4-28-2002

Monitoring Relative Abundance of American Shad in Virginia's Rivers 2001 Annual Report

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Funding Agencies:	US Fish and Wildlife Service and Virginia Marine Resources Commission Virginia Institute of Marine Science
Contract Number:	F-116-R-4
Project Period:	28 February 2001 - 27 February 2002
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Submitted To:

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28 April 2002

Executive Summary

- A staked gill net was set and fished two days per week on the James, York and Rappahannock rivers in the spring of 2001. This was the fourth 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 case of the York River, monitoring may allow assessment of current status relative to conditions during the 1950's.

- Sampling occurred for 13 weeks on the James River (18 February - 14 May 2001) and 12 weeks on the York and Rappahannock rivers (25 February - 21 May 2001). A total of 1,211 female American shad (1,705 kg total weight) was captured. The 2001 catch was larger than the catch in 1999 (575 females weighing 796 kg) and 2000 (904 females weighing 1,299 kg).

- Total numbers of females in 2001 were highest on the York River (n= 677). Equal numbers of females were captured on the James and Rappahannock rivers (n= 267). As in previous years, total numbers of males were low on all rivers (York, 43; James, 20; Rappahannock, 61). The total weight of all males captured was 144 kg.

- Based on age estimates from scales, the 1996 and 1997 year classes of female American shad were the most abundant on the James and Rappahannock rivers with age-specific seasonal catch rates exceeding 0.01 kg/m. On the York River, the 1995, 1996 and 1997 year classes were the most abundant (age-specific seasonal catch rates exceeding 0.01 kg/m). Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 1.07; James River, 1.35; and Rappahannock River, 1.29.

- Otoliths of all American shad captured in staked gill nets on the James River were scanned for hatchery marks and otoliths of 186 specimens captured on the York River were scanned. The proportion of the sample with hatchery marks on the James and York rivers was 40.2 % (103 of 256 fish) and 4.8 % (9 of 186 fish), respectively. In 1998 and 1999, prevalence of hatchery fish on the James River was low (4-8 %). The evidence suggests that the increase in catch rates observed on the James River in 2000 and 2001 is due to the first large-scale influx of mature hatchery fish since the restoration program began.

- Otoliths of 288 juvenile American shad collected during pushnet cruises in 2001 on the Pamunkey River were scanned for hatchery marks. The proportion of the sample with hatchery marks was 6.6 % (19 of 288 fish). By comparison, the proportion of the 2000 sample with hatchery marks was 7.0 % (7 of 100 fish) and the proportion with hatchery marks in 1999 was 6.0 % (3 of 50 fish).

- The geometric mean catch of juvenile American shad (based on weekly summer pushnet surveys) was 55.9 on the Mattaponi River and 9.8 on the Pamunkey River. The combined

integrated catch index for the York system (both the Pamunkey and Mattaponi rivers) was the second highest value observed thus far in the time-series average (average, 1,367.5; 2001 value, 5,502.6).

- Twenty-six species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 23,636 specimens. The total number of striped bass captured was 3,021 (James River, n= 1,093; York River, n= 889; Rappahannock River, n= 1,039) . Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 47.9 %; York River, 38.0 %; and the Rappahannock River, 40.9 %.

- A total of 110 American shad were tagged and released in the York River near Penniman Spit between 21 February and 27 March 2001. Five fish were recaptured after 8-29 days at large. Four fish were recaptured by drift net on the Mattaponi (n=3) and Pamunkey rivers (n= 1). In addition, one fish was captured by a recreational angler on the Delaware River near Yardley, Pa.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2001 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 2001 (12.97) was higher than the index in 2000 (4.82) and 1999 (4.85) and close to the 1998 value (13.47). The average of the historical data on the York River is 3.96. On the James River, the 2001 index (5.01) was less than the 2000 value (6.61) and higher than the values in 1999 and 1998 (2.57 and 2.99, respectively). The average of the historical data on the James River is 8.88 . The catch index on the Rappahannock River in 2001 (5.77) was higher than those obtained in previous years of monitoring (2000, 1.75; 1999, 1.30; 1998, 1.46). The average of the historical data on the Rappahannock River is 1.76.

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 in the Anadromous Fishes Program of 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.

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 fourth year in the sampling program (2001) are reported in this document. The results of the first three years of sampling (1998-2000) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b; Olney and Hoenig 2001a) .

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 in the York River system. This juvenile index 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 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).

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 is not well understood although recent evidence suggests that large numbers of mature hatchery fish are returning to the James River (Olney *et al.*, in press). In general, prevalence of hatchery fish returning as adults to the York system is low (~4 % each year; Olney and Hoenig 2000a, 2000b, 2001a). Annual monitoring of the abundance of juvenile *Alosa* (American shad, hickory shad, blueback herring and alewife) has been conducted annually on the Pamunkey River system since 1979. Since 1995, juveniles bearing the OTC mark have been collected. The data show that hatchery-released 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.

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) is conducted on the York River system with a pushnet developed in the late 1970s (Kriete and Loesch, 1980). Because of the negative phototropic behavior of juvenile *Alosa* (Loesch *et al*., 1982; Dixon, 1996), the pushnet is used at night to determine catch-per-unit-of-effort. The data record extends back to1979 but sampling was not conducted during 1987-1990. Pushnet sampling resumed in 1991 and survey methods were changed to include more stations and more cruises during each year. Thus, the most recent results (1990-2001) are not comparable to the older results (1979-1986). These data can be accessed through the VIMS website (http://www.fisheries.vims.edu/research.htm). Our progress towards validation of the index of juvenile abundance is summarized by Wilhite *et al.* (in press). Since our monitoring program began, eight papers on various aspects of the biology of American shad and the VIMS stock assessment program have been accepted or have appeared in peer-reviewed journals (Maki *et al.*, 2001a; Olney *et al.*, 2001; Olney and Hoenig, 2001b, Maki *et al.*, in press; Olney and McBride, in press; Olney *et al.*, in press; Walter and Olney, in press; Wilhite *et al.*, in press). Pre-prints or reprints of these papers are available on request.

Objectives

The primary objectives of the monitoring program have remained 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; (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 based on pushnet surveys in the York River system to relative year-class strength of spawning adults; and (5) to determine the amount of by-catch of other species in the staked gill nets.

Methods

The 2001 sampling methods were the same as those in 1998-2000. 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. Mark 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 each river (Figures 5-7). 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, high winds prevented the regularly scheduled sampling on Sunday and Monday, and sampling was either postponed or canceled. Sampling occurred for 13 weeks on the James River (18 February - 14 May 2001) and 12 weeks on the York and Rappahannock rivers (25 February - 21 May 2001). Surface water temperature was recorded at each sampling event.

We also sought to compare catch rates of American shad in multifilament nets (those used by fishers in the 1950s) with monofilament nets (those used by fishers just prior to the recent moratorium) to determine a calibration factor that can be used to adjust historic catch and effort data from the 1950s, and establish an appropriate restoration target for American shad stocks in Virginia. During March and April 2001, 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. On the first day, we randomly chose which location (shore side or channel side) got the old (multifilament) net type. 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. 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 ç 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; and $å_{hijk}$ 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, $\_\_{old}$:

$$H_o: \_\_{new} \leq \_\_{old}$$

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

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 the VDGIF (Mr. Dave Hopler) assisted in this evaluation.

Microchemical analyses of otoliths performed in 2000 to validate scale spawning marks were inconclusive, potentially due to mechanical error. To test this, we obtained four Hudson River American shad otoliths from Dr. Karin Limburg who had previously analyzed these otoliths utilizing a different wavelength dispersive electron microprobe (Cornell University, New York) than the one utilized by our 2000 analysis (University of Maryland, College Park, Maryland in cooperation with David Secor). These otoliths were re-polished and coated with carbon. Point measurements were taken across the annuli and x-ray intensities for strontium and calcium were quantified using the microprobe at College Park.

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 (K. Maki, VIMS) using the methods of Cating (1953).

Catch-at-age data were used to determine relative year-class strengths of American shad in the York River. These data can be compared to predictions of year-class strength based on analysis of historical trends in the juvenile index of abundance of American shad in the York River system. Annual surveys of juvenile abundance of alosines are conducted on the York River system with a pushnet developed in the late 1970's (Kriete and Loesch 1980). Because of the negative phototropic behavior of juvenile *Alosa*, the pushnet is deployed at night (Dixon, Goins and Olney 1997). Because the interpretation of indices of abundance is not always straightforward (Hoenig 1995; Aiken 2000), several measures of year class strength were computed.

Catch data from each river was summarized in terms of a standardized catch rate (the area under the curve of catch rate versus time of year). These catch rates were compared to summaries of historical logbook data to provide a measure of the relative size of the current shad runs.

We conducted a preliminary tagging study to determine the feasibility of successfully tagging pre-spawning American shad and releasing fish downstream of the tradition region of historic fishing effort. Commercial fishermen were contracted to fish a research pound net in the York River near Penniman Spit. The pound net was constructed in a traditional manner with a 30x30-ft pound consisting of 2" stretched mesh. The lead and bays are constructed of nets with varying mesh sizes. The pound net was fished at slack tide on a weekly basis following a 24-h or 48-h set of the gear. After fishing, the funnel of the pound was secured so that the trap did not fish. Scientists accompanied commercial fishermen and handled the catch of American shad. Each week, the pound net was fished on two days. On day 1, we determined the sex and maturity of the entire catch of American shad in a separate study to validate new methods of stock assessment. On day 2, the entire catch of shad was tagged and released. Since our intention was to tag only ripening fish on the up-migration to the spawning grounds, we ceased tagging when the composition of the pound net catch included fish that were spent or partially spent (i.e., fish that were on the down-migration away from the spawning grounds). Scales were removed from each tagged fish before release. In addition, fork length and tagging condition was recorded. On several occasions, part of the catch was used for a holding study. Fish were tagged and held in large, octagonal or circular, *in situ* holding pens. These tagged American shad were used to determine short-term tag loss and tag-induced mortality (but not released for recapture). We used red, conventional dart tags (Floy Tag Manufacturing Company) inserted in the dorsal musculature. These tags are currently being used by South Carolina in studies of fishing rate by recreational and commercial fishers. The tag bears a unique identifying number and a toll-free (800) telephone number of the Anadromous Fishes Research Program, Virginia Institute of Marine Science. A $50 reward was be offered for the return of each tag.

Results

Catches of American shad by staked gill nets in 2001

Fishing days, numbers of American shad captured, and catch rates (males and females) are reported in Tables 1-7 and Figures 8-9. A total of 1,335 American shad (124 males:1,211

females) were captured. The total weight of the sample was 1,848.8 kg. The 2001 catch was higher than that in 2000 when a total of 1,080 fish were captured and the total weight was 1,507.3 kg (Olney and Hoenig 2001a). Catches in 2001 were lowest on the James River (287 total fish, 20 males and 267 females), higher on the Rappahannock River (328 total fish, 61 males and 267 females) and highest on the York River (720 total fish, 43 males and 677 females).

On the James River, catches of females peaked on 1-9 April 2001 when catch rates exceeded 0.09 fish/m or 0.13 kg/m. During that period on the James River, 55.1 % (147 of 267) of the total number of females was captured. On the York River, catches of females peaked between 11 March and 15 April 2001 when catch rates exceeded 0.09 fish/m or 0.18 kg/m. During that period on the York River, 87.8 % (595 of 677) of the total number of females was captured. Catches of females on the Rappahannock River peaked between 20 March and 8 April 2001 when catch rates exceeded 0.09 fish/m or 0.13 kg/m. During that period on the Rappahannock River, 60.6 % (162 of 267) of the total number of females was captured. The highest recorded daily catch by weight occurred on 2 April 2001 when 123 female American shad (168.5 kg) were taken in the York River (Table 4). As in previous years of monitoring, numbers and catch rates of males were low throughout the period on all rivers.

The duration of the 2001 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 78 days on the James River (4 March - 7 May), 79 days on the York River (25 February - 14 May) and 72 days on the Rappahannock River (26 February - 14 May).

Biological characteristics of the American shad in 2001

Age, length (mm TL) and weight (g) of American shad in staked gill nets are summarized in Tables 8-9 and frequency distributions of total length are depicted in Figures 10-11. Mean total length at age of males and females ranged from 362-516 mm TL and 424-588 mm TL, respectively. Mean weight at age of males and females ranged from 0.47-1.44 kg and 0.95-1.99 kg, respectively.

Overall, the 1996 and 1997 year classes (ages 4 and 5) of female American shad were the most abundant on all three rivers (Tables 8-11). In all three rivers, more than one third of the total catch were age-5 or older. On the James River, seven age classes of females were represented (1992-1998) and the sample was dominated by age-5 fish (49.2 % of the total that were aged). Similarly on the York River, seven age classes of females were represented (1992-1998) and the sample was dominated by age-5 fish (45.1 % of the total that were aged). On the Rappahannock River, six age classes of females were taken (1992-1997) and age-5 fish dominated (55.4 % of the aged sample). Males were infrequently collected on the James and York rivers and no age class dominated. The 1996 year class (age 5) of male American shad was most abundant on the Rappahannock River.

Age-specific catch rates of American shad are reported in Tables 10-11 and depicted in Figure 12. 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. Estimates of Z for females for each stock were: James, 1.35 (r^2= 0.96); York, 1.07 (r^2= 0.97); and

Rappahannock, 1.29 (r^2= 0.92). Mortality of males was not estimated in 2001.

Spawning histories of American shad collected in 2001 are presented in Tables 12-13. On all rivers, fish (both sexes combined) ranged in age from 3-9 years with 0 (virgin) to 5 spawning marks. The following percentages in each river had a least one prior spawn: York River, 38.8 % (381 virgins in a sample of 623); James River 33.8 % (172 virgins in a sample of 260 fish); Rappahannock River 40.9 % (166 virgins in a sample of 281 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 % (Olney and Hoenig 2000a, 2000b, 2001a).

Microchemical results from the analysis of otoliths obtained from the Hudson River approximated those obtained by Dr. Limburg's analysis (Figure 13). Thus, we conclude from this comparative analysis that the inconclusive results obtained for the York River shad otoliths in 2000 were not due to mechanical error. It remains possible that otolith growth during freshwater incursion of York River shad is minimal and less than the resolution capabilities of the microprobe. These observations require further study.

Comparison of multifilament and monofilament nets

Catches in the comparison nets totaled 51 shad, 49 of which were females (Table 14). While mean lengths and weights were similar between the old (multifilament) and new (monofilament) nets, catches of females appeared to be somewhat higher in the monofilament net (30 females) than in the multifilament net (19 females). Mean age (5.1 yrs) was the same in both nets.

A Poisson main effects model yielded a significant difference in catch between the two net types (p=.04; Table 15). We also fitted a model with interactions. None of the interactions with the type of net were significant so this model was not considered further. The estimated effect of the monofilament net relative to the multifilament net (in essence, the log relative risk) was 0.6321. This value can be converted into a relative fishing power by exponentiating. Thus, the expected ratio of catches (current catch rates to historical catch rates) is exp(0.6321) = 1.88. In other words, the monofilament net appears to catch 88% more than the multifilament net used in the 1950s. The standard error (0.31) is quite large and the 95% confidence interval on the relative fishing power (exp(0.6321 ± 2*0.31)) is (1.01, 3.50). Thus, the monofilament net appears more efficient than the multifilament net, although the estimated relative efficiency has low precision. These data are preliminary and we plan to continue these comparison trials in 2002.

Evaluation of hatchery origin of American shad in 2001

James River - Otoliths of all American shad captured in staked gill nets on the James River were scanned for hatchery marks. The proportion of the 2001 sample with hatchery marks was 40.2 % (103 of 256 fish). The biological attributes of these specimens are presented in Table 16. 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 remained near that level in 2001 (40.2 %, 103 of 256). 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).

Most hatchery-reared adults taken in 2000 and 2001 had OTC marks on either daily ring 5 or daily ring 6, indicating that these specimens were released in 1995 or 1996. 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. 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=7) 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. In our 2000 and 2001 staked gill net catches, hatchery-reared fish were ages 3-7 (released as fry in 1992-1998), with the highest numbers released in 1995-1997. During 1995-1997, hatchery production exceeded 5 million fry released annually. The 1996 year class of hatchery-reared American shad was well represented in both 2000 and 2001. The 1995 year class was abundant in 2000 but its numbers decreased in 2001. The 1997 year class first appeared in moderate numbers in 2001, suggesting that additional recruitment might be expected in succeeding years.

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. Almost 34 % of all fish in the combined sample from the two years were repeat spawners (2000, 28.2 %; 2001, 39.8 %).

York River - Otoliths of 186 specimens captured on the York River were scanned for hatchery marks. The proportion of the sample with marks was 4.8 % (9 of 186 fish). The biological characteristics of these specimens is reported in Table 17. By comparison, the proportion of the 2000 sample with hatchery marks was 2.2% (4 of 180 fish)

Otoliths of 288 juvenile American shad collected during pushnet cruises in 2001 on the Pamunkey River were scanned for hatchery marks. The proportion of the sample with hatchery marks was 6.6% (19 of 288 fish). By comparison, the proportion of the 2000 sample with hatchery marks was 7.0% (7 of 100 fish) and the proportion with hatchery marks in 1999 was 6.0% (3 of 50 fish).

Juvenile abundance of American shad

Table 18 reports several forms of an index of juvenile abundance of American shad from the York River system. Traditionally, the juvenile index in Virginia has been reported as maximum geometric mean catch rate. However, the results of a recent analysis (Wilhite et al, in press) 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. The time series of the combined area under the catch curve for both rivers depicts above average (>1,367.5) 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 and 1999 (Figure 14).

By-catch of striped bass and other species in 2001

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 19-21. Twenty-six species of by-catch were captured. 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*). Eight Atlantic sturgeon were captured (James River, 7; York River, 1). Patterns of occurrence of by-catch differed between rivers (Figure 15). In the Rappahannock River, catches of menhaden predominated. In the York and James rivers, catches of gizzard shad predominated.

The total number of striped bass captured was 3,021 (James River, n= 1,093; York River, n= 889; Rappahannock River, n= 1,039) . Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 47.9 %; York River, 38.0 %; and the Rappahannock River, 40.9 %.

Seasonal catch indexes, 1980-1992 and 1998-2001

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2001 and for each year of the historical record of staked net catches on each river (Tables 22-24 and Figures 16-21). Seasonal catch indices in 2001 were: York River, 12.97; James River, 5.01; Rappahannock River, 5.77.

2001 Tagging study

A total of 110 pre-spawning American shad were tagged and released in the York River from 21 February to 27 March 2001. Dates and numbers released were: 2/21, 1; 3/1, 8; 3/16, 24; 3/23, 36; 3/27, 41. Five fish were recaptured by drift net on the Mattaponi (n=3) and Pamunkey rivers (n= 1). In addition, one fish was captured by hook and line on the Delaware River near Yardley, Pa (Table 24). One holding study was conducted to examine tag retention and tag-induced mortality. Seven fish were tagged and held with four untagged fish for 48-h between 23-25 March 2001. All fish survived and were released.

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 method available to determine the size of the spawning runs relative to what was obtained in the decade prior to the moratorium. The program also provides information for evaluating the 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 coincident observations of abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in our monitoring gear suggests the first large scale influx of mature virgin hatchery fish since the James River restoration program began in 1992. Furthermore, the age composition of the monitoring catch is consistent with the timing of releases of large numbers of hatchery released fish (Olney *et al.*, in press). While catches of wild American shad remained relatively constant during the four years of monitoring in the James River (200-300 kg annually), the catches of hatchery fish increased dramatically by two orders of magnitude. Thus, the increase in spawning biomass cannot be attributed to natural production of wild fish. The time series is short (1998-2001) but the data represent a hopeful sign of recovery for the severely depressed James River stock.

Patterns of maturation observed in hatchery-reared American shad in our 2000 and 2001 samples from the James River reflect maturity schedules predicted for wild fish (Maki *et al.*, 2001a). Most hatchery fish recruited to the monitoring gear at ages 4-5. Annual hatchery releases have remained high since 1995 (millions of fry released since 1997 are: 1998, 10; 1999, 7.3; 2000, 8.9; 2001, 9.3) and portions of only three cohorts (1995-1997) have matured thus far. Given this maturity schedule and assuming constant immature survival, we expect to see a continuation of strong levels of recruitment of virgin hatchery fish into the James River spawning stock, with the first strong appearance of the 1998 hatchery year class in the 2002 monitoring. Furthermore, if these strong cohorts of mature hatchery fish produce viable young that survive at constant rates, then we should see enhanced catches of wild fish (including the unmarked progeny of hatchery cohorts) beginning in 2004-2005. 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.

In 1998, tentative restoration targets and criteria were presented to the Plan Review Team of the ASMFC Shad and River Herring Management Board. 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.

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 22-24) and are as follows: Rappahannock River, 6; York River, 10; and James River, 29.

Suggested supplemental criteria for the Rappahannock, York and James rivers were as follows: (1) duration of the spawning run (defined as the numbers of days between the first and last observation of a catch rate that exceeds 0.01 female kg/m by a staked gill net) must be 50 days; (2) one third of the catch must be five years or older. These criteria would be established as three-year trends during which their terms must be met as judged by research and monitoring of the spawning run.

An additional criterion applicable to the James River and the York River system only, and relating to hatchery supplementation was also proposed. One recommendation was that the proportion of the catch of fish of hatchery origin should not exceed 50% for a period of three years.

Thus far, the proposed targets (Rappahannock River, 6; York River, 10; and James River, 29) have not been reached on either river. On the James River, the index in 2000 and 2001 is higher than historic index values in some years (1982, 1987, 1990, 1991). However, the 1998-2001 average (4.29) is well below the proposed restoration target of 29. Our overall assessment for the James River is that the stock remains at dangerously low levels. We believe that a continuation of the hatchery program in combination with the in-river moratorium is essential for the recovery of the James River stock.

On the Rappahannock River, the index in 2001 is the highest observed since monitoring began in 1998. Throughout the period of monitoring, catch rates are comparable to the historic record. The 1998-2001 average (2.57) is above the average of the historical data (1.76) but below the proposed target of 6. It should be noted that since the catch index for the Rappahannock River is low in the historical data, there is uncertainty about what an appropriate target level should be for this stock. We can conclude that there is little evidence of severe stock decline in the Rappahannock River, as reported by the most recent stock assessment (ASMFC 1999). We conclude that present status of the Rappahannock River stock is stable but low in abundance.

The index on the York River was high in 1998 (13.47), declined sharply in 1999 and 2000, and rose again in 2001 (12.97). The 1998-2001 average of York River index values (9.03) is above the average of the historical data (3.96) and close to the proposed target (10) based on logbook data from the 1980's and early 1990's. Substantial progress has been made towards the development and testing of stock assessment methods for the York River and the determination of appropriate target levels for this stock (Olney and Hoenig 2001b). In particular, comparison trials of nets used in the 1950's with those

used in current monitoring and in the recent logbook data have been conducted. While catches have been low thus far in these comparison trials, trials planned for 2002 include longer nets that should increase the numbers of shad captured. These trials should allow the determination of an efficiency factor that can be used to adjust current catch rates with monofilament nets to those based on catches of multifilament nets in the 1950's (Nichols and Massman 1963). The adjustments will lead to direct comparisons on current catch rates with those from the historic data (Table 26). Once targets are revised, we can evaluate the status of the York River stock relative to a period when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massman 1963).

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Table 1. Summary of sampling dates, total number and total weight of American shad captured in staked gill nets in the James, York and Rappahannock rivers, spring 2001.

Stock	Sampling dates in 2001	Total females	Total males	Total female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	2/18 - 5/14	267	20	378.6	23.7	287	402.3
York River	2/25 - 5/21	677	43	923.5	47.9	720	971.4
Rappahannock River	2/25 - 5/21	267	61	402.5	72.6	328	475.1
Totals		1,211	124	1,704.6	144.2	1,335	1,848.8

Table 2. 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 2001.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/18/2001	1	0.004	1,453.2	0.005
2/19/2001	0	0.000	0.0	0.000
2/25/2001	7	0.027	9,667.6	0.038
2/26/2001	1	0.004	1,151.3	0.004
3/4/2001	5	0.018	7,284.2	0.027
3/11/2001	9	0.038	12,146.8	0.051
3/12/2001	5	0.018	7,295.1	0.027
3/18/2001	18	0.066	26,726.1	0.097
3/19/2001	9	0.033	12,172.5	0.044
3/25/2001	17	0.065	26,415.7	0.100
3/26/2001	14	0.053	19,828.9	0.075
4/1/2001	57	0.208	78,094.4	0.285
4/2/2001	38	0.139	51,877.3	0.189
4/8/2001	24	0.091	34,351.8	0.131
4/9/2001	28	0.102	42,315.9	0.154
4/15/2001	6	0.023	8,355.2	0.032
4/16/2001	4	0.015	5,754.4	0.021
4/22/2001	6	0.022	8,762.1	0.033
4/23/2001	7	0.026	9,794.4	0.036
4/29/2001	3	0.011	4,159.3	0.015
4/30/2001	2	0.008	2,914.9	0.011
5/6/2001	2	0.007	2,521.8	0.009
5/7/2001	3	0.011	4,256.6	0.016
5/13/2001	1	0.004	1,274.0	0.005
5/14/2001	0	0.000	0.0	0.000
Total females	267		378,573.5	

Table 3. 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 2001.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2001	2	0.008	2,466.6	0.010
2/26/2001	1	0.004	1,030.0	0.004
3/4/2001	1	0.004	1,195.8	0.004
3/11/2001	2	0.008	2,183.5	0.009
3/12/2001	2	0.007	2,091.8	0.008
3/18/2001	4	0.015	4,556.1	0.017
3/25/2001	1	0.004	1,166.6	0.004
3/26/2001	1	0.004	1,303.5	0.005
4/2/2001	3	0.011	3,950.2	0.014
4/9/2001	1	0.004	1,154.2	0.004
4/29/2001	1	0.004	1,418.5	0.005
4/30/2001	1	0.004	1,223.0	0.005
Total males	20		23,739.8	

Table 4. 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 2001.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2001	6	0.023	8,463.9	0.032
3/11/2001	43	0.157	61,732.0	0.225
3/12/2001	45	0.164	62,771.9	0.229
3/18/2001	37	0.138	52,368.2	0.195
3/19/2001	71	0.259	96,630.5	0.352
3/25/2001	33	0.134	44,408.4	0.181
3/26/2001	65	0.237	89,255.8	0.325
4/1/2001	95	0.354	128,564.7	0.479
4/2/2001	123	0.458	168,459.3	0.627
4/8/2001	28	0.094	38,866.6	0.131
4/9/2001	30	0.114	41,681.4	0.159
4/15/2001	25	0.097	34,285.2	0.133
4/16/2001	11	0.039	14,629.1	0.052
4/22/2001	4	0.015	5,313.8	0.019
4/23/2001	2	0.007	1,932.6	0.007
4/29/2001	20	0.073	25,441.3	0.093
4/30/2001	25	0.091	29,694.0	0.108
5/6/2001	2	0.007	2,861.2	0.010
5/7/2001	4	0.014	4,843.0	0.017
5/13/2001	2	0.008	2,581.2	0.010
5/14/2001	6	0.022	8,708.8	0.032
5/20/2001	0	0.000	0.0	0.000
5/21/2001	0	0.000	0.0	0.000
Total females	677		923,492.9	

Table 5. 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 2001.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/11/2001	12	0.044	14,055.5	0.05
3/12/2001	9	0.033	11,047.6	0.04
3/19/2001	4	0.015	5,055.0	0.02
3/25/2001	2	0.008	2,445.0	0.01
3/26/2001	1	0.004	980.6	0.00
4/1/2001	3	0.011	3,059.4	0.01
4/2/2001	4	0.015	4,499.0	0.02
4/8/2001	1	0.003	749.6	0.00
4/15/2001	1	0.004	969.8	0.00
4/16/2001	1	0.004	1,002.4	0.00
4/30/2001	5	0.018	4,006.8	0.01
Total males	43		47,870.7	

Table 6. 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 2001.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2001	1	0.004	1,411.9	0.005
2/26/2001	2	0.007	2,799.1	0.010
3/4/2001	10	0.036	14,500.7	0.052
3/11/2001	17	0.061	25,667.7	0.092
3/12/2001	15	0.053	25,396.1	0.089
3/20/2001	25	0.090	35,838.3	0.129
3/25/2001	31	0.112	45,911.5	0.165
3/28/2001	27	0.101	38,900.4	0.146
4/1/2001	24	0.099	36,669.3	0.151
4/2/2001	31	0.112	46,167.9	0.166
4/8/2001	24	0.094	38,131.8	0.150
4/9/2001	10	0.036	16,780.4	0.060
4/15/2001	12	0.043	17,504.1	0.063
4/16/2001	7	0.025	10,397.7	0.037
4/22/2001	6	0.019	8,980.4	0.028
4/23/2001	8	0.029	13,130.7	0.047
4/29/2001	5	0.018	6,956.9	0.025
4/30/2001	3	0.011	4,177.0	0.015
5/6/2001	1	0.004	1,416.4	0.005
5/7/2001	3	0.011	4,216.6	0.015
5/13/2001	0	0.000	0.0	0.000
5/14/2001	5	0.018	7,521.7	0.027
5/20/2001	0	0.000	0.0	0.000
5/21/2001	0	0.000	0.0	0.000
Total females	267		402,476.6	

Table 7. 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 2001.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/25/2001	2	0.007	2,208.1	0.008
2/26/2001	3	0.011	3,684.9	0.013
3/4/2001	5	0.018	5,827.1	0.021
3/11/2001	12	0.043	14,551.7	0.052
3/12/2001	5	0.018	6,335.7	0.022
3/20/2001	7	0.025	9,161.4	0.033
3/25/2001	9	0.032	11,162.9	0.040
3/28/2001	9	0.034	9,111.9	0.034
4/1/2001	1	0.004	1,185.8	0.005
4/2/2001	6	0.022	6,914.0	0.025
4/15/2001	1	0.004	1,468.4	0.005
4/16/2001	1	0.004	1,012.4	0.004
5/13/2001	0	0.000	0.0	0.000
5/20/2001	0	0.000	0.0	0.000
5/21/2001	0	0.000	0.0	0.000
Total males	61		72,624.3	

Table 8. Mean total length (mm) and mean weight (g) of female American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2001. Abbreviations are: NA, not aged; Rapp, Rappahannock River; SD, standard deviation. 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	25	513.2	35.1	1,521.1	298.5
	1998	1	424.0		949.5	
	1997	88	486.5	19.8	1,292.1	145.8
	1996	119	505.4	20.3	1,421.1	168.4
	1995	26	538.7	30.8	1,691.0	261.4
	1994	6	552.3	17.7	1,728.0	230.3
	1993	1	544.0		1,337.7	
	1992	1	588.0		1,110.0	
York River	NA	87	505.3	30.4	1,420.6	258.8
	1998	1	492.0		1,296.7	
	1997	228	482.5	18.0	1,277.4	153.1
	1996	266	497.7	22.5	1,364.8	204.0
	1995	60	519.1	20.5	1,536.7	230.7
	1994	19	528.2	17.0	1,493.7	229.2
	1993	14	545.2	15.4	1,439.6	277.6
	1992	2	579.5	40.3	1,805.3	49.2
Rappahannock River	NA	34	505.5	21.4	1,472.1	212.1
	1997	55	487.5	16.5	1,368.6	128.5
	1996	129	505.8	18.6	1,490.8	174.9
	1995	38	528.2	24.1	1,692.3	215.5
	1994	9	554.8	17.2	1,903.9	323.4
	1993	1	574.0		1,400.3	
	1992	1	558.0		1,997.6	

Table 9. Mean total length (mm) and mean weight (g) of male American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2001. Abbreviations are: NA, not aged; SD, standard deviation. 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	2	501.0	24.0	1,273.1	343.8
	1997	4	470.8	21.3	1,139.0	112.8
	1996	11	483.8	28.3	1,154.9	195.5
	1995	3	505.3	6.4	1,311.3	25.7
York River	NA	10	476.4	34.7	1,103.6	245.8
	1997	10	469.9	34.1	1,085.9	310.4
	1996	11	462.7	18.5	1,040.6	163.0
	1995	7	483.6	11.0	1,193.8	116.0
	1994	4	507.8	25.5	1,272.4	176.2
	1993	1	486.0		1,082.9	
Rappahannock River	NA	13	480.2	18.8	1,220.3	152.6
	1998	1	362.0		468.8	
	1997	11	463.5	13.5	1,087.7	118.9
	1996	24	473.5	15.7	1,178.9	127.2
	1995	10	491.1	17.1	1,320.5	142.7
	1994	1	516.0		1,388.2	
	1993	1	502.0		1,441.8	

Table 10. 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, 2001. 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	1998	1	0.95	26.5	0.0001	0.0001
	1997	88	113.71	26.5	0.0121	0.0156
	1996	119	169.11	26.5	0.0164	0.0232
	1995	26	43.97	26.5	0.0036	0.0060
	1994	6	10.37	26.5	0.0008	0.0014
	1993	1	1.34	26.5	0.0001	0.0002
	1992	1	1.11	26.5	0.0001	0.0002
	na	25	38.03	26.5	0.0034	0.0052
York	1998	1	1.30	19.8	0.0002	0.0002
	1997	228	291.24	19.8	0.0419	0.0536
	1996	266	363.03	19.8	0.0489	0.0668
	1995	60	92.20	19.8	0.0110	0.0170
	1994	19	28.38	19.8	0.0035	0.0052
	1993	14	20.15	19.8	0.0026	0.0037
	1992	2	3.61	19.8	0.0004	0.0007
	NA	87	123.59	19.8	0.0160	0.0227
Rappahannock	1997	55	75.27	24.0	0.0083	0.0113
	1996	129	192.31	24.0	0.0194	0.0289
	1995	38	64.31	24.0	0.0057	0.0097
	1994	9	17.14	24.0	0.0014	0.0026
	1993	1	1.40	24.0	0.0002	0.0002
	1992	1	2.00	24.0	0.0002	0.0003
	NA	34	50.05	24.0	0.0051	0.0075

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 male American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 2001. 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	1997	4	4.56	26.5	0.0006	0.0006
	1996	11	12.70	26.5	0.0015	0.0017
	1995	3	3.93	26.5	0.0004	0.0005
		2	2.55	26.5	0.0003	0.0004
York	1997	10	10.86	19.8	0.0018	0.0020
	1996	11	11.45	19.8	0.0020	0.0021
	1995	7	8.36	19.8	0.0013	0.0015
	1994	4	5.09	19.8	0.0007	0.0009
	1993	1	1.08	19.8	0.0002	0.0002
	NA	10	11.04	19.8	0.0018	0.0020
Rappahannock	1998	1	0.47	24.0	0.0002	0.0001
	1997	11	11.96	24.0	0.0017	0.0018
	1996	24	28.29	24.0	0.0036	0.0042
	1995	10	13.20	24.0	0.0015	0.0020
	1994	1	1.39	24.0	0.0002	0.0002
	1993	1	1.44	24.0	0.0002	0.0002
	NA	13	15.86	24.0	0.0020	0.0024

Table 12. Spawning histories of American shad (sexes combined) collected in spring, 2001 in the York and James rivers. Table entries are numbers of fish (York River, n= 623; James River, n= 260). 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= 98) 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.*, 2001a).

		Age at Maturity				
York River Year Class	Age at Capture	3	4	5	6	7
1998	3	1	-	-	-	-
1997	4	8	230	-	-	-
1996	5	2	132	143	-	-
1995	6	0	39	21	7	-
1994	7	0	13	10	0	0
1993	8	0	8	7	0	0
1992	9	0	1	1	0	0

		Age at Maturity				
James River Year Class	Age at Capture	3	4	5	6	7
1998	3	**1 (0)**				
1997	4	0 (0)	**92 (27)**			
1996	5	1 (0)	53 (31)	**76 (31)**		
1995	6	0 (0)	13 (4)	13 (4)	**3 (1)**	
1994	7	0 (0)	5 (0)	1 (0)	0 (0)	**0 (0)**
1993	8	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)
1992	9	0 (0)	1 (0)	0 (0)	0 (0)	0 (0)

Table 13. Spawning histories of American shad (sexes combined) collected in spring, 2001 in the Rappahannock River. Table entries are numbers of fish (n= 281). 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.*, 2001a).

Year Class	Age at Capture	3	4	5	6	7
1998	3	1	-	-	-	-
1997	4	4	61	-	-	-
1996	5	2	63	88	-	-
1995	6	0	18	15	16	-
1994	7	0	5	5	0	0
1993	8	0	1	1	0	0
1992	9	0	0	1	0	0

Table 14. Comparison of catches in multifilament (4.75-in mesh) and monofilament nets (4.88-in mesh).

Net type	Sex	Number Caught	Mean Total Length (mm)	Mean Weight (g)
multifilament	male	0	NA	NA
multifilament	female	19	502	1351
monofilament	male	2	541	1599
monofilament	female	30	505	1369

Table 15. Analysis of parameter estimates for 2001 data from the Poisson main effects model.

Parameter	Degrees of freedom	Estimate	Std. Error	Chi Square	Pr>Chi
Intercept	1	-0.7159	0.5935	1.4549	0.2277
Week 1	1	0.7129	0.6133	1.3512	0.2451
Week 2	1	1.0314	0.5849	3.1097	0.0778
Week 3	1	1.5041	0.5528	7.4037	0.0065
Week 4	1	-0.6734	0.8667	0.6036	0.4372
Week 5	1	-0.2679	0.7645	0.1228	0.7260
Position (N)	1	0.7290	0.3147	5.3658	0.0205
Day (first)	1	-0.1857	0.2978	0.3890	0.5328
Net (current)	1	0.6321	0.3098	4.1627	0.0413

Table 16. 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 2001. Age estimates are based on scales following Cating (1953). Abbreviations are: Susq., Susquehanna River

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
3997	James 1995 or 1996	4	0	419	478	1,151.3	F
4006	James 1995 or 1996	5	0	440	500	1,327.6	F
4008	James 1995 or 1996	4	0	436	493	1,268.3	F
4011	Juniata 1996,1998-2001	5	0	444	518	1,477.8	F
4043	James 1997-2001	5	0	458	522	1,320.6	F
4046	James 1995 or 1996	5	1	380	432	893.2	M
4048	James 1995 or 1996	4	0	402	464	1,208.7	F
4051	James 1995 or 1996	4	0	426	490	1,313.1	F
4058	James 1994	6	2	464	526	1,646.7	F
4224	James 1995 or 1996	4	0	404	460	1,089.4	F
4227	James 1995 or 1996	4	0	414	476	1,178.0	F
4228	James 1995 or 1996	5	1	426	494	1,251.7	F
4230	James 1995 or 1996	5	1	426	486	1,233.5	F
4231	James 1997-2001	5	1	420	476	1,295.0	F
4238	James 1995 or 1996	5	0	440	509	1,467.9	F
4286	James 1995 or 1996	4	0	456	520	1,622.4	F
4287	James 1995 or 1996	5	1	460	524	1,522.8	F
4288	James 1995 or 1996	5	1	455	518	1,543.9	F
4289	James 1997-2001	4	0	430	485	1,271.6	F
4291	James 1995 or 1996	6	0	450	509	1,574.5	F
4292	James 1997-2001	4	0	400	456	1,010.2	F
4294	James 1995 or 1996	4	0	410	469	1,154.7	F
4464	James 1995 or 1996	5	0	472	540	1,763.2	F
4465	James 1997-2001	5	0	433	494	1,252.0	F
4473	James 1995 or 1996	5	1	456	516	1,396.7	F
4475	James 1995 or 1996	5	1	444	501	1,335.9	F
4476	James 1995 or 1996	5	0	421	478	1,297.5	F
4628	James 1995 or 1996	5	0	430	484	1,247.6	F
4631	James 1995 or 1996	6	2	456	523	1,573.2	F
4632	James 1997-2001	5	0	440	494	1,236.8	F
4635	James 1997-2001	4	0	437	490	1,361.5	F
4636	James 1995 or 1996	5	1	440	498	1,249.3	F
4637	James 1997-2001	5	0	416	472	1,255.2	F
4638	James 1997-2001	5	1	428	486	1,312.9	F
4640	James 1995 or 1996	5	0	443	506	1,422.4	F
4644	James 1997-2001	5	0	428	482	1,240.1	F
4645	James 1997-2001	5	0	424	482	1,303.6	F
4646	James 1995 or 1996	5	1	438	500	1,386.3	F

Table 16. Continued.

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
4651	James 1995 or 1996	5	0	434	501	1,336.8	F
4652	James 1997-2001	5	0	469	533	1,684.0	F
4654	James 1995 or 1996	5	1	462	523	1,491.9	F
4656	James 1997-2001	5	0	434	494	1,331.3	F
4657	James 1997-2001	6	2	436	498	1,394.2	F
4658	James 1997-2001	4	0	414	471	1,140.0	F
4660	James 1997-2001	4	0	439	494	1,333.2	F
4661	James 1995 or 1996	5	0	416	474	1,127.5	F
4666	James 1995 or 1996	5	0	408	459	1,225.4	F
4667	James 1995 or 1996	5	0	435	500	1,343.7	F
4669	James 1995 or 1996	5	0	441	502	1,314.3	F
4670	James 1995 or 1996	4	0	414	476	1,309.5	F
4676	James 1997-2001	5	1	430	489	1,369.5	F
4680	James 1997-2001	4	0	409	468	1,042.6	F
4681	James 1995 or 1996	4	0	406	462	1,053.8	F
4854	James 1995 or 1996	5	0	458	518	1,641.4	F
4855	James 1997-2001	5	1	441	507	1,387.8	F
4856	James 1995 or 1996	5	1	446	500	1,365.3	F
4857	James 1995 or 1996	4	0	434	494	1,233.2	F
4860	James 1995 or 1996	5	1	436	488	1,364.3	F
4862	James 1995 or 1996	4	0	415	477	1,303.8	F
4867	James 1995 or 1996	5	1	429	488	1,295.6	F
4869	James 1997-2001	5	1	445	512	1,631.8	F
4871	James 1995 or 1996	5	1	447	504	1,421.8	F
4874	James 1995 or 1996	4	0	394	440	1,119.8	F
4877	James 1995 or 1996	5	1	450	504	1,460.5	F
4878	James 1997-2001	5	1	460	512	1,325.2	F
4883	James 1995 or 1996	5	1	443	504	1,532.7	F
4885	James 1997-2001	4	0	425	474	1,202.3	F
4886	James 1995 or 1996	4	0	438	494	1,377.7	F
4889	James 1997-2001	5	1	419	474	1,280.2	F
4891	James 1995 or 1996	5	0	449	502	1,567.6	F
4893	James 1997-2001	4	0	433	490	1,282.8	F
5032	James 1995 or 1996	5	1	462	525	1,450.1	F
5033	James 1997-2001	5	0	430	493	1,317.3	F
5038	James 1997-2001	5	0	444	508	1,458.0	F
5043	James 1995 or 1996	6	1	466	532	1,605.5	F
5045	James 1995 or 1996	6	1	480	547	1,713.1	F
5049	James 1995 or 1996	5	0	427	484	1,240.7	F
5107	James 1995 or 1996	5	1	422	476	1,214.8	F

5108	James 1995 or 1996	5	1	462	530	1,537.3	F

Table 16. Continued.

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
5112	James 1995 or 1996	5	1	460	520	1,536.9	F
5114	James 1995 or 1996	6	1	460	518	1,660.5	F
5116	James 1995 or 1996	5	1	455	512	1548.6	F
5126	James 1995 or 1996	4	0	443	500	1425.9	F
5128	James 1997-2001	6	1	476	544	1886.7	F
5131	James 1995 or 1996	5	0	450	514	1410.1	F
5132	James 1997-2001	5	1	434	491	1192	F
5180	James 1995 or 1996	5	1	430	484	1290.1	F
5224	James 1997-2001	5	1	462	527	1563.9	F
5225	James 1997-2001	4	0	430	482	1242.6	F
5226	James 1995 or 1996	5	0	425	485	1376	F
5248	James 1995 or 1996	4	0	398	450	1101.6	F
5249	James 1995 or 1996	6	2	468	530	1831.8	F
5251	James 1997-2001	4	0	441	504	1442.3	F
5252	W. Branch Susq. 1997	5	0	450	517	1719.9	F
5253	James 1995 or 1996	5	0	450	502	1419.7	F
5327	James 1997-2001	4	0	422	482	1407.6	F
5328	James 1995 or 1996	5	0	464	522	1633.8	F
5356	James 1997-2001	5	0	404	468	1100.2	F

Table 17. 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 2001. Age estimates are based on scales following Cating (1953). Double asterisks denote a specimen of unknown hatchery origin.

Specimen	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
4317	unknown	unknown	435	495	1224.5	2
4332	4	0	413	471	1244.9	2
4729	5	0	444	504	1416.5	2
5008	4	0	438	486	1334.7	2
5064	4	0	385	428	749.6	1
5156**	4	0	426	478	1206.5	2
5213	5	1	432	488	1365.0	2
5300	4	0	366	410	638.7	2
5371	6	2	464	525	1575.1	2

Table 18. Indexes of abundance of juvenile American shad in pushnet surveys on the Mattaponi and Pamunkey rivers, 1979-2001. Geometric means (GM) and areas under the catch curve were estimated from cruise-specific catch rates for each year. Data are not available for 1998-1990. Values are re-calculated from earlier versions of this time series following Wilhite *et al.* (In press).

Year	Mattaponi Mean GM	Pamunkey Mean GM	Mattaponi Area under the Catch Curve	Pamunkey Area Under the catch Curve	Combined Area Under the catch Curve
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
Mean	**15.8**	**2.6**	**1,157.4**	**209.5**	**1,367.5**

Table 19. Daily numbers and seasonal totals of striped bass live or dead (SB) and other species captured by staked gill net in the York River, 2001.

Date	Live SB	Dead SB	Other	Total
2/25/01	49	13	10	72
3/11/01	249	91	97	437
3/12/01	152	87	57	296
3/18/01	23	28	212	263
3/19/01	24	29	284	337
3/25/01	6	6	80	92
3/26/01	11	8	207	226
4/1/01	10	5	176	191
4/2/01	7	3	345	355
4/8/01	4	8	276	288
4/9/01	1	9	195	205
4/15/01	2	0	551	553
4/16/01	0	0	230	230
4/22/01	1	2	130	133
4/23/01	1	4	170	175
4/29/01	2	7	318	327
4/30/01	6	10	528	544
5/6/01	3	6	223	232
5/7/01	0	15	178	193
5/12/01	0	1	115	116
5/14/01	0	6	192	198
Totals	551	338	4,574	5,463

Table 20. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2001.

Date	Live SB	Dead SB	Other	Total
2/18/01	48	33	20	101
2/19/01	22	9	28	59
2/25/01	51	9	45	105
2/26/01	66	20	124	210
3/4/01	23	8	27	58
3/11/01	119	37	127	283
3/12/01	70	32	99	201
3/18/01	8	3	55	66
3/19/01	14	13	91	118
3/25/01	10	5	51	66
3/26/01	11	4	59	74
4/1/01	14	20	155	189
4/2/01	12	17	114	143
4/8/01	28	23	150	201
4/9/01	8	18	165	191
4/15/01	3	9	769	781
4/16/01	0	4	565	569
4/22/01	0	3	77	80
4/23/01	1	11	130	142
4/29/01	11	23	117	151
4/30/01	26	66	113	205
5/6/01	15	81	81	177
5/7/01	7	60	118	185
5/13/01	1	7	46	54
5/14/01	1	4	22	27
5/20/01	0	2	72	74
5/21/01	0	3	71	74
Totals	569	524	3,491	4,584

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2001.

Date	Live SB	Dead SB	Other	Total
2/25/01	23	5	297	325
2/26/01	34	7	263	304
3/4/01	76	14	174	264
3/11/01	87	20	97	204
3/12/01	67	12	155	234
3/20/01	51	23	401	475
3/25/01	80	72	311	463
3/28/01	41	24	445	510
4/1/01	48	19	462	529
4/2/01	33	28	482	543
4/8/01	8	10	806	824
4/9/01	9	16	988	1,013
4/15/01	2	8	1,241	1,251
4/16/01	6	7	727	740
4/22/01	5	9	833	847
4/23/01	9	11	953	973
4/29/01	11	34	668	713
4/30/01	13	76	677	766
5/6/01	1	6	644	651
5/7/01	3	7	519	529
5/13/01	0	2	430	432
5/14/01	2	7	370	379
5/20/01	5	5	292	302
5/21/01	0	3	315	318
Totals	614	425	12,550	13,589

Table 22. 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

Table 23. 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	13.47
1999	6.3	65	0.209	0.075	4.85
2000	6.7	76	0.276	0.086	4.82
2001	6.3	79	0.627	0.163	12.97

Table 24. 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

Table 25. Release, recapture and biological data on American shad that were tagged in the York River and recaptured in 2001. Abbreviations are: DN, drift net; HL, hook and line; TL, total length; Wt, weight. Asterisks indicate eviscerated weight.

Tag number	Date released	Date recaptured	Days at large	River of recapture	Gear	Sex	TL (mm)	Wt (g)
20010051	3/23/01	3/31/01	8	Pamunkey	DN	F	497	1,073*
20010052	3/23/01	3/31/01	8	Mattaponi	DN	F	483	1,128*
20010089	3/27/01	4/5/01	9	Mattaponi	DN	F	522	1,659
20010043	3/23/01	4/11/01	19	Mattaponi	DN	M	426	642
20010050	3/23/01	4/21/01	29	Delaware	HL	M	---	---

Table 26. Seasonal catch rates of American shad in staked gill nets constructed with multifilament mesh on the York River in 1950-1959. Effort (100-yard days) and catch (lbs) data are taken from Nichols and Massman (1963).

Year	Total effort (100-yard net days)	Total effort (m)	Total catch (lbs)	Total catch (kg)	Seasonal catch rate (kg/m)
1953	12,614.0	1,146,612.6	231,727.0	136,310.0	0.119
1954	8,980.0	816,282.0	300,139.0	176,552.4	0.216
1955	11,509.0	1,046,168.1	251,484.0	147,931.8	0.141
1956	10,843.0	985,628.7	398,114.0	234,184.7	0.238
1957	10,060.0	914,454.0	399,844.0	235,202.4	0.257
1958	8,777.0	797,829.3	215,289.0	126,640.6	0.159
1959	11,308.0	1,027,897.2	223,184.0	131,284.7	0.128
Average	10,598.7	962,124.6	288,540.1	169,729.5	0.180