

Monitoring Relative Abundance of American Shad in Virginia Rivers

2010 Annual Report

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Summary

- A staked gill net was set and fished each week on the James, York and Rappahannock rivers in the spring of 2010. This was the thirteenth year of monitoring in a stock assessment program for American shad that was initiated in spring 1998. Our approach was to establish a sentinel fishery, based on traditional methods used prior to the imposition of the current in-river moratorium in 1994. The primary objective is to establish a time series of catch rates that can be compared to historical data recorded in logbooks voluntarily submitted by commercial fishers when the staked gill net fishery was active. The monitoring provides information on the current status of shad stocks relative to conditions prior to the moratorium dating to 1980 in the James and Rappahannock rivers. In the case of the York River, monitoring allows assessment of current status relative to catch rates recorded in the 1980s and the 1950s.
- In 2010, a second sampling location was added on the James River for comparative purposes. These results are presented separately from the traditional James River sampling location.
- Sampling occurred for twelve weeks on the James River (16 February to 4 May 2010). On the York and Rappahannock rivers, sampling occurred for eleven weeks (23 February to 4 May 2010) and ten weeks (1 March to 4 May 2010), respectively. After 12 April, post-spawning fish were mixed with pre-spawning fish in the catch on the York River. On the James River post spawning fish were encountered after 13 April. No post-spawning fish were observed on the Rappahannock River in 2010. Only pre-spawning fish were included in the calculation of catch indices for each river. A total of 702 pre-spawning female American shad (1010.8 kg total weight) were captured. The 2010 total catch increased from the 2009 catch (633 pre-spawning females weighing 900.5 kg).
- Total numbers and weights of females in 2010 were highest on the James River (n=383, 541.2 kg). Numbers of females were lower on the York River (n=225, 329.4 kg). The lowest catches of females were recorded on the Rappahannock River (n=94, 140.2 kg). Numbers of males captured was: James, 63; York, 45; Rappahannock, 15. The total weight of males captured on all rivers was 156.1 kg. The total catch and weight of males was higher than it was in 2009 (n=111, 133.0 kg).
- Based on age estimates from scales, the 2005 (age 5) year class of female American shad was the most abundant on the James and Rappahannock rivers, with peak age-specific seasonal catch rates exceeding 0.0310 kg/m and 0.0106 kg/m respectively. On the York River, the 2004 and 2005 (age 6 and 5) year classes were most abundant with seasonal catch rates of 0.0189 kg/m and 0.0159 kg/m. The 2004 (age 6) year class was also abundant on the James and Rappahannock rivers with seasonal catch rates exceeding 0.0251 kg/m and 0.0084 kg/m respectively. Total instantaneous mortality rates of females calculated from

age-specific catch rates were: York River, 0.99 ($r^2=0.87$); James River, 1.23 ($r^2=0.96$) and Rappahannock River, 1.05 ($r^2=0.93$). Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River, 0.42 ($r^2=0.48$) and James River, 0.49 ($r^2=0.99$).

- Otoliths of 149 American shad captured on the James River were scanned for hatchery marks. The proportion of the sample with hatchery marks on the James River was 34.9% (52 of 149 fish). In 2008 and 2009 the prevalence of fish with hatchery marks was 25.6% and 8.9%, respectively. Presence of hatchery fish on the York and Rappahannock rivers continues to be low at 3.3% and 0%, respectively in 2010.
- The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2010 was: James River (inclusive of Chickahominy River), 0.02 (0.121, 65); Chickahominy River, 0 (0, 10); Rappahannock River, 1.19 (1.166, 33); York River (inclusive of Pamunkey and Mattaponi rivers), 0.47 (0.823, 93); Mattaponi River, 0.97 (1.029, 50); and Pamunkey River, 0.06 (0, 38).
- Twenty-five species of fishes (total of 20,154 specimens) were caught as by-catch in the staked gill net monitoring gear. The total number of striped bass captured was 7,830 (James River, $n=3,769$; York River, $n=2,624$; Rappahannock River, $n=1,437$). Live striped bass captured in the gear were counted and released. A random subsample of the dead striped bass was brought back to the laboratory for analysis. Sex, fork length, and total weight were recorded for each specimen. The proportions of dead striped bass on each river were: James River, 14.1%; York River, 28.6%; and the Rappahannock River, 71.7%.
- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2010 and for each year of the historical record of staked gill net catches on each river. On the York River, the seasonal catch index in 2010 (4.19) increased from the 2009 value and is the highest value seen since 2007. During the eleven years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The geometric mean of the historical data during the 1980s on the York River is 3.22. The geometric mean of the current monitoring data is higher (6.02) but this mean is lower than the geometric mean of catch indexes from logbook records in the 1950s (17.44). These older data were adjusted for differences in the efficiency of multifilament and monofilament nets using the results of comparison trials in 2002 and 2003.
- On the James River, the 2010 index (6.90) increased from the 2009 value of 2.69. The geometric mean of the historical data during the 1980s on the James River is 6.40 while the geometric mean of the current monitoring data is lower (4.26). The stock continues to be dependent on hatchery inputs since recruitment of wild fish is negligible based on available data from juvenile abundance surveys.

- The catch index on the Rappahannock River in 2010 (2.03) decreased from the 2009 value (5.36), which is the highest value in the time series since 2004. The 2010 index is the lowest value seen since 2000 (1.75). The geometric mean of the historical data during the 1980s on the Rappahannock River is 1.45. The geometric mean of the current monitoring data is higher (3.14).

Preface

Concern about the decline in landings of American shad (*Alosa sapidissima*) along the Atlantic coast prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Management Program (ASMFC 1999). Legislation enables imposition of federal sanctions on fishing in those states that fail to comply with the FMP. To be in compliance, coastal states are required to implement and maintain fishery-dependent and fishery-independent monitoring programs as specified by the FMP. For Virginia, these requirements include spawning stock assessments, the collection of biological data on the spawning run (e.g., age-structure, sex ratio, and spawning history), estimation of total mortality, indices of juvenile abundance, biological characterization of permitted by-catch and evaluation of restoration programs by detection and enumeration of hatchery-released fish.

This annual report documents continued compliance with Federal law. Since 1998, scientists at the Virginia Institute of Marine Science have monitored the spawning run of American shad in the James, York and Rappahannock rivers. The information resulting from this program is reported annually to the ASMFC, has formed the basis for a significant number of technical papers published in the professional literature, formed the basis for a recent coast-wide stock assessment and peer review for American shad (ASMFC 2007a, 2007b) and is contributing substantially to our understanding of the status and conservation of this important species.

A number of individuals make significant contributions to the monitoring program and the preparation of this report. Commercial fishermen Raymond Kellum, Marc Brown and Jamie Sanders construct, set, and fish the sampling gear and offer helpful advice. They have participated in the sampling program since its beginning in 1998. Their contributions as authors of historic log books of commercial catches during the 1980s and as expert shad fishermen are essential elements of the monitoring program. We also extend our appreciation to several commercial fishers for their cooperation in our studies of by-catch of American Shad. In 2010, these individuals include: Kenneth Heath, Joseph Hinson, Robert Weagley, and Charles Williams. In 2010, the staff and students of the Virginia Institute of Marine Science who participated in the program were: B. Watkins, P. Crewe, A. Rhea, R. Norris and R. Harris. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. B. Watkins determined ages of fish. B. Watkins and A. Rhea determined hatchery origins of fish. Fish products from the sentinel fishery are donated to the Food Bank of Newport News, Virginia. We offer thanks to the Hunters for the Hungry (Virginia Hunters Who Care) organization for their assistance.

Introduction

A moratorium on the taking of American shad (*Alosa sapidissima*) in the Chesapeake Bay and its tributaries was established by the Virginia Marine Resources Commission (VMRC) beginning 1 January 1994. The prohibition applied to both recreational and commercial fishers, and was imposed at a time when commercial catch rates of American shad in Virginia's rivers were experiencing declines. At the time, data from the commercial fishery were the best available for assessing the status of individual stocks. Catch-per-unit-effort (CPUE) data were compiled from logbooks that recorded landings by commercial fishermen using staked gill nets at various locations throughout the middle reaches of the James, York and Rappahannock rivers. The logbooks were voluntarily provided to the Virginia Institute of Marine Science (VIMS) during the period 1980-1992, and subsequently used in an assessment of the status of American shad stocks along the Atlantic coast by the Atlantic States Marine Fisheries Commission (ASMFC) (ASMFC 1999).

Immediately following the moratorium, there were no monitoring programs that provided direct assessment of stock recovery. The ban on in-river fishing in Virginia remained in effect, creating a dilemma for managers who needed reliable information in order to make a rational decision on when the in-river ban could be lifted safely. To address this deficiency, a method of scientific monitoring was proposed to estimate catch rates relative to those recorded before the prohibition of in-river fishing in 1994. This monitoring program began in 1998 and consisted of sampling techniques and locations that were consistent with, and directly comparable to, those that generated historical logbook data collected by VIMS during the period 1980-1992 in the York, James and Rappahannock rivers. The results of the thirteenth year in the sampling program (2010) are reported in this document and compared to some results in previous years of monitoring. Detailed results of the first twelve years of sampling (1998-2009) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002; Olney 2003a, 2004, 2005; Olney and Delano 2006; Olney and Walter 2007; Olney and Watkins 2008, 2009; Olney et al. 2010). Copies of these reports are available upon request.

In addition to the objective of assessment of the status of stocks in Virginia's rivers, there are other significant information needs. First, extensive efforts are being made to rehabilitate shad stocks through release of hatchery-raised fish. Evaluating the success of these programs requires determination of the survival of the stocked fish to adulthood. Second, there is an extensive time series of observations on juvenile shad abundance from push net surveys in the York River and seine surveys in the James, York and Rappahannock rivers. These juvenile index data could have utility for predicting future spawning run sizes, detecting years of failed recruitment, and confirming the health of the stocks.

These ongoing studies of American shad in Virginia waters are directly significant to recreational fisheries and the ecological health of the river systems that support these important fisheries for at least three reasons.

- American shad fish well when angled using light tackle. Harvest of American shad by the recreational fishery in the James, York and Rappahannock rivers is prohibited but recreational fishing is popular in Florida, North Carolina, Maryland and several other states where these bans do not exist. Anecdotal information suggests that there were historical recreational fisheries for American shad on the James, Mattaponi and Rappahannock rivers. Currently, many anglers catch and release American shad and legally harvest hickory shad (*Alosa mediocris*) on the James River near Richmond, the Mattaponi River above Walkerton, and the Rappahannock River near Fredericksburg. Recreational fishing also occurs on the Nottoway and Blackwater rivers near Franklin, Virginia; these rivers, however, do not drain into the Chesapeake Bay and the ban on harvest does not apply to these spawning stocks. Continued development of a recreational shad fishery in Virginia could constitute an important opportunity to expand or restore recreational fishing opportunities if the stocks are rehabilitated and managed carefully.
- American shad are important for trophic and ecological reasons. Spawning site selection by adults as well as the abundance and occurrence of juveniles are closely linked to water quality and the availability of good fish habitat. Young shads and river herrings (*Alosa* spp.) form an important prey group for striped bass and other recreationally important species in Chesapeake Bay. The decaying carcasses of post-spawning anadromous fishes are known to play an important role in nutrient and mineral recycling in riverine and estuarine systems. In recent years, there have been shifts in community structure in the major tributaries to the Chesapeake Bay with striped bass and gizzard shad numbers increasing greatly. Monitoring changes in abundance of key species is essential for understanding community dynamics.
- Monitoring the shad spawning run using historic gear also allows for a description of the by-catch associated with a commercial fishery for shad in Virginia's rivers. This is important for determining the impact of the commercial fishery for shad on other recreationally important species, especially striped bass, if the ban on commercial and recreational harvest of American shad was lifted.

Background

Herring and shad have supported recreational and commercial fisheries along the east coast of the United States and within the Chesapeake Bay since colonial times. They also play a vital ecological role. Juvenile alosines are important prey for striped bass and other recreational species while they remain on their freshwater and upper estuarine nursery grounds. In the autumn they move to coastal waters where they are subjected to predation by many types of marine piscivores until they return to their native streams to spawn for the first time at ages 3 to 7 (Maki et al., 2001; Limburg et al. 2003; Tuckey and Olney, 2010).

Management and conservation of Virginia's stocks of American shad date to colonial times. Before Virginia was settled, Native Americans caught American shad in large quantities using a seine made of bushes (Walburg and Nichols 1967). Shad were so plentiful that they could be speared with pointed sticks as they swam on the flats (VCF 1875). Remains of American shad and Atlantic sturgeon have been found in archaeological digs at Jamestown, the site of first English settlement (Bowen and Andrews 2000). Apparently, these species were important dietary components during the starving time in 1609. The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, shad were less abundant, presumably due to fishing and obstructions that prevented them from reaching their spawning grounds. Concerned colonists passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (VCF 1875). In 1771, the Virginia Assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to the last day of May. However, due to the approaching conflict of the Revolutionary War, the law was never enforced (VCF 1875).

The shad fishery of Chesapeake Bay became important in about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and staked gill nets (Walburg and Nichols 1967). Catches reached a low in 1878, and the U.S. Fish Commission and Virginia Commission of Fisheries instituted an artificial hatching program in 1875. By 1879 the fishery began to improve, and the increase in catches led biologists to believe that the shad fishery was largely dependent upon artificial propagation. However, by the early 1900s the decline in shad harvests resumed despite improved hatching methods and increased numbers of fry released (Mansueti and Kolb 1953).

Stevenson (1899) provided important information on catch and effort in the American shad fishery in Virginia during the fishing season in 1896. Using an average weight per female of 1.7 kg, the following fishery statistics can be obtained from his report. On the lower James River, 60,750 females (approximate weight: 103,278 kg) were landed by staked gill nets totaling approximately 79,263 m in length. On the York River, 28,232 females (approximate weight: 49,994 kg) were landed by staked gill nets totaling approximately 5,874 m in length. The value of these roe shad in 1896 dollars was approximately \$4,000. On the Rappahannock River, 104,118 females (approximate weight: 177,000 kg) were landed by staked gill nets totaling 24,694 m in length. The local value of these shad was approximately \$8,000. Seasonal catch averages (total female weight/total length of net) depict higher seasonal catch rates on the York River (8.5 kg/m) and the Rappahannock River (7.2 kg/m) than on the James River (1.3 kg/m) in 1896. Stevenson (1899) also reported large catches of American shad on the Chickahominy and Appomattox rivers in 1896.

Nichols and Massmann (1963) estimated total catch, fishing rate, escapement and total biomass of American shad in the York River in 1959 and summarized landings during the period 1929-1959. Landings were low (~100,000 lbs annually) in the 1930s but rose abruptly in the years following World War II, reaching the highest levels

(400,000-700,000 lbs annually) in the 1950s. During this latter period of higher annual landings, catch-per-unit-effort remained relatively constant. Of the major gears used in the fishery in 1959 (pound nets, haul seines, fyke nets, stake gill nets and drift gill nets), gill nets (stake and drift combined) accounted for the greatest effort expended and the highest total catches. A tagging study conducted in 1959 produced the following estimates: overall fishing rate, 55.2%; estimated population biomass, 838,892 lbs; and estimated escapement, 375,768 lbs. Using catch and effort data, Nichols and Massmann (1963) estimated population biomass for the period 1953-1959 to range from 839,000-1,396,000 lbs. Sex composition of the catch was not reported. Using the average female weight of 3.2 lbs in 1959 and assuming that the sex ratio of the catch was 1:1, the estimated total number of females in the York River in 1953-1959 ranged from about 131,000-218,125.

Today, many American shad stocks along the eastern seaboard of the United States are in low abundance, based on commercial landings data (Figure 1). Large catches no longer occur as they did at the turn of the century and in many areas, including Chesapeake Bay, harvest is banned or severely restricted. Commercial American shad landings in Virginia decreased from 11.5 million pounds in 1897 to less than a million pounds in 1982. Over-fishing, dam construction, pollution, and loss of natural spawning grounds are a few of the factors that may be related to this decline. Historically, the majority of American shad were captured within the rivers. Beginning in 1984, the largest proportion of American shad taken in Virginia's fishery was captured offshore. The overall impact of this shift in the fishery on egg production and annual recruitment of Virginia stocks is unknown. Genetic studies of the catch composition of Virginia and Maryland's coastal landings have suggested that the intercept fishery claimed a highly variable proportion of Virginia's riverine stocks (Brown and Epifanio 1994). American shad were pursued by recreational fishermen in Virginia in the past, but the extent, success, and impact of this activity is not easily assessed.

In spring 1994, the Virginia Department of Game and Inland Fisheries (VDGIF) and the US Fish and Wildlife Service (USFWS) began a hatchery-restocking effort in the James and Pamunkey rivers. Adult shad from the Pamunkey River are used as brood stock, eggs are stripped and fertilized in the field, and larvae are reared in the VDGIF hatchery at Stephensville, Virginia, and the USFWS Harrison Lake National Fish Hatchery at Charles City, Virginia. Prior to release, the larvae are immersed in an oxytetracycline (OTC) solution that marks otoliths with a distinctive epifluorescent ring. The initial success of this ongoing program was documented by Olney et al. (2003) who reported that catch rates by monitoring gear increased in 2000-2002 as large numbers of mature hatchery fish returned to the James River.

Based on data from the current monitoring program, in most years, prevalence of hatchery fish returning as adults to the York system is low (~2-4 % each year). Annual monitoring of the abundance of juvenile *Alosa* spp. (American shad, hickory shad, blueback herring and alewife) was conducted on the Pamunkey River system during 1979-2002. After 1995, juveniles bearing the OTC mark were collected by VIMS and VDGIF. The data show that hatchery-released larval shad constituted 0.1-8 % of the total catch of juveniles on the Pamunkey River during the 4-y period (1995-1999). VDGIF

personnel also began a new hatchery-release program on the upper Rappahannock River in 2003. The restoration program uses progeny of Potomac River brood stock. The goal of this program is to restore American shad to historical spawning areas that were previously blocked by Embrey Dam.

Prior to 1991, there were no restrictions on the American shad commercial fishery in Virginia rivers and the Chesapeake Bay. A limited season (4 February - 30 April) was established for 1991 by the Virginia Marine Resources Commission (VMRC), and kept in place in 1992. In 1993, a further limitation to the season was established (15 March - 15 April 1993). However, due to bad weather conditions, the season was extended through 30 April. A complete moratorium was established in 1994. At that time, the regulation stated:

“On and after 1 January 1994 it shall be unlawful for any person to catch and retain possession of American shad from the Chesapeake Bay or its tidal tributaries.” (VMRC Regulation 450-01-0069).

In 1997 and 1998, during a series of public hearings, commercial-fishing interests asked that the in-river ban on shad fishing be lifted. This proposal was opposed by the VMRC staff, scientists of the Virginia Institute of Marine Science, and representatives of various other public and private agencies. The Commission decided to leave the ban in place but also decried the lack of information necessary to assess the recovery of Virginia stocks of American shad. The current monitoring project began in the spring of 1998 in response to the VMRC’s request for information.

In spring 2003, Virginia imposed a 40% reduction in effort on the ocean intercept (gillnet) fishery prosecuted on the coast. This reduction in effort was mandated by the ASMFC. According to Amendment 1 (ASMFC 1999), “[States] must begin phase-out reduction plans for the commercial ocean-intercept fishery for American shad over a five-year period. States must achieve at least a 40% reduction in effort in the first three years, beginning January 1, 2000.” The Virginia offshore fishery was closed on 31 December 2004.

In spring 2006, the VMRC authorized a limited by-catch fishery for American shad in specific areas. This by-catch authorization was extended into the 2010 fishing season (see Appendix 1). Fishers with special permits were allowed to possess fish caught in anchored or staked gill nets in the by-catch area. The by-catch area in 2010 was defined as those tidal waters of (i) the James River, from the James River Bridge upstream to a line connecting Dancing Point and New Sunken Meadow Creek; (ii) the York River, from the George P. Coleman Bridge upstream to the Rt. 33 Eltham and Lord Delaware bridges at West Point; and (iii) the Rappahannock River, from the Norris Bridge upstream to the Rt. 360 Downing Bridge at Tappahannock. Limits were 10 American shad per boat per day and fishers were required to phone in a weekly report of the harvest. In addition, American shad by-catch could only be possessed if equal numbers of other species (such as striped bass) were also landed.

Current Information

Historic and current catch data can be accessed through the VMRC website (<http://www.mrc.state.va.us>). Annual monitoring of the abundance of juvenile *Alosa* spp. (American shad, hickory shad, blueback herring and alewife) was conducted on the York River system with a push net developed in the late 1970s (Kriete and Loesch, 1980) until 2002. The data record extends back to 1979 but sampling was not conducted during 1987-1990. The push net survey was terminated in 2002 when it was determined that the survey results were highly correlated with those of the striped bass seine survey (Wilhite et al., 2003). Although fewer individual fish are collected each year in the seine survey as compared to the evening push net survey, the seine survey has larger geographic coverage (all three rivers in Virginia vs. the Mattaponi and Pamunkey Rivers only) and the data record is uninterrupted since 1979.

Since the American shad monitoring program at VIMS began in 1998, 24 papers on various aspects of the biology of American shad and the VIMS stock assessment program have appeared in peer-reviewed journals (Maki et al., 2001; Olney et al., 2001; Olney and Hoenig, 2001b; Maki et al., 2002; Bilkovic et al., 2002a, 2002b; Olney and McBride, 2003; Olney et al., 2003; Walter and Olney, 2003; Wilhite et al., 2003; Olney 2003b; Hoffman and Olney, 2005; McBride et al., 2005; Maki et al., 2006; Olney et al., 2006a, b; Hoffman et al. 2007; Hoffman et al. 2007a, b; Hoffman et al. 2008, Walther et al. 2008; Hoenig et al. 2008; Aunins and Olney 2009; Tuckey and Olney, 2010). Reprints of these papers are available on request.

A presentation summarizing the monitoring program was given at the 2010 Annual Meeting of the American Fisheries Society in a symposium on the restoration of American shad; a manuscript based on this presentation was recently submitted (Latour et al., in review).

VIMS' authors contributed to three peer-reviewed sections to the recent stock assessment for American shad (Olney 2007; Olney et al. 2007; Carpenter et al 2007). The current monitoring program has served as the basis for several theses and dissertations, including a description of the spawning grounds of American shad in the James River (Aunins 2006). Two additional studies formed the basis for a thesis and a dissertation that were supported in part by the monitoring program: a validation of age determination of American shad using otolith isotopes as natural tags (Upton 2008) and a study of the population dynamics of juvenile *Alosa* spp. in Virginia rivers (Tuckey 2009). Finally, our monitoring data have been used in a recent revision of the on-line Chesapeake Bay Report presented annually by the Chesapeake Bay Program of the Environmental Protection Agency (<http://www.chesapeakebay.net>).

Objectives

The primary objectives of the monitoring program have remained largely unchanged since 1998: (1) to establish a time series of relative abundance indices of adult American shad during the spawning runs in the James, York and Rappahannock rivers; (2) to relate contemporary indices of abundance of American shad to historical logbook data collected during the period 1980-1992 and older data if available; (3) to assess the relative contribution of hatchery-reared and released cohorts of American shad to adult stocks; (4) to relate recruitment indices (young-of-the-year index of abundance) of American shad to relative year-class strength and age-structure of spawning adults; and (5) to determine the amount of by-catch of other species in the staked gill nets.

In 2006 an additional objective (6) was added to monitor a new by-catch fishery for American shad established by the VMRC. The results of this monitoring in 2010 are appended as a report to the ASMFC American shad and river herring technical committee as Appendix I.

Methods

The 2010 sampling methods for the monitoring program were the same as those in 1998-2009 (see Appendix I for additional methods used to monitor the by-catch fishery). In 1998, a sentinel fishery was developed that was as similar as possible to traditional shad fishing methods in the middle reaches of Virginia's rivers. When the in-river fishing moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGNs) were allowed to retain priority rights for the locations of those stands in the various rivers. VIMS has records of the historic fishing locations (Figures 2-4), and one of these locations on each river (the James, York and Rappahannock) was used to monitor catch rates by SGNs in 1998-2010. Three commercial fishermen were contracted to prepare and set SGN poles, hang nets, replace or repair poles or nets, and set nets for each sampling event during the monitoring period. Two of these commercial fishermen, Mr. Raymond Kellum (Bena, Virginia) and Mr. Marc Brown (Rescue, Virginia), were authors of the historical logbooks on the James and York rivers. However, authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders, Warsaw, Virginia) who had previous experience in SGN fishing but who had not participated in the shad fishery on the Rappahannock River in the 1980s. In addition to the annually monitored fishing location (Station 1), a comparison net (Station 2) was constructed and fished on the James River in 2010. Historic records of American shad catches were not available for this net location, although the site used was formerly fished by the Brown family. Results of the James River net comparisons are presented separately from standard monitoring data in this report. Scientists accompanied commercial fishermen during each sampling trip and all catches were returned to the laboratory for analysis.

One SGN, 900 ft (approximately 274 m) in length, was set on the York and James rivers (Figures 5-6). One SGN, 912 ft (approximately 277 m) in length, was set on the Rappahannock River (Figure 7). Locations of the sets were as follows: lower James River near the James River Bridge at river mile 10 (36° 50.0' N, 76° 28.8' W); middle York River near Clay Bank at river mile 14 (37° 20.8' N, 76° 37.7' W); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock) at river mile 36 (37° 55.9' N, 76° 50.4' W). Historical catch-rate data on the York and James rivers were derived from nets constructed of 4 7/8" stretched-mesh monofilament netting, while historic data from the Rappahannock River were based on larger mesh sizes (nets constructed of 5" stretched-mesh). To insure that catch rates in the current monitoring program were comparable to logbook records, nets on the York and James rivers were constructed of 4 7/8" (12.4 cm) stretched-mesh monofilament netting, while nets on the Rappahannock River were constructed of 5" (12.7 cm) netting. Panel lengths were consistent with historical records (30 ft [9.14 m] each on the James and York rivers; 48 ft [14.63 m] each on the Rappahannock River). Each week, nets were fished on two succeeding days (two 24-h sets) and then hung in a non-fishing position until the next sampling episode. Occasionally, weather or other circumstances prevented the regularly scheduled sampling on Monday and Tuesday, and sampling was postponed, canceled or re-scheduled for other days. In 2010, sampling occurred for twelve weeks on the James River (16 February to 4 May 2010); eleven weeks on the York River (23 February to 4 May 2010); and ten weeks on the Rappahannock River (1 March to 4 May 2010). Surface water temperature and salinity were recorded at each sampling event.

Individual American shad collected from the monitoring sites were measured and weighed on a Limnoterra FMB IV electronic fish measuring board interfaced with a Mettler PM 30000-K electronic balance. The board recorded measurements (fork length and total length) to the nearest mm, received weight input to the nearest g from the balance, and allowed manual input of additional data (such as field data and comments) or subsample designations (such as gonadal tissue and otoliths) into a data file for subsequent analysis. Catches of all other species were recorded and enumerated on log sheets by observers on each river and released. For striped bass (*Morone saxatilis*), separate records were kept of the number of live and dead fish in the nets and released (if alive) or returned to the laboratory (if dead). Random subsamples of dead striped bass from each river were analyzed for sex, fork length and total weight.

Sagittal otoliths were removed from samples of adult American shad, placed in numbered tissue culture trays, and stored for subsequent screening for hatchery marks. To scan for hatchery marks, otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Otolith scanning was performed by B. Watkins and A. Rhea (VIMS) in 2005-2010. Scanning in previous years was performed by D. Hopler (VDGIF), J. Goins (VIMS) and G. Holloman (VIMS).

Scales for age determination were removed from a mid-lateral area on the left side posterior to the pectoral-fin base of each fish. Scales were cleaned with a dilute bleach solution, mounted and pressed on acetate sheets, and read on a microfilm projector by one individual (B. Watkins, VIMS) using the methods of Cating (1953). Ages were

determined by a different reader in 1998-2002 (K. Maki). To ensure consistency, B. Watkins has re-aged all scale samples collected during the monitoring program.

An ASMFC age-determination workshop using known-age fish from the Susquehanna River system was held at VIMS in August 2004 to test the validity of scale-age techniques (McBride et al., 2005). As a result of this analysis, the ASMFC stock assessment subcommittee chose to limit its use of age data in the 2007 coast-wide assessment but not abandon those data entirely (Olney 2007). One recommendation of the workshop was to validate age determination in all major stocks. Upton et al. (in review) used a unique stable isotope signature to track the 2002 cohort for three consecutive years (age-4, age-5, and age-6) in the York River. Neither scale-based methods nor whole otolith-based methods were found to be suitable for aging fish, with 50% and 62% of individuals incorrectly aged, respectively, with the assumption that the isotope signature accurately recorded the correct age.

Catch data from each river were used to calculate a standardized catch index (the area under the curve of daily catch rate versus time of year). The catch index, the duration of the run in days, the maximum daily catch rate in each year and the mean catch rate in each year were compared to summaries of historical logbook data to provide a measure of the relative size of the current shad runs. In the historical data, catches are reported daily through the commercial season with occasional instances of skipped days due to inclement weather or damaged fishing gear. In the current monitoring data, catches on two successive days are separated by up to five days (usually Tuesday-Saturday) in each week of sampling. In some rare cases, catches are separated by more than five days. To compute the catch index, we estimated catches on skipped days using linear interpolation between adjacent days of sampling.

Results

Evaluation of James River Comparison net in 2010

In 2010 a comparison net (Station 2) was set on the James River at river mile 17 near Days Point (37° 02.5' N, 76° 35.5' W). Results of this comparison are presented in Table 28. Although total numbers of American shad at the comparison net were lower than at the primary net (Station 1), catch trends, biological attributes and prevalence of hatchery fish were similar to those recorded at the primary net. While data from both stations are presented in all tables and figures, the following discussion and calculations are based only on data from Station 1 to provide continuity with annual reports from previous years.

Catches of American shad by staked gill nets in 2010

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-8 and Figures 8.1-15. After 12

April, post-spawning fish were mixed with pre-spawning fish in the catch on the York River. On 3 May, post-spawning fish were encountered on the James River. Post-spawning females were not encountered on the Rappahannock. Post-spawning fish were identified macroscopically and microscopically depending on gonad condition. Because the historic fishery was a roe fishery and spent or partially-spent fish were not routinely captured or marketed in the historic fishery, post-spawning fish were removed from the monitoring sample.

A total of 825 American shad (123 males; 702 females) were captured at primary sampling locations (Table 1). The total weight of the sample was 1166.96 kg (male, 156.13 kg; female, 1010.83 kg). Catches in 2010 were lowest on the Rappahannock River (109 total fish, 15 males and 94 females) and York River (270 total fish, 45 males and 225 females). Catches on the James River, Station 1 (446 total fish, 63 males and 383 females) were highest.

On the York River, catches of females peaked between 16 March – 6 April when catch rates usually exceeded 0.05 fish/m or 0.08 kg/m. During that period, 79% (177 of 225) of all females were captured on the York River. Surface temperatures during this time ranged from 9.5 – 17.4°C. The largest catch of pre-spawning female American shad on the York River (42 fish) occurred on 29 March when the surface temperature was 12.9°C (Figure 16; Table 5). On the James River, catches of females peaked between 15 March and 19 April, with catch rates generally exceeding 0.04 fish/m or 0.05 kg/m. During that period 96% (367 of 383) of all females were captured. Surface temperatures during this time ranged from 9.8°C – 16.0°C. The largest catch of pre-spawning female American shad (96 fish) occurred on 29 March when surface temperatures were 12.9°C (Figure 17; Table 3.1). Catches of females on the Rappahannock River peaked on 23 March – 19 April when catch rates exceeded 0.03 fish/m or 0.04 kg/m. During that period on the Rappahannock River, 83% (78 of 94) of all females was captured. Surface temperatures during this time ranged from 13.5°C – 18.9°C. The largest catch of pre-spawning female American shad on the Rappahannock River (17 fish) occurred on 5 April when the surface temperature was 17.2°C (Figure 16; Table 7). As in previous years of monitoring, numbers and catch rates of males were lower than catch rates of females throughout the period. Sex ratios (males:females) were: York River, 1:5.00; James River, 1:6.08 and Rappahannock River, 1:6.27. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish. Catches of males do not likely reflect true abundance.

The duration of the spawning run is defined as the number of days between the first and last observation of a catch rate that equals or exceeds 0.01 female kg/m. The 2010 spawning run duration was estimated to be 57 days on the James River (1 March – 26 April; Table 3.1), 44 days on the York River (8 March – 20 April; Table 5), and 50 days on the Rappahannock River (16 March – 4 May; Table 7).

Biological characteristics of the American shad catch in 2010

Age, mean length (mm TL) and mean weight (g) of American shad in staked gill nets are summarized in Tables 9-10. Patterns of mean age are depicted in Figure 18. Mean total length at age of males and females from all rivers ranged from 428.5-539.0 mm TL and 448.0–598.0 mm TL, respectively. Mean weight at age of males and females from all rivers ranged from 0.92–1.67 kg and 1.11–2.75 kg, respectively.

Using scale-based ageing methods, we estimated that the 2005 and 2004 year classes (ages 5 and 6) of female American shad were the most abundant on all rivers (Table 11). On the James River, seven age-classes of females were represented (2001-2007, ages 3-9), with the sample dominated by age-5 fish (44.4% of the total that was aged). On the York River, six age-classes of females were represented (2001-2006, ages 4-9), with the sample dominated by age-6 fish (39.6% of the total that was aged). On the Rappahannock River, five age-classes of females were taken (2000, 2003-2006, ages 10, 4-7), with the sample dominated by age-5 fish (48.8% of the total that was aged). Mean age of females in 2010 was 5.3 y (James River), 5.7 y (York River), and 5.5 y (Rappahannock River). These values are similar to the ones observed in 2009 (Figure 19).

The 2005 and 2004 year classes of males were the most abundant on the James River, constituting 59.6% of the fish that were aged (Table 12). On the York River, the 2003 and 2004 age classes of male fish were most abundant (70.6% of the total that was aged). The number of aged males was low on the Rappahannock (n=11), with the 2005 year class being most abundant (54.5% of the total aged).

Age-specific catch rates of American shad are reported in Tables 11 and 12 for prespawned females and males, respectively. Total instantaneous mortality (Z) was estimated using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve. Total instantaneous mortality rates of females were: York River, 0.99 ($r^2=0.87$); James River, 1.23 ($r^2=0.96$) and Rappahannock River, 1.05 ($r^2=0.93$). Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River, 0.42 ($r^2=0.48$) and James River, 0.49 ($r^2=0.99$).

Spawning histories of American shad collected in 2010 are presented in Tables 13-14. On the York River, fish (both sexes combined) ranged in age from 4–9 years with 0 (virgin) to 5 spawning marks. On the James River, fish (both sexes combined) ranged in age from 3-10 years with 0-6 spawning marks. On the Rappahannock River, fish (both sexes combines) ranged in age from 4-10 years with 0-5 spawning marks. The following percentages of fish in each river had at least one prior spawn (termed “repeat spawners”): York River, 62.4% (85 virgins in a sample of 226); James River, 43.4% (215 virgins in a sample of 380) and Rappahannock River 49.5% (46 virgins in a sample of 91 fish).

Evaluation of hatchery origin of American shad in 2010

James River - Otoliths of 149 American shad on the James River were processed for hatchery marks. The proportion of the 2010 sample with hatchery marks was 34.9% (52 of 149 fish). The biological attributes of these specimens are presented in Table 15. Prevalence of hatchery fish has been variable with a peak of 51.4% in 2003. From 2003 to 2006, prevalence declined to 10.3%. In 2007, the proportion of fish with hatchery tags once again rose to 32.2%. In 2008, prevalence was 25.6% and the 2009 value of 8.8% was the lowest value seen in 10 years of monitoring. In 2010 the hatchery prevalence rose to 34.9%, the highest value recorded since 2003. The strength of the James River catch index continues to rely on the prevalence of hatchery fish (Figure 20). A correlation analysis among the catch index and hatchery prevalence from 1998-2010 was statistically significant ($r = 0.754$, $df = 11$, $p = 0.003$). In most years, fish with hatchery tags from rivers other than the James River were detected in the monitoring sample. These strays were not included in the estimates of hatchery prevalence and are as follows (year captured as an adult, number, river of release): 1999, $n = 1$, Patuxent River (Maryland); 2000, $n = 7$, Pamunkey River (Virginia) and Juniata River (Pennsylvania); 2001, $n = 3$, Pamunkey River, Juniata River, and the western branch of the Susquehanna River (Pennsylvania); 2002, $n = 2$, Pamunkey River, $n = 2$ unknown tag; 2005, $n = 3$, tentatively Pamunkey River and Mattaponi River (Virginia); 2007, $n = 1$, Pamunkey River (Virginia); 2008, $n = 1$, Undetermined; 2009, $n = 1$, Chemung River (New York); 2010, $n = 2$, Susquehanna River (Pennsylvania). In 2003, 2004, 2006 there were no stray fish.

Most hatchery-reared adults taken in 2010 had OTC marks that indicated these specimens were released after 2003. These tags could not be easily differentiated microscopically, so we determined the year of release using scale-determined ages (Tables 13-16). Most of the fish in the sample were from the 2004, 2005 and 2006 year classes. All of the fish in 2006 year class were virgins. A large percentage of the 2004 and 2005 year classes, 46.2% and 77.8% were virgins. Only one fish was from the 2003 year class.

York and Rappahannock Rivers - Otoliths of 90 American shad (33.3% of the total that were caught) from the York River were processed for hatchery marks. Three specimens (3.3%) with OTC marks were detected. There were no strays present in the sample. In 2010, 37 American shad (33.9% of the total that were caught) from the Rappahannock river were scanned for the prevalence of hatchery marks. No fish with hatchery marks from the Rappahannock River were found. One stray from the Potomac River was discovered. Stocking of American shad in the Rappahannock River began in 2003.

Juvenile abundance of American shad

Tables 17 and 18 and Figures 21-24 report index values of juvenile abundance of American shad based on seine surveys (1979-2010) on the James and Chickahominy rivers, the Rappahannock River, the main stem of the York River, the Pamunkey River and the Mattaponi River. The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2010 was: James River, inclusive of Chickahominy River, 0.02 (0.121, 65); Chickahominy River, 0 (0, 10); Rappahannock River, 1.19 (1.166, 33); York River, inclusive of Pamunkey and Mattaponi Rivers, 0.47 (0.823, 93); Mattaponi River, 0.97 (1.029, 50); and Pamunkey River, 0.06 (0.189, 38). Calculations for all years were adjusted in 2009 to include fish greater than 72 mm, which had not been included in the indices in previous years. In 2010, additional stations were added to the index calculation on the James River.

The seine survey data on the James River (Table 17) in recent years (2006-2010) shows measureable recruitment. In years before this, recruitment numbers were sporadic, with no catches of juveniles in many years. In 2010, James River indices for all years were recalculated to include additional seine survey stations located in the upper James and Chickahominy rivers. Independent results from the Chickahominy River are also reported, although it is unknown whether fish captured in this river form a unique stock (i.e., distinct from that of the James River). Stocking of American shad took place on Chickahominy Lake in 2000 and on the Chickahominy River in 2004. Results from an independent survey below Boshers' Dam on the James River depict no measureable recruitment in most years (VDGIF, T. Gunter, pers. comm.). On the Rappahannock River, the highest JAI value in the time series was recorded in 2010. The Rappahannock River time series depicts no measurable recruitment in 1980-1981, 1985, 1988, 1991-1992, 1995, and 2002.

Within the York River system, except for 2003, the juvenile index values based on the seine survey are consistently higher on the Mattaponi River than they are on the Pamunkey River and the York River (Table 18). In the time series, recruitment is highest (>7.0 on the Mattaponi River and >3.0 on the York River) in 1982, 1984-85, 1996, 2003 and 2004. Recruitment was low (<0.10) on both of these rivers in 2009; there was no measureable recruitment in the Pamunkey River in 1986-1989, 1992-1993, 1999, and 2007-2009.

By-catch of striped bass and other species in 2010

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 19-21. Twenty-five species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 20,154 specimens. The most commonly encountered by-catch species were: gizzard shad (*Dorosoma cepedianum*), striped bass (*Morone saxatilis*), menhaden (*Brevoortia tyrannus*) and blue catfish (*Ictalurus furcatus*).

The total number of striped bass captured was 7,830 (James River, n=3,769; York River, n=2624; Rappahannock River, n=1437). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, Station 1, 14.1%; York River, 28.6%; and the Rappahannock River, 71.7%. A subsample of dead striped bass was collected on each river. Length of males and females ranged from 356 - 762 mm FL and 445 - 910 mm FL, respectively. Total weights of males and females ranged from 0.60 – 5.04 kg and 1.22 – 8.09 kg, respectively.

Seasonal catch indices, 1980-1992 and 1998-2010

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2010 and for each year of the historical record of staked net catches on each river (Tables 22-27 and Figures 25-28). Seasonal catch indices in 2010 were: York River, 4.19; Rappahannock River, 2.03; James River, 6.90.

Discussion

The staked gill net monitoring program continues to be useful for assessment of stocks of American shad in Virginia. It is the only direct method available to determine the size of the spawning runs relative to what was obtained in the decades prior to the moratorium. The program also provides information for evaluating the hatchery-based restoration program, validating the juvenile index of abundance and for determining the amount of by-catch that could be expected in a commercial fishery if the in-river fishing ban is lifted.

In 1998, states were required to develop and submit restoration targets for stocks under moratorium. Virginia presented preliminary targets to the Plan Review Team of the ASMFC Shad and River Herring Management Board with the proviso that these targets would be revised as appropriate historical data became available (see below). Criteria to achieve restoration targets were proposed as either: (1) a three-year period during which the catch index remains at or above the target level in the staked gill net monitoring of the spawning run; (2) a three-year period during which the average catch

index is above the target level and the target level is exceeded in two of the years; or (3) a significant increasing trend over a five-year period with the target exceeded in the last two years.

Voluntary logbooks of catches from the York River exist in the archives of the Department of Fisheries Science (Table 24). These historical records from the 1950s form the basis for gear comparison trials conducted in 2002 and 2003 in the York River (Maki et al., 2006). Based on these comparisons, we have concluded that the multifilament nets of the type used in the 1950s have approximately half of the fishing power of monofilament nets used in the 1980s and the current monitoring. Thus, the older data have been adjusted upward (by a factor of 2.16) to make appropriate comparisons with current monitoring results.

Voluntary log books from the 1950s also exist for the James River. The most extensive data are those of Mr. J. C. Smith who fished staked gill nets on the upper James River in 1954-1957, just above the mouth of the Chickahominy River. Current monitoring on the James River is well below this location, complicating direct comparisons with Smith's log books. There are no historic records in department archives for the Rappahannock River.

Using the information presented above and additional analysis, the ASMFC stock assessment subcommittee developed benchmarks for restoration of Virginia's stock of American shad (ASMFC 2007a). These benchmarks were reviewed and accepted by the ASMFC American shad stock assessment peer review panel in 2007 (ASMFC 2007b).

For the York River, a restoration target of 17.44 (the geometric mean of the catch index values observed in 1953-1957) was accepted as an appropriate benchmark to assess the stocks since American shad abundance in the 1980s was insufficient to support the fishery. In the 1950s, shad abundance was higher (estimated at 131,000-218,000 total females annually using data from Nichols and Massmann, 1962), and landings were relatively stable in the face of a high fishing rate (50%). Thus, restoring the York River shad stocks to a 1950s level could allow for a sustainable fishery operating at a lower level of exploitation.

For the James River, an interim target of 6.40 (the geometric mean of the catch index values observed in 1980-1993) is available. However, American shad abundance in the 1980s was insufficient to support the fishery. The James River stock is dependent on hatchery inputs and there is strong evidence of persistent recruitment failure of wild stocks.

For the Rappahannock River, an interim restoration target of 1.45 (the geometric mean of the catch index values observed in 1980-1993) is available.

On the York River, the seasonal catch index in 2010 was 4.19. This value is higher than the 2009 value of 2.92. During twelve years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other

years. The geometric mean of the historical data during the 1980s on the York River is 3.22. The geometric mean of the current monitoring data is higher (6.02), but this mean is lower than the benchmark based on 1950s data (17.44). In recent years of monitoring (2006 - 2010), mean age of females has increased as a result of lower proportions of younger fish in the monitoring catch (Figure 18). In 2009 and 2010 the proportion of age 4 female recruits was at an all time low (Figure 19). Catch indices have been trending downward in recent years and are close to all-time lows.

Our overall assessment of the York River stock is that it has recovered to a level that is close to its average abundance during the 1980s. However, as noted previously, the stock level was low during that period, and incapable of supporting an active fishery. Since 2004, the catch index has shown a significant decline and is cause for concern. Although there is a moratorium on American shad harvest in the Chesapeake Bay, there are fish taken in the York River each year from several sources. Since 2005 there has been a limited by-catch fishery of American shad. Results from this permitted activity in 2010 are reported in Appendix I. The Mattaponi and Pamunkey tribal governments harvest American shad but do not report landings to the VMRC, following the treaty of 1677. There are also losses to capture of brood stock on the Pamunkey River by the VDGIF. The stock is currently well below the proposed 1950s target (Figure 28) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann, 1963). As a result, the stock requires continued protection.

On the James River, the 2010 index (6.90) increased from 2009 (2.69). This value is still well below the peak catch index observed in the 1980s (29.20). Index values in 2000-2005 were higher than those in 1998 and 1999 (2.57 and 2.99, respectively). In 2006, the index fell to a value of 1.74, but recovered in 2007 to 4.45. The lowest value in the eleven year time-series was recorded in 2008 (1.51). The geometric mean of the historical data during the 1980s on the James River is 6.40. The geometric mean of the current monitoring data is lower (4.26). Hatchery cohorts are believed to be recruiting in high proportions to the population. Prevalence of hatchery fish on the James River continues to be high (34.9% of fish caught in 2010). Our overall assessment for the James River is that the stock remains at historically low levels and is dependent on hatchery inputs (Figure 20). Due to budget constraints stocking efforts of American shad on the James River have been reduced in recent years. The current reduction in stocking effort is projected to continue.

On the Rappahannock River, the 2010 index (2.03) decreased from 2009 (5.36) and is below the 1998–2010 geometric mean (3.14). The 2003-2004 index values were higher than any previous year of monitoring and higher than all years of the historic data. The 1998-2010 geometric mean (3.14) is above the mean of the historical data (1.45) and the 2003-2004 index values were above the proposed target of 6. However, 2005-2010 values have continued to stay below the proposed target of 6. It should be noted that since the catch index for the Rappahannock River is low in the historical data relative to the York and James rivers, there is uncertainty about what an appropriate target level should be for this stock.

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Table 1. Summary of sampling dates, total number, and total weight of American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2010.

Sampling Location	Sampling dates in 2010	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River, Station 1	2/16-5/4	383	63	541.22	83.52	446	624.74
James River, Station 2	2/22-5/4	78	13	113.36	15.84	91	129.20
York River	2/23-5/4	225	45	329.42	53.96	270	383.38
Rappahannock River	3/1-5/4	94	15	140.19	18.65	109	158.84
Totals		780	136	1124.19	171.97	916	1296.16

Table 2. Total length, fork length, and total weight of post-spawning female American shad taken in a staked gill net in the York River and James River, spring 2010. These individuals were removed from the monitoring data.

Sampling Location	Date	Specimen number	Total length (mm)	Fork length (mm)	Total weight (g)
York River	4/12/2010	15049	479	422	986.6
	4/13/2010	15086	459	414	882.0
	4/13/2010	15090	525	465	1381.4
	4/19/2010	15111	509	456	1264.3
	4/19/2010	15112	460	413	927.2
	4/19/2010	15113	471	424	1059.5
	4/19/2010	15114	500	445	1369.5
	4/19/2010	15116	502	447	1232.6
	4/19/2010	15120	549	493	1609.2
	4/19/2010	15121	470	410	988.2
	4/19/2010	15125	463	406	846.5
	4/19/2010	15129	455	403	948.6
	4/19/2010	15131	500	451	1105.0
	4/20/2010	15155	508	458	1212.4
	4/20/2010	15156	530	467	1428.6
	4/20/2010	15157	482	424	1064.7
	4/20/2010	15159	506	454	1127.9
	4/20/2010	15160	518	460	1649.3
	4/20/2010	15161	527	471	1287.6
	4/20/2010	15162	534	473	1454.2
	4/20/2010	15163	539	473	1505.5
	4/20/2010	15164	506	445	1312.9
	4/20/2010	15165	503	449	1417.6
	4/20/2010	15166	456	403	998.3
	4/20/2010	15167	530	476	1511.5
	4/26/2010	15183	514	450	1280.6
	4/26/2010	15184	495	440	1070.7
	4/26/2010	15185	476	420	972.3
	4/26/2010	15186	506	449	1086.1
	4/26/2010	15188	558	502	1530.2
	4/27/2010	15191	530	476	1432.0
	4/27/2010	15193	514	462	1178.8
	4/27/2010	15194	473	424	1139.3
James River Sta. 1	5/3/2010	15200	471	415	1107.6
James River Sta. 2	4/13/2010	15108	449	397	869.1
	4/13/2010	15109	533	476	1301.3
	4/27/2010	15199	527	470	1466.5

Table 3.1. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the James River: Station 1, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/16/2010	47	0	0	0	0
2/17/2010	48	0	0	0	0
2/22/2010	53	0	0	0	0
2/23/2010	54	0	0	0	0
3/1/2010	60	3	0.010	3831.6	0.013
3/2/2010	61	2	0.009	2850.8	0.012
3/8/2010	67	5	0.019	6892.8	0.027
3/9/2010	68	1	0.004	1267.9	0.005
3/15/2010	74	19	0.066	27875.9	0.097
3/16/2010	75	26	0.087	36002.0	0.120
3/22/2010	81	42	0.158	60186.8	0.226
3/23/2010	82	56	0.202	78684.8	0.284
3/29/2010	88	96	0.357	137690.4	0.513
3/30/2010	89	33	0.119	46212.6	0.167
4/5/2010	95	36	0.134	51017.5	0.190
4/6/2010	96	28	0.101	38445.5	0.139
4/12/2010	102	11	0.041	16879.8	0.064
4/13/2010	103	11	0.036	15983.6	0.052
4/19/2010	109	9	0.034	11092.3	0.042
4/20/2010	110	2	0.007	2593.6	0.009
4/26/2010	116	2	0.008	2525.5	0.010
4/27/2010	117	1	0.004	1183.8	0.004
5/3/2010	123	0	0	0	0
5/4/2010	124	0	0	0	0
Totals		383		541217.3	

Table 3.2. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the James River: Station 2, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/22/2010	53	0	0	0	0
2/23/2010	54	0	0	0	0
3/1/2010	60	0	0	0	0
3/8/2010	67	0	0	0	0
3/9/2010	68	0	0	0	0
3/15/2010	74	1	0.004	1194.1	0.004
3/16/2010	75	15	0.055	20899.4	0.076
3/22/2010	81	6	0.021	8568.9	0.030
3/23/2010	82	7	0.025	9478.5	0.034
3/29/2010	88	11	0.038	16370.1	0.057
3/30/2010	89	19	0.055	27794.1	0.080
4/5/2010	95	6	0.021	8947.0	0.031
4/6/2010	96	2	0.007	2942.7	0.011
4/12/2010	102	6	0.021	9604.8	0.034
4/13/2010	103	1	0.004	1482.6	0.006
4/19/2010	109	4	0.014	6074.5	0.022
4/20/2010	110	0	0	0	0
4/26/2010	116	0	0	0	0
4/27/2010	117	0	0	0	0
5/3/2010	123	0	0	0	0
5/4/2010	124	0	0	0	0
Totals		78		113356.7	

Table 4.1. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the James River: Station 1, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/16/2010	47	0	0	0	0
2/17/2009	48	0	0	0	0
2/22/2010	53	0	0	0	0
2/23/2010	54	0	0	0	0
3/1/2010	60	1	0.003	1274.7	0.004
3/2/2010	61	1	0.004	1365.9	0.006
3/8/2010	67	1	0.004	1169.9	0.005
3/9/2010	68	1	0.004	988.4	0.004
3/15/2010	74	5	0.017	6852.2	0.024
3/16/2010	75	8	0.027	10613.4	0.035
3/22/2010	81	10	0.038	13735.2	0.052
3/23/2010	82	6	0.022	7849.2	0.028
3/29/2010	88	18	0.067	23985.9	0.089
3/30/2010	89	6	0.022	8041.5	0.029
4/5/2010	95	4	0.015	5676.8	0.021
4/6/2010	96	1	0.004	1160.5	0.004
4/12/2010	102	0	0	0	0
4/13/2010	103	0	0	0	0
4/19/2010	109	0	0	0	0
4/20/2010	110	0	0	0	0
4/26/2010	116	0	0	0	0
4/27/2010	117	0	0	0	0
5/3/2010	123	0	0	0	0
5/4/2010	124	1	0.004	801.4	0.003
Totals		63		83515.0	

Table 4.2. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the James River: Station 2, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/22/2010	53	0	0	0	0
2/23/2010	54	0	0	0	0
3/1/2010	60	0	0	0	0
3/8/2010	67	0	0	0	0
3/9/2010	68	0	0	0	0
3/15/2010	74	3	0.011	3681.7	0.014
3/16/2010	75	3	0.011	3748.7	0.014
3/22/2010	81	1	0.003	1464.1	0.005
3/23/2010	82	1	0.004	1126.6	0.004
3/29/2010	88	0	0	0	0
3/30/2010	89	2	0.006	2420.6	0.007
4/5/2010	95	3	0.010	3394.3	0.012
4/6/2010	96	0	0	0	0
4/12/2010	102	0	0	0	0
4/13/2010	103	0	0	0	0
4/19/2010	109	0	0	0	0
4/20/2010	110	0	0	0	0
4/26/2010	116	0	0	0	0
4/27/2010	117	0	0	0	0
5/3/2010	123	0	0	0	0
5/4/2010	124	0	0	0	0
Totals		13		15836.0	

Table 5. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the York River, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/23/2010	54	0	0	0	0
2/24/2010	55	1	0.004	1355.3	0.005
3/1/2010	60	0	0	0	0
3/2/2010	61	1	0.004	1242.3	0.005
3/8/2010	67	5	0.018	7890.6	0.029
3/9/2010	68	4	0.015	6449.5	0.024
3/15/2010	74	5	0.018	7667.6	0.028
3/16/2010	75	26	0.095	38132.0	0.139
3/22/2010	81	15	0.055	21426.2	0.078
3/23/2010	82	22	0.080	33962.2	0.124
3/29/2010	88	42	0.156	61019.9	0.227
3/30/2010	89	23	0.080	32138.4	0.112
4/5/2010	95	22	0.080	33086.8	0.121
4/6/2010	96	27	0.098	39770.9	0.145
4/12/2010	102	9	0.034	13144.4	0.049
4/13/2010	103	3	0.011	4346.4	0.016
4/19/2010	109	11	0.040	15317.7	0.056
4/20/2010	110	7	0.026	9960.6	0.036
4/26/2010	116	1	0.004	1151.5	0.004
4/27/2010	117	0	0	0	0
5/3/2010	123	0	0	0	0
5/4/2010	124	1	0.004	1359.2	0.005
Totals		225		329421.5	

Table 6. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the York River, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/23/2010	54	0	0	0	0
2/24/2010	55	0	0	0	0
3/1/2010	60	0	0	0	0
3/2/2010	61	0	0	0	0
3/8/2010	67	4	0.015	3869.8	0.014
3/9/2109	68	6	0.022	7515	0.027
3/15/2010	74	5	0.018	6038.7	0.022
3/16/2010	75	5	0.018	6325.2	0.023
3/22/2010	81	2	0.007	2462	0.009
3/23/2010	82	3	0.011	4158.6	0.015
3/29/2010	88	6	0.022	8163.9	0.030
3/30/2010	89	4	0.014	4449.4	0.016
4/5/2010	95	4	0.015	4935.6	0.018
4/6/2010	96	2	0.007	2208.3	0.008
4/12/2010	102	0	0	0	0
4/13/2010	103	0	0	0	0
4/19/2010	109	2	0.007	2202.6	0.008
4/20/2010	110	1	0.004	821.2	0.003
4/26/2010	116	0	0	0	0
4/27/2010	117	1	0.004	812.1	0.003
5/3/2010	123	0	0	0	0
5/4/2010	124	0	0	0	0
Totals		45		53962.4	

Table 7. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/1/2010	60	0	0	0	0
3/2/2010	61	1	0.004	1207.1	0.004
3/8/2010	67	0	0	0	0
3/9/2010	68	0	0	0	0
3/15/2010	74	0	0	0	0
3/16/2010	75	3	0.012	3900.4	0.015
3/22/2010	81	2	0.007	3067.9	0.011
3/23/2010	82	9	0.032	14730.2	0.053
3/29/2010	88	14	0.050	22489.0	0.081
4/5/2010	95	17	0.061	24462.2	0.088
4/6/2010	96	13	0.047	18736.5	0.067
4/12/2010	102	11	0.041	14566.0	0.054
4/13/2010	103	6	0.022	9553.5	0.034
4/19/2010	109	8	0.030	11676.4	0.044
4/20/2010	110	5	0.018	8505.4	0.031
4/26/2010	116	0	0	0	0
4/27/2010	117	3	0.011	4503.3	0.016
5/3/2010	123	0	0	0	0
5/4/2010	124	2	0.007	2789.4	0.010
Totals		94		140187.3	

Table 8. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2010.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/1/2010	60	0	0	0	0
3/2/2010	61	0	0	0	0
3/8/2010	67	0	0	0	0
3/9/2010	68	0	0	0	0
3/15/2010	74	0	0	0	0
3/16/2010	75	5	0.020	6201.5	0.024
3/22/2010	81	1	0.004	1280.3	0.005
3/23/2010	82	2	0.007	2408.5	0.009
3/29/2010	88	2	0.007	3005.1	0.011
4/5/2010	95	1	0.004	1317.3	0.005
4/6/2010	96	3	0.011	3177.7	0.011
4/12/2010	102	0	0	0	0
4/13/2010	103	0	0	0	0
4/19/2010	109	0	0	0	0
4/20/2010	110	1	0.004	1262.8	0.005
4/26/2010	116	0	0	0	0
4/27/2010	117	0	0	0	0
5/3/2010	123	0	0	0	0
5/4/2010	124	0	0	0	0
Totals		15		18653.2	

Table 9. Mean total length and mean weight of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2010. The abbreviation NA is “not aged”. Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Mean total length (mm)	Standard deviation	Mean weight (g)	Standard deviation
James River Station 1	2007	1	448.0		1114.5	
	2006	49	467.4	24.1	1251.8	178.7
	2005	148	480.7	19.6	1367.8	163.5
	2004	111	492.0	21.6	1476.0	206.9
	2003	19	521.4	29.1	1773.9	280.1
	2002	4	545.5	39.5	1930.8	372.6
	2001	1	531.0		1787.2	
	NA	50	485.2	22.0	1385.6	193.9
James River Station 2	2006	8	477.4	24.2	1314.3	155.7
	2005	29	479.8	21.2	1357.0	156.8
	2004	15	496.7	18.8	1560.3	180.3
	2003	8	513.3	25.6	1741.3	295.4
	NA	18	489.4	31.2	1453.0	223.3
York River	2006	15	466.2	20.1	1241.9	136.7
	2005	70	475.2	18.3	1360.6	180.3
	2004	76	489.8	16.3	1488.1	154.7
	2003	22	512.7	17.6	1717.5	192.1
	2002	8	533.4	14.9	1873.0	195.2
	2001	1	528.0		1770.7	
	NA	33	487.9	20.5	1452.0	196.0
Rappahannock River	2006	5	459.8	25.6	1248.3	191.1
	2005	39	478.4	21.0	1420.0	158.7
	2004	28	492.8	20.5	1571.0	200.3
	2003	7	503.1	34.9	1614.6	244.5
	2000	1	598.0		2752.5	
	NA	14	487.6	20.1	1465.9	165.5

Table 10. Mean total length and mean weight of male American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2010. The abbreviation NA is “not aged”. Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Mean total length (mm)	Standard deviation	Mean weight (g)	Standard deviation
James River Station 1	2006	6	478.2	17.7	1273.0	116.8
	2005	16	481.3	31.5	1302.2	170.4
	2004	12	486.2	25.8	1310.0	183.5
	2003	7	489.7	15.9	1402.8	95.8
	2002	3	503.0	16.1	1551.1	63.3
	2001	2	513.0	9.9	1572.2	26.4
	2000	1	539.0		1667.2	
	NA	16	476.8	30.6	1252.3	263.1
James River Station 2	2006	3	450.7	6.7	1131.5	53.2
	2005	3	449.3	3.8	1038.4	122.9
	2004	2	468.0	17.0	1270.8	52.3
	2003	2	482.0	15.6	1329.1	277.8
	NA	3	487.7	28.1	1375.5	162.1
York River	2006	2	428.5	44.5	924.1	353.3
	2005	5	459.4	21.5	1208.2	111.9
	2004	12	459.3	15.5	1167.1	143.7
	2003	12	465.1	14.6	1144.4	172.0
	2002	2	486.5	29.0	1322.9	428.4
	2001	1	500.0		1539.9	
	NA	11	471.7	28.9	1286.3	260.1
Rappahannock River	2005	6	446.8	17.7	1063.1	157.4
	2004	2	457.5	7.8	1181.9	191.5
	2003	3	495.0	10.5	1530.2	237.1
	NA	4	477.8	26.7	1330.0	167.1

Table 11. Number, total weight, and seasonal catch rates by year class of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2010. The abbreviation NA is “not aged”. Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Total weight (kg)	Total effort (days)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
James River Station 1	2007	1	1.1	23.8	0.0002	0.0002
	2006	49	61.3	23.8	0.0075	0.0094
	2005	148	202.4	23.8	0.0227	0.0310
	2004	111	163.8	23.8	0.0170	0.0251
	2003	19	33.7	23.8	0.0029	0.0052
	2002	4	7.7	23.8	0.0006	0.0012
	2001	1	1.8	23.8	0.0002	0.0003
	NA	50	69.3	23.8	0.0077	0.0106
	James River Station 2	2006	8	10.5	21.4	0.0014
2005		29	39.4	21.4	0.0049	0.0067
2004		15	23.4	21.4	0.0026	0.0040
2003		8	13.9	21.4	0.0014	0.0024
NA		18	26.2	21.4	0.0031	0.0045
York River		2006	15	18.6	21.8	0.0025
	2005	70	95.2	21.8	0.0117	0.0159
	2004	76	113.1	21.8	0.0127	0.0189
	2003	22	37.8	21.8	0.0037	0.0063
	2002	8	15.0	21.8	0.0013	0.0025
	2001	1	1.8	21.8	0.0002	0.0003
	NA	33	47.9	21.8	0.0055	0.0080
	Rappahannock River	2006	5	6.2	18.8	0.0010
2005		39	55.4	18.8	0.0075	0.0106
2004		28	44.0	18.8	0.0054	0.0084
2003		7	11.3	18.8	0.0013	0.0022
2000		1	2.8	18.8	0.0002	0.0005
NA		14	20.5	18.8	0.0027	0.0039

Table 12. Number, total weight, and seasonal catch rates by year class of male American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2010. The abbreviation NA is “not aged”. Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Total weight (kg)	Total effort (days)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
James River Station 1	2006	6	7.6	23.8	0.0009	0.0012
	2005	16	20.8	23.8	0.0025	0.0032
	2004	12	15.7	23.8	0.0018	0.0024
	2003	7	9.8	23.8	0.0011	0.0015
	2002	3	4.7	23.8	0.0005	0.0007
	2001	2	3.1	23.8	0.0003	0.0005
	2000	1	1.7	23.8	0.0002	0.0003
	NA	16	20.0	23.8	0.0025	0.0031
	James River Station 2	2006	3	3.4	21.4	0.0005
2005		3	3.1	21.4	0.0005	0.0005
2004		2	2.5	21.4	0.0003	0.0004
2003		2	2.7	21.4	0.0003	0.0005
NA		3	4.1	21.4	0.0005	0.0007
York River	2006	2	1.8	21.8	0.0003	0.0003
	2005	5	6.0	21.8	0.0008	0.0010
	2004	12	14.0	21.8	0.0020	0.0023
	2003	12	13.7	21.8	0.0020	0.0023
	2002	2	2.6	21.8	0.0003	0.0004
	2001	1	1.5	21.8	0.0002	0.0003
	N/A	11	14.1	21.8	0.0018	0.0024
Rappahannock River	2005	6	6.4	18.8	0.0012	0.0012
	2004	2	2.4	18.8	0.0004	0.0005
	2003	3	4.6	18.8	0.0006	0.0009
	NA	4	5.3	18.8	0.0008	0.0010

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2010 in the James River. Table entries are total numbers of fish that were aged (James River Station 1, n = 380; James River Station 2, n = 70). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the James River, the number in parentheses is the number of aged fish out of the total that had hatchery marks on their otoliths (Station 1, n = 43; Station 2, n = 9). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

Age at Maturity						
James River Station 1 Year Class	Age at Capture	3	4	5	6	7
2007	3	1	-	-	-	-
2006	4	1	54(11)	-	-	-
2005	5	4(1)	28(3)	132(14)	-	-
2004	6	5	31(3)	59(4)	28(6)	-
2003	7	2	7(1)	12	5	0
2002	8	0	3	3	1	0
2001	9	1	2	0	0	0
2000	10	0	0	1	0	0

Age at Maturity						
James River Station 2 Year Class	Age at Capture	3	4	5	6	7
2006	4	1	10(1)	-	-	-
2005	5	0	8	24(2)	-	-
2004	6	0	5(1)	9(3)	3(1)	-
2003	7	0	5	4(1)	1	0

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2010 in the York and Rappahannock Rivers. Table entries are total numbers of fish that were aged (York River, n =226; Rapp. River, n=91). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For both rivers, the number in parentheses are the number of aged fish out of the total that had hatchery marks on their otoliths (York, n = 3; Rapp, n=1). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

Age at Maturity

York River Year Class	Age at Capture	3	4	5	6	7
2006	4	2	15	-	-	-
2005	5	4	23	48	-	-
2004	6	2	29	37	20(1)	-
2003	7	0	20	10(1)	2(1)	2
2002	8	0	7	3	0	0
2001	9	0	1	1	0	0

Age at Maturity

Rapp. River Year Class	Age at Capture	3	4	5	6	7
2006	4	0	5	-	-	-
2005	5	0	11	34	-	-
2004	6	0	9	14(1)	7	-
2003	7	0	0	10	0	0
2000	10	0	0	1	0	0

Table 15. River of origin, age, number of spawns, fork length (FL), total length (TL), total weight (TW), and sex of American shad with hatchery marks (n=70) taken in staked gill net monitoring in 2010. A total of 307 American shad were scanned for hatchery marks (JA. 1, n=149; JA. 2, n=31; RA, n=37; YK, n=90). Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged; Pam, Pamunkey; Matt, Mattaponi.

Specimen Number	River Capture	Station	River Origin	Sequence	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
14259	James	1	James	3	5	0	417	456	1375.3	Female
14273	James	1	James	3	6	0	393	445	1040.7	Female
14305	James	1	James	3	5	1	440	492	1608.8	Female
14308	James	1	James	3	5	2	451	503	1564.1	Female
14311	James	1	James	3	NA	NA	422	480	1234.3	Female
14314	James	1	James	3	7	3	445	495	1444.0	Male
14320	James	1	Susquehanna	3,6,12	NA	NA	454	513	1727.4	Male
14366	James	1	James	3	6	1	436	493	1493.6	Female
14369	James	1	James	3	NA	NA	438	492	1491.5	Female
14372	James	1	James	3	NA	NA	433	491	1443.6	Female
14378	James	1	James	3	NA	NA	418	471	1397.7	Female
14381	James	1	James	3	6	2	448	501	1539.7	Female
14384	James	1	James	3	5	0	425	493	1344.4	Female
14446	James	1	James	3	4	0	415	466	1149.2	Female
14449	James	1	James	3	5	0	434	489	1372.4	Female
14455	James	1	James	3	6	0	414	470	1243.7	Female
14470	James	1	James	3	4	0	415	466	1249.6	Female
14476	James	1	James	3	NA	NA	409	461	1107.0	Male
14488	James	1	James	3	5	1	428	476	1176.1	Female
14540	James	1	James	3	5	0	425	475	1323.0	Female

Specimen Number	River Capture	Station	River Origin	Sequence	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
14576	James	1	James	3	4	0	412	460	1207.8	Female
14582	James	1	James	3	6	2	412	470	1404.8	Female
14585	James	1	James	3	6	0	428	484	1319.8	Female
14588	James	1	James	3	5	0	415	465	1209.7	Female
14594	James	1	James	3	5	0	412	454	1110.3	Female
14693	James	1	James	3	5	0	424	475	1309.0	Female
14696	James	1	James	3	6	2	444	500	1661.1	Female
14714	James	1	James	3	NA	NA	418	471	1330.9	Female
14729	James	1	James	3	6	0	425	478	1314.2	Female
14738	James	1	James	3	5	0	425	472	1300.8	Female
14741	James	1	James	3	6	1	417	471	1178.7	Male
14747	James	1	James	3	4	0	393	445	1019.9	Female
14756	James	1	James	3	5	0	420	472	1266.9	Female
14759	James	1	James	3	NA	NA	433	487	1369.3	Female
14762	James	1	Susquehanna	3,6,9,12,15	4	0	418	472	1285.4	Female
14765	James	1	James	3	5	0	420	472	1295.2	Female
14771	James	1	James	3	4	0	409	460	1148.4	Female
14824	James	1	James	3	6	1	434	492	1362.0	Female
14839	James	1	James	3	5	0	410	459	1253.4	Female
14842	James	1	James	3	NA	NA	415	470	1289.3	Male
14946	James	1	James	3	6	1	411	463	1280.9	Female
14961	James	1	James	3	NA	NA	440	487	1581.0	Female
15021	James	1	James	3	5	0	425	472	1361.4	Female
15024	James	1	James	3	6	0	422	474	1440.1	Female
15027	James	1	James	3	5	0	428	481	1265.9	Female
15030	James	1	James	3	5	0	430	486	1299.1	Female
15033	James	1	James	3	NA	NA	421	467	1386.7	Female

Specimen Number	River Capture	Station	River Origin	Sequence	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
15039	James	1	James	3	4	0	393	438	1045.5	Female
15045	James	1	James	3	4	0	424	472	1381.7	Female
15100	James	1	James	3	6	0	438	496	1523.8	Female
15103	James	1	James	3	4	0	414	456	1188.4	Female
15106	James	1	James	3	5	1	434	488	1446.4	Female
15143	James	1	James	3	4	0	398	454	1116.4	Female
15146	James	1	James	3	4	0	391	442	1132.7	Female
14326	James	2	James	3	4	0	398	449	1127.0	Male
14402	James	2	James	3	6	1	458	514	1789.6	Female
14405	James	2	James	3	NA	NA	470	533	1626.7	Female
14408	James	2	James	3	5	0	412	466	1225.6	Female
14602	James	2	James	3	5	0	433	485	1355.1	Female
14858	James	2	James	3	NA	NA	399	452	1111.0	Female
14864	James	2	James	3	6	0	412	468	1360.9	Female
14873	James	2	James	3	6	1	403	456	1233.8	Male
14963	James	2	James	3	6	2	417	480	1307.8	Male
15081	James	2	James	3	6	1	429	482	1417.3	Female
15084	James	2	James	3	7	2	487	551	2227.9	Female
15154	James	2	James	3	NA	NA	455	510	1662.6	Female
14655	Rappahannock		Potomac	3,6	6	1	424	470	1554.9	Female
14347	York		Pam./Matt.	3	7	1	465	527	1978.2	Female
14610	York		Pam./Matt.	3	6	0	441	492	1608.1	Female
14981	York		Pamunkey	3.6	7	2	443	492	1495.0	Female

Table 16. Total numbers in nine year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2010. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (D. Fowler). Abbreviation: NA, not aged.

Hatchery Year Class	Hatchery Production (millions)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	% Total
1992	0.05		1												1	0.1
1993	0.5	7	2	1											10	1.3
1994	1.6	7	3	9			1								20	2.5
1995	5.3			59	9	8	4	3							83	10.6
1996	5.8			53	62	43	10	4	1						173	22.0
1997	5.9			2	27	78	57	5	4		1				174	22.2
1998	10					13	52	17	13						95	12.1
1999	7.3						14	29	7						50	6.7
2000	8.9						1	5	9		1				16	2.0
2001	9.3								3	4	3				10	1.3
2002	8.4									4	20	7	2		33	4.2
2003	8.7										12	8	1	1	22	2.8
2004	6.6										2	3	2	13	20	2.5
2005	6.0												1	18	19	2.4
2006	7.0													11	11	1.4
2007	6.5															
2008	6.2															
2009	3.8															
2010	3.7															
NA	--					12	3	5	3	1	9	2	2	11	48	6.1
Total	101.6	14	6	124	98	154	142	68	40	9	48	20	8	54	785	100.0

Table 17. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2010) on the James, Chickahominy and Rappahannock rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James	SD	N	Chickahominy	SD	N	Rappahannock	SD	N
1980	0.05	0.192	13	0		5	0		4
1981	0.30	0.707	20	0		4	0		4
1982	0		24	0		6	0.86	7.081	6
1983	0		16	0		4	0.32	0.549	4
1984	0.04	0.173	16	0		4	0.41	0.693	4
1985	0		32	0		8	0		8
1986	0.05	0.224	24	0		6	0.06	0.200	12
1987	0		32	0		8	0.17	0.345	16
1988	0		32	0		8	0		20
1989	0		52	0		8	0.56	0.932	25
1990	0		52	0		8	0.04	0.208	28
1991	0		65	0		10	0		31
1992	0		65	0		10	0		35
1993	0		65	0		10	0.25	0.526	31
1994	0.03	0.162	65	0		10	0.11	0.301	34
1995	0.01	0.087	63	0		10	0		33
1996	0		64	0		10	0.41	0.698	33
1997	0		65	0		10	0.30	0.610	35
1998	0.02	0.122	64	0		10	0.14	0.402	29
1999	0		69	0		10	0.02	0.117	35
2000	0		70	0		10	0.08	0.245	34
2001	0		70	0		10	0.34	0.434	35
2002	0		69	0		10	0		35
2003	0.10	0.303	70	0		10	0.59	0.659	28
2004	0.05	0.195	67	0		10	0.81	0.940	35
2005	0		66	0		10	0.27	0.656	33
2006	0.21	0.441	64	0.23	0.335	10	0.11	0.302	34
2007	0.04	0.255	65	0		10	0.40	0.504	34
2008	0.01	0.087	64	0		10	0.02	0.117	35
2009	0.02	0.121	65	0.07	0.219	10	0.13	0.360	34
2010	0.02	0.121	65	0		10	1.19	1.166	33

Table 18. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2010) on the Mattaponi, Pamunkey, and York rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	Mattaponi	SD	N	Pamunkey	SD	N	York	SD	N
1980	1.76	1.064	21	0.56	0.888	9	1.15	1.014	33
1981	0.37	0.594	16	0.33	0.588	16	0.35	0.582	32
1982	13.03	1.256	16	0.51	0.543	12	4.40	1.502	28
1983	2.82	0.961	16	0.63	0.775	12	1.65	0.970	28
1984	18.05	1.150	16	0.06	0.200	12	4.52	1.694	28
1985	7.53	1.349	32	0.98	1.031	24	3.56	1.415	56
1986	1.10	0.922	24	0		18	0.49	0.774	56
1987	0.33	0.609	24	0		18	0.17	0.477	42
1988	0.05	0.203	40	0		24	0.03	0.161	64
1989	0.71	0.846	40	0		32	0.32	0.666	76
1990	0.57	0.694	40	0.02	0.123	32	0.28	0.551	76
1991	0.33	0.609	50	0.02	0.111	39	0.17	0.467	94
1992	0		39	0		32	0		75
1993	0.31	0.626	50	0		39	0.15	0.474	94
1994	1.73	1.158	50	0.15	0.435	39	0.81	0.989	94
1995	0.28	0.586	50	0.03	0.174	40	0.15	0.451	95
1996	14.66	1.356	49	2.05	1.299	39	5.89	1.570	93
1997	2.25	1.112	50	0.48	0.782	40	1.19	1.038	95
1998	2.33	1.235	48	0.08	0.478	38	0.95	1.103	91
1999	0.26	0.584	47	0		38	0.13	0.441	88
2000	5.77	1.305	39	0.08	0.256	31	1.83	1.331	74
2001	0.58	0.697	49	0.15	0.357	40	0.35	0.577	94
2002	0.23	0.496	48	0.02	0.110	40	0.12	0.374	93
2003	8.57	1.317	50	13.11	1.057	39	9.04	1.295	94
2004	7.52	1.393	47	0.10	0.287	38	2.21	1.448	90
2005	1.66	1.353	50	0.05	0.203	40	0.70	1.092	95
2006	0.93	0.916	48	0.09	0.351	37	0.47	0.760	90
2007	0.30	0.509	47	0		36	0.15	0.393	88
2008	0.11	0.303	50	0		40	0.06	0.225	95
2009	0.02	0.160	47	0		40	0.01	0.115	92
2010	0.97	1.029	50	0.06	0.189	38	0.47	0.823	93

Table 19. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2010. DNR are days that by-catch was not recorded.

Station 1 Date	Live SB	Dead SB	Total SB	Other species	Total
2/16/2010	495	57	552	2	554
2/17/2010	447	76	523	4	527
2/22/2010	131	9	140	1	141
2/23/2010	110	31	141	0	141
3/1/2010	574	105	679	0	679
3/2/2010	204	47	251	2	253
3/8/2010	265	57	322	6	328
3/9/2010	406	37	443	3	446
3/15/2010	118	34	152	16	168
3/16/2010	226	3	229	15	244
3/22/2010	45	19	64	73	137
3/23/2010	46	12	58	85	143
3/29/2010	53	7	60	37	97
3/30/2010	33	0	33	61	94
4/5/2010	25	3	28	308	336
4/6/2010	11	0	11	309	320
4/12/2010	12	2	14	254	268
4/13/2010	8	3	11	270	281
4/19/2010	4	12	16	168	184
4/20/2010	12	3	15	155	170
4/26/2010	6	7	13	294	307
4/27/2010	6	6	12	298	310
5/3/2010	0	1	1	279	280
5/4/2010	0	1	1	215	216
Totals	3237	532	3769	2855	6624
Station 2 Date	Live SB	Dead SB	Total SB	Other Species	Total
2/22/2010	52	16	68	6	74
2/23/2010	30	5	35	5	40
3/1/2010	643	114	757	1	758
3/8/2010	190	51	241	11	252
3/9/2010	86	38	124	8	132
3/15/2010	93	19	112	30	142
3/16/2010	282	42	324	76	400
3/22/2010	39	30	69	127	196
3/23/2010	48	3	51	189	240
3/29/2010	38	10	48	392	440
3/30/2010	DNR	DNR	DNR	DNR	DNR
4/5/2010	16	4	20	405	425
4/6/2010	11	0	11	691	702
4/12/2010	12	0	12	367	379
4/13/2010	12	5	17	339	356
4/19/2010	24	11	35	319	354
4/20/2010	18	8	26	340	366
4/26/2010	19	12	31	430	461
4/27/2010	4	9	13	441	454
5/3/2010	2	4	6	247	253
5/4/2010	3	5	8	209	217
Totals	1622	386	2008	4633	6641

Table 20. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2010.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/23/2010	31	7	38	3	41
2/24/2010	277	75	352	19	371
3/1/2010	856	132	988	93	1081
3/2/2010	362	125	487	52	539
3/8/2010	101	27	128	18	146
3/9/2010	52	25	77	9	86
3/15/2010	47	55	102	24	126
3/16/2010	59	101	160	45	205
3/22/2010	35	48	83	38	121
3/23/2010	12	24	36	89	125
3/29/2010	7	24	31	89	120
3/30/2010	12	21	33	67	100
4/5/2010	0	16	16	842	858
4/6/2010	9	11	20	801	821
4/12/2010	2	8	10	440	450
4/13/2010	1	6	7	346	353
4/19/2010	2	12	14	477	491
4/20/2010	7	8	15	442	457
4/26/2010	0	8	8	406	414
4/27/2010	1	2	3	659	662
5/3/2010	1	6	7	768	775
5/4/2010	0	9	9	719	728
Totals	1874	750	2624	6446	9070

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2010.

Date	Live SB	Dead SB	Total SB	Other species	Total
3/1/2010	36	10	46	110	156
3/2/2010	42	23	65	77	142
3/8/2010	43	9	52	147	199
3/9/2010	46	16	62	190	252
3/15/2010	15	41	56	375	431
3/16/2010	61	117	178	78	256
3/22/2010	25	140	165	41	206
3/23/2010	31	116	147	114	261
3/29/2010	8	28	36	311	347
4/5/2010	52	290	342	67	409
4/6/2010	25	134	159	58	217
4/12/2010	2	9	11	239	250
4/13/2010	4	12	16	194	210
4/19/2010	8	23	31	228	259
4/20/2010	3	17	20	224	244
4/26/2010	1	12	13	158	171
4/27/2010	0	11	11	199	210
5/3/2010	4	11	15	68	83
5/4/2010	1	11	12	145	157
Totals	407	1030	1437	3023	4460

Table 22. Summary of historical catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia. Historical data are taken from the voluntary logbooks of Mr. M. Delano, Urbanna, Virginia.

Year	Effort (10 ³ m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve (SE)
1980	43.4	35	0.121	0.036	1.79
1981	112.1	57	0.032	0.011	1.89
1982	82.3	51	0.046	0.009	1.68
1983	106.7	59	0.093	0.031	0.59
1984	30.5	48	0.139	0.033	0.60
1985	77.2	60	0.136	0.029	1.83
1986	34.9	43	0.155	0.039	2.18
1987	23.3	37	0.090	0.023	0.97
1988	23.2	53	0.073	0.025	1.25
1989	16.2	44	0.856	0.123	6.19
1990	41.3	55	0.092	0.023	1.31
1991	25.9	54	0.129	0.022	1.13
1992	8.6	51	0.299	0.044	1.44
Geometric mean					1.45

Table 23. Summary of recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia.

Year	Effort (10 ³ m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1998	3.8	----	0.053	0.020	1.46
1999	5.7	42	0.055	0.026	1.30
2000	6.6	73	0.141	0.042	1.75
2001	6.6	72	0.167	0.070	5.77
2002	5.4	57	0.110	0.028	3.08
2003	7.2	72	0.311	0.094	7.10
2004	5.2	65	0.232	0.107	7.06
2005	5.5	65	0.164	0.054	3.69
2006	6.7	75	0.088	0.037	3.01
2007	5.2	64	0.130	0.042	2.60
2008	6.1	64	0.175	0.045	3.12
2009	5.6	50	0.259	0.093	5.36
2010	5.6	50	0.088	0.027	2.03
Geometric mean					3.14

Table 24. Historical catch and effort data of American shad captured by staked gill nets in the York River, Virginia. 1950s historical data are taken from the voluntary logbooks of Malvin Green, Aberdeen Creek, Virginia. The data were originally recorded as numbers of female shad per meter of net per day and were converted to weight (kg) of female shad per meter of net per day, assuming an average female weight of 1.45kg. Catch rates were multiplied by 2.16 to adjust for the lower fishing power of multifilament nets compared to current monofilament nets. 1980s historical data are taken from the voluntary logbooks of Mr. R. Kellum, Achilles, Virginia.

Year	Effort (10 ³ m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1953	36.0	56	0.549	0.443	14.88
1954	45.5	54	0.699	0.434	14.04
1955	40.1	55	0.310	0.270	8.70
1956	68.8	85	1.201	0.663	33.95
1957	56.2	65	0.955	0.667	26.14
Geometric mean					17.44
1980	79.4	44	0.556	0.268	10.15
1981	114.7	51	0.259	0.121	4.35
1982	86.4	44	0.326	0.101	5.31
1983	121.3	40	0.212	0.066	3.06
1984	171.4	48	0.548	0.139	8.21
1985	205.4	49	0.227	0.091	4.61
1986	185.2	38	0.145	0.055	2.17
1987	152.9	37	0.088	0.039	1.78
1988	126.2	40	0.134	0.028	1.34
1989	146.3	55	0.397	0.131	4.92
1990	106.9	38	0.951	0.037	1.31
1991	77.8	40	0.111	0.062	2.72
1992	60.8	41	0.079	0.041	1.60
Geometric mean					3.22

Table 25. Summary of recent catch and effort data of American shad by staked gill nets in the York River, Virginia.

Year	Effort (10 ³ m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1998	5.7	78	1.080	0.190	14.71
1999	6.3	65	0.209	0.075	5.42
2000	6.7	76	0.276	0.086	7.52
2001	6.3	79	0.627	0.163	12.97
2002	6.7	70	0.306	0.073	7.47
2003	6.0	70	0.390	0.111	8.98
2004	4.9	65	0.448	0.157	9.72
2005	5.5	73	0.135	0.063	4.64
2006	5.5	62	0.146	0.042	2.85
2007	5.8	70	0.243	0.069	5.04
2008	5.4	65	0.228	0.050	3.28
2009	6.0	69	0.131	0.042	2.92
2010	6.0	44	0.227	0.055	4.19
Geometric mean					6.02

Table 26. Summary of historical catch and effort data of American shad by staked gill nets in the James River, Virginia. Historical data are taken from the voluntary logbooks of the Brown family, Rescue, Virginia.

Year	Effort (10 ³ m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1980	20.5	41	2.239	0.699	29.20
1981	67.7	41	0.547	0.130	5.20
1982	49.3	35	0.331	0.115	4.20
1983	94.0	57	1.274	0.297	16.50
1984	89.7	50	0.897	0.036	19.30
1985	91.3	45	0.295	0.103	4.90
1986	31.5	26	1.289	0.152	6.10
1987	30.1	30	0.352	0.085	2.70
1988	19.1	20	0.487	0.193	9.30
1989	31.5	30	0.331	0.176	6.40
1990	29.7	25	0.184	0.079	2.10
1991	28.3	40	0.138	0.062	1.90
1992	59.8	50	0.562	0.232	7.70
Geometric mean					6.40

Table 27. Summary of recent catch and effort data of American shad by staked gill nets in the James River, Virginia

Year	Effort (10 ³ m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1998	3.8	50	0.198	0.051	2.57
1999	6.0	66	0.183	0.042	2.99
2000	7.2	70	0.279	0.086	6.61
2001	6.8	78	0.285	0.064	5.01
2002	6.5	71	0.205	0.054	5.62
2003	6.6	79	0.284	0.112	9.34
2004	6.0	78	0.234	0.090	7.41
2005	5.3	72	0.357	0.099	7.16
2006	4.6	54	0.078	0.032	1.74
2007	5.5	58	0.159	0.068	4.45
2008	4.6	58	0.069	0.025	1.51
2009	6.6	55	0.130	0.035	2.69
2010	6.6	57	0.513	0.082	6.90
Geometric mean					4.26

Table 28. Catch comparison of primary and secondary net on the James River in 2010. Abbreviations: N = number; TL = total length.

Catches of American shad	Primary Net	Secondary Net
Sampling Dates	16 Feb. – 4 May	22 Feb. – 4 May
Total Fish	447	94
Total Weight	625.8 kg	132.8 kg
Pre-spawn females	383	78
Males	63	13
Post-spawn Females	1	3
Largest catch of pre-spawn females (N)	29 March (96)	30 March (19)
Spawning run duration (Dates)	57 Days (1 Mar. – 26 Apr.)	35 Days (16 Mar. – 19 Apr.)
Biological Characteristics		
Mean age (males/females)	5.9 / 5.3	5.3 / 5.4
Mean total length at age (males/females)	478.2 - 539.0 mm TL/ 448.0 - 545.5 mm TL	449.3 - 482.0 mm TL/ 477.4 - 513.3 mm TL
Mean total weight at age (males/females)	1.3 - 1.7 kg / 1.1 – 1.9 kg	1.0 – 1.3 kg / 1.3 – 1.7 kg
Percentage of “repeat spawners”	43.4%	47.1%
Hatchery evaluation		
Hatchery prevalence	34.9% (52 of 149 fish)	38.7% (12 of 31 fish)
Year classes present in sample	2004,2005,2006	2003,2004,2005,2006
By-catch	15 species = 6624 fish	14 species = 6641 fish
Catch Indices	6.90	1.35

Figure 1. Commercial landings of American shad along the Atlantic coast and in Virginia since 1950. Data source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.

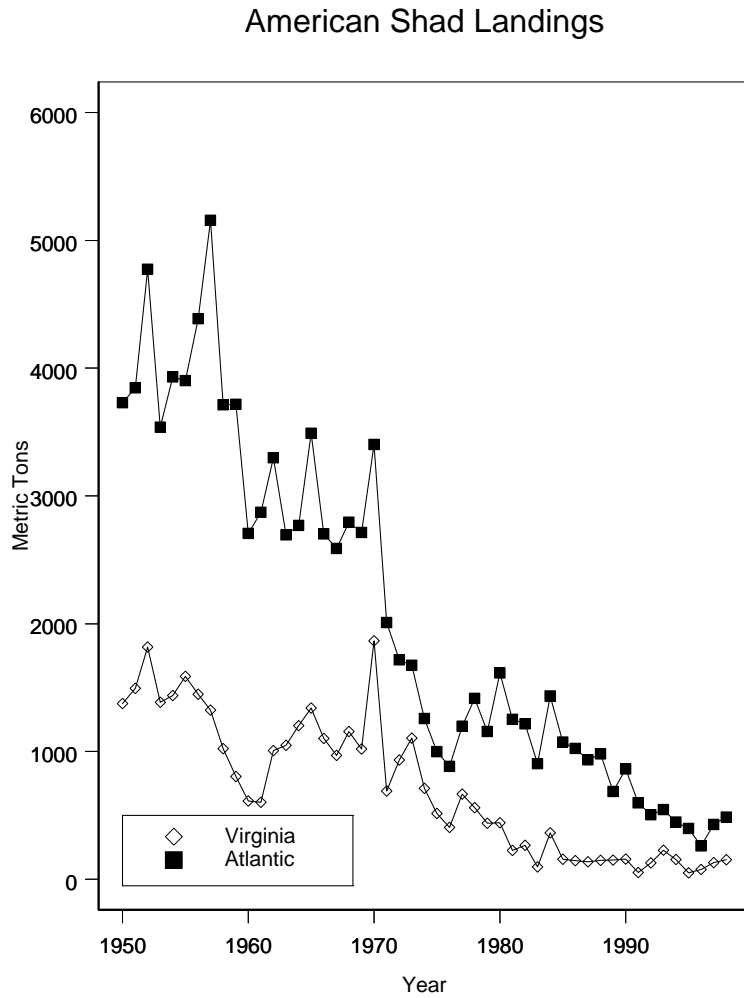


Figure 2. Number and location of staked gill nets on the James River in 1983.

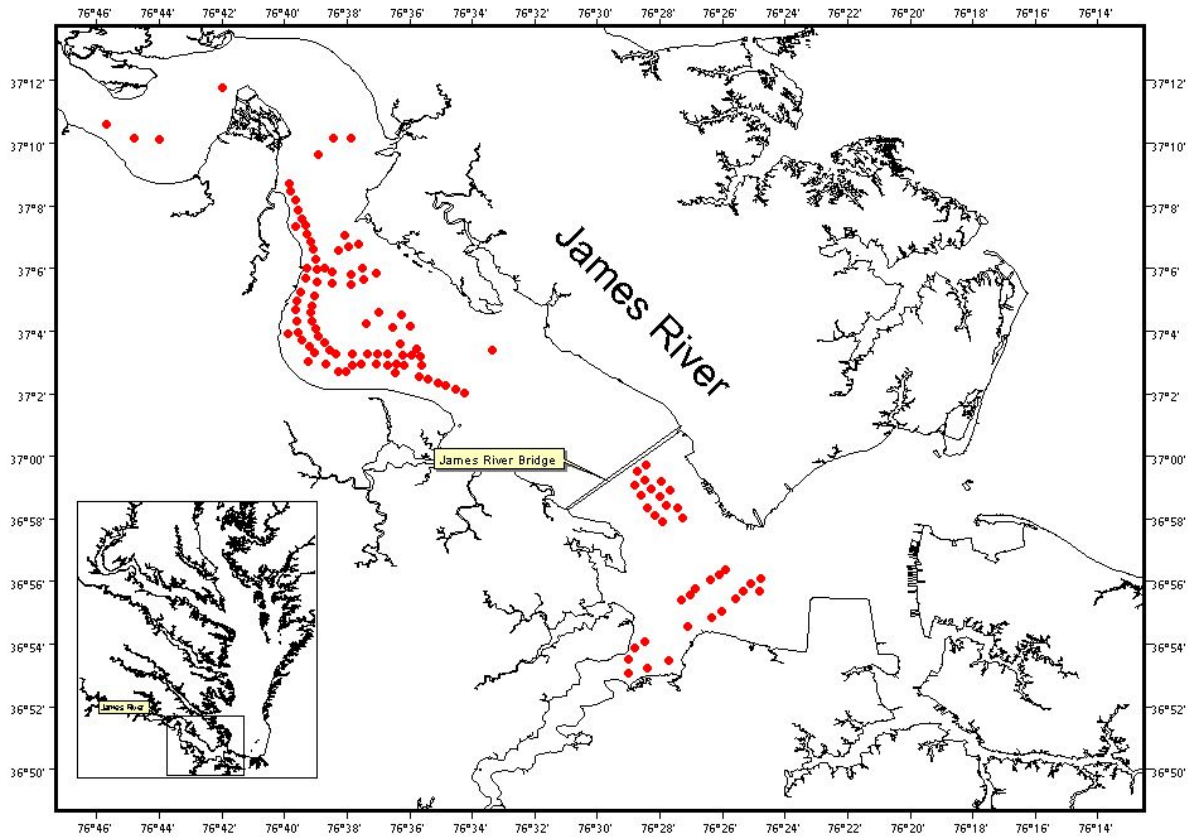


Figure 3. Number and location of staked gill nets on the York River in 1983.

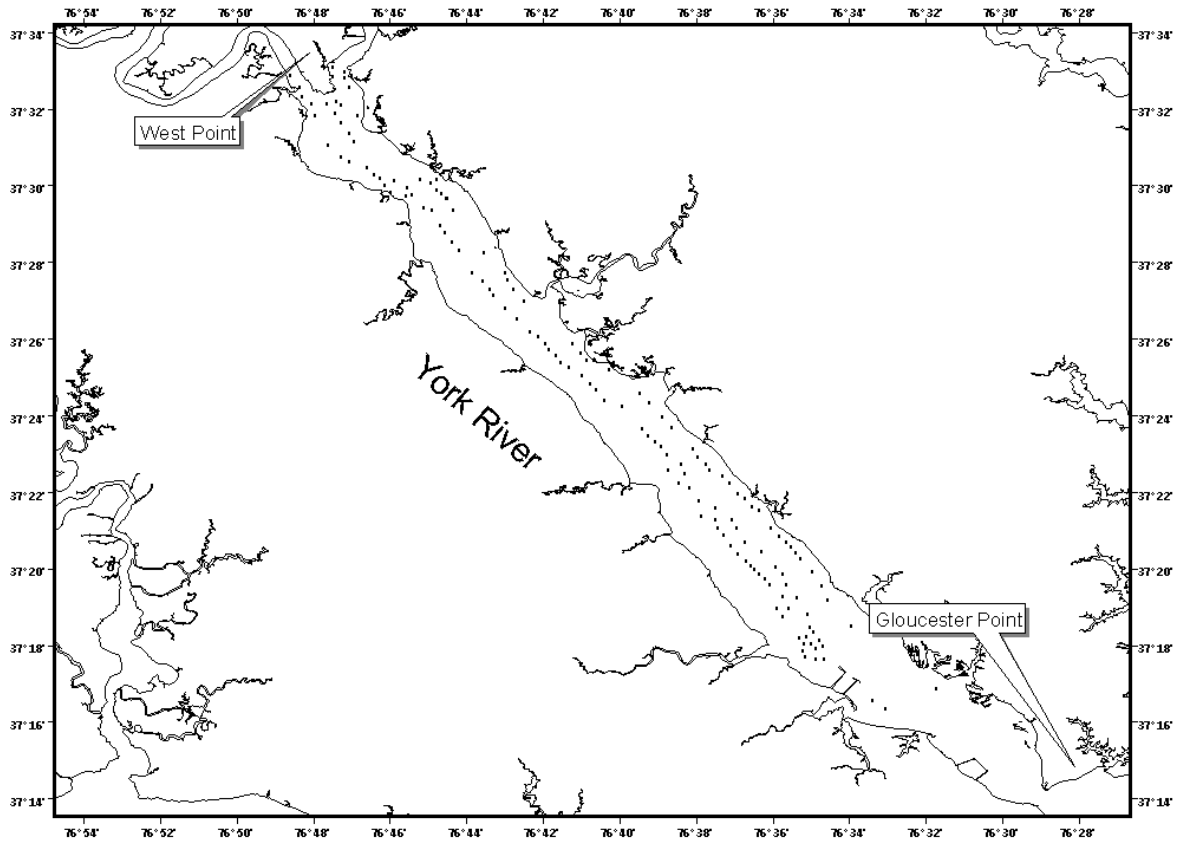


Figure 4. Number and location of staked gill nets on the Rappahannock River in 1983.

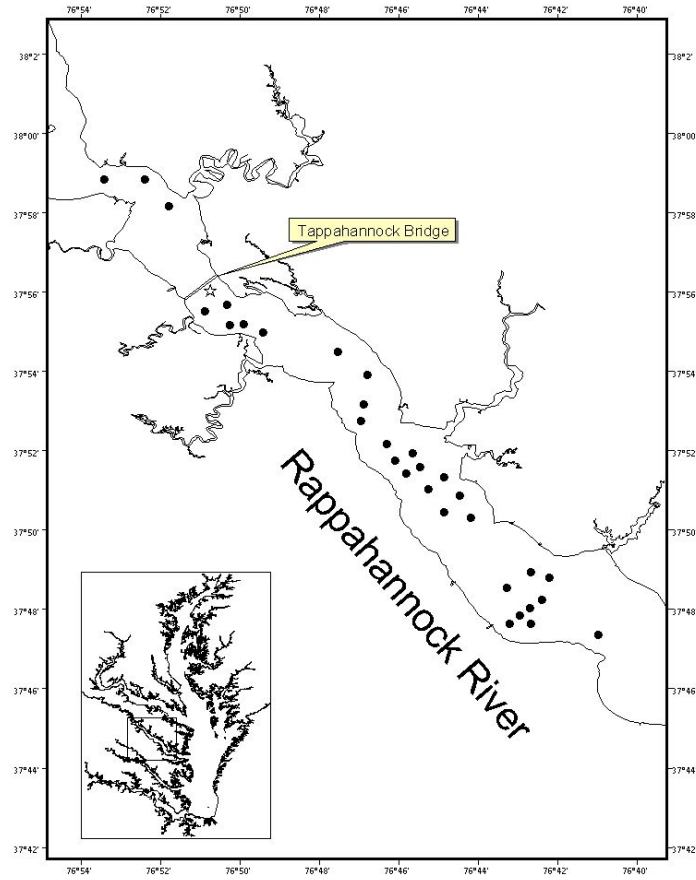


Figure 5. Location of the staked gill nets fished by Mr. Marc Brown on the James River.

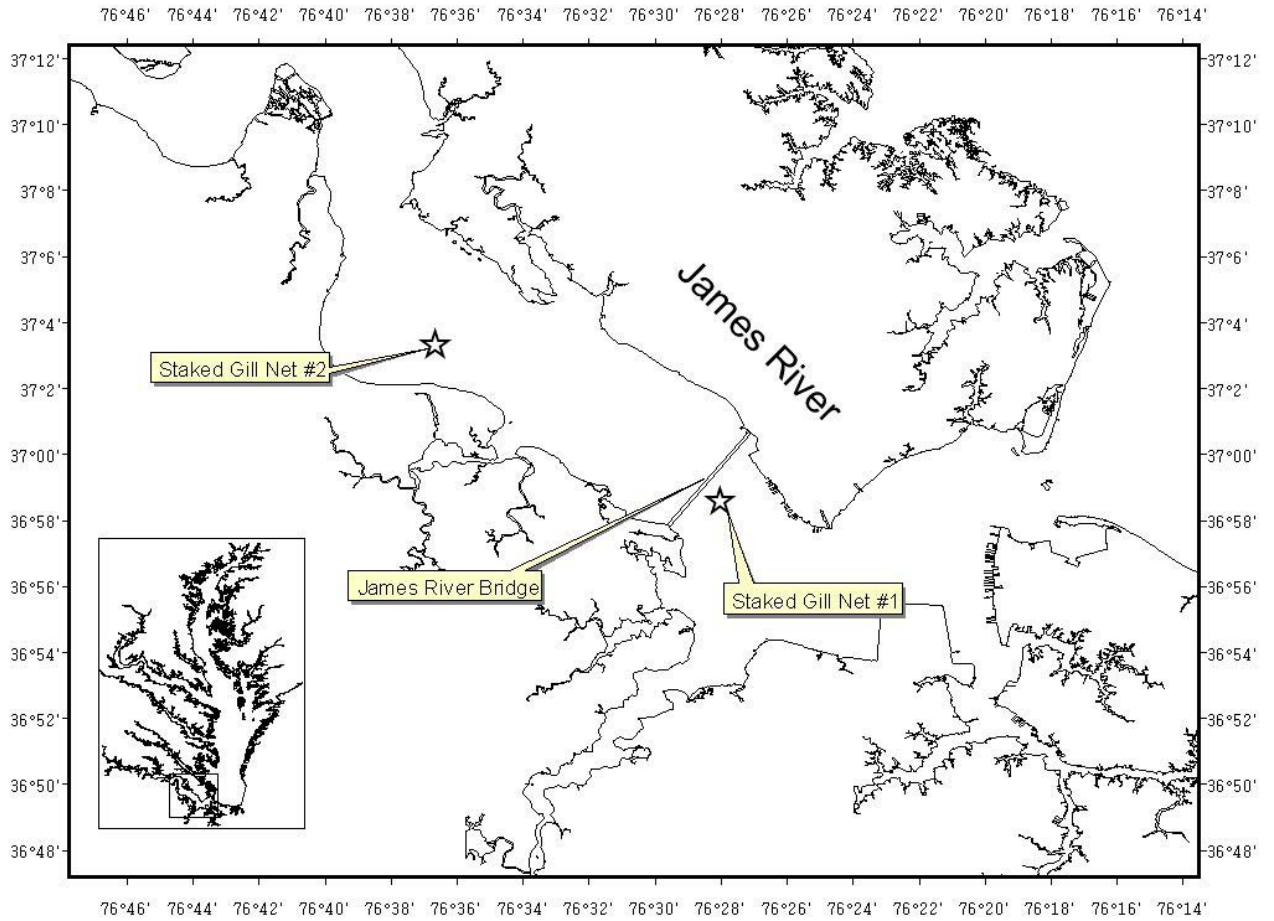


Figure 6. Location of the staked gill net fished by Mr. Raymond Kellum on the York River.

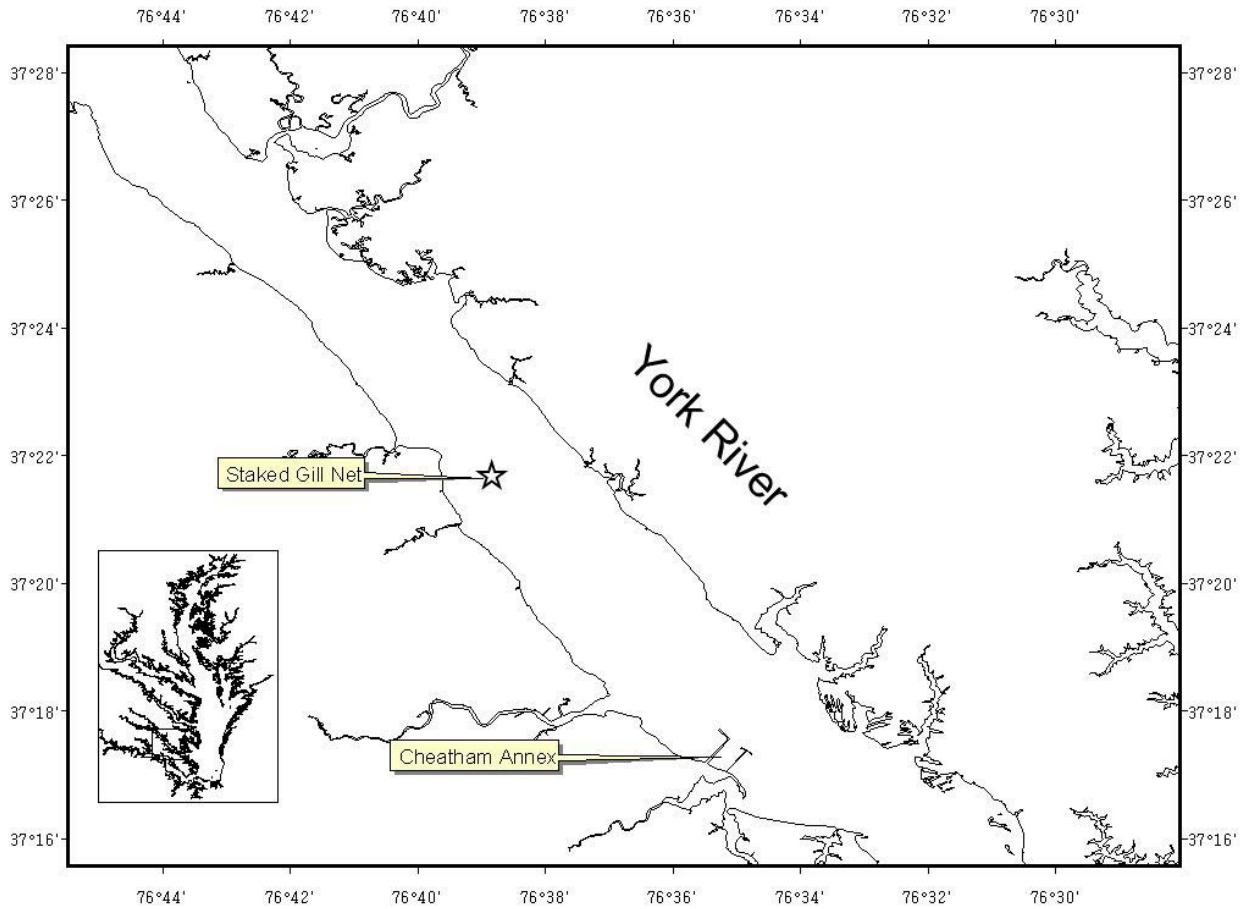


Figure 7. Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River.

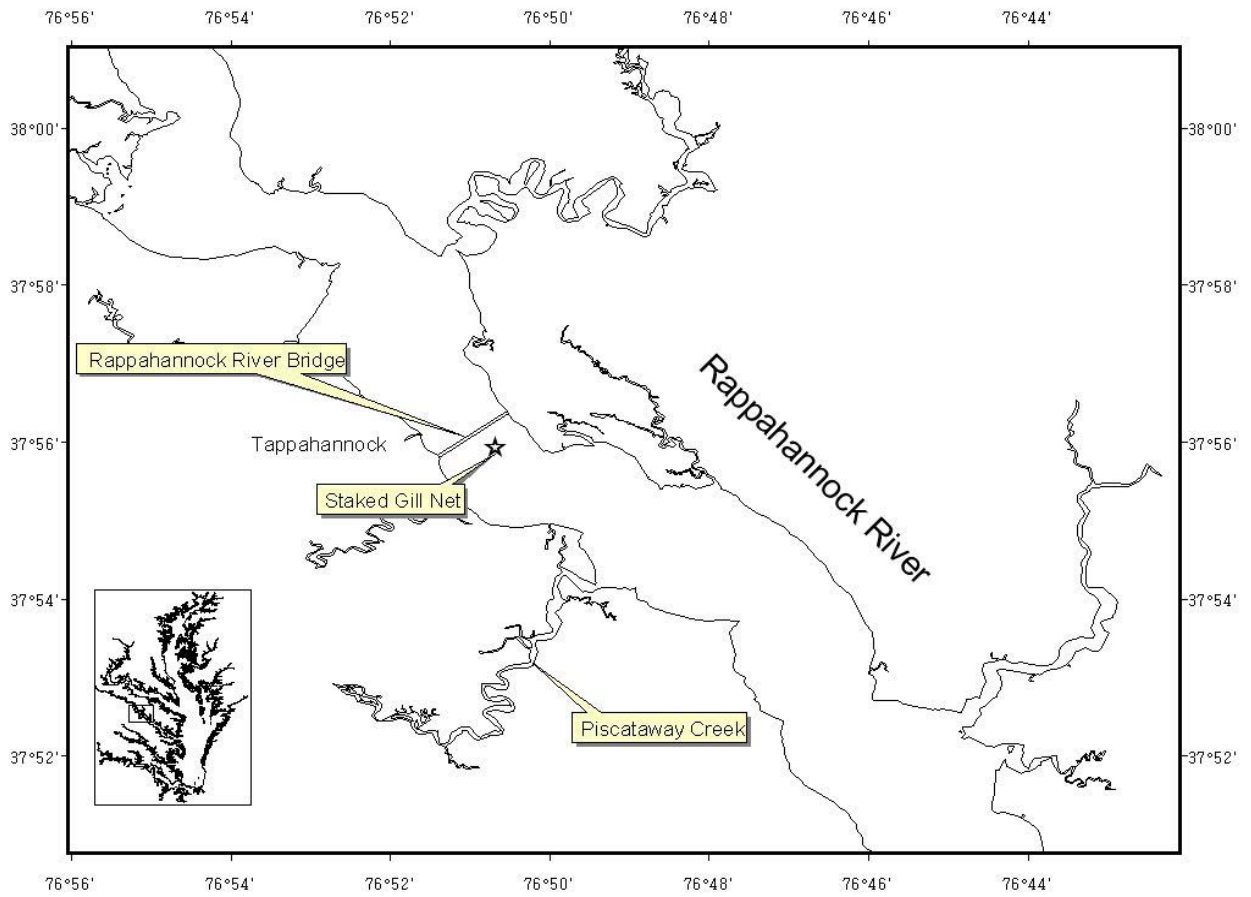


Figure 8.1. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the James River: station 1, spring 2010.

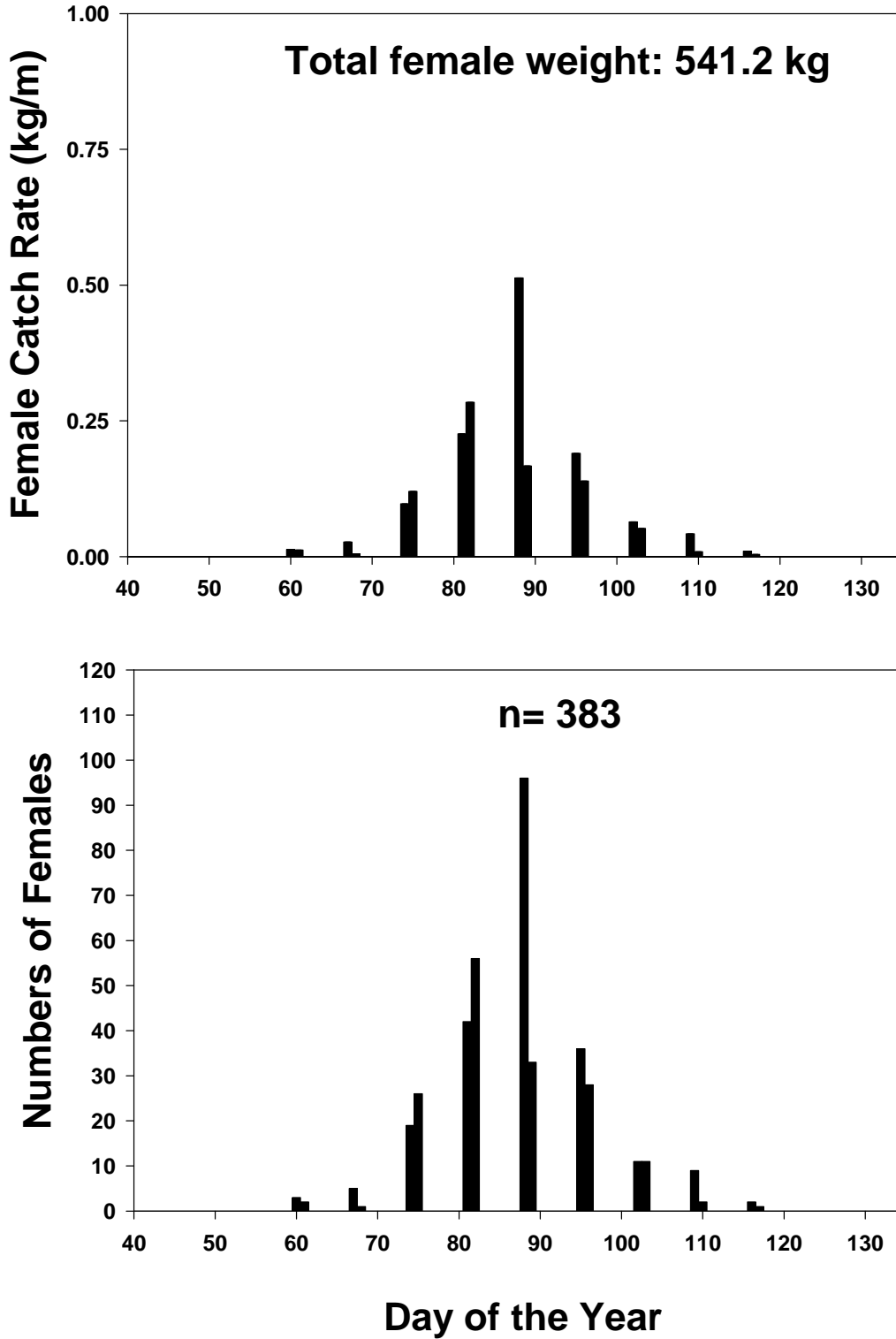


Figure 8.2. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the James River: station 2, spring 2010.

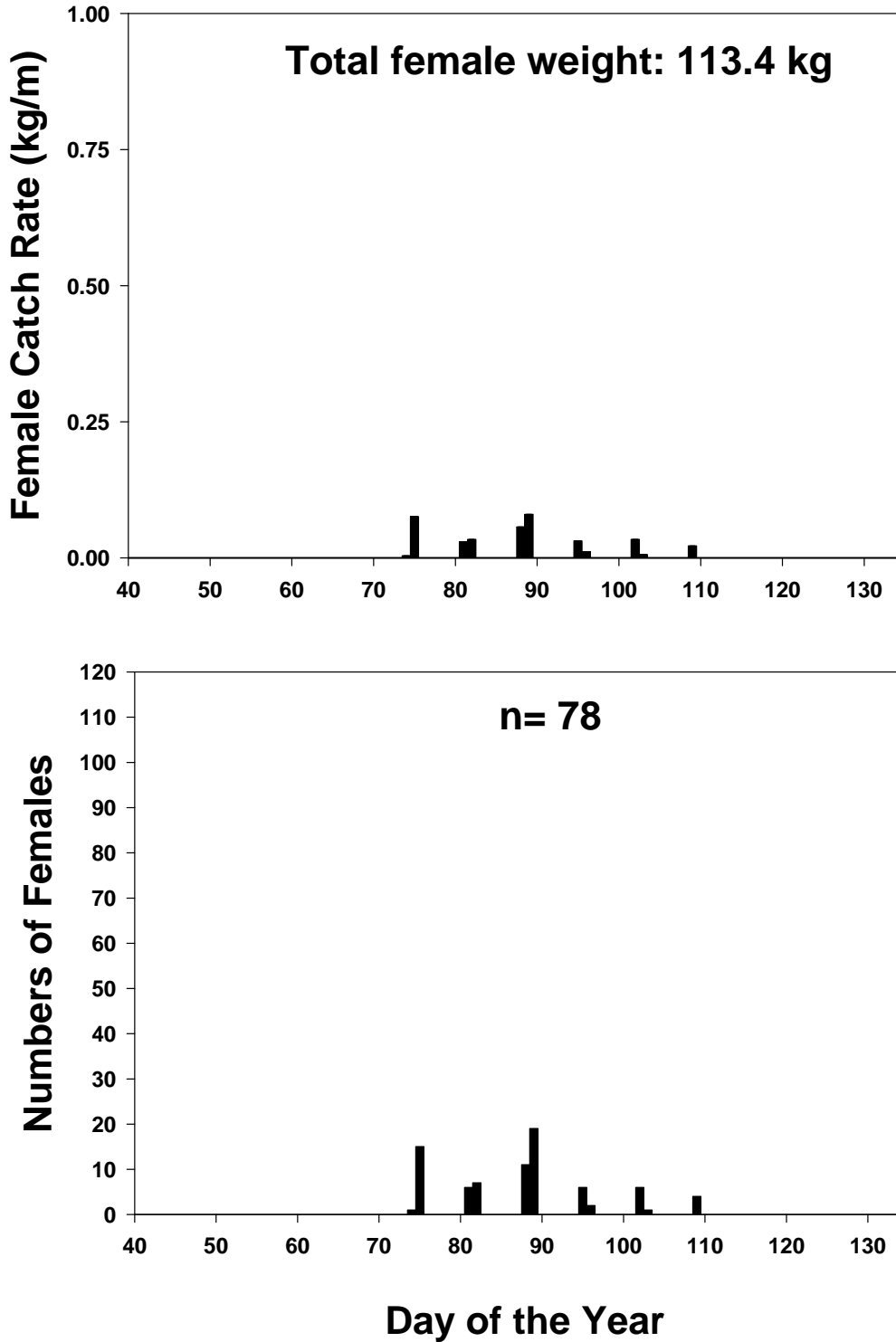


Figure 9. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the York River, spring 2010.

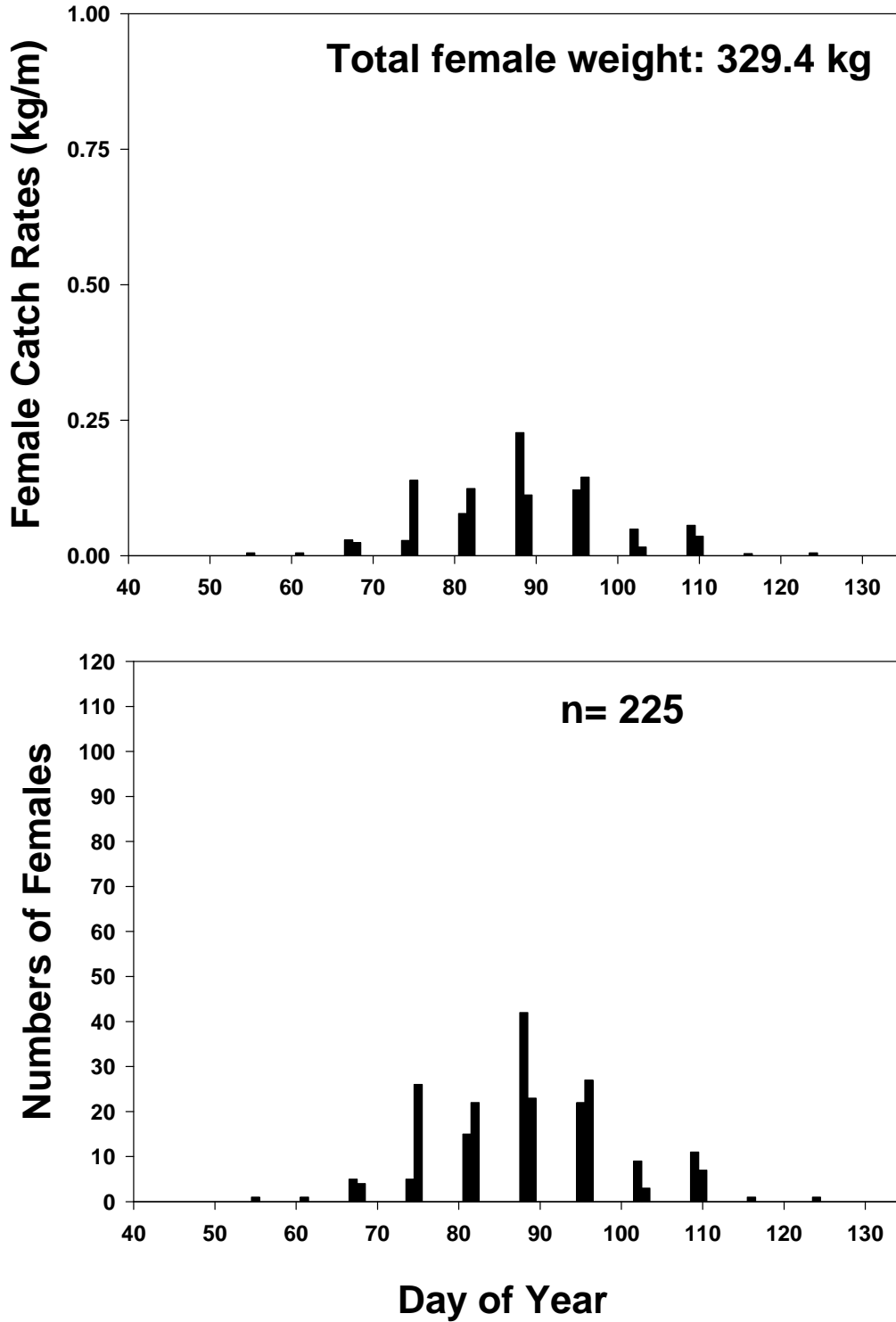


Figure 10. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the Rappahannock River, spring 2010.

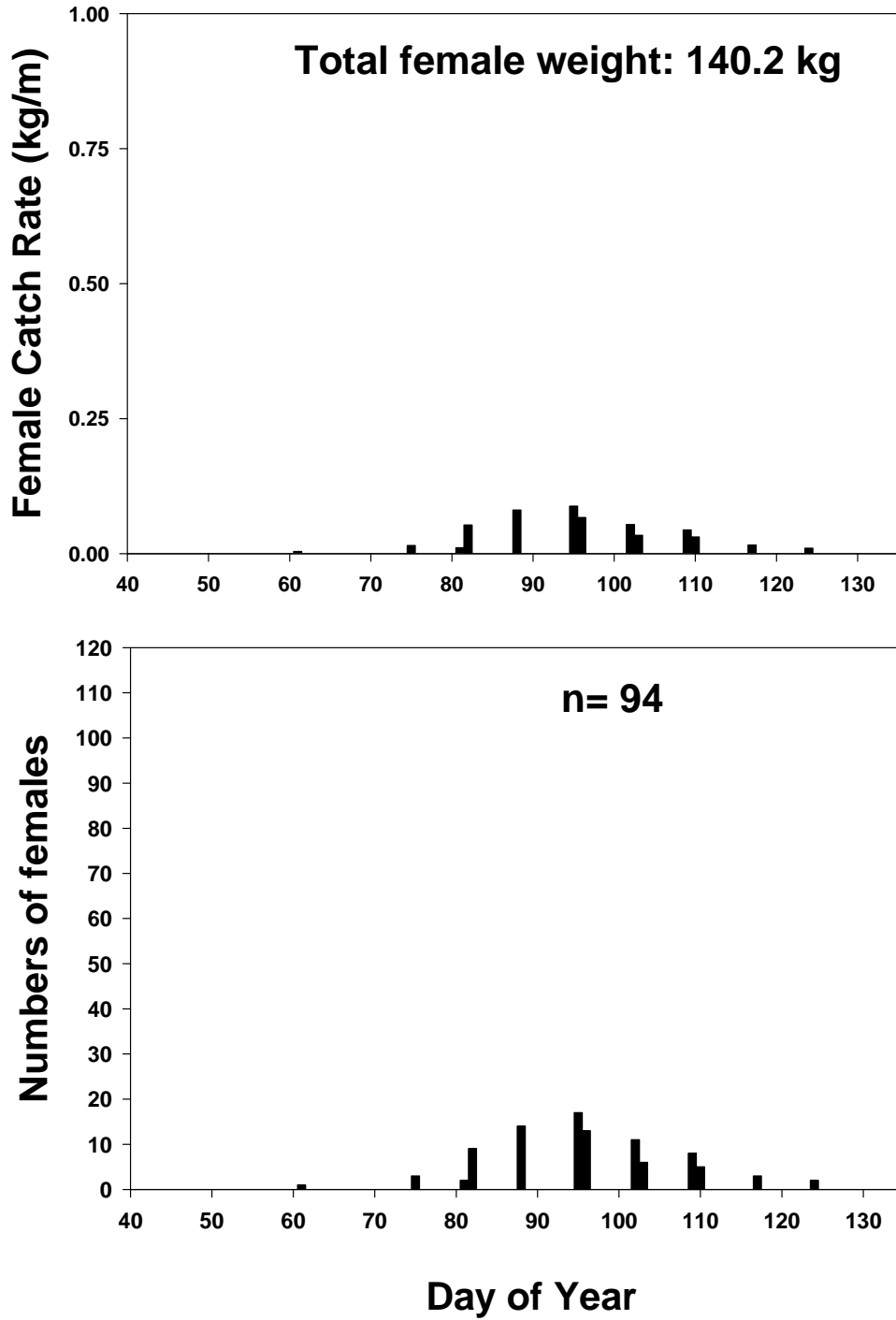


Figure 11.1. Catch rates and total numbers of male American shad taken by staked gill nets in the James River: Station 1, spring 2010.

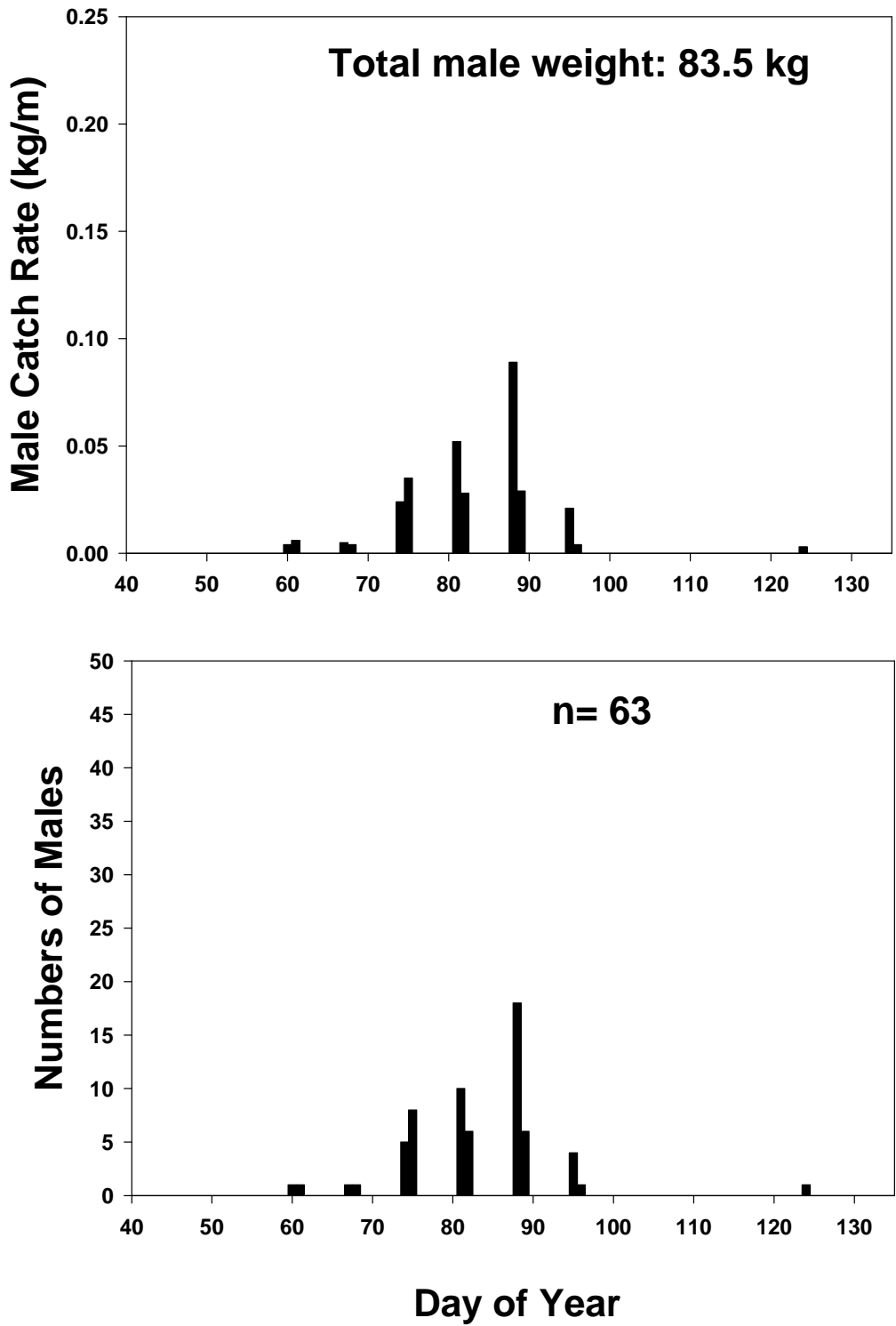


Figure 11.2. Catch rates and total numbers of male American shad taken by staked gill nets in the James River: Station 2, spring 2010.

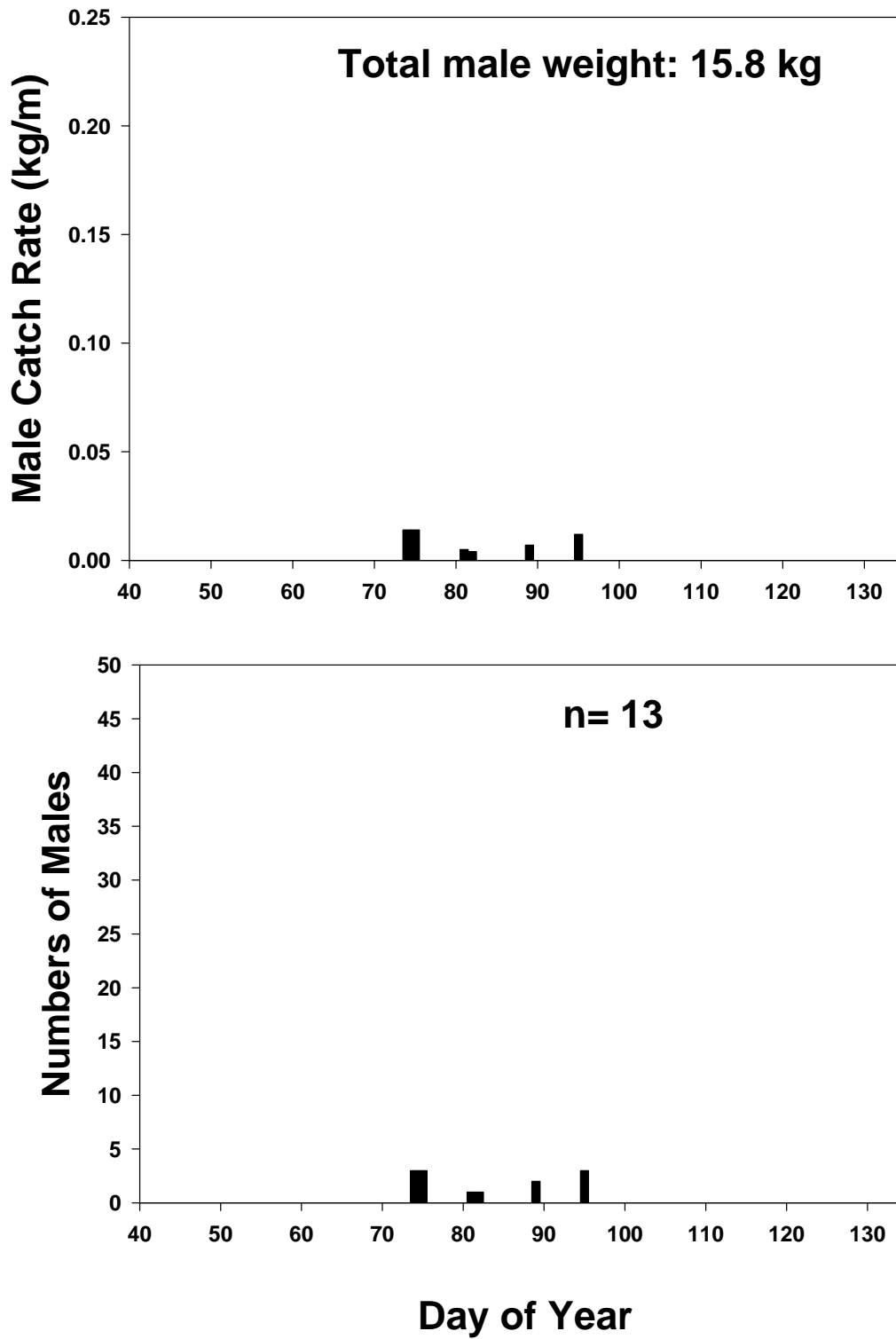


Figure 12. Catch rates and total numbers of male American shad taken by staked gill nets in the York River, spring 2010.

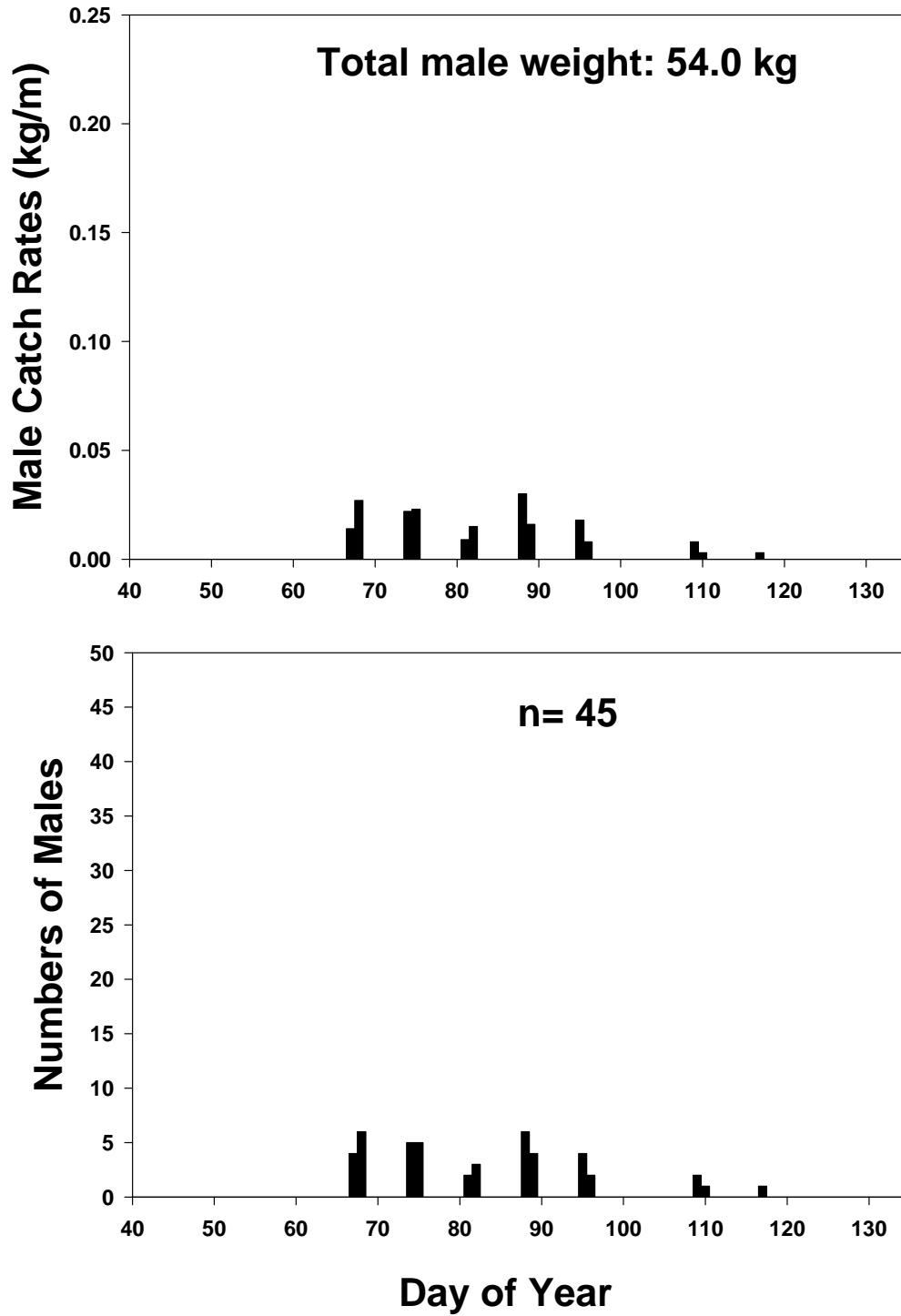


Figure 13. Catch rates and total numbers of male American shad taken by staked gill nets in the Rappahannock River, spring 2010.

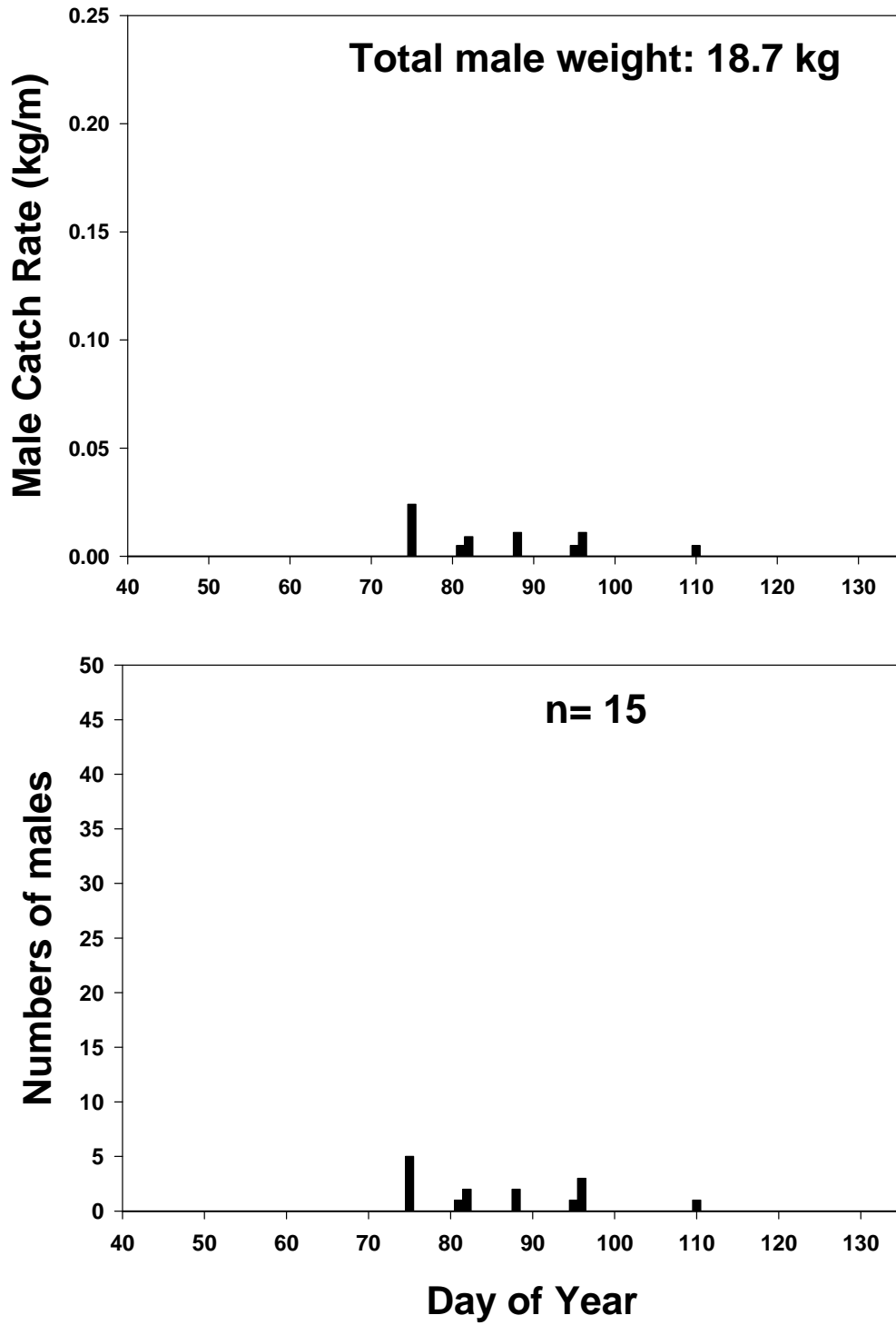


Figure 14. Total length (mm) frequency distributions for American shad captured in staked gill nets on the James River, spring 2010.

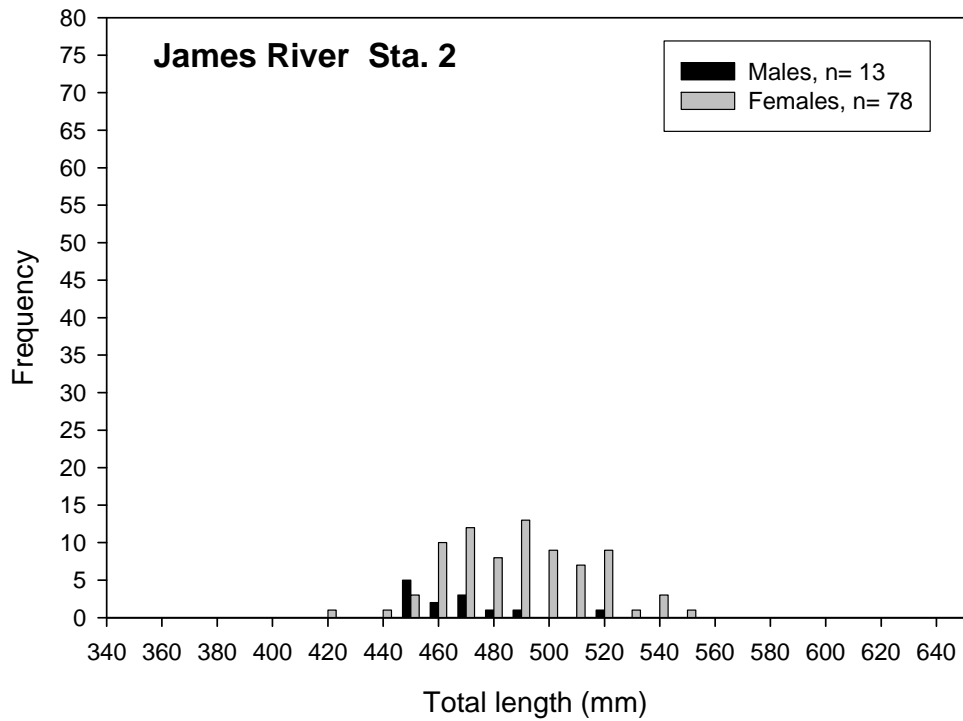
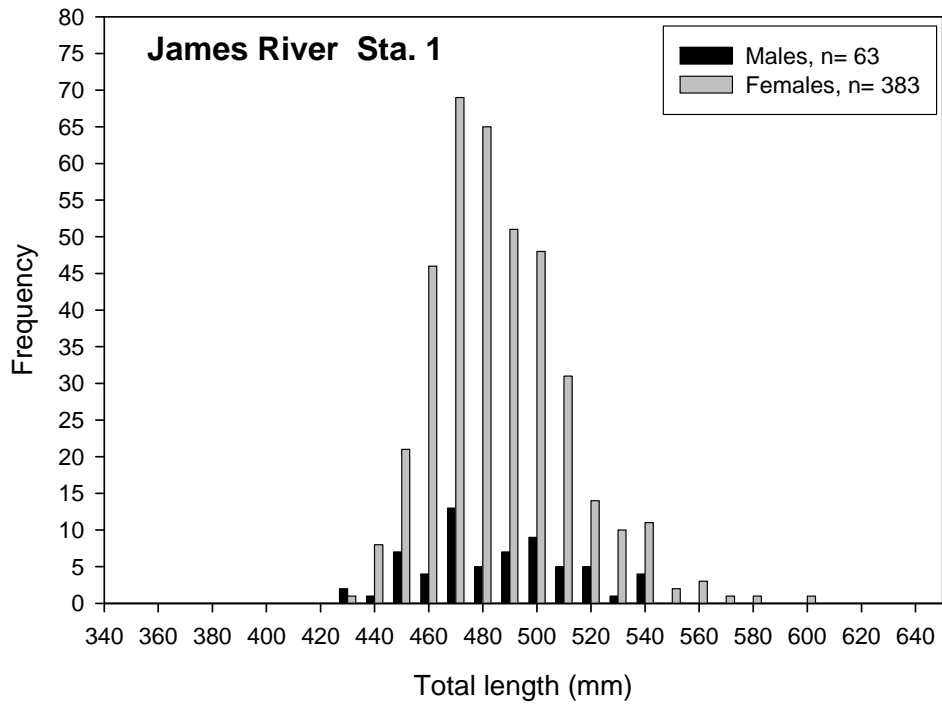


Figure 15. Total length (mm) frequency distributions for American shad captured in staked gill nets on the York and Rappahannock rivers, spring 2010.

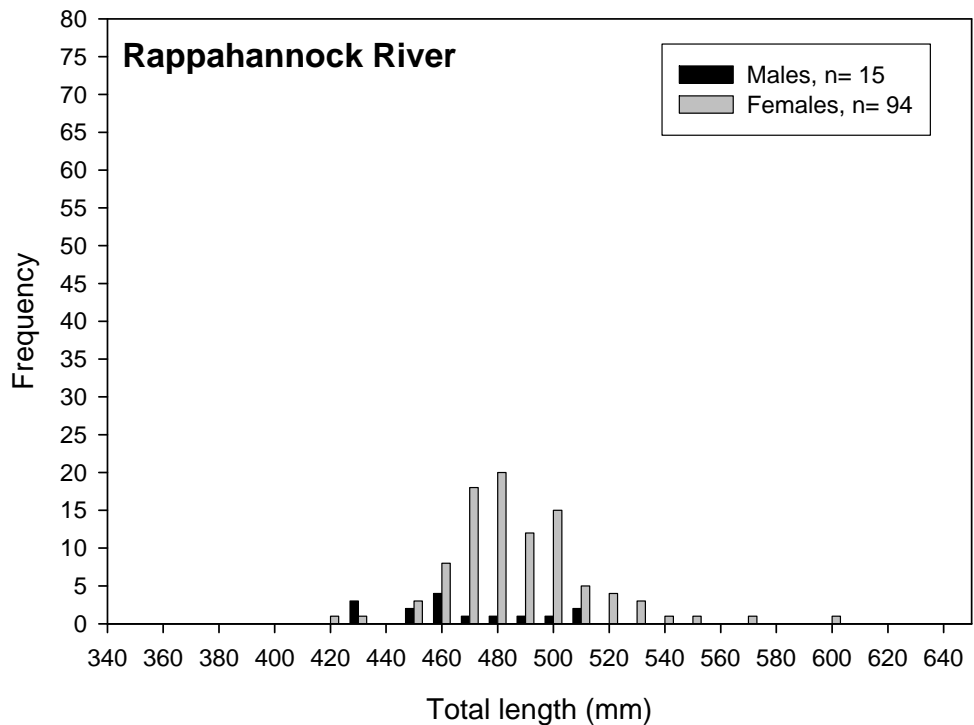
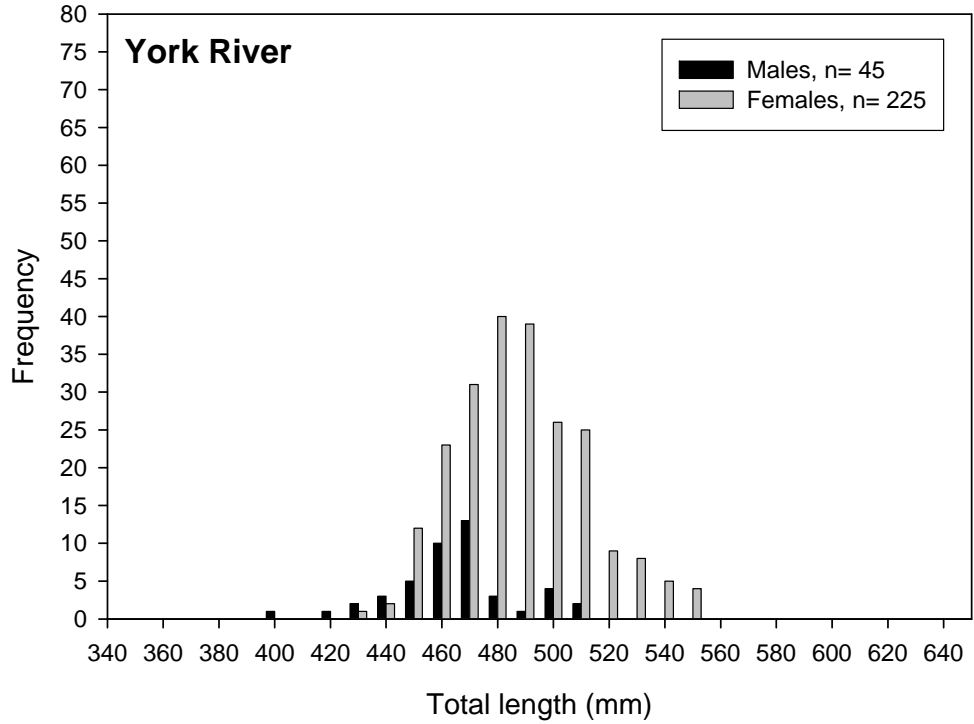


Figure 16. Total numbers of female American shad caught and surface temperature recorded at staked gill nets in the York and Rappahannock rivers, spring 2010.

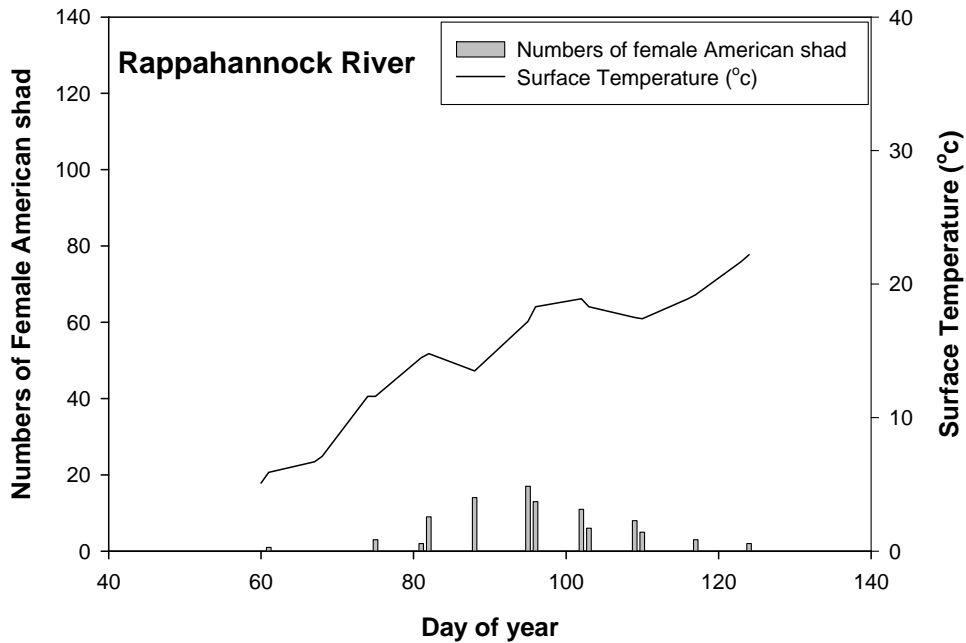
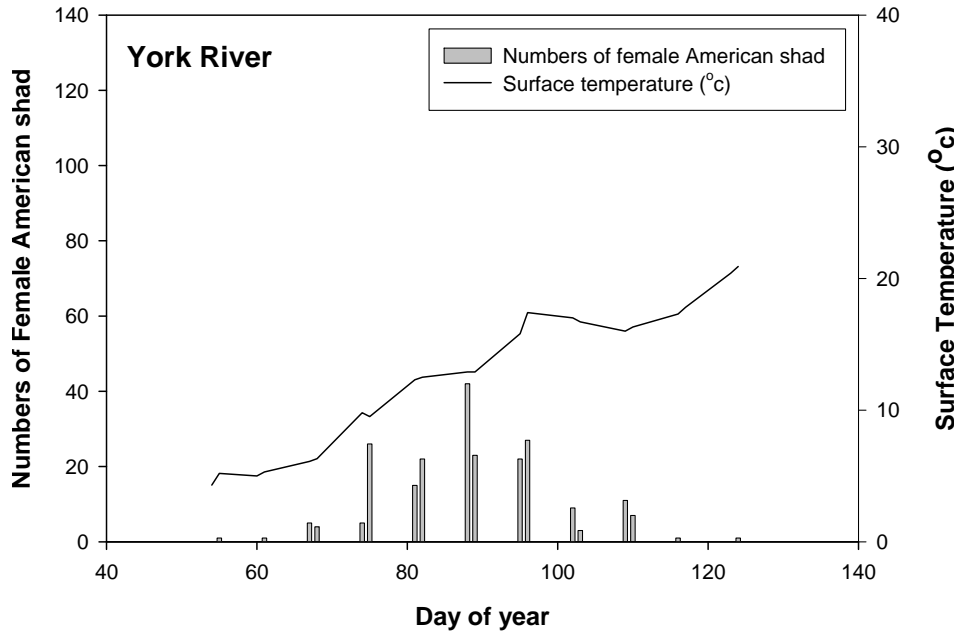


Figure 17. Total numbers of female American shad caught and surface temperature recorded at staked gill nets in the James River, spring 2010.

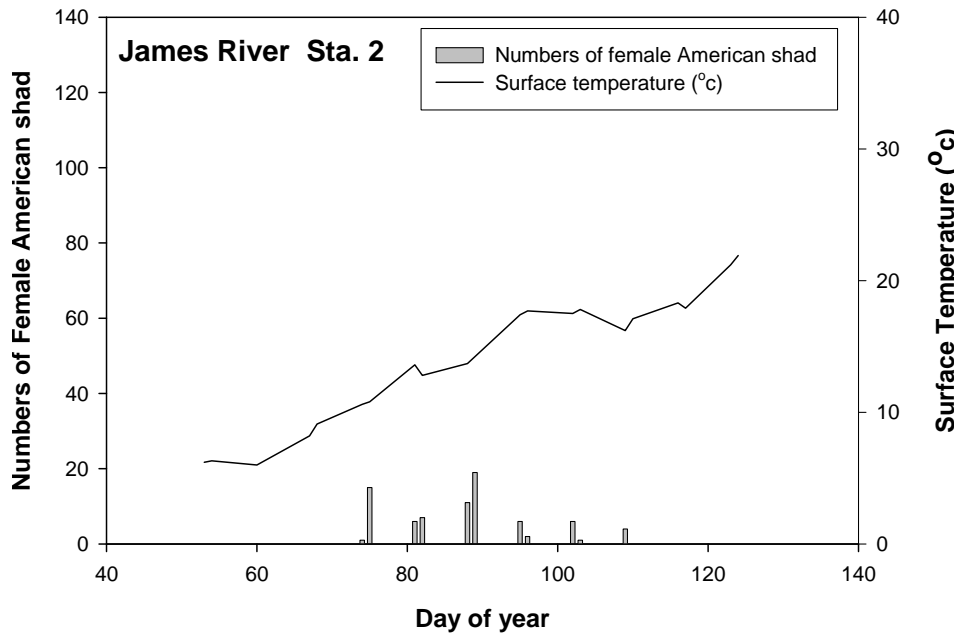
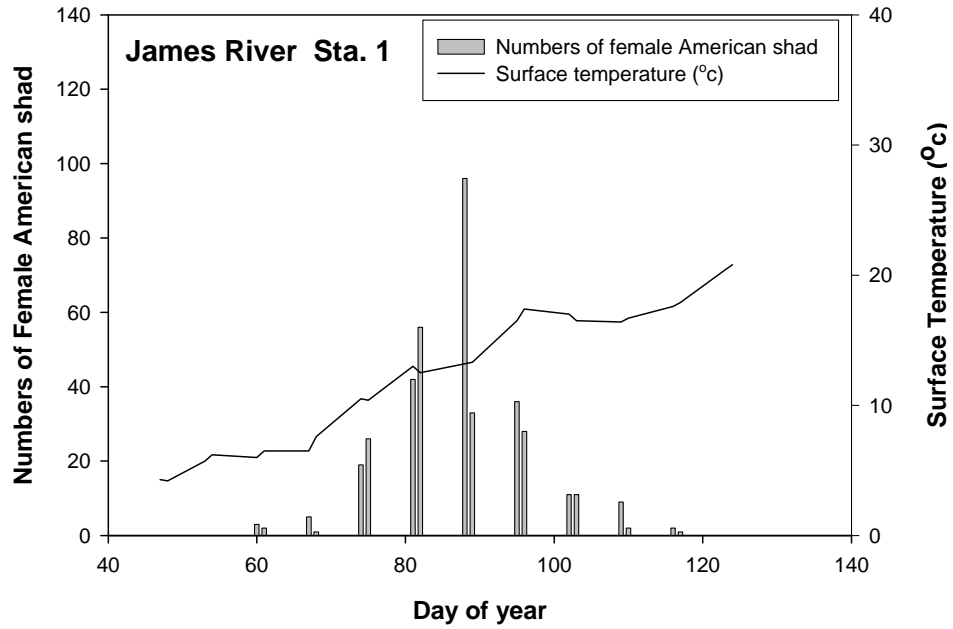


Figure 18. Mean age of females taken in staked gill nets in the James, York, and Rappahannock Rivers, 1998-2010.

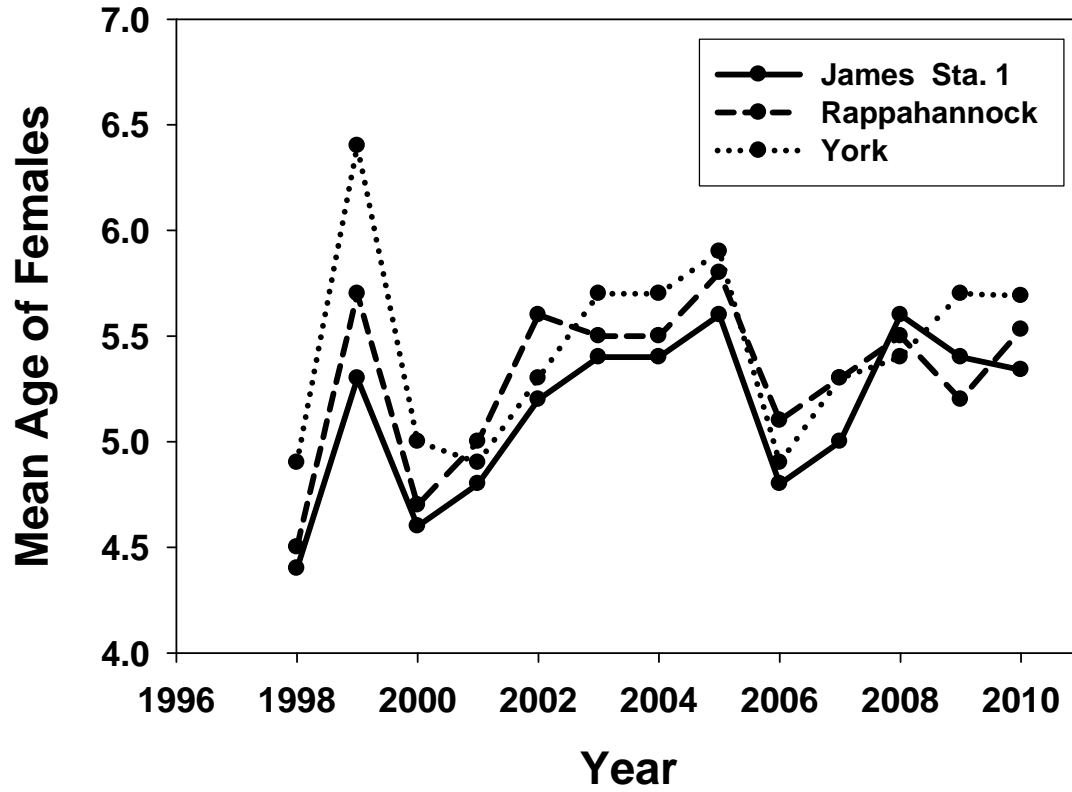


Figure 19. Mean age of females and the proportion of age-4 recruits in staked gill nets, 1998-2010.

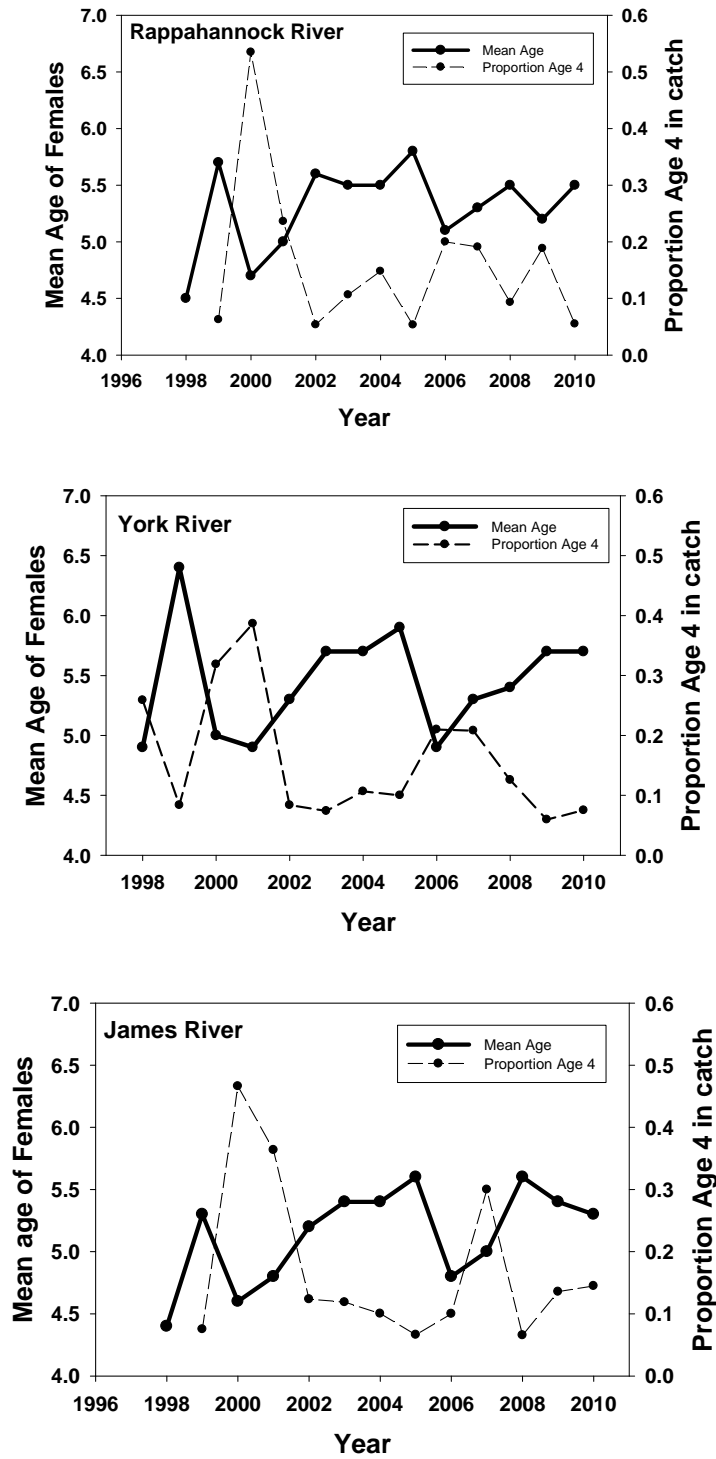


Figure 20. Comparison of the James River catch index to the percent of specimens with OTC hatchery marks.

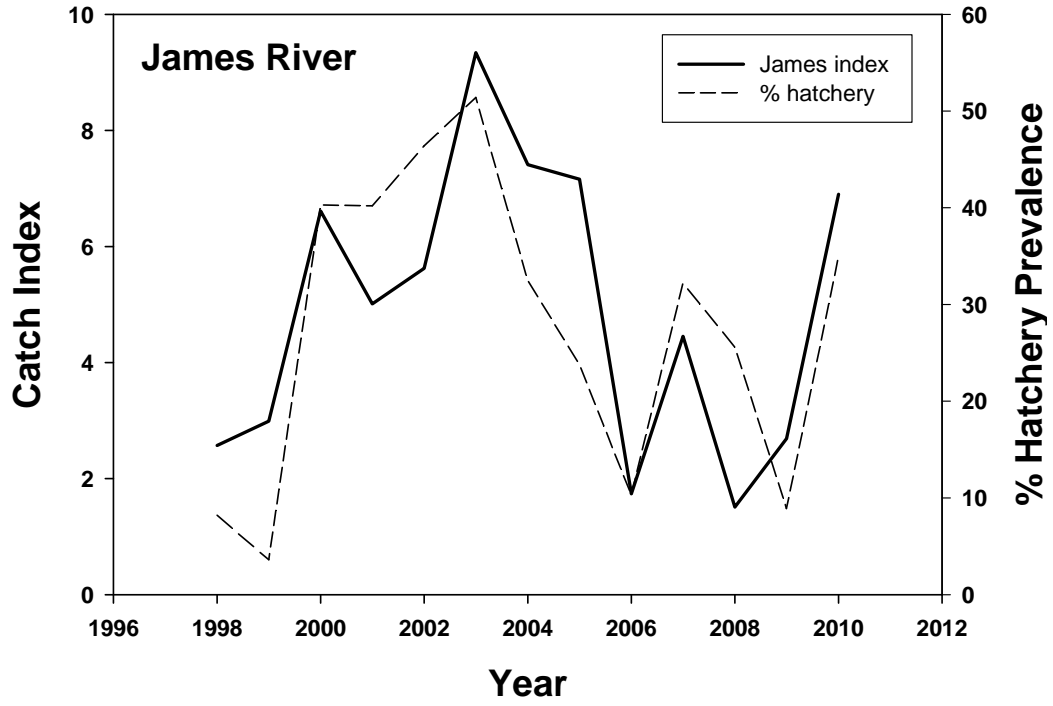


Figure 21. The index of juvenile abundance of American shad in the York River system as estimated by daylight seine surveys, 1980-2010. The index is the geometric mean number of American shad juveniles per seine haul.

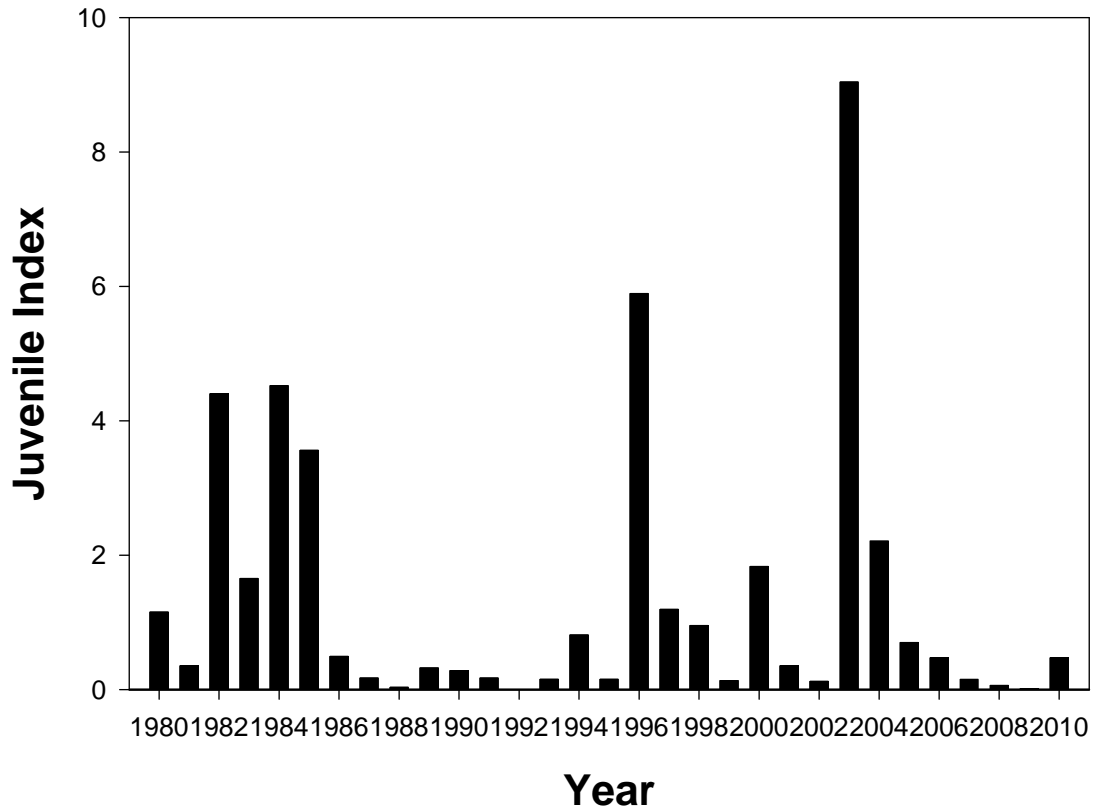


Figure 22. The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by daylight seine surveys, 1980-2010. The index is the geometric mean number of American shad juveniles per seine haul.

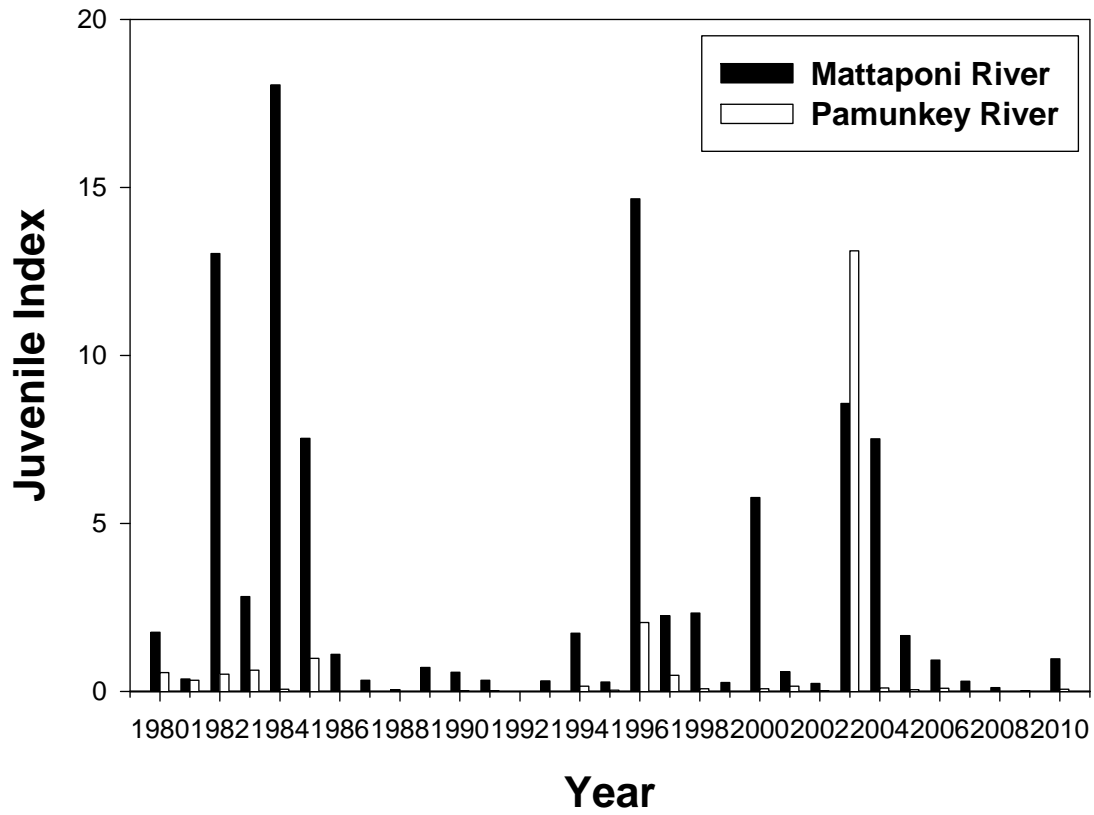


Figure 23. The index of juvenile abundance of American shad in the Rappahannock River as estimated by daylight seine surveys, 1980-2010. The index is the geometric mean number of American shad juveniles per seine haul. The index in 1980 and 1981 was zero.

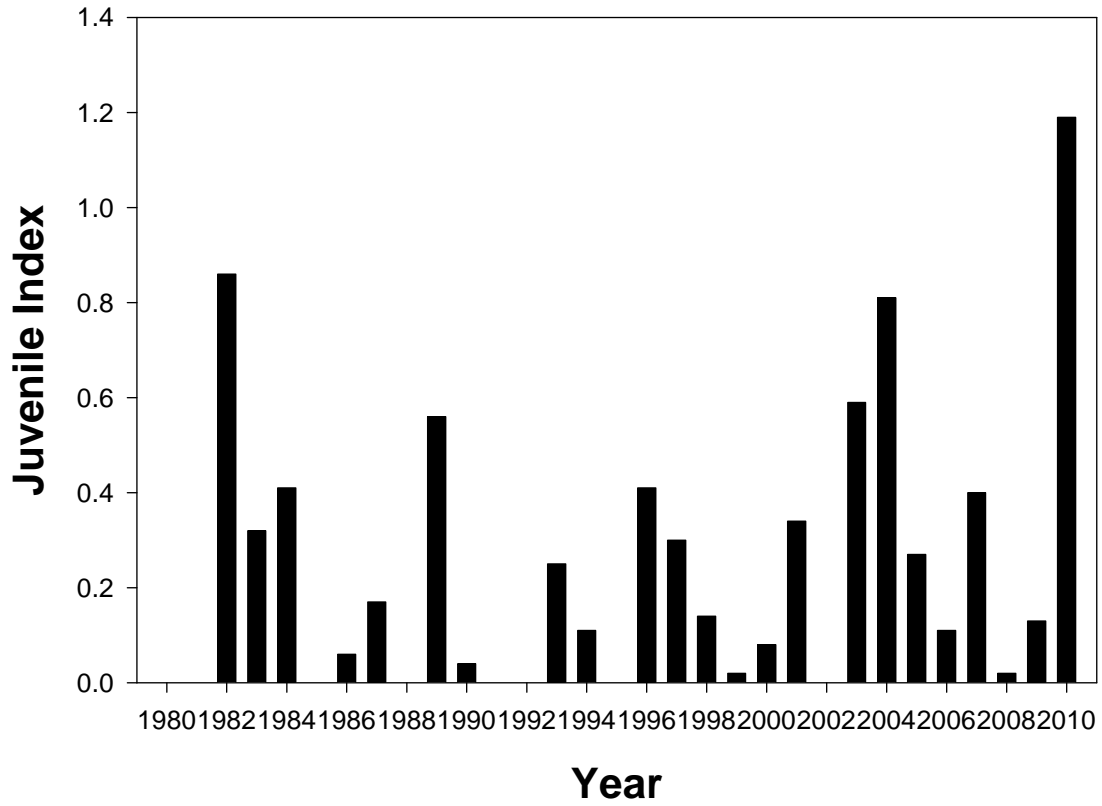


Figure 24. The index of juvenile abundance of American shad in the James River as estimated by daylight seine surveys, 1980-2010. The index is the geometric mean number of American shad juveniles per seine haul.

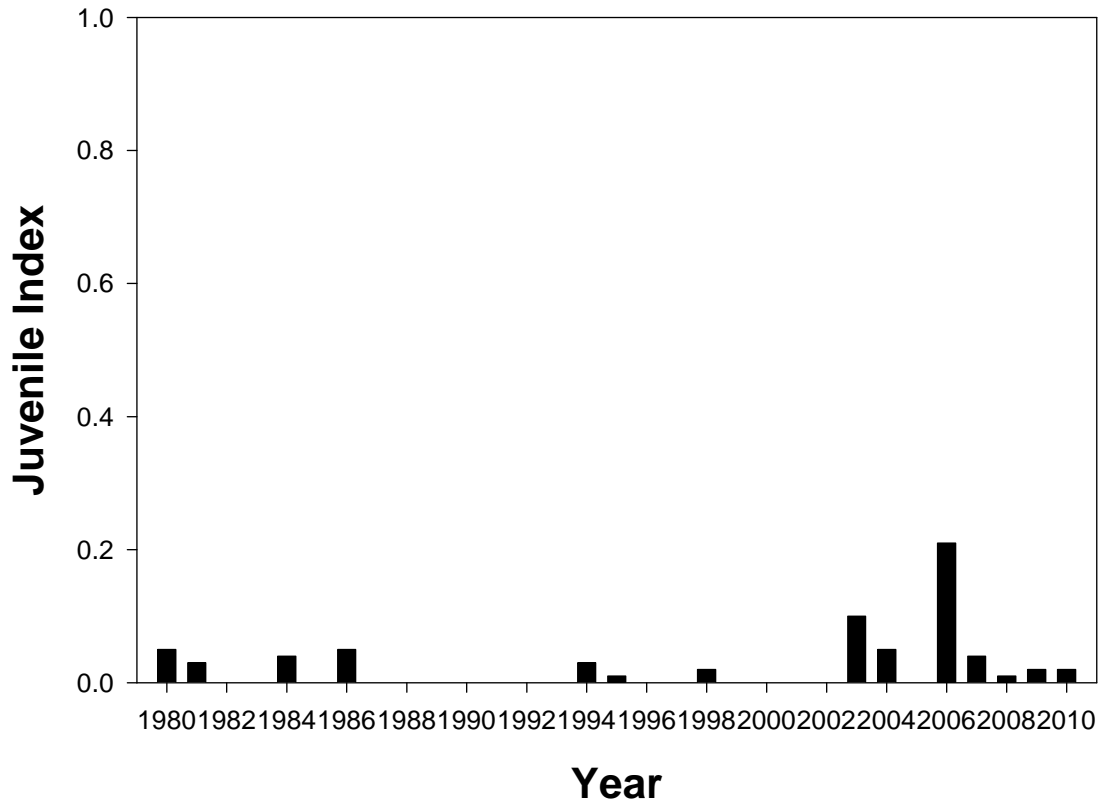


Figure 25. Recent (1998-2010) and historic values of the catch index of female American shad on the James River.

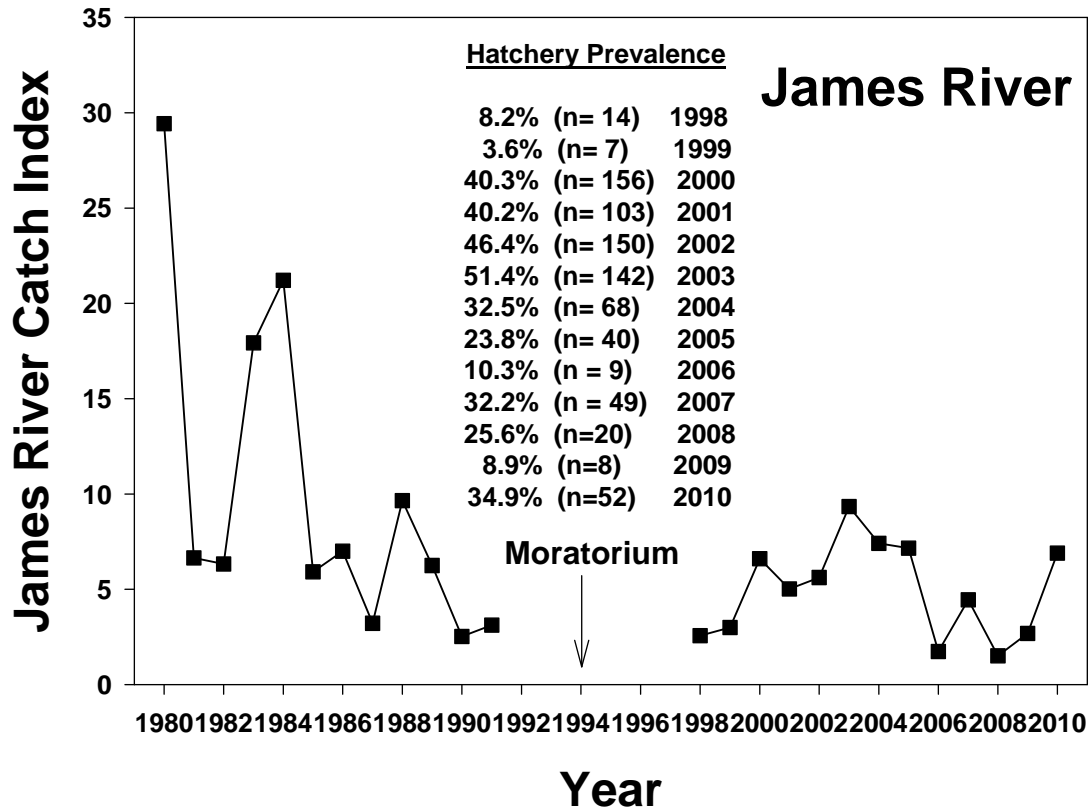


Figure 26. Recent (1998-2010) and historic values of the catch index of female American shad on the York River.

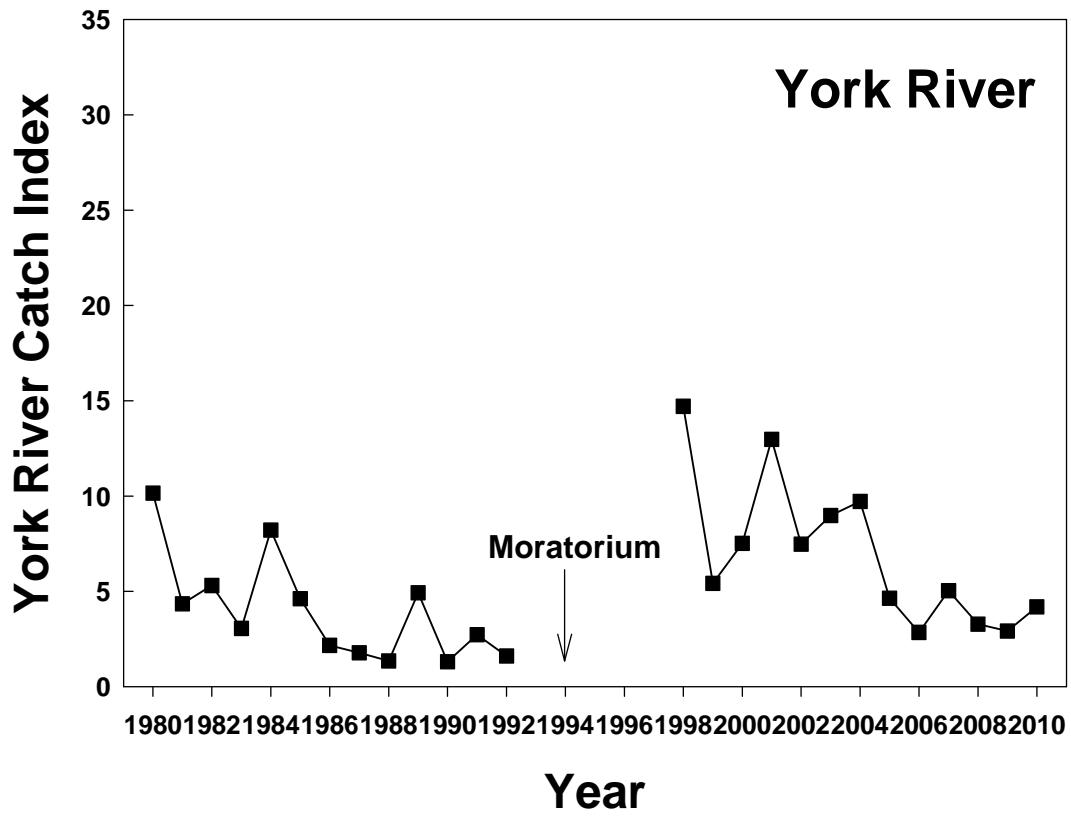


Figure 27. Recent (1998-2010) and historic values of the catch index of female American shad on the Rappahannock River.

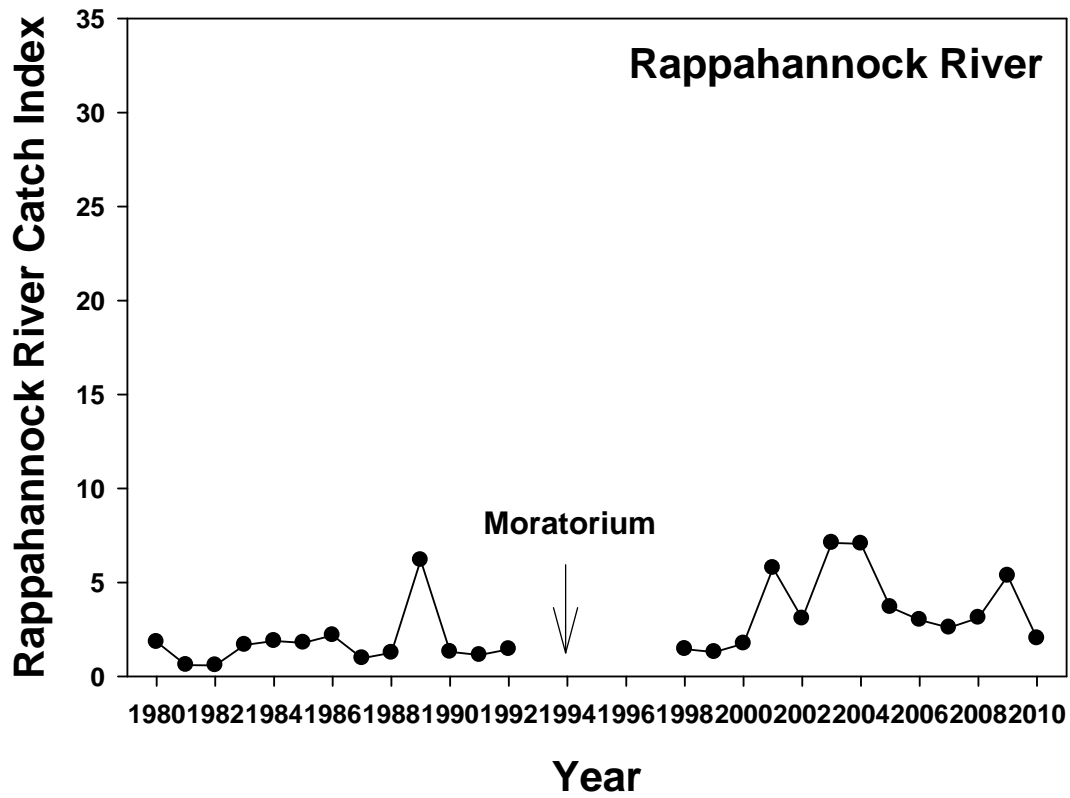
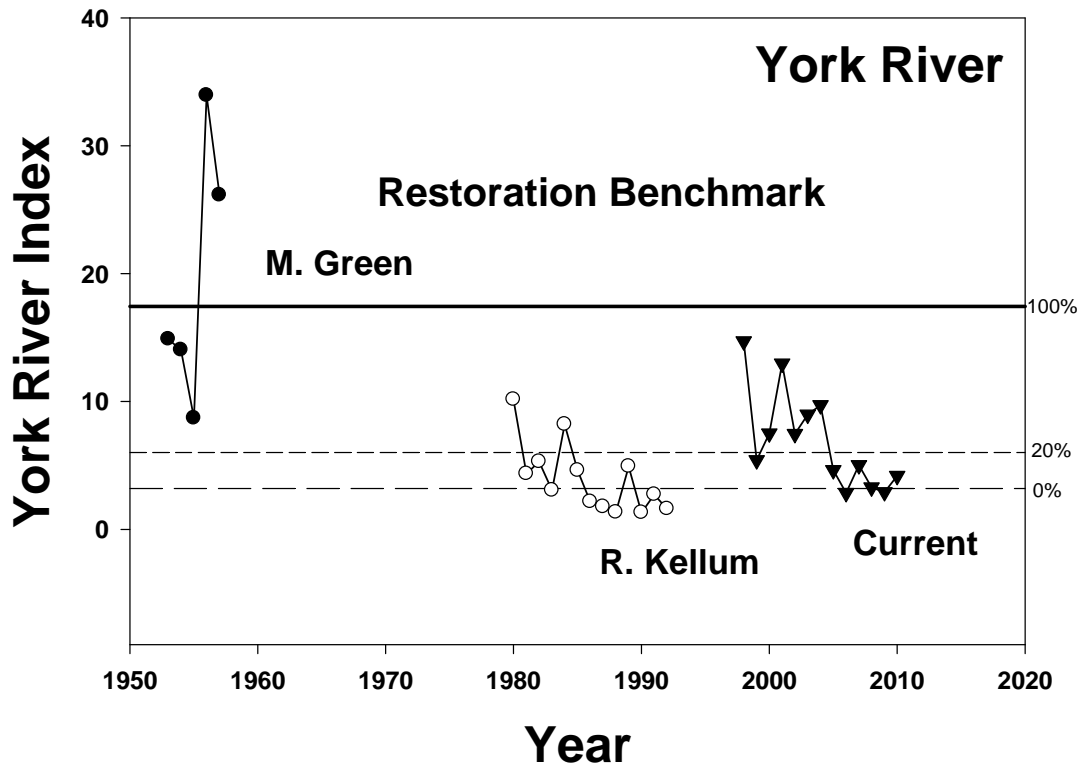


Figure 28. Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the geometric means of each data set (solid, 1950s; short dashes, current; long dashes, 1980s)



Appendix I

Assessment of the 2010 Virginia by-catch of American shad and the status of the Virginia stocks

Report to the Shad and River Herring Technical Committee of the Atlantic States Marine
Fisheries Commission (ASMFC)

Dr. Eric Hilton, Dr. Rob Latour and Brian Watkins
Department of Fisheries Science
Virginia Institute of Marine Science
Gloucester Point, VA 23062

Background

In spring 2010, scientists at the Virginia Institute of Marine Science (VIMS) interviewed and obtained samples of by-catch of American shad from permitted fishers who had agreed to participate in the ASMFC required monitoring program. Effort (total trips) in the 2010 American shad by-catch fishery on the York River was lower than in 2009. Effort in 2010 was slightly higher on the James River and much higher on the Rappahannock River than in 2009 (Table 1). In 2010 the reported catch from the Rappahannock River was estimated due to discrepancies and errors in reporting from that system. All fish that were obtained for biological analysis were captured in the York River. Cooperating fishers on the Rappahannock River were not available in 2010.

This report is a companion to a separate report of the 2010 by-catch prepared by the Virginia Marine Resources Commission (VMRC) and submitted separately.

Biological Characterization of the 2010 Permitted Gill Net By-Catch in Virginia

A subsample of the 2010 by-catch of American shad (n=136 fish, 54.8% of the total number of fish reported to VMRC) was obtained from four cooperating gill netters and processed for length, weight, sex, maturity stage, age, and the presence of hatchery (OTC) marks. The by-catch subsample contained 24 males and 112 females harvested in anchored and staked gill nets. The subsample ranged in size and age from 353-569 mm TL and 3-8 years (Table 2). Virgin and repeat spawners (54% and 46% respectively) were both present in the subsample. One hatchery-produced American shad was present in the by-catch subsample. Biological data on these fish are presented in Table 2.

By-Catch and Discards by Pound Nets in Virginia

In addition to the permitted by-catch samples of American shad taken in gill nets, VIMS scientists examined pound net samples from three pound net fishers operating at locations in the upper and lower portions of Chesapeake Bay, including the western and eastern shores (Figure 1). Pound net fishers had special permits to take American shad

for scientific monitoring, but their catches were not permitted to be sold or retained as by-catch by the VMRC. Daily log books were also obtained from two of these cooperating fishers.

Samples of up to 51 American shad were collected from each pound net fisher at intervals of approximately every two weeks (Figure 2). Fish in these samples were taken randomly from the total catch on a given day or represented the entire catch from a single fishing day. Some samples were taken more frequently when individual operations were catching American shad. A total of 399 American shad were processed for length, weight, sex, maturity stage, and age. Laboratory scans for hatchery marks are still in process. Biological information is recorded for each date of harvest in Tables 3-5. Year class composition from each pound net location is reported in Table 6.

Numbers of males and females captured were similar (193 males; 206 females). Sex ratios (males:females) were: Great Wicomico, 1:0.77; Rappahannock River, 1:1.1; Cape Charles, 1:1.5. Maturity stages were determined macroscopically for females in the laboratory. Spawning ratios (prespawning:postspawning) of females were: Great Wicomico, 1:0.01; Rappahannock River, 1:0.04; Cape Charles, 1:1.63.

Our monitoring indicated that post-spawning fish exiting the Chesapeake Bay were taken by pound nets on the eastern shore near the Bay mouth.

A total of 3023 discarded American shad were recorded in commercial log book records of two pound net fishers in the spring of 2010 (Figures 3-4). We were unable to obtain log books from one other operator although we did purchase fish for biological characterization from those nets.

Results of the 2010 Fishery-Independent Monitoring Studies

The catch index values (the area of the curve of catch rate versus day of the year) of pre-spawning American shad in fishery-independent staked gill net monitoring is depicted in Figure 5.

On the Rappahannock River, the 2010 index was 2.03, which is the lowest value seen since 2000.

In 2010 the catch index on the James River (6.90) increased from the 2009 value of 2.69. This is the highest value seen since 2005.

The 2010 York River index is 4.18. The trend of the York River monitoring data is a downward slope of catch index values through the 12-y time series.

Table 1. 2010 American shad by-catch permit and harvest data. Data provided by the Virginia Marine Resources Commission. Abbreviations : U, Unknown; *, estimate.

Water Body	Year	# Permit Holders	# Active Permits	Total Trips	# Shad Caught	# Shad Kept
James River	2010	9	0	7	0	0
	2009	8	1	6	2	0
	2008	6	2	3	3	3
	2007	16	7	58	119	52
	2006	32	5	27	24	23
York River	2010	9	5	43	229	208
	2009	11	6	97	302	288
	2008	10	6	85	89	89
	2007	15	8	104	199	199
	2006	31	5	198	233	228
Rappahannock River	2010	7	2	10	U	40*
	2009	1	0	0	0	0
	2008	3	1	8	81	57
	2007	5	2	23	22	20
	2006	14	2	8	3	3

Table 2. Biological characteristics by sampling date for American shad permitted by-catch samples processed at VIMS. Abbreviations: YK, York River; *, Unreadable; SGN, Staked Gill Net; AGN, Anchor Gill Net; X, Not processed.

Date	Fisherman	River	Gear	FL	TL	Weight (g)	Sex	Age	# Previous Spawns	OTC
3/8/2010	1	YK	SGN	433	486	1378.9	2	7	3	N
3/16/2010	2	YK	AGN	486	539	1957.8	2	*	*	X
3/16/2010	2	YK	AGN	410	457	1226.9	2	*	*	X
3/16/2010	2	YK	AGN	483	537	2065.5	2	7	3	N
3/16/2010	2	YK	AGN	434	482	1631.4	2	6	2	X
3/16/2010	2	YK	AGN	431	493	1664.1	2	7	2	X
3/16/2010	2	YK	AGN	459	517	1740.6	2	6	1	N
3/17/2010	2	YK	AGN	399	450	1239.7	1	6	2	X
3/17/2010	2	YK	AGN	438	497	1552	2	4	0	N
3/17/2010	2	YK	AGN	456	514	1750.3	2	*	*	X
3/17/2010	2	YK	AGN	460	515	1916.9	2	*	*	X
3/17/2010	2	YK	AGN	477	530	2125.4	2	*	*	X
3/17/2010	2	YK	AGN	433	480	1590.5	2	6	2	N
3/22/2010	2	YK	AGN	456	516	1786.5	2	*	*	X
3/22/2010	2	YK	AGN	478	539	2128.1	2	8	4	X
3/22/2010	2	YK	AGN	454	508	1685.6	2	6	2	N
3/22/2010	2	YK	AGN	481	550	1994.4	2	7	2	N
3/22/2010	2	YK	AGN	420	480	1161	1	5	1	X
3/22/2010	2	YK	AGN	436	483	1406.3	2	5	1	X
3/22/2010	2	YK	AGN	448	510	1686.9	2	6	2	N
3/21/2010	2	YK	AGN	510	569	2000.3	2	*	*	X
3/21/2010	2	YK	AGN	433	493	1549.6	2	6	2	X
3/21/2010	2	YK	AGN	447	502	1563.3	2	6	0	N
3/21/2010	2	YK	AGN	456	510	1869.3	2	7	2	X

3/21/2010	2	YK	AGN	455	511	1672.8	2	6	2	X
3/29/2010	1	YK	SGN	406	451	1316.1	2	5	0	X
3/29/2010	1	YK	SGN	429	482	1305.9	2	5	1	X
3/31/2010	1	YK	SGN	442	488	1393	2	6	0	N
3/31/2010	1	YK	SGN	457	511	1704.1	2	5	1	X
3/31/2010	1	YK	SGN	418	468	1356.2	1	7	3	X
4/2/2010	1	YK	SGN	445	504	1504.9	2	5	0	N
4/2/2010	1	YK	SGN	466	526	1822	2	5	0	X
4/2/2010	1	YK	SGN	440	495	1363.2	1	*	*	Y
4/2/2010	1	YK	SGN	420	480	1353.4	2	*	*	X
4/2/2010	1	YK	SGN	461	521	1747.4	2	6	2	X
4/3/2010	1	YK	SGN	414	477	1322.8	2	5	0	X
4/3/2010	1	YK	SGN	396	447	1124.8	2	*	*	X
4/3/2010	1	YK	SGN	431	473	1416.4	2	5	1	X
4/3/2010	1	YK	SGN	420	474	1431.5	2	5	0	X
4/3/2010	1	YK	SGN	437	499	1517.4	2	5	1	X
4/3/2010	1	YK	SGN	424	482	1502.1	2	5	0	N
4/3/2010	1	YK	SGN	429	492	1473.3	2	5	0	X
4/3/2010	1	YK	SGN	476	539	1943.1	2	6	3	X
4/3/2010	1	YK	SGN	414	472	1275	1	6	2	N
4/3/2010	1	YK	SGN	432	488	1504.9	2	5	0	N
4/3/2010	3	YK	AGN	458	518	1667.7	2	6	2	X
4/3/2010	3	YK	AGN	421	476	1454.1	2	*	*	X
4/3/2010	3	YK	AGN	422	473	1397.3	2	5	0	X
4/3/2010	3	YK	AGN	411	463	1280.2	2	5	0	N
4/3/2010	3	YK	AGN	418	474	1197.5	2	4	0	X
4/3/2010	3	YK	AGN	396	449	1288.1	2	4	0	X
4/3/2010	3	YK	AGN	422	472	1358.3	2	5	0	X
4/3/2010	3	YK	AGN	391	441	1025.2	1	5	1	N
4/3/2010	3	YK	AGN	412	470	1298.6	2	4	0	N
4/3/2010	3	YK	AGN	422	474	1483.1	2	5	0	N

4/4/2010	1	YK	SGN	438	493	1661.4	2	7	3	X
4/4/2010	1	YK	SGN	416	470	1325.6	2	5	0	X
4/4/2010	1	YK	SGN	422	475	1384.7	2	6	0	N
4/4/2010	1	YK	SGN	423	481	1485.5	2	5	0	X
4/4/2010	1	YK	SGN	429	486	1510.4	2	6	2	X
4/4/2010	1	YK	SGN	418	474	1241.9	2	5	0	X
4/4/2010	1	YK	SGN	420	472	1301.9	2	4	0	N
4/4/2010	1	YK	SGN	440	491	1539.8	2	6	0	X
4/4/2010	1	YK	SGN	442	502	1552.5	2	5	0	X
4/4/2010	1	YK	SGN	417	477	1260.7	2	4	0	N
4/4/2010	3	YK	AGN	414	472	1325.8	2	5	0	N
4/4/2010	3	YK	AGN	403	455	1203.5	2	4	0	X
4/4/2010	3	YK	AGN	444	501	1500	1	7	2	X
4/4/2010	3	YK	AGN	426	480	1479.1	2	5	0	N
4/4/2010	3	YK	AGN	440	492	1458.3	2	6	1	X
4/4/2010	3	YK	AGN	429	487	1404.6	2	5	1	X
4/4/2010	3	YK	AGN	428	482	1295.3	2	6	1	N
4/4/2010	3	YK	AGN	418	471	1136.2	1	4	0	X
4/4/2010	3	YK	AGN	434	491	1567.4	2	4	0	X
4/4/2010	3	YK	AGN	412	462	1415.6	2	5	2	X
4/5/2010	1	YK	SGN	447	505	1502.8	2	5	0	X
4/5/2010	1	YK	SGN	440	492	1668.8	2	7	3	N
4/5/2010	1	YK	SGN	434	492	1369.7	2	5	0	X
4/5/2010	1	YK	SGN	429	482	1512.4	2	5	0	X
4/5/2010	1	YK	SGN	454	508	1626.9	2	5	0	X
4/5/2010	1	YK	SGN	425	480	1414.4	2	6	1	N
4/5/2010	1	YK	SGN	455	513	1647.2	2	6	2	N
4/5/2010	3	YK	AGN	382	438	1049.5	2	*	*	N
4/5/2010	3	YK	AGN	461	515	1540.1	2	6	1	X
4/5/2010	3	YK	AGN	408	471	1216	2	*	*	N
4/5/2010	3	YK	AGN	432	482	1427.8	2	*	*	X

4/5/2010	3	YK	AGN	429	488	1167.5	1	7	3	X
4/5/2010	3	YK	AGN	444	495	1482.1	2	5	1	X
4/5/2010	3	YK	AGN	428	480	1231.4	2	5	0	X
4/5/2010	3	YK	AGN	370	422	785.5	1	4	1	X
4/5/2010	3	YK	AGN	408	460	1346.3	2	5	1	X
4/5/2010	3	YK	AGN	424	480	1422.8	2	6	1	N
4/5/2010	4	YK	AGN	315	353	520.1	1	3	0	X
4/5/2010	4	YK	AGN	336	382	579.7	1	4	0	X
4/5/2010	4	YK	AGN	345	393	609.8	1	4	0	N
4/5/2010	4	YK	AGN	331	370	513	1	3	0	X
4/6/2010	1	YK	SGN	500	565	2093.8	2	8	2	X
4/6/2010	1	YK	SGN	429	477	1468.5	2	4	0	N
4/6/2010	3	YK	AGN	429	488	1396.1	2	5	0	X
4/6/2010	3	YK	AGN	486	550	2023.9	2	*	*	X
4/6/2010	3	YK	AGN	420	467	1339	2	*	*	X
4/6/2010	3	YK	AGN	420	473	1305.9	2	5	0	N
4/6/2010	3	YK	AGN	406	465	1282.3	2	6	1	X
4/6/2010	3	YK	AGN	415	471	1404.4	2	6	1	X
4/6/2010	3	YK	AGN	441	496	1697.9	2	6	1	X
4/6/2010	3	YK	AGN	429	482	1262.3	2	4	0	N
4/6/2010	3	YK	AGN	386	438	1138.8	2	3	0	X
4/6/2010	3	YK	AGN	393	445	1128	2	5	0	N
4/6/2010	4	YK	AGN	313	355	470.5	1	3	0	N
4/6/2010	4	YK	AGN	336	379	545.8	1	5	0	X
4/6/2010	4	YK	AGN	350	392	697.5	1	4	0	X
4/6/2010	4	YK	AGN	314	357	487.5	1	4	0	N
4/6/2010	4	YK	AGN	390	440	1047	2	4	0	X
4/6/2010	4	YK	AGN	331	379	570.6	1	3	0	X
4/6/2010	4	YK	AGN	325	376	548.6	1	4	0	X
4/6/2010	4	YK	AGN	347	384	652.8	1	3	0	N
4/6/2010	4	YK	AGN	346	396	668	1	4	0	X

4/7/2010	3	YK	AGN	403	456	1272.9	2	5	0	N
4/7/2010	3	YK	AGN	456	510	1405.7	2	6	1	X
4/7/2010	3	YK	AGN	401	451	1162.8	1	6	1	X
4/7/2010	3	YK	AGN	420	471	1337.7	2	5	0	X
4/7/2010	3	YK	AGN	436	493	1544.6	2	5	0	N
4/7/2010	3	YK	AGN	461	519	1847.2	2	6	1	X
4/7/2010	3	YK	AGN	388	436	1078.5	2	4	0	X
4/7/2010	3	YK	AGN	414	461	1192.8	1	4	0	X
4/7/2010	3	YK	AGN	456	514	1816.7	2	6	2	N
4/7/2010	3	YK	AGN	445	497	1559.7	2	6	1	N
4/12/2010	3	YK	AGN	414	461	1243.7	2	*	*	X
4/12/2010	3	YK	AGN	431	487	1286.8	2	*	*	X
4/12/2010	3	YK	AGN	471	527	2100.7	2	6	1	N
4/12/2010	3	YK	AGN	429	478	1388.6	2	*	*	X
4/12/2010	3	YK	AGN	420	467	1335.7	2	*	*	X
4/12/2010	3	YK	AGN	408	463	1219.4	2	6	1	N
4/13/2010	3	YK	AGN	407	460	1205.8	2	5	0	N
4/13/2010	3	YK	AGN	397	445	1177.1	2	*	*	X
4/13/2010	3	YK	AGN	395	449	1043.5	2	4	0	X

Table 3. Biological data of American shad (n=161) collected from a pound net located at the mouth of the Great Wicomico River. Abbreviations: TW, total weight; Avg, Average; P. Spent, Partially Spent.

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
3/15/2010	Maturing	9	13.62	1513.69			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				29	28.16	970.99
3/29/2010	Maturing	4	6.38	1594.98			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				19	17.45	918.36
4/15/2010	Maturing	28	37.52	1339.87			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				19	16.57	872.25
4/29/2010	Maturing	18	24.27	1348.17			
	Hydrated						
	P. Spent	1	1.22	1220.10			
	Spent						
	Unstaged				8	7.91	988.28
5/12/2010	Maturing	10	12.87	804.66			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				16	13.56	1355.95
Total		70	95.88	1369.71	91	83.65	919.23

Table 4. Biological data of American shad (n=98) collected from a pound net located at the mouth of the Rappahannock River. Abbreviations: TW, total weight; Avg, Average; P. Spent, Partially Spent.

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
4/14/2010	Maturing	13	18.47	1420.85			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				19	15.86	834.73
4/26/2010	Maturing	11	12.83	1166.20			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				16	10.87	679.38
5/12/2010	Maturing	19	22.17	1166.88			
	Hydrated	2	3.06	1528.50			
	P. Spent						
	Spent						
	Unstaged				5	3.70	739.20
5/26/2010	Maturing	5	6.44	1288.40			
	Hydrated						
	P. Spent	1	1.14	1139.10			
	Spent	1	.80	799.20			
	Unstaged				6	4.50	750.70
Total		52	64.91	1248.27	46	34.93	759.35

Table 5. Biological data of American shad (n=140) collected from a pound net located in the vicinity of Cape Charles, VA. Abbreviations: TW, total weight; Avg, Average; P. Spent, Partially Spent.

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
4/2/2010	Maturing	10	13.16	1316.18			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				9	9.27	1030.20
4/5/2010	Maturing	12	16.47	1372.49			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				17	18.85	1108.97
5/3/2010	Maturing	8	9.99	1248.79			
	Hydrated						
	P. Spent	16	12.98	810.98			
	Spent	12	9.89	824.34			
	Unstaged				15	11.57	771.53
5/21/2010	Maturing	2	3.33	1662.70			
	Hydrated						
	P. Spent	15	11.96	797.11			
	Spent	9	7.20	800.08			
	Unstaged				15	11.15	743.27
Total		84	84.98	1011.67	56	50.84	907.86

Table 6. Year class composition of fish taken in pound nets in 2010, indicated as percent of aged catch from three pound net locations in Chesapeake Bay.

	Year Class	Great Wicomico	Cape Charles	Rappahannock
Males	2007	8.9	3.0	18.0
	2006	39.2	33.0	38.0
	2005	32.9	42.0	35.0
	2004	16.5	15.0	9.0
	2003	1.3	3.0	0.0
	2002	1.3	3.0	0.0
	2001	0.0	0.0	0.0
Females	2007	1.0	0.0	0.0
	2006	10.0	15.0	18.0
	2005	47.0	57.0	58.0
	2004	32.0	19.0	18.0
	2003	9.0	7.0	6.0
	2002	0.0	2.0	0.0
	2001	0.0	0.0	0.0

Figure 1. Location of pound net operations with special American Shad by-catch permits.



Figure 2. Number of American Shad processed by VIMS caught with special pound net by-catch permits. N is the number of samples obtained.

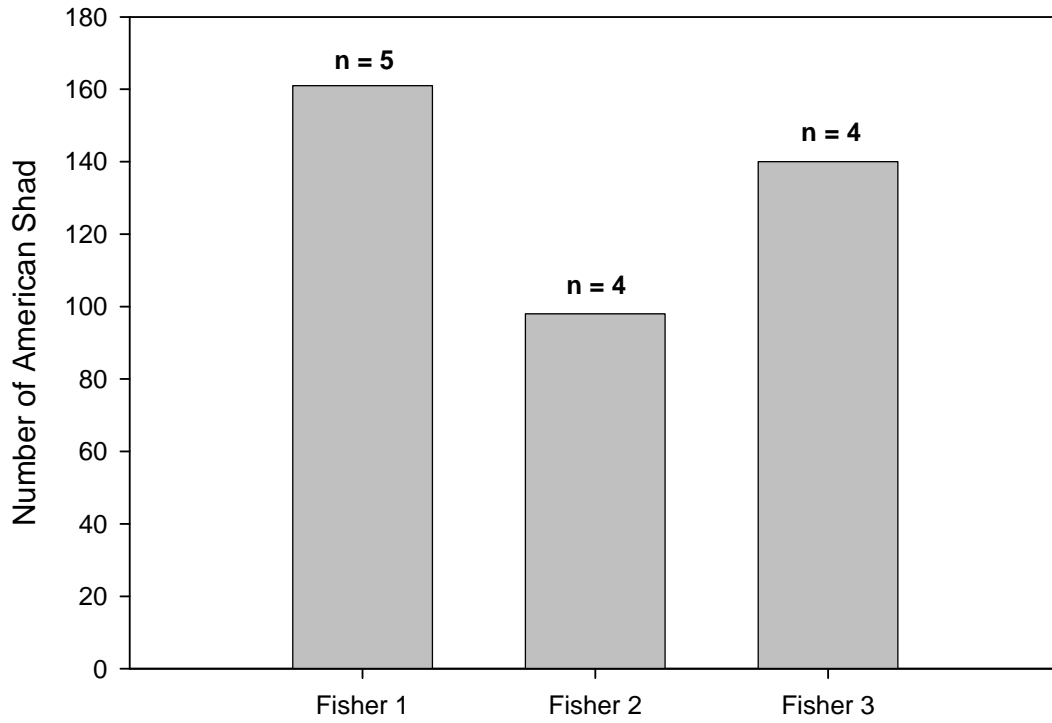


Figure 3. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Great Wicomico River. Data are taken from 2010 commercial fisher log books.

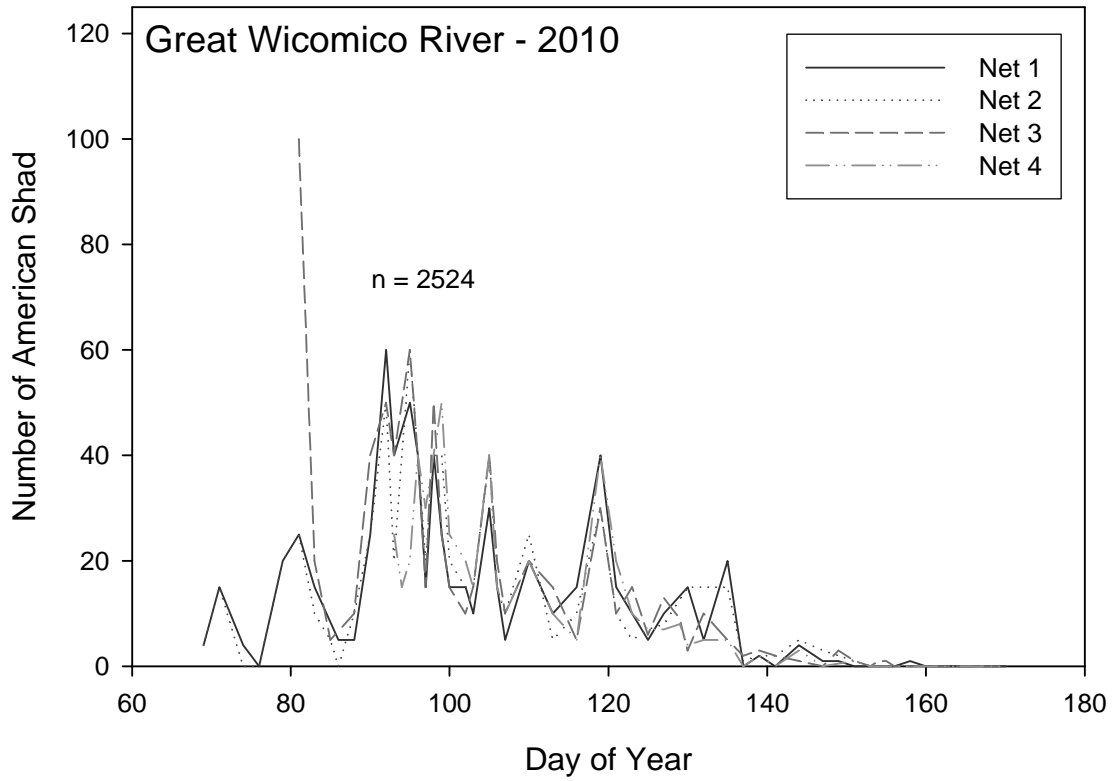


Figure 4. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Rappahannock River mouth. Data are taken from 2010 commercial fisher log books.

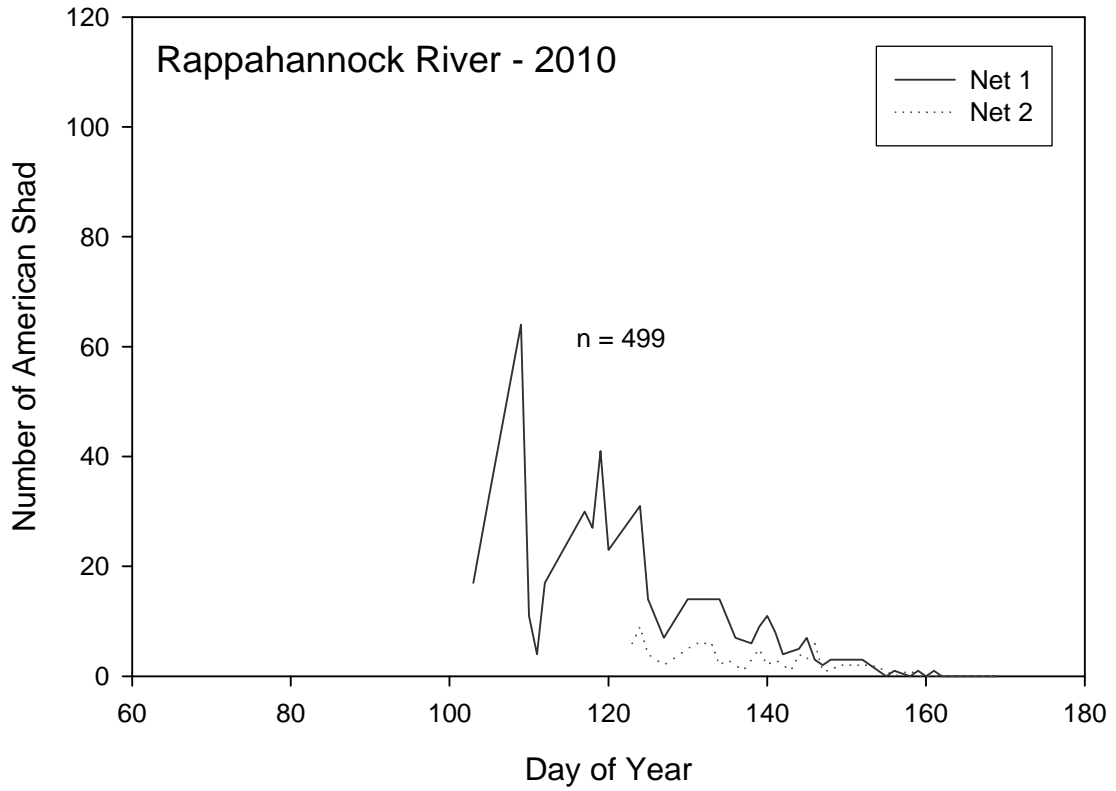


Figure 5. Time series of catch index from staked gill net monitoring in Virginia, 1998-2010.

