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Monitoring the Abundance of American Shad and River Herring in Virginia's Rivers 2021 Annual Report

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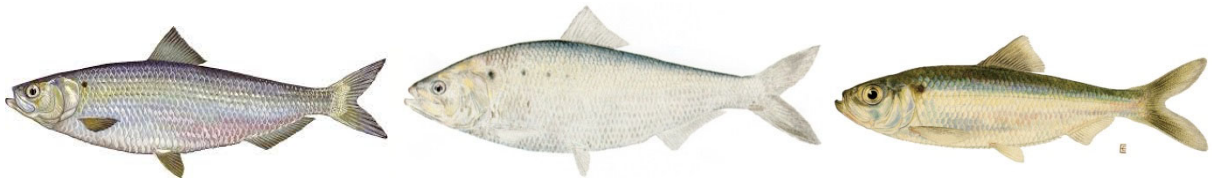
2021 Annual Report



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Summary

- This report describes the results of the twenty-fourth 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 2021, evaluating hatchery programs, and contributing to coast-wide assessments (ASMFC 2007, ASMFC 2020). We also report on two fishery-independent monitoring programs using anchor gillnets in the Rappahannock River (year 4) and the Chickahominy River (year 7; a major tributary of the James River), to determine relative abundance and stock structure for the adult spawning run of river herring (*A. pseudoharengus*, and *A. aestivalis*). Further, we report on the year 6 of a monitoring program for juvenile alosines by using nighttime surface trawls in the Chickahominy River and present an index of juvenile abundance from this survey. 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 eight weeks on the James River (4 March to 20 April 2021), ten weeks on the Rappahannock River (4 March to 3 May 2021), and eight weeks on the York River (5 March to 21 April 2020). No post-spawning fish were observed on the James, York, or Rappahannock rivers in 2021. Only pre-spawning females were included in the calculation of catch indices for each river. A total of 146 pre-spawning female American shad (200.4 kg total weight) were captured; this is a decrease in number from the 2020 catch (337 pre-spawning females; 466.8 kg total weight).
- Total numbers and weights of pre-spawning female American shad in 2021 were highest on the Rappahannock River (n=112, 155.1 kg). Numbers of females were lower on the York River (n=32, 43.0 kg). The lowest catches of females were recorded on the James River (n=2, 2.3 kg). Numbers of males captured were: Rappahannock, 3; James, 0; York, 3. Total weight of males captured on all rivers was 6.6 kg. The total catch and weight of males were lower than in 2020 (n=74, 86.8 kg).
- Based on age estimates from scales, the 2015 (age 6) year class of female American shad were the most abundant in the York River and the 2016 (age 5) year class were most abundant in the Rappahannock River. Age could not be determined for the two American Shad from the James River. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 0.99 (r^2=0.99); and Rappahannock River, 0.62 (r^2=0.89). Total instantaneous mortality rates of males were not calculated because all year classes present were not equally catchable by the sampling gear.
- Otoliths of 1 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 100.0% (1 of 1 fish). Otoliths of 27 American shad captured on the Rappahannock River were scanned for hatchery marks. The presence of hatchery fish on the Rappahannock River was 0.0% (0 of 27 fish). On the York River, there is currently no stocking of hatchery fish, and no specimens were examined from the York River in 2021.

- 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 2021 was: James River (including Chickahominy River), 0 (NA, 65); Chickahominy River, 0 (NA, 10); Rappahannock River, 3.36 (1.25, 35); York River (including Mattaponi and Pamunkey Rivers), 0.56 (0.74, 94); Mattaponi River, 1.26 (0.85, 50); and Pamunkey River, 0 (NA, 39).
- Eleven species of fishes (total of 7,208 specimens) were counted as bycatch in the staked gill net monitoring gear. The total number of striped bass counted was 870 (James River, n=77; York River, n=225; Rappahannock River, n=568). 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, 49.4%; York River, 58.7%; and the Rappahannock River, 60.2%.
- One Atlantic sturgeon was captured as bycatch in the American shad sampling (James River, n=1; 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 1998-2021 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 2021 (0.96) increased from the 2020 value (0.75). This is the second lowest value of the 24-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 (3.77) 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 2021 index (0.06) decreased from the 2020 value of 0.25. This is the lowest value of the 24-year time series. 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 2.59. In 2021 the hatchery prevalence was 100% (n=1). A correlation analysis among the catch index and hatchery prevalence from 1998-2021 was statistically not significant (r = 0..63, df = 22, p = 0.53).
    - The catch index on the Rappahannock River in 2021 (3.56) decreased from the 2020 value (10.62). With the exception of 2016, 2019, and 2021, since 2011 the annual index value has been above 4.0, with the highest value of the time series occurring in 2020. 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 (4.02).
- In 2021, gillnet sampling for river herring in the Chickahominy River occurred for thirteen weeks (4 February 2021 to 28 April 2021). A catch index for pre-spawning alewife and blueback herring was calculated for each species. Catches of alewife peaked 16 March. After 23 March, post-spawning alewives were present in the sample. Catches of blueback

herring peaked on 13 April. No post-spawning blueback herring were present in the sample. A total of 325 alewife (99 males; 223 pre-spawning females; 3 post-spawned females) and 37 blueback herring (12 males; 25 pre-spawning females; 0 post-spawned female) were captured.

- Using otolith-based ageing methods, the 2016-year class (age 5) of both female alewife and female blueback herring were dominant. The total instantaneous mortality rate of female alewife was 0.85. Total instantaneous mortality rate of female blueback herring was 0.94.

- The 2021 anchor gillnet seasonal catch indexes on the Chickahominy River, calculated by area under the CPUE curve: alewife, 0.97; blueback herring, 0.10. The index values were lower for alewife and blueback herring compared to the index values in 2020 (alewife, 1.54; blueback herring, 0.67).

- In 2021, the gillnet sampling season for river herring in the Rappahannock River occurred for fourteen weeks (9 February 2021 to 11 May 2021). A total of 233 alewife (84 males; 143 pre-spawning females; 6 post-spawned female) and 113 blueback herring (20 males; 92 pre-spawning females; 1 post-spawned female) were captured. Post-spawning females were present in the sample after 5 April for alewives and after 4 May for blueback herring. Catches of alewife peaked on 22 March. Catches of blueback herring peaked on 19 April.

- Using otolith-based ageing methods, the 2016-year class (age 5) of both female alewife and female blueback herring was dominant. The total instantaneous mortality rate of female alewife was 0.94. Total instantaneous mortality rate of female blueback herring was 0.97.

- The 2021 anchor gillnet seasonal catch indexes on the Rappahannock River, calculated by area under the CPUE curve: alewife, 1.21; blueback herring, 0.66. The index values were lower for alewife and blueback herring compared to the index values in 2020 (alewife, 1.85; blueback herring, 1.25).

- The geometric mean catch (followed by standard deviation or and number of seine hauls in parentheses) of juvenile alewife captured in daylight seine hauls in 2021 was: James River, 0.07 (0.22, 10); York River, 0 (NA, 54); Rappahannock River, 0.04 (0.22, 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 2021 was: James River, 0.38 (0.80, 40); York River, 0.20 (0.81, 34); Rappahannock River, 0.85 (1.24, 25).

- Catches in nighttime surface trawls on the Chickahominy River in 2021, were dominated by blueback herring (total alewife = 40; total blueback herring = 726). The 2021 seasonal catch index (geometric mean of CPUE) was 3.4 (cruise specific catch index ranged from 2.0 – 9.2) for blueback herring. The 2021 seasonal catch index (geometric mean of CPUE) was 1.2 (cruise specific catch index ranged from 0 – 1.4) for alewife.

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 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. George Trice, Hunter Sanders, and Jamie Sanders currently construct, set, and fish the sampling gear and offer helpful advice. We also extend our appreciation to several commercial fishers for their cooperation in our studies of bycatch of American Shad. In 2021, these individuals include: John Augustine, George Trice, John Dryden, RT Croswell, Walter Rogers, and Gary Waxmunski. In 2021, the staff of the Virginia Institute of Marine Science who participated in the program were: B. Watkins, A. Magee, P. McGrath, and S. Muffelman. 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. A. Magee determined the spawning phenology of river herring. B. Watkins determined hatchery origins of adult fish. Fish products from this program are donated to the Food Bank at Gleaning Baptist Church of Gloucester, 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 2021, evaluating hatchery programs and contributing to coast-wide assessments (ASMFC 2007a; ASMFC 2020). 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 runs in the Chickahominy River, a major tributary of the James River, and the Rappahannock 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 gillnet 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 gillnets 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 recent stock assessments for American shad (ASMFC 2007; 2020). The conclusions of the 2007 assessment were that 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. The conclusions related to the adult mortality and abundance of American shad in Virginia's rivers resulting from the 2020 assessment were as follows: for the Rappahannock River and York River, mortality was considered sustainable, although no trend in abundance was detected since the 2007 assessment; and for the James River adult mortality was unknown (for the last three-year period mortality could be calculated, this was

considered sustainable), but as for the other rivers, there was no trend in adult abundance. Since 2017 (the last year of monitoring data to be incorporated into the 2020 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 have been 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. From 2004 until 2014, a 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's 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. In addition, VIMS has monitored bycatch of American shad in pound nets located off Reedville, Virginia annually since 2002, and at the mouth of the Rappahannock River since 2007. In this program, samples of up to 50 American shad are collected and returned to VIMS 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 2017). 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 to 1979 but sampling was not conducted during 1987-1990. The push net survey was terminated in 2002 when it was determined that the survey results were highly correlated with those of the striped bass seine survey (Wilhite et al., 2003). Although fewer individual fish are collected each year in the seine survey as compared to the evening push net survey, the seine survey has larger geographic coverage (all three rivers in Virginia vs. the Mattaponi and Pamunkey Rivers only) and the data record is uninterrupted since 1979. A fishery-independent survey program for monitoring the spawning stocks of river herring in Virginia employing a drift gillnet was implemented on the Chickahominy River from 2014 to 2016. 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 1998-2020 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, 2017, 2018, 2019, 2020, 2021).

VIMS' authors contributed to peer-reviewed sections of the most recent stock assessment for American shad (Olney 2007; Olney et al. 2007; Carpenter et al 2007; also contributing to the ongoing assessment) and river herring (Lee et al., 2012; updated by Hilton for the 2017 stock assessment). 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). Results of this project will also support a petition to ASMFC for a limited commercial fishery for river herring in the Chickahominy River. 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 and Rappahannock rivers; (2) to relate contemporary indices of abundance of American shad to historical logbook data collected during the period 1980-1992 and older data if available; (3) to assess the relative contribution of hatchery-reared and released cohorts of American shad to adult stocks; (4) to relate recruitment 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 2021 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 2021 sampling methods for the American shad monitoring program in the Rappahannock river followed those employed in 1998-2020 (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 was used to monitor catch rates by SGNs from 1998 to 2019 on the James, 2020 on the York, and the present day on the Rappahannock. Mr. Jamie Sanders and Mr. Hunter Sanders 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 on the Rappahannock River. In 2020, the James River SGN was discontinued due to contractor health and logistical reasons. In 2020 and 2021, sampling on the James River was conducted using anchored gillnets by Mr. George Trice (Poquoson, Virginia). In 2021, the York River SGN was also discontinued due to logistical reasons and sampling was conducted using anchored gillnets by Mr. George Trice. Scientists accompanied commercial fishermen during each sampling trip and all catches were returned to the laboratory for analysis.

One SGN, 912 ft (approximately 277 m) in length, was set on the Rappahannock River (Figure 6). In the James and York rivers, three anchored gillnets (AGN), each 300 ft (~92 m) in length, were set. While this is inconsistent with past years for the James and York river, it was a necessary evolution of our approach to monitoring. We attempted to continue SGN fishing in the James and York rivers but were unable to secure new contractors. Staked gillnets have become infrequently used by commercial fisherman in the main rivers due to the logistical constraints (e.g., cutting down 30-ft tall trees for use as poles and bringing them into the river, and danger, having to hand drive poles into the sediment deep enough to withstand storms and high current). Current fisheries that use the fixed gear are minimal, further limiting the number of fishers utilizing staked gillnets. The availability of contractors with SGN experience continues to decline and has become absent in some regions. Anchored nets, which are both logistically easier to set and allow fisherman more flexibility are currently the most utilized gear for most gillnet fisheries in Chesapeake Bay. Locations of the nets were as follows: middle James River at river mile 37 (37° 10.2' N, 76° 45.3' W); middle York River near York River State Park at river mile 23 (37° 24.0' N, 76° 41.1' W); and middle Rappahannock River near the Downing 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 ensure that catch rates in the current monitoring program were comparable to logbook records, the 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 (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 either removed or 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 2021, sampling occurred for ten weeks on the Rappahannock River (4 March to 3 May 2021); eight weeks on the York River (5 March to 21 April 2021); eight weeks on the James River (4 March to 20 April 2021). 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 (VIMS) in 2021. Scanning in previous years was performed by D. Hopler (VDGIF), J. Goins (VIMS), G. Holloman (VIMS), and A. Magee (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. From 2015-2021, 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 anchored gillnets 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') anchored gillnets and two 3.0" [76.2 mm] stretched mesh (300' x 8') anchored 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. Two anchored gillnets were also set parallel to the current on the Rappahannock River near the Downing

bridge (at Tappahannock, VA) at river mile 36 (37° 55.8' N, 76° 50.7’ W). One net was a 2.5" [63.5 mm] stretched mesh (300' x 6') anchored gillnet and the other was a 3.0" [76.2 mm] stretched mesh (300' x 8') anchored gillnet. Each week, the anchored gillnets were fished for one 24 h set on each river. 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. Sampling on the Chickahominy River occurred over thirteen weeks (4 February to 28 April). In 2021, sampling on the Rappahannock River occurred over fourteen weeks (9 February to 11 May). Surface water temperature and salinity were recorded at each sampling event.

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 determine ages, 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 anchored 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). In 2015, the 3.0” mesh was determined to be inefficient at catching blueback herring; therefore, in 2015 and 2016, the catch indices for blueback herring were only calculated with catch data from 2.5” mesh. In 2017, blueback herring catches in the 3.0” mesh increased and in order to not exclude the larger females, catches from both 2.5” and 3.0” mesh were used in the catch index. The 2015 and 2016 catch indices for blueback herring were also recalculated to include the catch from the 3” mesh. In monitoring years 2015-2017, catch data occurred over two successive days and was separated by up to five days in each week of sampling. Since 2018, catches were separated by up to six days 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.

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 7.0 m skiff equipped with a 115 hp engine.

Ten weekly cruises were conducted in 2021 (28 June to 31 August). 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 gillnets in 2021

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-9. Post-spawning females were not encountered on the James, York, or Rappahannock rivers in 2021. 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 151 American shad (5 males; 146 females) were captured (Table 1). The total weight of the sample was 207.0 kg (male, 6.6 kg; female, 200.4 kg). Catches in 2021 were lowest on the James River (2 total fish, 0 males and 2 females) and York River (35 total fish, 3 males and 32 females). Catches on the Rappahannock River (114 total fish, 2 males and 112 females) were highest.

On the James River, catches of females only occurred on11 March (Table 2). Surface temperatures during this time was 9.7ºC. On the York River, catches of females peaked between 5 March – 7 April when catch rates typically exceeded 0.02 fish/m or 0.03 kg/m. During that

period, 97.0% (31 of 32) of all females were captured on the York River. Surface temperatures during this time ranged from 6.5ºC – 15.1ºC. The largest catch of pre-spawning female American shad on the York River (9 fish) occurred on 5 March when the surface temperature was 6.5ºC (Tables 2, 4). Catches of females on the Rappahannock River peaked on 4 March – 11 April when catch rates generally exceeded 0.04 fish/m or 0.06 kg/m. During that period on the Rappahannock River, 86.6% (97 of 112) of all females were captured. Surface temperatures during this time ranged from 6.9ºC – 18.1ºC. The largest catch of pre-spawning female American shad on the Rappahannock River (25 fish) occurred on 4 April when the surface temperature was 11.0ºC (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, 1:10.7; James River, 0:1.0 and Rappahannock River, 1:56.0. 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 2021 spawning run duration was estimated to be a minimum of 1 day on the James River (11 March; Table 3), 41 days on the York River (5 March – 14 April; Table 4), and 61 days on the Rappahannock River (4 March – 3 May; Table 6).

Biological characteristics of the American shad catch in 2021

Age, mean length (mm TL) and mean weight (kg) of American shad in staked gillnets are summarized in Tables 8-9. Mean total length at age of males and females from all rivers ranged from 452.0–496.0 mm TL and 472.0–553.5 mm TL, respectively. Mean weight at age of males and females from all rivers ranged from 0.9-1.2 kg and 1.3–1.6 kg, respectively.

Using scale-based ageing methods, we estimated that the 2015-year class (age 6) of female American shad were the most abundant on the York River (Table 8). The 2016-year class (age 5) of female American shad were the most abundant on the Rappahannock River. On the James River, none of the fish caught were able to be aged. On the York River, four age-classes of females were represented (2013-2016, ages 5-8). The sample was dominated by age-6 (53.3%) fish. On the Rappahannock River, six age-classes of females were taken (2012-2017, ages 4-9), with the sample dominated by age-5 fish (34.7%). Mean age of females in 2021 was 6.1 y on the York River and 6.1 y on the Rappahannock River. These values are slightly higher than those observed in 2020 on the Rappahannock River and equal on the York River. On the James, York, and Rappahannock rivers, low sample sizes of male shad were observed in 2021.

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, 0.99 (r^2=0.99); and Rappahannock River, 0.62 (r^2=0.89). 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 2021 are presented in Tables 12 and 13. On the York River, fish (sexes combined) ranged in age from 5-8 years with 0 (virgin) to 3

spawning marks. On the Rappahannock River, fish (sexes combined) ranged in age from 4-9 years with 0-4 spawning marks. The following percentages of fish in each river had at least one prior spawn (termed "repeat spawners"): York River, 33.3% (10 virgins in a sample of 15); and Rappahannock River 49.3% (38 virgins in a sample of 75 fish).

Seasonal American shad catch indices, 1980-1992 and 1998-2021

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2021 and for each year of the historical record of staked net catches on each river (Tables 14-19 and Figures 7-10). Seasonal catch indices in 2021 were: James River, 0.06; York River, 0.96; Rappahannock River, 3.56.

Evaluation of hatchery origin of American shad in 2021

James River - Otoliths of 1 American shad (50% of the total catch) on the James River were processed for hatchery marks; the proportion with hatchery marks was 100.0% (1 of 1 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 (Figure 11). A correlation analysis among the catch index and hatchery prevalence from 1998-2021 was not statistically significant ($r = 0.63$, df = 22, $p = 0.53$). In some 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, 2011-2021 there were no stray fish.

York and Rappahannock Rivers - Otoliths of American shad from the York River were not processed for hatchery marks. In 2021, 27 American shad (23.5 % of the total that were caught) from the Rappahannock river were scanned for the prevalence of hatchery marks. Zero fish 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 gillnets in 2021

Fishing days, numbers of river herring captured, catch rates (males and females) and length frequencies are reported in Tables 23-27 and 34-38. A total of 325 alewives (99 males; 223 pre-spawned females; 3 post-spawned females) and 37 blueback herring (12 males; 25 pre-spawned females; 0 post-spawned females) were captured on the Chickahominy River (Table 23). After 23 March, post-spawning alewives were mixed with pre-spawning alewives. No post-

spawning blueback herring were present in the sample. A total of 233 alewives (84 males; 143 pre-spawned females; 6 post-spawned female) and 113 blueback herring (20 males; 92 pre-spawned females; 1 post-spawned females) were captured on the Rappahannock River (Table 34). After 5 April, post-spawning alewives were mixed with pre-spawning alewives. After 4 May, 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.

On the Chickahominy River, catches of pre-spawned alewife peaked between 17 February and 30 March, with catch rates typically exceeding 0.03 fish/m/day or 0.01 kg/m/day (Table 24). Catches of blueback herring peaked between 30 March and 20 April with catch rates exceeding 0.01 fish/m/day or 0.002 kg/m/day (Table 26). Surface temperatures during these peaks ranged from 5.0ºC – 16.5ºC for alewife and from 15.1ºC – 17.9ºC for blueback herring. The largest catch of pre-spawned female alewife (47 fish) occurred on 16 March when surface temperatures were 10.8ºC and the largest catch of pre-spawned female blueback herring occurred on 13 April (8 fish) when surface temperatures were 19.2ºC. Sex ratio (males: females) for alewife was 1:2.28 and for blueback herring was 1:2.08. 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.

On the Rappahannock River, catches of pre-spawned alewife peaked between 3 March and 5 April, with catch rates typically exceeding 0.09 fish/m/day or 0.02 kg/m/day (Table 35; Figure 14). Catches of blueback herring peaked between 19 April and 27 April, with catch rates exceeding 0.11 fish/m/day or 0.02 kg/m/day (Table 37; Figure 15). Surface temperatures during these peaks ranged from 6.3ºC – 12.6ºC for alewife and from 15.9ºC – 17.1ºC for blueback herring. The largest catch of pre-spawned female alewife (33 fish) occurred on 22 March when surface temperatures were 10.1ºC and the largest catch of pre-spawned female blueback herring occurred on 19 April (25 fish) when surface temperatures were 17.1ºC. Sex ratio (males: females) for alewife was 1:1.77 and for blueback herring was 1:4.65.

Biological characteristics of river herring caught in anchored gillnets in 2021

Age, mean length (mm TL) and mean weight (kg) of river herring in anchored gillnets from the Chickahominy and Rappahannock Rivers are summarized in Table 28 and 39. Mean total length at age of pre-spawned female alewives and blueback herring from both rivers ranged from 261.8 – 326.0 mm TL and 275.0 – 305.8 mm TL, respectively. Mean weight at age of pre-spawned female alewives and blueback herring ranged from 0.17 – 0.35 kg and 0.19 – 0.25 kg, respectively.

Using otolith-based ageing methods, we estimated that the 2016-year class (age 5) of female alewife and blueback herring on both the Chickahominy and Rappahannock rivers was the most abundant (Tables 28 and 39, respectively). On the Chickahominy River, seven age-classes of female alewife were represented (2012 - 2018, ages 3 – 9), with the sample dominated by age-5 fish (32.3% of the total that was aged). Mean age of female alewives in 2021 was 4.89. Four age-classes of female blueback herring were represented (2014-2017, ages 4-7), with the sample dominated by age-5 fish (52.0% of the total that was aged). Mean age of female blueback herring in 2021 was 5.48. On the Rappahannock River, six age-classes of

female alewife were represented (2013 - 2018, ages 3 – 8), with the sample dominated by age-5 fish (32.8% of the total that was aged). Mean age of female alewives in 2021 was 4.96. Five age-classes of female blueback herring were represented (2013-2017, ages 4 - 8), with the sample dominated by age-5 fish (52.2% of the total that was aged). Mean age of female blueback herring in 2021 was 5.41.

Age-specific catch rates of female alewives and blueback herring are reported in Tables 28 and 39. Total instantaneous mortality (Z) of females was estimated using Chapman-Robson method. On the Chickahominy River, total instantaneous mortality and survival (S) rates of females were: alewife, Z = 0.85 and S = 0.43; blueback herring, Z = 0.94 and S = 0.39. On the Rappahannock River, total instantaneous mortality and survival (S) rates of females were: alewife, Z = 0.94 and S = 0.39; blueback herring, Z = 0.96 and S = 0.38. It is assumed that year classes above age-4 are equally catchable by the gear.

Spawning histories of alewife and blueback herring collected in 2021 are presented in Tables 30-31 and 41-42. On the Chickahominy River, alewife (sexes combined) ranged in age from 3-9 years with 0 (virgin) to 4 spawning marks and blueback herring (sexes combined) ranged in age from 4-7 years with 0 (virgin) to 3 spawning marks. On the Rappahannock River, alewife (sexes combined) ranged in age from 3-8 years with 0 (virgin) to 3 spawning marks and blueback herring (sexes combined) ranged in age from 4-8 years with 0 (virgin) to 3 spawning marks. The following percentages of alewife in each river had at least one prior spawn (termed "repeat spawners"): Chickahominy River, 48.5% (125 virgins in a sample of 243); and Rappahannock River 51.8% (82 virgins in a sample of 170 fish). The following percentages of blueback herring in each river had at least one prior spawn (termed "repeat spawners"): Chickahominy River, 61.3% (12 virgins in a sample of 31); and Rappahannock River 51.3% (37 virgins in a sample of 76 fish).

Seasonal river herring catch indices for 2021

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for 2021 (Tables 32-33, 43-44; Figures 12-15). Seasonal catch indices in 2021 on the Chickahominy River were: alewife, 0.97; blueback herring, 0.1. The index values were lower for alewife and blueback herring compared to the index values in 2020 (alewife, 1.54; blueback herring, 0.67). On the Rappahannock River, seasonal catch indices in 2021 were: alewife, 1.21; blueback herring, 0.66. The index values were lower for alewife and blueback herring compared to the index values in 2020 (alewife, 1.85; blueback herring, 1.25).

Juvenile abundance of American shad and river herring

Tables 45 and 46 report index values of juvenile abundance of American shad based on seine surveys (1980-2021) 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 2021 was: James River, 0 (NA, 65); Chickahominy River, 0 (NA, 10); Rappahannock River, 3.36 (1.25, 35); York River, 0.56 (0.74, 94); Mattaponi River, 1.26 (0.85, 50); and Pamunkey River,

0 (NA, 39). In 2009, calculations for all years were adjusted 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 45) showed below average recruitment of American shad in 2021 in all rivers except for the Rappahannock River. 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 measurable 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, 2016, and 2018-2020 (4.19, 4.17, 4.65, 11.65, and 8.13, 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 46). 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 measurable recruitment in the Pamunkey River in 1986-1989, 1992-1993, 1999, 2007-2009, and 2021.

Catches of river herring, mean length, mean weight, and the mean fish per tow from the nighttime surface trawls on the Chickahominy River in 2021 are reported in Table 47. Catches were dominated by blueback herring (total alewife = 40; total blueback herring = 726). Mean length of alewife ranged from 66.9 – 79.0 mm FL and mean weight ranged from 3.4 – 5.9 g. Mean length of blueback herring ranged from 42.0 – 54.4 mm FL and mean weight ranged from 0.9 – 1.8 g. Because of low catches at each sampling station, mean fish/tow and geometric means (cruise specific index) are not reliable for alewife. Mean fish/tow for blueback herring ranged from 2.1 – 13.7 fish per tow, and the geometric means ranged from 2.0 – 9.2. The cruise specific index of blueback herring peaked on the 12th of July.

Tables 48 and 49 report index values of juvenile abundance of alewife and blueback herring, respectively, based on seine surveys (1989-2021) 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 2021 was: James River, 0.07 (0.22, 10); York River, 0 (NA, 54); Rappahannock River, 0.04 (0.22, 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 2021 was: James River, 0.38 (0.80, 40); York River, 0.20 (0.81, 34); Rappahannock River, 0.85 (1.24, 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, 2011-2012, and 2020 and in the York River in 1990-1993, 1995, 1998-2000, 2006-2009, 2012-2014, 2017, and 2020-2021. 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 measurable 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 2021

Daily numbers and seasonal totals of striped bass and other species captured in staked or anchor gill nets are reported in Tables 50-52. Eleven species of fishes were counted as bycatch in the staked and anchored gillnet monitoring gear for a total of 7,208 specimens. The most commonly encountered bycatch species were: gizzard shad (*Dorosoma cepedianum*), blue catfish (*Ictalurus furcatus),* menhaden (*Brevoortia tyrannus*), and striped bass (*Morone saxatilis*).

The total number of striped bass recorded was 870 (James River, n=77; York River, n=225; Rappahannock River, n=568). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 49.4%; York River, 58.7%; and the Rappahannock River, 60.2%. A subsample of 154 dead striped bass were selected from the James, York, and Rappahannock rivers. Length of males and females ranged from 358 - 605 mm FL and 443 - 950 mm FL, respectively. Total weights of males and females ranged from 0.62 – 3.21 kg and 1.24 – 11.61 kg, respectively.

Atlantic sturgeon is taken as bycatch in the staked and anchored gillnets used to monitor abundance of adult American shad in the James, York, and Rappahannock rivers. In 2021, one Atlantic sturgeon was caught as bycatch in this sampling (James River, n=1; York River, n= 0; Rappahannock River, n=0; due to reduced effort sturgeon number data from 2015 to 2021 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), 2 (2016). 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), 2 (2016), 1 (2017), 11 (2018), 9 (2019), 7 (2020).

The total number of Atlantic menhaden recorded in the staked and anchored gillnets used to monitor abundance of adult American shad in 2021 was 2033 (James River, n= 5; York River, n=1704; Rappahannock River, n= 324). A portion (n=247) 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 159 – 371 mm TL. Total weights ranged from 0.45 – 0.52 kg.

Discussion

This 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 provision 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 gillnet 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 gillnets 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 2021 seasonal catch index (0.96) was the second lowest catch index on the York in the 24 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 (3.77), 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 at all-time lows.

Our overall assessment of the York River stock is that it persists at a low level that is 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 2021 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 seasonal catch index was 0.06. It was also below the geometric mean of the current monitoring data (2.59). 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. 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. In 2018, the stocking effort ceased operation on the James River.

On the Rappahannock River, the 2021 index was 3.56. The current geometric mean (4.02) 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 and 2021) 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 anchored gillnet 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 2021 indices were average for alewife and the lowest value for blueback herring during the seven years monitoring herring on the Chickahominy River. Despite 2019 and 2021, a positive trend is apparent for alewife during the current 7-year monitoring period. Blueback herring have a slightly negative trend during the current 7-year monitoring period.

This year marked the fourth year of an adult spawning stock survey of river herring using anchored gillnets on the Rappahannock River. No historical data exist to allow comparison of those data collected in this survey, and thus these values will provide a reference point for future comparisons. The 2021 index was lower for both alewife and blueback herring then the 2020 indices. It will take additional years of sampling data before a trend can be realized for river herring in the Rappahannock River.

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Table 1. Summary of sampling dates, total number, and total weight of American shad captured in gillnets in the James, York, and Rappahannock Rivers, spring 2021.

Sampling Location	Sampling dates in 2021	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	3/4 – 4/20	2	0	2.3	0	2	2.3
York River	3/5 – 4/21	32	3	43.0	3.5	35	46.5
Rappahannock River	3/4 – 5/3	112	3	155.1	3.1	115	158.2
Totals		146	6	200.4	6.6	152	207.0

Table 2. Daily temperature and number of American shad (both sexes combined) caught in gillnets on the James, York and Rappahannock rivers in 2021. 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
3/4/2021	8.1	0			6.9	20
3/5/2021			6.5	12		
3/9/2021					7.3	12
3/11/2021	9.7	2				
3/12/2021			9.5	7		
3/14/2021					10.2	11
3/17/2021			8.7	6		
3/18/2021	11.1	0				
3/21/2021					9.2	13
3/24/2021	11.7	0				
3/25/2021			11.7	2		
3/28/2021					15.9	4
3/30/2021	15.3	0				
3/31/2021			15.1	1		
4/4/2021					11.0	25
4/6/2021	14.3	0				
4/7/2021			14.4	6		
4/11/2021					18.1	15
4/13/2021	16.9	0				
4/14/2021			17.5	1		
4/18/2021					17.0	5
4/20/2021	17.9	0				
4/21/2021			16.5	0		
4/24/2021					14.5	9
5/23/2020					18.6	1

Table 3. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in anchored gillnet monitoring on the James River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/4/2021	63	0	0.0000	0.0	0.0000
3/11/2021	70	2	0.0073	2.2	0.0081
3/18/2021	77	0	0.0000	0.0	0.0000
3/24/2021	83	0	0.0000	0.0	0.0000
3/30/2021	89	0	0.0000	0.0	0.0000
4/6/2021	96	0	0.0000	0.0	0.0000
4/13/2021	103	0	0.0000	0.0	0.0000
4/20/2021	110	0	0.0000	0.0	0.0000
Totals		2		2.2	

Table 4. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in anchored gillnet monitoring on the York River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/5/2021	64	9	0.0375	11.6	0.0482
3/12/2021	71	7	0.0272	9.4	0.0366
3/17/2021	76	6	0.0219	7.9	0.0289
3/25/2021	84	2	0.0078	2.7	0.0106
3/31/2021	90	1	0.0043	1.6	0.0069
4/7/2021	97	6	0.0233	8.3	0.0321
4/14/2021	104	1	0.0042	1.5	0.0063
4/21/2021	111	0	0.0000	0.0	0.0000
Totals		32		43.0	

Table 5. Dates of capture, number, total weight, and catch rates of male American shad taken in anchored gillnet monitoring on the York River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/5/2021	64	3	0.0125	3.5	0.0145
3/12/2021	71	0	0.0000	0.0	0.0000
3/17/2021	76	0	0.0000	0.0	0.0000
3/25/2021	84	0	0.0000	0.0	0.0000
3/31/2021	90	0	0.0000	0.0	0.0000
4/7/2021	97	0	0.0000	0.0	0.0000
4/14/2021	104	0	0.0000	0.0	0.0000
4/21/2021	111	0	0.0000	0.0	0.0000
Totals		3		3.5	

Table 6. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gillnet monitoring on the Rappahannock River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/4/2021	63	18	0.0863	25.0	0.1197
3/9/2021	68	12	0.0450	17.3	0.0649
3/14/2021	73	11	0.0388	15.9	0.0562
3/21/2021	80	12	0.0476	15.8	0.0627
3/28/2021	87	4	0.0157	5.6	0.0218
4/4/2021	94	25	0.0959	35.1	0.1346
4/11/2021	101	15	0.0551	20.4	0.0750
4/18/2021	108	5	0.0190	6.7	0.0253
4/24/2021	114	9	0.0353	12.1	0.0473
5/3/2021	123	1	0.0038	1.4	0.0052
Totals		112		155.1	

Table 7. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gillnet monitoring on the Rappahannock River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
3/4/2021	63	2	0.0096	2.2	0.0104
3/9/2021	68	0	0.0000	0.0	0.0000
3/14/2021	73	0	0.0000	0.0	0.0000
3/21/2021	80	1	0.0040	0.9	0.0037
3/28/2021	87	0	0.0000	0.0	0.0000
4/4/2021	94	0	0.0000	0.0	0.0000
4/11/2021	101	0	0.0000	0.0	0.0000
4/18/2021	108	0	0.0000	0.0	0.0000
4/24/2021	114	0	0.0000	0.0	0.0000
5/3/2021	123	0	0.0000	0.0	0.0000
Totals		3		3.1	

Table 8. Mean total length and mean weight of pre-spawn female American shad captured in gillnets in the James, York, and Rappahannock Rivers, spring 2021. 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	NA	2	457.5	16.2	1.1	0.057
York River	2016	3	504.0	9.0	1.4	0.060
	2015	8	495.3	7.4	1.3	0.082
	2014	3	512.3	23.2	1.4	0.134
	2013	1	519.0		1.5	
	NA	17	498.0	16.0	1.3	0.174
Rappahannock River	2017	1	472.0		1.3	
	2016	26	500.7	15.4	1.4	0.132
	2015	25	505.2	12.3	1.4	0.089
	2014	15	522.0	19.3	1.5	0.136
	2013	6	529.0	13.1	1.5	0.101
	2012	2	553.5	4.9	1.6	0.152
	NA	37	501.9	17.1	1.3	0.125

Table 9. Mean total length and mean weight of male American shad captured in gillnets in the York and Rappahannock Rivers, spring 2021. 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
York River	2016	1	478.0		1.1	
	2010	1	496.0		1.2	
	NA	1	491.0		1.2	
Rappahannock River	2017	2	458.5	13.4	1.1	0.083
	2015	1	452.0		0.9	

Table 10. Number, total weight, and seasonal catch rates by year class of pre-spawn female American shad captured in gill nets in the James, York, and Rappahannock Rivers, spring 2021. 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	NA	2	2.2	7.8	0.0009	0.0010
York River	2016	3	4.1	7.3	0.0015	0.0021
	2015	8	10.6	7.3	0.0040	0.0053
	2014	3	4.1	7.3	0.0015	0.0021
	2013	1	1.5	7.3	0.0005	0.0007
	NA	17	22.8	7.3	0.0085	0.0115
Rappahannock River	2017	1	1.3	9.3	0.0004	0.0005
	2016	26	35.7	9.3	0.0101	0.0139
	2015	25	34.1	9.3	0.0097	0.0133
	2014	15	22.3	9.3	0.0058	0.0087
	2013	6	8.9	9.3	0.0023	0.0035
	2012	2	3.2	9.3	0.0008	0.0012
	NA	37	49.6	9.3	0.0144	0.0193

Table 11. Number, total weight, and seasonal catch rates by year class of male American shad captured in gillnets in the York and Rappahannock Rivers, spring 2021. 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)
York River	2016	1	1.1	7.3	0.0005	0.0006
	2010	1	1.2	7.3	0.0005	0.0006
	NA	1	1.2	7.3	0.0005	0.0006
Rappahannock River	2017	2	2.2	9.3	0.0008	0.0008
	2015	1	0.9	9.3	0.0004	0.0004

Table 12. Spawning histories of American shad (combined sexes) collected in spring, 2021 in the York River. Table entries are total numbers of fish that were aged (n=15). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

		Age at Maturity				
York River Year Class	Age at Capture	3	4	5	6	7
2016	5	-	-	**3**	-	-
2015	6	-	-	1	**7**	-
2014	7	-	-	1	2	**-**
2013	8	-	-	1	-	**-**

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2021 in the Rappahannock River. Table entries are total numbers of fish that were aged (n=75). 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=0). 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
2017	4	-	**1**	**-**	-	-
2016	5	-	-	**26**	-	-
2015	6	-	2	12	**11**	-
2014	7	-	-	3	12	**-**
2013	8	-	-	4	2	-
2012	9	-	-	2	-	-

Table 14. Summary of historical catch and effort data of American shad by staked gillnets 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 gillnets 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	3.7	----	0.053	0.020	1.46
1999	5.8	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	6.0	57	0.110	0.028	3.08
2003	7.3	72	0.311	0.094	7.10
2004	5.7	65	0.232	0.107	7.06
2005	5.7	65	0.164	0.054	3.69
2006	6.7	75	0.088	0.037	3.01
2007	5.8	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	5.2	50	0.088	0.027	2.03
2011	6.8	85	0.216	0.074	6.51
2012	7.0	62	0.313	0.080	7.28
2013	7.0	78	0.289	0.080	6.98
2014	5.1	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
2017	2.0	47	0.173	0.071	4.14
2018	2.3	50	0.557	0.178	9.78
2019	2.4	50	0.106	0.052	3.01
2020	3.5	84	0.371	0.121	10.62
2021	2.4	61	0.135	0.061	3.56
Geometric mean					**4.02**

Table 16. Historical catch and effort data of American shad captured by staked gillnets 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 gillnets in the York River, Virginia (* switched to anchored gillnets and therefore may not be directly comparable to previous years).

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	6.6	78	1.080	0.190	14.71
1999	6.3	65	0.209	0.075	5.42
2000	7.1	76	0.276	0.086	7.52
2001	5.7	79	0.627	0.163	12.97
2002	6.7	70	0.306	0.073	7.47
2003	6.1	70	0.390	0.111	8.98
2004	5.2	65	0.448	0.157	9.72
2005	5.8	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	5.7	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
2017	2.4	46	0.047	0.022	1.27
2018	2.2	50	0.043	0.021	1.36
2019	2.2	43	0.101	0.041	2.39
2020	1.6	26	0.055	0.019	0.75
2021*	2.0	41	0.048	0.021	0.96
Geometric mean					**3.77**

Table 18. Summary of historical catch and effort data of American shad by staked gillnets 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 gillnets in the James River, Virginia (* switched to anchored gillnets and therefore may not be directly comparable to previous years).

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	4.6	50	0.198	0.051	2.57
1999	6.0	66	0.183	0.042	2.99
2000	7.1	70	0.279	0.086	6.61
2001	7.3	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	5.9	78	0.234	0.090	7.41
2005	5.6	72	0.357	0.099	7.16
2006	4.6	54	0.078	0.032	1.74
2007	5.7	58	0.159	0.068	4.45
2008	5.2	58	0.069	0.025	1.51
2009	6.6	55	0.130	0.035	2.69
2010	6.9	57	0.513	0.082	6.90
2011	6.2	78	0.357	0.091	9.00
2012	5.1	72	0.294	0.076	6.06
2013	6.6	74	0.222	0.056	4.48
2014	5.1	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
2017	2.9	55	0.097	0.051	3.83
2018	2.0	43	0.049	0.022	1.30
2019	1.4	32	0.013	0.007	0.35
2020*	1.5	44	0.020	0.005	0.25
2021*	2.1	1	0.008	0.001	0.06
Geometric mean					**2.59**

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=1, Rappahannock=0) taken in gillnet monitoring in the James and Rappahannock rivers, 2021. A total of 28 American shad were scanned for hatchery marks (James=1, Rapp=27). 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
21394	James	James	3	NA	NA	395	446	1076.8	2

Table 21. Total numbers of hatchery-marked American shad taken in staked gillnets in the James River, 1998-2021. 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	2017	2018	2019	2020	2021	Total	% Total
1992	0.05		1																							1	0.1
1993	0.5	7	2	1																						10	0.9
1994	1.6	7	3	9			1																			20	1.9
1995	5.3			59	9	8	4	3																		83	7.8
1996	5.8			53	62	43	10	4	1																	173	16.2
1997	5.9			2	27	78	57	5	4		1															174	16.3
1998	10					13	52	17	13																	95	8.9
1999	7.3						14	29	7																	50	4.7
2000	8.9						1	5	9		1															16	1.5
2001	9.3								3	4	3															10	0.9
2002	8.4									4	20	7	2													33	3.1
2003	8.7										12	8	1	1	2											24	2.2
2004	6.6										2	3	2	13	4											24	2.2
2005	6.0												1	18	22	2	1									44	4.1
2006	7.0													11	35	5		3								54	5.1
2007	6.5														5	10	14	6								35	3.3
2008	6.2															4	19	13	2							38	3.6
2009	3.8																9	18	6							33	3.1
2010	3.7																	3	3	4	3					13	1.2
2011	2.4																			1	2	2				5	0.5
2012	5.4																				2	2				4	0.4
2013	4.8																					1	2			3	0.3
2014	3.3																					1				1	0.1
2015	3.5																							1		1	0.1
2016	1.01																									0	0.0
2017	1.88																									0	0.0
2018	0.0																									0	0.0
2019	0.0																									0	0.0
2020	0.0																									0	0.0
2021	0.0																									0	0.0
NA	--	0	2	20	0	12	3	5	3	1	9	2	2	11	15	7	9	16	1	1	2	2	0	0	1	124	11.6
Total	130.95	14	6	124	98	154	142	68	40	9	48	20	8	54	83	28	52	59	12	6	9	8	2	1	1	1068	100.0

Table 22. Total numbers of hatchery-marked American shad taken in staked gillnets in the Rappahannock River, 2007-2021. 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	2017	2018	2019	2020	2021	Total	% Total
2003	1.4																	
2004	3.2		1	2	1												4	9.5
2005	3.4			1		1		1									3	7.1
2006	6.3					1	1										2	4.8
2007	4.5					1	5	1	1								8	19.0
2008	4.8						1	2	1								4	9.5
2009	2.7								4	1	1						6	14.3
2010	3.9									1	2						3	7.1
2011	4.1									1		1	1				3	7.1
2012	6.0												1				1	2.4
2013	4.3													1	2		3	7.1
2014	4.3														1		1	2.4
2015	0.0																0	0.0
2016	0.0																0	0.0
2017	0.0																0	0.0
2018	0.0																0	0.0
2019	0.0																0	0.0
2020	0.0																0	0.0
2021	0.0																0	0.0
NA	--						1		1		1				1		4	9.5
Total	48.9	0	1	3	1	3	8	4	7	3	4	1	2	1	4	0	42	100.0

Table 23. Summary of catches of river herring in the Chickahominy River anchored gillnet survey, 2021 (# Females includes both pre- and post-spawn females). The * denotes first post-spawn female collected.

Date	# Alewife		# Blueback		Water Temp (C)
	3" Mesh (# Females)	2.5" Mesh (# Females)	3" Mesh (# Females)	2.5" Mesh (# Females)	
2/4/2021	5 (4)	4 (1)	0	0	3.4
2/10/2021	4 (3)	8 (3)	0	0	5.5
2/17/2021	11 (8)	15 (4)	0	0	5.0
2/24/2021	30 (28)	15 (4)	0	0	5.8
3/2/2021	26 (26)	47 (19)	0	0	7.9
3/10/2021	25 (24)	33 (17)	0	2 (1)	9.8
3/16/2021	20 (19)	34 (28)	0	4 (1)	10.8
3/23/2021	4 (4)	9 (6) *	0	1 (0)	11.7
3/30/2021	1 (1)	17 (12)	1 (1)	7 (4)	16.5
4/6/2021	4 (4)	0	1 (1)	5 (4)	15.1
4/13/2021	1 (1)	9 (7)	0	9 (8)	19.2
4/20/2021	0	2 (2)	0	5 (4)	17.9
4/28/2021	0	1 (1)	0	2 (1)	18.4
Totals	131 (122)	194 (104)	2 (2)	35 (23)	

Table 24. Dates of capture, number, total weight, and catch rates of pre-spawn female alewife taken in the 2.5” and 3” mesh anchored gillnets on the Chickahominy River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/4/2021	35	5	0.0139	1.26	0.0035
2/10/2021	41	6	0.0162	1.39	0.0038
2/17/2021	48	12	0.0342	3.04	0.0087
2/24/2021	55	32	0.0913	8.43	0.0240
3/2/2021	61	45	0.1122	11.42	0.0285
3/10/2021	69	41	0.1090	10.16	0.0270
3/16/2021	75	47	0.1285	10.46	0.0286
3/23/2021	82	9	0.0268	2.20	0.0065
3/30/2021	89	13	0.0376	2.46	0.0071
4/6/2021	96	4	0.0108	1.00	0.0027
4/13/2021	103	6	0.0155	1.20	0.0031
4/20/2021	110	2	0.0054	0.32	0.0009
4/28/2021	118	1	0.0026	0.18	0.0005
	Totals	223		53.52	

Table 25. Dates of capture, number, total weight, and catch rates of male alewife taken in the 2.5” and 3” mesh anchored gillnets on the Chickahominy River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/4/2021	35	4	0.0111	0.74	0.0021
2/10/2021	41	6	0.0162	1.10	0.0030
2/17/2021	48	14	0.0399	2.55	0.0073
2/24/2021	55	13	0.0371	2.56	0.0073
3/2/2021	61	28	0.0698	4.79	0.0119
3/10/2021	69	17	0.0452	2.78	0.0074
3/16/2021	75	7	0.0191	1.17	0.0032
3/23/2021	82	3	0.0089	0.49	0.0015
3/30/2021	89	5	0.0145	0.87	0.0025
4/6/2021	96	0	0.0000	0.00	0.0000
4/13/2021	103	2	0.0052	0.41	0.0011
4/20/2021	110	0	0.0000	0.00	0.0000
4/28/2021	118	0	0.0000	0.00	0.0000
	Totals	99		17.46	

Table 26. Dates of capture, number, total weight, and catch rates of pre-spawn female blueback herring taken in 2.5” and 3” mesh anchored gillnets on the Chickahominy River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/4/2021	35	0	0.0000	0.00	0.0000
2/10/2021	41	0	0.0000	0.00	0.0000
2/17/2021	48	0	0.0000	0.00	0.0000
2/24/2021	55	0	0.0000	0.00	0.0000
3/2/2021	61	0	0.0000	0.00	0.0000
3/10/2021	69	1	0.0027	0.28	0.0007
3/16/2021	75	1	0.0027	0.22	0.0006
3/23/2021	82	0	0.0000	0.00	0.0000
3/30/2021	89	5	0.0145	1.19	0.0034
4/6/2021	96	5	0.0135	1.08	0.0029
4/13/2021	103	8	0.0207	1.68	0.0043
4/20/2021	110	4	0.0107	0.86	0.0023
4/28/2021	118	1	0.0026	0.20	0.0005
	Totals	25		5.52	

Table 27. Dates of capture, number, total weight, and catch rates of male blueback herring taken in the 2.5” and 3” mesh gillnets on the Chickahominy River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/4/2021	35	0	0.0000	0.00	0.0000
2/10/2021	41	0	0.0000	0.00	0.0000
2/17/2021	48	0	0.0000	0.00	0.0000
2/24/2021	55	0	0.0000	0.00	0.0000
3/2/2021	61	0	0.0000	0.00	0.0000
3/10/2021	69	1	0.0027	0.18	0.0005
3/16/2021	75	3	0.0082	0.55	0.0015
3/23/2021	82	1	0.0030	0.16	0.0005
3/30/2021	89	3	0.0087	0.53	0.0015
4/6/2021	96	1	0.0027	0.18	0.0005
4/13/2021	103	1	0.0026	0.20	0.0005
4/20/2021	110	1	0.0027	0.20	0.0005
4/28/2021	118	1	0.0026	0.19	0.0005
	Totals	12		2.18	

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 an anchored gillnet survey in the Chickahominy River, spring 2021. 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	2018	37	261.8	0.17	6.46	0.0078	0.0014
	2017	47	272.9	0.20	9.51	0.0099	0.0020
	2016	70	292.3	0.25	17.84	0.0147	0.0037
	2015	41	303.0	0.28	11.54	0.0086	0.0024
	2014	12	304.5	0.30	3.61	0.0025	0.0008
	2013	7	308.6	0.29	2.05	0.0015	0.0004
	2012	3	326.0	0.35	1.06	0.0006	0.0002
	NA	6	285.0	0.24	1.46	0.0013	0.0003
Blueback herring	2017	2	275.0	0.19	0.38	0.0007	0.0001
	2016	13	284.2	0.21	2.78	0.0044	0.0009
	2015	6	290.7	0.22	1.35	0.0020	0.0005
	2014	4	299.3	0.25	1.01	0.0014	0.0003

Table 29. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of male alewife and blueback herring taken during an anchored gillnet survey in the Chickahominy River, spring 2021. 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	2018	25	257.9	0.16	3.93	0.0052	0.0008
	2017	48	261.8	0.17	8.14	0.0101	0.0017
	2016	14	274.5	0.20	2.82	0.0029	0.0006
	2015	9	287.7	0.23	2.04	0.0019	0.0004
	NA	3	267.0	0.18	0.53	0.0006	0.0001
Blueback herring	2017	1	270.0	0.19	0.19	0.0003	0.0001
	2016	6	275.2	0.19	1.13	0.0020	0.0004
	2015	5	273.4	0.17	0.87	0.0017	0.0003

Table 30. Spawning histories of male and female Alewife collected in spring 2021 in the Chickahominy River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=69; females, n=174). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

		Age at Maturity						
Males Year Class	Age at Capture	1	2	3	4	5	6	7
2018	3	-	-	**20**	-	-	**-**	-
2017	4	-	-	2	**33**	-	-	**-**
2016	5	-	-	2	4	**3**	-	-
2015	6	-	-	1	2	1	**1**	-

		Age at Maturity							
Females Year Class	Age at Capture	1	2	3	4	5	6	7	8
2018	3	-	-	**30**	-	-	**-**	-	-
2017	4	-	-	9	**28**	-	-	**-**	**-**
2016	5	-	4	19	26	**9**	-	-	-
2015	6	-	1	4	16	10	**1**	-	-
2014	7	-	-	-	4	3	3	-	**-**
2013	8	-	-	-	1	2	1	-	-
2012	9	-	-	-	-	1	1	1	-

Table 31. Spawning histories of male and female blueback herring collected in spring 2021 in the Chickahominy River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=11; females, n=20). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

		Age at Maturity						
Males Year Class	Age at Capture	1	2	3	4	5	6	7
2017	4	-	-	-	**1**	-	-	**-**
2016	5	-	-	-	2	**3**	-	-
2015	6	-	-	-	2	2	**1**	-

		Age at Maturity						
Females Year Class	Age at Capture	1	2	3	4	5	6	7
2016	4	-	-	1	**-**	-	-	-
2015	5	-	-	1	6	**4**	-	-
2014	6	-	-	1	1	-	**3**	-
2013	7	-	-	-	2	1	-	-

Table 32. Summary of recent catch and effort data of pre-spawn female alewife by anchored gillnets in the Chickahominy River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

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
2015	3.2	77	0.0421	0.0109	1.08
2016	9.1	85	0.0222	0.0070	0.60
2017	8.4	79	0.0337	0.0108	0.91
2018	4.1	78	0.0506	0.0144	1.03
2019	4.7	83	0.0155	0.0053	0.44
2020*	3.2	56	0.0668	0.0232	1.54
2021	4.8	84	0.0286	0.0111	0.97
Geometric mean					**0.88**

Table 33. Summary of recent catch and effort data of pre-spawn female blueback herring by anchored gillnets in the Chickahominy River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

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
2015	3.2	29	0.0181	0.0091	0.37
2016	6.2	57	0.0191	0.0062	0.37
2017	5.5	56	0.0333	0.0082	0.44
2018	4.1	78	0.0381	0.0069	0.57
2019	4.7	70	0.0179	0.0037	0.25
2020*	1.4	22	0.0262	0.0099	0.67
2021	4.8	50	0.0043	0.0019	0.10
Geometric mean					**0.34**

Table 34. Summary of catches of river herring in the Rappahannock River anchored gillnet survey, 2021 (# Females includes both pre- and post-spawn females). The * denotes first post-spawn female collected.

Date	# Alewife		# Blueback		Water Temp (C)
	3" Mesh (# Females)	2.5" Mesh (# Females)	3" Mesh (# Females)	2.5" Mesh (# Females)	
2/9/2021	4 (1)	1 (0)	0	0	3.9
2/16/2021	1 (0)	1 (0)	0	0	3.3
2/23/2021	0	0	0	0	2.8
3/3/2021	25 (18)	17 (8)	0	1 (1)	6.3
3/9/2021	6 (5)	1 (0)	0	0	7.6
3/15/2021	14 (12)	23 (10)	0	5 (3)	10.1
3/22/2021	22 (21)	22 (12)	0	0	10.1
3/29/2021	4 (4)	41 (24)	0	13 (9)	14.8
4/5/2021	8 (7)	25 (14) *	3 (2)	8 (7)	12.6
4/12/2021	2 (1)	10 (7)	1 (1)	8 (7)	19.0
4/19/2021	0	3 (2)	0	31 (25)	17.1
4/27/2021	1 (1)	0	0	26 (21)	15.9
5/4/2021	1 (1)	1 (1)	0	9 (9) *	19.6
5/11/2021	0	0	0	8 (8)	18.6
Totals	88 (71)	145 (78)	4 (3)	109 (90)	

Table 35. Dates of capture, number, total weight, and catch rates of pre-spawn female alewife taken in the 2.5” and 3” mesh anchored gillnet monitoring on the Rappahannock River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/9/2021	40	1	0.0052	0.27	0.0014
2/16/2021	47	0	0.0000	0.00	0.0000
2/23/2021	54	0	0.0000	0.00	0.0000
3/3/2021	62	26	0.1393	6.60	0.0354
3/9/2021	68	5	0.0259	1.35	0.0070
3/15/2021	74	22	0.1060	5.26	0.0253
3/22/2021	81	33	0.1759	8.50	0.0453
3/29/2021	88	28	0.1455	6.06	0.0315
4/5/2021	95	19	0.0915	4.35	0.0209
4/12/2021	102	5	0.0246	1.06	0.0052
4/19/2021	109	1	0.0047	0.23	0.0011
4/27/2021	117	1	0.0053	0.21	0.0011
5/4/2021	124	2	0.0098	0.45	0.0022
5/11/2021	131	0	0.0000	0.00	0.0000
	Totals	143		34.35	

Table 36. Dates of capture, number, total weight, and catch rates of male alewife taken in the 2.5” and 3” mesh anchored gillnets on the Rappahannock River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/9/2021	40	4	0.0209	0.95	0.0049
2/16/2021	47	2	0.0115	0.46	0.0026
2/23/2021	54	0	0.0000	0.00	0.0000
3/3/2021	62	16	0.0857	3.62	0.0194
3/9/2021	68	2	0.0103	0.36	0.0019
3/15/2021	74	15	0.0722	2.78	0.0134
3/22/2021	81	11	0.0586	1.91	0.0102
3/29/2021	88	17	0.0884	2.96	0.0154
4/5/2021	95	12	0.0578	2.07	0.0100
4/12/2021	102	4	0.0197	0.70	0.0034
4/19/2021	109	1	0.0047	0.19	0.0009
4/27/2021	117	0	0.0000	0.00	0.0000
5/4/2021	124	0	0.0000	0.00	0.0000
5/11/2021	131	0	0.0000	0.00	0.0000
	Totals	84		16.00	

Table 37. Dates of capture, number, total weight, and catch rates of pre-spawn female blueback herring taken in the 2.5” and 3” mesh anchored gillnet monitoring on the Rappahannock River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/9/2021	40	0	0.0000	0.00	0.0000
2/16/2021	47	0	0.0000	0.00	0.0000
2/23/2021	54	0	0.0000	0.00	0.0000
3/3/2021	62	1	0.0054	0.23	0.0012
3/9/2021	68	0	0.0000	0.00	0.0000
3/15/2021	74	3	0.0144	0.70	0.0034
3/22/2021	81	0	0.0000	0.00	0.0000
3/29/2021	88	9	0.0468	1.81	0.0094
4/5/2021	95	9	0.0433	2.07	0.0100
4/12/2021	102	8	0.0394	1.68	0.0083
4/19/2021	109	25	0.1177	5.08	0.0239
4/27/2021	117	21	0.1119	4.22	0.0225
5/4/2021	124	8	0.0392	1.70	0.0083
5/11/2021	131	8	0.0437	1.55	0.0085
	Totals	92		19.05	

Table 38. Dates of capture, number, total weight, and catch rates of male blueback herring taken in the 2.5” and 3” mesh anchored gillnet monitoring on the Rappahannock River, spring 2021.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (kg)	Catch rate (kg/m/day)
2/9/2021	40	0	0.0000	0.00	0.0000
2/16/2021	47	0	0.0000	0.00	0.0000
2/23/2021	54	0	0.0000	0.00	0.0000
3/3/2021	62	0	0.0000	0.00	0.0000
3/9/2021	68	0	0.0000	0.00	0.0000
3/15/2021	74	2	0.0096	0.42	0.0020
3/22/2021	81	0	0.0000	0.00	0.0000
3/29/2021	88	4	0.0208	0.71	0.0037
4/5/2021	95	2	0.0096	0.47	0.0023
4/12/2021	102	1	0.0049	0.17	0.0008
4/19/2021	109	6	0.0282	1.02	0.0048
4/27/2021	117	5	0.0266	0.85	0.0045
5/4/2021	124	0	0.0000	0.00	0.0000
5/11/2021	131	0	0.0000	0.00	0.0000
	Totals	20		3.64	

Table 39. 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 anchored gillnet survey in the Rappahannock River, spring 2021. 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	2018	16	263.1	0.17	2.71	0.0063	0.0011
	2017	31	274.1	0.20	6.15	0.0123	0.0024
	2016	45	293.2	0.26	11.59	0.0178	0.0046
	2015	37	299.9	0.27	10.04	0.0147	0.0040
	2014	4	307.8	0.28	1.14	0.0016	0.0005
	2013	4	309.3	0.29	1.17	0.0016	0.0005
	NA	6	297.2	0.26	1.55	0.0024	0.0006
Blueback herring	2017	11	275.7	0.19	2.06	0.0051	0.0009
	2016	47	283.0	0.20	9.55	0.0217	0.0044
	2015	20	289.0	0.21	4.15	0.0092	0.0019
	2014	8	298.0	0.24	1.92	0.0037	0.0009
	2013	4	305.8	0.24	0.98	0.0018	0.0005
	NA	2	278.0	0.20	0.40	0.0009	0.0002

Table 40. Number, mean total length (TL), mean weight, total weight, and seasonal catch rates by year class of male alewife and blueback herring taken during an anchored gillnet survey in the Rappahannock River, spring 2021. 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	2018	15	258.9	0.16	2.46	0.0059	0.0010
	2017	35	267.3	0.18	6.27	0.0139	0.0025
	2016	20	280.1	0.20	4.05	0.0079	0.0016
	2015	7	288.0	0.23	1.64	0.0028	0.0007
	2014	1	290.0	0.22	0.22	0.0004	0.0001
	2013	3	305.3	0.26	0.79	0.0012	0.0003
	2011	1	297.0	0.27	0.27	0.0004	0.0001
	NA	2	255.0	0.14	0.28	0.0008	0.0001
Blueback herring	2017	1	258.0	0.16	0.16	0.0005	0.0001
	2016	9	268.8	0.17	1.53	0.0042	0.0007
	2015	4	269.3	0.19	0.74	0.0018	0.0003
	2014	3	270.0	0.17	0.52	0.0014	0.0002
	2013	1	307.0	0.27	0.27	0.0005	0.0001
	2012	2	298.5	0.21	0.42	0.0009	0.0002

Table 41. Spawning histories of male and female Alewife collected in spring 2021 in the Rappahannock River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=62; females, n=108). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

		Age at Maturity						
Males Year Class	Age at Capture	1	2	3	4	5	6	7
2018	3	-	-	**12**	-	-	-	-
2017	4	-	-	6	**21**	-	-	-
2016	5	-	2	1	6	**6**	-	
2015	6	-	-	-	5	1	**-**	-
2014	7	-	-	-	1	1	-	**-**

		Age at Maturity						
Females Year Class	Age at Capture	1	2	3	4	5	6	7
2018	3	-	-	**12**	**-**	-	-	**-**
2017	4	-	-	4	**20**	-	-	**-**
2016	5	-	1	8	18	**10**	-	-
2015	6	-	-	2	14	12	**1**	-
2014	7	-	-	-	1	2	-	**-**
2013	8	-	-	-	-	1	2	-

Table 42. Spawning histories of male and female blueback herring collected in spring 2021 in the Rappahannock River. Table entries are total numbers of fish that were aged and had spawning marks counted (males, n=16; females, n=60). Ages are based on otolith analysis by one reader (P. McGrath) and spawning marks are based on scale analysis by one reader (B. Watkins).

		Age at Maturity						
Males Year Class	Age at Capture	1	2	3	4	5	6	7
2017	4	-	-	1	**-**	-	-	**-**
2016	5	-	-	3	3	**2**	-	-
2015	6	-	-	-	1	-	**3**	-
2014	7	-	-	-	-	-	1	**1**
2013	8	-	-	-	-	1	-	-

		Age at Maturity						
Females Year Class	Age at Capture	1	2	3	4	5	6	7
2017	4	-	-	-	**7**	-	-	-
2016	5	-	1	3	7	**22**	-	-
2015	6	-	-	1	4	5	**1**	**-**
2014	7	-	-	-	2	2	1	**1**
2013	8	-	-	-	-	1	2	-

Table 43. Summary of recent catch and effort data of pre-spawn female alewife by anchored gillnets in the Rappahannock River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

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
2018	4.6	77	0.950	0.0394	1.37
2019	2.2	71	0.0407	0.0126	0.97
2020*	1.6	49	0.0508	0.0263	1.85
2021	2.7	85	0.0453	0.0136	1.21
Geometric mean					**1.31**

Table 44. Summary of recent catch and effort data of pre-spawn female blueback herring by anchored gillnets in the Rappahannock River, Virginia (* sampling ceased early due to safety precautions related to COVID-19).

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
2018	3.8	63	0.2828	0.0710	2.33
2019	1.4	45	0.1294	0.0564	3.08
2020*	1.6	49	0.0309	0.0129	1.25
2021	2.7	70	0.0239	0.0087	0.66
Geometric mean					**1.56**

Table 45. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2021) 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
2017	0		65	0		10	0.87	1.27	35
2018	0.03	0.16	63	0		10	4.65	1.57	35
2019	0.13	0.33	65	0.07	0.22	10	11.65	1.75	35
2020	0		56	0		8	8.13	1.29	32
2021	0		65	0		10	3.36	1.25	35

Table 46. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2021) 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
2017	0.60	0.82	50	0.13	0.49	40	0.36	0.70	95
2018	4.72	1.28	49	1.14	0.76	40	2.51	1.17	94
2019	2.65	1.13	50	0.40	0.80	40	1.28	1.09	95
2020	0.73	0.78	42	0.06	0.20	34	0.36	0.62	81
2021	1.26	0.85	50	0		39	0.56	0.74	94

Table 47. Summary of catches of juvenile river herring in the Chickahominy River in 2021 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)
6/28/2021	Alewife	19	66.9	3.7	1.6	2.1 (2.0)
	Blueback	91	42.0	0.9	7.6	5.6 (2.9)
7/6/2021	Alewife	7	67.7	4.3	0.6	1.3 (1.7)
	Blueback	103	46.5	1.3	8.6	5.4 (3.2)
7/12/2021	Alewife	6	71.7	4.6	0.5	1.4 (1.5)
	Blueback	164	47.9	1.3	13.7	9.2 (2.9)
7/19/2021	Alewife	0			0	0
	Blueback	25	46.4	1.1	2.1	2.5 (2.0)
7/27/2021	Alewife	1	69.0	4.5	0.08	1.1 (1.2)
	Blueback	39	48.7	1.4	3.3	2.9 (2.6)
8/2/2021	Alewife	1	79	5.7	0.08	1.1 (1.2)
	Blueback	32	54.1	1.8	2.7	2.0 (2.5)
8/9/2021	Alewife	2	67.0	3.4	0.2	1.1 (1.3)
	Blueback	65	52.6	1.6	5.4	2.4 (3.3)
8/17/2021	Alewife	1	77	5.9	0.08	1.1 (1.2)
	Blueback	76	51.6	1.6	6.3	2.7 (3.7)
8/23/2021	Alewife	2	77.5	5.5	0.2	1.2 (1.4)
	Blueback	67	53.2	1.7	5.6	4.6 (2.4)
8/31/2021	Alewife	1	77	4.9	0.08	1.1 (1.2)
	Blueback	64	54.4	1.7	5.3	3.0 (3.5)
Season Totals	**Alewife**	**40**	**69.2**	**4.2**	**0.3**	**1.2 (1.5)**
	Blueback	**726**	**48.8**	**1.4**	**5.9**	**3.4 (3.1)**

Table 48. Indexes of abundance of juvenile alewife collected in beach seine surveys (1989-2021) 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		10	0.05	0.33	54	1.01	1.07	36
1990	0.00		10	0.00		55	0.05	0.19	40
1991	0.00		10	0.00		54	0.02	0.12	35
1992	0.00		10	0.00		54	0.04	0.22	40
1993	0.07	0.22	10	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		10	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		10	0.01	0.09	55	0.28	0.80	40
1998	0.07	0.22	10	0.00		51	0.12	0.47	33
1999	0.00		10	0.00		49	0.12	0.32	40
2000	0.00		10	0.00		51	0.17	0.50	39
2001	0.00		10	0.24	0.65	54	0.41	0.90	40
2002	0.00		10	0.01	0.10	53	0.02	0.11	40
2003	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		50	0.04	0.16	39
2007	0.55	1.39	10	0.00		48	0.30	0.77	39
2008	0.00		10	0.00		55	0.04	0.15	40
2009	0.30	0.63	10	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		10	0.05	0.21	49	0.98	1.32	39
2012	0.00		10	0.00		56	0.05	0.31	40
2013	0.12	0.35	10	0.00		55	0.16	0.41	40
2014	0.23	0.47	10	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
2017	0.20	0.57	10	0.00		55	0.13	0.67	40
2018	2.98	1.54	10	0.06	0.34	54	0.52	1.03	40
2019	0.12	0.35	10	0.03	0.22	55	0.19	0.57	39
2020	0.00		9	0.00		55	0.10	0.32	37
2021	0.07	0.22	10	0.00		54	0.04	0.22	40

Table 49. Indexes of abundance of juvenile blueback herring collected in beach seine surveys (1989-2021) 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
2017	0.87	1.38	40	0.20	0.57	35	0.69	0.99	25
2018	3.21	1.67	38	0.52	1.01	34	3.87	1.88	25
2019	3.85	1.82	40	0.09	0.31	35	2.66	1.59	25
2020	0.56	1.40	38	0.30	0.88	35	0.99	1.21	22
2021	0.38	0.80	40	0.20	0.81	34	0.85	1.24	25

Table 50. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by anchored gillnets in the James River, 2021.

Date	Live SB	Dead SB	Total SB	Other species	Total
3/4/2021	7	3	10	9	19
3/11/2021	13	4	17	6	23
3/18/2021	7	1	8	5	13
3/24/2021	8	12	20	18	38
3/30/2021	0	2	2	10	12
4/6/2021	1	0	1	4	5
4/13/2021	2	8	10	109	119
4/20/2021	1	8	9	47	56
Totals	39	38	77	208	285

Table 51. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by anchored gillnets in the York River, 2021.

Date	Live SB	Dead SB	Total SB	Other species	Total
3/5/2021	19	48	67	99	166
3/12/2021	48	25	73	225	298
3/17/2021	13	27	40	198	238
3/25/2021	10	18	28	776	804
3/31/2021	2	9	11	516	527
4/7/2021	0	1	1	724	725
4/14/2021	0	2	2	594	596
4/21/2021	1	2	3	665	668
Totals	93	132	225	3797	4022

Table 52. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gillnets in the Rappahannock River, 2021.

Date	Live SB	Dead SB	Total SB	Other species	Total
3/4/2021	19	14	33	131	164
3/9/2021	62	19	81	125	206
3/14/2021	38	152	190	288	478
3/21/2021	16	5	21	56	77
3/28/2021	39	64	103	267	370
4/4/2021	34	41	75	191	266
4/11/2021	13	36	49	537	586
4/18/2021	1	4	5	196	201
4/24/2021	3	5	8	318	326
5/3/2021	1	2	3	224	227
Totals	226	342	568	2333	2901

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

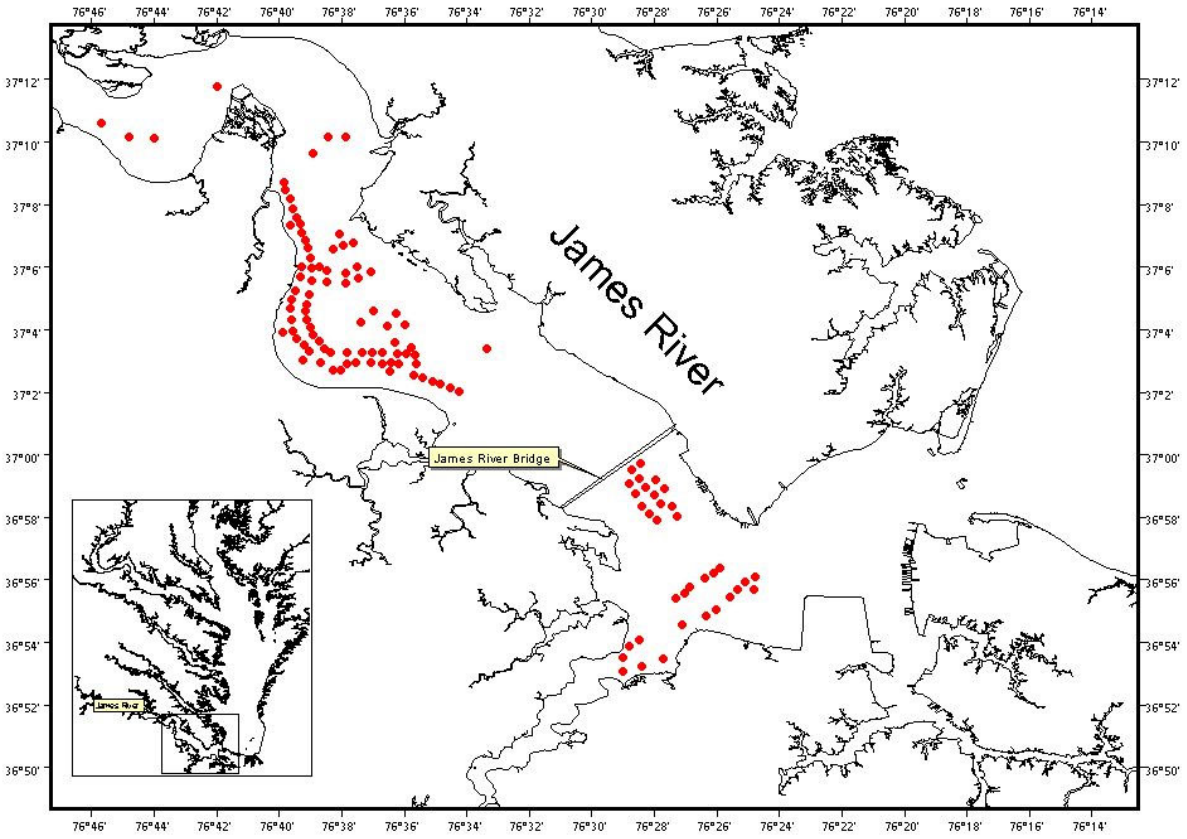


Figure 2. Number and location of staked gillnets on the York River in 1983.

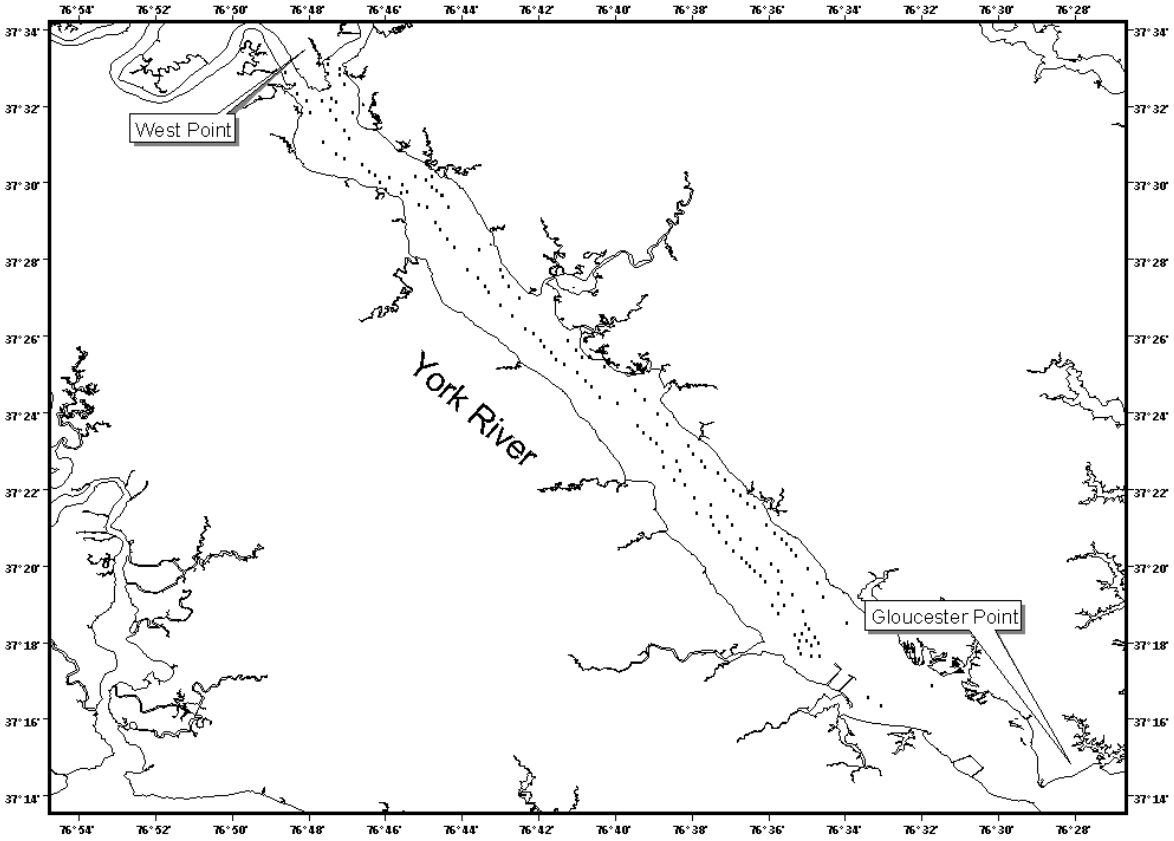


Figure 3. Number and location of staked gillnets on the Rappahannock River in 1983.

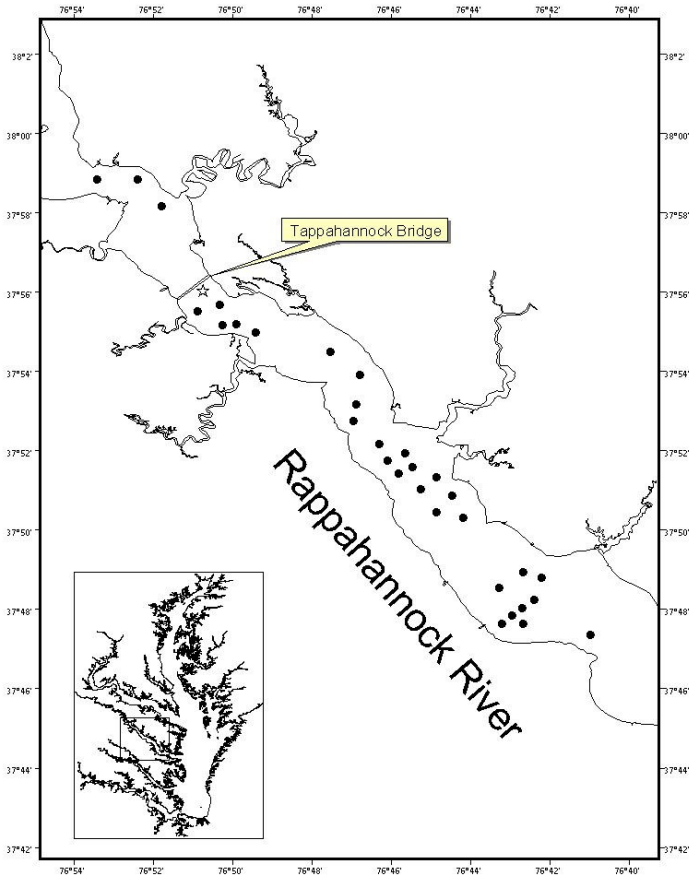


Figure 4. Location of the anchored gillnet fished by Mr. George Trice on the James River.

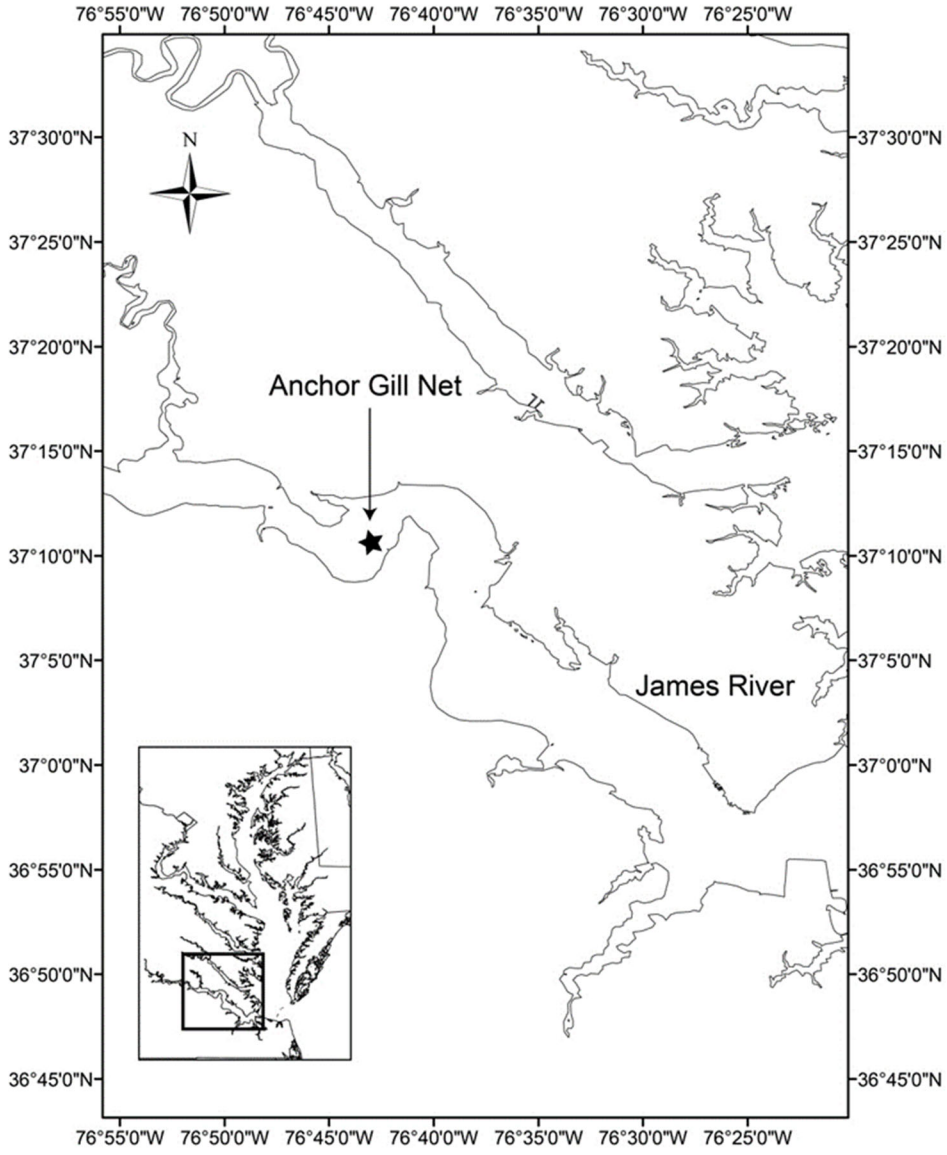


Figure 5. Location of the anchored gillnet fished by Mr. Raymond Kellum on the York River.

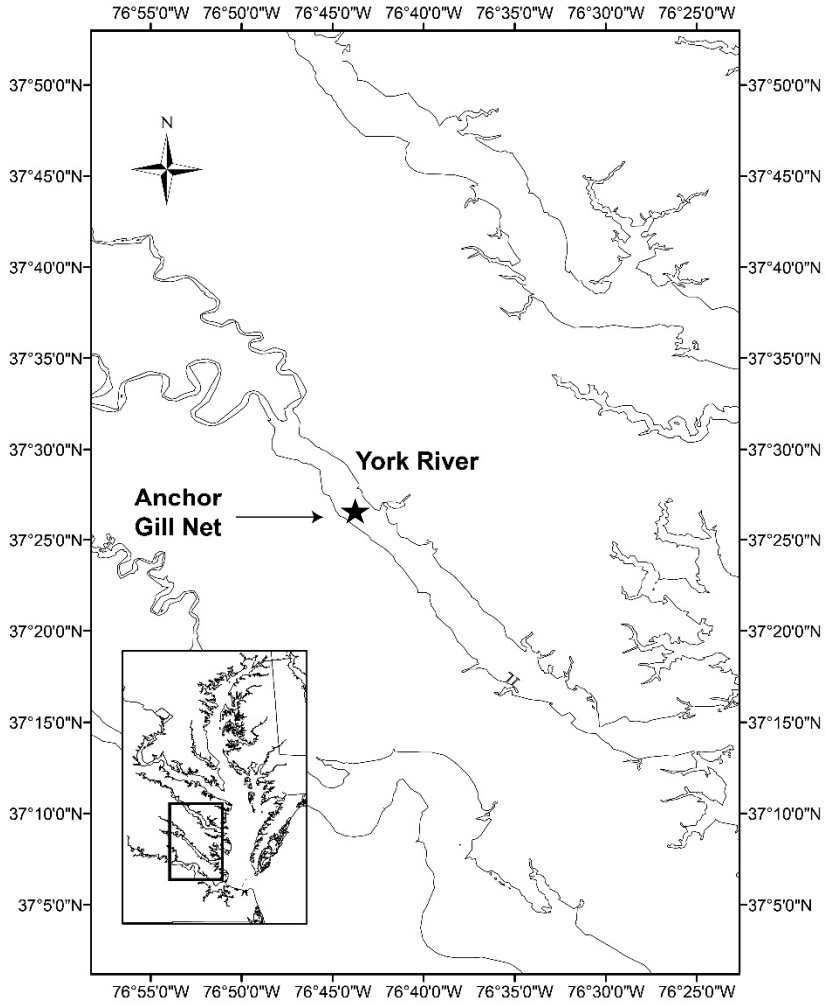


Figure 6. Location of the staked gillnet fished by Mr. Jamie Sanders on the Rappahannock River.

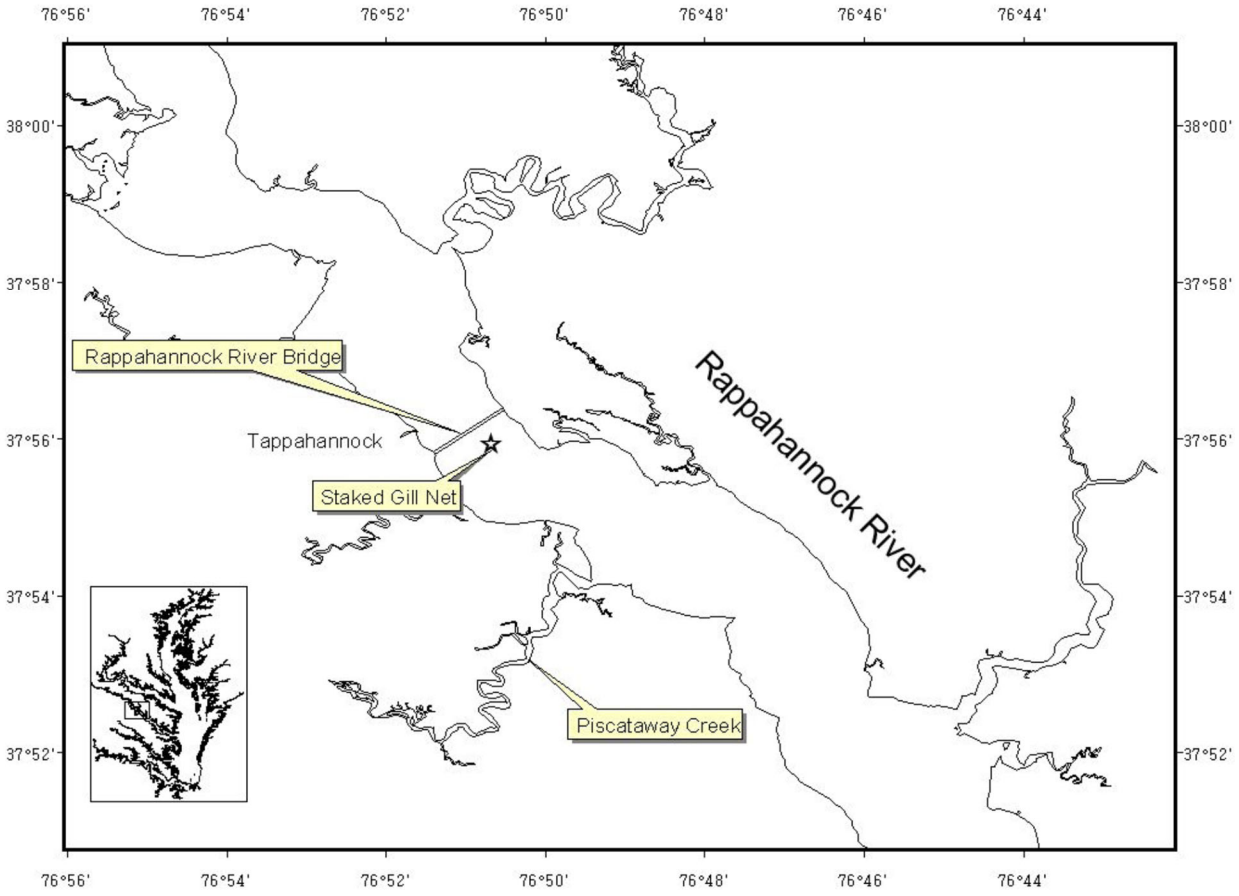


Figure 7. Recent (1998-2021) and historic values of the catch index of female American shad on the James River.

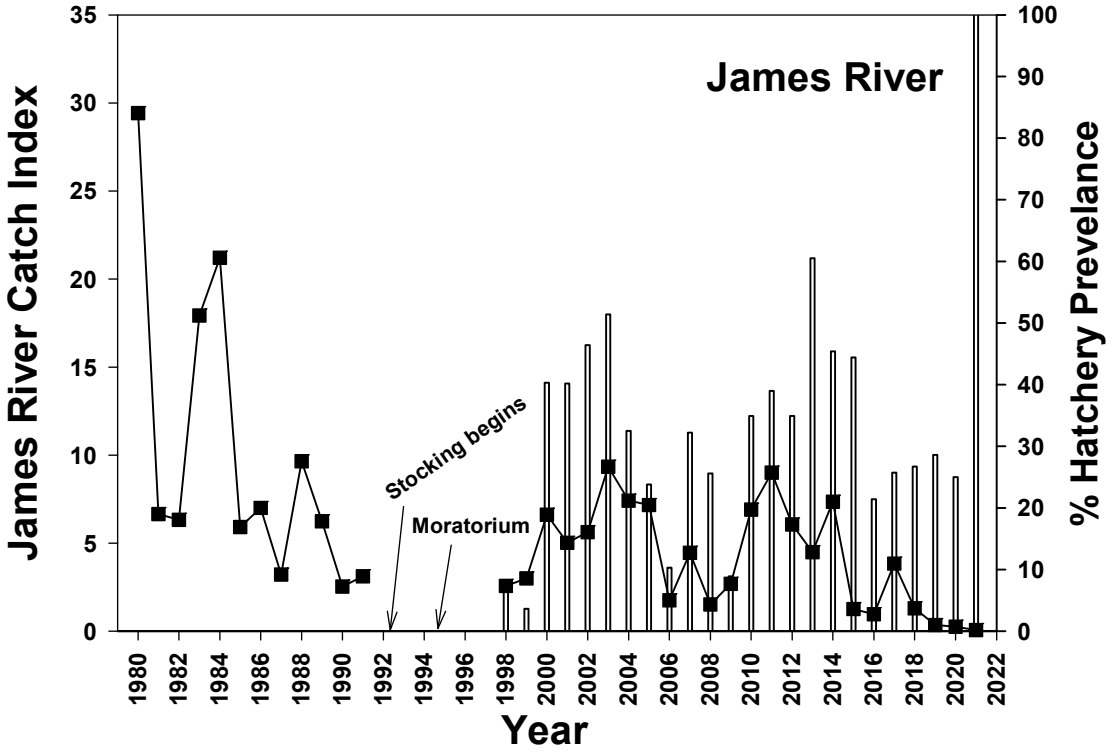


Figure 8. Recent (1998-2021) and historic values of the catch index of female American shad on the York River.

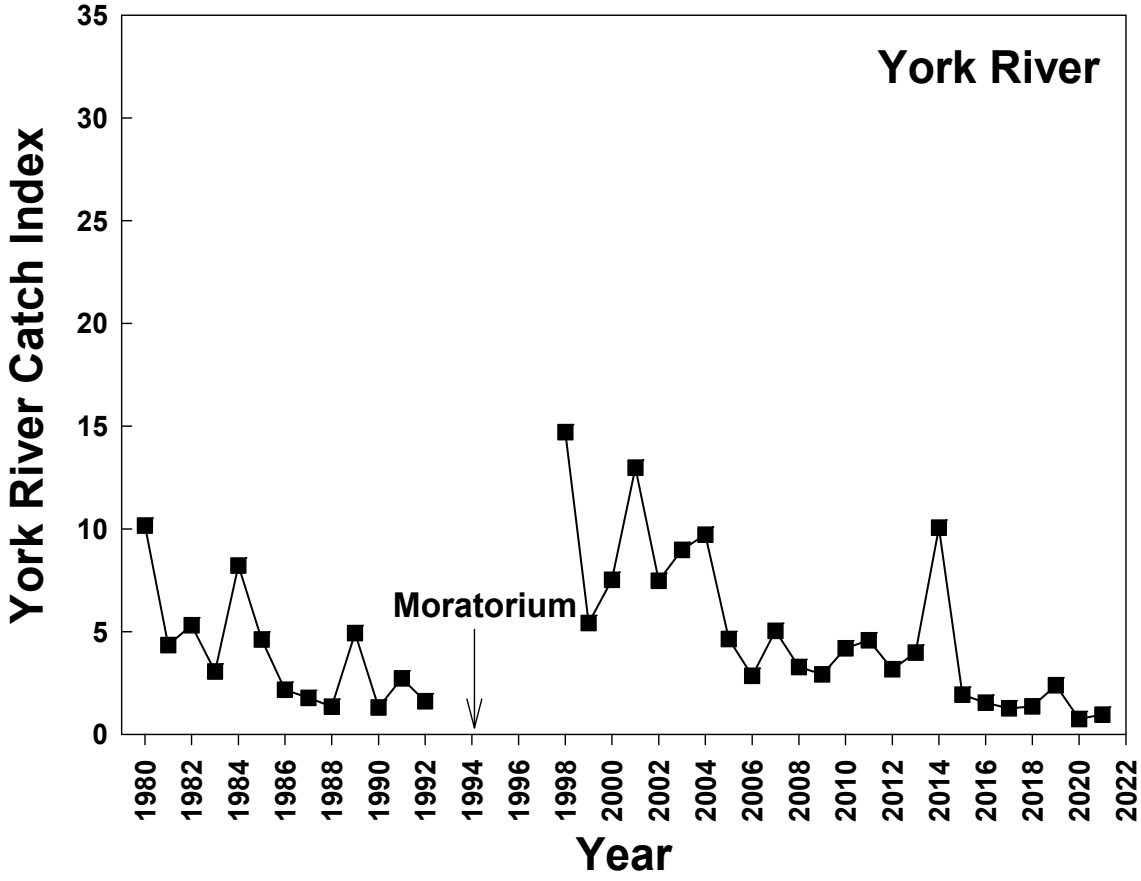


Figure 9. Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the geometric means of each data set (solid, 1950s; short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

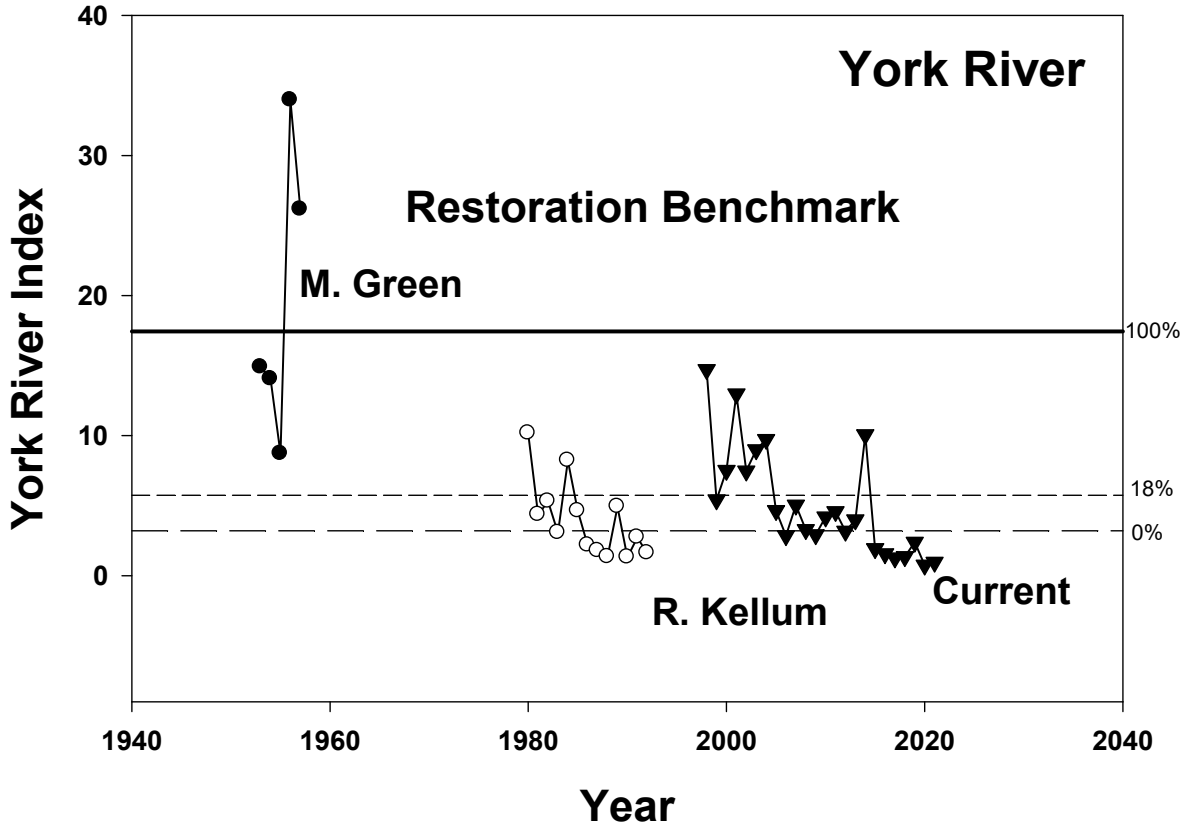


Figure 10. Recent (1998-2021) and historic values of the catch index of female American shad on the Rappahannock River.

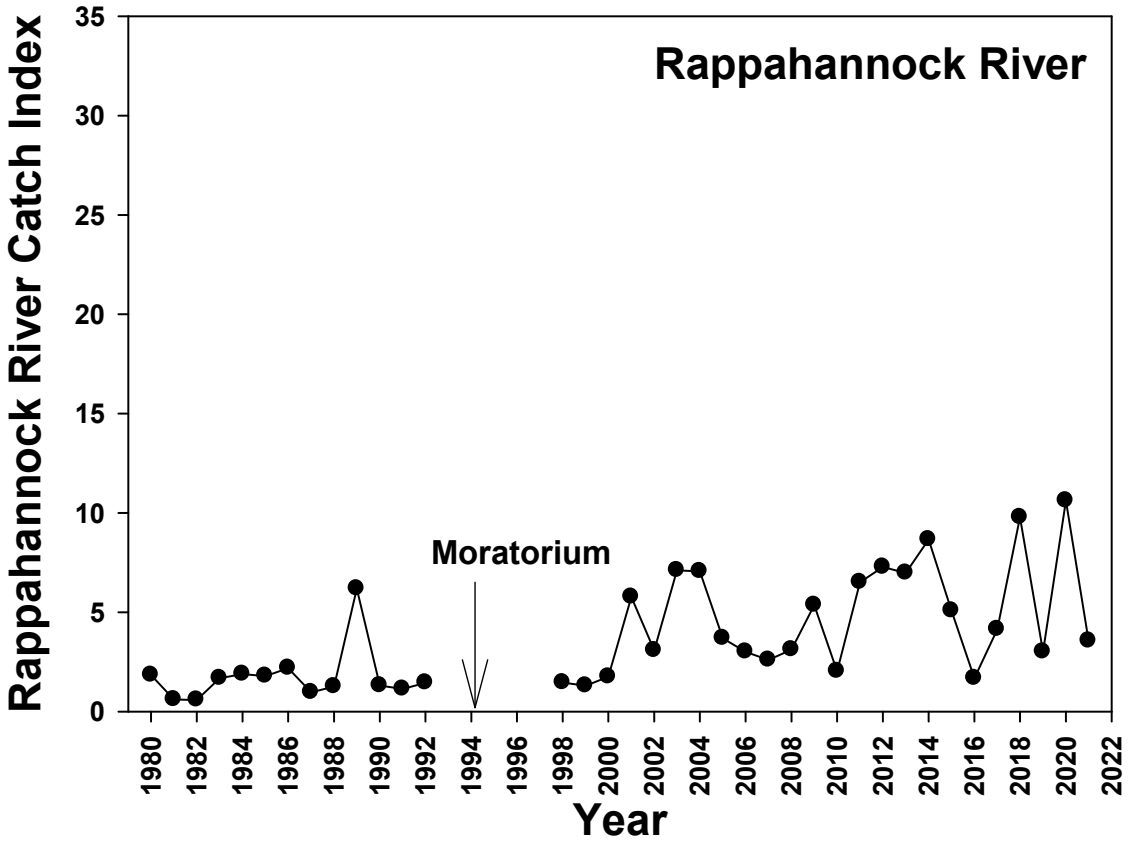


Figure 11. Comparison of the James River catch index to the percent of specimens with OTC hatchery marks.

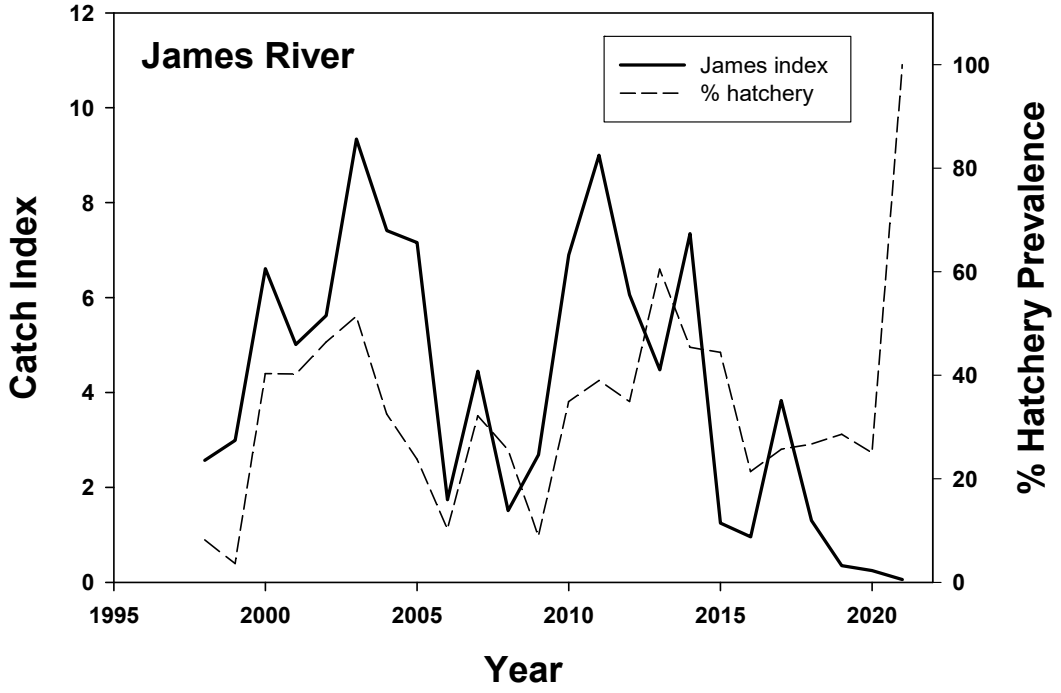


Figure 12. Recent (2015-2021) values of the catch index of female Alewife on the Chickahominy River.

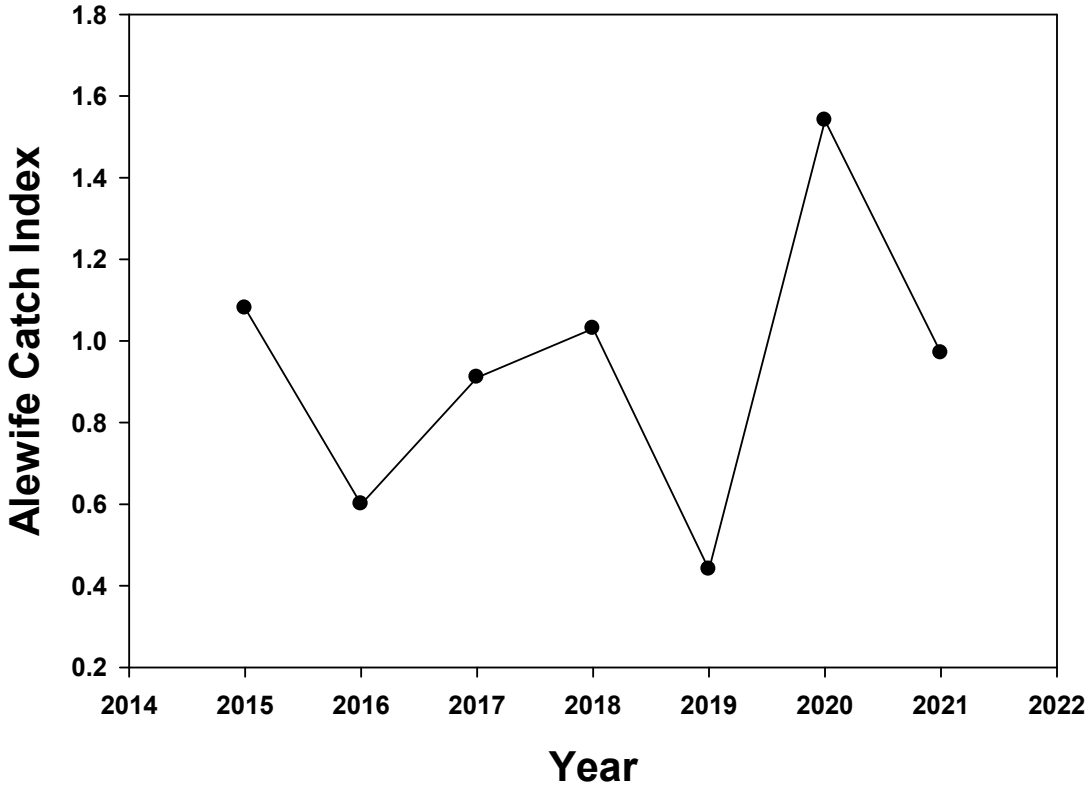


Figure 13. Recent (2015-2021) values of the catch index of female Blueback Herring on the Chickahominy River.

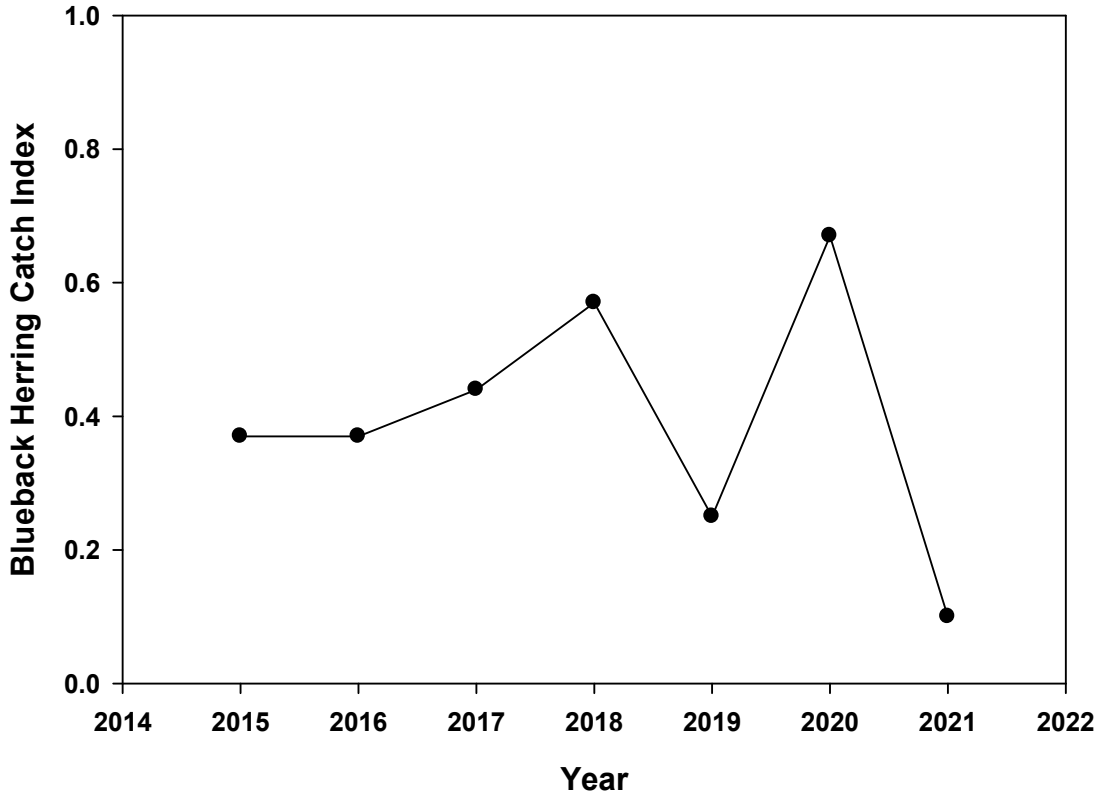


Figure 14. Recent (2015-2021) values of the catch index of female Alewife on the Rappahannock River.

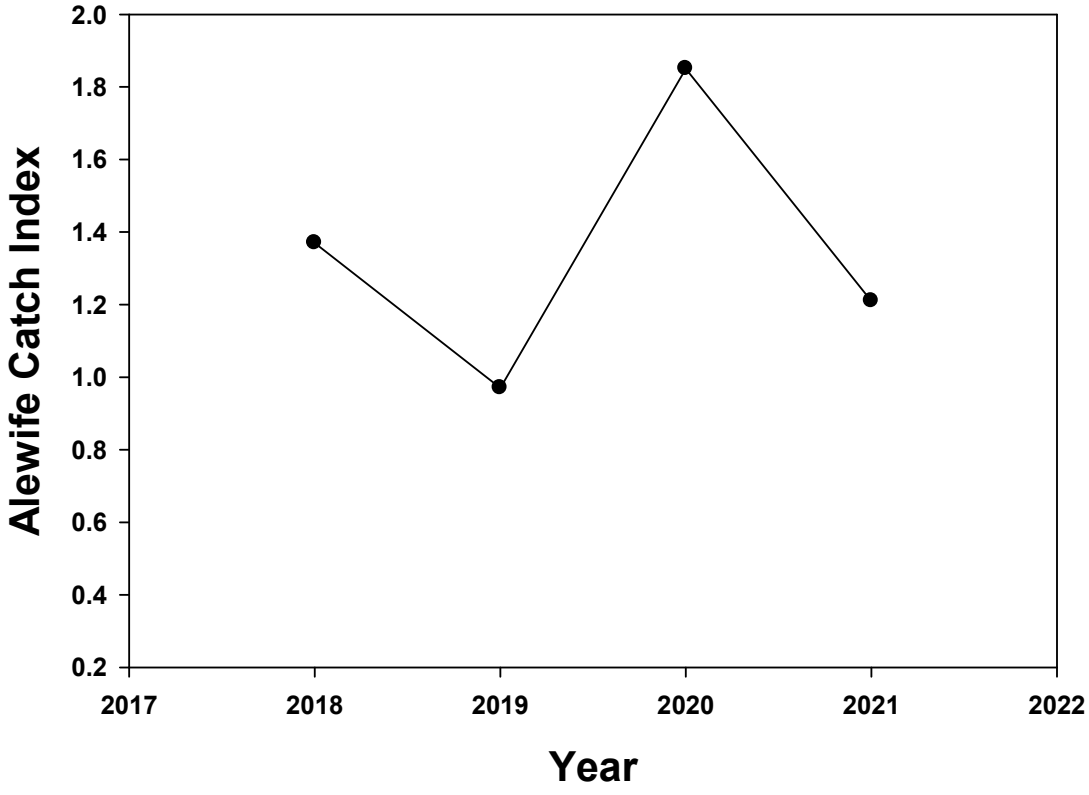
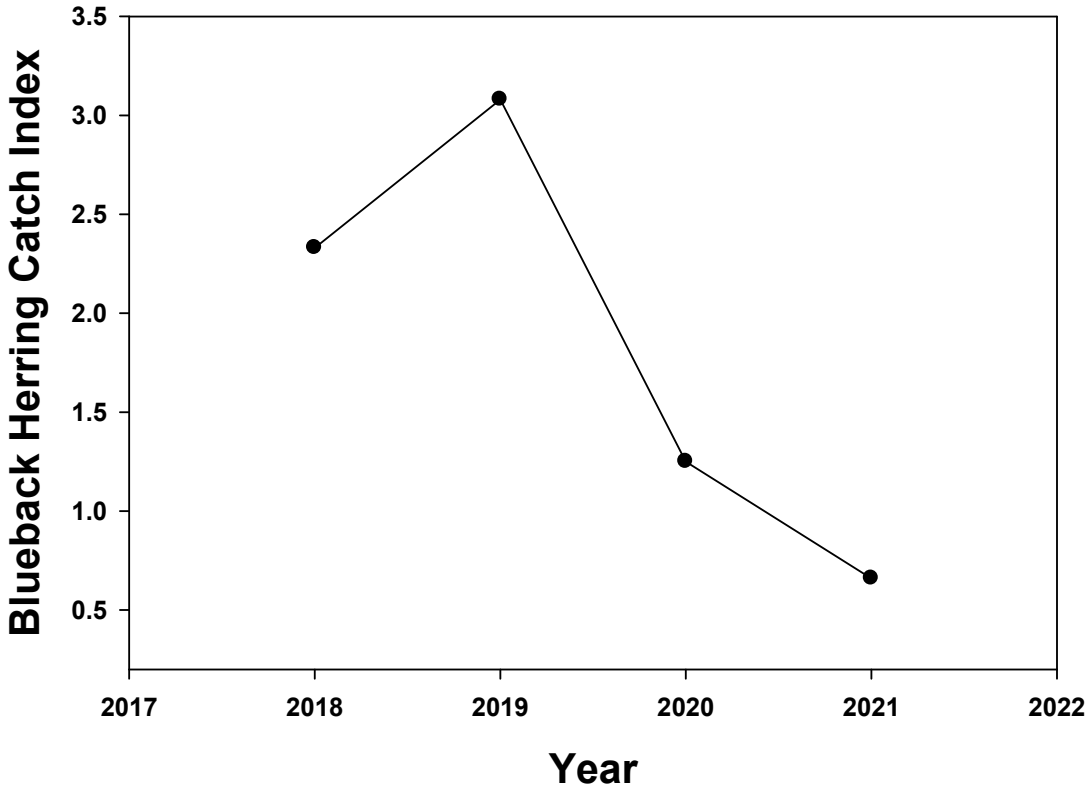


Figure 15. Recent (2015-2021) values of the catch index of female Blueback Herring on the Rappahannock River.



Appendix 1

Assessment of the 2021 Virginia by-catch of American shad and the status of the Virginia stocks

Report to the Atlantic States Marine Fisheries Commission (ASMFC)

October 1, 2021

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Background

In spring 2021, scientists at the Virginia Institute of Marine Science (VIMS) interviewed and obtained samples of by-catch of American shad from permitted fishers who had agreed to participate in the ASMFC required monitoring program. Total harvest (number of shad) in the 2021 American shad by-catch fishery decreased from 2020 on the James River, while harvest from the York and Rappahannock Rivers increased (Table 1). These two systems accounted for 97% of American shad harvest in 2021. A subsample of the by-catch of American shad (n=223), comprising fish from all three rivers, was obtained from five 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 report of the 2021 by-catch prepared by the Virginia Marine Resources Commission (VMRC) and submitted separately.

Biological Characterization of the 2021 Permitted Gill Net By-Catch in Virginia

James River

20 American shad (1 males and 19 females) were collected from two cooperating fishers on the James River. The subsample ranged in size and age from 380-478 mm FL and 4-9 years, respectively. Virgin and repeat spawners were both present in the sample (58.3% and 41.7%, respectively). Otoliths of 20 fish from the James River subsample were scanned for hatchery marks. The proportion with positive OTC marks was 60.0%. Biological descriptions of the James River subsample are presented in Table 2.

York River

100 American shad (7 males and 93 females) were collected from three cooperating fishers on the York River. The subsample ranged in size and age from 387-498 mm FL and 4-10 years, respectively. Virgin and repeat spawners were present in the sample (33.3% and 66.7%, respectively). No otoliths of fish from

the York River were scanned for hatchery marks. Biological descriptions of the York River subsample are presented in Table 2.

Rappahannock River

103 American shad (3 males and 100 females) were collected from two cooperating fishers on the Rappahannock River. The subsample ranged in size and age from 413-501 mm FL and 5-12 years, respectively. Virgin and repeat spawners were both present in the sample (69.7% and 30.3%, respectively). Otoliths of 51 fish from the Rappahannock River were scanned for hatchery marks. The proportion with positive OTC marks was 3.9%. Biological descriptions of the Rappahannock River subsample are presented in Table 2.

By-Catch and Discards by Pound Nets in Virginia

In addition to the permitted by-catch samples of American shad taken in gill nets, VIMS scientists examined pound-net samples from one pound-net fisher operating in the Great Wicomico River, a location in the upper western portion of Chesapeake Bay (Figure 1). The pound net fisher had a special permit to take American shad for scientific monitoring, but the catch was not permitted to be sold or retained as by-catch by the VMRC.

Samples of American shad were collected 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. A total of 77 American shad were processed for length, weight, sex, maturity stage, and age. Biological information is recorded for each date of harvest in Table 3. Year-class composition from the pound net location is reported in Table 4.

Numbers of males sampled was lower than the number of females (47 females; 30 males). Sex ratios (females: males) were 1:0.64. Maturity stages were determined macroscopically for females in the laboratory (Table 3).

Results of the 2021 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 3.

On the Rappahannock River, the 2021 index was 3.56, which is a decrease from the 2020 index (10.62).

In 2021, the catch index on the James River was 0.06. This is a decrease from 2020 (0.25).

The 2021 York River index is 0.96. This is an increase from 2020 (0.75). 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 by-catch permits, active permits, and fishing activity reported by river system, 2006-2021. 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. Confidential data have been redacted.

†Due to COVID-19, 2020 data is only available through the VMRC Mandatory Harvest Reporting Program. Number of American shad kept is estimated by dividing the pounds reported by 3.57, the average fish weight according to the VMRC Biological Sampling Program.

Water Body	Year	# Permit Holders	# Active Permits	Total Trips	# Shad Caught	# Shad Kept	% of Bycatch for Year
James River	2021	8	5	69	31	31	3
	2020†	8	5	19		76	
	2019						
	2018	10	3	18	32	32	2
	2017	12	3	72	277	277	48
	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						
	2011	9	3	25	42	42	32
	2010	9	0	0	0	0	0
	2009						
	2008						
	2007	16	7	58	119	52	19
	2006	32	5	27	24	23	9

Water Body	Year	# Permit Holders	# Active Permits	Total Trips	# Shad Caught	# Shad Kept	% of Bycatch for Year
York River	2021	14	10	116	550	516	43
	2020†	15	8	93		439	
	2019	11	8	128	257	254	25
	2018	10	6	143	288	284	22
	2017	9	5	45	148	146	25
	2016						
	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

Water Body	Year	# Permit Holders	# Active Permits	Total Trips	# Shad Caught	# Shad Kept	% of Bycatch for Year
Rappahannock River	2021	8	6	88	1415	652	54
	2020†	7	7	49		427	
	2019	9	9	99	1025	740	73
	2018	10	11	156	992	894	76
	2017	9	4	48	155	155	27
	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	[redacted]					
	2011						
	2010						
	2009	1	0	0	0	0	0
	2008	[redacted]					
	2007						
	2006						

Table 2. Biological descriptions by river and sex for American shad permitted by-catch samples processed at VIMS. Abbreviations: M, Male; F, Female; #, Number; Avg., Average; Yrs, Years; NA, Not applicable; 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	380.0	380.0	1	4	100.0	NA	1	0
	F	19	445.6	1378.7	11	5-9	36.4	0.0	19	12
	Combined	20	442.4	1348.0	12	4-9	41.7	0.0	20	12
York	M	7	415.7	1116.6	5	5-8	100.0	NA	NA	NA
	F	93	445.0	1385.4	52	4-10	63.5	0.0	NA	NA
	Combined	100	442.9	1366.6	57	4-10	66.7	0.0	NA	NA
Rap	M	3	423.0	1103.4	1	5	0.0	NA	0	NA
	F	100	449.0	1421.1	75	5-12	30.7	0.0	51	2
	Combined	103	448.3	1411.9	76	5-12	30.3	0.0	51	2

Table 3. Biological data of American shad (n=77) 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)
3/29/2021	Maturing	11	12.2	1111.3			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				14	11.3	807.9
4/12/2021	Maturing	14	17.1	1218.0			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				7	5.2	736.2
4/26/2021	Maturing	6	8.0	1332.6			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				8	5.9	739.8
5/10/2021	Maturing	12	15.3	1275.7			
	Hydrated	1	1.4	1448.8			
	P. Spent	3	3.1	1039.4			
	Spent						
	Unstaged				1	0.9	919.1
Total		47	57.1	1237.6	30	23.3	800.8

Table 4. Year class composition of fish taken in pound nets in 2021, indicated as percent of aged catch from one pound net locations in Chesapeake Bay.

	Year Class	Great Wicomico
Males	2017	60.0
	2016	10.0
	2015	10.0
	2014	20.0
Females	2017	26.3
	2016	26.3
	2015	15.8
	2014	15.8
	2013	10.5
	2012	5.3

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

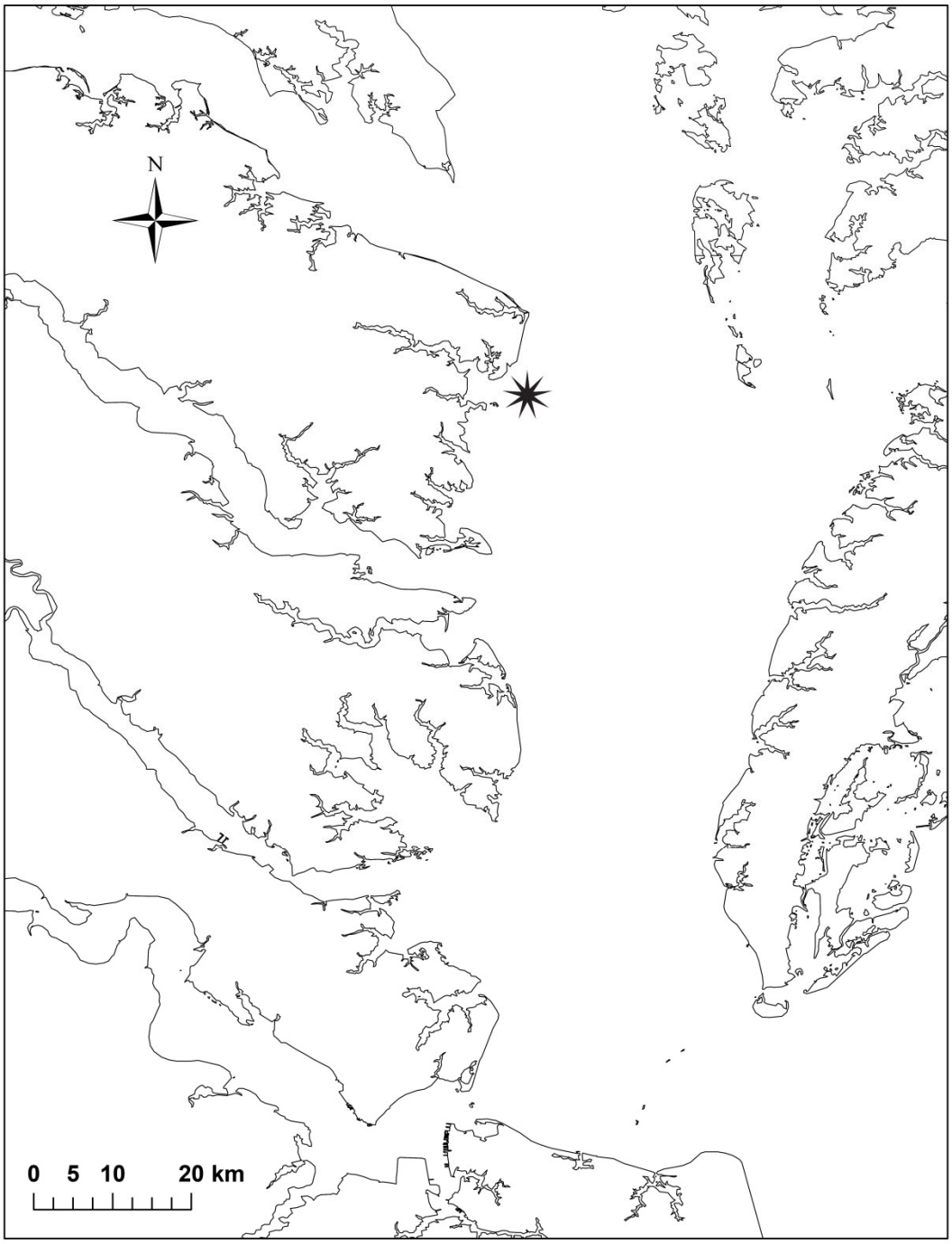

Figure 2. Total number (all samples combined) of American Shad processed by VIMS caught with special pound net by-catch permits in 2021. N is the number of samples obtained.

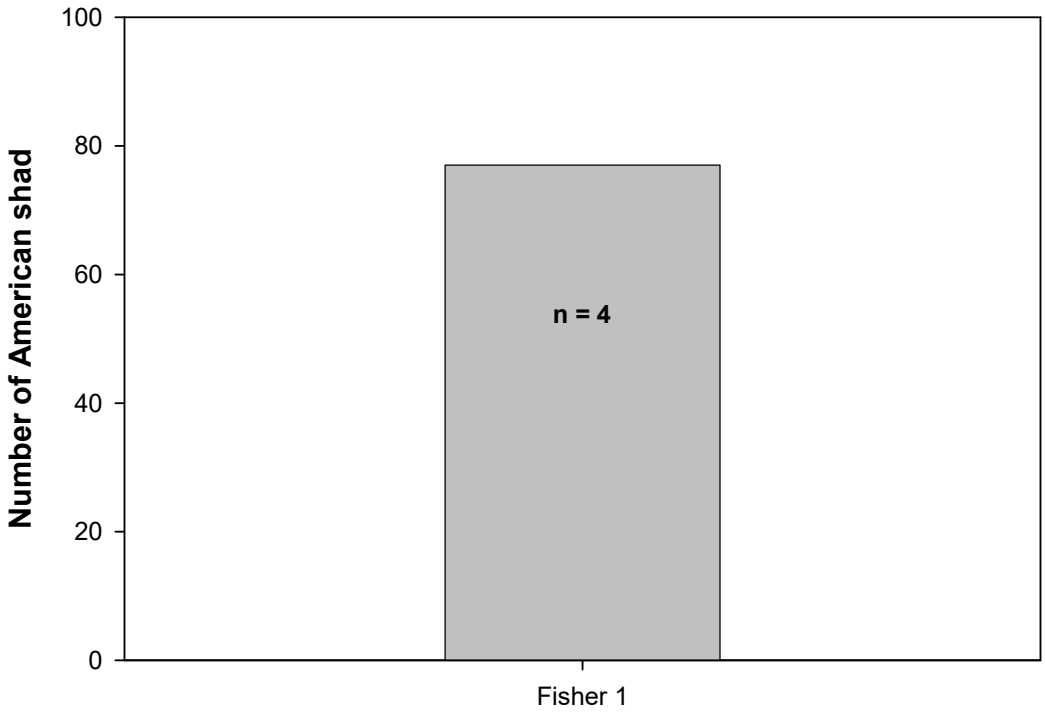

Figure 3. Time series of catch index from staked gill net monitoring in Virginia, 1998-2021.