver station on the upper Neuse River, and no striped bass were detected in Contentnea Creek. A single fish was detected in the Trent River near River Bend. Striped bass were detected at multiple receiver locations in the lower Neuse River including Adams Creek, Clubfoot Creek, Hancock Creek, Slocum Creek, Beard Creek, and Dawson Creek.

In summer 2014, striped bass were only detected at the Kinston receiver in the upper Neuse River, but were detected at three of five Contentnea Creek receivers. A single fish was detected in the

Trent River near River Bend. In the lower Neuse River, striped bass were only detected at the receivers near Fairfield Harbor and Flanners Beach.

In fall 2014, no striped bass were detected in the upriver portion of the Neuse River, Contentnea Creek, or the Trent River. There were multiple detections in the lower Neuse River at the receivers near Fairfield Harbor, Flanners Beach, Slocum Creek, and Hancock Creek.

In winter 2014, no striped bass were detected in the upriver portion of the Neuse River, Contentnea Creek, or the Trent River. In the lower Neuse River, the only detections occurred at the receivers near Fairfield harbor and Flanners Beach.

#### 3.5.2.2 2015

In 2015, 41 striped bass were tagged in the Neuse River. Based on the lifespan of acoustic transmitters used to tag striped bass in 2014 (768 days), it was assumed that all fish tagged in 2014 were able to be detected (61 total tags). Based on tag returns, a maximum of 60 tags were available to be detected in fall and winter. Of the available tags, 74 percent were detected in the spring, 41 percent were detected in the summer, 35 percent were detected in the fall, and 20 percent were detected in the winter (Table 8). Fish tagged in the Neuse River in 2015 were detected from April 1, 2015 through August 1, 2017. Of the fish tagged in Neuse River, the highest percentage of detections occurred in the upper, upper/middle, and middle Neuse River during the spring, and the upper/middle Neuse River during the summer, fall, and winter (Figure 16). Of the individual striped bass detected each season in 2015 the highest percentage of individuals were detected in the upper Neuse River during the spring, and upper/middle Neuse during the summer, fall and winter (Figure 17).

One striped bass tagged in the Neuse River was initially detected at the receiver near Goldsboro and was then consistently detected at receivers near New Bern and Fairfield Harbor from May 28, 2015 to March 28, 2016. The fish then moved up the Neuse River to the receiver in Goldsboro in May 2016, moved back down river and was detected at New Bern, Fairfield Harbor, Oriental, and Clubfoot Creek receivers until February 2017. Many striped bass exhibited this pattern of residency in the middle and upper/middle portion of the Neuse River with some detected making multiple seasonal spawning runs. One striped bass tagged in the Neuse River in 2015 was initially detected at Slocum Creek on April 1, 2015 and was then detected at the Mauls Point to Ragged Point receiver gate in the Pamlico River on April 21, 2015. The fish was detected moving up the Pamlico and Tar rivers to the receiver at Rocky Mount on April 27, 2015. The fish was detected throughout the entire Pamlico River in 2015 before moving back up the Tar River in the spring of 2016. The fish was last detected at the South Creek receiver gate in July 2016. One striped bass tagged in the Neuse River in 2015 was initially detected at the receiver near Hancock Creek on April 1, 2015. The fish was consistently detected at receivers near New Bern between September 2015 and April 2016, never moving into the upper Neuse River. The last detection for this fish was April 2, 2016 at receivers in New Bern. The fish was then detected on April 9, 2016 at a receiver in the Atlantic Ocean off the coast of the Chesapeake Bay.

In spring 2015, striped bass were detected at every receiver station in the upper Neuse River with most detections occurring near Kinston, Goldsboro and Smithfield. There were no striped bass detected in Contentnea Creek. Two striped bass were detected at receivers in the Trent River. Striped bass were detected throughout the lower Neuse River with most detections occurring near Fairfield Harbor, Flanners Beach, Slocum Creek, and Hancock Creek. Striped bass were also detected at Beard Creek, Clubfoot Creek, Oriental, and Garbacon Shoal.

In summer 2015, no striped bass were detected in the upper Neuse River, but two fish were detected in Contentnea Creek and five fish were detected in the Trent River. Striped bass were detected throughout the lower Neuse River with most detections occurring near Fairfield Harbor, Flanners Beach, Slocum Creek, and Beard Creek. Fish were also detected at Hancock Creek, Dawson Creek, and South River.

In fall 2015, no striped bass were detected in the upper Neuse River or Contentnea Creek. Multiple fish were detected in the Trent River, and at receivers in the New Bern area. Most lower Neuse River detections occurred at the Fairfield Harbor, Flanners Beach, Slocum Creek, Hancock Creek, and Beard Creek locations but detections also occurred at Dawson Creek, Oriental, Garbacon Shoal, and Adams Creek.

In winter 2015, no striped bass were detected in the upper Neuse River or Contentnea Creek. Multiple fish were detected at receivers in the New Bern area including the lower Trent River. Most detections in the lower Neuse River occurred at the Fairfield Harbor, Flanners Beach, Slocum Creek, and Hancock Creek locations, but detections also occurred at Beard Creek, Dawson Creek, Oriental, Garbacon Shoal, and Adams Creek.

#### 3.5.2.3 2016

Based on the lifespan of acoustic transmitters used to tag striped bass in the Neuse River in 2014 (20 tags at 768 days) and 2015 (21 tags at 1,227 days; 20 tags at 3,650 days), and tag returns, it was assumed that 60 would still be active in the spring and winter (January and February) of 2016, and 39 would still be active in the summer, and fall of 2016. Of the available tags, 27 percent were detected in the spring, 18 percent were detected in the summer, 15 percent were detected in the fall, and 22 percent were detected in the winter (Table 8). Of the fish tagged in the Neuse River, the highest percentage of detections occurred in the upper/middle Neuse River for all seasons (Figure 18). Of the individual striped bass detected each season in 2016 the highest percentage of individuals were detected in the upper/middle, and upper Neuse River during the spring, the upper/middle Neuse during the summer and fall, and the middle Neuse and upper/middle Neuse during the winter (Figure 19).

In spring 2016, striped bass were detected at all upper Neuse River receivers except for the receiver at Raleigh. A single striped bass was detected at three of the five receivers in Contentnea Creek. Two striped bass were detected at receivers in the Trent River. Multiple detections occurred at receivers in the New Bern area. In the lower Neuse River detections occurred most frequently at Fairfield Harbor, Flanners Beach, Slocum Creek, and Beard Creek. Detections also occurred at Hancock Creek, Dawson Creek, and Garbacon Shoal.

In summer 2016, no striped bass were detected at upper Neuse River locations. Two striped bass were detected in the lower Trent River and a single fish was detected at three locations in Contentnea Creek. In the lower Neuse River, there were multiple detections at receivers in the New Bern area and less frequent detections at Fairfield Harbor, Flanners Beach, and Slocum Creek.

In fall 2016, no striped bass were detected in the upper Neuse River, or Contentnea Creek. There were multiple detections in the New Bern area, and a single striped bass was detected in the lower Trent River. In the lower Neuse River detections occurred most frequently at Fairfield Harbor, Flanners Beach, and Slocum Creek. Detections also occurred at Hancock Creek, Beard Creek, Clubfoot Creek, Oriental, Garbacon Shoal, and the mouth of the Neuse River. A single striped bass was detected at the mouth of the Bay River.

In winter 2016, no striped bass were detected in the upper Neuse River, or Contentnea Creek. There were multiple detections in the New Bern area and three fish were detected in the lower Trent River. In the lower Neuse River detections occurred frequently at Fairfield Harbor, Flanners Beach, Slocum Creek, Hancock Creek, and Beard Creek. No other receiver locations in the lower Neuse River had detections of striped bass.

#### 3.5.2.4 2017

Based on the lifespan of acoustic transmitters used to tag striped bass in the Neuse River in 2014 (20 tags at 768 days) and 2015 (21 tags at 1,227 days; 20 tags at 3,650 days) and tag returns, it was assumed that 39 would still be active in the spring and winter (January and February) of 2017, and 38 would still be active in the summer of 2017. Of the available tags, 13 percent were detected in every season (fall 2017 not included; winter 2017 only includes January and February; Table 8). Of the fish tagged in the Neuse River, the highest percentage of detections occurred in the upper/middle Neuse River during the spring with high percentages of detections in the middle and upper Neuse River (Figure 20). The highest percentages of detections from the summer and winter occurred in the upper/middle Neuse River. Of the individual striped bass detected each season in 2017 the highest percentage of individuals were detected in the upper/middle Neuse River during the spring, the upper/middle Neuse during the summer, and the middle Neuse River during the winter (Figure 21).

In spring 2017, striped bass were detected at every upper Neuse River receiver except for the receiver at Smithfield. There were no striped bass detected in Contentnea Creek. Two striped bass were detected at the receivers in the Trent River. There were multiple detections of striped bass at receivers near New Bern. In the lower Neuse River, striped bass were detected at Fairfield Harbor, Flanners Beach, Slocum Creek, Hancock Creek, Beard Creek, Oriental, and Garbacon Shoal. A single striped bass was detected at the entrance to the ICW heading south toward Bay River. The same fish was then detected at the other end of the ICW at Bay River, and at the mouth of Bay River.

In summer 2017, striped bass were detected at the Kinston and Goldsboro receivers in the upper Neuse River and at the Grifton receiver in Contentnea Creek. A single striped bass was detected at receivers in the Trent River, and there were multiple striped bass detections at receivers in the New Bern area. In the lower Neuse River, striped bass were detected at Fairfield Harbor and Flanners Beach.

Striped bass detection data from the winter of 2017 only includes data from January and February. No striped bass were detected in the upper Neuse River, Contentnea Creek, or the Trent River. There were multiple striped bass detections at receivers in the New Bern area. In the lower Neuse River, striped bass were detected at Beard Creek and Slocum Creek.

### 3.5.3 Tar/Pamlico River

#### 3.5.3.1 2014

In 2014, 19 striped bass were tagged in the Tar/Pamlico River. Of the available tags (19 in every season), 89 percent were detected in the spring, 68 percent were detected in the summer, 53 percent were detected in the fall, and 32 percent were detected in the winter (Table 8). Fish tagged in the Tar/Pamlico River in 2014 were detected from March 26, 2014 through October 8, 2015. Of the fish tagged in the Tar/Pamlico River, the highest percentage of detections occurred in the middle Pamlico River and Tar River during the spring, and the middle Pamlico River during the summer,

fall, and winter (Figure 22). Of the individual striped bass detected each season in 2014, the highest percentage of individuals were detected in the middle Pamlico River and Tar River during the spring, and the middle Pamlico River during the summer, fall and winter (Figure 23).

Most striped bass tagged in the Tar/Pamlico River in 2014 were detected at Tar River receivers in the spring and were then detected at receivers in the Washington to Ragged Point area of the Pamlico River through the summer, fall, and winter. A few fish tagged in the Tar/Pamlico River were detected moving up and down river in multiple years. One fish tagged in the Tar/Pamlico River was initially detected at the Mauls Point to Ragged Point receiver gate on April 13, 2014. The fish was then detected at the ICW heading south toward Bay River on April 24, 2014 and at Slocum Creek on April 26, 2014. The fish was detected moving throughout the Neuse and Trent rivers in April and May 2014 before moving back through the ICW heading toward the Pamlico River. The fish was then detected moving up the Pamlico and Tar rivers to the receiver in Tarboro during June, and July 2014. The fish was detected throughout the middle Pamlico River in 2014, moved up the Tar River to the receiver in Rocky Mount in May 2015 and was last detected in the middle Pamlico River in July 2015. Another striped bass tagged in the Tar/Pamlico River was initially detected at the Mauls Point to Ragged Point receiver gate on April 7, 2014. The fish was then detected moving up the Pungo River to the entrance of the ICW heading north toward Alligator River on April 13, 2014. The fish was then detected moving throughout the Chowan River from April 16, 2014-May 12, 2014. The last detection for this fish occurred on May 26, 2014 when it was detected in the Pungo River near the entrance to the ICW, apparently moving back in to the Pamlico River.

In spring 2014, striped bass were detected at five of six Tar River receivers (receiver at Old Sparta not deployed until 2015), with multiple detections of striped bass at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. In the Pamlico River, striped bass were detected at the Maules Point to Ragged Point receiver gate and at the South Creek receiver gate. Two striped bass were detected at the entrance to the ICW heading south toward Bay River. A single striped bass was detected at the Pungo River gate, then detected at the mouth of the ICW heading north toward Alligator River.

In summer 2014, striped bass were detected at four of six Tar River receivers, with the furthest upstream detections occurring at Tarboro. There were multiple detections of striped bass at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. Multiple striped bass were detected at the Maules Point to Ragged Point receiver gate, and a single striped bass was detected at the Core Point receiver.

In fall 2014, no striped bass were detected at Tar River receivers, but there were multiple detections at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. There were multiple striped bass detections at the Maules Point to Ragged Point receiver gate, and the Core Point receiver. Striped bass were also detected at the Indian Island receiver, the western side of the Pungo River receiver gate, and at the entrance to the ICW heading south toward Bay River.

In winter 2014, no striped bass were detected at Tar River receivers but there were detections at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. There were few detections throughout the Pamlico River but striped bass were detected at the Maules Point to Ragged Point receiver gate, Indian Island, and the entrance to the ICW heading south toward Bay River.

#### 3.5.3.2 2015

In 2015, 40 striped bass were tagged in the Tar/Pamlico River. Based on the lifespan of acoustic transmitters used to tag striped bass in 2014 (768 days), it was assumed that all fish tagged in 2014 were able to be detected (59 total tags). However, based on tag returns, a maximum of 58 tags in the summer, 57 tags in the fall, and 55 tags in the winter were available to be detected. Of the available tags, 78 percent were detected in the spring, 48 percent were detected in the summer, 26 percent were detected in the fall, and 29 percent were detected in the winter (Table 8). Fish tagged in the Tar/Pamlico River in 2015 were detected from April 24, 2015 through August 21, 2017. Of the fish tagged in the Tar/Pamlico River, the highest percentage of detections occurred in the middle Pamlico River and Tar River during the spring, and the middle Pamlico River during the summer, fall, and winter (Figure 24). Of the individual striped bass detected each season in 2015 the highest percentage of individuals were detected in the middle Pamlico River and Tar River during the spring, and the middle Pamlico River during the summer, fall and winter (Figure 25).

Most striped bass tagged in the Tar/Pamlico River in 2015 were detected at Tar River receivers in the spring and were then detected at receivers in the Washington to Ragged Point area of the Pamlico River through the summer, fall, and winter. A few fish tagged in the Pamlico River were detected moving up and down river in multiple years. One fish tagged in the Tar/Pamlico River in 2015 was initially detected at the Tarboro receiver on May 13, 2015. The fish was then detected throughout the Tar, Pamlico and Pungo rivers in May 2015. The fish was detected again in March and April 2016 moving up the Pamlico and Tar rivers to the receiver at Rocky Mount. The fish was then detected throughout the Tar, Pamlico and Pungo rivers during 2016, and the spring of 2017. In spring 2017, the fish was detected moving through the ICW into the Bay River, then into the Neuse River where it was last detected at Beard Creek on April 1, 2017. One fish, tagged in 2015, was initially detected at the receiver in Tarboro on May 12, 2015 and was detected moving down the Tar and Pamlico rivers to the receiver at South Creek over the course of three days. The last detection for this fish in the Pamlico River occurred at South Creek on May 14, 2015. The fish was then detected at the mouth of Delaware Bay on May 31, 2015. This was the same fish that was eventually harvested near Rhode Island in September 2015.

In spring 2015, striped bass were detected at every receiver location in the Tar River with most detections occurring at the six receivers from Dunbar Road to Pactolus. Multiple Striped bass were also detected at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. In the Pamlico River, striped bass were frequently detected at the Maules Point to Ragged point receiver gate, Goose Creek, Blounts Creek, Bath Creek, Durham Creek and Indian Island. Striped bass detections also occurred at the receiver gate in the Pungo River, South Creek, and the entrance to the ICW heading south toward Bay River.

In summer 2015, striped bass were only detected at the Greenville, and Pactolus receivers in the Tar River. Multiple detections occurred at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. Striped bass in the Pamlico River were most frequently detected at the Maules Point to Ragged Point receiver gate, Goose Creek, Blounts Bay, Bath Creek, and Indian Island. Detections also occurred at Durhams Creek, and South Creek.

In fall 2015, no striped bass were detected in the Tar River. However, multiple detections occurred at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. In the Pamlico River, frequent detections occurred at the Maules Point to Ragged Point receiver gate, Goose Creek, Blounts Creek, Durham Creek, Bath Creek, and Indian Island.

In winter 2015, no striped bass were detected in the Tar River but multiple detections occurred at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. Detections in the Pamlico River occurred most frequently at the Maules Point to Ragged Point receiver gate, Goose Creek, Blounts Creek, Bath Creek, and Indian Island. Detections also occurred at Durham Creek, and the Pungo River receiver gate.

#### 3.5.3.3 2016

Based on the lifespan of acoustic transmitters used to tag striped bass in the Tar/Pamlico River in 2014 (19 tags at 768 days) and 2015 (20 tags at 1,227 days; 20 tags at 3,650 days), and tag returns, it was assumed that 55 would still be active in the spring and winter (January and February) of 2016, and 36 would still be active in the summer, and fall of 2016. Of the available tags, 24 percent were detected in the spring, 25 percent were detected in the summer, 17 percent were detected in the fall, and 20 percent were detected in the winter (Table 8). Of the fish tagged in the Tar/Pamlico River, the highest percentage of detections occurred in the middle Pamlico River during the spring, summer, fall, and winter (Figure 26). Of the individual striped bass detected each season in 2016, the highest percentage of individuals were detected in the middle Pamlico River and Tar River during the spring, and the middle Pamlico River during the summer, fall and winter (Figure 27).

In spring 2016, striped bass were detected at every receiver location in the Tar River and there were multiple detections at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. In the Pamlico River, there were numerous detections at the Maules Point to Ragged Point receiver gate, Goose Creek, Blounts Creek, Durham Creek, Core Point, Indian Island, and South Creek.

In summer 2016, there were no striped bass detected in the Tar River, but there were multiple detections at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. In the Pamlico River, striped bass were detected at the Maules Point to Ragged Point receiver gate, Goose Creek, Broad Creek, Blounts Creek, Core Point, South Creek, and Indian Island. A single striped bass was detected in the Pungo River near Belhaven.

In fall 2016, there were no striped bass detected in the Tar River, or at the mouth of the Tar River, the Washington waterfront, or Chocowinity Bay. In the Pamlico River, striped bass were detected at the Maules Point to Ragged Point receiver gate, Goose Creek, Broad Creek, Blounts Creek, Core Point, Bath Creek, and Indian Island. A single striped bass was detected in the Pungo River near Belhaven and Pungo Creek on multiple days.

In winter 2016, the only Tar River receiver that detected striped bass was the receiver at Pactolus. There were multiple detections of striped bass at the mouth of the Tar River, the Washington waterfront, and Chocowinity Bay. In the Pamlico River, striped bass were detected frequently at the Maules Point to Ragged Point receiver gate, Goose Creek, Broad Creek, Blounts Creek, Core Point, and Indian Island.

#### 3.5.3.4 2017

Based on the lifespan of acoustic transmitters used to tag striped bass in the Tar/Pamlico River in 2014 (19 tags at 768 days) and 2015 (20 tags at 1,227 days; 20 tags at 3,650 days), and tag returns, it was assumed that 36 would still be active in the spring, summer and winter (January and February) of 2016. Of the available tags, eight percent were detected in the spring, six percent were detected in the summer, and 11 percent were detected in the winter (fall 2017 not included; winter 2017 only includes January and February; Table 8). Of the fish tagged in the Tar/Pamlico

River, the highest percentage of detections occurred in the lower, and middle Pamlico River during the spring, the lower Pamlico River during the summer, and the lower and middle Pamlico River during the winter (Figure 28). Of the individual striped bass detected each season in 2017, the highest percentage of individuals were detected in the lower Pamlico River, middle Pamlico River and Tar River during the spring, the lower and middle Pamlico River during the summer and the middle Pamlico River during the winter (Figure 29).

In spring 2017, a single striped bass was detected at all Tar River receivers except for the Rocky Mount location. The fish was detected moving up and downriver over the course of 20 days in April and May. There were also multiple striped bass detections at the mouth of the Tar River and the Washington waterfront. In the Pamlico River, striped bass were only detected at Indian Island, and South Creek. A single fish was detected in the Pungo River near Belhaven.

In summer 2017, no striped bass were detected at receivers in the Tar River and a single striped bass was detected at the mouth of the Tar River, and the Washington waterfront. A single fish was detected at the Indian Island receiver.

Striped bass detection data from the winter of 2017 only includes data from January and February. No striped bass were detected at receivers in the Tar River and a single striped bass was detected at the mouth of the Tar River and the Washington waterfront. In the Pamlico River, a single striped bass was detected at the Indian Island receiver, and a single striped bass was detected at the Maules Point to Ragged Point receiver gate. A single striped bass was detected in the Pungo River near Belhaven.

### 3.5.4 Migration and River Discharge

Maximum river kilometer for striped bass detections in the Neuse River was 339 kilometers (Raleigh receiver) and maximum river kilometer for striped bass in the Tar/Pamlico River was 124 kilometers (Rocky Mount receiver).

Striped bass detected in the Neuse River showed a clear pattern of seasonal upstream and downstream movement (Figure 30). During the spring, the average river kilometer of striped bass detections increased (compared to other seasons) with the average being at or close to the maximum in 2014 and 2017. The average river kilometer of striped bass detections in spring 2015 was below 300 kilometers and below 250 kilometers in spring 2016. After upriver migration, striped bass moved down river with an average around river kilometer 50, which is roughly around New Bern, NC. Striped bass that were tagged in the Tar/Pamlico River but detected in the Neuse River were detected an average of around 40-45 river kilometers up the Neuse River and did not appear to make spawning migrations in the Neuse River.

Neuse River discharge data was downloaded from the USGS website for the monitoring station near Clayton, NC for the period from March 1, 2014 to August 31, 2017. Discharge ranged from 222 $ft^3$/second to 18,800 $ft^3$/second, fluctuating widely throughout the time series (Figure 31). There did not appear to be any clear relationship between mean river kilometer of striped bass detections and mean river discharge. However, in 2017 when river discharge spiked the mean river kilometer of striped bass detections also increased though this might be the result of fewer overall detections in 2017.

Striped bass detected in the Tar/Pamlico River showed a clear pattern of seasonal upstream and downstream movement (Figure 32). During the spring, the average river kilometer of striped bass detections increased with the maximum average being at or close to the maximum river kilometer

in 2016. The maximum average river kilometer of striped bass detections in spring 2014 was below 120 kilometers, below 100 kilometers in spring 2015, and below 120 kilometers in spring 2017. After upriver migration, striped bass moved down river generally falling somewhere between river kilometer 20-40, which is roughly around Washington, NC. Striped bass that were tagged in the Neuse River but detected in the Tar/Pamlico River were detected throughout the river and appeared to make spawning runs in the Tar/Pamlico river in 2014, 2015, and 2016.

Tar River discharge data was downloaded from the USGS website for the monitoring station near Rocky Mount, NC for the period from March 1, 2014 to August 31, 2017. Discharge ranged from 53 $ft^3$/second to 21,400 $ft^3$/second, with flow generally decreasing in the summer (Figure 33). There appeared to be little relationship between mean river kilometer of striped bass detections and mean river discharge. However, river discharge generally increased in the early spring, and there was some indication that striped bass moved upriver following this increase or moved upriver during the increase.

### 3.5.5 Other Detections

Other animals that were not tagged as part of this study but detected by acoustic receivers utilized in this study included weakfish (*Cynoscion regalis*), Atlantic sturgeon (*Acipenser oxyrinchus*), American shad tagged by other agencies/universities, striped bass tagged by other agencies/universities, green sea turtle (*Chelonia mydas*), cownose ray (*Rhinoptera bonasus*), and sand tiger shark (*Carcharias taurus*). Records of detections, as well as location information for receiver stations were sent to appropriate researchers who deployed the tags.

## 4 CONCLUSIONS

A portion of the American shad tagged in the Neuse River migrated to the receiver in Raleigh, but most detections occurred downstream of Smithfield particularly around Goldsboro. Results indicate American shad likely utilize upstream portions of the Neuse River as spawning areas but primary spawning areas are likely downstream of Raleigh, and probably between Smithfield and Goldsboro. However, the upriver extent of American shad spawning areas likely varies from year to year depending on river flow which may enhance or restrict access to upriver areas (Burdick and Hightower 2006). The NCDMF has previously found anadromous fish spawning areas in the Neuse River to occur from New Bern to Raleigh. For American shad this finding is likely to broad. While the downriver portions of the Neuse River are important migratory corridors, and may be important for other aspects of American shad life history, American shad spawning areas likely occur in smaller river segments of the Neuse River between Goldsboro and Raleigh. No American shad were detected in Contentnea Creek. However, because all American shad were tagged in the upper Neuse River it is difficult to draw any conclusions about American shad spawning activity in Contentnea Creek.

No American shad were detected moving downstream in 2014 or 2015 indicating they either succumb to senescence, were harvested, or were able to move downriver without being detected by receivers. American shad in North Carolina are at the boundary of the north to south gradient of semelparity (Greene et al. 2009), so lack of downriver detections potentially indicates American shad in the Neuse River die after spawning.

A large portion of the American shad tagged in the Tar/Pamlico River migrated to the receiver in Rocky Mount and were detected throughout the Tar River. The highest number of detections occurred between Tarboro and Rocky Mount indicating primary spawning locations likely fall in

this area, though some spawning may occur in downstream tributaries (Smith and Rulifson 2015). As in the Neuse River, American shad spawning habitat in the Tar River is likely enhanced or restricted to some extent by river flow. The NCDMF previously found anadromous fish spawning areas in the Tar River to occur from Washington to Rocky Mount. This finding is likely to broad for American shad. While the entire Tar/Pamlico River is an important migratory corridor, and may be important for other aspects of American shad life history, American shad spawning areas likely occur most commonly at the upriver portions of the Tar River near Rocky Mount.

In 2014, American shad were detected moving down the Tar and Pamlico rivers with one fish detected moving through Oregon Inlet. However, in 2015, few American shad were detected moving down the Tar River and no American shad were detected moving down the Pamlico River. Year to year differences in downstream migration indicates there may be some degree of semelparity in Tar/Pamlico River American shad that could be influenced by environmental factors.

In both the Neuse and Tar/Pamlico rivers there appeared to be little relationship between river flow and mean river kilometer of American shad detections. However, other environmental factors, like water temperature, may play a role in the migration timing of American shad and, at least in the Pamlico River, may influence semelparity.

Generally, striped bass utilized the upper/middle Neuse River as habitat with frequent detections in this area throughout the year. Seasonal movements of striped bass in the Neuse River were apparent with striped bass moving into the upper Neuse River during the spring. Striped bass were generally only detected in the upper Neuse River during the three months that encompassed the spring season and were down river by the beginning of summer. While there were detections of striped bass as far upriver as Raleigh, most upriver detections occurred downstream of Smithfield, particularly the area between Goldsboro and Smithfield. Frequent detections of striped bass in this area during the spring suggests this area is likely a primary spawning area. The NCDMF has previously found anadromous fish spawning areas in the Neuse River to occur from New Bern to Raleigh. While the downriver portions of the Neuse River are important migratory corridors, and may be important for other aspects of striped bass life history, the designation as striped bass spawning area is likely too broad. Primary striped bass spawning areas in the Neuse River probably occur between Goldsboro and Smithfield. However, similar to American shad in the Neuse River, access to upriver spawning locations by striped bass is likely limited or enhanced by river flow (Burdick and Hightower 2006). In years of higher river flow during the spring access to upriver spawning areas is likely increased, and primary striped bass spawning habitat may occur upstream of Goldsboro and Smithfield. There were few striped bass detected in Contentnea Creek or the upper part of the Trent River during the spring in any year of this study. Lack of striped bass detections in these tributaries during the spawning season indicates striped bass are likely not using these areas as spawning habitat. Throughout the entire study there were few striped bass detected in Contentnea Creek suggesting this area may not contain suitable striped bass habitat. Striped bass were frequently detected in the lower Trent River throughout the study indicating this area is likely important striped bass habitat.

There were frequent striped bass detections at the mouths of Slocum and Hancock creeks, but generally few detections of striped bass in the lower reaches of the Neuse River. NCDMF electrofishing data shows high abundance of striped bass in Slocum and Hancock creeks. In addition, the mouths of both creeks are narrow and the receivers in these locations were located at the mouth of the creeks. So, while Slocum and Hancock creeks likely serve as important striped

bass habitat the probability of detection in these creeks was also high. The lack of striped bass detections in the lower Neuse River is likely due to the large area in the lower Neuse River decreasing the probability of detection.

Striped bass commonly utilized the middle Tar/Pamlico River, generally between the mouth of the Tar River to Maules Point, as habitat with frequent detections in this area throughout the year. However, compared to striped bass habitat use in the Neuse River, striped bass in the Pamlico River seemed to utilize a larger river area with frequent detections in the lower Pamlico River. Seasonal movements of striped bass in the Tar/Pamlico River were apparent with striped bass moving into the Tar River during the spring. In comparison to striped bass in the Neuse River, where the upper Neuse was only utilized as habitat during the spring, striped bass utilized the Tar River, particularly the mouth, at various times throughout the year with some upriver detections in the winter and summer. While there were detections of striped bass as far upriver as Rocky Mount, detections at this receiver were infrequent with most Tar River detections occurring at or below the Dunbar Road receiver, suggesting that primary striped bass spawning habitat in the Tar River is located downriver of Dunbar Road, though some spawning may occur at downstream tributaries (Smith and Rulifson 2015). The NCDMF has previously found anadromous fish spawning areas in the Tar/Pamlico River to occur from Washington to Rocky Mount. While the downriver portions of the Tar River are important migratory corridors, and may be important for other aspects of striped bass life history, the designation as striped bass spawning area is likely to broad. Primary striped bass spawning areas in the Tar/Pamlico River likely occur between Tarboro and Dunbar Road. Based on detection data, there appears to be little evidence of striped bass spawning at the upper reaches of the Tar River in Rocky Mount. Stretches of the Tar River above Dunbar Road are often shallow, particularly during periods of low flow, which may limit access to upriver areas. Similar to the Neuse River, access to upriver spawning locations in the Tar River seems to be limited or enhanced by river flow.

From this study, it is difficult to draw conclusions as to striped bass utilization of the Pungo River and South Creek as habitat because of the damage to and loss of receivers in these areas. However, striped bass were frequently detected in South Creek throughout the study and there were detections of striped bass at receivers in the Pungo River.

In most years striped bass were detected at the receivers located the furthest upstream, particularly in the Neuse River. Although there was little seasonal fluctuation in Neuse River discharge, when discharge increased in the spring of 2014 and 2017, average river kilometer of striped bass detections also increased. In the Tar River, there did appear to be seasonal fluctuations in river discharge. In the spring of 2014 and 2017 when river discharge increased the average river kilometer of striped bass detections also increased. In 2015 and 2016 peak discharge occurred before striped bass moved up the Tar River and average river kilometer of striped bass detections in these years was lower. Shallow water in the Neuse and Tar rivers likely limits the ability of striped bass to effectively move upstream during periods of low flow and in years with higher discharge upstream areas become more accessible. It is unclear how the location of striped bass spawning in both rivers may impact spawning success and recruitment. There does seem to be some indication that when upriver habitats in the Neuse and Tar rivers are accessible they will be utilized by striped bass. Future studies of striped bass life history in these river systems should consider river flow when sampling for spawning fish or striped bass eggs and larvae. Increased river discharge does not appear to impact striped bass migration timing indicating that other

environmental variables, like water temperature, may play a role in migration timing of striped bass in these systems.

Striped bass tagged in both the Neuse and Tar/Pamlico rivers were detected moving between the two rivers via the Bay River and ICW. Limited movement (<2.0%) between the Neuse and Tar/Pamlico rivers was detected by Bradley (2016) for acoustically tagged adult striped bass in the Neuse River. While migration between the two rivers was more common in striped bass tagged in the Neuse River, there does appear to be some migration between the two systems which may need to be considered when assessing the Neuse and Pamlico river striped bass stocks and recommending management action.

Striped bass tagged in both rivers appeared to migrate out of the system and were detected in the Albemarle Sound and the Atlantic Ocean as far north as New York. This is interesting as the CSMA striped bass population is considered non-migratory. Nearly 100% of the striped bass in the Neuse and Tar/Pamlico Rivers are considered of hatchery origin based on parentage based genetic analysis of striped bass collected on the spawning grounds (O'Donnell et al. 2015; Rachels and Ricks 2015) and stocked striped bass in the Neuse and Tar/Pamlico rivers exhibit high site fidelity with minimal movement outside of the system (Callihan et al. 2014a). An expanded parentage based tagging study with samples provided by NCDMF for striped bass collected throughout the lower Neuse and Pamlico rivers found 15.5% of striped bass in the Neuse and Tar/Pamlico rivers did not come from known hatchery origin (Farrae and Darden 2016). The migration patterns detected in the current study and the results of the genetics study suggest that some portion of striped bass from the Atlantic migratory stock, or the Albemarle/Roanoke stock may use the Neuse and Tar/Pamlico rivers as habitat for some part of their life. Analyzing traditional tagging data for Albemarle/Roanoke stock striped bass Callihan et al. (2014b) found movement to adjacent estuarine systems (i.e., Tar/Pamlico and Neuse rivers) during periods of high abundance in Albemarle Sound further suggesting that fish tagged in this study that exhibited migratory behavior likely originated in other systems. Further research investigating the migratory behavior of striped bass in these systems should be conducted, as variability in life history traits would impact management of striped bass in the CSMA.

In both river systems, the percentage of individual striped bass detected dropped off significantly immediately after the season they were tagged despite the multiple year life span of acoustic tags. This indicates that the fish migrated out of the system completely, avoided detection, or succumbed to fishing or natural mortality. Callihan et al. (2014a) found that total mortality of Roanoke River origin striped bass stocked in the Neuse and Tar/Pamlico rivers was higher than fish stocked in their natal river (Roanoke River), and using acoustic data Bradley (2016) found that striped bass in the Neuse River experience high levels of mortality.

## 5 DEVIATIONS

Downloads did not occur monthly due to staff vacancies and bad weather. The entire acoustic array was not complete for the majority of the study due to lost or stolen receivers. See methods section for specific deviations.

# JOB 2: TELEMETRY OF ANADROMOUS FISHES IN THE CAPE FEAR RIVER BASIN

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## ABSTRACT

An acoustic telemetry study was conducted in the Cape Fear River basin to identify and map spawning grounds, spawning habitat, and movement patterns of American shad and striped bass. Acoustic receivers (hydrophones) were deployed throughout the inland and coastal portions of the Cape Fear, Black, and Northeast Cape Fear rivers in areas suspected or known to be habitat for American shad and striped bass. When possible, attempts were made to deploy receivers, or groups of receivers, at locations that would cover the entire width of the waterway to ensure up or down river migration and movement out of the study area was detected. Nineteen American shad were tagged on the Northeast Cape Fear River in 2014, 10 American shad were tagged on the Black River in 2015, and 21 American shad were tagged on the Northeast Cape Fear River in 2016. By 2014, 128 striped bass were previously tagged and released by the North Carolina Division of Marine Fisheries and North Carolina State University in the Cape Fear River Basin, with an additional 39 tagged in 2014, 54 in 2015, and 41 in 2016. Attempts were made to download receivers monthly during the project period. A total of 29 American shad and 249 striped bass were detected during this project between January 2013 and August 2016. American shad were detected only during the spring in 2014 through 2016, and none were detected in multiple years. American shad were detected during the spring spawning season at the upper stations of the Black and Northeast Cape Fear rivers. Striped bass in the Cape Fear River were generally detected at a core region near downtown Wilmington during all seasons. One large striped bass was detected emigrating from the system. Many striped bass showed fidelity to and made repeated spring migrations each year up the Northeast and Cape Fear rivers, suggesting spawning migrations or behavioral contingents.

# 6 INTRODUCTION

Historical evidence shows the Cape Fear River once supported thriving stocks of anadromous fishes including American shad and striped bass (Yarrow 1874; Earl 1887). Over the years anadromous fish stocks have been significantly impacted by overfishing, loss of habitat, declining water quality, and blockage of upstream spawning migrations (ASMFC 2007; Limburg and Waldman 2009). In a previous attempt to protect critical spawning habitats for anadromous fishes, the NCDMF began a study in 1974 to document Anadromous Fish Spawning Areas (AFSA) throughout North Carolina. The study found AFSA to occur Cape Fear River from below the mouth of Town Creek and continues upstream as far as Lillington, NC (Sholar 1977). Three locks and dams were constructed on the main stem of the Cape Fear River between Riegelwood and Tar Heel NC, with the lowermost being completed in 1915 and the uppermost in 1935. These impediments to passage reduced the ability of striped bass and American shad to reach historic spawning areas near Smiley falls at the fall line in Lillington, NC (Nichols and Louder 1970). As a response to low numbers of documented spawning adults and limited evidence of juvenile recruitment, NCDMF implemented a moratorium on both the commercial and recreational harvest of striped bass in the Cape Fear River in 2008, which is still in effect. Striped bass have been stocked into the Cape Fear River since at least 1980 using broodstock fish sourced outside of the Cape Fear River Basin (Roanoke River); however, beginning in 2010 the North Carolina Wildlife Resources Commission (NCWRC) annually stocked fish produced from broodstock sourced in the Cape Fear. Studies have collected eggs and larvae (Smith 2009; Smith and Hightower 2012) or captured adult fish (Ashley and Rachels 2006) to show evidence of spawning and/or spawning migrations in the main stem of the Cape Fear River. The Black and Northeast Cape Fear rivers are major tributaries in the Cape Fear River Basin which have not had blockages to fish passage. However, anadromous fish migrations and spawning have not been well documented in these systems.

This project will allow NCDMF and NCWRC to use acoustic telemetry to map American shad and striped bass migrations and habitat use in the Cape Fear River Basin, and to document current potential spawning grounds in the Black and Northeast Cape Fear rivers.

## 6.1 Objective

Conduct a telemetry study in the lower Cape Fear, Northeast Cape Fear, and Black rivers to identify and map spawning grounds, spawning habitat, and movement patterns of American shad and striped bass. This study will also provide data to evaluate the effectiveness of and improve current NCDMF and NCWRC fishery-independent surveys meant to characterize the spawning stocks.

# 7 METHODS

## 7.1 Receiver Deployment

Acoustic receivers (VEMCO VR2W hydrophones; Figure 34) were deployed throughout the lower, middle, and upper portions of the Cape Fear, Northeast Cape Fear, and Black rivers. Initial receiver deployments occurred in January 2011 in the Cape Fear basin, and were in place prior to the beginning of this study. Receiver coverage was expanded upriver in the Northeast Cape Fear and Black rivers in 2014 and 2015, with attempts made to deploy receivers at upriver locations prior to any acoustic tagging of fish. When possible, attempts were made to deploy receivers in locations that would cover the entire width of the waterway to ensure up or down river migration

and movement out of the study area was detected. Receivers were deployed and attached to shoreline or in river structure (i.e., railroad trestle, channel markers, large trees, etc.) by a steel cable.

An existing array of 26 acoustic receiver stations extending approximately 145 river kilometers inland was present in the Cape Fear River Basin at the onset of this study, and was expanded in 2014 and 2015 to include eventually 34 receiver stations extending 183 river kilometers inland (Figure 35). Receiver stations were grouped into six river stretches based on position (upper, middle, lower) and which branch or tributary (Cape Fear River, Northeast Cape Fear River, Black River) they were deployed in (Table 9).

A gate consisting of two receivers at the mouth of the Cape Fear River at the Atlantic Ocean was formed by a receiver mounted on channel markers east on the Bald Head Island side of the river and west on the Caswell Beach side. An additional gate receiver was placed on a channel marker on the eastern side of Snow's Cut, near the Carolina Beach Yacht Basin entrance. These gate receivers as well as an additional receiver located on a channel marker at river kilometer 18 near the western end of Snow's Cut, comprised the lower Cape Fear River stations. Six receivers located on Channel Markers at Campbell island, the southern end of the Brunswick River, The State Port Turning Basin, Sutton Lake Discharge, as well as pilings for the S. Thomas Rhodes and Navassa Railroad bridge formed the middle Cape Fear River stations. Seven receivers were deployed in the upper Cape Fear River, four were attached to large trees at the confluence of the Black River, south of the entrance of Lyon Thorofare, at Double Branch Creek and downstream of Lock and Dam #1. The remaining three were attached to the structure in the lock chamber, and just upstream of Lock and Dam #1, and downstream of Lock and Dam #2. Multiple additional acoustic receiver stations are maintained by North Carolina State University (NSCU) and North Carolina Wildlife Resources Commission (NCWRC) upriver from Lock and Dam #2 upstream to Jordan Lake, however data from those stations are not included in this study.

Four Black River receiver stations are located above the confluence with the Cape Fear River. Two stations were mounted on large trees and in place at the onset of this study, one at Racoon Island, and one at Thorofare Island. An additional two receivers were deployed in 2015 to expand upriver coverage on the Black River, one on the NC 210 Bridge and one on the NC 53 Bridge.

Three initial receivers were deployed in the lower Northeast Cape Fear River, one on a channel marker just upstream from the confluence with the mainstem of the Cape Fear River, and two on USGS stations at Rat Island and near Fishing Creek. The third was added in 2014 on the Castle Hayne Road Bridge in Smith Creek. Four upper Northeast Cape Fear receivers were first in place and mounted on large trees at Turkey Creek, The I40 Bridge, Island Creek, and near Morgan Cove. Five additional upper Northeast Cape Fear River receivers were added to expand upriver coverage. Three were added in 2014 at the Holly Shelter NCWRC boat ramp, the NC 53 Bridge, and the Deep Bottom Road Bridge. The remaining two were deployed in 2015 at the NCWRC Chinquapin boat ramp, and the Hallsville Road Bridge.

### 7.2 Tagging

Captured American shad were held in a holding tank with supplemental oxygen for 10 minutes to determine if they were healthy enough to be tagged. American shad, deemed healthy enough to be tagged, were implanted with VEMCO V9 tags (Figure 34). Transponders were implanted into the stomach cavity through the mouth. This method was used by Beasley and Hightower (2000) and experimentally used by NCDMF in the Cape Fear River in 2011 with low mortality rates.

Passive Integrated Transponder (PIT) tags were inserted into the back just anterior to the dorsal fin of each fish.

Captured striped bass, deemed healthy enough to be tagged, were held in a holding tank while surgical equipment was prepared. All surgical equipment and materials (i.e., surgical suture, PIT tag, internal anchor tag, acoustic tag, and scalpel) were held in a 22.0 cm X 5.1 cm metal pan containing 91% isopropyl rubbing alcohol until needed. Once equipment was prepped, fish were removed from the holding tank and placed on a wooden cradle lined with damp sponges. Gills were continuously irrigated with water recirculated from the holding tank. Fish were initially sedated during the 2014 tagging season by using a dose of MS-222 (Tricaine methanesulfonate) at a concentration of 120 mg/L. The anesthetic was premeasured and stored in envelopes to result in the proper concentration when added to 5 gallons of water. Tagging in 2015 and 2016 employed electronarcosis (anesthesia, accompanied by muscle relaxation, through electrical inhibition) using procedures and equipment similar to those described in Hudson et al. (2011). Briefly, metal plates lining the holding chamber were connected to a 12V 7Ah battery (Enercell Sealed Lead-Acid Battery) using alligator clips allowing electrical current to pass through the fish causing electronarcosis. PIT tags, inserted into the left operculum, and internal anchor tags (type FM-84), inserted into the left side of the abdomen, were implanted in each fish. Individually coded VEMCO V9 or V13 ultrasonic transmitters (Figure 34) were inserted into each fish. Scales covering the incision location were removed using a scalpel. The incision location was swabbed with betadine solution and an incision approximately the width of the tag was made anterior to the right pelvic girdle and the tag was inserted. The incision was then closed with 2-4 interrupted sutures (Ethicon Monocryl 2-0 CT-1 27”). After surgery, fish were allowed to recover in the oxygenated holding tank until they were well oriented and swimming (approximately 15-20 minutes). Before release, Triple Antibiotic (Ever Ready First Aid and Medical Supply Company) was applied to the incision location. Environmental data including surface and bottom temperature, salinity, and dissolved oxygen was recorded at each tagging location. Temperature, salinity, and dissolved oxygen of water in the holding tank was monitored during tagging events.

### 7.3 Receiver Downloads

Attempts were made to download receivers once per month during the duration of the project. Receiver batteries were scheduled to be changed once annually during the first download of the calendar year.

### 7.4 7.4 Data Analysis

Detection data was downloaded into VUE Software (VEMCO), filtered by species and season, then exported as a comma-separated value (CSV) format. Seasons were defined as: spring, which included March, April, and May; summer, which included June, July, and August; fall, which included September, October, and November; winter, which included January, February, and December. CSV files were imported into Microsoft Excel for summary of detections and analysis. For this study, all detections of individual tags were summarized over a daily 24-hour period for each receiver station. This resulted in a detection being considered as one individual tagged fish per station per day. Mean river kilometer (measured from the river mouth from a line drawn from Bald Head Island to Caswell Beach, NC) of detections, and river discharge was plotted daily for both American shad and striped bass by river branch. Number of detections and percent of total individuals detected was plotted by river stretch and season for striped bass. Seasonal distribution

# 8 RESULTS

## 8.1 Tag Deployment

Tagging of American shad occurred over 14 days in March, April, and May 2014, 12 days in April 2015, and 10 days in March and April 2016. In 2014, two American shad were captured with actively fished gill nets, and the remainder of the fish captured with a boat mounted electroshocking unit. In the Northeast Cape Fear River, 19 acoustic tags were deployed in American shad in 2014, and 21 in 2016. In the Black River, 10 acoustic tags were deployed in American shad in 2015 (Table 10).

In 2014, American shad were targeted in the Northeast Cape Fear River. Out of 14 sampling days, only seven resulted in the capture of American shad, with a maximum of seven shad caught during any trip. Fork lengths of tagged shad ranged from 380 mm to 493 mm, with an average fork length of 440 mm (Table 10). Of the 19 shad tagged 53 percent were female and 47 percent were male. Shad were first captured in March around Cowpen Landing; however, in April they were captured near the NCWRC Holly Shelter boat ramp and in May near the NCWRC Chinquapin boat ramp. Fish captured in May were observed to be ripe and running.

In 2015, American shad were targeted in the Black River. Out of 12 sampling days, only six resulted in the capture of American shad, with a maximum of two caught during any trip. Fork lengths of tagged shad ranged from 322 mm to 427 mm, with an average fork length of 395 mm (Table 10). Of the nine American shad tagged, 100 percent were male. All of the American shad were captured in April in the vicinity of the Hunt's Bluff NCWRC boat ramp.

In 2015, American shad were targeted in the Northeast Cape Fear River. Out of 10 sampling days, six resulted in the capture of American shad, with a maximum of 11 fish caught during any trip. Fork lengths of tagged American shad ranged from 366 mm to 481 mm, with an average fork length of 436 mm (Table 10). Of the 21 shad tagged, 52 percent were female and 48 percent were male. American shad were first captured in March near the NCWRC Holly Shelter boat ramp and in April near the NCWRC Cypress Hole and NCWRC Chinquapin boat ramps. Fish captured in the vicinity of Deep Bottom Road were observed to be ripe and running in April.

Striped bass had been acoustically tagged in the Cape Fear River Basin by both NCDMF and NCSU since 2011. Prior to January 2014, there were 128 acoustic tags in striped bass, 97 released by NCSU and 31 by NCDMF. These fish ranged from 430 mm to 774 mm fork length, with an average fork length of 593 mm. Sixty fish were tagged and released in the lower Northeast Cape Fear River, 23 in the middle Cape Fear River, and 45 in the upper Cape Fear River (Table 11). Seven percent were identified as male, seven percent were identified as female and 89 percent were of unknown sex.

In the Cape Fear Basin in 2014, 39 striped bass were tagged ranging in length from 445 mm fork length to 755 mm fork length, with an average fork length of 624 mm. Twenty-nine fish were tagged and released in the middle Cape Fear River, and 10 in the upper Cape Fear River (Table 11). One-hundred percent of tagged striped bass were of unknown sex. The 29 fish that were tagged in the middle Cape Fear River were primarily caught in the vicinity of downtown Wilmington, between the State Port and the Sutton Lake discharge between January and May. The remaining 10 were tagged by NCSU at the base of Lock and Dam #1 in October.

In 2015, 54 striped bass were tagged in the Cape Fear River Basin. These fish ranged from 522 mm to 790 mm fork length, with an average fork length of 626 mm. Twenty-nine fish were tagged

and released in the lower Northeast Cape Fear River, 11 in the middle Cape Fear River, four in the upper Northeast Cape Fear River, and 10 in the Black River (Table 11). Five percent were identified as female, 15 percent were identified as male, and 80 percent were of unknown sex. Striped bass were primarily captured in the middle Cape Fear River (Campbell Island to Navassa) and Lower Northeast Cape Fear River (Confluence to Rat Island) between January and April. Striped Bass were targeted in the Black River in May, where 10 were tagged. Two of these fish were captured upstream of the Highway 53 Bridge, and the remainder were captured between Thorofare Island and the confluence with the Cape Fear River.

In 2016, 41 striped bass were tagged in the Cape Fear River Basin. These fish ranged from 441 mm to 741 mm fork length, with an average fork length of 612 mm. Fourteen fish were tagged and released in the lower Northeast Cape Fear River, 10 in the middle Cape Fear River, and 17 in the upper Northeast Cape Fear River (Table 11). Two percent were identified as female, 12 percent were identified as male and 86 percent were of unknown sex. The majority of striped bass tagged were captured between January and February in the middle Cape Fear River (Mallory Creek to Sutton Lake Discharge) and lower Northeast Cape Fear River (Confluence to Rat Island). In April, the upper Northeast Cape Fear River was targeted for striped bass. Ten fish were captured in the Northeast Cape Fear River above Wallace (7 ripe and running males, 3 unidentified). Six of these fish were captured above Deep Bottom Road.

### 8.2 Receiver Downloads and Maintenance

Receiver downloads had been ongoing on a monthly to quarterly schedule since 2011. A monthly schedule was implemented in March 2014 through December 2016. Downloads did not occur in November and or December 2014; November and or December 2015; or in May, August, and September 2016. In 2017, downloads only occurred in February, March, and August (Table 12). Deviations in receiver download schedules occurred due to bad weather, staff shortages, and other field sampling responsibilities. Receiver batteries were changed annually when possible.

During no season between 2013 and 2016 were all 34 receiver stations active. Varying start times of receiver deployments and equipment loss and malfunction resulted in a maximum of 32 active stations during fall 2015, and a minimum of 16 active stations during summer 2016 (Table 13). Areas of high receiver loss had been during the early deployment of receivers in 2011, and stations in the lower reaches of the Cape Fear River were reduced to avoid constant equipment loss. Receivers attached to infrastructure such as bridges or channel markers typically experienced less loss than anchored and buoyed receivers. Receiver malfunction due to age, and loss to large weather events significantly reduced the number of active receivers by summer 2016.

In 2014, two receivers were lost, or not functioning, for the entirety of the season. Receiver BK02, the second station in the Black River had become entangled under a large log. The battery of BK02 was dead and the receiver could not be retrieved for the battery to be replaced. In December 2014, the receiver was able to be freed from the log after it had moved downstream and the battery was replaced. Receiver CF05, located across from the State Port in the middle Cape Fear River on a channel marker, went missing. This receiver was not replaced until 2015 due to the dredging operations frequently occurring in this area associated with Wilmington Harbor.

In 2015, receiver CF06 in the upper Cape Fear River went missing after the entire large cypress tree it was cabled to fell into the river and washed away. The receiver was not found or recovered. This station was not replaced due to the relatively few detections occurring on it, as well as there being functioning receivers within 8 km upstream and downstream of this location. Receiver

NE06, located in the upper Northeast Cape Fear River just upstream of the Castle Hayne NCWRC boat ramp, went missing in summer 2015. This receiver was marked with a buoy and in a relatively high traffic area. This station was also not replaced due to the proximity to the boat ramp.

In 2016, an additional 16 receivers were lost or malfunctioned by summer, leaving only 16 active stations in the Cape Fear River Basin. Six receivers (BR01, CF12, CF17, NE02, NE03, NE04) had malfunctioned (stopped offloading data, or internal clock error). Storm events in 2016 also resulted in the loss of a significant number of receivers, impairing the detection ability in the Cape Fear River Basin.

### 8.3 Detections

A total of 29 (58 percent of tagged fish) American shad and 249 (95 percent of tagged fish) striped bass were detected between December 2012 and August 2016 in the Cape Fear River Basin. Maps of American shad detections for the spring of 2014, 2015, and 2016 can be found in Appendix D. Maps of striped bass detections from by season for 2013-2016 can be found in Appendix E.

### 8.4 American shad

In 2014, 19 American shad were tagged in the upper Northeast Cape Fear River and 15 (79 percent) were detected at least once (Table 14). American shad tagged in 2014 were detected in the spring and summer, between March 19 and July 11. However, movement between receivers or out of detection range stopped in June and tags detected in the summer appear to be stationary and from fish which may have died. All fish detected displayed fall back downstream from the initial tagging locations in the upper Northeast Cape Fear River to the lower Northeast Cape Fear River. Five fish moved downstream all the way to the lower Cape Fear River within five days of tagging, with one being detected at the river mouth, before resuming upstream migration. Ten fish were detected at the uppermost two active receivers in the Northeast Cape Fear River, at Deep Bottom Road and the NC 53 Bridge. One fish, which was tagged and first detected on May 19, displayed fall back behavior to the lower Cape Fear River, then migrated up the mainstem of the Cape Fear River where it was detected at the station below Lock and Dam #2 in Elizabethtown on April 4. There was no evidence of post spawn emigration from the system, and the last detections of all tags were in the middle or upper river sections. No American shad tagged in 2013 were detected in the Black River.

In 2015, 10 American shad were tagged in the Black River, and nine (90 percent) were detected at least once (Table 14). All American shad tagged in 2015 were only detected in the spring, between April 7 and May 27. Two fish tagged in April displayed fall back behavior from the tagging location in the upper Black River. One fish which fell back to the upper Cape Fear River was last detected just upstream of the confluence of the Black River in the Cape Fear River, while the second fish fell back to Campbell Island in the middle Cape Fear River where it was last detected three days after tagging. The remaining fish were only detected in the upper Black River mostly at the station at the NC 53 Bridge, and with one fish detected at the station at the NC 210 Bridge. All American Shad detections in 2015 detections were primarily limited to the uppermost active station in the Black River (NC 53), and there was no evidence of post spawn emigration, as the last detections for tagged fish were also from that station. No American shad tagged in 2015 were detected in the Northeast Cape Fear River.

In 2016, 21 American Shad were tagged in the upper Northeast Cape Fear River, and five (24 percent) were detected at least once (Table 14). All American shad tagged in 2016 were detected

in the spring between March 23 and May 13. Of the five fish detected, none displayed any fall back behavior. One tagged fish was briefly and last detected at a receiver in the middle Cape Fear River; however, it only had one detection and was not detected at any other receivers between this station and the upper Northeast River station where it was tagged. There were relatively few shad detections in 2016. Two of the five fish were detected at stations above where they were tagged in the upper Northeast Cape Fear River, Deep Bottom Road and the NCWRC Chinquapin boat ramp. No American shad were detected at the uppermost Northeast Cape Fear River station, Hallsville Road. There was no evidence of post spawn emigration, as the last detections of tagged fish were in the upper Northeast Cape Fear River.

### 8.4.1 River Kilometer and River Discharge

Maximum river kilometer for American shad tag detections across all years in the Cape Fear River mainstem was 145 kilometers (Lock and Dam #2 receiver), in the Black River was 96 kilometers (NC 53 Bridge receiver), and in the Northeast Cape Fear River was 168 kilometers (NCWRC Chinquapin boat ramp).

### 8.4.2 2014

American shad tagged in the Northeast Cape Fear River in 2014 showed upstream migration after initial fall back behavior from tagging. Mean American shad detections dropped to under 20 river kilometers during this fall back period, but quickly reached over 100 river kilometers as fish migrated upriver (Figure 36). Shad detections reached a maximum of 163 river kilometers (most upriver active station) in the Northeast Cape Fear River, and 145 river kilometers (most upriver active station) in the Cape Fear River mainstem during this year. Mean detection distance dropped to around 50 kilometers by the end of spring and into summer, and most movement between receivers stopped.

Northeast Cape Fear River discharge data for the monitoring station near Chinquapin, NC was downloaded from the USGS website for the period from March 19, 2014 to July 19, 2014. Mean daily discharge ranged from 37 $ft^3$/second to 7,680 $ft^3$/second with three clear large spikes between April and May (Figure 36). There was not a clear correlation between mean river kilometer of American shad detections and mean river discharge, with peaks in mean detection river kilometer occurring during periods of low and high flows.

### 8.4.3 2015

American shad tagged in the Black River in 2015 showed fall back behavior from tagging. Two distinct decreases, to below 80 and 40 kilometers respectively, in mean river kilometer of American shad detections reflect the two fish which moved downstream after tagging. Nearly all fish detected remained at the uppermost station near where they had been captured and tagged (Figure 37). American shad detections reached a maximum of 96 river kilometers (most upriver active station) in the Black River, and 72 river kilometers in the Cape Fear River mainstem during 2015. Mean detection distance did not drop by the end of spring, and remaining active tags, which did not display fall back behavior, were last detected at river kilometer 96 in the Black River.

Black River discharge data for the monitoring station near Currie, NC was downloaded from the USGS website for the period from April 7, 2015 to May 26, 2015. Discharge ranged from 238 $ft^3$/second to 2,371 $ft^3$/second, with a peak flow at the end of April, and a second smaller peak in May (Figure 37). There appeared to be a slight decline in mean river kilometer of American shad detections occurring right after the peak flow period during April, and most tags stopped being detected during the second high flow event.

### 8.4.4 2016

American shad tagged in the Northeast Cape Fear River in 2016 showed upstream migration, and did not display fall back behavior after tagging. Mean shad detections increased from 115 river kilometers in March to a peak of over 160 river kilometers in April as fish migrated upriver (Figure 38). Shad detections reached a maximum of 168 river kilometers in the Northeast Cape Fear River during this year. Mean detection distance dropped to around 40 river kilometers by the end of spring, based on one tag that was detected once in the middle Cape Fear River. Mean detection distance remained high at the end of the spring, with the last detections of tags occurring at upper stations in the Northeast Cape Fear River.

Northeast Cape Fear River discharge data for the monitoring station near Chinquapin, NC was downloaded from the USGS website for the period from March 22, 2014 to May 10, 2016. Mean daily discharge ranged from 213 $ft^3$/second to 1,653 $ft^3$/second with a large peak during early May (Figure 38). There was not a clear correlation between mean river kilometer of American shad detections and mean river discharge.

## 8.5 Striped Bass

### 8.5.1 Recreational Hook and Line Recaptures

Between January 2013 and August 2016, 13 acoustic tagged striped bass were reported as captured and released by hook and line recreational anglers (Table 15). All of the recaptured fish were reported to be within the Cape Fear River Basin. Of the fish that were caught and released, eight were detected multiple times at various locations after being released by anglers. Three of the recaptured fish which were not detected after capture were caught after the battery life of the implanted tags had expired, and the remaining two fish without detections were not detected on any receiver ever over the course of the study. One fish without any detections was reported captured and released on the same day it was surgically implanted with the acoustic tag, and the absence of detections likely represents the mortality of that fish, or tag failure. The second fish without any detections was reported captured and released 21 days after receiving an acoustic tag. This fish may have not passed by any active stations during this time period and did not survive the hook and line release, or this fish represents an acoustic tag malfunction or expulsion. Five of the tagged fish which were caught by anglers were captured at one of the three locks and dams. These fish were detected by receivers at the lock and dams between one and seven days before and after the catch and release event.

### 8.5.2 2013

In 2013, 108 total striped bass were tagged in the Cape Fear Basin, 17 in the middle Cape Fear River, 45 in the upper Cape Fear River and 46 in the lower Northeast Cape Fear River. By fall 2013, 128 total striped bass with acoustic tags had been released into the Cape Fear River Basin. Of the tags active and available each season, 78 percent were detected in the winter, 94 percent were detected in the spring, 84 percent were detected in the summer, and 72 percent were detected in the fall (Table 16). Striped bass were detected from January 1 until December 31 in 2013. Of the fish tagged, the highest percentage of detections occurred in the lower Northeast Cape Fear River, followed by the middle Cape Fear River for all seasons. No detections occurred in the lower Cape Fear River in all seasons except for less than one percent occurring in summer. The distribution of detection percentages shifted to include the upper Cape Fear River, Black River, and upper Northeast Cape Fear River during the spring (Figure 39). Of the individual striped bass detected each season in 2013, the highest percentage of individuals were detected in the lower

Northeast and middle Cape Fear rivers during the spring. The upper Cape Fear, Northeast, and Black rivers saw an increase in the percent of individuals detected during the spring, and this period was also the peak season of percent individuals detected for these stretches of river. The lower Cape Fear River had the lowest percent of individuals, with few detections only occurring in summer (Figure 40).

In winter 2013, striped bass were primarily and frequently detected at all stations in the lower Northeast and middle Cape Fear rivers, centered around downtown Wilmington. Only the most downriver stations of the upper Northeast, upper Cape Fear, and Black rivers had detections of striped bass during this season, and were typically a small percentage of total individuals tagged.

In spring 2013, striped bass continued to be detected at the lower Northeast Cape Fear River and middle Cape Fear River stations; however, percent of individual fish and overall percent of detections increased at upriver stations. Thirty-one striped bass (35 percent of all tags detected this season) were detected at the uppermost deployed stations in the basin during this season. Between the two uppermost deployed stations in the main stem of the Cape Fear River, nine striped bass (10 percent of all tags detected this season) were detected by at least one station. Between the two uppermost deployed stations in the Northeast Cape Fear River, 22 striped bass (25 percent of all tags detected this season) were detected by at least one station. No striped bass were detected at either of the uppermost stations in the Black River (Table 17).

In summer 2013, detections of individual striped bass in the upper stretches of river decreased as the percentage of total detections increased for the middle Cape Fear and lower Northeast rivers. One individual striped bass was detected at the most upriver station in the lower Cape Fear near the western end of Snow's Cut. This individual was not detected at any other downriver station, and quickly returned to being detected in the middle Cape Fear River. The majority of striped bass detections during this time came from stations located near downtown Wilmington.

In fall 2013, most detections continued to occur between the lower Northeast Cape Fear River and middle Cape Fear River. However, there was an increase in detections of striped bass in the upper Cape Fear River, as 31 additional tags were deployed at Lock and Dam #1 during this season. No detections of striped bass occurred in the lower Cape Fear River.

### 8.5.3 2014

In 2014, 39 total striped bass were tagged in the Cape Fear River Basin, 29 in the middle Cape Fear River, and 10 in the upper Cape Fear River. By fall 2014, 167 total striped bass with acoustic tags had been released into the Cape Fear River Basin. Of the tags active and available each season, 73 percent were detected in the winter, 75 percent were detected in the spring, 56 percent were detected in the summer, and 54 percent were detected in the fall (Table 16). Striped bass were detected from January 1 until December 31 in 2014. Of the fish tagged, the highest percentage of detections occurred in the lower Northeast Cape Fear River, followed by the middle Cape Fear River for all seasons except for spring when that pattern was reversed. No detections occurred in the lower Cape Fear River in all seasons, except for less than one percent occurring in summer. The distribution of detections percentages shifted to include more from the Black River, and upper Northeast Cape Fear River during the spring; however, detection percentage dropped between winter and spring for the upper Cape Fear (Figure 41). Of the individual striped bass detected each season in 2014 the highest two percentages of individuals were detected in the middle Cape Fear River and lower Northeast Cape Fear River in the spring. The upper Cape Fear, Northeast Cape Fear, and Black rivers saw an increase in the percent of individuals detected during

the spring, and this time period was also the peak season of percent individuals detected for these stretches of river. The lower Cape Fear River had the lowest percent of individuals, with few detections only occurring in summer (Figure 42).

In winter 2014, striped bass were primarily and frequently again detected at all stations in the lower Northeast Cape Fear and middle Cape Fear rivers, centered around downtown Wilmington. Only the most downriver stations of the upper Northeast, and Black rivers had detections of striped bass during this season, and were typically a small percentage of total individuals tagged. There was an increase in the number and percentage of individuals detected in the upper Cape Fear River, driven by tagging and detections of striped bass at Lock and Dam #1.

In spring 2014, striped bass continued to be detected at the lower Northeast and middle Cape Fear stations; however, percent of individual fish and overall percent of detections increased at upriver stations. Forty-six (37 percent of all tags detected this season) were detected at the uppermost deployed stations in the basin during this season. Between the two uppermost deployed stations in the mainstem of the Cape Fear River, 25 striped bass (20 percent of all tags detected this season) were detected by at least one station. Three of these fish were at the same stations in 2013, and represent 38 percent of tags still active from fish detected at these stations the previous year. Between the two uppermost deployed stations in the Northeast Cape Fear River, 21 striped bass (17 percent of all tags detected this season) were detected by at least one station. Six of these fish were at the most upriver Northeast Cape Fear River stations in 2013, and represent 55 percent of tags still active from fish detected at these stations the previous year. No striped bass were detected at either of the uppermost stations in the Black River (Table 17).

In summer 2014, detections of individual striped bass in the upper stretches of river decreased as the percentage of total detections increased for the middle Cape Fear and lower Northeast Cape Fear rivers. One individual striped bass was detected at the most upriver station in the lower Cape Fear River near Snow's Cut. This individual was not detected at any other downriver station, and returned upriver after several days of detections at this station. The majority of striped bass detections during this time came from stations located near downtown Wilmington.

In fall 2013, most detections continued to occur between the lower Northeast Cape Fear and middle Cape Fear River. However, there were increased detections of striped bass in the upper Cape Fear River, as multiple individual fish moved upriver to the base of Lock and Dam #1 in October. No detections of striped bass occurred in the lower Cape Fear River.

### 8.5.4 2015

In 2015, 54 total striped bass were tagged in the Cape Fear Basin, 11 in the middle Cape Fear, four in the upper Northeast Cape Fear Rive, 29 in the lower Northeast Cape Fear, and 10 in the Black River. By fall 2015, 221 total striped bass with acoustic tags had been released into the Cape Fear basin, however based on the battery life of the acoustic tags, 129 would be expected to be active. Striped bass were detected from January 1 until December 31 in 2015. Of the tags active and available each season, 49 percent were detected in the winter, 83 percent were detected in the spring, 74 percent were detected in the summer, and 73 percent were detected in the fall (Table 16). Of the fish tagged, the highest percentage of detections occurred in the lower Northeast Cape Fear River and middle Cape Fear River. In the summer and fall, detection percentages were highest in the lower Northeast Cape Fear River followed by the middle Cape Fear River, and then that pattern was reversed in winter and spring. A small percent of detections of striped bass occurred in the lower Cape Fear River in all seasons except for the winter. The distribution of

detection percentages shifted to include less from the Black River between winter and spring; however, detection percentage increased slightly between winter and spring for the upper Cape Fear River and upper Northeast Cape Fear River (Figure 43). Of the individual striped bass detected each season in 2015, the highest percentage of individuals were detected in the middle Cape Fear River and lower Northeast River in the spring. The upper Cape Fear, Northeast, and Black rivers saw an increase in the percent of individuals detected during the spring, and this time period was also the peak season of percent individuals detected for these stretches of river. The lower Cape Fear River had the lowest percent of individuals, with few detections occurring in spring, then increasing slightly in the summer (Figure 44).

In winter 2015, striped bass were again primarily and frequently again detected at all stations in the lower Northeast Cape Fear and middle Cape Fear rivers, centered around downtown Wilmington. Only the most downriver stations of the upper Northeast Cape Fear River and Black River had detections of striped bass during this season, and were typically a small percentage of total individuals tagged. There was a larger amount of winter detections in the upper detection Cape Fear River than in 2013, but fewer than 2014. There were no individuals detected in the lower portion of the Cape Fear River during this time.

In spring 2015, striped bass continued to be detected at the lower Northeast Cape Fear River and middle Cape Fear stations; however, percent of individual fish, increased at upriver stations. Sixty-seven (54 percent of all tags detected this season) were detected at the uppermost deployed stations in the basin during this season. Between the two uppermost deployed stations in the mainstem of the Cape Fear River, 44 striped bass (36 percent of all tags detected this season) were detected by at least one station. Thirteen of these fish were at the same stations in 2014, and represent 81 percent of tags still active from fish detected at these stations since 2013. Between the two uppermost stations in the Northeast Cape Fear River, 22 striped bass (18 percent of all tags detected this season) were detected by at least one station. Six of these fish were detected at the most upriver Northeast Cape Fear River stations in 2014, and represent 67 percent of tags still active from fish detected at these stations since 2013. One striped bass (less than one percent of all tags detected this season) was detected between both of the uppermost stations in the Black River (Table 17). Two individual striped bass were detected in the lower Cape Fear River. Of these fish, one was detected at the station near the western end of Snow's Cut, then later returned upriver and was detected at multiple stations in the middle Cape Fear River. The second fish, tag A69-9002-12568, was detected moving downriver by multiple middle and lower Cape Fear River stations between April 4 and April 9, then last detected leaving the Cape Fear River system by the gate station at Caswell Beach on April 10, 2015. This fish was not detected in the Cape Fear River again by any station.

In summer 2015, detections of individual striped bass in the upper stretches of river decreased as the percentage of total detections increased for the lower Northeast Cape Fear River. The majority of detections during this season come from stations located in the lower Northeast Cape Fear River and middle Cape Fear near downtown Wilmington. One striped bass was detected in the lower Cape Fear River near Snow's Cut, but returned upriver after one detection at this station.

In fall 2015, most detections continued to occur between the lower Northeast Cape Fear River and middle Cape Fear River stations. However, there were increased detections of striped bass in the upper Cape Fear River, as multiple individual fish moved upriver to the base of Lock and Dam #1 in October. Multiple detections of striped bass occurred in the lower Cape Fear River at the station

near the western end of Snow's cut, but no fish were detected by any of the gate receivers and were later detected at stations upriver.

### 8.5.5 2016

In 2016, 41 total striped bass were tagged in the Cape Fear River Basin, 10 in the middle Cape Fear River, 14 in the lower Northeast Cape Fear River and 17 in the upper Northeast Cape Fear River. By summer 2016, 262 total striped bass with acoustic tags had been released into the Cape Fear River Basin; however, based on the battery life of the acoustic tags, 124 would be expected to be active. Of the tags active and available each season, 76 percent were detected in the winter, 85 percent were detected in the spring, and 60 percent were detected in the summer (Table 16). Striped bass were detected from January 1 until August 31 in 2016. Of the fish tagged, the highest percentage of detections occurred at the middle Cape Fear River stations in all seasons. The greatest percent of detections observed for striped bass in the lower Cape Fear River occurred in winter 2016. The distribution of detections shifted to include the highest percentage observed in the Black River, and upper Cape Fear and Northeast rivers in spring (Figure 45). Of the individual striped bass detected each season in 2016, the highest percent of individuals was detected at the middle Cape Fear River stations during spring. The upper Cape Fear, and Black rivers saw an increase in the percent of individuals detected during the spring, and this time was also the peak season of percent individuals detected for these stretches of river. The lower Cape Fear River had multiple individuals detected during the winter season (Figure 46).

In winter 2016, striped bass were again primarily and frequently again detected at all stations in the lower Northeast River and middle Cape Fear River, centered around downtown Wilmington. However, this distribution was shifted further south and more detections occurred at Campbell Island than during previous years. All stretches of river had detections of striped bass during this season, with multiple detections of striped bass at the lower Cape Fear River stations. Multiple striped bass were detected at the station to the west of Snow's Cut, but no fish were detected at any of the gate receivers. All of these fish were later detected at upriver stations later in the year.

In spring 2016, striped bass continued to be detected at the lower Northeast Cape Fear River and middle Cape Fear River stations; however, the percent of individual fish increased at upriver stations. Sixty-three (59 percent of all tags detected this season) were detected at the uppermost deployed stations in the basin during this season. Between the two uppermost deployed stations in the mainstem of the Cape Fear River, 37 striped bass (35 percent of all tags detected this season) were detected by at least one station. Six of these fish were at the same stations in 2015, and represent 67 percent of tags still active from fish detected at these stations since 2013. Between the two uppermost deployed stations in the Northeast Cape Fear River, 20 striped bass (19 percent of all tags detected this season) were detected by at least one station. Six of these fish were at the uppermost stations in the Northeast Cape Fear River in 2015, and represent 46 percent of tags still active from fish detected at these stations since 2013. Six striped bass (six percent of all tags detected this season) were detected between at two of the uppermost stations in the Black River (Table 17).

In summer 2016, detections of individual striped bass in the upper stretches of river decreased as the percentage of total detections increased for the middle Cape Fear River. Most detections during this season come from stations located in middle of the Cape Fear River near downtown Wilmington. However, by summer 2016 many of the receivers in the lower Northeast Cape Fear River were lost or had malfunctioned.

### 8.5.6 Migration and River Discharge

Maximum river kilometer for striped bass detections in the Cape Fear River Basin was observed at the uppermost active stations during spring seasons at, Lock and Dam #2 in the Cape Fear River (145 kilometers), NC 53 Bridge on the Black River (96 kilometers), and Hallsville Road on the Northeast Cape Fear River (183 kilometers), and minimum detection distance (0 kilometers) at the lowest gate station in mouth of the Cape Fear River at Caswell Beach.

All striped bass detected across the Cape Fear River Basin showed patterns of seasonal upstream and downstream movement (Figure 47). Maximum average river kilometer of striped bass detections increased in 2014 and 2016 as receiver coverage was expanded up river. Peaks in average detections distance occurred between April and May, reflecting upriver migration and detection on upper receiver stations. Average detection distance for all striped bass across seasons is 56 river kilometers, which is upstream of downtown Wilmington, NC and the confluence of the Cape Fear and Northeast Cape Fear rivers at 44 river kilometers.

Cape Fear River discharge data was downloaded from the USGS website for the monitoring station at Lock and Dam #1 near Riegelwood, NC for the period from January 1, 2013 to August 31, 2016. Discharge ranged from 685 $ft^3$/second to 30,700 $ft^3$/second, displaying seasonal periods of high and low flows throughout the time series. The flow data were plotted with mean daily detection distance of all striped bass detected in any reach of the Cape Fear River for this time period (Figure 48). There did not appear to be a consistent correlation between mean river kilometer of striped bass detections and mean river discharge. However, in the fall of 2015 and winter of 2016 when river discharged spiked and reached the maximum observed, the mean river kilometer of striped bass detections decreased to the minimum observed. Other smaller decreases in mean detection distance were also observed at times of higher flow events. Maximum mean detection distances occur in both periods during the spring and fall in the upper Cape Fear River.

Black River discharge data was downloaded from the USGS website for the monitoring station near Currie, NC for the period from January 1, 2013 to August 31, 2016. Discharge ranged from 40 $ft^3$/second to 7,287 $ft^3$/second, with flow generally lowest in the summer. The flow data were plotted with mean daily detection distance of striped bass detected in the Black River for this time period (Figure 49) There appeared to be little correlation between mean river kilometer of striped bass detections and mean river discharge. Peaks in mean detection distance above 80 river kilometers occurred in the spring of 2015 and 2016, as well as the fall of 2015.

Northeast Cape Fear River discharge data was downloaded from the USGS website for the monitoring station near Chinquapin, NC for the period from January 1, 2013 to June 1, 2016. Discharge ranged from 20 $ft^3$/second to 7,413 $ft^3$/second, with flow generally lowest in the summer. The flow data were plotted with mean daily detection distance of striped bass detected in the lower and upper Northeast Cape Fear River for this time period (Figure 50). There appeared to be little correlation between mean river kilometer of striped bass detections and mean river discharge. Peaks in mean detection distance above 80 river kilometers occurred in the spring of all years. A significant increase in maximum average detection distance was observed in 2016 due to the addition of stations 20 river kilometers above what was present in 2015 as well as not having detection data from many of the lower Northeast Cape Fear River receivers.

### 8.5.7 Other Detections

Other fish that were not tagged as part of this study but detected by acoustic receivers used in this study included Atlantic sturgeon (*Acipenser oxyrinchus*), lemon shark (*Negaprion brevirostris*),

and sand tiger shark (*Carcharias taurus*). Records of detections, as well as location information for receiver stations were sent to the appropriate researchers who deployed tags.

## 9 CONCLUSIONS

American shad in spawning condition were tagged and detected in upriver reaches of both the Black and Northeast Cape Fear rivers. There appeared to be little correlation between river flow and mean river kilometer of American shad detections. Observation and detection of migration behavior of tagged American shad were often limited by fish which displayed fall back behavior after tagging and were not detected moving upriver again. One fish, after it was tagged in the upper Northeast Cape Fear River, fell back and subsequently migrated up the main stem of the upper Cape Fear River, which did not show fidelity to the river which it was initially captured. American shad were not easily captured in the lower reaches of the Northeast Cape Fear or Black rivers with boat electrofishing gear. Initially in 2014, an actively fished 5.5-inch floating drift net was employed to target American shad in the lower Northeast Cape Fear River. Very few fish were captured over many drifts, and most were not in good enough condition for tagging. Electrofishing provided fish in excellent condition for tagging, but was only effective at upriver locations. This prevented the tagging of fish early or low in either river system, resulting in most American shad being captured and tagged near their likely spawning areas.

In the Northeast Cape Fear River, tagged American shad were detected during the spawning season as far upstream as the NCWRC Chinquapin boat ramp (kilometer 168). Historic maximum upstream migration of American shad in the Northeast Cape Fear River was documented to near Albertson, NC (kilometer 281) (Walburg and Nichols 1967). No American shad were detected at the uppermost station at Hallsville Road (kilometer 183); however, American shad in post spawn condition were captured in April 2016 above the NCWRC Chinquapin boat ramp and were not tagged. Adult ripe and running American shad were captured and tagged at sites downstream of the NCRWRC Chinquapin boat ramp downriver to the NCWRC Holly Shelter boat ramp, a 58 kilometer stretch of river. Winslow et al. (1983) listed areas upriver of the NC 53 Bridge (kilometer 122) to Hallsville Road as probable American shad spawning areas, and areas from Highway NC 53 to Lillington Creek (approximately station NC08, kilometer 98) as then known American shad spawning areas. The primary historic spawning areas of American Shad were considered between the NC 53 Bridge and Croomsbridge Road (kilometer 130) (Walburg and Nichols 1967). Results of this study suggest American Shad do currently use the Northeast Cape Fear River from upriver of the NC 53 Bridge to at least Chinquapin NC as spawning areas. This would expand known American shad spawning areas to over an 82 kilometer stretch of river from Lillington Creek to Chinquapin, with additional spawning areas still probable upriver.

In the Black River, tagged American shad were detected during the spawning season as far upstream as Highway NC 53 Bridge (kilometer 96). There were no active stations upstream from this point. Historic maximum upriver migration of American shad in the Black River was documented to near Clinton, NC (kilometer 224). Due to difficulty in capturing American shad in the Black River, most tags were not deployed until mid to late April. All American shad captured and tagged in the Black River were near the NCWRC Hunt's Bluff boat ramp, and in ripe and running condition. Historic spawning areas for American Shad in the Black River were considered to primarily be between Highway NC 53 to near Tomahawk, NC (kilometer 150). Although migration of American shad tagged in the Black river was not observed, this study confirms that these fish continue to use this tributary upriver to at least the Highway NC 53 Bridge during the spawning season.

American shad spawn over sand and gravel substrates, often below obstructions (Walburg and Nichols 1967). After release and fertilization in open water, American shad eggs become negatively buoyant, and become lodged in large substrates downstream of the spawning site (Chittenden 1969). In the Roanoke and Neuse rivers in North Carolina, American shad spawn over gravel and cobble substrate in the high gradient region near the fall line (Beasley and Hightower 2000; Hightower and Sparks 2003). In the mainstem of the Cape Fear River, American shad which navigate the three locks and dams, use the same rocky high gradient regions near the fall line as spawning areas (Smith and Hightower 2012). Both the Black and Northeast Cape Fear rivers are considered sand-bottomed, blackwater systems which do not reach the fall line, crossing only from the coastal plain ecoregion into the rolling coastal plain ecoregion (NCDENR 2004). American shad are spawning in the Black and Northeast Cape Fear rivers over the available sand substrates in areas which are relatively low gradient. Large woody debris was frequently observed in the shallow and sandy regions of the Black and Northeast Cape Fear Rivers where ripe and running American shad were collected and likely serves as important substrate for egg settlement. American shad eggs have been collected at the greatest density in areas where the immediate shorelines were greater than 60 percent forested, and declines in both egg and larval densities have been shown when more than 40 percent of the surrounding land use was agricultural (Bilkovic et al. 2002). Land adjacent to the Black River in the area considered to be American shad spawning grounds is primarily undisturbed forest, with approximately 80 percent of the surrounding basin forested, and has been classified as Outstanding Resource Water (NCDENR 2004). Land use in the Northeast Cape Fear River in the area considered to be American shad spawning area is 40 percent agricultural, and 58 percent forested (NCDENR 2004). This area has large concentrations of confined animal feeding operations, and both spills and nonpoint pollution from these activities has reduced water quality (NCDENR 2004). Both land use and water quality impacts need to be considered when examining population declines of anadromous fish in the Northeast Cape Fear River.

There was no evidence of downstream movement of American shad after spawning, as the only downstream movements that were detected were fall back behavior after tagging. American shad tags were typically last detected in the upper to mid reaches of the basin, suggesting the possible mortality of the tagged fish in that location. American shad in North Carolina are at the boundary of the north to south gradient of semelparity for this species (Greene et al. 2009). Previous investigation into repeat spawning of American shad in the Cape Fear River found less than one percent of fish aged were second time spawners (Winslow et al. 1983), and the lack of detections at lower river stations likely indicates most American shad in the Cape Fear River Basin die after spawning. Tagged American shad in this study were vulnerable to both commercial and recreational fishing mortality. However, due to their relatively low abundance in these tributaries, no commercial and limited recreational shad fishing was observed in the Black or Northeast Cape Fear rivers. Tagged adult American shad may have also suffered predation mortality before detection between receivers. In multiple reaches of both the upper Northeast Cape Fear and Black rivers, numerous large (>700 mm TL) flathead catfish (*Pylodictis olivaris*) were captured simultaneously with adult American shad. When the stomach contents of these catfish were examined, several were determined to have preyed on multiple adult American shad. Predation of adult American shad by flathead catfish has been previously documented in the Cape Fear River Basin (Ashley and Buff 1988), and flathead catfish had been documented to selectively prey on American shad during their spawning migrations (Schmitt et al. 2017). The overall impacts to

anadromous fish stocks by non-native catfish species in the Cape Fear River Basin remains unknown.

Striped bass were consistently detected at stations ranging from Campbell Island in the Cape Fear River below Wilmington to upriver near Fishing Creek in the Northeast Cape Fear River and upriver to near Sutton Lake in the Cape Fear River. All striped bass tagged and detected in the Cape Fear River Basin have been detected at stations within this core range. This area represents an important area for striped bass, likely for foraging in the high productivity region at the freshwater saltwater interface, and possibly during the summer in the deeper shipping channel which may serve as a thermal refuge. Typically, all tagged striped bass regardless of initial capture and tagging location were in this central core area during the winter months. Detections of fish during the winter months typically centered around the confluence of the Northeast Cape Fear River at downtown Wilmington. Nearly constant detection of many individual fish over many days typically occurred at stations in this core region. This distribution shift downriver during high flow events, as was observed in the fall of 2015 and winter of 2016. This observed typical distribution of striped bass and downriver shift during high flow was also observed in other NCDMF finfish sampling programs. Striped bass begin upriver migrations in the spring out of the core range, and more individuals are detected at a greater frequency at stations in upriver locations. Not all striped bass tagged were observed to leave the core region in the spring or migrate upriver. An average of 53 percent of detected fish in the spring did not exhibit upstream movement on a given year. By late spring striped bass were detected at the most upriver stations, and then again returned to the core range centered around the confluence of the Northeast Cape Fear River for the summer and fall seasons. There was a small upriver migration out of the core range by some striped bass to the base of Lock and Dam # 1 during the fall months. These fish then returned to the core range during the winter months and may be migrating to this location to take advantage of the potential food source of out-migrating young of the year Alosids, which concentrate before passing downstream and over the dam and fish passage structure.

In the Northeast Cape Fear River, between 19 and 25 percent of all active striped bass tags were detected at the uppermost active stations each year during the spawning season. The uppermost station on the Northeast Cape Fear River was located at Hallsville Road. Based on detection patterns of striped bass at that station and the station below, fish likely moved upstream beyond that location. Ripe and running male striped bass were captured and tagged between Chinquapin and White Stocking, NC. Several very large ripe fish were stunned (but not captured) by the electrofishing equipment and observed to release a cloud of gametes into the water near the NCWRC Cypress Hole boat ramp. Winslow et al. (1983) documented striped bass spawning areas to be located from Croomsbridge Road (kilometer 130) to Ness Creek (kilometer 47) in the lower Northeast Cape Fear River, and stated that peak spawning occurred in the area downstream of Lanes Ferry (kilometer 93). This study determined that tagged striped bass migrate to at least near Hallsville, NC (kilometer 183), and mature fish were captured and tagged between White Stocking, NC (kilometer 118) and Chinquapin, NC (kilometer 168). It is likely that striped bass spawning activity is currently taking place in areas of the Northeast Cape Fear River at least 53 kilometers further up river than previously documented. As striped bass eggs are semi-buoyant and quickly drift down river, the use of locations where egg and larval striped bass were collected as a proxy for spawning locations by Winslow et al. (1983) likely underestimated the upriver extent to which fish were migrating and reproducing.

The upper stations of the Black River detected relatively few fish, with an average of less than two percent of the total active striped bass in the spring detected across years. The majority of Black River striped bass detections occurred at the confluence with the Cape Fear River. All striped bass detected in the spring at upper Black River stations were later detected during the same season at Lock and Dam #1. Winslow et al. (1983) did not report striped bass eggs or larvae, or document spawning areas for the Black River. The results of this study also suggest the Black River may not be a tributary where striped bass migrate to spawn.

In other North Carolina river systems striped bass typically spawn in the high energy riverine areas near the fall line, where the semi-buoyant eggs will remain suspended and hatch before reaching the estuary (Carmichael et al. 1998; Beasley and Hightower 2000). Striped bass in the mainstem of the Cape Fear River, which navigate the three locks and dams, also use the high energy areas near the fall line as spawning areas (Smith and Hightower 2012). Striped bass have had unimpeded access to the entire drainage of the Northeast Cape Fear River, and have been documented to use this tributary as spawning habitat. However, the Northeast Cape Fear River does not reach the fall line, and is characterized by slower velocities and sandy substrates (NCDENR 2004). Striped bass eggs have been demonstrated to be adapted to the velocities and physical energy of the watershed in which they originate, with eggs becoming larger and lighter as velocity decreased (Bergey et al. 2003). It would be expected that striped bass successfully reproducing in the Northeast Cape Fear River would have egg characteristics significantly different than those successfully reproducing near the fall line in the mainstem of the Cape Fear River.

With the exception of striped bass that were detected at both the upper Black River stations and Lock and Dam #1, striped bass making spring migrations up one branch did not migrate up another branch or tributary during the same season. Striped bass that were detected for multiple years showed high fidelity to either the Northeast Cape Fear River, or mainstem Cape Fear River when making spawning runs. Out of all striped bass that were detected for multiple years, only two individual fish (less than 1 percent of average active tags in spring) were detected at the uppermost stations of one branch or tributary then in the subsequent year were detected at the uppermost stations in a different branch or tributary. Striped bass that did not make migrations in the spring remained in the area near downtown Wilmington. Each year between 38 and 81 percent of all striped bass that were actively detected in the spring season and had made a migration to the upper Cape Fear River returned to the upper Cape Fear River the following spring. A similar pattern was observed for the Northeast Cape Fear River, with between 17 and 25 percent making repeat migrations. Prescott et al. (2016) suggests that there are three stable behavioral contingents of striped bass in the Cape Fear River Basin. These groups are comprised of a migratory contingent that migrates up the mainstem of the Cape Fear River, a migratory contingent that migrates up the Northeast Cape Fear River, and an a nonmigratory contingent that remains near downtown Wilmington.

The percentage of individual striped bass detected dropped significantly immediately after the season they were tagged despite the multiple year life span of acoustic tags. This would indicate that the tagged fish suffered fishing or natural mortality, emigrated out of the system and detection range, or the tag malfunctioned before the end of the battery life. The moratorium in place on the commercial and recreational harvest of striped bass in the Cape Fear River should limit fishing mortality on striped bass in this system, but potential mortality from bycatch in commercial shad gear as well as incidental mortality from recreational catch and release is a possibility.

Hatchery reared striped bass are stocked into the Cape Fear River system annually. Anderson et al. (2014) did not detect any genetic difference between Cape Fear and Roanoke river striped bass sampled between 2009-2011, and attributed this to the extensive historic stocking of Roanoke hatchery origin fish. It has been found that total mortality of Roanoke River origin striped bass stocked outside their natal river was higher than for fish stocked back into the Roanoke River (Callihan et al. 2014a). Egg characteristics of striped bass stocked outside of their natal river may prevent stocked fish from successfully reproducing in the new system (Bergey et al. 2003). Since 2010 NCWRC has been using striped bass captured within the Cape Fear River for hatchery brood stock when stocking the Cape Fear River. However, how the egg characteristics of these hatchery fish may impact their successful reproduction in either the mainstem Cape Fear River or Northeast Cape Fear River has not been determined.

There was evidence for one striped bass emigrating from the system. This fish was captured in the middle section of the Cape Fear River in January 2015 and was detected for three months in the middle to lower Cape Fear River, before it was detected by the lowest gate receivers and emigrated from the river in April. This fish was also the largest fish tagged during this study with a total length of 836 mm. Only four other striped bass were captured and tagged with total lengths over 800 mm, and none of the others of this size were detected in the lower portion of the river. It has been assumed that Cape Fear River striped bass are resident fish, as most striped bass populations south of Albemarle Sound do not typically enter the Atlantic stock (Greene et al. 2009). This large fish which emigrated from the Cape Fear River may represent a wandering fish from the Atlantic stock, or may have reached a size where Cape Fear River fish enter the ocean. It was believed that not all individuals in the Albemarle Sound/Roanoke (A/R) population undergo coastal migrations. Otolith microchemical analysis suggested that multiple life history strategies exist for this group of fish, with some living as permanent residents of the river system with others joining the larger anadromous stock in the Coastal Atlantic (Morris et al. 2003). However, recent acoustic tagging work has shown that most large A/R striped bass (>800 mm total length) are anadromous and migratory, and a truncated size/age structure prior to the species full recovery in the system may have led to assumptions about the life history of smaller fish (Callihan et al. 2014a). Striped bass in the Cape Fear River may not exhibit anadromy and join the Coastal Atlantic stock due to not yet being fully recovered in the system, or may remain resident due to other limiting factors.

Anderson et al. (2014) did suggest that despite the genetic findings of similarity between Roanoke and Cape Fear river fish, natural reproduction of striped bass was likely occurring in the Cape Fear River. This was attributed to the calculated effective population size, and it was not likely that all analyzed individuals were first generation stocked fish. It was determined that 28 percent of the total number of striped bass sampled for DNA in 2015 from the Cape Fear River were unable to be assigned as known hatchery fish using a genetic approach (Farrae and Darden 2016). Whether there is successful recruitment from striped bass spawning in the Northeast Cape Fear River and what that contribution is to the overall Cape Fear River stock remains unknown. Analysis of DNA samples taken from acoustic tagged fish in the Cape Fear River Basin may help to clarify the genetic structure or hatchery origin of the behavioral contingents of striped bass in the Cape Fear River Basin.

## 10 DEVIATIONS

Downloads did not occur monthly due to staff vacancies and bad weather. The entire acoustic array was not complete for the majority of the study due to lost or stolen receivers. Reduced

detection ability due to limited active receiver stations in the Cape Fear River Basin (due to equipment loss and malfunction) after summer 2016 prevented adequate striped bass movement data for 2017 to be collected and included in this analysis. Striped bass data from 2013 was incorporated to have four years of movement data covered in this report.

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## 12 TABLES

Table 1. Date, tagging location, length, weight, sex, transmitter serial number, and tag life for American shad implanted with acoustic tags in the Neuse and Pamlico rivers during 2014 and 2015.

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 3 | 20 | Neuse | 374 | 441 | 0.72 | M | 1172303 | 417 |
| 2014 | 3 | 20 | Neuse | 452 | 520 | 1.43 | F | 1172306 | 417 |
| 2014 | 3 | 20 | Neuse | 414 | 470 | 0.98 | M | 1172309 | 417 |
| 2014 | 3 | 20 | Neuse | 428 | 484 | 1.11 | F | 1172316 | 417 |
| 2014 | 3 | 26 | Neuse | 466 | 522 | 1.53 | F | 1172302 | 417 |
| 2014 | 3 | 26 | Neuse | 384 | 433 | 0.80 | M | 1172307 | 417 |
| 2014 | 3 | 26 | Neuse | 376 | 422 | 0.75 | M | 1172308 | 417 |
| 2014 | 3 | 26 | Neuse | 442 | 504 | 1.40 | F | 1172311 | 417 |
| 2014 | 3 | 26 | Neuse | 490 | 560 | 1.80 | F | 1172312 | 417 |
| 2014 | 3 | 26 | Neuse | 402 | 452 | 0.89 | M | 1172313 | 417 |
| 2014 | 4 | 10 | Pamlico | 483 | 531 | 1.67 | F | 1172298 | 417 |
| 2014 | 4 | 10 | Pamlico | 488 | 546 | 1.53 | F | 1172300 | 417 |
| 2014 | 4 | 10 | Pamlico | 474 | 538 | 1.49 | F | 1172301 | 417 |
| 2014 | 4 | 10 | Pamlico | 457 | 501 | 1.04 | M | 1172304 | 417 |
| 2014 | 4 | 10 | Pamlico | 428 | 485 | 1.02 | M | 1172305 | 417 |
| 2014 | 4 | 10 | Pamlico | 455 | 512 | 1.33 | F | 1172310 | 417 |
| 2014 | 4 | 10 | Pamlico | 434 | 493 | 0.98 | M | 1172314 | 417 |
| 2014 | 4 | 10 | Pamlico | 429 | 484 | 0.96 | M | 1172315 | 417 |
| 2014 | 4 | 10 | Pamlico | 458 | 509 | 1.21 | F | 1172317 | 417 |
| 2015 | 3 | 31 | Neuse | 476 | 540 | 1.59 | F | 1198019 | 704 |
| 2015 | 3 | 31 | Neuse | 480 | 544 | 1.58 | F | 1198020 | 704 |
| 2015 | 3 | 31 | Neuse | 438 | 492 | 1.13 | M | 1198021 | 704 |
| 2015 | 3 | 31 | Neuse | 386 | 430 | 0.73 | M | 1198022 | 704 |
| 2015 | 3 | 31 | Neuse | 446 | 506 | 1.11 | F | 1198025 | 704 |
| 2015 | 3 | 31 | Neuse | 376 | 428 | 0.69 | M | 1198026 | 704 |
| 2015 | 3 | 31 | Neuse | 432 | 494 | 0.99 | M | 1198027 | 704 |
| 2015 | 3 | 31 | Neuse | 450 | 508 | 1.34 | F | 1198028 | 704 |
| 2015 | 3 | 31 | Neuse | 354 | 402 | 0.58 | M | 1198031 | 704 |
| 2015 | 3 | 31 | Neuse | 412 | 466 | 0.89 | M | 1198032 | 704 |
| 2015 | 3 | 31 | Neuse | 336 | 496 | 1.22 | F | 1198033 | 704 |
| 2015 | 3 | 31 | Neuse | 462 | 520 | 1.33 | F | 1198034 | 704 |
| 2015 | 3 | 31 | Neuse | 468 | 530 | 1.15 | F | 1198037 | 704 |
| 2015 | 3 | 31 | Neuse | 396 | 452 | 0.80 | M | 1198038 | 704 |

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2015 | 3 | 31 | Neuse | 452 | 508 | 1.50 | F | 1198039 | 704 |
| 2015 | 3 | 31 | Neuse | 348 | 394 | 0.55 | M | 1198040 | 704 |
| 2015 | 3 | 31 | Neuse | 354 | 402 | 0.56 | M | 1198043 | 704 |
| 2015 | 4 | 7 | Pamlico | 468 | 527 | 0.60 | F | 1198044 | 704 |
| 2015 | 4 | 7 | Pamlico | 478 | 541 | 1.38 | F | 1198067 | 704 |
| 2015 | 4 | 7 | Pamlico | 436 | 493 | 0.91 | M | 1198068 | 704 |
| 2015 | 4 | 7 | Pamlico | 390 | 442 | 0.76 | M | 1198069 | 704 |
| 2015 | 4 | 7 | Pamlico | 379 | 433 | 0.65 | M | 1198070 | 704 |
| 2015 | 4 | 7 | Pamlico | 389 | 444 | 0.77 | M | 1198071 | 704 |
| 2015 | 4 | 7 | Pamlico | 460 | 524 | 1.26 | F | 1198072 | 704 |
| 2015 | 4 | 7 | Pamlico | 367 | 419 | 0.60 | M | 1201023 | 704 |
| 2015 | 4 | 8 | Pamlico | 410 | 470 | 0.81 | M | 1198045 | 704 |
| 2015 | 4 | 8 | Pamlico | 463 | 527 | 1.67 | F | 1198050 | 704 |
| 2015 | 4 | 8 | Pamlico | 396 | 451 | 0.88 | M | 1198051 | 704 |
| 2015 | 4 | 8 | Pamlico | 393 | 447 | 0.78 | M | 1198055 | 704 |
| 2015 | 4 | 8 | Pamlico | 442 | 500 | 1.16 | F | 1198056 | 704 |
| 2015 | 4 | 8 | Pamlico | 437 | 497 | 1.26 | F | 1198057 | 704 |
| 2015 | 4 | 8 | Pamlico | 450 | 512 | 1.28 | F | 1198061 | 704 |
| 2015 | 4 | 8 | Pamlico | 402 | 456 | 0.88 | M | 1198062 | 704 |
| 2015 | 4 | 8 | Pamlico | 386 | 440 | 0.71 | M | 1198063 | 704 |
| 2015 | 4 | 8 | Pamlico | 460 | 522 | 1.41 | F | 1998049 | 704 |

Table 2. Date, tagging location, length, weight, sex, transmitter serial number, and tag life for striped bass implanted with acoustic tags in the Neuse and Pamlico rivers during 2014 and 2015.

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 3 | 27 | Neuse | 573 | 611 | 2.63 | F | 1172390 | 768 |
| 2014 | 3 | 27 | Neuse | 605 | 644 | 3.49 | M | 1172391 | 768 |
| 2014 | 3 | 27 | Neuse | 597 | 638 | 3.00 | M | 1172392 | 768 |
| 2014 | 3 | 27 | Neuse | 575 | 614 | 2.62 | Unknown | 1172397 | 768 |
| 2014 | 4 | 9 | Neuse | 852 | 909 | . | M | 1172382 | 768 |
| 2014 | 4 | 10 | Neuse | 582 | 620 | 2.62 | F | 1172362 | 768 |
| 2014 | 4 | 10 | Neuse | 564 | 610 | 2.20 | F | 1172367 | 768 |
| 2014 | 4 | 10 | Neuse | 758 | 807 | 5.10 | M | 1172372 | 768 |
| 2014 | 4 | 10 | Neuse | 585 | 623 | 2.83 | F | 1172376 | 768 |
| 2014 | 4 | 10 | Neuse | 630 | 672 | 3.55 | F | 1172381 | 768 |
| 2014 | 4 | 10 | Neuse | 568 | 604 | 2.60 | M | 1172386 | 768 |
| 2014 | 4 | 11 | Neuse | 864 | 923 | 8.80 | F | 1172366 | 768 |
| 2014 | 4 | 14 | Neuse | 663 | 708 | 4.25 | F | 1172359 | 768 |
| 2014 | 4 | 14 | Neuse | 598 | 632 | 2.99 | M | 1172364 | 768 |
| 2014 | 4 | 24 | Neuse | 578 | 621 | 3.07 | F | 1172358 | 768 |
| 2014 | 4 | 24 | Neuse | 591 | 625 | 2.57 | M | 1172363 | 768 |
| 2014 | 4 | 24 | Neuse | 570 | 609 | 2.57 | F | 1172368 | 768 |
| 2014 | 4 | 24 | Neuse | 579 | 621 | 2.50 | F | 1172373 | 768 |
| 2014 | 4 | 24 | Neuse | 608 | 653 | 3.23 | F | 1172383 | 768 |
| 2014 | 4 | 24 | Neuse | 617 | 656 | 3.21 | M | 1172384 | 768 |
| 2014 | 3 | 24 | Pamlico | 565 | 603 | 2.64 | F | 1172377 | 768 |
| 2014 | 3 | 24 | Pamlico | 634 | 673 | 3.70 | M | 1172394 | 768 |
| 2014 | 3 | 24 | Pamlico | 710 | 753 | 5.40 | Unknown | 1172395 | 768 |
| 2014 | 3 | 24 | Pamlico | 573 | 615 | 2.76 | F | 1172396 | 768 |
| 2014 | 3 | 27 | Pamlico | 596 | 637 | 2.88 | F | 1172389 | 768 |
| 2014 | 4 | 1 | Pamlico | 567 | 608 | 1.98 | Unknown | 1172387 | 768 |
| 2014 | 4 | 1 | Pamlico | 571 | 608 | 2.28 | F | 1172388 | 768 |
| 2014 | 4 | 23 | Pamlico | 650 | 696 | 3.96 | F | 1172360 | 768 |
| 2014 | 4 | 23 | Pamlico | 741 | 789 | 5.79 | M | 1172361 | 768 |
| 2014 | 4 | 23 | Pamlico | 619 | 658 | 3.12 | F | 1172365 | 768 |
| 2014 | 4 | 23 | Pamlico | 664 | 708 | 4.38 | M | 1172369 | 768 |
| 2014 | 4 | 23 | Pamlico | 608 | 649 | 3.24 | M | 1172370 | 768 |
| 2014 | 4 | 23 | Pamlico | 656 | 700 | 3.94 | F | 1172371 | 768 |
| 2014 | 4 | 23 | Pamlico | 676 | 715 | 4.32 | F | 1172374 | 768 |
| 2014 | 4 | 23 | Pamlico | 821 | 875 | 6.90 | F | 1172375 | 768 |
| 2014 | 4 | 23 | Pamlico | 658 | 703 | 4.13 | F | 1172378 | 768 |

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 4 | 23 | Pamlico | 641 | 680 | 4.25 | F | 1172379 | 768 |
| 2014 | 4 | 23 | Pamlico | 620 | 664 | 3.34 | M | 1172380 | 768 |
| 2014 | 4 | 23 | Pamlico | 568 | 608 | 2.61 | M | 1172385 | 768 |
| 2015 | 3 | 31 | Neuse | 603 | 636 | 3.12 | M | 1197886 | 3,650 |
| 2015 | 3 | 31 | Neuse | 674 | 720 | 4.50 | M | 1197889 | 3,650 |
| 2015 | 3 | 31 | Neuse | 717 | 761 | 5.31 | F | 1197892 | 3,650 |
| 2015 | 3 | 31 | Neuse | 698 | 744 | 5.55 | M | 1197894 | 3,650 |
| 2015 | 3 | 31 | Neuse | 611 | 653 | 3.40 | F | 1197895 | 3,650 |
| 2015 | 3 | 31 | Neuse | 655 | 699 | 4.40 | M | 1197897 | 3,650 |
| 2015 | 3 | 31 | Neuse | 644 | 684 | 3.74 | F | 1197898 | 3,650 |
| 2015 | 3 | 31 | Neuse | 630 | 670 | 3.99 | F | 1197900 | 3,650 |
| 2015 | 3 | 31 | Neuse | 636 | 677 | 3.85 | F | 1197901 | 3,650 |
| 2015 | 3 | 31 | Neuse | 628 | 666 | 3.42 | M | 1197903 | 3,650 |
| 2015 | 4 | 20 | Neuse | 667 | 711 | 3.91 | M | 1197910 | 3,650 |
| 2015 | 4 | 20 | Neuse | 616 | 654 | 3.65 | M | 1197918 | 3,650 |
| 2015 | 4 | 21 | Neuse | 580 | 612 | 2.90 | F | 1197887 | 3,650 |
| 2015 | 4 | 21 | Neuse | 578 | 609 | 2.69 | M | 1197890 | 3,650 |
| 2015 | 4 | 21 | Neuse | 558 | 598 | 2.10 | M | 1197893 | 3,650 |
| 2015 | 4 | 21 | Neuse | 567 | 602 | 2.50 | M | 1197896 | 3,650 |
| 2015 | 4 | 21 | Neuse | 571 | 604 | 2.10 | M | 1197899 | 3,650 |
| 2015 | 4 | 21 | Neuse | 588 | 622 | 2.90 | M | 1197902 | 3,650 |
| 2015 | 4 | 21 | Neuse | 541 | 578 | 1.85 | M | 1197904 | 3,650 |
| 2015 | 4 | 21 | Neuse | 531 | 556 | 1.80 | M | 1197921 | 3,650 |
| 2015 | 4 | 21 | Neuse | 548 | 582 | 2.20 | M | 1197995 | 1,227 |
| 2015 | 4 | 21 | Neuse | 600 | 642 | 2.70 | M | 1197996 | 1,227 |
| 2015 | 4 | 22 | Neuse | 617 | 661 | 3.00 | F | 1197990 | 1,227 |
| 2015 | 4 | 22 | Neuse | 618 | 665 | 3.80 | M | 1197994 | 1,227 |
| 2015 | 4 | 27 | Neuse | 668 | 711 | 3.90 | M | 1197964 | 1,227 |
| 2015 | 4 | 27 | Neuse | 582 | 620 | 2.40 | M | 1197969 | 1,227 |
| 2015 | 4 | 27 | Neuse | 602 | 642 | 2.90 | M | 1197970 | 1,227 |
| 2015 | 4 | 27 | Neuse | 635 | 668 | 2.70 | F | 1197974 | 1,227 |
| 2015 | 4 | 27 | Neuse | 661 | 698 | 3.30 | M | 1197975 | 1,227 |
| 2015 | 4 | 27 | Neuse | 780 | 830 | 4.80 | F | 1197979 | 1,227 |
| 2015 | 4 | 27 | Neuse | 705 | 752 | 4.50 | M | 1197980 | 1,227 |
| 2015 | 4 | 27 | Neuse | 667 | 710 | 3.60 | M | 1197981 | 1,227 |
| 2015 | 4 | 27 | Neuse | 675 | 723 | 4.20 | M | 1197984 | 1,227 |
| 2015 | 4 | 27 | Neuse | 676 | 720 | 3.90 | M | 1197985 | 1,227 |
| 2015 | 4 | 27 | Neuse | 736 | 778 | 5.70 | M | 1197986 | 1,227 |
| 2015 | 4 | 27 | Neuse | 712 | 749 | 5.60 | M | 1197989 | 1,227 |
| 2015 | 4 | 27 | Neuse | 635 | 674 | 3.20 | M | 1197991 | 1,227 |

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2015 | 4 | 28 | Neuse | 631 | 669 | 2.80 | M | 1197965 | 1,227 |
| 2015 | 4 | 28 | Neuse | 582 | 617 | 2.40 | F | 1197966 | 1,227 |
| 2015 | 4 | 28 | Neuse | 585 | 620 | 2.90 | M | 1197971 | 1,227 |
| 2015 | 4 | 28 | Neuse | 574 | 615 | 2.50 | M | 1197976 | 1,227 |
| 2015 | 4 | 23 | Pamlico | 610 | 646 | 3.00 | Unknown | 1197908 | 3,650 |
| 2015 | 4 | 23 | Pamlico | 570 | 604 | 2.10 | F | 1197911 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 627 | 674 | 3.23 | M | 1197888 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 596 | 637 | 2.90 | M | 1197905 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 564 | 605 | 2.18 | M | 1197906 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 585 | 627 | 2.51 | M | 1197907 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 597 | 631 | 3.00 | M | 1197912 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 558 | 598 | 2.40 | M | 1197914 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 576 | 602 | 2.60 | M | 1197917 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 573 | 610 | 2.50 | F | 1197920 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 596 | 631 | 2.25 | F | 1197925 | 3,650 |
| 2015 | 4 | 30 | Pamlico | 923 | 977 | 10.00 | F | 1197968 | 1,227 |
| 2015 | 4 | 30 | Pamlico | 674 | 713 | 3.85 | M | 1197997 | 1,227 |
| 2015 | 5 | 5 | Pamlico | 555 | 594 | 2.40 | M | 1197891 | 3,650 |
| 2015 | 5 | 5 | Pamlico | 567 | 607 | 2.70 | F | 1197909 | 3,650 |
| 2015 | 5 | 5 | Pamlico | 598 | 631 | 2.90 | F | 1197915 | 3,650 |
| 2015 | 5 | 5 | Pamlico | 573 | 616 | 2.30 | M | 1197922 | 3,650 |
| 2015 | 5 | 5 | Pamlico | 561 | 596 | 2.65 | F | 1197923 | 3,650 |
| 2015 | 5 | 5 | Pamlico | 550 | 590 | 2.25 | F | 1197924 | 3,650 |
| 2015 | 5 | 5 | Pamlico | 665 | 708 | 4.00 | F | 1198006 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 591 | 629 | 2.50 | M | 1197913 | 3,650 |
| 2015 | 5 | 6 | Pamlico | 588 | 630 | 2.50 | F | 1197916 | 3,650 |
| 2015 | 5 | 6 | Pamlico | 571 | 611 | 2.70 | F | 1197919 | 3,650 |
| 2015 | 5 | 6 | Pamlico | 645 | 675 | 3.00 | M | 1197967 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 575 | 606 | 2.50 | F | 1197972 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 556 | 601 | 2.10 | M | 1197973 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 553 | 592 | 1.90 | M | 1197978 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 652 | 695 | 4.00 | F | 1198004 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 621 | 663 | 2.90 | M | 1198005 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 669 | 708 | 4.10 | M | 1198007 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 593 | 632 | 2.20 | M | 1198008 | 1,227 |
| 2015 | 5 | 6 | Pamlico | 557 | 596 | 2.10 | M | 1201024 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 564 | 604 | 2.20 | M | 1197977 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 875 | 930 | 9.20 | F | 1197982 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 566 | 605 | 2.35 | F | 1197983 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 650 | 688 | 3.20 | M | 1197987 | 1,227 |

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2015 | 5 | 7 | Pamlico | 611 | 649 | 2.70 | M | 1197988 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 714 | 760 | 5.10 | M | 1197992 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 570 | 608 | 2.19 | M | 1197993 | 1,227 |
| 2015 | 5 | 7 | Pamlico | 595 | 635 | 2.50 | M | 1197998 | 1,227 |

Table 3. Timing of receiver downloads in the Neuse and Pamlico rivers, April 2014-August 2017.

| Month | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| January | | x | x | |
| February | | x | x | x |
| March | | x | x | |
| April | x | | x | x |
| May | x | x | x | x |
| June | x | x | | |
| July | x | x | x | |
| August | x | x | x | x |
| September | x | | | |
| October | x | x | x | |
| November | x | x | x | |
| December | | | | |

Table 4. Number of samples, mean and standard error for environmental data recorded in the Neuse and Pamlico rivers during receiver downloads by region, June 2015-August 2017.

| | | | | Surface | | | Bottom | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | | Depth (m) | Secchi Depth (cm) | Temp. (°C) | Salinity (ppt) | D.O. (mg/L) | Temp. (°C) | Salinity (ppt) | D.O. (mg/L) |
| Up Tar/Pam | n | 51 | 52 | 52 | 52 | 51 | 49 | 49 | 48 |
| | Mean | 1.8 | 78.7 | 18.5 | 0.1 | 7.9 | 18.8 | 0.1 | 7.4 |
| | SE | 0.1 | 4.8 | 1.2 | 0.0 | 0.3 | 1.2 | 0.0 | 0.4 |
| Mid Tar/Pam | n | 107 | 108 | 105 | 105 | 105 | 105 | 105 | 105 |
| | Mean | 2.6 | 76.3 | 21.5 | 1.9 | 8.1 | 21.0 | 3.5 | 6.0 |
| | SE | 0.1 | 2.6 | 0.8 | 0.2 | 0.3 | 0.8 | 0.3 | 0.4 |
| Low Tar/Pam | n | 55 | 50 | 54 | 54 | 54 | 54 | 54 | 54 |
| | Mean | 3.1 | 81.5 | 24.4 | 6.3 | 8.6 | 23.7 | 7.5 | 6.6 |
| | SE | 0.1 | 2.5 | 0.8 | 0.4 | 0.6 | 0.8 | 0.4 | 0.4 |
| Pungo | n | 35 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |
| | Mean | 2.5 | 57.1 | 25.2 | 5.3 | 6.6 | 24.5 | 6.3 | 5.1 |
| | SE | 0.1 | 3.6 | 1.3 | 0.5 | 0.7 | 1.2 | 0.5 | 0.6 |
| Up Neuse | n | 73 | 74 | 78 | 78 | 72 | 69 | 69 | 63 |
| | Mean | 1.8 | 68.6 | 20.2 | 0.1 | 6.9 | 19.7 | 0.1 | 6.8 |
| | SE | 0.1 | 3.1 | 0.9 | 0.0 | 0.3 | 0.9 | 0.0 | 0.3 |
| Up/Mid Neuse | n | 74 | 73 | 74 | 74 | 74 | 74 | 74 | 74 |
| | Mean | 3.1 | 90.8 | 21.3 | 1.9 | 7.5 | 20.7 | 4.2 | 5.1 |
| | SE | 0.1 | 3.0 | 1.0 | 0.3 | 0.4 | 1.0 | 0.6 | 0.5 |
| Mid Neuse | n | 40 | 39 | 39 | 39 | 39 | 39 | 39 | 39 |
| | Mean | 2.5 | 71.8 | 23.6 | 7.3 | 8.0 | 22.8 | 9.0 | 6.4 |
| | SE | 0.1 | 2.2 | 1.3 | 0.8 | 0.5 | 1.4 | 0.8 | 0.6 |
| Low Neuse | n | 36 | 36 | 36 | 36 | 36 | 36 | 36 | 36 |
| | Mean | 3.4 | 93.0 | 21.6 | 11.5 | 8.9 | 21.3 | 13.3 | 8.0 |
| | SE | 0.1 | 4.8 | 1.5 | 0.9 | 0.8 | 1.5 | 0.9 | 0.9 |

| | | | | Surface | | | Bottom | | |
|---|---|---|---|---|---|---|---|---|---|
| Region | | Depth (m) | Secchi Depth (cm) | Temp. (°C) | Salinity (ppt) | D.O. (mg/L) | Temp. (°C) | Salinity (ppt) | D.O. (mg/L) |
| Trent | n | 17 | 17 | 17 | 17 | 17 | 16 | 17 | 16 |
| | Mean | 3.4 | 91.6 | 22.2 | 0.3 | 4.6 | 21.7 | 0.6 | 4.4 |
| | SE | 0.3 | 8.2 | 1.9 | 0.2 | 0.7 | 1.9 | 0.3 | 0.7 |
| Bay | n | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| | Mean | 3.4 | 95.1 | 23.4 | 11.7 | 7.9 | 23.0 | 13.4 | 6.7 |
| | SE | 0.1 | 5.3 | 1.6 | 0.8 | 0.8 | 1.5 | 0.7 | 0.7 |

Table 5. Active receiver stations by year and season in the Neuse and Pamlico rivers, 2014-2017. An “x” denotes the station was active and operating, and “o” denotes the station was inactive for that time period.

| | 2014 | | | | 2015 | | | | 2016 | | | | 2017 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Staton Name | Spring | Summer | Fall | Winter | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer |
| BY010 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| BY020 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| BY030 | x | x | x | x | x | x | x | x | x | x | x | x | x | o | o |
| BY050 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE010 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE020 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | o |
| NE030 | o | o | o | o | o | o | o | o | o | x | x | x | x | x | x |
| NE035 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE040 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE045 | x | o | o | o | o | o | o | o | o | o | o | o | o | o | o |
| NE047 | o | o | o | o | x | x | x | x | x | x | x | x | x | x | x |
| NE050 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE055 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE060 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE225 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE260 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE315 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE330 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE350 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE425 | x | x | x | x | x | x | x | x | o | x | o | o | o | o | x |
| NE430 | x | x | o | o | o | o | o | o | o | o | o | o | o | o | o |
| NE432 | o | o | o | o | x | x | x | x | x | x | x | x | x | x | x |
| NE450 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE455 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE460 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE475 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE575 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |

| | 2014 | | | | 2015 | | | | 2016 | | | | 2017 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Staton Name | Spring | Summer | Fall | Winter | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer |
| PU020 | x | x | x | x | x | x | x | x | o | x | x | x | x | x | x |
| PU025 | o | o | o | o | o | o | o | o | o | o | x | x | x | x | x |
| PU050 | x | x | x | x | x | x | x | x | x | x | x | o | o | x | x |
| PU055 | o | o | o | o | o | o | o | o | o | o | x | x | x | x | x |
| PU061 | x | x | x | x | x | x | x | x | x | o | o | o | o | o | o |
| PU063 | x | x | x | x | x | x | x | x | o | o | o | o | o | o | o |
| PU065 | x | x | o | o | o | o | o | o | o | o | o | o | o | o | o |
| PU067 | x | x | o | o | o | o | o | o | o | o | o | o | o | o | o |
| PU069 | x | x | x | x | x | x | x | x | x | o | o | o | o | o | o |
| PU071 | x | o | x | x | x | x | x | x | x | o | o | o | o | o | o |
| TP010 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP020 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP030 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP035 | o | o | o | o | x | x | x | x | x | x | x | x | x | x | x |
| TP040 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP050 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP060 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP070 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP080 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP101 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP121 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| TP123 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| TP135 | o | o | o | o | o | o | o | o | o | o | x | x | x | x | x |
| TP140 | o | o | o | o | x | x | x | x | x | x | x | x | x | o | o |
| TP150 | o | o | o | o | x | x | x | x | x | x | x | x | x | x | x |
| TP201 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP203 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP205 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP207 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |

| | 2014 | | | | 2015 | | | | 2016 | | | | 2017 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Staton Name | Spring | Summer | Fall | Winter | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer |
| TP209 | o | o | o | o | o | o | o | o | o | o | x | x | x | x | x |
| TP230 | o | o | o | o | x | x | x | x | x | x | x | x | x | x | x |
| TP231 | o | o | o | o | o | o | o | o | o | o | x | x | x | x | x |
| TP250 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TP330 | o | o | o | o | o | o | o | o | o | o | x | x | x | o | o |
| TP339 | o | o | o | o | o | o | o | o | o | x | x | x | x | x | x |
| TP340 | o | o | o | o | o | o | o | o | o | x | x | x | x | x | x |
| TP341 | x | x | x | x | x | x | x | o | o | o | o | o | o | o | o |
| TP343 | x | x | x | x | x | x | x | o | o | o | o | o | o | o | o |
| TP345 | x | x | x | x | x | x | x | o | o | o | o | o | o | o | o |
| TP347 | x | o | o | o | o | o | o | o | o | o | o | o | o | o | o |
| TP360 | o | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TR050 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| TR100 | o | o | o | o | x | x | x | x | x | x | x | x | x | x | x |
| LT1 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| LT2 | o | o | o | o | o | o | o | x | x | x | x | x | x | o | o |
| LT3 | o | o | o | o | o | o | o | x | x | o | o | o | o | o | o |
| LT5 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| LTRENT2 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| RT1 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| RT2 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| RT3 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| RT4 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| CH50B | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| CH53 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | x |
| LT6 | o | o | o | o | o | o | o | x | x | x | x | x | x | x | o |

Table 6. Number and percent of individual American shad detected in the Neuse and Tar/Pamlico rivers in 2014 and 2015. American shad were only detected in the spring of the year they were tagged.

| | Neuse | | Pamlico | |
|---|---|---|---|---|
| Year | Count | Percent | Count | Percent |
| 2014 | 5 | 50 | 7 | 78 |
| 2015 | 8 | 47 | 8 | 44 |

Table 7. Tagging and recapture information for striped bass tagged in the Neuse and Pamlico rivers and returned from this study.

| | Tagging Information | | | | Capture Information | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Acoustic Tag | Year | Month | Day | River | Year | Month | Day | Location | Status |
| A69-1601-26246 | 2014 | 4 | 23 | Tar/Pam | 2014 | 11 | 3 | Tar/Pam | Released |
| A69-1601-26276 | 2014 | 3 | 27 | Neuse | 2014 | 12 | 15 | Bay River | Released |
| A69-1601-23436 | 2015 | 5 | 6 | Tar/Pam | 2015 | 5 | 16 | Tar/Pam | Harvested |
| A69-1601-26280 | 2014 | 3 | 24 | Tar/Pam | 2015 | 6 | 9 | Tar/Pam | Released |
| A69-9001-24009 | 2015 | 5 | 5 | Tar/Pam | 2015 | 6 | 11 | Tar/Pam | Harvested |
| A69-1601-23448 | 2015 | 4 | 27 | Neuse | 2015 | 7 | 2 | Neuse | Released |
| A69-1601-26243 | 2014 | 4 | 24 | Neuse | 2015 | 7 | 20 | Neuse | Released |
| A69-1601-23438 | 2015 | 4 | 27 | Neuse | 2015 | 8 | 6 | Neuse | Harvested |
| A69-1601-23451 | 2015 | 5 | 7 | Tar/Pam | 2015 | 9 | 13 | Atlantic Ocean (Rhode Island) | Harvested |
| A69-1601-26279 | 2014 | 3 | 24 | Tar/Pam | 2015 | 10 | 10 | Tar/Pam | Harvested |
| A69-9001-23981 | 2015 | 3 | 31 | Neuse | 2016 | 3 | 2 | Neuse | Harvested |
| A69-1601-26244 | 2014 | 4 | 14 | Neuse | 2016 | 3 | 14 | Neuse | Released |
| A69-1601-23466 | 2015 | 4 | 30 | Tar/Pam | 2016 | 4 | 6 | Tar/Pam | Released |
| A69-9001-23991 | 2015 | 4 | 30 | Tar/Pam | 2017 | 4 | 2 | Neuse | Harvested |

Table 8. Number and percent of individual striped bass detected in the Neuse and Tar/Pamlico rivers by year and season. Individuals detected in fall 2017 were not included and winter 2017 only includes individual detected in January and February.

| | | Neuse | | Pamlico | |
|---|---|---|---|---|---|
| Year | Season | Count | Percent | Count | Percent |
| 2014 | Spring | 15 | 75 | 17 | 89 |
| | Summer | 4 | 20 | 13 | 68 |
| | Fall | 9 | 45 | 10 | 53 |
| | Winter | 3 | 15 | 6 | 32 |
| 2015 | Spring | 45 | 74 | 46 | 78 |
| | Summer | 25 | 41 | 28 | 48 |
| | Fall | 21 | 35 | 15 | 26 |
| | Winter | 12 | 20 | 16 | 29 |
| 2016 | Spring | 16 | 27 | 13 | 24 |
| | Summer | 7 | 18 | 9 | 25 |
| | Fall | 6 | 15 | 6 | 17 |
| | Winter | 13 | 22 | 11 | 20 |
| 2017 | Spring | 5 | 13 | 3 | 8 |
| | Summer | 5 | 13 | 2 | 6 |
| | Fall | . | . | . | . |
| | Winter | 5 | 13 | 4 | 11 |

Table 9. Station name, coordinates, year deployed, general location, river stretch, and river kilometer from Atlantic Ocean for receivers deployed in the Cape Fear River Basin during this study. River stretches are abbreviated as, Upper Cape Fear (UCF), Middle Cape Fear (MCF), Lower Cape Fear (LCF), Upper Northeast Cape Fear (UNECF), Lower Northeast Cape Fear (LNECF), and Black River (BLR).

| Station Name | Latitude | Longitude | Year Deployed | Location | River Stretch | River Kilometer |
|---|---|---|---|---|---|---|
| BK01 | 34.33722 | -78.04667 | 2011 | Black River Confluence | UCF | 64 |
| BK02 | 34.3716 | -78.07111 | 2011 | Black River | BLR | 71 |
| BK03 | 34.40192 | -78.09611 | 2011 | Black River | BLR | 77 |
| BK04 | 34.431622 | -78.143823 | 2015 | Black River | BLR | 86 |
| BK05 | 34.474855 | -78.201258 | 2015 | Black River | BLR | 96 |
| BR01 | 34.18475 | -77.96742 | 2011 | Brunswick River | MCF | 37 |
| BR02 | 34.2585 | -77.98516 | 2011 | Brunswick River | MCF | 45 |
| CF01 | 33.87917 | -78.00117 | 2011 | Cape Fear Inlet | LCF | 0 |
| CF02 | 33.89533 | -78.01428 | 2011 | Cape Fear Inlet | LCF | 0 |
| CF04 | 34.02283 | -77.93617 | 2011 | Cape Fear | LCF | 18 |
| CF05 | 34.12394 | -77.93389 | 2011 | Cape Fear | MCF | 31 |
| CF06 | 34.20803 | -77.95922 | 2011 | Cape Fear | MCF | 45 |
| CF11 | 34.24244 | -77.95728 | 2011 | Cape Fear Confluence | MCF | 42 |
| CF12 | 34.28492 | -77.99286 | 2011 | Cape Fear | MCF | 51 |
| CF13 | 34.360089 | -78.112508 | 2011 | Cape Fear | UCF | 72 |
| CF15 | 34.38169 | -78.23858 | 2011 | Cape Fear | UCF | 87 |
| CF16 | 34.40194 | -78.29167 | 2011 | Cape Fear | UCF | 95 |
| CF17 | 34.4046 | -78.29375 | 2011 | Cape Fear L&D1 | UCF | 95 |
| CF18 | 34.62628 | -78.57688 | 2013 | Cape Fear L&D2 | UCF | 145 |
| IN01 | 34.40404 | -78.29356 | 2011 | In Lock Chamber L&D1 | UCF | 95 |
| NE01 | 34.24606 | -77.95539 | 2011 | Mouth of Northeast | LNECF | 43 |
| NE02 | 34.30486 | -77.96069 | 2011 | Northeast | LNECF | 50 |
| NE03 | 34.33925 | -77.99497 | 2011 | Northeast | LNECF | 57 |
| NE04 | 34.38328 | -77.96281 | 2011 | Northeast | UNECF | 65 |
| NE06 | 34.36417 | -77.89394 | 2011 | Northeast | UNECF | 78 |
| NE07 | 34.38933 | -77.82389 | 2011 | Northeast | UNECF | 86 |
| NE08 | 34.48064 | -77.83772 | 2011 | Northeast | UNECF | 98 |
| NE09 | 34.54867 | -77.81644 | 2014 | Northeast | UNECF | 110 |
| NE10 | 34.59822 | -77.87404 | 2014 | Northeast | UNECF | 122 |
| NE11 | 34.78419 | -77.83713 | 2014 | Northeast | UNECF | 163 |
| NE12 | 34.83085 | -77.83207 | 2015 | Northeast | UNECF | 168 |
| NE13 | 34.90601 | -77.84082 | 2015 | Northeast | UNECF | 183 |
| SC01 | 34.057534 | -77.890531 | 2011 | Snows Cut | LCF | 25 |
| SM01 | 34.25895 | -77.93904 | 2014 | Smith Creek | LNECF | 47 |

Table 10. Date, tagging location, length, weight, sex, transmitter number, and tag life for American shad implanted with acoustic tags in the Cape Fear River Basin between 2014 and 2016.

| Year | Month | Day | River | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 3 | 19 | Northeast | 493 | 575 | . | F | A69-1601-13539 | 445 |
| 2014 | 3 | 25 | Northeast | 490 | 555 | . | F | A69-1601-13537 | 445 |
| 2014 | 4 | 7 | Northeast | 416 | 473 | . | M | A69-1601-13523 | 445 |
| 2014 | 4 | 7 | Northeast | 421 | 478 | . | M | A69-1601-13521 | 445 |
| 2014 | 4 | 14 | Northeast | 459 | 520 | . | M | A69-1601-13524 | 445 |
| 2014 | 4 | 14 | Northeast | 461 | 528 | . | F | A69-1601-13531 | 445 |
| 2014 | 4 | 16 | Northeast | 440 | 503 | . | F | A69-1601-13532 | 445 |
| 2014 | 5 | 8 | Northeast | 381 | 433 | . | M | A69-1601-13528 | 445 |
| 2014 | 5 | 8 | Northeast | 384 | 435 | . | M | A69-1601-13530 | 445 |
| 2014 | 5 | 8 | Northeast | 380 | 439 | . | F | A69-1601-13529 | 445 |
| 2014 | 5 | 8 | Northeast | 395 | 449 | . | M | A69-1601-13536 | 445 |
| 2014 | 5 | 8 | Northeast | 450 | 513 | . | F | A69-1601-13535 | 445 |
| 2014 | 5 | 8 | Northeast | 471 | 519 | . | F | A69-1601-13525 | 445 |
| 2014 | 5 | 8 | Northeast | 473 | 536 | . | F | A69-1601-13533 | 445 |
| 2014 | 5 | 27 | Northeast | 442 | 499 | . | M | A69-1601-13527 | 445 |
| 2014 | 5 | 27 | Northeast | 442 | 500 | . | M | A69-1601-13534 | 445 |
| 2014 | 5 | 27 | Northeast | 451 | 505 | . | F | A69-1601-13526 | 445 |
| 2014 | 5 | 27 | Northeast | 451 | 519 | . | M | A69-1601-13522 | 445 |
| 2014 | 5 | 27 | Northeast | 463 | 525 | . | F | A69-1601-13520 | 445 |
| 2015 | 4 | 1 | Black | 375 | 413 | . | M | A69-1601-20250 | 704 |
| 2015 | 4 | 1 | Black | 405 | 462 | . | M | A69-1601-20269 | 704 |
| 2015 | 4 | 8 | Black | 432 | 493 | . | M | A69-1601-20263 | 704 |
| 2015 | 4 | 14 | Black | 322 | 365 | . | M | A69-1601-20245 | 704 |
| 2015 | 4 | 14 | Black | 425 | 481 | . | M | A69-1601-20257 | 704 |
| 2015 | 4 | 15 | Black | 362 | 413 | . | M | A69-1601-20251 | 704 |
| 2015 | 4 | 15 | Black | 400 | 450 | . | M | A69-1601-20239 | 704 |
| 2015 | 4 | 24 | Black | 376 | 426 | . | M | A69-1601-20233 | 704 |
| 2015 | 4 | 24 | Black | 411 | 468 | . | M | A69-1601-20227 | 704 |
| 2015 | 4 | 30 | Black | 447 | 516 | . | F | A69-1601-20252 | 704 |
| 2016 | 3 | 20 | Northeast | 366 | 435 | . | F | A69-1601-13538 | 704 |
| 2016 | 3 | 21 | Northeast | 473 | 519 | . | F | A69-1601-20228 | 704 |
| 2016 | 3 | 22 | Northeast | 383 | 434 | . | M | A69-1601-20240 | 704 |
| 2016 | 4 | 5 | Northeast | 404 | 454 | . | M | A69-1601-39849 | 651 |
| 2016 | 4 | 5 | Northeast | 414 | 466 | . | M | A69-1601-20262 | 704 |
| 2016 | 4 | 5 | Northeast | 415 | 466 | . | M | A69-1601-39850 | 651 |
| 2016 | 4 | 5 | Northeast | 421 | 475 | . | F | A69-1601-39872 | 651 |
| 2016 | 4 | 5 | Northeast | 420 | 477 | . | M | A69-1601-20234 | 704 |
| 2016 | 4 | 5 | Northeast | 429 | 485 | . | M | A69-1601-39863 | 651 |
| 2016 | 4 | 5 | Northeast | 440 | 495 | . | F | A69-1601-20256 | 704 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2016 | 4 | 5 | Northeast | 439 | 496 | . | M | A69-1601-20258 | 704 |
| 2016 | 4 | 5 | Northeast | 452 | 513 | . | F | A69-1601-20264 | 704 |
| 2016 | 4 | 5 | Northeast | 450 | 516 | . | F | A69-1601-39871 | 651 |
| 2016 | 4 | 5 | Northeast | 480 | 539 | . | F | A69-1601-20270 | 704 |
| 2016 | 4 | 6 | Northeast | 419 | 470 | . | M | A69-1601-39864 | 651 |
| 2016 | 4 | 6 | Northeast | 435 | 494 | . | F | A69-1601-39857 | 651 |
| 2016 | 4 | 6 | Northeast | 463 | 520 | . | M | A69-1601-39856 | 651 |
| 2016 | 4 | 6 | Northeast | 464 | 522 | . | F | A69-1601-39866 | 651 |
| 2016 | 4 | 6 | Northeast | 468 | 526 | . | F | A69-1601-39865 | 651 |
| 2016 | 4 | 11 | Northeast | 437 | 493 | . | M | A69-1601-39867 | 651 |
| 2016 | 4 | 11 | Northeast | 481 | 540 | . | F | A69-1601-39868 | 651 |

Table 11. Date, tagging location, length, weight, sex, transmitter number, and tag life, for Striped Bass implanted with acoustic tags in the Cape Fear River Basin between 2012 and 2016.

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2012 | 1 | 14 | MCF | 485 | 522 | 2.0 | U | A69-1303-51776 | 1,030 |
| 2012 | 1 | 14 | LNECF | 520 | 555 | 2.0 | U | A69-1303-51773 | 1,030 |
| 2012 | 1 | 14 | MCF | 570 | 600 | 2.5 | U | A69-1303-51779 | 1,030 |
| 2012 | 1 | 14 | LNECF | 585 | 620 | 3.0 | U | A69-1303-51770 | 1,030 |
| 2012 | 1 | 14 | LNECF | 622 | 660 | . | U | A69-1303-51771 | 1,030 |
| 2012 | 1 | 14 | LNECF | 639 | 668 | 4.0 | U | A69-1303-51775 | 1,030 |
| 2012 | 1 | 14 | LNECF | 635 | 675 | 3.5 | U | A69-1303-51765 | 1,030 |
| 2012 | 1 | 14 | LNECF | 689 | 725 | 4.5 | U | A69-1303-51772 | 1,030 |
| 2012 | 1 | 14 | LNECF | 698 | 748 | 4.5 | U | A69-1303-51777 | 1,030 |
| 2012 | 1 | 14 | LNECF | 705 | 750 | 4.8 | U | A69-1303-51774 | 1,030 |
| 2012 | 1 | 14 | LNECF | 774 | 823 | 6.5 | U | A69-1303-51778 | 1,030 |
| 2012 | 1 | 20 | MCF | 560 | 596 | 2.3 | U | A69-1303-51766 | 1,030 |
| 2012 | 1 | 25 | MCF | 555 | 592 | 2.3 | U | A69-1303-51769 | 1,030 |
| 2012 | 1 | 25 | MCF | 575 | 610 | 2.5 | U | A69-1303-51768 | 1,030 |
| 2012 | 1 | 25 | MCF | 600 | 636 | 3.0 | U | A69-1303-51767 | 1,030 |
| 2012 | 2 | 1 | LNECF | 629 | 654 | 3.5 | U | A69-1303-51762 | 1,030 |
| 2012 | 2 | 1 | LNECF | 631 | 672 | 3.5 | U | A69-1303-51763 | 1,030 |
| 2012 | 2 | 1 | LNECF | 674 | 723 | 4.2 | U | A69-1303-51764 | 1,030 |
| 2012 | 2 | 2 | LNECF | 711 | 754 | 4.9 | U | A69-1303-51760 | 1,030 |
| 2012 | 2 | 2 | LNECF | 716 | 760 | 6.0 | U | A69-1303-51761 | 1,030 |
| 2013 | 1 | 19 | LNECF | 527 | 563 | 2.1 | U | A69-1303-33104 | 1,030 |
| 2013 | 1 | 19 | LNECF | 570 | 609 | 2.7 | U | A69-1303-33103 | 1,030 |
| 2013 | 1 | 19 | LNECF | 595 | 633 | 2.9 | U | A69-1303-33110 | 1,030 |
| 2013 | 1 | 19 | LNECF | 616 | 659 | 3.2 | U | A69-1303-33106 | 1,030 |
| 2013 | 1 | 19 | LNECF | 627 | 663 | 4.1 | U | A69-1303-33107 | 1,030 |
| 2013 | 1 | 19 | LNECF | 701 | 726 | 4.1 | U | A69-1303-33108 | 1,030 |
| 2013 | 1 | 19 | LNECF | 699 | 735 | 4.3 | U | A69-1303-33109 | 1,030 |
| 2013 | 1 | 19 | LNECF | 713 | 752 | 4.6 | U | A69-1303-33105 | 1,030 |
| 2013 | 1 | 22 | LNECF | 614 | 651 | 3.4 | U | A69-1601-2987 | 651 |
| 2013 | 1 | 22 | LNECF | 627 | 666 | 3.2 | U | A69-1601-2986 | 651 |
| 2013 | 1 | 23 | MCF | 653 | 685 | 3.6 | U | A69-1303-33112 | 1,030 |
| 2013 | 1 | 23 | LNECF | 720 | 764 | 4.8 | U | A69-1303-33111 | 1,030 |
| 2013 | 2 | 1 | LNECF | 545 | 574 | 2.4 | U | A69-1601-2991 | 651 |
| 2013 | 2 | 1 | LNECF | 577 | 619 | 2.7 | U | A69-1601-2992 | 651 |
| 2013 | 2 | 1 | LNECF | 591 | 625 | 3.0 | U | A69-1601-29026 | 651 |
| 2013 | 2 | 1 | LNECF | 600 | 634 | 2.9 | U | A69-1601-29027 | 651 |

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | 2 | 1 | LNECF | 611 | 648 | 3.1 | U | A69-1601-2988 | 651 |
| 2013 | 2 | 1 | LNECF | 659 | 697 | 3.9 | U | A69-1601-2989 | 651 |
| 2013 | 2 | 1 | LNECF | 658 | 699 | 3.7 | U | A69-1601-2990 | 651 |
| 2013 | 2 | 1 | LNECF | 673 | 712 | 4.3 | U | A69-1601-2993 | 651 |
| 2013 | 2 | 1 | LNECF | 712 | 758 | 4.9 | U | A69-1601-2994 | 651 |
| 2013 | 2 | 4 | MCF | 662 | 707 | 3.8 | U | A69-1303-33113 | 1,030 |
| 2013 | 2 | 5 | MCF | 578 | 615 | 2.8 | U | A69-1601-29029 | 651 |
| 2013 | 2 | 5 | MCF | 584 | 616 | 3.1 | U | A69-1601-29030 | 651 |
| 2013 | 2 | 5 | MCF | 590 | 635 | 2.9 | U | A69-1601-29028 | 651 |
| 2013 | 2 | 6 | MCF | 548 | 589 | 2.1 | U | A69-1601-29032 | 651 |
| 2013 | 2 | 6 | MCF | 658 | 704 | 3.8 | U | A69-1601-29031 | 651 |
| 2013 | 2 | 7 | MCF | 538 | 577 | 2.1 | U | A69-1601-29035 | 651 |
| 2013 | 2 | 7 | MCF | 540 | 581 | 2.2 | U | A69-1601-29034 | 651 |
| 2013 | 2 | 7 | MCF | 655 | 695 | 4.1 | U | A69-1601-29033 | 651 |
| 2013 | 2 | 14 | LNECF | 514 | 550 | 1.7 | F | A69-1601-29012 | 651 |
| 2013 | 2 | 14 | LNECF | 517 | 553 | 2.3 | U | A69-1601-29042 | 651 |
| 2013 | 2 | 14 | LNECF | 515 | 554 | 2.1 | U | A69-1601-29036 | 651 |
| 2013 | 2 | 14 | LNECF | 542 | 566 | 2.0 | U | A69-1601-29019 | 651 |
| 2013 | 2 | 14 | LNECF | 537 | 574 | 2.5 | U | A69-1601-29040 | 651 |
| 2013 | 2 | 14 | LNECF | 553 | 589 | 2.1 | U | A69-1601-29018 | 651 |
| 2013 | 2 | 14 | LNECF | 573 | 610 | 2.3 | F | A69-1601-29017 | 651 |
| 2013 | 2 | 14 | LNECF | 600 | 637 | 3.0 | U | A69-1601-29037 | 651 |
| 2013 | 2 | 14 | LNECF | 611 | 646 | 3.0 | U | A69-1601-29041 | 651 |
| 2013 | 2 | 14 | LNECF | 612 | 654 | 3.6 | F | A69-1601-29044 | 651 |
| 2013 | 2 | 14 | LNECF | 619 | 663 | 3.2 | U | A69-1601-29045 | 651 |
| 2013 | 2 | 14 | LNECF | 648 | 687 | 4.4 | U | A69-1601-29039 | 651 |
| 2013 | 2 | 14 | LNECF | 670 | 695 | 3.6 | U | A69-1601-29013 | 651 |
| 2013 | 2 | 14 | LNECF | 669 | 715 | 4.9 | U | A69-1601-29043 | 651 |
| 2013 | 2 | 14 | LNECF | 690 | 724 | 4.9 | U | A69-1601-29011 | 651 |
| 2013 | 2 | 14 | LNECF | 702 | 743 | 4.8 | U | A69-1601-29015 | 651 |
| 2013 | 2 | 14 | LNECF | 699 | 743 | 5.7 | U | A69-1601-29038 | 651 |
| 2013 | 2 | 14 | LNECF | 708 | 747 | 4.9 | U | A69-1601-29016 | 651 |
| 2013 | 2 | 14 | LNECF | 754 | 791 | 6.0 | U | A69-1601-29014 | 651 |
| 2013 | 2 | 15 | MCF | 475 | 509 | 1.5 | M | A69-1601-29050 | 651 |
| 2013 | 2 | 15 | MCF | 546 | 582 | 2.4 | U | A69-1601-29047 | 651 |
| 2013 | 2 | 15 | MCF | 555 | 582 | 2.6 | U | A69-1601-29049 | 651 |
| 2013 | 2 | 15 | LNECF | 585 | 626 | 2.3 | U | A69-1601-29046 | 651 |
| 2013 | 2 | 15 | LNECF | 593 | 635 | 3.1 | U | A69-1601-29024 | 651 |
| 2013 | 2 | 15 | MCF | 601 | 636 | 3.1 | F | A69-1601-29048 | 651 |
| 2013 | 2 | 15 | LNECF | 610 | 654 | 3.8 | U | A69-1601-29020 | 651 |

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | 2 | 15 | LNECF | 645 | 684 | 4.8 | U | A69-1601-29022 | 651 |
| 2013 | 2 | 15 | LNECF | 668 | 712 | 5.3 | U | A69-1601-29023 | 651 |
| 2013 | 2 | 15 | LNECF | 680 | 721 | 4.9 | F | A69-1601-29025 | 651 |
| 2013 | 2 | 15 | LNECF | 688 | 727 | 4.8 | F | A69-1601-29021 | 651 |
| 2013 | 4 | 3 | UCF | . | 542 | . | M | A69-1601-29051 | 651 |
| 2013 | 4 | 11 | UCF | 510 | 541 | . | M | A69-1601-29052 | 651 |
| 2013 | 4 | 17 | UCF | . | 541 | . | M | A69-1601-29055 | 651 |
| 2013 | 4 | 17 | UCF | . | 599 | . | M | A69-1601-29056 | 651 |
| 2013 | 4 | 17 | UCF | . | 641 | . | M | A69-1601-29053 | 651 |
| 2013 | 4 | 17 | UCF | . | 722 | . | M | A69-1601-29054 | 651 |
| 2013 | 4 | 22 | UCF | 627 | 666 | . | F | A69-1601-29057 | 651 |
| 2013 | 4 | 30 | UCF | 634 | 674 | . | U | A69-1601-29060 | 651 |
| 2013 | 4 | 30 | UCF | 631 | 675 | . | F | A69-1601-29059 | 651 |
| 2013 | 4 | 30 | UCF | 713 | 754 | . | F | A69-1601-29058 | 651 |
| 2013 | 5 | 15 | UCF | 480 | 510 | . | U | A69-1601-29077 | 651 |
| 2013 | 5 | 15 | UCF | 500 | 530 | . | U | A69-1601-29074 | 651 |
| 2013 | 5 | 15 | UCF | 510 | 540 | . | M | A69-1601-29076 | 651 |
| 2013 | 5 | 15 | UCF | 540 | 580 | . | M | A69-1601-29075 | 651 |
| 2013 | 9 | 30 | UCF | 430 | 457 | . | U | A69-1601-12431 | 651 |
| 2013 | 9 | 30 | UCF | 503 | 531 | . | U | A69-1601-12430 | 651 |
| 2013 | 9 | 30 | UCF | 516 | 545 | . | U | A69-1601-12429 | 651 |
| 2013 | 9 | 30 | UCF | 520 | 550 | . | U | A69-1601-12428 | 651 |
| 2013 | 10 | 18 | UCF | 454 | 481 | . | U | A69-1601-12435 | 651 |
| 2013 | 10 | 18 | UCF | 499 | 522 | . | U | A69-1601-12436 | 651 |
| 2013 | 10 | 18 | UCF | 495 | 525 | . | U | A69-1601-12433 | 651 |
| 2013 | 10 | 18 | UCF | 530 | 559 | . | U | A69-1601-12432 | 651 |
| 2013 | 10 | 18 | UCF | 555 | 587 | . | U | A69-1601-12434 | 651 |
| 2013 | 10 | 25 | UCF | 547 | 574 | . | U | A69-1601-12450 | 651 |
| 2013 | 10 | 25 | UCF | 540 | 580 | . | U | A69-1601-12449 | 651 |
| 2013 | 10 | 30 | UCF | 495 | 525 | . | U | A69-1601-12469 | 651 |
| 2013 | 11 | 6 | UCF | 515 | 550 | . | U | A69-1601-12473 | 651 |
| 2013 | 11 | 6 | UCF | 635 | 570 | . | U | A69-1601-12472 | 651 |
| 2013 | 11 | 6 | UCF | 540 | 575 | . | U | A69-1601-12470 | 651 |
| 2013 | 11 | 6 | UCF | 560 | 595 | . | U | A69-1601-12471 | 651 |
| 2013 | 11 | 22 | UCF | 455 | 485 | . | U | A69-1601-12475 | 651 |
| 2013 | 11 | 22 | UCF | 520 | 555 | . | U | A69-1601-12474 | 651 |
| 2013 | 11 | 22 | UCF | 520 | 555 | . | U | A69-1601-12479 | 651 |
| 2013 | 11 | 22 | UCF | 565 | 600 | . | U | A69-1601-12477 | 651 |
| 2013 | 11 | 22 | UCF | 570 | 605 | . | U | A69-1601-12476 | 651 |
| 2013 | 11 | 22 | UCF | 630 | 670 | . | U | A69-1601-12478 | 651 |

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2013 | 11 | 25 | UCF | 530 | 560 | . | U | A69-1601-12481 | 651 |
| 2013 | 11 | 25 | UCF | 545 | 580 | . | U | A69-1601-12482 | 651 |
| 2013 | 11 | 25 | UCF | 565 | 605 | . | U | A69-1601-12480 | 651 |
| 2013 | 12 | 4 | UCF | 505 | 536 | . | U | A69-1601-12486 | 651 |
| 2013 | 12 | 4 | UCF | 505 | 541 | . | U | A69-1601-12483 | 651 |
| 2013 | 12 | 4 | UCF | 534 | 565 | . | U | A69-1601-12485 | 651 |
| 2013 | 12 | 4 | UCF | 546 | 585 | . | U | A69-1601-12484 | 651 |
| 2013 | 12 | 11 | UCF | 548 | 580 | . | U | A69-1601-12487 | 651 |
| 2013 | 12 | 11 | UCF | 613 | 655 | . | U | A69-1601-12488 | 651 |
| 2013 | 12 | 18 | MCF | 515 | 545 | . | U | A69-1601-12491 | 651 |
| 2013 | 12 | 18 | MCF | 545 | 582 | . | U | A69-1601-12490 | 651 |
| 2013 | 12 | 18 | MCF | 655 | 697 | . | U | A69-1601-12489 | 651 |
| 2014 | 1 | 18 | MCF | 650 | 691 | 2.1 | U | A69-1303-33121 | 1,030 |
| 2014 | 1 | 18 | MCF | 675 | 720 | 2.1 | U | A69-1601-26204 | 1,626 |
| 2014 | 1 | 18 | MCF | 722 | 764 | 2.4 | U | A69-1303-33122 | 1,030 |
| 2014 | 1 | 28 | MCF | 643 | 686 | 4.3 | U | A69-1303-33119 | 1,030 |
| 2014 | 2 | 20 | MCF | 655 | 700 | 4.4 | U | A69-1601-26207 | 1,626 |
| 2014 | 2 | 20 | MCF | 695 | 730 | 5.0 | U | A69-1601-26208 | 1,626 |
| 2014 | 3 | 11 | MCF | 645 | 689 | 4.2 | U | A69-1601-26206 | 1,626 |
| 2014 | 3 | 11 | MCF | 703 | 745 | 5.2 | U | A69-1601-26203 | 1,626 |
| 2014 | 3 | 11 | MCF | 720 | 761 | 6.2 | U | A69-1601-26205 | 1,626 |
| 2014 | 3 | 24 | MCF | 528 | 561 | 2.0 | U | A69-1303-33118 | 1,030 |
| 2014 | 3 | 24 | MCF | 569 | 600 | 2.4 | U | A69-1601-26238 | 1,626 |
| 2014 | 3 | 24 | MCF | 618 | 665 | 4.0 | U | A69-1601-26242 | 1,626 |
| 2014 | 3 | 24 | MCF | 625 | 786 | 4.5 | U | A69-1601-26239 | 1,626 |
| 2014 | 3 | 27 | MCF | 755 | 800 | 7.8 | U | A69-1601-26241 | 1,626 |
| 2014 | 4 | 10 | MCF | 665 | 705 | 3.7 | U | A69-1601-26218 | 1,626 |
| 2014 | 4 | 14 | MCF | 670 | 716 | 4.4 | U | A69-1601-26213 | 1,626 |
| 2014 | 4 | 24 | MCF | 544 | 575 | 2.6 | U | A69-1601-26228 | 1,626 |
| 2014 | 4 | 24 | MCF | 602 | 640 | 3.3 | U | A69-1601-26233 | 1,626 |
| 2014 | 4 | 28 | MCF | 660 | 704 | 3.6 | U | A69-1601-26220 | 1,626 |
| 2014 | 4 | 28 | MCF | 692 | 739 | 4.9 | U | A69-1601-26215 | 1,626 |
| 2014 | 4 | 28 | MCF | 695 | 741 | 5.5 | U | A69-1601-26214 | 1,626 |
| 2014 | 4 | 28 | MCF | 716 | 763 | 5.9 | U | A69-1601-26222 | 1,626 |
| 2014 | 5 | 1 | MCF | 578 | 610 | 2.6 | U | A69-1601-26225 | 1,626 |
| 2014 | 5 | 1 | MCF | 627 | 672 | 3.6 | U | A69-1601-26229 | 1,626 |
| 2014 | 5 | 1 | MCF | 667 | 712 | 3.7 | U | A69-1601-26234 | 1,626 |
| 2014 | 5 | 1 | MCF | 682 | 720 | 4.5 | U | A69-1601-26231 | 1,626 |
| 2014 | 5 | 1 | MCF | 679 | 721 | 4.4 | U | A69-1601-26226 | 1,626 |
| 2014 | 5 | 1 | MCF | 715 | 756 | 4.6 | U | A69-1601-26230 | 1,626 |

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 5 | 5 | MCF | 560 | 605 | 2.5 | U | A69-1601-26224 | 1,626 |
| 2014 | 10 | 23 | UCF | 445 | 470 | . | U | A69-1601-12448 | 651 |
| 2014 | 10 | 23 | UCF | 484 | 516 | . | U | A69-1601-12445 | 651 |
| 2014 | 10 | 23 | UCF | 515 | 551 | . | U | A69-1601-12446 | 651 |
| 2014 | 10 | 23 | UCF | 522 | 556 | . | U | A69-1601-12447 | 651 |
| 2014 | 10 | 23 | UCF | 526 | 558 | . | U | A69-1601-12442 | 651 |
| 2014 | 10 | 23 | UCF | 555 | 585 | . | U | A69-1601-12444 | 651 |
| 2014 | 10 | 23 | UCF | 558 | 590 | . | U | A69-1601-12443 | 651 |
| 2014 | 10 | 23 | UCF | 582 | 615 | . | U | A69-1601-12441 | 651 |
| 2014 | 10 | 23 | UCF | 612 | 631 | . | U | A69-1601-12439 | 651 |
| 2014 | 10 | 23 | UCF | 596 | 635 | . | U | A69-1601-12440 | 651 |
| 2015 | 1 | 21 | MCF | 614 | 656 | 3.2 | U | A69-1601-26236 | 1,626 |
| 2015 | 1 | 21 | MCF | 790 | 836 | 6.5 | U | A69-9002-12568 | 844 |
| 2015 | 1 | 27 | MCF | 626 | 665 | 3.5 | U | A69-9002-12578 | 844 |
| 2015 | 1 | 27 | MCF | 638 | 671 | 3.6 | U | A69-9002-12576 | 1,626 |
| 2015 | 1 | 27 | MCF | 644 | 687 | 3.7 | U | A69-1601-26221 | 1,626 |
| 2015 | 1 | 29 | LNECF | 726 | 772 | 6.5 | U | A69-9002-12548 | 844 |
| 2015 | 2 | 12 | MCF | 621 | 663 | 3.7 | U | A69-1601-26217 | 1,626 |
| 2015 | 2 | 18 | UNECF | 570 | 602 | 2.7 | U | A69-1601-26227 | 1,626 |
| 2015 | 2 | 18 | UNECF | 591 | 631 | 2.9 | U | A69-9002-12526 | 844 |
| 2015 | 2 | 18 | UNECF | 601 | 640 | 2.7 | U | A69-1601-26216 | 1,626 |
| 2015 | 2 | 18 | UNECF | 618 | 667 | 3.7 | U | A69-9002-12524 | 844 |
| 2015 | 2 | 27 | MCF | 612 | 656 | 3.8 | U | A69-9002-12572 | 844 |
| 2015 | 2 | 27 | LNECF | 654 | 697 | 4.2 | U | A69-9002-12556 | 844 |
| 2015 | 3 | 2 | LNECF | 522 | 559 | 2.2 | U | A69-1601-23471 | 1,227 |
| 2015 | 3 | 2 | LNECF | 742 | 786 | 5.9 | U | A69-9002-12570 | 844 |
| 2015 | 3 | 2 | LNECF | 755 | 804 | 6.9 | U | A69-9002-12520 | 844 |
| 2015 | 3 | 3 | LNECF | 569 | 601 | 2.4 | U | A69-1601-26237 | 1,626 |
| 2015 | 3 | 3 | LNECF | 566 | 605 | 2.4 | U | A69-1601-26240 | 1,626 |
| 2015 | 3 | 5 | LNECF | 638 | 677 | 3.9 | U | A69-9002-12528 | 844 |
| 2015 | 3 | 5 | LNECF | 694 | 733 | 4.6 | U | A69-9002-12566 | 844 |
| 2015 | 3 | 5 | LNECF | 705 | 754 | 5.0 | U | A69-9002-12554 | 844 |
| 2015 | 3 | 9 | LNECF | 565 | 606 | 2.4 | U | A69-1601-23470 | 1,227 |
| 2015 | 3 | 9 | LNECF | 636 | 679 | 3.1 | U | A69-9002-12536 | 844 |
| 2015 | 3 | 9 | LNECF | 670 | 706 | 4.4 | U | A69-9002-12574 | 844 |
| 2015 | 3 | 11 | LNECF | 603 | 642 | 3.0 | U | A69-1601-26211 | 1,626 |
| 2015 | 3 | 11 | LNECF | 617 | 654 | 2.7 | U | A69-1601-23469 | 1,227 |
| 2015 | 3 | 11 | LNECF | 615 | 655 | 2.8 | U | A69-1601-26219 | 1,626 |
| 2015 | 3 | 11 | LNECF | 730 | 774 | 4.8 | U | A69-1601-26232 | 1,626 |
| 2015 | 3 | 13 | LNECF | 600 | 645 | 2.9 | U | A69-1601-26235 | 1,626 |

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2015 | 3 | 13 | LNECF | 585 | 624 | 2.6 | U | A69-1601-23472 | 1,227 |
| 2015 | 3 | 13 | LNECF | 639 | 679 | 3.4 | U | A69-1601-26210 | 1,626 |
| 2015 | 3 | 13 | LNECF | 635 | 684 | 3.8 | U | A69-1601-23468 | 1,227 |
| 2015 | 3 | 17 | LNECF | 539 | 571 | 2.2 | U | A69-1601-26209 | 1,626 |
| 2015 | 3 | 23 | LNECF | 611 | 650 | 2.7 | U | A69-9002-12532 | 844 |
| 2015 | 3 | 25 | BLR | 553 | 593 | 2.3 | U | A69-1601-23429 | 1,227 |
| 2015 | 5 | 4 | BLR | 535 | 574 | 2.3 | U | A69-1601-23418 | 1,227 |
| 2015 | 5 | 12 | BLR | 605 | 641 | 2.8 | U | A69-1601-23421 | 1,227 |
| 2015 | 5 | 13 | BLR | 595 | 635 | 3.0 | U | A69-1601-23431 | 1,227 |
| 2015 | 5 | 13 | BLR | 678 | 721 | 4.9 | F | A69-1601-23428 | 1,227 |
| 2015 | 5 | 13 | BLR | 765 | 811 | 5.6 | U | A69-1601-26212 | 1,227 |
| 2015 | 5 | 18 | BLR | 532 | 567 | 1.8 | M | A69-1601-23427 | 1,227 |
| 2015 | 5 | 18 | BLR | 550 | 587 | 2.0 | M | A69-1601-23420 | 1,227 |
| 2015 | 5 | 19 | BLR | 560 | 597 | 2.1 | M | A69-1601-23423 | 1,227 |
| 2015 | 5 | 19 | BLR | 655 | 695 | 3.4 | M | A69-1601-23425 | 1,227 |
| 2015 | 5 | 20 | LNECF | 524 | 564 | 1.8 | M | A69-1601-23425 | 1,227 |
| 2015 | 5 | 20 | LNECF | 536 | 576 | 2.2 | M | A69-1601-23422 | 1,227 |
| 2015 | 5 | 20 | LNECF | 548 | 584 | 1.9 | M | A69-1601-23424 | 1,227 |
| 2015 | 5 | 20 | LNECF | 571 | 615 | 2.2 | F | A69-1601-23430 | 1,227 |
| 2015 | 5 | 20 | LNECF | 631 | 676 | 3.3 | M | A69-1601-23432 | 1,227 |
| 2015 | 5 | 20 | LNECF | 686 | 729 | 4.3 | F | A69-1601-23419 | 1,227 |
| 2015 | 11 | 17 | MCF | 633 | 668 | 3.1 | U | A69-9002-12534 | 844 |
| 2015 | 11 | 17 | MCF | 674 | 721 | 3.8 | U | A69-9002-12538 | 844 |
| 2015 | 11 | 17 | MCF | 759 | 806 | . | U | A69-9002-12550 | 844 |
| 2015 | 11 | 20 | MCF | 716 | 761 | 4.1 | U | A69-9002-12558 | 844 |
| 2016 | 1 | 20 | LNECF | 569 | 612 | 2.4 | U | A69-1601-23411 | 1,227 |
| 2016 | 1 | 20 | LNECF | 585 | 619 | 2.5 | U | A69-1601-23416 | 1,227 |
| 2016 | 1 | 20 | LNECF | 598 | 637 | 3.2 | U | A69-1601-23414 | 1,227 |
| 2016 | 1 | 21 | LNECF | 570 | 609 | 2.6 | F | A69-1601-23415 | 1,227 |
| 2016 | 1 | 21 | LNECF | 578 | 614 | 2.6 | U | A69-9002-12530 | 844 |
| 2016 | 1 | 21 | LNECF | 589 | 632 | 2.9 | U | A69-9002-12564 | 844 |
| 2016 | 1 | 21 | LNECF | 635 | 672 | . | U | A69-1601-23417 | 1,227 |
| 2016 | 1 | 21 | LNECF | 705 | 746 | 4.5 | U | A69-1601-23412 | 1,227 |
| 2016 | 1 | 26 | MCF | 634 | 679 | 3.4 | U | A69-9002-12560 | 844 |
| 2016 | 1 | 26 | MCF | 666 | 709 | 4.5 | U | A69-9002-12544 | 844 |
| 2016 | 1 | 26 | MCF | 708 | 744 | 4.0 | U | A69-9002-12562 | 844 |
| 2016 | 1 | 26 | MCF | 741 | 785 | 5.2 | U | A69-9002-12546 | 844 |
| 2016 | 2 | 2 | MCF | 615 | 654 | 3.0 | U | A69-9002-12542 | 844 |
| 2016 | 2 | 10 | LNECF | 604 | 650 | . | U | A69-9002-12552 | 844 |
| 2016 | 2 | 10 | LNECF | 615 | 655 | . | U | A69-9002-12522 | 844 |

| Year | Month | Day | River Stretch | Fork Length (mm) | Total Length (mm) | Weight (kg) | Sex | Transmitter | Tag Life (days) |
|---|---|---|---|---|---|---|---|---|---|
| 2016 | 2 | 10 | LNECF | 683 | 725 | . | U | A69-9002-12540 | 844 |
| 2016 | 2 | 10 | LNECF | 692 | 737 | 3.9 | U | A69-1601-23410 | 1,227 |
| 2016 | 2 | 17 | MCF | 548 | 589 | 2.5 | U | A69-1601-23408 | 1,227 |
| 2016 | 2 | 17 | MCF | 585 | 624 | 2.6 | U | A69-1601-23413 | 1,227 |
| 2016 | 2 | 17 | MCF | 597 | 640 | 2.6 | U | A69-1601-23409 | 1,227 |
| 2016 | 2 | 18 | LNECF | 577 | 616 | 2.5 | U | A69-1601-23403 | 1,227 |
| 2016 | 2 | 26 | UNECF | 561 | 596 | 2.0 | U | A69-1601-23406 | 1,227 |
| 2016 | 2 | 26 | UNECF | 559 | 602 | 2.2 | U | A69-1601-23398 | 1,227 |
| 2016 | 2 | 26 | UNECF | 565 | 602 | 2.3 | U | A69-1601-23407 | 1,227 |
| 2016 | 2 | 26 | UNECF | 625 | 656 | 3.0 | U | A69-1601-23402 | 1,227 |
| 2016 | 2 | 26 | MCF | 631 | 673 | 3.6 | U | A69-1601-23401 | 1,227 |
| 2016 | 2 | 26 | MCF | 695 | 736 | 4.0 | U | A69-1601-23400 | 1,227 |
| 2016 | 2 | 26 | UNECF | 703 | 749 | 4.9 | U | A69-1601-23399 | 1,227 |
| 2016 | 2 | 26 | UNECF | 701 | 750 | 4.6 | U | A69-1601-23405 | 1,227 |
| 2016 | 2 | 26 | UNECF | 726 | 772 | 4.9 | U | A69-1601-23404 | 1,227 |
| 2016 | 2 | 29 | LNECF | 700 | 740 | 4.5 | U | A69-1601-39873 | 651 |
| 2016 | 4 | 5 | UNECF | 570 | 606 | . | U | A69-1601-39870 | 651 |
| 2016 | 4 | 5 | UNECF | 581 | 610 | 2.5 | U | A69-1601-20268 | 704 |
| 2016 | 4 | 5 | UNECF | 642 | 684 | 3.7 | U | A69-1601-39855 | 651 |
| 2016 | 4 | 13 | UNECF | 617 | 657 | 3.1 | U | A69-1601-39869 | 651 |
| 2016 | 4 | 20 | UNECF | 441 | 471 | 1.0 | M | A69-1601-39861 | 651 |
| 2016 | 4 | 20 | UNECF | 515 | 553 | 1.9 | M | A69-1601-39852 | 651 |
| 2016 | 4 | 20 | UNECF | 528 | 564 | 2.0 | M | A69-1601-39862 | 651 |
| 2016 | 4 | 20 | UNECF | 540 | 575 | 2.1 | M | A69-1601-39860 | 651 |
| 2016 | 4 | 20 | UNECF | 545 | 580 | 2.2 | M | A69-1601-39858 | 651 |
| 2016 | 4 | 20 | UNECF | 556 | 595 | 2.1 | M | A69-1601-39851 | 651 |

Table 12. Months with receiver downloads for the Cape Fear River Basin, 2014 through 2017.

| Month | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| January | | x | x | |
| February | | x | x | x |
| March | x | x | x | x |
| April | x | x | x | |
| May | x | x | | |
| June | x | x | x | |
| July | x | x | x | |
| August | x | x | | x |
| September | x | x | | |
| October | x | x | x | |
| November | | | x | |
| December | | | x | |

Table 13. Active receiver stations in the Cape Fear River Basin by year and season. An “x” denotes the station is deployed and operating, and “o” denotes a lost or malfunctioning receiver for that time period, and a blank space indicates that station was yet to be deployed.

| Station Name | 2013 | | | | 2014 | | | | 2015 | | | | 2016 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer |
| BK01 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| BK02 | x | x | x | x | o | o | o | o | x | x | x | x | x | x | x |
| BK03 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| BK04 | | | | | | | | | x | x | x | x | x | x | x |
| BK05 | | | | | | | | | x | x | x | x | x | x | x |
| BR01 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| BR02 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| CF01 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| CF02 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| CF04 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | o |
| CF05 | x | x | x | x | o | o | o | o | x | x | x | x | x | x | o |
| CF06 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | o |
| CF11 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | o |
| CF12 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| CF13 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| CF15 | x | x | x | x | x | x | x | x | o | o | o | o | o | o | o |
| CF16 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| CF17 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | o |
| CF18 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| IN01 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x |
| NE01 | x | x | x | x | x | x | x | x | x | x | x | x | x | o | o |
| NE02 | x | x | x | x | x | x | x | x | x | x | x | x | x | x | o |
| NE03 | x | x | x | x | x | x | x | x | x | x | x | x | x | o | o |
| NE04 | x | x | x | x | x | x | x | x | x | x | x | x | x | o | o |
| NE06 | x | x | x | x | x | x | x | x | x | x | o | o | o | o | o |

| Station Name | 2013 | | | | 2014 | | | | 2015 | | | | 2016 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer | Fall | Winter | Spring | Summer |
| NE07 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| NE08 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| NE09 | | | | | x | x | x | x | x | x | x | x | x | x | x |
| NE10 | | | | | x | x | x | x | x | x | x | x | x | x | x |
| NE11 | | | | | x | x | x | x | x | x | x | x | x | x | x |
| NE12 | | | | | | | | | | | | x | x | x | x |
| NE13 | | | | | | | | | | | | x | x | x | x |
| SC01 | x | x | x | x | x | x | x | x | x | x | x | x | o | o | o |
| SM01 | | | | | | | | x | x | x | x | x | x | x | o |

Table 14. Number and percent of individual American shad detected in Cape Fear River Basin in 2014 and 2015. American shad were only detected in the spring of the year they were tagged.

| | Individuals Tagged | Individuals Detected | |
|---|---|---|---|
| Year | Number | Count | Percent |
| 2014 | 19 | 15 | 79 |
| 2015 | 10 | 9 | 90 |
| 2016 | 21 | 5 | 24 |

Table 15. Tagging and recapture information for striped bass recreationally caught during this study in the Cape Fear River Basin.

| | Tagging Information | | | | Recapture Information | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Acoustic Tag | Year | Month | Day | River Stretch | Year | Month | Day | River Stretch | Status |
| A69-1601-2990 | 2013 | 2 | 1 | LNECF | 2013 | 3 | 8 | LNECF | Released |
| A69-1601-29027 | 2013 | 2 | 1 | LNECF | 2014 | 3 | 15 | LNECF | Released |
| A69-1303-33113 | 2013 | 2 | 4 | MCF | 2013 | 5 | 13 | UCF (L&D2) | Released |
| A69-1601-26225 | 2014 | 5 | 1 | MCF | 2015 | 1 | 31 | MCF | Released |
| A69-1601-26230 | 2014 | 5 | 1 | MCF | 2015 | 5 | 3 | UCF(L&D3) | Released |
| A69-9002-12572 | 2015 | 2 | 27 | MCF | 2015 | 4 | 24 | MCF | Released |
| A69-1601-23471 | 2015 | 3 | 2 | LNECF | 2016 | 4 | 7 | UCF (L&D1) | Released |
| A69-1601-26237 | 2015 | 3 | 3 | LNECF | 2016 | 2 | 8 | MCF | Released |
| A69-1601-26237 | 2015 | 3 | 3 | LNECF | 2016 | 11 | 27 | UCF (L&D1) | Released |
| A69-1601-23423 | 2015 | 5 | 19 | BLR | 2016 | 4 | 29 | UCF (L&D1) | Released |
| A69-1601-23422 | 2015 | 5 | 20 | LNECF | 2014 | 4 | 21 | UCF (L&D1) | Released |
| A69-1601-23422 | 2015 | 5 | 20 | LNECF | 2015 | 5 | 6 | UCF(L&D3) | Released |
| A69-9002-12538 | 2015 | 11 | 17 | MCF | 2016 | 2 | 26 | UNECF | Released |
| A69-1601-23415 | 2016 | 1 | 21 | LNECF | 2016 | 2 | 12 | LNECF | Released |
| A69-1601-23401 | 2016 | 2 | 26 | MCF | 2016 | 10 | 20 | LCF | Released |
| A69-1601-23407 | 2016 | 2 | 26 | UNECF | 2016 | 11 | 16 | MCF | Released |

Table 16. Number of individual striped bass tagged, number expected to have active batteries, count of individuals detected, and percent of active tags detected for year and season in the Cape Fear River Basin.

| | | Individuals Tagged | | Individuals Detected | |
|---|---|---|---|---|---|
| Year | Season | To Date | Active | Count | Percent |
| | Winter | 80 | 80 | 62 | 78 |
| | Spring | 94 | 94 | 88 | 94 |
| 2013 | Summer | 94 | 94 | 79 | 84 |
| | Fall | 129 | 129 | 93 | 72 |
| | Winter | 144 | 144 | 105 | 73 |
| | Spring | 167 | 167 | 126 | 75 |
| 2014 | Summer | 167 | 167 | 94 | 56 |
| | Fall | 167 | 167 | 91 | 54 |
| | Winter | 180 | 180 | 89 | 49 |
| | Spring | 217 | 148 | 123 | 83 |
| 2015 | Summer | 217 | 134 | 99 | 74 |
| | Fall | 221 | 129 | 94 | 73 |
| | Winter | 251 | 113 | 86 | 76 |
| | Spring | 262 | 124 | 106 | 85 |
| 2016 | Summer | 262 | 124 | 75 | 60 |

Table 17. Number and percent of individual striped bass detected in the upper stations of each reach in the Cape Fear River Basin.

| Year | | Upper Cape Fear | Black River | Upper Northeast |
|---|---|---|---|---|
| 2013 | Number of Individuals Detected | 9 | 0 | 22 |
| | Percent of Total Available Active Tags | 10 | 0 | 25 |
| | Number of Individuals Repeating | . | . | . |
| | Percent Repeats of Active Detected Previously | . | . | . |
| 2014 | Number of Individuals Detected | 25 | 0 | 21 |
| | Percent of Total Available Active Tags | 20 | 0 | 17 |
| | Number of Individuals Repeating | 3 | . | 6 |
| | Percent Repeats of Active Detected Previously | 38 | . | 55 |
| 2015 | Number of Individuals Detected | 44 | 1 | 22 |
| | Percent of Total Available Active Tags | 36 | >1 | 18 |
| | Number of Individuals Repeating | 13 | . | 6 |
| | Percent Repeats of Active Detected Previously | 81 | . | 67 |
| 2016 | Number of Individuals Detected | 37 | 6 | 20 |
| | Percent of Total Available Active Tags | 35 | 6 | 19 |
| | Number of Individuals Repeating | 6 | 0 | 6 |
| | Percent Repeats of Active Detected Previously | 67 | 0 | 46 |

## 13 FIGURES

Figure 1. Picture of receiver on concrete base.

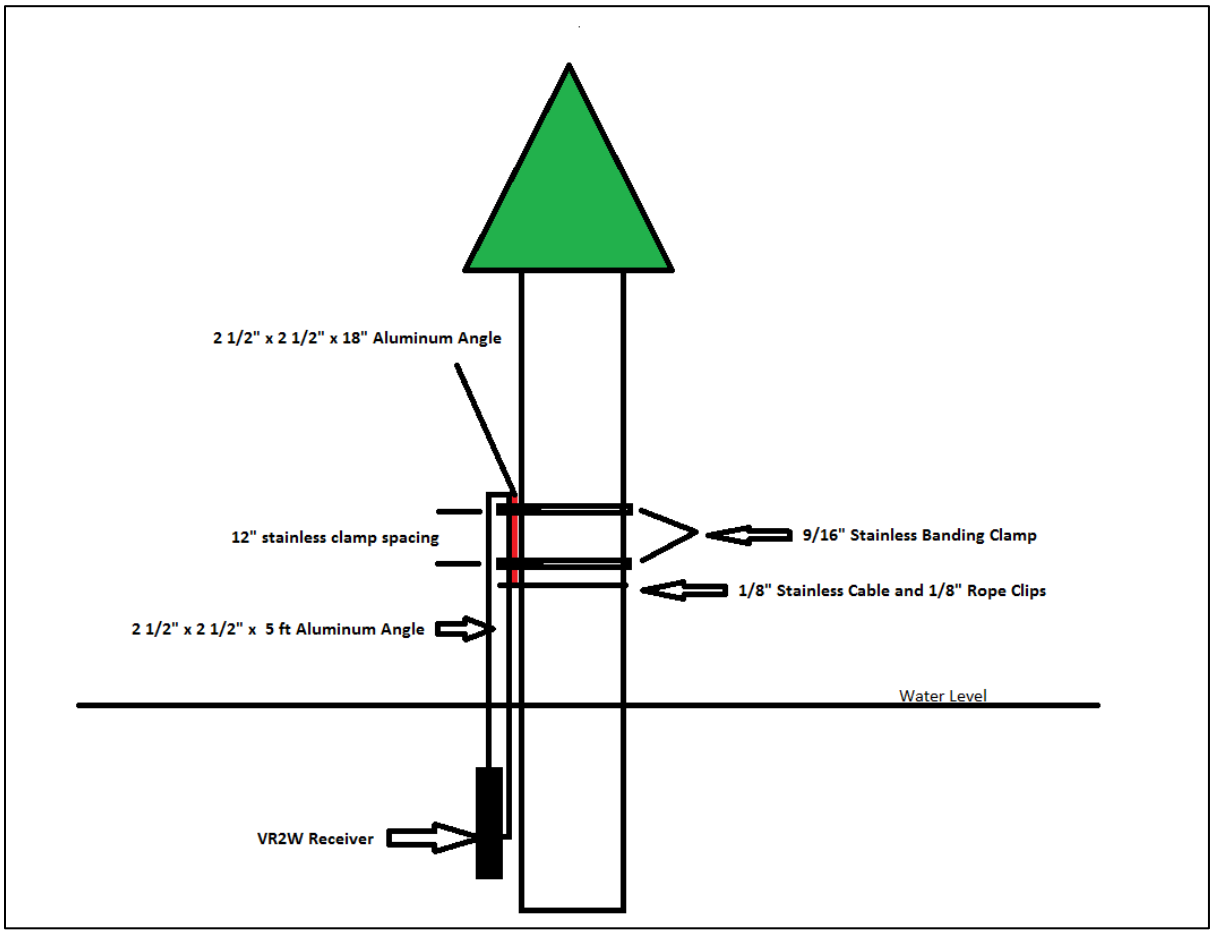


Figure 2. Diagram of receiver strapped to channel marker.

Figure 3. Picture of receiver connected to high flyer.

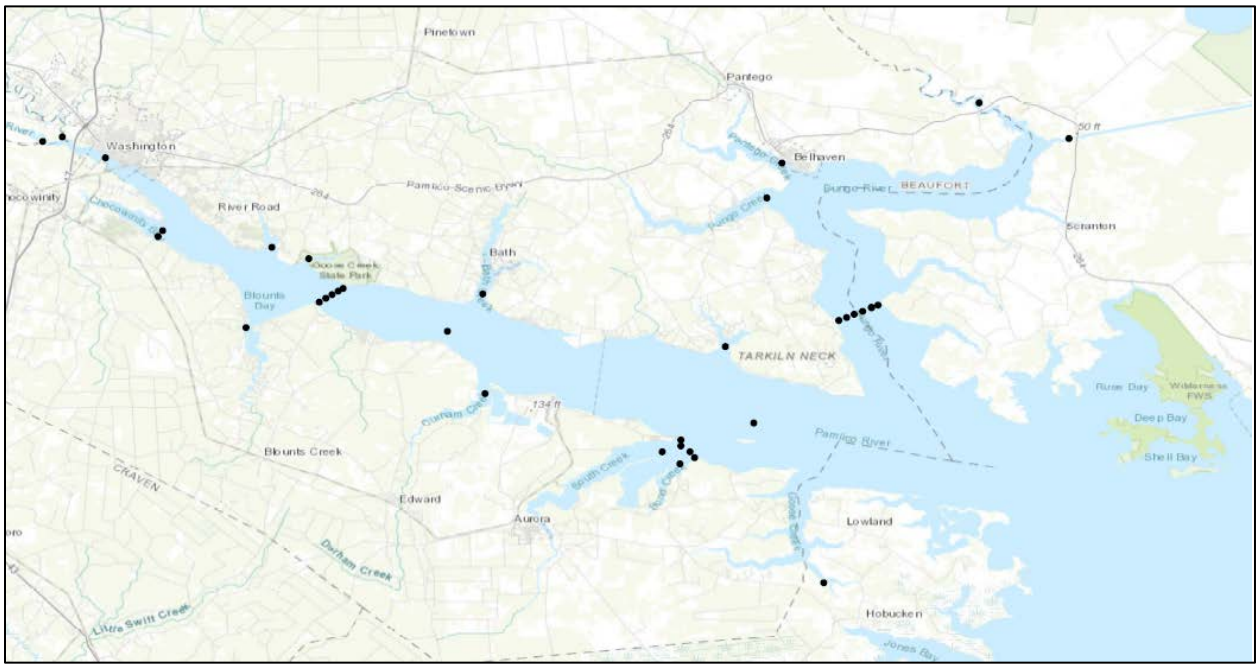


Figure 4. Map of Pamlico River receivers.

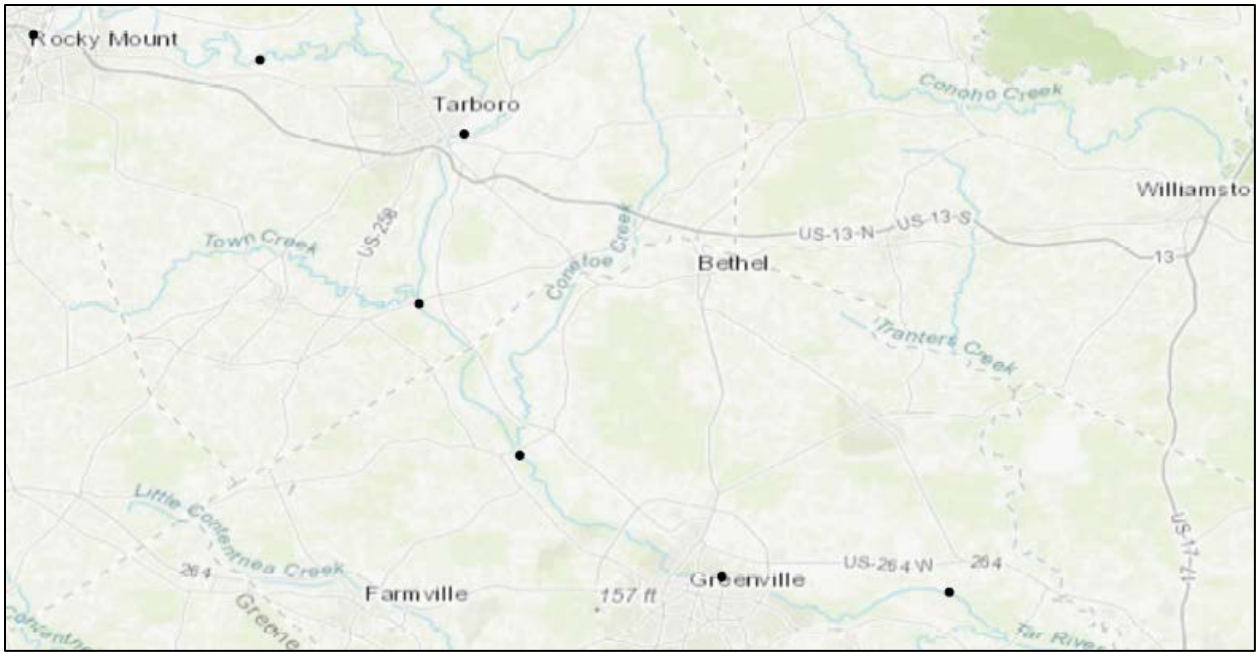


Figure 5. Map of Tar River receivers.

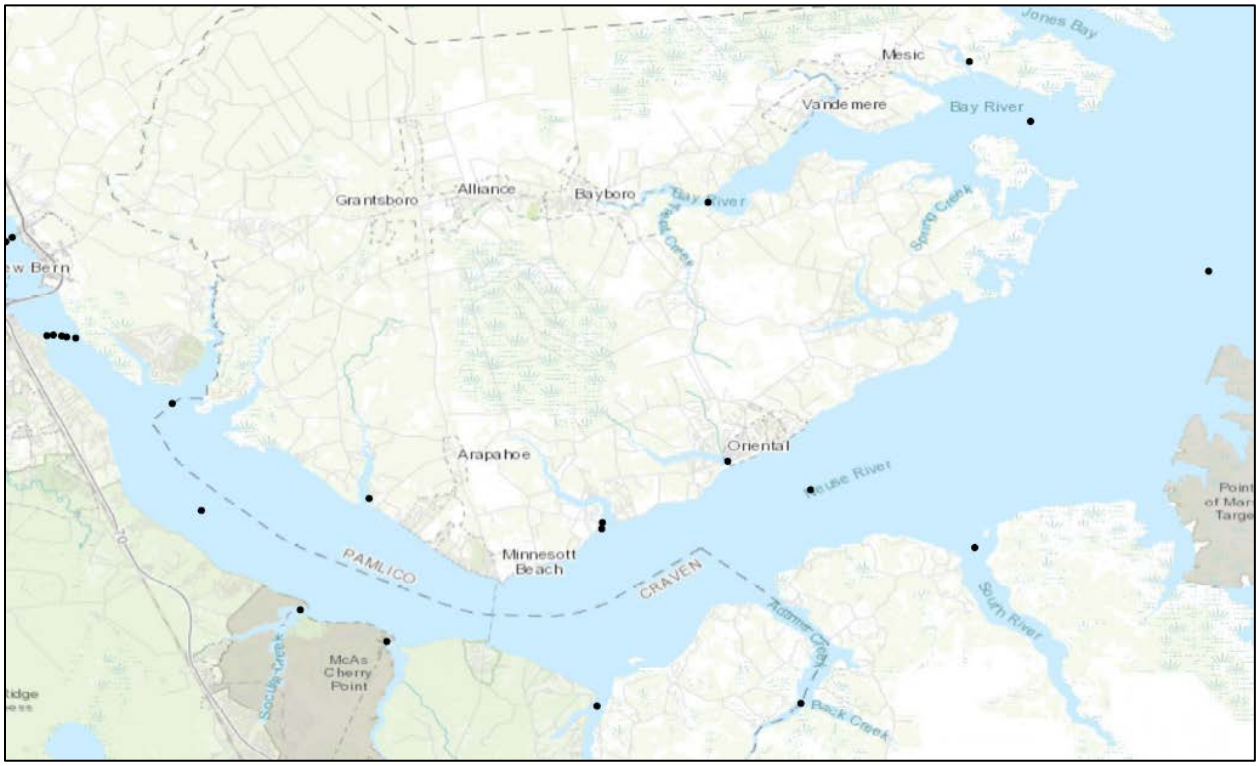


Figure 6. Map of lower Neuse River receivers.

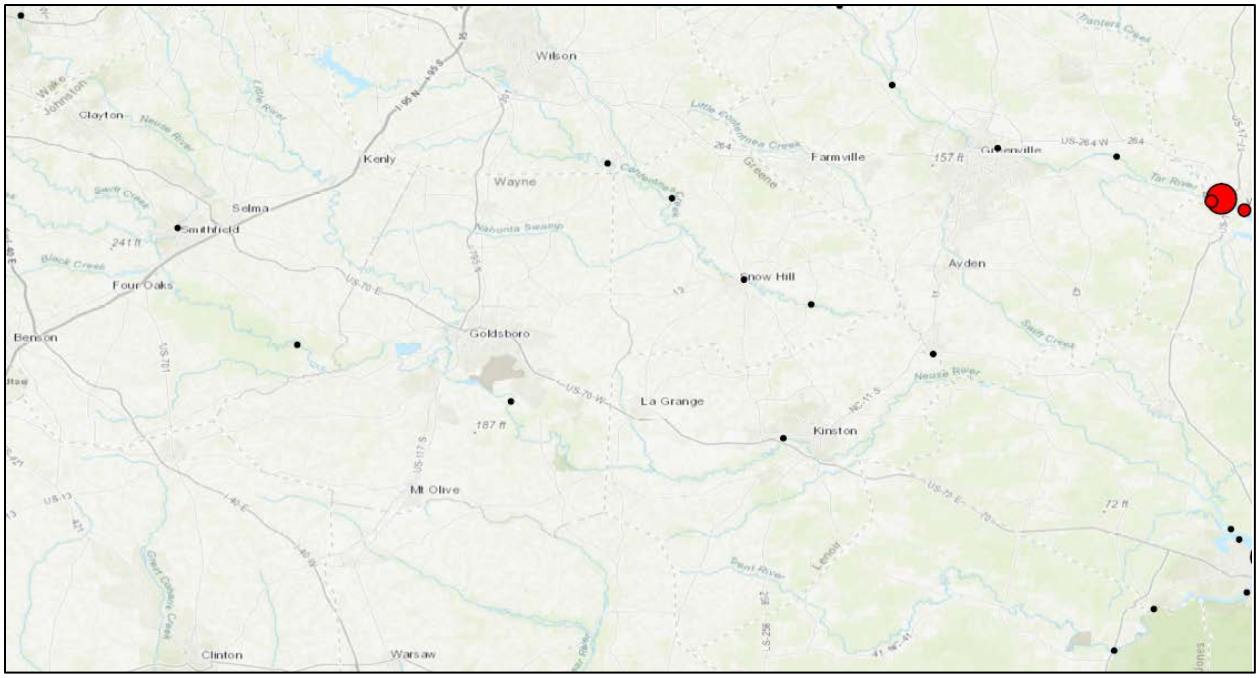


Figure 7. Map of upper Neuse River receivers

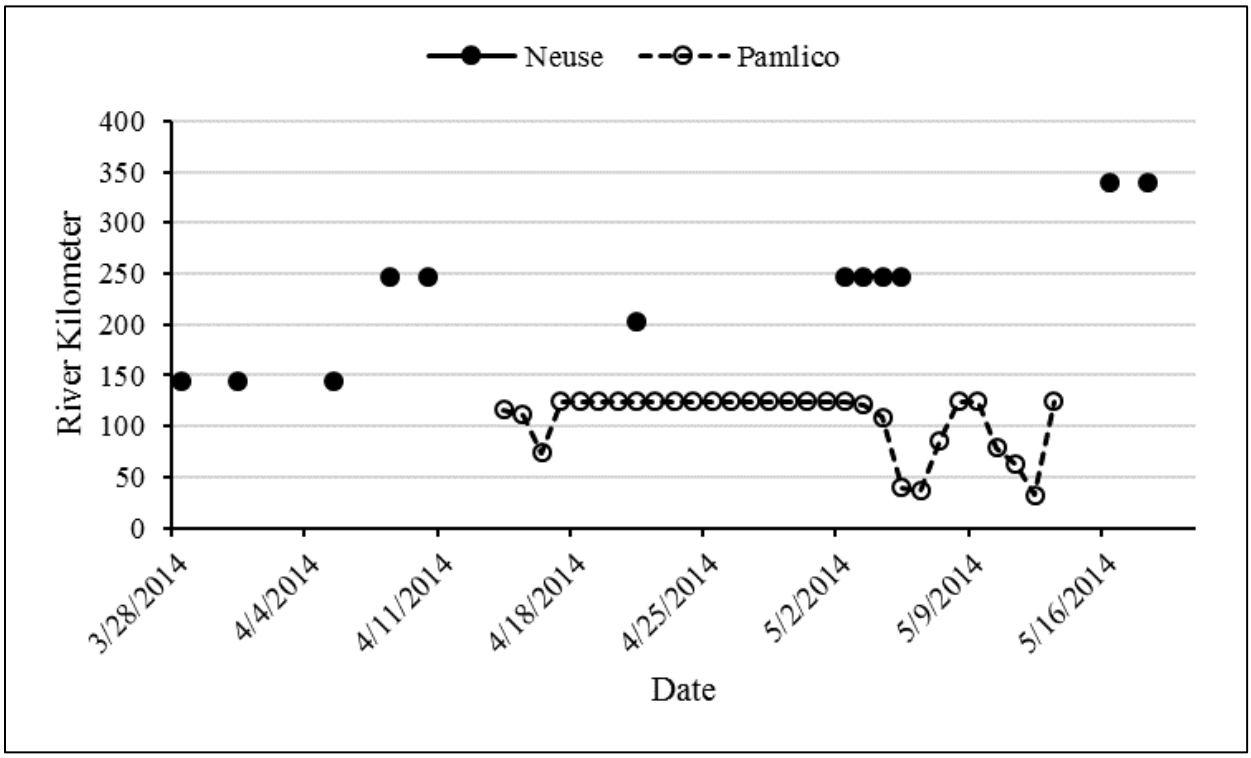


Figure 8. Mean river kilometer of American shad detections in the Neuse and Tar/Pamlico rivers, 2014. American shad tagged in the Neuse River are black circles with black line; American shad tagged in the Tar/Pamlico River are open circles with dashed line.

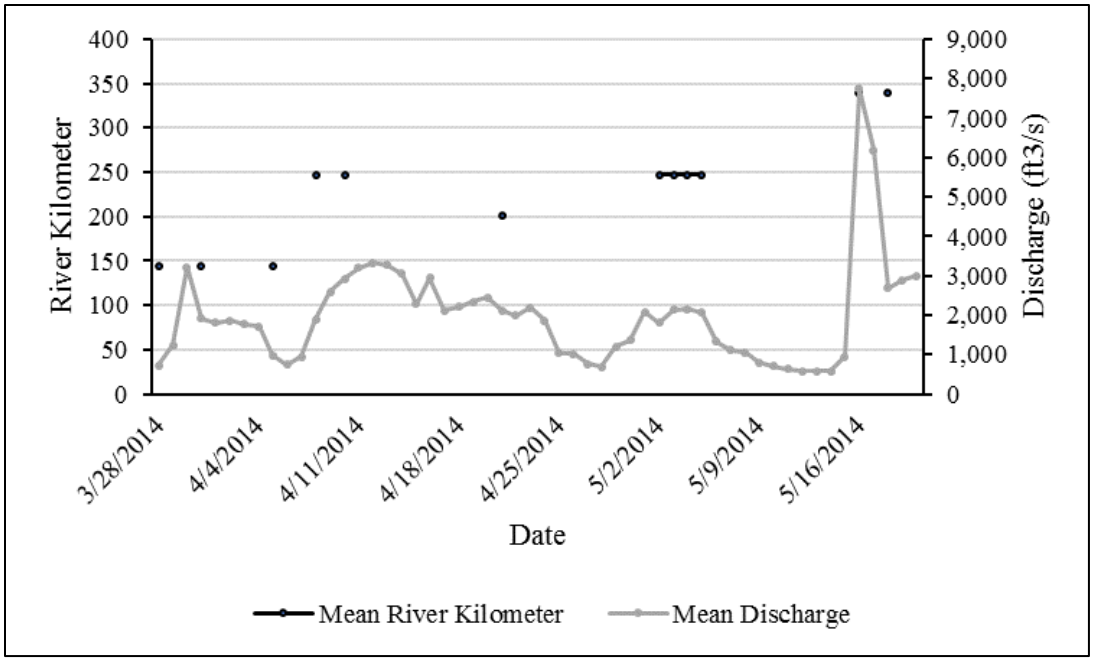


Figure 9. Mean daily discharge of the Neuse River measured at the monitoring station at Clayton, NC (gray circles, gray line) and mean river kilometer of American shad detections in the Neuse River (black circles, black line), March 28, 2014-May 20, 2014.

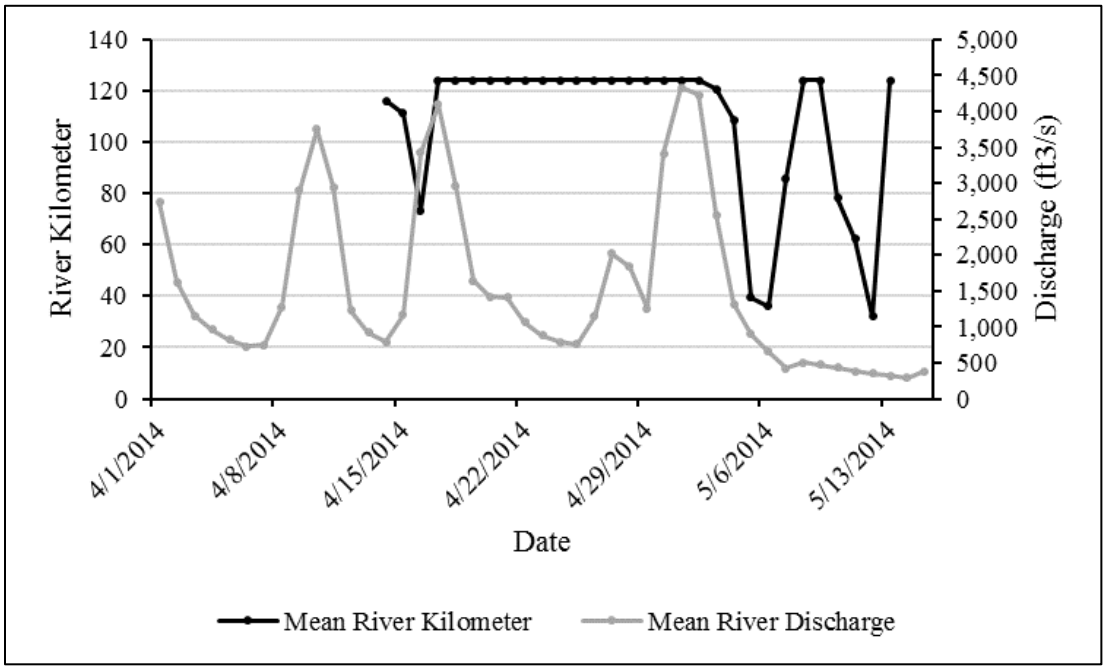


Figure 10. Mean daily discharge of the Tar River measured at the monitoring station at Rocky Mount, NC (gray circles, gray line) and mean river kilometer of American shad detections in the Tar/Pamlico River (black circles, black line), April 1, 2014-May 20, 2014.

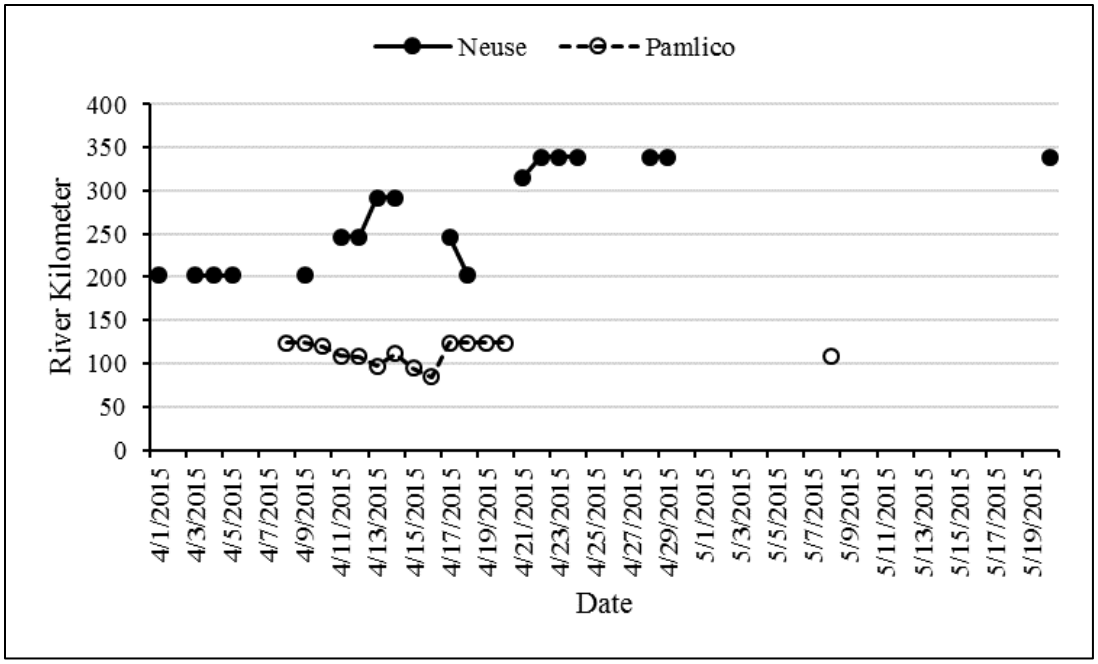


Figure 11. Mean river kilometer of American shad detections in the Neuse and Tar/Pamlico rivers, 2015. American shad tagged in the Neuse River are black circles with black line; American shad tagged in the Tar/Pamlico River are open circles with dashed line.

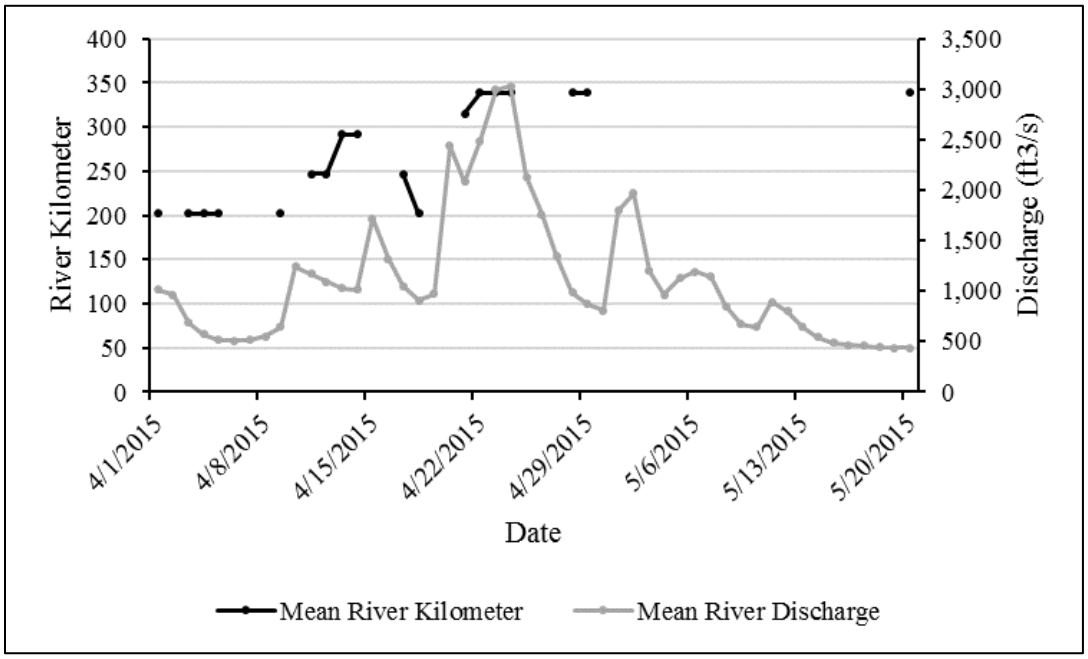


Figure 12. Mean daily discharge of the Neuse River measured at the monitoring station at Clayton, NC (gray circles, gray line) and mean river kilometer of American shad detections in the Neuse River (black circles, black line), April 1, 2015-May 20, 2015.

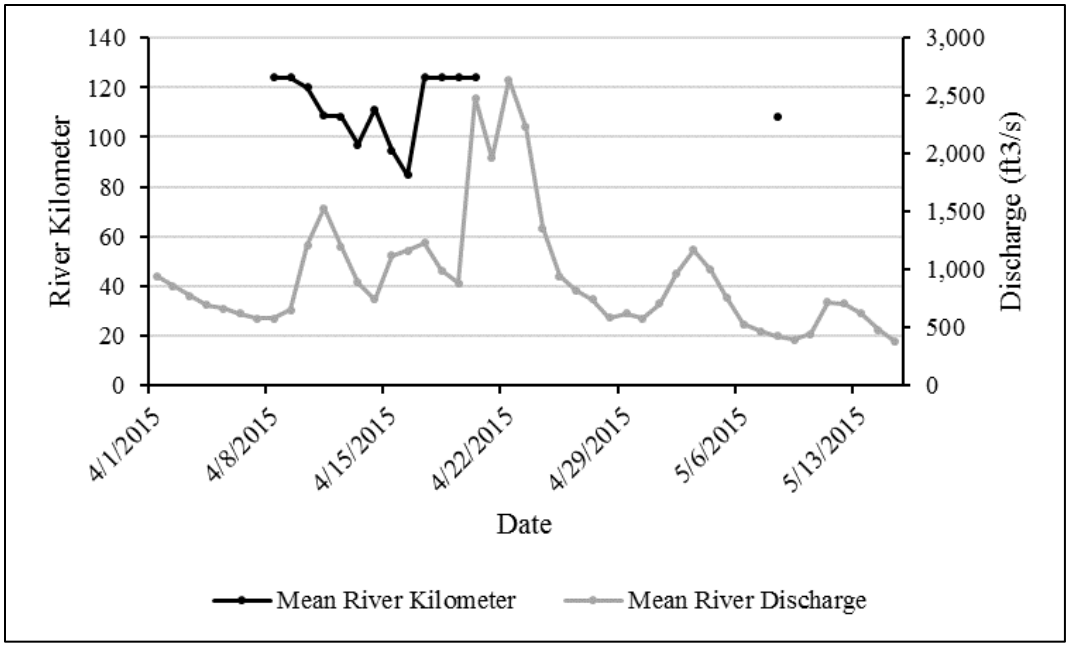


Figure 13. Mean daily discharge of the Tar River measured at the monitoring station at Rocky Mount, NC (gray circles, gray line) and mean river kilometer of American shad detections in the Tar/Pamlico River (black circles, black line), April 1, 2015-May 20, 2015.

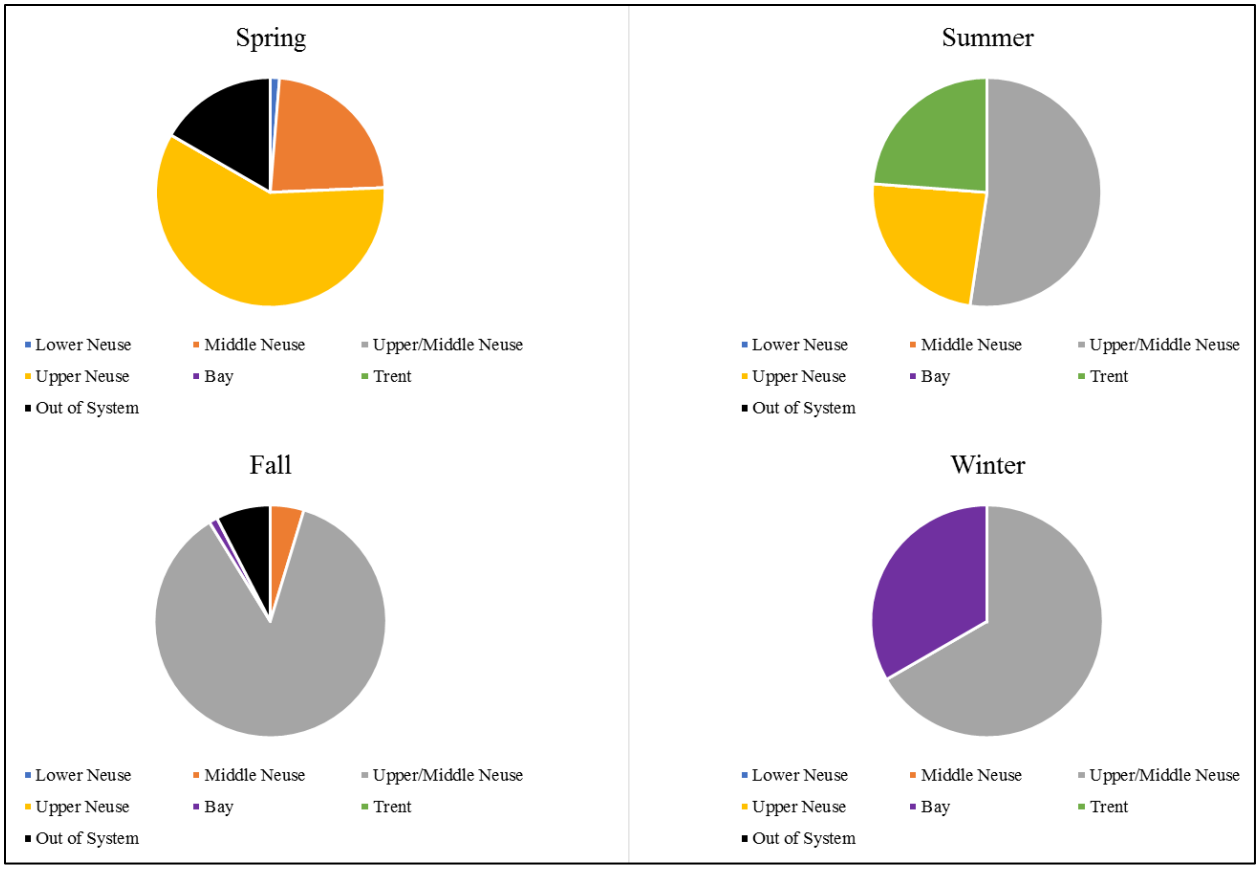


Figure 14. Percent of striped bass detections by region and season for striped bass tagged in the Neuse River, 2014.

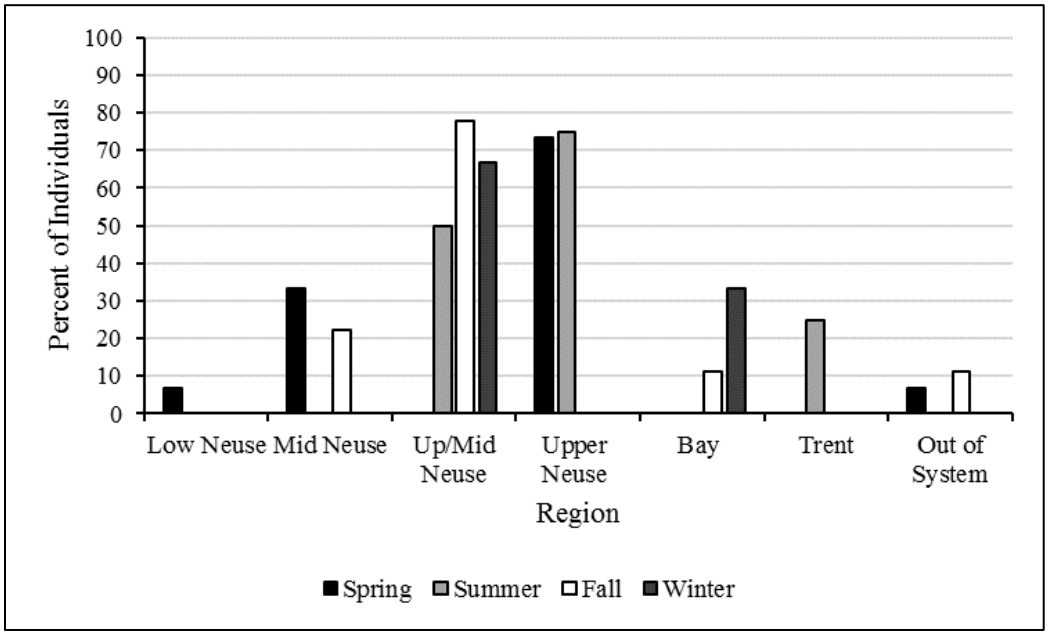


Figure 15. Percent of individual striped bass detected by Neuse River region by season, 2014.

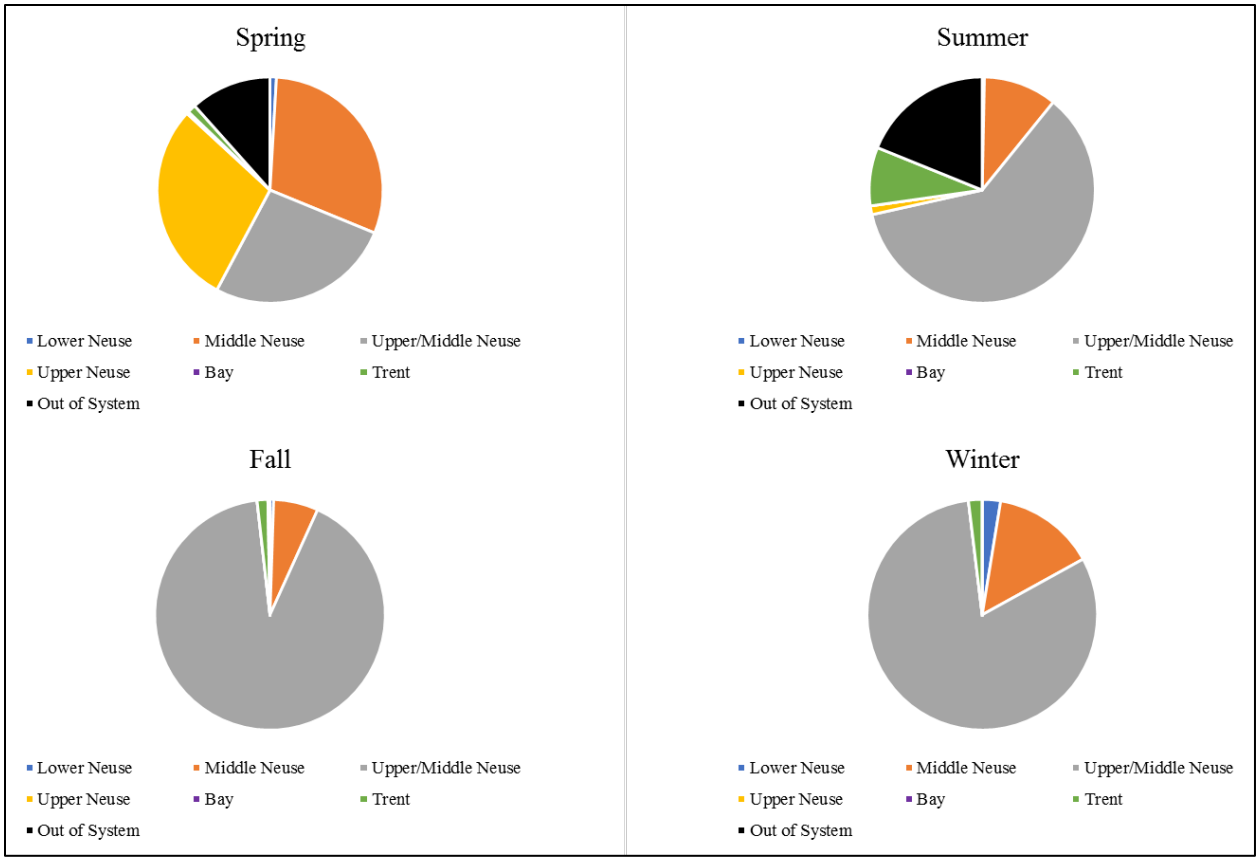


Figure 16. Percent of striped bass detections by region and season for striped bass tagged in the Neuse River, 2015.

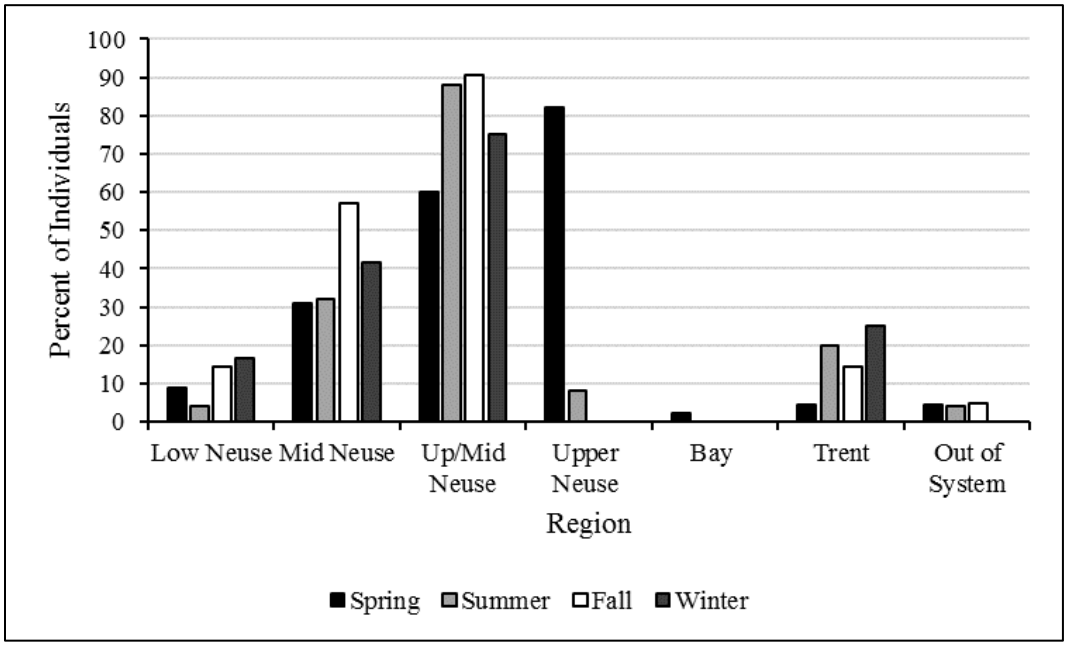


Figure 17. Percent of individual striped bass detected by Neuse River region by season, 2015.

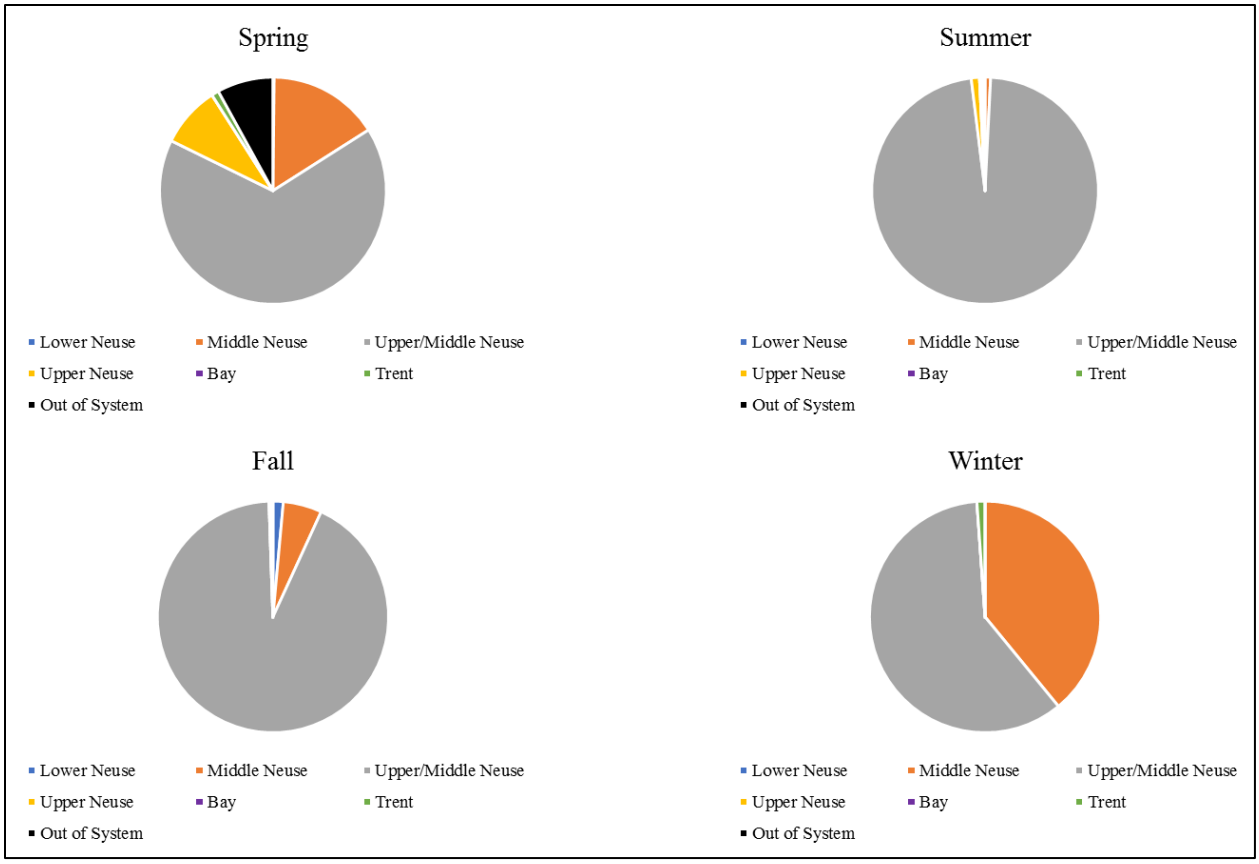


Figure 18. Percent of striped bass detections by region and season for striped bass tagged in the Neuse River, 2016.

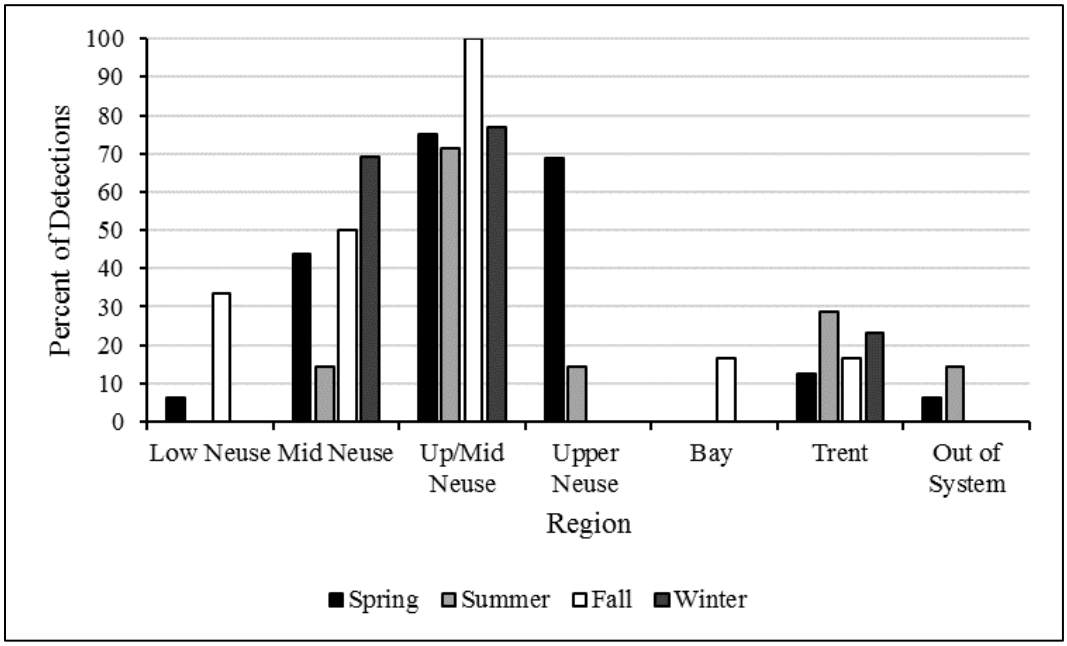


Figure 19. Percent of individual striped bass detected by Neuse River region by season, 2016.

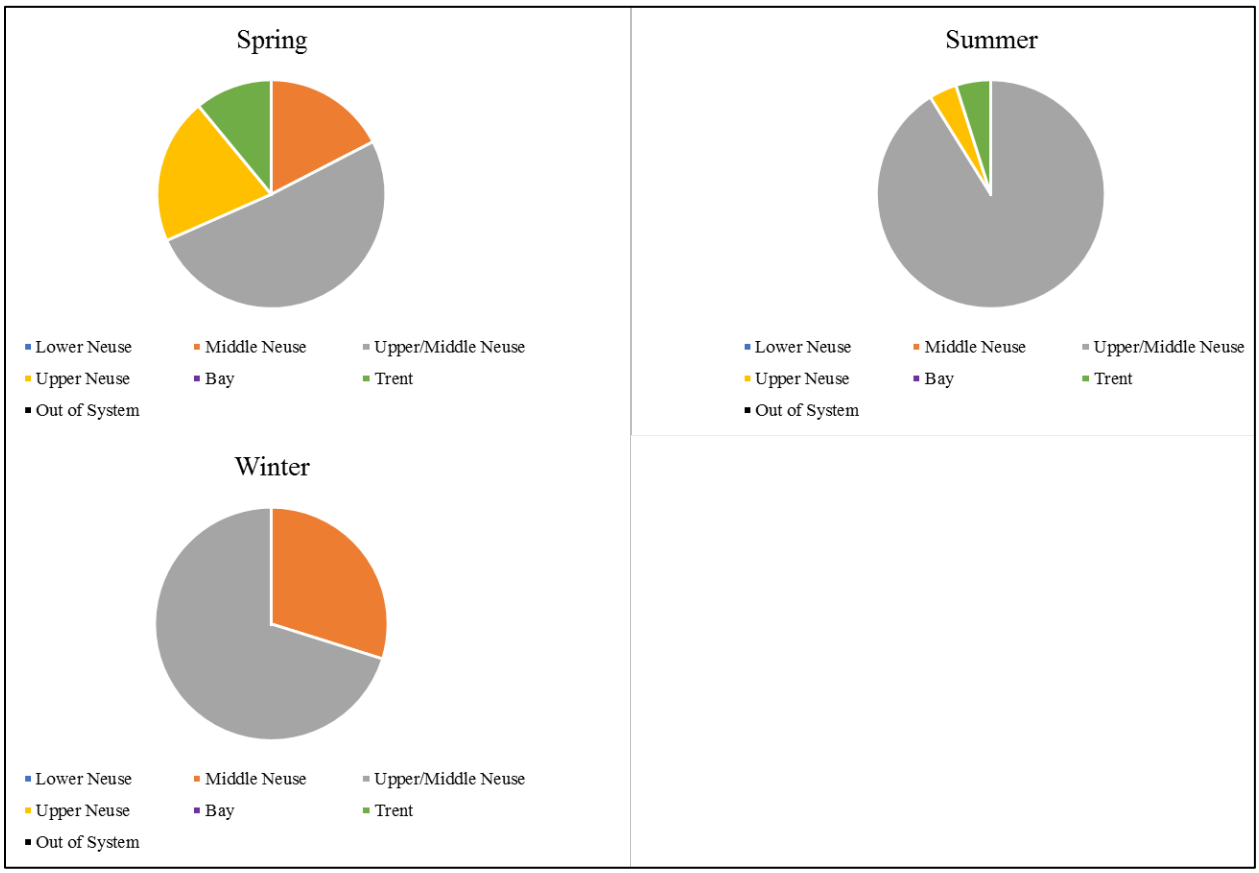


Figure 20. Percent of striped bass detections by region and season for striped bass tagged in the Neuse River, 2017.

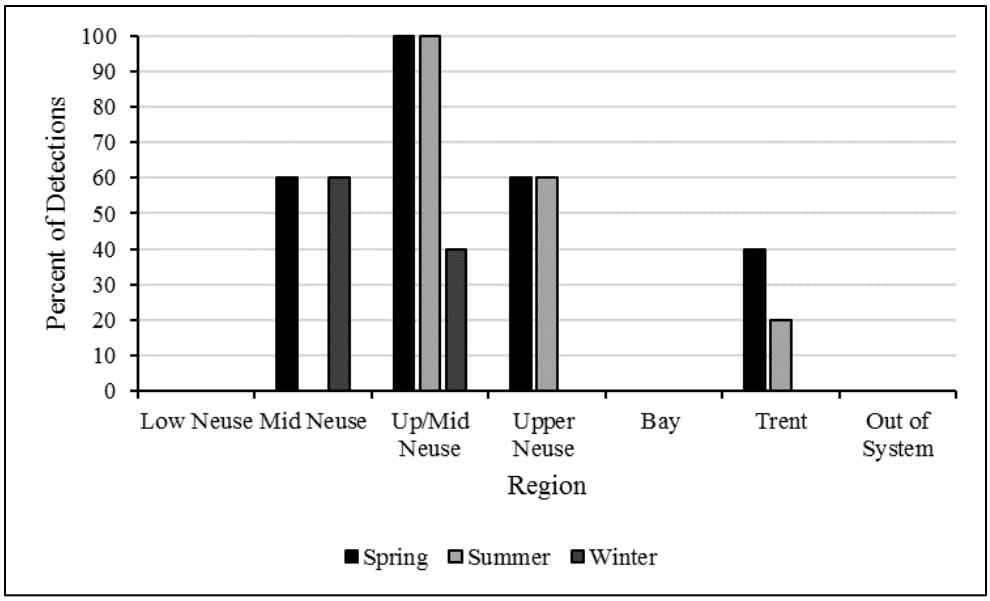


Figure 21. Percent of individual striped bass detected by Neuse River region by season, 2017.

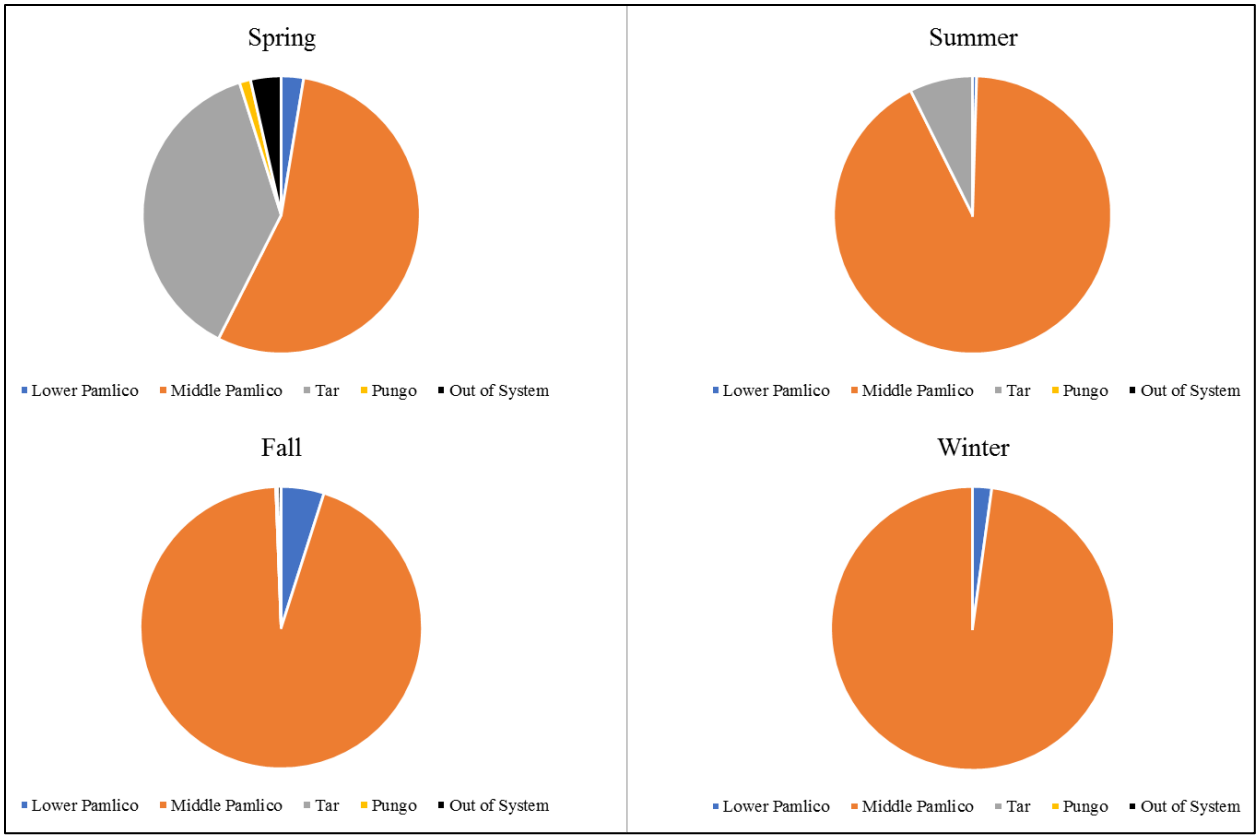


Figure 22. Percent of striped bass detections by region and season for striped bass tagged in the Tar/Pamlico River, 2014.

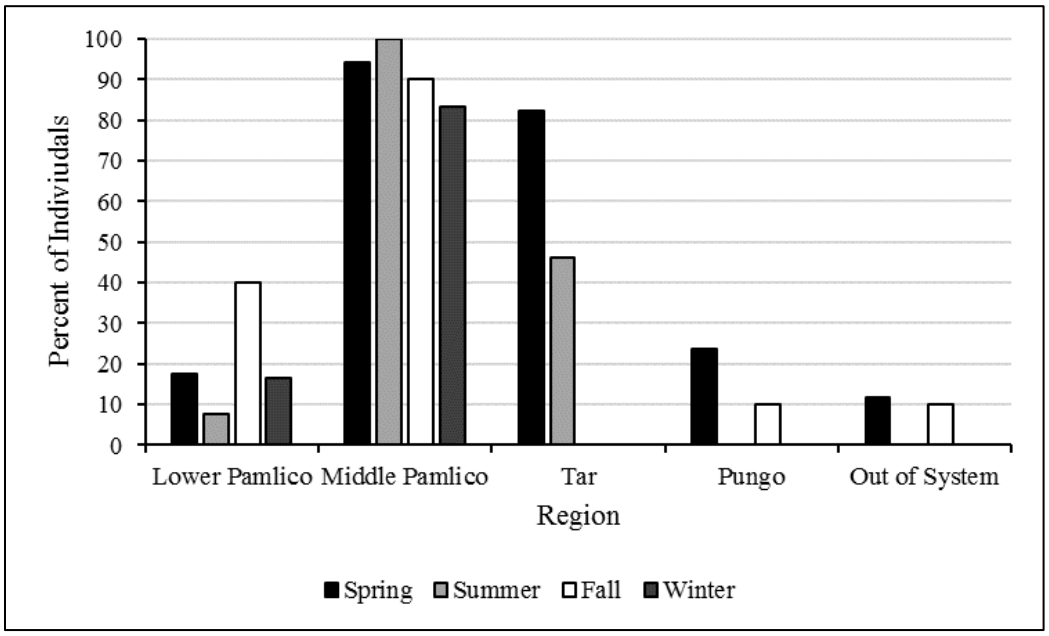


Figure 23. Percent of individual striped bass detected by Tar/Pamlico River region by season, 2014.

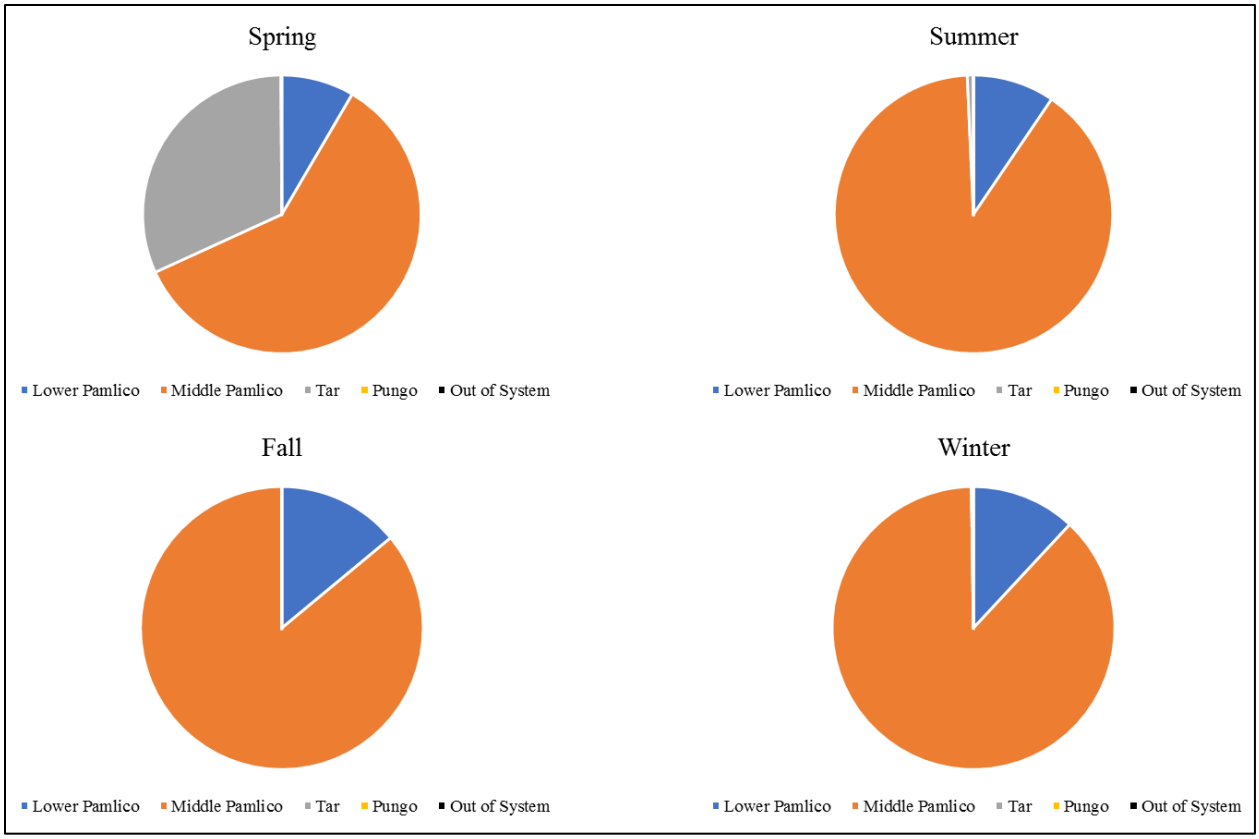


Figure 24. Percent of striped bass detections by region and season for striped bass tagged in the Tar/Pamlico River, 2015.

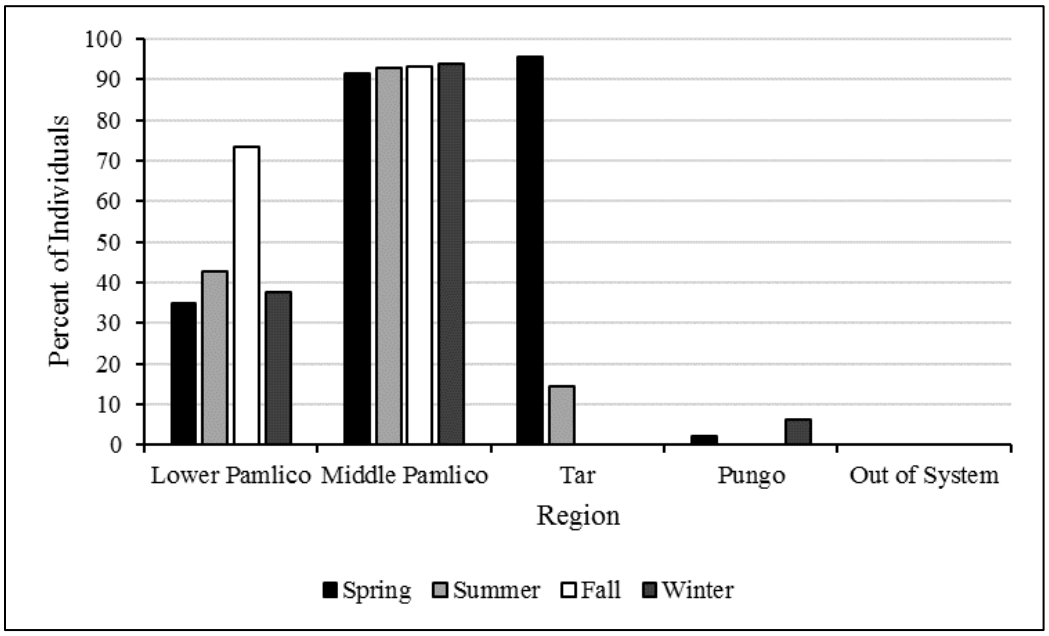


Figure 25. Percent of individual striped bass detected by Tar/Pamlico River region by season, 2015.

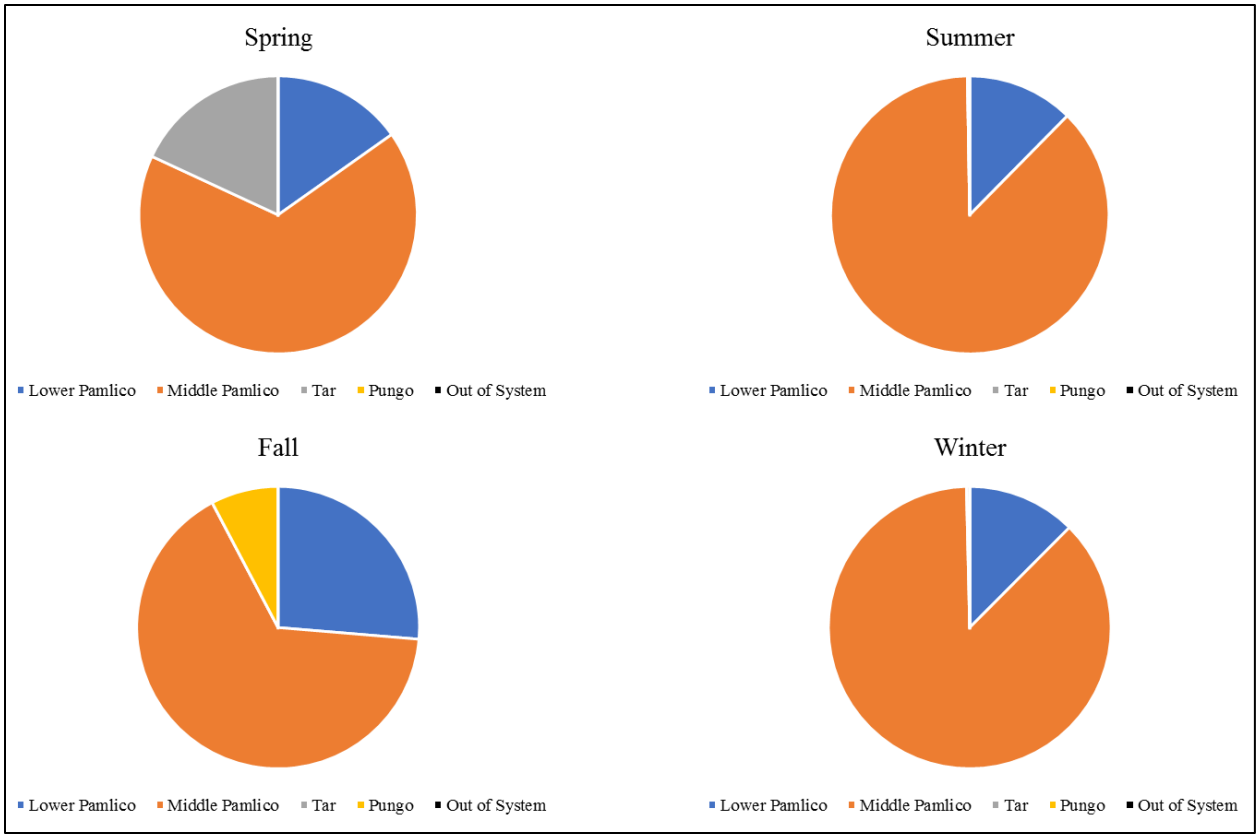


Figure 26. Percent of striped bass detections by region and season for striped bass tagged in the Tar/Pamlico River, 2016.

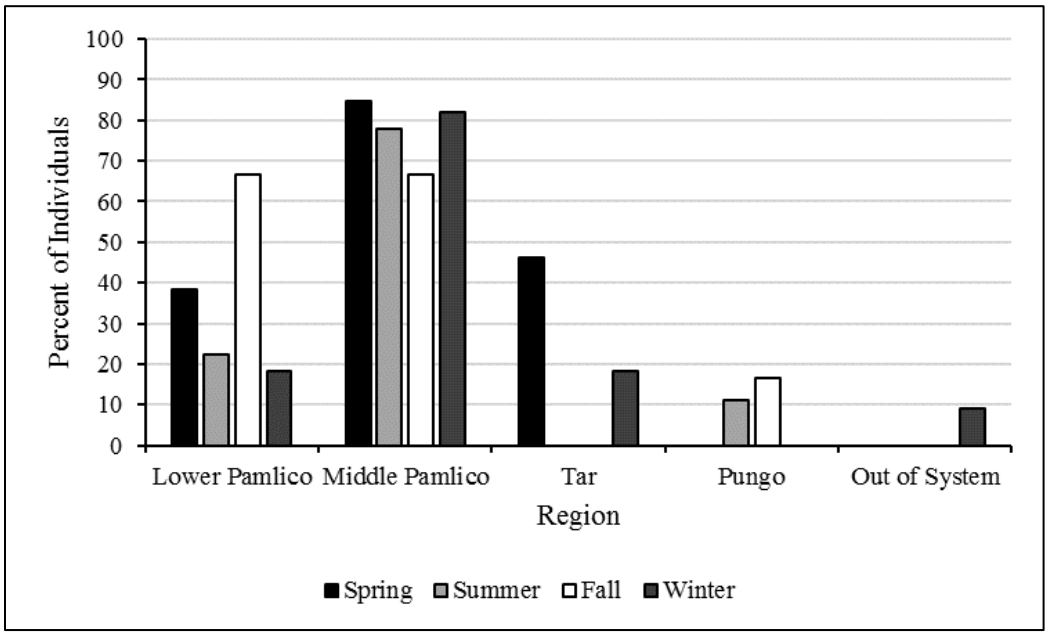


Figure 27. Percent of individual striped bass detected by Tar/Pamlico River region by season, 2016.

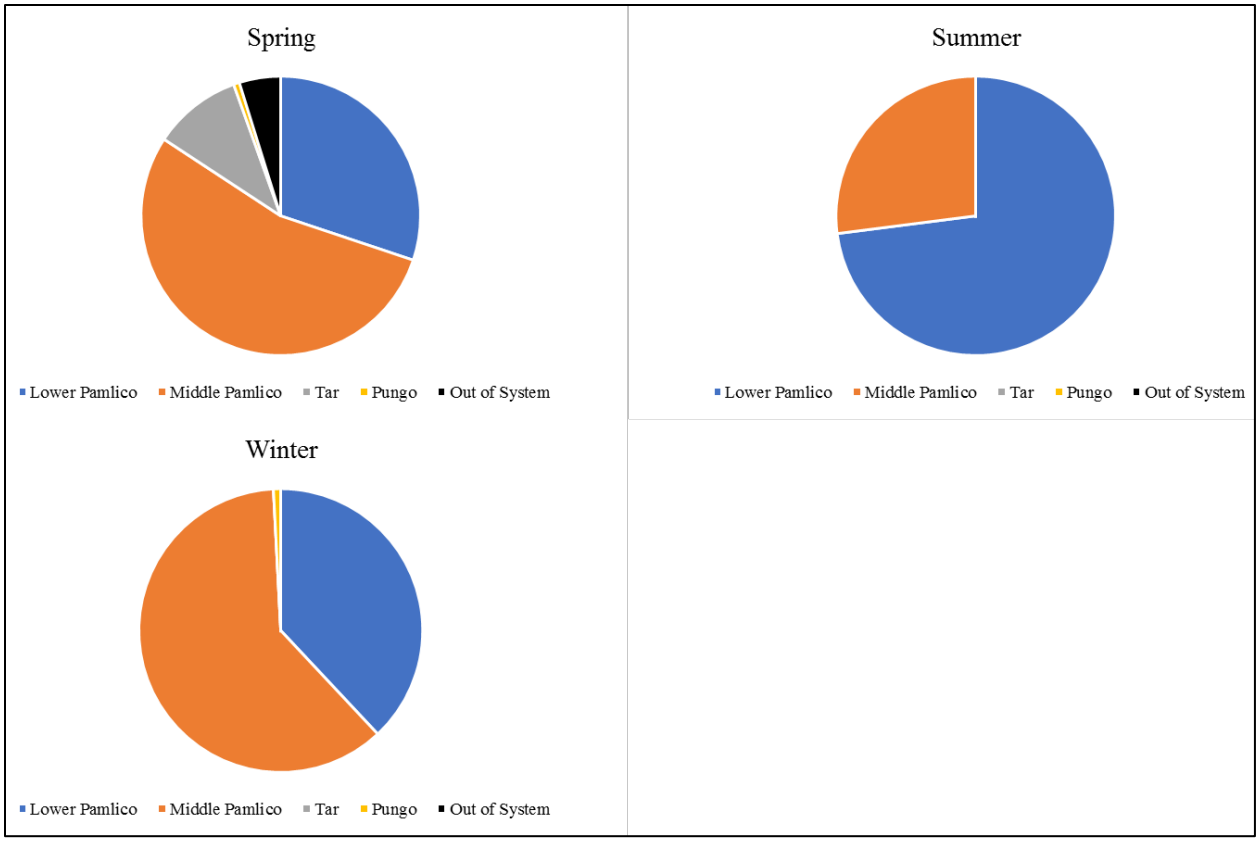


Figure 28. Percent of striped bass detections by region and season for striped bass tagged in the Tar/Pamlico River, 2017.

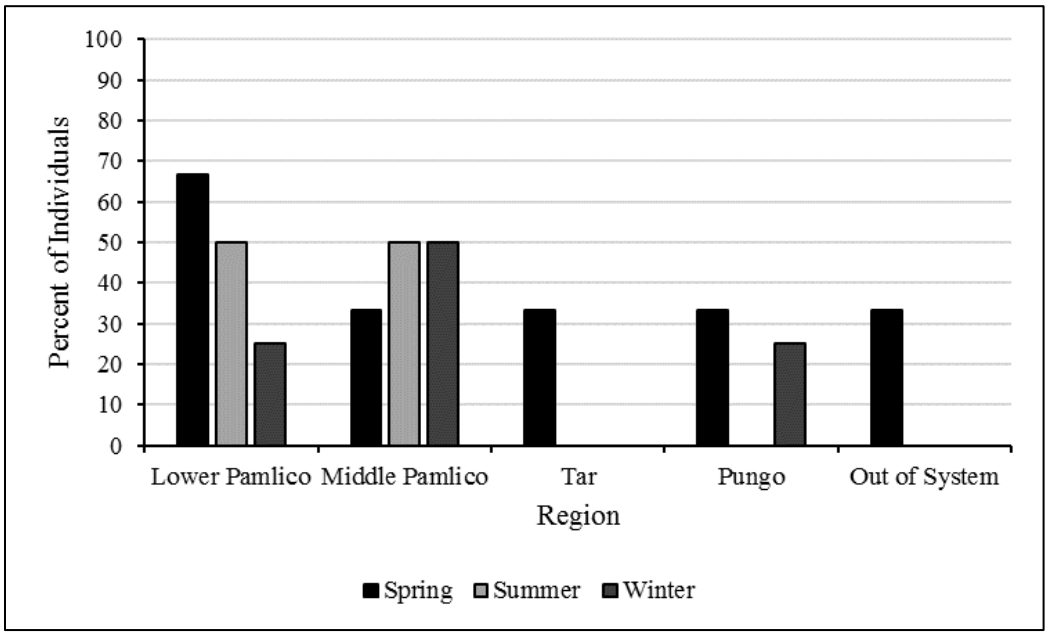


Figure 29. Percent of individual striped bass detected by Tar/Pamlico River region by season, 2017.

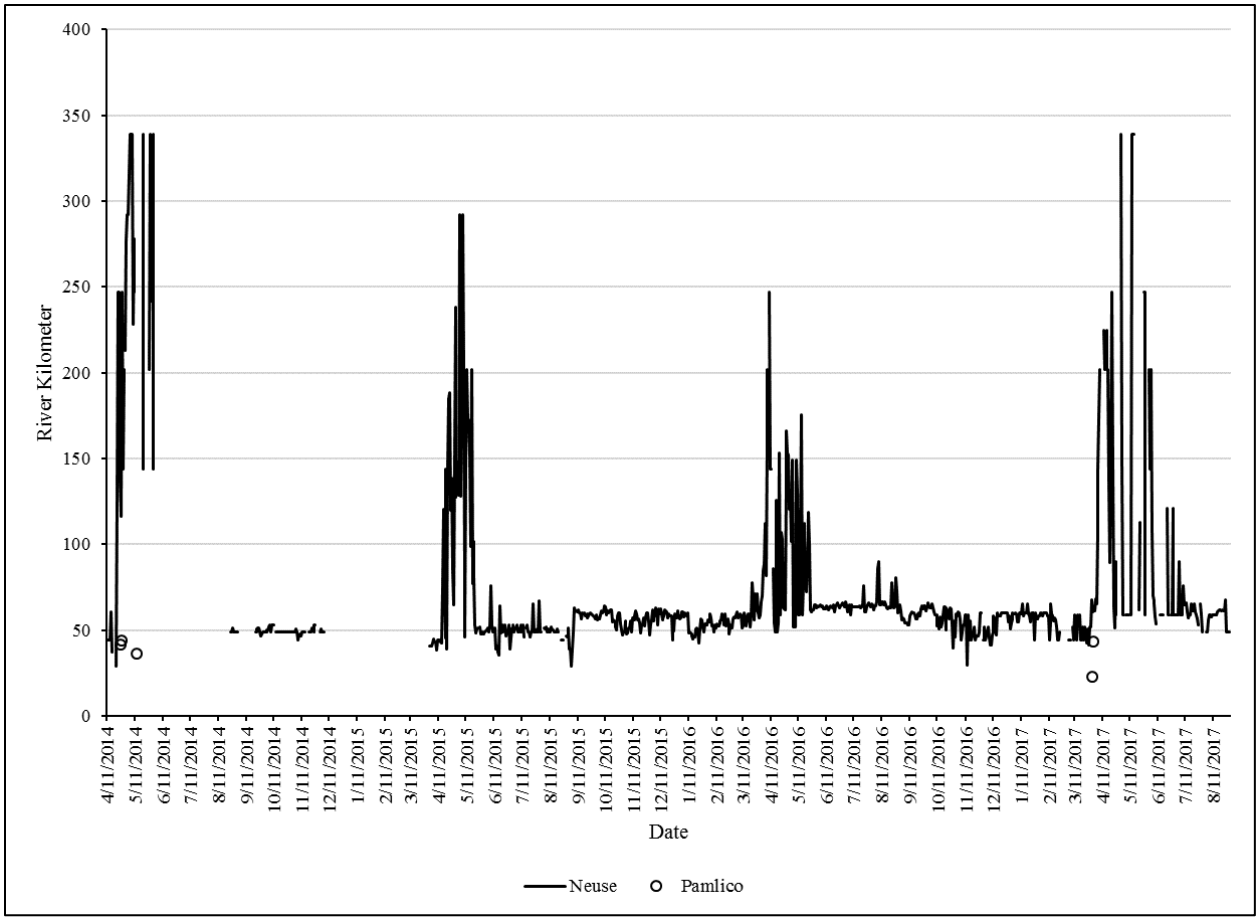


Figure 30. Mean river kilometer of Striped bass detections in the Neuse River, April 11, 2014-August 30, 2017. Striped bass tagged in the Neuse River are black circles with black line; Striped bass tagged in the Pamlico River are open circles.

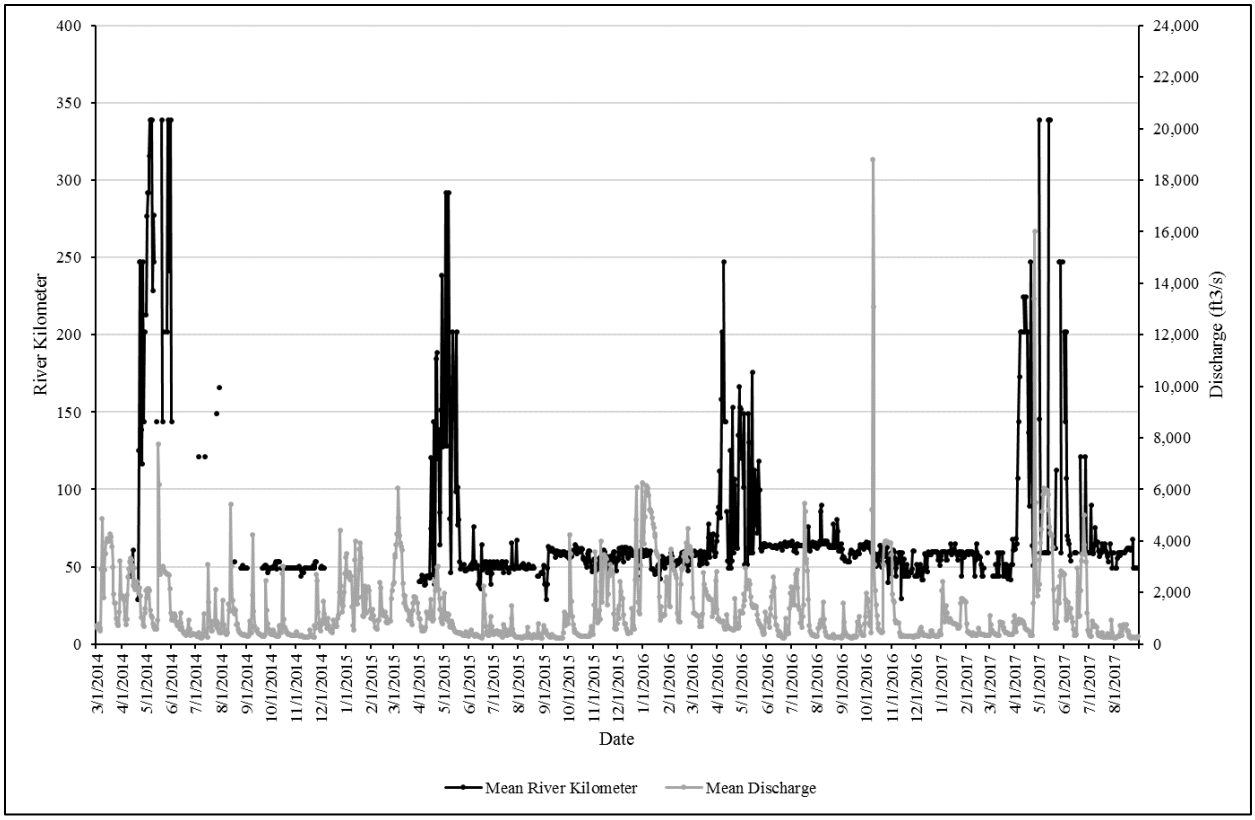


Figure 31. Mean daily discharge of the Neuse River measured at the monitoring station at Clayton, NC (gray circles, gray line) and mean river kilometer of striped bass detections in the Neuse River (black circles, black line), March 1, 2014-August 31, 2017.

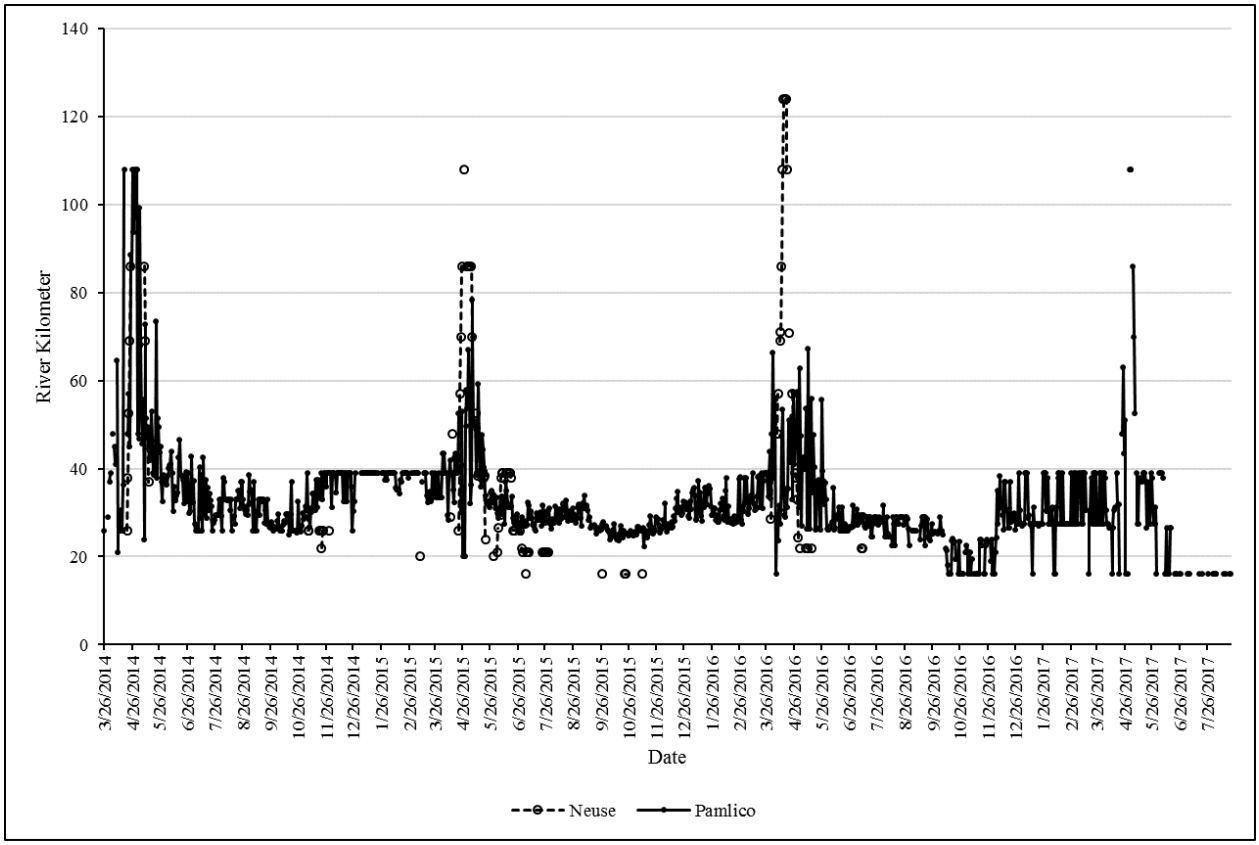


Figure 32. Mean river kilometer of striped bass detections in the Tar/Pamlico River, March 26, 2014-August 21, 2017. Striped bass tagged in the Tar/Pamlico River are black circles with black line; striped bass tagged in the Neuse River are open circles with dashed line.

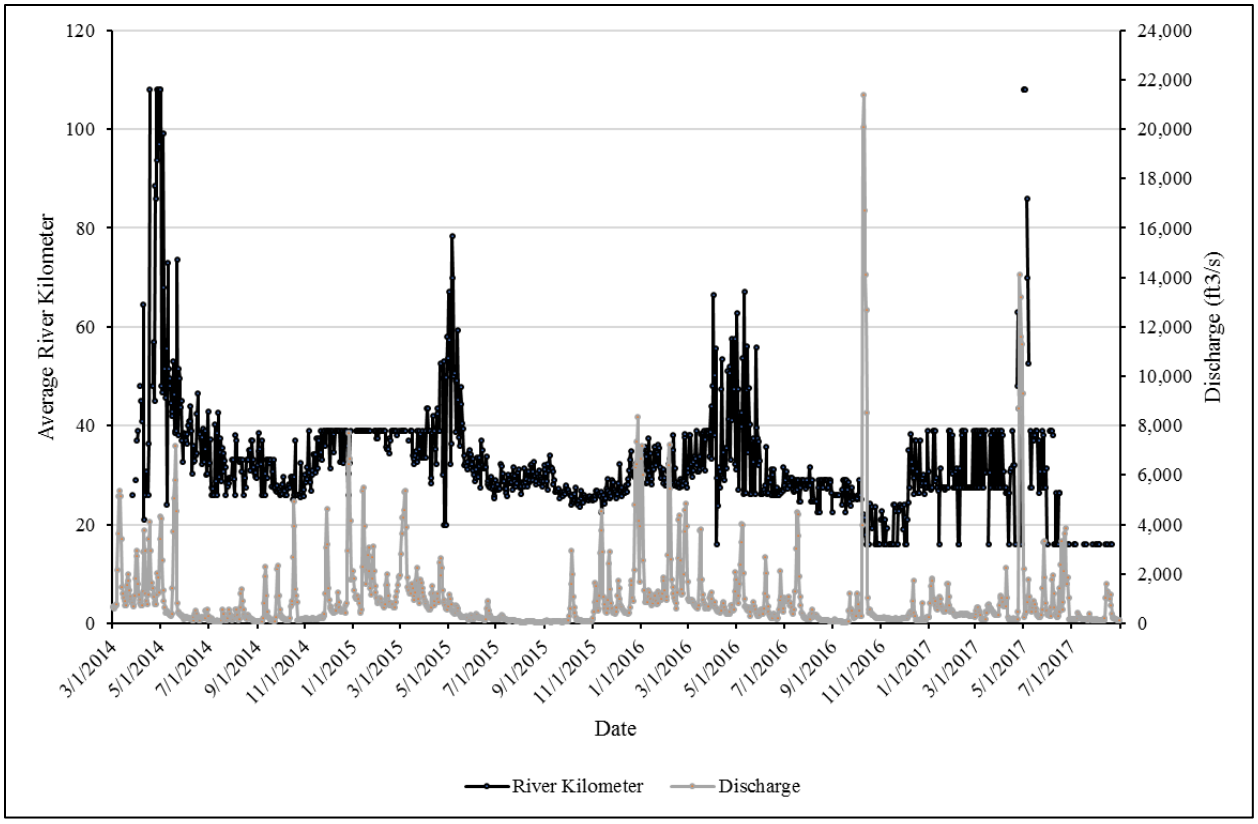


Figure 33. Mean daily discharge of the Tar River measured at the monitoring station at Rocky Mount, NC (gray circles, gray line) and mean river kilometer of striped bass detections in the Tar/Pamlico River (black circles, black line), March 1, 2014-August 31, 2017.

Figure 34. Vemco acoustic tags (V9 and V13), and receiver (VR2W).

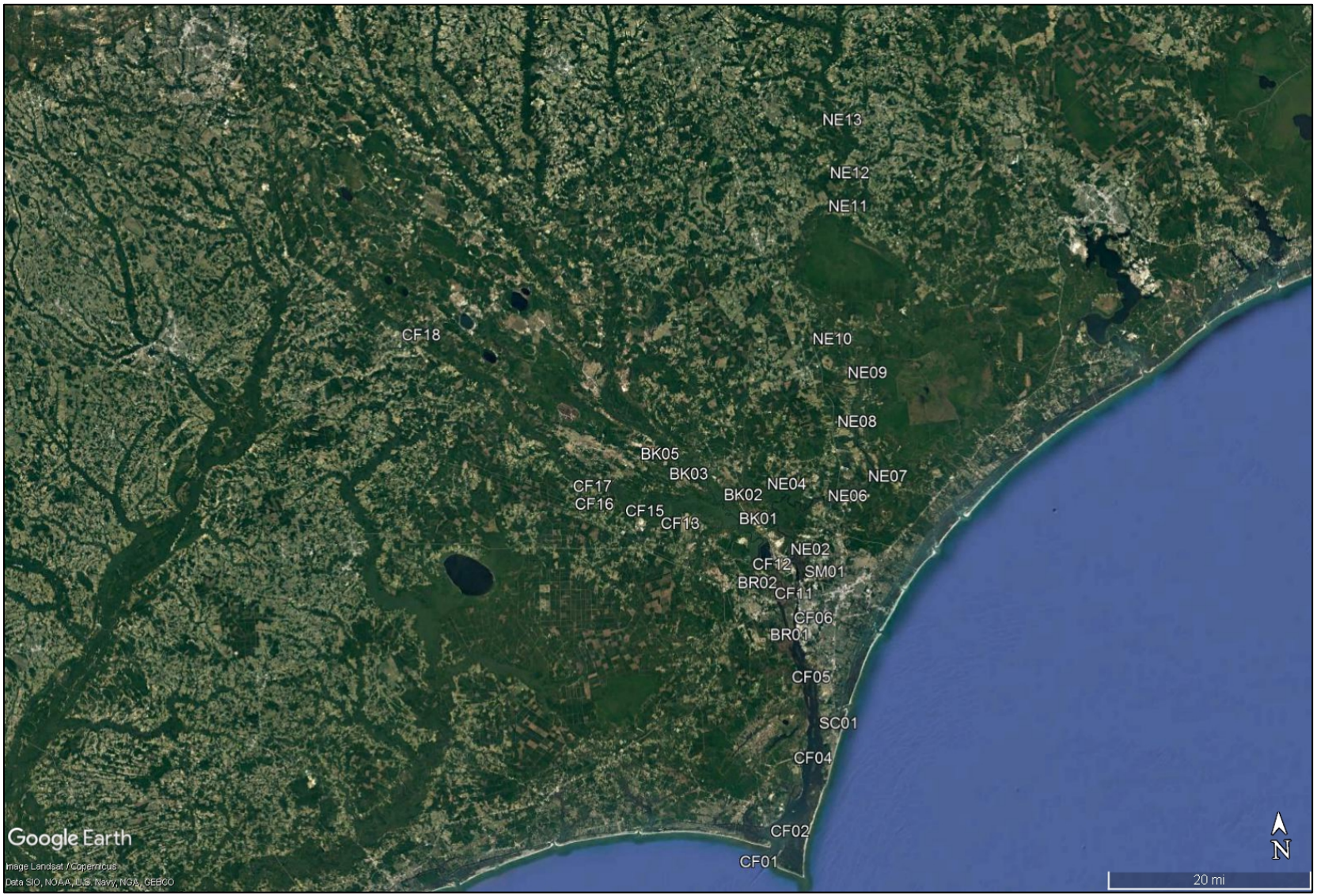


Figure 35. Map of receiver stations in the Cape Fear River Basin.

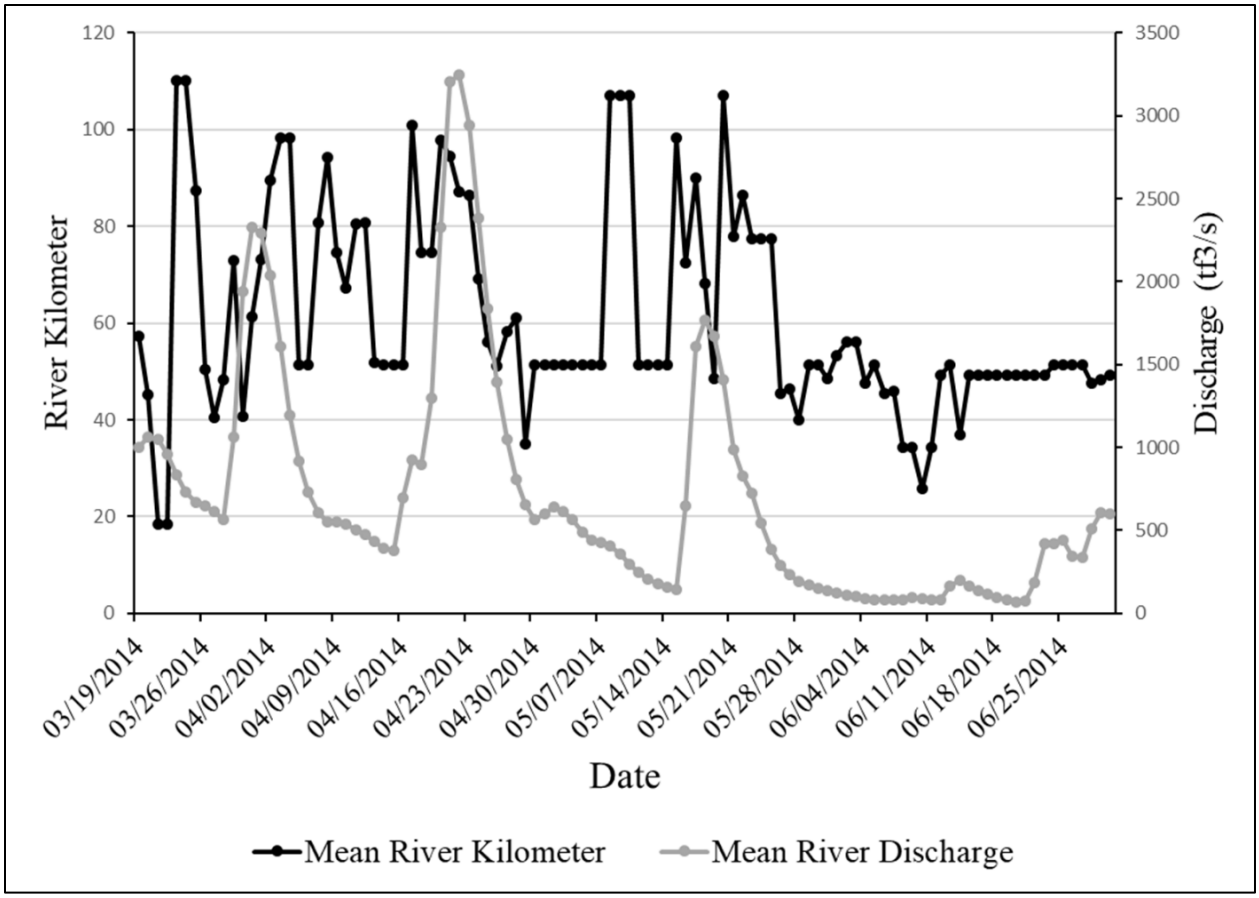


Figure 36. Mean daily discharge of the Northeast Cape Fear River measured at the monitoring station near Chinquapin, NC (gray circles, gray line) and mean daily river kilometer of American shad detections in the Northeast Cape Fear River (black circles, black line), March 19, 2014 to June 30, 2014.

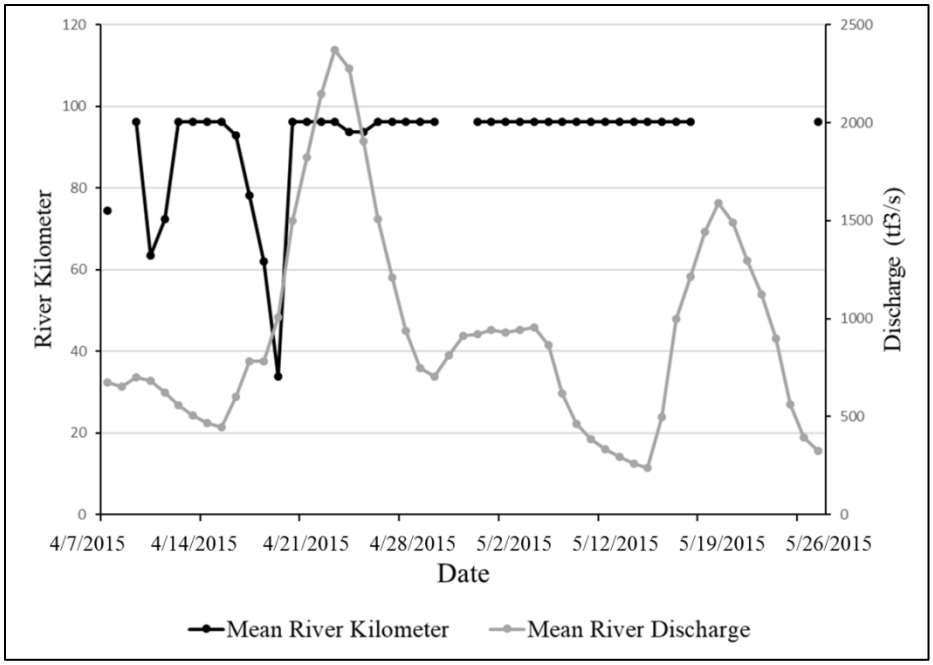


Figure 37. Mean daily discharge of the Black River measured at the monitoring station near Currie, NC (gray circles, gray line) and mean daily river kilometer of American shad detections in the Black River (black circles, black line), April 7, 2015 to May 30, 2015.

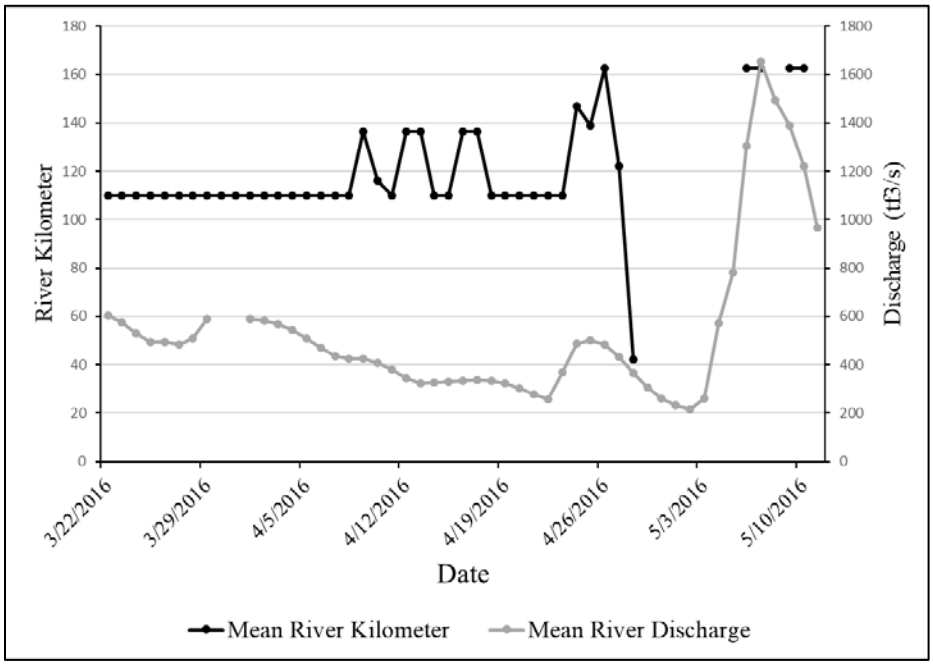


Figure 38. Mean daily discharge of the Northeast Cape Fear River measured at the monitoring station near Chinquapin, NC (gray circles, gray line) and mean daily river kilometer of American shad detections in the Northeast Cape Fear River (black circles, black line), May 22, 2016 to May 10, 2014.

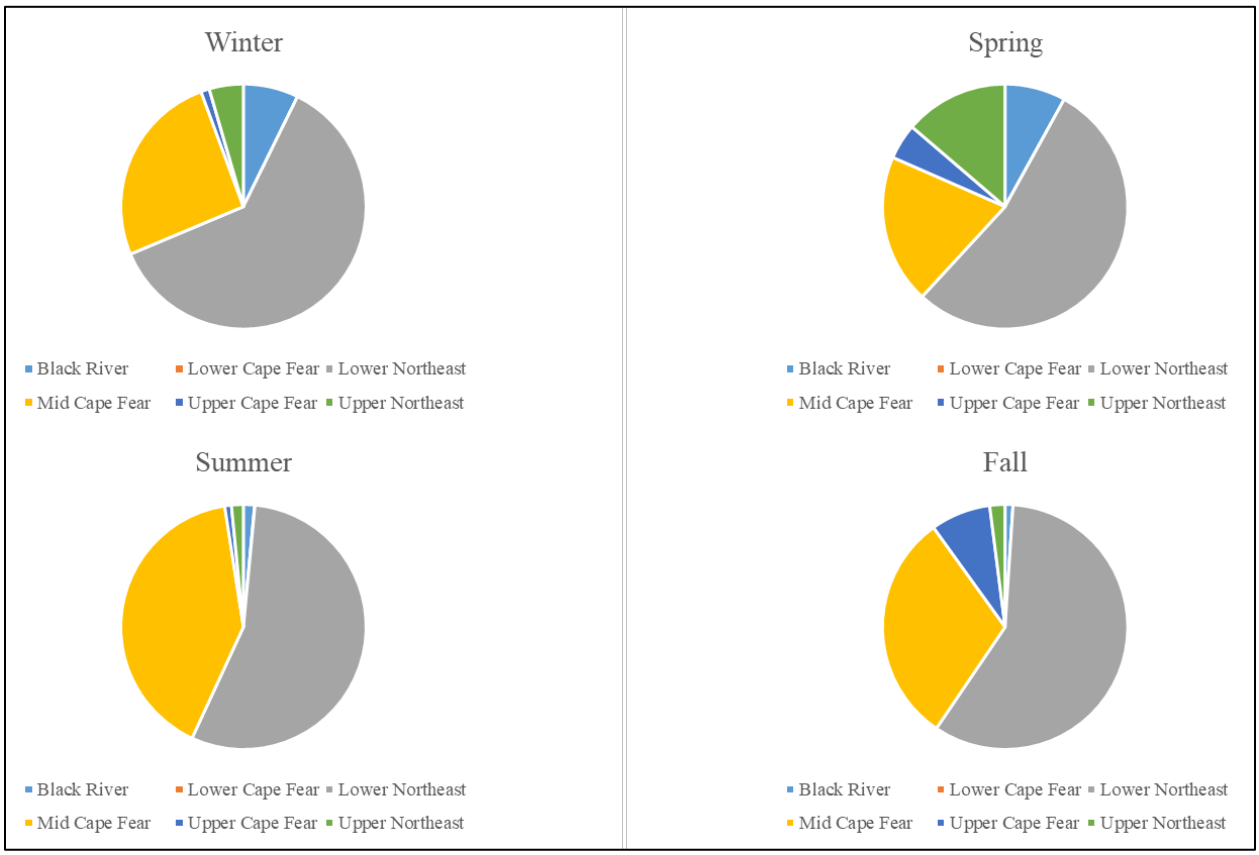


Figure 39. Percent of striped bass detections by region and season for striped bass tagged in the Cape Fear River Basin, 2013.

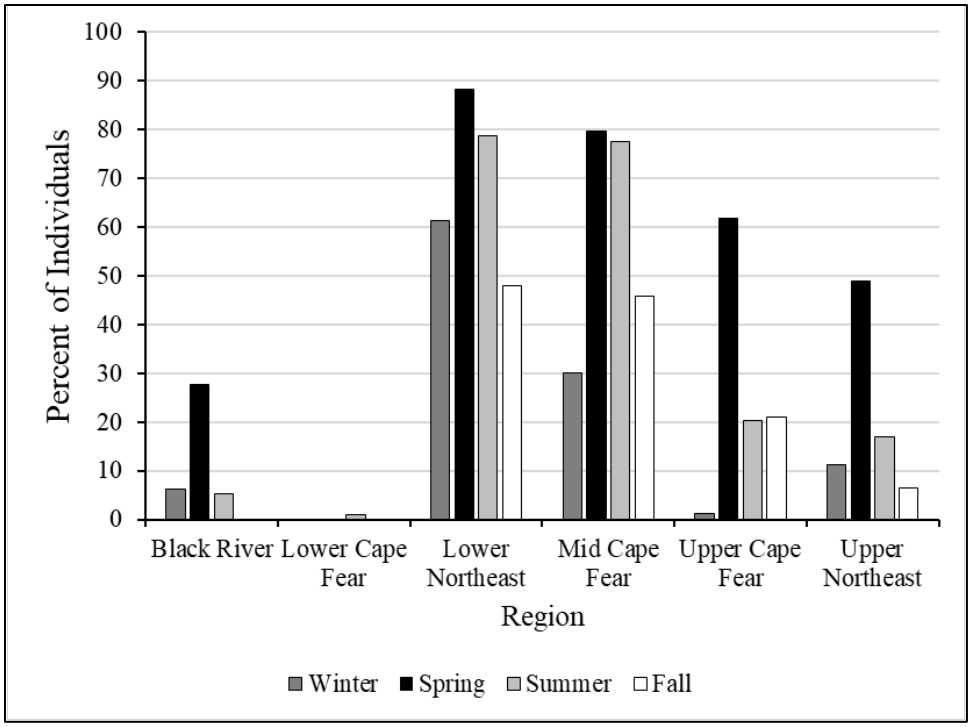


Figure 40. Percent of individual striped bass detected by region in the Cape Fear River Basin by season, 2013.

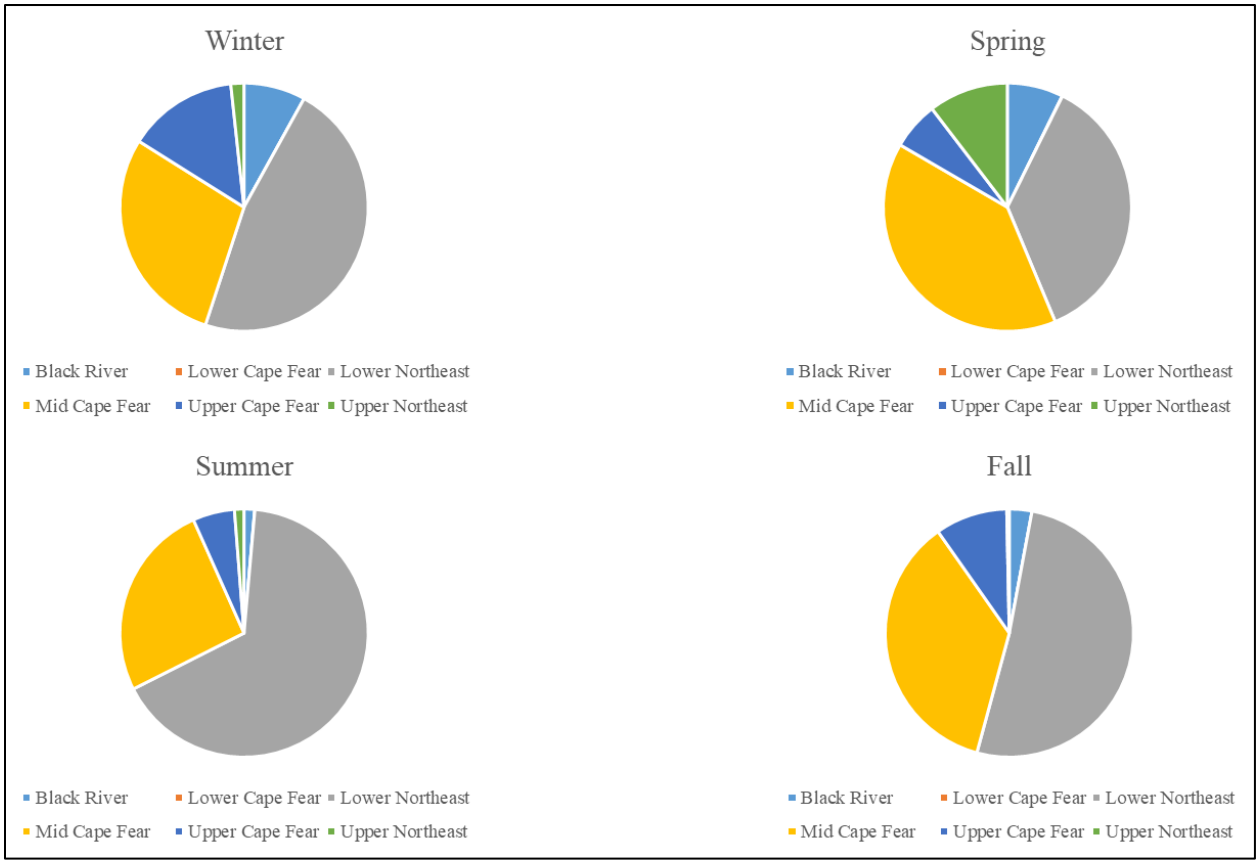


Figure 41. Percent of striped bass detections by region and season for striped bass tagged in the Cape Fear River Basin, 2014.

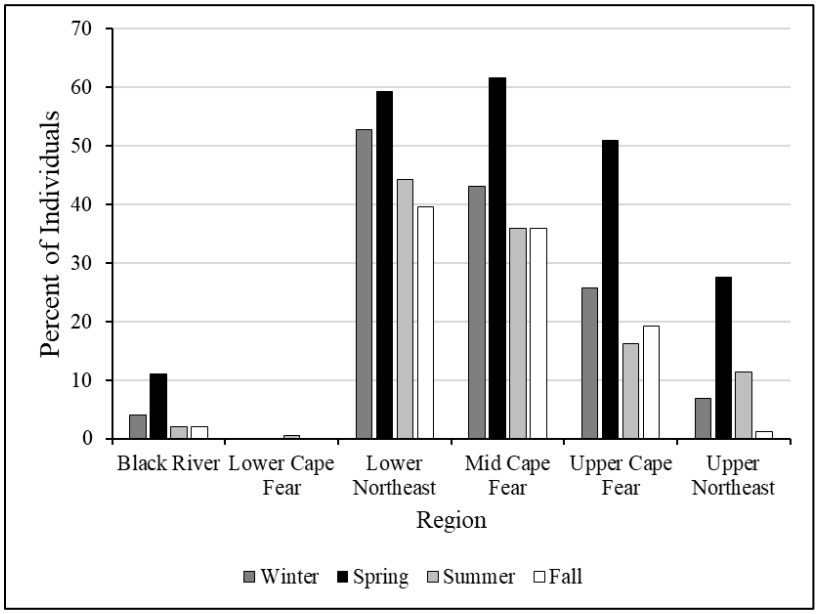


Figure 42. Percent of individual striped bass detected by region in the Cape Fear River Basin by season, 2014.

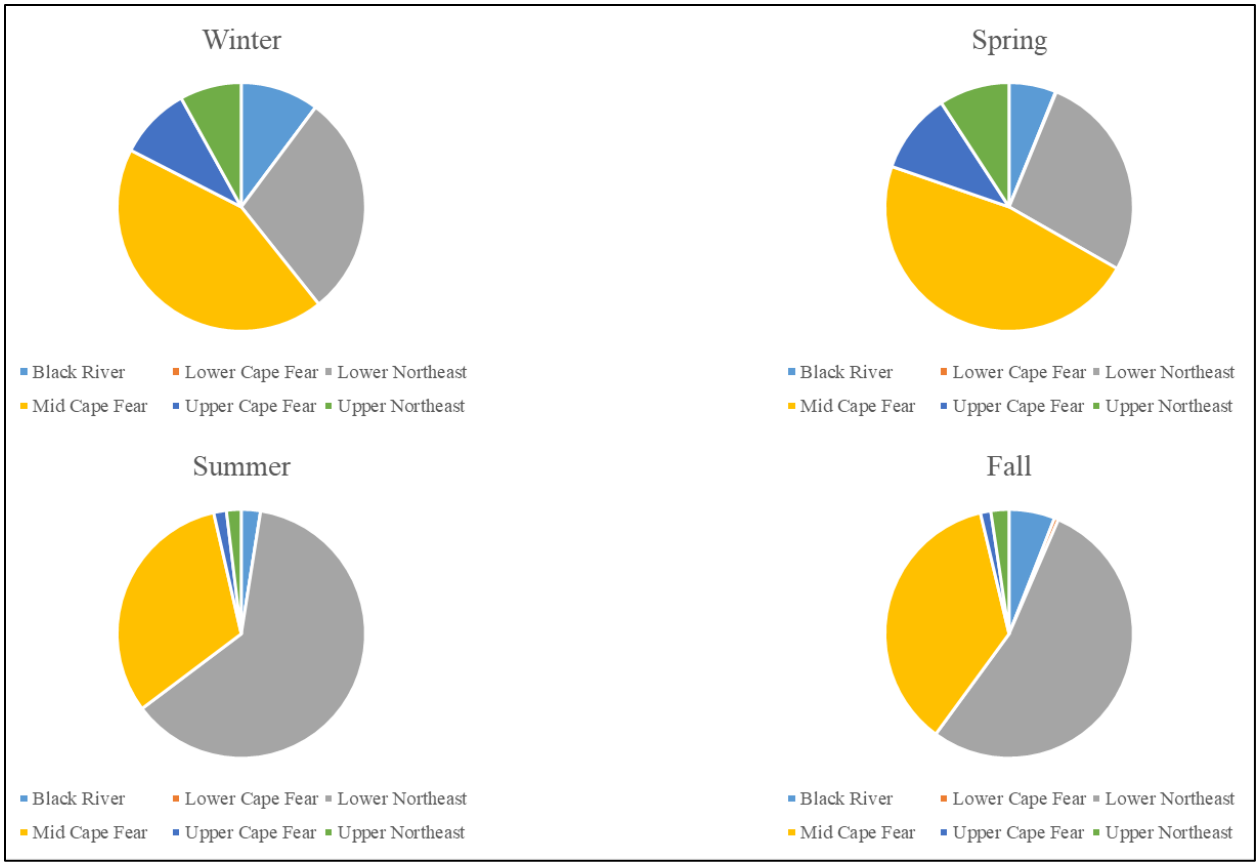


Figure 43. Percent of striped bass detections by region and season for striped bass tagged in the Cape Fear River Basin, 2015.

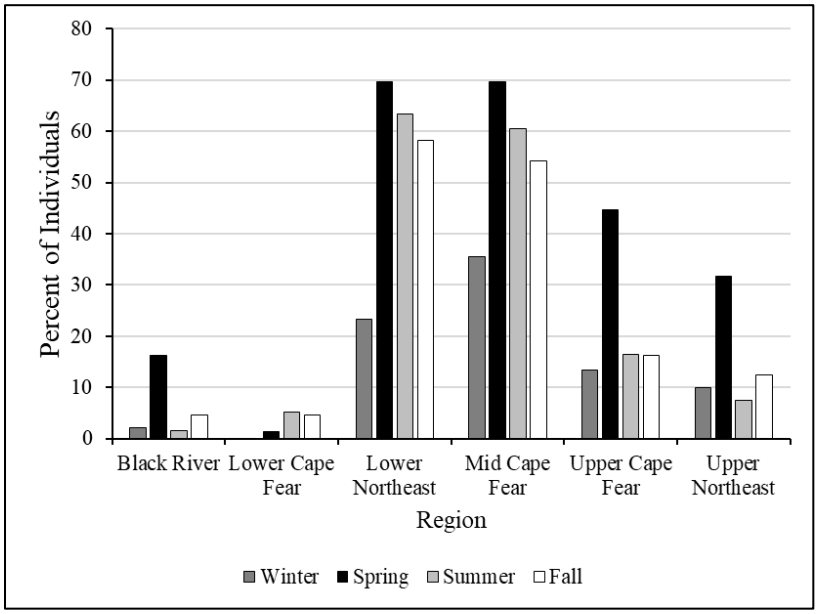


Figure 44. Percent of individual striped bass detected by region in the Cape Fear River Basin by season, 2015.

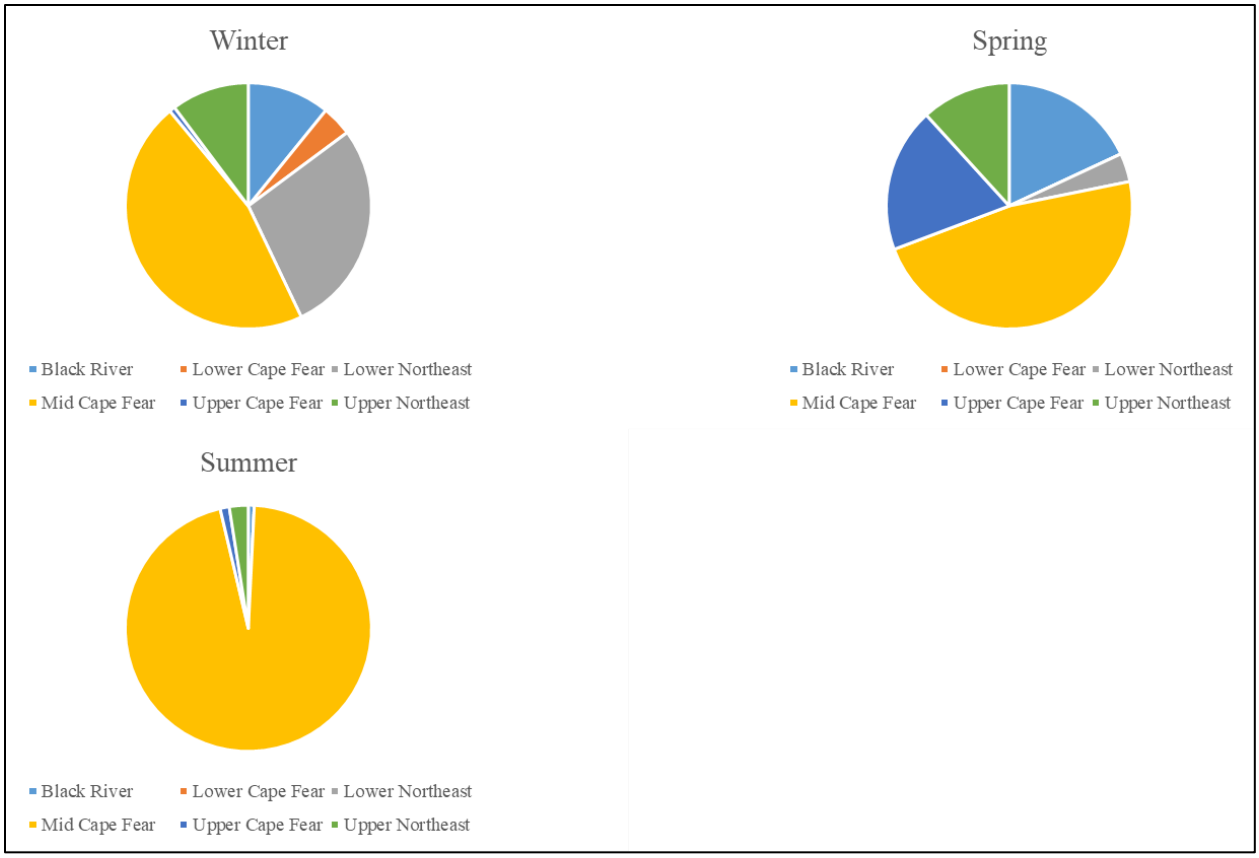


Figure 45. Percent of striped bass detections by region and season for striped bass tagged in the Cape Fear River Basin, 2016.

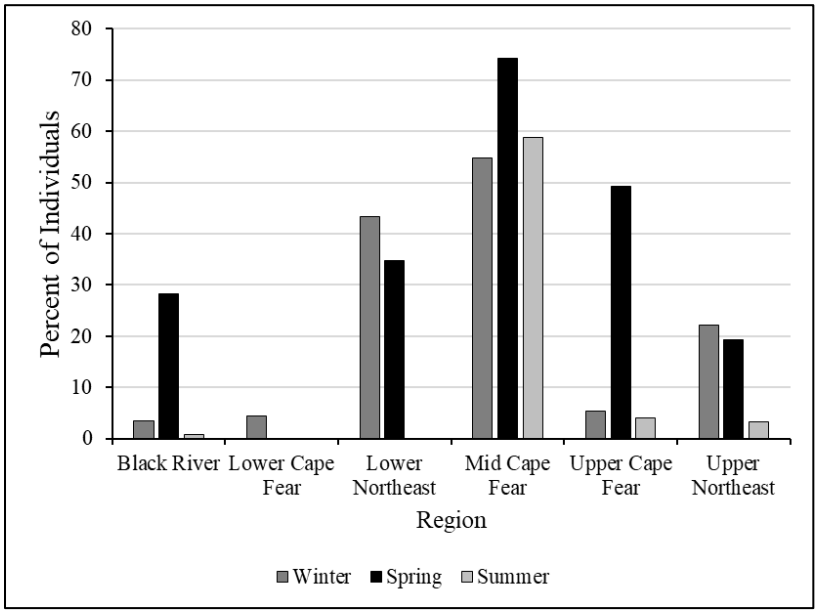


Figure 46. Percent of individual striped bass detected by region in the Cape Fear River Basin by season, 2016.

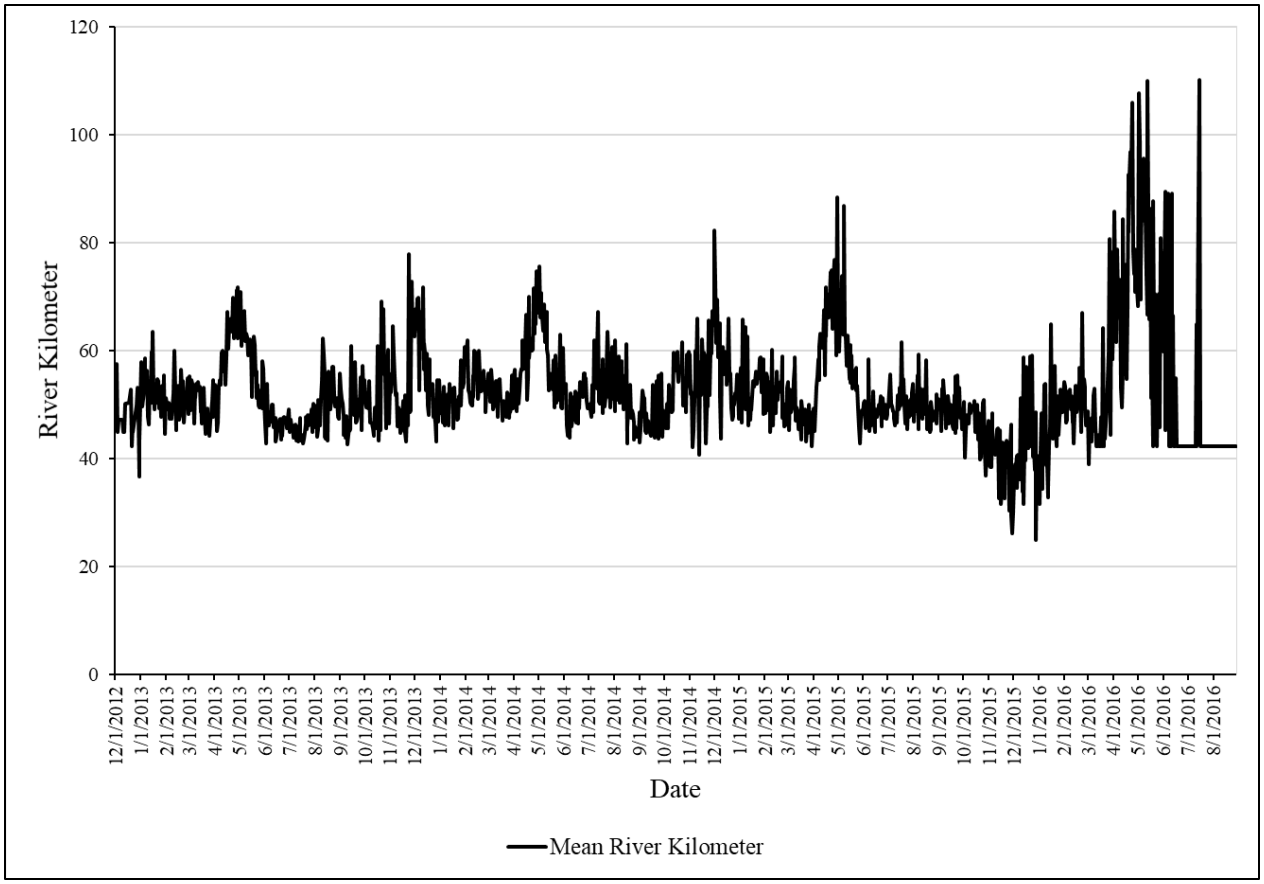


Figure 47. Mean daily river kilometer of all striped bass detections across the Cape Fear River Basin, December 1, 2012 through August 30, 2016.

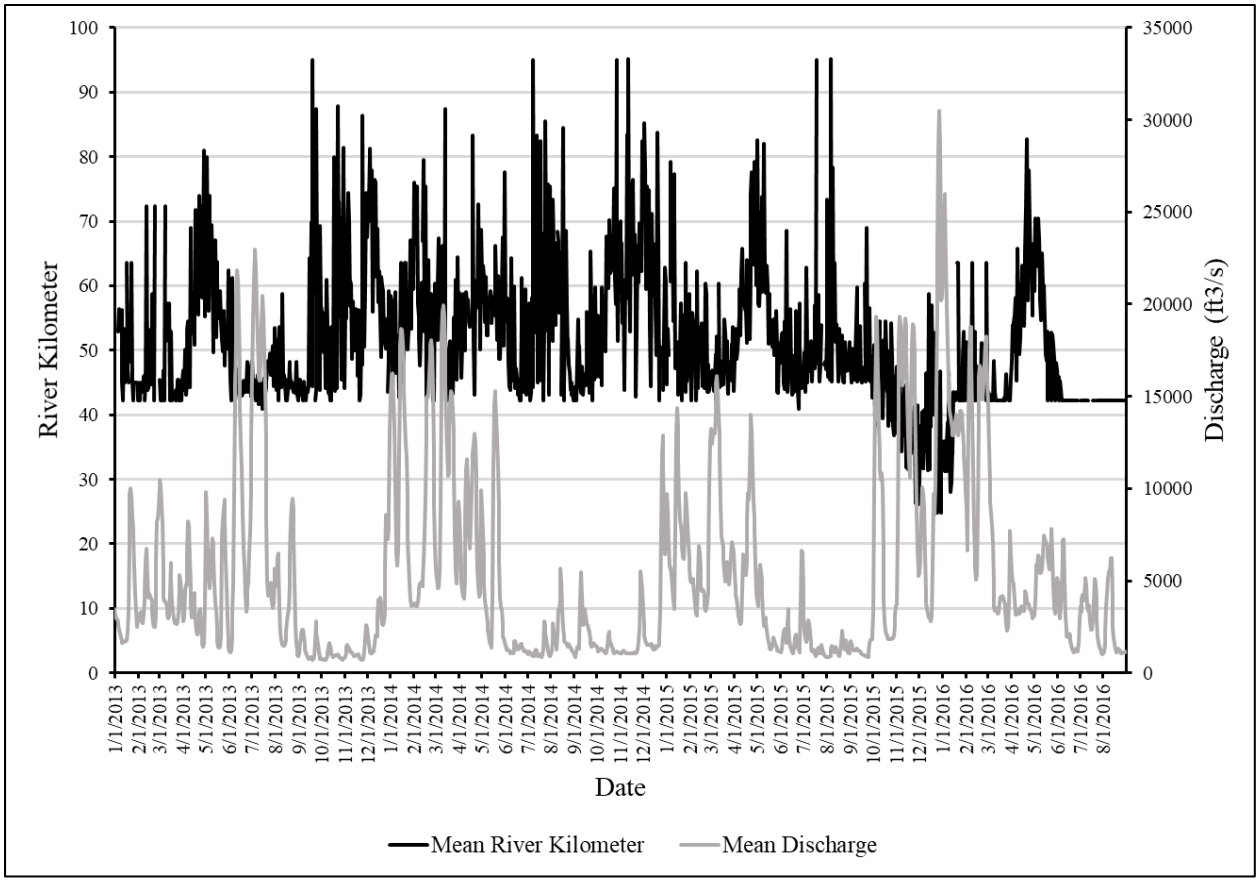


Figure 48. Mean daily discharge of the Cape Fear River measured at the monitoring station at Lock and Dam 1 near Riegelwood, NC (gray line) and mean daily river kilometer of striped bass detections in the Cape Fear River (black line), January 1, 2013 through August 31, 2016.

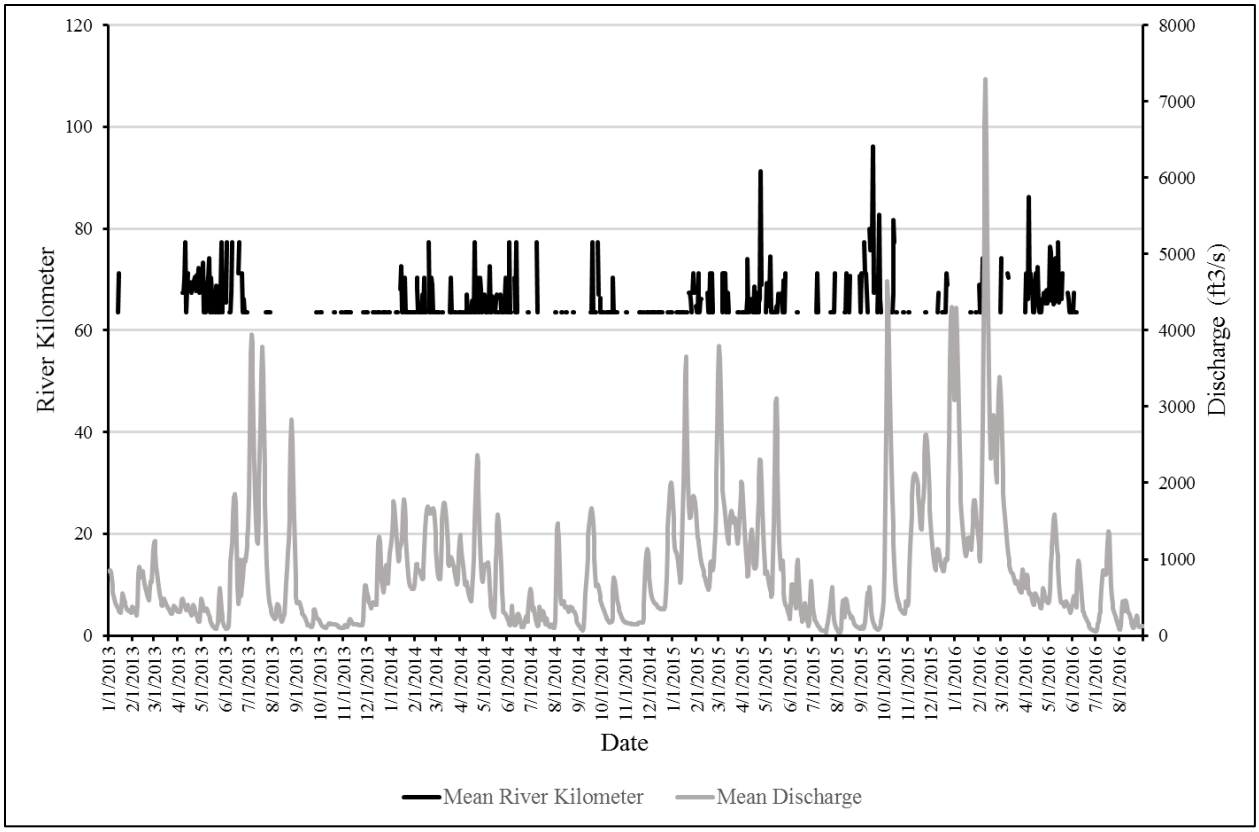


Figure 49. Mean daily discharge of the Black River measured at the monitoring station near Currie, NC (gray line) and mean daily river kilometer of striped bass detections in the Black River (black line), January 1, 2013 through August 31, 2016.

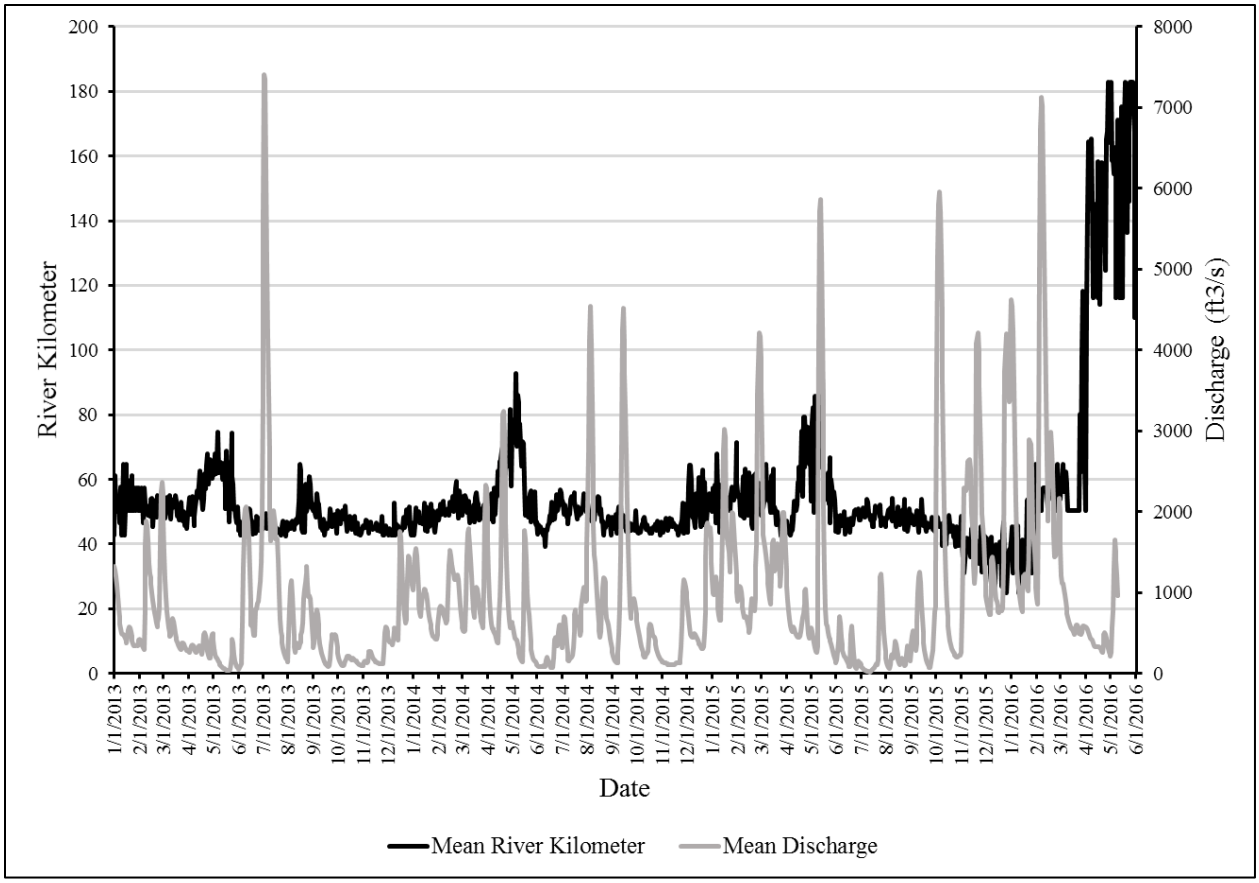


Figure 50. Mean daily discharge of the Black River measured at the monitoring station near Chinquapin, NC (gray line) and mean daily river kilometer of striped bass detections in the Cape Fear River (black line), January 1, 2013 through June 30, 2016.

# 14 APPENDIX A: MAPS OF AMERICAN SHAD DETECTIONS IN THE TAR/PAMLICO AND NEUSE RIVER

# 15 APPENDIX B: MAPS OF STRIPED BASS DETECTIONS IN THE NEUSE RIVER BY SEASON, 2014-2017

# 16 APPENDIX C: MAPS OF STRIPED BASS DETECTIONS IN THE TAR/PAMLICO RIVER BY SEASON, 2014-2017

# 17 APPENDIX D: MAPS OF AMERICAN SHAD DETECTIONS IN THE CAPE FEAR RIVER BASIN

# 18 APPENDIX E: MAPS OF STRIPED BASS DETECTIONS IN THE CAPE FEAR RIVER BASIN BY SEASON, 2013-2016