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Monitoring Relative Abundance of American Shad in Virginia's Rivers 2002 Annual Report

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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 2002. This was the fifth 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 12 weeks on the James and York rivers (24 February - 13 May 2002) and 11 weeks on the Rappahannock River (24 February - 6 May 2002). A total of 787 female American shad (1,260 kg total weight) was captured. The 2002 catch was smaller than the catch in 2001 (1,211 females weighing 1,705 kg total weight).

- Total numbers and weights of females in 2002 were highest on the York River (n= 384, 599 kg). James River catches of females (n= 280, 447 kg) exceeded those in the Rappahannock River (n= 123, 214 kg). Numbers of males captured were: York River, 162; James, 85; Rappahannock, 36. The total weight of all males captured was 357 kg.

- Based on age estimates from scales, the 1996 and 1997 year classes of female American shad were the most abundant on all three rivers, with 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, 1.41; James River, 1.59; and Rappahannock River, 1.03. Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River, 1.39; James River, 1.07; and Rappahannock River, 1.04.

- Otoliths of all American shad captured in staked gill nets on the James River were scanned for hatchery marks and otoliths of 104 specimens captured on the York River were scanned. The proportion of the sample with hatchery marks on the James and York rivers was 42.8 % (139 of 325 fish) and 4.8 % (5 of 104 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 in 1995-1998. Of these hatchery-released cohorts, the 1996 year class has dominated catches thus far in the monitoring program.

- The geometric mean catch of juvenile American shad (based on weekly summer pushnet surveys) was 8.9 on the Mattaponi River and 1.8 on the Pamunkey River. The combined integrated catch index for the York system (both the Pamunkey and Mattaponi rivers) was 800.1. The juvenile index was very low in 2002 compared to recent years (average, 1,536.9; 2001 value, 5,502.6; 2000 value, 4,184.7).

- Fifteen species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 12,587 specimens. The total number of striped bass captured was 1,617 (James River, n= 625; York River, n= 288; Rappahannock River, n= 704) . Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 51.4 %; York River, 49.6 %; and the Rappahannock River, 52.7 %.

- A total of 217 American shad were captured in 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). Of the total, 64 fish were captured in multifilament nets and 153 fish were captured in monofilament nets during seven weeks of deployment, 10 March-21 April 2002. A Poisson main effects model yielded a highly significant difference in catch between the two net types. The expected ratio of the catches (current and 1980's catch rates to 1950's catch rates) was estimated to be 2.37 (with 95% confidence limits of 2.07, 2.67).

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2002 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 2002 was 7.47. During the five years of monitoring, the index has been somewhat variable with high values (>12) in 1998 and 2001 and lower values (<8) in other years. The average of the historical data during the 1980's on the York River is 3.96. On the James River, the 2002 index (5.62) was less than the 2000 value (6.61) but higher than the 2001 value (5.01). Index values in 2000-2002 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 catch index on the Rappahannock River in 2002 (3.08) was lower than the 2001 value (5.77) but higher than those obtained in previous years of monitoring (2000, 1.75; 1999, 1.30; 1998, 1.46). The average of the historical data during the 1980's 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 fifth year in the sampling program (2002) are reported in this document. The results of the first four years of sampling (1998-2001) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b; Olney and Hoenig 2001a; Olney and Maki 2002). 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 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.

C 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).

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.

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*. (in press) 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) has been conducted annually on the Pamunkey River system since 1979. Since 1995, juveniles bearing the OTC mark have been collected by VIMS and VDGIF. 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.

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) 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 (1990-2002) 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, ten papers on various aspects of the biology of American shad and the VIMS stock assessment program are in press or 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, 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 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 of spawning adults; and (5) to determine the amount of by-catch of other species in the staked gill nets.

In 2002, an additional objective was to determine an efficiency factor that can used to relate catch rates of multifilament nets (used in the 1950s) to monofilament nets (used 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. Using this approach, we hope to establish appropriate restoration targets for the York River stock.

Methods

The 2002 sampling methods were the same as those in 1998-2001. 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 the York and James rivers (Figures 5-6). One staked gill net, 912 ft (approximately 276 m), 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, high winds prevented the regularly scheduled sampling on Sunday and Monday, and sampling was either postponed or canceled. Sampling occurred for 12 weeks on the James and York rivers (24 February - 13 May 2002) and 11 weeks on the Rappahannock River (24 February - 5 May 2002). Surface water temperature 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 from 10 March to 22 April 2002. 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:

$$\ln(catch_{hijk}) = h + pos_h + day_i + wk_j + net_k + e_{hijk}$$

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 e_{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, μ_{new}, is less than or equal to the mean of the old net type, μ_{old} :

$$H_o: \mu_{new} \text{ , } \mu_{old}$$
$$H_a: \mu_{new} > \mu_{old}$$

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.

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. 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. To compute the catch index, we estimated catches on skipped days using linear interpolation between the weekend averages of two days' sampling.

Results

Catches of American shad by staked gill nets in 2002

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 1,070 American shad (283 males:787 females) were captured. The total weight of the sample was 1,616.9 kg. The 2002 catch was smaller than the catch in 2001 (1,211 females weighing 1,705 kg total weight; Olney and Maki 2002). Catches in 2002 were lowest on the Rappahannock River (159 total fish, 36 males and 123 females), higher on the James River (365 total fish, 85 males and 280 females) and highest on the York River (546 total fish, 162 males and 384 females).

On the James River, catches of females peaked on 31 March-14 April 2002 when catch rates exceeded 0.06 fish/m or 0.095 kg/m. During that period on the James River, 47.5 % (133 of 280) of the total number of females was captured. On the York River, catches of females peaked between 4 March and 21 April 2002 when catch rates approached or exceeded 0.03 fish/m or 0.05 kg/m. During that period on the York River, 92.9 % (357 of 384) of the total number of females was captured. Catches of females on the Rappahannock River peaked between 11-17 March and again on31 March to 15 April 2002 when catch rates approached or exceeded 0.03 fish/m or 0.05 kg/m. During those periods on the Rappahannock River, 73.9 % (91 of 123) of the total number of females was captured. The highest recorded daily catch by weight occurred on 25 March 2002 when 55 female American shad (87.3 kg) were taken in the York River (Table 4). As in previous years of monitoring, numbers and catch rates of males were generally low throughout the period on all rivers. Sex ratios (males:females) were: York River, 0.297:0.703; James River, 0.233:0.767; Rappahannock River, 0.226:0.774. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish.

The duration of the 2002 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 71 days on the James River (24 February - 6 May), 70 days on the York River (24 February - 5 May) and 57 days on the Rappahannock River (4 March - 29 April).

Biological characteristics of the American shad in 2002

Age, mean length (mm TL) and mean 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 432-512 mm TL and 445-556 mm TL, respectively. Mean weight at age of males and females ranged from 0.99-1.65 kg and 0.95-2.17 kg, respectively.

Overall, the 1996 and 1997 year classes (ages 5 and 6) of female American shad were the most abundant on all three rivers (Tables 10-11). On the James River, six age classes of females were

represented (1994-1999) and the sample was dominated by age-5 fish (55.8 % of the total that were aged). On the York River, five age classes of females were represented (1994-1998) and the sample was dominated by age-5 fish (55.6 % of the total that were aged). On the Rappahannock River, six age classes of females were taken (1993-1999). Age-5 fish made up 43.2 % of the aged sample and age-6 fish made up 40.5% of the sample. The 1996 and 1997 year classes of males were the most abundant on all three rivers. On the York River, the 1996 year class (age 6) of male American shad constituted 54.0% of the aged sample.

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. Total instantaneous mortality rates of females were: York River, 1.41 (r^2= 0.91); James River, 1.59 (r^2= 0.95); and Rappahannock River, 1.03 (r^2= 0.82). Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River, 1.39 (r^2= 0.99); James River, 1.07 (r^2= 0.96); and Rappahannock River, 1.04 (r^2= 0.82).

Spawning histories of American shad collected in 2002 are presented in Tables 12-13. On the York and Rappahannock rivers, fish (both sexes combined) ranged in age from 3-9 years with 0 (virgin) to 5 spawning marks. On the James River, fish (both sexes combined) ranged in age from 3-8 years with 0-4 spawning marks. The following percentages in each river had a least one prior spawn: York River, 59.5 % (196 virgins in a sample of 484); James River 47.2 % (169 virgins in a sample of 320 wild fish); Rappahannock River 64.2 % (53 virgins in a sample of 148 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 % (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002).

Comparison of multifilament and monofilament nets

Catches in the comparison nets totaled 217 shad, 158 of which were females (Table 14). Mean lengths and weights were similar between the old (multifilament) and new (monofilament) nets. Catches of females were higher in the monofilament net (111 females) than in the multifilament net (47 females). Catches were highest during the week of 17 March in these trials (Fig. 13).

A Poisson main effects model yielded a highly significant difference in catch between the two net types ($p<0.0001$; Table 15). The estimated effect of the monofilament net relative to the multifilament net (in essence, the log relative risk) was 0.8631. 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(0.8631) = 2.37. 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 (0.149) is small and the 95% lower and upper confidence intervals on the relative fishing power (exp(0.8631 ± 2*0.149)) are 2.07 and 2.67, respectively. Thus, the monofilament net is more efficient than the multifilament net and the estimated has reasonably high precision. These comparison trials will be repeated in 2003.

Evaluation of hatchery origin of American shad in 2002

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 2002 sample with hatchery marks was 42.8 % (139 of 325 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); 2002, n= 1, Pamunkey River, n= 2 unknown tag.

Most hatchery-reared adults taken in 2000-2002 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 12 and 17). 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 17). In our 2000-2002 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 1995-1998, 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 and declines slightly in 2002. This year class has constituted 41 % of the hatchery-marked catch (Table 17). The 1995 year class was abundant in 2000 but its numbers decreased in 2001 and 2002. The 1997 year class has continued to recruit since 2000 and has contributed almost 30 % to the total hatchery-marked fish captured thus far. The 1998 year class first appeared in moderate numbers in 2002, 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. 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).

York River - Otoliths of 104 adult specimens captured in staked gill nets on the York River were scanned for hatchery marks. The proportion of the sample with marks was 4.8 % (5 of 104 fish). The biological characteristics of these specimens is reported in Table 18. By comparison, the proportion of the 2001 sample with marks was 4.8 % (9 of 186 fish) and that proportion in 2000 was 2.2% (4 of 180 fish).

Juvenile abundance of American shad

Table 19 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 (>1,536.9) 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 14).

By-catch of striped bass and other species in 2002

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 20-22. Fifteen species of by-catch were captured for a total of 12,587 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*), cownose ray (*Rhinoptera bonasus*) and summer flounder (*Paralichthys dentatus*). One Atlantic sturgeon was captured in the James River. Patterns of occurrence of by-catch differed between rivers (Figure 15). In the Rappahannock River, catches of menhaden and Atlantic croaker predominated. In the York and James rivers, catches of gizzard shad predominated.

The total number of striped bass captured was 1,617 (James River, n= 625; York River, n= 288; Rappahannock River, n= 704) . Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 51.4 %; York River, 49.6 %; and the Rappahannock River, 52.7 %.

Seasonal catch indexes, 1980-1992 and 1998-2002

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2002 and for each year of the historical record of staked net catches on each river (Tables 23-25 and Figures 16-21). Seasonal catch indices in 2002 were: York River, 7.47; James River, 5.62; Rappahannock River, 3.08.

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 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.

Abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in our monitoring gear in recent years (2000-2002) confirm a large scale influx of mature virgin hatchery fish since the James River restoration program began in 1992 (Olney *et al.*, in press). 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 remained relatively constant during the five 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 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, 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 23-25) These values are: Rappahannock River, 6; York River, 10; and James River, 29. There exist two additional sources of historical data upon which to judge current stock status. The first is the report by Stevenson (1899) on catch and effort in the American shad fishery in Virginia during the fishing season in 1896. In addition, voluntary logbooks of catches from the York and James rivers exist in the archives of the Department of Fisheries Science (VIMS). The York River historical records from the 1950s forms the basis for the current gear comparison trials (Fig. 22; Olney and Hoenig 2001). Thus far, it appears that 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 require upward adjustment (by a factor of ~2) to make appropriate comparisons with current monitoring results. Such adjustment of the 1950s data yields revised restoration targets for the York River stocks as depicted in Figure 23. Following a repeat of gear comparison trials in 2003, these new targets will be presented to

the Technical Committee and the Management Board for discussion.

Thus far, the originally proposed 1980s 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 2000-2002 is higher than historic index values in some years (1982, 1987, 1990, 1991). However, the 1998-2002 average (4.56) is well below the proposed restoration target of 29. Our overall assessment for the James River is that the stock remains at a very low level of abundance and requires continued protection and restoration.

On the Rappahannock River, the index in 2002 is below that of the previous year but higher than the first years of the monitoring program (1998-2000). Throughout the period of monitoring, catch rates are comparable to the historic record. The 1998-2002 average (2.67) 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, 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 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) and then declined sharply in 2002. The 1998-2002 average of York River index values (9.62) 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. Once targets are revised (see previous discussion), we can evaluate the status of the York River stock relative to a period in the 1950s when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann 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 2002.

Stock	Sampling dates in 2002	Total females	Total males	Total female weight (kg)	Total male weight (kg)	Total Fish	Total weight (kg)
James River	2/24-5/13	280	85	446.8	107.5	365	554.3
York River	2/24-5/13	384	162	599.3	202.2	546	801.5
Rappahannock River	2/24-5/6	123	36	213.8	47.4	159	261.2
Totals		787	283	1,259.9	357.0	1,070	1,616.9

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 2002.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/24/2002	54	4	0.015	7,053.4	0.026
2/25/2002	55	2	0.007	3,630.7	0.013
3/3/2002	62	3	0.011	5,289.6	0.020
3/4/2002	63	5	0.019	8,885.0	0.034
3/10/2002	69	11	0.040	18,184.1	0.066
3/11/2002	70	15	0.055	25,398.6	0.093
3/17/2002	76	7	0.027	12,491.5	0.048
3/18/2002	77	16	0.058	25,274.2	0.092
3/24/2002	83	22	0.080	34,644.1	0.126
3/25/2002	84	12	0.044	18,467.3	0.067
3/31/2002	90	26	0.095	44,540.2	0.162
4/1/2002	91	17	0.061	26,711.9	0.095
4/7/2002	97	26	0.097	40,228.5	0.150
4/8/2002	98	29	0.106	44,995.0	0.164
4/14/2002	104	35	0.133	54,003.7	0.205
4/15/2002	105	15	0.055	23,222.5	0.085
4/21/2002	111	15	0.055	21,824.0	0.080
4/22/2002	112	6	0.022	9,114.6	0.033
4/28/2002	118	4	0.016	7,090.6	0.028
4/29/2002	119	4	0.015	5,806.4	0.021
5/5/2002	125	3	0.011	5,187.6	0.019
5/6/2002	126	3	0.011	4,727.4	0.017
5/12/2002	132	0	0.000	0.0	0.000
5/13/2002	133	0	0.000	0.0	0.000
Totals		280		446,770.9	

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 2002.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/24/2002	54	12	0.045	14,546.5	0.054
2/25/2002	55	7	0.026	8,892.2	0.032
3/3/2002	62	8	0.030	10,773.5	0.040
3/4/2002	63	4	0.015	5,702.7	0.022
3/10/2002	69	6	0.022	7,264.3	0.026
3/11/2002	70	5	0.018	5,806.7	0.021
3/17/2002	76	4	0.015	5,159.9	0.020
3/18/2002	77	7	0.026	9,402.1	0.034
3/24/2002	83	8	0.029	9,689.4	0.035
3/31/2002	90	5	0.018	6,697.3	0.024
4/1/2002	91	4	0.014	5,553.0	0.020
4/7/2002	97	6	0.022	7,083.6	0.026
4/8/2002	98	3	0.011	3,622.0	0.013
4/14/2002	104	4	0.015	4,342.9	0.017
4/21/2002	111	1	0.004	1,651.1	0.006
4/28/2002	118	1	0.004	1,323.1	0.005
Total		85		107,510.3	

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 2002.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/24/2002	54	2	0.007	3,237.1	0.115
2/25/2002	55	2	0.007	2,768.1	0.010
3/3/2002	62	5	0.018	7,744.9	0.028
3/4/2002	63	24	0.087	38,133.2	0.139
3/10/2002	69	17	0.061	28,460.3	0.102
3/11/2002	70	26	0.117	39,179.1	0.176
3/17/2002	76	34	0.119	54,117.9	0.189
3/18/2002	77	25	0.091	39,525.0	0.144
3/24/2002	83	31	0.113	47,261.2	0.172
3/25/2002	84	55	0.200	87,344.1	0.318
3/31/2002	90	15	0.055	24,044.5	0.088
4/1/2002	91	21	0.077	33,075.9	0.121
4/7/2002	97	44	0.154	68,718.0	0.240
4/8/2002	98	20	0.078	30,482.1	0.119
4/14/2002	104	8	0.029	13,231.3	0.048
4/15/2002	105	27	0.085	39,510.4	0.124
4/21/2002	111	10	0.035	14,705.0	0.052
4/22/2002	112	7	0.024	10,920.6	0.038
4/28/2002	118	4	0.014	6,173.6	0.022
4/29/2002	119	3	0.011	4,089.4	0.015
5/5/2002	125	2	0.007	3,048.3	0.011
5/6/2002	126	1	0.004	1,998.9	0.007
5/12/2002	132	1	0.004	1,526.3	0.005
5/13/2002	133	0	0.000	0.0	0.000
Total		384		599,295.2	

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 2002.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/24/2002	54	8	0.028	10,099.7	0.036
2/25/2002	55	3	0.011	3,948.3	0.014
3/3/2002	62	7	0.026	8,909.8	0.032
3/4/2002	63	26	0.095	33,262.7	0.121
3/10/2002	69	10	0.036	12,556.5	0.045
3/11/2002	70	19	0.085	23,945.3	0.107
3/17/2002	76	18	0.063	21,980.1	0.077
3/18/2002	77	19	0.069	23,259.8	0.085
3/24/2002	83	13	0.047	16,189.4	0.059
3/25/2002	84	21	0.077	25,993.9	0.095
3/31/2002	90	1	0.004	1,198.3	0.004
4/1/2002	91	5	0.018	6,654.1	0.024
4/7/2002	97	6	0.021	7,469.6	0.026
4/8/2002	98	2	0.008	2,086.5	0.008
4/14/2002	104	1	0.004	944.4	0.003
4/15/2002	105	2	0.006	2,510.0	0.008
4/28/2002	118	1	0.004	1,149.4	0.004
Total		162		202,157.8	

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 2002.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/24/2002	54	1	0.004	1,912.3	0.007
2/25/2002	55	1	0.004	1,816.5	0.007
3/4/2002	63	4	0.014	7,526.0	0.027
3/11/2002	70	12	0.043	22,563.3	0.081
3/17/2002	76	17	0.061	30,591.2	0.110
3/18/2002	77	2	0.007	3,171.5	0.011
3/24/2002	83	3	0.012	5,463.5	0.022
3/25/2002	84	8	0.029	14,211.9	0.051
3/31/2002	90	13	0.047	23,050.3	0.083
4/1/2002	91	12	0.044	21,208.4	0.077
4/7/2002	97	11	0.042	18,280.7	0.070
4/8/2002	98	9	0.032	12,925.8	0.047
4/14/2002	104	9	0.034	15,949.2	0.061
4/15/2002	105	8	0.029	13,662.2	0.049
4/21/2002	111	1	0.004	1,492.2	0.005
4/22/2002	112	3	0.011	4,985.9	0.018
4/28/2002	118	2	0.007	2,756.1	0.010
4/29/2002	119	6	0.022	10,573.9	0.038
5/5/2002	125	1	0.004	1,660.3	0.006
5/6/2002	126	0	0.000	0.0	0.000
Total		123		213,801.2	

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 2002.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/24/2002	54	4	0.014	5,777.0	0.021
2/25/2002	55	2	0.007	2,913.9	0.010
3/3/2002	62	2	0.007	2,561.7	0.009
3/4/2002	63	1	0.004	1,271.0	0.004
3/10/2002	69	7	0.026	8,962.0	0.034
3/11/2002	70	1	0.004	1,469.0	0.005
3/17/2002	76	6	0.022	7,912.5	0.028
3/18/2002	77	4	0.014	4,826.3	0.017
3/24/2002	83	1	0.004	1,439.3	0.006
3/31/2002	90	2	0.007	2,569.0	0.009
4/1/2002	91	1	0.004	1,533.4	0.006
4/7/2002	97	2	0.008	2,311.8	0.009
4/8/2002	98	1	0.004	1,087.1	0.004
4/22/2002	112	1	0.004	1,329.5	0.005
4/29/2002	119	1	0.004	1,412.5	0.005
		36		47,376.0	

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 2002. 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	29	515.5	27.3	1,686.9	314.3
	1999	2	444.5	6.4	949.5	224.4
	1998	31	490.8	23.0	1,430.6	204.5
	1997	140	501.0	22.0	1,561.8	227.6
	1996	67	513.3	19.5	1,672.1	193.9
	1995	10	531.2	26.3	1,875.5	366.9
	1994	1	547.0		2,168.5	
York River	NA	37	506.1	26.4	1,599.7	271.0
	1998	29	487.5	24.7	1,404.0	192.8
	1997	193	498.4	19.6	1,517.8	212.9
	1996	115	508.6	19.5	1,635.6	223.9
	1995	7	525.4	15.2	1,700.0	269.3
	1994	3	545.0	18.7	2,156.4	353.1
Rappahannock River	NA	8	515.3	22.8	1,808.7	287.5
	1999	1	456.0		1,317.5	
	1998	6	471.7	37.5	1,390.9	322.7
	1997	48	508.2	23.1	1,633.4	203.4
	1996	45	530.2	17.8	1,853.9	253.5
	1995	8	539.0	13.9	1,957.7	204.8
	1994	1	548.0		1,530.6	
	1993	2	556.0	5.7	1,561.2	34.2

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 2002. 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	16	472.0	23.4	1,291.7	229.8
	1998	9	452.1	9.8	1,131.8	94.3
	1997	34	465.9	19.0	1,202.9	159.8
	1996	21	478.6	19.7	1,337.3	165.4
	1995	4	495.8	29.4	1,505.8	258.1
	1994	1	512.0		1,650.3	
York River	NA	25	470.4	13.5	1,225.5	116.5
	1999	1	452.0		1,092.6	
	1998	3	449.7	20.6	1,070.3	127.3
	1997	42	465.9	16.5	1,188.8	124.6
	1996	74	475.5	15.8	1,265.9	119.4
	1995	12	489.3	16.2	1,401.7	127.1
	1994	4	484.5	8.3	1,331.5	160.2
	1993	1	492.0		1,463.0	
Rappahannock River	NA	1	488.0		1,439.3	
	1998	2	432.0	7.1	995.5	93.6
	1997	10	462.5	15.8	1,201.9	104.0
	1996	16	485.1	17.7	1,382.5	123.6
	1995	2	503.0	9.9	1,514.0	83.3
	1993	2	508.5	0.7	1,473.0	85.5

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, 2002. 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	2	1.90	23.8	0.0003	0.0003
	1998	31	44.35	23.8	0.0048	0.0068
	1997	140	218.65	23.8	0.0215	0.0335
	1996	67	112.03	23.8	0.0103	0.0172
	1995	10	18.75	23.8	0.0015	0.0029
	1994	1	2.17	23.8	0.0002	0.0003
	NA	29	48.92	23.8	0.0044	0.0075
York River	1998	29	40.72	24.4	0.0043	0.0061
	1997	193	292.93	24.4	0.0288	0.0438
	1996	115	188.09	24.4	0.0172	0.0281
	1995	7	11.90	24.4	0.0010	0.0018
	1994	3	6.47	24.4	0.0004	0.0010
	NA	37	59.19	24.4	0.0055	0.0088
Rappahannock River	1999	1	1.32	19.7	0.0002	0.0002
	1998	6	8.35	19.7	0.0011	0.0015
	1997	48	78.40	19.7	0.0088	0.0143
	1996	45	83.43	19.7	0.0082	0.0152
	1995	8	15.66	19.7	0.0015	0.0029
	1994	1	1.53	19.7	0.0002	0.0003
	1993	2	3.12	19.7	0.0004	0.0006
	NA	8	14.47	19.7	0.0015	0.0026

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, 2002. 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	1998	9	10.19	23.8	0.0014	0.0016
	1997	34	40.90	23.8	0.0052	0.0063
	1996	21	28.08	23.8	0.0032	0.0043
	1995	4	6.02	23.8	0.0006	0.0009
	1994	1	1.65	23.8	0.0002	0.0003
	NA	16	20.67	23.8	0.0025	0.0032
York River	1999	1	1.09	24.4	0.0001	0.0002
	1998	3	3.21	24.4	0.0004	0.0005
	1997	42	49.93	24.4	0.0063	0.0075
	1996	74	93.68	24.4	0.0111	0.0140
	1995	12	16.82	24.4	0.0018	0.0025
	1994	4	5.33	24.4	0.0006	0.0008
	1993	1	1.46	24.4	0.0001	0.0002
	NA	25	30.64	24.4	0.0037	0.0046
Rappahannock River	1998	2	1.99	19.7	0.0004	0.0004
	1997	10	12.02	19.7	0.0018	0.0022
	1996	16	22.12	19.7	0.0029	0.0040
	1995	2	3.03	19.7	0.0004	0.0006
	1993	2	2.95	19.7	0.0004	0.0005
	NA	1	1.44	19.7	0.0002	0.0003

Table 12. Spawning histories of American shad (combined sexes) collected in spring, 2002 in the York and James rivers. Table entries are numbers of fish (York River, n = 484; James River, n = 320). 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 = 142) 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
1999	3	**1**	-	-	-	-
1998	4	5	**27**	-	-	-
1997	5	5	98	**132**	-	-
1996	6	0	85	68	**36**	-
1995	7	0	8	10	1	**0**
1994	8	0	3	4	0	0
1993	9	0	1	0	0	0

		Age at Maturity				
James River Year Class	Age at Capture	3	4	5	6	7
1999	3	**2**	-	-	-	-
1998	4	8 (5)	**32** (8)	-	-	-
1997	5	5 (5)	63 (25)	**106** (48)	-	-
1996	6	0	31 (20)	29 (15)	**28** (8)	-
1995	7	0	5 (2)	8 (5)	0	**1** (1)
1994	8	0	0	1	1	0
1993	9	0	0	0	0	0

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2002 in the Rappahannock River. Table entries are numbers of fish (n = 148). 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				
Year Class	Age at Capture	3	4	5	6	7
1999	3	**1**	-	-	-	-
1998	4	2	**7**	-	-	-
1997	5	1	25	**36**	-	-
1996	6	0	31	22	**8**	-
1995	7	0	1	7	1	**1**
1994	8	0	1	0	0	0
1993	9	0	3	1	0	0

Table 14. Comparison of catches in multifilament (4.75-in mesh) and monofilament nets (4.88-in mesh) during spring 2002. Both nets are constructed with #139 twine-sized material.

Net type	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		

Table 15. Analysis of parameter estimates for 2002 data from the Poisson main effects model.

Parameter	Degrees of freedom	Estimate	Std. Error	Chi Square	Pr>Chi
Intercept	1	-1.1147	0.5946	3.51	0.0608
Week 1	1	2.5763	0.5987	18.52	<0.0001
Week 2	1	3.0463	0.5908	26.58	<0.0001
Week 3	1	2.6390	0.5976	19.50	<0.0001
Week 4	1	2.0369	0.6138	11.01	0.0009
Week 5	1	1.4663	0.6405	5.24	0.0221
Week 6	1	2.3532	0.6039	1.16	<0.0001
Position	1	0.4035	0.1395	8.37	0.0038
Day	1	0.1728	0.1377	1.57	0.2096
Net	1	0.8631	0.1490	33.53	<0.0001

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 2002. Age estimates are based on scales following Cating (1953).

SpecimenNumber	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
5394	James 95 or 96	7	2	420	475	1285	M
5395	James 95 or 96	6	2	423	474	1267.2	M
5403	James 97-01	5	1	402	464	1175.4	M
5404	James 97-01	4	1	390	446	1119.5	M
5412	Unknown Stray	6	0	423	476	1330.3	M
5414	James 97-01	5	0	386	444	1055.2	M
5416	James 97-01	5	1	408	462	1260	M
5417	James 97-01	6	2	445	507	1654.3	M
5419	James 95 or 96	6	2	414	470	1217.6	M
5430	James 95 or 96	7	3	464	520	1795.6	M
5431	James 97-01	4	1	406	464	1250.8	M
5434	James 95 or 96	5	1	454	517	1869.2	F
5435	James 97-01	6	2	419	478	1276.1	M
5437	James 97-01	5	1	404	466	1171.5	M
5438	James 97-01	5	0	470	530	1794.8	F
5439	James 95 or 96	6	2	433	487	1600.5	M
5440	James 97-01	5	0	381	442	998.8	M
5518	James 95 or 96	6	2	434	489	1363.7	M
5528	James 97-01	5	1	398	458	1261.5	M
5529	James 95 or 96	6	2	466	528	1918.9	F
5534	James 97-01	5	1	440	506	1715.4	F
5645	James 95 or 96	6	2	446	508	1667.8	F
5647	James 97-01	5	0	425	487	1571.4	F
5648	James 97-01	5	0	433	496	1537.7	F
5649	James 95 or 96	7	2	476	544	2148.1	F
5651	James 97-01	5	2	420	476	1220	M

5652	James 97-01	6	1	438	494	1518.2	F
5654	James 95 or 96	7	2	472	530	1967	F
5656	James 95 or 96	5	2	413	471	1223.3	M
5657	James 95 or 96	6	1	448	507	1720.3	F
5687	James 97-01	5	1	488	552	2126.1	F
5688	James 95 or 96	6	2	428	468	1259.3	M
5858	James 95 or 96	5	2	400	462	1303.3	M
5859	James 97-01	5	1	440	497	1693.8	F
5860	James 97-01	6	0	456	516	1711.3	F
5865	James 95 or 96	6	2	418	474	1231.1	M
5868	James 97-01	5	1	403	460	1261.6	F
5870	James 97-01	5	1	472	536	1923.6	F
5871	James 97-01	5	0	414	478	1456.4	F
5873	James 95 or 96	6	2	439	492	1522.2	M
5874	James 97-01	6	2	422	484	1386.3	M
5875	James 95 or 96	5	1	462	530	1867.8	F
5879	James 95 or 96	6	1	442	512	1609.3	F
5880	James 97-01	4	0	422	482	1357.2	F
5911	James 97-01	6	1	435	496	1523.2	F
5916	James 95 or 96	6	2	416	479	1269	M
5917	James 95 or 96	6	2	411	472	1329.5	M
5919	James 97-01	4	0	396	450	1155.7	F
5920	James 95 or 96	5	0	444	502	1611.9	F
5924	James 97-01	6	2	408	461	1181	M
5925	James 97-01	5	0	433	498	1549.4	F
5926	James 97-01	5	0	450	506	1595.2	F
5928	James 97-01	6	1	440	496	1574.2	F
5931	James 97-01	4	1	408	462	1175.3	M
5935	James 97-01	5	0	438	490	1644.3	F
5937	James 95 or 96	5	1	444	494	1569.8	F
6012	James 97-01	4	0	400	457	1175.2	F

6015	Unknown Stray	5	1	426	476	1287	F
6016	James 97-01	5	0	457	518	1644.7	F
6018	James 95 or 96	6	1	465	520	1880.1	F
6128	James 95 or 96	5	0	468	532	1718.5	F
6132	James 95 or 96	6	1	474	537	1860.9	F
6133	James 95 or 96	6	1	469	528	1897.6	F
6136	James 95 or 96	5	1	473	532	1821.7	F
6138	James 97-01	5	0	451	514	1696.5	F
6140	James 95 or 96	6	1	484	542	2055.3	F
6143	James 95 or 96	6	2	420	473	1410.4	M
6144	James 97-01	5	0	428	485	1374.5	F
6145	James 95 or 96	5	0	436	495	1416.8	F
6148	James 95 or 96	5	2	414	470	1284.6	M
6152	James 95 or 96	7	2	509	572	2524.3	F
6155	James 97-01	5	0	448	512	1699.9	F
6201	James 97-01	5	0	416	471	1349.9	F
6202	James 95 or 96	5	0	432	491	1379.3	F
6203	James 97-01	5	0	430	492	1459.6	F
6205	Pamunkey 95 or 96	5	1	419	474	1248.9	M
6206	James 97-01	6	1	456	512	1721.6	F
6208	James 95 or 96	5	1	428	486	1398.2	M
6209	James 97-01	6	0	441	500	1480.1	F
6211	James 97-01	7	0	454	513	1711.1	F
6212	James 95 or 96	5	0	452	518	1934.1	F
6213	James 97-01	5	0	430	494	1455.7	F
6214	James 97-01	6	2	448	516	1535.1	F
6220	James 97-01	5	0	443	512	1442.5	F
6301	James 97-01	5	0	456	523	1743.2	F
6302	James 97-01	4	1	441	505	1547.5	F
6303	James 95 or 96	6	1	484	548	1832.3	F
6304	James 97-01	5	0	438	498	1496.8	F

6305	James 95 or 96	5	0	420	482	1394.5	F
6308	James 97-01	5	0	438	498	1538.1	F
6309	James 97-01	5	2	412	464	1251.3	M
6312	James 97-01	6	2	458	516	1648.6	F
6314	James 97-01	5	0	435	495	1339.3	F
6316	James 95 or 96	5	0	430	484	1241	F
6317	James 97-01	6	0	446	511	1711.1	F
6318	James 97-01	5	0	427	486	1449.8	F
6322	James 95 or 96	4	0	410	465	1302.3	F
6327	James 95 or 96	5	0	443	508	1433.8	F
6330	James 95 or 96	5	0	407	460	1060.8	M
6331	James 97-01	4	0	414	469	1216.4	F
6332	James 97-01	4	0	413	468	1266.5	F
6414	James 97-01	5	0	406	464	1266.2	F
6417	James 95 or 96	6	0	418	462	1272.2	F
6421	James 97-01	5	1	454	506	1537.9	F
6422	James 97-01	5	1	440	488	1475.2	F
6423	James 97-01	5	1	452	506	1417.9	F
6425	James 95 or 96	6	1	443	503	1708.1	F
6426	James 97-01	6	2	434	486	1466.9	F
6432	James 95 or 96	6	0	439	492	1361.1	F
6434	James 95 or 96	5	1	473	530	1960.4	F
6435	James 97-01	5	0	422	478	1380.5	F
6436	James 95 or 96	4	1	456	508	1788.4	F
6437	James 97-01	5	1	414	466	1211.2	M
6439	James 97-01	5	1	422	474	1169.5	M
6448	James 95 or 96	5	0	453	508	1749.4	F
6449	James 95 or 96	5	0	432	490	1284.9	F
6456	James 97-01	5	0	428	482	1428.9	F
6458	James 95 or 96	6	1	456	516	1769.6	F
6460	James 97-01	5	1	450	512	1617.3	F

6463	James 95 or 96	5	0	420	478	1453	F
6464	James 97-01	5	0	468	526	1935.8	F
6465	James 97-01	5	0	433	492	1395.2	F
6469	James 97-01	5	0	424	488	1348.2	F
6471	James 97-01	5	0	438	497	1547.8	F
6473	James 97-01	5	0	452	504	1617.5	F
6476	James 97-01	4	0	436	487	1395.2	F
6481	James 97-01	5	0	406	462	1243.7	F
6485	James 97-01	7	2	442	497	1726	F
6487	James 95 or 96	4	0	444	506	1455.6	F
6492	James 97-01	6	0	460	522	1814.1	F
6493	James 95 or 96	5	0	432	496	1475	F
6495	James 97-01	5	0	409	464	1121.3	F
6496	James 95 or 96	5	1	466	526	1632	F
6587	James 97-01	6	2	438	491	1315.4	F
6600	James 95 or 96	7	3	464	522	1651.1	M
6617	James 95 or 96	5	1	458	517	1629.2	F
6633	James 97-01	5	0	464	526	1936.8	F
6637	James 97-01	6	0	450	508	1632.7	F
6638	James 95 or 96	6	1	420	482	1240.8	F
6641	James 97-01	5	0	435	493	1450.6	F
6660	James 97-01	6	1	450	516	1743	F
6665	James 97-01	5	0	450	516	1666.7	F

Table 17. Total numbers in seven year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2002. Ages are based on examination of scales.

Hatchery Year Class	Hatchery Production (millions)	1998	1999	2000	2001	2002	Total	Percent Contribution
1992	0.05		1				1	0.3
1993	0.50	7	2	1			10	2.6
1994	1.60	7	3	9			19	4.9
1995	5.30			59	9	8	76	19.8
1996	5.80			53	62	43	158	41.1
1997	5.90			2	27	78	107	27.9
1998	10.0					13	13	3.4
Total		14	6	124	98	142	384	100.0

Table 18. 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 2002. Age estimates are based on scales following Cating (1953).

Specimen	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
5808	4	0	478	424	1303.5	Female
6295	4	1	506	450	1420.5	Female
6363	6	0	510	458	1531.2	Female
6376	5	0	504	440	1645.4	Female
6516	6	0	486	428	1465.1	Female

Table 19. 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.* (In press).

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 20. Daily numbers and seasonal totals of striped bass live or dead (SB) and other species captured by staked gill net in the York River, 2002.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/24/2002	38	26	64	31	95
2/25/2002	17	12	29	50	79
3/3/2002	35	35	70	841	911
3/4/2002	21	24	45	370	415
3/10/2002	5	4	9	196	205
3/11/2002	7	9	16	208	224
3/17/2002	2	2	4	227	231
3/18/2002	2	4	6	208	214
3/24/2002	2	1	3	85	88
3/25/2002	2	2	4	105	109
3/31/2002	0	1	1	56	57
4/1/2002	2	1	3	72	75
4/7/2002	3	1	4	93	97
4/8/2002	2	3	5	91	96
4/14/2002	0	0	0	58	58
4/15/2002	0	2	2	113	115
4/21/2002	0	1	1	115	116
4/22/2002	0	1	1	55	56
4/28/2002	0	1	1	63	64
4/29/2002	3	6	9	106	115
5/5/2002	0	0	0	87	87
5/6/2002	0	5	5	92	97
5/12/2002	3	1	4	112	116
5/13/2002	1	1	2	117	119
Totals	145	143	288	3,551	3,839

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2002.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/24/2002	38	44	82	43	125
2/25/2002	35	25	60	74	134
3/3/2002	84	23	107	39	146
3/4/2002	32	14	46	16	62
3/10/2002	22	9	31	58	89
3/11/2002	9	26	35	19	54
3/17/2002	2	7	9	64	73
3/18/2002	15	4	19	88	107
3/24/2002	7	2	9	173	182
3/25/2002	10	0	10	79	89
3/31/2002	5	3	8	53	61
4/1/2002	6	4	10	44	54
4/7/2002	2	6	8	192	200
4/8/2002	0	5	5	161	166
4/14/2002	7	5	12	197	209
4/15/2002	3	4	7	135	142
4/21/2002	5	33	38	81	119
4/22/2002	4	64	68	86	154
4/28/2002	9	10	19	157	176
4/29/2002	6	21	27	112	139
5/5/2002	0	4	4	13	17
5/6/2002	1	4	5	20	25
5/12/2002	2	1	3	23	26
5/13/2002	0	3	3	19	22
Totals	304	321	625	1,946	2,571

Table 22. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2002.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/24/2002	37	3	40	261	301
2/25/2002	12	5	17	67	84
3/3/2002	18	3	21	55	76
3/4/2002	38	16	54	78	132
3/10/2002	25	33	58	196	254
3/11/2002	103	93	196	149	345
3/17/2002	18	31	49	227	276
3/18/2002	14	29	43	274	317
3/24/2002	12	8	20	436	456
3/25/2002	19	8	27	419	446
3/31/2002	4	8	12	222	234
4/1/2002	5	7	12	318	330
4/7/2002	8	13	21	367	388
4/8/2002	4	10	14	326	340
4/14/2002	2	9	11	370	381
4/15/2002	0	2	2	333	335
4/21/2002	0	37	37	357	394
4/22/2002	4	12	16	297	313
4/28/2002	4	10	14	178	192
4/29/2002	1	15	16	187	203
5/5/2002	1	12	13	205	218
5/6/2002	4	7	11	151	162
Totals	333	371	704	5,473	6,177

Table 23. 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	9.6	57	0.110	0.028	3.08

Table 24. 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	11.1	70	0.306	0.073	7.47

Table 25. 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	10.9	71	0.205	0.054	5.62