4-15-2017

Monitoring the Abundance of American Shad and River Herring in Virginia's Rivers - 2016 Annual Report

Eric J. Hilton
Virginia Institute of Marine Science

Robert Latour
Virginia Institute of Marine Science

Patrick E. McGrath
Virginia Institute of Marine Science

Brian Watkins
Virginia Institute of Marine Science

Ashleigh Magee
Virginia Institute of Marine Science

Monitoring the Abundance of American Shad and River Herring in Virginia's Rivers

2016 Annual Report

Dr. Eric J. Hilton, Dr. Rob Latour,

Dr. Patrick E. McGrath, Brian Watkins, and Ashleigh Magee

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

Funding Agencies:	US Fish and Wildlife Service Virginia Marine Resources Commission Virginia Institute of Marine Science
Contract Number:	F-116-R-19
Project Period:	15 February 2016 - 14 February 2017
Principal Investigator:	Eric J. Hilton

Submitted To:

Virginia Marine Resources Commission
P.O. Box 756
Newport News, VA 23607-0756

15 April 2017

Summary

- This report describes the results of the nineteenth year of a continuing study to estimate the relative abundance and assess the status of American shad (*Alosa sapidissima*) stocks in Virginia by monitoring the spawning runs in the James, York and Rappahannock rivers in spring 2016, evaluating hatchery programs, and contributing to coast-wide assessments (ASMFC 2007). We also report on a new fishery-independent monitoring program using staked gillnets to determine relative abundance and stock structure for the adult spawning run of river herring (*A. pseudoharengus*, and *A. aestivalis*) in the Rappahannock River. Data are also reported from two separate fishery-independent monitoring programs using a drift gillnet (year 3) and anchor gillnets (year 2) to assess the status of the spawning run of river herring in the Chickahominy River, a major tributary of the James River. Further, we report on the second year of a monitoring program for juvenile alosines by using nighttime surface trawls in the Chickahominy River and calculate an index of juvenile abundance. Additional objectives were to monitor bycatch of American shad in a permitted gill-net fishery and American shad and river herring in pound-net fisheries.
- Sampling for American shad occurred for nine weeks on the James River (28 February to 1 May 2016), eleven weeks on the Rappahannock River (21 February to 1 May 2016), and ten weeks on the York River (21 February to 25 April 2016). No post-spawning fish were observed on the James, York, or Rappahannock rivers in 2016. Only pre-spawning females were included in the calculation of catch indices for each river. A total of 116 pre-spawning female American shad (160.9 kg total weight) was captured; this is a decrease in number from the 2015 catch (169 pre-spawning females; 242.1 kg total weight).
- Total numbers and weights of pre-spawning female American shad in 2016 were highest on the Rappahannock River (n=45, 64.2 kg). Numbers of females were lower on the York River (n=43, 60.3 kg). The lowest catches of females were recorded on the James River (n=28, 36.4 kg). Numbers of males captured were: Rappahannock, 4; James, 2; York, 0. Total weight of males captured on all rivers was 5.8 kg. The total catch and weight of males were lower than in 2015 (n=21, 25.0 kg).
- Based on age estimates from scales, the 2010 (age 6) and 2009 (age 7) 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, 0.95 (r^2=0.68); James River, 0.915 (r^2=0.99) and Rappahannock River, 0.86 (r^2=1.00, only 2 age classes used for calculation). Total instantaneous mortality rates of males were not calculated because all year classes present were not equally catchable by the sampling gear.
- Otoliths of 28 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 21.4% (6 of 28 fish). Otoliths of 45 American shad captured on the Rappahannock River were scanned for hatchery marks. The presence of hatchery fish on the Rappahannock River was 8.9% (4 of 45 fish). On the York River, there is currently no stocking of hatchery fish, and no specimens with hatchery marks were detected on the York River in 2016.

- 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 2016 was: James River (including Chickahominy River), 0.01 (0.09, 65); Chickahominy River, 0.00 (NA, 10); Rappahannock River, 4.17 (1.63, 35); York River (including Mattaponi and Pamunkey Rivers), 0.64 (0.91, 95); Mattaponi River, 0.99 (1.05, 50); and Pamunkey River, 0.36 (0.71, 40).
- Twenty-one species of fishes (total of 7,625 specimens) were caught as bycatch in the staked gill net monitoring gear. The total number of striped bass captured was 559 (James River, n=36; York River, n=250; Rappahannock River, n=273). Live striped bass captured in the gear were counted and released. A random subsample of 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, 2.8%; York River, 29.2%; and the Rappahannock River, 30.0%.
- Two Atlantic sturgeon were captured as bycatch in the American shad sampling (James River, n=2; York River, n= 0; Rappahannock River, n=0).
- A seasonal catch index for American shad was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2016 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 2016 (1.54) decreased from the 2015 value (1.93). This is the lowest value of the 19-year time series. 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 (5.05) 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 2016 index (0.96) decreased from the 2015 value of 1.25. 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 4.04. In 2015 the hatchery prevalence was 21.4%. A correlation analysis among the catch index and hatchery prevalence from 1998-2016 was statistically significant ($r = 0.54$, df = 17, $p = 0.02$). The strength of the spawning run index on the James River continues to depend heavily on the presence of hatchery fish.
    - The catch index on the Rappahannock River in 2016 (1.68) decreased from the 2015 value (5.08). With the exception of 2016, since 2011 the annual index value has been above 5.0, with the highest value of the time series occurring in 2014. 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 (3.72).
- In 2016, the anchored gillnet sampling season for river herring in the Chickahominy River lasted fourteen weeks (2 February 2016 to 4 May 2016). Catch indexes for alewife and blueback herring were calculated using pre-spawned females. Catches of alewife peaked 9 March. After 29 March, post-spawning alewives were caught with pre-spawning fish. Catches of blueback herring peaked 5 April. After 13 April, post-spawning blueback herring

were mixed with pre-spawning fish. A total of 451 alewife (139 males; 260 pre-spawning females; 52 post-spawned females) and 241 blueback herring (53 males; 186 pre-spawning females; 2 post-spawned female) were captured.

- Using otolith-based ageing methods, the 2011 year class (age 5) of both female alewife and female blueback herring was dominant. Total instantaneous mortality rates of female alewife were 1.42. Total instantaneous mortality rate of female blueback herring was 1.23.

- The 2016 anchor gillnet seasonal catch indexes on the Chickahominy River, calculated by area under the CPUE curve: alewife, 0.6; blueback herring, 0.73. The index values were lower for alewife and higher for blueback herring compared to the index values in 2015 (alewife, 1.08; blueback herring, 0.56).

- In 2016, the drift gillnet sampling season for river herring in the Chickahominy River lasted ten weeks (29 February 2016 to 2 May 2016). A total of 32 alewife (17 males; 15 females) and 91 blueback herring (26 males; 65 females) were captured. Catches of alewife peaked between 4 April and 11 April and catches of blueback herring peaked between 28 March and 18 April.

- Catches from the drift gillnet were dominated by the 2012 year classes (age 4) of both female alewife and female blueback herring.

- The 2016 drift gillnet seasonal catch indexes on the Chickahominy River, calculated by summing the daily catch per unit effort (fish/meter of net/hour), were: alewife, 0.035; blueback herring, 0.100. These index values were lower for alewife and higher for blueback herring than the indexes in 2015 (alewife, 0.238; blueback herring, 0.077).

- The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile alewife captured in daylight seine hauls in 2016 was: James River, 0.98 (1.15, 11); York River, 0.09 (0.28, 55); Rappahannock River, 0.11 (0.45, 40). The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile blueback herring captured in daylight seine hauls in 2016 was: James River, 0.72 (1.28, 40); York River, 0.26 (0.61, 35); Rappahannock River, 2.60 (1.55, 25).

- In nighttime surface trawls on the Chickahominy River in 2016, catches were dominated by blueback herring (total alewife = 31; total blueback herring = 30,951). The 2016 seasonal catch index (geometric mean of CPUE) was 39.8 (cruise specific catch index ranged from 7.7 – 122.6) for blueback herring. Mean fish/tow and seasonal catch index were not calculated for alewife due to low catches at each sampling station.

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). Similarly, as early as the 1970s a substantial decline in the stocks of river herring coast wide was noted, and resulted in the ASMFC to require moratoria on fisheries unless stocks within a jurisdiction were shown to be sustainable (ASMFC 2009). Legislation enables imposition of federal sanctions on fishing in those states that fail to comply with the FMPs. To be in compliance, coastal states are required to implement and maintain fishery-dependent and fishery-independent monitoring programs as specified by the FMPs. For Virginia, these requirements for American shad and river herring 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 bycatch and evaluation of restoration programs by detection and enumeration of hatchery-released fish for American shad.

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, Steve 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 thank Robert Weagley for constructing, setting, and fishing the drift gill net for river herring sampling, and for contributing his advice. We also extend our appreciation to several commercial fishers for their cooperation in our studies of bycatch of American Shad. In 2016, these individuals include: Gary Waxmunski, John Augustine, Joseph Hinson, JC West, George Trice, Walter Rogers, and Charles Williams. In 2016, the staff of the Virginia Institute of Marine Science who participated in the program were: B. Watkins, A. Magee, P. McGrath, and P. Konstantinidis. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. B. Watkins determined ages of adult shad. P. McGrath determined ages of adult river herring. B. Watkins and A. Magee 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

This report describes the results of a continuing study to estimate the relative abundance and assess the status of American shad (*Alosa sapidissima*) stocks in Virginia by monitoring the spawning runs in the James, York and Rappahannock rivers in spring 2016, evaluating hatchery programs and contributing to coast-wide assessments (ASMFC 2007a). We also report on a relatively new aspect of this program: a fishery-independent monitoring program to determine abundance and stock structure of river herring (*A. pseudoharengus*, and *A. aestivalis*) in Virginia by evaluating the adult spawning run in the Chickahominy River, a major tributary of the James River. Further, a recently added objective of this study was to complement the monitoring of the adult spawning population of American shad and river herring in the James River system by monitoring juvenile alosines by using nighttime surface trawls in the Chickahominy River and calculate an index of juvenile abundance. Additional objectives were to monitor bycatch of American shad in a permitted gill-net fishery and American shad and river herring in pound net fisheries.

American shad. A moratorium on the taking of American shad 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. The moratorium was imposed at a time when commercial catch rates of American shad in Virginia's rivers were experiencing declines, especially in the York River. Data from the commercial fishery were the best available for assessing the status of individual stocks. Catch-per-unit-effort data were compiled from logbooks that recorded landings by commercial fishermen using staked gill nets at various locations throughout the middle reaches of the three rivers. The logbooks were voluntarily provided to the Virginia Institute of Marine Science (VIMS) during the period 1980-1993, 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) (Crecco 1998, ASMFC 1998, Olney & Hoenig 2001a).

Prior to 1998, there were no existing monitoring programs that provided direct assessment of American shad stock recovery in Virginia. The ban on in-river fishing 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, VIMS initiated scientific monitoring to estimate catch rates relative to those recorded before the prohibition of in-river fishing in 1994 (Olney & Hoenig 2001a). This monitoring program 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 1980-1993 in the York, James and Rappahannock rivers. The results of the first eight years of monitoring (1998-2005) formed the basis for the most recent stock assessment for American shad (ASMFC 2007a). The conclusions of the 2007 assessment were as follows: the James River stock remains at a low level of abundance and requires further protection and restoration; the Rappahannock River stock is stable with recent evidence of increasing abundance; in the York River, catch indexes have been trending downward but there is evidence of some recovery from the severe declines in the 1980s. Since 2005 (the last year of monitoring data to be incorporated into the 2007 assessment), catch indexes have remained at low levels in both the James and York rivers. The VMRC has not lifted the ban on recreational or commercial fishing, and asked that the monitoring program be continued.

River herring. River herring, including alewife (*Alosa pseudoharengus*) and blueback herring (*A. aestivalis*), were once the most valuable food fishes in Virginia (Atran et al. 1983). These species experienced decline in their value to the fisheries resources of Virginia, and as early as the 1970s a significant decline in the stocks of these fishes was noted. This range-wide decline of stocks culminated in the ASMFC requiring moratoria on fisheries unless stocks within a jurisdiction were shown to be sustainable (ASMFC 2009). Due in part to lack of available data to address the question of sustainability of river herring stocks in the Commonwealth, the VMRC implemented a ban on the possession of alewife and blueback herring to begin January 1, 2012. The ASMFC conducted a stock assessment for river herring that was completed in 2012 (ASMFC 2012), and which concluded that stocks coast-wide are at or near historically low levels. Due to this observed decline of river herring range-wide, the National Marine Fisheries Service (NMFS) received a petition from the Natural Resources Defense Council (NDRC) on August 5, 2011 (Federal Register, vol. 76, no. 212, Nov. 2, 2011) to list river herring, inclusive of both species, as Threatened under the Endangered Species Act (ESA). Although listing was not found to be warranted at the present time (Federal Register, vol. 78, no. 155, Aug. 8, 2013), this process highlighted the need for further data collection for many stocks of river herring, including those in Virginia.

General alosine information needs. In addition, there are other significant information needs relevant to American shad, river herring, or both in Virginia:

1. Extensive efforts are being made to rehabilitate the stocks of American shad through release of hatchery-raised fish. Evaluating the success of these programs is an ASMFC mandate and requires determination of the survival of the stocked fish to adulthood.
2. VMRC specifies a bycatch allowance of American shad in certain commercial fisheries. Bycatch of American shad currently exists in the Virginia commercial striped bass fishery, where mortality is presumed to be high. The VMRC regulation permits a limited number of commercial fishers to utilize this bycatch by selling fish in certain regions of each river. The ASMFC requires monitoring the biological characteristics, hatchery prevalence and magnitude of this harvest.
3. There is a need to evaluate mixed stock contributions to the pound net bycatch in Virginia's portion of Chesapeake Bay. Preliminary evidence using hatchery marks confirms that this bycatch includes adult shad from upper Bay stocks (Hoenig et al. 2008). Geochemical signatures in otoliths can be used to determine natal origins of American shad and estimate mixed stock contributions. This powerful technique has been validated in a recent study by Walther et al. (2008).
4. By the Treaty of 1677, Virginia tribal governments exercise their fishing rights in the York River and elsewhere. Brood stock is collected to support the activities of hatcheries on the Pamunkey and Mattaponi rivers. The total harvest of American shad is currently unknown but believed to be small. Detailed information concerning this harvest and its characteristics could aid future stock assessments.

The ongoing monitoring of American shad and river herring in Virginia waters is directly significant to recreational fisheries and the ecological health of the river systems that support these important fisheries for at least five reasons:

1. American shad fight well when angled using light tackle and were pursued by recreational fishermen in Virginia in the past, but the extent and success of this activity is not easily assessed. Recreational fishers catch and release shad on the James, Rappahannock, Mattaponi, Piankatank and Nottaway rivers; under moratorium, fishermen are not permitted to keep these fish. A recreational shad fishery in Virginia would constitute an important opportunity to expand or restore recreational fishing opportunities if the Chesapeake stocks are rehabilitated and managed carefully.
2. Until the moratorium took effect in 2012, river herring were recreationally harvested in Virginia's rivers. Lack of scientific data on the status of river herring stocks has been cited as a contributing factor for the inability to determine the sustainability of the stocks in Virginia, which led to the moratorium. This study addresses that shortcoming with the goal of informing management agencies for the objective of rebuilding river herring stocks to lift the moratorium.
3. American shad and river herring are important for trophic and ecological reasons. The abundance of juveniles is closely linked to water quality and the availability of good fish habitat. The shads and river herrings form an important prey group for striped bass and other recreationally important species in Chesapeake Bay. In recent years, there have been shifts in community structure in the major tributaries to the Bay with striped bass and gizzard shad numbers increasing greatly. Monitoring changes in abundance of key species is essential for understanding community dynamics.
4. This study characterizes the bycatch associated with commercial fisheries for American shad and river herring in Virginia's rivers. This is important for determining the impact of reopened commercial fisheries for shad and river herring on other recreationally important species, especially striped bass, as well as protected species such as Atlantic sturgeon.
5. Considerable effort and sport fishing funds are being devoted to enhancement of shad stocks through hatchery programs. This monitoring program provides an opportunity to identify returning hatchery fish. This is important for determining benefits to recreational fishers from the program. In 2004, a new hatchery-release program for American shad began on the Rappahannock River. This restoration effort is designed specifically for enhancement of recreational fishing and restoration of historic spawning habitat.

Background

American shad and river herring have supported recreational and commercial fisheries along the east coast of the United States and within the Chesapeake Bay since colonial times. Here we provide a brief review of the status and current regulations for American shad and river herring. See Atran et al. (1983), Loesch and Atran (1994), and Hilton et al. (2013) for further background on the stocks, fisheries, and management of these fishes in Virginia.

American shad. Concern about the significant decline in landings of American shad along the Atlantic coast prompted the development of an interstate fisheries management plan under the auspices of the ASMFC (ASMFC 1999). Prior to 1991, there were no restrictions on the American shad commercial fishery in Virginia rivers and the Chesapeake Bay. A limited season (4 Feb - 30 Apr) 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 Mar - 15 Apr 1993). However, due to bad weather conditions, the season was extended through 30 Apr. A complete moratorium was established in 1994.

In 1997 and 1998, during a series of public hearings, commercial and recreational fishing interests asked that the in-river ban on shad fishing be lifted. This proposal was opposed by the VMRC staff, VIMS fishery scientists, and 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. The initial results of the program provided the basis for the Commission to uphold the ban in December, 1998. The VMRC requested that VIMS continue its monitoring and stock assessment activities.

In 2003 and again in 2005, the ASMFC shad and river herring technical committee considered VMRC proposals for allowance of shad caught as bycatch. VMRC proposed to permit Virginia fishermen to retain American shad, caught as bycatch in Chesapeake Bay and tributary waters. The technical committee did not support either proposal. Members expressed concerns that the proposals included the catches of mixed stocks, had the potential to harvest substantial number of fish, and had the potential to impact other stocks which are under intensive restoration. A modified version of the 2006 proposal was subsequently approved by the Shad and River Herring Management Board. Since this date, bycatch allowances have been continually approved by the Management Board (2015 is the third of a five-year allowance of this bycatch fishery). Additionally, VIMS has monitored bycatch of American shad in pound nets located off Reedville, Virginia annually since 2002. In this program, fisherman are contracted to log daily catches of shad prior to their release. Additional nets were monitored at the mouth of the Rappahannock River (2007-2015) and Virginia's eastern shore (2007-2009). Subsamples of up to 50 American shad were also collected from these locations bi-weekly and returned to the laboratory for biological analysis.

The current regulation (effective date January 1, 1994) states that: "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 4 VAC 20-530-10 ET SEQ) except as specified, related to a bycatch fishery allotment (as amended March 1, 2013).

Under Amendment 3 of the Interstate Fishery Management Plan for American Shad and River Herring (ASMFC 2010), Virginia is mandated to conduct the following, for the Rappahannock, York, and James rivers:

1) Annual spawning stock survey to include passage counts, CPUE, or some other abundance index and representative subsamples that describe size, age, and sex;
2) composition of the spawning stock;
3) calculation of mortality and/or survival estimates where possible;
4) juvenile abundance survey (GM);
5) hatchery evaluation.

River herring. The most recent stock assessment for river herring concluded that stocks coast wide are severely depleted (ASMFC 2012). As early as the 1970s a substantial decline in the stocks of river herring coast wide was noted, and resulted in the ASMFC to require moratoria on fisheries unless stocks within a jurisdiction were shown to be sustainable (ASMFC 2009). Due in part to lack of available fishery-independent data to address the question of sustainability of river herring stocks in the Commonwealth, the VMRC voted to implement a ban on the possession of alewife and blueback herring to begin January 1, 2012.

The current regulation (effective date January 1, 2012) states, in part, that "It shall be unlawful for any person to catch and retain possession of any river herring from Virginia tidal waters." (VMRC Regulation 4 VAC-20-1260-30).

Amendment 2 of the Interstate Fishery Management Plan for Shad and River Herring (ASMFC 2009: table 15) mandates the following fishery-independent monitoring of river herring in Virginia (including the James, York, and Rappahannock rivers):

1) Annual spawning stock survey and representative sampling for biological data (excluding York River);
2) calculation of mortality and/or survival estimates;
3) calculation of juvenile abundance indices (JAI) as a geometric mean.

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 to1979 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 2014, fishery-independent survey program for monitoring the spawning stocks of river herring in Virginia employing a drift gillnet was implemented on the Chickahominy River. In 2015, an anchor gillnet fishery-independent survey was also implemented on the Chickahominy River to monitor the spawning stocks of river herring. Currently, there is a moratorium on both river herring species (i.e., no fishery-dependent data are available).

Since the alosine monitoring program at VIMS began in 1998, 27 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, 2001a; 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. 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; Hyle et al. 2014). Reprints of these papers are available on request. The 1998-2013 results of the monitoring program are reported by Olney & Hoenig (2000a, b, 2001b), Olney & Maki (2002), Olney (2003a, 2004, 2005), Olney & Delano (2006, 2007), Olney & Watkins (2008, 2009), Olney et al. (2010), and Hilton et al. (2011, 2012, 2013, 2014, 2015, 2016).

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) and river herring (Lee et al., 2012). The current monitoring program has also served as the basis for several theses and dissertations, including a study of the reproductive biology of American shad in the Mattaponi River (Hyle, 2004) and 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). Bycatch of Atlantic sturgeon is recorded and these data are reported to ASMFC.

Objectives

The primary objectives of the monitoring program (1) to continue a time series of relative abundance indices and biological structure of adult American shad during the spawning runs in the James, York and Rappahannock rivers and to establish a time series of relative abundance indices and biological structure of adult river herring in the Chickahominy River; (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 indexes (young-of-the-year index of abundance) of American shad and river herring to relative year-class strength and age-structure of spawning adults; (5) to determine the amount of bycatch of other species in the staked gill nets for American shad; and (6) to monitor the American shad bycatch fishery established by the VMRC. The results of this bycatch monitoring in 2016 are provided here as an appendix comprising a report on this fishery to the ASMFC (Appendix I).

Methods

Collection and processing of adult American shad

The 2016 sampling methods for the American shad monitoring program followed those employed in 1998-2015 (see Appendix I for additional methods used to monitor the bycatch fishery),with the exception that effort was reduced from two to one day per week in 2015. 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 1-3), and one of these locations on each river (the James, York and Rappahannock) was used to monitor catch rates by SGNs in 1998-2016. 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 4-5). One SGN, 912 ft (approximately 277 m) in length, was set on the Rappahannock River (Figure 6). 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 for one day (i.e., a 24-h set) and then hung in a non-fishing position until the next sampling episode. Occasionally, weather or other circumstances prevented the regularly scheduled sampling on Sunday, and sampling was postponed, canceled or re-scheduled for another day. In 2016, sampling occurred for eleven weeks on the Rappahannock River (21 February to 1 May 2016); ten weeks on the York River (21 February to 25 April2016); nine weeks on the James River (28 February to1 May 2016). Surface water temperature and salinity were recorded at each sampling event.

Individual American shad collected from the monitoring sites were measured and weighed on an electronic fish measuring board interfaced with an electronic balance. The board recorded measurements (fork length (FL) and total length (TL)) 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 gonad tissue and otoliths) into a data file for subsequent analysis.

Sagittal otoliths were removed from samples of adult American shad, placed in numbered tissue culture trays, and stored for subsequent screening for hatchery marks. To scan for hatchery marks, otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Otolith scanning was performed by B. Watkins and A. Magee (VIMS) in 2016. 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.

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 monitoring years 1998-2014, catches on two successive days were separated by up to five days (usually Tuesday-Saturday) in each week of sampling. In 2015 and 2016, catches were separated by up to six days (usually Monday-Saturday) in each week of sampling. In some rare cases, catches are separated by more than six days. To compute the catch index during all monitoring years, we estimated catches on skipped days using linear interpolation between adjacent days of sampling.

Collection and processing of adult river herring

Four anchor gill nets were set parallel to the current on the Chickahominy River approximately 2 miles [1.6-3.2 km] upstream from the mouth of the river. Two 2.5" [63.5 mm] stretched mesh (300' x 6') anchor gillnets and two 3.0" [76.2 mm] stretched mesh (300' x 8') anchor gillnets were constructed with top float lines and lead bottom lines. Additional larger floats are added every 50’ to ensure that fishing occurs from the surface down. Each week, nets were fished on two succeeding days (two 24-h sets). Occasionally, weather or other circumstances prevented the regularly scheduled sampling on Tuesday and Wednesday, and sampling was postponed, canceled or re-scheduled for other days. In 2016, sampling occurred over fourteen weeks (2 February to 4 May 2016). Surface water temperature and salinity were recorded at each sampling event.

One drift gill net was set on the Chickahominy River approximately 700 yards [640 m] below Walkers Dam once a week; in 2016 the sampling season lasted ten weeks (29 February 2016 to 2 May 2016). The net was 300-feet long and consisted of six alternating 3” [76.2 mm] and 2 ½” [63.5 mm] stretched-mesh monofilament netting panels (50-feet [15.2 m] each). One-hour net drifts were performed as close to slack tide as possible during morning hours. On

occasion, multiple sets or net relocation was required per one-hour drift due to environmental conditions.

One SGN, 300 ft (approximately 91.5 m) in length, was set on the Rappahannock River near the Rappahannock River bridge (at Tappahannock, VA) at river mile 36 (37° 55.8' N, 76° 50.7' W). The net consisted of six panels (50 ft [15.2 m] in length) of monofilament netting; three panels were constructed of 2.88" (7.3 cm) stretched mesh and three panels were constructed of 3" (7.6 cm) stretched-mesh.

Individual alewife and blueback herring were measured (FL and TL) to nearest mm and weighed to nearest g. Sagittal otoliths were removed, placed in numbered tissue culture trays, and stored for age determination. To age, otoliths were submersed in water with the sulcus facing downward, and viewed under a stereomicroscope with reflected light and a magnification of 2.0x. Ages were determined by one individual (P. McGrath) using methods recommended by the ASMFC (ASMFC 2014). Digital imaging software was used in conjunction with the stereomicroscope for ageing and for archiving all images. Scales were collected for future use.

Catch data from anchor gillnets were used to calculate a standardized catch index (the area under the curve of daily catch rate for pre-spawning females versus time of year). The 3.0" mesh was determined to be inefficient at catching blueback herring; therefore, the catch index for blueback herring was only calculated with catch data from 2.5" mesh. Catch data occurred over two successive days and was separated by up to five days (usually Thursday-Monday) in each week of sampling. In some rare cases, catches were separated by more than six days. To compute the catch index, catches on skipped days were estimated using linear interpolation between adjacent days of sampling. 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 will serve as the starting point for future comparisons to determine annual relative abundance of river herring. Age composition and sex ratio, among other attributes of the spawning stock of each species, are reported. Mortality was estimated for pre-spawning females using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve.

Catch data from the drift gillnet were used to calculate a daily and seasonal catch per unit of effort (fish/m/hr) per species; these will be compared between years. Age composition and sex ratio, among other attributes of the spawning stock of each species, are also reported.

Collection of other species

In both American shad and river herring sampling, catches of all other species were recorded and enumerated on log sheets by observers on each river and released. In the American shad sampling, 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. Random subsamples of Atlantic menhaden (*Brevoortia tyrannus*) were collected weekly from each river and returned to the laboratory for processing. Individual specimens were measured (mm), weighed (g) and had scales removed for future age analysis.

Collection of juvenile alosines

Juvenile alewife and blueback herring were captured in the Chickahominy River using the mamou trawl. The mamou trawl is a 6.7 m x 1.8 m floating surface trawl constructed of 35 mm high density polyethylene netting. The cod end is made from 36 mm netting with a 20 mm removable liner. The net consists of 15.2 m bridles connected to 36 x 18 floating mullet doors and 30.5 m tow lines. Tows were conducted using a 6.4 m skiff equipped with a 90 hp engine.

Seventeen weekly cruises were conducted in 2016 (7 June to 26 September). During each cruise, three stations were randomly chosen within each of four adjacent 9.3 river km long blocks. Stations were designated at every 1.9 river km, beginning approximately 1.2 km (c. 2 miles) below Walker's Dam and ending at the river mouth. Night time sampling was conducted when juvenile *Alosa* spp. are most susceptible to surface trawling (Loesch et al. 1982). Each tow lasted 5 minutes and was conducted along the central axis of the river channel. All tows were performed with the prevailing current.

Alewife and blueback herring caught at each station were identified and counted. Ten randomly selected individuals of each species from each station were measured and weighed. The geometric mean of the catch per tow was calculated for each cruise and the season (seasonal catch index).

Data of catches of American shad and river herring from the VIMS Striped Bass Seine Survey are also reported, as this survey provides greater spatial coverage within the tributaries of the Chesapeake Bay.

Results

Catches of American shad by staked gill nets in 2016

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-7. Post-spawning females were not encountered on the James, York, or Rappahannock Rivers in 2016. 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 122 American shad (6 males; 116 females) were captured (Table 1). The total weight of the sample was 166.6 kg (male, 5.8 kg; female, 160.9 kg). Catches in 2016 were lowest on the James River (30 total fish, 2 males and 28 females) and York River (43 total fish, 0 males and 43 females). Catches on the Rappahannock River (49 total fish, 4 males and 45 females) were highest.

On the James River, catches of females peaked between 28 February and 2 April, with catch rates usually exceeding 0.01 fish/m or 0.02 kg/m. During that period 92.9% (26 of 28) of all females were captured. Surface temperatures during this time ranged from 8.3^{o}C – 16.5^{o}C. The largest catch of pre-spawning female American shad (7 fish) occurred on 6 March when surface temperatures were 8.5^{o}C (Tables 2, 3). On the York River, catches of females peaked

between 27 February – 19 March when catch rates exceeded 0.02 fish/m or 0.03 kg/m. During that period, 67.4% (29 of 43) of all females were captured on the York River. Surface temperatures during this time ranged from 6.4 – 13.3^{o}C. The largest catch of pre-spawning female American shad on the York River (12 fish) occurred on 27 February when the surface temperature was 6.4^{o}C (Tables 2, 5). Catches of females on the Rappahannock River peaked on 6 March – 26 March when catch rates generally exceeded 0.02 fish/m or 0.03 kg/m. During that period on the Rappahannock River, 66.6% (30 of 45) of all females were captured. Surface temperatures during this time ranged from 6.7^{o}C – 13.2^{o}C. The largest catch of pre-spawning female American shad on the Rappahannock River (16 fish) occurred on 26 March when the surface temperature was 13.2^{o}C (Tables 2, 6). 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, 0:43; James River, 1:14.0 and Rappahannock River, 1:11.3. 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 2016 spawning run duration was estimated to be a minimum of 56 days on the James River (28 February – 24 April; Table 3), 50 days on the York River (27 February – 17 April; Table 5), and 49 days on the Rappahannock River (28 February –17 April; Table 6).

Biological characteristics of the American shad catch in 2016

Age, mean length (mm TL) and mean weight (kg) of American shad in staked gill nets are summarized in Tables 8-9. Mean total length at age of males and females from all rivers ranged from 423.0 – 526.0 mm TL and 485.0 – 556.5 mm TL, respectively. Mean weight at age of males and females from all rivers ranged from 0.7 - 1.4 kg and 1.2 - 1.6 kg, respectively.

Using scale-based ageing methods, we estimated that the 2010 and 2009 year classes (ages 6 and 7) of female American shad were the most abundant on all rivers (Table 10). On the James River, four age-classes of females were represented (2008-2011, ages 5-8), with the sample dominated by age-6 fish (51.9% of the total that was aged). On the York River, five age-classes of females were represented (2007-2011, ages 5-9). The sample was dominated by age-6 (56.1%) fish. On the Rappahannock River, three age-classes of females were taken (2009-2011, ages 5-7), with the sample dominated by age-6 fish (61.0%). Mean age of females in 2016 was 6.2 y (James River), 6.5 y (York River), and 6.1 y (Rappahannock River). These values are slightly higher than those observed in 2015. Three age-classes (2007, 2010-2011, ages 5-6, 9) of male American shad were collected on the Rappahannock River. The sample was dominated by age 5 fish (50.0%) fish. On the James and York Rivers, low sample sizes of male shad were observed in 2016.

Age-specific catch rates of American shad are reported in Tables 10 and 11 for females and males, respectively. Total instantaneous mortality (Z) of females 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, 0.95 (r^2=0.68); James River, 0.915 (r^2=0.99) and Rappahannock River, 0.86 (r^2=1.00, only two age classes used for calculation). It is assumed that year classes above age-4 are equally catchable by the gear.

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 2016 are presented in Tables 12 and 13. On the York River, fish (sexes combined) ranged in age from 5-9 years with 0 (virgin) to 4 spawning marks. On the Rappahannock River, fish (sexes combined) ranged in age from 5-9 years with 0-4 spawning marks. On the James River, fish (sexes combined) ranged in age from 5-8 years with 0-2 spawning marks. The following percentages of fish in each river had at least one prior spawn (termed "repeat spawners"): York River, 58.5% (24 virgins in a sample of 41); James River, 57.1% (16 virgins in a sample of 28) and Rappahannock River 48.9% (22 virgins in a sample of 45 fish).

Seasonal American shad catch indices, 1980-1992 and 1998-2016

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2016 and for each year of the historical record of staked net catches on each river (Tables 14-29 and Figures 7-10). Seasonal catch indices in 2016 were: James River, 0.96; York River, 1.54; Rappahannock River, 1.68.

Evaluation of hatchery origin of American shad in 2016

James River - Otoliths of 28 American shad (93.3% of the total catch) on the James River were processed for hatchery marks; the proportion with hatchery marks was 21.4% (6 of 28 fish). The biological attributes of these specimens are presented in Table 20. 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 2013 the hatchery percentage of fish with hatchery marks was 60.5% on the James. The strength of the James River catch index continues to rely on the prevalence of hatchery fish (Figure 11). A correlation analysis among the catch index and hatchery prevalence from 1998-2016 was statistically significant ($r = 0.54$, df = 17, $p = 0.02$). 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, 2011-2016there were no stray fish.

Most hatchery-reared adults taken on the James River in 2016 had OTC marks that indicated these specimens were released after 2010. These tags could not be easily differentiated microscopically, so we determined the year of release using scale-determined ages (Tables 20, 21). Most of the fish in the sample were from the 2010 year class (4 of 5 fish). 40.0% of hatchery marked fish in the ageing sample were repeat spawners. The oldest year class present was 2010.

York and Rappahannock Rivers - Otoliths of 38 American shad (88.4% of the total that were caught) from the York River were processed for hatchery marks. There were no specimens

with hatchery marks detected. In 2016, 45 American shad (91.8% of the total that were caught) from the Rappahannock river were scanned for the prevalence of hatchery marks. Four fish (8.9%) with hatchery marks were detected (Table 20, 22). Stocking of American shad in the Rappahannock River began in 2003 and ended in 2014.

Catches of river herring by anchored gill nets in 2016

Fishing days, numbers of river herring captured, catch rates (males and females) and length frequencies are reported in Tables 23-28. A total of 451 alewives (139 males; 260 pre-spawned females; 52 post-spawned females) and 243 blueback herring (53 males; 188 pre-spawned females; 2 post-spawned females) were captured (Table 23). After 29 March, post-spawning alewives were mixed with pre-spawning alewives. After 13 April, post-spawning blueback herring were mixed with pre-spawning blueback herring. Post-spawning fish were identified macroscopically in the laboratory. Because the historical fishery was a roe fishery and spent or partially-spent fish were not routinely captured or marketed in the fishery, post-spawning fish were not included in the monitoring sample.

Catches of pre-spawned alewife peaked between 23 February and 30 March, with catch rates exceeding 0.05 fish/m/day or 0.01 kg/m/day (Table 24; Figure 12). Catches of blueback herring peaked between 15 March and 13 April, with catch rates exceeding 0.08 fish/m/day or 0.01 kg/m/day (Table 26; Figure 12). Surface temperatures during these peaks ranged from 9.1^{o}C – 17.6^{o}C for alewife and from 13.7^{o}C – 17.6^{o}C for blueback herring. The largest catch of female alewife (30 fish) occurred on 9 March when surface temperatures were 12.6^{o}C and the largest catch of female blueback herring occurred on 5 April (43 fish) when surface temperatures were 14.1^{o}C. Sex ratio (males: females) for alewife was 1:1.87 and for blueback herring was 1:3.51. It is important to note that the monitoring gear is selective for mature female blueback herring and catches of male blueback herring do not likely reflect true sex ratio for that species.

Biological characteristics of river herring caught in anchored gillnets in 2016

Age, mean length (mm TL) and mean weight (kg) of river herring in anchored gill nets are summarized in Table 28. Mean total length at age of pre-spawned female alewives and blueback herring ranged from 263.0 – 306.5 mm TL and 267.2 – 305.5 mm TL, respectively. Mean weight at age of pre-spawned female alewives and blueback herring ranged from 0.16 – 0.28 kg and 0.18 – 0.27 kg, respectively.

Using otolith-based ageing methods, we estimated that the 2010 - 2012 year classes (ages 4 - 6) of female alewife and blueback herring were the most abundant (Table 28). Six age-classes of female alewife were represented (2008 - 2013, ages 3 - 8), with the sample dominated by age-5 fish (55.5% of the total that was aged). Mean age of female alewives in 2016 was 4.98. Six age-classes of female blueback herring were represented (2008-2013, ages 3-8), with the sample dominated by age-5 fish (54.7% of the total that was aged). Mean age of female alewives in 2016 was 5.13.

Age-specific catch rates of female alewives and blueback herring are reported in Table 28. Total instantaneous mortality (Z) of females was estimated using Chapman-Robson method. Total instantaneous mortality and survival (S) rates of females were: alewife, Z = 1.43 and S =

0.24; blueback herring, Z = 1.23 and S = 0.29. It is assumed that year classes above age-4 are equally catchable by the gear.

Seasonal river herring catch indices for 2016 (anchored gill net survey)

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for 2016 (Tables 24 and 26). Seasonal catch indices in 2016 were: alewife, 0.60; blueback herring, 0.73.

Catches and biological characteristics of river herring by drift gill nets in 2016

Fishing days, numbers of river herring captured (males and females), and water temperature are reported in Table 29. A total of 32 alewife (17 males; 15 females) and 91 blueback herring (26 males; 65 females) were captured. Catches of pre-spawned female alewives peaked between 4 April and 11 April and catches of blueback herring peaked between 28 March and 18 April, with catch rates exceeding 0.1 fish/m/hr (Table 30; Figure 13). Peak catches for both species occurred when surface temperatures ranged from 13.9°C – 16.5°C. The largest catch of female alewife (7 fish) occurred on 11 April when surface temperatures were 13.9^{o}C and the largest catch of female blueback herring occurred on 4 April and 11 April (19 fish) when surface temperatures were 16.0^{o}C and 13.9^{o}C, respectively. Sex ratios (males: females) were: alewife, 1:0.88; blueback herring, 1:2.50.

Age, mean length (mm TL) and mean weight (kg) of river herring in the drift gill net sampling are summarized in Table 31. Using otolith-based ageing methods, we estimated that the 2012 year class (age 4) of both female alewife and female blueback herring was dominant. Female alewife ranged in age from 4-5 years and female blueback herring ranged in age from 3-5 years.

Total instantaneous mortality (Z) was not calculated from the drift gill net sampling due to low catches of alewife, and the presence of few age classes of blueback herring.

Seasonal river herring catch indices for 2016 (drift gill net survey)

A seasonal catch index was calculated by summing the daily catch per unit effort (fish/meter of net/hour) (Table 30). Seasonal catch indices in 2016 were: alewife, 0.035; blueback herring, 0.0995.

Catches of river herring from the Rappahannock River by staked gill nets in 2016

Fishing days, numbers of river herring captured, catch rates (males and females) and length frequencies are reported in Tables 32 - 37. A total of 53 alewives (6 males; 47 pre-spawned females) and 15 blueback herring (1 male; 14 pre-spawned females) were captured (Table 32). After 26 March, post-spawning alewives (n=3) were mixed with pre-spawning alewives. No post-spawning blueback herring were encountered. Post-spawning fish were identified macroscopically in the laboratory. Because the historical 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.

Catches of pre-spawned alewife peaked between 13 March and 2 April, with catch rates exceeding 0.08 fish/m/day or 0.02 kg/m/day (Table 33; Figure 14). Catches of blueback herring peaked between 26 March and 2 April, with catch rates exceeding 0.06 fish/m/day or 0.016 kg/m/day (Table 35; Figure 14). Surface temperatures during these peaks ranged from 12.0 °C – 16.5 °C for alewife and from 13.2 °C – 16.5 °C for blueback herring. The largest catch of female alewife (12 fish) occurred on 13 March when surface temperatures were 12.5 °C and the largest catch of female blueback herring occurred on 2 April (8 fish) when surface temperatures were 16.5 °C. Sex ratio (males: females) for alewife was 1:7.33 and for blueback herring was 1:14. It is important to note that the monitoring gear is selective for mature female alewife and blueback herring, and catches of males likely do not reflect true sex ratio.

Biological characteristics of river herring caught by staked gill nets in 2016

Age, mean length (mm TL) and mean weight (kg) of river herring in anchored gill nets are summarized in Table 37. Mean total length at age of pre-spawned female alewives and blueback herring ranged from 285.8 – 291.8 mm TL and 289.2 – 293.0 mm TL, respectively. Mean weight at age of pre-spawned female alewives and blueback herring ranged from 0.24 – 0.27 kg and 0.24 – 0.27 kg, respectively.

Using otolith-based ageing methods, we estimated that the 2011 year class (age 5) of female alewife and blueback herring were the most abundant (Table 37). Three age-classes of female alewives were represented (2010 - 2012, ages 4 - 6), with the sample dominated by age-5 fish (77.3% of the total that was aged). Mean age of female alewives in 2016 was 5.05. Three age-classes of female blueback herring were represented (2009-2011, ages 5-7), with the sample dominated by age-5 fish (64.3% of the total that was aged). Mean age of female alewives in 2016 was 5.43.

Age-specific catch rates of female alewives and blueback herring are reported in Table 37. Total instantaneous mortality (Z) of females was estimated using Chapman-Robson method. Total instantaneous mortality and survival (S) rates of females were: alewife, Z = 2.01 and S = 0.13; blueback herring, Z = 1.15 and S = 0.32. It is assumed that year classes above age-4 are equally catchable by the gear.

Juvenile abundance of American shad and river herring

Tables 38 and 39 report index values of juvenile abundance of American shad based on seine surveys (1980-2016) on the James (including the Chickahominy), Chickahominy, Rappahannock, York (including the Mattaponi and Pamunkey Rivers), Pamunkey, and Mattaponi Rivers. 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 2016 was: James River, 0.01 (0.09, 65); Chickahominy River, 0.00 (NA, 10); Rappahannock River, 4.17 (1.63, 35); York River, 0.64 (0.91, 95); Mattaponi River, 0.99 (1.05, 50); and Pamunkey River, 0.36 (0.71, 40). 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 38) showed low recruitment of American shad in 2016. 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 Bosher's 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 2015 and 2016 (4.19 and 4.17, respectively). 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 (Table 39). 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.

Catches, mean length, mean weight, and the mean fish per tow from the nighttime surface trawls on the Chickahominy River in 2016 are reported in Table 40. Catches were dominated by blueback herring (total alewife = 31; total blueback herring = 30951). Mean length of alewife ranged from 42.5-83.0 mm FL and mean weight ranged from 1.03-8.26 g. Mean length of blueback herring ranged from 30.9-49.5 mm FL and mean weight ranged from 0.32-1.19 g. Because of low catches at each sampling station, mean fish/tow and geometric means (cruise specific index) were not calculated for alewife. Mean fish/tow for blueback herring ranged from 14.2-374.9 fish per tow, and the geometric means ranged from 7.7-122.6 for blueback herring. Peak catches of blueback herring occurred on 23 August.

Tables 41 and 42 report index values of juvenile abundance of alewife and blueback herring, respectively, based on seine surveys (1989-2016) on the James, York (includes the Mattaponi and Pamunkey Rivers), and the Rappahannock rivers. The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile alewife captured in daylight seine hauls in 2016 was: James River, 0.98 (1.15, 11); York River, 0.09 (0.28, 55); Rappahannock River, 0.11 (0.45, 40). The geometric mean catch (followed by standard deviation and number of seine hauls in parentheses) of juvenile blueback herring captured in daylight seine hauls in 2016 was: James River, 0.72 (1.28, 40); York River, 0.26 (0.61, 35); Rappahannock River, 2.60 (1.55, 25).

Indexes of juvenile abundance based on the seine survey data are variable, but are almost always higher for blueback herring than for alewife, and the Rappahannock River most often shows the highest abundance for both species. No measurable recruitment of alewife was seen in the James River in 1989-1992, 1995, 1999-2003, 2008, and 2011-2012, and in the York River in 1990-1993, 1995, 1998-2000, 2006-2009, and 2012-2014. In the Rappahannock River, indexes of juvenile alewife abundance have been relatively low (e.g., <0.1) in many years (1990-1992, 1995, 2002, 2004-2006, 2008, 2012), but there has always been measureable recruitment throughout the time series. The only instances of no measurable recruitment of blueback herring within the time series occurred in the York River, and in the years 1990, 1992-1993, 1995, 1998-1999, 2002, 2005-2006, 2009, 2012-2013.

Bycatch of striped bass and other species in 2016

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 43-45. Twenty-two species of fishes were taken as bycatch in the staked gill net monitoring gear for a total of 7,625 specimens. The most commonly encountered bycatch species were: gizzard shad (*Dorosoma cepedianum*), menhaden (*Brevoortia tyrannus*), striped bass (*Morone saxatilis*), and blue catfish (*Ictalurus furcatus).*

The total number of striped bass captured was 559 (James River, n=36; York River, n=250; Rappahannock River, n=273). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 2.8%; York River, 29.2%; and the Rappahannock River, 39.6%. A subsample of 156 dead striped bass was selected from all rivers. Length of males and females ranged from 373 - 699 mm FL and 455 - 620 mm FL, respectively. Total weights of males and females ranged from 0.675 – 3.61 kg and 1.09 – 3.37 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 2016, two Atlantic sturgeon were caught as bycatch in this sampling (James River, n=2; York River, n= 0; Rappahannock River, n=0; due to reduced effort in 2015 and 2016, this number cannot be directly compared to previous years). The total numbers of Atlantic sturgeon captured in this survey from previous years were: 37 (1998), 24 (1999), 16 (2000), 8 (2001), 1 (2002), 3 (2003), 6 (2004), 25 (2005), 40 (2006), 30 (2007), 9 (2008), 7 (2009), 10 (2010), 12 (2011), 4 (2012), 11 (2013), 20 (2014), 10 (2015). Most of these fish were taken in the James River during each year: 30 (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); 11 (2011); 4 (2012); 6 (2013); 20 (2014), 9 (2015).

The total number of Atlantic menhaden captured in the staked gill nets used to monitor abundance of adult American shad in 2016 was 1,367 (James River, n= 545; York River, n=333; Rappahannock River, n= 489). A portion (n=402) of this catch was returned to the laboratory and processed for length (mm) and weight (g). Scale samples were collected for future age analysis. Individual lengths ranged from 119 - 377 mm TL. Total weights ranged from 0.02 - 0.57 kg.

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 bycatch 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 16). 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 prior to 1980 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 2016 was 1.54; this is the lowest catch index on the York in the 19 years of monitoring the American shad spawning stock. Since 2005 index values have been low, but stable. In years prior (1998-2004) index values were higher (5.42-14.71). 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 (5.05), 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, with the exception of 2014, are close to all-time lows.

Our overall assessment of the York River stock is that it persists at a low level that is close to or lower than its average abundance during the 1980s. As noted previously, the stock level was low during that period and was evidently incapable of supporting an active fishery. Since 2005, the catch index has shown no recovery to the higher levels seen earlier in the time series, and is cause for concern and continued monitoring. 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 bycatch fishery of American shad, results of which for 2016 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. In past years there have also been losses to capture of brood stock on the Pamunkey River by the VDGIF. In comparison to other rivers in Virginia, there is currently no stocking of hatchery fish in the York River. The stock is currently well below the proposed 1950s target (Figure 9) 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 2016 index (0.96) was the lowest catch index in the 19 years of monitoring American shad runs on the James. This value is well below the peak catch index observed in the 1980s (29.20). 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 (4.04). Hatchery cohorts are believed to be recruiting in high proportions to the population. Prevalence of hatchery fish on the James River reached an all-time high of 60.5% in 2013. Our overall assessment for the James River is that the stock remains at historically low levels and is dependent on hatchery inputs (Figure 11). Due to budget constraints and absence of brood stock, 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 2016 index was 1.68. The current geometric mean (3.72) 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 occurred between 2003 and 2012, using the progeny of Potomac River brood stock. 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 8.9% (2016). Due to the low level of return, VDGIF has ceased stocking American shad in the Rappahannock River for the foreseeable future.

The anchor gill net survey on the Chickahominy River began in 2015 and was intended to monitor the relative abundance, stock structure, mortality, and biological characteristics of river herring in a major tributary of the James River that, prior to the moratorium, was the focus of a fishery. No historical data exist to allow comparison of those data collected in this survey, and thus the 2015 values will provide a reference point for future comparisons. This survey proved to be effective, although there is significant variation in levels of catches between species and

sexes. Catches of adult blueback herring were significantly lower than adult alewife, although in summertime nighttime surface trawls, blueback herring dominated the catches in the Chickahominy River. This suggests that there is variation in species specific catchability, either because of gear (e.g., mesh size) or biological characteristics of the species (e.g., habitat use of juveniles). The 2016 index was lower for alewife and higher for blueback herring. It will take several more years of data before a trend can be realized.

The drift gill net survey on the Chickahominy River began in 2014 and was intended to monitor the relative abundance and biological characteristics of river herring by mimicking the historic fishery. No historical data exist to allow comparison of those data collected in this survey, and thus the values from 2014 will provide a reference point for future comparisons. The 2016 index value continued an increasing trend for blueback herring, but was lower for alewife.

This year marked the first year of adult spawning stock survey of river herring on the Rappahannock River. Due to logistical issues, the SGN was not set until mid-March, so it is possible that a portion of the alewife run was missed. This monitoring program is based on historical data for herring catches on the Rappahannock River that recently became available from the archives of the VIMS Fisheries Department. It is possible that species and sex ratios for alewife and blueback herring are biased due to specific aspects of this survey (e.g., mesh size is not ideal for catching blueback herring but reflects that used in the historical fishery). Analysis of these historical data and how they relate to our current monitoring is ongoing.

Literature Cited

ASMFC. 1998. American shad stock assessment peer review report. Atlantic States Marine Fisheries Commission, March, 1998.

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. 2009. Amendment 2 to the interstate fishery management plan for shad and river herring. ASMFC, Washington, D.C. 166 p.

ASMFC. 2010. Amendment 3 to the Interstate Fishery Management Plan for Shad and River Herring (American Shad Management). 158 pp.

ASMFC. 2012. River herring stock assessment report for peer review. Vol II., Section 15: Status of American shad in Virginia. Contributors: L.M. Lee, J.E. Olney, B. Watkins, E. J. Hilton, J. Cimino, and A. Weaver. Pages 489-548. Stock Assessment Report No. 12-02.

ASMFC. 2014. 2013 River Herring Ageing Workshop Report. 112 pp.

Atran, S.M., J.G. Loesch, and W.H. Kriete, Jr. 1983. An overview of the status of *Alosa* stocks in Virginia. VIMS Marine Resources Report No. 82-10. 47 p.

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.

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.

Crecco, V. 1998. Stock assessment of American shad from selected Atlantic coast rivers. Report to the External Peer Review Panel, March 1998.

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.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2013. *Monitoring relative abundance of American shad in Virginia rivers.* 2012 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-15, 15 April 2013.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2014. *Monitoring relative abundance of American shad in Virginia rivers.* 2013 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-16, 15 April 2014.

Hilton, E. J., R. Latour, B. Watkins, & A. Rhea. 2015. *Monitoring relative abundance of American shad and river herring in Virginia rivers.* 2014 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-17, 15 April 2015.

Hilton, E. J., R. Latour, P.E. McGrath, B. Watkins, & A. Magee. 2016. Monitoring relative abundance of American shad and river herring in Virginia rivers. 2015 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-18, 15 April 2016.

Hoenig, 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.

Hyle, R.H., R.S. McBride, and J. E. Olney. 2014. Determinate versus indeterminate fecundity in American shad, an anadromous clupeid. Transactions of the American Fisheries Society 143:618–633.

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.

Loesch, J.G., and S.M. Atran. 1994. History of *Alosa* fisheries management: Virginia, a case study. Pages 1–6 *In*: J.E. Cooper, R.T. Eades, R.J. Klauda, and J.G. Loesch (editors), Anadromous *Alosa* Symposium. Tidewater Chapter, American Fisheries Society, Bethesda, Maryland.

Loesch, J.G., W.H. Kriete Jr. and E.J. Foell. 1982. Effects of light intensity on the catchability of juvenile anadromous *Alosa* species. Transactions of the American Fisheries Society 111: 41-44.

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.

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.

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. Managing a fishery under moratorium: assessment opportunities for Virginia's stocks of American shad (*Alosa sapidissima*). Fisheries 26(2): 6-12.

Olney, J. E. and J. M. Hoenig. 2001b. 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., 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 P□che 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. Hopler, 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.

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.

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 2016.

Sampling Location	Sampling dates in 2016	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	2/28 – 5/1	28	2	36.4	1.4	30	37.7
York River	2/21 - 4/25	43	0	60.3	0	43	60.3
Rappahannock River	2/21 – 5/1	45	4	64.2	4.4	49	68.6
Totals		116	6	160.9	5.8	122	166.6

Table 2. Daily temperature and number of American shad (both sexes combined) caught in staked gill nets on the James, York and Rappahannock rivers in 2016. Numbers in parentheses are the number of post-spawning fish caught. Abbreviations: N, number of shad caught; ND, no data. Highlighted cell are non-fishing days.

	James		York		Rappahannock	
Date	Temp ˚C	N	Temp ˚C	N	Temp ˚C	N
2/21/2016			5.7	0	3.8	1
2/27/2016			6.4	12		
2/28/2016	8.3	5			6.3	5
3/6/2016	8.5	7	6.5	2	6.7	10
3/13/2016	12.7	1	11.7	7	12.5	4
3/19/2016	14.9	3	13.3	8		
3/20/2016					12	2
3/26/2016	13.6	6	13.8	3	13.2	17
4/2/2016	16.5	6			16.5	2
4/7/2016			12.9	5		
4/11/2016			11.5	2	10.9	5
4/17/2016	12.9	0	13.3	3	14.1	3
4/24/2016	16.5	2			17.6	0
4/25/2016			16.8	1		
5/1/2016	17.1	0			17.5	0

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 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/28/2016	59	5	0.0182	6.0	0.0220
3/6/2016	66	7	0.0255	8.7	0.0318
3/13/2016	73	1	0.0036	1.6	0.0058
3/19/2016	79	3	0.0109	4.2	0.0153
3/26/2016	86	6	0.0219	7.8	0.0283
4/2/2016	93	4	0.0146	5.5	0.0199
4/17/2016	108	0	0.0000	0.0	0.0000
4/24/2016	115	2	0.0073	2.6	0.0095
5/1/2016	122	0	0.0000	0.0	0.0000
Totals		28		36.4	

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 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/28/2016	59	0	0.0000	0.0	0.0000
3/6/2016	66	0	0.0000	0.0	0.0000
3/13/2016	73	0	0.0000	0.0	0.0000
3/19/2016	79	0	0.0000	0.0	0.0000
3/26/2016	86	0	0.0000	0.0	0.0000
4/2/2016	93	2	0.0073	1.4	0.0051
4/17/2016	108	0	0.0000	0.0	0.0000
4/24/2016	115	0	0.0000	0.0	0.0000
5/1/2016	122	0	0.0000	0.0	0.0000
Totals		2		1.4	

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 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/21/2016	51	0	0.0000	0.0	0.0000
2/27/2016	58	12	0.0437	17.1	0.0622
3/6/2016	66	2	0.0073	2.7	0.0099
3/13/2016	73	7	0.0266	9.6	0.0367
3/19/2016	79	8	0.0298	10.9	0.0406
3/26/2016	86	3	0.0109	4.6	0.0167
4/7/2016	98	5	0.0182	6.5	0.0238
4/11/2016	102	2	0.0109	2.9	0.0159
4/17/2016	108	3	0.0114	4.5	0.0170
4/25/2016	116	1	0.0036	1.5	0.0055
Totals		43		60.3	

Table 6. 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 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/21/2016	52	1	0.0036	1.3	0.0047
2/28/2016	59	5	0.0180	7.0	0.0251
3/6/2016	66	10	0.0360	14.7	0.0530
3/13/2016	73	3	0.0115	4.1	0.0155
3/20/2016	80	1	0.0035	1.5	0.0052
3/26/2016	86	16	0.0576	23.4	0.0842
4/2/2016	93	2	0.0108	2.9	0.0154
4/11/2016	102	4	0.0171	5.4	0.0232
4/17/2016	108	3	0.0106	3.9	0.0137
4/24/2016	115	0	0.0000	0.0	0.0000
5/1/2016	122	0	0.0000	0.0	0.0000
Totals		45		64.2	

Table 7. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/21/2016	52	0	0.0000	0.0	0.0000
2/28/2016	59	0	0.0000	0.0	0.0000
3/6/2016	66	0	0.0000	0.0	0.0000
3/13/2016	73	1	0.0038	1.4	0.0054
3/20/2016	80	1	0.0035	1.1	0.0037
3/26/2016	86	1	0.0036	1.2	0.0044
4/2/2016	93	0	0.0000	0.0	0.0000
4/11/2016	102	1	0.0043	0.7	0.0031
4/17/2016	108	0	0.0000	0.0	0.0000
4/24/2016	115	0	0.0000	0.0	0.0000
5/1/2016	122	0	0.0000	0.0	0.0000
Totals		4		4.4	

Table 8. 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 2016. 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	2011	5	485.2	27.5	1.2	0.172
	2010	14	495.5	16.6	1.3	0.116
	2009	6	510.5	24.4	1.4	0.181
	2008	2	534.0	1.4	1.4	0.056
	NA	1	488.0		1.3	
York River	2011	2	495.0	0.0	1.4	0.030
	2010	23	504.2	19.2	1.4	0.136
	2009	13	517.1	15.6	1.4	0.125
	2008	1	510		1.3	
	2007	2	556.5	9.2	1.6	0.168
	NA	2	485.0	26.9	1.3	0.156
Rappahannock River	2011	6	486.2	6.1	1.3	0.129
	2010	25	503.6	13.8	1.4	0.127
	2009	10	518.4	25.8	1.5	0.199
	NA	4	487.3	18.3	1.4	0.202

Table 9. Mean total length and mean weight of male American shad captured in staked gill nets in the James and Rappahannock Rivers, spring 2016. 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	2011	1	435.0		0.7	
	NA	1	423.0		0.7	
Rappahannock River	2011	2	442.0	36.8	1.0	0.353
	2010	1	466.0		1.1	
	2007	1	526.0		1.4	

Table 10. 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 2016. 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	2011	5	6.2	9	0.0020	0.0025
	2010	14	17.7	9	0.0057	0.0072
	2009	6	8.3	9	0.0024	0.0034
	2008	2	2.8	9	0.0008	0.0012
	NA	1	1.3	9	0.0004	0.0005
York River	2011	2	2.7	9.5	0.0008	0.0010
	2010	23	32.1	9.5	0.0088	0.0123
	2009	13	18.3	9.5	0.0050	0.0070
	2008	1	1.3	9.5	0.0004	0.0005
	2007	2	3.2	9.5	0.0008	0.0012
	NA	2	2.6	9.5	0.0008	0.0010
Rappahannock River	2011	6	7.8	10.5	0.0021	0.0027
	2010	25	35.7	10.5	0.0086	0.0122
	2009	10	15.1	10.5	0.0034	0.0052
	NA	4	5.5	10.5	0.0014	0.0019

Table 11. Number, total weight, and seasonal catch rates by year class of male American shad captured in staked gill nets in the James and Rappahannock Rivers, spring 2016. 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	2011	1	0.7	9	0.0004	0.0002
	NA	1	0.7	9	0.0003	0.0002
Rappahannock River	2011	2	1.9	10.5	0.0007	0.0007
	2010	1	1.1	10.5	0.0003	0.0004
	2007	1	1.4	10.5	0.0003	0.0005

Table 12. Spawning histories of American shad (combined sexes) collected in spring, 2016 in the James and York rivers. Table entries are total numbers of fish that were aged (James River, n=28; York River, n=41). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the James River, the number in parentheses is the number of aged fish out of the total that had hatchery marks on their otoliths (James, n=5). 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
2011	5	-	-	**6 (1)**	-	-
2010	6	-	2	7 (2)	**5 (2)**	-
2009	7	-	-	2	3	**1**
2008	8	-	-	-	2	-

		Age at Maturity				
York River Year Class	Age at Capture	3	4	5	6	7
2011	5	-	-	**2**	-	-
2010	6	-	2	6	**15**	-
2009	7	-	-	2	11	**0**
2008	8	-	-	-	1	-
2007	9	-	-	1	1	-

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2016 in the Rappahannock River. Table entries are total numbers of fish that were aged (Rapp. River, n=45). 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=3). The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

		Age at Maturity				
Rapp. River Year Class	Age at Capture	3	4	5	6	7
2011	5	-	1	**7**	-	-
2010	6	-	2	9(1)	**15 (1)**	-
2009	7	-	-	1	8 (1)	**1**
2007	9	-	-	1	-	-

Table 14. 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*days)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
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 15. Summary of recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia.

Year	Effort (10^3 m*days)	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
2013	7.2	78	0.289	0.080	6.98
2014	6.7	57	0.322	0.122	8.66
2015	2.7	63	0.200	0.053	5.08
2016	2.9	56	0.085	0.022	1.68
Geometric mean					**3.72**

Table 16. 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 (10^3m*days)	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 17. Summary of recent catch and effort data of American shad by staked gill nets in the York River, Virginia.

Year	Effort (10^3m*days)	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
2013	7.1	78	0.189	0.045	3.98
2014	6.4	70	0.611	0.139	10.06
2015	2.8	58	0.033	0.020	1.93
2016	2.6	58	0.062	0.023	1.54
Geometric mean					**5.05**

Table 18. 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 (10^3m*days)	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 19. Summary of recent catch and effort data of American shad by staked gill nets in the James River, Virginia.

Year	Effort (10^3m*days)	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
2013	6.6	74	0.222	0.056	4.48
2014	5.5	60	0.251	0.113	7.35
2015	2.1	49	0.057	0.023	1.25
2016	2.5	56	0.032	0.015	0.96
Geometric mean					**4.04**

Table 20. Specimen number, river of capture, river of origin, sequence of hatchery marks, age, number of spawns, fork length (FL), total length (TL), total weight (TW), and sex of American shad with hatchery marks (James=6, Rapp=4) taken in staked gill net monitoring in the James and Rappahannock rivers, 2016. A total of 111 American shad were scanned for hatchery marks (James=28, Rapp=45). Data are sorted by river, age, and spawning history. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged; Sex: 1, Male; 2, Female.

Specimen Number	River Capture	River Origin	Sequence	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
20017	James	James	3	6	1	413	470	1099.0	2
20037	James	James	3	6	0	436	488	1303.9	2
20065	James	James	3	NA	NA	436	488	1263.1	2
20089	James	James	3	6	0	438	495	1262.8	2
20092	James	James	3	5	0	446	508	1462.4	2
20098	James	James	3	6	1	442	498	1364.2	2
20020	Rappahannock	Rappahannock	3	6	1	449	509	1449.7	2
20083	Rappahannock	Rappahannock	3	7	1	480	546	1584.5	2
20109	Rappahannock	Rappahannock	3	NA	NA	434	492	1370.4	2
20119	Rappahannock	Rappahannock	3	6	0	446	512	1393.9	2

Table 21. Total numbers of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2016. 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	2013	2014	2015	2016	Total	% Total
1992	0.05		1																		1	0.1
1993	0.5	7	2	1																	10	1.0
1994	1.6	7	3	9			1														20	2.0
1995	5.3			59	9	8	4	3													83	8.1
1996	5.8			53	62	43	10	4	1												173	16.9
1997	5.9			2	27	78	57	5	4		1										174	17.0
1998	10					13	52	17	13												95	9.3
1999	7.3						14	29	7												50	4.9
2000	8.9						1	5	9		1										16	1.6
2001	9.3								3	4	3										10	1.0
2002	8.4									4	20	7	2								33	3.2
2003	8.7										12	8	1	1	2						24	2.3
2004	6.6										2	3	2	13	4						24	2.3
2005	6.0												1	18	22	2	1				44	4.3
2006	7.0													11	35	5		3			54	5.3
2007	6.5														5	10	14	6			35	3.4
2008	6.2															4	19	13	2		38	3.7
2009	3.8																9	18	6		33	3.2
2010	3.7																	3	3	4	10	1.0
2011	2.4																			1	1	0.1
2012	5.4																					
2013	4.8																					
2014	3.3																					
2015	3.5																					
2016	1.01																					
NA	--					12	3	5	3	1	9	2	2	11	15	7	9	16	1	1	97	9.5
Total	130.95	14	6	124	98	154	142	68	40	9	48	20	8	54	83	28	52	59	12	6	1025	100.0

Table 22. Total numbers of hatchery-marked American shad taken in staked gill nets in the Rappahannock River, 2007-2016. 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	2013	2014	2015	2016	Total	% Total
2003	1.4												
2004	3.2		1	2	1							4	11.8
2005	3.4			1		1		1				3	8.8
2006	6.3					1	1					2	5.9
2007	4.5					1	5	1	1			8	23.5
2008	4.8						1	2	1			4	11.8
2009	2.7								4	1	1	6	17.6
2010	3.9									1	2	3	8.8
2011	4.1									1		1	2.9
2012	6.0												0.0
2013	4.3												0.0
2014	4.3												0.0
2015	0.0												0.0
2016	0.0												
NA	--						1		1		1	3	8.8
Total	48.9	0	1	3	1	3	8	4	7	3	4	34	100.0

Table 23. Summary of catches of river herring in the Chickahominy River anchor gillnet survey, 2016 (# Females includes both pre- and post-spawn females).

Date	# Alewife		# Blueback		Water Temp (C)
	3" Mesh (# Females)	2.5" Mesh (# Females)	3" Mesh (# Females)	2.5" Mesh (# Females)	
2/2/2016	6 (2)	2 (2)	0	0	7.1
2/3/2016	11 (6)	9 (5)	0	0	8.6
2/9/2016	2 (2)	4 (2)	0	0	9.2
2/10/2016	4 (1)	1 (1)	0	0	8.9
2/17/2016	8 (6)	7 (0)	0	0	8.2
2/18/2016	5 (1)	3 (2)	0	0	7.7
2/23/2016	14 (12)	20 (10)	0	0	9.4
2/24/2016	2 (2)	1 (1)	0	0	9.1
3/1/2016	17 (13)	19 (10)	0	1 (0)	11.8
3/2/2016	19 (15)	24 (11)	0	0	12.4
3/8/2016	6 (6)	18 (13)	0	1 (0)	11.5
3/9/2016	22 (21)	15 (9)	0	1 (1)	12.6
3/15/2016	11 (11)	10 (8)	0	24 (15)	15.9
3/16/2016	5 (5)	16 (11)	0	25 (15)	16.2
3/22/2016	3 (3)	11 (8)	0	13 (11)	14.7
3/23/2016	11 (10)	13 (6)	0	10 (7)	15.2
3/29/2016	4 (3)	31 (25)	0	14 (12)	17.5
3/30/2016	6 (6)	40 (29)	0	15 (12)	17.6
4/5/2016	0	11 (8)	0	48 (43)	14.1
4/6/2016	0	11 (4)	2 (2)	25 (23)	13.7
4/12/2016	3 (3)	2 (1)	0	8 (5)	14.5
4/13/2016	2 (2)	10 (8)	0	21 (18)	14.9
4/19/2016	0	4 (3)	0	6 (5)	17.5
4/20/2016	0	2 (2)	0	11 (6)	18.1
4/26/2016	0	2 (2)	0	5 (4)	19.4
4/27/2016	0	1 (1)	0	4 (4)	20.3
5/3/2016	0	0	0	5 (4)	21.8
5/4/2016	0	3 (0)	0	4 (3)	22.3
Totals	161 (130)	290 (182)	2 (2)	241 (188)	

Table 24. Dates of capture, number, total weight, and catch rates of pre-spawn female alewife taken in the 2.5" and 3" mesh anchor gillnets on the Chickahominy River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/2/2016	33	4	0.0112	0.89	0.0025
2/3/2016	34	11	0.0306	2.86	0.0080
2/9/2016	40	4	0.0111	0.88	0.0024
2/10/2016	41	2	0.0054	0.57	0.0015
2/17/2016	48	6	0.0185	1.69	0.0052
2/18/2016	49	3	0.0080	0.73	0.0019
2/23/2016	54	22	0.0573	5.57	0.0145
2/24/2016	55	3	0.0082	0.68	0.0018
3/1/2016	61	23	0.0624	5.61	0.0152
3/2/2016	62	26	0.0713	6.69	0.0183
3/8/2016	68	19	0.0515	4.42	0.0120
3/9/2016	69	30	0.0826	8.07	0.0222
3/15/2016	75	19	0.0526	4.55	0.0126
3/16/2016	76	16	0.0443	3.74	0.0103
3/22/2016	82	10	0.0274	2.00	0.0055
3/23/2016	83	16	0.0436	3.93	0.0107
3/29/2016	89	10	0.0271	2.19	0.0060
3/30/2016	90	19	0.0533	4.54	0.0127
4/5/2016	96	4	0.0090	0.77	0.0017
4/6/2016	97	1	0.0034	0.22	0.0007
4/12/2016	103	3	0.0084	0.81	0.0023
4/13/2016	104	5	0.0140	1.30	0.0036
4/19/2016	110	2	0.0054	0.47	0.0013
4/20/2016	111	0	0.0000	0.00	0.0000
4/26/2016	117	1	0.0027	0.21	0.0005
4/27/2016	118	1	0.0028	0.16	0.0004
5/3/2016	124	0	0.0000	0.00	0.0000
5/4/2016	125	0	0.0000	0.00	0.0000
	Totals	260		63.55	

Table 25. Dates of capture, number, total weight, and catch rates of male alewife taken in the 2.5” and 3” mesh anchor gillnets on the Chickahominy River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/2/2016	33	4	0.0112	0.81	0.0023
2/3/2016	34	9	0.0251	2.02	0.0056
2/9/2016	40	2	0.0055	0.52	0.0014
2/10/2016	41	3	0.0082	0.79	0.0022
2/17/2016	48	9	0.0283	1.70	0.0053
2/18/2016	49	5	0.0133	1.21	0.0032
2/23/2016	54	12	0.0312	2.35	0.0061
2/24/2016	55	13	0.0349	2.70	0.0072
3/1/2016	61	17	0.0463	3.44	0.0094
3/2/2016	62	5	0.0134	1.02	0.0027
3/8/2016	68	7	0.0192	1.31	0.0036
3/9/2016	69	2	0.0055	0.34	0.0009
3/15/2016	75	5	0.0138	0.89	0.0025
3/16/2016	76	3	0.0082	0.52	0.0014
3/22/2016	82	8	0.0218	1.30	0.0036
3/23/2016	83	7	0.0190	1.22	0.0033
3/29/2016	89	11	0.0308	1.90	0.0053
3/30/2016	90	3	0.0068	0.53	0.0012
4/5/2016	96	7	0.0236	1.18	0.0040
4/6/2016	97	1	0.0029	0.19	0.0005
4/12/2016	103	2	0.0056	0.39	0.0011
4/13/2016	104	1	0.0027	0.17	0.0005
4/19/2016	110	0	0.0000	0.00	0.0000
4/20/2016	111	0	0.0000	0.00	0.0000
4/26/2016	117	0	0.0000	0.00	0.0000
4/27/2016	118	0	0.0000	0.00	0.0000
5/3/2016	124	0	0.0000	0.00	0.0000
5/4/2016	125	3	0.0083	0.49	0.0014
	Totals	139		26.99	

Table 26. Dates of capture, number, total weight, and catch rates of pre-spawn female blueback herring taken in 2.5" mesh anchor gillnets on the Chickahominy River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/9/2016	69	1	0.0055	0.27	0.0015
3/15/2016	75	15	0.0829	3.35	0.0185
3/16/2016	76	15	0.0829	3.30	0.0182
3/22/2016	82	11	0.0603	2.31	0.0127
3/23/2016	83	7	0.0382	1.47	0.0080
3/29/2016	89	12	0.0667	2.41	0.0134
3/30/2016	90	12	0.0672	2.59	0.0145
4/5/2016	96	43	0.1938	8.46	0.0381
4/6/2016	97	23	0.1545	4.61	0.0310
4/12/2016	103	5	0.0283	1.08	0.0061
4/13/2016	104	17	0.0949	3.44	0.0192
4/19/2016	110	5	0.0272	1.06	0.0058
4/20/2016	111	6	0.0350	1.23	0.0072
4/26/2016	117	3	0.0163	0.61	0.0033
4/27/2016	118	4	0.0221	0.78	0.0043
5/3/2016	124	4	0.0218	0.78	0.0042
5/4/2016	125	3	0.0166	0.56	0.0031
	Totals	186		38.31	

Table 27. Dates of capture, number, total weight, and catch rates of male blueback herring taken in the 2.5” mesh gillnets on the Chickahominy River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/1/2016	61	1	0.0055	0.21	0.0012
3/2/2016	62	0	0.0000	0.00	0.0000
3/8/2016	68	1	0.0054	0.17	0.0009
3/9/2016	69	0	0.0000	0.00	0.0000
3/15/2016	75	9	0.0497	1.63	0.0090
3/16/2016	76	10	0.0553	2.03	0.0112
3/22/2016	82	2	0.0109	0.37	0.0020
3/23/2016	83	3	0.0163	0.49	0.0026
3/29/2016	89	2	0.0110	0.31	0.0017
3/30/2016	90	3	0.0168	0.55	0.0031
4/5/2016	96	5	0.0224	0.77	0.0034
4/6/2016	97	2	0.0135	0.34	0.0023
4/12/2016	103	3	0.0170	0.53	0.0030
4/13/2016	104	3	0.0168	0.57	0.0032
4/19/2016	110	1	0.0054	0.12	0.0006
4/20/2016	111	5	0.0292	0.79	0.0046
4/26/2016	117	1	0.0055	0.17	0.0010
4/27/2016	118	0	0.0000	0.00	0.0000
5/3/2016	124	1	0.0055	0.17	0.0009
5/4/2016	125	1	0.0055	0.16	0.0009
	Totals	53		9.39	

Table 28. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of pre-spawn female alewife and blueback herring taken during anchor gillnet survey in the Chickahominy River, spring 2016. The abbreviation NA is "not aged".

Species	Year class	Number	Mean TL (mm)	Mean weight (kg)	Total weight (kg)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
Alewife	2013	1	263.0	0.16	0.16	0.0001	0.0000
	2012	62	265.8	0.19	11.52	0.0068	0.0013
	2011	141	291.8	0.26	36.28	0.0155	0.0040
	2010	42	300.5	0.28	11.73	0.0046	0.0013
	2009	6	301.7	0.26	1.57	0.0007	0.0002
	2008	2	306.5	0.28	0.56	0.0002	0.0000
	NA	6	302.8	0.28	1.70	0.0007	0.0002
Blueback herring	2013	3	269.3	0.18	0.55	0.0010	0.0002
	2012	31	267.2	0.18	5.54	0.0101	0.0018
	2011	99	276.9	0.20	20.16	0.0321	0.0065
	2010	38	287.8	0.23	8.66	0.0123	0.0028
	2009	8	293.6	0.25	1.97	0.0026	0.0006
	2008	2	305.5	0.27	.54	0.0006	0.0002
	NA	7	273.7	0.19	1.35	0.0023	0.0004

Table 29. Summary of catches of river herring in the Chickahominy River drift gillnet survey, 2016.

Date	# Alewife		# Blueback		Water Temp (C)
	3" Mesh (# Females)	2.5" Mesh (# Females)	3" Mesh (# Females)	2.5" Mesh (# Females)	
2/29/2016	0	4 (1)	0	1 (1)	8.5
3/7/2016	0	0	0	0	8
3/14/2016	0	2 (0)	0	1 (0)	15
3/21/2016	1 (1)	3 (0)	0	2 (2)	14
3/28/2016	0	2 (1)	0	13 (8)	15.9
4/4/2016	1 (1)	8 (4)	2 (0)	28 (19)	16
4/11/2016	0	11 (7)	1 (0)	24 (19)	13.9
4/18/2016	0	0	0	10 (9)	16.5
4/25/2016	0	0	0	7 (5)	19.8
5/2/2016	0	0	0	2 (2)	19.4
Totals	2 (2)	30 (13)	3 (0)	88 (65)	

Table 30. Catch per unit effort (fish/meter of net/hour) of river herring in the Chickahominy River drift gillnet survey, 2016. Sexes have been combined.

Date	Effort (hrs)	Total Number		CPUE (fish/m/hr)	
		Alewife	Blueback	Alewife	Blueback
2/29/2016	1.0	4	1	0.0437	0.0109
3/7/2016	1.0	0	0	0.0000	0.0000
3/14/2016	1.0	2	1	0.0219	0.0109
3/21/2016	1.0	4	2	0.0437	0.0219
3/28/2016	1.0	2	13	0.0219	0.1422
4/4/2016	1.0	9	30	0.0984	0.3281
4/11/2016	1.0	11	25	0.1203	0.2734
4/18/2016	1.0	0	10	0.0000	0.1094
4/25/2016	1.0	0	7	0.0000	0.0766
5/2/2016	1.0	0	2	0.0000	0.0219
2016 Totals	**10.0**	**32**	**91**	**0.0350**	**0.0995**

Table 31. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of pre-spawn female alewife and blueback herring captured in drift gillnets in the Chickahominy River, spring 2016. The abbreviation NA is "not aged".

Species	Year class	Number	Mean TL (mm)	Mean weight (kg)	Total weight (kg)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
Alewife	2012	6	253.5	0.15	0.93	0.0066	0.0010
	2011	3	290.7	0.25	0.74	0.0033	0.0008
	NA	1	254.0	0.16	0.16	0.0011	0.0002
Blueback herring	2013	1	268.0	0.17	0.17	0.0011	0.0002
	2012	39	261.3	0.16	6.43	0.0427	0.0070
	2011	21	271.7	0.18	3.86	0.0230	0.0042
	NA	3	283.3	0.22	0.66	0.0033	0.0007

Table 32. Summary of catches of river herring in the Rappahannock River staked gillnet survey, 2016 (# Females includes both pre- and post-spawn females).

Date	# Alewife		# Blueback		Water Temp (C)
	3" Mesh (# Females)	2.88" Mesh (# Females)	3" Mesh (# Females)	2.88" Mesh (# Females)	
3/13/2016	5 (4)	11 (8)	0	0	12.5
3/20/2016	1 (1)	7 (7)	0	0	12
3/26/2016	2 (2)	8 (7)	3 (3)	2 (2)	13.2
4/2/2016	2 (2)	10 (9)	0	9 (8)	16.5
4/11/2016	2 (2)	2 (2)	0	0	10.9
4/17/2016	1 (1)	2 (2)	0	0	14.1
4/24/2016	0	0	0	1 (1)	17.6
5/1/2016	0	0	0	0	17.5
Totals	13 (12)	40 (35)	3 (3)	12 (11)	

Table 33. Dates of capture, number, total weight, and catch rates of pre-spawn female alewife taken in the 2.88" and 3" mesh staked gillnet monitoring on the Rappahannock River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/13/2016	73	12	0.1465	3.16	0.0385
3/20/2016	80	8	0.0894	1.97	0.0220
3/26/2016	86	8	0.0954	2.08	0.0248
4/2/2016	93	10	0.1750	2.55	0.0447
4/11/2016	102	3	0.0404	0.73	0.0099
4/17/2016	108	3	0.0335	0.77	0.0086
4/24/2016	115	0	0.0000	0.00	0.0000
5/1/2016	122	0	0.0000	0.00	0.0000
	Totals	44		11.26	

Table 34. Dates of capture, number, total weight, and catch rates of male alewife taken in the 2.88” and 3” mesh staked gillnets on the Rappahannock River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/13/2016	73	4	0.0488	0.86	0.0105
3/20/2016	80	0	0.0000	0.00	0.0000
3/26/2016	86	1	0.0122	0.24	0.0029
4/2/2016	93	1	0.0122	0.25	0.0030
4/11/2016	102	0	0.0000	0.00	0.0000
4/17/2016	108	0	0.0000	0.00	0.0000
4/24/2016	115	0	0.0000	0.00	0.0000
5/1/2016	122	0	0.0000	0.00	0.0000
	Totals	6		1.35	

Table 35. Dates of capture, number, total weight, and catch rates of pre-spawn female blueback herring taken in the 2.88" and 3" mesh staked gillnet monitoring on the Rappahannock River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/13/2016	73	0	0.0000	0.00	0.0000
3/20/2016	80	0	0.0000	0.00	0.0000
3/26/2016	86	5	0.0610	1.31	0.0160
4/2/2016	93	8	0.0977	2.04	0.0249
4/11/2016	102	0	0.0000	0.00	0.0000
4/17/2016	108	0	0.0000	0.00	0.0000
4/24/2016	115	1	0.0122	0.24	0.0030
5/1/2016	122	0	0.0000	0.00	0.0000
	Totals	14		3.59	

Table 36. Dates of capture, number, total weight, and catch rates of male blueback herring taken in the 2.88" and 3" mesh staked gillnet monitoring on the Rappahannock River, spring 2016.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/13/2016	73	0	0.0000	0.00	0.0000
3/20/2016	80	0	0.0000	0.00	0.0000
3/26/2016	86	0	0.0000	0.00	0.0000
4/2/2016	93	1	0.0122	0.13	0.0016
4/11/2016	102	0	0.0000	0.00	0.0000
4/17/2016	108	0	0.0000	0.00	0.0000
4/24/2016	115	0	0.0000	0.00	0.0000
5/1/2016	122	0	0.0000	0.00	0.0000
	Totals	1		0.13	

Table 37. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of pre-spawn female alewife and blueback herring taken at during staked gillnet survey in the Rappahannock River, spring 2016. The abbreviation NA is "not aged".

Species	Year class	Number	Mean TL (mm)	Mean weight (kg)	Total weight (kg)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
Alewife	2012	4	285.8	0.24	0.98	0.0061	0.0015
	2011	34	288.3	0.25	8.66	0.0519	0.0132
	2010	6	291.8	0.27	1.62	0.0092	0.0025
Blueback herring	2011	9	289.2	0.25	2.27	0.0137	0.0035
	2010	4	292.3	0.27	1.09	0.0061	0.0017
	2009	1	293.0	0.24	0.24	0.0015	0.0004

Table 38. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2016) 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	0.36	18	0		5	0.32	2.77	4
1985 - 89	0.01	0.22	34	0		8	0.16	0.49	16
1990 - 94	0.01	0.16	62	0		10	0.08	0.35	32
1995 - 99	0.01	0.11	65	0		10	0.17	0.46	33
2000	0		70	0		10	0.08	0.25	34
2001	0		70	0		10	0.34	0.43	35
2002	0		69	0		10	0		35
2003	0.10	0.30	70	0		10	0.59	0.66	28
2004	0.05	0.20	67	0		10	0.81	0.94	35
2005	0		66	0		10	0.27	0.66	33
2006	0.21	0.44	64	0.23	0.34	10	0.11	0.30	34
2007	0.04	0.26	65	0		10	0.40	0.50	34
2008	0.01	0.09	64	0		10	0.02	0.12	35
2009	0.02	0.12	65	0.07	0.22	10	0.13	0.36	34
2010	0.02	0.12	65	0		10	1.19	1.17	33
2011	0.15	0.39	59	0		10	1.15	1.05	27
2012	0.01	0.09	57	0		10	0.19	0.42	35
2013	0		65	0		10	0.35	0.61	35
2014	0.07	0.24	55	0.15	0.29	10	3.79	1.55	35
2015	0.25	0.57	59	0.56	0.94	10	4.19	1.52	28
2016	0.01	0.09	65	0		10	4.17	1.63	35

Table 39. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2016) 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	1.01	17	0.42	0.60	12	2.41	1.15	30
1985 - 89	1.94	0.79	32	0.20	1.03	23	0.91	0.70	59
1990 - 94	0.59	0.77	46	0.04	0.22	36	0.28	0.62	87
1995 - 99	3.96	0.98	49	0.53	0.68	39	1.66	0.92	92
2000	5.77	1.31	39	0.08	0.26	31	1.83	1.33	74
2001	0.58	0.70	49	0.15	0.36	40	0.35	0.58	94
2002	0.23	0.50	48	0.02	0.11	40	0.12	0.37	93
2003	8.57	1.32	50	13.11	1.06	39	9.04	1.30	94
2004	7.52	1.39	47	0.10	0.29	38	2.21	1.45	90
2005	1.66	1.35	50	0.05	0.20	40	0.70	1.09	95
2006	0.93	0.92	48	0.09	0.35	37	0.47	0.76	90
2007	0.30	0.51	47	0		36	0.15	0.39	88
2008	0.11	0.30	50	0		40	0.06	0.23	95
2009	0.02	0.16	47	0		40	0.01	0.12	92
2010	0.97	1.03	50	0.06	0.19	38	0.47	0.82	93
2011	1.16	1.39	48	0.27	0.55	35	0.67	1.11	88
2012	0.01	0.10	48	0.02	0.11	39	0.02	0.10	93
2013	0.12	0.36	50	0.05	0.20	40	0.10	0.32	95
2014	1.58	0.94	50	0.12	0.28	41	0.72	0.54	96
2015	2.96	1.22	49	0.89	0.88	40	1.69	1.13	94
2016	0.99	1.05	50	0.36	0.71	40	0.64	0.91	95

Table 40. Summary of catches of juvenile river herring in the Chickahominy River in 2016 during nighttime surface trawls. Cruise specific indexes are reported as geometric means of all stations. There were insufficient catches of alewife to present indexes of abundance.

Date	Species	N	Mean FL (mm)	Mean WT (g)	Mean (fish/tow)	Cruise specific index (SD)
6/7/2016	Alewife	20	42.5	1.03		
	Blueback	300	32.1	0.33	25.0	11.2 (4.3)
6/13/2016	Alewife	0				
	Blueback	170	30.9	0.32	14.2	12.1 (2.1)
6/20/2016	Alewife	4	53.3	2.56		
	Blueback	960	33.5	0.47	80.0	62.5 (2.0)
6/27/2016	Alewife	1	49.0	1.61		
	Blueback	2006	34.5	0.47	167.2	95.4 (3.7)
7/5/2016	Alewife	0				
	Blueback	1827	36.2	0.59	152.3	75.9 (4.2)
7/11/2016	Alewife	1	75.0	4.70		
	Blueback	1050	39.6	0.73	87.5	47.4 (3.8)
7/18/2016	Alewife	1	73.0	4.05		
	Blueback	1829	42.2	0.89	152.4	71.7 (4.1)
7/25/2016	Alewife	1	76.0	5.42		
	Blueback	2016	42.9	0.93	168.0	56.6 (5.2)
8/1/2016	Alewife	1	83.0	7.71		
	Blueback	4340	45.9	1.01	361.7	78.0 (12.7)
8/8/2016	Alewife	1	83.0	8.26		
	Blueback	3921	43.9	0.94	326.8	73.5 (7.1)
8/15/2016	Alewife	0				
	Blueback	1225	45.2	0.92	102.1	60.7 (4.4)
8/23/2016	Alewife	1	71.0	4.34		
	Blueback	4499	43.8	0.91	374.9	122.6 (9.2)
8/29/2016	Alewife	0				
	Blueback	2818	43.1	0.94	234.8	64.1 (10.4)
9/6/2016	Alewife	0				
	Blueback	1291	46.5	1.04	107.6	21.2 (10.5)
9/12/2016	Alewife	0				
	Blueback	661	46.2	1.01	55.1	7.7 (10.5)
9/20/2016	Alewife	0				
	Blueback	1008	48.7	1.14	84.0	26.2 (8.2)
9/26/2016	Alewife	0				
	Blueback	1030	49.5	1.19	85.8	11.2 (11.5)
Season Totals	**Alewife**	**31**				
	Blueback	**30951**			**151.7**	**39.8 (7.1)**

Table 41. Indexes of abundance of juvenile alewife collected in beach seine surveys (189-2016) on the James, York, and Rappahannock rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James	SD	N	York	SD	N	Rappahannock	SD	N
1989	0.00	0.00	10	0.05	0.33	54	1.01	1.07	36
1990	0.00	0.00	10	0.00	0.00	55	0.05	0.19	40
1991	0.00	0.00	10	0.00	0.00	54	0.02	0.12	35
1992	0.00	0.00	10	0.00	0.00	54	0.04	0.22	40
1993	0.07	0.22	10	0.00	0.00	54	0.21	0.57	36
1994	0.07	0.22	10	0.12	0.54	54	0.22	0.52	39
1995	0.00	0.00	10	0.00	0.00	55	0.09	0.35	37
1996	0.66	1.07	10	0.11	0.40	53	0.61	1.08	37
1997	0.00	0.00	10	0.01	0.09	55	0.28	0.80	40
1998	0.07	0.22	10	0.00	0.00	51	0.12	0.47	33
1999	0.00	0.00	10	0.00	0.00	49	0.12	0.32	40
2000	0.00	0.00	10	0.00	0.00	51	0.17	0.50	39
2001	0.00	0.00	10	0.24	0.65	54	0.41	0.90	40
2002	0.00	0.00	10	0.01	0.10	53	0.02	0.11	40
2003	0.00	0.00	10	0.04	0.24	54	0.25	0.61	39
2004	0.28	0.58	10	0.01	0.10	50	0.05	0.19	40
2005	0.44	1.16	10	0.02	0.15	55	0.03	0.18	37
2006	0.28	0.42	10	0.00	0.00	50	0.04	0.16	39
2007	0.55	1.39	10	0.00	0.00	48	0.30	0.77	39
2008	0.00	0.00	10	0.00	0.00	55	0.04	0.15	40
2009	0.30	0.63	10	0.00	0.00	52	0.12	0.40	39
2010	0.07	0.22	10	0.23	0.61	53	0.36	0.74	38
2011	0.00	0.00	10	0.05	0.21	49	0.98	1.32	39
2012	0.00	0.00	10	0.00	0.00	56	0.05	0.31	40
2013	0.12	0.35	10	0.00	0.00	55	0.16	0.41	40
2014	0.23	0.47	10	0.00	0.00	53	0.17	0.37	40
2015	3.29	1.66	10	0.07	0.23	55	0.25	0.53	40
2016	0.98	1.15	11	0.09	0.28	55	0.11	0.45	40

Table 42. Indexes of abundance of juvenile blueback herring collected in beach seine surveys (1989-2016) on the James, York, and Rappahannock rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James	SD	N	York	SD	N	Rappahannock	SD	N
1989	0.5	0.89	45	0.32	0.69	35	8.93	1.63	22
1990	0.46	1.11	45	0.00	0.00	35	1.89	1.14	25
1991	0.26	0.64	45	0.04	0.16	35	0.15	0.45	21
1992	0.08	0.53	45	0.00	0.00	34	0.06	0.19	25
1993	0.72	1.37	45	0.00	0.00	34	2.05	1.39	21
1994	0.44	1.01	43	0.14	0.39	34	1.48	1.58	24
1995	0.03	0.15	43	0.00	0.00	35	0.40	0.50	23
1996	0.56	1.18	44	0.39	1.05	34	6.14	1.77	22
1997	0.18	0.80	45	0.06	0.26	35	1.51	1.54	25
1998	0.23	0.57	44	0.00	0.00	33	1.97	1.78	19
1999	0.03	0.14	49	0.00	0.00	32	0.46	0.89	25
2000	0.45	1.27	50	0.43	1.09	32	1.47	1.64	24
2001	0.42	1.07	50	0.27	0.92	34	3.30	1.43	25
2002	0.14	0.54	49	0.00	0.00	34	0.34	0.72	25
2003	0.74	1.28	50	0.82	1.10	34	3.22	1.62	25
2004	0.4	0.94	47	0.07	0.31	32	1.80	1.32	25
2005	0.47	1.02	46	0.00	0.00	35	1.29	1.53	23
2006	0.02	0.11	44	0.00	0.00	31	0.93	1.37	24
2007	0.51	1.09	45	0.11	0.44	30	1.30	1.03	24
2008	0.02	0.11	44	0.05	0.22	35	0.46	0.73	25
2009	0.16	0.64	45	0.00	0.00	33	0.65	1.19	24
2010	0.13	0.72	45	0.12	0.67	35	1.35	1.26	25
2011	1.15	1.49	39	0.26	0.10	30	9.14	2.12	24
2012	0.26	0.70	38	0.00	0.00	33	0.31	0.95	25
2013	0.08	0.37	40	0.00	0.00	35	0.45	1.07	25
2014	1.99	1.85	40	0.23	0.59	36	5.02	1.66	25
2015	2.82	1.84	40	1.41	1.59	35	15.84	2.20	25
2016	0.72	1.28	40	0.26	0.61	35	2.60	1.55	25

Table 43. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2016.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/28/2016	35	1	36	37	73
3/6/2016	0	0	0	18	18
3/13/2016	0	0	0	94	94
3/19/2016	0	0	0	39	39
3/26/2016	0	0	0	63	63
4/2/2016	0	0	0	114	114
4/17/2016	0	0	0	198	198
4/24/2016	0	0	0	146	146
5/1/2016	0	0	0	119	119
Totals	35	1	36	828	864

Table 44. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2016.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/21/2016	52	2	54	16	70
2/27/2016	92	26	118	531	649
3/6/2016	7	1	8	17	25
3/13/2016	10	25	35	72	107
3/19/2016	7	6	13	123	136
3/26/2016	0	3	3	235	238
4/7/2016	6	7	13	141	154
4/11/2016	1	1	2	408	410
4/17/2016	0	0	0	128	128
4/25/2016	2	2	4	227	231
Totals	177	73	250	1898	2148

Table 45. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2016.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/21/2016	44	12	56	13	69
2/28/2016	62	17	79	338	417
3/6/2016	36	12	48	822	870
3/13/2016	7	21	28	474	502
3/20/2016	3	15	18	790	808
3/26/2016	6	10	16	580	596
4/2/2016	0	8	8	319	327
4/11/2016	6	6	12	214	226
4/17/2016	1	2	3	366	369
4/24/2016	0	5	5	289	294
5/1/2016	0	0	0	135	135
Totals	165	108	273	4340	4613

Figure 1. Number and location of staked gill nets on the James River in 1983.

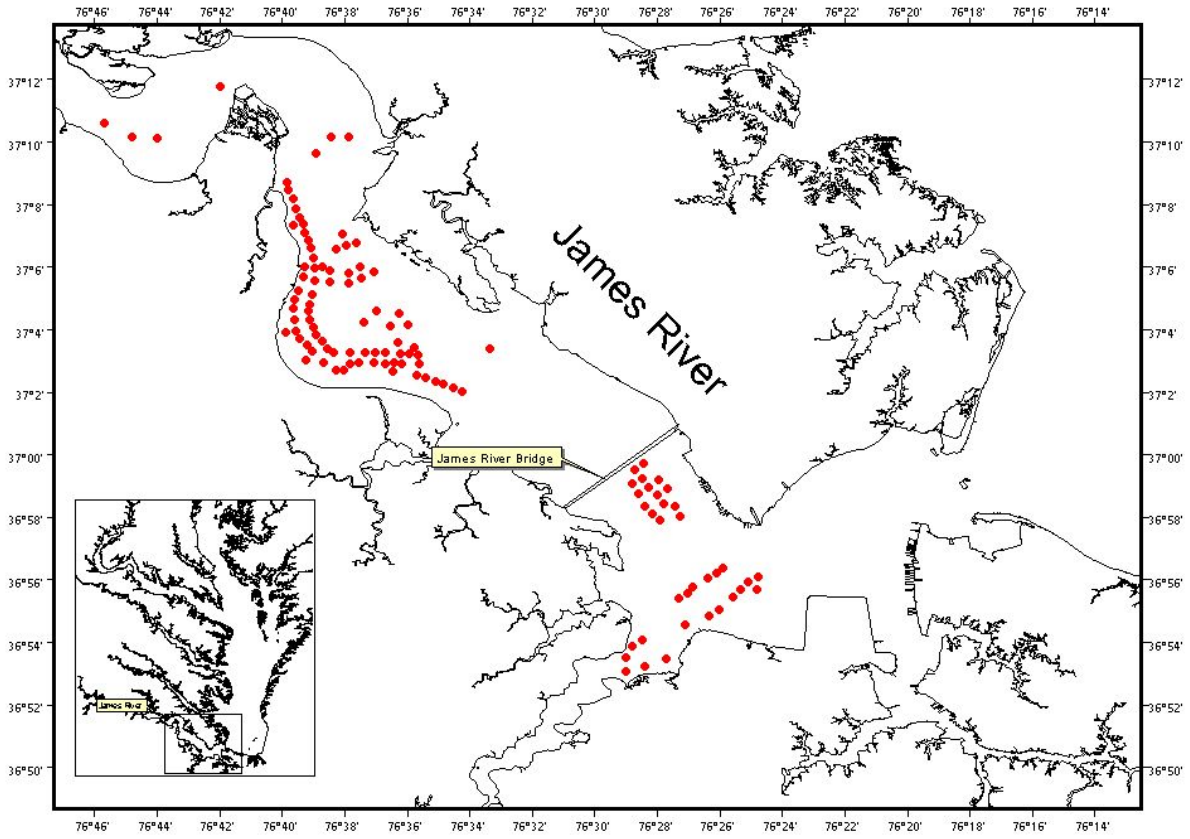


Figure 2. Number and location of staked gill nets on the York River in 1983.

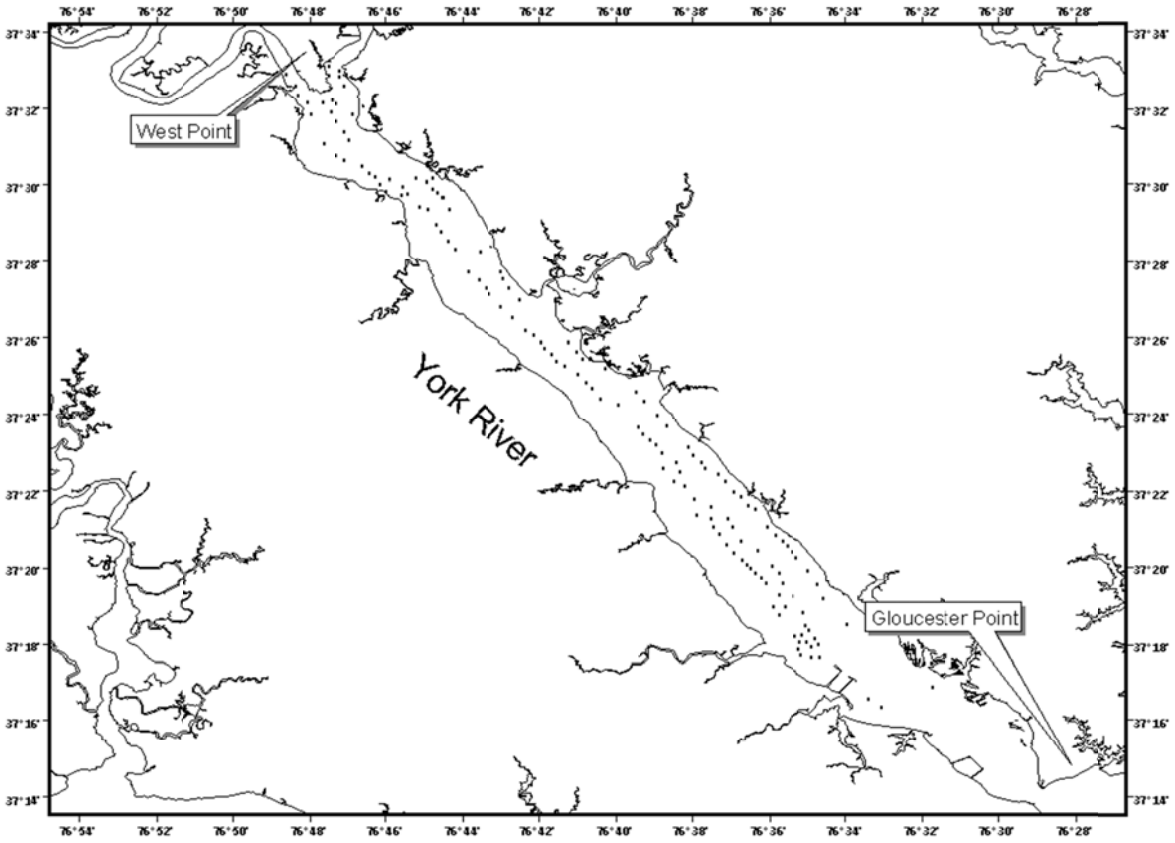


Figure 3. Number and location of staked gill nets on the Rappahannock River in 1983.

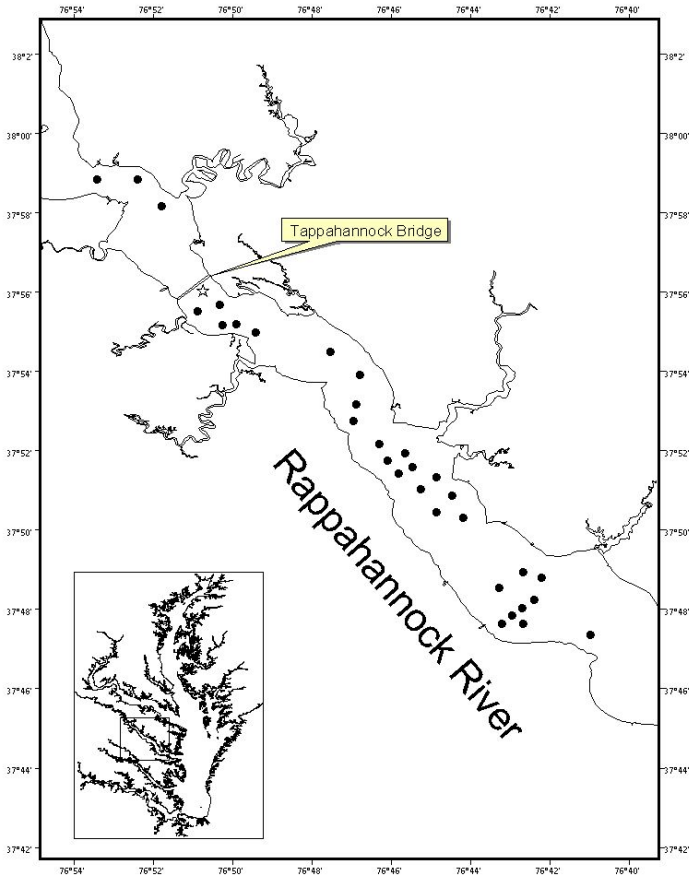


Figure 4. Location of the staked gill net fished by Mr. Marc Brown on the James River.

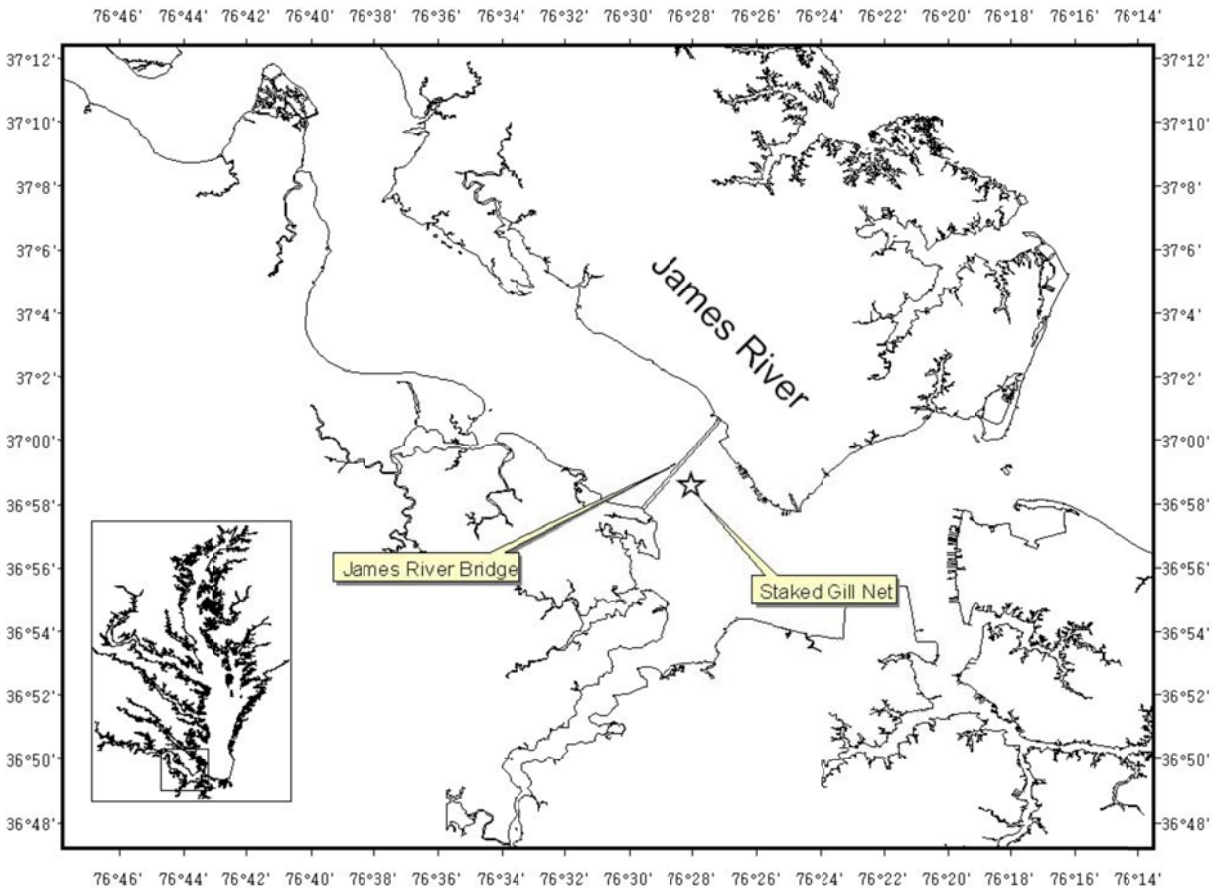


Figure 5. Location of the staked gill net fished by Mr. Raymond Kellum on the York River.

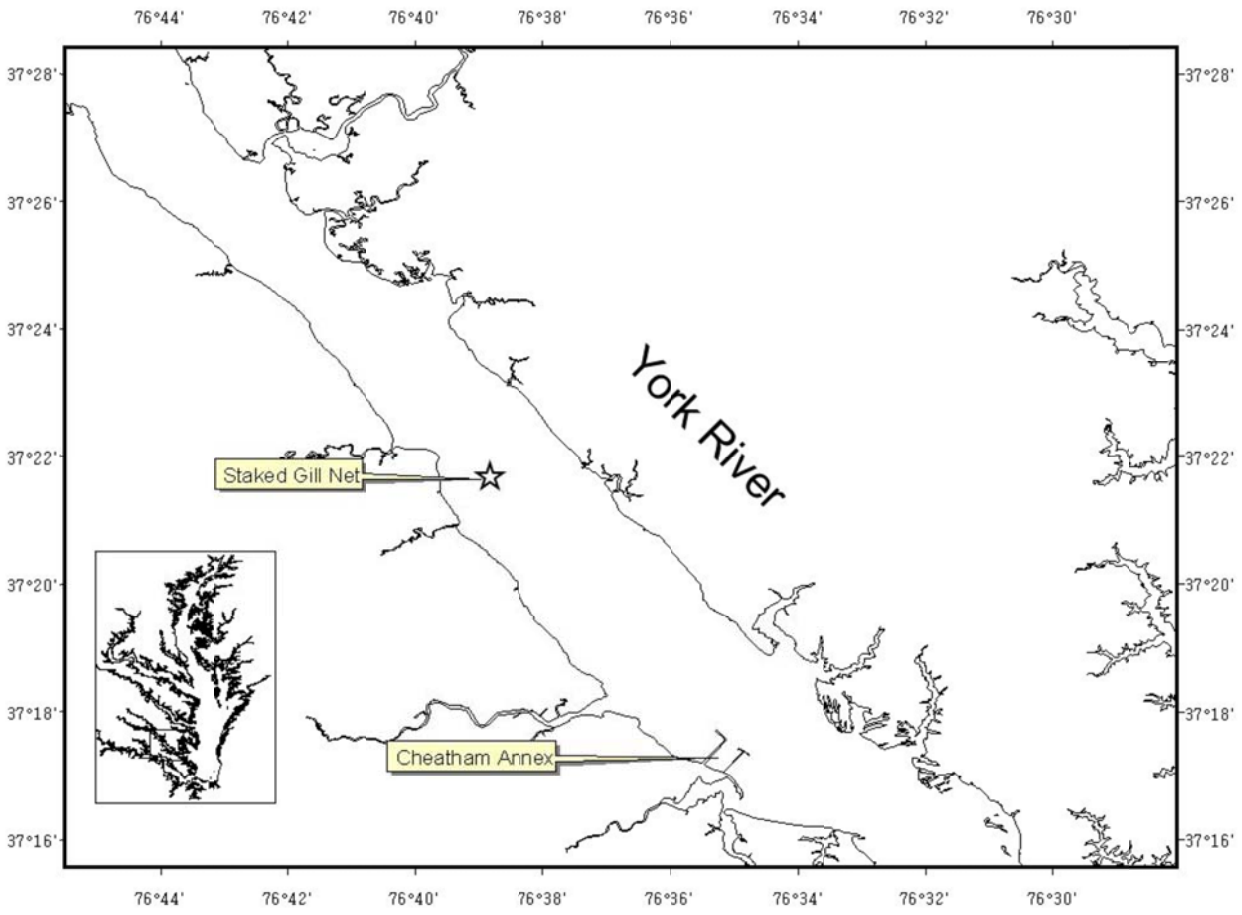


Figure 6. Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River.

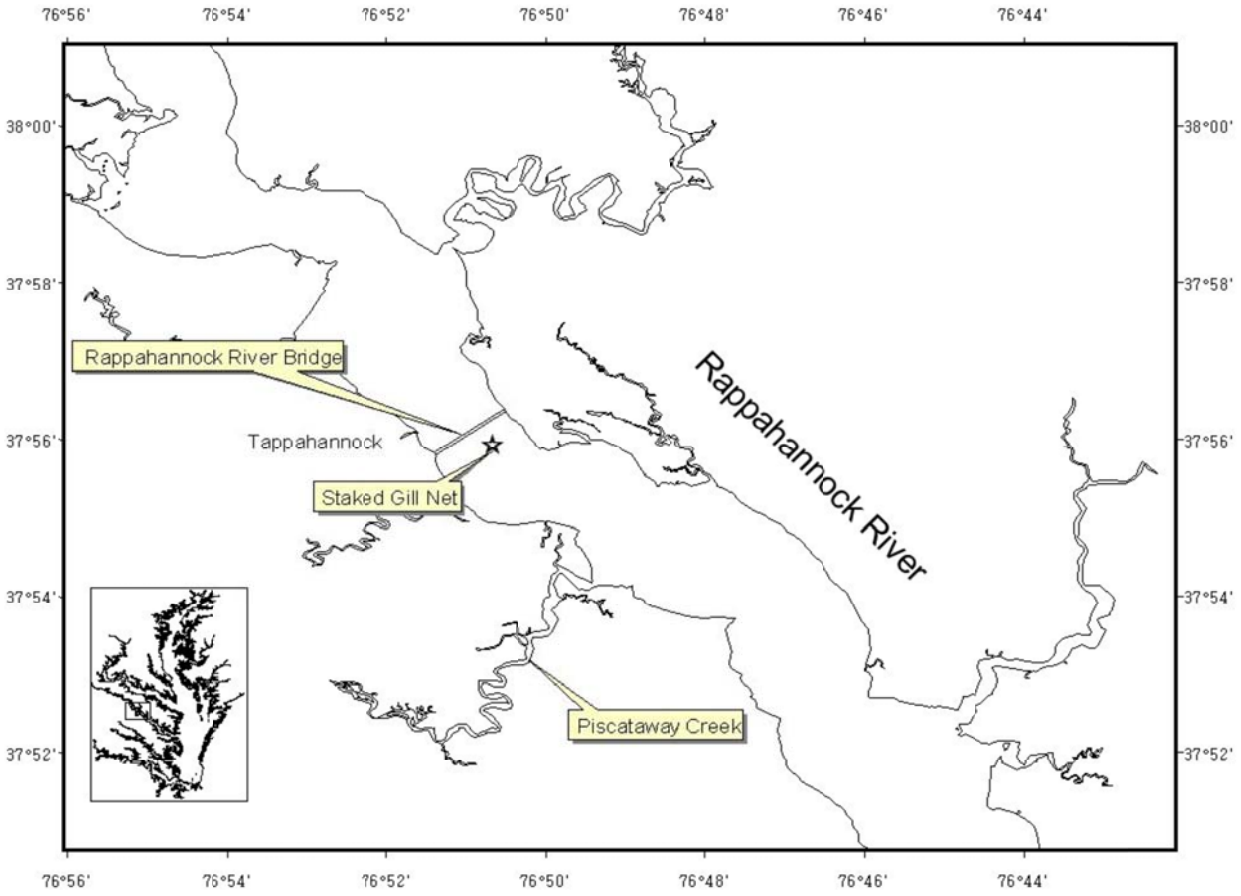


Figure 7. Recent (1998-2015) and historic values of the catch index of female American shad on the James River.

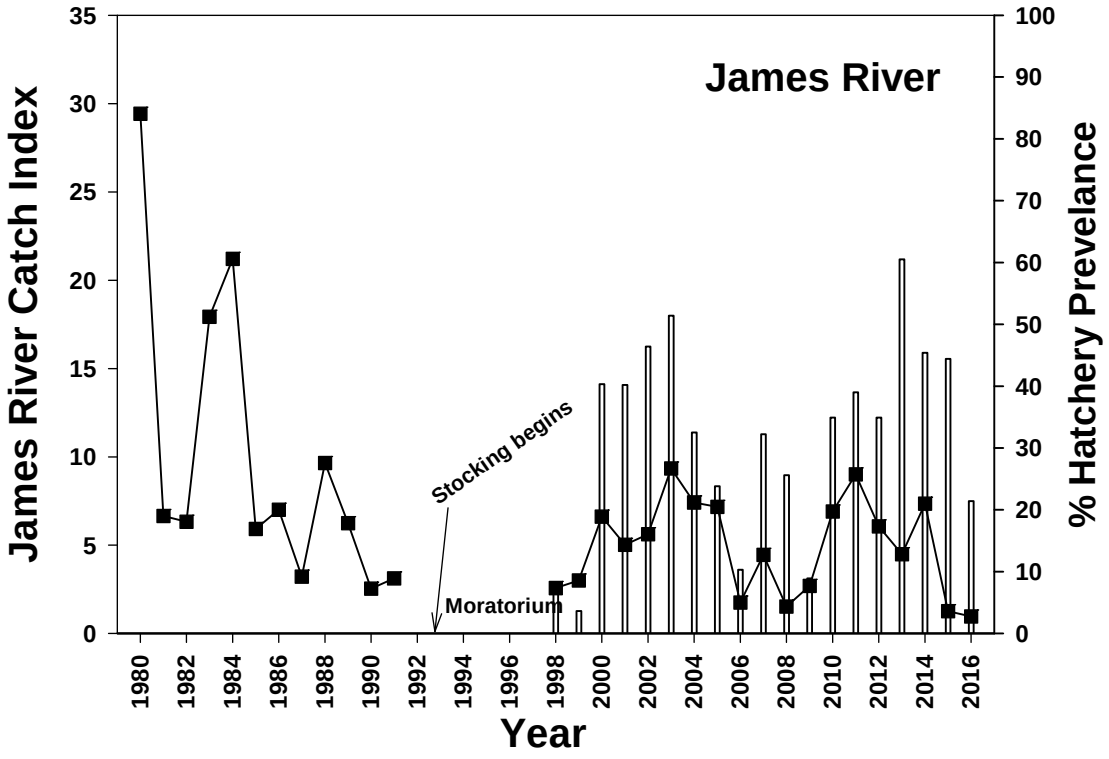


Figure 8. Recent (1998-2016) and historic values of the catch index of female American shad on the York River.

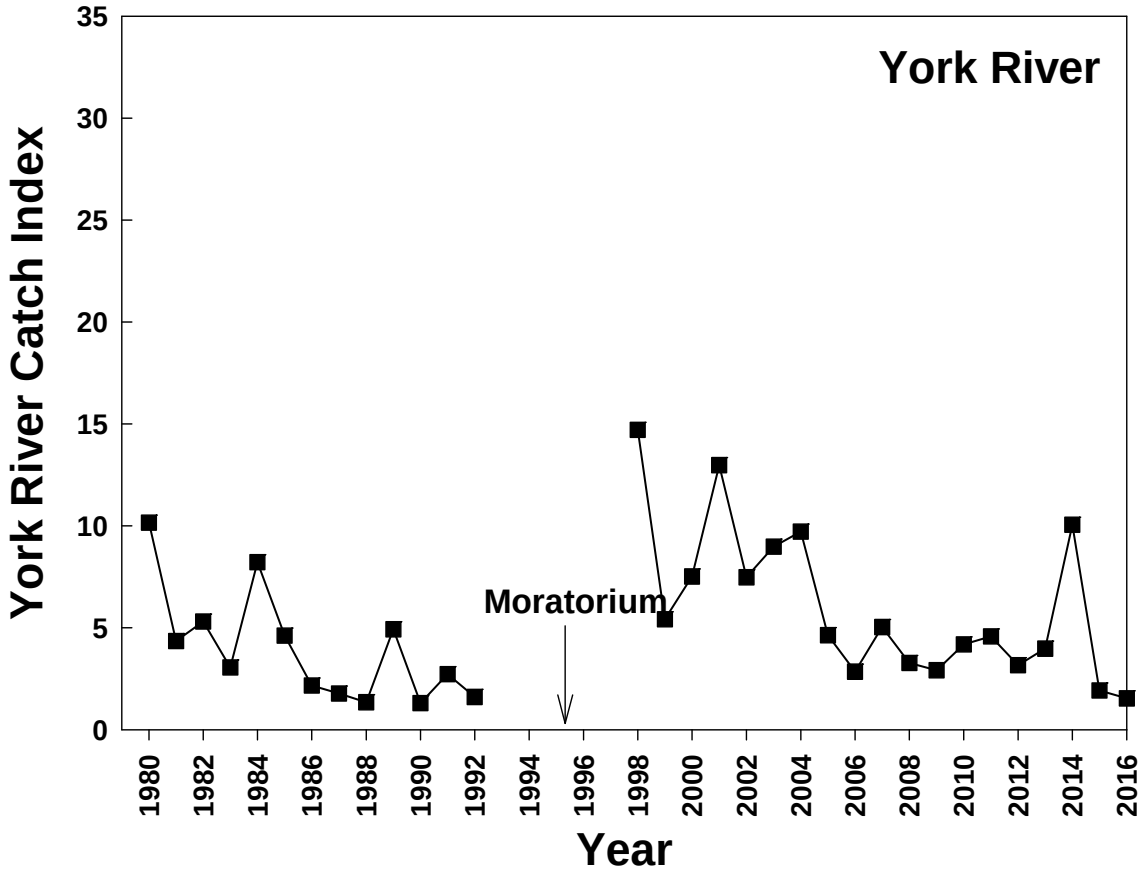


Figure 9. Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the geometric means of each data set (solid, 1950s; short dashes, current; long dashes, 1980s)

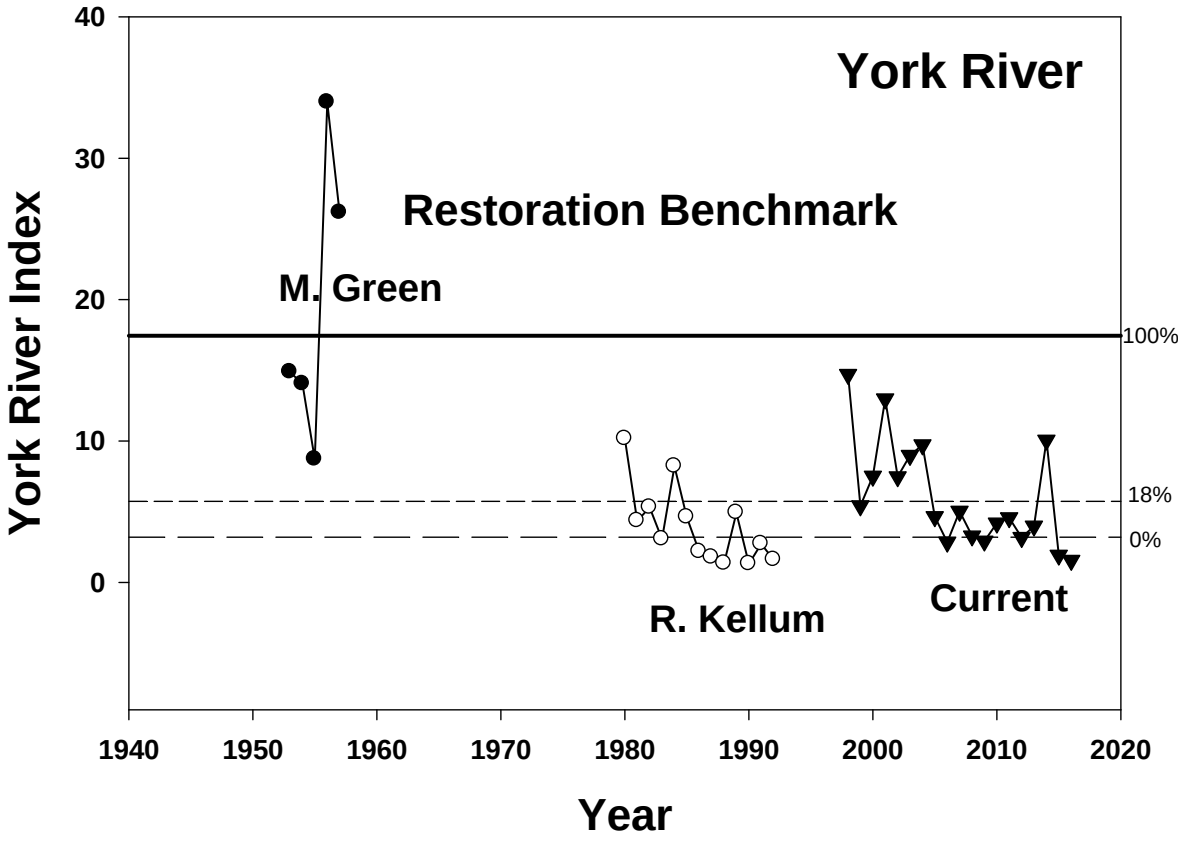


Figure 10. Recent (1998-2016) and historic values of the catch index of female American shad on the Rappahannock River.

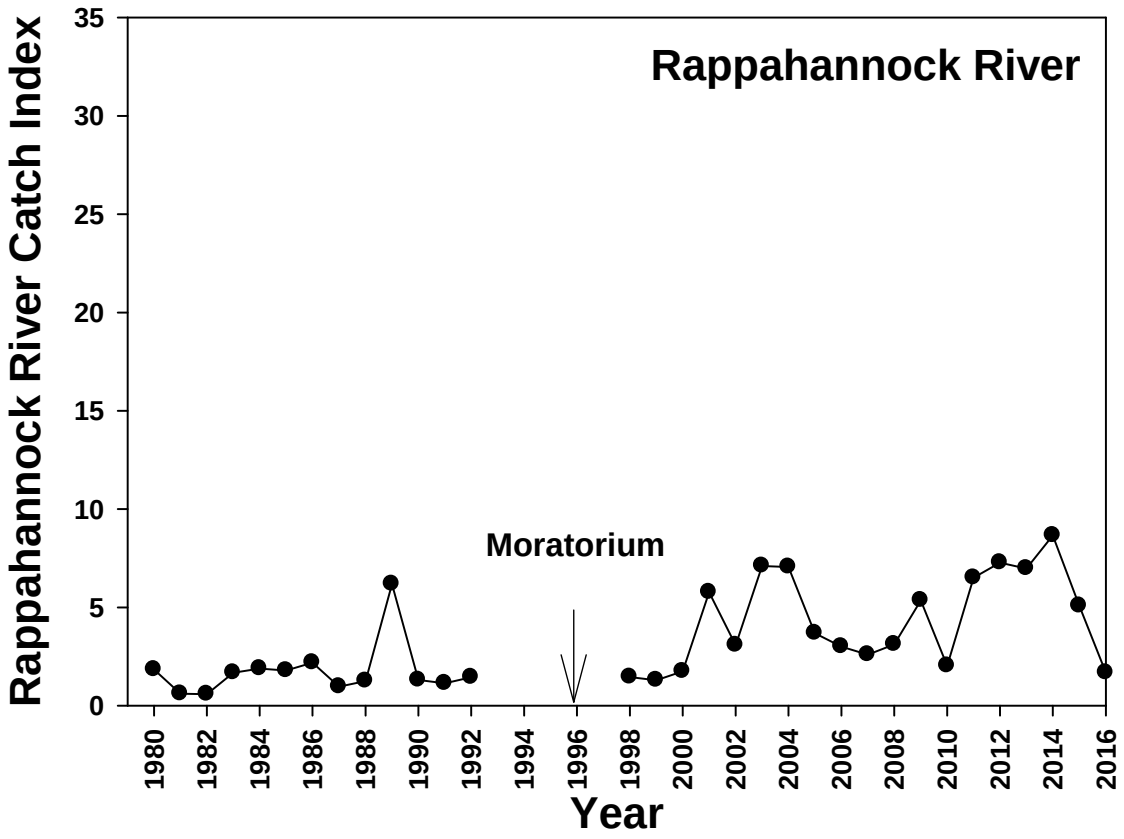


Figure 11. Comparison of the James River catch index to the percent of specimens with OTC hatchery marks.

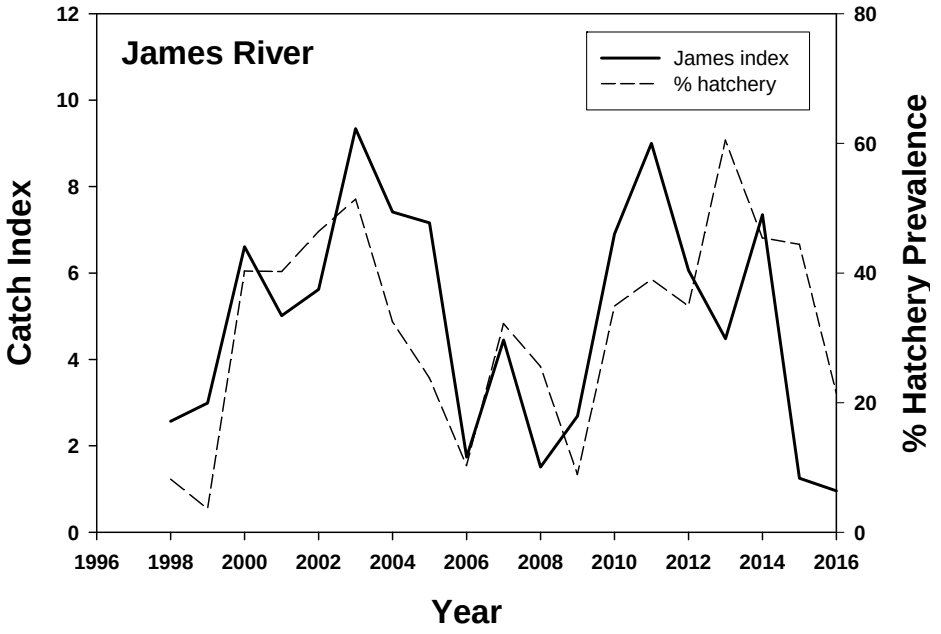


Figure 12. Anchor gill net catches of pre-spawned female river herring on the Chickahominy River in 2016.

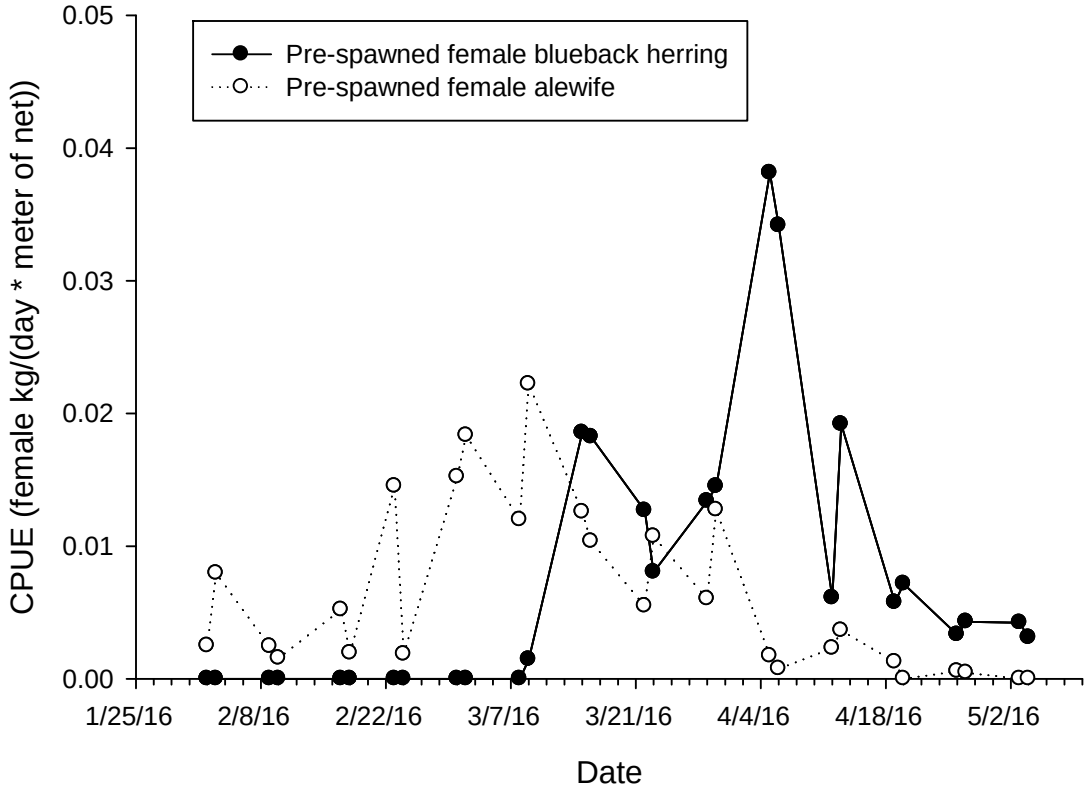


Figure 13. Drift gill net catches of pre-spawned female river herring on the Chickahominy River in 2016.

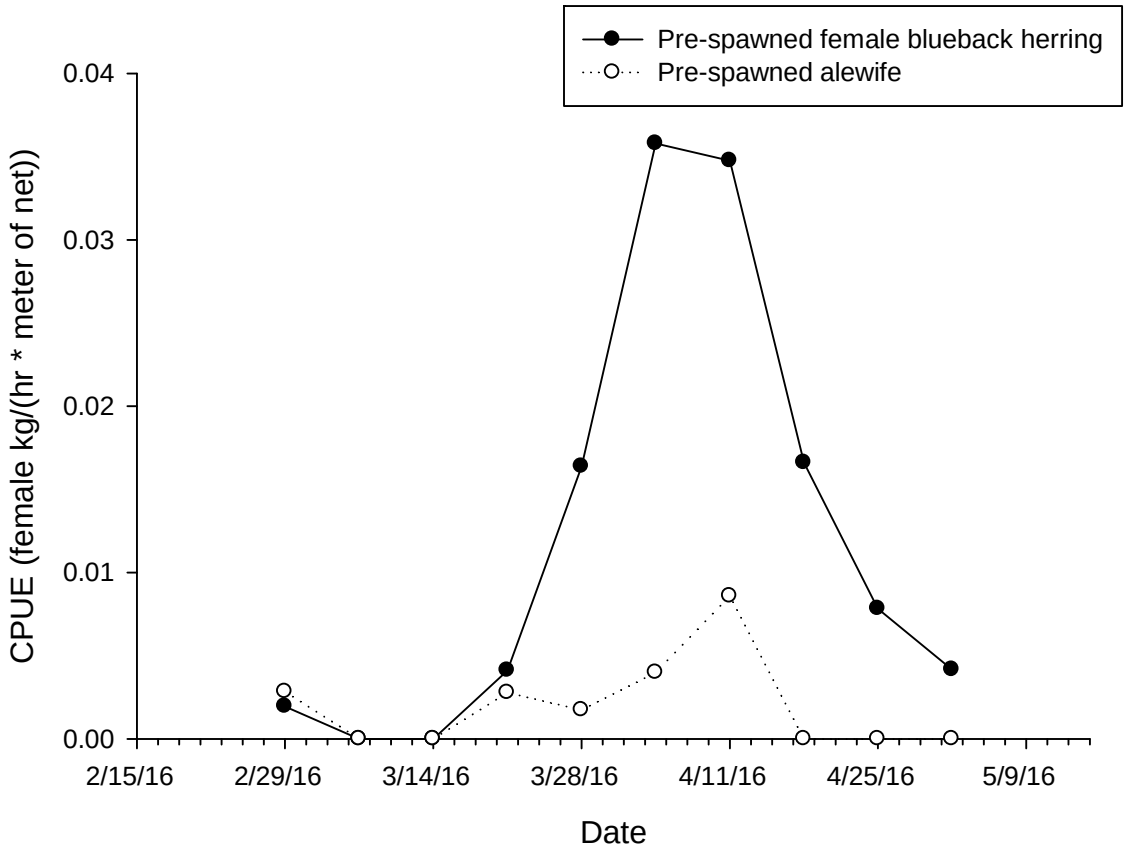
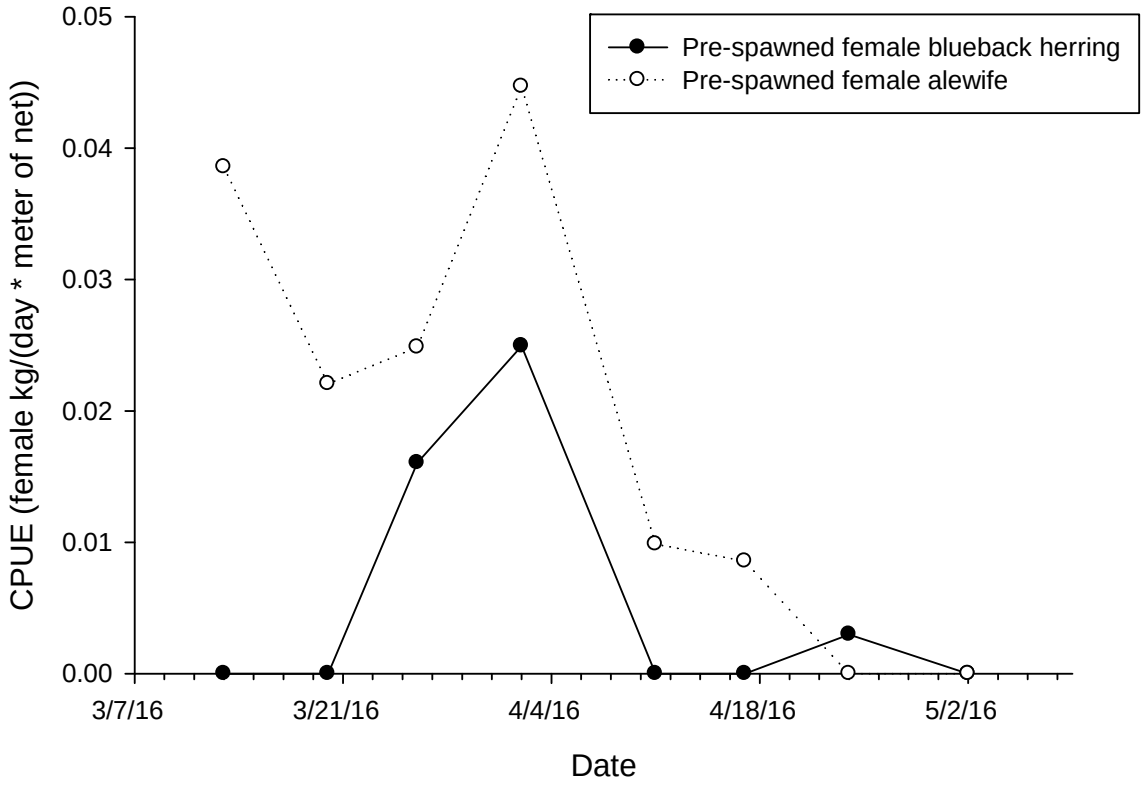


Figure 14. Staked gill net catches of pre-spawned female river herring on the Rappahannock River in 2016.



Appendix 1

Assessment of the 2016 Virginia bycatch of American shad
and the status of the Virginia stocks

Report to the Atlantic States Marine Fisheries Commission (ASMFC)

October 1, 2016

Dr. E.J. Hilton, Dr. R.J. Latour, Dr. P.E. McGrath, B.E. Watkins and A. Magee
Department of Fisheries Science
Virginia Institute of Marine Science
Gloucester Point, VA 23062

Background

In spring 2016, scientists at the Virginia Institute of Marine Science (VIMS) interviewed and obtained samples of bycatch of American shad from permitted fishers who had agreed to participate in the ASMFC required monitoring program. Total effort (number of trips) in the 2016 American shad bycatch fishery increased compared to effort recorded in 2015 on the James, York and Rappahannock Rivers (Table 1). A subsample of the bycatch of American shad (n=36), comprising fish from all three rivers, was obtained from four cooperating fishers; these samples were 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 2016 bycatch prepared by the Virginia Marine Resources Commission (VMRC) and submitted separately.

Biological Characterization of the 2016 Permitted Gill Net Bycatch in Virginia

James River

21 American shad (1 male and 20 females) were collected from two cooperating fishers on the James River. The subsample ranged in size and age from 364-490 mm FL and 5-8 years, respectively. Virgin and repeat spawners were both present in the sample (47.1% and 52.9%, respectively). Otoliths of 18 fish from the James River subsample were scanned for hatchery marks. The proportion with positive OTC marks was 33.3% (6 fish). Biological descriptions of the James River subsample are presented in Table 2.

York River

8 American shad (0 males and 8 females) were collected from one cooperating fisher on the York River. The subsample ranged in size and age from 422-468mm FL and 5-8 years, respectively. Virgin and repeat spawners were present in the sample (20.0% and 80.0%, respectively). Otoliths of 7 fish from the York River subsample were scanned for hatchery marks. No specimens with a hatchery mark

were detected. Biological descriptions of the York River subsample are presented in Table 2.

Rappahannock River

7 American shad (1 male and 6 females) were collected from one cooperating fisher on the Rappahannock River. The subsample ranged in size and age from 362-463 mm FL and 5-6 years, respectively. Virgin and repeat spawners were both present in the sample (80.0% and 20.0%, respectively). Otoliths of 7 fish from the Rappahannock River were scanned for hatchery marks. No specimens with a hatchery mark were detected. Biological descriptions of the Rappahannock River subsample are presented in Table 2.

Bycatch and Discards by Pound Nets in Virginia

In addition to the permitted bycatch 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 western portion of Chesapeake Bay (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 bycatch by the VMRC. Daily log books were also obtained from three of these cooperating fishers.

Samples of 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 422 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 3-6. Year-class composition from each pound net location is reported in Table 7.

Numbers of females sampled was higher than the number of males (219females; 203 males). Sex ratios (females: males) were: Great Wicomico, 1:0.81; Rappahannock River, 1:1.13. Maturity stages were determined macroscopically for females in the laboratory (Tables 3-6).

A total of 6,172 discarded American shad were recorded in commercial log books of three pound net fishers in the spring of 2016 (Figures 3-5).

Results of the 2016 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 6.

On the Rappahannock River, the 2016 index was 1.68, which is a decrease from the 2015 index (5.08).

In 2016 the catch index on the James River was 0.96. This is decrease from 2015 (1.25) and the lowest index during the 19 years of monitoring.

The 2016 York River index is 1.54. This is a decrease from 2015 (1.93) and also the lowest index value recorded for the York River. The index value is consistent with the last ten years of monitoring, which depicts a low, but stable population.

Table 1. Number of fishermen with American shad bycatch permits, active permits, and fishing activity reported by river system, 2006-2016. Permits are considered active if one or more pounds of American shad were reported. *One fisherman in the Rappahannock River did not record the total number of shad caught, so 40 was used.

Water Body	Year	# Permit Holders	# Active Permits	Total Trips	# Shad Caught	# Shad Kept	% of Bycatch for Year
James River	2016	14	4	107	24	22	26
	2015	14	8	58	31	21	8
	2014	14	9	54	114	112	15
	2013	10	4	55	150	139	32
	2012	10	2	7	10	7	3
	2011	9	3	25	42	42	32
	2010	9	0	7	0	0	0
	2009	8	1	6	2	0	0
	2008	6	2	3	3	3	2
	2007	16	7	58	119	52	19
	2006	32	5	27	24	23	9
York River	2016	11	2	64	40	40	44
	2015	10	9	36	302	279	76
	2014	8	5	85	453	453	61
	2013	12	6	116	212	203	47
	2012	13	5	71	207	207	94
	2011	11	4	51	88	87	67
	2010	9	5	43	229	208	84
	2009	11	6	97	302	288	100
	2008	10	6	85	89	89	60
	2007	15	8	104	199	199	73
	2006	31	5	198	233	228	90
Rappahannock River	2016	5	4	129	27	27	30
	2015	6	5	25	63	63	16
	2014	8	4	49	182	173	23
	2013	7	6	24	273	89	21
	2012	2	1	2	7	7	3
	2011	3	1	1	1	1	1
	2010	7	2	10	40*	40*	16
	2009	1	0	0	0	0	0
	2008	3	1	8	81	57	38
	2007	5	2	23	22	20	7
	2006	14	2	8	3	3	2

Table 2. Biological descriptions by river and sex for American shad permitted bycatch samples processed at VIMS. Abbreviations: M, Male; F, Female; #, Number; Avg., Average; Yrs, Years; NA, Not applicable; Rap, Rappahannock.

River	Sex	#	Avg. FL (mm)	Avg. Wt (g)	# Aged	Age Range (yrs)	% Repeat Spawner	% Post Spawner	# Hatchery Scanned	# Hatchery Origin
James	M	1	364.0	600.6	0	NA	NA	NA	1	0
	F	20	444.5	1377.1	17	5-8	52.9	0	17	6
	Combined	21	440.6	1340.2	17	5-8	52.9	0	18	6
York	M	0	NA	NA	NA	NA	NA	NA	NA	NA
	F	8	445.4	1346.4	5	5-8	80.0	0	7	0
	Combined	8	445.4	1346.4	5	5-8	80.0	0	7	0
Rap	M	1	362.0	675.2	1	5	0.0	NA	1	0
	F	6	441.5	1299.9	4	5-6	25.0	0	6	0
	Combined	7	430.1	1210.6	5	5-6	25.0	0	7	0

Table 3. Biological data of American shad (n=169) collected from a pound net fisher (1) 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)
3/9/2016	Maturing	3	3.3	1100.9			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				18	14.8	823.2
3/23/2016	Maturing	5	5.1	1022.4			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				10	7.6	757.3
4/6/2016	Maturing	17	22.4	1316.4			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				11	9.1	827.7
4/19/2016	Maturing	10	10.8	1082.5			
	Hydrated	1	1.2	1207.6			
	P. Spent	1	1.1	1121.0			
	Spent						
	Unstaged				12	8.9	745.1
5/5/2016	Maturing	13	13.3	1025.7			
	Hydrated						
	P. Spent						
	Spent	1	0.9	941.1			
	Unstaged				12	9.0	747.3
5/18/2016	Maturing	10	11.6	1159.1			
	Hydrated	2	1.9	963.1			
	P. Spent						
	Spent						
	Unstaged				13	8.9	686.7
6/1/2016	Maturing	7	8.0	1149.5			
	Hydrated	5	5.1	1027.7			
	P. Spent	2	1.6	798.9			
	Spent						
	Unstaged				18	11.4	633.9
Total		75	86.5	1123.7	94	69.7	741.9

Table 4. Biological data of American shad (n=117) collected from a pound net fisher (2) 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)
3/23/2016	Maturing	2	2.7	1339.0			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				3	2.2	724.3
4/6/2016	Maturing	21	25.1	1196.4			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				9	7.8	866.0
4/19/2016	Maturing	7	8.1	1155.3			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				25	16.9	675.6
5/5/2016	Maturing	11	11.5	1046.1			
	Hydrated						
	P. Spent						
	Spent	2	1.4	720.1			
	Unstaged				13	8.9	685.3
5/17/2016	Maturing	8	8.6	612.2			
	Hydrated	1	0.9	924.0			
	P. Spent						
	Spent						
	Unstaged				14	8.6	1078.5
6/1/2016	Maturing						
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				1	0.7	681.8
Total		52	58.3	1121.1	65	45.0	692.6

Table 5. Biological data of American shad (n=134) 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)
3/7/2016	Maturing	7	8.1	1158.7			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				9	7.3	811.0
3/23/2016	Maturing	5	5.8	1157.3			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				13	9.8	755.7
4/6/2016	Maturing	4	4.3	1078.6			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged						
4/22/2016	Maturing	12	13.9	1154.7			
	Hydrated						
	P. Spent	1	1.0	1026.0			
	Spent	1	0.8	795.4			
	Unstaged				3	2.3	767.1
5/5/2016	Maturing	18	20.5	1140.4			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				23	15.0	653.2
5/25/2016	Maturing	20	21.8	1087.8			
	Hydrated	3	3.7	1229.7			
	P. Spent						
	Spent						
	Unstaged				15	10.2	681.9
Total		71	79.9	1125.4	63	44.6	707.9

Table 6. Year class composition of fish taken in pound nets in 2016, indicated as percent of aged catch from two pound net locations in Chesapeake Bay.

	Year Class	Great Wicomico	Rappahannock
Males	2013	0.9	0.0
	2012	28.3	14.8
	2011	25.0	8.2
	2010	7.8	4.7
	2009	4.0	2.9
	2008	2.5	0.0
	2007	0.9	0.0
Females	2012	4.5	5.0
	2011	57.3	34.1
	2010	26.1	21.5
	2009	13.1	6.3
	2008	42.8	2.6
	2007	0.0	0.0
	2006	1.1	0.0

Figure 1. Location of pound net operations with special American Shad bycatch permits.

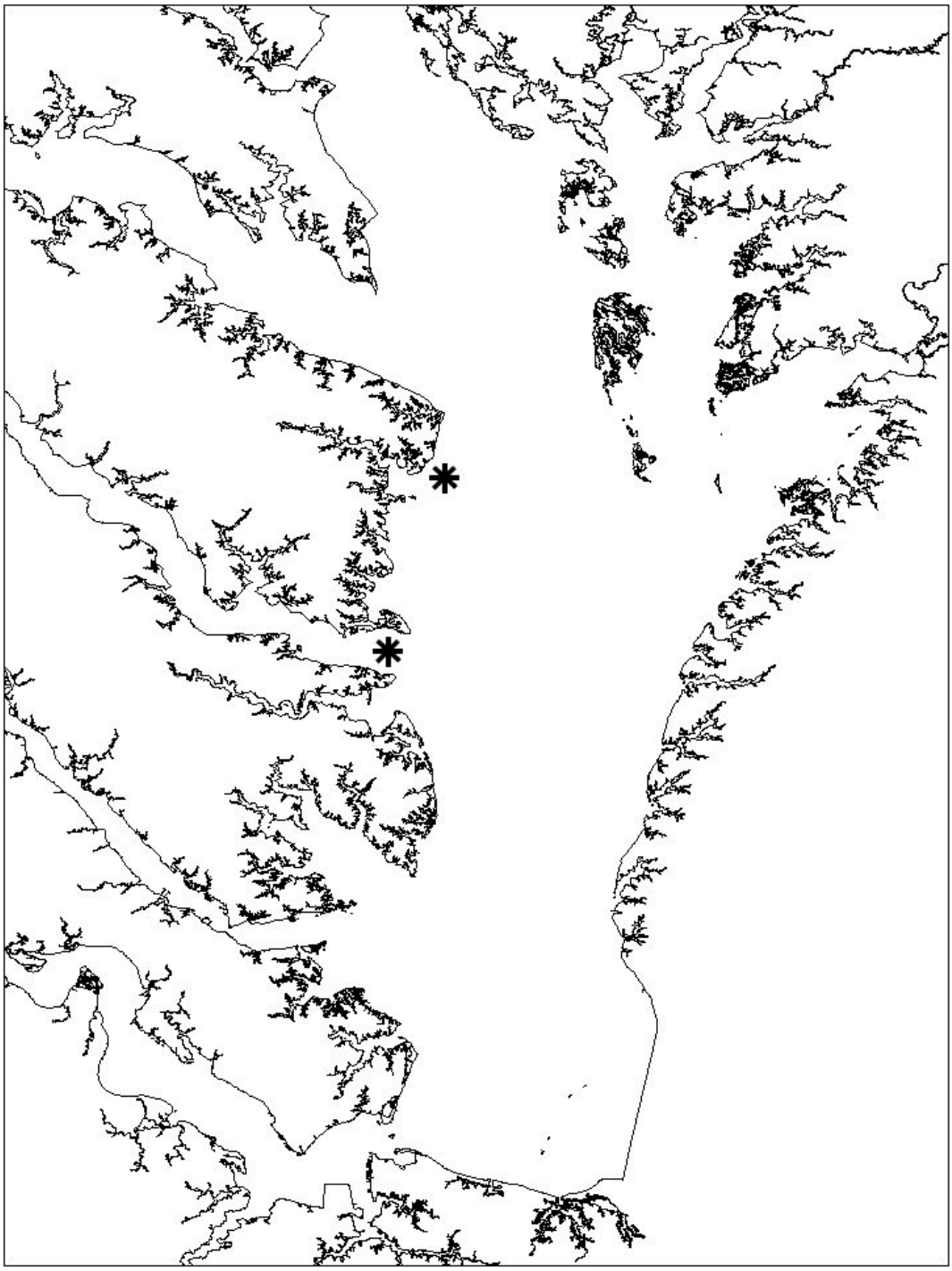


Figure 2. Total number (all samples combined) of American Shad processed by VIMS caught with special pound net bycatch permits in 2016. N is the number of samples obtained.

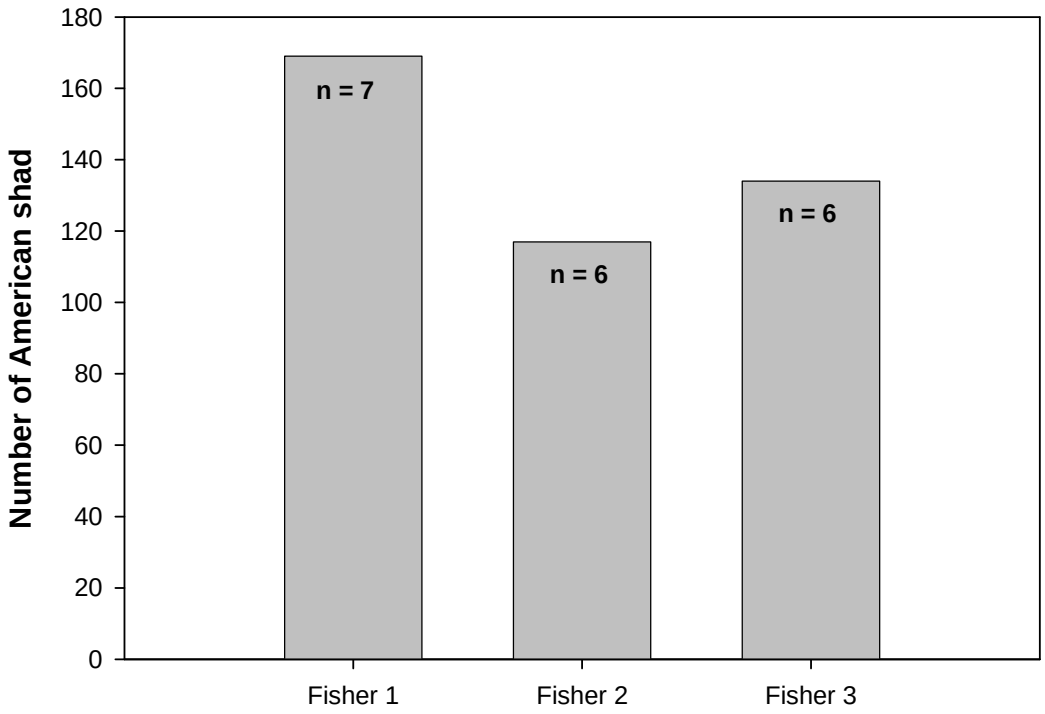


Figure 3. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Great Wicomico River. Data are taken from 2016 pound net fisher 1 log books.

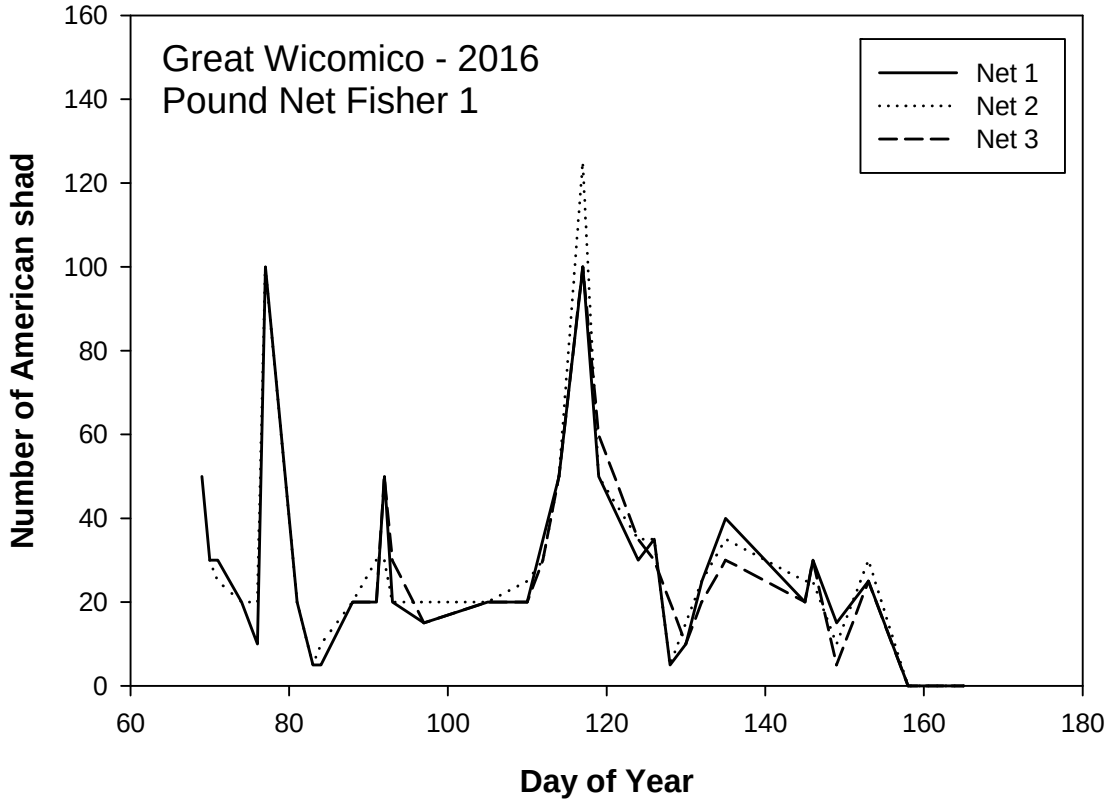


Figure 4. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Great Wicomico River. Data are taken from 2016 pound net fisher 2 log books.

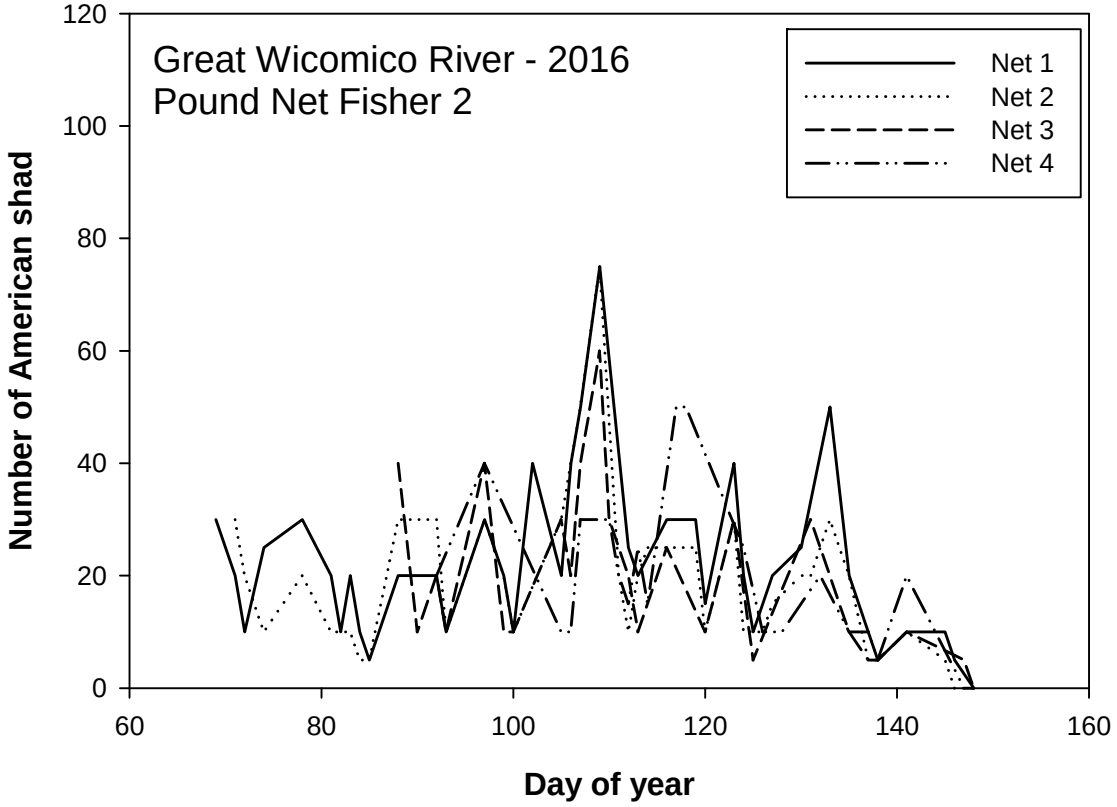


Figure 5. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the mouth of the Rappahannock River. Data are taken from 2016 commercial fisher log books.

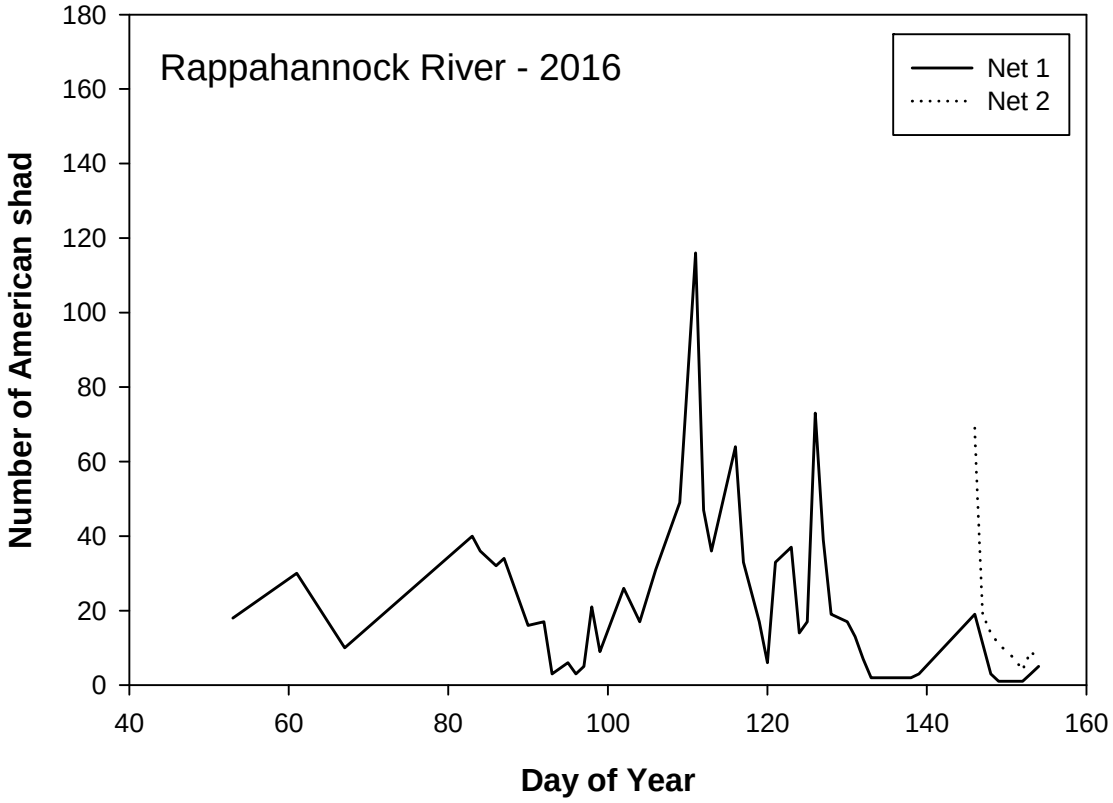


Figure 6. Time series of catch index from staked gill net monitoring in Virginia, 1998-2016.