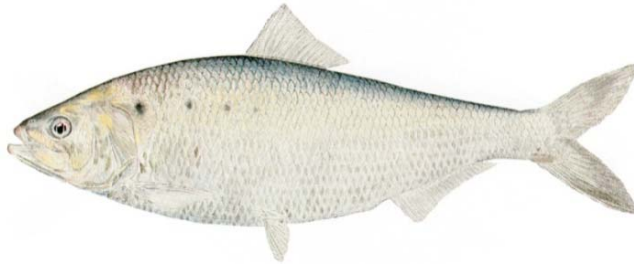


Monitoring Relative Abundance of American Shad in Virginia Rivers
2012 Annual Report



Prepared By:

Dr. Eric J. Hilton, Dr. Rob Latour, Brian Watkins and Ashleigh Rhea

Department of Fisheries Science
School of Marine Science
Virginia Institute of Marine Science
The College of William and Mary
Gloucester Point, VA 23062-1346

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Summary

- This was the fifteenth 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.
- Sampling occurred for eleven weeks on the James and York rivers (5 February to 21 April 2012 and 5 February to 16 April 2012, respectively). On the Rappahannock River, sampling occurred for thirteen weeks (15 February to 7 May 2012). After 26 March, post-spawning fish were mixed with pre-spawning fish in the catch on the York River. On the Rappahannock River post-spawning fish were encountered after 9 April. No post-spawning fish were observed on the James River in 2012. Only pre-spawning fish were included in the calculation of catch indices for each river. A total of 815 pre-spawning female American shad (1259.0 kg total weight) were captured; this is a decrease from the 2011 catch (994 pre-spawning females weighing 1437.5 kg).
- Total numbers and weights of females in 2012 were highest on the Rappahannock River (n=368, 560.4 kg). Numbers of females were lower on the James River (n=262, 428.9 kg). The lowest catches of females were recorded on the York River (n=185, 269.7 kg). Numbers of males captured were: Rappahannock, 30; James, 29; York, 32. The total weight of males captured on all rivers was 109.3 kg. The total catch and weight of males were lower than in 2011 (n=184, 216.7 kg).
- Based on age estimates from scales, the 2008 (age 4), 2007 (age 5), and 2006 (age 6) year classes of female American shad were the most abundant on all rivers. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 0.49 ($r^2=0.54$); James River, 0.74 ($r^2=0.64$) and Rappahannock River, 0.63 ($r^2=0.66$). Total instantaneous mortality rates of males were not calculated since all year classes present were not equally catchable by the sampling gear.
- Otoliths of 82 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 34.1% (28 of 82 fish). In 2010 and 2011 the prevalence of fish with hatchery marks was 34.9% and 39.0%, respectively. Presence of hatchery fish on the Rappahannock River was 6.8% (8 of 117 fish) in 2012. This is the highest

value observed since stocking began in 2003. Presence of hatchery fish on the York River continued to be low in 2012 at 1.9%.

- 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 2012 was: James River (inclusive of Chickahominy River), 0.01 (0.092, 57); Chickahominy River, 0 (0, 10); Rappahannock River, 0.19 (0.422, 35); York River (inclusive of Pamunkey and Mattaponi rivers), 0.02 (0.101, 93); Mattaponi River, 0.01 (0.099, 49); and Pamunkey River, 0.02 (0.111, 39).
- Fyke net sampling was conducted to assess the abundance and downstream migration of young-of-the-year American shad. This sampling occurred weekly at five locations along the Mattaponi River for fifteen weeks (16 May to 21 August). A total of 1 juvenile American shad was captured in this sampling (70 mm FL). Estimated otolith age of this specimen was 81 days.
- Twenty-three species of fishes (total of 17,847 specimens) were caught as by-catch in the staked gill net monitoring gear. The total number of striped bass captured was 1,533 (James River, n=421; York River, n=575; Rappahannock River, n=537). 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, 39.7%; York River, 38.1%; and the Rappahannock River, 66.1%.
- A seasonal catch index for American shad was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2012 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 2012 (3.17) decreased from the 2011 value (4.58). During the fifteen 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 (5.66) 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 2012 index (6.06) decreased from the 2011 value of 9.00 which is the highest value recorded since 2003. 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 4.59. In 2012 the hatchery prevalence was 34.1%. The strength of the spawning run index on the James River continues to depend of the presence of hatchery fish.

- The catch index on the Rappahannock River in 2012 (7.28) increased from the 2011 value (6.51). The 2012 index is the highest value recorded since monitoring began in 1998. 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 (3.49).

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 2012, these individuals include: Lee Flanders, Chris Hager, Kenneth Heath, Joseph Hinson, George Trice, Robert Weagley, JC West and Charles Williams. In 2012, the staff and students of the Virginia Institute of Marine Science who participated in the program were: B. Watkins, A. Rhea, P. Crewe, and R. Norris. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. B. Watkins determined ages of adult fish. A. Rhea determined ages of juvenile fish. R. Norris and B. Watkins determined hatchery origins of adult 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 fifteenth year in the sampling program (2012) are reported in this document and compared to some results in previous years of monitoring. Detailed results of the first fourteen years of sampling (1998-2011) 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; Hilton et al. 2011, 2012). 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 related to American shad in Virginia. 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. A new survey utilizing small-mesh fyke nets was established in the Mattaponi River in 2011 to direct more effort at predicting juvenile shad abundance. 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 fight 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 restore or expand 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, as well as other species of concern (e.g., Atlantic sturgeon), 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, prevalence of hatchery fish returning as adults to the York system is low in most years (~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, which was removed in 2004.

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 2012 fishing season (see Appendix 1). Fishers with special permits were allowed to possess American shad caught in anchored or staked gill nets in the by-catch area. The by-catch area in 2012 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. In 2011 a new survey utilizing small-mesh fyke nets was initiated to complement the currently available data on juvenile *Alosa* spp. The new survey allows for a more rigorous assessment of alosine recruitment and downstream migration of these fishes in the York River

Since the American shad monitoring program at VIMS began in 1998, 26 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; Latour et al. 2012; Upton et al. 2012). Reprints of these papers are available on request.

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 also 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, these 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; (5) to determine the amount of by-catch of other species in the staked gill nets; and (6) to monitor the American shad by-catch fishery established by the VMRC. The results of this by-catch monitoring in 2012 are provided here as an appendix comprising a report on this fishery to the ASMFC (Appendix I).

Methods

Collection of Adult American shad

The 2012 sampling methods for the monitoring program were the same as those in 1998-2011 (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 1998-2012. 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. 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, Virginia) 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 2012, sampling occurred for eleven weeks on the York River (5 February to 16 April 2012); eleven weeks on the James River (5 February to 21 April 2012); and thirteen weeks on the Rappahannock River (15 February to 7 May 2012). 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, A. Rhea, and R. Norris (VIMS) in 2005-2012. 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. (2012) 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.

Collection of juvenile American shad

In 2012, fyke net sampling for juvenile American shad was conducted in the Mattaponi River (York River System) between Melrose Landing and Walkerton. The sampling gear consisted of five fyke nets constructed from ¼" Ace mesh. Each net included four hoops, two throats, and one cab, with a 15.2 m leader and 7.6 m wings. Each fyke net was set perpendicular to the current with leaders running onshore. The locations of the five sets were as follows : Walkerton Landing at river mile 53 (37° 43.4' N, 77° 01.0' W); Upriver of Garnetts Creek at river mile 49 (37° 41.4' N, 76° 57.5' W); Sandy Point State Forest at river mile 46 (37° 40.9' N, 76° 55.0' W); Wakema at river mile 43 (37° 39.3' N, 76° 53.5' W); and Melrose Landing at river mile 41 (37° 38.6' N, 77° 52.0' W). Nets were mostly set on Monday of each week and fished the next day (24-h set). Alternate set days were selected if dictated by weather. After fishing, each net was removed from the sampling site. Sampling occurred for fifteen weeks (16 May to 21 August 2012). Surface water temperature and salinity were recorded at each sampling event.

All species present in the catch were identified and counted; all alosines were returned to the laboratory for further analysis. Individual juvenile alosines collected from monitoring stations were measured (FL) and weighed (g) using the same equipment and guidelines that were used for adult fish. Sagittal otoliths from subsamples were removed and stored in individual collection vials for ageing and hatchery analysis. Otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Daily ages were determined by counting daily incremental rings using a

Nikon 80i compound microscope and Nikon Elements imaging software. Ages were determined by A. Rhea.

Results

Catches of American shad by staked gill nets in 2012

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-8 and Figures 8-15. After 26 March, post-spawning fish were mixed with pre-spawning fish in the catch on the York River. On 9 April, post-spawning fish were encountered on the Rappahannock River. Post-spawning females were not encountered on the James River in 2012. Post-spawning fish were identified macroscopically in the laboratory. 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 not included in the monitoring sample.

A total of 906 American shad (91 males; 815 females) were captured (Table 1). The total weight of the sample was 1368.3 kg (male, 109.3 kg; female, 1259.0 kg). Catches in 2012 were lowest on the York River (217 total fish, 32 males and 185 females) and James River (291 total fish, 29 males and 262 females). Catches on the Rappahannock River (398 total fish, 30 males and 368 females) were highest. Data for post-spawning females (removed from analyses) are provided in Table 2.

On the James River, catches of females peaked between 26 February and 16 April, with catch rates exceeding 0.02 fish/m or 0.04 kg/m. During that period 90% (236 of 262) of all females were captured. Surface temperatures during this time ranged from 7.8°C – 17.8°C. The largest catch of pre-spawning female American shad (53 fish) occurred on 19 March when surface temperatures were 14.1°C (Figure 16; Table 3). On the York River, catches of females peaked between 27 February – 1 April when catch rates exceeded 0.01 fish/m or 0.03 kg/m. During that period, 79% (146 of 285) of all females were captured on the York River. Surface temperatures during this time ranged from 7.6 – 18.5°C. The largest catch of pre-spawning female American shad on the York River (38 fish) occurred on 26 March when the surface temperature was 17.1°C (Figure 16; Table 5). Catches of females on the Rappahannock River peaked on 26 March – 16 April when catch rates generally exceeded 0.08 fish/m or 0.11 kg/m. During that period on the Rappahannock River, 76% (280 of 368) of all females were captured. Surface temperatures during this time ranged from 15.1°C – 18.5°C. The largest catch of pre-spawning female American shad on the Rappahannock River (53 fish) occurred on 2 April when the surface temperature was 16.3°C (Figure 17; 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, 1:5.78; James River, 1:9.03 and Rappahannock River, 1:12.27. 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 2012 spawning run duration was estimated to be 51 days on the James River (26 February – 16 May; Table 3), 66 days on the York River (5 February – 10 April; Table 5), and 62 days on the Rappahannock River (29 February – 30 April; Table 7).

Biological characteristics of the American shad catch in 2012

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 428.8-497.0 mm TL and 473.0–527.8 mm TL, respectively. Mean weight at age of males and females from all rivers ranged from 0.9–1.6 kg and 1.3-1.8 kg, respectively.

Using scale-based ageing methods, we estimated that the 2007 and 2006 year classes (ages 5 and 6) of female American shad were the most abundant on all rivers (Table 11). On the Rappahannock River the 2008 year class of female shad (age 4) was also abundant. On the James River, five age-classes of females were represented (2004-2008, ages 4-8), with the sample dominated by age-5 fish (49.0% of the total that was aged). On the York River, four age-classes of females were represented (2005-2008, ages 4-7). The sample was dominated by age-5 (50.3%) fish. On the Rappahannock River, six age-classes of females were taken (2004-2009, ages 3-8), with the sample dominated by age-5 fish (50.5%). Mean age of females in 2012 was 5.2 y (James River), 5.0 y (York River), and 5.2 y (Rappahannock River). These values are similar to those observed in 2011 (Figure 19).

The 2007 year class of males was the most abundant on all rivers (Table 12). This year class (ages 5) of male American shad constituted 62.5% (James River), 76.2% (York River), and 44.0% (Rappahannock River) of the aged sample.

Age-specific catch rates of American shad are reported in Tables 11 and 12 for 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, 0.49 ($r^2=0.54$); James River, 0.74 ($r^2=0.64$) and Rappahannock River, 0.63 ($r^2=0.66$). It is assumed that year classes above age-3 are equally catchable by the gear. On the Rappahannock River this assumption may falsely decrease Z due to the larger mesh size being used. Instantaneous mortality rates of males were not calculated because all year classes present are not equally catchable by the sampling gear.

Spawning histories of American shad collected in 2012 are presented in Tables 13-14. On the York River, fish (sexes combined) ranged in age from 4-8 years with 0 (virgin) to 4 spawning marks. On the Rappahannock River, fish (sexes combined) ranged in age from 3-8 years with 0-4 spawning marks. On the James River, fish (sexes combined) ranged in age from 4-8 years with 0-3 spawning marks. The following

percentages of fish in each river had at least one prior spawn (termed “repeat spawners”): York River, 45.6% (98 virgins in a sample of 180); James River, 44.6% (123 virgins in a sample of 222) and Rappahannock River 39.6% (204 virgins in a sample of 338 fish).

Evaluation of hatchery origin of American shad in 2012

James River - Otoliths of 82 American shad on the James River were processed for hatchery marks; the proportion with hatchery marks was 34.1% (28 of 82 fish). The biological attributes of these specimens are presented in Table 15. In most years since 2000, the prevalence of hatchery fish in the James River has been high (>20%); in 2006 and 2009 there were lower proportions of fish with hatchery tags (10.3% and 8.9% respectively). In 2003 the percentage of hatchery marked fish peaked at 51.4%. 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 1998-2012 was statistically significant ($r = 0.755$, $df = 13$, $p = 0.001135$). 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, 2011, and 2012 there were no stray fish.

Most hatchery-reared adults taken in 2012 had OTC marks that indicated these specimens were released after 2004. 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 2006, 2007 and 2008 year classes. 61.9% of hatchery marked fish in the ageing sample were repeat spawners. There were two fish from an older year class (2005) in the sample.

York and Rappahannock Rivers - Otoliths of 53 American shad (24.4% of the total that were caught) from the York River were processed for hatchery marks. One specimen (1.9%) with an OTC mark was detected. There were no strays present in the sample. In 2012, 117 American shad (29.4% of the total that were caught) from the Rappahannock river were scanned for the prevalence of hatchery marks. Eight fish (6.8%) with hatchery marks were found (Table 17). Stocking of American shad in the Rappahannock River began in 2003.

Juvenile abundance of American shad

Tables 18 and 19 and Figures 21-24 report index values of juvenile abundance of American shad based on seine surveys (1979-2012) 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 2012 was: James River, inclusive of Chickahominy River, 0.01 (0.092, 57); Chickahominy River, 0 (0, 10); Rappahannock River, 0.19 (0.422, 35); York River, inclusive of Pamunkey and Mattaponi Rivers, 0.02 (0.101, 93); Mattaponi River, 0.01 (0.099, 48); and Pamunkey River, 0.02 (0.111, 39). 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.

The seine survey data on the James River (Table 18) in recent years (2006-2012) 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 values in the time series were recorded in 2010 and 2011. 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 and 2012, 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 19). 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.

In 2012, fyke net sampling for juvenile alosines in the Mattaponi River was conducted to provide an alternative measure of recruitment for American shad. A total of one American shad was caught in this sampling (70mm FL). This specimen had an estimated hatch date of May 19 (81 days old). In comparison, 441 juvenile American shad were collected using the same methods in 2011.

By-catch of striped bass and other species in 2012

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 20-22. Twenty-three species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 17,847 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 1,533 (James River, n=421; York River, n=575; Rappahannock River, n=537). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 39.7%; York River, 38.1%; and the Rappahannock River, 66.1%. A subsample of 443 dead striped bass was selected from all rivers. Length of males and females ranged from 330 - 710 mm FL and 380 - 1040 mm FL, respectively. Total weights of males and females ranged from 0.60 – 5.56 kg and 0.78 – 15.05 kg, respectively.

Atlantic sturgeon is taken as bycatch in the staked gill nets used to monitor abundance of adult American shad in the James, York, and Rappahannock rivers. In 2012, four Atlantic sturgeon were caught as by-catch in this sampling (all in the James River). The total numbers of Atlantic sturgeon captured in this survey from previous years were 34 (1998), 24 (1999), 16 (2000), 8 (2001), 1 (2002), 3 (2003), 6 (2004), 26 (2005), 41 (2006), 30 (2007), 9 (2008), 7 (2009) and 10 (2010). Most of these fish were taken in the James River during each year: 27 (1998); 22 (1999); 15 (2000); 7 (2001); 1 (2002); 3 (2003); 4 (2004); 22 (2005); 31 (2006); 22 (2007); 7 (2008); 6 (2009); 7 (2010); 10 (2011).

Seasonal catch indices, 1980-1992 and 1998-2012

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2012 and for each year of the historical record of staked net catches on each river (Tables 23-28 and Figures 26-29). Seasonal catch indices in 2012 were: James River, 6.06; York River, 3.17; Rappahannock River, 7.28.

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 25). 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). These benchmarks have been upheld with the adoption of Amendment 3 to the Interstate Fishery Management Plan for American shad (ASMFC 2010).

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 1980-1992) 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 1980-1992) is available. Because effort of the historical fishery was lower on the Rappahannock than the other rivers, it is possible that this benchmark is artificially lower.

On the York River, the seasonal catch index in 2012 was 3.17. This value is the second lowest value seen since monitoring began in 1998. During fifteen years of monitoring, the index has been variable with high values (>12) in 1998 and 2001. Since 2005 index numbers have been low (<5). 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 (5.66), but this mean is still much lower than the benchmark based on 1950s data (17.44). In contrast to trends in the other two rivers, catch indices in the York River have been trending downward through the time series 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 was evidently 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 of which for 2012 are reported in Appendix I. The Mattaponi and Pamunkey tribal governments harvest American shad from the York River system 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 29) 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 2012 index (6.06) decreased from 2011 (9.00). This value is well below the peak catch index observed in the 1980s (29.20). The lowest value in the time-series (1.51) was recorded in 2008. 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 (4.59). 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 (34.1% of fish caught in 2012). 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 2012 index (7.28) increased from 2011 (6.51). This value is the highest recorded since monitoring began in 1998. The current geometric mean (3.49) is higher than the mean of the historical data (1.45). 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. There is little evidence of severe stock decline in the Rappahannock River, and this stock is considered to be low but stable (ASMFC 2007a). Stocking of American shad on the Rappahannock River began in 2003, using the progeny of Potomac River brood stock. In 2012, the highest percentage of fish with positive

hatchery marks was observed (6.8%). In the years since stocked hatchery fish would be expected to return (i.e., age 4 fish in 2007), the percent hatchery origin fish encountered in the Rappahannock River ranged from 0% (2007) to 6.8% (2012).

Peculiarities in the 2012 American shad run

The winter of 2011-2012 was characterized by unseasonably warm temperatures. In response to these conditions the American shad monitoring program began sampling on the James and York rivers in early February; American shad were collected during the first sampling event (February 5) on both the James and York rivers. Both rivers appeared to have an early run of maturing American shad in February, with numbers declining towards the end of February. This early run was small, and followed by a larger, average run of fish during mid-march. On the York River, post-spawning shad were encountered as early as 26 March (Table 2). This is the earliest record of a post-spawn female American shad since monitoring began in 1998 and confirms the occurrence of early spawning run activity on the York River.

On the Rappahannock River, water temperatures were closer to average in the early winter, and the first occurrence of American shad in our sampling was in late February (Table 29). Although the shad run on the Rappahannock River appeared to be average, post-spawning female American shad were captured as early as 9 April, which suggests early spawning activity in the Rappahannock River. The extent of this early spawning activity is unknown, although it appears to be lower on the Rappahannock River compared to the James and York rivers. The James and York River sampling locations are in closer proximity to the river mouths than the Rappahannock River. This increases the chances of encountering individuals that are staging before the spawning run at the James and York River locations.

Literature Cited

- ASMFC. 1999. Amendment 1 to the Interstate Fishery Management Plan for Shad and River Herring. Fishery Management Rept. No. 35, 76 pp.
- ASMFC. 2007a. American Shad Stock Assessment Report for Peer Review. Vols. I-III. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 Supplement.
- ASMFC. 2007b. Terms of Reference & Advisory Report to the American Shad Stock Assessment Peer Review. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01
- ASMFC. 2010. Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management). 158 pp.
- Aunins, A.W. 2006. Migratory and spawning behavior of American shad in the James River, Virginia. A thesis presented to the School of Marine Science, College of William and Mary, 99 pp.
- Aunins, A.W. and J.E. Olney. 2009. Migration and spawning behavior of American shad in the James River, Virginia. Transactions of the American Fisheries Society. 138:1392-1404.
- Bilkovic, D.M., C.H. Hershner and J.E. Olney. 2002a. Macroscale assessment of American shad spawning and nursery habitat in the Mattaponi and Pamunkey rivers, Virginia. North American Journal of Fisheries Management 22: 1176-1192.
- Bilkovic, D.M., J.E. Olney and C.H. Hershner. 2002b. Spawning of American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*) in the Mattaponi and Pamunkey rivers, Virginia. Fishery Bulletin 100: 632-640.
- Bowen, J. and S.T. Andrews. 2000. The Starving Time at Jamestown. Faunal Analysis of Pit 1, Pit 3, the Bulwark Ditch, Ditch 6, Ditch 7, and Midden 1. James City County, Virginia. Association for the Preservation of Virginia Antiquities Report, 150 pp.
- Brown, B. L. and J. M. Epifanio. 1994. Mixed-stock analysis of American shad in Virginia's and Maryland's coastal intercept fisheries. Final report to the VMRC, Sport Fish Restoration Project F-110-R.
- Cating, J.P. 1953. Determining age of Atlantic shad from their scales. U.S. Fish Wildl. Serv. Fish. Bull. 54: 187-199.
- Carpenter, A.C. and nine co-authors including K. Delano, J. Olney, and R. Latour. 2007.

- Status of the Potomac River stock. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement) 3:133-197.
- Hilton, E.J., R. Latour, B. Watkins, and A. Rhea. 2011. Monitoring relative abundance of American shad in Virginia's rivers. 2010 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-13, 15 April 2011.
- Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2012. *Monitoring relative abundance of American shad in Virginia rivers*. 2011 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-14, 15 April 2012.
- Hoening, J.M., R.J. Latour and J.E. Olney. 2008. Estimating stock composition of American shad (*Alosa sapidissima*) using mark-recovery data. North American Journal of Fisheries Management
- Hoffman, J. and J.E. Olney. 2005. Cohort dynamics of juvenile American shad (*Alosa sapidissima*) in the Pamunkey River, Virginia. Transactions of the American Fisheries Society 134:1-18.
- Hoffman J.C., Bronk D.A. and Olney J.E. 2007a. Contribution of allochthonous carbon to American shad production in the Mattaponi River, Virginia using stable isotopes. Estuaries and Coasts 30(6):1034-1048.
- Hoffman J.C., Bronk D.A. and Olney J.E. 2007b. Tracking nursery habitat use by young American shad using stable isotopes. Transactions of the American Fisheries Society 136: 1285-2197.
- Hoffman J.C, K.E. Limburg, D.A. Bronk and J.E. Olney. 2008. Overwintering habitats of migratory juvenile American shad in Chesapeake Bay. Environmental Biology of Fishes 81(3):329-345.
- Hyle, R. H. 2004. Reproductive biology of American shad, *Alosa sapidissima*, in the Mattaponi River. A thesis presented to the School of Marine Science, College of William and Mary, 88 pp.
- Kriete, W.H. Jr. and J.G. Loesch. 1980. Design and relative efficiency of a bow-mounted pushnet for sampling juvenile pelagic fishes. Transactions of the American Fisheries Society 109(6): 649-652.
- Latour, R. J., E. J. Hilton, P. D. Lynch, T. D. Tuckey, B. E. Watkins, and J. E. Olney. In press. Evaluating the current status of American shad (*Alosa sapidissima*) stocks in Virginia. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science 4: 302-311.
- Limburg, K.E., K.A. Hatalla and A. Kahnle. 2003. American shad in its native range. American Fisheries Society Symposium 35: 125-140.

- Maki, K. L., J. M. Hoenig and J. E. Olney. 2001. Estimating proportion mature at age when immature fish are unavailable for study, with application to American shad (*Alosa sapidissima*) in the York River, Virginia. *J. North American Fisheries Management* 21: 703-716.
- Maki, K. L., J. M. Hoenig and J. E. Olney. 2002. Interpreting Maturation Data for American Shad in the Presence of Fishing Mortality - A Look at Historical Data from the York River, Virginia. *J. North American Fisheries Management*.
- Maki, K.L., J.M. Hoenig, J.E. Olney and D.M. Heisey. 2006. Comparing historical catches of American shad in multifilament and monofilament nets: a step toward setting restoration targets for Virginia stocks. *North American Journal of Fisheries Management* 26: 282-288.
- Mansueti, R. J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. MD. Dept. Res. and Educ., Pub. No. 97. 293 pp.
- Maunder, M. N. and A. Punt. 2003. Standardizing catch and effort data: a review of recent approaches. *Fisheries Research* 70:141-159.
- McBride, R., M. Hendricks, and J.E. Olney. 2005. Testing the validity of Cating's criteria for age estimation from a Pennsylvania River. *Fisheries* 30:10-18.
- McCullagh, P. and J. A. Nelder. 1989. *Generalized Linear Models*, 2nd edition, Chapman & Hall, London.
- Nichols, P.R. and W.H. Massmann. 1963. Abundance, age and fecundity of shad, York River, VA., 1953-59. *U. S. Fishery Bulletin* 63: 179-187.
- Olney, J.E. 2003a. Monitoring relative abundance of American shad in Virginia's rivers. 2002 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-5, 15 April 2003.
- Olney, J.E. 2003b. Incorrect use of the names "Alosidae" and "Alosid" when referring to the shads in the subfamily Alosinae (Teleostei, Clupeidae). *American Fisheries Society Symposium* 35: xiii-xv.
- Olney, J.E. 2004. Monitoring relative abundance of American shad in Virginia's rivers. 2003 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-6, 15 April 2004.
- Olney, J.E. 2005. Monitoring relative abundance of American shad in Virginia's rivers. 2004 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-7, 15 April 2005.

- Olney, J.E. 2007. Age determination in American shad. Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement), 1: 38-41.
- Olney, J. E. and J. M. Hoenig. 2000a. Monitoring relative abundance of American shad in Virginia's rivers. 1998 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-1, 24 January 2000.
- Olney, J. E. and J. M. Hoenig. 2000b. Monitoring relative abundance of American shad in Virginia's rivers. 1999 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-2, 7 July 2000.
- Olney, J. E. and J. M. Hoenig. 2001a. Monitoring relative abundance of American shad in Virginia's rivers. 2000 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-3, 29 April 2001.
- Olney, J.E. and J.M. Hoenig. 2001b. Managing a fishery under moratorium: assessment opportunities for Virginia's stocks of American shad (*Alosa sapidissima*). Fisheries 26(2): 6-12.
- Olney, J.E., S.C. Denny and J.M. Hoenig. 2001. Criteria for determining maturity stage in female American shad, *Alosa sapidissima*, and the mystery of partial spawning. Bull. Francais de la Pêche et de la Pisciculture 362/363: 881-901.
- Olney, J.E. and K.L. Maki. 2002. Monitoring relative abundance of American shad in Virginia's rivers. 2001 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-4, 28 April 2002.
- Olney, J.E. and R.S. McBride. 2003. Intraspecific variation in batch fecundity of American shad (*Alosa sapidissima*): revisiting the paradigm of reciprocal trends in reproductive traits. American Fisheries Society Symposium 35: 185-192.
- Olney, J.E., D.A. Hopley, Jr., T.P. Gunther Jr., K.L. Maki and J.M. Hoenig. 2003. Signs of recovery of American shad, *Alosa sapidissima*, in the James River, Virginia. American Fisheries Society Special Symposium 35: 323-329.
- Olney, J.E. and K. Delano. 2006. Monitoring relative abundance of American shad in Virginia's rivers. 2005 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-8, 15 April 2006.
- Olney, J.E., D.M. Bilkovic, C.H. Hershner, L.M. Varnell, H. Wang and R.L. Mann. 2006a. Six fish and 600,000 thirsty folks – a fishing moratorium on American shad thwarts a controversial municipal reservoir project in Virginia, USA. American Fisheries Society Symposium, 2006.
- Olney, J.E., R.J. Latour, B.E. Watkins and D.G. Clarke. 2006b. Migratory behavior of American shad (*Alosa sapidissima*) in the York River, Virginia with implications

- for estimating in-river exploitation from tag recovery data. *Transactions of the American Fisheries Society* 135: 889-896.
- Olney, J.E. and B.E. Watkins. 2008. Monitoring relative abundance of American shad in Virginia's rivers. 2007 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-10, 15 April 2008.
- Olney, J.E. and B.E. Watkins. 2009. Monitoring relative abundance of American shad in Virginia's rivers. 2008 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-11, 15 April 2009.
- Olney, J.E., B.E. Watkins and E.J. Hilton. 2010. Monitoring relative abundance of American shad in Virginia's rivers. 2009 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-12, 15 April 2010.
- Olney, J.E. and K.D. Walter. 2007. Monitoring relative abundance of American shad in Virginia's rivers. 2006 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-9, 15 April 2007.
- Olney, J.E., K.A. Delano, R.J. Latour, T.P. Gunter, Jr., and L.A. Weaver. 2007. Status of American shad stocks in Virginia. *Atlantic States Marine Fisheries Commission Stock Assessment Report No. 07-01 (Supplement) 3:198-250.*
- Stevenson, C. H. 1899. The shad fisheries of the Atlantic coast of the United States. U.S. Commission of Fish and Fisheries, Report of the Commissioner for 1998 XXIV:101-269.
- Tuckey, T. 2009. Variability in juvenile growth, mortality, maturity and abundance of American shad and blueback herring in Virginia. Doctoral Dissertation, School of Marine Science, College of William and Mary, 175 pp.
- Tuckey, T., and J. E. Olney. 2010. Maturity schedules of female American shad vary at small spatial scales in Chesapeake Bay. *North American Journal of Fisheries Management* 30: 1020-1031.
- Upton, S. A. 2008. Novel use of a natural isotope to track recruitment and evaluate age determination for the 2002 year class of American shad in the York River, Virginia. Master's thesis, School of Marine Science, College of William and Mary, 75 pp.
- Upton, S.A., B.D. Walther, S.R. Thorrold, and J.E. Olney. 2012. Use of a natural isotopic signature in otoliths to evaluate scale-based age determination for American shad. *Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science*. 4: 346-357.
- VCF (Virginia Commission of Fisheries). 1875. Annual report for 1875. Richmond,

VA.38 pp.

Walburg, C. H. and P. R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. U. S. Fish. Wildl. Serv. Sci. Rep. Fish. No. 550. 105 pp.

Walter, J.F. and J.E. Olney. 2003. Feeding behavior of American shad during the spawning migration in the York River, Virginia. American Fisheries Society Symposium 35: 201-209.

Walther, B.D., S.R. Thorrold and J.E. Olney. 2008. Geochemical signatures in otoliths record natal origins of American shad. Transactions of the American Fisheries Society 137:57-69

Wilhite, M.L., K.L. Maki, J.M. Hoenig and J.E. Olney. 2003. Towards validation of a juvenile index of abundance for American shad in the York River, Virginia (USA). American Fisheries Society Symposium 35: 285-294.

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 2012.

Sampling Location	Sampling dates in 2012	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	2/5 - 4/21	262	29	428.9	35.3	291	464.2
York River	2/5 - 4/16	185	32	269.7	39.3	217	309.0
Rappahannock River	2/15 - 5/7	368	30	560.4	34.70	398	595.1
Totals		815	91	1259.0	109.3	906	1368.3

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 Rappahannock River, spring 2012. These individuals were removed from the monitoring data.

Sampling Location	Date	Specimen number	Total length (mm)	Fork length (mm)	Total weight (g)
York River	3/26/2012	16836	458	407	818.3
	4/1/2012	16911	531	473	1300.4
	4/2/2012	16999	503	449	1181.0
Rappahannock River	4/9/2012	17116	520	469	1514.1
	4/15/2012	17202	523	468	1193.9
	4/16/2012	17242	541	473	1340.3
	4/22/2012	17270	545	482	1275.8
	4/22/2012	17263	455	407	800.0
	4/30/2012	17297	502	442	1139.2

Table 3. 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, spring 2012.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/5/2012	36	17	0.066	23.9	0.093
2/6/2012	37	3	0.011	4.4	0.016
2/14/2012	45	3	0.011	4.9	0.018
2/15/2012	46	1	0.004	1.8	0.007
2/21/2012	52	2	0.008	3.4	0.013
2/22/2012	53	0	0	0	0
2/26/2012	57	6	0.022	10.2	0.038
2/27/2012	58	12	0.044	16.6	0.061
3/4/2012	64	18	0.067	27.5	0.102
3/5/2012	65	12	0.044	17.4	0.063
3/11/2012	71	21	0.077	32.3	0.118
3/18/2012	78	41	0.153	61.0	0.227
3/19/2012	79	53	0.193	80.7	0.294
3/25/2012	85	13	0.046	19.8	0.071
4/1/2012	92	30	0.107	45.6	0.163
4/2/2012	93	27	0.098	38.9	0.142
4/15/2012	106	0	0	0	0
4/16/2012	107	3	0.011	5.2	0.019
4/21/2012	112	0	0	0	0
Totals		262		393.6	

Table 4. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the James River, spring 2012.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/5/2012	36	3	0.012	3.3	0.013
2/6/2012	37	0	0	0	0
2/14/2012	45	2	0.007	2.0	0.007
2/15/2012	46	0	0	0	0
2/21/2012	52	1	0.004	1.3	0.005
2/22/2012	53	1	0.005	1.2	0.006
2/26/2012	57	5	0.019	6.6	0.025
2/27/2012	58	0	0	0	0
3/4/2012	64	3	0.011	3.5	0.013
3/5/2012	65	1	0.004	1.5	0.006
3/11/2012	71	2	0.007	2.7	0.010
3/18/2012	78	4	0.015	4.6	0.017
3/19/2012	79	5	0.018	6.3	0.023
3/25/2012	85	0	0	0	0
4/1/2012	92	0	0	0	0
4/2/2012	93	2	0.007	2.3	0.008
4/15/2012	106	0	0	0	0
4/16/2012	107	0	0	0	0
4/21/2012	112	0	0	0	0
Totals		29		35.3	

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 2012.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/5/2012	36	4	0.015	5.7	0.021
2/6/2012	37	7	0.025	9.3	0.033
2/14/2012	45	0	0	0	0
2/15/2012	46	2	0.007	2.8	0.010
2/21/2012	52	6	0.022	9.1	0.034
2/22/2012	53	4	0.015	6.4	0.024
2/27/2012	58	17	0.062	24.4	0.089
2/28/2012	59	11	0.041	16.2	0.060
3/4/2012	64	4	0.015	5.7	0.021
3/5/2012	65	7	0.025	10.5	0.038
3/11/2012	71	13	0.047	17.9	0.065
3/12/2012	72	6	0.022	8.3	0.030
3/18/2012	78	13	0.051	20.1	0.078
3/19/2012	79	15	0.055	22.1	0.080
3/25/2012	85	6	0.023	8.9	0.034
3/26/2012	86	38	0.141	55.4	0.206
4/1/2012	92	16	0.062	24.5	0.095
4/2/2012	93	5	0.018	7.0	0.025
4/9/2012	100	5	0.018	7.0	0.026
4/10/2012	101	5	0.018	7.1	0.026
4/15/2012	106	1	0.004	1.4	0.005
4/16/2012	107	0	0	0	0
Totals		185		269.8	

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 2012.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/5/2012	36	2	0.007	2.7	0.010
2/6/2012	37	1	0.004	1.0	0.004
2/14/2012	45	0	0	0	0
2/15/2012	46	1	0.004	1.2	0.004
2/21/2012	52	2	0.007	2.5	0.009
2/22/2012	53	1	0.004	1.0	0.004
2/27/2012	58	3	0.011	3.2	0.012
2/28/2012	59	4	0.015	5.3	0.020
3/4/2012	64	2	0.007	2.1	0.008
3/5/2012	65	2	0.007	2.1	0.008
3/11/2012	71	4	0.015	4.5	0.017
3/12/2012	72	0	0	0	0
3/18/2012	78	3	0.012	4.1	0.016
3/19/2012	79	5	0.018	6.6	0.024
3/25/2012	85	0	0	0	0
3/26/2012	86	1	0.004	1.1	0.004
4/1/2012	92	0	0	0	0
4/2/2012	93	0	0	0	0
4/9/2012	100	0	0	0	0
4/10/2012	101	1	0.004	1.7	0.006
4/15/2012	106	0	0	0	0
4/16/2012	107	0	0	0	0
Totals		32		39.1	

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 2012.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/15/2012	46	0	0	0	0
2/16/2012	47	0	0	0	0
2/21/2012	52	0	0	0	0
2/22/2012	53	0	0	0	0
2/29/2012	60	3	0.011	4.3	0.016
3/1/2012	61	3	0.011	4.9	0.018
3/4/2012	64	0	0	0	0
3/5/2012	65	2	0.007	3.8	0.014
3/11/2012	71	4	0.014	6.5	0.023
3/12/2012	72	9	0.033	14.2	0.052
3/18/2012	78	9	0.032	15.1	0.054
3/19/2012	79	8	0.030	13.1	0.049
3/25/2012	85	8	0.029	12.2	0.044
3/26/2012	86	39	0.146	60.7	0.228
4/1/2012	92	40	0.144	60.5	0.217
4/2/2012	93	53	0.199	83.3	0.313
4/9/2012	100	45	0.167	68.1	0.253
4/10/2012	101	52	0.187	79.1	0.285
4/15/2012	106	30	0.110	45.4	0.167
4/16/2012	107	21	0.079	30.4	0.114
4/22/2012	113	11	0.041	15.0	0.056
4/23/2012	114	11	0.040	16.0	0.058
4/29/2012	120	8	0.030	11.6	0.044
4/30/2012	121	12	0.046	16.4	0.063
5/6/2012	127	0	0	0	0
5/7/2012	128	0	0	0	0
Totals		368		560.6	

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 2012.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/15/2012	46	0	0	0	0
2/16/2012	47	0	0	0	0
2/21/2012	52	0	0	0	0
2/22/2012	53	1	0.004	1.4	0.005
2/29/2012	60	1	0.004	1.1	0.004
3/1/2012	61	2	0.007	2.3	0.009
3/4/2012	64	0	0	0	0
3/5/2012	65	2	0.007	2.5	0.009
3/11/2012	71	2	0.007	2.1	0.007
3/12/2012	72	5	0.018	5.7	0.021
3/18/2012	78	2	0.007	2.3	0.008
3/19/2012	79	0	0	0	0
3/25/2012	85	1	0.004	1.4	0.005
3/26/2012	86	3	0.011	3.4	0.013
4/1/2012	92	3	0.011	2.8	0.010
4/2/2012	93	1	0.004	1.2	0.004
4/9/2012	100	4	0.015	5.0	0.018
4/10/2012	101	1	0.004	1.5	0.005
4/15/2012	106	0	0	0	0
4/16/2012	107	0	0	0	0
4/22/2012	113	0	0	0	0
4/23/2012	114	0	0	0	0
4/29/2012	120	0	0	0	0
4/30/2012	121	2	0.008	2.0	0.008
5/6/2012	127	0	0	0	0
5/7/2012	128	0	0	0	0
Totals		30		34.7	

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 2012. 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 (kg)	Standard deviation
James River	2008	39	479.2	22.9	1.4	194.4
	2007	100	484.9	20.1	1.4	167.6
	2006	53	499.5	18.9	1.6	199.8
	2005	12	520.8	14.9	1.8	191.6
	2004	2	521	14.1	1.6	477.9
	NA	56	491.7	23.2	1.5	210.6
	York River	2008	41	473.0	18.2	1.3
2007		80	479.8	19.2	1.5	151.3
2006		30	495.3	24.2	1.5	231.8
2005		8	518.3	18.8	1.8	163.6
NA		26	483.0	25.1	1.5	283.7
Rappahannock River		2009	1	477	–	1.3
	2008	68	481.8	14.0	1.4	128.0
	2007	163	494.6	19.2	1.5	188.7
	2006	62	510.2	18.9	1.7	195.8
	2005	24	523.5	15.7	1.8	199.4
	2004	5	527.8	9.8	1.8	147.6
	NA	45	494.0	20.2	1.5	190.6

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 2012. 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	2008	2	471	12.7	1.1	48.6
	2007	10	448	15.1	1.1	120.5
	2006	3	454.3	26.1	1.2	159.8
	2005	1	441	–	1.0	–
	NA	13	464.2	27.5	1.3	195.0
York River	2008	2	464.5	37.5	1.1	311.2
	2007	16	455.6	21.1	1.2	148.3
	2006	2	430.5	4.9	1.1	82.2
	2004	1	499	–	1.6	–
	NA	11	460.5	34.0	1.2	214.7
Rappahannock River	2008	6	428.8	28.6	0.9	231.2
	2007	11	464.7	17.0	1.2	174.4
	2006	7	465.9	11.0	1.3	95.0
	2005	1	497	–	1.2	–
	NA	5	471.4	33.4	1.2	190.1

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 2012. 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	2008	39	54.3	18.5	0.0077	0.0107
	2007	100	144.5	18.5	0.0197	0.0285
	2006	53	85.5	18.5	0.0104	0.0168
	2005	12	21.4	18.5	0.0024	0.0042
	2004	2	3.3	18.5	0.0004	0.0007
	NA	56	84.5	18.5	0.0110	0.0167
	York River	2008	41	54.5	21.8	0.0069
2007		80	116.2	21.8	0.0134	0.0194
2006		30	46.3	21.8	0.0050	0.0077
2005		8	14.5	21.8	0.0013	0.0024
NA		26	38.2	21.8	0.0043	0.0064
Rappahannock River	2009	1	1.3	25.4	0.0001	0.0002
	2008	68	92.6	25.4	0.0096	0.0131
	2007	163	244.3	25.4	0.0231	0.0346
	2006	62	102.4	25.4	0.0088	0.0145
	2005	24	43.9	25.4	0.0034	0.0062
	2004	5	9.2	25.4	0.0007	0.0013
	NA	45	66.8	25.4	0.0064	0.0095

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 2012. 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	2008	2	2.3	18.5	0.0004	0.0005
	2007	10	11.3	18.5	0.0020	0.0022
	2006	3	3.6	18.5	0.0006	0.0007
	2005	1	1.0	18.5	0.0002	0.0002
	NA	13	17.1	18.5	0.0026	0.0034
York River	2008	2	2.2	21.8	0.0003	0.0004
	2007	16	19.7	21.8	0.0027	0.0033
	2006	2	2.2	21.8	0.0003	0.0004
	2004	1	1.6	21.8	0.0002	0.0003
	NA	11	13.7	21.8	0.0018	0.0023
Rappahannock River	2008	6	5.6	25.4	0.0009	0.0008
	2007	11	12.9	25.4	0.0016	0.0018
	2006	7	8.8	25.4	0.0010	0.0013
	2005	1	1.2	25.4	0.0001	0.0002
	NA	5	6.2	25.4	0.0007	0.0009

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2012 in the James and York rivers. Table entries are total numbers of fish that were aged (James River, n = 222; York River, n = 180). 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 is the number of aged fish out of the total that had hatchery marks on their otoliths (James, n =21 York, n=1). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

		Age at Maturity				
James River Year Class	Age at Capture	3	4	5	6	7
2008	4	5(2)	36(2)	-	-	-
2007	5	8(2)	35(2)	67(6)	-	-
2006	6	1(1)	6	29(4)	20	-
2005	7	0	1	7(1)	5(1)	0
2004	8	0	0	1	1	0

		Age at Maturity				
York River Year Class	Age at Capture	3	4	5	6	7
2008	4	3	40	-	-	-
2007	5	6	37	53	-	-
2006	6	3	4	20(1)	5	-
2005	7	0	1	3	4	0
2004	8	0	1	0	0	0

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2012 in the Rappahannock River. Table entries are total numbers of fish that were aged (Rapp. River, n=348). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the Rappahannock river, the number in parentheses are the number of aged fish out of the total that had hatchery marks on their otoliths (Rapp, n=7). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

Rapp. River Year Class	Age at Capture	Age at Maturity				
		3	4	5	6	7
2009	3	1	-	-	-	-
2008	4	9	65(1)	-	-	-
2007	5	8	52(1)	114(4)	-	-
2006	6	0	10	36(1)	23	-
2005	7	0	2	13	9	1
2004	8	0	1	2	2	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=37) taken in staked gill net monitoring in 2012. A total of 255 American shad were scanned for hatchery marks (JA, n=82; RA, n=120; YK, n=53). Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged.

Specimen Number	River Capture	River Origin	Sequence	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
16405	James	James	3	6	3	422	473	1435.2	F
16462	James	James	3	5	2	434	492	1685.1	F
16468	James	James	3	5	0	408	466	1415.0	F
16471	James	James	3	6	1	445	505	1645.5	F
16474	James	James	3	4	1	389	450	1178.1	F
16543	James	James	3	4	1	429	478	1655.0	F
16552	York	York	3	6	1	425	483	1473.0	F
16564	James	James	3	NA	NA	401	458	1270.0	F
16591	James	James	3	NA	NA	453	507	1513.1	M
16609	James	James	3	4	0	451	507	1518.4	F
16657	James	James	3	NA	NA	454	506	1544.8	F
16660	James	James	3	NA	NA	430	487	1368.8	F
16681	James	James	3	6	1	445	502	1452.3	F
16687	James	James	3	5	1	425	479	1414.1	F
16688	James	James	3	6	1	445	497	1706.8	F
16693	James	James	3	NA	NA	451	505	1481.3	F
16696	James	James	3	5	0	430	483	1378.3	F
16732	James	James	3	NA	NA	431	492	1425.3	M
16735	James	James	3	6	1	438	492	1465.9	F
16738	James	James	3	5	0	458	521	1691.4	F
16744	James	James	3	5	0	412	467	1145.1	F

Specimen Number	River Capture	River Origin	Sequence	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
16756	James	James	3	5	0	433	494	1542.5	2
16771	James	James	3	4	0	446	503	1637.9	2
16872	Rappahannock	Rappahannock	3	NA	NA	441	494	1543.2	2
16935	James	James	3	7	1	435	494	1574.3	2
16997	Rappahannock	Rappahannock	3	5	0	446	503	1632.8	2
17004	James	James	3	5	1	435	490	1280.7	2
17022	James	James	3	NA	NA	438	494	1419.6	2
17028	James	James	3	5	2	422	479	1292.4	2
17031	James	James	3	5	0	411	467	1168.9	2
17067	Rappahannock	Rappahannock	3	5	0	421	473	1424.0	2
17079	Rappahannock	Rappahannock	3	4	0	422	479	1275.8	2
17085	Rappahannock	Rappahannock	3	5	0	434	487	1389.5	2
17136	Rappahannock	Rappahannock	3	5	1	450	500	1369.1	2
17166	Rappahannock	Rappahannock	3	5	0	420	477	1334.1	2
17181	Rappahannock	Rappahannock	3	6	1	437	494	1601.0	2
17234	James	James	3	7	2	453	512	1443.6	2

Table 16. Total numbers of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2012. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (E. Brittle). Abbreviation: NA; not aged.

Hatchery Year Class	Hatchery Production (millions)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total	% Total
1992	0.05		1														1	0.1
1993	0.5	7	2	1													10	1.1
1994	1.6	7	3	9			1										20	2.2
1995	5.3			59	9	8	4	3									83	9.3
1996	5.8			53	62	43	10	4	1								173	19.3
1997	5.9			2	27	78	57	5	4		1						174	19.4
1998	10					13	52	17	13								95	10.6
1999	7.3						14	29	7								50	5.6
2000	8.9						1	5	9		1						16	1.8
2001	9.3								3	4	3						10	1.1
2002	8.4									4	20	7	2				33	3.7
2003	8.7										12	8	1	1	2		24	2.7
2004	6.6										2	3	2	13	4		24	2.7
2005	6.0												1	18	22	2	43	4.8
2006	7.0													11	35	5	51	5.7
2007	6.5														5	10	15	1.7
2008	6.2															4	4	0.4
2009	3.8																	
2010	3.7																	
2011	2.4																	
2012	5.4																	
NA	--					12	3	5	3	1	9	2	2	11	15	7	70	7.8
Total	119.35	14	6	124	98	154	142	68	40	9	48	20	8	54	83	28	896	100

Table 17. Total numbers of hatchery-marked American shad taken in staked gill nets in the Rappahannock River, 2007-2012. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (E. Brittle). Abbreviation: NA; not aged.

Hatchery Year Class	Hatchery Production (millions)	2007	2008	2009	2010	2011	2012	Total	% Total
2003	1.4								
2004	3.2		1	2	1			4	25.0
2005	3.4			1		1		2	12.5
2006	6.3					1	1	2	12.5
2007	4.5					1	5	6	37.5
2008	4.8						1	1	6.25
2009	2.7								
2010	3.9								
2011	4.1								
2012	6.0								
NA	--						1	1	6.25
Total	40.3	0	1	3	1	3	8	16	100

Table 18. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2012) on the James, Chickahominy and Rappahannock rivers. The index is the geometric mean catch per haul. Means are reported for five year increments for years 1980 – 1999. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James	SD	N	Chickahominy	SD	N	Rappahannock	SD	N
1980 - 84	0.08	0.357	18	0		5	0.32	2.774	4
1985 - 89	0.01	0.224	34	0		8	0.16	0.492	16
1990 - 94	0.01	0.162	62	0		10	0.08	0.345	32
1995 - 99	0.01	0.105	65	0		10	0.17	0.457	33
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
2011	0.15	0.391	59	0		10	1.15	1.052	27
2012	0.01	0.092	57	0		10	0.19	0.422	35

Table 19. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2012) on the Mattaponi, Pamunkey, and York rivers. The index is the geometric mean catch per haul. Means are reported for five year increments for years 1980 – 1999. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	Mattaponi	SD	N	Pamunkey	SD	N	York	SD	N
1980 - 84	7.21	1.005	17	0.42	0.599	12	2.41	1.152	30
1985 - 89	1.94	0.786	32	0.20	1.031	23	0.91	0.699	59
1990 - 94	0.59	0.772	46	0.04	0.223	36	0.28	0.620	87
1995 - 99	3.96	0.975	49	0.53	0.683	39	1.66	0.921	92
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
2011	1.16	1.387	48	0.27	0.554	35	0.67	1.114	88
2012	0.01	0.099	48	0.02	0.111	39	0.02	0.101	93

Table 20. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2012.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/5/2012	6	4	10	8	18
2/6/2012	2	1	3	6	9
2/14/2010	56	14	70	9	79
2/15/2012	12	4	16	2	18
2/21/2012	24	17	41	6	47
2/22/2012	5	2	7	1	8
2/26/2010	29	43	72	20	92
2/27/2010	41	22	63	16	79
3/4/2012	14	9	23	39	62
3/5/2012	19	10	29	43	72
3/11/2012	36	28	64	108	172
3/18/2012	4	0	4	139	143
3/19/2012	4	5	9	116	125
3/25/2012	0	3	3	318	321
4/1/2012	2	3	5	128	133
4/2/2012	0	0	0	83	83
4/15/2012	0	0	0	23	23
4/16/2012	0	0	0	26	26
4/21/2012	0	2	2	118	120
Totals	254	167	421	1209	1630

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2012.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/5/2012	42	31	73	96	169
2/6/2012	25	8	33	115	148
2/14/2010	60	9	69	827	896
2/15/2012	49	15	64	818	882
2/21/2012	50	13	63	698	761
2/22/2012	35	19	54	180	234
2/27/2012	31	35	66	619	685
2/28/2012	11	16	27	64	91
3/4/2012	6	0	6	41	47
3/5/2012	6	5	11	242	253
3/11/2012	7	21	28	929	957
3/12/2012	6	7	13	1055	1068
3/18/2012	2	4	6	522	528
3/19/2012	3	9	12	536	548
3/25/2012	3	7	10	952	962
3/26/2012	1	4	5	573	578
4/1/2012	6	2	8	155	163
4/2/2012	2	0	2	143	145
4/9/2012	2	5	7	263	270
4/10/2012	1	5	6	279	285
4/15/2012	6	3	9	116	125
4/16/2012	2	1	3	173	176
Totals	356	219	575	9396	9971

Table 22. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2012.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/15/2012	5	5	10	37	47
2/16/2012	3	0	3	16	19
2/21/2012	5	0	5	55	60
2/22/2012	6	2	8	50	58
2/29/2012	30	13	43	69	112
3/1/2012	11	13	24	476	500
3/4/2012	13	16	29	194	223
3/5/2012	10	12	22	129	151
3/11/2012	8	25	33	97	130
3/12/2012	14	22	36	61	97
3/18/2012	8	32	40	279	319
3/19/2012	10	18	28	460	488
3/25/2012	4	35	39	290	329
3/26/2012	2	39	41	595	636
4/1/2012	2	5	7	343	350
4/2/2012	5	7	12	274	286
4/9/2012	10	27	37	238	275
4/10/2012	8	20	28	241	269
4/15/2012	6	9	15	240	255
4/16/2012	5	14	19	225	244
4/22/2012	7	13	20	238	258
4/23/2012	4	8	12	430	442
4/29/2012	2	2	4	119	123
4/30/2012	1	4	5	203	208
5/6/2012	1	7	8	158	166
5/7/2012	2	7	9	192	201
Totals	182	355	537	5709	6246

Table 23. 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 24. 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
2011	7.0	85	0.216	0.074	6.51
2012	7.2	62	0.313	0.080	7.28
Geometric mean					3.49

Table 25. 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 26. 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
2011	6.0	58	0.219	0.060	4.58
2012	6.0	66	0.206	0.045	3.17
Geometric mean					5.66

Table 27. 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 28. 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
2011	6.3	78	0.357	0.091	9.00
2012	5.2	72	0.294	0.076	6.06
Geometric mean					4.59

Table 29. Daily temperature, salinity and number of American shad (both sexes combined) caught in staked gill nets on the James, York and Rappahannock rivers in 2012. Numbers in parentheses are the number of post-spawning fish caught. Abbreviations: N, number of shad caught. Highlighted cells are non-fishing days.

Date	James		York		Rappahannock	
	Temp °C	N	Temp °C	N	Temp °C	N
2/5/2012	9.2	20	8.3	6		
2/6/2012	8.1	3	7.6	8		
2/14/2012	6.3	5	6.4	0		
2/15/2012	6.5	1	6.7	3	5.6	0
2/16/2012					6.2	0
2/21/2012	7.5	3	6.9	8	6.5	0
2/22/2012	7.3	1	7.4	5	6.8	1
2/26/2012	7.8	11				
2/27/2012	7.9	12	7.6	20		
2/28/2012			8.7	15		
2/29/2012					8.3	4
3/1/2012					9.1	5
3/4/2012	10.3	21	10.2	6	9.9	0
3/5/2012	9.3	13	9.1	9	8.9	4
3/11/2012	9	23	9.3	17	9.3	6
3/12/2012			9.9	6	9.8	14
3/18/2012	13.5	45	14.3	16	16.2	11
3/19/2012	14.1	58	14.4	20	16.2	8
3/25/2012	17.8	13	18.5	6	19.2	9
3/26/2012			17.1	40(1)	18.5	42
4/1/2012	16	30	15.4	17(1)	15.7	43
4/2/2012	16	29	15.7	6(1)	16.3	54
4/9/2012			15.5	5	15.1	50(1)
4/10/2012			15.5	6	15.2	53
4/15/2012	15	0	15.3	1	15.5	31(1)
4/16/2012	16.7	3	17	0	17.6	22(1)
4/21/2012	17.7	0				
4/22/2012					19.2	13(2)
4/23/2012					17.5	11
4/29/2012					15.9	8
4/30/2012					16.5	15(1)
5/6/2012					21.4	0
5/7/2012					20.8	0

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.

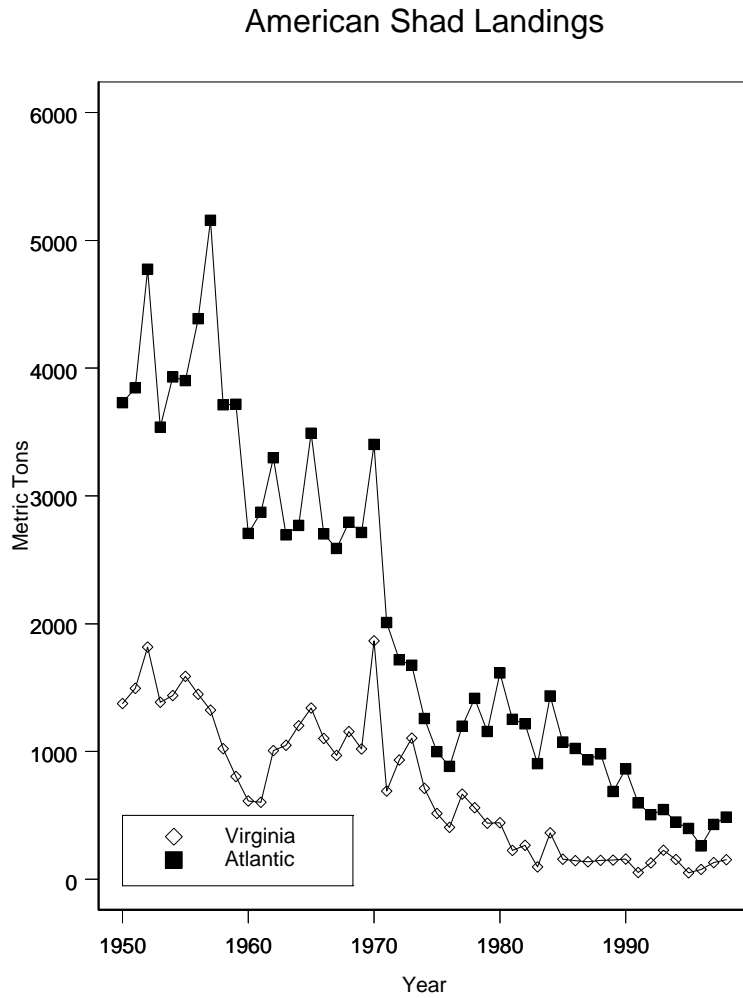


Figure 2. Number and location of staked gill nets on the James River in 1983.

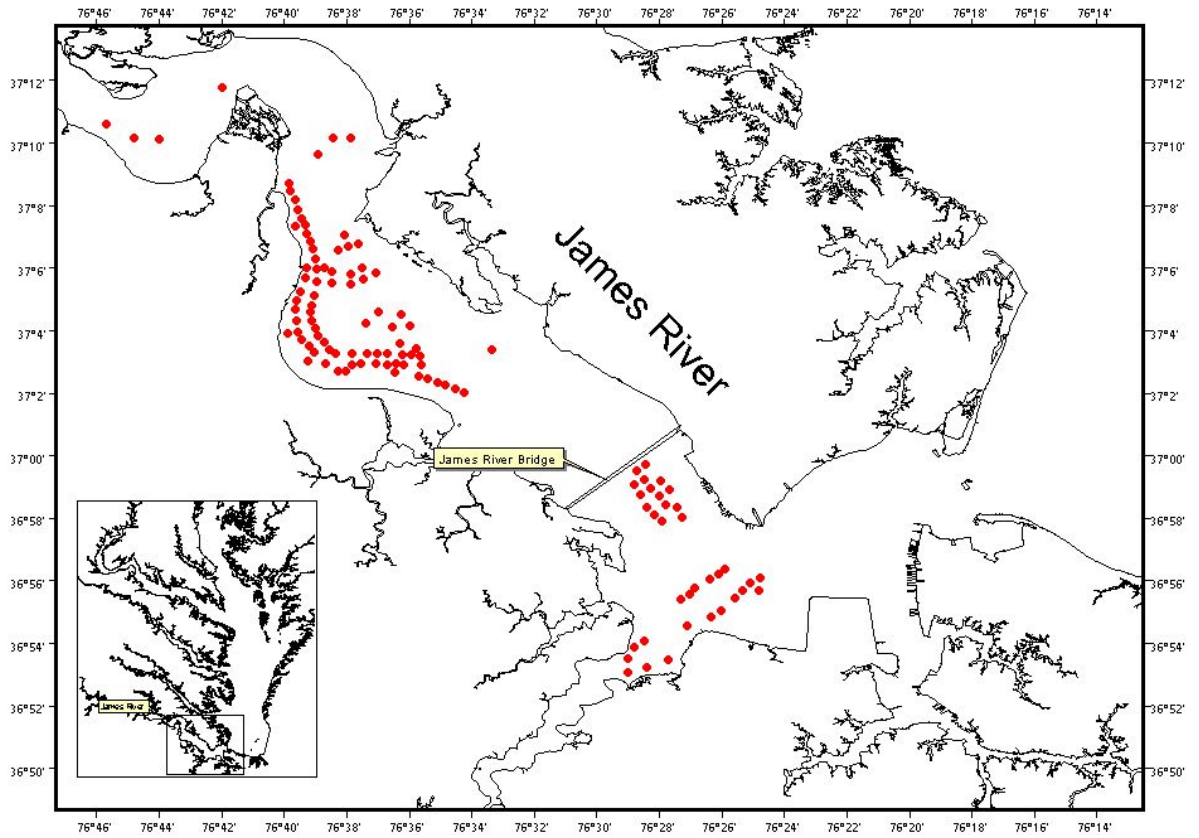


Figure 3. Number and location of staked gill nets on the York River in 1983.

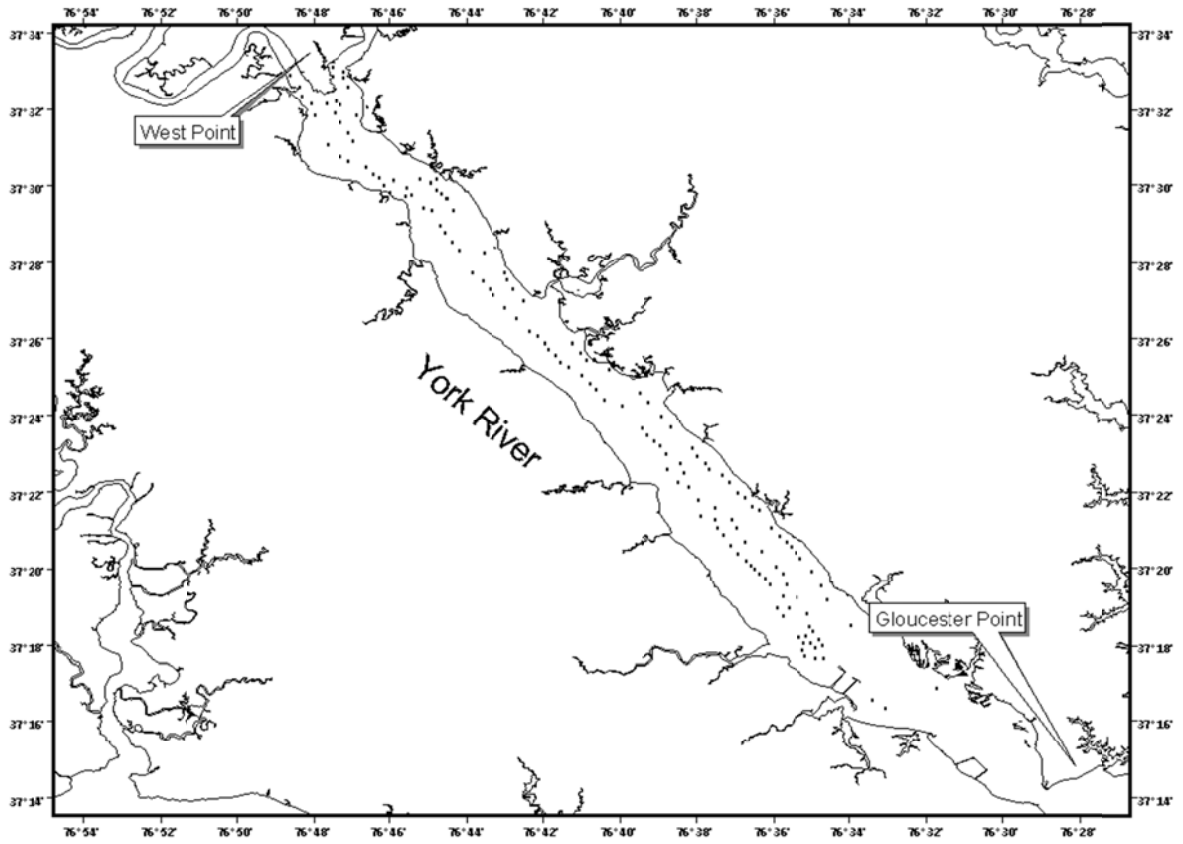


Figure 4. Number and location of staked gill nets on the Rappahannock River in 1983.

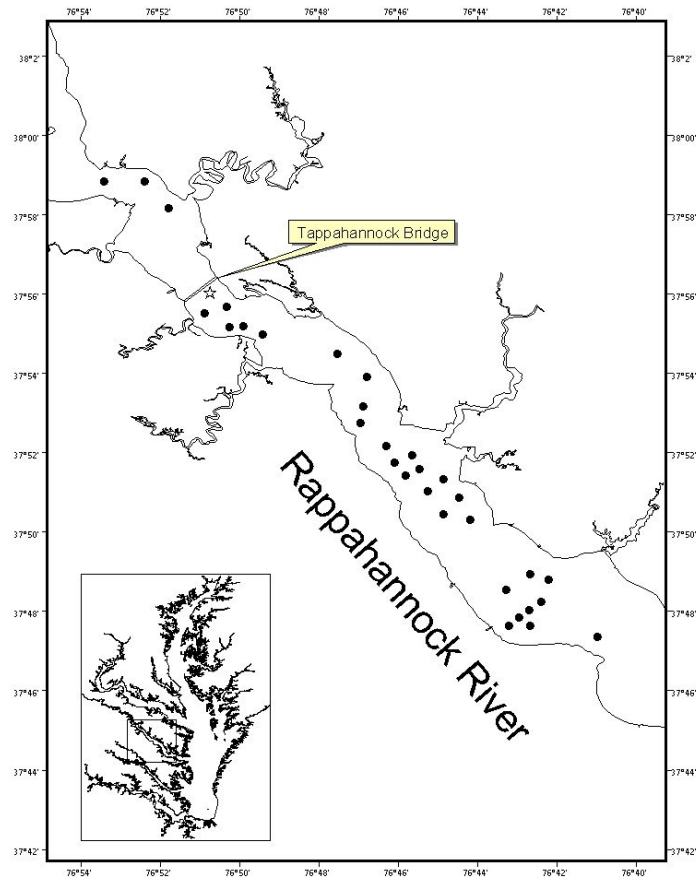


Figure 5. Location of the staked gill net fished by Mr. Marc Brown on the James River.

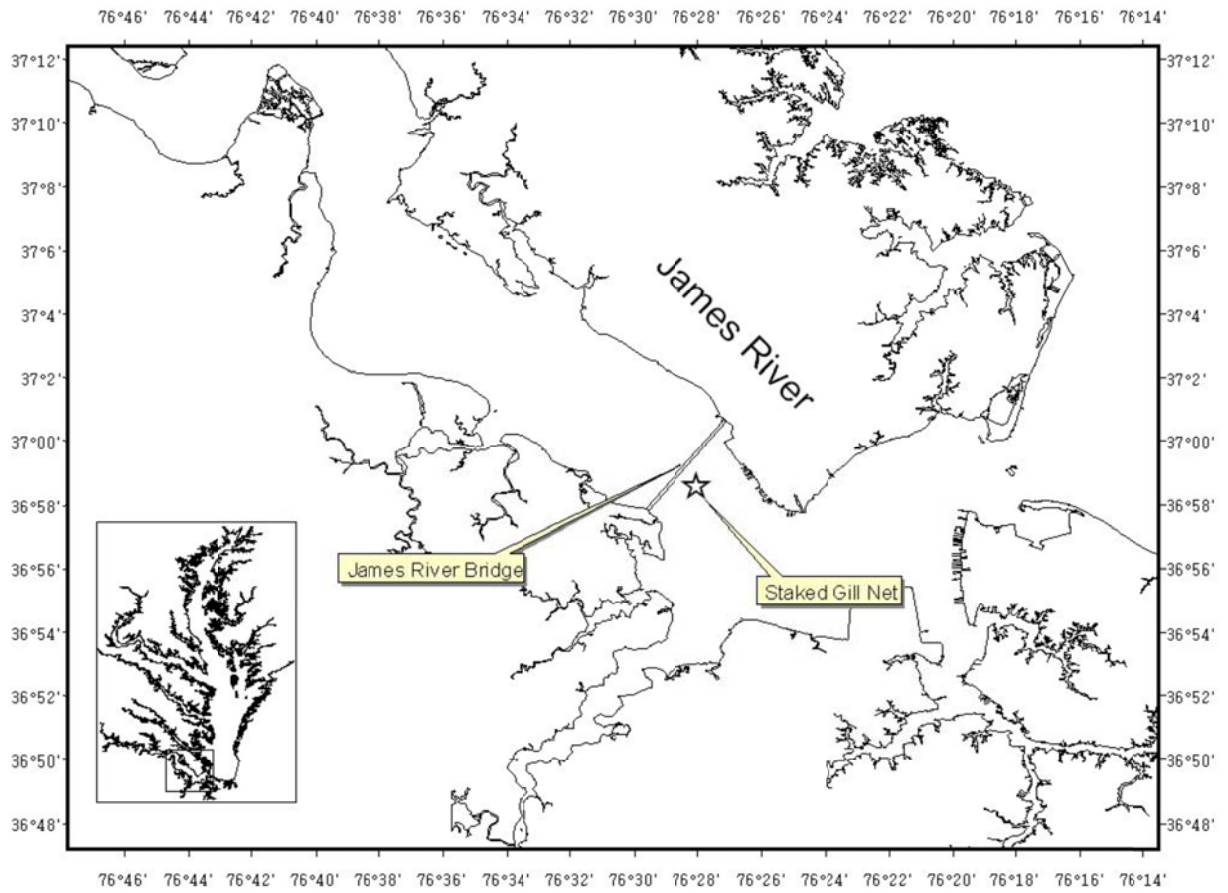


Figure 6. Location of the staked gill net fished by Mr. Raymond Kellum on the York River.

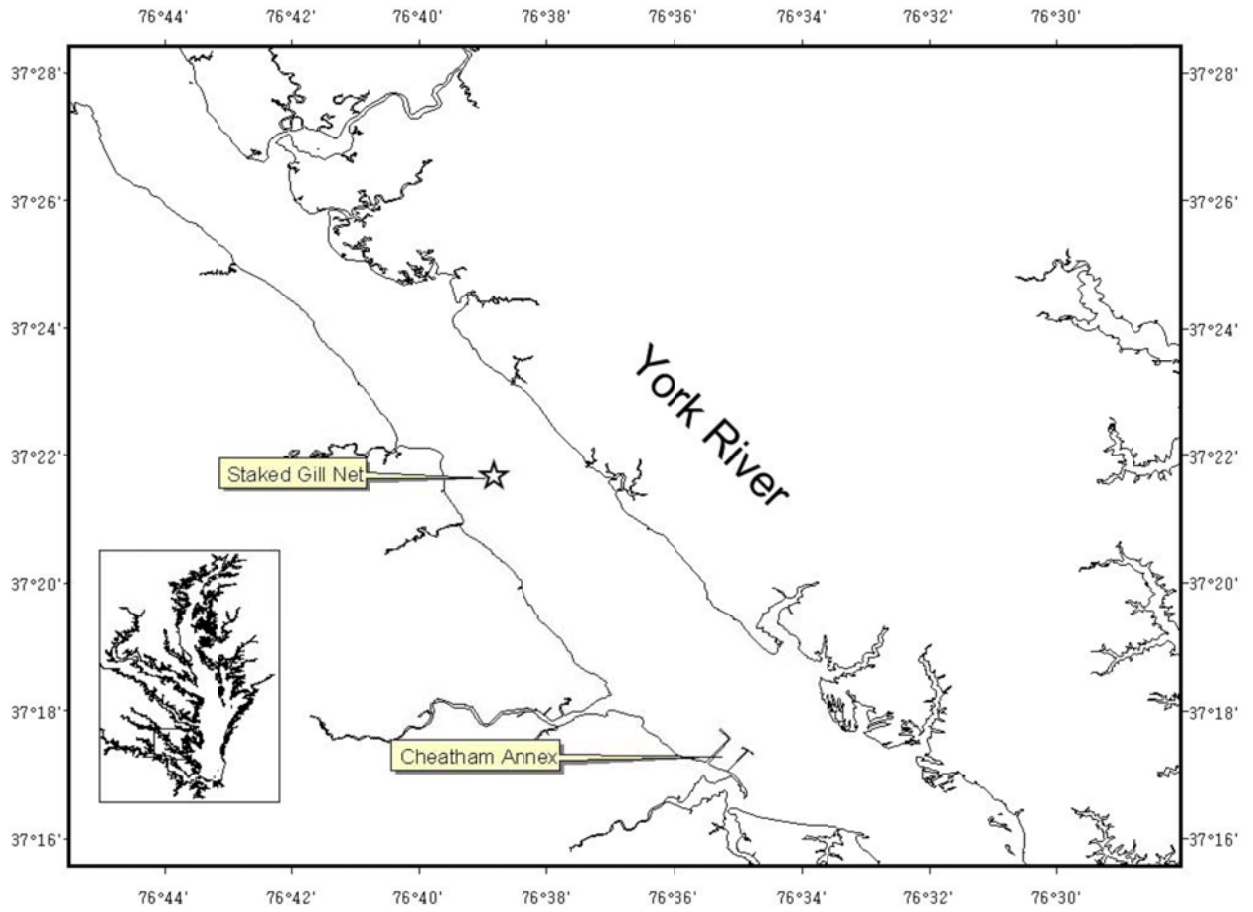


Figure 7. Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River.

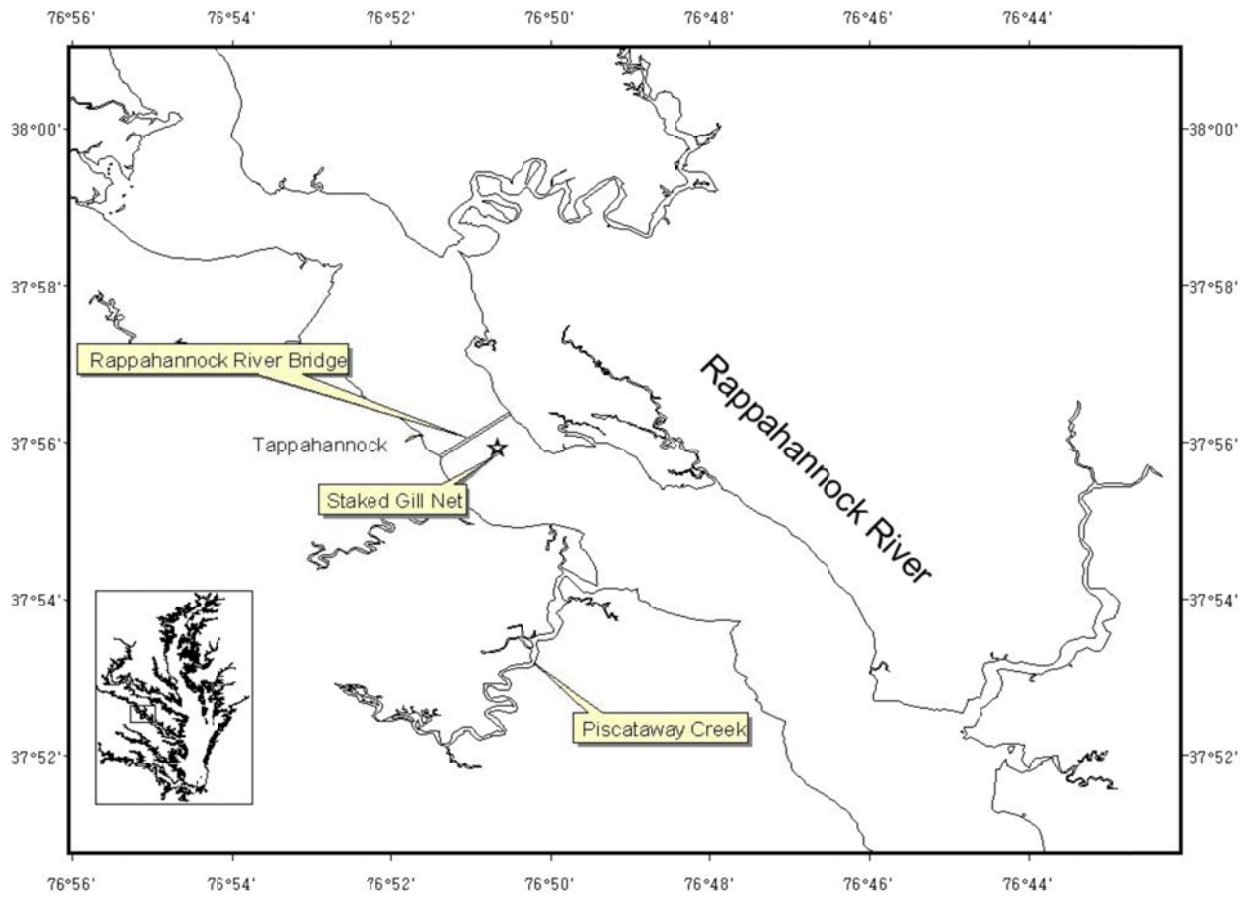


Figure 8. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the James River, spring 2012.

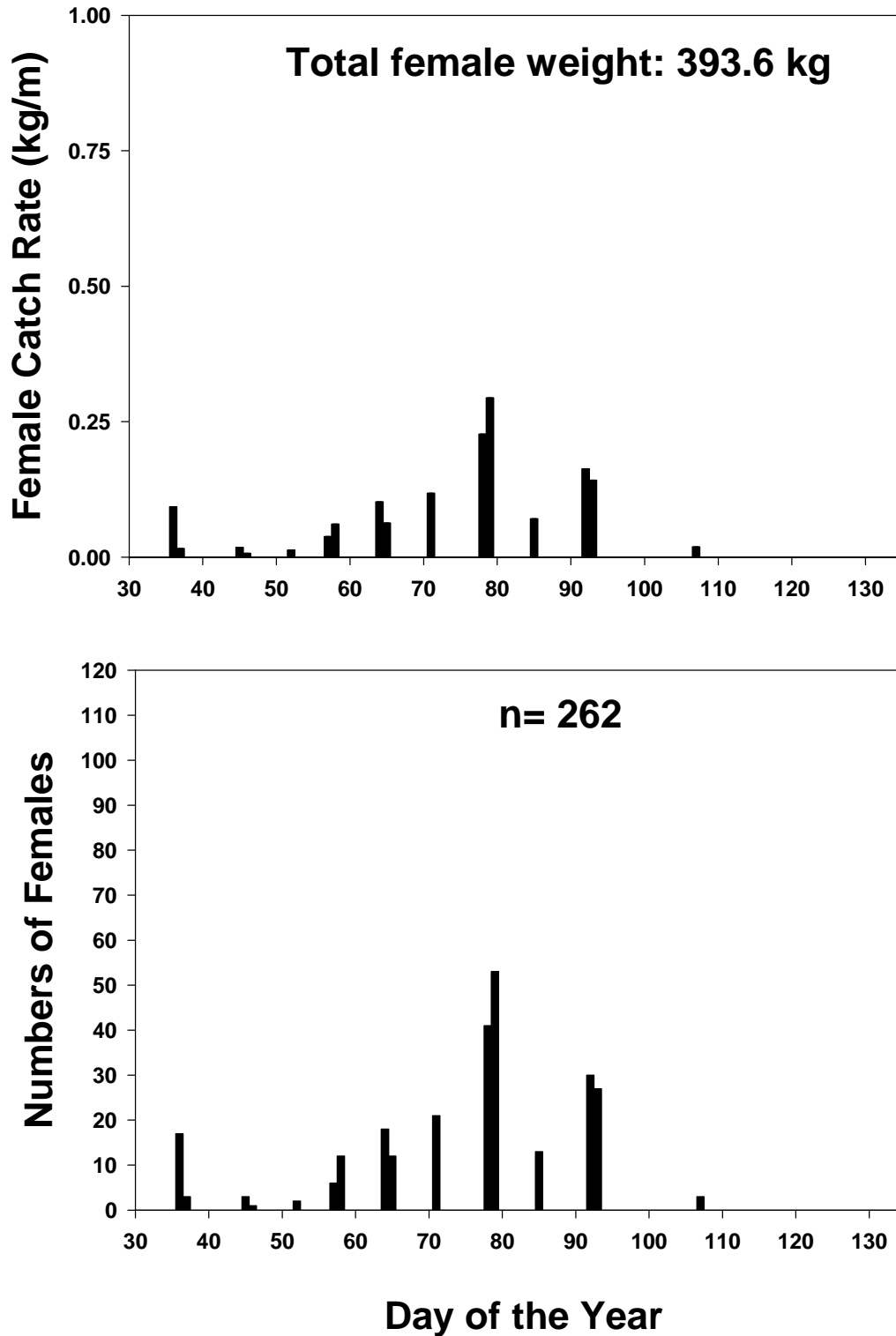


Figure 9. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the York River, spring 2012.

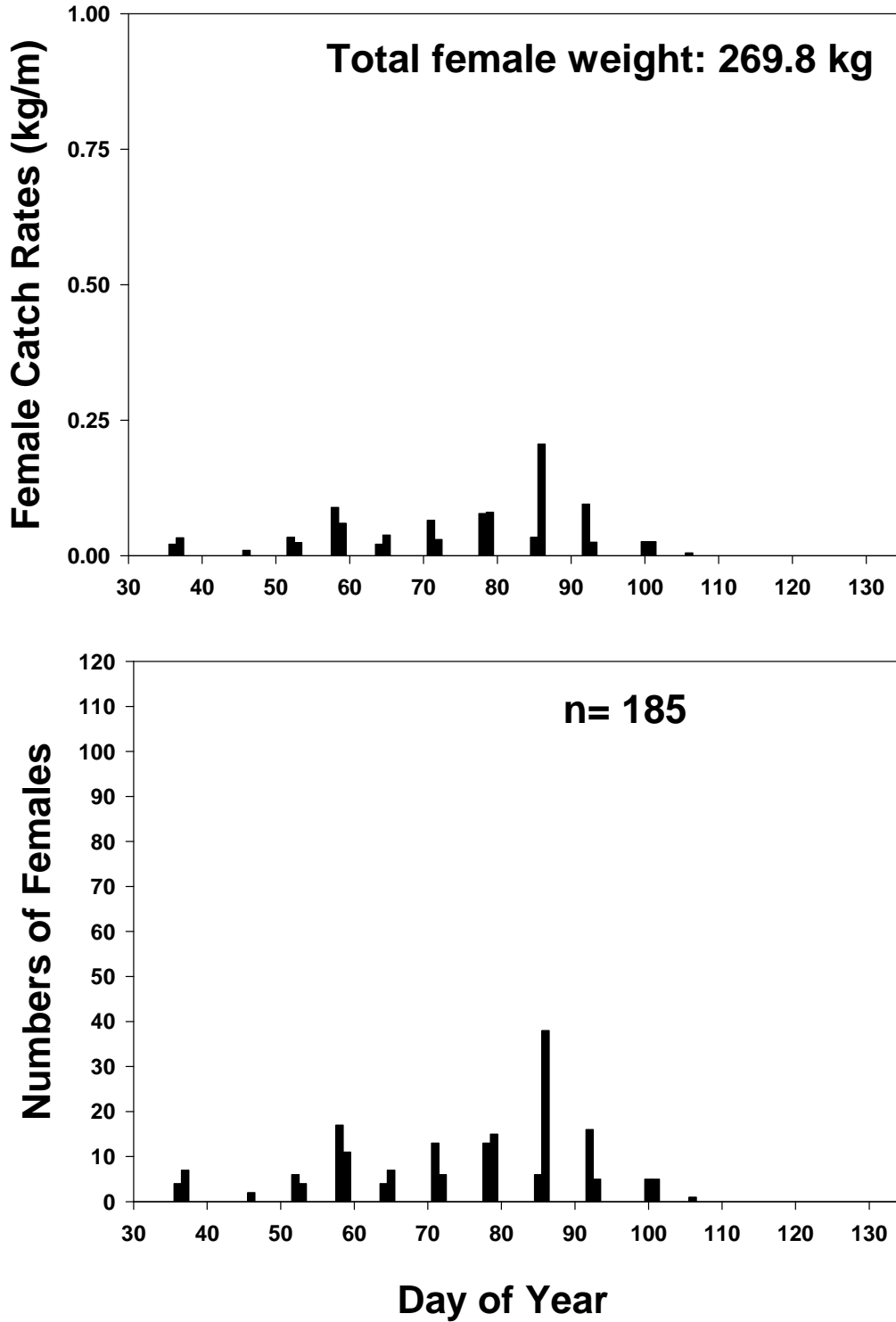


Figure 10. Catch rates and total numbers of pre-spawn female American shad taken by staked gill nets in the Rappahannock River, spring 2012.

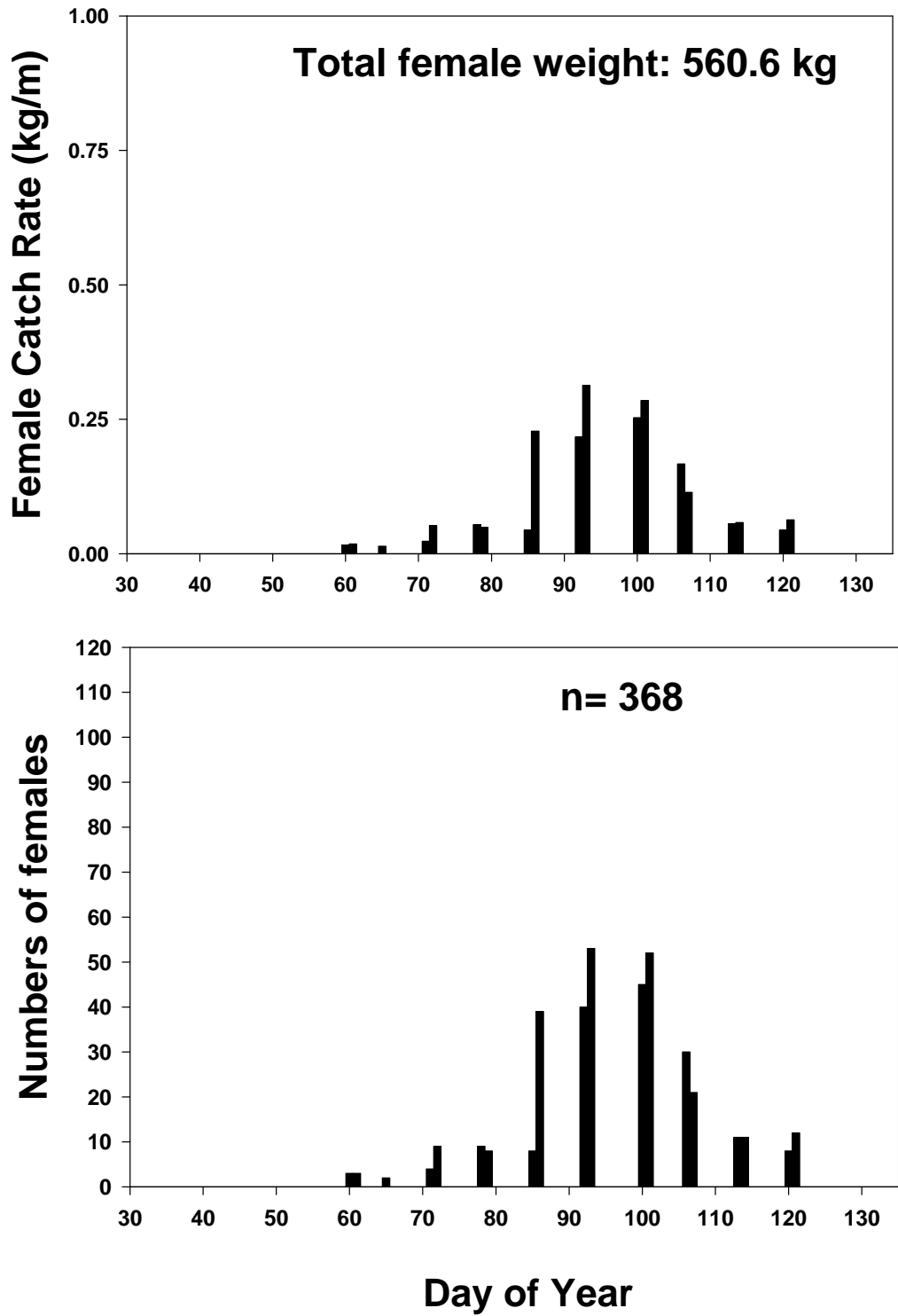


Figure 11. Catch rates and total numbers of male American shad taken by staked gill nets in the James River, spring 2012.

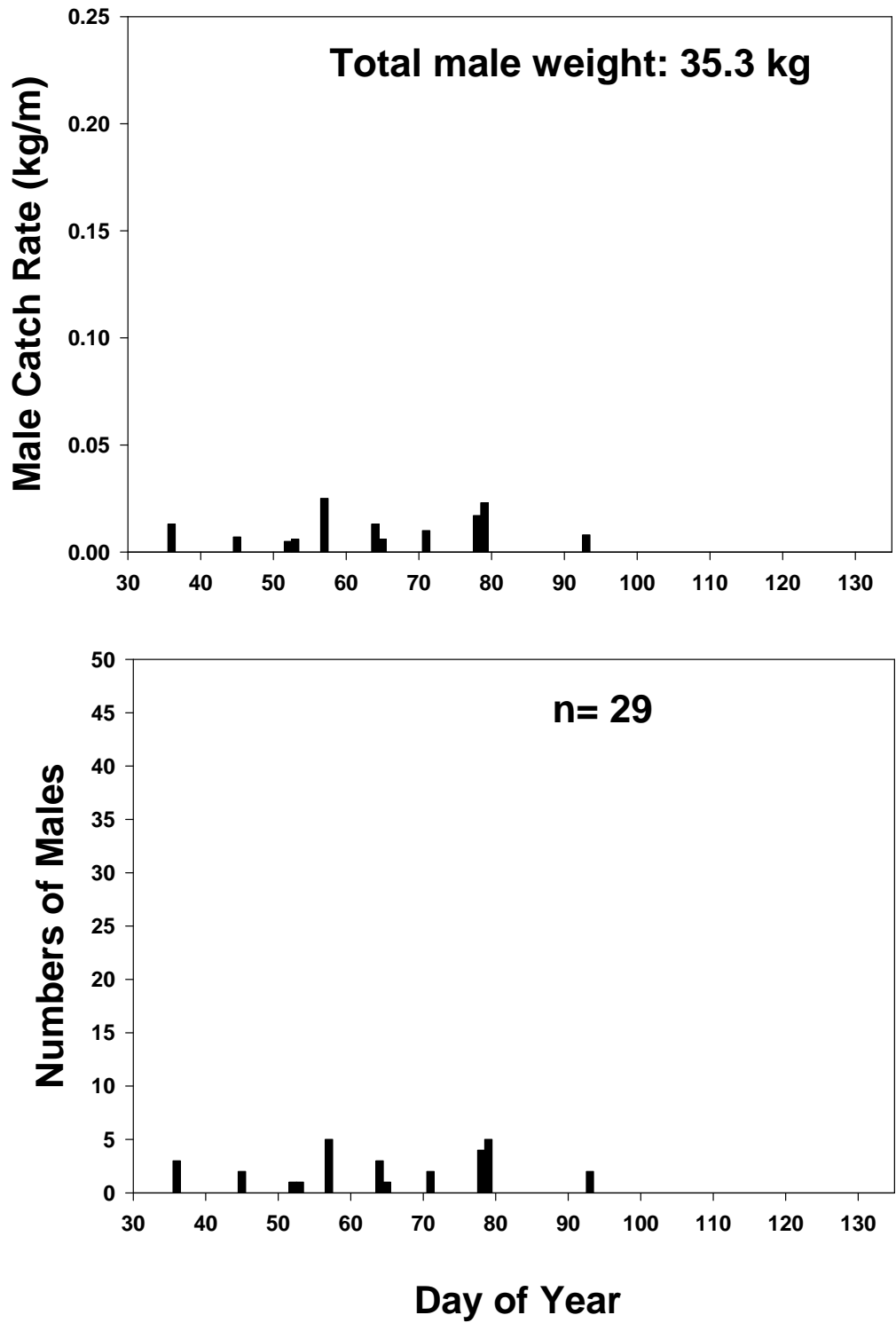


Figure 12. Catch rates and total numbers of male American shad taken by staked gill nets in the York River, spring 2012.

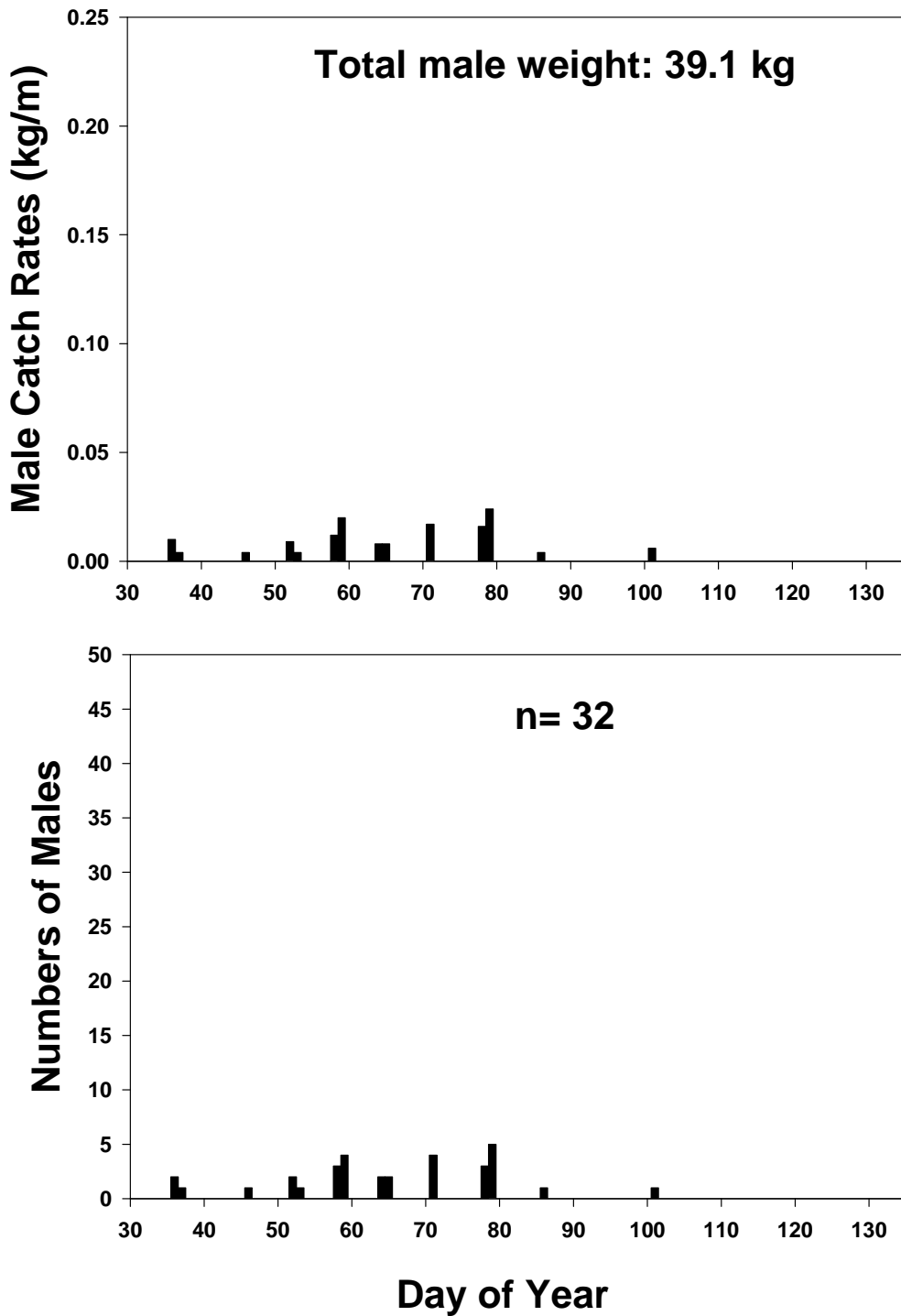


Figure 13. Catch rates and total numbers of male American shad taken by staked gill nets in the Rappahannock River, spring 2012.

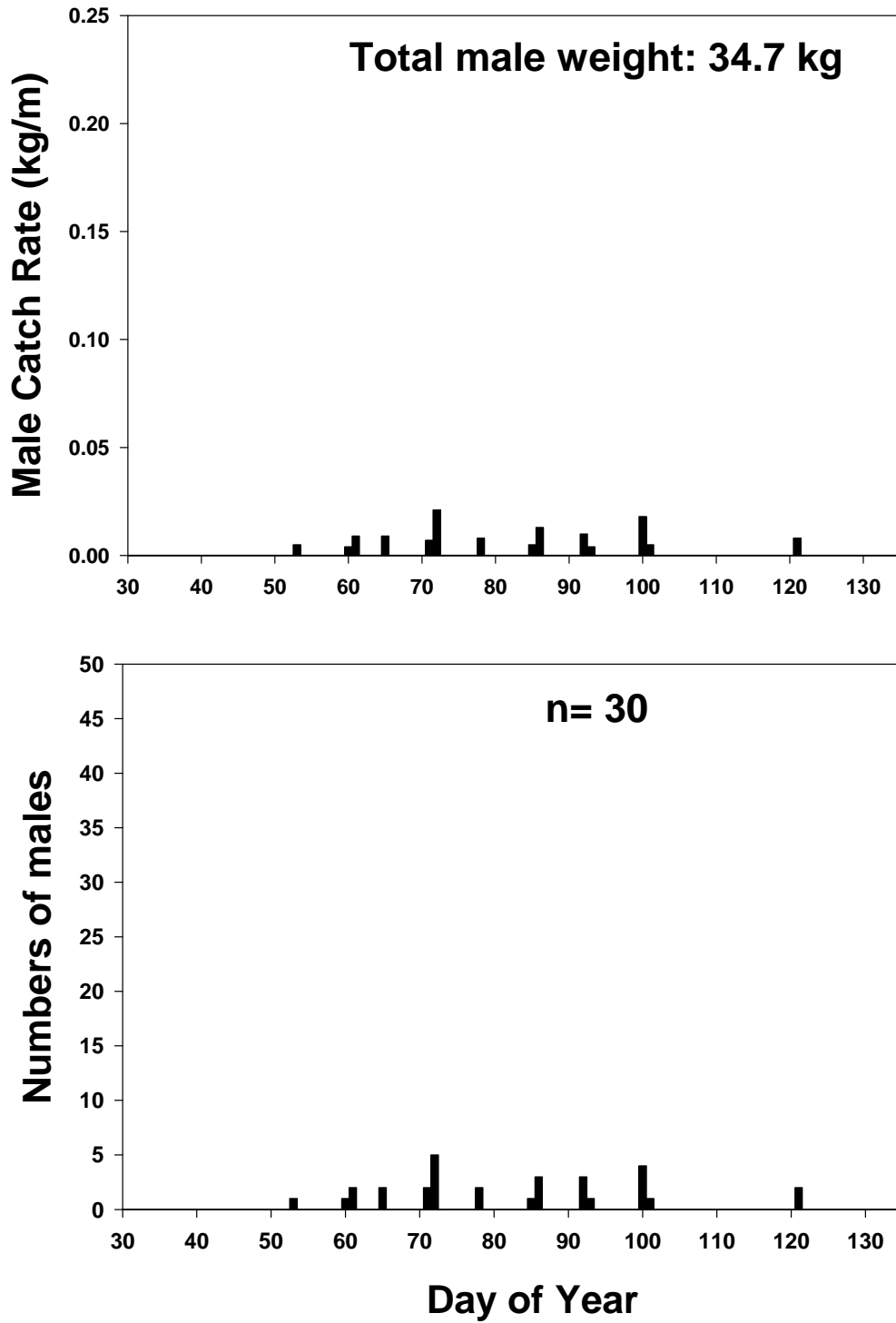


Figure 14. Total length (mm) frequency distributions for American shad captured in staked gill nets on the James and York rivers, spring 2012.

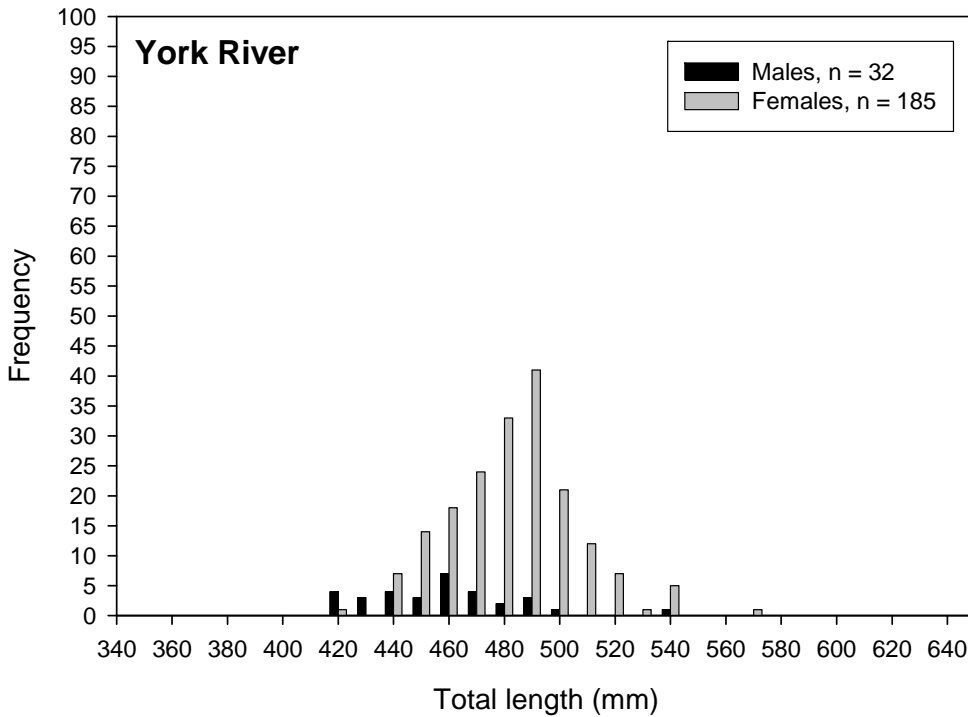
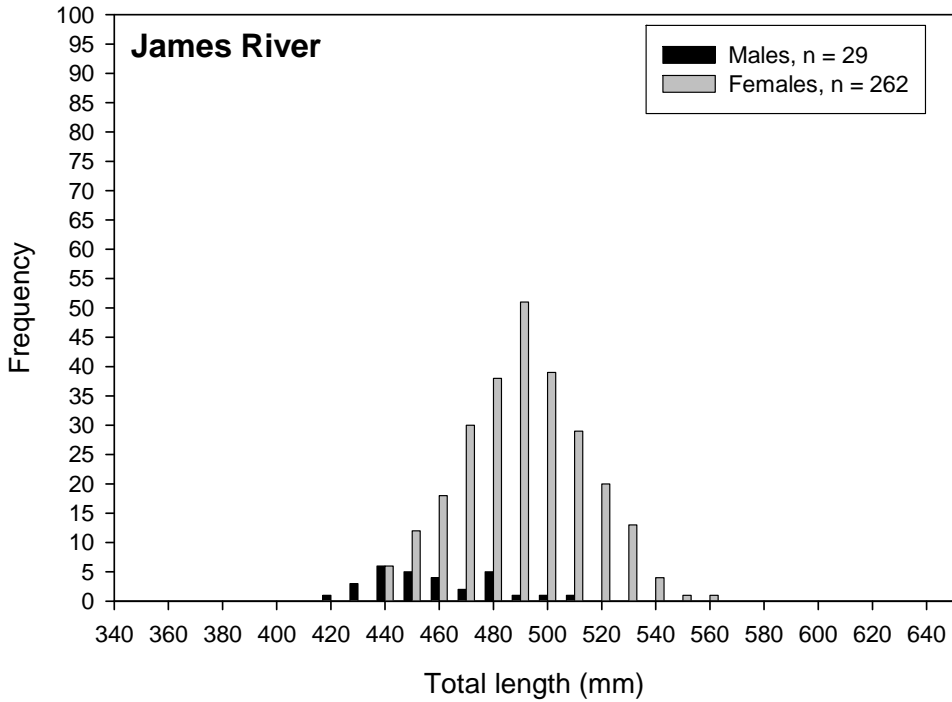


Figure 15. Total length (mm) frequency distributions for American shad captured in staked gill nets on the Rappahannock River, spring 2012.

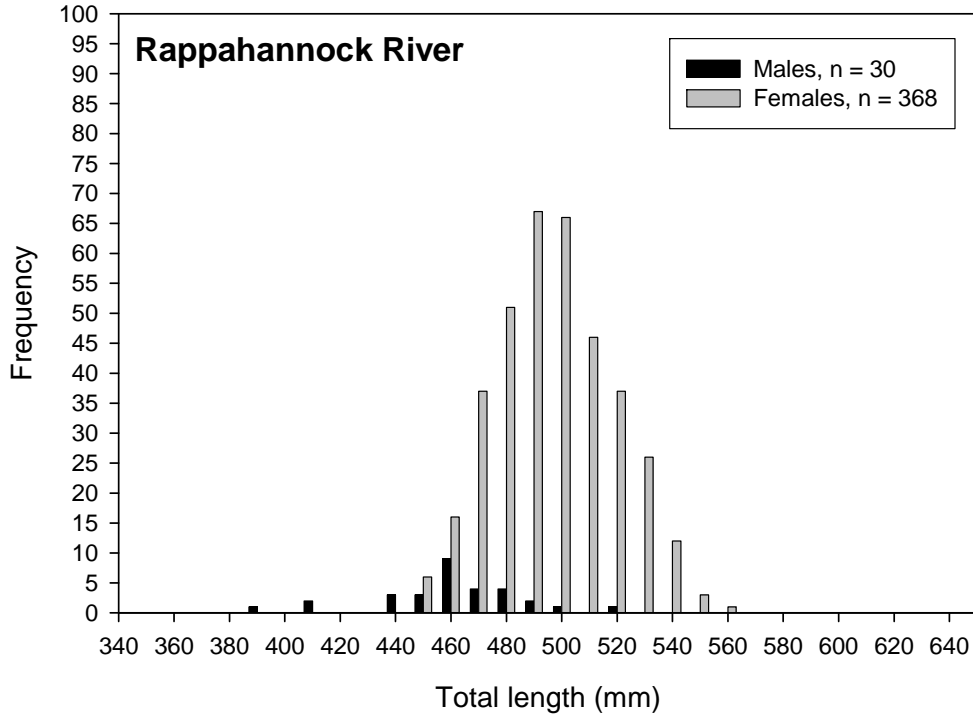


Figure 16. Total numbers of female American shad caught and surface temperature recorded at staked gill nets in the James and York rivers, spring 2012.

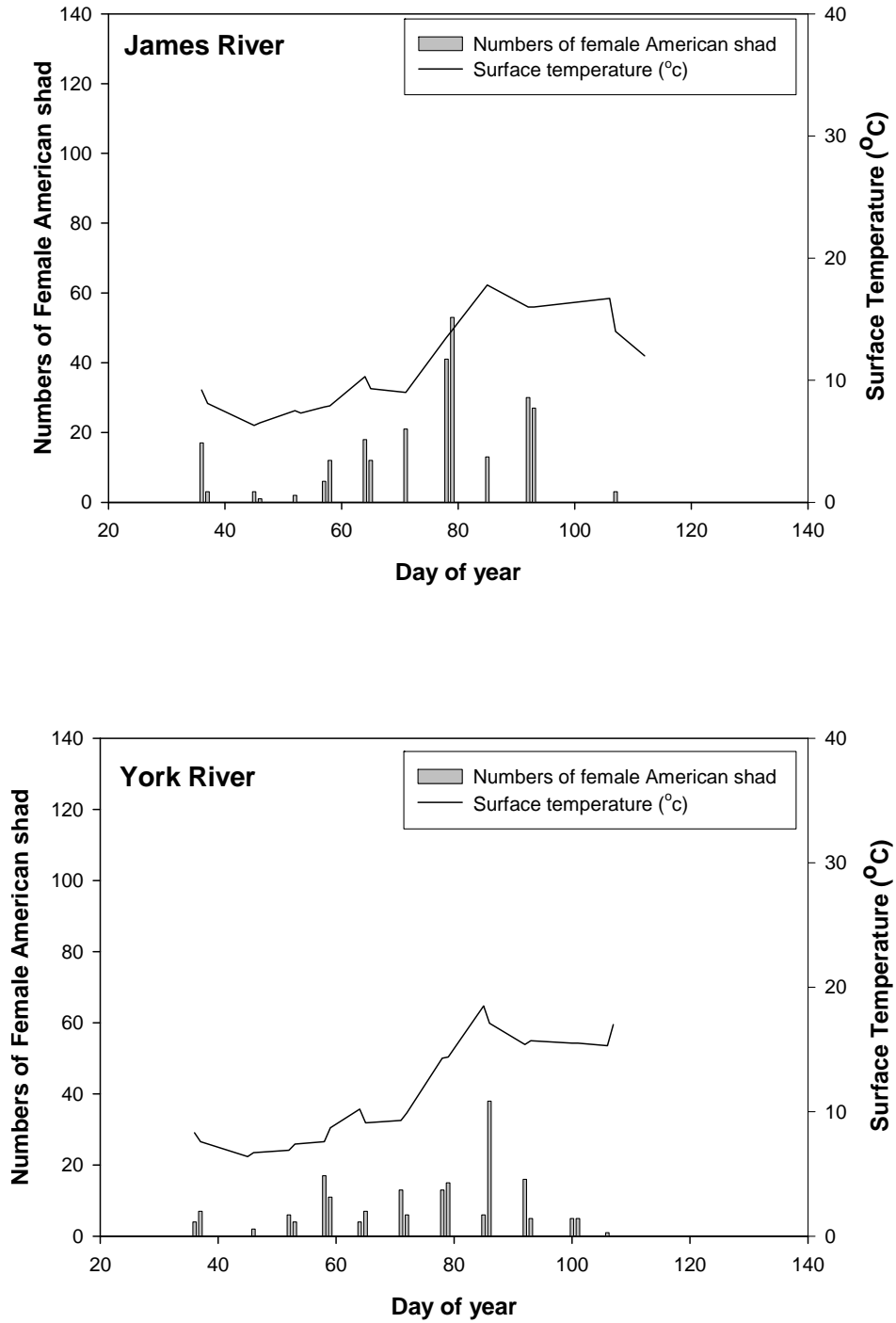


Figure 17. Total numbers of female American shad caught and surface temperature recorded at staked gill nets in the Rappahannock River, spring 2012.

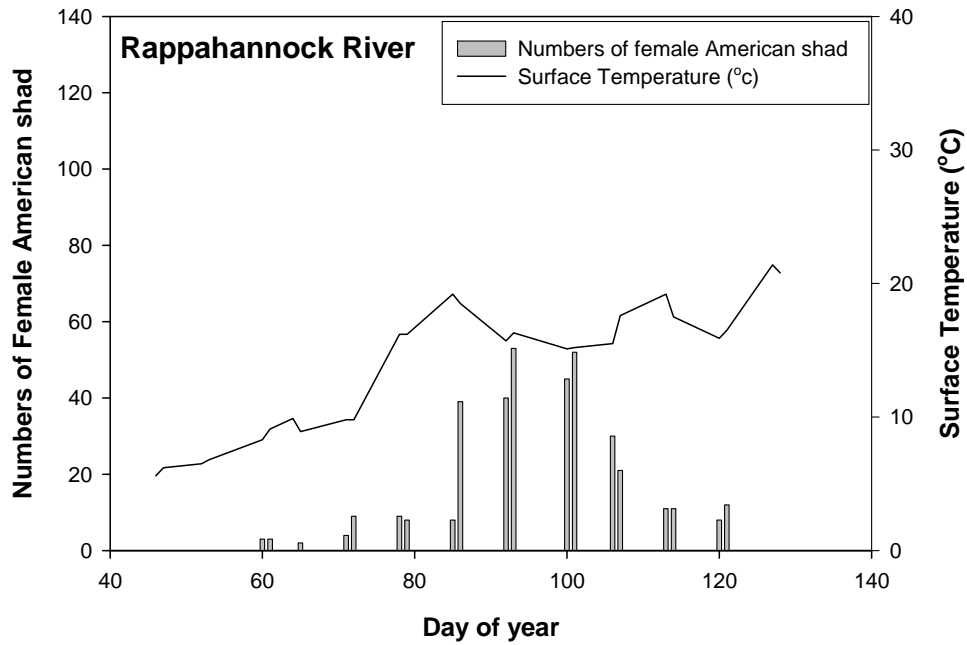


Figure 18. Mean age of females taken in staked gill nets in the James, York, and Rappahannock Rivers, 1998-2012.

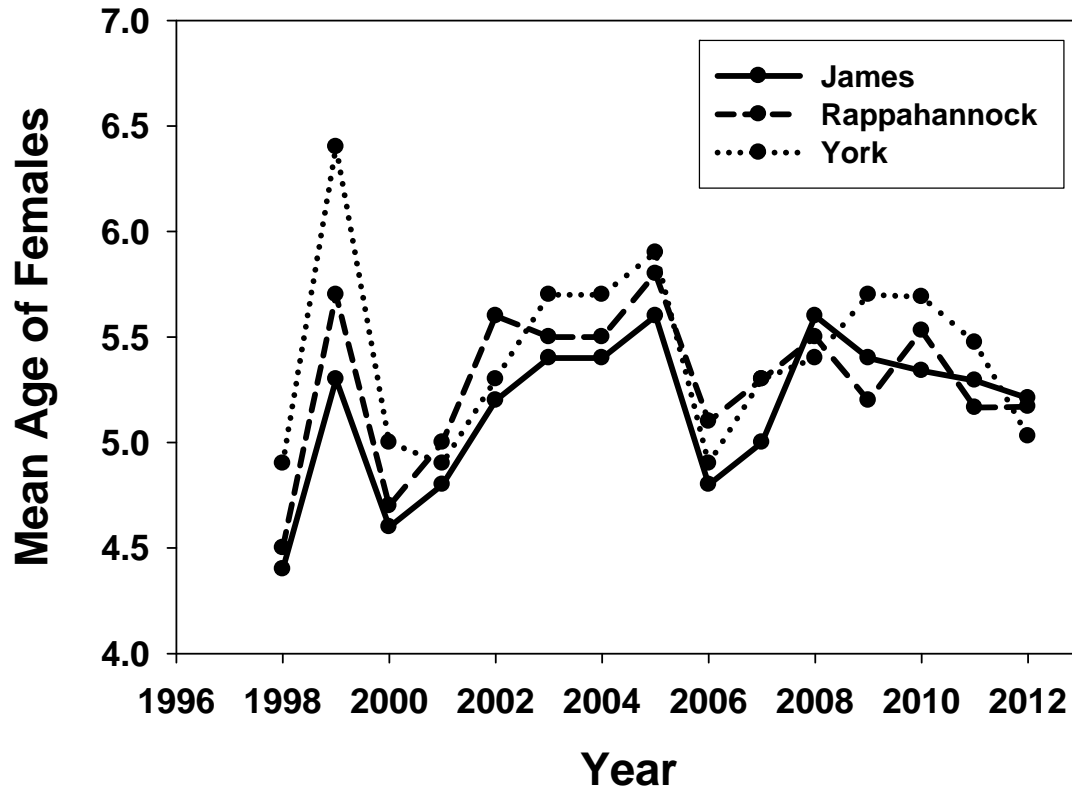


Figure 19. Mean age of females and the proportion of age-4 female recruits in staked gill nets, 1998-2012.

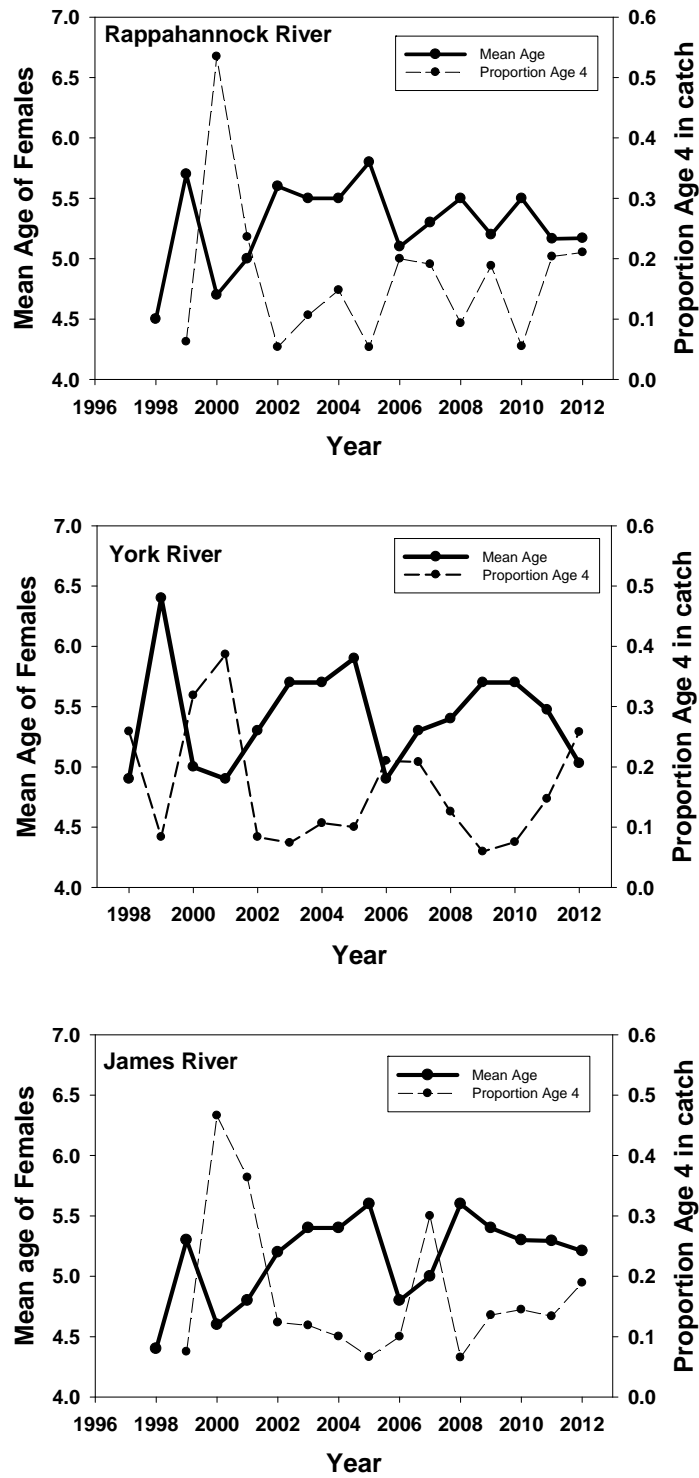


Figure 20. Comparison of the James River catch index to the percent of specimens with OTC hatchery marks.

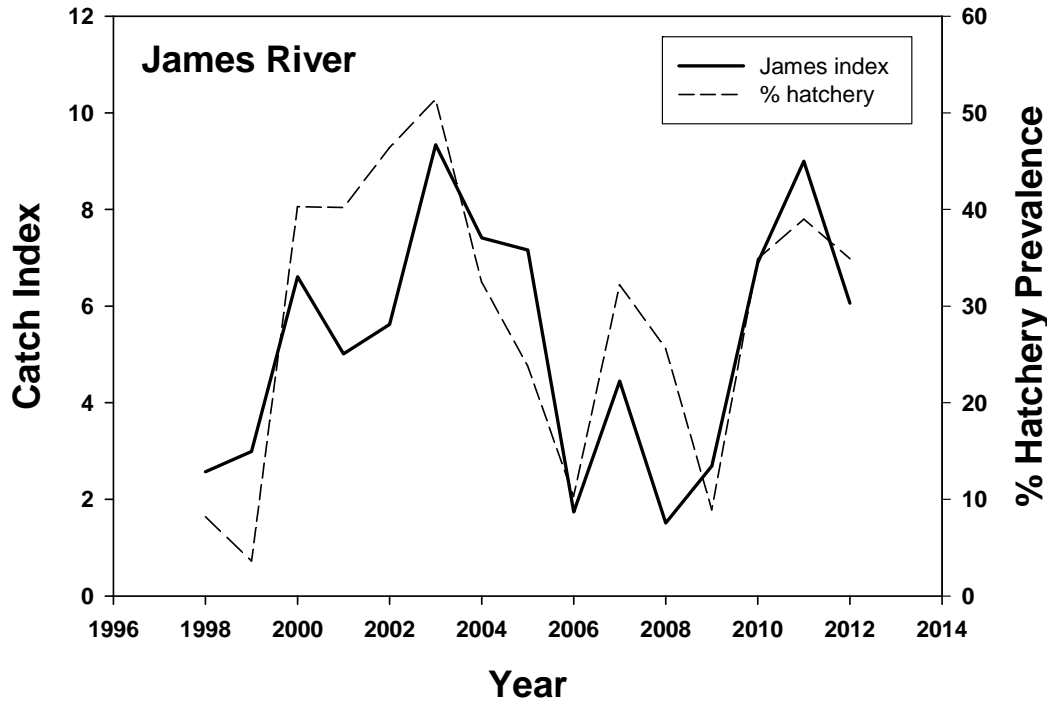


Figure 21. The index of juvenile abundance of American shad in the York River system as estimated by daylight seine surveys, 1980-2012. The index is the geometric mean number of American shad juveniles per seine haul.

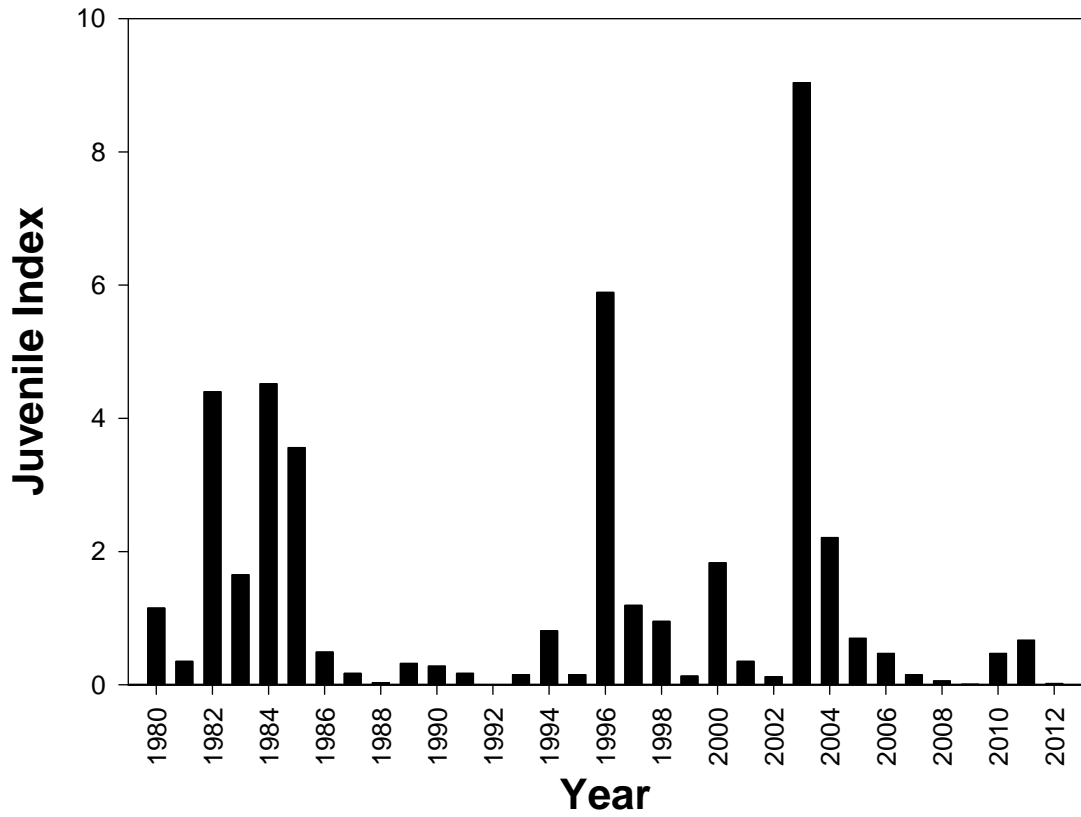


Figure 22. The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by daylight seine surveys, 1980-2012. The index is the geometric mean number of American shad juveniles per seine haul.

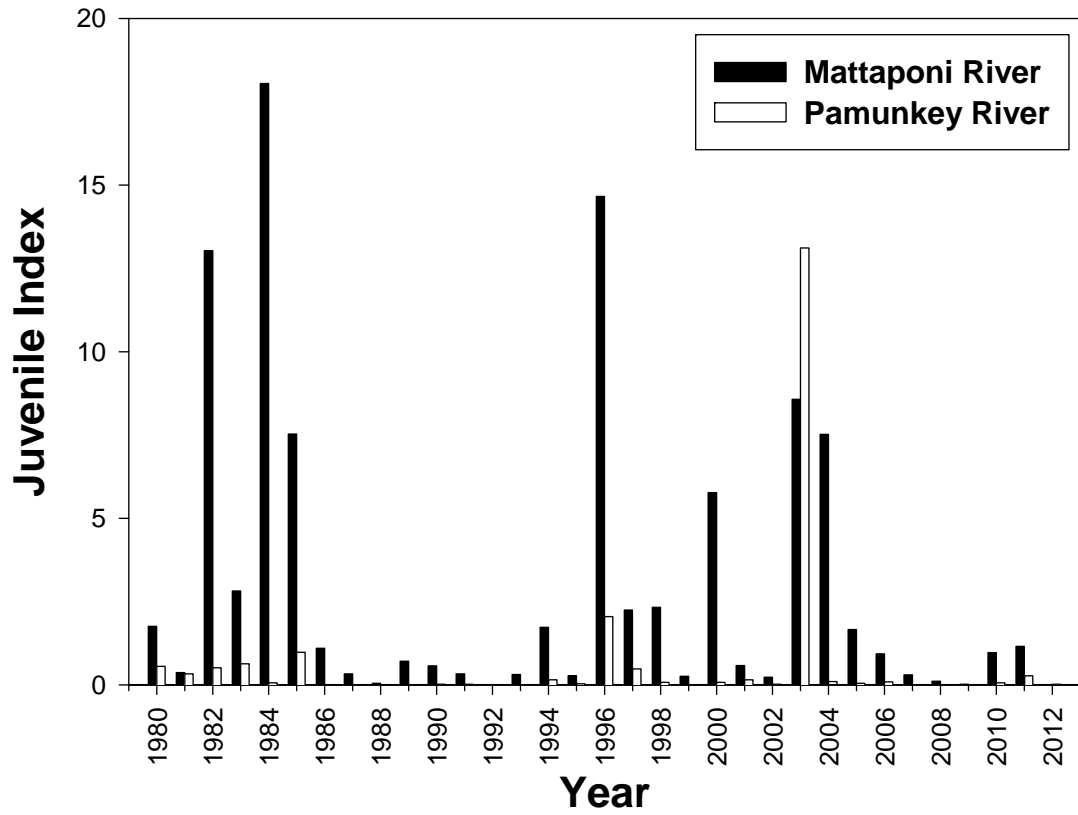


Figure 23. The index of juvenile abundance of American shad in the Rappahannock River as estimated by daylight seine surveys, 1980-2012. The index is the geometric mean number of American shad juveniles per seine haul. The index in 1980 and 1981 was zero.

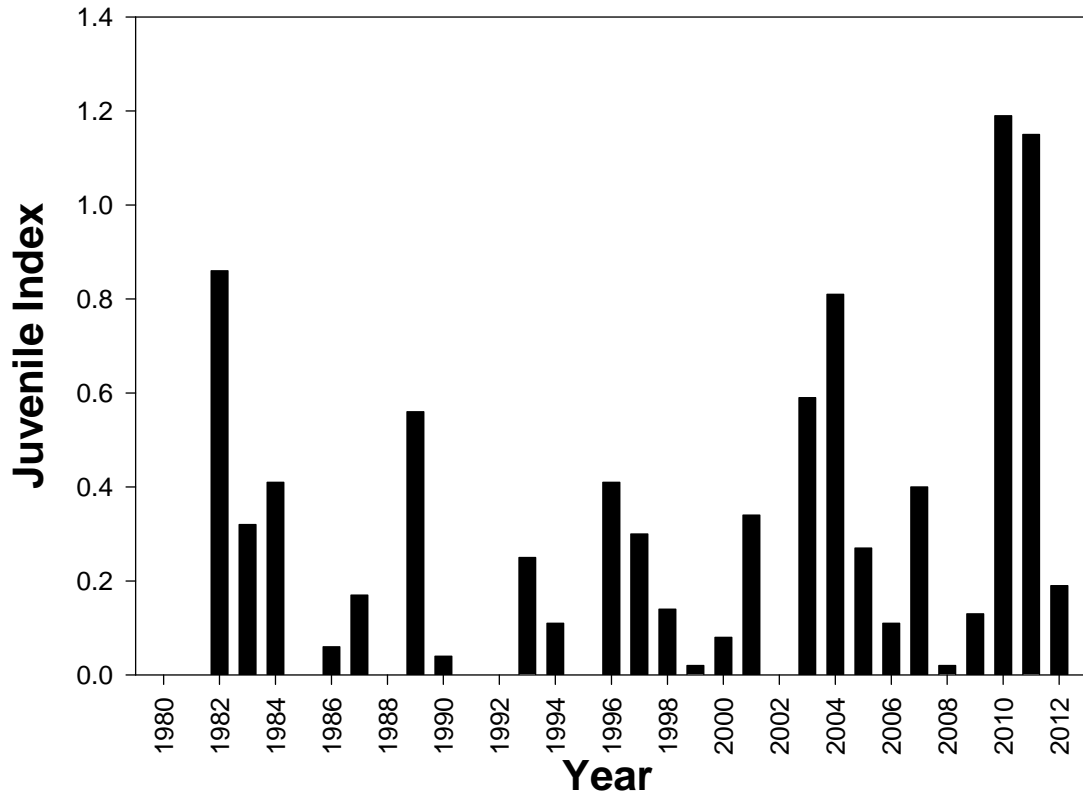


Figure 24. The index of juvenile abundance of American shad in the James River as estimated by daylight seine surveys, 1980-2012. The index is the geometric mean number of American shad juveniles per seine haul.

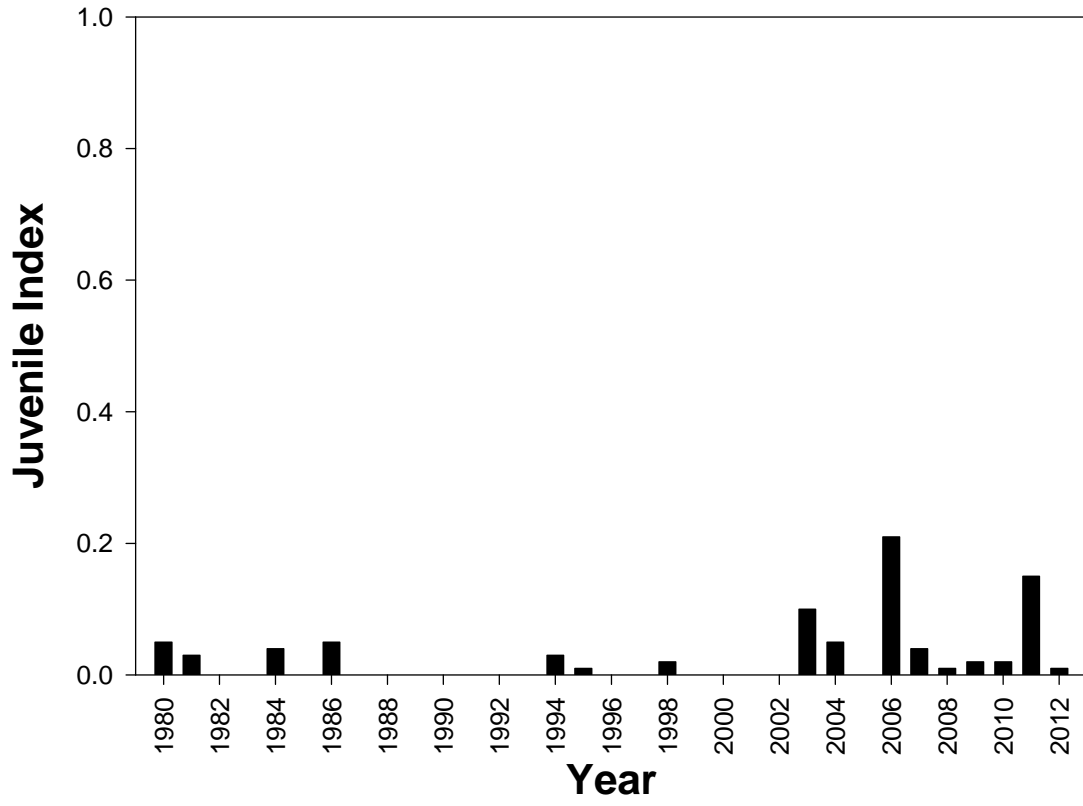


Figure 25. Recent (1998-2012) and historic values of the catch index of female American shad on the James River.

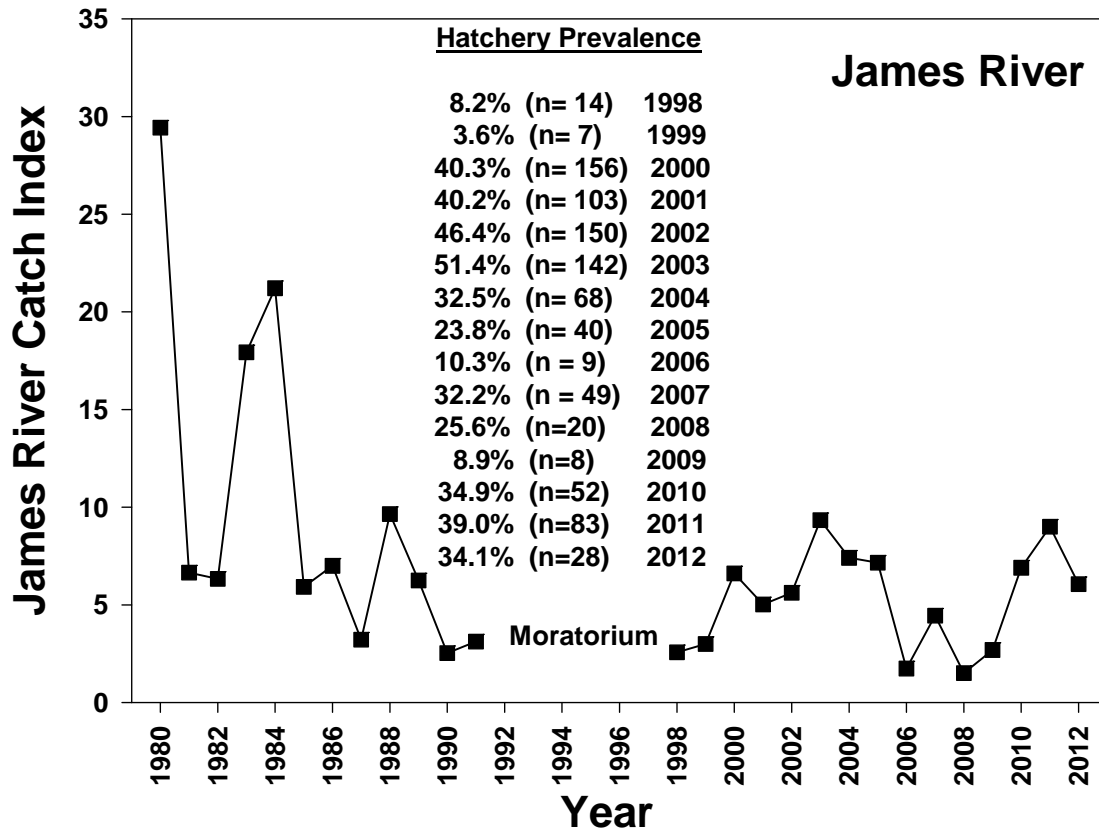


Figure 26. Recent (1998-2012) and historic values of the catch index of female American shad on the York River.

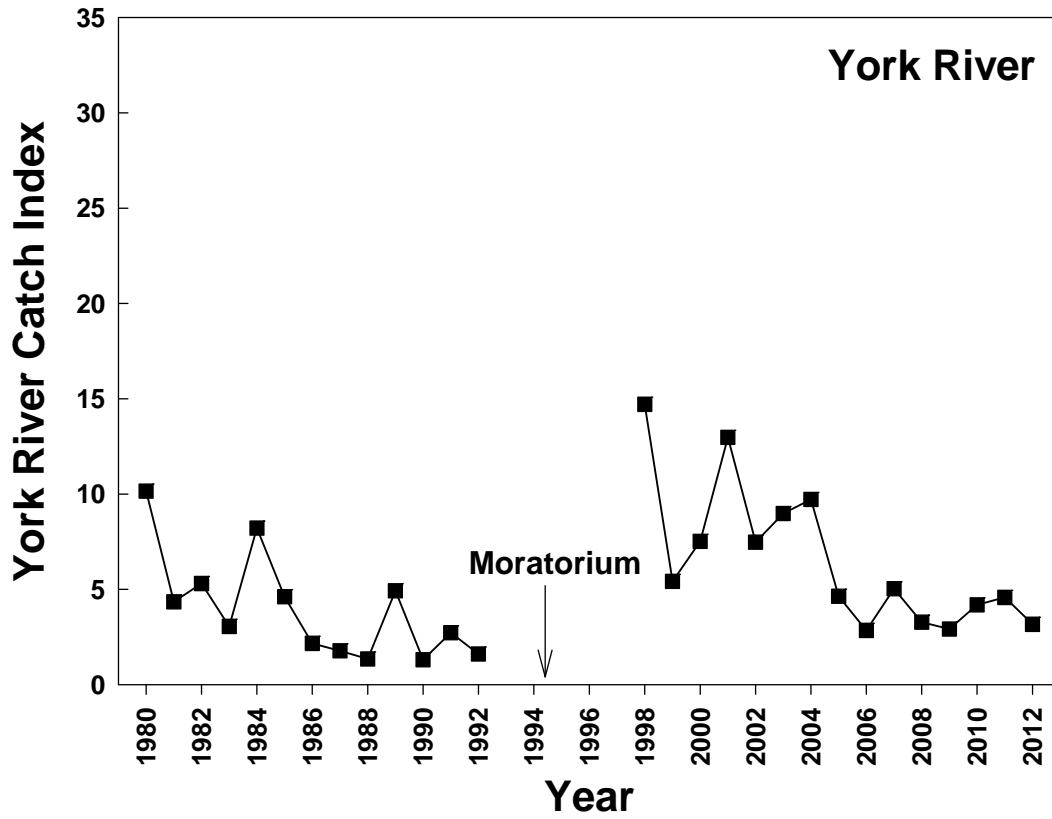


Figure 27. Recent (1998-2012) and historic values of the catch index of female American shad on the Rappahannock River.

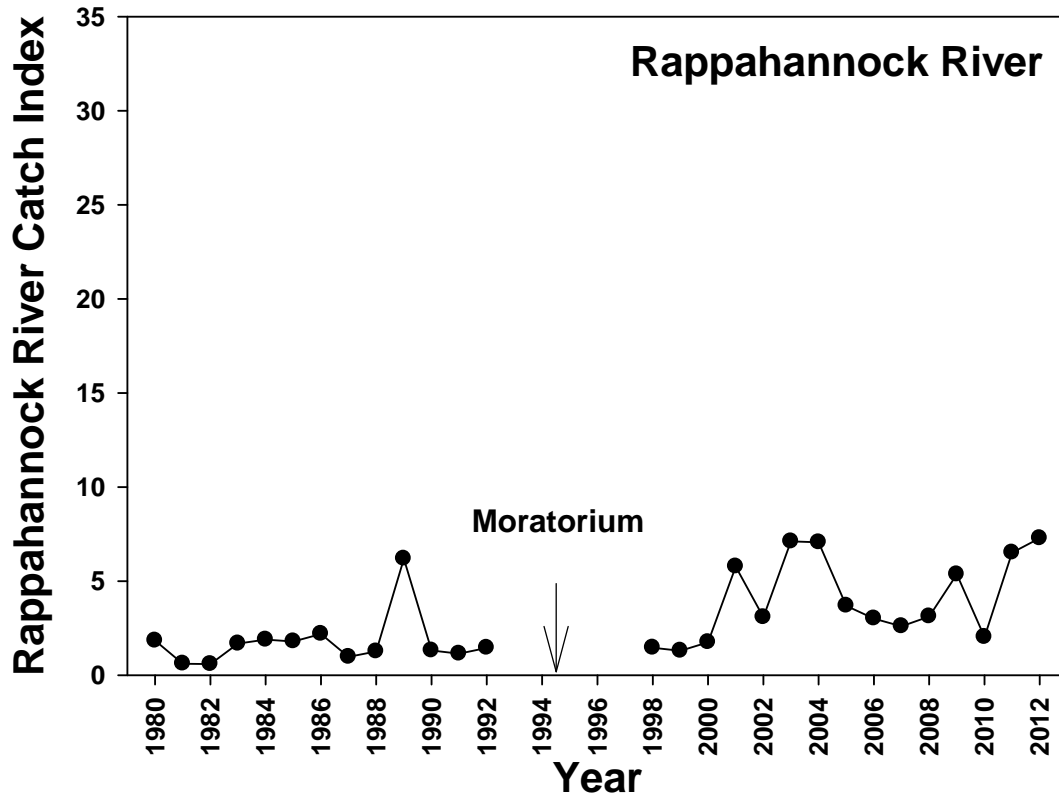
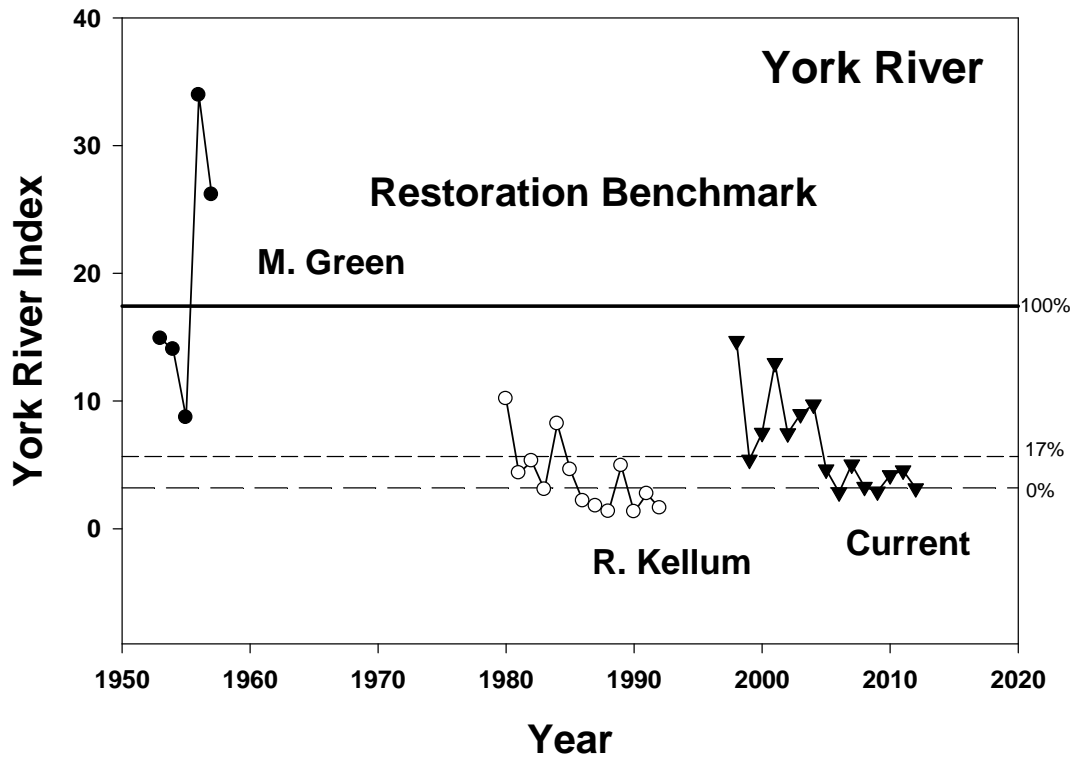


Figure 28. Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the geometric means of each data set (solid, 1950s; short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



Appendix I

Assessment of the 2012 Virginia by-catch of American shad and the status of the Virginia stocks

Report to the Atlantic States Marine Fisheries Commission (ASMFC)

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

Background

In spring 2012, 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 2012 American shad by-catch fishery on the Rappahannock River was similar to effort in 2011. Effort in 2012 was higher on the James and York Rivers than in 2011 (Table 1). A subsample of the 2012 by-catch of American shad (n=87) was obtained from four cooperating gill netters and processed for length, weight, sex, maturity stage, age, and the presence of hatchery (OTC) marks.

This report is a companion to a separate report of the 2012 by-catch prepared by the Virginia Marine Resources Commission (VMRC) and submitted separately.

Biological Characterization of the 2012 Permitted Gill Net By-Catch in Virginia

James River

52 American shad (4 males and 48 females) were collected from two cooperating fishers on the James River. The subsample ranged in size and age from 367-473 mm FL and 4-8 years. Virgin and repeat spawners were both present in the sample (52.5% and 47.5%, respectively). Otoliths of 48 fish from the James River subsample were scanned for hatchery marks. The proportion with positive OTC marks was 33.3% (16 fish). Biological descriptions of the James River subsample are presented in Table 2.

York River

35 American shad (2 males and 33 females) were collected from two cooperating fishers on the York River. The subsample ranged in size and age from 381-484 mm FL and 4-7 years. Virgin and repeat spawners were equally present in the sample (48.1% and 51.9%, respectively). Otoliths of 27 fish from the York River

subsample were scanned for hatchery marks. The proportion with positive OTC marks was 3.7% (1 fish). Biological descriptions of the York River subsample are presented in table 2.

Rappahannock River

No fish were collected from the Rappahannock River.

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 129 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 353 American shad were processed for length, weight, sex, maturity stage, and age. Laboratory scans for hatchery marks are still in the process of being completed. 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 captured was slightly higher than the number of females (213 males; 140 females). Sex ratios (males:females) were: Great Wicomico, 1:0.44; Rappahannock River, 1:0.54; Cape Charles, 1:1.16. Maturity stages were determined macroscopically for females in the laboratory. Spawning ratios (prespawning:postspawning) of females were: Great Wicomico, 1:0; Rappahannock River, 1:1.12; Cape Charles, 1:1.03.

Our monitoring continues to indicate that post-spawning fish exit the system on the eastern side of the Chesapeake Bay.

A total of 3228 discarded American shad were recorded in commercial log books of two pound net fishers in the spring of 2012 (Figures 3-4). We were unable to obtain log books from one other fisher although we did purchase fish for biological characterization from those nets.

Results of the 2012 Fishery-Independent Monitoring Studies

The catch index values (the area under 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 2012 index was 7.28, which is the highest value seen since monitoring began in 1998.

In 2012 the catch index on the James River was 6.06. Index values have been high (>6.0) since 2010 due to an increasing proportion of hatchery origin fish.

The 2012 York River index is 3.17. The trend of the York River monitoring data is a downward slope of catch index values through the 15-y time series, although the index has remained relatively stable, with some variation, at a low level since 2005.

Table 1. 2012 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	2012	10	4	82	71	71
	2011	9	3	25	42	42
	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	2012	13	5	71	207	207
	2011	11	4	51	88	87
	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	2012	2	1	2	7	7
	2011	3	1	1	1	1
	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 descriptions by river and sex for American shad permitted by-catch samples processed at VIMS. Abbreviations: M, Male; F, Female; #, Number; Avg., Average; Yrs, Years; NA, Not applicable.

River	Sex	#	Avg. FL (mm)	Avg. Wt (g)	# Aged	Age Range (yrs)	% Repeat Spawner	% Post Spawner	# Hatchery Scanned	# Hatchery Origin
James	M	4	398	1250.9	3	4 - 7	66.7	NA	2	0
	F	48	441	1593.6	37	5 - 8	45.9	2.1	46	16
	Combined	52	437	1567.2	40	4 - 8	47.5	2.1	48	16
York	M	2	385	1058.0	2	4 - 5	100.0	NA	1	0
	F	33	444	1716.4	25	4 - 7	48.0	0.0	26	1
	Combined	35	441	1678.8	27	4 - 7	51.9	0.0	27	1

Table 3. Biological data of American shad (n=91) 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)
3/13/2012	Maturing	5	8.92	1783.62			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				12	10.74	1117.32
3/26/2012	Maturing	12	15.51	1292.75			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				24	18.08	753.14
4/16/2012	Maturing	3	4.04	1347.0			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				11	8.80	800.00
5/2/2012	Maturing	8	9.83	1228.14			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				16	11.06	690.94
Total		28	38.30	1367.86	63	48.68	772.70

Table 4. Biological data of American shad (n=152) 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)
4/26/2012	Maturing	3	3.73	1243.53			
	Hydrated						
	P. Spent						
	Spent	1	1.14	1138.60			
	Unstaged				7	5.30	756.86
5/7/2012	Maturing	18	22.73	1262.57			
	Hydrated						
	P. Spent	9	7.71	856.46			
	Spent	18	15.37	854.11			
	Unstaged				84	54.09	643.98
5/22/2012	Maturing	4	5.00	1249.35			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				8	5.39	673.74
Total		53	55.68	1050.57	99	64.78	654.34

Table 5. Biological data of American shad (n=110) 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)
3/21/2012	Maturing	6	8.03	1339.12			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				23	19.60	852.18
4/10/2012	Maturing	23	33.92	1474.97			
	Hydrated						
	P. Spent	3	2.49	831.07			
	Spent						
	Unstaged				14	13.05	932.47
5/9/2012	Maturing						
	Hydrated						
	P. Spent	13	11.10	853.92			
	Spent	14	13.04	931.65			
	Unstaged				14	9.10	650.00
Total		59	68.58	1162.37	51	41.75	818.63

Table 6. Year class composition of fish taken in pound nets in 2012, indicated as percent of aged catch from three pound net locations in Chesapeake Bay.

	Year Class	Great Wicomico	Cape Charles	Rappahannock
Males	2009	18.0	17.4	9.2
	2008	50.0	30.0	48.7
	2007	32.0	43.0	31.6
	2006	0.0	9.0	7.9
	2005	0.0	0.0	2.6
	2004	0.0	0.0	0.0
Females	2009	0.0	0.0	2.3
	2008	25.0	15.8	25.0
	2007	65.0	44.7	50.0
	2006	5.0	28.9	13.6
	2005	5.0	8.0	6.8
	2004	0.0	2.6	2.3

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



Figure 2. Total number (all samples combined) of American Shad processed by VIMS caught with special pound net by-catch permits in 2012. N is the number of samples obtained.

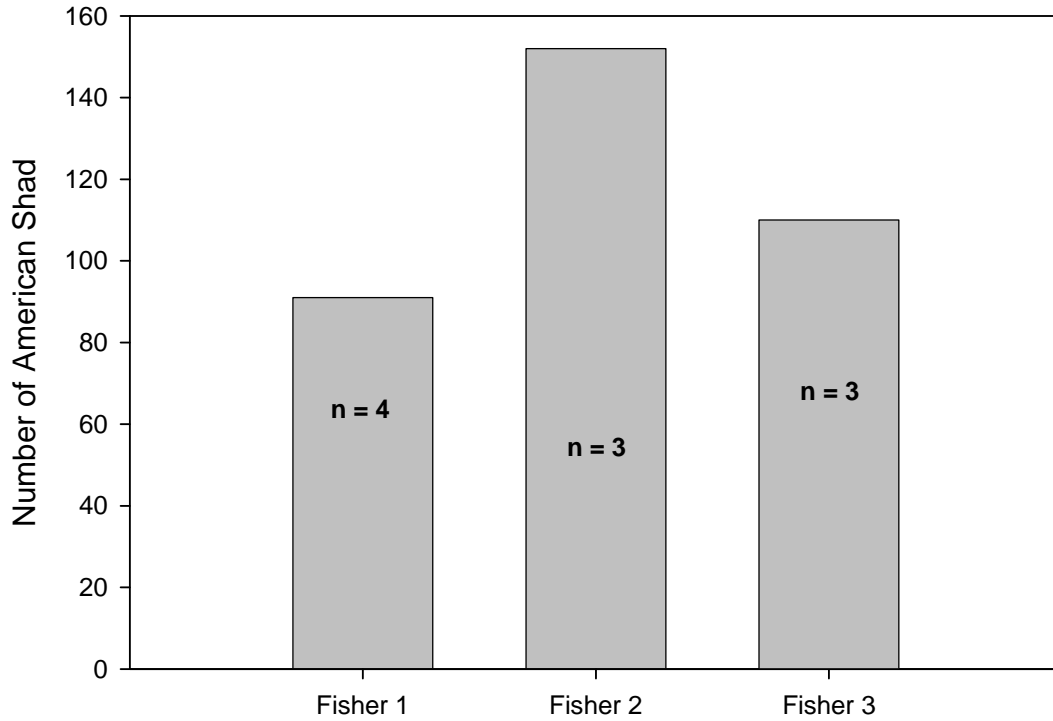


Figure 3. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Great Wicomico River. Data are taken from 2012 commercial fisher log books.

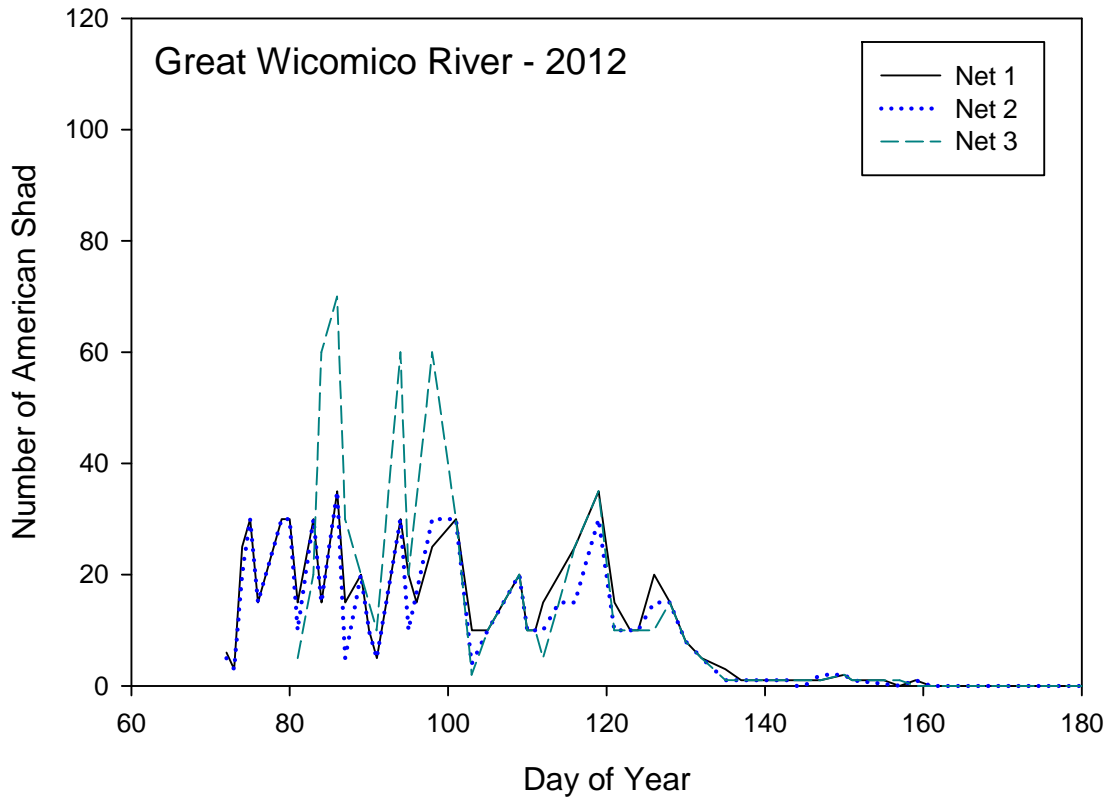


Figure 4. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Rappahannock River mouth. Data are taken from 2012 commercial fisher log books.

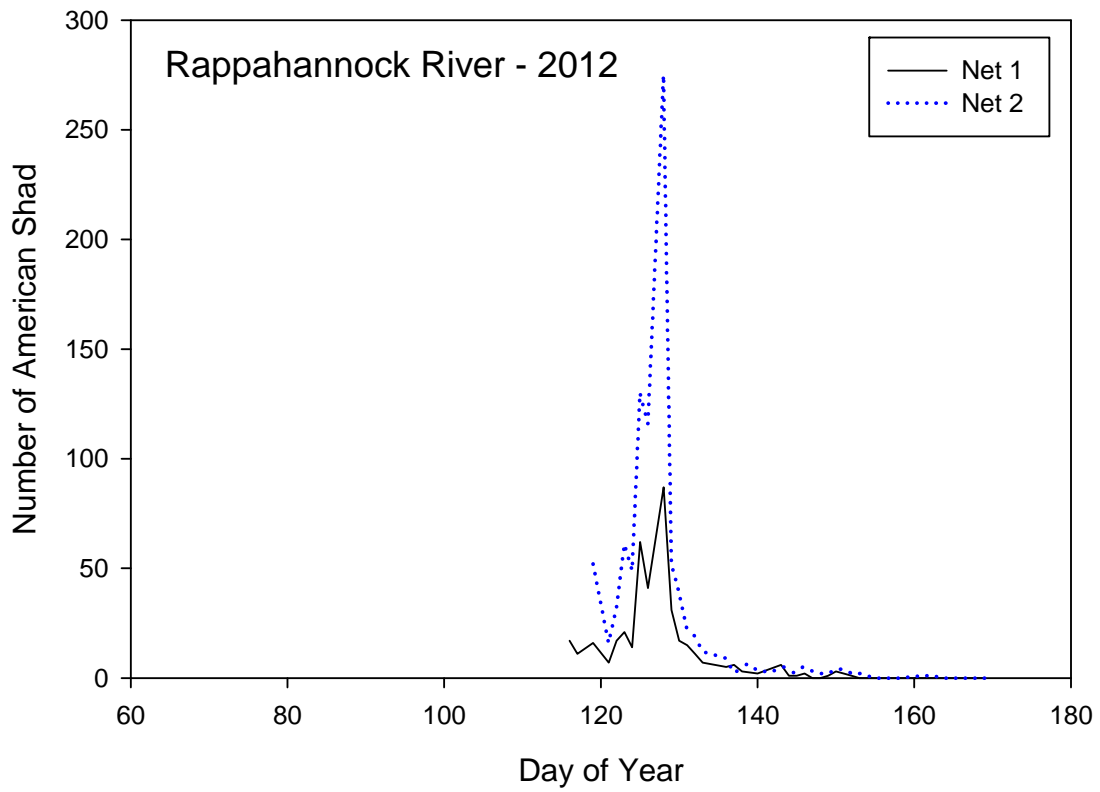


Figure 5. Time series of catch index from staked gill net monitoring in Virginia, 1998-2012.

