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Monitoring Relative Abundance of American Shad in Virginia Rivers 2004 Annual Report

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2004 Annual Report

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Summary

- A staked gill net was set and fished each week on the James, York and Rappahannock rivers in the spring of 2004. This was the seventh 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 in-river moratorium in 1994. The monitoring 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 catch rates recorded in the 1980s and the 1950's.

- Sampling occurred for 10 weeks on the York River (29 February to 3 May 2004), 11 weeks on the Rappahannock River (29 February - 10 May 2004), and 12 weeks on the James River (29 February - 17 May 2004). After 18 April, post-spawning fish were mixed with pre-spawning fish in the catch on the James and York rivers. After 25 April, post-spawning fish were mixed with pre-spawning fish on the Rappahannock River. Only pre-spawning fish were included in the monitoring summaries. A total of 1,107 rpe-spawning female American shad (1.857.1 kg total weight) was captured. The 2004 catch was slightly smaller than the 2003 catch (1,168 females weighing 1,970 kg) and larger than the 2002 catch (787 females weighing 1,260 kg).

- Total numbers and weights of females in 2004 were highest on the York River (n= 460, 775 kg). The number of females on the James River (n= 326, 535 kg) slightly exceeded that on the Rappahannock River (n= 321, 547 kg). Numbers of males captured were: York River, 235; James, 144; Rappahannock, 254. The total weight of males captured on all rivers was 822 kg.

- Based on age estimates from scales, the 1999 (age 5) year class of female American shad was the most abundant on all three rivers, with peak age-specific seasonal catch rates exceeding 0.03 kg/m. The 1998 and 1997 year classes (ages 6 and 7) were abundant on the York River with seasonal catch rates also exceeding 0.03 kg/m. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 1.34; James River, 0.98; and Rappahannock River, 1.07. Total instantaneous mortality rates of males calculated from age-specific catch rates were: James River, 0.71; and Rappahannock River, 1.34. Total instantaneous mortality was not calculated for males on the York River.

- Otoliths of 209 American shad captured on the James River and otoliths of 90 specimens captured on the York River were scanned for hatchery marks. The proportion of the sample with hatchery marks on the James and York rivers was 32.5 % (68 of 209 fish) and 2.2 % (2 of 90 fish), respectively. In 1998 and 1999, prevalence of hatchery fish on the James River was low (4-8 %). The increase in catch rates observed on the James River since 2000 is due to the influx of mature hatchery fish released since 1995. Of these hatchery-released cohorts, the 1996 and 1997 year classes have dominated catches

thus far, contributing approximately 55% of all hatchery fish captured in the monitoring program. In all, nine year classes (1992-2000) of hatchery fish have been captured in the monitoring program.

- The geometric mean catch (standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2004 was: James River, 0.04 (0.155, 20); Rappahannock River, 0.70 (0.901, 35); York River (inclusive of Pamunkey and Mattaponi rivers), 2.10 (1.454, 90); Mattaponi River, 7.40 (1.389, 47); and Pamunkey River, 0.05 (0.208, 38). The evening push net survey in the Mattaponi and Pamunkey rivers was discontinued in 2002.

- Thirty-four species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 19,224 specimens. The total number of striped bass captured was 4,504 (James River, n= 1,881; York River, n= 617; Rappahannock River, n= 2,006). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 55.6%; York River, 40.0%; and the Rappahannock River, 53.5%.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2004 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 2004 was 9.72. During the seven years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The average of the historical data during the 1980's on the York River is 3.96. The average of the current monitoring data is higher (9.54) but this average is lower than the average of catch indexes from log book records in the 1950s (19.54). These older data were adjusted for differences in the efficiency of multifilament and monofilament nets using the results of comparison trails in 2002 and 2003.

- On the James River, the 2004 index (7.41) is the second highest value recorded since 1998. Index values in 2000-2004 are higher than those in 1998 and 1999 (2.57 and 2.99, respectively). The average of the historical data during the 1980's on the James River is 8.88. The average of the current monitoring data is lower (5.65).

- The catch index on the Rappahannock River in 2003 (7.06) is almost equivalent to the value in 2003. The 2003-04 values are higher than any previous year of monitoring and higher than all years in the historical data. The average of the historical data during the 1980's on the Rappahannock River is 1.76. The average of the current monitoring data is higher (3.93).

- In recent years of monitoring (2000-2004), mean age of females has increased on all rivers, suggesting higher survival. In 1999, mean age abruptly increased on all rivers then dropped again in 2000. One possible explanation for this change is the failure of age-4 fish to recruit in 1999. This may have been the result of low juvenile abundance in 1995. All forms of the juvenile index (push net and seine survey) depict failed recruitment on all rivers in 1995.

- An age-determination workshop, sponsored by the Atlantic States Marine Fisheries Commission and hosted by the Virginia Institute of Marine Science, was held in August 2004 to test the validity of scale-age techniques. Thirteen biologists from New Hampshire to Florida were assembled to read a set of scales from 53 known-age American shad. Performance of each reader was evaluated by measures of precision, accuracy and bias. Accuracy of evaluated ages was poor (mean= 31.4% of all evaluated ages were accurate). Accuracy was highest for age-3 fish (48.5%), ranged from 33.7 to 37.8 % for age-4 to age-6, dropped noticeably for age-7 fish (12.1%), and was lowest for age-8 fish (3.9%).

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, and spawning history), estimation of total mortality, indices of juvenile abundance, and evaluation of restoration programs by detection and enumeration of hatchery-released fish. This annual report documents continued compliance with Federal law. Since 1998, scientists at the Virginia Institute of Marine Science have monitored the spawning run of American shad in the James, York and Rappahannock rivers. The information resulting from this program is reported annually to the ASMFC, has formed the basis for a significant number of technical papers published in the professional literature, and is contributing substantially to our understanding of the status and conservation of this important species. Data collected in the Virginia monitoring program will be used in revised stock assessment of American shad scheduled for peer review in 2005-2006.

A number of individuals make significant contributions to the monitoring program and the preparation of this report. Commercial fishermen Tony Kellum, Raymond Kellum, Marc Brown and Jamie Saunders construct, set and fish the sampling gear and offer helpful advice. They have participated in the sampling program since its beginning in 1998, and their contributions as authors of historic log books during the 1980s and expert shad fishermen are essential elements of the monitoring program. The current staff and students of the American shad monitoring and research program are: K. Delano, B. Watkins, P. Crewe, A. Rhea, R. Harris, J. Hoffman, T. Tuckey and A. Aunins. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. K. Delano and R. Harris prepared data summaries for this report and B. Watkins determined ages of fish.

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).

Immediately following the moratorium, there were 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 be lifted safely. To address this deficiency, a method of scientific monitoring was proposed 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 seventh year in the sampling program (2004) are reported in this document and compared to some results in previous years of monitoring. Detailed results of the first six years of sampling (1998-2003) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b; Olney and Hoenig 2001a; Olney and Maki 2002, Olney 2003a, Olney 2004). Copies of these reports are available upon request.

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

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

- American shad fight well when angled using light tackle. Harvest of American shad by the recreational fishery in the James, York and Rappahannock rivers is prohibited but recreational fishing is popular in Florida, North Carolina, Maryland and several other states where these bans do not exist. Anecdotal information suggests that there were historical recreational fisheries for American shad on the James, Mattaponi and Rappahannock rivers. Currently, many anglers catch and release American shad and

legally harvest hickory shad (*Alosa mediocris*) on the James River near Richmond, the Mattaponi River above Walkerton, the Rappahannock River near Fredericksburg. Recreational fishing also occurs on the Nottoway and Black rivers near Franklin, Virginia. These rivers do not drain into the Chesapeake Bay and the ban on harvest does not apply to these spawning stocks. Continued 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. Young shads and river herrings (*Alosa*) 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 Chesapeake 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 the commercial fishery for shad on other recreationally important species, especially striped bass, if the ban on commercial and recreational harvest was lifted.

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).

Management and conservation of Virginia's stocks of American shad date to colonial times. Before Virginia was settled, native Americans caught American shad in large quantities using a seine made of bushes (Walburg and Nichols 1967). Shad were so plentiful that they could be speared with pointed sticks as they swam on the flats (VCF 1875). The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, shad were less abundant, presumably due to fishing and obstructions that prevented the fish from reaching their spawning grounds. Concerned colonists passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (VCF 1875). In 1771, the Virginia Assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to

the last day of May. However, due to the approaching conflict of the Revolutionary War, the law was never enforced (VCF 1875).

The shad fishery of Chesapeake Bay became important about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and staked gill nets (Walburg and Nichols 1967). Catches reached a low in 1878, and the U.S. Fish Commission and Virginia Commission of Fisheries instituted an artificial hatching program in 1875. By 1879 the fishery began to improve, and the increase in catches led biologists to believe that the shad fishery was largely dependent upon artificial propagation. However, by the early 1900's the decline in shad harvests resumed despite improved hatching methods and increased numbers of fry released (Mansueti and Kolb 1953).

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

Nichols and Massmann (1963) estimated total catch, fishing rate, escapement and total biomass of American shad in the York River in 1959 and summarized landings during the period 1929-1959. Landings were low (~100,000 lbs annually) in the 1930's but rose abruptly in the years following the world war, reaching the highest levels (400,000-700,000 lbs annually) in the 1950's. During this latter period of higher annual landings, catch-per-unit-effort remained relatively constant. Of the major gears used in the fishery in 1959 (pound nets, haul seines, fyke nets, stake gill nets and drift gill nets), gill nets (both stake and drift) accounted for the greatest effort expended and the highest total catches. A tagging study conducted in 1959 produced the following estimates: overall fishing rate, 55.2%; estimated population biomass, 838,892 lbs; and estimated escapement, 375,768 lbs. Using catch and effort data, Nichols and Massmann (1963) estimated population biomass for the period 1953-1959 to range from 839,000-1,396,000 lbs. Sex composition of the catch was not reported. Using the average female weight of 3.2 lbs in 1959 and assuming that the sex ratio of the catch was 1:1, the estimated total number of females in the York River in 1953-1959 ranged from about 131,000-218,125.

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. Over-fishing, dam construction, pollution, and loss of natural spawning grounds are a few of the factors that may be related to this decline. Historically, the majority of American shad were captured within the rivers. Beginning in 1984, the largest proportion of American shad taken in Virginia's fishery was captured offshore. The overall impact of this shift in the fishery on egg production and annual recruitment of Virginia stocks is unknown. Genetic studies of the catch composition of Virginia and Maryland's coastal landings have suggested that the intercept fishery claims a highly variable proportion of Virginia's riverine stocks (Brown and Epifanio 1994). American shad were pursued by recreational fishermen in Virginia in the past, but the extent and success of this activity is not easily assessed.

In spring 1994, the Virginia Department of Game and Inland Fisheries (VDGIF) and the US Fish and Wildlife Service (USFWS) began a hatchery-restocking effort in the James and Pamunkey rivers. Adult shad from the Pamunkey River are used as brood stock, eggs are stripped and fertilized in the field, and larvae are reared in the VDGIF hatchery at Stephensville, Virginia, and the USFWS hatchery at Harrison Lake, Virginia. Prior to release, the larvae are immersed in an oxytetracycline (OTC) solution that marks otoliths with a distinctive epifluorescent ring. The success of this ongoing program has recently been documented by Olney *et al.* (2003) who report that catch rates by monitoring gear are increasing as large numbers of mature hatchery fish are returning to the James River. In general, prevalence of hatchery fish returning as adults to the York system is low (~2-4 % each year; Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002, Olney 2003a, Olney 2004). Annual monitoring of the abundance of juvenile *Alosa* (American shad, hickory shad, blueback herring and alewife) was conducted on the Pamunkey River system during 1979-2002. After 1995, juveniles bearing the OTC mark were collected by VIMS and VDGIF. The data show that hatchery-released larval shad constituted 0.1-8 % of the total catch of juveniles on the Pamunkey River during the 4-y period (1995-1999).

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

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

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

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

Current Information

There is mandatory reporting of offshore catches to the VMRC. These data can be accessed through the VMRC website (http://www.state.va.us/mrc/homepage.htm). Annual monitoring of the abundance of juvenile *Alosa* (American shad, hickory shad, blueback herring and alewife) was conducted on the York River system with a push net developed in the late 1970s (Kriete and Loesch, 1980). The data record extends back to1979 but sampling was not conducted during 1987-1990. The push net survey was terminated in 2002 when it was determined that the survey results were highly correlated with those of the striped bass seine survey (Wilhite *et al.*, 2003). Although fewer individual fish are collected each year in the seine survey as compared to the evening push net survey, the seine survey has larger geographic coverage (all three rivers in Virginia vs. the Mattaponi and Pamunkey river only) and the data record is uninterrupted since 1979.

Since the American shad monitoring program at VIMS began in 1998, eleven papers on various aspects of the biology of American shad and the VIMS stock assessment program have appeared in peer-reviewed journals (Maki *et al.*, 2001a; Olney *et al*., 2001; Olney and Hoenig, 2001b, Maki *et al.*, 2002; Bilkovic et al. 2002a; Bilkovic *et al*. 2002b; Olney and McBride, 2003; Olney *et al.*, 2003; Walter and Olney, 2003; Wilhite *et al.*, 2003, Hoffman and Olney 2005). Reprints of these papers are available on request.

Currently, five manuscripts are in various stages of review [a report on migration of American shad in the York River based on acoustic telemetry (Olney *et al*., in review); a report on the role of the moratorium in the regulatory process related to the King William reservoir project (Olney *et al.*, in review); results of a mixed-stock analysis of Virginia's intercept fishery in 2000-2001 (Hoenig *et al*., in review); a comparison of

catch rates of monofilament and multifilament gill nets (Maki *et al*., in review) and a report summarizing the results of a 2004 workshop on age determination in American shad (McBride *et al*., in review)]. Titles, dates of submission, a list of authors and abstracts of these manuscripts are in Appendix 1.

Objectives

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

In 2002 and 2003, an additional objective was to determine an efficiency factor that can used to relate catch rates of multifilament nets (used by shad fishers in the 1950s) to monofilament nets (used by fishers in the 1980s and in current monitoring). These comparison trials were required to make the data available from voluntary logbooks in the 1950s comparable to more recent data (see Maki *et al.* in Appendix 1). Using this approach, we have established proposed restoration targets for the York River stock.

Methods

The 2004 sampling methods were the same as those in 1998-2003. In 1998, a fishery-independent monitoring protocol was developed that was as similar as possible to traditional shad fishing methods in the middle reaches of Virginia's rivers. When the in-river fishing moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGNs) were allowed to retain priority rights for the locations of those stands in the various rivers. VIMS has records of the historic fishing locations (Figures 2-4), and one of these locations on each river (the James, York and Rappahannock) was used to monitor catch rates by SGN's in 1998-2000. Three commercial fishermen were contracted to prepare and set SGN poles, hang nets, replace or repair poles or nets, and set nets for each sampling event during the monitoring period. Two of these commercial fishermen, Mr. Raymond Kellum (Bena, Virginia) and Mr. Marc Brown (Rescue, Va), were authors of the historical logbooks on the James and York rivers. However, authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders, Warsaw, Va) who had previous experience in SGN fishing but who had not participated in the shad fishery on the Rappahannock River in the 1980's. Scientists accompanied commercial fishermen during each sampling trip, and returned the catch to the laboratory.

One SGN, 900 ft (approximately 273 m) in length, was set on the York and James rivers (Figures 5-6). One staked gill net, 912 ft (approximately 276 m) in length, was set on the Rappahannock River (Figure 7). Locations of the sets were as follows: lower James River near the James River Bridge at river mile 10 (36^0 50.0' N, 76^0 28.8' W); middle York River near Clay Bank at river mile 14 (37^0 20.8' N, 76^0 37.7' W); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock) at river mile 36 (37^0 55.9' N, 76^0 50.4' W). Historical catch-rate data on the York and James rivers were derived from nets constructed of 4 7/8" stretched-mesh monofilament netting, while historic data from the Rappahannock River were based on larger mesh sizes (nets constructed of 5" stretched-mesh). To insure that catch rates in the current monitoring program were comparable to logbook records, nets on the York and James rivers were constructed of 4 7/8" (12.4 cm) stretched-mesh monofilament netting, while nets on the Rappahannock River were constructed of 5" (12.7 cm) netting. Panel lengths were consistent with historical records (30 ft each on the James and York rivers; 48 ft each on the Rappahannock River). Each week, nets were fished on two succeeding days (two 24-h sets) and then hung in a non-fishing position until the next sampling episode. Occasionally, weather prevented the regularly scheduled sampling on Sunday and Monday, and sampling was postponed, canceled or re-scheduled for other days. Sampling occurred for 10 weeks on the York River (29 February to 3 May 2004), 11 weeks on the Rappahannock River (29 February - 10 May 2004), and 12 weeks on the James River (29 February - 17 May 2004). Surface water temperature and salinity 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 screening for hatchery marks. To do this, otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Personnel from Virginia Commonwealth University (Mr. Dave Hopler) assisted in this evaluation.

Scales for age determination were removed from a mid-lateral area on the left side posterior to the pectoral-fin base of each fish. Scales were cleaned with a dilute bleach solution, mounted and pressed on acetate sheets, and read on a microfilm projector by one individual (B. Watkins, VIMS) using the methods of Cating (1953). Ages were determined by a different reader in 1998-2002 (K. Maki). To assess the differences between readers, 49 samples were randomly chosen from 2003 samples and aged by each

reader twice in 2003. Each reader then made a third reading on those fish for which the initial two readings disagreed and established a final age and spawning mark assignment. In addition, 48 scales were randomly chosen from 2000 samples. In the case of these comparisons, there was only one reading by each reader. Results of these comparisons were reported in Olney (2004).

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

Results

Catches of American shad by staked gill nets in 2004

Fishing days, numbers of American shad captured, and catch rates (males and females) are reported in Tables 1-8 and Figures 8-13. After 18 April 2004 on the James and York rivers and after 25 April on the Rappahannock River, post-spawning American shad were mixed with pre-spawning ("roe") fish in the catch (Table 2). Post-spawning fish were identified histologically (following Olney et al. 2001). Since the historic fishery was a roe fishery and spent or partially spent fish were not routinely captured or marketed in the historic fishery. Thus, post-spawning fish were removed from the monitoring sample.

A total of 1,740 American shad (633 males; 1,107 females) were captured. The total weight of the sample was 2,678.6 kg (male, 821.5 kg; female, 1,857.1 kg). The 2004 catch was almost equivalent to the catch in 2003 (1,168 females; Olney 2004). Catches in 2004 were lowest on the James River (470 total fish, 144 males and 326 females), higher on the Rappahannock River (575 total fish, 254 males and 321 females) and highest on the York River (695 total fish, 235 males and 460 females).

On the James River, catches of females peaked on 8 March-12 April 2004 when catch rates usually exceeded 0.07 fish/m or 0.11 kg/m. During that period on the James River, 75% (245 of 326) of the total number of females was captured. On the York River, catches of females peaked between 28 March and 11 April 2004 when catch rates approached or exceeded 0.12 fish/m or 0.21 kg/m. During that period on the York River, 52% (241 of 460) of the total number of females was captured. Catches of females on the Rappahannock River peaked 15 March-7 April 2004 when catch rates usually exceeded 0.06 fish/m or 0.11 kg/m. During that period on the Rappahannock River, 61% (196 of

321) of the total number of females was captured. The highest recorded daily catch by weight occurred on 28 March 2004 when 71 female American shad (123.01 kg) were taken in the York River (Table 5). As in previous years of monitoring, numbers and catch rates of males were lower than catch rates of females throughout the period. Sex ratios (males:females) were: York River, 0.338:0.662; James River, 0.306:0.694; Rappahannock River, 0.442:0.558. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish.

The duration of the 2004 spawning run (defined as the number of days between the first and last observation of a catch rate that equals or exceeds 0.01 female kg/m) was estimated to be 78 days on the James River (1 March - 17 May), 65 days on the York River (29 February - 3 May) and 65 days on the Rappahannock River (7 March - 10 May).

Biological characteristics of the American shad in 2004

Age, mean length (mm TL) and mean weight (g) of American shad in staked gill nets are summarized in Tables 9-10. Mean total length at age of males and females ranged from 414-520 mm TL and 446-580 mm TL, respectively. Mean weight at age of males and females ranged from 0.86-1.72 kg and 1.09-2.54 kg, respectively.

The 1998 and 1999 year classes (ages 5 and 6) of female American shad were the most abundant on all three rivers (Table 11). On the James River, six age classes of females were represented (1995-2000, ages 4-9) and the sample was dominated by age-5 fish (54.0% of the total that was aged). On the York River, seven age classes of females were represented (1995-2001, ages 3-9) and the sample was dominated by age-5 fish (35.0% of the total that was aged). On the Rappahannock River, eight age classes of females were taken (1994-2001, ages 5-10). Age-5 fish made up 40.0% of the aged sample. The 1997, 1998 and 1999 year classes of males were the most abundant on all three rivers (Table 12). These year classes (ages 5-7) of male American shad constituted 76.3% (York River), 83.9% (Rappahannock River) and 79.3% (James River) of the aged sample.

Age-specific catch rates of American shad are reported in Tables 11-12. 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, 1.34 (r^2= 0.93); James River, 0.98 (r^2= 0.98); and Rappahannock River, 1.07 (r^2= 0.97). Total instantaneous mortality rates of males calculated from age-specific catch rates were: James River, 0.71 (r^2= 0.96); and Rappahannock River, 1.35 (r^2= 0.91). Total instantaneous mortality was not estimated for York River males.

Spawning histories of American shad collected in 2004 are presented in Tables 13-14. On the James and York rivers, fish (both sexes combined) ranged in age from 3-9 years with 0 (virgin) to 5 spawning marks. On the Rappahannock River, fish (both sexes combined) ranged in age from 4-10 years with 0-5 spawning marks. The following

percentages of fish in each river had a least one prior spawn (termed “repeat spawners”): York River, 70.6% (191 virgins in a sample of 650); James River 50.9% (218 virgins in a sample of 444); Rappahannock River 67.2% (180 virgins in a sample of 548 fish). The percentages of fish with at least one prior spawn on the York River in previous years were: 1998, 40.2%; 1999, 67.3%; 2000, 31.1 %; 2001, 38.8 % ; 2002, 59.5%; 2003, 70.8% (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002; Olney 2003a; Olney 2004).

Evaluation of hatchery origin of American shad in 2004

James River - Otoliths of 209 American shad captured in staked gill nets on the James River were scanned for hatchery marks. The proportion of the 2004 sample with hatchery marks was 32.5% (68 of 209 fish). The biological attributes of these specimens are presented in Table 15. 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 through 2003. The 2004 prevalence (32.5%) is lower that all values reported since 2000 (40.2%-51.4%). In most years, fish with hatchery tags from rivers other than the James River were among those counted. These strays were not included in the estimates of hatchery prevalence and are as follows (year captured as an adult, number, river of release): 1999, n= 1, Patuxent River (Maryland); 2000, n= 7, Pamunkey River (Virginia) and Juniata River (Pennsylvania); 2001, n= 3, Pamunkey River, Juniata River, and the western branch of the Susquehanna River (Pennsylvania); 2002, n= 1, Pamunkey River, n= 2 unknown tag. In 2003 and 2004, there were no stray fish.

Most hatchery-reared adults taken in 2000-2004 had OTC marks that indicated these specimens were released in 1995 or 1996 or in 1997-2001. These tags could not be easily differentiated microscopically, however. Because of this, we determined the year of release of hatchery fish using scale-determined ages (Tables 13, 15-16). 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 16). Since 1995, hatchery production has exceeded 5 million fry released annually.

During 2000-2004, hatchery-reared fish captured in the staked gill nets were ages 3-9 (released as fry in 1993-2000). The highest numbers captured thus far were released in 1995-1998. The 1996 year class of hatchery-reared American shad first appeared as age 4, continues to recruit and is well represented in 2000-2002 samples. This year class has constituted 28.4% of the hatchery-marked catch. The 1997 year class first appeared at age 3 and its contribution (27.9%) is almost equivalent to the 1996 year class. The 1998 year class first appeared in moderate numbers in 2002 and its recruitment increased substantially in 2003 but dropped in 2004. Additional recruitment of the 1998, 1999 and 2000 year classes is expected in future years of monitoring.

Most hatchery fish captured in the James River in 2000 and 2001 were virgins (no spawning marks on the scales) that had matured at age 4 or 5. In these two years, proportions of the sample that had spawned at least once were: 2000, 28.2 %; 2001, 39.8 %. In 2002, the proportion of repeat spawners increased to 54.2 % (65 virgins in a sample of 142 fish). In 2003, the proportion of repeat spawners was 48.2% (71 virgins in a sample of 137 hatchery fish). In 2004, the proportion of repeat spawners was 65.1% (22 virgins in a sample of 63 hatchery fish).

York River - Otoliths of 90 adult specimens captured in staked gill nets on the York River were scanned for hatchery marks. The proportion of the sample with marks was 2.2 % (2 of 90 fish). The biological characteristics of these specimens are reported in Table 17. By comparison, the proportion of previous samples with marks was 3.2% (3 of 96 fish in 2003); 4.8% (5 of 104 fish in 2002), 4.8 % (9 of 186 fish in 2001) and 2.2% (4 of 180 fish in 2000).

Juvenile abundance of American shad

Tables 18 and 19 and Figures 14-16 report index values of juvenile abundance of American shad based on seine surveys (1979-2004) on the James and Rappahannock rivers, the main stem of the York River, the Pamunkey River and the Mattaponi River. The geometric mean catch (standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2004 was: James River, 0.04 (0.155, 20); Rappahannock River, 0.70 (0.901, 35); York River (inclusive of Pamunkey and Mattaponi rivers), 2.10 (1.454, 90); Mattaponi River, 7.40 (1.389, 47); and Pamunkey River, 0.05 (0.208, 38). The evening push net survey in the Mattaponi and Pamunkey rivers was discontinued in 2002 (see Wilhite *et al*. 2003 for a summary of these results).

The seine survey data on the James River (Table 18) depict no measurable recruitment during most years. This observation is consistent with those of independent survey results below Bosher's Dam on the James River (VDGIF, T. Gunter, pers. comm.). A few juveniles were captured in 1984, 1998, 2003 and 2004. On the Rappahannock River , the highest JAI values (>0.5) were recorded in 1982, 1989, 2003 and 2004. The Rappahannock River time series depicts no measurable recruitment in 1980-1981, 1985, 1988, 1991-1992, 1995 and 2002.

With the exception of 2003 data, juvenile index values based on the seine survey are consistently higher on the Mattaponi River than they are on the Pamunkey River and the York River (Table 19). In the time series, recruitment is highest (>7.0 on the Mattaponi River and >3.0 on the York River) in 1982, 1984-85, 1996 and 2003.

In recent years of monitoring (2000-2004), mean age of females has increased on all rivers, suggesting higher survival. In 1999, mean age abruptly increased on all rivers then dropped again in 2000 (Figure 17). One possible explanation for this change is the failure of age-4 fish to recruit in 1999. This may have been the result of low juvenile

abundance in 1995. All forms of the juvenile index (push net and seine survey) depict failed recruitment on all rivers in 1995.

By-catch of striped bass and other species in 2004

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 20-22. Thirty-four species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 19,224 specimens. The most commonly encountered by-catch species were: menhaden (*Brevoortia tyrannus*), gizzard shad (*Dorasoma cepedianum*), striped bass (*Morone saxatilis*), white catfish (*Ictalurus catus*), blue catfish (*Ictalurus furcatus*), channel catfish (*Ictalurus punctatus*), white perch (*Morone americana*), hickory shad (*Alosa mediocris*), Atlantic croaker (*Microponias undulatus*), weakfish (*Cynoscion regalis*) and summer flounder (*Paralichthys dentatus*).

The total number of striped bass captured was 4,504 (James River, n= 1,881; York River, n= 617; Rappahannock River, n= 2,006). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 55.6%; York River, 40.0%; and the Rappahannock River, 53.5%.

Seasonal catch indexes, 1980-1992 and 1998-2004

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2004 and for each year of the historical record of staked net catches on each river (Tables 23-26 and Figures 18-21). Seasonal catch indices in 2004 were: York River, 9.72; James River, 7.41; Rappahannock River, 7.06.

Age determination workshop

An age-determination workshop, sponsored by the Atlantic States Marine Fisheries Commission and hosted by the Virginia Institute of Marine Science, was held in August 2004 to test the validity of scale-age techniques. Thirteen biologists from New Hampshire to Florida were assembled to read a set of scales from 53 known-age American shad. Performance of each reader was evaluated by measures of precision, accuracy and bias. Accuracy of evaluated ages was poor (mean= 31.4% of all evaluated ages were accurate). Accuracy was highest for age-3 fish (48.5%), ranged from 33.7 to 37.8 % for age-4 to age-6, dropped noticeably for age-7 fish (12.1%), and was lowest for age-8 fish (3.9%). A manuscript detailing these results has been submitted and the title, abstract and date of submission appear in Appendix 1.

Discussion

The staked gill net monitoring program continues to be useful for assessment of the current status of stocks of American shad in Virginia. It is the only direct method

available to determine the size of the spawning runs relative to what was obtained in the decades prior to the moratorium. The program also provides information for evaluating the hatchery-based restoration program, validating the juvenile index of abundance and for determining the amount of by-catch that could be expected in a commercial fishery if the in-river fishing ban is lifted. The program will provide required data for the upcoming coast-wide stock assessment, scheduled for peer review in late 2005.

Abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in our monitoring gear in recent years (2000-2004) confirm a large scale influx of mature virgin hatchery fish since the James River restoration program began in 1992 (Olney *et al.*, 2003). The age composition of the monitoring catch is consistent with the timing of releases of large numbers of hatchery released fish. While catches of wild American shad have been relatively constant during the six years of monitoring in the James River (200-300 kg annually), the catches of hatchery fish have increased dramatically by two orders of magnitude. Thus, the increase in spawning biomass cannot be attributed to natural production of wild fish. The monitoring data suggest that a continuation of the hatchery program at present levels of production, in combination with fishing moratoria, are effective components of a recovery program for this stock. Additional data on the movements, reproductive behavior and genetic integrity of wild fish in the James River would serve to clarify the effects of the introduced hatchery cohorts on the wild stocks. Reproductive isolation of wild fish from the hatchery-introduced cohorts (and their progeny) could enhance genetic heterogeneity in the stock. Isolation could be achieved if wild cohorts spawn in locations (i.e., down-river of the existing fish passage at Bosher's Dam) that are not chosen by hatchery cohorts. This could be determined through a detailed study of movements, residency and spawning behavior of the stock. Since we cannot distinguish the progeny of hatchery fish using OTC markers, a genetic survey that could identify wild and hatchery components could enhance our understanding of stock dynamics and the extent to which hatchery fish dominate the population. A separately funded telemetry study of American shad movements in the James River was initiated in spring 2005 and may address some of these questions.

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; or (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/day 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.

Voluntary logbooks of catches from the York River exist in the archives of the Department of Fisheries Science (Table 26). These historical records from the 1950s form the basis for gear comparison trials conducted in 2002 and 2003 in the York River (Maki *et al*., in review; see Appendix 1). Based on these comparisons, we have concluded that the multifilament nets of the type used in the 1950s have approximately half of the fishing power of monofilament nets used in the 1980s and the current monitoring. Thus, the older data have been adjusted upward (by a factor of 2.16) to make appropriate comparisons with current monitoring results. This adjustment of the 1950s data yields revised restoration targets for the York River stocks as depicted in Figure 30. The 1950s data (Table 26) include two years of a high index (26-33), two years of a moderate index (14) and one low index year (8.7, 1955). Rather than using a maximum catch index of 10 such as observed in the 1980s for the York River, we propose a revised target catch index of 19.5, the mean of the catch index values observed in 1953-1957. This is a more appropriate target since American shad abundance in the 1980s was insufficient to support the fishery. In the 1950s, shad abundance was higher (estimated at 131,000-218,000 total females annually using data from Nichols and Massmann 1962) and landings were relatively stable in the face of a high fishing rate (50%). Thus, restoring the York River shad stocks to a 1950s level could allow for a sustainable fishery operating at a lower level of exploitation.

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

On the York River, the seasonal catch index in 2004 was 9.72. During the seven years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The average of the historical data during the 1980's on the York River is 3.96. The average of the current monitoring data is higher (11.70) but this average is lower than the average of catch indexes from log book records in the 1950s (19.54). In recent years of monitoring (2000-2004), mean age of females has increased, suggesting higher survival. Our overall assessment of the York River stock is that it has recovered to a level that is close to its abundance during the 1980s. However, as noted previously, the stock level was low during that period, and incapable of supporting an active fishery. The stock is currently well below the proposed 1950s target (Figure 30) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann 1963).

On the James River, the 2004 index (7.41) is the second highest value recorded since 1998 but well below the proposed target of 29. Index values in 2000-2004 are higher than those in 1998 and 1999 (2.57 and 2.99, respectively). The average of the historical data during the 1980's on the James River is 8.88. The average of the current

monitoring data is lower (5.65). As noted previously, hatchery cohorts are recruiting in high proportions to the population and mean age of females has increased in recent years of monitoring (2000-2003). Our overall assessment for the James River is that the stock remains at a low level of abundance and requires continued protection and restoration.

On the Rappahannock River, the index in 2004 (7.06) is almost equivalent to the 2003 value. The 2003-2004 index values are higher than any previous year of monitoring and higher than all years of the historic data. The 1998-2003 average (3.41) is above the average of the historical data (1.76) and the 2003-2004 index values are above the proposed target of 6. In recent years of monitoring (2000-2004), mean age of females has increased, suggesting higher survival. It should be noted that since the catch index for the Rappahannock River is low in the historical data relative to the York and James rivers, there is uncertainty about what an appropriate target level should be for this stock. There is little evidence of severe stock decline in the Rappahannock River, although such a decline was reported in the most recent stock assessment (ASMFC 1999). We conclude that present status of the Rappahannock River stock is stable with evidence of increasing abundance. It should be noted that VDGIF personnel began a hatchery-release program on the upper Rappahannock River in spring 2003. The restoration program uses progeny of Potomac River brood stock. The goal of this program is to restore American shad to historical spawning areas that were previously blocked by Embrey Dam.

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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 2004.

Stock	Sampling dates in 2004	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total Fish	Total weight (kg)
James River	2/29-5/17	326	144	535.0	184.9	470	719.9
York River	2/29-5/3	460	235	774.8	299.2	695	1,074.0
Rappahannock River	2/29-5/10	321	254	547.3	337.4	575	884.7
Totals		1,107	633	1,857.1	821.5	1,740	2,678.6

Table 2. Total length, fork length and total weight of post-spawning female American shad taken in staked gill nets in the James, York and Rappahannock rivers, spring 2004. These individuals were removed from the monitoring data.

River	Date	Specimen Number	Total Length (mm)	Fork Length (mm)	Total Weight (g)
James River	4/18/2004	10133	532	472	1292.4
	4/19/2004	10174	456	403	1124.5
	4/25/2004	10243	530	464	1237.2
	4/25/2004	10254	528	467	1798.5
	4/25/2004	10256	558	502	1741.7
	4/25/2004	10259	481	424	1059.1
	4/26/2004	10335	536	474	1728.4
	4/26/2004	10339	516	460	1744.8
	4/26/2004	10341	512	453	1162.5
	4/26/2004	10342	488	433	1173.4
	4/26/2004	10343	522	458	1318.6
	5/2/2004	10363	518	461	1192.8
	5/2/2004	10364	535	483	1607.1
	5/2/2004	10366	542	479	1527.1
	5/2/2004	10367	550	489	1453.2
	5/2/2004	10368	507	460	1298.2
	5/2/2004	10369	534	478	1388.1
	5/2/2004	10370	529	475	1320.5
	5/2/2004	10371	493	447	1278.9
	5/2/2004	10372	549	490	1664.1
	5/2/2004	10373	549	500	1600.5
	5/2/2004	10374	522	468	1396
	5/2/2004	10375	556	500	1547.3
	5/2/2004	10376	482	431	1145.4
	5/2/2004	10377	485	431	1153.4
	5/3/2004	10506	557	491	1300.7
	5/3/2004	10508	536	476	1500.2

Table 2 cont.	5/3/2004	10509	556	494	1718.5
	5/3/2004	10510	608	538	2049.8
	5/3/2004	10511	542	482	1306.7
	5/3/2004	10512	565	500	1502.3
	5/3/2004	10513	533	464	1278.6
	5/9/2004	10654	558	494	1390.8
	5/16/2004	10661	542	480	1616.2
Rappahannock River	4/25/2004	10267	539	474	1287.3
	4/25/2004	10269	520	462	1246.6
	4/25/2004	10274	548	482	1287.4
	4/26/2004	10332	508	445	1179.6
	5/2/2004	10349	520	463	1284.4
	5/2/2004	10350	527	471	1378
	5/2/2004	10351	522	464	1359.1
	5/2/2004	10352	519	457	1488.8
	5/2/2004	10353	525	468	1244.7
	5/3/2004	10519	547	487	1368.9
	5/3/2004	10520	508	452	1230.4
York River	4/18/2004	10143	551	486	1706
	4/18/2004	10151	516	463	1285
	4/18/2004	10154	516	456	1412.8
	4/18/2004	10158	484	434	1143.8
	4/18/2004	10160	510	446	1255.1
	4/18/2004	10164	538	475	1274
	4/19/2004	10203	532	469	1292.9
	4/19/2004	10205	548	486	1514.7
	4/19/2004	10214	551	484	1541.9
	4/19/2004	10218	558	493	1619.2
	4/19/2004	10221	585	516	1616.9
	4/19/2004	10227	536	471	1561.4
	4/19/2004	10229	518	465	1283.2

Table 2 cont.	4/19/2004	10230	470	420	1181.4
	4/19/2004	10233	490	431	1067.4
	4/19/2004	10234	554	494	1656.5
	4/19/2004	10241	544	480	1813.5
	4/19/2004	10242	570	508	2194.5
	4/25/2004	10277	554	494	1764.7
	4/25/2004	10278	509	453	1583.1
	4/25/2004	10279	560	492	1343.9
	4/25/2004	10280	530	469	1411.7
	4/25/2004	10282	549	490	1729.5
	4/25/2004	10283	529	471	1292
	4/25/2004	10284	532	469	1299.5
	4/25/2004	10285	528	466	1037
	4/25/2004	10287	590	526	1864.8
	4/25/2004	10289	552	490	1570.7
	4/25/2004	10292	551	488	1440.7
	4/25/2004	10294	540	476	1343.5
	4/25/2004	10295	505	444	1295.2
	4/25/2004	10298	536	472	1335.7
	4/25/2004	10299	560	493	1633.1
	4/25/2004	10303	563	500	1434
	4/25/2004	10305	528	460	1258.5
	4/25/2004	10307	542	474	1505.3
	4/25/2004	10308	560	492	1504
	4/26/2004	10309	566	498	1532.7
	4/26/2004	10310	536	471	1169.5
	4/26/2004	10315	521	460	1217.6
	4/26/2004	10316	542	482	1189.6
	4/26/2004	10319	536	478	1294.3
	4/26/2004	10320	552	488	1503.8
	4/26/2004	10323	566	499	1471.7
	4/26/2004	10324	516	464	1294.3

Table 2 cont.	4/26/2004	10326	523	458	1569
	4/26/2004	10328	530	468	1272.6
	5/2/2004	10378	468	424	1033.4
	5/2/2004	10379	524	472	1379
	5/2/2004	10380	527	467	1152.6
	5/2/2004	10381	482	438	1011.3
	5/2/2004	10382	548	498	1525.9
	5/2/2004	10383	550	497	1558.6
	5/2/2004	10384	546	494	1577.4
	5/2/2004	10385	562	505	1469.4
	5/2/2004	10386	554	498	1529.7
	5/2/2004	10387	541	484	1502.4
	5/2/2004	10389	544	498	1411.8
	5/2/2004	10390	539	484	1393.1
	5/2/2004	10391	552	493	1390.3
	5/2/2004	10392	493	442	1057.2
	5/2/2004	10393	531	478	1293.1
	5/2/2004	10394	551	500	1495.3
	5/2/2004	10395	559	498	1540.3
	5/2/2004	10396	511	464	1191.1
	5/2/2004	10398	537	476	1294.9
	5/2/2004	10399	554	496	1300.8
	5/2/2004	10401	572	518	1537.8
	5/2/2004	10402	485	434	997.4
	5/2/2004	10403	552	492	1351.7
	5/2/2004	10404	558	490	1488.7
	5/2/2004	10405	526	467	1293.3
	5/2/2004	10406	537	480	1454.7
	5/2/2004	10407	545	486	1445.7
	5/2/2004	10408	521	467	1167.7
	5/2/2004	10410	534	480	1414.5
	5/2/2004	10411	536	486	1521

Table 2 cont.	5/2/2004	10412	520	469	1192.7
	5/2/2004	10413	536	478	1336.1
	5/2/2004	10414	579	516	1549.2
	5/2/2004	10415	533	478	1394.1
	5/2/2004	10416	530	479	1585.1
	5/2/2004	10417	538	477	1241
	5/2/2004	10418	520	469	1311.4
	5/2/2004	10419	515	464	1262.9
	5/2/2004	10420	529	468	1280.6
	5/2/2004	10423	539	484	1436.2
	5/2/2004	10424	566	505	1681.9
	5/2/2004	10426	504	455	1102.3
	5/2/2004	10427	501	448	1123.7
	5/2/2004	10428	549	487	1484.7
	5/2/2004	10429	512	456	1149.4
	5/2/2004	10430	543	483	1365.1
	5/2/2004	10431	540	483	1213.3
	5/2/2004	10432	528	476	1269.7
	5/2/2004	10434	484	429	1148.6
	5/2/2004	10435	541	477	1302.4
	5/2/2004	10436	572	517	1615.4
	5/2/2004	10437	536	483	1451.9
	5/2/2004	10440	494	444	1095.3
	5/2/2004	10442	541	480	1375.9
	5/2/2004	10443	537	480	1344.8
	5/2/2004	10444	526	473	1255.5
	5/2/2004	10445	492	446	1027.6
	5/2/2004	10446	550	487	1462.9
	5/2/2004	10447	542	479	1304.8
	5/2/2004	10448	554	497	1347.6
	5/2/2004	10449	560	502	1599.1
	5/2/2004	10450	550	487	1568.2

Table 2 cont.	5/2/2004	10451	546	497	1481.8
	5/2/2004	10452	502	453	1125.6
	5/2/2004	10453	558	499	1533.1
	5/2/2004	10454	534	478	1309.7
	5/2/2004	10455	528	471	1428.7
	5/2/2004	10456	534	471	1397.6
	5/2/2004	10457	536	486	1397.1
	5/2/2004	10458	545	496	1432.5
	5/2/2004	10459	514	461	1221.5
	5/2/2004	10462	542	488	1421
	5/2/2004	10463	536	483	1522.7
	5/2/2004	10464	534	485	1331.7
	5/2/2004	10465	542	487	1475.7
	5/2/2004	10466	535	480	1324.4
	5/2/2004	10467	534	482	1393.3
	5/2/2004	10470	507	459	1159.3
	5/2/2004	10471	551	493	1564
	5/2/2004	10472	574	520	1744.9
	5/2/2004	10473	560	490	1595.2
	5/2/2004	10474	522	473	1159.8
	5/2/2004	10475	553	496	1626.8
	5/2/2004	10476	539	479	1344.8
	5/2/2004	10477	517	462	1082.1
	5/2/2004	10478	541	481	1378.9
	5/2/2004	10479	508	462	1230.5
	5/2/2004	10480	546	485	1316.7
	5/2/2004	10481	524	462	1235.7
	5/2/2004	10483	506	454	1166.7
	5/2/2004	10484	553	493	1191.6
	5/2/2004	10485	520	464	1259.7
	5/2/2004	10486	528	475	1282.1
	5/2/2004	10487	526	465	1179.8

Table 2 cont.	5/2/2004	10488	528	476	1320.4
	5/2/2004	10489	546	485	1874.5
	5/2/2004	10490	552	490	1264.3
	5/2/2004	10491	528	468	1223.8
	5/2/2004	10492	495	440	928.3
	5/2/2004	10493	550	498	1487.1
	5/2/2004	10494	526	464	1211.3
	5/2/2004	10495	544	491	1339.3
	5/2/2004	10496	497	444	1132.1
	5/2/2004	10497	534	483	1414.5
	5/2/2004	10498	558	492	1462.2
	5/2/2004	10499	536	478	1349.8
	5/2/2004	10500	532	476	1371.6
	5/2/2004	10501	494	442	1021.9
	5/2/2004	10502	543	479	1538.1
	5/2/2004	10503	529	473	1325.7
	5/2/2004	10504	509	443	1039.1
	5/2/2004	10505	535	483	1471.7
	5/3/2004	10528	566	505	1656.6
	5/3/2004	10529	528	462	1280.9
	5/3/2004	10531	530	468	1352.7
	5/3/2004	10532	517	460	1189.7
	5/3/2004	10533	548	486	1213.3
	5/3/2004	10534	556	492	1378.5
	5/3/2004	10535	542	478	1361.5
	5/3/2004	10537	567	498	1544.3
	5/3/2004	10539	599	526	1791.3
	5/3/2004	10540	545	482	1353.7
	5/3/2004	10541	566	498	1569.8
	5/3/2004	10542	513	454	1429.4
	5/3/2004	10543	551	485	1460.7
	5/3/2004	10544	565	503	1354.1

Table 2 cont.	5/3/2004	10545	566	498	1218.9
	5/3/2004	10546	526	464	1265.3
	5/3/2004	10547	547	484	1506.4
	5/3/2004	10549	558	494	1386.4
	5/3/2004	10551	538	477	1373.2
	5/3/2004	10553	454	402	777.1
	5/3/2004	10555	601	527	1990.7
	5/3/2004	10556	574	500	1502.4
	5/3/2004	10557	532	466	1418
	5/3/2004	10559	552	486	1242.8
	5/3/2004	10560	562	497	1434.6
	5/3/2004	10562	522	456	1157.7
	5/3/2004	10564	557	495	1369.2
	5/3/2004	10565	544	488	1478.4
	5/3/2004	10568	542	478	1255.6
	5/3/2004	10569	562	503	1522.6
	5/3/2004	10570	590	520	1544.6
	5/3/2004	10571	562	498	1490.4
	5/3/2004	10572	535	466	1294.1
	5/3/2004	10573	570	508	1631.7
	5/3/2004	10574	528	468	1237.9
	5/3/2004	10575	582	518	1777
	5/3/2004	10576	520	458	1096.1
	5/3/2004	10577	563	494	1318.9
	5/3/2004	10578	516	456	1151.6
	5/3/2004	10580	547	478	1437.3
	5/3/2004	10581	566	493	1431.3
	5/3/2004	10582	521	468	1307.7
	5/3/2004	10584	522	461	1156.3
	5/3/2004	10585	542	481	1314.4
	5/3/2004	10586	578	514	1572.8
	5/3/2004	10587	535	478	1290

Table 2 cont.	5/3/2004	10589	536	473	1286.4
	5/3/2004	10590	548	487	1355.6
	5/3/2004	10591	550	486	1416
	5/3/2004	10592	572	504	1567.6
	5/3/2004	10593	586	523	1573.4
	5/3/2004	10594	542	480	1303.1
	5/3/2004	10595	595	528	1636.7
	5/3/2004	10596	554	490	1282.1
	5/3/2004	10598	564	496	1376
	5/3/2004	10599	536	474	1360
	5/3/2004	10601	520	468	1082.1
	5/3/2004	10602	514	460	1172.6
	5/3/2004	10603	547	484	1346.7
	5/3/2004	10604	532	471	1329.8
	5/3/2004	10605	566	511	1406.1
	5/3/2004	10606	532	477	1207.3
	5/3/2004	10607	554	494	1574.5
	5/3/2004	10608	540	476	1318.4
	5/3/2004	10609	536	473	1167.9
	5/3/2004	10610	574	510	1744.2
	5/3/2004	10611	520	460	1262.2
	5/3/2004	10612	561	498	1414
	5/3/2004	10613	526	469	1338
	5/3/2004	10614	550	486	1332.6
	5/3/2004	10615	460	410	838.1
	5/3/2004	10617	528	470	1211.3
	5/3/2004	10618	537	471	1285
	5/3/2004	10620	541	478	1359.2
	5/3/2004	10621	542	477	1533.5
	5/3/2004	10622	590	530	1560.2
	5/3/2004	10623	570	506	1442.5
	5/3/2004	10624	532	473	1212.9

Table 2 cont.	5/3/2004	10625	539	478	1528.4
	5/3/2004	10626	559	490	1310.3
	5/3/2004	10627	585	508	1312.6
	5/3/2004	10628	548	482	1420.8
	5/3/2004	10629	562	503	1579.5
	5/3/2004	10630	566	500	1644.5
	5/3/2004	10631	542	477	1355.8
	5/3/2004	10632	536	477	1267.1
	5/3/2004	10633	531	470	1310.3
	5/3/2004	10635	562	497	1416.7
	5/3/2004	10637	526	462	1232
	5/3/2004	10638	591	527	1765.9
	5/3/2004	10639	556	493	1704.6
	5/3/2004	10640	558	494	1512.1
	5/3/2004	10641	524	464	1302.9
	5/3/2004	10642	535	473	1418.7
	5/3/2004	10643	562	491	1682.7
	5/3/2004	10644	570	509	1682.2
	5/3/2004	10645	542	479	1195.2
	5/3/2004	10646	546	484	1307.1
	5/3/2004	10647	524	470	1154.8
	5/3/2004	10649	558	498	1287.6
	5/3/2004	10651	544	478	1366.1
	5/3/2004	10652	568	504	1554.1
	5/3/2004	10653	560	497	1442.7

Table 3. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of pre-spawn female American shad taken in staked gill net monitoring on the James River, spring 2004.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/29/2004	60	1	0.004	1167.7	0.004
3/1/2004	61	4	0.015	6055.1	0.023
3/7/2004	67	13	0.054	22740.0	0.095
3/8/2004	68	20	0.073	32570.4	0.119
3/14/2004	74	25	0.093	42171.0	0.157
3/15/2004	75	33	0.119	52486.2	0.190
3/21/2004	81	15	0.058	27057.4	0.104
3/22/2004	82	12	0.045	22079.2	0.083
3/28/2004	88	31	0.118	50481.8	0.192
3/29/2004	89	40	0.143	65639.6	0.234
4/4/2004	95	25	0.091	42387.0	0.155
4/11/2004	102	20	0.074	32831.6	0.122
4/12/2004	103	22	0.081	33417.7	0.123
4/18/2004	109	11	0.040	17084.7	0.062
4/19/2004	110	11	0.042	18454.8	0.070
4/25/2004	116	14	0.052	23484.2	0.087
4/26/2004	117	8	0.029	13338.6	0.049
5/2/2004	123	9	0.033	13047.7	0.048
5/3/2004	124	4	0.015	6071.5	0.022
5/9/2004	130	2	0.007	3243.3	0.012
5/10/2004	131	3	0.011	4526.3	0.016
5/17/2004	138	3	0.011	4642.2	0.017
Totals		326		534,978.0	

Table 4. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the James River, spring 2004.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/29/2004	60	9	0.033	11,431.6	0.042
3/1/2004	61	5	0.019	6,704.6	0.025
3/7/2004	67	10	0.042	12,728.2	0.053
3/8/2004	68	17	0.062	21,112.2	0.077
3/14/2004	74	22	0.082	28,913.4	0.108
3/15/2004	75	21	0.076	28,710.0	0.104
3/21/2004	81	9	0.035	12,277.7	0.047
3/22/2004	82	8	0.030	10,618.7	0.040
3/28/2004	88	10	0.038	12,049.3	0.046
3/29/2004	89	16	0.057	19,365.7	0.069
4/4/2004	95	2	0.007	2,556.6	0.009
4/11/2004	102	3	0.011	4,248.3	0.016
4/12/2004	103	4	0.015	5,030.5	0.019
4/18/2004	109	1	0.004	1,072.9	0.004
4/25/2004	116	3	0.011	3,327.1	0.012
4/26/2004	117	1	0.004	1,155.1	0.004
5/2/2004	123	1	0.004	1,214.0	0.004
5/3/2004	124	2	0.007	2,419.7	0.009
Totals		144		184,935.6	

Table 5. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of pre-spawn female American shad taken in staked gill net monitoring on the York River, spring 2004.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/29/2004	60	3	0.011	4,958.0	0.018
3/1/2004	61	3	0.011	5,247.9	0.019
3/7/2004	67	13	0.048	23,236.3	0.087
3/14/2004	74	27	0.101	47,296.1	0.177
3/15/2004	75	30	0.109	51,551.2	0.188
3/21/2004	81	22	0.080	35,290.1	0.129
3/24/2004	84	16	0.060	28,342.7	0.106
3/28/2004	88	71	0.259	123,006.6	0.448
3/29/2004	89	53	0.193	87,588.5	0.319
4/4/2004	95	35	0.128	61,007.4	0.222
4/7/2004	98	48	0.175	79,838.5	0.291
4/11/2004	102	34	0.125	57,679.5	0.212
4/12/2004	103	23	0.083	35,746.8	0.129
4/18/2004	109	26	0.093	44,440.6	0.159
4/19/2004	110	28	0.100	45,780.7	0.163
4/25/2004	116	15	0.055	23,598.0	0.086
4/26/2004	117	10	0.036	15,688.1	0.057
5/3/2004	124	3	0.011	4,502.4	0.017
Totals		460		774,799.4	

Table 6. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the York River, spring 2004.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/29/2004	60	4	0.015	4,900.3	0.018
3/1/2004	61	6	0.021	7,872.5	0.028
3/7/2004	67	17	0.063	24,918.9	0.093
3/14/2004	74	45	0.168	58,583.5	0.219
3/15/2004	75	19	0.069	23,540.4	0.086
3/21/2004	81	14	0.051	17,825.8	0.065
3/24/2004	84	5	0.019	5,646.7	0.021
3/28/2004	88	28	0.102	37,499.1	0.137
3/29/2004	89	26	0.095	35,242.8	0.128
4/4/2004	95	10	0.036	13,909.8	0.051
4/7/2004	98	10	0.036	12,250.6	0.045
4/11/2004	102	2	0.007	1,928.0	0.007
4/12/2004	103	8	0.029	9,970.5	0.036
4/19/2004	110	4	0.014	4,296.0	0.015
4/26/2004	117	1	0.004	1,291.3	0.005
5/2/2004	123	16	0.059	17,680.2	0.065
5/3/2004	124	20	0.073	21,844.7	0.080
Totals		235		299,201.1	

Table 7. Dates of capture, number, total weight (g) and catch rates (numbers per m; kg per m) of pre-spawn female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2004.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
3/7/2004	67	9	0.035	14,282.1	0.055
3/8/2004	68	11	0.045	20,624.3	0.084
3/14/2004	74	16	0.056	28,080.4	0.099
3/15/2004	75	25	0.111	43,290.3	0.192
3/21/2004	81	38	0.137	64,395.6	0.232
3/24/2004	84	16	0.058	28,189.8	0.101
3/28/2004	88	30	0.107	51,715.1	0.185
3/29/2004	89	17	0.061	29,559.3	0.105
4/4/2004	95	41	0.149	69,985.1	0.254
4/7/2004	98	29	0.104	51,820.4	0.186
4/11/2004	102	22	0.079	33,515.8	0.121
4/12/2004	103	18	0.064	29,231.8	0.104
4/18/2004	109	22	0.079	37,520.6	0.135
4/19/2004	110	13	0.053	21,625.1	0.089
4/25/2004	116	7	0.025	11,961.2	0.042
4/26/2004	117	1	0.004	1,930.7	0.007
5/2/2004	123	1	0.004	1,739.5	0.006
5/3/2004	124	4	0.014	6,220.1	0.022
5/10/2004	131	1	0.004	1,617.4	0.006
Totals		321		547,304.6	

Table 8. Dates of capture, number, total weight and catch rates (numbers per m; kg per m) of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2004.

Date	Day of year	Number	Catch Rate (count/m)	Total weight (g)	Catch Rate (kg/m)
2/29/2004	60	1	0.003	1,298.1	0.004
3/1/2004	61	3	0.013	3,815.1	0.016
3/7/2004	67	16	0.062	21,307.5	0.083
3/8/2004	68	26	0.106	35,279.0	0.143
3/14/2004	74	36	0.127	47,522.6	0.167
3/15/2004	75	34	0.151	45,757.7	0.203
3/21/2004	81	45	0.162	59,198.0	0.213
3/24/2004	84	21	0.076	28,383.0	0.102
3/28/2004	88	13	0.046	17,854.9	0.064
3/29/2004	89	24	0.085	31,357.6	0.112
4/4/2004	95	12	0.044	14,508.5	0.053
4/7/2004	98	7	0.025	8,565.1	0.031
4/11/2004	102	4	0.014	5,330.0	0.019
4/12/2004	103	3	0.011	4,408.8	0.016
4/19/2004	110	3	0.012	4,275.7	0.018
4/25/2004	116	1	0.004	1,586.4	0.006
4/26/2004	117	2	0.007	2,850.2	0.010
5/3/2004	124	3	0.011	4,059.5	0.015
Totals		254		337,357.7	

Table 9. Mean total length (mm) and mean weight (g) of pre-spawn female American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2004. 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	17	514.12	19.97	1694.44	309.90
	2000	31	477.26	26.06	1369.35	216.37
	1999	167	496.60	20.96	1526.52	214.07
	1998	75	524.87	21.93	1805.01	255.76
	1997	23	538.74	22.81	1975.49	276.70
	1996	10	544.70	17.19	2109.50	298.24
	1995	3	556.33	17.10	2295.80	537.40
York River	NA	29	530.48	33.46	1881.52	336.01
	2001	5	446.20	21.34	1094.34	288.70
	2000	46	465.48	15.05	1272.93	135.86
	1999	151	495.34	22.50	1531.83	213.33
	1998	113	519.04	20.57	1744.03	230.92
	1997	90	538.29	21.15	1934.32	246.37
	1996	24	550.29	20.51	2067.34	246.23
	1995	2	545.00	1.41	2060.70	15.41
Rappahannock River	NA	17	499.71	26.79	1683.28	259.92
	2001	2	461.50	0.71	1230.20	159.52
	2000	45	472.00	17.30	1341.34	137.90
	1999	122	499.06	18.45	1588.45	176.17
	1998	92	521.75	18.79	1849.42	212.01
	1997	25	539.92	14.50	2001.92	200.71
	1996	15	558.13	19.57	2303.89	239.88
	1995	2	574.00	1.41	2543.20	34.93
	1994	1	580.00		2237.60	

Table 10. Mean total length (mm) and mean weight (g) of male American shad captured in gill nets in the James, York and Rappahannock rivers, spring 2004. 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	9	479.33	35.02	1278.68	304.81
	2001	1	456.00		1137.20	
	2000	18	461.94	26.80	1170.43	184.65
	1999	56	470.27	22.82	1233.98	167.50
	1998	32	472.69	22.35	1273.31	176.68
	1997	19	492.58	32.20	1407.06	234.00
	1996	7	512.71	24.07	1598.76	232.29
	1995	2	520.00	31.11	1724.25	191.84
York River	NA	16	480.56	32.30	1293.22	290.96
	2001	1	436.00		931.50	
	2000	9	436.11	18.27	963.28	157.41
	1999	53	464.06	18.41	1157.86	146.13
	1998	53	473.36	16.72	1249.45	157.52
	1997	61	490.75	19.84	1337.09	208.55
	1996	35	499.57	21.40	1402.59	217.54
	1995	7	514.71	16.60	1524.00	249.86
Rappahannock River	NA	11	477.27	31.69	1303.66	247.13
	2001	4	414.25	20.07	868.58	207.39
	2000	20	444.40	12.53	1083.39	80.68
	1999	79	467.24	16.29	1249.84	119.13
	1998	88	478.43	17.32	1373.47	153.15
	1997	37	496.05	20.50	1449.08	161.83
	1996	14	510.36	18.66	1639.55	163.60
	1995	1	510.00		1702.90	

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 pre-spawn female American shad in the James, York and Rappahannock rivers captured in staked gill nets, spring 2004. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James River	2000	31	42.45	22.6	0.0050	0.0068
	1999	167	254.93	22.6	0.0269	0.0411
	1998	75	135.38	22.6	0.0121	0.0218
	1997	23	45.44	22.6	0.0037	0.0073
	1996	10	21.10	22.6	0.0016	0.0034
	1995	3	6.89	22.6	0.0005	0.0011
	NA	17	28.81	22.6	0.0027	0.0046
York River	2001	5	5.47	19.0	0.0010	0.0011
	2000	46	58.56	19.0	0.0088	0.0112
	1999	151	231.31	19.0	0.0290	0.0444
	1998	113	197.08	19.0	0.0217	0.0379
	1997	90	174.09	19.0	0.0173	0.0334
	1996	24	49.62	19.0	0.0046	0.0095
	1995	2	4.12	19.0	0.0004	0.0008
	NA	29	54.56	19.0	0.0056	0.0105
Rappahannock River	2001	2	2.46	21.5	0.0003	0.0004
	2000	45	60.36	21.5	0.0075	0.0101
	1999	122	193.79	21.5	0.0204	0.0324
	1998	92	170.15	21.5	0.0154	0.0285
	1997	25	50.05	21.5	0.0042	0.0084
	1996	15	34.56	21.5	0.0025	0.0058
	1995	2	5.09	21.5	0.0003	0.0009
	1994	1	2.24	21.5	0.0002	0.0004
	NA	17	28.62	21.5	0.0028	0.0048

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 2004. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year Class	Number	Total Weight (kg)	Total effort (days)	Catch Rate (numbers per m)	Catch Rate (kg per m)
James River	2001	1	1.14	22.6	0.0002	0.0002
	2000	18	21.07	22.6	0.0029	0.0034
	1999	56	69.10	22.6	0.0090	0.0111
	1998	32	40.75	22.6	0.0052	0.0066
	1997	19	26.73	22.6	0.0031	0.0043
	1996	7	11.19	22.6	0.0011	0.0018
	1995	2	3.45	22.6	0.0003	0.0006
	NA	9	11.51	22.6	0.0014	0.0019
York River	2001	1	0.93	19.0	0.0002	0.0002
	2000	9	8.67	19.0	0.0017	0.0017
	1999	53	61.37	19.0	0.0102	0.0118
	1998	53	66.22	19.0	0.0102	0.0127
	1997	61	81.56	19.0	0.0117	0.0157
	1996	35	49.09	19.0	0.0067	0.0094
	1995	7	10.67	19.0	0.0013	0.0020
	NA	16	20.69	19.0	0.0031	0.0040
Rappahannock River	2001	4	3.47	21.5	0.0007	0.0006
	2000	20	21.67	21.5	0.0033	0.0036
	1999	79	98.74	21.5	0.0132	0.0165
	1998	88	120.87	21.5	0.0147	0.0202
	1997	37	53.62	21.5	0.0062	0.0090
	1996	14	22.95	21.5	0.0023	0.0038
	1995	1	1.70	21.5	0.0002	0.0003
	NA	11	14.34	21.5	0.0018	0.0024

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2004 in the York and James rivers. Table entries are numbers of fish (York River, n = 650; James River, n = 444). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. Numbers in parentheses are the numbers of fish in the James River (n = 63) 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
2001	3	**6**	-	-	-	-
2000	4	6	**49**	-	-	-
1999	5	16	84	**104**	-	-
1998	6	6	62	66	**32**	-
1997	7	12	75	47	17	0
1996	8	0	38	17	4	0
1995	9	0	3	6	0	0

James River Year Class	Age at Capture	3	4	5	6	7
2001	3	**1**(0)	-	-	-	-
2000	4	7(1)	**42**(4)	-	-	-
1999	5	8(0)	67(13)	**148**(16)	-	-
1998	6	2(0)	45(9)	35(6)	**25**(2)	-
1997	7	2(0)	14(1)	15(2)	9(2)	**2**(0)
1996	8	0	8(2)	6(1)	3(1)	0
1995	9	0	0	4(2)	0	1(1)

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2004 in the Rappahannock River. Table entries are numbers of fish (n = 548). Ages are based on scale analysis by one reader (B. Watkins). 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).

Rapp. River Year Class	Age at Capture	**2**	**3**	**4**	**5**	**6**	**7**
2001	3	1	**5**		-	-	-
2000	4	0	17	**48**	-	-	-
1999	5	0	15	83	**103**	-	-
1998	6	0	3	83	71	**24**	-
1997	7	0	2	25	24	11	0
1996	8	0	0	22	5	2	0
1995	9	0	0	2	0	1	0
1994	10	0	0	0	0	1	0

Table 15. 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 2004. Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged.

Specimen Number	Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
8772	James 95-96	5	0	432	480	1464	F
8870	James 95-96	5	0	428	470	1270	F
9037	James 95-96	5	0	473	523	1742	F
9462	James 97-01	4	0	446	505	1431	F
9472	James 97-01	4	0	400	448	1224	F
9957	James 97-01	4	0	436	484	1360	F
10136	James 97-01	4	0	414	472	1182	F
8866	James 97-01	5	0	420	471	1238	M
8774	James 97-01	5	0	466	516	1766	F
8788	James 97-01	5	0	439	488	1501	F
8802	James 97-01	5	0	437	496	1448	F
8878	James 97-01	5	0	449	509	1655	F
8892	James 97-01	5	0	458	512	1892	F
9484	James 97-01	5	0	425	482	1378	F
9687	James 97-01	5	0	454	508	1569	F
9780	James 97-01	5	0	430	487	1454	F
9786	James 97-01	5	0	426	488	1456	F
9953	James 97-01	5	0	419	466	1346	F
10127	James 97-01	5	0	438	493	1192	F
10260	James 97-01	5	0	462	518	1839	F
9778	James 97-01	6	0	462	518	1603	F
10051	James 97-01	6	0	484	540	2126	F
9249	James 95-96	5	1	432	482	1451	F
9490	James 95-96	5	1	468	523	1737	F
9255	James 97-01	4	1	412	462	1094	M
8630	James 97-01	5	1	408	443	1003	M
8806	James 97-01	5	1	427	481	1477	M
9045	James 97-01	5	1	440	484	1336	M
9478	James 97-01	5	1	420	476	1330	M
9130	James 97-01	5	1	443	502	1636	F
9132	James 97-01	5	1	404	464	1227	F
9138	James 97-01	5	1	451	512	1631	F
9776	James 97-01	5	1	439	496	1719	F
9963	James 97-01	5	1	452	506	1753	F
10045	James 97-01	5	1	424	480	1274	F
10517	James 97-01	5	1	464	523	1611	F

Table 15 cont.							
9116	James 97-01	6	1	414	477	1256	M
8906	James 97-01	6	1	484	534	2169	F
8907	James 97-01	6	1	476	530	1827	F
9721	James 97-01	6	1	476	529	2069	F
9947	James 97-01	6	1	482	544	1943	F
9955	James 97-01	6	1	462	522	1752	F
9784	James 97-01	7	1	489	560	2140	F
9941	James 97-01	7	1	491	554	2126	F
9715	James 95-96	6	2	456	513	1567	F
8880	James 97-01	6	2	427	468	1295	M
9154	James 97-01	6	2	440	498	1409	M
9498	James 97-01	6	2	427	484	1330	M
9673	James 97-01	6	2	404	451	1159	M
8719	James 97-01	6	2	484	536	1986	F
9265	James 97-01	6	2	483	526	1886	F
9500	James 97-01	6	2	464	529	1708	F
10027	James 97-01	6	2	460	518	1793	F
9253	James 97-01	7	2	473	536	2213	F
9496	James 97-01	7	2	473	536	2218	F
8884	James 97-01	8	2	504	551	2071	F
9480	James 97-01	9	2	479	548	1955	F
9049	James 97-01	7	3	482	539	1919	F
8727	James 97-01	8	3	507	564	2526	F
9943	James 95-96	8	4	455	509	1586	M
8862	James 97-01	8	4	450	495	1640	M
9041	James 97-01	9	4	482	542	1860	M
8786	James 97-01	9	4	487	545	2017	F
8898	James 95-96	NA		491	542	2265	F
9142	James 97-01	NA		439	502	1389	M
9047	James 97-01	NA		458	514	1822	F
9685	James 97-01	NA		464	507	1693	F
10175	James 97-01	NA		452	510	1449	F

Table 16. Total numbers in nine year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2004. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (T. Gunther). Abbreviation: NA, not aged.

Hatchery Year Class	Hatchery Production (millions)	1998	1999	2000	2001	2002	2003	2004	Total	Percent Contribution
1992	0.05		1						1	0.2
1993	0.5	7	2	1					10	1.7
1994	1.6	7	3	9			1		20	3.3
1995	5.3			59	9	8	4	3	83	13.7
1996	5.8			53	62	43	10	4	172	28.4
1997	5.9			2	27	78	57	5	169	27.9
1998	10					13	52	17	82	13.5
1999	7.3						14	29	43	7.1
2000	8.9						1	5	6	1.0
2001	9.3									
2002	8.4									
2003	8.7									
2004	16.4									
NA	--					12	3	5	20	3.3
Total	88.15	14	6	124	98	154	142	68	606	100.0

Table 17. Age, number of spawns, fork length (FL), total length (TL), total weight (TW) and sex of American shad with York River hatchery marks taken in staked gill net monitoring on the York River in 2004. A total of 90 American shad were randomly selected and their otoliths scanned for hatchery marks. Sample selection was weighted by sample size across all dates. Age estimates are based on scales following Cating (1953).

Specimen	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
9423	7	4	436	492	1,251.7	male
9892	5	0	451	518	1,610.0	female

Table 18. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2003) on the James and Rappahannock rivers.. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James River	SD	N	Rappahannock River	SD	N
1980	0		11	0		4
1981	0		12	0		4
1982	0		12	0.88	1.081	16
1983	0		8	0.32	0.549	4
1984	0.09	0.245	8	0.41	0.693	4
1985	0		16	0		8
1986	0		12	0.06	0.200	12
1987	0		16	0.12	0.315	16
1988	0		16	0		20
1989	0		16	0.52	0.894	25
1990	0		16	0.03	0.131	28
1991	0		20	0		31
1992	0		20	0		35
1993	0		20	0.13	0.441	31
1994	0		20	0.05	0.220	34
1995	0		20	0		33
1996	0		20	0.35	0.655	32
1997	0		20	0.16	0.444	35
1998	0.04	0.155	20	0.12	0.341	29
1999	0		20	0.02	0.117	35
2000	0		20	0.03	0.188	34
2001	0		20	0.04	0.163	35
2002	0		20	0		35
2003	0.04	0.155	20	0.59	0.659	28
2004	0.04	0.155	20	0.70	0.901	35

Table 19. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2003) on the Mattaponi, Pamunkey and York rivers.. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	Mattaponi River	SD	N	Pamunkey River	SD	N	York River	SD	N
1980	1.75	1.059	21	0.51	0.825	9	1.13	1.000	33
1981	0.35	0.564	16	0.33	0.588	16	0.34	0.567	32
1982	13.03	1.256	16	0.51	0.543	12	4.40	1.502	28
1983	2.80	0.954	16	0.63	0.775	12	1.65	0.965	88
1984	16.97	1.125	16	0.06	0.200	12	4.34	1.660	28
1985	7.21	1.369	32	0.56	0.631	24	3.03	1.381	56
1986	0.87	0.902	24	0.00		18	0.43	0.744	42
1987	0.17	0.461	24	0.00		18	0.09	0.354	42
1988	0.00		40	0.00		24	0.00		64
1989	0.41	0.631	40	0.00		32	0.20	0.487	34
1990	0.18	0.473	40	0.00		32	0.09	0.351	76
1991	0.04	0.253	50	0.02	0.111	39	0.03	0.197	94
1992	0.00		39	0.00		32	0.00		75
1993	0.18	0.489	50	0.00		39	0.09	0.365	94
1994	1.69	1.142	50	0.15	0.435	39	0.80	0.977	94
1995	0.03	0.137	50	0.00		40	0.01	0.100	95
1996	14.61	1.352	49	1.97	1.294	39	5.79	1.572	93
1997	2.23	1.107	50	0.36	0.672	40	1.11	1.017	95
1998	2.11	1.206	48	0.06	0.356	38	0.86	1.052	91
1999	0.14	0.407	47	0.00		38	0.07	0.303	88
2000	5.56	1.33	39	0.06	0.23	31	1.76	1.338	74
2001	0.52	0.665	48	0.11	0.296	40	0.30	0.541	94
2002	0.17	0.408	48	0.02	0.11	40	0.09	0.308	93
2003	8.55	1.315	50	13.11	1.057	39	9.04	1.294	94
2004	7.40	1.389	47	0.05	0.208	38	2.10	1.454	90

Table 20. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2004.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/29/2004	169	31	200	101	301
3/1/2004	120	68	193	46	239
3/7/2004	88	131	219	60	279
3/8/2004	57	116	173	201	374
3/14/2004	55	70	125	124	249
3/15/2004	44	38	82	96	178
3/21/2004	28	33	61	93	154
3/22/2004	31	57	88	101	189
3/28/2004	50	44	94	151	245
3/29/2004	15	23	38	108	146
4/4/2004	15	11	26	121	147
4/11/2004	8	6	14	80	94
4/12/2004	9	14	23	86	109
4/18/2004	11	26	37	158	195
4/19/2004	8	21	29	159	188
4/25/2004	7	32	39	282	321
4/26/2004	11	44	55	147	202
5/2/2004	25	104	129	154	283
5/3/2004	42	71	113	75	188
5/9/2004	19	62	81	121	202
5/10/2004	15	29	44	107	151
5/16/2004	4	6	10	54	64
5/17/2004	0	8	8	36	44
Totals	831	1045	1881	2661	4542

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2004.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/29/2004	105	32	137	123	260
3/1/2004	64	22	93	96	189
3/7/2004	45	37	82	147	229
3/14/2004	34	31	65	271	336
3/15/2004	23	20	43	172	215
3/21/2004	21	17	38	133	171
3/24/2004	16	10	26	178	204
3/28/2004	5	6	11	173	184
3/29/2004	0	3	3	214	217
4/4/2004	4	8	12	248	260
4/7/2004	9	12	21	323	344
4/11/2004	9	6	15	94	109
4/12/2004	4	3	7	77	84
4/18/2004	3	4	7	316	323
4/19/2004	13	6	19	328	347
4/25/2004	0	9	9	647	656
4/26/2004	1	6	7	355	362
5/2/2004	3	14	17	288	305
5/3/2004	4	1	5	248	253
Totals	363	247	617	4431	5048

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, 2004.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/29/2004	183	58	245	212	457
3/1/2004	220	36	256	189	445
3/7/2004	30	61	86	303	389
3/8/2004	62	90	152	267	419
3/14/2004	29	25	54	560	614
3/15/2004	30	25	55	334	389
3/21/2004	49	56	105	118	223
3/24/2004	42	28	70	72	142
3/28/2004	91	140	231	132	363
3/29/2004	53	114	167	265	432
4/4/2004	39	52	91	473	564
4/7/2004	7	9	16	544	560
4/11/2004	9	8	17	439	456
4/12/2004	24	18	42	467	509
4/18/2004	5	35	40	467	507
4/19/2004	21	99	120	410	530
4/25/2004	28	111	139	507	646
4/26/2004	3	68	71	317	388
5/2/2004	3	22	25	395	420
5/3/2004	3	10	13	620	633
5/9/2004	0	5	5	286	291
5/10/2004	1	5	6	251	257
Totals	932	1075	2006	7628	9634

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/m.

Year	Effort (10^3 m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve (standard error)
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** (0.39)
1998	3.8	----	0.053	0.020	1.46
1999	5.7	42	0.055	0.026	1.30
2000	6.6	73	0.141	0.042	1.75
2001	6.6	72	0.167	0.070	5.77
2002	5.4	57	0.110	0.028	3.08
2003	7.2	72	0.311	0.094	7.10
2004	5.2	65	0.232	0.107	7.06
Average of current data					**3.93** (0.99)

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/m.

Year	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve (standard error)
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** (0.77)
1998	5.7	78	1.080	0.190	14.71
1999	6.3	65	0.209	0.075	5.42
2000	6.7	76	0.276	0.086	7.52
2001	6.3	79	0.627	0.163	12.97
2002	6.7	70	0.306	0.073	7.47
2003	6.0	70	0.390	0.111	8.98
2004	4.9	65	0.448	0.157	9.72
Average of current data					**9.54** (1.24)

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 (standard error)
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** (2.23)
1998	3.8	50	0.198	0.051	2.57
1999	6.0	66	0.183	0.042	2.99
2000	7.2	70	0.279	0.086	6.61
2001	6.8	78	0.285	0.064	5.01
2002	6.5	71	0.205	0.054	5.62
2003	6.6	79	0.284	0.112	9.34
2004	6.0	78	0.234	0.090	7.41
Average of current data					**5.65** (0.91)

Table 26. Historical catch and effort data of American shad by staked gill nets in the York River, Virginia. Historical data are taken from the voluntary log books of Malvin Green, Aberdeen Creek,Virginia. The data were originally recorded as numbers of female shad per day and converted using average female weight of 3.2 lbs. Catch rates are expressed as female kg/d and multiplied by 2.16 to adjust for the lower fishing power of multifilament nets compared to monofilament nets.

Year	Total females	Effort (10^3m/yr)	Duration of run (d)	Highest Catch Rate	Mean Catch Rate	Area under the Catch Curve
1953	2161	36.0	56	0.549	0.443	14.88
1954	3046	45.5	54	0.699	0.434	14.04
1955	1643	40.1	55	0.310	0.270	8.70
1956	6835	68.8	85	1.201	0.663	33.95
1957	5645	56.2	65	0.955	0.667	26.14
Mean						**19.54**

Appendix 1
Titles and Abstracts of four Manuscripts in Review

(1) Migratory behavior of American shad (*Alosa sapidissima*) in the York River, Virginia with implications for estimating in-river exploitation from tag-recovery data (submitted to Transactions of the American Fisheries Society, 4/05)

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

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

(2) Estimating offshore stock composition of American shad (*Alosa sapidissima*) using mark-recovery data (submitted to North American Journal of Fisheries Management, 4/05)

John M Hoenig[1], Robert J. Latour, and John E. Olney

Abstract
Information on the stock composition of mixed-stock fisheries is often needed to develop management regulations for anadromous fishes. Although several methods can be used to infer stock composition, marking studies have long been identified as a promising

approach. We explore the utility of using marking to determine the stock composition of mixed-stock fisheries of American shad (*Alosa sapidissima*) along the east coast of North America. Our analysis focuses on the impact of the Virginia coastal ocean fishery on the American shad produced in the James and Pamunkey rivers, Virginia, and our results suggest that this fishery harvested relatively small proportions of these stocks. The method requires that juvenile shad be uniquely marked in the rivers in their first year of life. The proportion of the offshore catch from a particular river is inferred by comparing the proportion of the offshore catch with marks from the river with the proportion of the fish returning to the river with marks. We also examine the usefulness of tagging adult fish on the offshore fishing grounds and show that if tagging only occurs in a single offshore location, information on stock composition cannot be obtained. In contrast, if tagging occurs in at least *k* offshore locations that each reflects a unique composition of *k* stocks, it is theoretically possible to infer stock composition. However, under this latter scenario, the information obtained is not likely to be reliable due to impracticalities associated with implementing the study design.

(3) Comparing historical catch rates of American shad in multifilament and monofilament nets: A step towards setting restoration targets for stocks under moratorium in Virginia (submitted to North American Journal of Fisheries Management, 3/05)

Kristin L. Maki, John M. Hoenig, Dennis M. Heisey, John E. Olney

Abstract
Recreational and commercial harvest of American shad in Virginia waters of the Chesapeake Bay and its tributaries has been prohibited since 1994. The Shad and River Herring Management Plan requires that Virginia develop restoration targets for its shad populations but estimates of their size are not available and there is little information about historic population levels. Thus, establishing restoration targets based on population size is problematic. A current spawning stock monitoring program yields catch rate information that is comparable with historic catch records recorded in commercial logbooks from the 1950s and the 1980s. However, multifilament gill nets were used in the 1950s and monofilament nets were used in the 1980s (as well as in the current monitoring program). A Latin square design was employed to test the differences in relative fishing power of the two gear types over two years of seasonal sampling on the York River, Virginia. Estimates suggest that monofilament nets are roughly twice as efficient as the multifilament nets. Reported catch rates in the 1950s and 1980s are roughly equivalent. However, when adjustments are made for differences in fishing gear, catch rates for the 1950s are twice as high as during the 1980s. These results provide valuable information for setting restoration targets for Virginia stocks of American shad.

(4) Testing the validity of Cating's criteria for age estimation of American Shad from the Lehigh River (submitted to Fisheries, 2/05)

R. McBride, M. Hendricks and J. Olney

Abstract
Cating's (1953) method for ageing American shad in the Hudson River using scales has been the standard for over 50 years, largely because Judy (1961) validated the method for ages 4-6 in the Connecticut River. There have been no other validation studies. To test the method on older fish in another river, we assessed precision, accuracy, and bias of 13 experienced biologists using 53 known-age fish from the Lehigh River. Biologists had reasonably good precision but accuracy was poor. Percent accuracy was highest for age 3-6 (33.7-48.5%) but dropped for age-7 (12.1%) and age-8 (3.9%). There was substantial variation among readers and the inaccuracies were biased. Ages of younger fish were overestimated while those of older fish were underestimated. Cating's method may not be applicable to all American shad stocks. Thus, we recommend caution in applying age-based assessment techniques to stocks that lack age validation across all ages.

(5) Six Fish and 600,000 Thirsty Folks - A Fishing Moratorium on American Shad Thwarts a Controversial Municipal Reservoir Project in Virginia, USA (submitted to American Fisheries Society Fisheries Congress book editor, 3/04)

Olney, J.E., C.H. Hershner, D.M. Bilkovic, H. Wang, L.M. Varnell, and R.L. Mann

Abstract

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

Figure 1. **Commercial landings of American shad along the Atlantic coast and in Virginia since 1950. Data source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.**

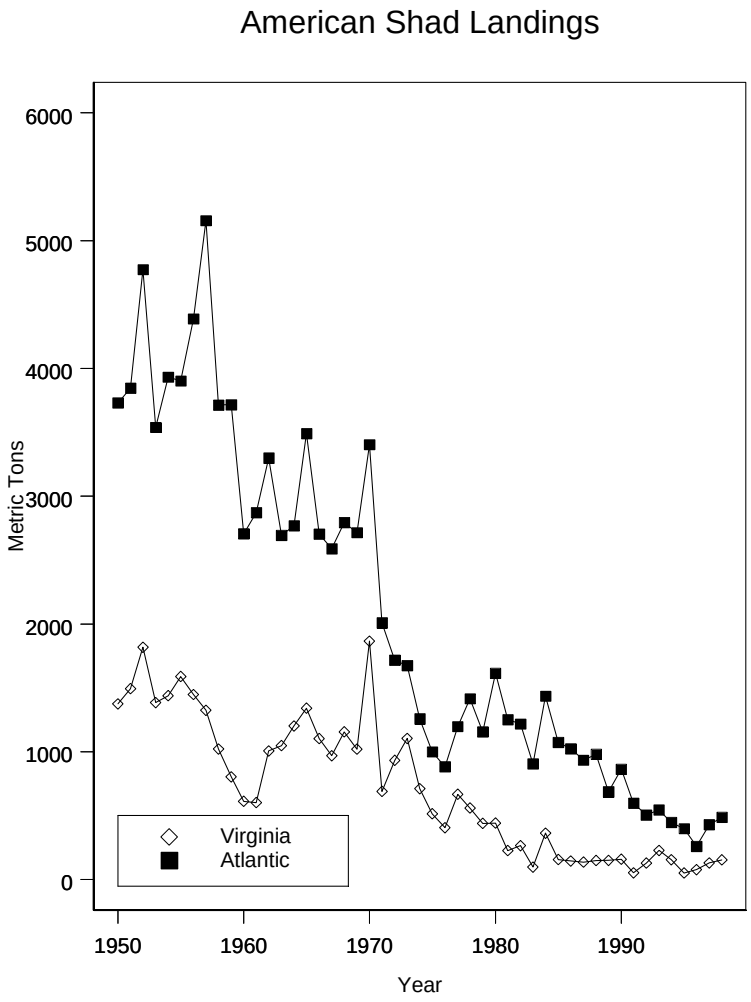

Figure 2. Number and location of staked gill nets on the James River in 1983.

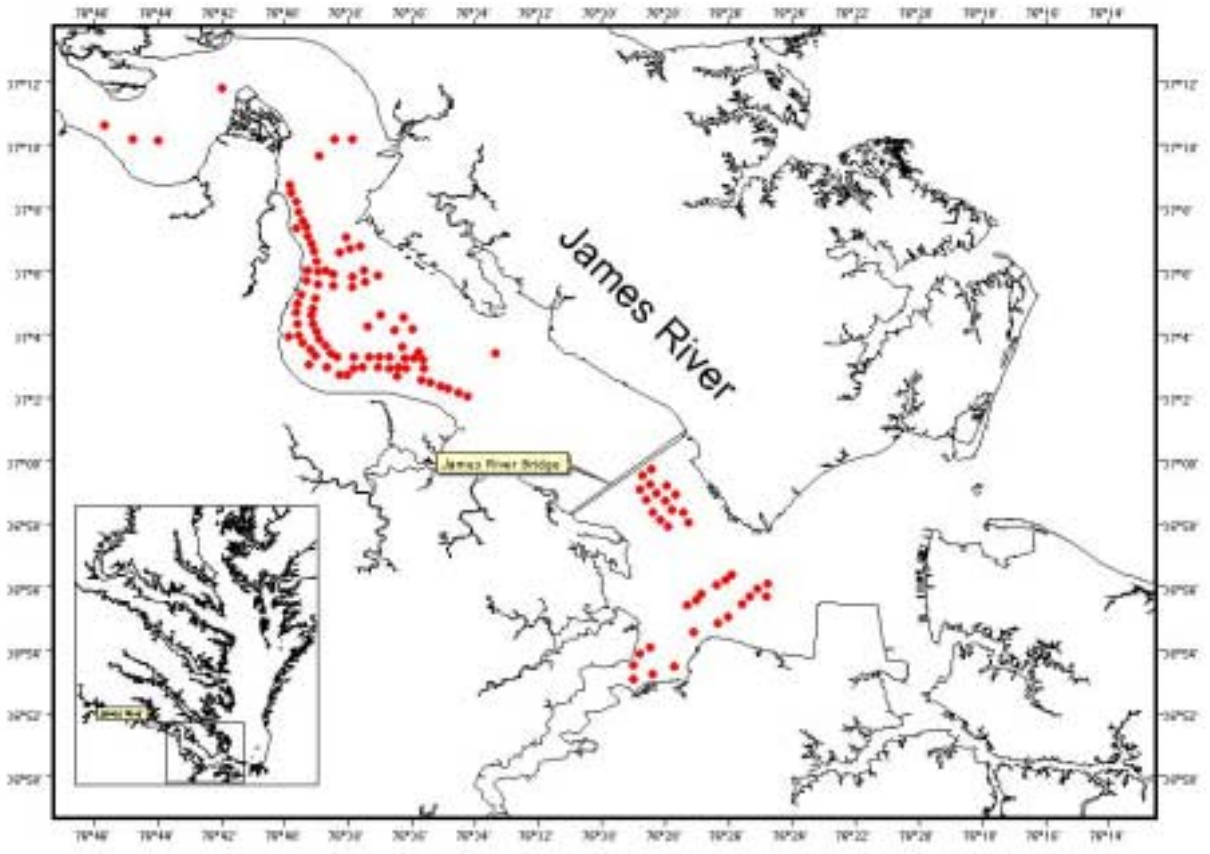

Figure 3. Number and location of staked gill nets on the York River in 1983.

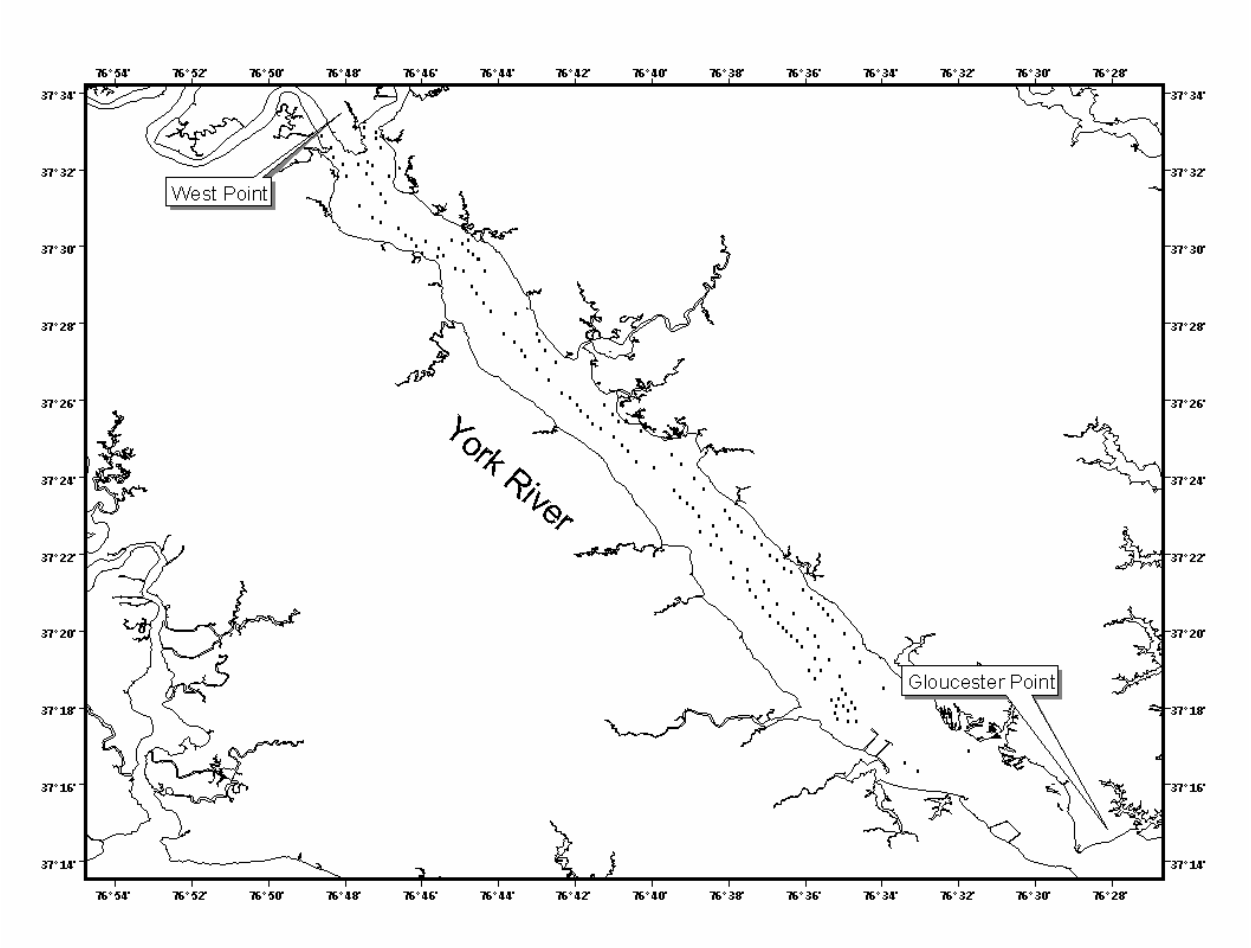

Figure 4. **Number and location of staked gill nets on the Rappahannock River in 1983.**

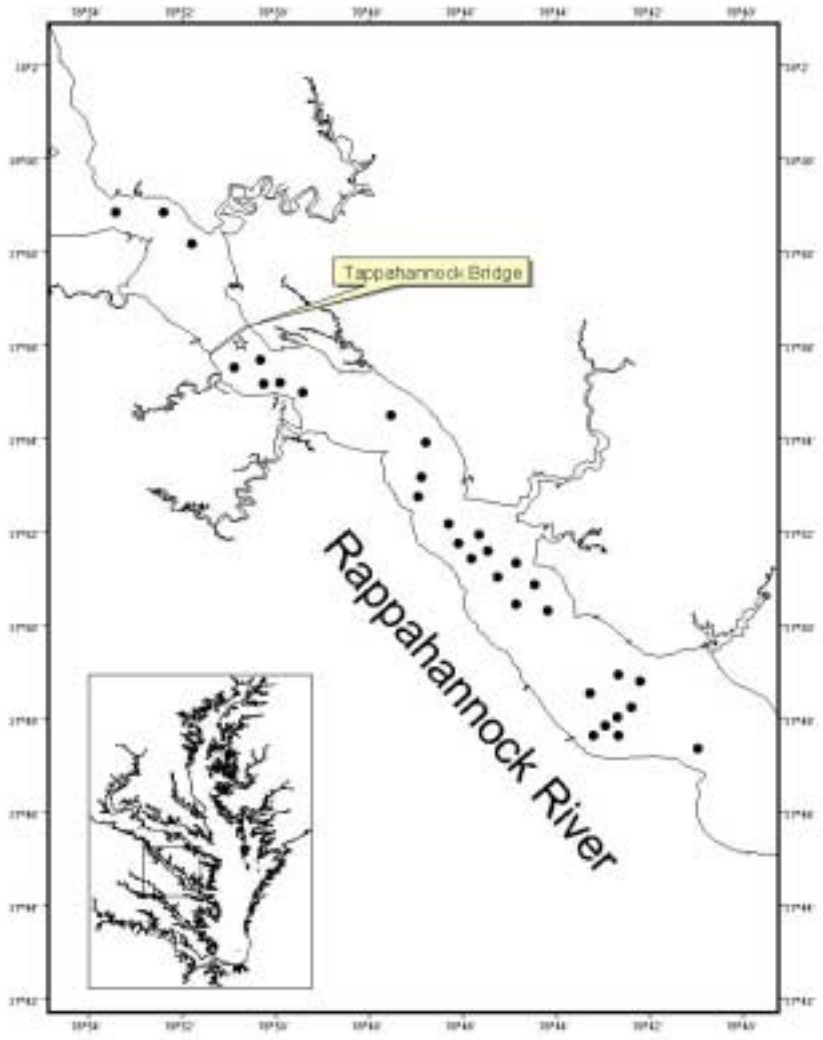

Figure 5. Location of the staked gill net fished by Mr. Marc Brown on the James River. The length of the net (273 m) is not to scale.

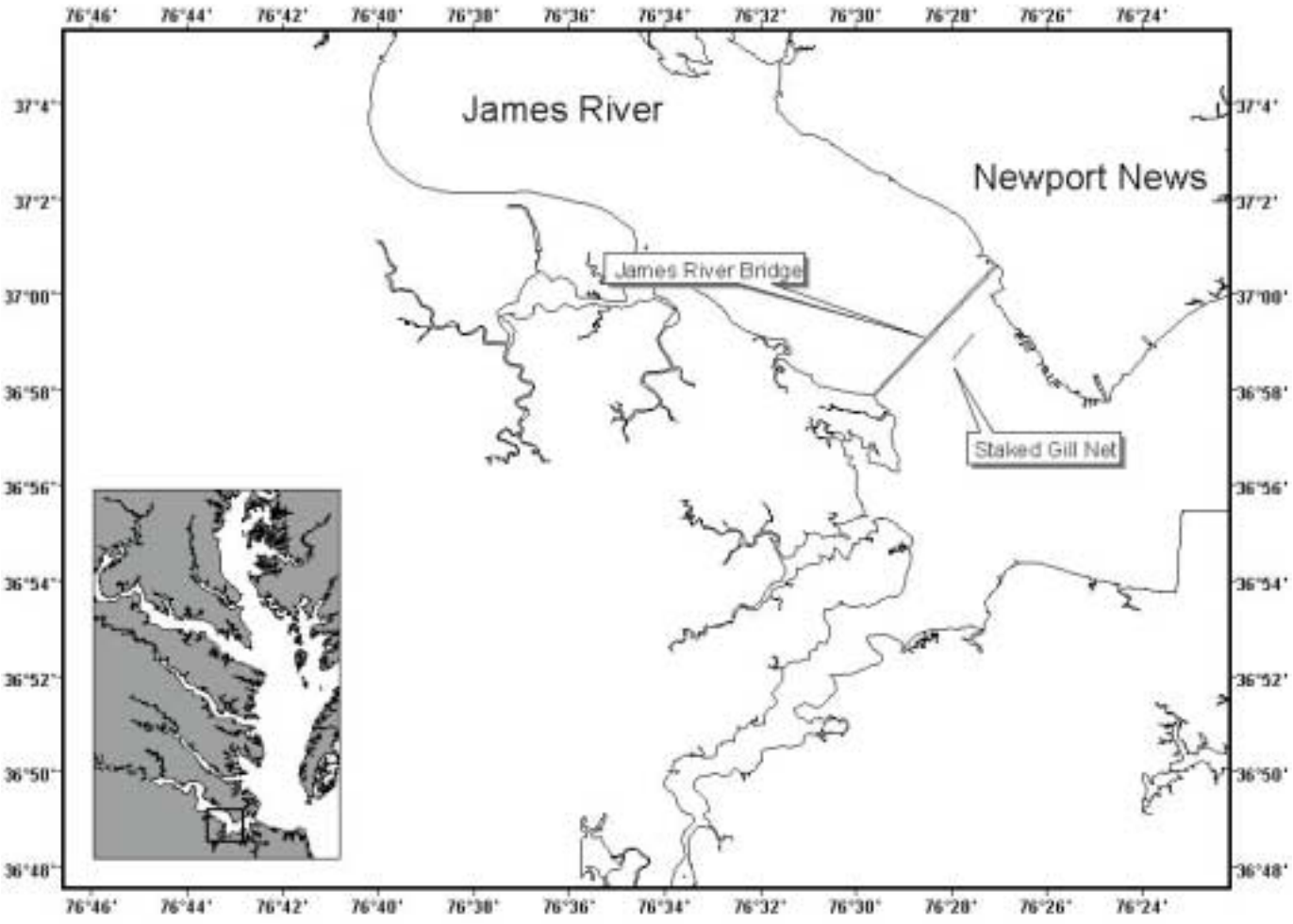

Figure 6. Location of the staked gill net fished by Mr. Raymond Kellum on the York River. The length of the net (273 m) is not to scale.

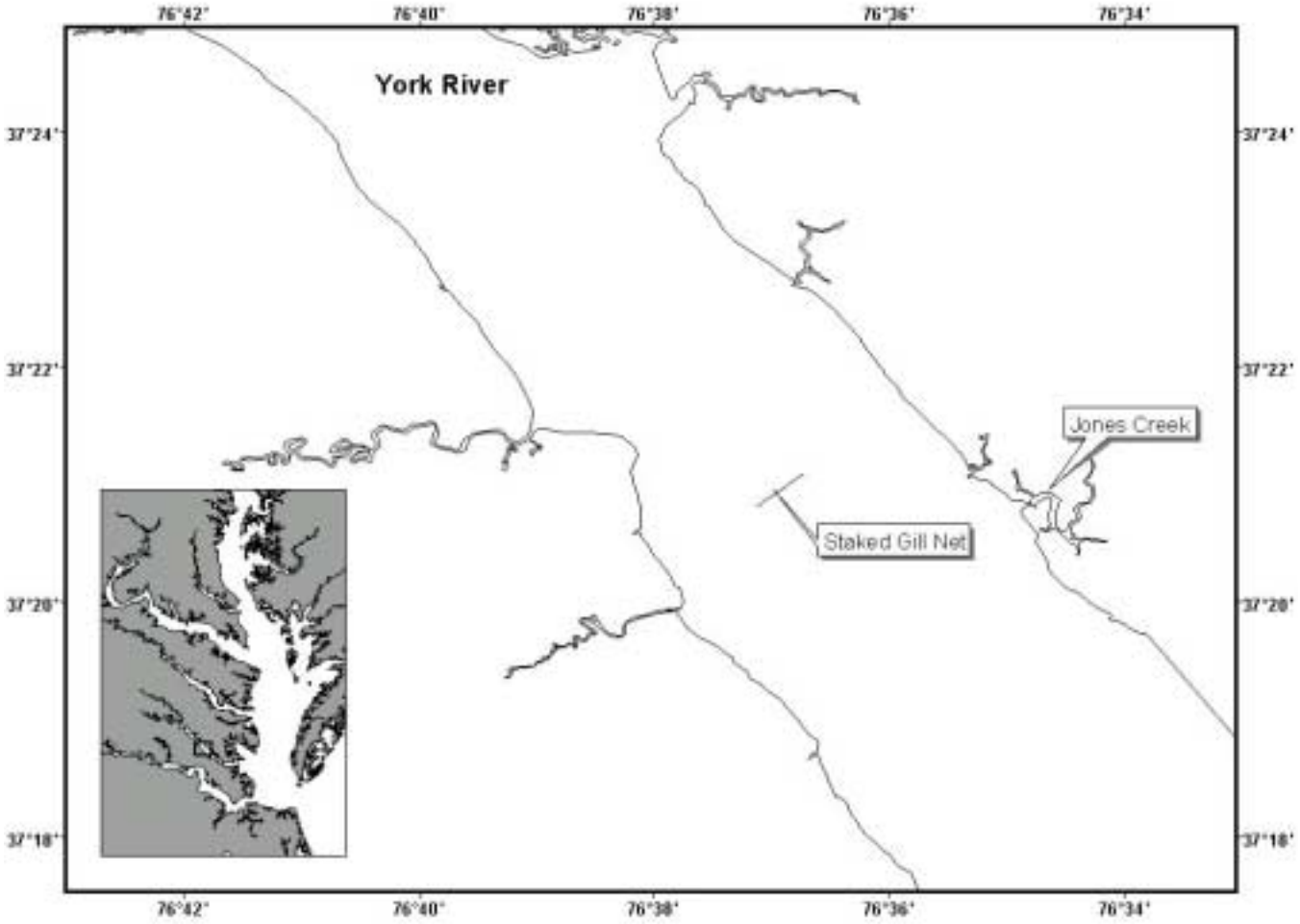

Figure 7. **Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River. The length of the net (276 m) is not to scale.**

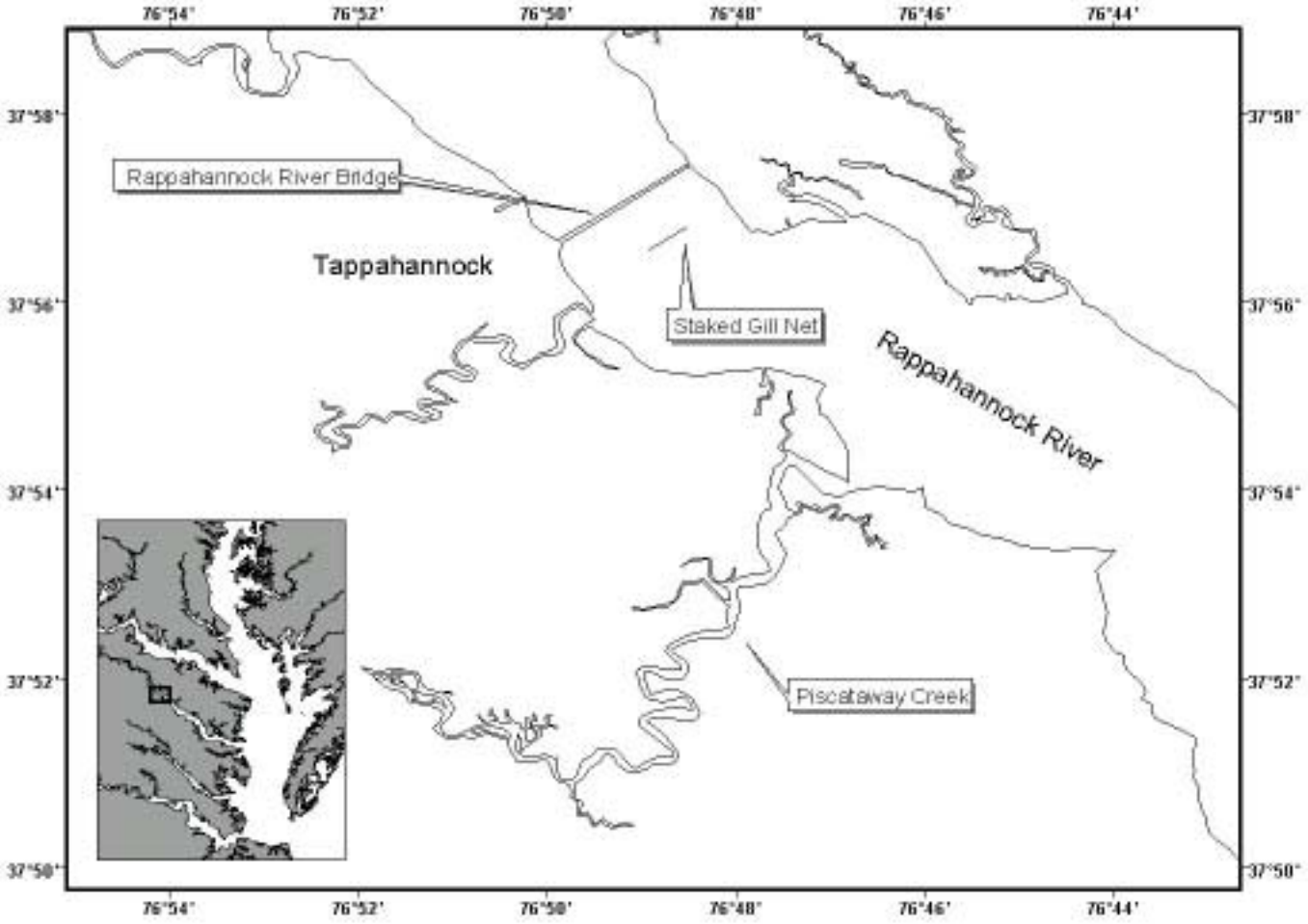

Figure 8. **Catch rates and total numbers of female American shad taken by staked gill nets in the James River, spring 2004.**

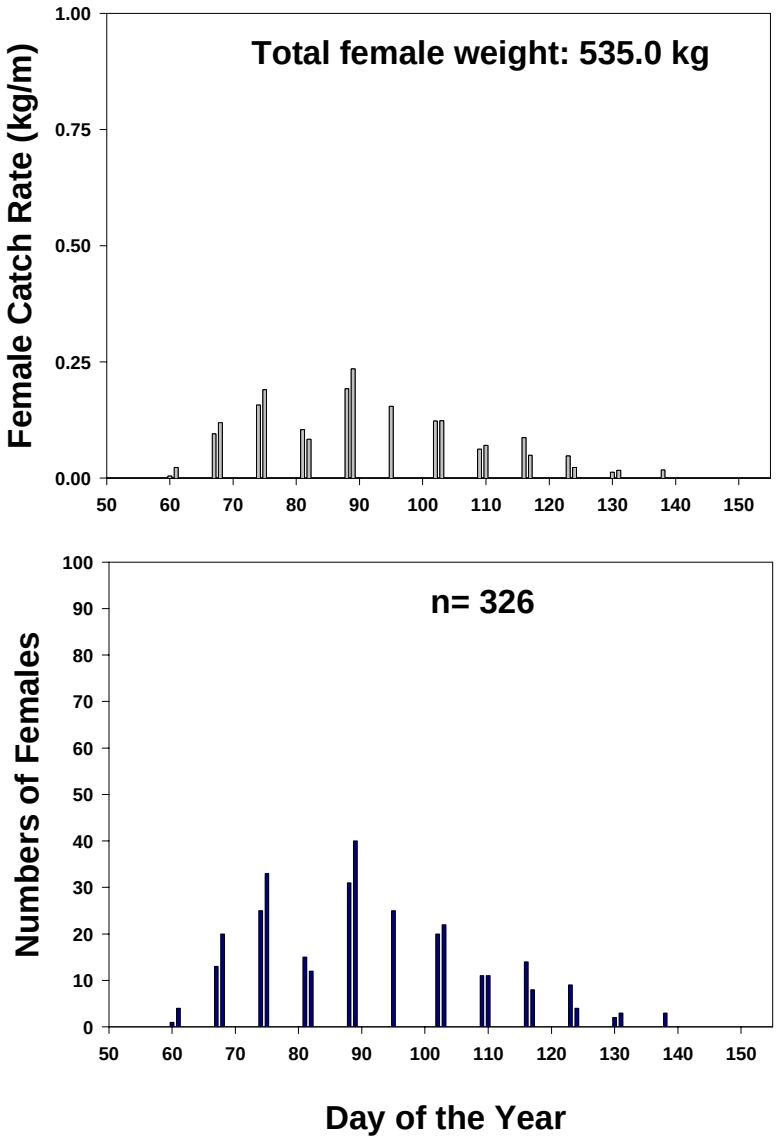

Figure 9. **Catch rates and total numbers of female American shad taken by staked gill nets in the York River, spring 2004.**

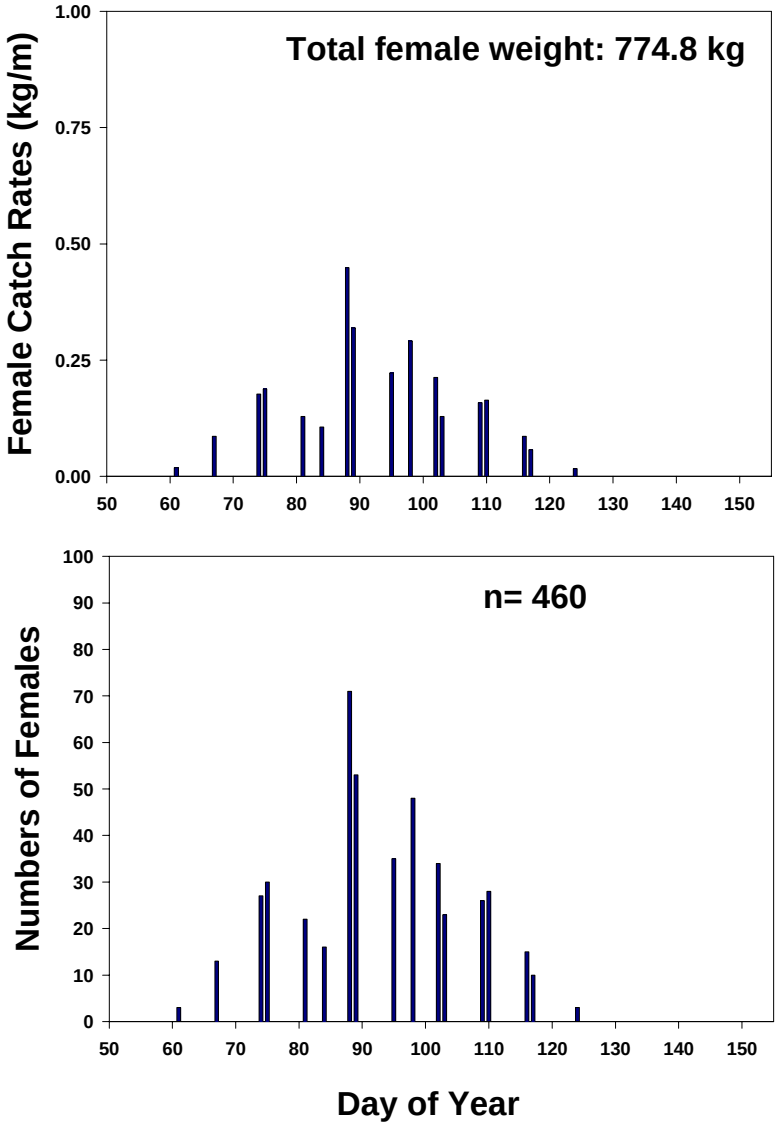

Figure 10. **Catch rates and total numbers of female American shad taken by staked gill nets in the Rappahannock River, spring 2004.**

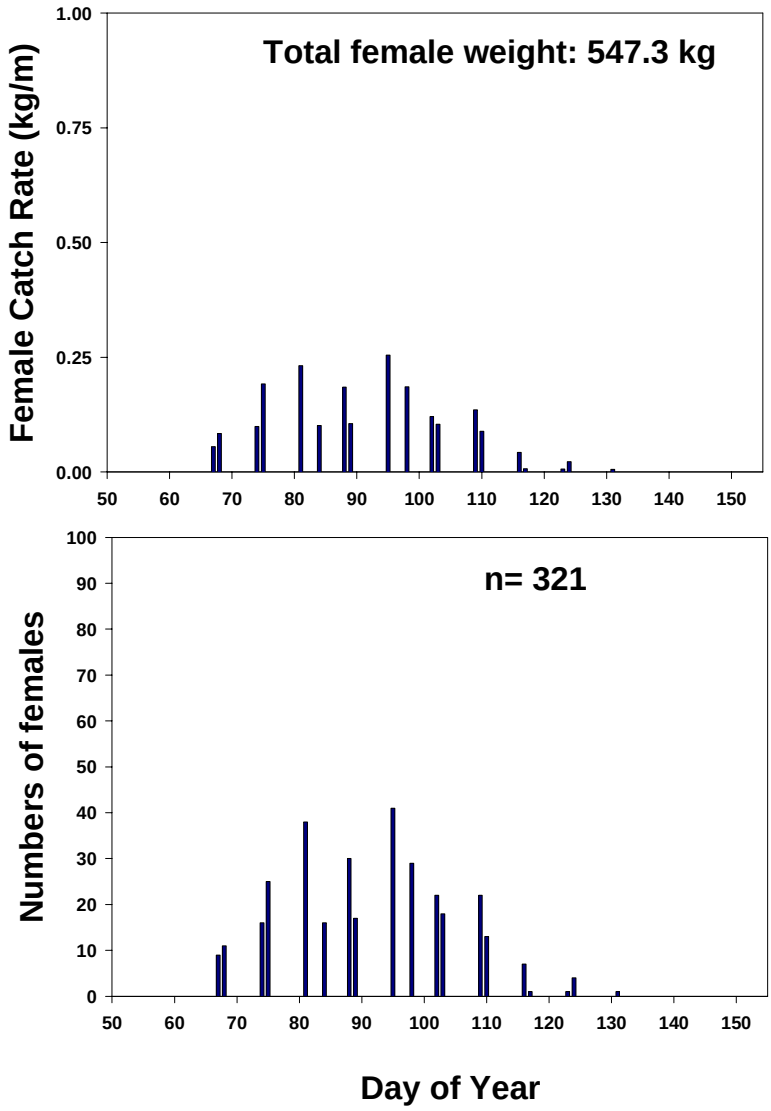

Figure 11. Catch rates and total numbers of male American shad taken by staked gill nets in the James River, spring 2004.

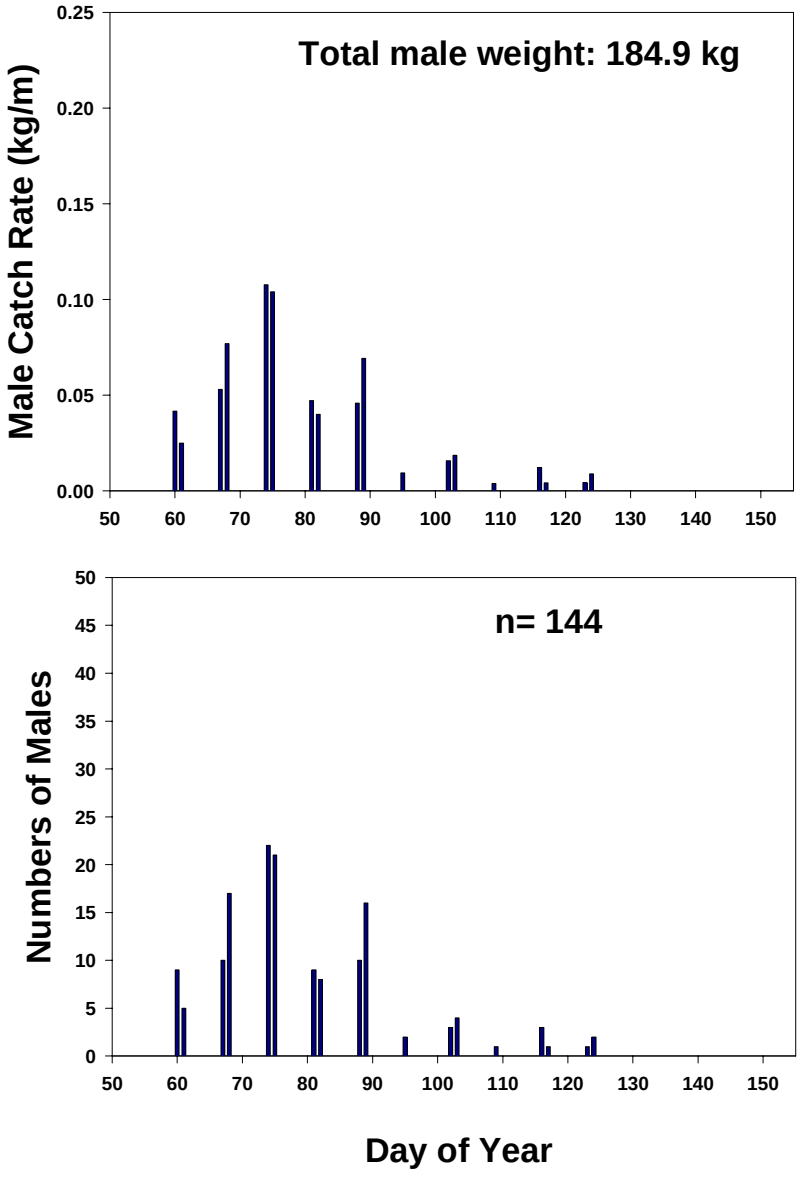

Figure 12. **Catch rates and total numbers of male American shad taken by staked gill nets in the York River, spring 2004.**

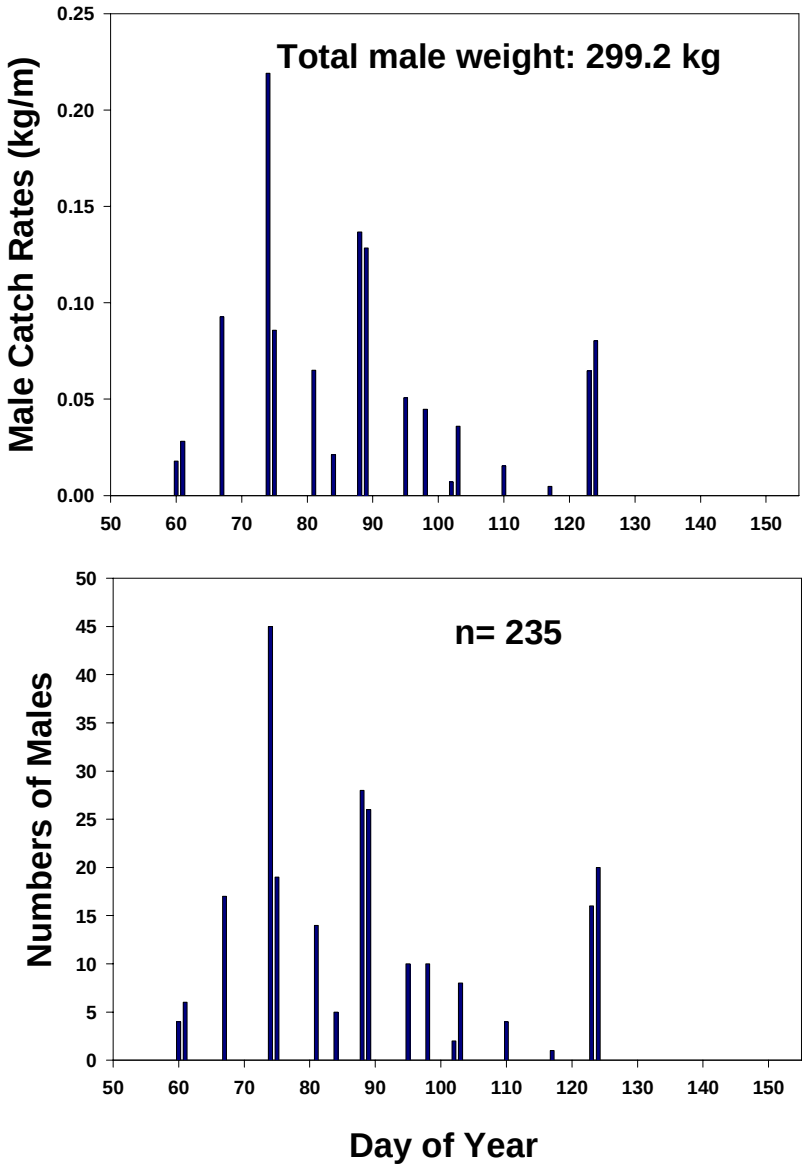

Figure 13. Catch rates and total numbers of female American shad taken by staked gill nets in the Rappahannock River, spring 2004.

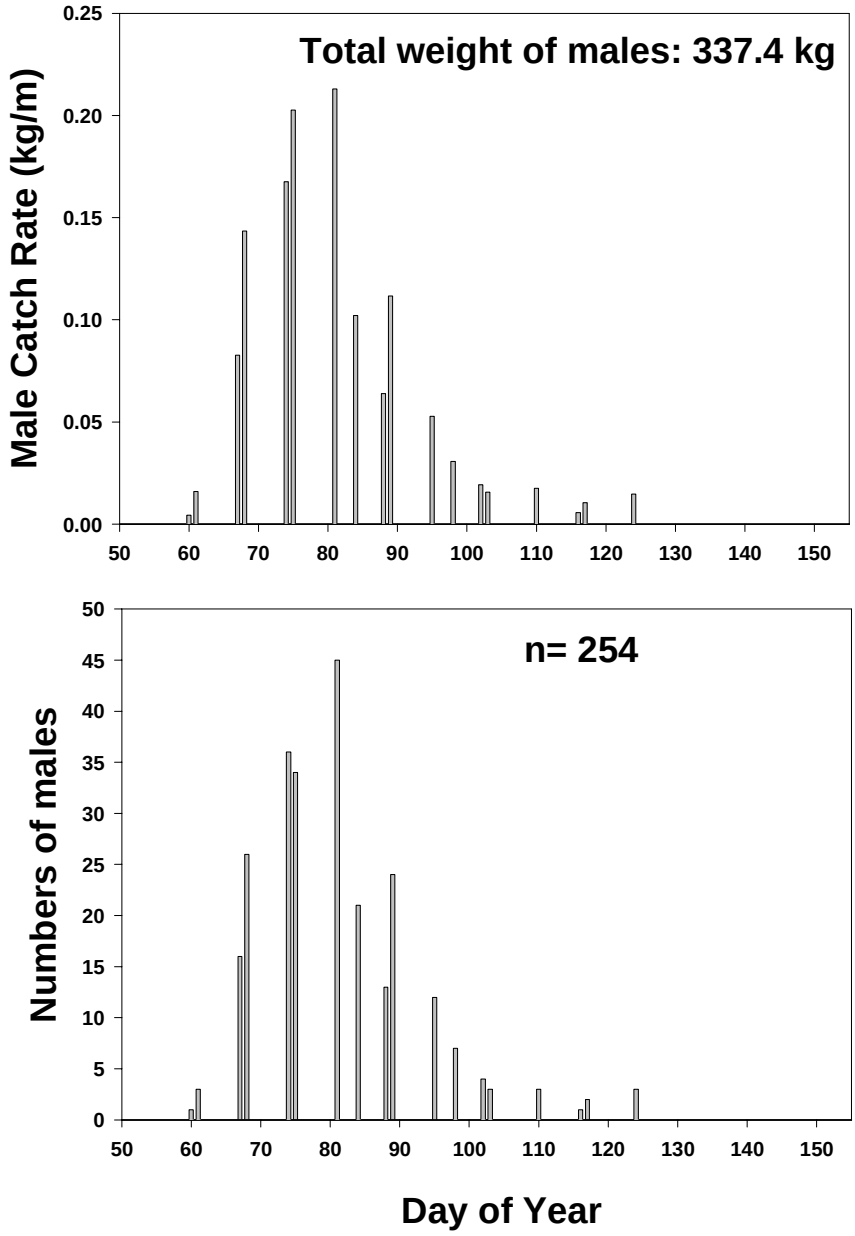

Figure 14. **The index of juvenile abundance of American shad in the York River system as estimated by daylight seine surveys, 1980-2004. The index is the geometric mean number of American shad juveniles per seine haul.**

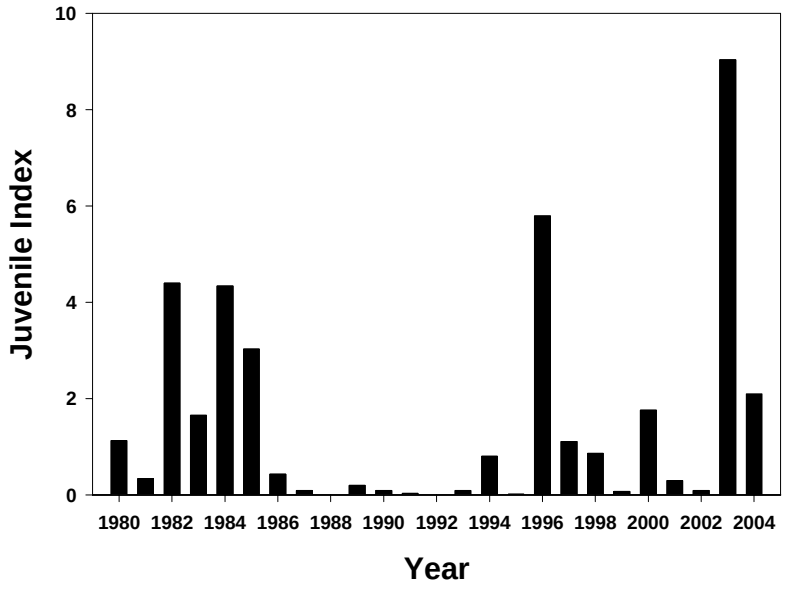

Figure 15. **The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by daylight seine surveys, 1980-2004. The index is the geometric mean number of American shad juveniles per seine haul.**

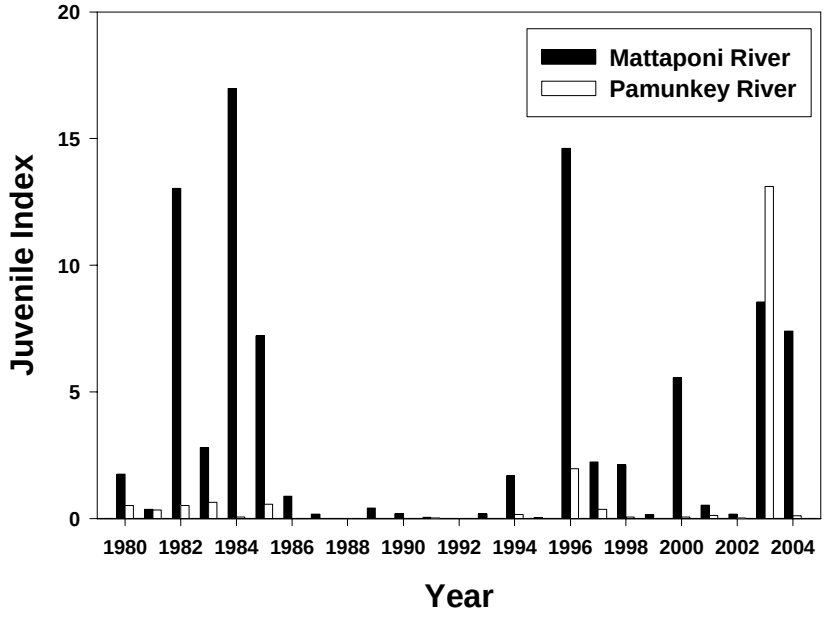

Figure 16. **The index of juvenile abundance of American shad in the Rappahannock River as estimated by daylight seine surveys, 1980-2004. The index is the geometric mean number of American shad juveniles per seine haul. The index in 1980 and 1981 was zero.**

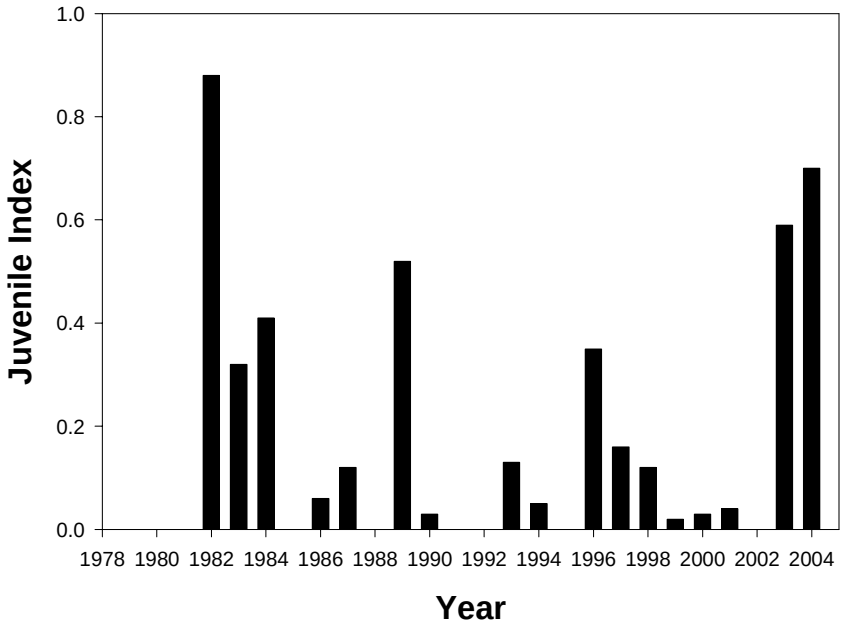

Figure 17. Mean age of females taken in staked gill nets in the James, York and Rappahannock rivers, 1998-2004.

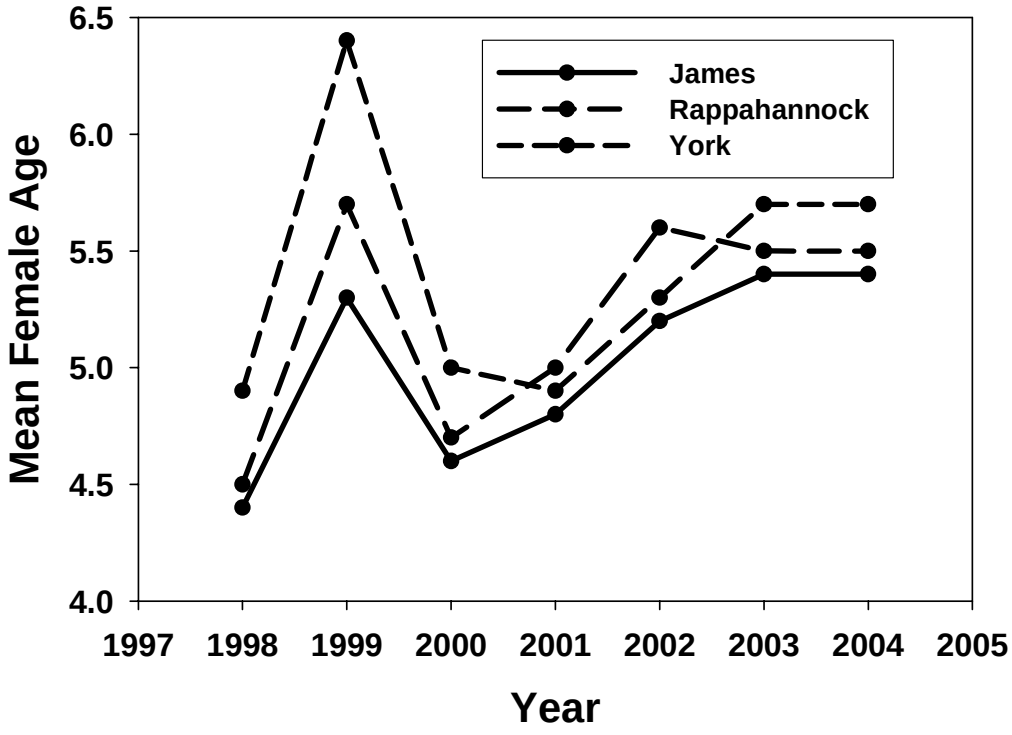

Figure 18. **Recent (1998-2004) and historic values of the catch index of female American shad on the James River. Hatchery prevalence is the percent of the total catch (both sexes combined) that had hatchery marks on the otoliths.**

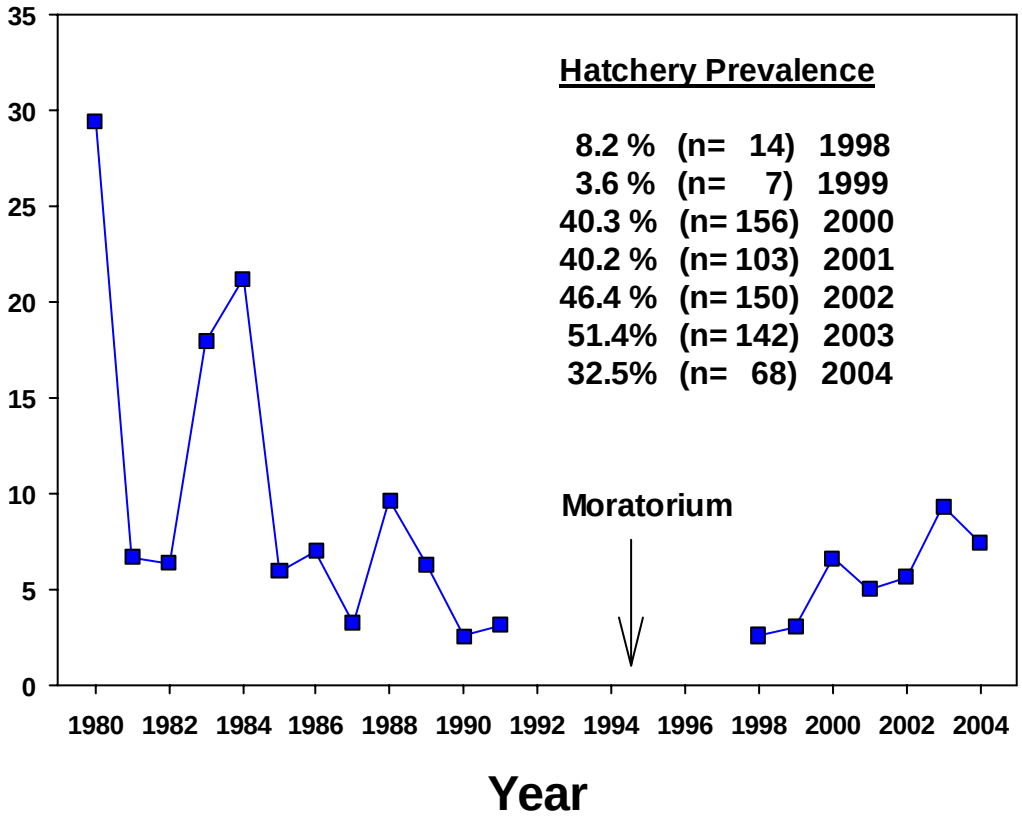

Figure 19. **Recent (1998-2004) and historic values of the catch index of female American shad on the York River.**

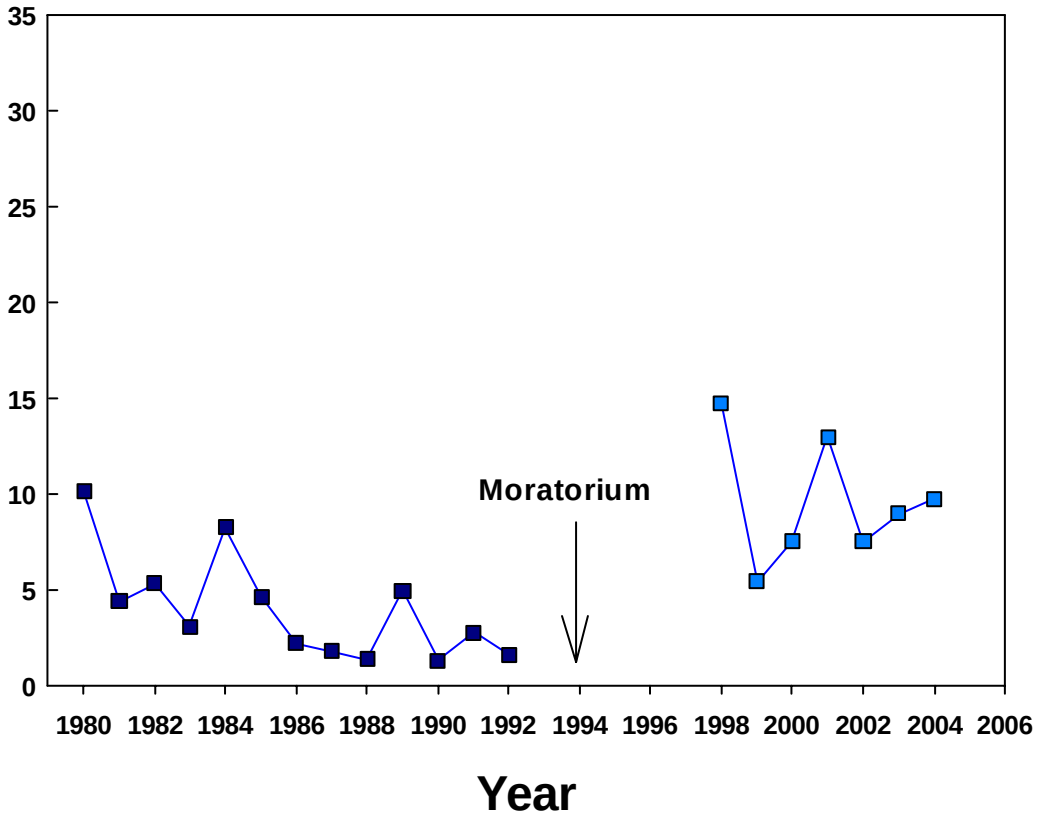

Figure 20. **Recent (1998-2004) and historic values of the catch index of female American shad on the Rappahannock River.**

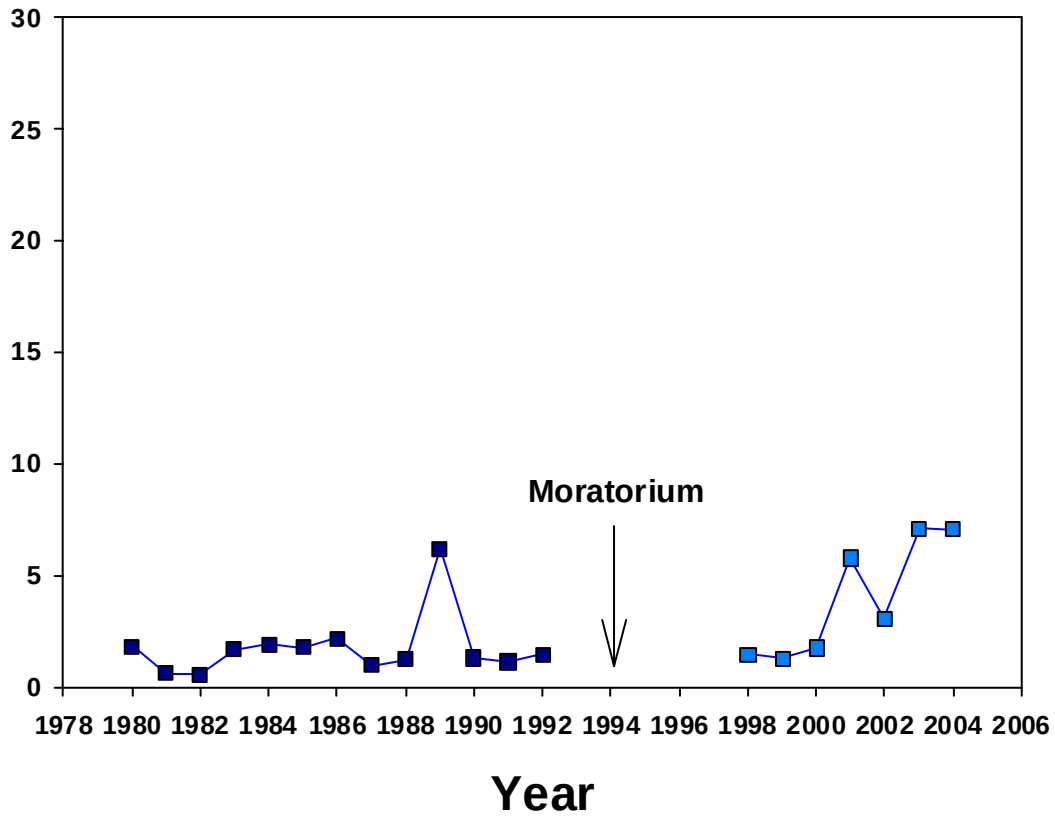

Figure 21. **Catch indexes of historical logbook data from the 1950s (M. Greene), the 1980s (R. Kellum) and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the means of each data set (solid, 1950s; short dashes, current; long dashes, 1980s)**