Monitoring Relative Abundance of American Shad in Virginia's Rivers

2003 Annual Report

Funding Agencies: US Fish and Wildlife Service
Virginia Marine Resources Commission
Virginia Institute of Marine Science

Contract Number: F-116-R-6

Project Period: 15 February 2003 - 14 February 2004

Principal Investigator: John E. Olney

Prepared By:

John E. Olney

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

Submitted To:

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

15 April 2004

Summary

- A staked gill net was set and fished each week on the James, York and Rappahannock rivers in the spring of 2003. This was the sixth year of monitoring in a stock assessment program for American shad that was initiated in spring 1998. The primary objective is to establish a time series of catch rates that can be compared to historical catch rates recorded in logbooks voluntarily submitted by commercial fishers prior to the imposition of the current moratorium. The monitoring effort provides information on the current status of shad stocks relative to conditions prior to the moratorium dating to 1980 in the James and Rappahannock rivers. In the case of the York River, monitoring and additional gear calibration trials allow assessment of current status relative to conditions during the 1980s and the 1950's.

- Sampling occurred for 11 weeks on the York River (25 February to 5 May 2003), 12 weeks on the James River (25 February - 12 May 2003) and 13 weeks on the Rappahannock River (25 February - 19 May 2003). After 21 April, post-spawning fish were mixed with pre-spawning fish in the catch on all rivers. Only pre-spawning fish were included in the monitoring summaries. A total of 1,168 female American shad (1,970 kg total weight) was captured. The 2003 catch was larger than the catch in 2002 (787 females weighing 1,260 kg total weight).

- Total numbers and weights of females in 2003 were highest on the James River (n= 453, 751 kg). York River catches of females (n= 376, 633 kg) exceeded those in the Rappahannock River (n= 339, 586 kg). Numbers of males captured were: York River, 203; James, 179; Rappahannock, 100. The total weight of all males captured was 629 kg.

- Based on age estimates from scales, the 1998 (age 5) year class of female American shad was the most abundant on all three rivers, with age-specific seasonal catch rates exceeding 0.03 kg/m. The 1997 year class (age 6) was abundant on the James and York rivers with seasonal catch rates also exceeding 0.03 kg/m. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River,1.20; James River,1.09; and Rappahannock River, 0.77. Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River,1.38; James River,1.07; and Rappahannock River, 0.62.

- Otoliths of 276 American shad captured on the James River and otoliths of 96 specimens captured on the York River were scanned for hatchery marks. The proportion of the sample with hatchery marks on the James and York rivers was 51.4 % (142 of 276 fish) and 3.1 % (3 of 96 fish), respectively. In 1998 and 1999, prevalence of hatchery fish on the James River was low (4-8 %). The increase in catch rates observed on the James River since 2000 is due to the influx of mature hatchery fish released since 1995. Of these hatchery-released cohorts, the 1996 and 1997 year classes have dominated catches thus far. In all, nine year classes (1992-2000) of hatchery fish have been captured in the monitoring program.

- The geometric mean catch of juvenile American shad captured in daylight seine hauls in 2003 was: James River, 0.04; Rappahannock River, 0.659; York River (below

Westpoint), 9.04; Mattaponi River, 8.55; Pamunkey River, 13.11. The evening push net survey in the Mattaponi and Pamunkey rivers was discontinued in 2002.

- Between-reader comparisons of age determination using scales were conducted. In separate trials, two trained readers agreed 52.1% (trial 1) and 59.2% (trial 2) of the time when both age and number of spawning marks were considered; 62.5% (trial 1) and 67.3% (trial 2) of the time when only age was considered. Test of symmetry in both trials yielded significant results ($p<0.05$), indicating that there were systematic differences between the readers when they disagreed. In both comparisons, one reader consistently assigned an age that was one year greater than the other reader when they disagreed.

- Twenty-six species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 23,225 specimens. The total number of striped bass captured was 5,645 (James River, n= 3,742; York River, n= 1,291; Rappahannock River, n= 612). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 54.1%; York River, 28.9%; and the Rappahannock River, 62.3%.

- Comparison trials of multifilament nets (identical to the type used in the 1950's) and monofilament nets (used in the 1980's and in current monitoring) were conducted in 2002 and 2003. A Poisson main effects model yielded a significant difference in catch between the two net types in each year and when data from both years were combined. The expected ratio of the catches (current monitoring and 1980's catch rates to 1950's catch rates) was estimated to be 2.16 (with 95% confidence limits of 1.65, 2.83). This correction factor was applied to the 1950s log book data of Mr. Malvin Green and used to establish a proposed restoration target for the York River.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2003 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 2003 was 8.98. During the five years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The average of the historical data during the 1980's on the York River is 3.96. The average of the current monitoring data is higher (11.70) but this average is lower than the average of catch indexes from log book records in the 1950s (19.54). These older data were adjusted for differences in the efficiency of multifilament and monofilament nets using the results of comparison trails in 2002 and 2003.

- On the James River, the 2003 index (9.34) is the highest value recorded since 1998. Index values in 2000-2003 are higher than those in 1998 and 1999 (1.46 and 1.30, respectively). The average of the historical data during the 1980's on the James River is 8.88. The average of the current monitoring data is lower (5.36).

- The catch index on the Rappahannock River in 2003 (7.10) is higher than any previous year of monitoring and higher than all years in the historical data. The average of the historical data during the 1980's on the Rappahannock River is 1.76. The average of the current monitoring data is higher (3.41).

- In recent years of monitoring (2000-2003), mean age of females has increased on all rivers, suggesting higher survival. In 1999, mean age abruptly increased on all rivers and then dropped again in 2000. One possible explanation for this change is failure of age-4 fish to recruit in 1999. This may have been a result of low juvenile abundance in 1995. All forms of the juvenile index (push net and seine data) depict failed juvenile recruitment on all rivers in that year.

Preface

Concern about the decline in landings of American shad (*Alosa sapidissima*) along the Atlantic coast prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Management Program (ASMFC 1999). Legislation enables imposition of federal sanctions on fishing in those states that fail to comply with the FMP. To be in compliance, coastal states are required to implement and maintain fishery-dependent and fishery-independent monitoring programs as specified by the FMP. For Virginia, these requirements include spawning stock assessments, the collection of biological data on the spawning run (e.g., age-structure, sex ratio, spawning history), estimation of total mortality, indices of juvenile abundance, and evaluation of restoration programs by detection and enumeration of hatchery-released fish. This annual report documents continued compliance with Federal law. Since 1998, scientists at the Virginia Institute of Marine Science have monitored the spawning run of American shad in the James, York and Rappahannock rivers. The information resulting from this program is reported annually to the ASMFC, has formed the basis for a number of technical papers published in the professional literature, and is contributing substantially to our understanding of the status and conservation of this important species. Data collected in the Virginia monitoring program will be used in revised stock assessment of American shad scheduled for peer review in 2005.

Introduction

A moratorium on the taking of American shad (*Alosa sapidissima*) in the Chesapeake Bay and its tributaries was established by the Virginia Marine Resources Commission (VMRC) beginning 1 January 1994. The prohibition applied to both recreational and commercial fishers, and was imposed at a time when commercial catch rates of American shad in Virginia's rivers were experiencing declines. At the time, data from the commercial fishery were the best available for assessing the status of individual stocks. Catch-per-unit-effort (CPUE) data were compiled from logbooks that recorded landings by commercial fishermen using staked gill nets at various locations throughout the middle reaches of the James, York and Rappahannock rivers. The logbooks were voluntarily provided to the Virginia Institute of Marine Science (VIMS) during the period 1980-1993, 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) (ASMFC 1999).

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

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

These ongoing studies of American shad in Virginia waters are significant for recreational fisheries for at least three reasons.

- American shad fight well when angled using light tackle. The recreational fishery is closed in Virginia but is popular in Florida, North Carolina, Maryland and several other states. Anecdotal information suggests that there were historical recreational fisheries for American shad on the James, Mattaponi and Rappahannock rivers. Currently, many anglers catch and release American shad and legally harvest hickory shad (*Alosa mediocris*) on the James River near Richmond, the Mattaponi River above Walkerton, the Rappahannock River near Fredricksburg as well as the Nottoway and Black rivers near

Franklin, Virginia. Thus, development of a recreational shad fishery in Virginia could constitute an important opportunity to expand or restore recreational fishing opportunities if the stocks are rehabilitated and managed carefully.

- American shad are important for trophic and ecological reasons. Spawning site selection by adults as well as the abundance and occurrence of juveniles are closely linked to water quality and the availability of good fish habitat. The shads and river herrings (*Alosa* and *Dorosoma*) form an important prey group for striped bass and other recreationally important species in Chesapeake Bay. The decaying carcasses of post-spawning anadromous fishes are known to play an important role in nutrient and mineral recycling in riverine and estuarine systems. In recent years, there have been shifts in community structure in the major tributaries to the Bay with striped bass and gizzard shad numbers increasing greatly. Monitoring changes in abundance of key species is essential for understanding community dynamics.

- Monitoring the shad spawning run using historic gear also allows for a description of the by-catch associated with a commercial fishery for shad in Virginia's rivers. This is important for determining the impact of a re-opened commercial fishery for shad on other recreationally important species, especially striped bass.

Background

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

Attempts to manage and conserve Virginia's stocks of American shad date to colonial times. Before Virginia was settled, native Americans caught American shad in large quantities using a seine made of bushes (Walburg and Nichols 1967). Shad were so plentiful that they could be speared with pointed sticks as they swam on the flats (VCF 1875). The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, shad were less abundant, presumably due to fishing and obstructions that prevented the fish from reaching their spawning grounds. Concerned colonists passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (VCF 1875). In 1771, the Virginia Assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to the last day of May. However, due to the approaching conflict of the Revolutionary War, the law was never enforced (VCF 1875).

The shad fishery of Chesapeake Bay became important about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and staked gill nets (Walburg and Nichols 1967). Catches reached a low in 1878, and the U.S. Fish Commission and

Virginia Commission of Fisheries instituted an artificial hatching program in 1875. By 1879 the fishery began to improve, and the increase in catches led biologists to believe that the shad fishery was largely dependent upon artificial propagation. However, by the early 1900's the decline in shad harvests resumed despite improved hatching methods and increased numbers of fry released (Mansueti and Kolb 1953).

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

Today, many American shad stocks along the eastern seaboard of the United States are in low abundance (Figure 1) and there is evidence of recent and persistent stock declines of American shad in three of 12 systems, based on a recently completed stock assessment (ASMFC 1999). Two of these are Virginia stocks in the Rappahannock and York rivers. Large catches no longer occur as they did at the turn of the century. Commercial American shad landings in Virginia decreased from 11.5 million pounds in 1897 to less than a million pounds in 1982 (Figure 1). Over-fishing, dam construction, pollution, and loss of natural spawning grounds are a few of the factors that may be related to this decline. Historically, the majority of American shad were captured within the rivers. Beginning in 1984, the largest proportion of American shad taken in Virginia's fishery was captured offshore. The overall impact of this shift in the fishery on egg production and annual recruitment of Virginia stocks is unknown. Genetic studies of the catch composition of Virginia and Maryland's coastal landings have suggested that the intercept fishery claims a highly variable proportion of Virginia's riverine stocks (Brown and Epifanio 1994). American shad were pursued by recreational fishermen in Virginia in the past, but the extent and success of this activity is not easily assessed.

In spring 1994, the Virginia Department of Game and Inland Fisheries (VDGIF) and the US Fish and Wildlife Service (USFWS) began a hatchery-restocking effort in the James and Pamunkey rivers. Adult shad from the Pamunkey River are used as brood stock, eggs are stripped and fertilized in the field, and larvae are reared in the VDGIF hatchery at Stephensville, Virginia, and the USFWS hatchery at Harrison Lake, Virginia. Prior to release, the larvae are immersed in an oxytetracycline (OTC) solution that marks otoliths with a distinctive epifluorescent ring. The success of this ongoing program has recently been documented by Olney *et al.* (2003) who report that catch rates by monitoring gear are increasing as large numbers of mature hatchery fish are returning to the James River. In general, prevalence of hatchery fish returning as adults to the York system is low (~4 % each year; Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002). Annual monitoring of the abundance of juvenile *Alosa* (American shad, hickory shad, blueback herring and alewife) was conducted on the Pamunkey River system during 1979-2002. After

1995, juveniles bearing the OTC mark were collected by VIMS and VDGIF. The data show that hatchery-released larval shad constituted 0.1-8 % of the total catch of juveniles on the Pamunkey River during the 4-y period (1995-1999).

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

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

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

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

Current Information

There is mandatory reporting of offshore catches to the VMRC. These data can be accessed through the VMRC website (http://www.state.va.us/mrc/homepage.htm). Annual monitoring of the abundance of juvenile *Alosa* (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). The data record extends back to1979 but sampling was not conducted during 1987-1990. The push net survey was terminated in 2002 when it was determined that the survey results were highly correlated with those of the striped bass seine survey (Wilhite *et al.*, 2003). Although fewer individual fish are collected each year in the seine survey as compared to the evening push net survey, the seine survey has larger geographic coverage (all three rivers in Virginia vs. the Mattaponi and Pamunkey river only) and the data record is uninterrupted since 1979. Since the American shad monitoring program began in 1998, ten 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.*, 2001a; Olney *et al.*, 2001; Olney and Hoenig, 2001b, Maki *et al.*, 2002; Bilkovic et al. 2002a; Bilkovic et al. 2002b; Olney and McBride, 2003; Olney *et al.*, 2003; Walter and Olney, 2003; Wilhite *et al.*, 2003). Reprints of these papers are available on

request. Currently, one manuscript that reports patterns of survival and growth of juvenile American shad on the Pamunkey River is in review. In addition, two draft manuscripts (one reporting migratory habits of American shad in the York River; another reporting the role of the moratorium in the regulatory process related to the King William reservoir project) are completed (please see abstracts as Appendix 1).

Objectives

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

In 2002 and 2003, an additional objective was to determine an efficiency factor that can used to relate catch rates of multifilament nets (used by shad fishers in the 1950s) to monofilament nets (used by fishers in the 1980s and in current monitoring). These comparison trials are required to make the data available from voluntary logbooks in the 1950s comparable to more recent data (see Olney and Hoenig 2001 for background). Using this approach, we have established proposed restoration targets for the York River stock.

Methods

The 2003 sampling methods were the same as those in 1998-2002. In 1998, a fishery-independent monitoring protocol was developed that was as similar as possible to traditional shad fishing methods in the middle reaches of Virginia's rivers. When the in-river fishing moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGNs) were allowed to retain priority rights for the locations of those stands in the various rivers. VIMS has records of the historic fishing locations (Figures 2-4), and one of these locations on each river (the James, York and Rappahannock) was used to monitor catch rates by SGN's in 1998-2000. Three commercial fishermen were contracted to prepare and set SGN poles, hang nets, replace or repair poles or nets, and set nets for each sampling event during the monitoring period. Two of these commercial fishermen, Mr. Raymond Kellum (Bena, Virginia) and Mr. Marc Brown (Rescue, Va), were authors of the historical logbooks on the James and York rivers. However, authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders, Warsaw, VA) who had previous experience in SGN fishing but who had not participated in the shad fishery on the Rappahannock River in the 1980's. Scientists accompanied commercial fishermen during each sampling trip, and returned the catch to the laboratory.

One SGN, 900 ft (approximately 273 m) in length, was set on the York and James rivers (Figures 5-6). One staked gill net, 912 ft (approximately 276 m) in length, was set on the Rappahannock River (Figure 7). Locations of the sets were as follows: lower James River near

the James River Bridge at river mile 10 (36^0 50.0' N, 76^0 28.8' W); middle York River near Clay Bank at river mile 14 (37^0 20.8' N, 76^0 37.7' W); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock) at river mile 36 (37^0 55.9' N, 76^0 50.4' W). Historical catch-rate data on the York and James rivers were derived from nets constructed of 4 7/8" stretched-mesh monofilament netting, while historic data from the Rappahannock River were based on larger mesh sizes (nets constructed of 5" stretched-mesh). To insure that catch rates in the current monitoring program were comparable to logbook records, nets on the York and James rivers were constructed of 4 7/8" (12.4 cm) stretched-mesh monofilament netting, while nets on the Rappahannock River were constructed of 5" (12.7 cm) netting. Panel lengths were consistent with historical records (30 ft each on the James and York rivers; 48 ft each on the Rappahannock River). Each week, nets were fished on two succeeding days (two 24-h sets) and then hung in a non-fishing position until the next sampling episode. Occasionally, weather prevented the regularly scheduled sampling on Sunday and Monday, and sampling was either postponed, canceled or re-scheduled for other days. Sampling occurred for 11 weeks on the York River (25 February to 5 May 2003), 12 weeks on the James River (25 February - 12 May 2003) and 13 weeks on the Rappahannock River (25 February - 19 May 2003). Surface water temperature and salinity was recorded at each sampling event.

To compare catch rates of American shad in multifilament nets with monofilament nets, we fished a staked gill net consisting of five 30-ft panels of multifilament net (4.75 inch stretched mesh) adjacent to five equally sized panels of monofilament net (4.88 inch stretched mesh) for each of two consecutive days each week (usually the same days of regular monitoring) in March and April. On the first day, we randomly chose the location (shore side or channel side) where the old (multifilament) net type was fished. On the next day, the locations of the two nets were switched by removing the nets and rehanging them in reverse order. Mr. Raymond Kellum was contracted to do the fishing and a scientist accompanied the fisher each time the net was fished. It is important to note that the location of this test fishing was in the same York River segment where the 1950s data originated. All fish caught were brought back to the laboratory for processing in the same manner as those fish caught at the monitoring sites. We modeled the logarithm of the catches as:

where η is the grand mean; pos_h is the effect of position h; day_i, the effect of day I; wk_j, the effect of week j; net_k, the effect of net type k; $year_l$, the effect of each year and ε_{hijk} is a Poisson error term. Our null hypothesis is that the mean catch of female American shad per standard set of the new net type, $\_{new}$, is less than or equal to the mean of the old net type, $\_{old}$:

$$H_o: \_{new} \square \_{old}$$
$$H_a: \_{new} > \_{old}$$

SAS procedure GENMOD with a Poisson error and log link was used to fit this generalized linear model. We tested a one-sided hypothesis because we felt it was likely that changes in fishing practices would increase fishing power rather than decrease it. By rejecting the above null hypothesis, we establish that an increase in efficiency has occurred.

Individual American shad collected from the monitoring sites were measured and weighed on a Limnoterra FMB IV electronic fish measuring board interfaced with a Mettler PM

30000-K electronic balance. The board recorded measurements (fork length, total length and body depth) to the nearest mm, received weight input from the balance, and allowed manual input of additional data (such as field data and comments) or subsample designations (such as gonadal tissue and otoliths) into a data file for subsequent analysis. Catches of all other species were recorded on log sheets by observers on each river. By-catch was recorded in the field and released (if alive) or returned to the laboratory (if dead). For striped bass (*Morone saxatilis*), separate records were kept of the number of live and dead fish in the nets.

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 do this, otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Personnel from Virginia Commonwealth University (Mr. Dave Hopler) assisted in this evaluation.

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 assess the differences between readers, 49 samples were randomly chosen from 2003 samples and aged by each reader twice. Each reader then made a third reading on those fish for which the initial two readings disagreed and established a final age and spawning mark assignment. In addition, 48 scales were randomly chosen from 2000 samples. In the case of these comparisons, there was only one reading by each reader. Differences between readers were analyzed using a test of symmetry (Hoenig *et al.* 1995). The test is performed as a chi square test. A significant chi square statistic indicates that there is a systematic difference between aging methods.

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

Results

Catches of American shad by staked gill nets in 2003

Fishing days, numbers of American shad captured, and catch rates (males and females) are reported in Tables 1-7 and Figures 9-10. After 21 April 2004, post-spawning American shad were mixed with pre-spawning ("roe") fish in the catch on all rivers (Table 2). Post-spawning fish were identified macroscopically (following Olney et al. 2001) and had lower total weights at size (Figure 8). Post-spawning fish have not been previously observed in the staked gill net monitoring program and their appearance may have been related to above average stream flow and low water

temperatures in spring 2003. Since the historic fishery was a roe fishery, since spent or partially spent fish were not routinely captured or marketed in the historic fishery, and since spent or partially-spent fish have not been previously observed in regular monitoring, post-spawning fish were removed from the monitoring sample.

A total of 1,650 pre-spawning American shad (482 males:1,168 females) were captured. The total weight of the sample was 2,598.4 kg. The 2003 catch was larger than the catch in 2002 (1,070 females weighing 1,617 kg total weight; Olney 2003). Catches in 2003 were lowest on the Rappahannock River (439 total fish, 100 males and 339 females), higher on the York River (579 total fish, 203 males and 376 females) and highest on the James River (632 total fish, 179 males and 453 females).

On the James River, catches of females peaked on 16 March-22 April 2003 when catch rates exceeded 0.42 fish/m or 0.10 kg/m. During that period on the James River, 81% (365 of 453) of the total number of females was captured. On the York River, catches of females peaked between 16 March and 6 April 2003 when catch rates approached or exceeded 0.48 fish/m or 0.10 kg/m. During that period on the York River, 63% (235 of 376) of the total number of females was captured. Catches of females on the Rappahannock River peaked 24 March-21 April 2003 and again on 4-5 May when catch rates exceeded 0.50 fish/m or 0.08 kg/m. During those periods on the Rappahannock River, 87% (296 of 339) of the total number of females was captured. The highest recorded daily catch by weight occurred on 4 April 2003 when 65 female American shad (106.9 kg) were taken in the York River (Table 5). As in previous years of monitoring, numbers and catch rates of males were lower than catch rates of females throughout the period. Sex ratios (males:females) were: York River, 0.351:0.649; James River, 0.283:0.712; Rappahannock River, 0.228:0.772. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish.

The duration of the 2003 spawning run (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) was estimated to be 72 days on the James River (25 February - 12 May), 70 days on the York River (25 February - 4 May) and 79 days on the Rappahannock River (3 March - 19 May).

Biological characteristics of the American shad in 2003

Age, mean length (mm TL) and mean weight (g) of American shad in staked gill nets are summarized in Tables 9-10 and frequency distributions of total length are depicted in Figures 11-12. Mean total length at age of males and females ranged from 462-558 mm TL and 462-588 mm TL, respectively. Mean weight at age of males and females ranged from 1.14-2.28 kg and 1.16-2.48 kg, respectively.

The 1997 and 1998 year classes (ages 5 and 6) of female American shad were the most abundant on all three rivers (Table 11). On the James River, eight age classes of females were represented (1993-2000, ages 3-10) and the sample was dominated by age-5 fish (51.4% of the total that were aged). On the York River, eight age classes of females were represented (1993-2000, ages 3-10) and the sample was dominated by age-5 fish (41.1% of the total that were aged). On the Rappahannock River, five age classes of females were taken (1994-1998, ages 5-9). Age-5 fish made up 59.2% of the aged sample. The 1996, 1997 and 1998 year classes of males were the most abundant on all three rivers (Table 12). These year classes (ages 5-7) of

male American shad constituted 90.1% (York River), 94.5% (Rappahannock River) and 84.9% (James River) of the aged sample.

Age-specific catch rates of American shad are reported in Tables 11-12 and depicted in Figure 13. Total instantaneous mortality (Z) was estimated using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve. Total instantaneous mortality rates of females were: York River, 1.20 (r^2= 0.98); James River, 1.09 (r^2= 0.98); and Rappahannock River, 0.77 (r^2= 0.99). Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River, 1.38 (r^2= 0.94); James River, 1.07 (r^2= 0.88); and Rappahannock River, 0.62 (r^2= 0.92).

Spawning histories of American shad collected in 2003 are presented in Tables 13-14. On the James and York rivers, fish (both sexes combined) ranged in age from 3-10 years with 0 (virgin) to 5 spawning marks. On the Rappahannock River, fish (both sexes combined) ranged in age from 4-9 years with 0-5 spawning marks. The following percentages of fish in each river had a least one prior spawn (termed "repeat spawners"): York River, 70.8% (162 virgins in a sample of 554); James River 45.9% (330 virgins in a sample of 611); Rappahannock River 45.8% (231 virgins in a sample of 426 fish). The percentages of fish with at least one prior spawn on the York River in previous years were: 1998, 40.2%; 1999, 67.3%; 2000, 31.1 %; 2001, 38.8 % ; 2002, 59.5% (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002; Olney 2003).

Comparison of multifilament and monofilament nets

Catches in the comparison nets (Table 15) totaled 217 shad in 2002 (158 were females) and 160 fish in 2003 (124 females). Mean lengths and weights of males and females were similar between the old (multifilament) and new (monofilament) nets. Catches of females in the combined sample (2002 and 2003 data) were higher in the monofilament net (188 females) than in the multifilament net (94 females). Catches were highest during the week of 17 March in 2002 and 23 March in 2003 (Figures 14-15).

A Poisson main effects model yielded a highly significant difference in catch between the two net types in 2002 ($p<0.0001$, Table 16) and a significant difference in 2003 ($p<0.01$, Table 17). When data from both years were combined, the estimated effect of the monofilament net relative to the multifilament net (in essence, the log relative risk) was 0.7703. This value can be converted into a relative fishing power by exponentiation. Thus, the expected ratio of catches (current catch rates to historical catch rates) is $\exp(0.7703) = 2.16$. In other words, in these trials, the monofilament net caught more than twice as many females as the multifilament net used in the 1950s. The standard error (0.13) is small and the 95% lower and upper confidence intervals on the relative fishing power ($\exp(0.7703 \pm 2*0.13)$) are 1.65 and 2.83, respectively. Thus, the monofilament net is more efficient than the multifilament net and the estimation has reasonably high precision. This correction factor (2.16) was applied to the historic log book data (catches in 1953-1957) of Mr. Malvin Green , who used multifilament nets in his staked gill net sets in the York River near Aberdeen creek (Olney and Hoenig 2001). The resulting corrected data are depicted in Table 19. During the 1950s, Malvin Green's corrected annual catch index ranged from 8.70-33.95. The mean corrected catch index was 19.54.

Evaluation of hatchery origin of American shad in 2003

James River - Otoliths of 276 American shad captured in staked gill nets on the James River were scanned for hatchery marks. The proportion of the 2003 sample with hatchery marks was 51.4% (142 of 276 fish). The biological attributes of these specimens are presented in Table 20. The prevalence of hatchery-reared fish was low in spring 1998 (8.2 %; 14 of 170 adults) and 1999 (3.6 %; 7 of 177 adults). Prevalence rose abruptly in spring 2000 (40.3 %; 156 of 387 adults) and has remained near that level. In most years, fish with hatchery tags from rivers other than the James River were among those counted. 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= 1, Pamunkey River, n= 2 unknown tag. In 2003, there were no stray fish.

Most hatchery-reared adults taken in 2000-2003 had OTC marks that indicated these specimens were released in 1995 or 1996 or in 1997-2001. These tags could not be easily differentiated microscopically, however. Because of this, we determined the year of release of hatchery fish using scale-determined ages (Tables 13, 20 and 21). In 1998, hatchery-reared fish captured in our monitoring gear (n= 14) were ages 4 or 5 (released as fry in 1993 or 1994). In 1999, hatchery-reared fish (n=6) were ages 5, 6 or 7 (released as fry in 1992, 1993 or 1994). In these years (1992-1994), hatchery production was below 2 million fry annually (Table 21). Since 1995, hatchery production has exceeded 5 million fry released annually.

During 2000-2003, hatchery-reared fish captured in the staked gill nets were ages 3-9 (released as fry in 1992-2000). The highest numbers captured thus far were released in 1995-1998. The 1996 year class of hatchery-reared American shad first appeared as age 4, continues to recruit and is well represented in 2000-2002 samples. This year class has constituted 32.3% of the hatchery-marked catch (Table 21). The 1997 year class first appeared at age 3 and its contribution (31.3%) is almost equivalent to the 1996 year class. The 1998 year class first appeared in moderate numbers in 2002 and its recruitment increased substantially in 2003. Additional recruitment of the 1998, 1999 and 2000 year classes is expected in future years of monitoring.

Most hatchery fish captured in the James River in 2000 and 2001 were virgins (no spawning marks on the scales) that had matured at age 4 or 5. In these two years, proportions of the sample that had spawned at least once were: 2000, 28.2 %; 2001, 39.8 %. In 2002, the proportion of repeat spawners increased to 54.2 % (65 virgins in a sample of 142 fish). In 2003, the proportion of repeat spawners was 42.2% (71 virgins in a sample of 137 hatchery fish).

York River - Otoliths of 96 adult specimens captured in staked gill nets on the York River were scanned for hatchery marks. The proportion of the sample with marks was 3.1 % (3 of 96 fish). The biological characteristics of these specimens is reported in Table 22. By comparison, the proportion of previous samples with marks was 4.8% (5 of 104 fish in 2002), 4.8 % (9 of 186 fish in 2001) and 2.2% (4 of 180 fish in 2000).

Juvenile abundance of American shad

Tables 23-25 report index values of juvenile abundance of American shad based on push

net surveys on the Pamunkey and Mattaponi rivers (1979-2002) and seine surveys (1979-2003) on the James and Rappahannock rivers, the main stem of the York River, the Pamunkey River and the Mattaponi River. Traditionally, the push net juvenile index has been reported as maximum geometric mean catch rate. However, the results of a recent analysis (Wilhite *et al.*, 2003) of the push net data indicates that this form of the index is not preferred. Instead, cruise-specific catch rates of juvenile American shad, reported as mean catch rates over all stations sampled each week, were used to estimate the annual geometric mean catch for each river, the area under the catch curve for each river annually, and the combined area under the catch curve of both rivers annually. In the push net data, the time series of the combined area under the catch curve for both rivers depicts above average (>1,536.9) abundance of juveniles in the York River system in 1996-1998 and 2000-2001 relative to the other years in the recent record (since 1991), while index values were low in 1991, 1992, 1995, 1999 and 2002 (Figure 16). This survey was discontinued in 2002.

The seine survey data on the James River (Table 24) depict no measurable recruitment during most years. This observation is consistent with those of independent survey results below Bosher's Dam on the James River (VDGIF, T. Gunter, pers. comm.). A few juveniles were captured in 1984, 1998 and 2003. On the Rappahannock River, the highest JAI values (>0.5) were recorded in 1982, 1989 and 2003. The Rappahannock River time series depicts no measurable recruitment in 1980-1981, 1985, 1988, 1991-1992, 1995 and 2002.

With the exception of 2003 data, juvenile index values based on the seine survey are consistently higher on the Mattaponi River than they are on the Pamunkey River and the York River (Table 25). 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 and 2003.

Low or no measurable juvenile abundance in any year could result in a proportional decrease in recruitment of mature fish into the river at age 4 or 5. Figure 20 depicts mean age of females captured by staked gill nets since 1998. With the exception of 1999, mean age increases in the time series, probably reflecting higher survival of mature fishes, especially repeat spawners. In 1999, mean age increased abruptly on all three rivers reflecting the low abundance of age 4 and age 5 fish relative to older cohorts. It is noteworthy that all forms of the juvenile index (push net and seine survey) depict failed or low recruitment on all rivers in 1995, an observation that could be related to the rise in mean age of the 1999 catch of age-4 adults in the monitoring program. Low abundance of juvenile American shad was also observed in 2001 and 2002 surveys of on all rivers. A similar signal (abrupt increase in mean age) in the 2005 and 2006 adult monitoring sample could serve to validate the ability of the JAI to predict years of failed recruitment.

Between-reader aging comparisons

Ages determined from scales by two readers (K. Maki and B. Watkins) are reported in Table 26. In the case of 2000 scale comparisons, the two readers agreed 52.1% of the time when both age and number of spawning marks were considered and 62.5% of the time when only age was considered. The test of symmetry yielded a significant result ($p<0.05$), indicating that there were systematic differences between the readers when they disagreed. In the second trial (2003 scale comparisons), the two readers agreed 59.2% of the time when both age and number of spawning marks were considered and 67.3% of the time when only age was considered. As in the

previous comparison, the test of symmetry yielded a significant value ($p<0.05$) indicating that there were systematic differences between the readers when they disagreed. In both the 2000 and 2003 comparisons, one reader consistently assigned an age that was one year greater than the other reader when they disagreed.

By-catch of striped bass and other species in 2003

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 27-29. Twenty-six species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 23,225 specimens. The most commonly encountered by-catch species were: menhaden (*Brevoortia tyrannus*), gizzard shad (*Dorasoma cepedianum*), striped bass (*Morone saxatilis*), white catfish (*Ictalurus catus*), blue catfish (*Ictalurus furcatus*), channel catfish (*Ictalurus punctatus*), white perch (*Morone americana*), hickory shad (*Alosa mediocris*), Atlantic croaker (*Microponias undulatus*), weakfish (*Cynoscion regalis*) and summer flounder (*Paralichthys dentatus*). Three Atlantic sturgeon were captured and released on the James River in 2003. Patterns of occurrence of by-catch differed between rivers (Figures 21-22). In the York and Rappahannock rivers, catches of menhaden and gizzard shad predominated. In James River, catches of menhaden and striped bass predominated.

The total number of striped bass captured was 5,645 (James River, n= 3,742; York River, n= 1,291; Rappahannock River, n= 612). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 54.1%; York River, 28.9%; and the Rappahannock River, 62.3%.

Seasonal catch indexes, 1980-1992 and 1998-2003

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2003 and for each year of the historical record of staked net catches on each river (Tables 30-32 and Figures 23-28). Seasonal catch indices in 2003 were: York River, 8.98; James River, 9.34; Rappahannock River, 7.10.

Discussion

The staked gill net monitoring program continues to be useful for assessment of the current status of stocks of American shad in Virginia. It is the only direct method available to determine the size of the spawning runs relative to what was obtained in the decades prior to the moratorium. The program also provides information for evaluating the hatchery-based restoration program, validating the juvenile index of abundance and for determining the amount of by-catch that could be expected in a commercial fishery if the in-river fishing ban is lifted. The program will provide required data for the upcoming coast wide stock assessment, scheduled for peer review in early 2005. In June 2004, VIMS scientists will join other scientists in the Chesapeake Bay region to compile data for a regional stock assessment at an ASMFC-sponsored workshop in Baltimore.

Abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in our monitoring gear in recent years (2000-2003) confirm a large scale influx of mature virgin hatchery fish since the James River restoration program began in 1992 (Olney *et al.*,

2003). The age composition of the monitoring catch is consistent with the timing of releases of large numbers of hatchery released fish. While catches of wild American shad have been relatively constant during the six years of monitoring in the James River (200-300 kg annually), the catches of hatchery fish have increased dramatically by two orders of magnitude. Thus, the increase in spawning biomass cannot be attributed to natural production of wild fish. The monitoring data suggest that a continuation of the hatchery program at present levels of production, in combination with fishing moratoria, are effective components of a recovery program for this stock. Additional data on the movements, reproductive behavior and genetic integrity of wild fish in the James River would serve to clarify the effects of the introduced hatchery cohorts on the wild stocks. Reproductive isolation of wild fish from the hatchery-introduced cohorts (and their progeny) could enhance genetic heterogeneity in the stock. Isolation could be achieved if wild cohorts spawn in locations (i.e., down-river of the existing fish passage at Bosher's Dam) that are not chosen by hatchery cohorts. This could be determined through a detailed study of movements, residency and spawning behavior of the stock. Since we cannot distinguish the progeny of hatchery fish using OTC markers, a genetic survey that could identify wild and hatchery components could enhance our understanding of stock dynamics and the extent to which hatchery fish dominate the population.

In 1998, states were required to develop and submit restoration targets for stocks under moratorium. Virginia presented preliminary targets to the Plan Review Team of the ASMFC Shad and River Herring Management Board with the proviso that these targets would be revised as appropriate historical data became available. Criteria to achieve restoration targets were proposed as either:

1) a three-year period during which the catch index remains at or above the target level in the staked gill net monitoring of the spawning run.

2) a three-year period during which the average catch index is above the target level and the target level is exceeded in two of the years

3) a significant increasing trend over a five-year period with the target exceeded in the last two years.

At that time, targets were proposed as the maximum catch index (kg/m per season rounded to the nearest whole number) observed during the 13-y period 1980-1992 (Tables 30-32) These values are: Rappahannock River, 6; York River, 10; and James River, 29.

Voluntary logbooks of catches from the York River exist in the archives of the Department of Fisheries Science (Figure 29). These historical records from the 1950s form the basis for the gear comparison trials conducted in 2002 and 2003 in the York River. 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. This adjustment of the 1950s data yields revised restoration targets for the York River stocks as depicted in Figure 30. The 1950s data (Table 19) include two years of a high index (26-33), two years of a moderate index (14) and one low index year (8.7, 1955). Rather than using a maximum catch index of 10 observed in the 1980s for the York River, we propose a revised catch index of 19.5, the mean of the catch index values

observed in 1953-1957 (Table 19).

Voluntary log books from the 1950s also exist for the James River. The most extensive data are those of Mr. J. C. Smith who fished staked gill nets on the upper James River in 1954-1957, just above the mouth of the Chickahominy River. Current monitoring on the James River is well below this location, complicating comparisons with Smith's log books. We are continuing to search the microfilm records in hopes of discovering additional data that may be more useful. There are no historic records in department archives for the Rappahannock River. As a result, we have not revised the originally proposed targets for the James and Rappahannock rivers.

On the York River, the seasonal catch index in 2003 was 8.98. During the five years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The average of the historical data during the 1980's on the York River is 3.96. The average of the current monitoring data is higher (11.70) but this average is lower than the average of catch indexes from log book records in the 1950s (19.54). In recent years of monitoring (2000-2003), mean age of females has increased, suggesting higher survival. Our overall assessment of the York River stock is that it has recovered to a level that exceeds its abundance during the 1980s. However, during that period, the stock level was low and incapable of supporting an active fishery. The stock is currently well below the proposed 1950s target (Figure 30) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann 1963).

On the James River, the 2003 index (9.34) is the highest value recorded since 1998 but below the proposed target of 29. Index values in 2000-2003 are higher than those in 1998 and 1999 (1.46 and 1.30, respectively). The average of the historical data during the 1980's on the James River is 8.88. The average of the current monitoring data is lower (5.36). As noted previously, hatchery cohorts are recruiting in high proportions to the population and mean age of females has increased in recent years of monitoring (2000-2003). Our overall assessment for the James River is that the stock remains at a low level of abundance and requires continued protection and restoration.

On the Rappahannock River, the index in 2003 (7.10) is higher than any previous year of monitoring and higher than all years of the historic data. The 1998-2003 average (3.41) is above the average of the historical data (1.76) and the 2003 index is above the proposed target of 6. In recent years of monitoring (2000-2003), mean age of females has increased, suggesting higher survival. 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, although such a decline was reported in the most recent stock assessment (ASMFC 1999). We conclude that present status of the Rappahannock River stock is stable with evidence of increasing abundance. It should be noted that VDGIF personnel began a hatchery-release program on the upper Rappahannock River in spring 2003. The restoration program uses progeny of Potomac River brood stock.

Literature Cited

ASMFC. 1999. Amendment 1 to the Interstate Fishery Management Plan for Shad and River Herring. Fishery Management Rept. No. 35, 76 pp.

Bilkovic, D.M., C.H. Hershner and J.E. Olney. 2002a. Macroscale assessment of American shad spawning and nursery habitat in the Mattaponi and Pamunkey rivers, Virginia. North American Journal of Fisheries Management 22: 1176-1192.

Bilkovic, D.M., J.E. Olney and C.H. Hershner. 2002b. Spawning of American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*) in the Mattaponi and Pamunkey rivers, Virginia. Fishery Bulletin 100: 632-640.

Brown, B. L. and J. M. Epifanio. 1994. Mixed-stock analysis of American shad in Virginia's and Maryland's coastal intercept fisheries. Final report to the VMRC, Sport Fish Restorarion Project F-110-R.

Cating, J.P. 1953. Determining age of Atlantic shad from their scales. U.S. Fish Wildl. Serv. Fish. Bull. 54: 187-199.

Hoenig, J.M., M.J. Morgan and C.A. Brown. 1995. Analysing differences between two age determination methods by tests of symmetry. Canadian Journal of Fisheries and Aquatic Sciences 52: 364-368.

Kriete, W.H. Jr. and J.G. Loesch. 1980. Design and relative efficiency of a bow-mounted pushnet for sampling juvenile pelagic fishes. Transactions of the American Fisheries Society 109(6): 649-652.

Maki, K. L., J. M. Hoenig and J. E. Olney. 2001. Estimating proportion mature at age when immature fish are unavailable for study, with application to American shad (*Alosa sapidissima*) in the York River, Virginia. J. North American Fisheries Management 21: 703-716.

Maki, K. L., J. M. Hoenig and J. E. Olney. 2002. Interpreting Maturation Data for American Shad in the Presence of Fishing Mortality - A Look at Historical Data from the York River, Virginia. J. North American Fisheries Management.

Mansueti, R. J. and H. Kolb. 1953. A historical review of the shad fisheries of North America. MD. Dept. Res. and Educ., Pub. No. 97. 293 pp.

Nichols, P.R. and W.H. Massmann. 1963. Abundance, age and fecundity of shad, York River, VA., 1953-59.

Olney, J.E. 2003a. Monitoring relative abundance of American shad in Virginia's rivers. 2002 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-5, 15 April 2003.

Olney, J.E. 2003b. Incorrect use of the names "Alosidae" and "Alosid" when referring to the

shads in the subfamily Alosinae (Teleostei, Clupeidae). American Fisheries Society Symposium 35: xiii-xv.

Olney, J. E. and J. M. Hoenig. 2000a. Monitoring relative abundance of American shad in Virginia's rivers. 1998 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-1, 24 January 2000.

Olney, J. E. and J. M. Hoenig. 2000b. Monitoring relative abundance of American shad in Virginia's rivers. 1999 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-2, 7 July 2000.

Olney, J. E. and J. M. Hoenig. 2001a. Monitoring relative abundance of American shad in Virginia's rivers. 2000 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-3, 29 April 2001.

Olney, J.E. and J.M. Hoenig. 2001b. Managing a fishery under moratorium: assessment opportunities for Virginia's stocks of American shad (*Alosa sapidissima*). Fisheries 26(2): 6-12.

Olney, J.E., S.C. Denny and J.M. Hoenig. 2001. Criteria for determining maturity stage in female American shad, *Alosa sapidissima*, and the mystery of partial spawning. Bull. Francais de la Pêche et de la Pisciculture 362/363: 881-901.

Olney, J.E. and K.L. Maki. 2002. Monitoring relative abundance of American shad in Virginia's rivers. 2001 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-4, 28 April 2002.

Olney, J.E. and R.S. McBride. 2003. Intraspecific variation in batch fecundity of American shad *(Alosa sapidissima*): revisiting the paradigm of reciprocal trends in reproductive traits. American Fisheries Society Symposium 35: 185-192.

Olney, J.E., D.A. Hopler, Jr., T.P. Gunther Jr., K.L. Maki and J.M. Hoenig. 2003. Signs of recovery of American shad, *Alosa sapidissima*, in the James River, Virginia. American Fisheries Society Special Symposium 35: 323-329.

Stevenson, C. H. 1899. The shad fisheries of the Atlantic coast of the United States. U.S. Commission of Fish and Fisheries, Report of the Commissioner for 1998 XXIV:101-269.

VCF (Virginia Commission of Fisheries). 1875. Annual report for 1875. Richmond, VA. 38 pp.

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

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

201-209.

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

Table 1. Summary of sampling dates, total number and total weight of American shad captured in staked gill nets in the James, York and Rappahannock rivers, spring 2003.

Stock	Sampling dates in 2003	Total females	Total males	Total female weight (kg)	Total male weight (kg)	Total Fish	Total weight (kg)
James River	2/25-5/12	453	179	750.5	235.8	632	986.4
York River	2/25-5/5	376	203	633.1	261.7	579	894.8
Rappahannock River	2/25-5/19	339	100	585.9	131.3	439	717.2
Totals		1,168	482	1,969.5	628.8	1,650	2,598.4

Table 2. Total length, fork length and total weight of post-spawning female American shad taken in staked gill nets in the James, York and Rappahannock rivers, spring 2003. These individuals were removed from the monitoring data.

River	Date	Specimen Number	Total Length (mm)	Fork Length (mm)	Total Weight (g)
James River	5/4/2003	8585	491	430	1054.7
	5/5/2003	8456	525	464	1237.7
	5/5/2003	8457	569	508	1492.2
	5/5/2003	8458	468	414	1216.6
	5/5/2003	8459	543	474	1321.7
	5/11/2003	8595	488	436	1190.7
	5/11/2003	8596	572	512	1597.7
	5/11/2003	8598	542	478	1419.6
Rappahannock River	5/4/2003	8580	566	512	1354.9
	5/5/2003	8443	532	474	1285.1
	5/11/2003	8601	546	478	1238.4
	5/12/2003	8610	518	454	1190
	5/18/2003	8615	548	491	1486
York River	4/21/2003	8214	552	489	1565.3
	4/21/2003	8216	536	474	1437.3
	4/21/2003	8220	521	456	1212.9
	4/21/2003	8225	564	494	1532.2
	4/21/2003	8234	512	451	1645.7
	4/27/2003	8333	527	465	1367.7
	4/27/2003	8335	505	443	1088.6
	4/27/2003	8336	526	460	1181
	4/27/2003	8338	546	480	1377.9
	4/27/2003	8339	540	472	1324.2
	4/27/2003	8340	556	486	1422.8
	4/27/2003	8341	505	439	1095.3
	4/27/2003	8342	528	462	1301.9
	4/27/2003	8343	554	486	1599.4

York River	4/27/2003	8344	450	395	793.4
	4/27/2003	8346	574	512	1496.6
	4/27/2003	8347	546	478	1359.7
	4/27/2003	8348	510	445	1175.9
	4/27/2003	8349	522	464	1145.2
	4/27/2003	8350	548	481	1557.3
	4/27/2003	8351	517	458	1070.8
	4/27/2003	8353	573	508	1541.3
	4/27/2003	8354	549	479	1368.8
	4/27/2003	8356	552	488	1487
	4/27/2003	8358	524	462	1140.7
	4/27/2003	8359	519	456	1155.1
	4/27/2003	8360	548	488	1416.6
	4/27/2003	8361	572	504	1581.1
	4/27/2003	8362	542	476	1320.8
	4/27/2003	8363	474	418	908.4
	4/28/2003	8374	528	466	1294.6
	4/28/2003	8375	551	486	1408.5
	4/28/2003	8376	562	493	1456.4
	4/28/2003	8377	510	456	1261.8
	4/28/2003	8378	576	504	1445.3
	4/28/2003	8379	538	476	1284.1
	4/28/2003	8380	551	489	1345.9
	4/28/2003	8381	538	476	1246.4
	4/28/2003	8382	522	464	1158.9
	4/28/2003	8383	547	478	1332.1
	4/28/2003	8384	534	472	1366.2
	4/28/2003	8385	544	482	1327.5
	4/28/2003	8386	542	482	1253.5
	4/28/2003	8387	535	469	1531.1
	4/28/2003	8388	548	476	1242.8
	4/28/2003	8389	580	522	1709

	4/28/2003	8390	518	457	1272.6
York River	4/28/2003	8391	553	492	1422.6
	4/28/2003	8392	526	462	1236.9
	4/28/2003	8393	538	477	1451.4
	4/28/2003	8394	534	468	1278.1
	4/28/2003	8395	520	460	1241
	4/28/2003	8396	545	478	1397.5
	4/28/2003	8397	548	482	1443.4
	4/28/2003	8398	540	472	1338.7
	4/28/2003	8399	514	454	1332.3
	4/28/2003	8400	505	451	993.6
	4/28/2003	8401	537	473	1220.9
	4/28/2003	8402	564	492	1550.8
	5/4/2003	8502	533	474	1383.9
	5/4/2003	8503	586	518	1729.4
	5/4/2003	8505	543	482	1284.7
	5/4/2003	8507	540	471	1395.1
	5/4/2003	8508	553	490	1451.6
	5/4/2003	8509	516	454	1081.7
	5/4/2003	8510	528	466	1176.9
	5/4/2003	8511	522	464	1362.9
	5/4/2003	8512	536	472	1361.2
	5/4/2003	8513	532	474	1279.8
	5/4/2003	8514	556	490	1421.4
	5/4/2003	8515	536	474	1290.3
	5/4/2003	8516	516	454	1061
	5/4/2003	8517	511	442	958.9
	5/4/2003	8518	558	488	1518.8
	5/4/2003	8520	556	492	1448.8
	5/4/2003	8521	531	474	1267.2
	5/4/2003	8522	536	476	1362.3
	5/4/2003	8523	552	489	1368.6

	5/4/2003	8524	548	485	1336.3
	5/4/2003	8525	538	482	1361.7
York River	5/4/2003	8526	544	488	1346.9
	5/4/2003	8527	562	498	1397.9
	5/4/2003	8528	558	488	1535.1
	5/4/2003	8530	575	509	1444.6
	5/4/2003	8531	544	482	1285.9
	5/4/2003	8532	524	454	1119.4
	5/4/2003	8533	525	462	1186.4
	5/4/2003	8534	542	478	1371.1
	5/4/2003	8535	580	508	1629
	5/4/2003	8536	544	479	1329.5
	5/4/2003	8538	536	474	1356.9
	5/4/2003	8539	508	453	1174.4
	5/4/2003	8540	566	500	1756.7
	5/4/2003	8541	525	464	1298.9
	5/4/2003	8542	482	424	983
	5/4/2003	8543	482	429	956.2
	5/4/2003	8544	536	476	1205
	5/4/2003	8545	528	468	1305.8
	5/4/2003	8546	536	465	1331.9
	5/4/2003	8547	548	484	1507.5
	5/4/2003	8548	565	502	1481.6
	5/4/2003	8549	528	471	1218.1
	5/4/2003	8550	527	471	1221.7
	5/4/2003	8552	530	468	1413.7
	5/4/2003	8553	540	480	1293.3
	5/4/2003	8554	582	514	1719.5
	5/5/2003	8469	552	487	1181.8
	5/5/2003	8470	524	456	1097.8
	5/5/2003	8471	542	472	1307
	5/5/2003	8472	512	450	1231.3

	5/5/2003	8474	555	486	1373.7
	5/5/2003	8480	528	470	1464.8
	5/5/2003	8481	550	490	1362.2
York River	5/5/2003	8482	533	472	1351
	5/5/2003	8483	492	432	970.1
	5/5/2003	8484	570	499	1468.3
	5/5/2003	8485	555	498	1525.7
	5/5/2003	8486	544	488	1299.7
	5/5/2003	8488	551	488	1329
	5/5/2003	8491	547	482	1462
	5/5/2003	8492	552	495	1332.5
	5/5/2003	8493	528	471	1341.2
	5/5/2003	8494	560	495	1562.8
	5/5/2003	8495	522	462	1225.9
	5/5/2003	8497	530	464	1218.4
	5/5/2003	8498	521	464	1327.2
	5/5/2003	8499	536	474	1167.7

Table 3. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the James River, spring 2003.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2003	56	4	0.086	7,082.8	0.025
2/26/2003	57	3	0.066	5,098.8	0.019
3/2/2003	62	4	0.089	6,299.7	0.023
3/3/2003	63	3	0.066	5,176.5	0.019
3/9/2003	69	10	0.223	20,074.7	0.075
3/10/2003	70	13	0.284	24,623.0	0.090
3/16/2003	76	33	0.693	59,955.1	0.210
3/17/2003	77	31	0.678	54,252.7	0.198
3/23/2003	83	31	0.678	52,282.7	0.191
3/24/2003	84	37	0.809	58,832.3	0.214
3/30/2003	90	53	1.030	87,797.5	0.284
3/31/2003	91	25	0.547	37,768.8	0.138
4/6/2003	97	29	0.634	49,198.2	0.179
4/7/2003	98	45	0.984	71,007.7	0.259
4/13/2003	104	21	0.459	34,668.2	0.126
4/14/2003	105	19	0.416	31,752.0	0.116
4/21/2003	112	21	0.459	33,775.8	0.123
4/22/2003	113	20	0.437	32,396.8	0.118
4/27/2003	118	13	0.279	19,919.0	0.071
4/28/2003	119	16	0.357	24,666.7	0.092
5/4/2003	125	9	0.201	14,989.6	0.056
5/5/2003	126	9	0.197	12,543.9	0.046
5/11/2003	132	2	0.037	2,875.8	0.009
5/12/2003	133	2	0.050	3,510.9	0.015
Totals		453		750,549.2	

Table 4. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the James River, spring 2003.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2003	56	12	0.257	15929.7	0.057
2/26/2003	57	2	0.044	2725.3	0.010
3/2/2003	62	6	0.134	7517.2	0.028
3/3/2003	63	3	0.066	4319.8	0.016
3/9/2003	69	15	0.335	19501.5	0.073
3/10/2003	70	19	0.416	23830.8	0.087
3/16/2003	76	34	0.714	46958.0	0.164
3/17/2003	77	26	0.569	33866.8	0.123
3/23/2003	83	23	0.503	30278.7	0.110
3/24/2003	84	11	0.241	15650.0	0.057
3/30/2003	90	8	0.156	9947.3	0.032
3/31/2003	91	2	0.044	2831.0	0.010
4/6/2003	97	4	0.087	4560.8	0.017
4/7/2003	98	5	0.109	6194.0	0.023
4/13/2003	104	2	0.044	3019.1	0.011
4/14/2003	105	2	0.044	2267.9	0.008
4/21/2003	112	2	0.044	2172.8	0.008
4/22/2003	113	2	0.044	3061.8	0.011
4/28/2003	119	1	0.022	1201.2	0.004
Totals		179		235833.7	

Table 5. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the York River, spring 2003.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2003	56	1	0.022	1,384.1	0.005
2/26/2003	57	9	0.197	16,308.3	0.059
3/2/2003	62	3	0.066	4,458.2	0.016
3/3/2003	63	12	0.214	18,544.4	0.055
3/9/2003	69	13	0.284	21,853.6	0.080
3/10/2003	70	14	0.306	24,807.9	0.090
3/16/2003	76	24	0.525	46,342.4	0.169
3/17/2003	77	25	0.547	46,526.5	0.170
3/23/2003	83	33	0.815	54,806.2	0.226
3/24/2003	84	38	0.831	63,741.2	0.232
4/4/2003	95	65	1.422	106,986.5	0.390
4/5/2003	96	28	0.639	45,917.7	0.175
4/6/2003	97	22	0.481	34,774.5	0.127
4/7/2003	98	16	0.350	25,722.3	0.094
4/14/2003	105	13	0.284	22,675.4	0.083
4/15/2003	106	17	0.372	28,565.3	0.104
4/20/2003	111	12	0.262	20,149.4	0.073
4/21/2003	112	16	0.350	26,508.7	0.097
4/27/2003	118	8	0.181	12,536.8	0.047
5/4/2003	125	3	0.043	4,234.3	0.015
5/5/2003	126	4	0.084	6,244.4	0.022
Totals		376		632,038.9	

Table 6. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the York River, spring 2003.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2003	56	18	0.394	23,149.9	0.084
2/26/2003	57	16	0.350	20,919.4	0.076
3/2/2003	62	5	0.109	7,350.7	0.027
3/3/2003	63	19	0.338	24,945.1	0.074
3/9/2003	69	16	0.350	20,209.7	0.074
3/10/2003	70	15	0.328	19,957.6	0.073
3/16/2003	76	15	0.328	20,088.8	0.073
3/17/2003	77	22	0.481	29,294.7	0.107
3/23/2003	83	13	0.321	16,685.3	0.069
3/24/2003	84	22	0.481	28,752.4	0.105
4/4/2003	95	7	0.153	9,156.2	0.033
4/5/2003	96	3	0.068	3,577.2	0.014
4/6/2003	97	6	0.131	7,714.7	0.028
4/7/2003	98	4	0.087	4,983.4	0.018
4/14/2003	105	2	0.044	2,830.9	0.010
4/15/2003	106	1	0.022	1,145.6	0.004
4/20/2003	111	1	0.022	981.2	0.004
4/21/2003	112	4	0.087	5,287.9	0.019
4/27/2003	118	2	0.045	2,210.8	0.008
5/4/2003	125	6	0.129	6,101.5	0.022
5/5/2003	126	6	0.125	6,365.7	0.022
Totals		203		261,708.7	

Table 7. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2003.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/9/2003	69	1	0.004	1,604.6	0.006
3/10/2003	70	1	0.004	2,225.1	0.008
3/16/2003	76	7	0.025	13,552.3	0.049
3/17/2003	77	3	0.011	5,856.6	0.021
3/23/2003	83	5	0.018	9,080.8	0.033
3/24/2003	84	15	0.054	30,866.3	0.111
4/2/2003	95	42	0.151	77,834.9	0.280
4/3/2003	96	50	0.180	86,363.2	0.311
4/6/2003	97	37	0.133	59,958.4	0.216
4/7/2003	98	23	0.072	38,314.1	0.120
4/13/2003	105	21	0.072	35,291.7	0.121
4/14/2003	106	29	0.104	49,483.8	0.178
4/20/2003	111	14	0.050	25,108.1	0.090
4/21/2003	112	16	0.051	25,983.1	0.083
4/27/2003	118	5	0.021	7,787.2	0.033
4/28/2003	119	9	0.031	14,759.5	0.051
5/4/2003	125	27	0.095	46,363.7	0.163
5/5/2003	126	22	0.079	37,130.0	0.134
5/11/2003	132	2	0.007	2,776.5	0.010
5/12/2003	133	7	0.025	11,432.5	0.041
5/18/2003	139	2	0.007	2,682.6	0.010
5/19/2003	140	1	0.004	1,469.3	0.005
Totals		339		585,924.3	

Table 8. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2003.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/9/2003	69	2	0.008	2,384.1	0.009
3/10/2003	70	3	0.011	4,359.4	0.016
3/16/2003	76	4	0.014	5,507.8	0.020
3/17/2003	77	2	0.007	2,955.1	0.011
3/23/2003	83	5	0.018	7,279.0	0.026
3/24/2003	84	10	0.036	14,341.2	0.052
4/2/2003	95	19	0.068	24,024.6	0.086
4/3/2003	96	34	0.122	43,861.7	0.158
4/6/2003	97	2	0.007	2,020.3	0.007
4/7/2003	98	3	0.009	4,100.9	0.013
4/13/2003	105	7	0.024	8,756.5	0.030
4/14/2003	106	2	0.007	2,731.7	0.010
4/20/2003	111	1	0.004	1,411.5	0.005
4/21/2003	112	3	0.010	3,701.7	0.012
4/27/2003	118	1	0.004	1,210.7	0.005
5/4/2003	125	1	0.004	1,420.0	0.005
5/12/2003	133	1	0.004	1,235.7	0.004
Totals		100		131,301.9	

Table 9. Mean total length (mm) and mean weight (g) of female American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2003. The abbreviation NA is "not aged." Age estimates are based on examination of scales following Cating (1953).

River	Year Class	Number	Mean length	Standard Deviation	Mean Weight	Standard Deviation
James River	NA	23	514.2	32.3	1,541.8	343.4
	2000	2	459.5	16.3	1,240.0	207.0
	1999	52	483.2	20.9	1,389.8	203.1
	1998	225	506.3	22.9	1,577.2	226.4
	1997	113	525.4	21.9	1,779.6	274.1
	1996	33	555.8	24.5	2,039.1	400.4
	1995	10	553.4	16.7	2,050.0	259.1
	1994	2	582.5	19.1	2,476.7	140.2
	1993	1	575.0		2,158.7	
York River	NA	138	535.6	24.3	1,355.4	206.5
	2000	1	462.0		1,155.1	
	1999	27	480.0	18.0	1,319.3	147.4
	1998	150	502.6	22.2	1,549.8	224.9
	1997	114	525.2	24.0	1,785.1	266.4
	1996	51	540.9	22.4	1,913.1	277.0
	1995	18	548.8	19.8	2,001.2	349.4
	1994	3	579.3	32.6	2,341.2	309.6
	1993	1	548.0		1,570.8	
Rappahannock River	NA	15	514.3	34.9	1,511.8	307.0
	1999	35	479.1	22.6	1,388.3	190.3
	1998	174	502.8	20.6	1,590.0	209.2
	1997	72	531.7	23.3	1,897.0	278.4
	1996	31	557.3	21.1	2,174.9	307.3
	1995	12	571.1	22.5	2,351.3	395.2
	1994	5	588.2	15.7	2,464.7	263.1

Table 10. Mean total length (mm) and mean weight (g) of male American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2003. The abbreviation NA is "not aged." Age estimates are based on examination of scales following Cating (1953).

River	Year Class	Number	Mean length	Standard Deviation	Mean Weight	Standard Deviation
James River	NA	6	491.3	23.3	1352.7	215.4
	1999	21	465.8	23.8	1143.3	156.3
	1998	62	469.5	21.7	1201.5	174.1
	1997	58	490.4	20.4	1378.5	200.1
	1996	27	504.9	24.8	1482.2	190.9
	1995	3	506.7	20.0	1563.4	272.3
	1994	2	557.5	2.1	2275.2	49.2
York River	NA	14	486.9	16.9	1366.9	115.6
	2000	1	387.0		493.2	
	1999	9	458.6	19.3	1139.9	145.0
	1998	44	471.4	15.8	1204.2	146.5
	1997	74	487.7	16.5	1314.2	167.2
	1996	53	488.5	15.5	1309.5	172.6
	1995	7	507.7	17.1	1506.1	183.2
	1994	1	530.0		1637.6	
Rappahannock River	NA	4	474.3	17.2	1211.5	135.3
	1999	5	462.2	12.5	1137.5	121.9
	1998	50	475.8	17.8	1243.0	140.5
	1997	20	487.3	14.2	1350.3	137.7
	1996	16	504.3	16.0	1489.6	131.0
	1995	5	512.4	9.9	1556.3	141.5

Table 11. Number, total weight and seasonal catch rates (total number per season per m; total weight per season per m) by year class of female American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 2003. Age estimates are based on examination of scales following Cating (1953). Abbreviations are: NA, not aged.

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James River	2000	2	2.48	24.2	0.0003	0.0004
	1999	52	72.27	24.2	0.0078	0.0109
	1998	225	354.87	24.2	0.0339	0.0535
	1997	113	201.10	24.2	0.0170	0.0303
	1996	33	67.29	24.2	0.0050	0.0102
	1995	10	20.50	24.2	0.0015	0.0031
	1994	2	4.95	24.2	0.0003	0.0007
	1993	1	2.16	24.2	0.0002	0.0003
	NA	23	35.46	24.2	0.0035	0.0053
York River	2000	1	1.16	22.1	0.0002	0.0002
	1999	27	35.62	22.1	0.0045	0.0059
	1998	150	232.47	22.1	0.0247	0.0383
	1997	114	203.50	22.1	0.0188	0.0336
	1996	51	97.57	22.1	0.0084	0.0161
	1995	18	36.02	22.1	0.0030	0.0059
	1994	3	7.02	22.1	0.0005	0.0012
	1993	1	1.57	22.1	0.0002	0.0003
	NA	138	187.04	22.1	0.0228	0.0308
Rappahannock	1999	35	48.59	26.2	0.0048	0.0067
	1998	174	276.67	26.2	0.0239	0.0380
	1997	72	136.59	26.2	0.0099	0.0188
	1996	31	67.42	26.2	0.0043	0.0093
	1995	12	28.22	26.2	0.0016	0.0039
	1994	5	12.32	26.2	0.0007	0.0017
	NA	15	22.68	26.2	0.0021	0.0031

Table 12. Number, total weight and seasonal catch rates (total number per season per m; total weight per season per m) by year class of male American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 2003. Age estimates are based on examination of scales following Cating (1953). Abbreviations are: NA, not aged.

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James River	1999	21	24.01	24.2	0.0032	0.0036
	1998	62	74.49	24.2	0.0094	0.0112
	1997	58	79.96	24.2	0.0087	0.0121
	1996	27	40.02	24.2	0.0041	0.0060
	1995	3	4.69	24.2	0.0005	0.0007
	1994	2	4.55	24.2	0.0003	0.0007
NA		6	8.12	24.2	0.0009	0.0012
York River	2000	1	0.49	22.1	0.0002	0.0001
	1999	9	10.26	22.1	0.0015	0.0017
	1998	44	52.99	22.1	0.0073	0.0087
	1997	74	97.25	22.1	0.0122	0.0160
	1996	53	69.40	22.1	0.0087	0.0114
	1995	7	10.54	22.1	0.0012	0.0017
	1994	1	1.64	22.1	0.0002	0.0003
NA		14	19.14	22.1	0.0023	0.0032
Rappahannock River	1999	5	5.69	26.2	0.0007	0.0008
	1998	50	62.15	26.2	0.0069	0.0085
	1997	20	27.01	26.2	0.0027	0.0037
	1996	16	23.83	26.2	0.0022	0.0033
	1995	5	7.78	26.2	0.0007	0.0011
NA		4	4.85	26.2	0.0005	0.0007

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2003 in the York and James rivers. Table entries are numbers of fish (York River, n = 554; James River, n = 611). Ages are based on scale analysis. Numbers in bold are virgins in year class. Numbers in parentheses are the numbers of fish in the James River (n = 137) with hatchery marks on otoliths. Dashes indicate that age at maturity of individuals in some year classes is yet to be determined. 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
2000	3	**2**	-	-	-	-
1999	4	2	**34**	-	-	-
1998	5	5	78	**111**	-	-
1997	6	7	97	69	**15**	-
1996	7	0	52	40	12	0
1995	8	0	9	10	6	0
1994	9	0	2	1	1	0
1993	10	0	0	1	0	0

		Age at Maturity				
James River Year Class	Age at Capture	3	4	5	6	7
2000	3	**2**(1)	-	-	-	-
1999	4	1(1)	**72**(13)	-	-	-
1998	5	1(0)	75(20)	**211**(32)	-	-
1997	6	5(0)	65(19)	57(22)	**44**(15)	
1996	7	0	22(2)	32(8)	5(0)	**1**(0)
1995	8	0	2(1)	8(1)	3(1)	0
1994	9	0	0	1(0)	3(1)	0
1993	10	0	0	1(0)	0	0

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2003 in the Rappahannock River. Table entries are numbers of fish (n = 426). Ages are based on scale analysis. Numbers in bold are virgins in year class. Dashes indicate that age at maturity of individuals in some year classes is yet to be determined. The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

		Age at Maturity				
Rappahannock River Year Class	Age at Capture	3	4	5	6	7
2000	3	0	-	-	-	-
1999	4	0	**40**	-	-	-
1998	5	0	51	**173**	-	-
1997	6	1	33	41	**18**	-
1996	7	0	25	18	4	0
1995	8	0	4	12	1	0
1994	9	0	2	2	1	0
1993	10	0	0	0	0	0

Table 15. Comparison of catches in multifilament (4.75-in mesh) and monofilament nets (4.88-in mesh) during spring 2002 and 2003. Both nets are constructed with #139 twine-sized material.

Net type in 2002	Sex	Number Caught	Mean Total Length (mm)	Mean Weight (g)
multifilament	male	17	475	1,245
multifilament	female	47	502	1,543
monofilament	male	42	478	1,259
monofilament	female	111	506	1,602
Total		217		

Net type in 2003	Sex	Number Caught	Mean Total Length (mm)	Mean Weight (g)
multifilament	male	12	480	1,223
multifilament	female	47	449	1,615
monofilament	male	24	486	1,319
monofilament	female	77	513	1,638
Total		160		

Table 16. Analysis of parameter estimates for 2002 data from the Poisson main effects model (females only).

Parameter	DF	Estimate	Std Err	Chi Square	Pr>Chi
Intercept	1	-1.1723	0.6024	3.79	0.0517
Week 1	1	1.8315	0.6215	8.69	0.0032
Week 2	1	2.6173	0.5969	20.03	<0.0001
Week 3	1	2.3026	0.6055	14.46	0.0001
Week 4	1	1.8458	0.6213	8.83	0.0030
Week 5	1	1.2993	0.6513	3.98	0.0461
Week 6	1	2.2883	0.6058	14.27	0.0002
Position	1	0.4861	0.1656	8.61	0.0033
Day	1	0.1428	0.1621	0.78	0.3784
Net	1	0.8966	0.1769	25.69	<0.0001

Table 17. Analysis of parameter estimates for 2003 data from the Poisson main effects model (females only).

Parameter	DF	Estimate	Std Err	Chi Square	Pr>Chi
Intercept	1	1.1495	0.3175	13.11	0.0003
Week 1	1	0.8494	0.3087	7.57	0.0059
Week 2	1	0.2385	0.3455	0.48	0.4900
Week 3	1	0.5878	0.3220	3.33	0.0680
Week 4	1	-1.3197	0.5628	5.50	0.0190
Position	1	-0.0528	0.2004	0.07	0.7924
Day	1	-0.2842	0.2022	1.98	0.1598
Net	1	0.5766	0.2084	7.66	0.0057

Table 18. Results of the Poisson main effects model (net type, females only) for 2002 and 2003.

Year	Estimate	p-value	Relative Fishing Power	Standard Error	95% Confidence Interval
2002	0.8966	<0.0001	2.45	0.18	1.72, 3.49
2003	0.5766	0.0057	1.78	0.21	1.17, 2.70
2002 & 2003	0.7703	<0.0001	2.16	0.13	1.65, 2.83

Table 19. Historical catch and effort data of American shad by staked gill nets in the York River, Virginia. Historical data are taken from the voluntary log books of Malvin Green, Aberdeen Creek,Virginia. The data were originally recorded as numbers of female shad per day and converted using average female weight of 3.2 lbs. Catch rates are expressed as female kg/d and multiplied by 2.16 to adjust for the lower fishing power of multifilament nets compared to monofilament nets.

Year	Total females	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve
1953	2161	36.0	56	0.549	0.205	14.88
1954	3046	45.5	54	0.699	0.201	14.04
1955	1643	40.1	55	0.310	0.125	8.70
1956	6835	68.8	85	1.201	0.307	33.95
1957	5645	56.2	65	0.955	0.309	26.14
Mean						**19.54**

Table 20. River of origin, age, number of spawns, fork length (FL), total length (TL), total weight (TW) and sex of American shad with hatchery marks taken in staked gill net monitoring on the James River in 2003. Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953).

Specimen Number	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
7515	97-01 James	3	0	399	448	1,093.6	F
6826	97-01 James	4	0	415	469	1,184.8	M
6873	95-96 James	4	0	428	484	1,355.8	F
6926	97-01 James	4	0	420	475	1,422.8	F
6928	95-96 James	4	0	384	434	917.6	M
7107	95-96 James	4	0	418	475	1,251.9	M
7135	97-01 James	4	0	428	490	1,445.9	F
7181	97-01 James	4	0	432	483	1,246.5	F
7193	97-01 James	4	0	408	464	1,285.7	F
7451	97-01 James	4	0	392	446	1,147.6	F
7461	97-01 James	4	0	425	478	1,354.5	F
7481	95-96 James	4	0	426	486	1,518.7	F
7495	97-01 James	4	0	427	482	1,385.5	F
7874	97-01 James	4	0	414	474	1,221.7	F
6822	97-01 James	5	0	462	526	1,736.8	F
6834	97-01 James	5	0	427	483	1,375.0	M
6956	97-01 James	5	0	432	487	1,277.7	F
6966	97-01 James	5	0	468	536	1,812.5	F
7113	97-01 James	5	0	450	517	1,686.1	F
7159	97-01 James	5	0	468	526	1,666.9	F
7169	97-01 James	5	0	397	456	1,084.9	M
7278	97-01 James	5	0	441	500	1,680.8	F
7310	97-01 James	5	0	392	450	1,023.6	F
7314	97-01 James	5	0	438	502	1,432.0	F
7318	97-01 James	5	0	441	504	1,516.4	F
7324	95-96 James	5	0	448	506	1,606.3	F
7463	97-01 James	5	0	445	512	1,718.0	F

7469	97-01 James	5	0	450	500	1,738.5	F
7475	95-96 James	5	0	448	514	1,677.6	F
7513	97-01 James	5	0	418	474	1,330.3	F
7872	97-01 James	5	0	442	508	1,434.0	F
7884	97-01 James	5	0	446	506	1,557.2	F
7890	97-01 James	5	0	450	520	1,524.3	F
7894	95-96 James	5	0	419	478	1,364.8	F
7908	97-01 James	5	0	433	497	1,484.8	F
8018	97-01 James	5	0	456	528	1,745.3	F
8034	97-01 James	5	0	394	458	1,144.1	M
8048	97-01 James	5	0	436	494	1,486.8	F
8052	95-96 James	5	0	450	516	1,750.2	F
8264	97-01 James	5	0	486	552	2,190.3	F
8274	97-01 James	5	0	418	472	1,313.4	F
8280	97-01 James	5	0	475	536	1,585.0	F
8309	97-01 James	5	0	441	495	1,507.2	F
8317	95-96 James	5	0	462	526	1,550.5	F
8422	97-01 James	5	0	429	486	1,386.0	F
8432	97-01 James	5	0	459	528	1,771.2	F
6687	97-01 James	6	0	427	488	1,378.5	F
6922	95-96 James	6	0	426	484	1,386.7	M
7121	97-01 James	6	0	486	555	2,283.6	F
7517	97-01 James	6	0	475	536	1,910.4	F
7906	97-01 James	6	0	438	495	1,532.6	F
8026	97-01 James	6	0	450	518	1,683.4	F
8046	97-01 James	6	0	462	536	2,026.0	F
8134	97-01 James	6	0	456	526	1,644.0	F
8144	97-01 James	6	0	446	518	1,716.6	F
8148	95-96 James	6	0	456	520	1,845.0	F
8150	97-01 James	6	0	462	522	1,723.9	F
8266	97-01 James	6	0	464	525	1,705.8	F
8412	95-96 James	6	0	494	564	2,259.0	F

8430	97-01 James	6	0	450	514	1,568.3	F
7101	97-01 James	4	1	395	450	1,062.6	M
6701	97-01 James	5	1	392	442	992.7	M
6728	95-96 James	5	1	464	519	1,598.4	F
6867	97-01 James	5	1	449	516	1,448.6	M
6918	97-01 James	5	1	474	539	1,936.3	F
6938	97-01 James	5	1	400	460	1,088.7	M
6946	97-01 James	5	1	420	477	1,214.0	M
6958	97-01 James	5	1	407	464	1,182.0	M
6970	97-01 James	5	1	458	523	1,875.6	F
6974	95-96 James	5	1	490	551	2,017.7	F
7099	97-01 James	5	1	428	487	1,112.0	M
7117	97-01 James	5	1	464	523	1,753.4	F
7177	97-01 James	5	1	436	498	1,434.3	M
7288	97-01 James	5	1	415	468	1,187.1	M
7306	97-01 James	5	1	464	526	1,746.0	F
7312	97-01 James	5	1	428	480	1,507.8	F
7316	95-96 James	5	1	417	475	1,163.8	F
7471	97-01 James	5	1	466	538	1,897.6	F
7521	97-01 James	5	1	435	497	1,345.3	F
8058	97-01 James	5	1	436	492	1,404.2	F
8408	95-96 James	5	1	446	516	1,565.3	F
6752	97-01 James	6	1	466	534	1,923.5	F
6754	97-01 James	6	1	464	530	1,845.7	F
6838	95-96 James	6	1	478	538	1,988.1	F
6840	97-01 James	6	1	414	468	1,315.9	M
6851	97-01 James	6	1	494	554	2,306.9	F
6859	97-01 James	6	1	456	522	1,768.8	F
6865	97-01 James	6	1	462	536	1,959.8	F
6879	95-96 James	6	1	432	486	1,273.1	M
6912	97-01 James	6	1	407	470	1,130.7	M
6916	97-01 James	6	1	492	550	1,977.1	F

6920	97-01 James	6	1	480	546	2,214.6	F
7147	97-01 James	6	1	472	536	1,818.5	F
7167	95-96 James	6	1	469	540	1,875.0	F
7173	95-96 James	6	1	432	483	1,382.4	F
7437	97-01 James	6	1	460	522	1,473.1	F
7455	97-01 James	6	1	416	476	1,292.9	F
7479	95-96 James	6	1	459	518	1,782.7	F
8016	97-01 James	6	1	480	546	1,971.1	F
8030	97-01 James	6	1	466	540	1,863.5	F
8032	95-96 James	6	1	434	503	1,374.0	F
8313	95-96 James	6	1	470	529	1,968.1	F
8416	97-01 James	6	1	452	520	1,232.2	F
6693	97-01 James	6	2	438	494	1,388.1	M
6742	95-96 James	6	2	419	474	1,369.7	M
6744	95-96 James	6	2	474	532	1,983.5	F
6748	97-01 James	6	2	392	446	1,022.5	M
6830	95-96 James	6	2	456	512	1,731.1	F
6849	97-01 James	6	2	431	484	1,333.1	M
6863	97-01 James	6	2	492	560	2,207.0	F
6930	97-01 James	6	2	443	504	1,559.3	M
6934	95-96 James	6	2	425	478	1,355.3	M
6944	97-01 James	6	2	441	506	1,383.5	M
6950	95-96 James	6	2	428	478	1,340.2	M
7137	97-01 James	6	2	446	507	1,502.4	M
7139	97-01 James	6	2	413	464	1,148.3	M
7199	97-01 James	6	2	427	479	1,260.1	M
7290	97-01 James	6	2	449	501	1,750.5	F
7439	95-96 James	6	2	485	546	1,859.2	F
8060	97-01 James	6	2	486	556	1,982.9	F
8136	95-96 James	6	2	466	536	1,905.2	F
8272	97-01 James	6	2	466	526	1,672.5	F
6730	97-01 James	7	2	420	477	1,381.0	M

6732	95-96 James	7	2	516	581	2,422.2	F
6818	95-96 James	7	2	474	548	2,075.3	F
6871	97-01 James	7	2	490	564	2,219.0	F
6932	97-01 James	7	2	411	474	1,219.5	M
6948	95-96 James	7	2	512	572	2,479.3	F
7207	97-01 James	7	2	444	508	1,661.6	F
8428	97-01 James	7	2	490	558	1,521.7	F
6756	94 James	8	2	443	508	1,582.4	M
7294	97-01 James	7	3	451	512	1,549.8	M
8424	95-96 James	7	3	485	554	1,391.3	F
6697	95-96 James	8	3	487	549	2,200.4	F
8022	95-96 James	9	3	527	596	2,575.8	F
6691	95-96 James	8	4	460	526	1,825.7	M

Table 21. Total numbers in seven year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2003. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries.

Hatchery Year Class	Hatchery Production (millions)	1998	1999	2000	2001	2002	2003	Total	Percent Contribution
1992	0.05		1					1	0.2
1993	0.50	7	2	1				10	1.9
1994	1.60	7	3	9			1	19	3.7
1995	5.30			59	9	8	3	79	15.2
1996	5.80			53	62	43	10	168	32.3
1997	5.90			2	27	78	56	163	31.3
1998	10.00					13	52	65	12.5
1999	7.30						14	14	2.7
2000	8.90						1	1	0.2
2001	9.3								
2002	8.4								
2003	8.7								
Total	71.75	14	6	124	98	142	137	520	97.1

Table 22. Age, number of spawns, fork length (FL), total length (TL), total weight (TW) and sex of American shad with York River hatchery marks taken in staked gill net monitoring on the York River in 2003. Age estimates are based on scales following Cating (1953).

Specimen	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
7777	6	1	468	534	2,083.0	female
8255	5	0	456	508	1,672.3	female
8487	7	3	425	480	993.0	male

Table 23. Indexes of abundance of juvenile American shad in pushnet surveys on the Mattaponi and Pamunkey rivers, 1979-2002. Geometric means (GM) and areas under the catch curve (AUC) were estimated from cruise-specific catch rates for each year. Data are not available for 1988-1990. Values are re-calculated from earlier versions of this time series following Wilhite *et al.* (2003).

Year	Mattaponi Mean GM	Pamunkey Mean GM	Mattaponi AUC	Pamunkey AUC	Combined AUC
1979	7.1	5.1	1,163.5	940.5	2,104.1
1980	6.6	1.2	635.8	126.5	762.3
1981	1.2	1.1	343.2	107.1	450.3
1982	4.4	0.6	327.9	32.5	360.4
1983	3.6	1.7	300.1	105.1	405.2
1984	9.5	0.7	446.2	26.6	472.8
1985	10.7	3.3	585.8	143.2	729.0
1986	11.2	3.2	616.5	116.7	733.2
1987	2.6	0.1	229.0	4.8	233.8
1991	1.4	1.8	92.9	128.9	221.8
1992	0.4	0.0	40.7	1.9	42.6
1993	15.2	0.2	973.4	11.0	984.4
1994	14.7	2.2	1,074.0	172.3	1,246.3
1995	4.2	0.9	274.4	87.2	361.6
1996	88.9	14.8	6,325.7	1,082.5	7,408.2
1997	29.8	2.4	2,102.6	169.1	2,271.7
1998	28.6	1.1	2,540.0	89.5	2,629.5
1999	3.0	0.8	301.9	67.9	369.8
2000	57.9	8.8	3,617.7	567.1	4,184.7
2001	55.9	9.8	4,576.6	925.9	5,502.6
2002	8.9	1.8	663.8	136.3	800.1
Mean	**17.4**	**2.9**	**1,296.7**	**240.1**	**1,536.9**

Table 24. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2003) on the James and Rappahannock rivers.. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James River	SD	N	Rappahannock River	SD	N
1980	0		11	0		4
1981	0		12	0		4
1982	0		12	0.88	1.081	16
1983	0		8	0.32	0.549	4
1984	0.09	0.245	8	0.41	0.693	4
1985	0		16	0		8
1986	0		12	0.06	0.200	12
1987	0		16	0.12	0.315	16
1988	0		16	0		20
1989	0		16	0.52	0.894	25
1990	0		16	0.03	0.131	28
1991	0		20	0		31
1992	0		20	0		35
1993	0		20	0.13	0.441	31
1994	0		20	0.05	0.220	34
1995	0		20	0		33
1996	0		20	0.35	0.655	32
1997	0		20	0.16	0.444	35
1998	0.04	0.155	20	0.12	0.341	29
1999	0		20	0.02	0.117	35
2000	0		20	0.03	0.188	34
2001	0		20	0.04	0.163	35
2002	0		20	0		35
2003	0.04	0.155	20	0.59	0.659	28

Table 25. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2003) on the Mattaponi, Pamunkey and York rivers.. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	Mattaponi River	SD	N	Pamunkey River	SD	N	York River	SD	N
1980	1.75	1.059	21	0.51	0.825	9	1.13	1.000	33
1981	0.35	0.564	16	0.33	0.588	16	0.34	0.567	32
1982	13.03	1.256	16	0.51	0.543	12	4.40	1.502	28
1983	2.80	0.954	16	0.63	0.775	12	1.65	0.965	88
1984	16.97	1.125	16	0.06	0.200	12	4.34	1.660	28
1985	7.21	1.369	32	0.56	0.631	24	3.03	1.381	56
1986	0.87	0.902	24	0.00		18	0.43	0.744	42
1987	0.17	0.461	24	0.00		18	0.09	0.354	42
1988	0.00		40	0.00		24	0.00		64
1989	0.41	0.631	40	0.00		32	0.20	0.487	34
1990	0.18	0.473	40	0.00		32	0.09	0.351	76
1991	0.04	0.253	50	0.02	0.111	39	0.03	0.197	94
1992	0.00		39	0.00		32	0.00		75
1993	0.18	0.489	50	0.00		39	0.09	0.365	94
1994	1.69	1.142	50	0.15	0.435	39	0.80	0.977	94
1995	0.03	0.137	50	0.00		40	0.01	0.100	95
1996	14.61	1.352	49	1.97	1.294	39	5.79	1.572	93
1997	2.23	1.107	50	0.36	0.672	40	1.11	1.017	95
1998	2.11	1.206	48	0.06	0.356	38	0.86	1.052	91
1999	0.14	0.407	47	0.00		38	0.07	0.303	88
2000	5.56	1.33	39	0.06	0.23	31	1.76	1.338	74
2001	0.52	0.665	48	0.11	0.296	40	0.30	0.541	94
2002	0.17	0.408	48	0.02	0.11	40	0.09	0.308	93
2003	8.55	1.315	50	13.11	1.057	39	9.04	1.294	94

Table 26. Ages of 48 American shad collected in 2000 and 49 American shad collected in 2003 as determined by two independent readers of scales. Bold numbers are where the two readers agree. Numbers with the same superscript are compared in the test of symmetry.

2000			Reader 2 ages				
Reader 1 ages	3	4	5	6	7	8	9
3	**1**	$0^{(1)}$					
4	$1^{(1)}$	**12**	$11^{(2)}$	$1^{(5)}$			
5		$2^{(2)}$	**8**	$4^{(3)}$			
6		$0^{(5)}$	$0^{(3)}$	**3**	$1^{(4)}$		
7				$1^{(4)}$	**2**		
8						**0**	
9							**1**

2003			Reader 2 ages			
Reader 1 ages	3	4	5	6	7	8
3	**0**	$1^{(1)}$				
4	$0^{(1)}$	**2**	$2^{(2)}$			
5		$0^{(2)}$	**14**	$4^{(3)}$		
6			$0^{(3)}$	**13**	$5^{(4)}$	
7				$1^{(4)}$	**4**	$3^{(5)}$
8					$0^{(5)}$	**0**

Table 27. Daily numbers and seasonal totals of striped bass live or dead (SB) and other species captured by staked gill net in the York River, 2003.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/25/2003	181	57	238	51	289
2/26/2003	116	29	145	29	174
3/2/2003	160	16	176	48	224
3/3/2003	195	63	258	18	276
3/9/2003	45	8	53	140	193
3/10/2003	72	15	87	118	205
3/16/2003	25	8	33	78	111
3/17/2003	13	8	21	123	144
3/23/2003	30	23	53	278	331
3/24/2003	15	16	31	241	272
4/4/2003	17	14	31	549	580
4/5/2003	8	10	18	729	747
4/6/2003	5	14	19	609	628
4/7/2003	3	12	15	944	959
4/14/2003	12	20	32	425	457
4/15/2003	6	15	21	689	710
4/20/2003	6	4	10	473	483
4/21/2003	2	12	14	713	727
4/27/2003	1	4	5	633	638
4/28/2003	4	3	7	985	992
5/4/2003	1	7	8	509	517
5/5/2003		16	16	296	312
Totals	917	374	1,291	8,678	9,969

Table 28. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2003.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/25/2003	210	103	313	35	348
2/26/2003	248	203	451	78	529
3/2/2003	321	159	480	63	543
3/3/2003	220	114	334	82	416
3/9/2003	88	106	194	67	261
3/10/2003	121	160	281	66	347
3/16/2003	83	161	244	60	304
3/17/2003	68	105	173	69	242
3/23/2003	53	94	147	160	307
3/24/2003	46	87	133	385	518
3/30/2003	27	81	108	329	437
3/31/2003	23	46	69	409	478
4/6/2003	9	13	22	172	194
4/7/2003	20	19	39	386	425
4/13/2003	25	41	66	362	428
4/14/2003	26	46	72	261	333
4/21/2003	11	36	47	517	564
4/22/2003	6	32	38	283	321
4/27/2003	6	34	40	410	450
4/28/2003	9	40	49	241	290
5/4/2003	43	97	140	237	377
5/5/2003	29	58	87	226	313
5/11/2003	17	70	87	154	241
5/12/2003	9	119	128	146	274
Totals	1,718	2,024	3,742	5,198	8,940

Table 29. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2003.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/25/03				10	10
2/26/03	3	1	4	7	11
3/2/03	5	1	6	58	64
3/9/03				2	2
3/10/03	1	1	2	4	6
3/16/03	31	20	51	22	73
3/17/03	21	16	37	18	55
3/23/03	11	7	18	3	21
3/24/03	45	45	90	6	96
4/2/03	27	23	50	142	192
4/3/03	16	17	33	99	132
4/6/03	9	14	23	162	185
4/7/03	7	28	35	132	167
4/13/03	11	10	21	140	161
4/14/03	10	14	24	118	142
4/20/03	6	15	21	167	188
4/21/03	10	10	20	145	165
4/27/03	1	6	7	312	319
4/28/03	1	5	6	333	339
5/4/03	8	41	49	369	418
5/5/03	6	44	50	427	477
5/11/03		33	33	316	349
5/12/03	1	19	20	286	306
5/18/03		6	6	257	263
5/19/03	1	5	6	173	179
	231	381	612	3,708	4,320

Table 30. Summary of historical and recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia. Historical data are taken from the voluntary log books of Mr. M. Delano, Urbanna, Virginia. Catch rates are expressed as female kg/d. Duration of the run was not estimated in 1998 since monitoring began late in the season.

Year	Effort (10^3 m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	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
Average of historical data					**1.76**
1998	3.8	----	0.053	0.020	1.46
1999	5.7	42	0.055	0.026	1.30
2000	6.6	73	0.141	0.042	1.75
2001	6.6	72	0.167	0.070	5.77
2002	5.4	57	0.110	0.028	3.08
2003	7.2	72	0.311	0.094	7.10
Average of current data					**3.41**

Table 31. Summary of historical and recent catch and effort data of American shad by staked gill nets in the York River, Virginia. Historical data are taken from the voluntary log books of Mr. R. Kellum, Achilles, Virginia. Catch rates are expressed as female kg/d.

Year	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve
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
Average of historical data					**3.96**
1998	5.7	78	1.080	0.190	14.71
1999	6.3	65	0.209	0.075	5.42
2000	6.7	76	0.276	0.086	7.52
2001	6.3	79	0.627	0.163	12.97
2002	6.7	70	0.306	0.073	7.47
2003	6.0	70	0.390	0.111	8.98
Average of current data					**11.70**

Table 32. Summary of historical and recent catch and effort data of American shad by staked gill nets in the James River, Virginia. Historical data are taken from the voluntary log books of the Brown family, Rescue, Virginia. Catch rates are expressed as female kg/d.

Year	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	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
Average of historical data					**8.88**
1998	3.8	50	0.198	0.051	2.57
1999	6.0	66	0.183	0.042	2.99
2000	7.2	70	0.279	0.086	6.61
2001	6.8	78	0.285	0.064	5.01
2002	6.5	71	0.205	0.054	5.62
2003	6.6	79	0.284	0.112	9.34
Average of current data					**5.36**

Appendix 1 Abstracts of two recent manuscripts on American shad

Migratory behavior of American shad (*Alosa sapidissima*) in the York River, Virginia and a modified analytical model to estimate in-river exploitation from tag-recovery data

John E. Olney, Robert J. Latour, Brian E. Watkins, and Douglas G. Clarke

Abstract

Capture, handling and tagging American shad (*Alosa sapidissima*) may alter migratory behavior of ripening fish, causing some tagged individuals to cease the spawning run and return to sea. In a tagging study designed to assess fishery impacts, this altered behavior would reduce the number of tagged fish available to the target fishery, and result in under-estimation of exploitation rate and fishing mortality. This outcome assumes that the target fishery is prosecuted on ripening fish in the natal river and that tagging takes place in the river below the fishing grounds. To investigate this possibility, 29 pre-spawning adults were fitted with acoustic tags and released in the middle reaches of the York River, Virginia. Movements of individuals were remotely monitored at three hydrophone stations; one seven km downriver of the release site and one on each of the spawning tributaries, 48 and 56 km upriver of the release location. Almost half of the fish were apparently affected by capture, handling and tagging since these individuals either abandoned the migration or were detected at the downriver station and delayed in their upstream movements. All but two individuals were detected at least once at either upriver location. Movements of some fish appeared to be unaffected by capture since they were not detected at the downriver station and were detected on the spawning grounds 2-5 days after release. Eighteen fish remained on the spawning grounds for 17-51 days (average residency, 34.4 days) and were last detected at the downriver location, presumably migrating seaward. Residence time on the spawning grounds declined with successive releases. We were unable to account for eight fish that migrated to the spawning grounds but were not detected again. Fifteen shad (57% of the total that migrated) originally selected spawning grounds on the Mattaponi River; the remaining fish selected the Pamunkey River. One fish resided for several weeks on both tributaries, suggesting some mixing of spawning locations. We conclude that tagging protocols designed to measure the impacts of fishing on American shad should include monitoring to assess altered migratory behavior and losses of tagged fish due to abandonment of migration. Furthermore, analytical methods to assess fishing mortality for American shad require modification and may remain subject to bias imposed by delayed migration.

Six fish and 600,000 thirsty folks - a fishing moratorium on American shad thwarts a controversial municipal reservoir project in Virginia, USA

John Olney, Carl Hershner, Donna Bilkovic, Harry Wang, Lyle Varnell and Roger Mann

Abstract

Moratoria on fishing directly impact fishers, distributors, marketers and consumers of product and can have serious socio-economic implications. Moratoria can impact communities but usually populations closely linked to the banned activity. In an unprecedented example, a moratorium on fishing in Virginia has directly impacted a non-fishing citizenry by thwarting plans for a public utility. In May 2003, a panel empowered to regulate marine resources denied permission to withdraw raw water from a pristine freshwater river, the Mattaponi. The controversial action spoiled a multi-million dollar plan to establish the King William Reservoir, a water source considered essential to future growth and development in the region. The facility was designed to serve a projected 600,000 people in 2040 but the Mattaponi Indians, environmentalists, local citizens and commercial fishers opposed the plan. A central issue was conservation of American shad (*Alosa sapidissima*), an anadromous clupeid native to the U.S. east coast. An in-river moratorium on fishing for American shad imposed in 1994 remains in effect. In the reservoir debate, scientists advised the panel that the project would withdraw water in the center of the larval nursery area for this species and in a river that accounted for the highest statewide production of juveniles. Scientists recommended relocating the intake since losses of larvae to withdrawal could be counter to restoration goals of the moratorium. Using quantitative models of adult equivalency, municipal authorities argued that only six American shad would be lost annually to impingement or entrainment. The panel rejected this argument and proposals to mitigate losses.