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Monitoring Relative Abundance of American Shad in Virginia's Rivers 2000 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 2000. This was the third 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 (1980-1992).

- Sampling occurred for 12 weeks on the York and Rappahannock rivers (27 February - 15 May 2000) and 13 weeks on the James River (20 February - 15 May 2000).

- A total of 904 female American shad (1,297.9 kg total weight) were captured in 2000. The 2000 catch was larger than that in 1999 when a total of 575 females were captured and the total weight was 796.1 kg (Olney and Hoenig 2000b).

- Total numbers of females in 2000 were highest on the York River (381 females) and James River (367 females). Catches were lowest on the Rappahannock River (156 females). As in previous years, total numbers of males were low on all rivers (York, 91; James, 67; Rappahannock, 18).

- Based on age estimates from scales using the methods of Cating (1953), the 1994, 1995 and 1996 year classes of American shad females were the most abundant on the James and York rivers. On the Rappahannock River, the 1995 and 1996 year classes were the most abundant. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 0.96; James River, 1.31; and Rappahannock River, 1.02. Total instantaneous mortality rates of males calculated from age-specific catch rates were: York River, 0.45; James River, 0.99; and Rappahannock River, 0.35.

- Otoliths of all American shad captured in staked gill nets on the James River were scanned for hatchery marks and otoliths of 180 specimens captured on the York River were scanned. The proportion of the catch with hatchery marks on the James and York rivers were 43.0 % (160 of 372 fish) and 2.2 % (4 of 180 fish), respectively. In previous years, prevalence of hatchery fish in the catch on the James River was low (4-8 %). The evidence suggests that the increase in catch rates observed on the James River in spring 2000 is due to the first large-scale influx of mature hatchery fish since the restoration program began. Four specimens captured in the James River were strays from other systems: the Pamunkey River (n= 2) and the Juniata River (n= 2).

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

- Three forms of an index of juvenile abundance were calculated. The maximal geometric mean catch of juvenile American shad (based on weekly summer pushnet surveys) was well above the time-series average on the Mattaponi River (average, 36.6; 2000 value, 115.7), and on the Pamunkey River (average 7.9; 2000 value 26.3). The geometric mean catch was 57.9 on the Mattaponi River (time-series average, 15.7) and 8.6 on the Pamunkey River (average 2.6). 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, 1,384.0; 2000 value, 4,194.7).

- Twenty-four species of by-catch were taken in the staked gill net monitoring gear for a total of 29,819 specimens. Almost 5,500 striped bass were captured (James River, n= 3,140; York River, n= 1,440; Rappahannock River, n= 848) . Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 32.6 %; York River, 60.2 %; and the Rappahannock River, 47.9 %.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2000 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 2000 (4.82) was similar to the 1999 value (4.85) and well below the 1998 value (13.47). The average of the historical data on the York River is 3.96. On the James River, the 2000 index (4.46) was higher than the values in 1998 and 1999 (2.60 in each year) but below the average of the historical data (8.88). The catch index on the Rappahannock River in 2000 (1.75) was higher than those obtained in previous years of monitoring (1999, 1.30; 1998, 1.46) and almost equal to the average of the historical data (1.76).

Introduction and need

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 1980-1992, 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 until this project began in 1998. 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 third year in the sampling program (2000) are reported in this document. The results of the first two years of sampling (1998 and 1999) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b) .

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. Furthermore, estimates of the prevalence of mature fish with hatchery marks in the rivers can be used to investigate the stock composition of the offshore mixed-stock fishery. 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. However, it needs to be critically evaluated since the ASMFC has mandated sampling for juveniles starting in 2000.

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 most of 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,

some 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 for this species if the stocks are rehabilitated and managed carefully.

- American shad are important for trophic and other ecological reasons. The abundance and occurrence of juveniles is 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 some 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 and ecosystem health.

- Monitoring the shad spawning run using historic gear also allows for a description of the bycatch 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.*, in press).

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 (Fig. 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. Native adult shad 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. 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, the Virginia Institute of Marine Science, and various other public and private agencies. The Commission decided to leave the ban in place but also decried the lack of information necessary to assess the recovery of Virginia stocks of American shad. The current monitoring project began in the spring of 1998 in response to the VMRC's request for information.

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 (1990-1999) 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). The utility of the index of juvenile abundance in the York River system was the subject of a recently completed graduate thesis (Aiken, 2000) Three papers summarizing various aspects of the reproductive biology of American shad and the VIMS stock assessment program have recently been accepted or have appeared in peer-reviewed journals (Maki *et al.*, in press; Olney *et al.*, in press; Olney and Hoenig, 2001). A fourth manuscript (Maki *et al.*) has been submitted for review.

Objectives

The 2000 objectives were the same as for 1998 and 1999: (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 bycatch of other species in the staked gill nets.

Methods

The 2000 methods were the same as for 1998 and 1999. 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 (for examples, see Figures 2 and 3), 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 and Mr. Mark Brown) were authors of the historical logbooks on the York and James rivers, respectively. However, authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders) with 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 4-6). 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 York and Rappahannock rivers (27 February - 15 May 2000) and 13 weeks on the James River (20 February - 15 May 2000). Surface water temperature was recorded at each sampling event.

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 aging. Whole otoliths were cleaned by immersing in a 10% bleach and hydrogen peroxide bath. After immersion, the cleaning solution was drawn off by pipette, and otoliths were rinsed with distilled water. Otoliths were examined under a dissecting microscope at 40x with reflected light under immersion oil, and aged by one individual (J. Goins, VIMS). An otolith annulus was considered to be one opaque zone and its successive hyaline zone. One otolith taken from every fish on the James River and a randomly selected subsample of fish taken on the York River were scanned for hatchery marks using epifluorescent microscopy. To do this, otoliths were mounted on slides and ground and polished by hand using wet laboratory-grade sandpaper. Personnel from the VDGIF (D. Hopler) assisted in this evaluation.

Scales 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.

Results

Catches of American shad by staked gill nets in 2000

Fishing days, numbers of American shad captured, and catch rates (males and females) are reported in Tables 1-6 and Figures 7 and 8. A total of 1,080 American shad (176 males:904 females) were captured. The total weight of the sample was 1,507.3 kg (3,315.9 lbs). The 2000 catch was higher than that in 1999 when a total of 629 fish was captured and the total weight was 859.0 kg (Olney and Hoenig 2000b). Catches in 2000 were low on the Rappahannock River (174 total fish, 18 males and 156 females), higher on the James River (434 total fish, 67 males and 367 females) and highest on the York River (472 total fish, 91 males and 381 females). On the James River, catches of females peaked on 26 March through 10 April 2000 when catch rates

exceeded 0.08 fish/m or 0.11 kg/m. During that period on the James River, 56.9 % (209 of 367) of the total number of females was captured. On the York River, catches of females peaked between 12 March and 12 April 2000 when catch rates exceeded 0.06 fish/m or 0.08 kg/m. During that period on the York River, 80.3 % (306 of 381) of the total number of females was captured. Catches of females on the Rappahannock River peaked between 19 March and 12 April 2000 when catch rates exceeded 0.03 fish/m or 0.05 kg/m. During that period on the Rappahannock River, 65.4 % (102 of 156) of the total number of females was captured. The highest recorded daily catch by weight occurred on 26 March 2000 when 53 female American shad (76.5 kg or 168.3 lbs) were taken in the York River (Table 3). As in previous years of monitoring, catches of males were low throughout the period on all rivers.

The duration of the 2000 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 70 days on the James River (27 February - 7 May), 76 days on the York River (28 February - 14 May) and 73 days on the Rappahannock River (5 March - 15 May).

Biological characteristics of the American shad in 2000

Age, length (mm TL) and weight (g) of American shad in staked gill nets are summarized in Tables 7-8 and frequency distributions of total length are depicted in Figures 9-10. Mean total length at age of males and females ranged from 434-549 mm TL and 452-586 mm TL, respectively. Mean weight at age of males and females ranged from 0.94-1.84 kg and 1.11-2.55 kg, respectively. Overall, the 1996 and 1995 year classes (ages 4 and 5) of female American shad were the most abundant on all three rivers. Males were infrequently collected on the Rappahannock River and no age class dominated. The 1994-1996 year classes (ages 4-6) of male American shad were most abundant on the James and York rivers. On the James River, five age classes of females were represented (1993-1997) and the sample was dominated by age-4 fish (46.5 % of the total that were aged). On the York River, eight age classes of females were represented (1990-1997) and the sample was dominated by age-5 fish (39.1 % of the total that were aged). On the Rappahannock River, seven age classes of females were taken (1991-1997) and age-4 fish dominated (53.8 % of the aged sample).

Spawning histories of female American shad collected in 2000 are presented in Tables 9 and 10. On the York River, females ranged in age from 3 to 10 years with 0 (virgin) to 5 spawning marks. On the James River, females ranged in age from 3-8 years with 0 (virgin) to 4 spawning marks. On the Rappahannock River, females ranged in age from 3-9 years with up to 4 spawning marks. The following percentages of females in each river had a least one prior spawn: York River, 31.1 % (233 virgins in a sample of 338); James River 28.7 % (271 virgins in a sample of 380 fish); Rappahannock River 25.9 % (106 virgins in a sample of 143 fish). In previous years on the York River, 40.2% of all females (171 virgins in a sample of 286) had a least one prior spawn in 1998 and 67.3% of all females (82 virgins in a sample of 251) had a least one prior spawn in 1999 (Olney and Hoenig 2000a, 2000b).

Age-specific catch rates of American shad are reported in Tables 11-12 and depicted in Figure 11. 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. For

females, the catch at ages 5-8 (James River), 5-10 (York River) and 4-8 (Rappahannock River were used in regressions. Estimates of Z for females for each stock were: James, 1.31 (r^2= 0.97); York, 0.96 (r^2= 0.90); and Rappahannock, 1.02 (r^2= 0.97). For males, the catch at ages 5-8 (James River) and 5-7 (York and Rappahannock rivers) were used in regressions. Estimates of Z for males for each stock were: James, 0.99 (r^2= 0.78); York, 0.45 (r^2= 0.91); and Rappahannock, 0.35 (r^2= 0.99).

Evaluation of hatchery origin of American shad in 2000

Otoliths of all adult American shad taken in the James River were scanned for hatchery marks. The proportion of the staked gill net catch in 2000 with hatchery marks was 43.0 % (160 of 372 fish). In previous years, the proportion of the staked gill net catch on the James River with hatchery marks were 8.4 % in 1998 and 4.5 % in 1999. The abrupt jump in hatchery prevalence in 2000 coincides with a doubling of catch rates on the James River. The evidence suggests that the increase in catch rates is due to the first large-scale influx of mature virgin hatchery fish since the restoration program began. The biological attributes of these specimens are presented in Table 13. Ages of hatchery fish ranged from 3-7 years and 29.2 % of these fish were judged to be repeat spawners (42 of 144 fish).

Otoliths of 180 fish taken on the York River were scanned for hatchery marks. The proportion of the sample with marks was 2.2 % (4 of 180 fish). The biological characteristics of these specimens is reported in Table 14.

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

Juvenile abundance of American shad

Tables 15 and 16 report 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 of the weekly geometric mean catch rate. This index is defined as the maximal geometric mean catch (the maximal mean CPUE) in a sampling period (i.e., during any one week of sampling) that exceeds the mean CPUE in all other periods (i.e., over a series of weekly cruises). The maximal geometric mean catch in 2000 was well above the time-series average of abundance on the Mattaponi River (average, 36.6; 2000 value, 115.7), and the Pamunkey River (average 7.9; 2000 value 26.3).

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 (Table 16). The time series of the combined area under the catch curve for both rivers depicts above average (> 1,384.0) abundance of juveniles in the York River system in 1994, 1996-1998 and 2000 relative to the other years in the record (dating back to 1991), while index values were low in 1991, 1992, 1995 and 1999 (Figure 12).

By-catch of striped bass and other species in 2000

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 17-19 and Figure 13. Twenty-four 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*). Sixteen Atlantic sturgeon were captured (James River, 15; York River, 1). Almost 5,500 striped bass were captured by the gear (York River, 1,440; James, 3,140; Rappahannock, 848). We counted and released live striped bass that were captured. The proportions of dead striped bass on each river were: James River, 32.6 %; York River, 60.2 %; and the Rappahannock River, 47.9 %.

Seasonal catch indexes, 1980-1992 and 1998-2000

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2000 and for each year of the historical record of staked net catches on each river (Tables 20-22 and Figures 14-19). On the York River, the seasonal catch index in 2000 (4.82) was similar to the 1999 value (4.85) and well below the 1998 value (13.47). The average of the historical data on the York River is 3.96. On the James River, the 2000 index (4.46) was higher than the values in 1998 and 1999 (2.60 in each year) but below the average of the historical data (8.88). The catch index on the Rappahannock River in 2000 (1.75) was higher than those obtained in previous years of monitoring (1999, 1.3; 1998, 1.5) and almost equal to the average of the historical data (1.76).

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 occurred in the decade prior to the moratorium. The program also provides information for validating the juvenile index of abundance and for determining the amount of bycatch that could be expected in a commercial fishery if the in-river fishing ban is lifted.

In 1998, 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 20-22) 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 number 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.

On the James River, the catch rate increased in 2000 relative to 1998 and 1999, perhaps as a result of an influx of mature virgin hatchery fish that were released in 1994 and 1995. The James River index in 2000 was higher than historic index values in 1982, 1987, 1990 and 1991. However, the 1998-2000 average on the James River (3.22) 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 fishing moratoria is essential for the recovery of the James River stock.

On the Rappahannock River, recent catch rates are comparable to the historic record. The 1998-2000 average (1.50) is below the average of the historical data (1.76) and below the proposed target of 6. It should be noted that since the catch index for the Rappahannock River is low throughout 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 believe that present status of the Rappahannock River stock is stable but low in abundance.

The index on the York River was high in 1998 but declined sharply in 1999 and 2000. The 1998-2000 average of York River index values (7.71) is above the average of the historical data (3.96) but below the proposed target (10). 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 2001). However, we believe that high catch rates (annual indexes >10) on the York River should be observed for additional successive years before concluding abundance is now higher than at the time the moratorium was imposed.

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Table 1. 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 2000

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/27/00	9	0.031	13,172.90	0.045
2/28/00	22	0.075	34,460.10	0.117
3/5/00	13	0.047	18,313.00	0.067
3/6/00	14	0.051	19,536.10	0.071
3/12/00	23	0.084	32,664.90	0.119
3/13/00	19	0.069	28,484.70	0.104
3/19/00	6	0.015	9,139.80	0.024
3/20/00	17	0.062	23,515.80	0.086
3/26/00	52	0.190	71,430.80	0.260
3/27/00	54	0.197	75,813.10	0.276
4/2/00	25	0.091	34,952.60	0.127
4/3/00	28	0.102	41,396.10	0.151
4/9/00	29	0.106	42,205.10	0.154
4/10/00	21	0.077	28,916.70	0.105
4/16/00	9	0.031	12,426.50	0.043
4/17/00	10	0.038	14,401.50	0.055
4/23/00	2	0.008	4,119.60	0.016
4/24/00	2	0.007	2,364.90	0.009
4/30/00	6	0.022	8,837.10	0.032
5/7/00	3	0.011	3,906.80	0.014
5/8/00	2	0.008	1,840.20	0.007
5/14/00	1	0.004	1,583.20	0.006
	367		523,481.50	

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Table 2. 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 2000.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/20/00	1	0.004	1,112.90	0.004
2/21/00	1	0.004	1,155.00	0.005
2/27/00	7	0.024	8,808.80	0.030
2/28/00	8	0.027	10,738.80	0.036
3/5/00	6	0.022	7,213.00	0.026
3/6/00	2	0.007	2,640.30	0.010
3/12/00	6	0.022	7,124.20	0.026
3/13/00	6	0.022	6,964.10	0.025
3/20/00	3	0.011	3,472.50	0.013
3/26/00	10	0.036	12,070.60	0.044
3/27/00	9	0.033	12,002.30	0.044
4/2/00	2	0.007	2,090.20	0.008
4/3/00	1	0.004	1,244.10	0.005
4/9/00	3	0.011	3,051.00	0.011
4/10/00	1	0.004	1,105.70	0.004
5/7/00	1	0.004	1,044.30	0.004
	67		81,837.80	

Table 3. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the York River, spring 2000.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/27/00	1	0.003	1,323.80	0.005
2/28/00	8	0.031	13,244.80	0.052
3/5/00	4	0.016	5,212.00	0.021
3/6/00	4	0.015	6,694.10	0.024
3/12/00	45	0.164	64,679.40	0.236
3/13/00	51	0.186	73,225.20	0.267
3/19/00	15	0.058	20,306.00	0.079
3/20/00	16	0.058	22,741.60	0.083
3/26/00	53	0.193	76,513.00	0.279
3/27/00	47	0.171	68,202.70	0.249
4/2/00	32	0.112	45,186.70	0.158
4/11/00	27	0.098	36,793.70	0.134
4/12/00	20	0.073	27,272.50	0.099
4/16/00	11	0.042	14,235.90	0.054
4/17/00	5	0.018	7,246.80	0.025
4/23/00	9	0.033	11,586.70	0.042
4/24/00	11	0.040	14,581.10	0.053
4/30/00	10	0.040	13,019.40	0.052
5/1/00	4	0.015	5,239.10	0.020
5/7/00	3	0.012	2,788.80	0.011
5/8/00	2	0.008	3,032.40	0.012
5/14/00	2	0.007	3,265.30	0.012
5/15/00	1	0.004	1,362.20	0.005
Total	381		537,753.20	

Table 4. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the York River, spring 2000.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/27/00	6	0.021	6,886.00	0.024
2/28/00	10	0.039	11,694.00	0.045
3/5/00	2	0.008	2,057.70	0.008
3/6/00	5	0.018	5,555.00	0.020
3/12/00	11	0.040	12,760.70	0.047
3/13/00	18	0.066	20,636.20	0.075
3/19/00	2	0.008	1,663.60	0.006
3/20/00	5	0.018	5,488.50	0.020
3/26/00	10	0.036	12,833.80	0.047
3/27/00	8	0.029	8,773.30	0.032
4/2/00	2	0.007	1,935.40	0.007
4/12/00	4	0.015	4,648.60	0.017
4/16/00	2	0.008	2,083.90	0.008
4/17/00	1	0.004	1,311.10	0.005
4/24/00	2	0.007	2,334.00	0.009
5/1/00	2	0.008	2,334.20	0.009
5/14/00	1	0.004	1,021.90	0.004
Totals	91		104,017.90	

Table 5. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2000.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/27/00	1	0.004	1,619.70	0.006
2/28/00	1	0.004	1,642.10	0.006
3/5/00	4	0.014	5,547.20	0.020
3/6/00	1	0.004	1,351.60	0.005
3/12/00	4	0.014	6,351.70	0.023
3/13/00	2	0.007	2,506.20	0.009
3/19/00	9	0.033	13,940.20	0.051
3/20/00	9	0.032	13,604.80	0.049
3/26/00	9	0.032	14,919.90	0.054
3/27/00	10	0.036	17,409.00	0.063
4/2/00	18	0.069	26,339.00	0.101
4/3/00	25	0.096	36,635.80	0.141
4/11/00	12	0.049	17,777.60	0.073
4/12/00	10	0.036	15,883.20	0.057
4/16/00	5	0.018	6,853.90	0.025
4/17/00	7	0.025	10,515.70	0.038
4/23/00	7	0.025	10,180.60	0.037
4/24/00	7	0.025	10,886.20	0.039
5/1/00	9	0.032	13,906.10	0.050
5/7/00	2	0.007	2,870.60	0.010
5/15/00	4	0.014	5,891.20	0.021
Totals	156		236,632.30	

Table 6. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2000.

Date	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/27/00	2	0.007	2,791.80	0.010
3/5/00	4	0.014	5,220.30	0.019
3/13/00	2	0.007	2,752.20	0.010
3/19/00	2	0.007	3,156.90	0.012
3/26/00	1	0.004	1,310.40	0.005
4/2/00	1	0.004	1,064.80	0.004
4/3/00	3	0.012	3,742.30	0.014
4/11/00	1	0.004	1,253.60	0.005
4/30/00	0	0.000	0.00	0.000
5/1/00	1	0.004	1,141.20	0.004
5/8/00	1	0.004	1,076.50	0.004
Totals	18		23,510.00	

Table 7. Number captured, mean total length (mm) and mean weight (g) of female American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2000. 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	SD	Mean weight	SD
James River	NA	40	490.08	29.15	1,426.25	249.19
	1997	11	466.18	16.47	1,180.97	99.47
	1996	152	478.87	21.18	1,335.03	186.81
	1995	135	493.81	20.21	1,484.72	197.00
	1994	25	510.96	21.97	1,649.54	273.50
	1993	4	550.75	34.33	2,209.98	526.43
York River	NA	44	490.41	24.81	1,435.96	244.13
	1997	9	452.56	19.76	1,106.92	148.83
	1996	110	470.84	19.82	1,282.95	179.68
	1995	135	489.41	19.45	1,435.95	213.07
	1994	70	507.90	21.40	1,548.12	278.94
	1993	16	521.63	15.39	1,460.11	292.24
	1992	2	556.00	19.80	1,842.70	444.49
	1991	2	560.00	5.66	1,834.80	539.95
	1990	1	572.00		2,452.50	
Rapp. River	NA	28	493.11	24.10	1,495.76	216.06
	1997	1	462.00		1,280.50	
	1996	70	486.50	19.51	1,433.55	169.44
	1995	40	493.35	16.87	1,494.20	145.97
	1994	14	515.07	20.36	1,792.31	205.25
	1993	3	545.33	11.02	2,036.93	261.96
	1992	1	586.00		2,300.40	
	1991	1	577.00		2,553.40	

Table 8. Number captured, mean total length (mm) and mean weight (g) of male American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2000. 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	SD	Mean Weight	SD
James River	NA	14	476.71	33.46	1,228.06	228.96
	1997	2	434.50	31.82	949.60	264.46
	1996	15	455.33	16.86	1,131.50	177.74
	1995	21	474.19	20.14	1,234.62	162.75
	1994	13	476.62	14.41	1,277.00	124.33
	1993	1	495.00		1,407.90	
	1992	1	549.00		1,837.30	
York River	NA	16	449.94	25.42	1,053.11	194.29
	1997	2	434.00	25.46	942.30	204.92
	1996	22	449.05	20.93	1,034.96	145.96
	1995	27	468.15	12.65	1,180.65	110.57
	1994	21	469.95	16.51	1,218.09	105.71
	1993	10	485.70	31.47	1,266.98	242.35
Rapp. River	NA	5	468.20	15.66	1,195.02	137.05
	1997	1	456.00		1,174.90	
	1996	2	451.50	12.02	1,103.00	54.02
	1995	5	477.00	13.84	1,289.70	130.06
	1994	3	506.33	14.98	1,577.50	94.94
	1993	2	493.00	1.41	1,486.50	157.40

Table 9. Spawning histories of American shad collected in spring, 2000 in the York and James rivers. Table entries are numbers of fish (York River, n= 338; James River, n= 380). 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= 124) 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.*, in press).

		Age at Maturity				
York River Year Class	Age at Capture	3	4	5	6	7
1997	3	**9**	-	-	-	-
1996	4	1	**107**	-	-	-
1995	5	1	30	**100**	-	-
1994	6	0	36	18	**16**	-
1993	7	0	3	11	1	**1**
1992	8	0	1	1	0	0
1991	9	0	1	0	0	0
1990	10	0	0	1	0	0

		Age at Maturity				
James River Year Class	Age at Capture	3	4	5	6	7
1997	3	**13 (2)**				
1996	4	2 (0)	**165 (53)**			
1995	5	4 (0)	63 (25)	**89 (34)**		
1994	6	3 (0)	26 (7)	5 (2)	**4 (0)**	
1993	7	0 (0)	4 (1)	1 (0)	0	**0 (0)**
1992	8	0	1	0	0	0

Table 10. Spawning histories of American shad collected in spring, 2000 in the Rappahannock River. Table entries are numbers of fish (n= 143). 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.*, in press).

Year Class	Age at Capture	3	4	5	6	7
1997	3	**2**				
1996	4	0	**72**			
1995	5	0	14	**31**		
1994	6	0	9	7	**1**	
1993	7	0	2	3	0	**0**
1992	8	0	1	0	0	0
1991	9	0	0	1	0	0

Table 11. Number, total weight and seasonal catch rates (total number per season per m; total weight per season per m) by year class of female American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 2000. Age estimates are based on examination of scales following Cating (1953). Abbreviations are: NA, not aged; Rapp, Rappahannock River.

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James River	1997	11	12.99	26.33	0.0015	0.0018
	1996	152	202.92	26.33	0.0210	0.0281
	1995	135	200.44	26.33	0.0187	0.0277
	1994	25	41.24	26.33	0.0035	0.0057
	1993	4	8.84	26.33	0.0006	0.0012
	NA	40	57.05	26.33	0.0055	0.0079
York River	1997	9	9.96	24.60	0.0013	0.0015
	1996	110	141.12	24.60	0.0163	0.0209
	1995	135	193.85	24.60	0.0200	0.0287
	1994	70	108.37	24.60	0.0104	0.0161
	1993	16	23.36	24.60	0.0024	0.0035
	1992	2	3.69	24.60	0.0003	0.0005
	1991	2	3.67	24.60	0.0003	0.0005
	1990	1	2.45	24.60	0.0001	0.0004
	NA	44	63.18	24.60	0.0065	0.0094
Rapp. River	1997	1	1.28	23.69	0.0002	0.0002
	1996	70	100.35	23.69	0.0106	0.0152
	1995	40	59.77	23.69	0.0061	0.0091
	1994	14	25.09	23.69	0.0021	0.0038
	1993	3	6.11	23.69	0.0005	0.0009
	1992	1	2.30	23.69	0.0002	0.0003
	1991	1	2.55	23.69	0.0002	0.0004
	NA	28	41.88	23.69	0.0043	0.0064

Table 12. Number, total weight and seasonal catch rates (total number per season per m; total weight per season per m) by year class of male American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring, 2000. Age estimates are based on examination of scales following Cating (1953). Abbreviations are: NA, not aged; Rapp., Rappahannock River.

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James River	1997	2	1.90	26.33	0.0003	0.0003
	1996	15	16.97	26.33	0.0021	0.0024
	1995	21	25.93	26.33	0.0029	0.0036
	1994	13	16.60	26.33	0.0018	0.0023
	1993	1	1.41	26.33	0.0001	0.0002
	1992	1	1.84	26.33	0.0001	0.0003
	NA	14	17.19	26.33	0.0019	0.0024
York River	1997	2	1.88	24.60	0.0003	0.0003
	1996	22	22.77	24.60	0.0033	0.0034
	1995	27	31.88	24.60	0.0040	0.0047
	1994	21	25.58	24.60	0.0031	0.0038
	1993	10	12.67	24.60	0.0015	0.0019
	NA	16	16.85	24.60	0.0024	0.0025
Rapp. River	1997	1	1.17	23.69	0.0002	0.0002
	1996	2	2.21	23.69	0.0003	0.0003
	1995	5	6.45	23.69	0.0008	0.0010
	1994	3	4.73	23.69	0.0005	0.0007
	1993	2	2.97	23.69	0.0003	0.0005
	NA	5	5.98	23.69	0.0008	0.0009

Table 13. 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 2000. Age estimates are based on scales following Cating (1953). Abbreviations are: Pam - Pamunkey River.

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
2115	James 1995 or 1996			417	476	1,155.0	M
2131	James 1995 or 1996			429	492	1,378.5	M
2135	James 1995 or 1996	4	0	409	468	1,284.8	F
2137	James 1995 or 1996			414	473	1,236.3	M
2139	James 1995 or 1996	5	0	436	486	1,485.1	F
2140	James 1995 or 1996	5	0	408	460	1,215.4	F
2142	James 1995 or 1996	5	0	428	484	1,341.7	F
2144	James 1995 or 1996			440	495	1,589.6	F
2146	James 1995 or 1996	7	3	434	495	1,407.9	M
2147	James 1995 or 1996	4	0	420	472	1,257.4	F
2148	James 1995 or 1996	4	0	411	470	1,146.7	F
2149	James 1994	6	1	410	464	1,196.6	M
2152	James 1995 or 1996			446	502	1,467.5	F
2159	James 1994	6	1	466	532	1,854.4	F
2161	Pam. 1995 or 1996	5	1	426	488	1,224.3	M
2163	James 1995 or 1996	4	0	427	478	1,432.1	F
2165	James 1995 or 1996	5	0	426	486	1,428.9	F
2167	James 1994			472	538	1,690.3	F
2168	James 1995 or 1996	4	0	447	511	1,568.7	F
2170	James 1995 or 1996	5	1	410	470	1,276.8	F
2174	James 1995 or 1996	4	0	460	522	1,584.4	F
2208	James 1995 or 1996	6	2	414	470	1,275.7	F
2210	James 1995 or 1996	5	1	400	448	1,032.6	M
2213	James 1994	6	2	450	507	1,725.3	F
2222	James 1995 or 1996			392	440	1,053.8	F
2225	James 1995 or 1996	5	0	434	484	1,303.3	F
2226	James 1995 or 1996	5	1	432	493	1,357.6	M
2249	James 1995 or 1996	5	0	418	466	1,297.0	F
2250	James 1995 or 1996	4	0	434	492	1,378.3	F
2251	James 1995 or 1996	4	0	451	510	1,682.4	F
2252	James 1995 or 1996	4	0	440	494	1,371.5	F
2253	James 1994	5	1	445	502	1,445.4	F
2257	James 1995 or 1996			418	476	1,349.9	F
2260	James 1995 or 1996	4	0	412	468	1,189.9	F
2339	James 1995 or 1996	4	0	409	464	1,247.9	F
2341	James 1995 or 1996	5	1	434	494	1,430.8	F
2343	James 1995 or 1996	4	0	380	434	1,042.4	M
2345	James 1995 or 1996	5	0	428	488	1,408.5	F
2347	James 1995 or 1996	4	0	448	508	1,750.2	F

Table 13. Continued.

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
2348	James 1995 or 1996	4	0	404	456	1,095.3	F
2356	James 1995 or 1996			439	501	1,555.1	F
2360	James 1995 or 1996	3	0	396	450	1,180.5	F
2363	James 1995 or 1996			398	456	1,278.5	F
2370	Juniata 1994	5	1	434	498	1,605.9	F
2381	James 1995 or 1996	4	0	423	486	1,317.4	F
2576	James 1995 or 1996	4	0	404	458	1,190.1	F
2578	James 1995 or 1996	5	0	414	469	1,232.6	F
2591	James 1995 or 1996	5	1	452	518	1,699.8	F
2593	James 1995 or 1996	4	0	395	452	1,142.1	F
2595	James 1995 or 1996	4	0	410	464	1,133.0	F
2597	James 1995 or 1996			482	534	1,669.2	F
2598	James 1995 or 1996	4	0	432	486	1,433.7	F
2599	James 1995 or 1996	4	0	416	470	1,252.4	F
2601	James 1994	5	1	402	458	1,016.4	M
2602	James 1995 or 1996	5	0	421	477	1,350.1	F
2603	James 1995 or 1996	4	0	430	486	1,390.0	F
2605	James 1995 or 1996	5	0	453	512	1,626.2	F
2606	James 1995 or 1996	5	0	424	480	1,357.6	F
2607	James 1995 or 1996	4	0	434	497	1,390.7	F
2608	James 1995 or 1996	4	0	433	498	1,444.3	F
2610	James 1995 or 1996	4	0	394	444	1,041.0	F
2722	James 1995 or 1996	4	0	420	471	1,291.9	F
2723	Pam. 1995 or 1996	4	0	432	488	1,402.6	F
2726	James 1995 or 1996	4	0	415	473	1,296.2	F
2730	James 1995 or 1996	4	0	421	468	1,274.5	F
2731	James 1997-2000	4	0	402	436	1,146.7	F
2736	James 1995 or 1996	5	1	400	444	1,169.4	M
2737	James 1995 or 1996	4	0	417	460	1,100.4	F
2740	James 1995 or 1996	4	0	443	488	1,516.4	F
2742	James 1995 or 1996	5	0	452	504	1,842.1	F
2743	James 1995 or 1996	5	1	445	491	1,689.1	F
2744	James 1995 or 1996	4	0	400	440	1,073.9	M
2745	James 1995 or 1996	4	0	390	430	976.4	F
2747	James 1995 or 1996	5	1	457	499	1,737.3	F
2749	James 1994			440	494	1,433.0	M
2750	James 1994	5	1	455	499	1,698.0	F
2757	James 1994	5	0	444	495	1,626.3	F
2760	James 1995 or 1996	4	0	426	466	1,200.9	F
2764	James 1995 or 1996	5	0	412	458	1,173.8	F
2765	James 1995 or 1996	5	0	412	459	1,189.0	F

Table 13. Continued.

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
2768	James 1994	5	1	475	529	1,879.9	F
2769	James 1995 or 1996	4	0	422	473	1,463.3	F
2770	James 1995 or 1996	4	0	433	480	1,394.2	F
2772	na	5	1	450	502	1,477.1	F
2775	James 1995 or 1996	4	0	438	491	1,445.8	F
2779	James 1995 or 1996	5	1	464	512	1,890.1	F
2780	James 1995 or 1996	5	1	462	514	1,847.8	F
2877	James 1995 or 1996	6	2	444	502	1,639.9	F
2880	James 1995 or 1996	5	1	392	442	1,069.3	M
2883	James 1995 or 1996	4	0	410	464	1,251.3	F
2885	James 1995 or 1996	5	1	441	502	1,559.9	F
2886	James 1993	4	0	426	476	1,309.6	F
2887	James 1995 or 1996	5	1	435	488	1,450.0	F
2889	James 1995 or 1996			432	484	1,369.6	F
2890	James 1995 or 1996	6	2	428	488	1,383.5	F
2891	James 1995 or 1996	5	0	428	490	1,370.8	F
2898	James 1995 or 1996	5	1	404	464	1,254.5	M
2900	James 1995 or 1996	5	0	450	507	1,492.9	F
2901	James 1995 or 1996	5	0	435	492	1,562.0	F
2905	James 1995 or 1996	4	0	427	482	1,396.6	F
2909	James 1994	5	1	448	510	1,328.1	F
2910	James 1995 or 1996	5	0	432	490	1,473.1	F
2912	James 1995 or 1996	5	0	430	489	1,406.6	F
2913	James 1995 or 1996	4	0	394	440	1,075.1	F
2914	James 1995 or 1996	5	1	436	495	1,467.7	F
2919	James 1995 or 1996	5	0	418	468	1,278.3	F
2930	James 1995 or 1996	5	1	409	464	1,196.4	F
2933	James 1995 or 1996	5	0	406	460	1,267.8	F
2935	James 1995 or 1996	5	1	440	498	1,458.8	F
2936	James 1995 or 1996	5	1	412	465	1,343.0	F
2937	James 1995 or 1996	5	0	465	520	1,709.7	F
2939	James 1994	5	0	452	518	1,539.8	F
3129	James 1993	5	1	430	484	1,505.1	F
3130	James 1995 or 1996	4	0	422	484	1,418.4	F
3131	James 1995 or 1996	4	0	442	498	1,367.4	F
3134	James 1995 or 1996	4	0	400	456	1,156.1	F
3135	Juniata 1996	4	0	425	478	1,221.5	F
3141	James 1995 or 1996	4	0	440	485	1,423.0	F
3143	James 1995 or 1996	5	0	442	494	1,497.9	F
3145	Pam. 1995 or 1996	4	0	456	512	1,640.9	F
3138	James 1995 or 1996	4	0	434	492	1,672.8	F

Table 13. Continued.

Spec	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
3147	James 1995 or 1996	5	0	428	476	1,283.9	F
3148	James 1995 or 1996	5	0	405	458	1,266.1	F
3149	James 1995 or 1996	5	0	414	460	1,189.1	F
3150	James 1995 or 1996			428	480	1,390.3	F
3152	James 1993	5	1	482	540	1,882.2	F
3174	James 1995 or 1996	4	0	402	453	1,169.3	F
3175	James 1995 or 1996	5	0	424	480	1,395.4	F
3176	James 1995 or 1996	6	2	419	472	1,244.1	M
3177	James 1994	5	1	468	523	1,921.3	F
3178	James 1995 or 1996	4	0	405	454	1,092.9	F
3181	Juniata 1988 -1994	4	0	460	514	1,658.1	F
3183	James 1995 or 1996	5	0	456	510	1,550.9	F
3186	James 1995 or 1996	4	0	442	493	1,431.6	F
3187	James 1995 or 1996	4	0	416	464	1,288.5	F
3188	James 1995 or 1996	5	0	460	518	1,892.9	F
3189	James 1995 or 1996	4	0	448	508	1,680.9	F
3191	James 1995 or 1996	5	0	435	492	1,436.1	F
3196	James 1995 or 1996	5	1	414	464	1,315.7	F
3197	James 1995 or 1996	5	0	428	480	1,323.2	F
3200	James 1995 or 1996	5	1	452	505	1,594.8	F
3201	Pam. 1995 or 1996	5	1	448	498	1,560.8	F
3366	James 1995 or 1996	4	0	388	442	1,098.6	F
3367	James 1995 or 1996	4	0	410	470	1,272.4	F
3368	James 1993	6	2	425	478	1,410.5	F
3371	James 1995 or 1996	4	0	416	478	1,295.1	F
3375	James 1995 or 1996	4	0	435	496	1,497.4	F
3376	James 1993	4	0	406	462	1,169.9	F
3379	James 1995 or 1996	4	0	434	496	1,559.4	F
3380	James 1995 or 1996	4	0	436	498	1,355.6	F
3381	James 1995 or 1996	4	0	404	471	1,306.4	F
3385	James 1995 or 1996			390	452	1,247.1	F
3387	James 1995 or 1996	4	0	420	473	1,253.8	F
3390	James 1995 or 1996			420	474	1,421.7	F
3396	James 1995 or 1996	6	2	464	527	1,844.2	F
3397	James 1995 or 1996	5	0	445	506	1,604.1	F
3403	James 1995 or 1996	5	0	454	508	1,488.6	F
3407	James 1997-2000	3	0	356	412	762.6	M
3616	James 1995 or 1996	4	0	426	484	1,369.8	F
3657	James 1995 or 1996	4	0	412	468	1,231.3	F

Table 14. 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 York River in 2000. Age estimates are based on scales following Cating (1953).

Specimen	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
2285	5	0	455	512	1,645.6	
2304	6	2	424	488	1,240.2	
2324	4	0	420	479	1,283.8	
2428	5	0	382	439	891.5	

Table 15. Summary of maximum geometric mean catch rate (numbers of juveniles per standard tow) for juvenile blueback herring, alewife, and American shad in the Pamunkey and Mattaponi rivers: 1979-1999.

River	Year	Blueback herring	Alewife	American shad
		Maximum CPUE	Maximum CPUE	Maximum CPUE
Pamunkey	1979	49.1	3.5	32.0
	1980	50.2	2.9	3.5
	1981	6.1	2.7	3.3
	1982	177.2	11.6	1.9
	1983	59.4	1.9	3.6
	1984	25.0	0.9	1.0
	1985	61.2	5.9	10.1
	1986	33.3	3.7	4.4
	1987	80.1	2.9	0.4
	1988	*	*	*
	1989	*	*	*
	1990	*	*	*
	1991	7.5	1.2	6.3
	1992	0.1	0.0	0.1
	1993	2.3	0.1	0.7
	1994	59.3	3.9	9.5
	1995	5.9	0.1	2.2
	1996	66.1	4.4	31.5
	1997	39.7	0.5	8.2
	1998	29.7	0.8	3.5
	1999	4.2	0.2	2.2

River	Year	Blueback herring	Alewife	American shad
		Maximum CPUE	Maximum CPUE	Maximum CPUE
	2000	34.9	1.0	26.3
Mattaponi	1979	24.4	2.9	24.3
	1980	3.8	1.3	18.5
	1981	9.0	5.0	13.5
	1982	92.3	18.3	9.3
	1983	17.1	3.2	7.3
	1984	93.4	19.0	22.6
	1985	127.2	13.6	26.0
	1986	15.5	7.1	26.1
	1987	14.6	0.8	7.3
	1988	*	*	*
	1989	*	*	*
	1990	*	*	*
	1991	4.6	0.3	7.0
	1992	0.2	0.0	1.5
	1993	5.1	0.2	30.3
	1994	38.8	12.8	51.5
	1995	0.4	0.1	6.4
	1996	63.6	22.4	144.2
	1997	27.4	6.6	95.4
	1998	68.1	6.8	77.3
	1999	42.1	2.7	11.8
	2000	26.4	3.5	115.7

* No sampling was conducted in 1988 and 1989, and only partial sampling was conducted in 1990.

Table 16. Indexes of abundance of juvenile American shad in pushnet surveys on the Mattaponi and Pamunkey rivers, 1979-2000. 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 Aiken (2000).

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	7.4	5.1	1,134.0	1,258.9	2,392.9
1980	6.6	1.1	636.2	228.1	864.3
1981	1.2	1.1	43.6	106.4	150.0
1982	4.4	0.6	342.2	32.0	374.2
1983	3.6	1.7	300.5	105.4	405.9
1984	9.5	0.7	446.2	25.7	471.9
1985	9.6	3.3	410.8	156.5	567.3
1986	10.7	3.2	598.2	112.8	711.0
1987	2.6	0.1	228.9	6.0	234.9
1991	1.4	1.8	93.5	129.0	222.5
1992	0.4	0.0	37.3	1.9	39.2
1993	15.2	0.2	973.4	12.0	985.4
1994	14.7	2.2	1,055.0	571.0	1,626.0
1995	4.2	0.9	273.2	88.6	361.8
1996	88.9	14.8	6,325.1	1,082.5	7,407.6
1997	29.8	2.4	2,103.4	169.2	2,272.6
1998	26.8	1.0	2,544.2	91.2	2,635.4
1999	3.0	0.8	298.0	79.8	377.8
2000	57.9	8.6	3,627.7	567.0	4,194.7
Mean	**15.7**	**2.6**	**1,130.1**	**253.9**	**1,384.0**

Table 17. Daily numbers and seasonal totals of striped bass (SB) and other species captured by staked gill net in the York River, 2000.

Date	Live SB	Dead SB	Other	Total
Feb. 27, 2000	43	230	325	598
Feb. 28, 2000	197	213	911	1,321
March 5, 2000	86	100	499	685
March 6, 2000	82	71	374	527
March 12, 2000	20	33	744	797
March 13, 2000	35	51	692	778
March 19, 2000	10	25	661	696
March 20, 2000	13	14	405	432
March 26, 2000	6	11	606	623
March 27, 2000	12	14	665	691
April 2, 2000	17	11	424	452
April 3, 2000	9	18	377	404
April 11, 2000	0	6	417	423
April 12, 2000	0	1	267	268
April 16, 2000	3	7	366	376
April 17, 2000	4	6	382	392
April 23, 2000	9	10	605	624
April 24, 2000	1	3	383	387
April 30, 2000	3	3	70	76
May 1, 2000	2	6	110	118
May 7, 2000	5	14	269	288
May 8, 2000	8	2	152	162
May 14, 2000	0	7	117	124
May 15, 2000	1	6	84	91
May 21, 2000	1	2	40	43
May 22, 2000	6	3	37	46
Totals	573	867	9,982	11,422

Table 18. Daily numbers and seasonal totals of striped bass and other species captured by staked gill net in the James River, 2000.

Date	Live SB	Dead SB	Other	Total
Feb. 20, 2000	810	299	5	1,114
Feb. 21, 2000	511	98	1	610
Feb. 27, 2000	254	113	119	486
Feb. 28, 2000	102	52	258	412
March 5, 2000	44	33	113	190
March 6, 2000	76	44	109	229
March 12, 2000	32	37	88	157
March 13, 2000	40	20	91	151
March 19, 2000	28	32	226	286
March 20, 2000	36	19	184	239
March 26, 2000	29	22	213	315
March 27, 2000	22	16	285	323
April 2, 2000	13	18	134	165
April 3, 2000	11	19	152	182
April 10, 2000	14	25	117	156
April 9, 2000	16	56	204	276
April 16, 2000	8	16	300	324
April 17, 2000	8	9	162	179
April 23, 2000	9	15	229	253
April 24, 2000	4	3	81	88
April 30, 2000	12	19	53	84
May 1, 2000	4	4	53	61
May 7, 2000	16	26	114	156
May 8, 2000	17	18	78	113
May 14, 2000	0	4	134	138
May 15, 2000	1	6	66	73
Totals	2,117	1,023	3,569	6,760

Table 19. Daily numbers and seasonal totals of striped bass and other species captured by staked gill net in the Rappahannock River, 2000.

Date	Live SB	Dead SB	Other	Total
Feb. 27, 2000	29	6	153	188
Feb. 8, 2000	46	12	138	196
March 5, 2000	40	29	569	638
March 6, 2000	42	19	528	589
March 12, 2000	14	14	425	453
March 13, 2000	20	24	633	677
March 19, 2000	39	44	327	410
March 20, 2000	41	38	309	388
March 26, 2000	36	28	489	553
March 27, 2000	22	17	565	604
April 2, 2000	5	5	643	653
April 3, 2000	6	8	861	875
April 11, 2000	25	17	458	500
April 12, 2000	9	19	492	520
April 16, 2000	6	17	607	630
April 17, 2000	10	12	468	490
April 23, 2000	14	28	589	631
April 24, 2000	15	19	414	448
April 30, 2000	11	7	391	409
May 1, 2000	9	21	530	560
May 7, 2000	1	12	394	407
May 8, 2000	1	5	359	365
May 14, 2000	1	3	213	217
May 15, 2000	0	2	234	236
Totals	442	406	10,789	11,637

Table 20. 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	6.5	73	0.141	0.042	1.75

Table 21. 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

Table 22. 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	2.60
1999	6.0	66	0.183	0.042	2.60
2000	7.2	70	0.279	0.086	4.46