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Monitoring Relative Abundance of American Shad in Virginia Rivers 2005 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 2005. This was the eighth 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 data 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 (27 February to 10 May 2005), the Rappahannock River (27 February - 9 May 2005), and the James River (27 February - 9 May 2005). 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 959 pre-spawning female American shad (1,482.3 kg total weight) were captured. The 2005 catch continued to decrease slightly from the 2004 catch (1,107 females weighing 1,857.1 kg) and 2003 catch (1,168 females weighing 1,970 kg), but was still larger than the 2002 catch (787 females weighing 1,260 kg).

- Total numbers and weights of females in 2005 were highest on the James River (n= 329, 530 kg). The number of females on the York River (n= 222, 348 kg) slightly exceeded that on the Rappahannock River (n= 181, 299 kg). Numbers of males captured were: James River, 93; Rappahannock, 78; York, 56. The total weight of males captured on all rivers was 306 kg.

- Based on age estimates from scales, the 2000 (age 5) year class of female American shad was the most abundant on the James and York Rivers, with peak age-specific seasonal catch rates exceeding 0.03 kg/m and 0.01 kg/m, respectively. The 1999 (age 6) year class was the most abundant on the Rappahannock River with peak age-specific seasonal catch rates exceeding 0.01 kg/m. The 2000 (age 5) year class on the Rappahannock River and the 1999 (age 6) year class on the James River were also abundant with seasonal catch rates exceeding 0.01 kg/m and 0.03 kg/m, respectively. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 0.72; James River, 1.17; and Rappahannock River, 0.98. Total instantaneous mortality rates of males calculated from age-specific catch rates were: James River, 0.63; York River, 0.66; and Rappahannock River, 0.91.

- Otoliths of 168 American shad captured on the James River and otoliths of 83 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 23.8 % (40 of 168 fish) and 9.6 % (8 of 83 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, ten year classes (1992-2001) 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 2005 was: James River, 0 (0, 20); Rappahannock River, 0.18 (0.592, 33); York River (inclusive of Pamunkey and Mattaponi rivers), 0.68 (1.091, 95); Mattaponi River, 1.66 (1.351, 50); and Pamunkey River, 0.02 (0.110, 40). The evening push net survey in the Mattaponi and Pamunkey rivers was discontinued in 2002.

- Twenty-one species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 22,711 specimens. The total number of striped bass captured was 3,831 (James River, n= 1,518; York River, n= 752; Rappahannock River, n= 1,561). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 42.8%; York River, 45.9%; and the Rappahannock River, 54.4%.

- In recent years of monitoring (2000-2005), mean age of females has increased as a result of lower proportions of younger fish in the monitoring catch. Abundance of juvenile fish was low in 1997-2002 in the York and Rappahannock rivers, suggesting recruitment failure in some years. Recruitment is below levels of detection on the James River in most years. The 1997-2002 age classes are recruiting now to the monitoring gear.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2005 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 2005 was 4.64. During the eight 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 (8.93) 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 2005 index (7.16) is the third highest value recorded since 1998. Index values in 2000-2005 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 while the average of the current monitoring data is lower (5.84).

- The catch index on the Rappahannock River in 2005 (3.69) has dropped with respect to 2003-2004 and is almost equivalent to the value in 2002. The 2003-04 values are higher than any other years 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 (3.90).

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 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 Sanders 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, A. Aunins, S. Upton, and M. Chattin. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. K. Delano 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 eighth year in the sampling program (2005) are reported in this document and compared to some results in previous years of monitoring. Detailed results of the first seven years of sampling (1998-2004) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b; Olney and Hoenig 2001a; Olney and Maki 2002, Olney 2003a, Olney 2004, Olney 2005). 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, and 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 Chickahominy 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 most years, 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, Olney 2005). In 2005, prevalence rose to approximately 10%. 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

Historic and current catch 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 Rivers only) and the data record is uninterrupted since 1979.

Since the American shad monitoring program at VIMS began in 1998, 15 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; McBride *et al*., 2005; Maki *et al*., in press; Olney et al., in press; Olney *et al.*, in review). Reprints of these papers are available on request.

Currently, one manuscript reporting the results of a mixed-stock analysis of Virginia's offshore and in-bay fisheries is in review (Hoenig *et al*., in review; see Appendix 1). Another report on seasonal fecundity of shad in the York River is in preparation (Hyle 2004).

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 press). Using this approach, we have established proposed restoration targets for the York River stock.

Methods

The 2005 sampling methods were the same as those in 1998-2004. 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. In 2005, sampling occurred for 10 weeks on the York River (27 February to 10 May 2005), Rappahannock River (27 February - 9 May 2005), and James River (27 February - 9 May 2005). 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 enumerated in the field and released. For striped bass (*Morone saxatilis*), separate records were kept of the number of live and dead fish in the nets and released (if alive) or returned to the laboratory (if dead).

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. Otolith scanning was performed by B. Watkins (VIMS) in 2005. Scanning in previous years was performed by D. Hopler (VDGIF), J. Goins (VIMS) and G. Holloman (VIMS).

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).

An ASMFC age-determination workshop using known age fish from the Susquehanna system was held at VIMS in August 2004 to test the validity of scale-age techniques (McBride et al 2005). One recommendation of the workshop was to validate age determination in all major stocks. We are currently assembling materials to conduct these trials on the York River stock in collaboration with Dr. Simon Thorrold (Woods Hole Oceanographic Institution).

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 2005

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-8 and Figures 8-15. 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 macroscopically. Since the historic fishery was a roe fishery and spent or partially spent fish were not routinely captured or marketed in the historic fishery, post-spawning fish were removed from the monitoring sample.

A total of 959 American shad (227 males; 732 females) were captured. The total weight of the sample was 1,482.3 kg (male, 305.5 kg; female, 1176.7 kg). The 2005 catch was almost equivalent to the catch in 2002 (787 females; Olney 2003a). Catches in 2005 were lowest on the Rappahannock River (259 total fish, 78 males and 181 females), higher on the York River (278 total fish, 56 males and 222 females) and highest on the James River (422 total fish, 93 males and 329 females).

On the James River, catches of females peaked on 27 March-19 April 2004 when catch rates usually exceeded 0.07 fish/m or 0.11 kg/m. During that period on the James

River, 70% (232 of 329) of the total number of females was captured. On the York River, catches of females peaked between 28 March and 19 April 2005 when catch rates approached or exceeded 0.05 fish/m or 0.08 kg/m. During that period on the York River, 52% (115 of 222) of the total number of females was captured. Catches of females on the Rappahannock River peaked 20 March-28 March 2005 when catch rates usually exceeded 0.04 fish/m or 0.07 kg/m. During that period on the Rappahannock River, 46% (84 of 181) of the total number of females was captured. The highest recorded daily catch by weight occurred on 4 April 2005 when 59 female American shad (98.03 kg) were taken in the James River (Table 3). 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, 1:4.0; James River, 1:3.5; Rappahannock River, 1:2.3. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish.

The duration of the spawning run is 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. In 2005, catch rates had already exceeded 0.01 female kg/m when sampling was initiated and sampling was terminated prior to catch rates falling below this threshold, therefore spawning run duration estimates for this year are slightly conservative. The 2005 spawning run duration was estimated to be 71 days on the James River (27 February - 9 May), 72 days on the York River (27 February - 10 May), and 71 days on the Rappahannock River (27 February - 9 May).

Biological characteristics of the American shad in 2005

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 368-556 mm TL and 457-598 mm TL, respectively. Mean weight at age of males and females ranged from 0.48-2.02 kg and 1.05-2.52 kg, respectively.

The 1999 and 2000 year classes (ages 5 and 6) of female American shad were the most abundant on all three rivers (Table 11). On the James River, seven age classes of females were represented (1996-2002, ages 3-9) and the sample was dominated by age-5 fish (41.7% of the total that was aged). On the York River, eight age classes of females were represented (1995-2002, ages 3-10) and the sample was dominated by age-5 fish (36.2% of the total that was aged). On the Rappahannock River, eight age classes of females were taken (1995-2002, ages 3-10). Age-6 fish dominated the catch on the Rappahannock and made up 36.9% of the aged sample. The 1998, 1999 and 2000 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 68.8% (York River), 91.5% (Rappahannock River) and 73.0% (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, 0.71 (r^2= 0.94); James River,

1.17 (r^2= 0.96); and Rappahannock River, 0.98 (r^2= 0.98). Total instantaneous mortality rates of males calculated from age-specific catch rates were: James River, 0.63 (r^2= 0.84); York River, 0.66 (r^2= 0.90); and Rappahannock River, 0.91 (r^2= 0.86).

Spawning histories of American shad collected in 2005 are presented in Tables 13-14. On the Rappahannock and York rivers, fish (both sexes combined) ranged in age from 3-10 years with 0 (virgin) to 5 spawning marks. On the James River, fish (both sexes combined) ranged in age from 3-11 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, 62.4% (97 virgins in a sample of 258); James River 52.9% (177 virgins in a sample of 376); Rappahannock River 70.0% (72 virgins in a sample of 240 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%; 2004, 70.6% (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002; Olney 2003a; Olney 2004; Olney 2005).

Evaluation of hatchery origin of American shad in 2005

James River - Otoliths of 168 American shad captured in staked gill nets on the James River were scanned for hatchery marks. The proportion of the 2005 sample with hatchery marks was 23.8% (40 of 168 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%) was lower than all values reported since 2000 (40.2%-51.4%). Prevalence of hatchery fish on the James River continued to decline in 2005 (23.8%). 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= 2, Pamunkey River, n= 2 unknown tag; 2005, n=3, tentatively Pamunkey River and Mattaponi River (Virginia). In 2003 and 2004 there were no stray fish.

Most hatchery-reared adults taken in 2000-2005 had OTC marks that indicated these specimens were either released in 1995 or 1996 or in 1997-2001. These tags could not be easily differentiated microscopically, so we determined the year of release using scale-determined ages (Tables 13, 15-16). During 2000-2005, hatchery-reared fish captured in the staked gill nets were ages 3-9 (released as fry in 1993-2001). 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. The highest numbers captured thus far were fish released from 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 26.8% of the hatchery-marked catch. The 1997 year class first appeared at age 3 and its contribution (26.8%) is 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 2004-05. Additional recruitment of the 1999-2001 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 and 2004, the proportions of repeat spawners were 48.2% and 65.1%. In 2005, the proportion of repeat spawners was 30.0% (12 virgins in a sample of 40 hatchery fish).

York River - Otoliths of 83 adult specimens captured in staked gill nets on the York River were scanned for hatchery marks. The proportion of the sample with marks was 9.6 % (8 of 83 fish). The biological characteristics of these specimens are reported in Table 17. By comparison, the proportion of previous samples with marks was 2.2 % (2 of 90 fish); 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 16-18 report index values of juvenile abundance of American shad based on seine surveys (1979-2005) 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 2005 was: James River, 0 (0, 20); Rappahannock River, 0.18 (0.592, 33); York River (inclusive of Pamunkey and Mattaponi rivers), 0.68 (1.091, 95); Mattaponi River, 1.66 (1.351, 50); and Pamunkey River, 0.02 (0.110, 40). 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.

Since 2000, mean age of females has increased steadily on all rivers (Figure 19). An analysis of age composition of the monitoring catch (1998-2005, not presented here) depicts a smaller contribution of younger age cohorts to the population in recent years.

By-catch of striped bass and other species in 2005

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 20-22. Twenty-one species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 22,711 specimens. The most commonly encountered by-catch species were: menhaden (*Brevoortia tyrannus*), gizzard shad (*Dorasoma cepedianum*), striped bass (*Morone saxatilis*), blue catfish (*Ictalurus furcatus*), white perch (*Morone americana*), hickory shad (*Alosa mediocris*), Atlantic croaker (*Microponias undulatus*), and summer flounder (*Paralichthys dentatus*).

The total number of striped bass captured was 3,831 (James River, n= 1,518; York River, n= 752; Rappahannock River, n= 1,561). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 42.8%; York River, 45.9%; and the Rappahannock River, 54.4%.

Seasonal catch indexes, 1980-1992 and 1998-2005

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2005 and for each year of the historical record of staked net catches on each river (Tables 23-26 and Figures 20-23). Seasonal catch indices in 2005 were: York River, 4.64; James River, 7.16; Rappahannock River, 3.69.

Discussion

The staked gill net monitoring program continues to be useful for assessment 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 has also provided required data for the upcoming coast-wide stock assessment, scheduled for peer review in 2006.

Abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in our monitoring gear in recent years (2000-2003) indicate 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 bearing OTC marks is consistent with the timing of releases of large numbers of hatchery fish. The prevalence of hatchery fish increased dramatically in 2000-2003 (40-51%) but has

decreased in recent years of monitoring (2004, 33%; 2005, 24%). The pattern is consistent with recent recruitment of unmarked progeny of hatchery components of the stock, especially the 2000-2002 year classes.

The monitoring data suggest that a continuation of the hatchery release program at present levels of production in the James River, 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 press). 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 23. 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. To establish restorations targets using these records, we will recommend a new staked net location in the upper James River in spring 2007. There are no historic records in department archives for the Rappahannock River.

On the York River, the seasonal catch index in 2005 was 4.64. During the eight 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 (8.93) 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 (2000-2005), mean age of females has increased as a result of lower proportions of younger fish in the monitoring catch. Abundance of juvenile fish in the York River system was low in 1997-2002. The JAI time series suggests recruitment failure in 1999, 2001 and 2002. Catch indices have been trending downward in recent years. Our overall assessment of the York River stock is that it has recovered to a level that is close to its average 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 23) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann 1963).

On the James River, the 2005 index (7.16) is the third highest value recorded since 1998 but well below the proposed target of 29. Index values in 2000-2005 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 (5.84), but slowly increasing. 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 (2000-2005). Our overall assessment for the James River is that the stock remains at a low level of abundance but is slowly recovering. The stock requires continued protection and hatchery-based restoration.

On the Rappahannock River, the index in 2005 (3.69) declined with respect to 2003-2004 values and is almost equivalent to the 2002 value. The 2003-2004 index values were higher than any previous year of monitoring and higher than all years of the historic data. The 1998-2005 average (3.90) is above the average of the historical data (1.76) and the 2003-2004 index values were above the proposed target of 6, however,

2005 values have dropped below the proposed target of 6. In recent years of monitoring (2000-2005), mean age of females has increased as a result of reduced catches of younger fish in the monitoring gear. Abundance of juvenile fish in the Rappahannock River was very low in 1999-2001. No juveniles were captured in 2002. However, recruitment has increased in recent years. 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 new hatchery-release program on the upper Rappahannock River. 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.

Literature Cited

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

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

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

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

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

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

Hyle, R. H. 2004. Reproductive biology of American shad, *Alosa sapidissima*, in the Mattaponi River. A thesis presented to the School of Marine Science, College of William and Mary, 88 pp.

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

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

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

Maki, K.L., J.M. Hoenig, J.E. Olney and D.M. Heisey. In press. Comparing historical catches of American shad in multifilament and monofilament nets: a step toward

setting restoration targets for Viginia stocks. North American Journal of Fisheries Management 2006.

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

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

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

Olney, J.E. 2003b. Incorrect use of the names "Alosidae" and "Alosid" when referring to the shads in the subfamily Alosinae (Teleostei, Clupeidae). American Fisheries Society Symposium 35: xiii-xv.

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

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

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

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

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

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

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

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

Olney, J.E. 2004. Monitoring relative abundance of American shad in Virginia's rivers. 2003 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-6, 15 April 2004.

Olney, J.E. 2005. Monitoring relative abundance of American shad in Virginia's rivers. 2004 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-7, 15 April 2005.

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

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

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

Walter, J.F. and J.E. Olney. 2003. Feeding behavior of American shad during the spawning migration in the York River, Virginia. American Fisheries Society Symposium 35: 201-209.

Wilhite, M.L., K.L. Maki, J.M. Hoenig and J.E. Olney. 2003. Towards validation of a juvenile index of abundance for American shad in the York River, Virginia (USA). American Fisheries Society Symposium 35: 285-294.

Appendix 1

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

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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.

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 2005.

Stock	Sampling dates in 2005	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	2/27-5/9	329	93	530.0	126.9	422	656.8
York River	2/27-5/10	222	56	347.9	72.6	278	420.6
Rappahannock River	2/27-5/9	181	78	298.8	106.0	259	404.9
Totals		732	227	1176.7	305.5	959	1482.3

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 2005. These individuals were removed from the monitoring data.

River	Date	Specimen number	Total length (mm)	Fork length (mm)	Total weight (g)
James River	4/18/05	11445	508	449	1175.9
	4/24/05	11555	522	463	1401.0
	5/1/05	11638	550	482	1224.3
	5/1/05	11632	512	452	1857.9
	5/2/05	11631	546	476	1237.6
	5/2/05	11629	514	458	1196.0
	5/2/05	11627	546	475	1371.4
	5/2/05	11626	500	442	1310.9
	5/9/05	11710	496	446	1228.9
	5/9/05	11709	547	490	1304.4
	5/9/05	11708	458	417	1274.9
Rappahannock River	4/25/05	11589	518	462	1264.7
	5/8/05	11711	547	486	1086.1
	5/9/05	11659	516	458	1233.5
York River	4/18/05	11434	584	518	1793.5
	4/18/05	11435	560	496	1513.4
	4/18/05	11437	570	508	1675.5
	4/19/05	11488	527	476	1410.7
	4/24/05	11544	589	520	1751.9
	4/24/05	11542	590	524	1694.8
	4/24/05	11538	580	510	2087.8
	4/24/05	11543	579	508	1702.1
	4/25/05	11573	545	494	1195.8
	4/25/05	11568	518	458	1298.0
	4/25/05	11574	558	490	1808.8
	4/25/05	11570	515	456	1130.2

Table 2 cont.	4/25/05	11569	538	470	1355.5
	4/25/05	11576	550	490	1378.4
	4/25/05	11564	558	492	1703.9
	4/25/05	11578	534	474	1320.8
	4/25/05	11579	557	488	1623.4
	4/25/05	11561	610	534	1715.0
	5/1/05	11643	506	442	1171.3
	5/1/05	11647	534	470	1271.0
	5/1/05	11650	542	474	1291.8
	5/1/05	11645	520	465	1152.2
	5/1/05	11642	562	499	1391.8
	5/1/05	11651	572	505	1727.9
	5/1/05	11646	554	491	1538.6
	5/1/05	11644	564	502	1493.3
	5/1/05	11652	611	544	1973.9
	5/2/05	11610	532	468	1364.6
	5/2/05	11608	528	468	1147.0
	5/2/05	11607	554	493	1369.0
	5/2/05	11599	522	462	1199.6
	5/2/05	11594	524	459	1195.4
	5/2/05	11623	534	481	1521.5
	5/2/05	11620	550	490	1536.4
	5/2/05	11615	502	444	1100.0
	5/2/05	11612	534	471	1483.6
	5/2/05	11616	524	465	1236.9
	5/2/05	11617	546	478	1380.8
	5/2/05	11619	541	476	1347.7
	5/2/05	11622	537	473	1568.0
	5/2/05	11595	493	431	977.4
	5/2/05	11600	592	522	1735.8
	5/2/05	11601	562	500	1427.2
	5/2/05	11597	510	452	1151.9

Table 2 cont.	5/9/05	11668	506	451	1250.1
	5/9/05	11672	560	495	1441.8
	5/9/05	11681	547	486	1437.5
	5/9/05	11680	558	501	1402.7
	5/9/05	11679	548	486	1467.8
	5/9/05	11678	527	473	1300.5
	5/9/05	11677	552	489	1487.0
	5/9/05	11675	537	480	1274.7
	5/9/05	11673	553	496	1291.7
	5/9/05	11667	531	476	1348.2
	5/9/05	11666	530	464	1261.2
	5/9/05	11665	514	464	1270.8
	5/9/05	11664	524	462	1112.5
	5/9/05	11683	547	490	1515.2
	5/10/05	11690	529	474	1433.4
	5/10/05	11689	550	498	1442.1
	5/10/05	11688	506	450	1082.6
	5/10/05	11686	568	510	1435.0
	5/10/05	11685	550	494	1385.7
	5/10/05	11693	579	521	1788.2
	5/10/05	11702	549	498	1533.8
	5/10/05	11687	547	492	1420.1
	5/10/05	11694	569	506	1833.3
	5/10/05	11695	544	486	1587.4
	5/10/05	11696	567	515	1843.7
	5/10/05	11697	547	499	1340.0
	5/10/05	11698	508	453	1204.2
	5/10/05	11699	559	501	1698.7
	5/10/05	11701	555	503	1260.4
	5/10/05	11703	556	501	1638.5
	5/10/05	11704	470	421	1091.1
	5/10/05	11700	558	505	1664.1

Table 3. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the James River, spring 2005.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/05	58	12	0.054	19498.5	0.087
3/6/05	65	9	0.031	15036.5	0.053
3/7/05	66	16	0.058	25141.8	0.092
3/13/05	72	8	0.030	13078.3	0.049
3/14/05	73	6	0.022	9119.3	0.033
3/21/05	80	6	0.022	9886.8	0.036
3/22/05	81	11	0.041	17496.4	0.064
3/27/05	86	19	0.072	32874.5	0.125
3/28/05	87	7	0.026	11188.7	0.041
4/3/05	93	20	0.074	32120.6	0.118
4/4/05	94	59	0.215	98031.8	0.357
4/10/05	100	58	0.221	92419.1	0.352
4/11/05	101	34	0.121	54419.7	0.194
4/18/05	108	14	0.051	20229.4	0.073
4/19/05	109	21	0.078	33572.0	0.125
4/24/05	114	9	0.034	12837.8	0.048
4/25/05	115	5	0.019	8365.4	0.032
5/1/05	121	8	0.029	12753.5	0.046
5/2/05	122	4	0.016	5706.7	0.023
5/9/05	129	3	0.012	6208.6	0.025
Totals		329		529,985.4	

Table 4. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the James River, spring 2005.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/05	58	4	0.018	5104.1	0.023
3/6/05	65	2	0.007	2486.4	0.009
3/7/05	66	14	0.051	18237.6	0.066
3/13/05	72	4	0.015	5653.1	0.021
3/14/05	73	5	0.018	7066.0	0.026
3/21/05	80	3	0.011	4025.1	0.015
3/22/05	81	12	0.044	16358.0	0.060
3/27/05	86	6	0.023	8341.7	0.032
3/28/05	87	2	0.007	2304.9	0.008
4/3/05	93	5	0.018	7470.4	0.028
4/4/05	94	17	0.062	24236.1	0.088
4/10/05	100	6	0.023	8967.5	0.034
4/11/05	101	8	0.029	10162.4	0.036
4/18/05	108	2	0.007	2688.8	0.010
4/19/05	109	3	0.011	3759.4	0.014
Totals		93		126,861.5	

Table 5. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the York River, spring 2005.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/05	58	4	0.015	6549.5	0.024
3/6/05	65	11	0.040	17135.9	0.062
3/7/05	66	13	0.047	22497.9	0.081
3/13/05	72	13	0.048	19357.5	0.072
3/14/05	73	14	0.051	20663.0	0.075
3/21/05	80	3	0.011	4302.8	0.016
3/27/05	86	9	0.033	14768.9	0.054
3/28/05	87	15	0.052	23556.6	0.082
4/3/05	93	16	0.057	24339.2	0.087
4/4/05	94	16	0.058	24862.7	0.091
4/10/05	100	17	0.065	25678.3	0.099
4/11/05	101	16	0.058	22744.7	0.083
4/18/05	108	12	0.044	20769.7	0.076
4/19/05	109	23	0.083	37483.7	0.135
4/24/05	114	5	0.018	7010.5	0.026
4/25/05	115	8	0.028	14266.7	0.050
5/1/05	121	3	0.011	4114.6	0.015
5/2/05	122	14	0.051	22218.4	0.081
5/9/05	129	8	0.029	12841.8	0.047
5/10/05	130	2	0.007	2784.4	0.010
Totals		222		347,946.8	

Table 6. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the York River, spring 2005.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/05	58	3	0.011	4381.4	0.016
3/6/05	65	6	0.022	7562.0	0.027
3/7/05	66	2	0.007	2078.2	0.007
3/13/05	72	4	0.015	5000.0	0.019
3/14/05	73	3	0.011	4506.1	0.016
3/20/05	79	6	0.022	8356.4	0.030
3/21/05	80	1	0.004	1236.1	0.005
3/27/05	86	7	0.026	9614.8	0.035
3/28/05	87	1	0.003	1218.4	0.004
4/3/05	93	4	0.014	5128.7	0.018
4/4/05	94	3	0.011	3551.2	0.013
4/10/05	100	2	0.008	2662.9	0.010
4/11/05	101	2	0.007	2439.0	0.009
4/18/05	108	3	0.011	4340.4	0.016
4/19/05	109	4	0.014	5661.7	0.020
4/24/05	114	2	0.007	1095.8	0.004
4/25/05	115	1	0.003	1532.9	0.005
5/2/05	122	1	0.004	1320.8	0.005
5/9/05	129	1	0.004	940.9	0.003
Totals		56		72,627.7	

Table 7. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2005.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/6/05	65	5	0.019	6554.3	0.024
3/7/05	66	1	0.004	2161.6	0.009
3/13/05	72	8	0.029	14365.9	0.052
3/14/05	73	4	0.014	6411.0	0.023
3/20/05	79	28	0.099	46448.5	0.164
3/21/05	80	28	0.099	46469.7	0.164
3/27/05	86	12	0.043	20749.9	0.074
3/28/05	87	16	0.064	27127.8	0.108
4/3/05	93	6	0.021	11204.0	0.040
4/4/05	94	5	0.020	7480.9	0.030
4/10/05	100	10	0.035	16959.0	0.059
4/11/05	101	11	0.040	18459.9	0.068
4/18/05	108	10	0.036	16075.4	0.057
4/19/05	109	8	0.029	14562.6	0.052
4/24/05	114	10	0.035	15541.0	0.055
4/25/05	115	10	0.036	14788.5	0.054
5/3/05	123	1	0.004	1145.9	0.004
5/4/05	124	2	0.007	3053.7	0.011
5/8/05	128	2	0.007	2935.1	0.010
5/9/05	129	4	0.015	6336.5	0.023
Totals		181		298,831.2	

Table 8. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2005.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/05	58	1	0.004	1039.8	0.004
3/6/05	65	2	0.007	2359.6	0.009
3/13/05	72	6	0.022	8475.1	0.030
3/14/05	73	3	0.011	3988.0	0.014
3/20/05	79	17	0.060	23959.1	0.085
3/21/05	80	20	0.071	27065.9	0.096
3/27/05	86	4	0.014	5293.3	0.019
3/28/05	87	12	0.048	17022.7	0.068
4/3/05	93	2	0.007	2506.4	0.009
4/10/05	100	3	0.010	3771.7	0.013
4/11/05	101	1	0.004	1225.6	0.005
4/18/05	108	3	0.011	3999.7	0.014
4/19/05	109	3	0.011	4276.0	0.015
4/25/05	115	1	0.004	1059.9	0.004
Totals		78		106,042.8	

Table 9. Mean total length and mean weight of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2005. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Mean total length (mm)	Standard deviation	Mean weight (g)	Standard deviation
James River	2002	2	481.5	24.7	1147.5	29.7
	2001	20	486.0	25.7	1343.7	161.7
	2000	126	501.0	28.9	1510.5	274.4
	1999	107	517.0	28.4	1640.2	288.8
	1998	31	535.7	27.9	1894.1	277.1
	1997	14	551.5	25.5	2116.1	277.9
	1996	2	556.5	6.4	2239.0	78.1
	NA	27	510.5	29.9	1562.0	325.5
York River	2002	1	459.0		1050.0	
	2001	21	472.5	18.6	1281.3	167.7
	2000	76	488.0	20.7	1379.9	192.1
	1999	56	510.2	26.2	1600.3	264.5
	1998	27	528.3	22.6	1751.7	188.9
	1997	21	547.8	14.9	1926.0	239.1
	1996	6	580.8	38.8	2243.2	592.3
	1995	2	597.5	6.4	2344.6	262.2
	NA	12	521.1	39.2	1634.2	339.5
Rappahannock River	2002	1	457.0		1220.4	
	2001	9	476.3	20.0	1398.5	179.0
	2000	60	491.8	26.4	1470.8	245.2
	1999	62	511.1	24.7	1675.3	237.1
	1998	23	527.7	21.4	1836.5	251.7
	1997	11	556.5	21.0	2148.6	285.9
	1996	2	590.0	2.8	2518.9	27.6
	1995	1	586.0		2267.5	
	NA	12	509.3	31.3	1644.3	317.4

Table 10. Mean total length and mean weight of male American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2005. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Mean total length (mm)	Standard deviation	Mean weight (g)	Standard deviation
James River	2002	3	494.7	12.7	1274.2	82.6
	2001	6	470.8	32.5	1174.7	200.2
	2000	21	477.7	29.3	1255.6	186.0
	1999	26	493.2	23.3	1392.1	183.5
	1998	7	503.0	25.2	1406.0	252.4
	1997	8	506.3	17.4	1549.7	178.9
	1996	1	503.0		1686.7	
	1995	1	556.0		2019.9	
	1994	1	514.0		1659.4	
	NA	19	498.1	29.9	1359.0	212.1
York River	2002	1	368.0		479.3	
	2001	2	420.0	12.7	753.8	194.2
	2000	6	454.2	13.5	1138.0	148.4
	1999	15	485.1	28.9	1404.1	277.8
	1998	12	492.6	23.2	1326.6	162.2
	1997	7	499.9	30.9	1324.7	203.6
	1996	4	502.0	22.6	1441.8	149.3
	1995	1	528.0		1320.8	
	NA	8	483.3	23.4	1309.0	130.6
Rappahannock River	2001	1	426.0		986.9	
	2000	14	453.1	13.9	1140.8	99.0
	1999	27	475.6	21.7	1345.0	187.6
	1998	24	495.8	20.7	1459.7	209.9
	1997	3	521.0	19.1	1605.8	244.7
	1995	2	525.5	10.6	1698.8	118.2
	NA	7	487.6	28.1	1360.4	288.1

Table 11. Number, total weight, and seasonal catch rates by year class of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2005. 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)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
James River	2002	2	2.30	20.5	0.0004	0.0004
	2001	20	26.87	20.5	0.0036	0.0048
	2000	126	190.32	20.5	0.0224	0.0339
	1999	107	175.50	20.5	0.0190	0.0312
	1998	31	58.72	20.5	0.0055	0.0104
	1997	14	29.62	20.5	0.0025	0.0053
	1996	2	4.48	20.5	0.0004	0.0008
	NA	27	42.17	20.5	0.0048	0.0075
Rappahannock River	2002	1	1.22	20.7	0.0002	0.0002
	2001	9	12.59	20.7	0.0016	0.0022
	2000	60	88.25	20.7	0.0105	0.0154
	1999	62	103.87	20.7	0.0108	0.0181
	1998	23	42.24	20.7	0.0040	0.0074
	1997	11	23.63	20.7	0.0019	0.0041
	1996	2	5.04	20.7	0.0003	0.0009
	1995	1	2.27	20.7	0.0002	0.0004
	NA	12	19.73	20.7	0.0021	0.0034
York River	2002	1	1.05	21.1	0.0002	0.0002
	2001	21	26.91	21.1	0.0036	0.0047
	2000	76	104.87	21.1	0.0132	0.0182
	1999	56	89.62	21.1	0.0097	0.0155
	1998	27	47.30	21.1	0.0047	0.0082
	1997	21	40.45	21.1	0.0036	0.0070
	1996	6	13.46	21.1	0.0010	0.0023
	1995	2	4.69	21.1	0.0003	0.0008
	NA	12	19.61	21.1	0.0021	0.0034

Table 12. Number, total weight, and seasonal catch rates by year class of male American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2005. 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)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
James River	2002	3	3.82	20.5	0.0005	0.0007
	2001	6	7.05	20.5	0.0011	0.0013
	2000	21	26.37	20.5	0.0037	0.0047
	1999	26	36.20	20.5	0.0046	0.0064
	1998	7	9.84	20.5	0.0012	0.0018
	1997	8	12.40	20.5	0.0014	0.0022
	1996	1	1.69	20.5	0.0002	0.0003
	1995	1	2.02	20.5	0.0002	0.0004
	1994	1	1.66	20.5	0.0002	0.0003
	NA	19	25.82	20.5	0.0034	0.0046
Rappahannock River	2001	1	0.99	20.7	0.0002	0.0002
	2000	14	15.97	20.7	0.0024	0.0028
	1999	27	36.32	20.7	0.0047	0.0063
	1998	24	35.03	20.7	0.0042	0.0061
	1997	3	4.82	20.7	0.0005	0.0008
	1995	2	3.40	20.7	0.0003	0.0006
	NA	7	9.52	20.7	0.0012	0.0017
York River	2002	1	0.48	21.1	0.0002	0.0001
	2001	2	1.51	21.1	0.0003	0.0003
	2000	6	6.83	21.1	0.0010	0.0012
	1999	15	21.06	21.1	0.0026	0.0036
	1998	12	15.92	21.1	0.0021	0.0028
	1997	7	9.27	21.1	0.0012	0.0016
	1996	4	5.77	21.1	0.0007	0.0010
	1995	1	1.32	21.1	0.0002	0.0002
	NA	8	10.47	21.1	0.0014	0.0018

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2005 in the York and James rivers. Table entries are total numbers of fish that were aged (York River, n = 258; James River, n = 376). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the James River, the number in parentheses is the number of fish out of the total that had hatchery marks on their otoliths (n = 40). 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
2002	3	**2**	-	-	-	-
2001	4	3	**20**	-	-	-
2000	5	4	26	**52**	-	-
1999	6	7	20	22	**22**	-
1998	7	1	14	14	9	**1**
1997	8	0	11	14	2	1
1996	9	1	2	5	0	2
1995	10	0	1	2	0	0

James River Year Class	Age at Capture	3	4	5	6	7
2002	3	**5**	-	-	-	-
2001	4	4	**22(3)**	-	-	-
2000	5	12	32(3)	**103(6)**	-	-
1999	6	4(1)	25(1)	61(3)	**43(2)**	-
1998	7	1	9(3)	17(5)	7(4)	**4(1)**
1997	8	1	9	6(2)	5(2)	**1**
1996	9	0	1	2(1)	0	0
1995	10	1	0	0	0	0
1994	11	1	0	0	0	0

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2005 in the Rappahannock River. Table entries are numbers of fish (n = 240). 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	3	4	5	6	7
2002	3	**1**	-	-	-	-
2001	4	2	**8**	-	-	-
2000	5	5	27	**42**	-	-
1999	6	5	29	36	**19**	-
1998	7	1	17	19	8	**2**
1997	8	0	3	10	1	0
1996	9	0	1	1	0	0
1995	10	0	0	1	2	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 2005. A total of 168 American shad were randomly selected and their otoliths scanned for hatchery marks. Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged.

Specimen Number	Marked	River Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
11553	9	James 97-01	4	0	396	448	1045.3	female
11412	9	James 97-01	4	0	424	477	1269.5	female
11447	9	James 97-01	4	0	428	490	1441.7	female
10673	9	James 97-01	5	0	404	452	1180.2	female
11520	9	James 97-01	5	0	406	445	1202.7	female
11449	9	James 97-01	5	0	423	478	1203.2	female
10788	3,6?	Pam?	5	0	432	485	1462.4	female
11461	9	James 97-01	5	0	454	515	1633.2	female
10703	9	James 97-01	5	0	478	535	2011.5	female
10856	9	James 97-01	5	1	432	488	1402.1	female
10749	3,6,9,12,15	James 2001	5	1	433	477	1241.1	male
11628	9	James 97-01	5	1	461	520	1499.4	female
11549	9	James 97-01	6	0	430	490	1327.3	female
11148	9	James 97-01	6	0	464	518	1754.9	female
11015	9	James 97-01	6	1	424	483	1202.3	male
11247	9	James 97-01	6	1	448	510	1520.6	female
11170	9	James 97-01	6	1	469	518	1621	female
10790	9	James 97-01	6	2	440	492	1590	male
10795	9	James 97-01	6	3	450	500	1531.5	male
11187	9	James 97-01	7	0	484	541	1999.4	female
11119	9	James 97-01	7	1	438	492	1559.2	female
10745	9	James 97-01	7	1	456	506	1674.7	female
10697	9	James 97-01	7	1	468	518	1709.7	female
10786	9	James 97-01	7	1	473	536	1821.8	female
10971	9	James 97-01	7	2	440	491	1196.8	male
11267	9	James 97-01	7	2	476	537	1742.1	male
10747	9	James 97-01	7	2	479	537	1661.8	female
11185	9	James 97-01	7	2	488	552	2238.6	female
11559	9	James 97-01	7	2	514	578	2235.1	female
10829	6,15?	Mat?	7	3	424	480	1289.1	male
11261	9	James 97-01	7	3	435	498	1272.4	male
11275	15?	Pam/York?	7	3	446	510	1840.9	female
11638	9	James 97-01	8	2	482	550	1224.3	female

Specimen Number	Marked	River Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
11269	9	James 97-01	8	2	508	572	2056.3	female
11457	9	James 97-01	8	3	446	511	1465	male
11255	9	James 97-01	8	3	507	574	2103.3	female
11709	9	James 97-01	9	4	490	547	1304.4	female
10973	9	James 97-01	NA	NA	408	460	1054.1	male
10969	3,6,9,12,15	James 2001	NA	NA	446	501	1318.8	male
11063	9	James 97-01	NA	NA	462	522	1693	female

Table 16. Total numbers in nine year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2005. 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	2005	Total	% Total
1992	0.05		1							1	0.2
1993	0.5	7	2	1						10	1.5
1994	1.6	7	3	9			1			20	3.1
1995	5.3			59	9	8	4	3		83	12.8
1996	5.8			53	62	43	10	4	1	173	26.8
1997	5.9			2	27	78	57	5	4	173	26.8
1998	10					13	52	17	13	95	14.7
1999	7.3						14	29	7	50	7.7
2000	8.9						1	5	9	15	2.3
2001	9.3								3	3	0.5
2002	8.4										
2003	8.7										
2004	6.6										
2005	6										
NA	--					12	3	5	3	23	3.6
Total	84.35	14	6	124	98	154	142	68	40	646	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 2005. A total of 83 American shad were randomly selected and their otoliths scanned for hatchery marks. Sample selection was weighted by sample size across all dates. Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged.

Specimen	Marked	River Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
10800	6,15	Mat 00-	5	1	423	477	1333.9	F
11336	6,15	Mat 00-	5	1	434	488	1419.2	F
10769	6,15	Mat 00-	5	2	409	458	1313.7	M
10860	15	Yrk 99 or Pam 01-02	6	0	453	512	1656.1	F
11102	3,6,12,15	Yrk 99-01 or Pam 97-98	7	2	471	532	1710.1	F
11003	15	Yrk 99 or Pam 01-02	7	2	502	569	1916.7	F
10841	9?	James 97-01?	8	3	424	478	1232.4	M
10802	3,6?	Pam 02-	NA	NA	428	483	1272.8	M

Table 18. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2005) 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
2005	0	0	20	0.18	0.592	33

Table 19. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2005) 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
2005	1.66	1.351	50	0.02	0.110	40	0.68	1.091	95

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, 2005.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/27/05	57	12	69	28	97
3/6/05	161	51	212	23	235
3/7/05	147	32	179	15	194
3/13/05	115	34	149	80	229
3/14/05	64	33	97	130	227
3/21/05	86	41	127	557	684
3/22/05	59	72	131	516	647
3/27/05	17	26	43	121	164
3/28/05	9	14	23	34	57
4/3/05	34	47	81	123	204
4/4/05	23	58	81	459	540
4/10/05	11	27	38	371	409
4/11/05	12	26	38	167	205
4/18/05	11	11	22	388	410
4/19/05	7	11	18	187	205
4/24/05	8	10	18	137	155
4/25/05	4	15	19	126	145
5/1/05	7	53	60	121	181
5/2/05	29	32	61	201	262
5/9/05	6	38	44	185	229
5/10/05	2	6	8	35	43
Totals	869	649	1518	4004	5522

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, 2005.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/27/05	63	3	66	882	948
3/6/05	65	16	81	824	905
3/7/05	23	17	40	744	784
3/13/05	25	7	32	255	287
3/14/05	17	17	34	403	437
3/20/05	38	1	39	872	911
3/21/05	5	19	24	1104	1128
3/27/05	26	20	46	169	215
3/28/05	24	14	38	133	171
4/3/05	18	45	63	485	548
4/4/05	48	44	92	346	438
4/10/05	17	14	31	328	359
4/11/05	8	14	22	443	465
4/18/05	2	22	24	556	580
4/19/05	10	3	13	614	627
4/24/05	5	8	13	485	498
4/25/05	2	18	20	733	753
5/1/05	3	18	21	504	525
5/2/05	4	17	21	502	523
5/9/05	2	15	17	270	287
5/10/05	2	13	15	202	217
Totals	407	345	752	10854	11606

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, 2005.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/27/05	20	4	24	51	75
3/6/05	63	10	73	225	298
3/7/05	76	15	91	162	253
3/13/05	35	8	43	83	126
3/14/05	42	13	55	99	154
3/20/05	56	16	72	115	187
3/21/05	41	28	69	187	256
3/27/05	61	75	136	166	302
3/28/05	61	100	161	144	305
4/3/05	50	63	113	106	219
4/4/05	21	46	67	80	147
4/10/05	24	157	181	193	374
4/11/05	34	126	160	183	343
4/18/05	28	32	60	198	258
4/19/05	75	91	166	175	341
4/24/05	3	16	19	436	455
4/25/05	5	7	12	366	378
5/3/05	2	9	11	276	287
5/4/05	7	14	21	332	353
5/8/05	2	8	10	206	216
5/9/05	6	11	17	239	256
Totals	712	849	1561	4022	5583

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.

Year	Effort (10^3 m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve (SE)
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
2005	5.5	65	0.164	0.054	3.69
Average of current data					**3.90** (0.86)

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.

Year	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve (SE)
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
2005	5.5	73	0.135	0.0633	4.64
Average of current data					**8.93** (1.23)

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.

Year	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve (SE)
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
2005	5.3	72	0.357	0.099	7.16
Average of current data					**5.84** (0.81)

Table 26. Historical catch and effort data of American shad captured 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 meter of net per day and were converted to weight (kg) of female shad per meter of net per day, assuming an average female weight of 1.45kg. Catch rates were multiplied by 2.16 to adjust for the lower fishing power of multifilament nets compared to current monofilament nets.

Year	Total females	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	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**

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.**

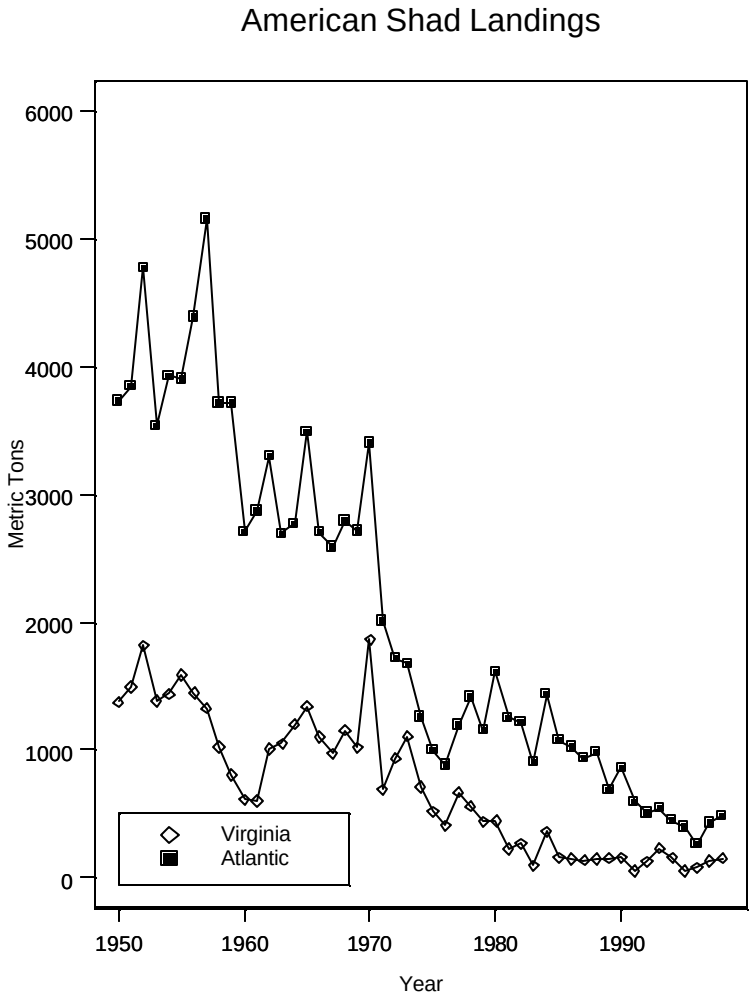

Figure 2. Number and location of staked gill nets on the James River in 1983.

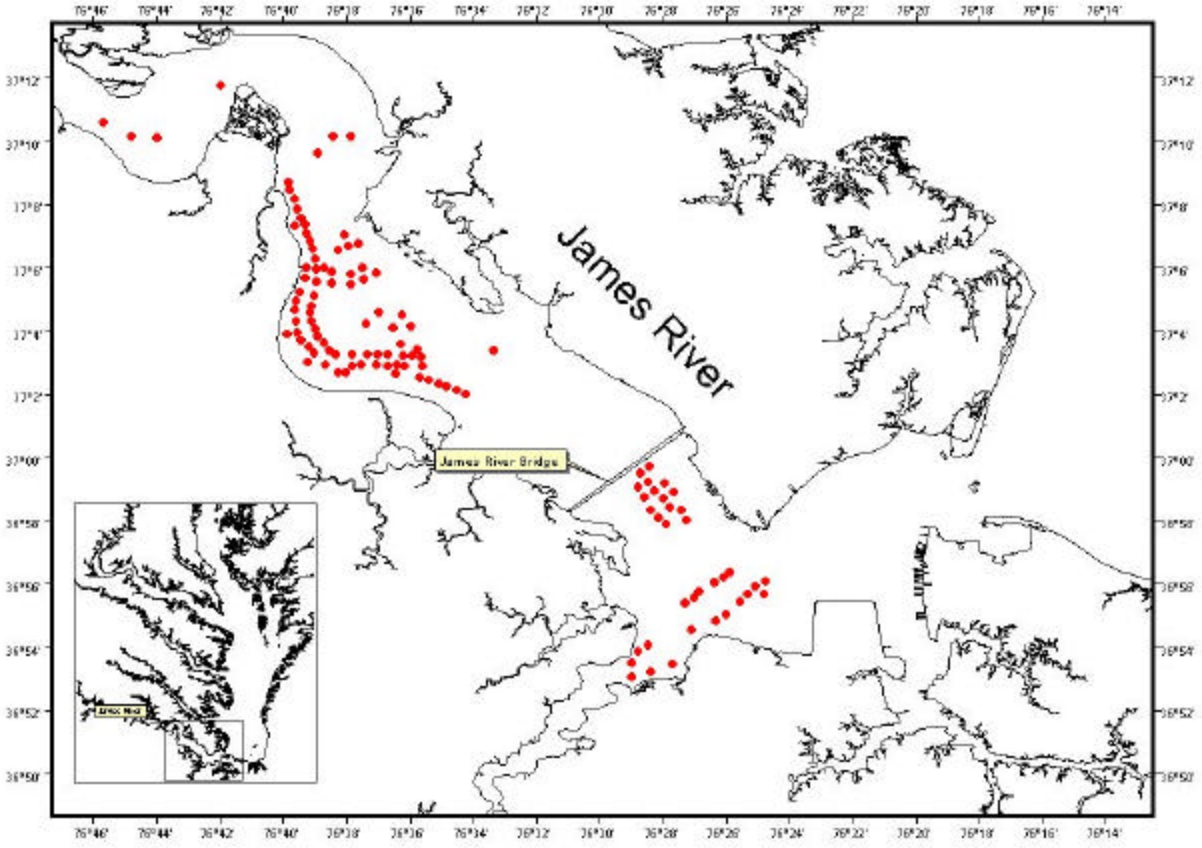

Figure 3. Number and location of staked gill nets on the York River in 1983.

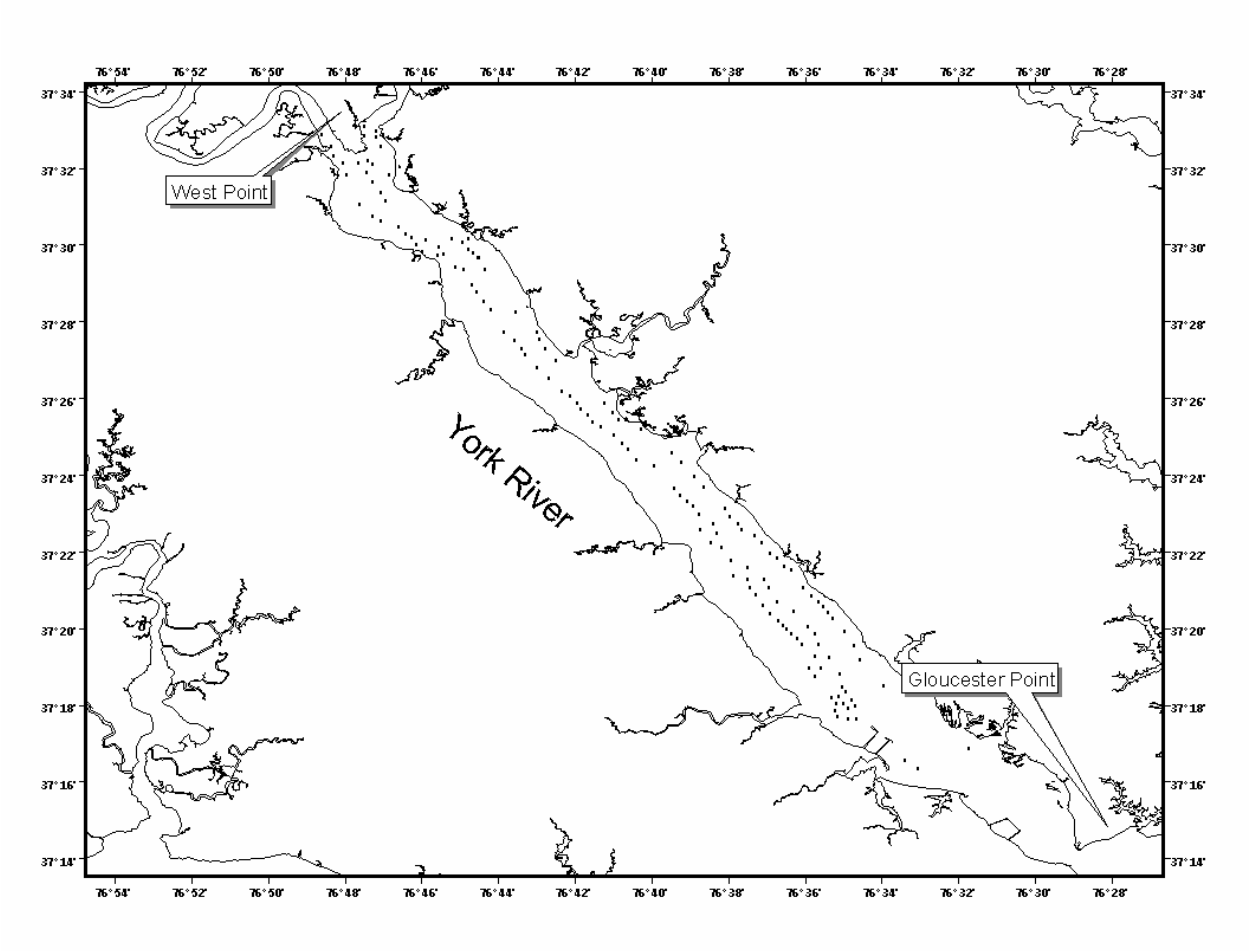

Figure 4. Number and location of staked gill nets on the Rappahannock River in 1983.

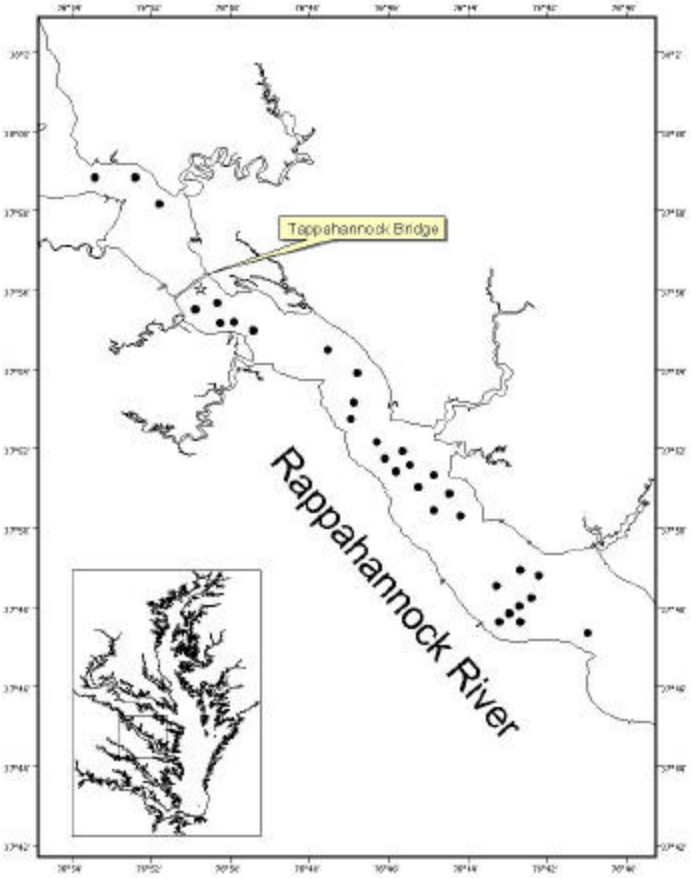

Figure 5. Location of the staked gill net fished by Mr. Marc Brown on the James River. The length of the net (273 m) is not to scale.

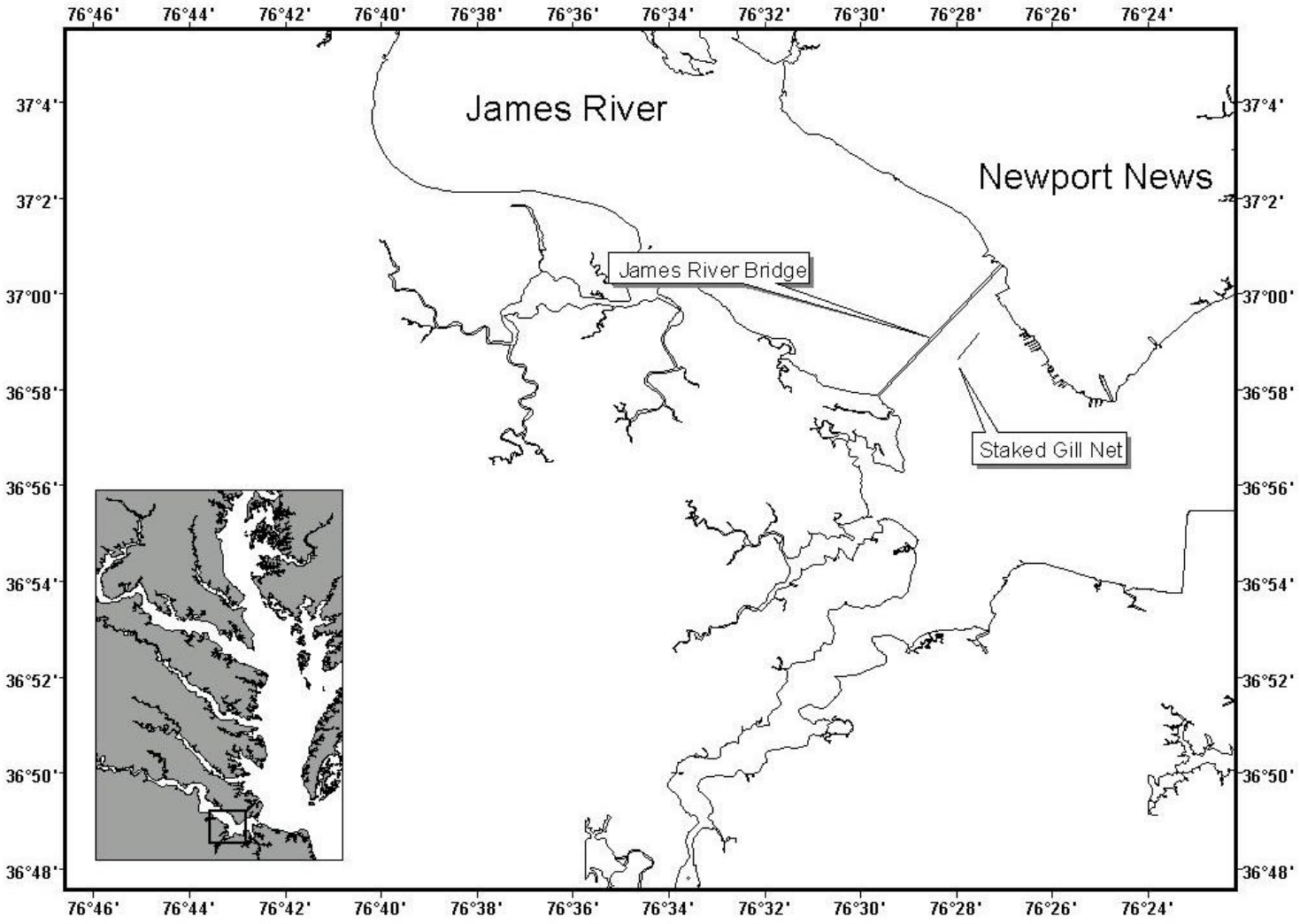

Figure 6. Location of the staked gill net fished by Mr. Raymond Kellum on the York River. The length of the net (273 m) is not to scale.

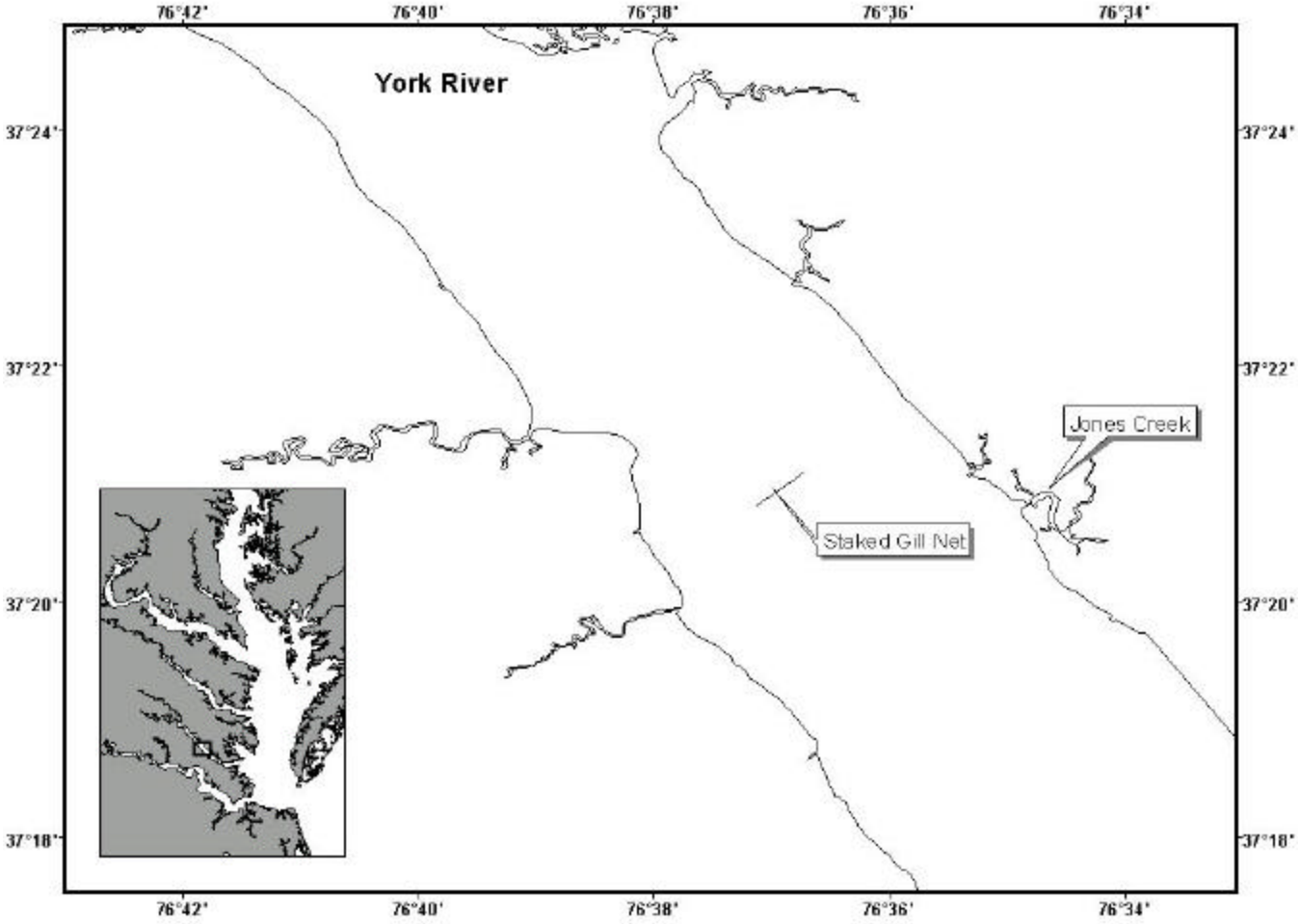

Figure 7. Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River. The length of the net (276 m) is not to scale.

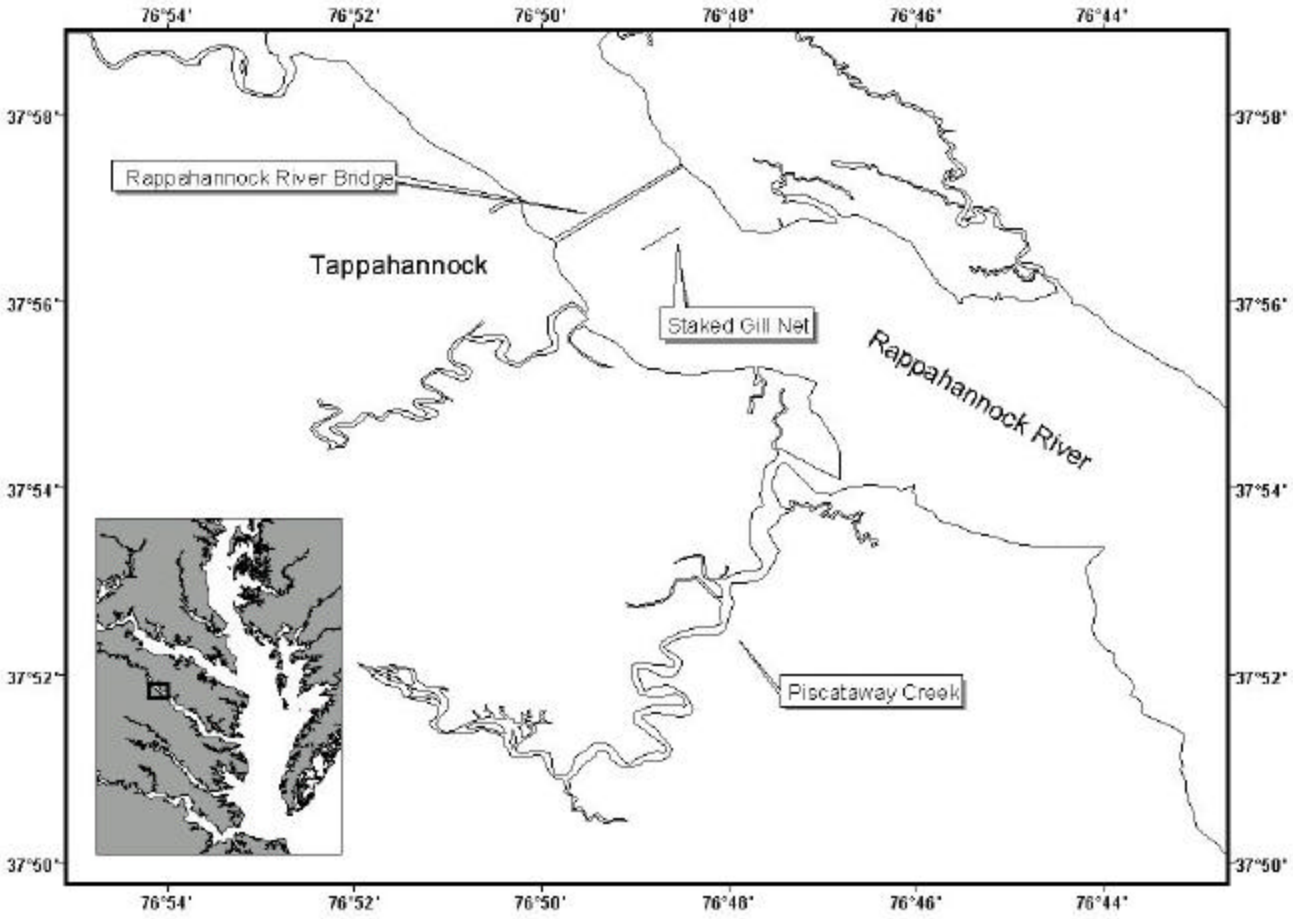

Figure 8. Catch rates and total numbers of female American shad taken by staked gill nets in the James River, spring 2005.

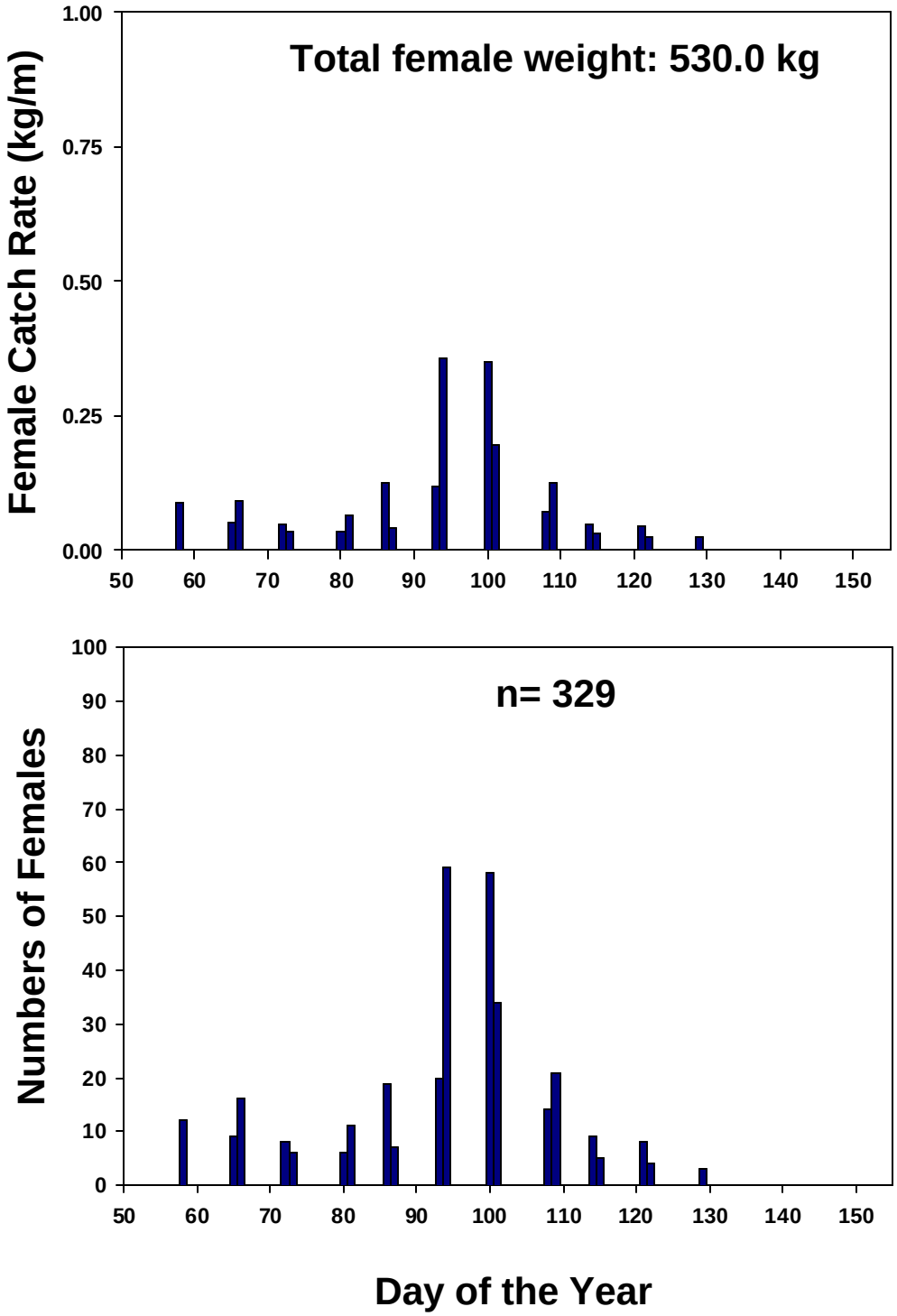

Figure 9. **Catch rates and total numbers of female American shad taken by staked gill nets in the York River, spring 2005.**

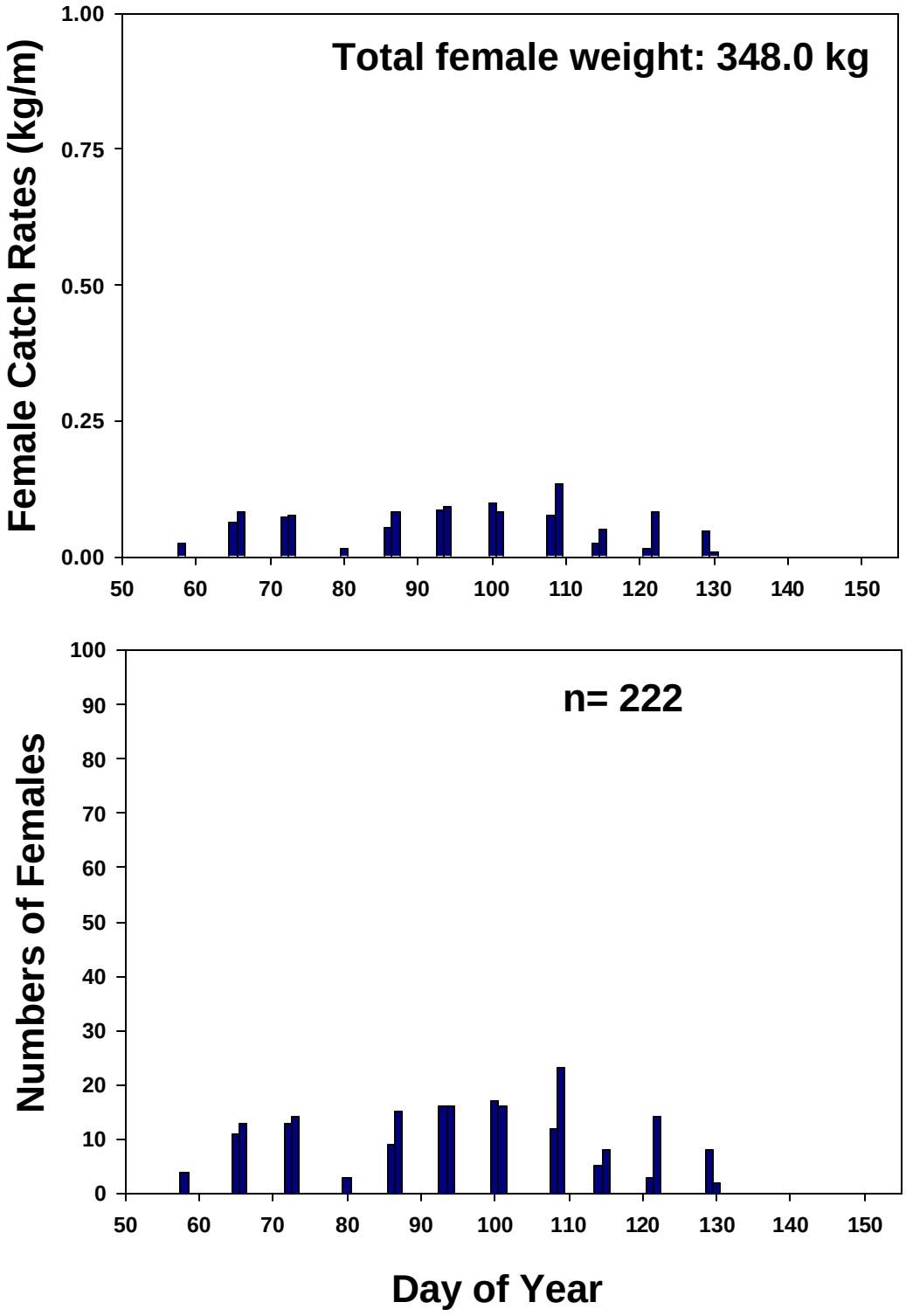

Figure 10. Catch rates and total numbers of female American shad taken by staked gill nets in the Rappahannock River, spring 2005.

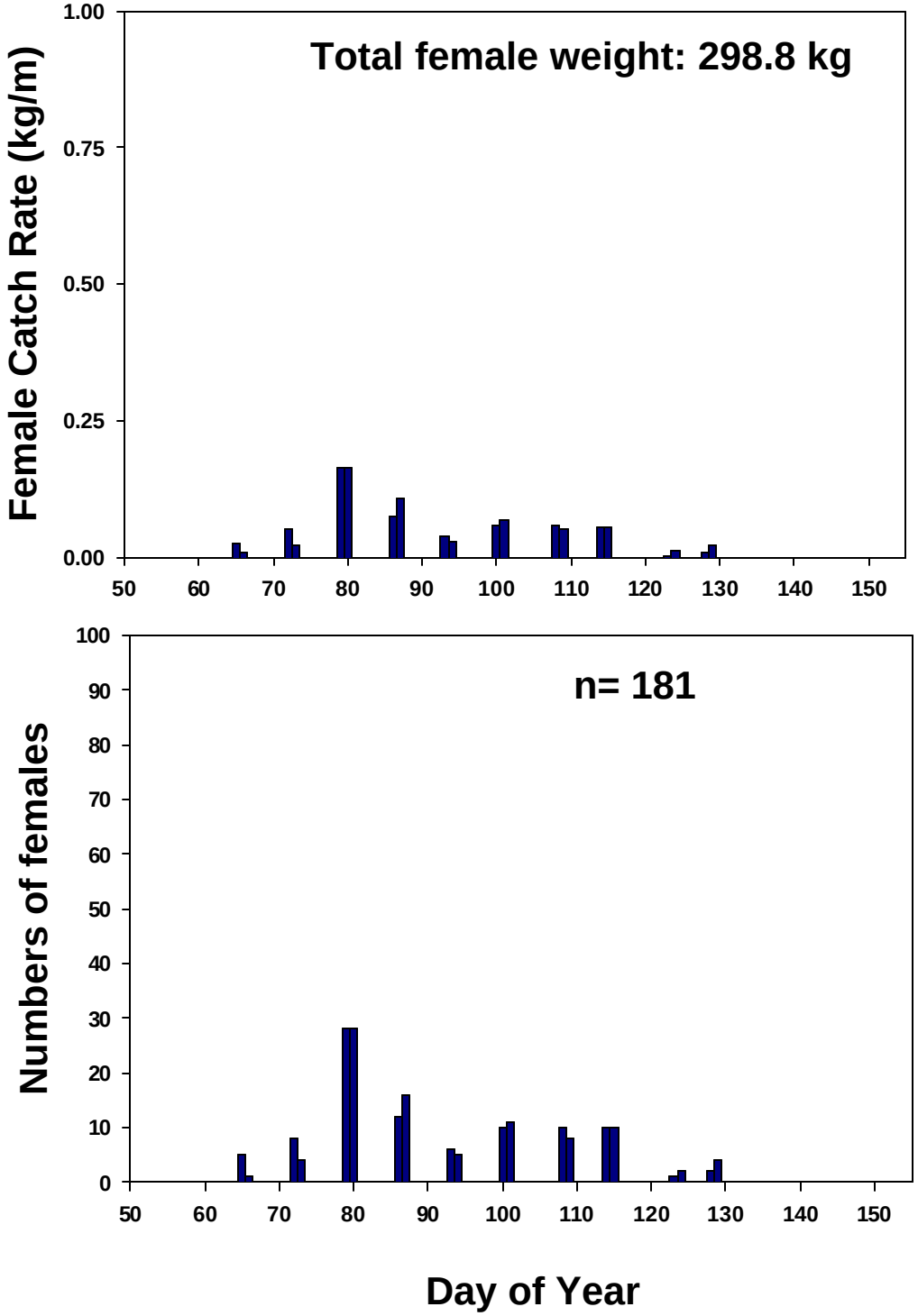

Figure 11. Catch rates and total numbers of male American shad taken by staked gill nets in the James River, spring 2005.

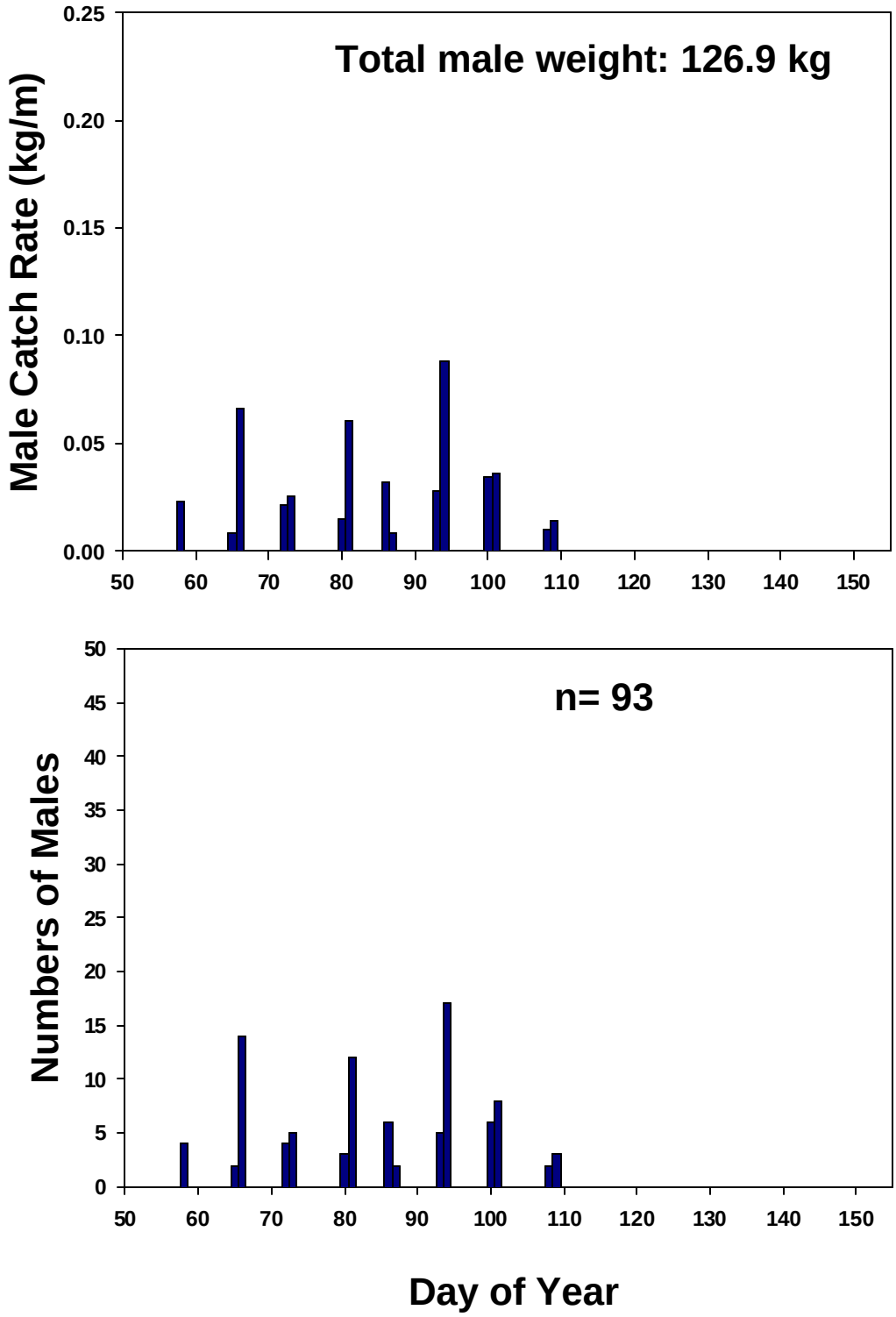

Figure 12. **Catch rates and total numbers of male American shad taken by staked gill nets in the York River, spring 2005.**

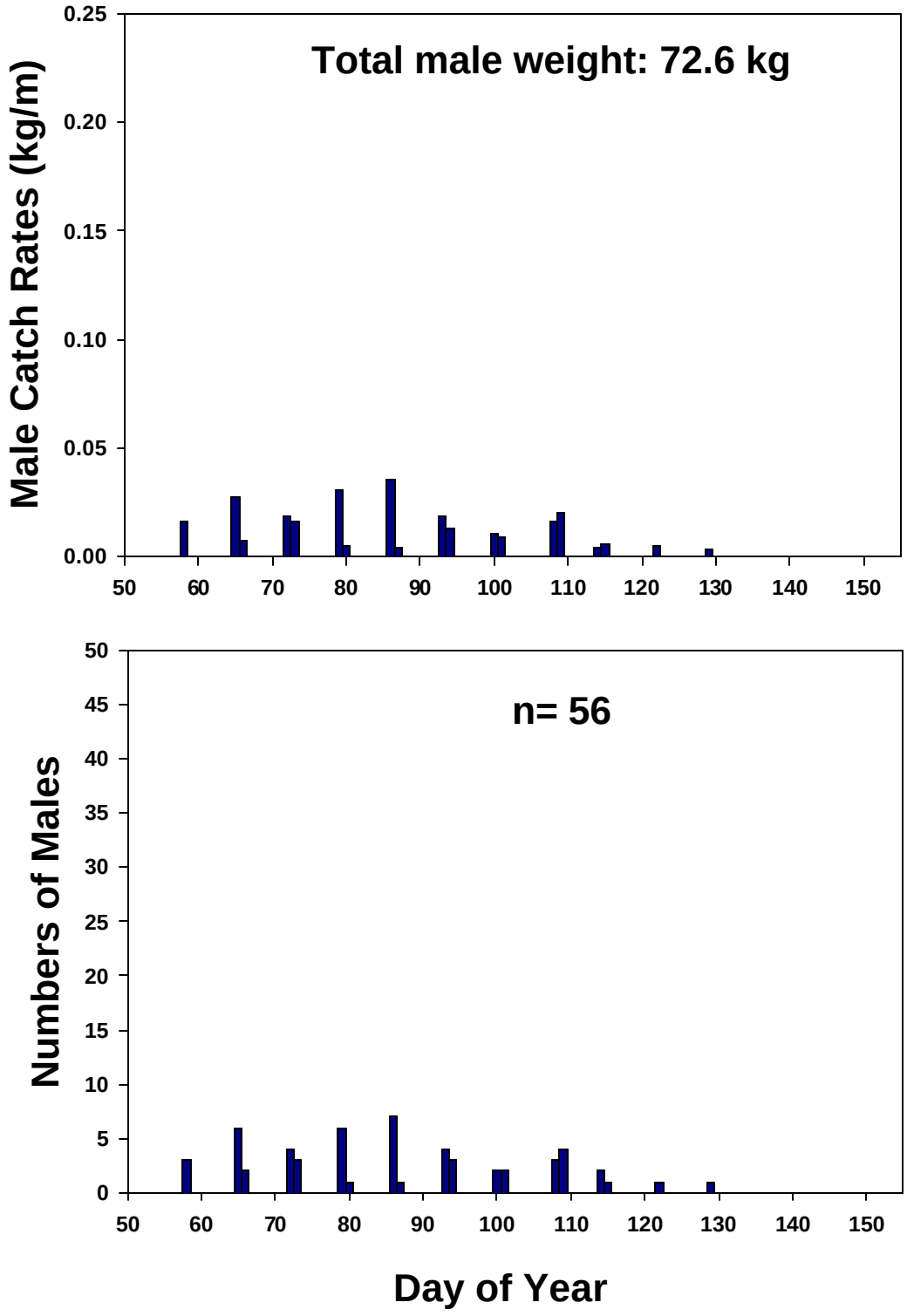

Figure 13. Catch rates and total numbers of male American shad taken by staked gill nets in the Rappahannock River, spring 2005.

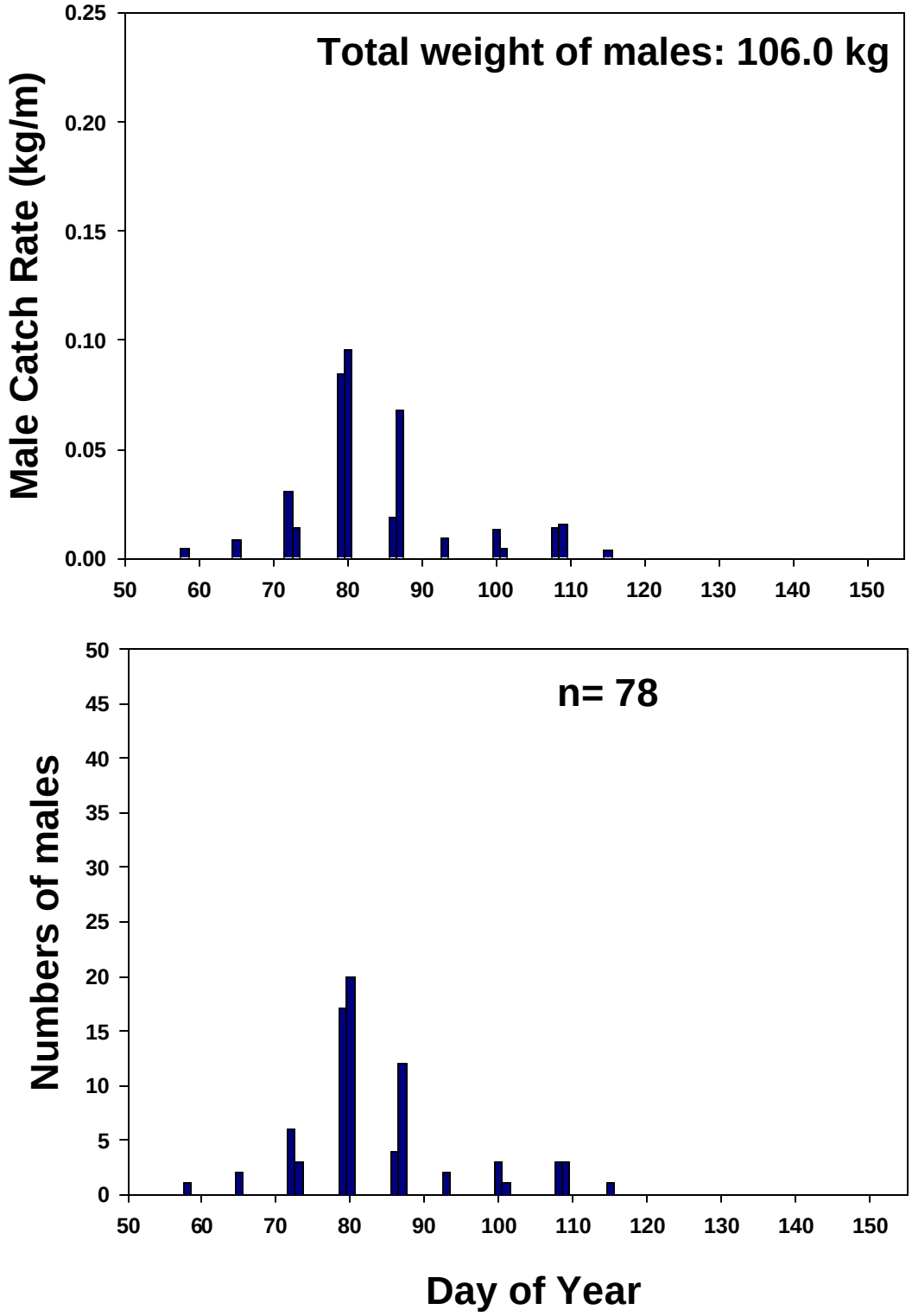

Figure 14. Total length (mm) frequency distributions for American shad captured in staked gill nets on the James and York rivers, spring 2005.

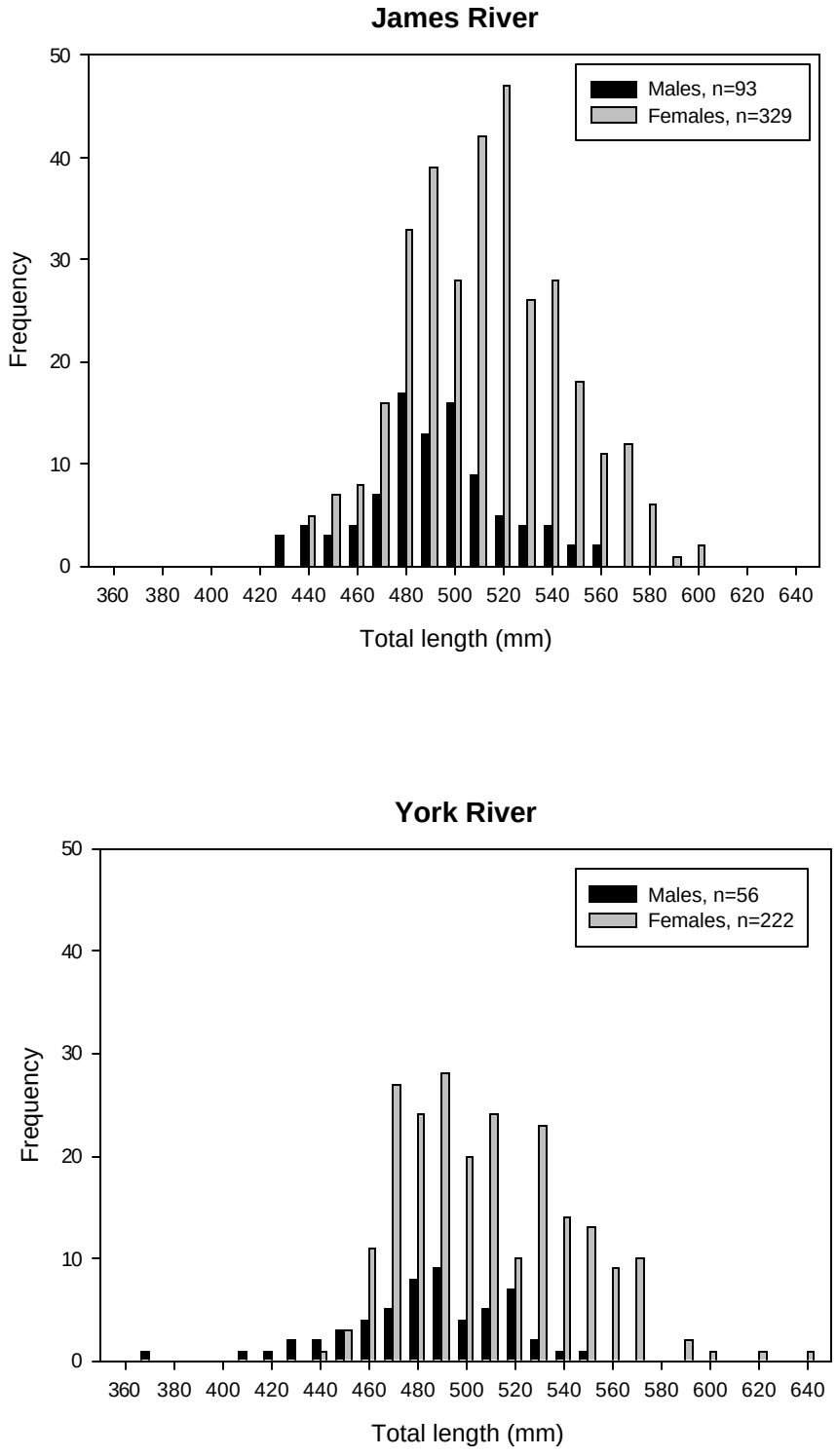

Figure 15. Total length (mm) frequency distributions for American shad captured in staked gill nets on the Rappahannock River, spring 2005.

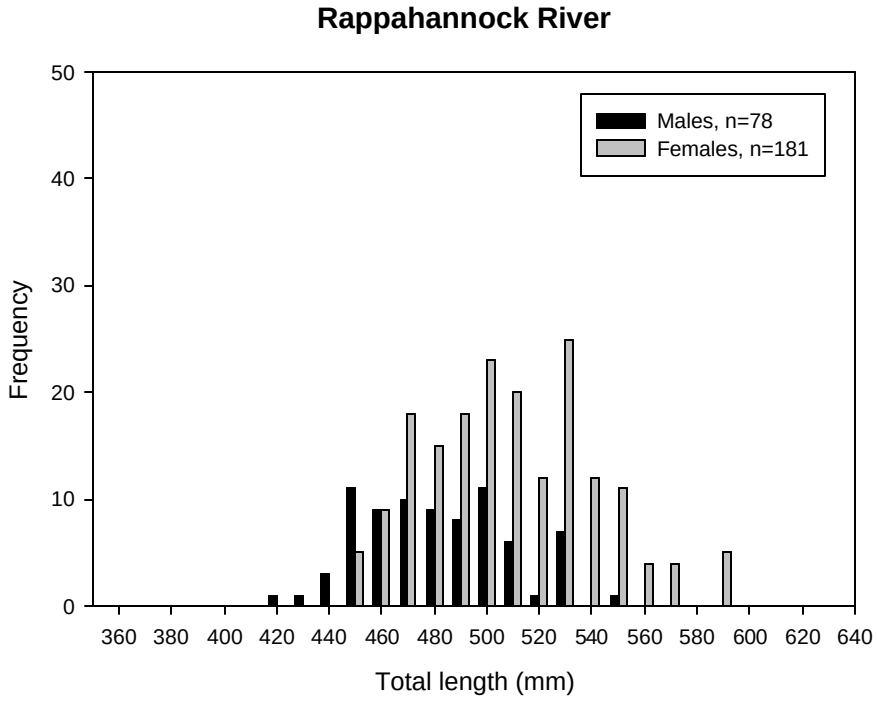

Figure 16. **The index of juvenile abundance of American shad in the York River system as estimated by daylight seine surveys, 1980-2005. The index is the geometric mean number of American shad juveniles per seine haul.**

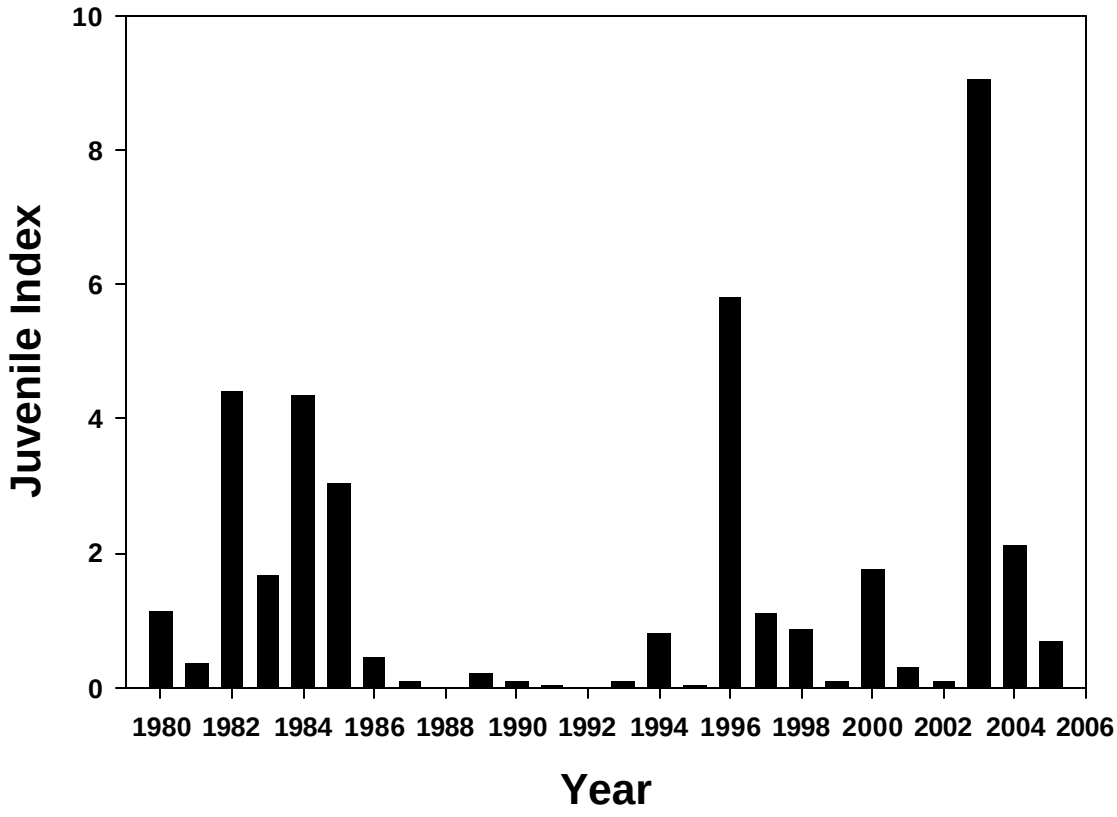

Figure 17. **The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by daylight seine surveys, 1980-2005. The index is the geometric mean number of American shad juveniles per seine haul.**

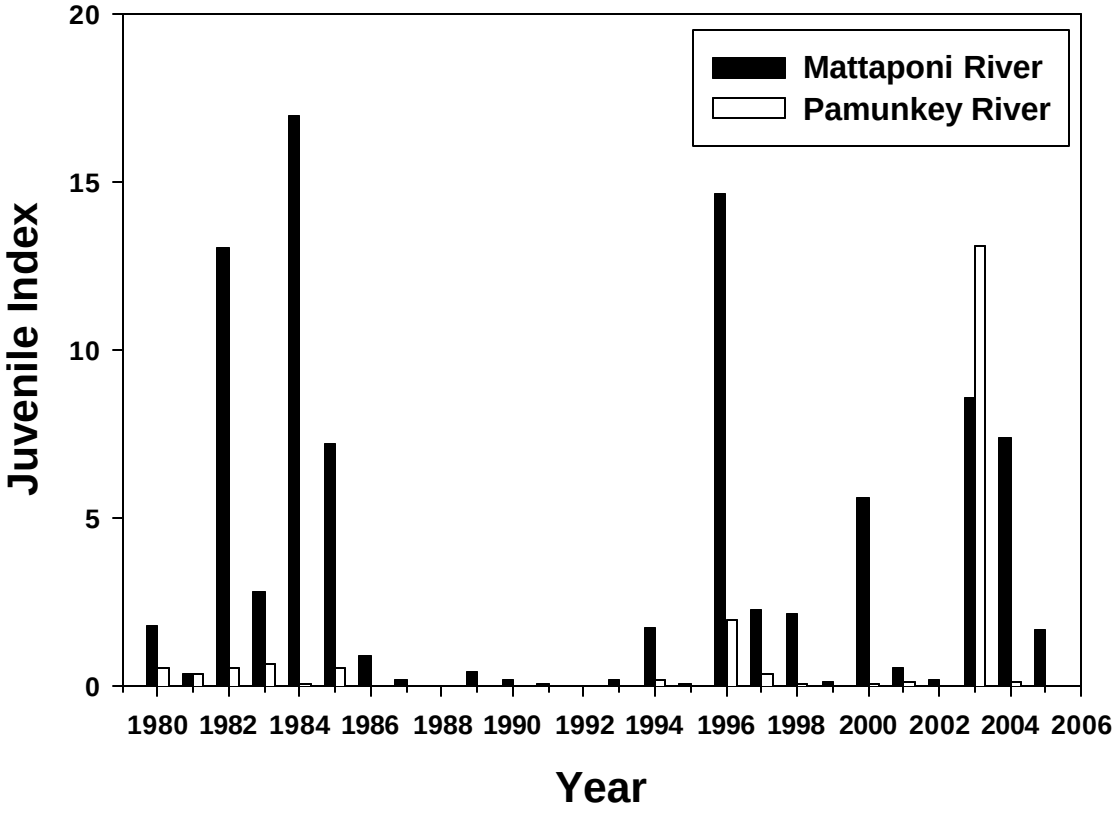

Figure 18. **The index of juvenile abundance of American shad in the Rappahannock River as estimated by daylight seine surveys, 1980-2005. The index is the geometric mean number of American shad juveniles per seine haul. The index in 1980 and 1981 was zero.**

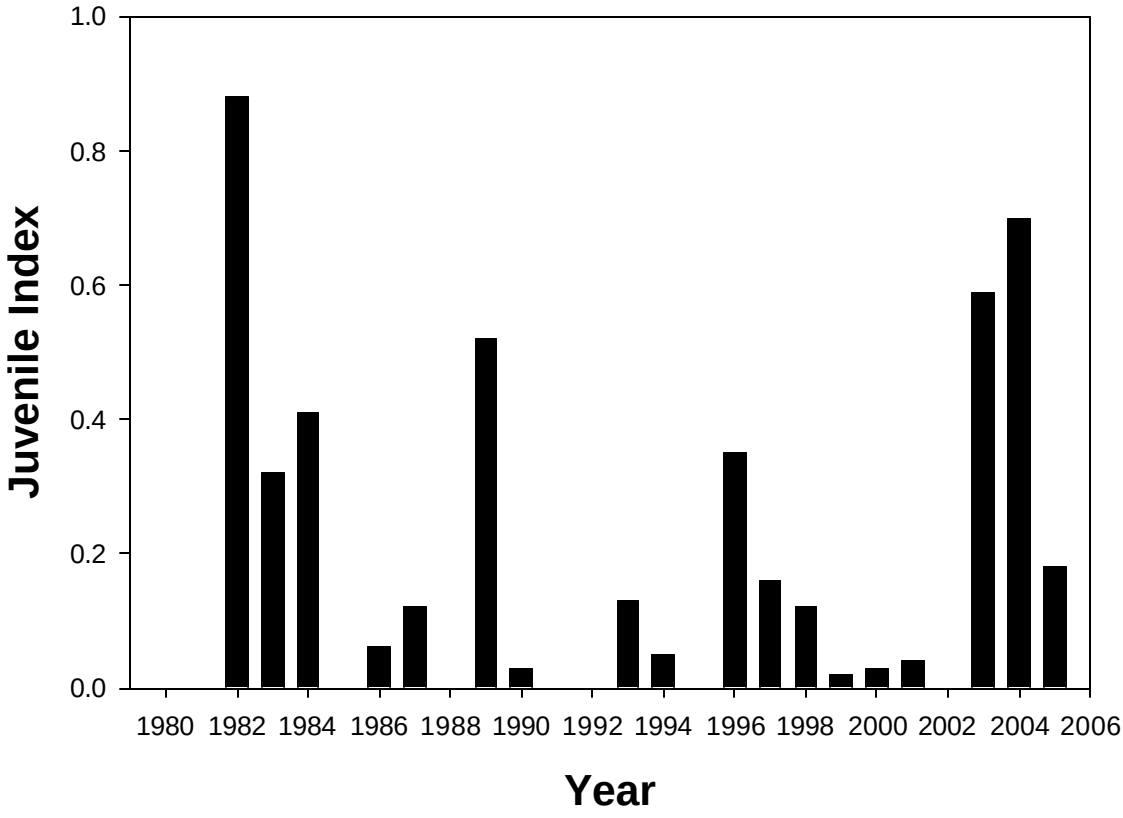

Figure 19. Mean age of females taken in staked gill nets in the James, York, and Rappahannock Rivers, 1998-2005.

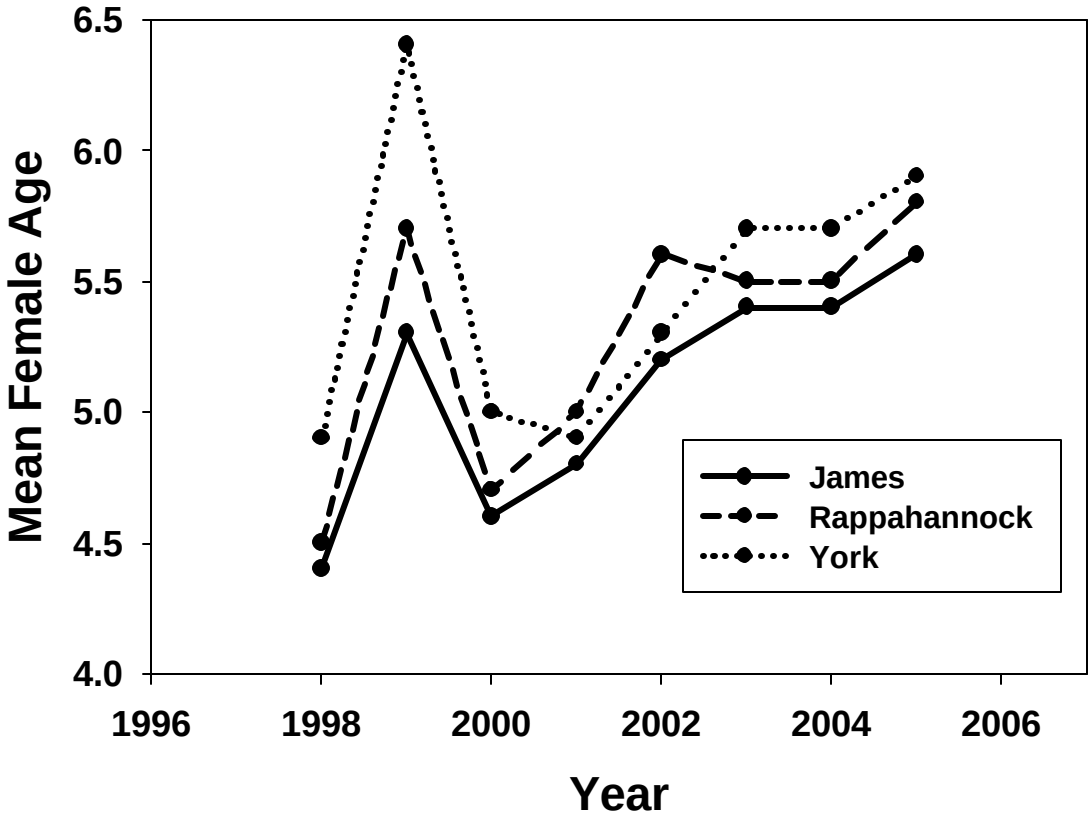

Figure 20. **Recent (1998-2005) and historic values of the catch index of female American shad on the James River.**

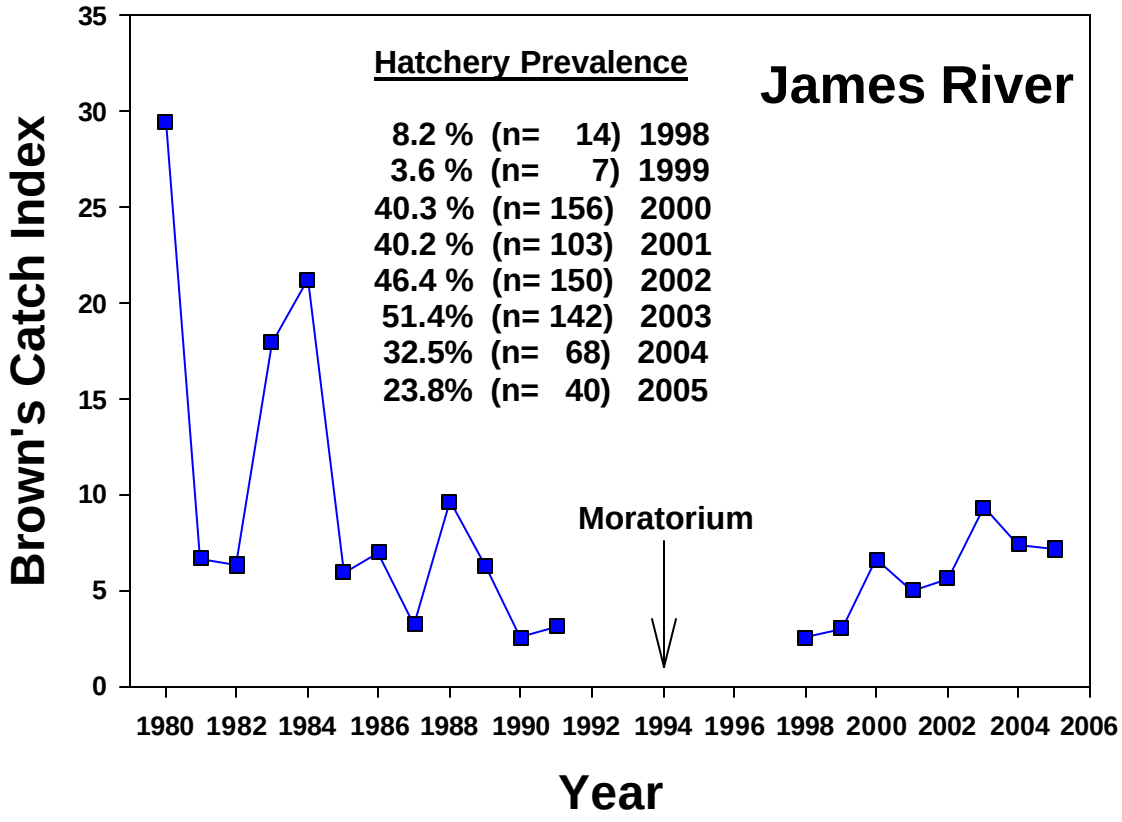

Figure 21. **Recent (1998-2005) and historic values of the catch index of female American shad on the York River.**

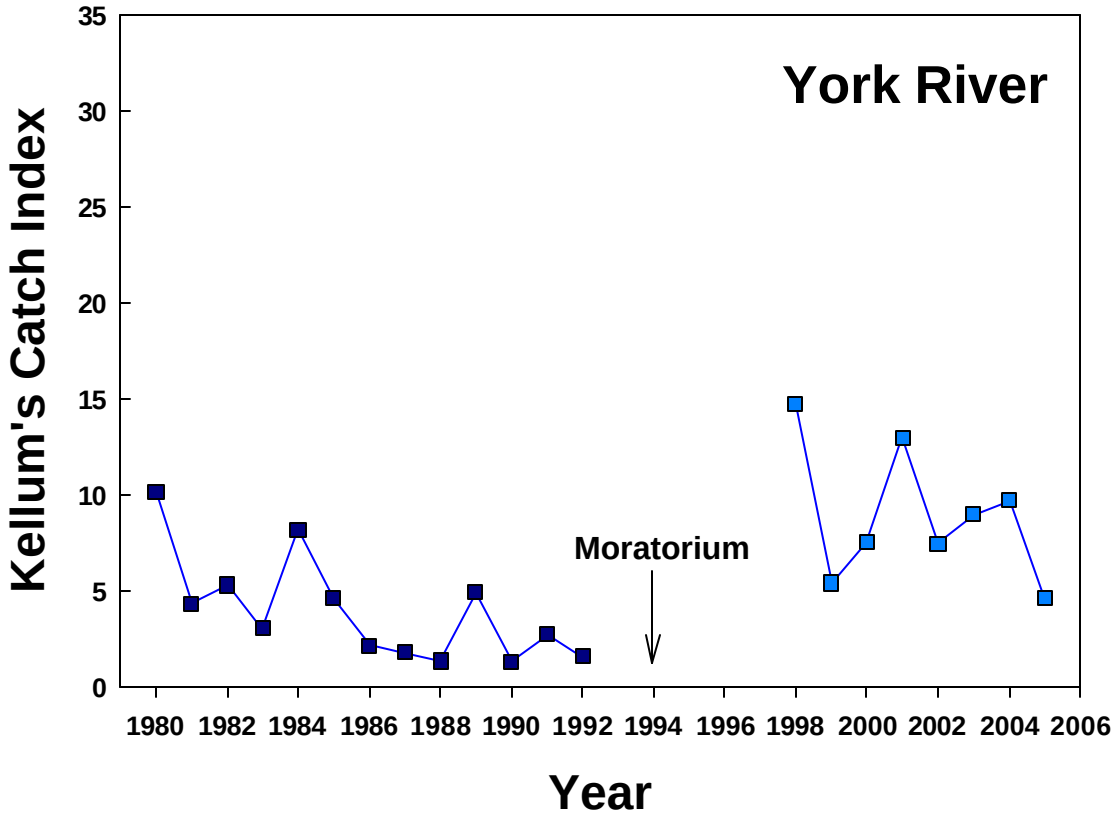

Figure 22. **Recent (1998-2005) and historic values of the catch index of female American shad on the Rappahannock River.**

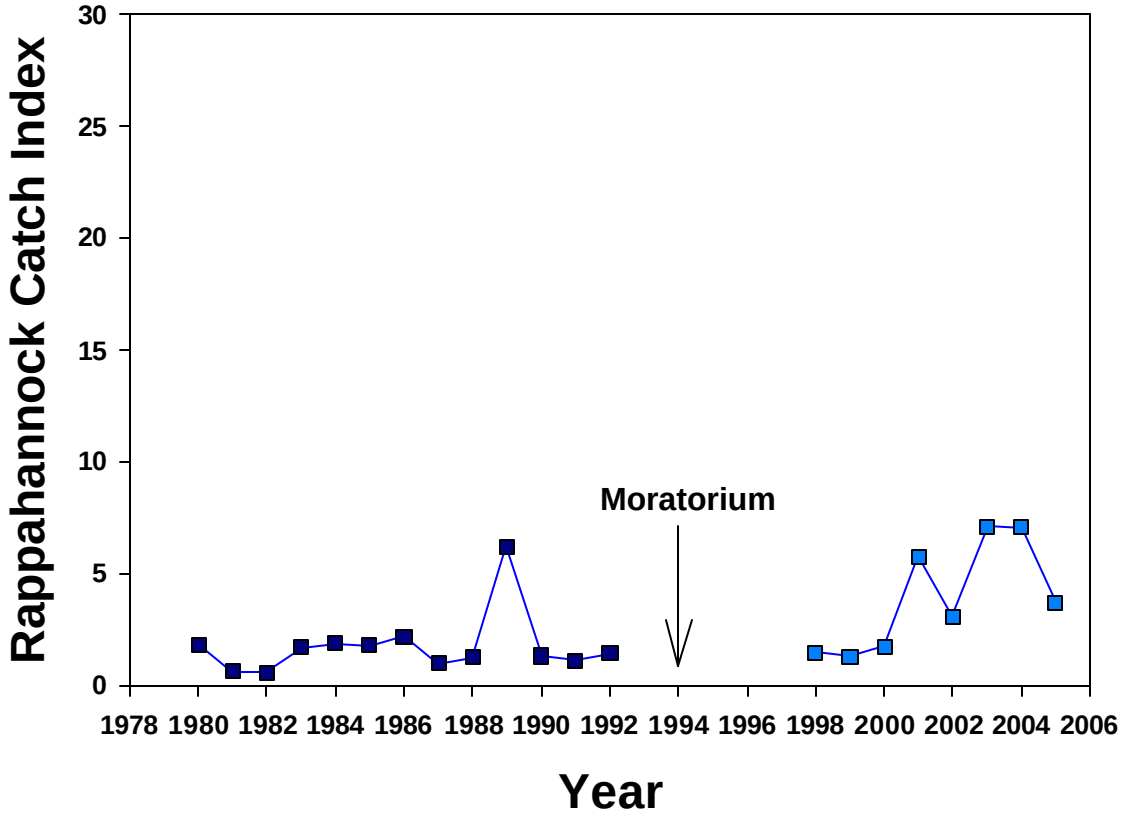

Figure 23. **Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the means of each data set (solid, 1950s; short dashes, current; long dashes, 1980s)**