



W&M ScholarWorks

---

Reports

---


4-15-2007

## Monitoring Relative Abundance of American Shad in Virginia Rivers 2006 Annual Report

John E. Olney  
*Virginia Institute of Marine Science*

Kristen Delano Walter  
*Virginia Institute of Marine Science*

Follow this and additional works at: <https://scholarworks.wm.edu/reports>

 Part of the [Aquaculture and Fisheries Commons](#), and the [Natural Resources Management and Policy Commons](#)

---

### Recommended Citation

Olney, J. E., & Walter, K. D. (2007) Monitoring Relative Abundance of American Shad in Virginia Rivers 2006 Annual Report. Virginia Institute of Marine Science, College of William and Mary. <https://doi.org/10.21220/V5MS5S>

This Report is brought to you for free and open access by W&M ScholarWorks. It has been accepted for inclusion in Reports by an authorized administrator of W&M ScholarWorks. For more information, please contact [scholarworks@wm.edu](mailto:scholarworks@wm.edu).

Monitoring Relative Abundance of American Shad in Virginia Rivers

2006 Annual Report

Funding Agencies: US Fish and Wildlife Service  
Virginia Marine Resources Commission  
Virginia Institute of Marine Science

Contract Number: F-116-R-9

Project Period: 15 February 2006 - 14 February 2007

Principal Investigator: John E. Olney

Prepared By:

John E. Olney and Kristen Delano Walter

Department of Fisheries Science  
School of Marine Science  
Virginia Institute of Marine Science  
The College of William and Mary  
Gloucester Point, VA 23062-1346

Submitted To:

Virginia Marine Resources Commission  
P.O. Box 756  
Newport News, VA 23607-0756

15 April 2007

## Summary

- A staked gill net was set and fished each week on the James, York and Rappahannock Rivers in the spring of 2006. This was the ninth year of monitoring in a stock assessment program for American shad that was initiated in spring 1998. Our approach has been to establish a sentinel fishery, based on traditional methods used prior to the imposition of the current in-river moratorium in 1994. 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 when the staked gill net fishery was active. 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 allow assessment of current status relative to catch rates recorded in the 1980s and the 1950's.
- Sampling occurred for nine weeks on the York River (28 February to 1 May 2006), 11 weeks on the Rappahannock River (1 March - 15 May 2006), and eight weeks on the James River (25 February - 20 April 2006). After 16 April, post-spawning fish were mixed with pre-spawning fish in the catch on the York River. After 23 April, post-spawning fish were mixed with pre-spawning fish on the James and Rappahannock Rivers. Only pre-spawning fish were included in the monitoring summaries. A total of 413 pre-spawning female American shad (600.7 kg total weight) were captured. The 2006 total catch decreased from the 2005 catch (959 females weighing 1,482.3 kg) and 2004 catch (1,107 females weighing 1,857.1 kg) to the lowest value seen since the inception of monitoring in 1998.
- Total numbers and weights of females in 2006 were highest on the Rappahannock (n= 162, 246.8 kg) and York (n= 157, 220.1 kg) Rivers. The lowest catches of females were on the James River (n= 94, 133.8 kg). Numbers of males captured were: Rappahannock, 25; York, 22; James River, 8. The total weight of males captured on all rivers was 66.8 kg.
- Based on age estimates from scales, the 2001 (age 5) year class of female American shad was the most abundant on the James, York, and Rappahannock Rivers, with peak age-specific seasonal catch rates exceeding 0.015 kg/m, 0.016 kg/m, and 0.018kg/m respectively. The 2002 (age 4) year class was also abundant on all three rivers with seasonal catch rates exceeding 0.009 kg/m. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 0.69 ( $r^2= 0.90$ ); James River, 1.14 ( $r^2= 0.93$ ); and Rappahannock River, 0.74 ( $r^2= 0.95$ ). Total instantaneous mortality rates of males calculated from age-specific catch rates were: Rappahannock River, 0.60 ( $r^2= 0.96$ ). Total instantaneous mortality was not estimated for York or James River males.

- Otoliths of 87 American shad captured on the James River were scanned for hatchery marks. The proportion of the sample with hatchery marks on the James River was 10.3% (9 of 87 fish). 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 from 2000-2005 was due to an influx of mature hatchery fish released since 1995. The recent decrease in prevalence may be related to spawning success of hatchery fish and the subsequent influx on un-marked hatchery progeny. Of the hatchery-released cohorts since 1994, 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, eleven year classes (1992-2002) of hatchery fish have been captured in the monitoring program in the James River.
- The geometric mean catch (standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2006 was: James River, 0.11 (0.254, 20); Rappahannock River, 0.08 (0.245, 34); York River (inclusive of Pamunkey and Mattaponi rivers), 0.14 (0.422, 90); Mattaponi River, 0.29 (0.554, 48); and Pamunkey River, 0 (0, 37).
- Twenty-two species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 17,982 specimens. The total number of striped bass captured was 4,256 (James River, n= 544; York River, n= 1,475; Rappahannock River, n= 2,237). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 4245.6%; York River, 34.0%; and the Rappahannock River, 43.2%.
- 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. In 2006, mean age of females decreased sharply, signaling an influx of younger fish on all three rivers. 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 1998-2006 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 2006 (2.85) is the lowest value recorded since monitoring began in 1998. During the nine 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 (8.25) 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 trials in 2002 and 2003.

- On the James River, the 2006 index (1.74) is the lowest value recorded since monitoring began in 1998 and is well below the proposed target of 29. Index values in 2000-2005 were 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 (5.38).
- The catch index on the Rappahannock River in 2006 (3.01) declined with respect to 2003-2004 values and is equivalent to the 2002 value. The 2003-04 values were 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 (3.80).

## 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 was recently used in a revised stock assessment of American shad scheduled for peer review in summer 2007.

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. Their contributions as authors of historic log books during the 1980s and as expert shad fishermen are essential elements of the monitoring program. In 2006, the staff and students of the Virginia Institute of Marine Science who participated in the program were: 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. Fish product from the sentinel fishery are donated to the Food Bank of Newport News, Virginia. We offer our thanks to Mr. Bud Davenport who facilitates this donation and to the Hunters for the Hungry (Virginia Hunters Who Care) organization for their assistance.

## 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 ninth year in the sampling program (2006) are reported in this document and compared to some results in previous years of monitoring. Detailed results of the first eight years of sampling (1998-2005) 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, Olney and Delano 2006). 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, Limburg *et al.* 2003).

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). Large catches no longer occur as they did at the turn of the century and in many areas, including Chesapeake Bay, harvest is banned or severely restricted. 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 claimed 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 initial success of this ongoing program was documented by Olney *et al.* (2003) who reported that catch rates by monitoring gear increased in 2000-2002 as large numbers of mature hatchery fish returned to the James River. More recently, hatchery prevalence in the James River has decreased, presumably due to a dilution effect caused by the increased abundance of returning unmarked, hatchery progeny. This hypothesis has not been tested, however.

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). 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). VDGIF personnel also began a new hatchery-release program on the upper Rappahannock River in 2005. 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.

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.

In spring 2006, the VMRC authorized a limited bycatch fishery for American shad in specific areas. Fishers with special permits were allowed to possess fish caught in anchored or staked gill nets when fished in areas above the first bridge on the James, York and Rappahannock rivers. Limits were imposed on this take (10 fish per boat per day) and fishers were required to phone in a weekly report of the harvest. In addition, American shad bycatch could only be possessed if equal numbers of other species (such as striped bass) were also landed.

### **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 to 1979 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, 17 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.*, 2006; Olney *et al.*, 2006; Olney *et al.*, 2006; Hoffman *et al.* 2007; Hoffman *et al.*, in press; Hoffman *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 (Hoenig *et al.*) and two manuscripts reporting various aspects of food web analysis using stable isotope analysis are in review (Hoffman *et al.*). In addition, manuscripts describing the spawning grounds of American shad in the James River (Aunins 2006) and seasonal fecundity of shad in the York River (Hyle 2004) are in preparation.

### **2007 ASMFC Stock Assessment**

A coast-wide assessment of stocks of American shad is nearing completion and is scheduled for technical committee review in May 2007 and peer review in summer 2007. Scientists at VIMS (J. Olney, R. Latour and K. Delano) served on the stock assessment sub-committee and were authors of several sections to the report (introduction on age determination; assessment of Virginia stocks; assessment of the Potomac River stock). Data from the Virginia monitoring program and the foregoing peer-reviewed literature based on this program were primary sources of these documents. The last assessment of Chesapeake Bay stocks was prepared in 1998 (ASMFC 1999). Draft executive summaries of the new 2007 assessments are appended as Appendix I and II.

### **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 2006, an additional objective was to monitor a new bycatch fishery for American shad established by the VMRC. The results of this monitoring are appended as a report to the American shad and river herring technical committee as Appendix III.

## Methods

The 2006 sampling methods for the monitoring program were the same as those in 1998-2005 (see Appendix III for additional methods used to monitor the bycatch fishery). In 1998, a sentinel fishery 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 ( $36^{\circ} 50.0' N$ ,  $76^{\circ} 28.8' W$ ); middle York River near Clay Bank at river mile 14 ( $37^{\circ} 20.8' N$ ,  $76^{\circ} 37.7' W$ ); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock) at river mile 36 ( $37^{\circ} 55.9' N$ ,  $76^{\circ} 50.4' W$ ). Historical catch-rate data on the York and James rivers were derived from nets constructed of  $4 \frac{7}{8}$ " 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  $4 \frac{7}{8}$ " (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 2006, sampling occurred for nine weeks on the York River (28 February to 1 May 2006), 11 weeks on the Rappahannock River (1 March - 15 May 2006), and eight weeks on the

James River (25 February - 20 April 2006). 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 head length) 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 and enumerated on log sheets by observers on each river 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 scan for hatchery marks, 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 2005-2006. 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 insure consistency, Watkins has re-aged all scale samples collected during the monitoring program.

An ASMFC age-determination workshop using known age fish from the Susquehanna River 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. In an ongoing study (in collaboration with Dr. Simon Thorrold, Woods Hole Oceanographic Institution), VIMS scientists are using stable isotope as natural markers to distinguish the 2002 and 2003 year classes of returning adults. These known-age samples will be used to validate age-4 and age 5 fish.

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 2006*

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 16 April 2006 on the York River and after 23 April on the James and Rappahannock rivers, 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 468 American shad (55 males; 413 females) were captured. The total weight of the sample was 667.5 kg (male, 66.8 kg; female, 600.7 kg). The 2006 catch was the lowest catch recorded in the nine year history of the monitoring program. Catches in 2006 were lowest on the James River (112 total fish, 8 males and 94 females), higher on the York River (179 total fish, 22 males and 157 females) and highest on the Rappahannock River (187 total fish, 25 males and 162 females).

On the Rappahannock River, catches of females peaked on 20 March- 17 April 2006 when catch rates usually exceeded 0.04 fish/m or 0.07 kg/m. During that period on the Rappahannock River, 63% (102 of 162) of the total number of females was captured. On the York River, catches of females peaked between 26 March and 3 April 2006 when catch rates approached or exceeded 0.06 fish/m or 0.08 kg/m. During that period on the York River, 50% (79 of 157) of the total number of females was captured. Catches of females on the James River peaked 12 March- 2 April 2006 when catch rates usually exceeded 0.03 fish/m or 0.06 kg/m. During that period on the James River, 67% (63 of 94) of the total number of females was captured. The highest recorded daily catch by weight occurred on 27 March 2006 when 29 female American shad (41.3 kg) were taken in the York River (Table 5). As in previous years of monitoring, numbers and catch rates of males were lower than catch rates of females throughout the period. Sex ratios (males:females) were: York River, 1:7.1; James River, 1:11.8; Rappahannock River, 1:6.5. 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 2006, catch rates on the York and Rappahannock Rivers were equal or had already exceeded 0.01 female kg/m when sampling was initiated; therefore spawning run duration estimates for this year are slightly conservative. The 2006 spawning run duration was estimated to be 54 days on the James River (25 February - 20 April), 62 days on the York River (28 February to 1 May), and 75 days on the Rappahannock River (1 March - 15 May).

### *Biological characteristics of the American shad in 2006*

Age, mean length (mm TL) and mean weight (g) of American shad in staked gill nets are summarized in Tables 9-10. Patterns of mean age are depicted in Figure 16. Mean total length at age of males and females ranged from 428-550 mm TL and 447-595 mm TL, respectively. Mean weight at age of males and females ranged from 0.95-1.85 kg and 1.17-2.98 kg, respectively.

The 2002 and 2001 year classes (ages 4 and 5) of female American shad were the most abundant on all three rivers (Table 11). On the James River, five age classes of females were represented (1998-2002, ages 4-8) and the sample was dominated by age-5 fish (57.0% of the total that was aged). On the York River, eight age classes of females were represented (1996-2003, ages 3-10) and the sample was dominated by age-5 fish (50.0% of the total that was aged). On the Rappahannock River, seven age classes of females were taken (1996-2003, ages 3-10) and the sample was dominated by age-5 fish (53.7% of the total that was aged). The 1999, 2000 and 2001 year classes of males were the most abundant on the York, James, and Rappahannock Rivers, respectively (Table 12). These year classes (ages 5-7) of male American shad constituted 43.8% (York River), 40.0% (James River) and 54.5% (Rappahannock River) of the aged sample. Mean age of females in each river have followed similar patterns throughout the period of monitoring, increasing steadily from 2000-2005. Mean age decreased in 2006 to 4.4 y (James River), 4.5 y (Rappahannock River) and 4.9 y (York River).

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, 0.69 ( $r^2 = 0.90$ ); James River, 1.14 ( $r^2 = 0.93$ ); and Rappahannock River, 0.74 ( $r^2 = 0.95$ ). Total instantaneous mortality rates of males calculated from age-specific catch rates were: Rappahannock River, 0.60 ( $r^2 = 0.96$ ). Total instantaneous mortality was not estimated for York or James River males.

Spawning histories of American shad collected in 2006 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 4-9 years with 0-5 spawning marks. The following percentages of fish in each river had at least one prior spawn (termed "repeat spawners"): York River, 35.5% (98 virgins in a sample of 152); James River 26.4% (67 virgins in a sample of 91); Rappahannock River 37.3% (106 virgins in a sample of 169 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%; 2005, 62.4% (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002; Olney 2003a; Olney 2004; Olney 2005; Olney and Delano 2006).



### *Evaluation of hatchery origin of American shad in 2006*

James River - Otoliths of 87 American shad captured in staked gill nets on the James River were processed for hatchery marks. The proportion of the 2006 sample with hatchery marks was 10.3% (9 of 87 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%) and continued to decline in 2005 (23.8%). In 2006 hatchery prevalence declined to 10.3%. 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, 2004, and 2006 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 1999-2002 year classes is being seen in 2006.

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). In 2006, there were no repeat spawners (9 virgins in a sample of 9 hatchery fish).

York River – Otoliths were not scanned for hatchery marks on the York River in 2006. These samples were used in an ongoing age validation study. The cores of otoliths of York River fish were removed and processed to determine isotopic composition.

#### *Juvenile abundance of American shad*

Tables 17 and 18 and Figures 17-19 report index values of juvenile abundance of American shad based on seine surveys (1979-2006) 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 2006 was: James River, 0.11 (0.254, 20); Rappahannock River, 0.08 (0.245, 34); York River (inclusive of Pamunkey and Mattaponi rivers), 0.14 (0.422, 90); Mattaponi River, 0.29 (0.554, 48); and Pamunkey River, 0 (0, 37).

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 Boshers' Dam on the James River (VDGIF, T. Gunter, pers. comm.). A few juveniles were captured in 1984, 1998, 2003, 2004, and 2006. 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.

#### *By-catch of striped bass and other species in 2006*

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 19-21. Twenty-two species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 17,982 specimens. The most commonly encountered by-catch species were: menhaden (*Brevoortia tyrannus*), gizzard shad (*Dorosoma cepedianum*), striped bass (*Morone saxatilis*), blue catfish (*Ictalurus furcatus*), hickory shad (*Alosa mediocris*), Atlantic croaker (*Micropogonias undulatus*), and summer flounder (*Paralichthys dentatus*).

The total number of striped bass captured was 4,256 (James River, n= 544; York River, n= 1,475; Rappahannock River, n= 2,237). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 45.6%; York River, 34.0%; and the Rappahannock River, 43.2%.

### *Seasonal catch indexes, 1980-1992 and 1998-2006*

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2006 and for each year of the historical record of staked net catches on each river (Tables 22-25 and Figures 21-23). Seasonal catch indices in 2006 were: York River, 2.85; James River, 1.74; Rappahannock River, 3.01. These values were the lowest recorded in the James and York rivers since monitoring began in 1998.

### **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 current coast-wide stock assessment, scheduled for peer review in 2007.

Abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in 2000-2003 indicated 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 during those years was 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%; 2006, 10.3%). The pattern is consistent with a hypothesis of recent recruitment of unmarked progeny of hatchery components of the stock, especially the 2000-2002 year classes. 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. Such studies are currently underway at Virginia Commonwealth University (A. Aunins and B. Brown, pers. comm.). Regardless, the monitoring data suggest 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.

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.*, 2006). 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 restoration 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 2006 was 2.85, the lowest value recorded since 1998. During the nine 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 (8.25) 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 (Figure 20). 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. However, in 2006 mean age of females has decreased as a result of increased proportions of younger fish in the monitoring catch. 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 2006 index (1.74) is the lowest value recorded since 1998 and is well below the proposed target of 29. Index values in 2000-2005 were 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 (5.38), but slowly increasing. As noted previously, hatchery cohorts are believed to be recruiting in high proportions to the population, mean age of females has increased in recent years of monitoring (2000-2005), and an increase in the proportion of younger year classes entering the monitoring gear was observed in 2006 (Figure 20). 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 2006 (3.01) declined with respect to 2003-2004 values and is 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 1998-2006 average (3.80) is above the average of the historical data (1.76) and the 2003-2004 index values were above the proposed target of 6, however, 2006 values have continued to stay 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 (Figure 20). 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 and in 2006 mean age of females decreased due to an increase in younger year classes entering the monitoring gear. 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.
- Aunins, A. 2006. Migratory and spawning behavior of American shad in the James River, Virginia. A thesis presented to the School of Marine Science, College of William and Mary, 99 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 Restoration 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.
- Hoening, 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.
- Hoffman JC, KE Limburg, DA Bronk and JE Olney. 2007. Overwintering habitats of migratory juvenile American shad in Chesapeake Bay. *Environmental Biology of Fishes* – currently online (<http://dx.doi.org/10.1007/s10641-007-9204-y>)
- Hoffman JC, Bronk DA and Olney JE. In press. Tracking nursery habitat use by young American shad using stable isotopes. *Transactions of the American Fisheries Society*.
- 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.

- Limburg, K.E., K.A. Hatalla and A. Kahnle. 2003. American shad in its native range. American Fisheries Society Symposium 35: 125-140.
- 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. 2006. Comparing historical catches of American shad in multifilament and monofilament nets: a step toward setting restoration targets for Virginia stocks. North American Journal of Fisheries Management 26: 282-288.
- 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.
- Olney, J.E. and K. Delano. 2006. Monitoring relative abundance of American shad in Virginia's rivers. 2005 Annual report to the Virginia Marine Resources Commission, Contract No. F-116-R-8, 15 April 2006.
- Olney, J.E., D.M. Bilkovic, C.H. Hershner, L.M. Varnell, H. Wang and R.L. Mann. 2006. Six fish and 600,000 thirsty folks – a fishing moratorium on American shad thwarts a controversial municipal reservoir project in Virginia, USA. American Fisheries Society Symposium, 2006.
- Olney, J.E., R.J. Latour, B. E. Watkins and D. G. Clarke. 2006. Migratory behavior of American shad (*Alosa sapidissima*) in the York River, Virginia with implications for estimating in-river exploitation from tag recovery data. Transactions of the American Fisheries Society 135: 889-896.
- 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.

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 2006.

Stock	Sampling dates in 2006	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	2/25-4/20	94	8	133.8	9.6	112	143.4
York River	2/28-5/1	157	22	220.1	25.6	179	245.7
Rappahannock River	3/1-5/15	162	25	246.8	31.6	187	278.4
Totals		413	55	600.7	66.8	478	667.5

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 2006. These individuals were removed from the monitoring data.

River	Date	Specimen number	Total length (mm)	Fork length (mm)	Total weight (g)
James River	4/24/06	12167	556	498	1624.20
Rappahannock River	4/23/06	12146	526	469	1312.30
	4/24/06	12161	531	481	1233.00
	4/24/06	12166	538	483	1361.10
York River	4/16/06	12083	560	507	1727.30
	4/23/06	12135	548	494	1394.30
	4/23/06	12131	538	486	1685.60
	4/23/06	12130	490	440	1011.60
	4/23/06	12136	576	523	1705.80
	4/23/06	12132	511	458	1186.80
	4/24/06	12140	498	440	1131.20
	4/24/06	12145	554	498	1505.20
	4/24/06	12144	499	443	1048.30
	4/24/06	12143	602	528	1870.30
	4/24/06	12141	526	471	1386.40
	4/24/06	12142	529	471	1238.10
	4/30/06	12170	578	514	1656.50
	5/1/06	12187	578	512	1742.50
	5/1/06	12181	560	499	1674.50
	5/1/06	12185	512	452	1170.80
	5/1/06	12184	544	480	1414.10

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 2006.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/25/06	56	2	0.007	2,717.0	0.010
3/6/06	65	6	0.023	7,612.2	0.029
3/7/06	66	3	0.011	4,371.8	0.016
3/12/06	71	8	0.029	15,338.6	0.056
3/13/06	72	5	0.018	8,963.7	0.033
3/19/06	78	15	0.055	21,402.8	0.078
3/20/06	79	13	0.048	16,450.2	0.061
3/26/06	85	5	0.018	7,433.9	0.027
3/27/06	86	5	0.018	7,029.1	0.026
4/2/06	92	12	0.045	16,413.5	0.061
4/3/06	93	3	0.011	3,809.0	0.014
4/9/06	99	7	0.022	9,691.9	0.031
4/10/06	100	1	0.004	1,040.8	0.004
4/16/06	106	7	0.026	9,254.2	0.034
4/20/06	110	2	0.007	2,292.6	0.008
Totals		94		133,821.3	

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 2006.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/25/06	56	1	0.004	1,220.7	0.004
3/6/06	65	2	0.008	2,084.9	0.008
3/12/06	71	1	0.004	373.2	0.001
3/19/06	78	1	0.004	1,595.6	0.006
4/2/06	92	2	0.007	2,804.9	0.010
4/9/06	99	1	0.003	1,483.0	0.005
Totals		8		9,562.3	

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 2006.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/28/06	59	2	0.007	2,928.6	0.011
3/1/06	60	4	0.015	5,718.3	0.021
3/6/06	65	12	0.043	15,414.0	0.055
3/7/06	66	5	0.018	7,372.0	0.027
3/12/06	71	8	0.029	13,503.9	0.049
3/13/06	72	3	0.011	3,782.9	0.014
3/19/06	78	13	0.047	15,989.9	0.058
3/26/06	85	18	0.066	24,812.3	0.090
3/27/06	86	29	0.103	41,260.8	0.146
4/2/06	92	16	0.058	22,170.4	0.081
4/3/06	93	16	0.058	22,859.3	0.083
4/9/06	99	3	0.010	4,585.9	0.015
4/10/06	100	4	0.015	5,390.2	0.020
4/16/06	106	5	0.018	6,838.6	0.025
4/17/06	107	7	0.026	8,922.2	0.033
4/23/06	113	2	0.007	3,010.7	0.011
4/24/06	114	3	0.011	4,668.4	0.017
4/30/06	120	5	0.018	7,219.4	0.026
5/1/06	121	2	0.007	3,648.1	0.013
Totals		157		220,095.9	

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 2006.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/28/06	59	1	0.004	884.5	0.003
3/6/06	65	2	0.007	1,952.4	0.007
3/7/06	66	6	0.022	6,094.2	0.022
3/12/06	71	1	0.004	1,078.2	0.004
3/19/06	78	3	0.011	3,995.3	0.015
3/26/06	85	4	0.015	5,293.2	0.019
3/27/06	86	3	0.011	3,561.2	0.013
4/10/06	100	1	0.004	1,139.1	0.004
5/1/06	121	1	0.004	1,572.0	0.006
Totals		22		25,570.1	

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 2006.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/1/06	60	1	0.004	1,811.4	0.007
3/2/06	61	1	0.004	2,435.8	0.010
3/6/06	65	4	0.014	6,697.6	0.024
3/7/06	66	2	0.007	3,635.7	0.013
3/12/06	71	3	0.011	4,742.4	0.017
3/13/06	72	2	0.007	4,402.7	0.016
3/19/06	78	8	0.029	12,831.9	0.046
3/20/06	79	12	0.043	18,795.5	0.068
3/26/06	85	12	0.043	19,664.7	0.071
3/27/06	86	8	0.028	11,855.9	0.042
4/2/06	92	3	0.011	4,031.7	0.015
4/3/06	93	15	0.053	24,644.0	0.088
4/9/06	99	10	0.035	14,534.1	0.051
4/10/06	100	15	0.055	22,884.4	0.083
4/16/06	106	12	0.042	18,839.6	0.066
4/17/06	107	15	0.053	21,702.5	0.077
4/23/06	113	7	0.025	8,735.7	0.031
4/24/06	114	10	0.036	13,450.6	0.048
4/30/06	120	7	0.025	9,721.4	0.035
5/1/06	121	5	0.018	7,500.7	0.027
5/7/06	127	5	0.018	7,155.8	0.025
5/8/06	128	3	0.011	3,681.3	0.013
5/14/06	134	1	0.004	1,463.7	0.005
5/15/06	135	1	0.003	1,555.3	0.005
Totals		162		246,774.4	



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 2006.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/2/06	61	2	0.008	2,220.7	0.009
3/6/06	65	2	0.007	2,730.7	0.010
3/7/06	66	1	0.004	1,853.8	0.007
3/19/06	78	1	0.004	1,646.2	0.006
3/20/06	79	6	0.022	6,961.1	0.025
3/26/06	85	6	0.022	7,227.3	0.026
3/27/06	86	2	0.007	2,278.6	0.008
4/2/06	92	1	0.004	1,266.0	0.005
4/16/06	106	3	0.011	3,951.7	0.014
4/24/06	114	1	0.004	1,500.0	0.005
Totals		25		31,636.1	

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 2006. 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	29	466.0	22.8	1253.4	169.0
	2001	49	488.3	24.2	1400.6	197.9
	2000	5	524.6	34.2	1787.0	512.4
	1999	2	579.5	51.6	2551.1	799.2
	1998	1	550.0		1906.2	
	NA	8	507.3	45.7	1612.7	397.4
	York River	2003	3	460.0	22.7	1174.9
2002		44	464.5	18.7	1249.5	160.5
2001		68	476.0	19.3	1342.9	153.9
2000		11	513.0	27.3	1674.7	240.5
1999		6	543.0	32.6	1954.9	295.7
1998		2	550.0	5.7	2108.4	78.5
1997		1	582.0		2985.9	
1996		1	595.0		2540.2	
NA		21	485.0	38.4	1446.6	384.5
Rappahannock River		2003	1	447.0		1176.7
	2002	34	474.6	21.0	1335.2	179.6
	2001	79	490.0	24.1	1492.7	218.1
	2000	22	506.9	25.3	1625.8	328.6
	1999	6	550.2	28.8	2114.3	404.3
	1998	4	524.3	37.3	1701.4	250.4
	1996	1	588.0		2435.8	
	NA	15	508.1	31.5	1638.8	301.8

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 2006. 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	1	452.0		1072.0	
	2001	1	462.0		1239.2	
	2000	2	481.5	29.0	1408.2	265.1
	1997	1	550.0		1483.0	
	NA	3	431.7	79.0	983.9	596.8
York River	2002	3	432.7	20.5	949.2	91.1
	2001	4	428.0	10.9	1015.7	88.9
	2000	1	498.0		1367.3	
	1999	7	488.4	29.2	1308.1	239.6
	1998	1	512.0		1477.7	
	NA	6	451.8	31.4	1109.6	242.1
Rappahannock River	2002	2	452.0	2.8	1018.1	30.3
	2001	12	461.6	16.7	1138.6	113.9
	2000	4	491.0	24.0	1387.8	185.1
	1999	3	495.0	5.2	1428.1	62.3
	1998	1	518.0		1853.8	
	NA	3	495.7	21.1	1415.9	244.9

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 2006. 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	29	36.3	17.0	0.0062	0.0078
	2001	49	68.6	17.0	0.0105	0.0147
	2000	5	8.9	17.0	0.0011	0.0019
	1999	2	5.1	17.0	0.0004	0.0011
	1998	1	1.9	17.0	0.0002	0.0004
	NA	8	12.9	17.0	0.0017	0.0028
	Rappahannock River	2003	1	1.2	24.0	0.0001
2002		34	45.4	24.0	0.0051	0.0068
2001		79	117.9	24.0	0.0118	0.0176
2000		22	35.8	24.0	0.0033	0.0054
1999		6	12.7	24.0	0.0009	0.0019
1998		4	6.8	24.0	0.0006	0.0010
1996		1	2.4	24.0	0.0001	0.0004
NA		15	24.6	24.0	0.0022	0.0037
York River	2003	3	3.5	20.2	0.0005	0.0006
	2002	44	55.0	20.2	0.0079	0.0099
	2001	68	91.3	20.2	0.0123	0.0165
	2000	11	18.4	20.2	0.0020	0.0033
	1999	6	11.7	20.2	0.0011	0.0021
	1998	2	4.2	20.2	0.0004	0.0008
	1997	1	3.0	20.2	0.0002	0.0005
	1996	1	2.5	20.2	0.0002	0.0005
	NA	21	30.4	20.2	0.0038	0.0055

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 2006. 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	1	1.1	17.0	0.0002	0.0002
	2001	1	1.2	17.0	0.0002	0.0003
	2000	2	2.8	17.0	0.0004	0.0006
	1997	1	1.5	17.0	0.0002	0.0003
	NA	3	3.0	17.0	0.0006	0.0006
Rappahannock River	2002	2	2.0	24.0	0.0003	0.0003
	2001	12	13.7	24.0	0.0018	0.0020
	2000	4	5.6	24.0	0.0006	0.0008
	1999	3	4.3	24.0	0.0004	0.0006
	1998	1	1.9	24.0	0.0001	0.0003
	NA	3	4.2	24.0	0.0004	0.0006
York River	2002	3	2.8	20.2	0.0005	0.0005
	2001	4	4.1	20.2	0.0007	0.0007
	2000	1	1.4	20.2	0.0002	0.0002
	1999	7	9.2	20.2	0.0013	0.0017
	1998	1	1.5	20.2	0.0002	0.0003
	NA	6	6.7	20.2	0.0011	0.0012

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2006 in the York and James Rivers. Table entries are total numbers of fish that were aged (York River, n = 152; James River, n = 91). 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 aged fish out of the total that had hatchery marks on their otoliths (n = 8). Asterisks 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
2003	3	<b>3</b>	-	-	-	-
2002	4	1	<b>46</b>	-	-	-
2001	5	1	25	<b>46</b>	-	-
2000	6	*	4	5	<b>3</b>	-
1999	7	*	9	4	*	*
1998	8	*	2	*	*	*
1997	9	*	1	*	*	*
1996	10	*	*	1	*	*

Age at Maturity

James River Year Class	Age at Capture	3	4	5	6	7
2002	4	1	<b>25(4)</b>	-	-	-
2001	5	1	13	<b>32(4)</b>	-	-
2000	6	*	4	1	<b>2</b>	-
1999	7	*	1	1	*	*
1998	8	*	*	1	*	*
1997	9	*	1	*	*	*

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2006 in the Rappahannock River. Table entries are total numbers of fish that were aged (n = 169). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. Asterisks 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	Age at Maturity				
		3	4	5	6	7
2003	3	<b>1</b>	-	-	-	-
2002	4	*	<b>36</b>	-	-	-
2001	5	2	24	<b>65</b>	-	-
2000	6	2	11	9	<b>4</b>	-
1999	7	*	7	1	1	*
1998	8	*	1	4	*	*
1997	9	*	*	*	*	*
1996	10	*	*	1	*	*

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 (n= 9) taken in staked gill net monitoring on the James River in 2006. Otoliths of all American shad captured on the James in 2006 (n= 87) were 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
11794	3	James 02-03	4	0	478	536	1869.7	female
11814	9	James 97-01	4	0	388	435	1172.9	female
12015	3	James 02-03	4	0	442	492	1313.8	female
12017	9	James 97-01	4	0	401	458	1102.1	female
12020	3	James 02-03	5	0	440	494	1479.4	female
12084	3,6,15	James 00 or Chick 00	5	0	408	457	1183.3	female
12085	9	James 97-01	5	0	448	500	1562.7	female
12129	3,6,9,12,15	James 01	5	0	423	472	1399.8	female
12167	3,6,15	James 00 or Chick 00	NA	NA	498	556	1624.2	female



Table 16. Total numbers in nine year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2006. 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	2006	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	12.7
1996	5.8			53	62	43	10	4	1		173	26.4
1997	5.9			2	27	78	57	5	4		173	26.4
1998	10					13	52	17	13		95	14.5
1999	7.3						14	29	7		50	7.6
2000	8.9						1	5	9		15	2.3
2001	9.3								3	4	7	1.1
2002	8.4									4	4	0.6
2003	8.7											
2004	6.6											
2005	6											
2006	*											
NA	--					12	3	5	3	1	24	3.7
Total	84.35*	14	6	124	98	154	142	68	40	9	655	100.0

\* Hatchery production data for 2006 is not currently available.

Table 17. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2006) 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
2006	0.11	0.254	20	0.08	0.245	34

Table 18. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2006) 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
2006	0.29	0.554	48	0.00	0.00	37	0.14	0.422	90

Table 19. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2006.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/25/06	23	3	26	16	42
3/6/06	58	15	73	21	94
3/7/06	25	5	30	45	75
3/12/06	10	3	13	13	26
3/13/06	7	1	8	10	18
3/19/06	13	3	16	22	38
3/20/06	13	9	22	36	58
3/26/06	18	3	21	31	52
3/27/06	51	4	55	62	117
4/2/06	5	4	9	88	97
4/3/06	0	4	4	35	39
4/9/06	14	14	28	196	224
4/10/06	4	4	8	85	93
4/16/06	9	53	62	273	335
4/20/06	13	31	48	260	308
4/23/06	14	74	88	255	343
4/24/06	12	18	33	162	195
Totals	289	248	544	1,610	2,154

Table 20. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2006.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/28/06	171	55	226	365	591
3/1/06	233	92	325	151	476
3/6/06	281	134	415	309	724
3/7/06	139	50	189	156	345
3/12/06	41	30	71	35	106
3/13/06	19	14	33	26	59
3/19/06	6	17	23	460	483
3/26/06	14	3	19	358	377
3/27/06	20	26	46	431	477
4/2/06	3	13	16	449	465
4/3/06	8	10	18	226	244
4/9/06	0	1	1	279	280
4/10/06	3	5	8	209	217
4/16/06	2	5	7	165	172
4/17/06	8	3	11	179	190
4/23/06	4	3	7	88	95
4/24/06	1	2	3	90	93
4/30/06	6	12	18	121	139
5/1/06	8	12	20	58	78
5/7/06	4	15	19	66	85
Totals	971	502	1,475	4,221	5,696

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2006.

Date	Live SB	Dead SB	Total SB	Other species	Total
3/1/06	130	14	144	576	720
3/2/06	82	19	101	142	243
3/6/06	161	15	176	182	358
3/7/06	157	14	171	422	593
3/12/06	180	139	319	208	527
3/13/06	126	140	266	169	435
3/19/06	50	50	100	409	509
3/20/06	89	65	154	337	491
3/26/06	61	44	105	171	276
3/27/06	68	37	105	549	654
4/2/06	7	30	37	201	238
4/3/06	34	40	74	277	351
4/9/06	33	71	104	457	561
4/10/06	29	33	62	288	350
4/16/06	14	67	81	526	607
4/17/06	18	42	60	522	582
4/23/06	12	61	73	344	417
4/24/06	4	29	33	391	424
4/30/06	6	27	33	297	330
5/1/06	4	9	13	321	334
5/7/06	1	4	5	403	408
5/8/06	0	5	5	237	242
5/14/06	5	3	8	279	287
5/15/06	0	8	8	187	195
Totals	1,271	966	2,237	7,895	10,132

Table 22. Summary of historical and recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia. Historical data are taken from the voluntary log books of Mr. M. Delano, Urbanna, Virginia.

Year	Effort (10 <sup>3</sup> 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					<b>1.76 (0.39)</b>
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
2006	6.7	75	0.088	0.037	<b>3.01</b>
Average of current data					<b>3.80 (0.77)</b>

Table 23. Summary of historical and recent catch and effort data of American shad by staked gill nets in the York River, Virginia. Historical data are taken from the voluntary log books of Mr. R. Kellum, Achilles, Virginia.

Year	Effort (10 <sup>3</sup> 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	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					<b>3.96</b> (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	0.063	4.64
2006	5.5	62	0.146	0.042	2.85
Average of current data					<b>8.25</b> (1.28)



Table 24. Summary of historical and recent catch and effort data of American shad by staked gill nets in the James River, Virginia. Historical data are taken from the voluntary log books of the Brown family, Rescue, Virginia.

Year	Effort (10 <sup>3</sup> 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	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					<b>8.88</b> (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
2006	4.6	54	0.078	0.032	1.74
Average of current data					<b>5.38</b> (0.85)

Table 25. 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 <sup>3</sup> 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
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						<b>19.54</b>

**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.**

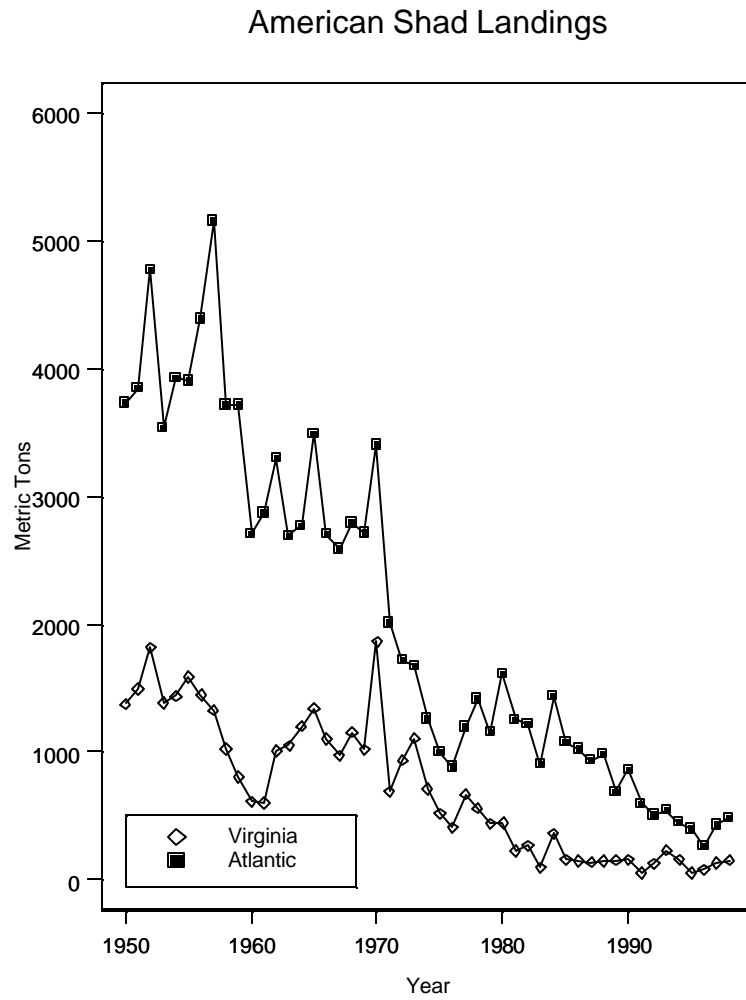
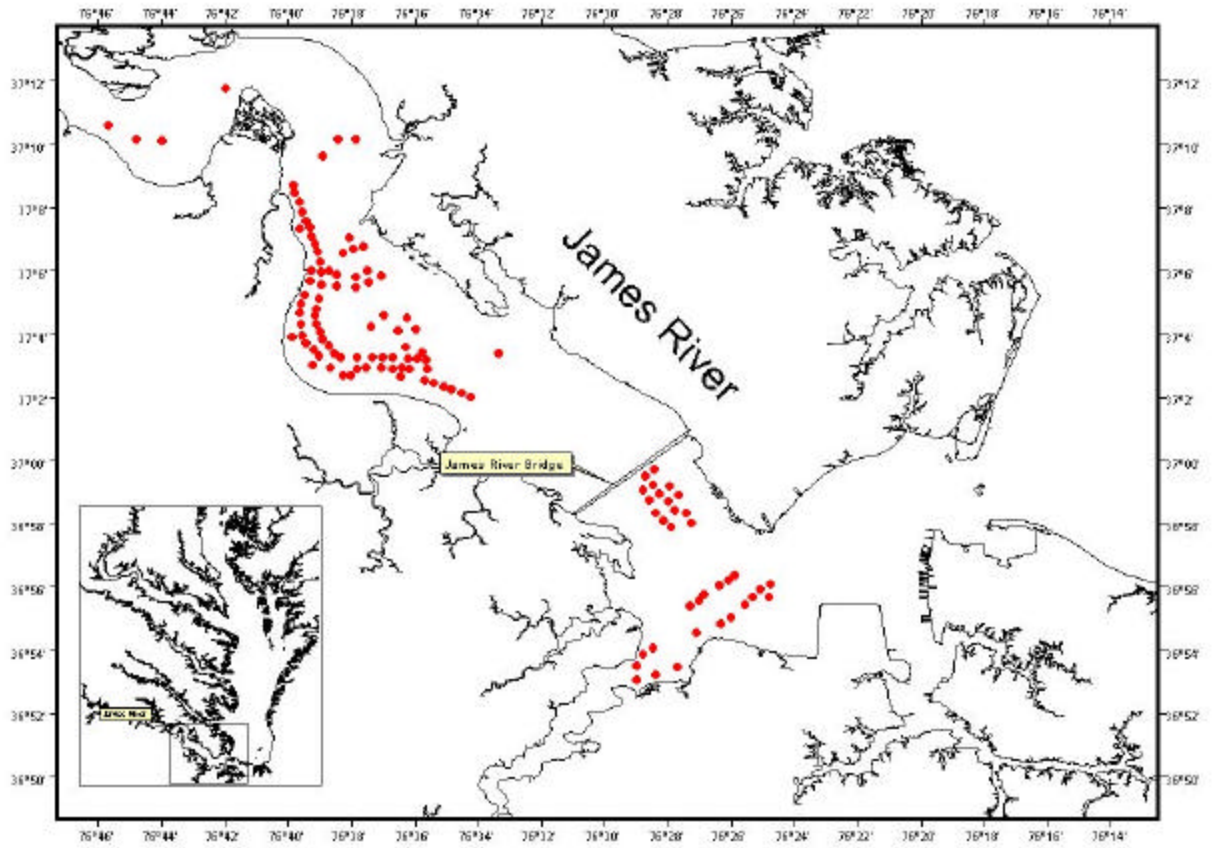
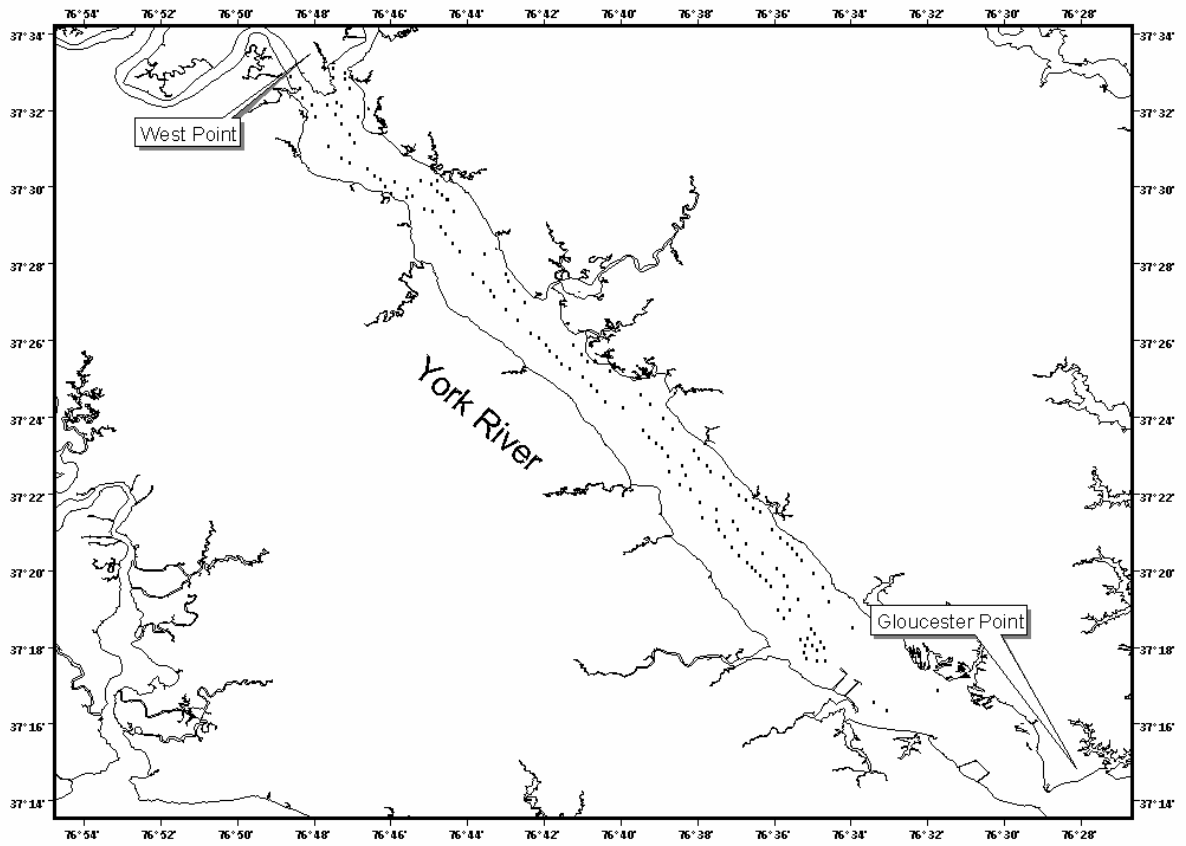


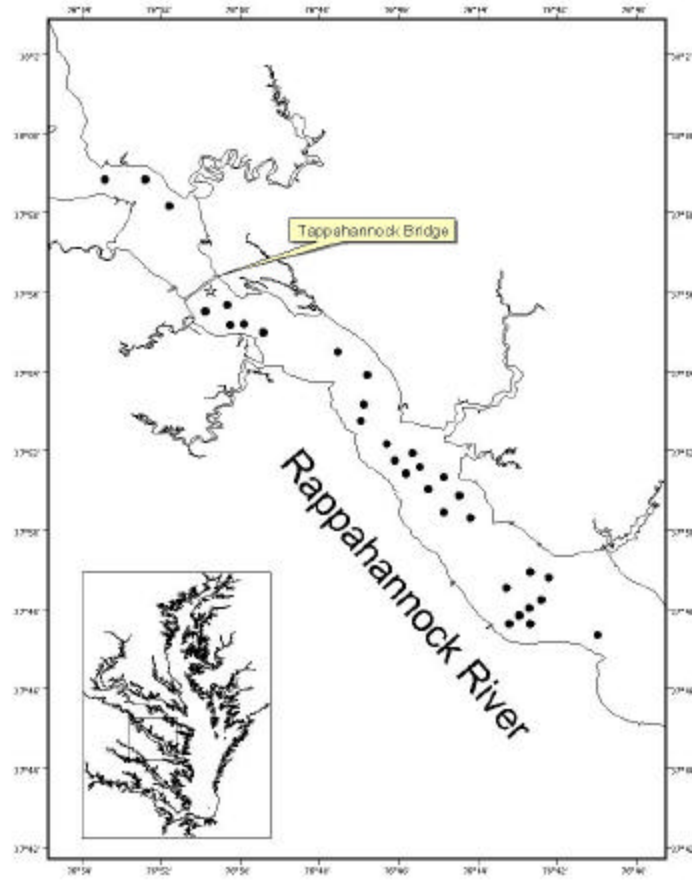
Figure 2. Number and location of staked gill nets on the James River in 1983.



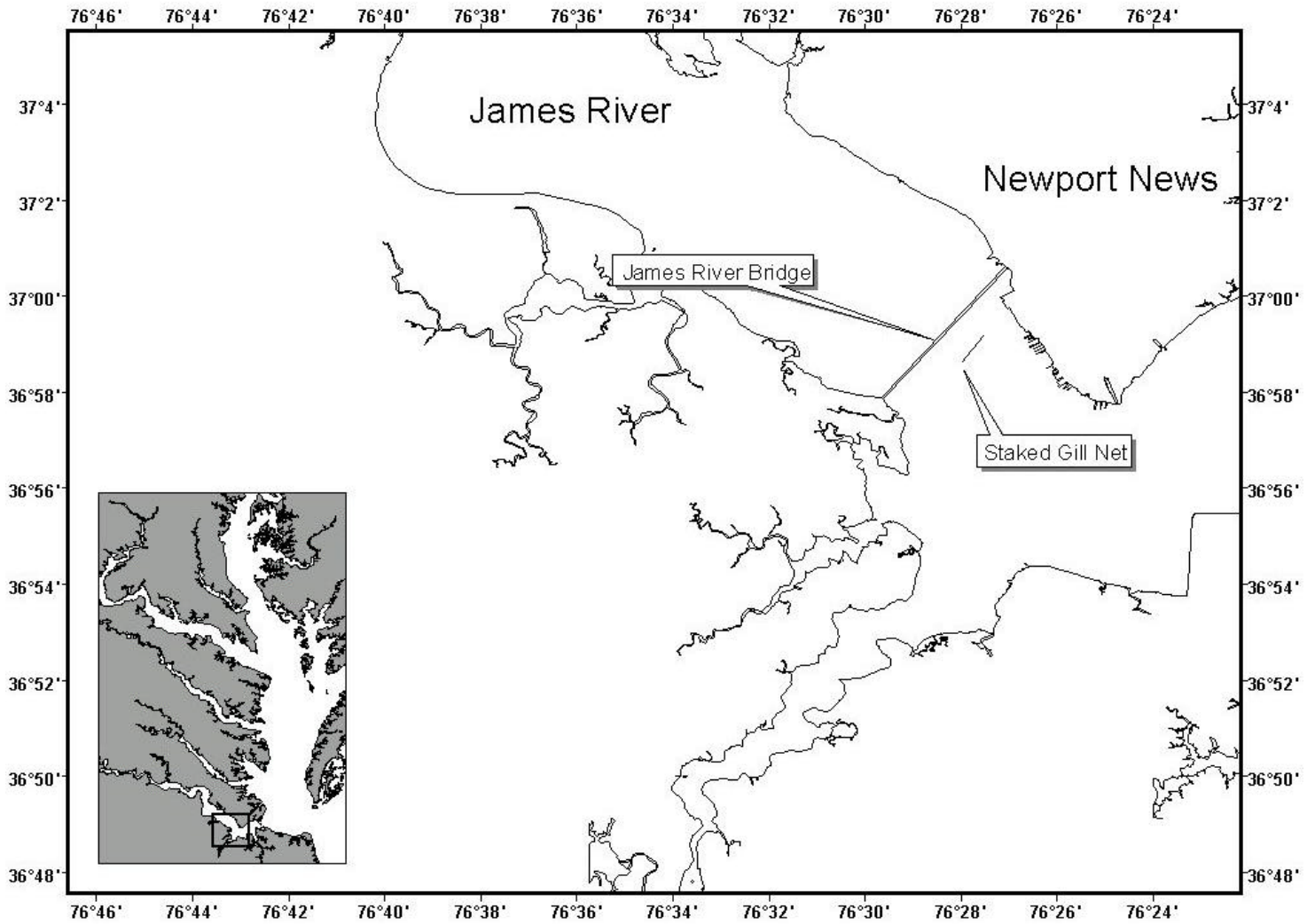
**Figure 3. Number and location of staked gill nets on the York River in 1983.**



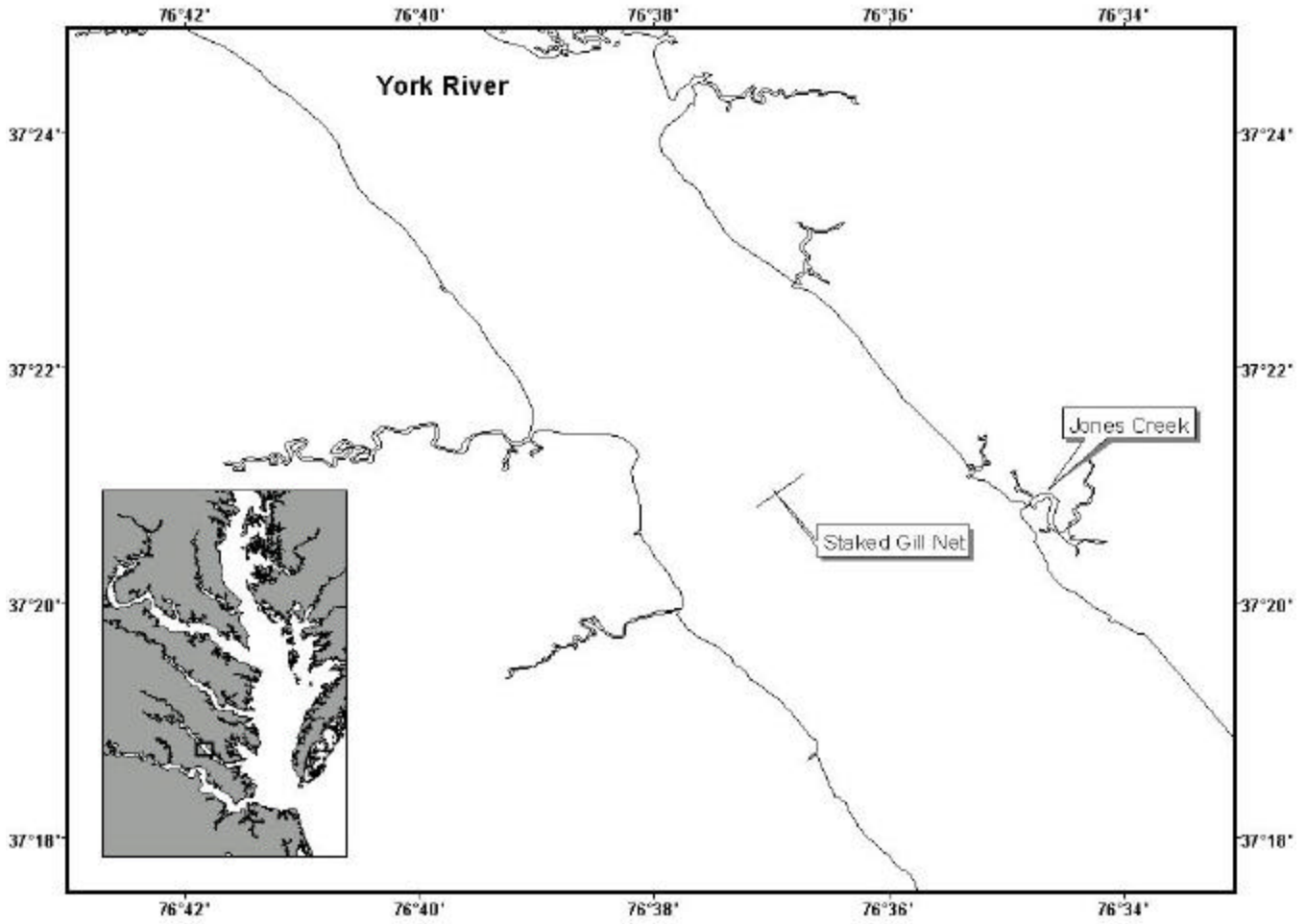
**Figure 4. Number and location of staked gill nets on the Rappahannock River in 1983.**



**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.**

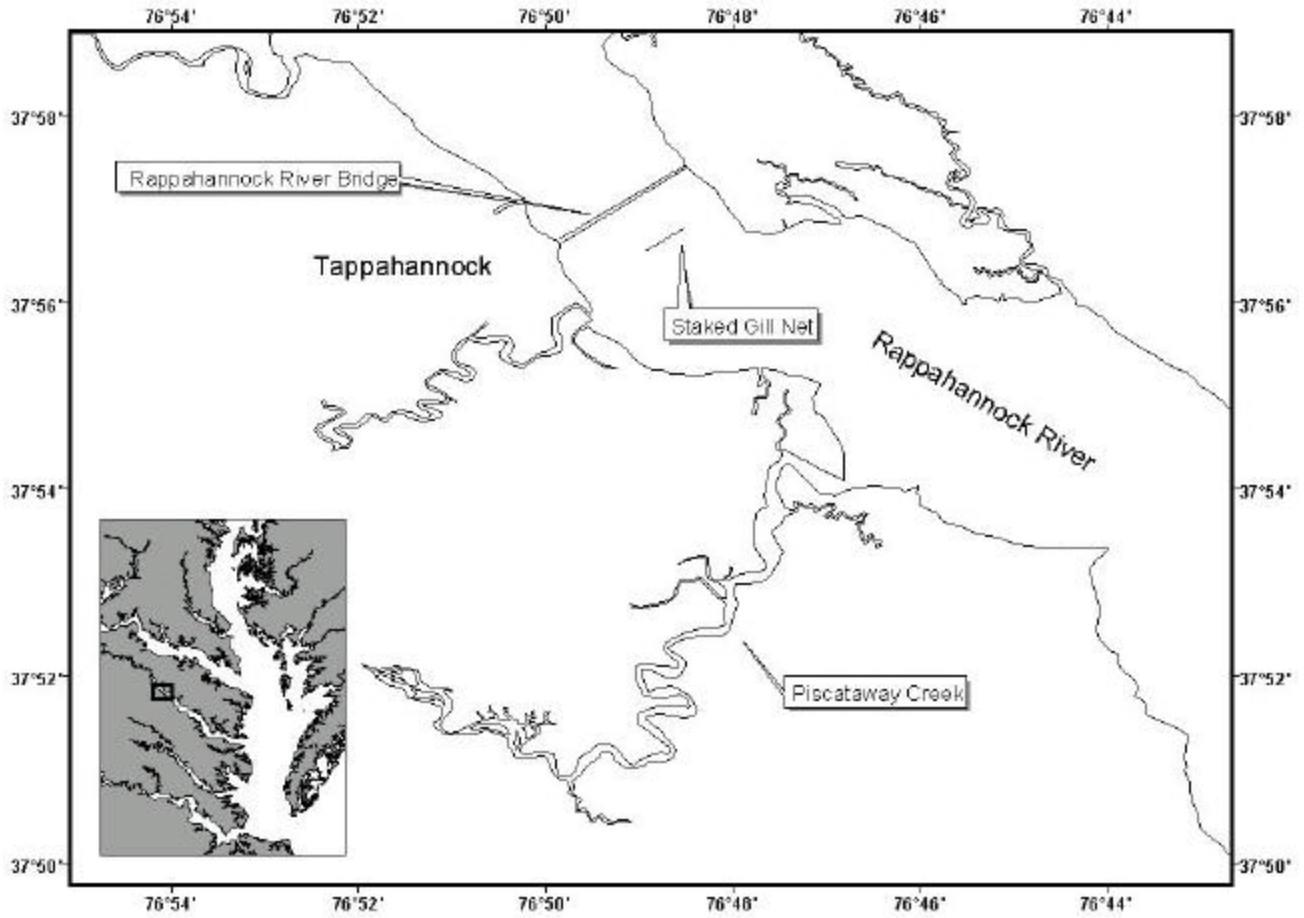


**Figure 6.** Location of the staked gill net fished by Mr. Raymond Kellum on the York River. The length of the net (273 m) is not to scale.





**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 2006.**

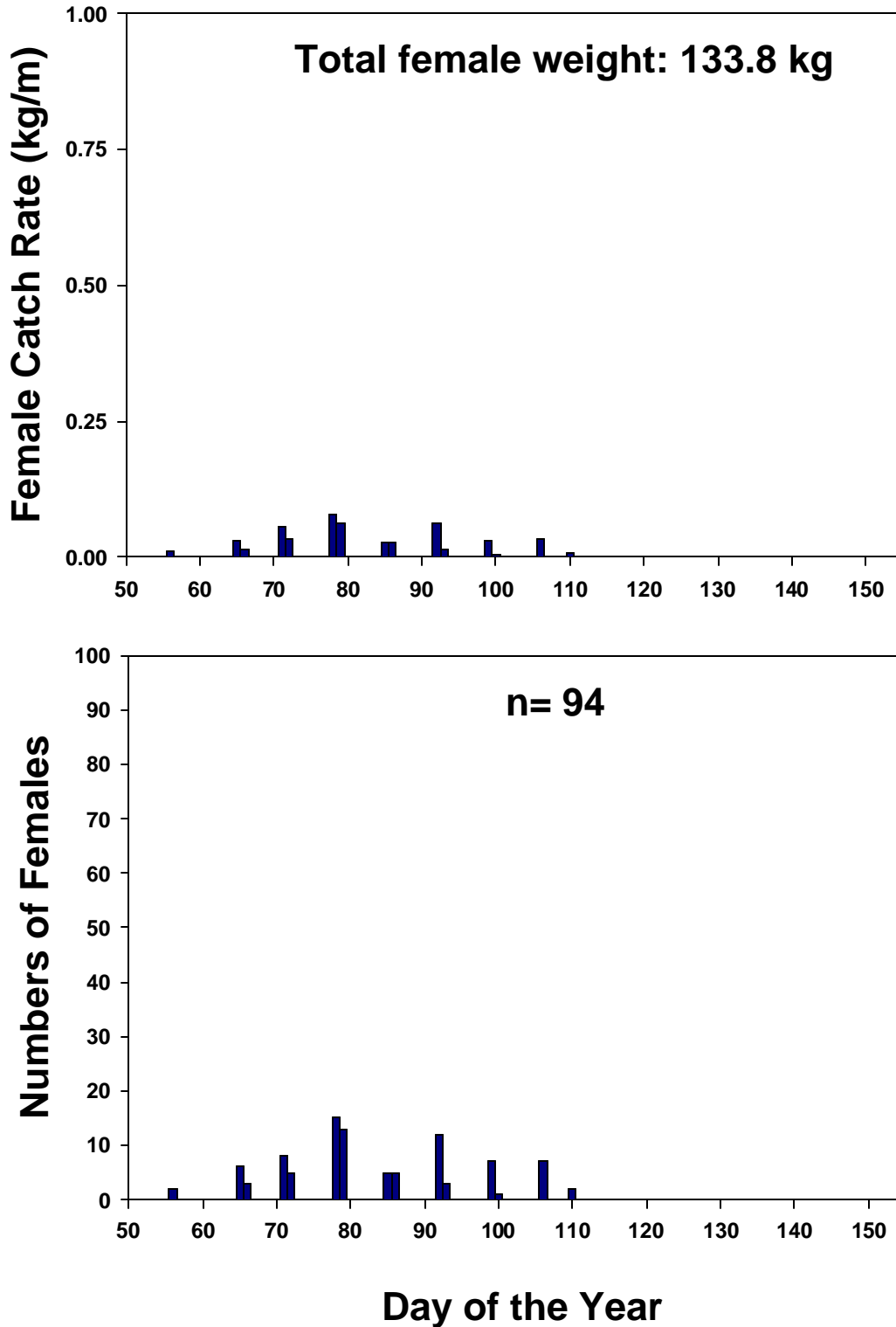


Figure 9. Catch rates and total numbers of female American shad taken by staked gill nets in the York River, spring 2006.

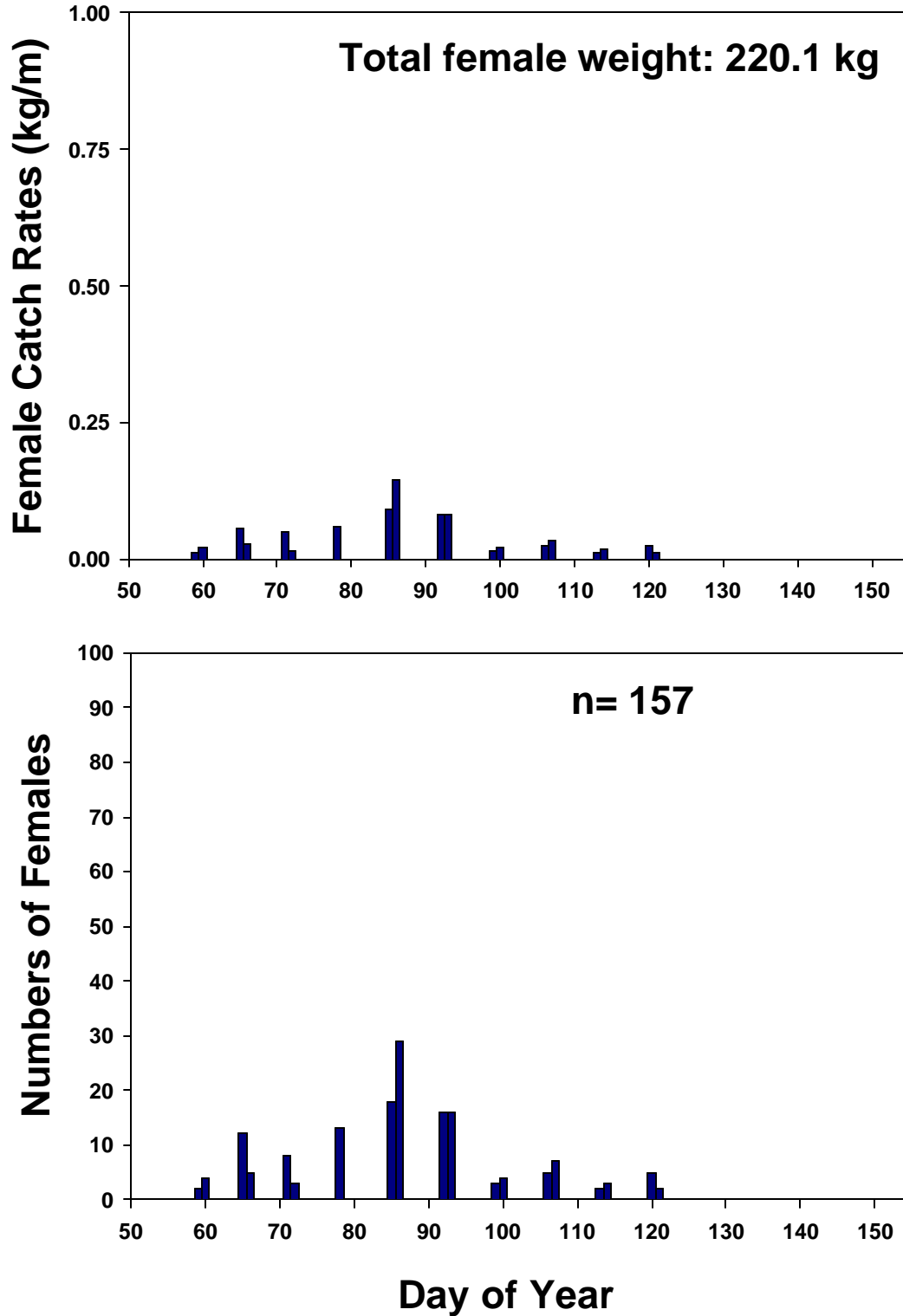


Figure 10. Catch rates and total numbers of female American shad taken by staked gill nets in the Rappahannock River, spring 2006.

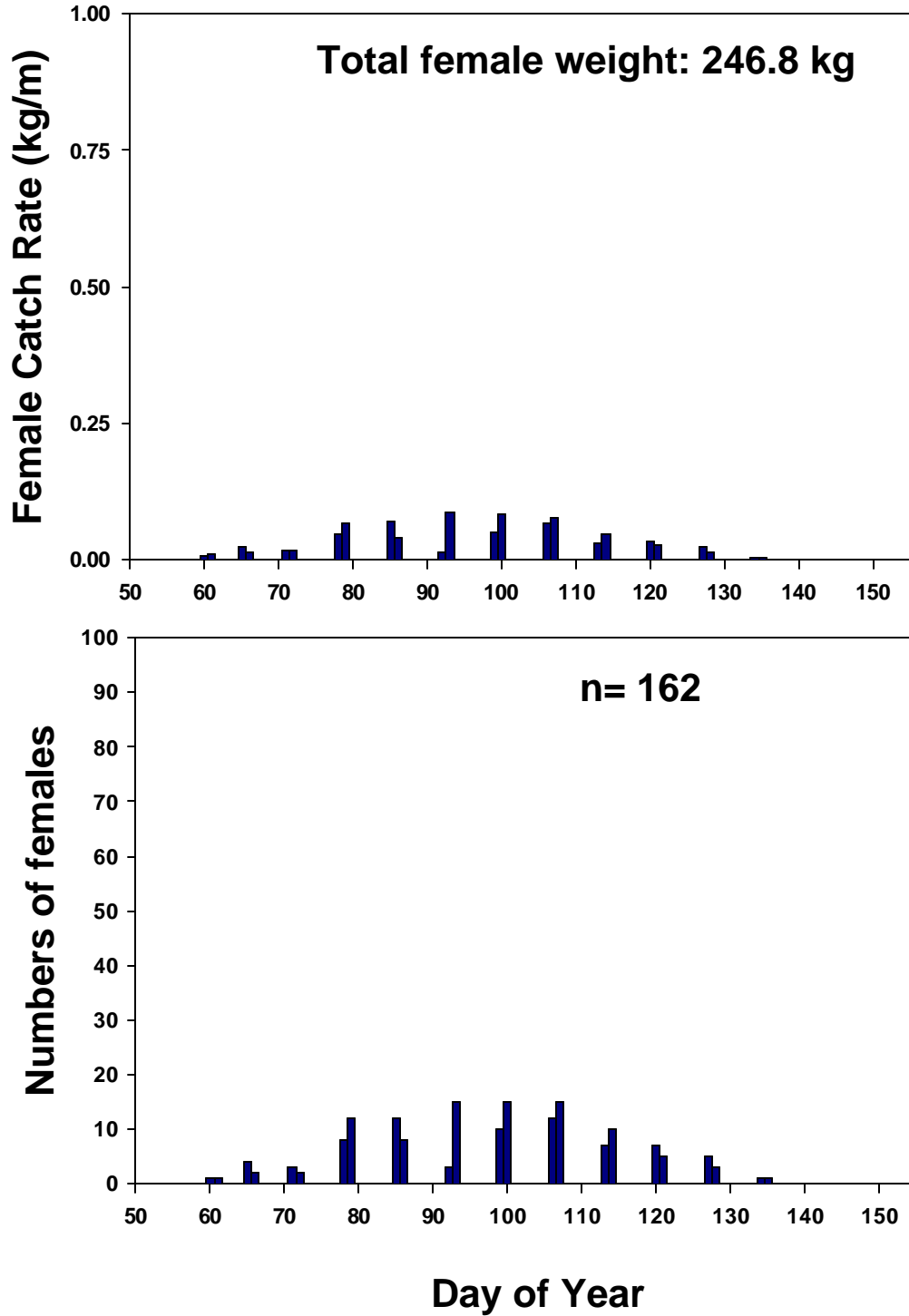


Figure 11. Catch rates and total numbers of male American shad taken by staked gill nets in the James River, spring 2006.

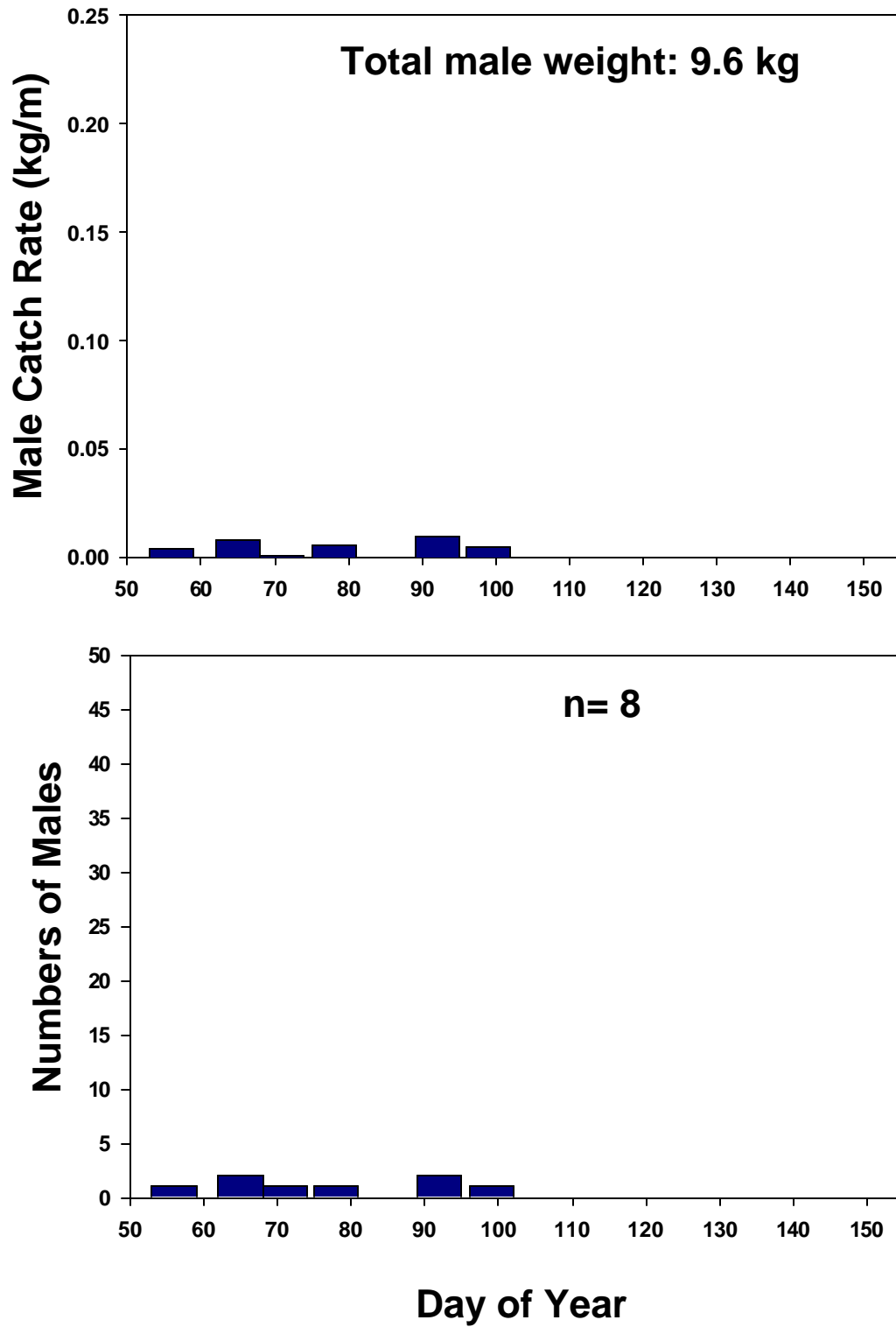


Figure 12. Catch rates and total numbers of male American shad taken by staked gill nets in the York River, spring 2006.

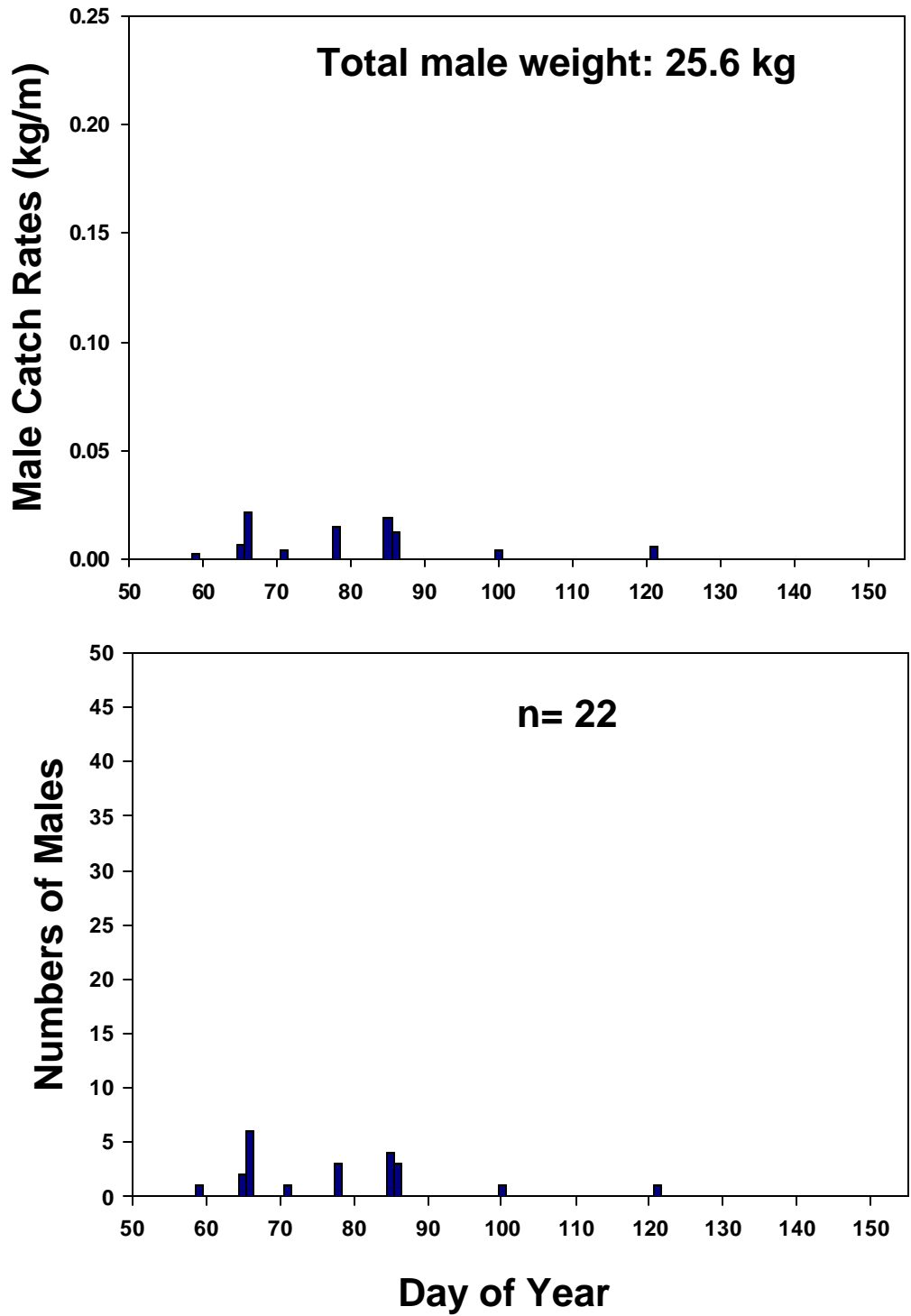
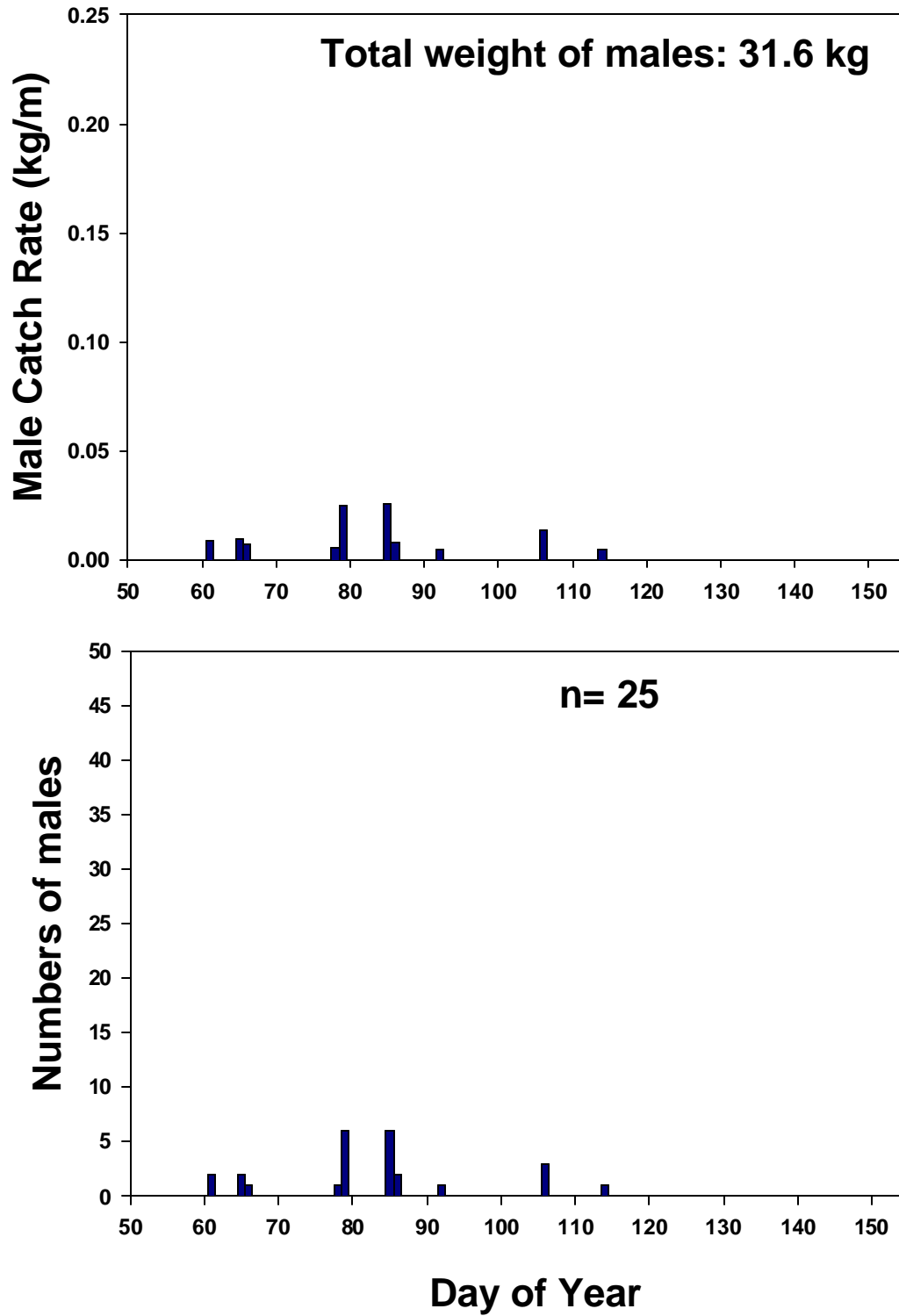
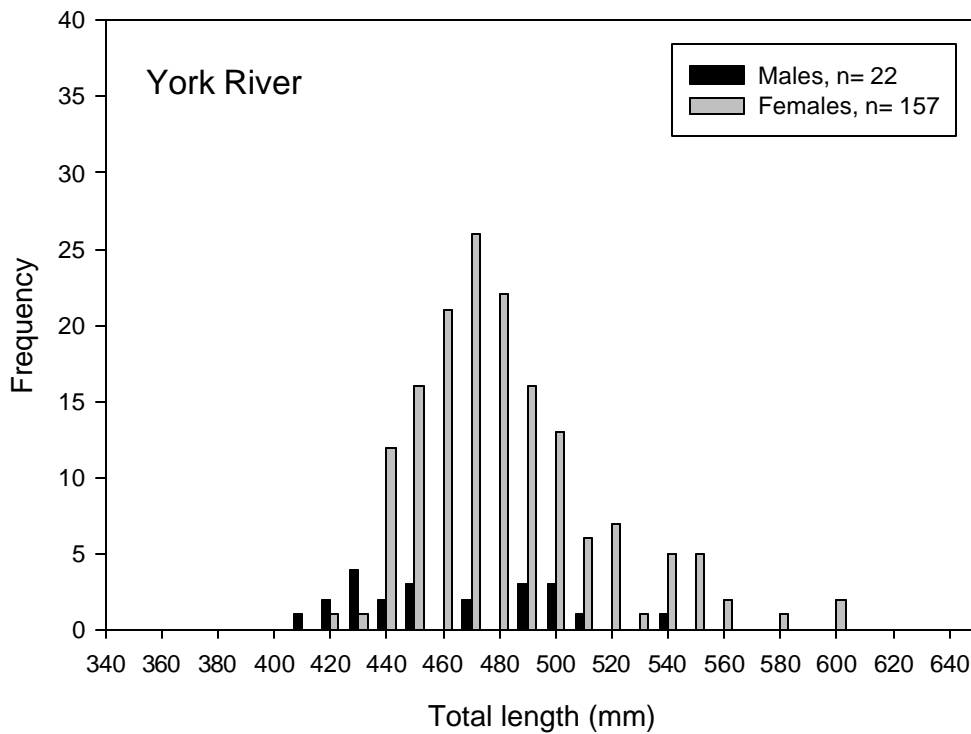
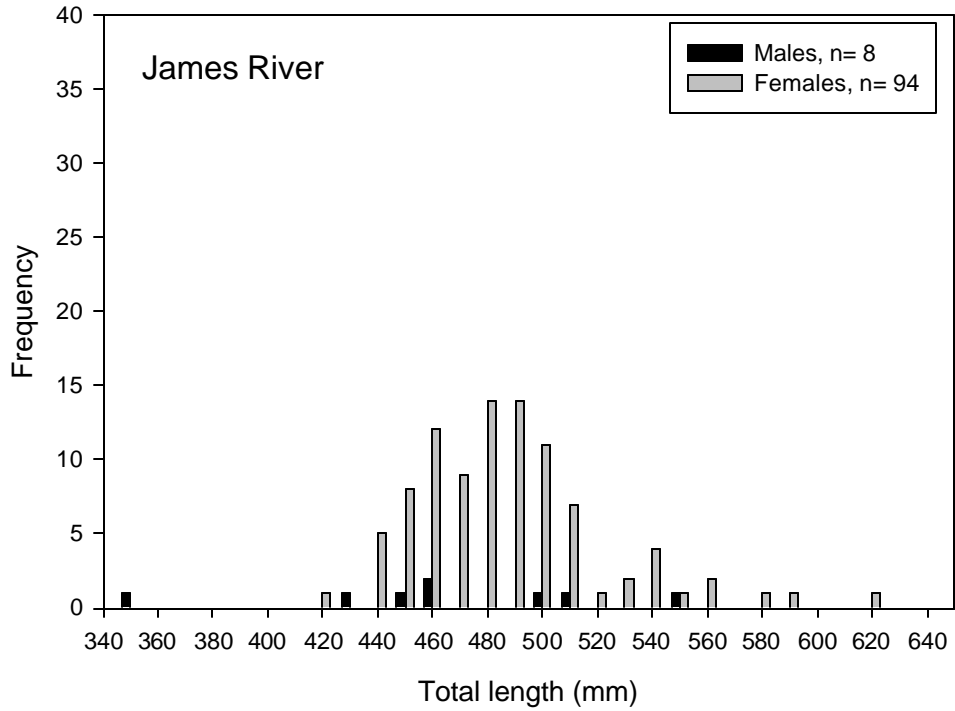


Figure 13. Catch rates and total numbers of male American shad taken by staked gill nets in the Rappahannock River, spring 2006.

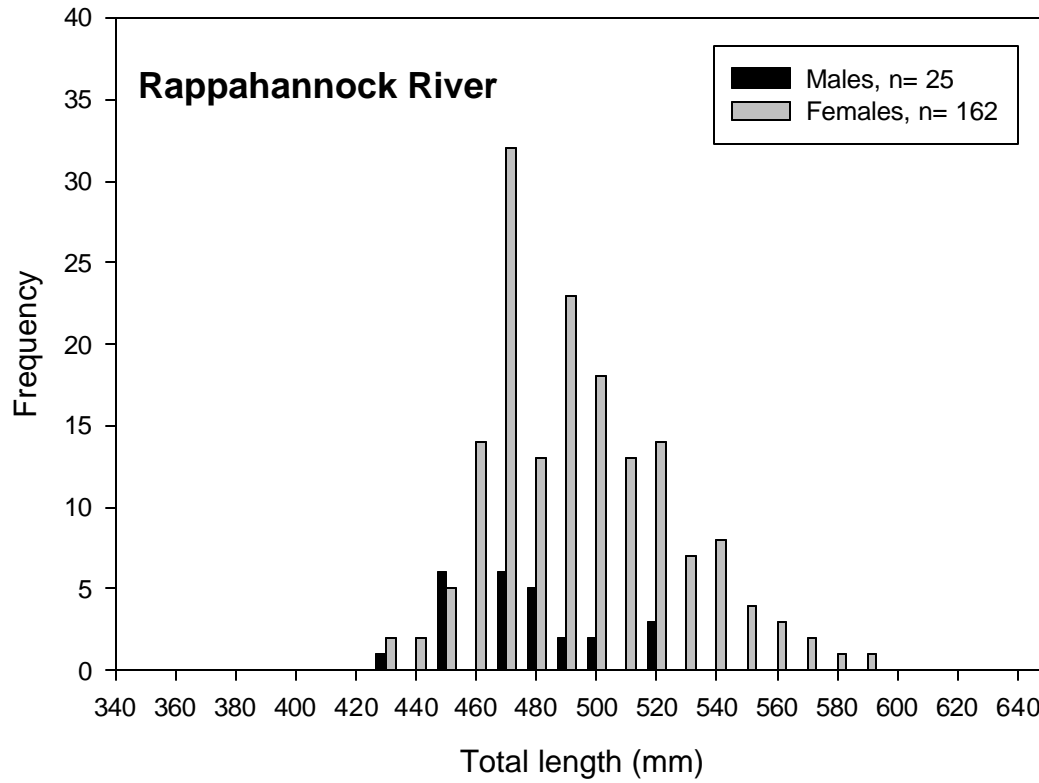


**Figure 14. Total length (mm) frequency distributions for American shad captured in staked gill nets on the James and York rivers, spring 2006.**





**Figure 15. Total length (mm) frequency distributions for American shad captured in staked gill nets on the Rappahannock River, spring 2006.**



**Figure 16.** The index of juvenile abundance of American shad in the York River system as estimated by daylight seine surveys, 1980-2006. The index is the geometric mean number of American shad juveniles per seine haul.

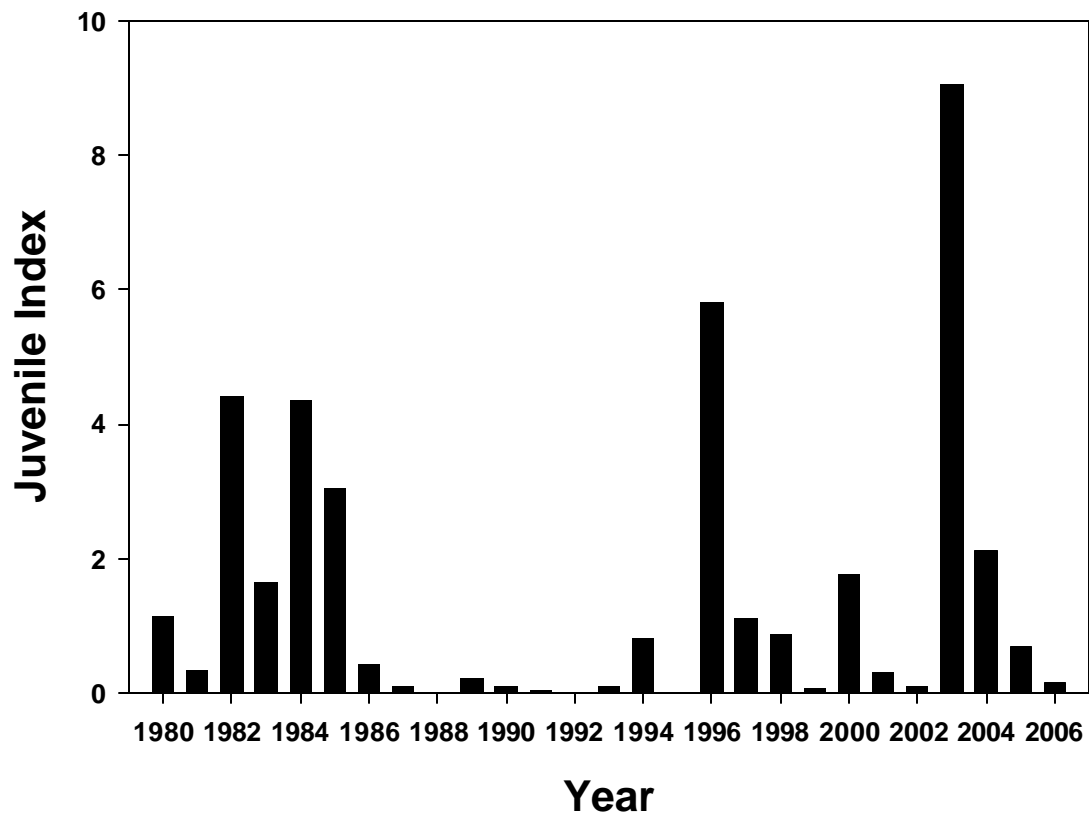
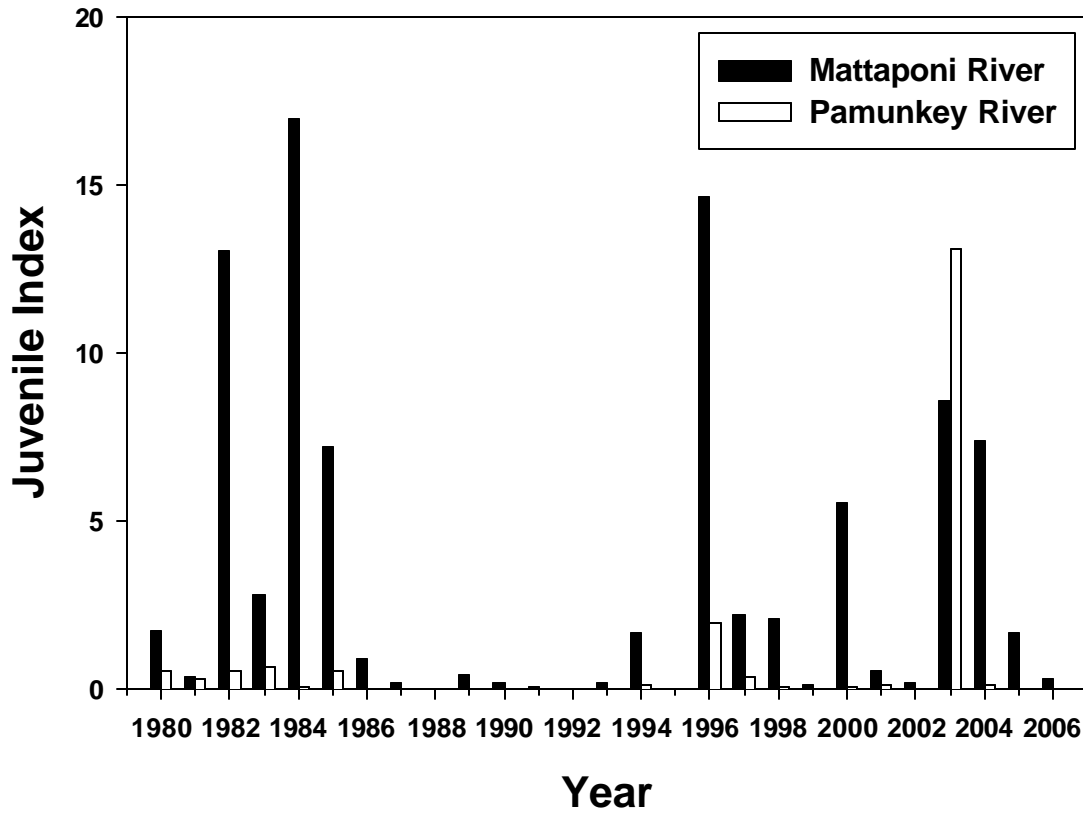


Figure 17. The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by daylight seine surveys, 1980-2006. The index is the geometric mean number of American shad juveniles per seine haul.



**Figure 18. The index of juvenile abundance of American shad in the Rappahannock River as estimated by daylight seine surveys, 1980-2006. The index is the geometric mean number of American shad juveniles per seine haul. The index in 1980 and 1981 was zero.**

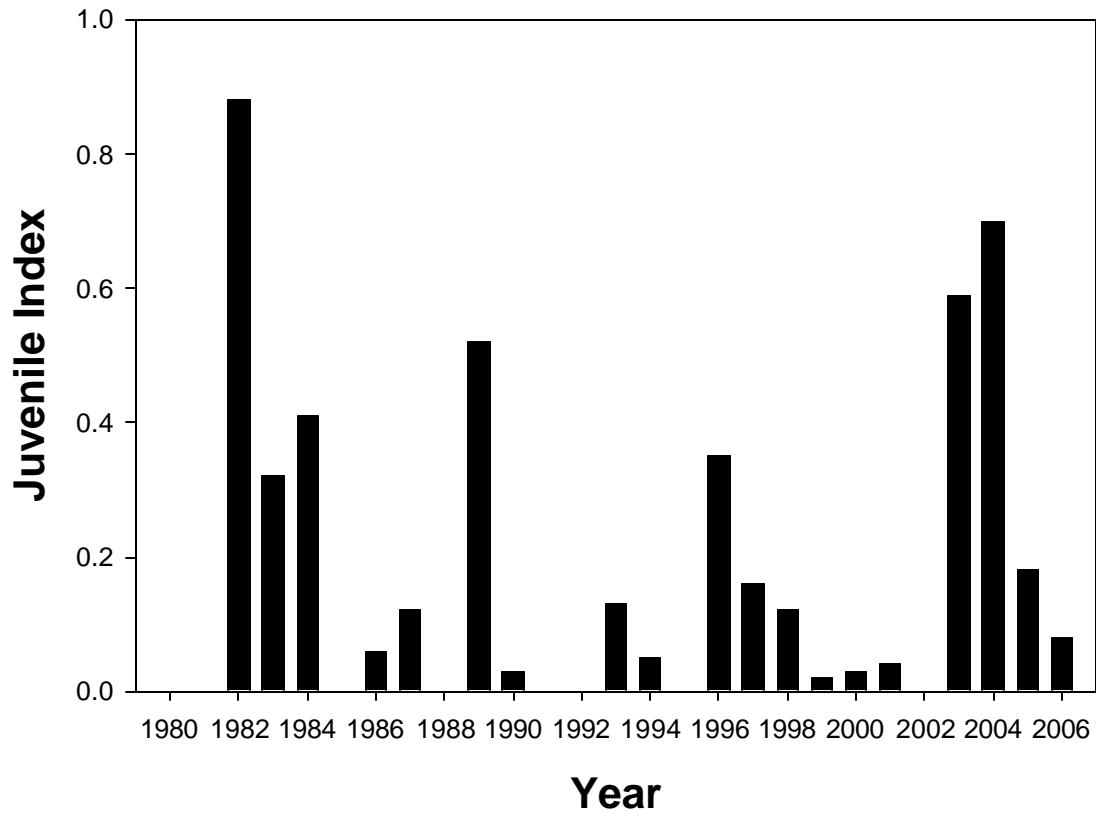


Figure 19. Mean age of females taken in staked gill nets in the James, York, and Rappahannock Rivers, 1998-2006.

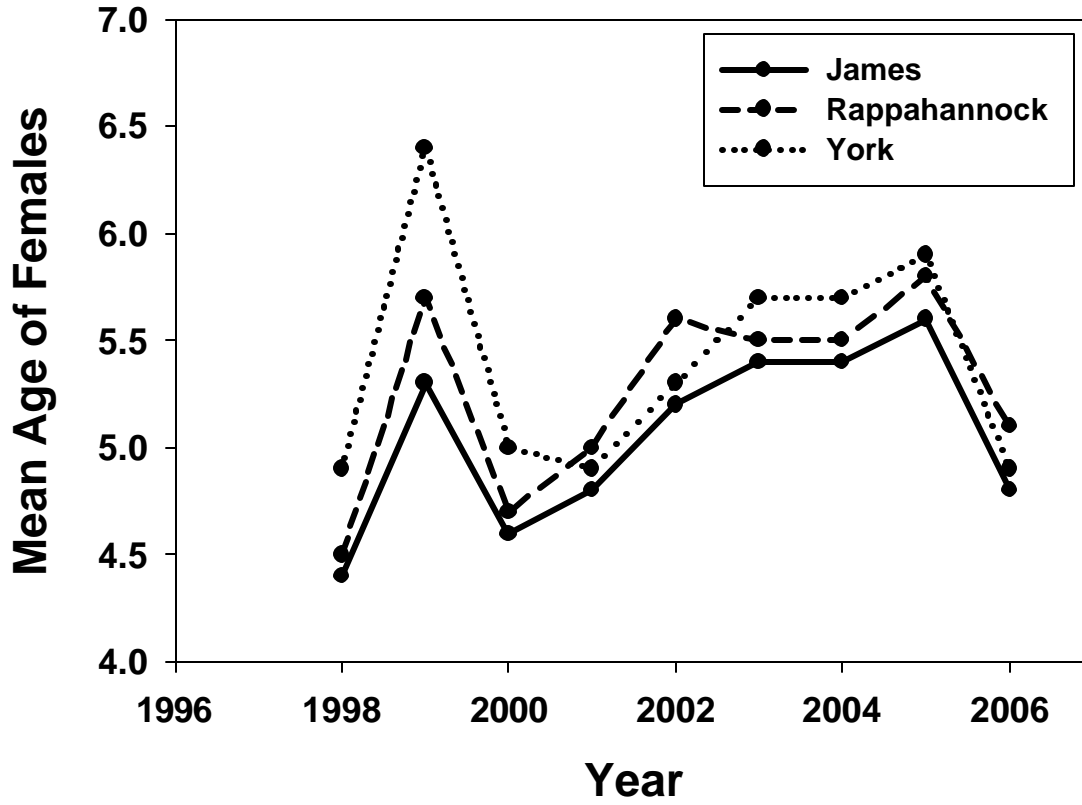


Figure 20. Mean age of females and the proportion of age-4 recruits in staked gill nets, 1998-2006.

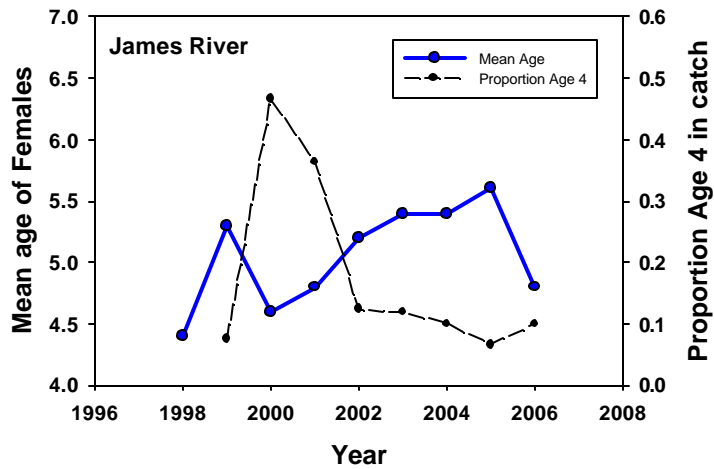
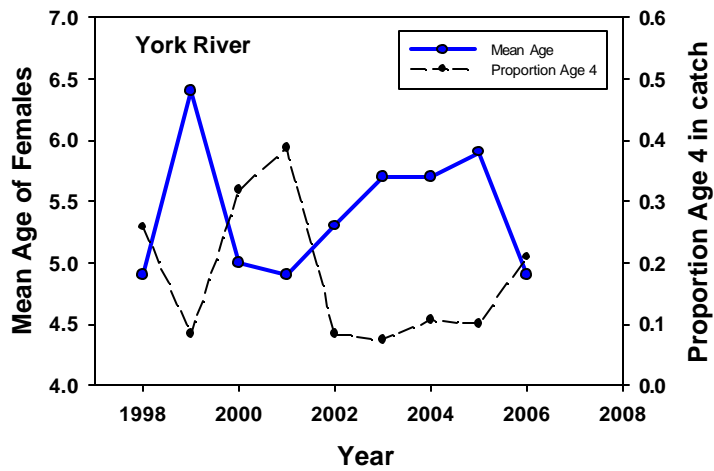
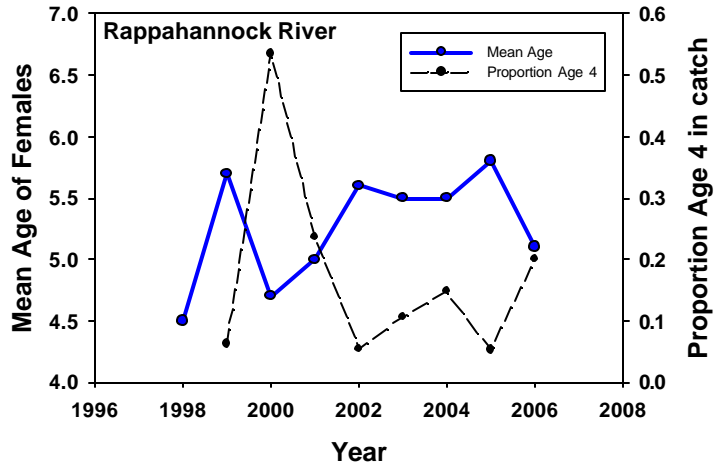


Figure 20. Recent (1998-2006) and historic values of the catch index of female American shad on the James River.

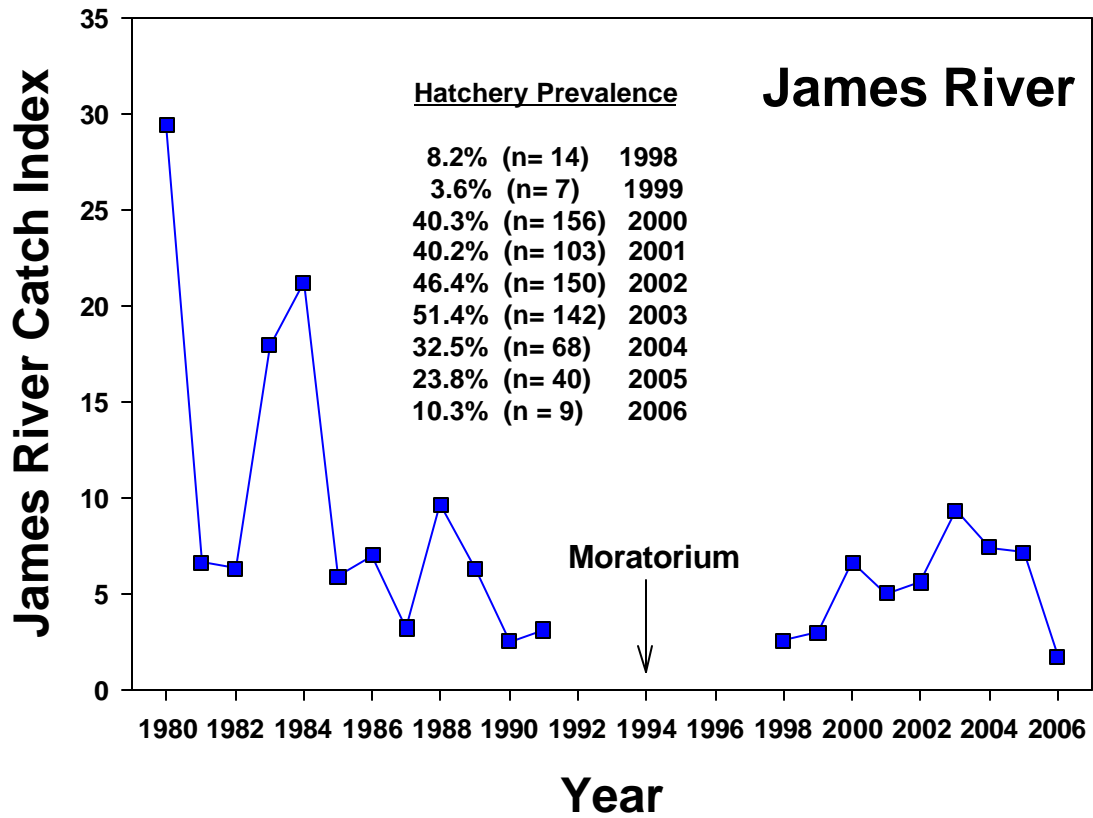


Figure 21. Recent (1998-2006) and historic values of the catch index of female American shad on the York River.

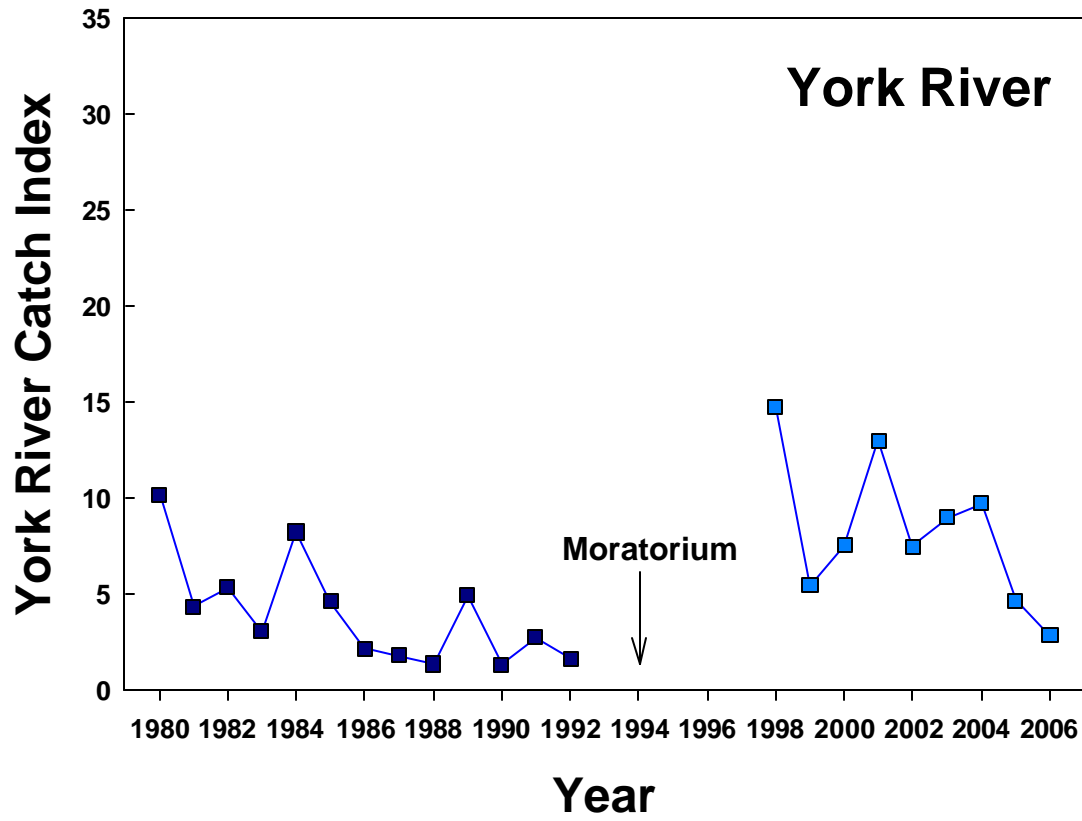
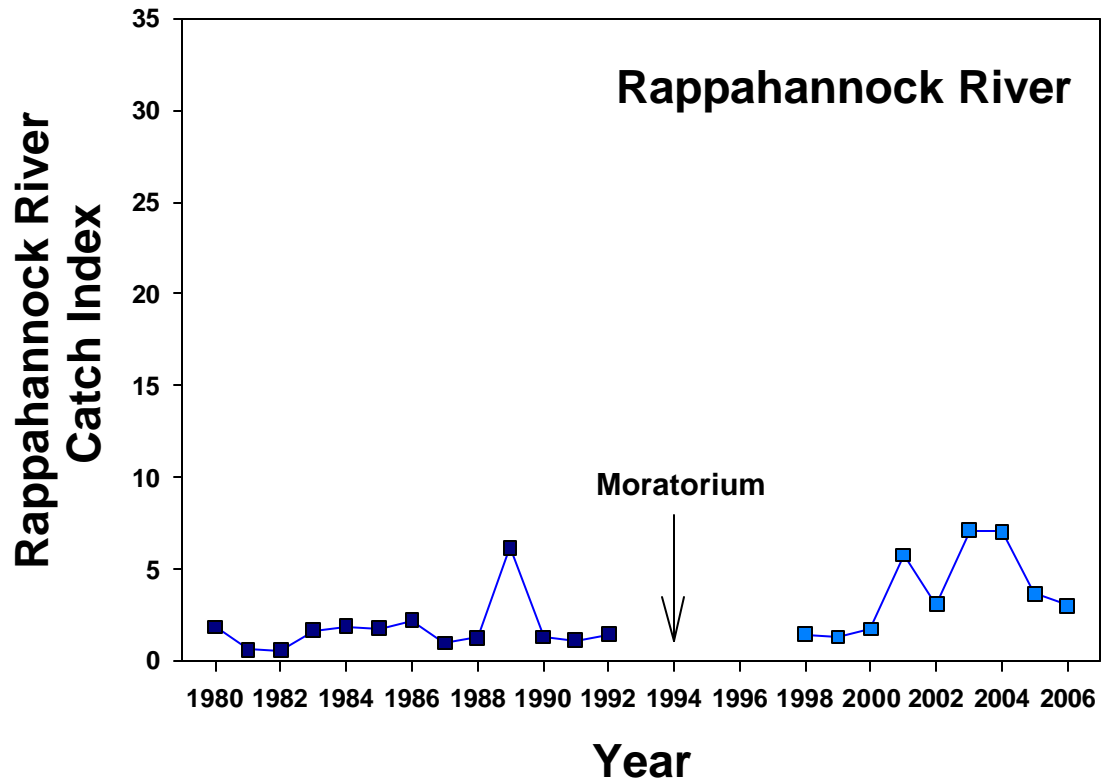
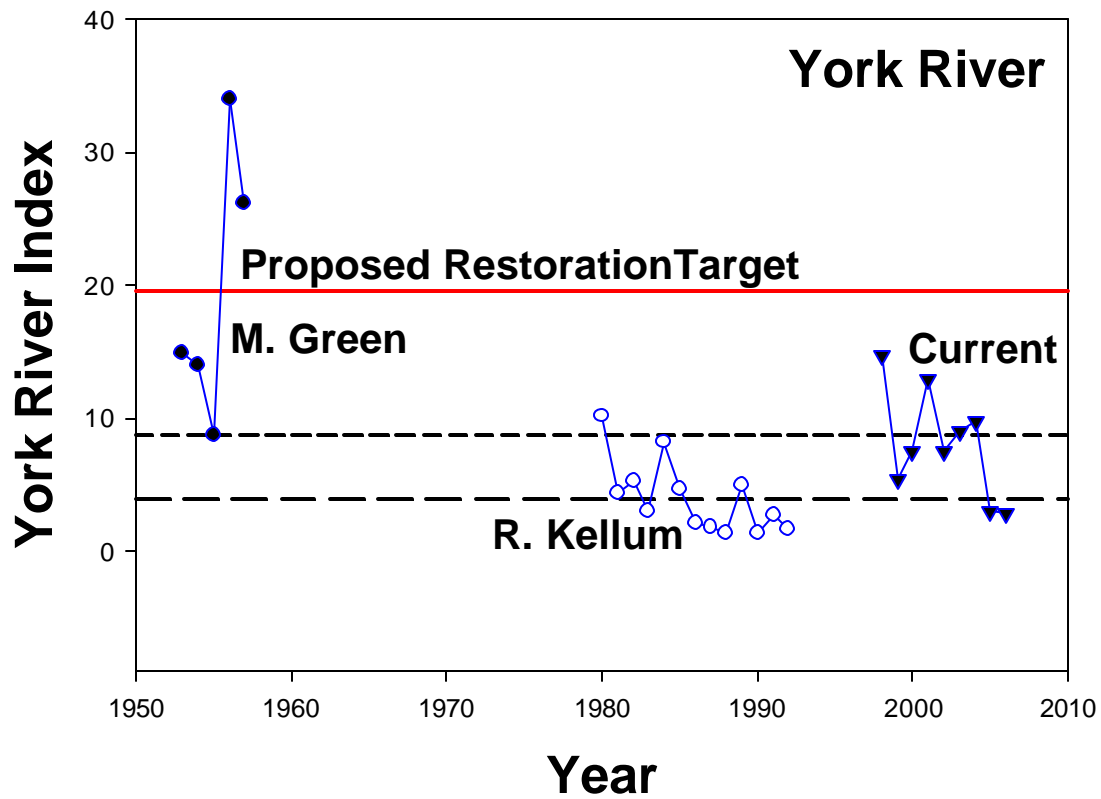




Figure 22. Recent (1998-2006) and historic values of the catch index of female American shad on the Rappahannock River.



**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)



## **Appendix I**

### **Status of the stocks of American shad in Virginia Rivers**

#### Contributors

John E. Olney, Kristen A. Delano and Robert J. Latour  
School of Marine Science  
Virginia Institute of Marine Science  
Gloucester Point, Virginia 23062

Thomas P. Gunter, Jr. and L. Alan Weaver  
Virginia Department of Game and Inland Fisheries  
Ashland, Virginia 23005

#### **Executive Summary**

A moratorium on the taking of American shad in Virginia rivers and the Chesapeake Bay was imposed by the Virginia Marine Resources Commission in 1994 in response to sharp declines in commercial landings. The offshore intercept fishery in Virginia coastal waters was closed in December 2004. Drift-net fishing by two Native American tribal governments and the taking of brood stock by the Virginia Department of Game and Inland Fisheries on the spawning grounds of the York River system for stock restoration in the James River are permitted. An active catch and release recreational fishery exists on the James and Rappahannock rivers and to a lesser extent, the York River. Currently, monitoring of American shad stocks in Virginia is conducted cooperatively by the Virginia Marine Resources Commission (VMRC), the U.S. Fish and Wildlife Service (USFWS), the Virginia Department of Game and Inland Fisheries (VDGIF) and the Virginia Institute of Marine Science (VIMS). Primary fishery-independent data sources are: fish passage counts, hatchery evaluations, catch rates of staked gill nets, and juvenile abundance surveys. Fishery-dependent data are limited to creel surveys for recreational catch and effort, and historic landings and effort data prior to the moratorium. Currently, age determination is not validated for American shad stocks in Virginia rivers. Indexes of juvenile abundance are validated for certain maturing age classes on the York River. Assessment approaches are (1) evaluating current status by comparing contemporary catch indexes (the area under the curve of daily catch rates versus time in staked gill net monitoring) to those recorded in voluntary commercial log books of fishers in the 1950s and from 1980 to 1993, and (2) examining patterns of juvenile recruitment and hatchery restoration success (prevalence of hatchery-marked mature fish). A yield-per-recruit model using York River stock-specific growth parameters was constructed for the Native American tribal drift gill net fishery to provide a baseline overfishing definition.

Restoration targets are established using geometric mean catch index values from historic log books. Restoration targets based on historic data from the 1950s are considered appropriate since commercial landings in that period were relatively stable, suggesting a sustainable fishery. The 1950s gill nets were constructed of multi-filament rather than

monofilament material. As a result, gear comparisons were required to relate the current catch index to the 1950s logbook data. Targets based on more recent data (the catch index values of the 1980s) are less desirable. Stock level was low during that period, and incapable of supporting an active fishery. In the 1980s and early 1990s, catches of American shad declined sharply and the harvest could not be sustained. It is important to note that shad fisheries in the upper Chesapeake Bay (Maryland waters) were closed in 1980 due to severe declines in harvest.

On the York River, the geometric mean of the historical catch index during the 1980s is 3.22. The geometric mean of the current catch index is higher (8.34), indicating some recovery from the severe declines in the 1980s and early 1990s. The comparison suggests that the York River stock has recovered to a level that is close to its abundance during the 1980s. However, the stock level was low during that period and incapable of supporting an active fishery. Additionally, catch indexes have been trending downward in recent years on the York River. A restoration target of 17.44 (the geometric mean of the catch index values observed in 1953 to 1957) is appropriate to assess the stocks. The geometric mean of the current catch index (8.34) is lower than the average of catch indexes from log book records in the 1950s (17.44). Poor juvenile production in 1995 and 1997 to 1999 has reduced recruitment of age-4 fish to the spawning population in recent years and increased mean age. A baseline overfishing definition ( $F_{30}$ ) for the York River gill net fishery of the tribal governments is 0.27 (at  $M= 0.35$ ).

On the James River, the geometric mean of the historical catch index during the 1980s is 6.40. The average of the current catch index is lower (5.39), indicating that the James River stock has not recovered from the severe declines in the 1980s and early 1990s. Although densities of larval shad are often high on the spawning grounds, there is little evidence of recruitment success and the James River stock is dependent on hatchery inputs. Hatchery cohorts are recruiting in higher proportions and catch rates by staked gill nets are increasing. Fish passage counts at Boshers' Dam peaked in 2002 but have declined recently. Low juvenile production has resulted in an increase in mean age in recent years. Logbook data from the 1950s are available but are not directly comparable to the current monitoring location. The James River stock remains at a low level of abundance relative to the historical data.

On the Rappahannock River, recent values of the catch index are higher than all but one year (1989) in the historical data. The geometric mean of the historical catch index during the 1980s on the Rappahannock River is 1.45. The geometric mean of the current catch index is higher (3.20). Low juvenile production in 1995 and 1997 to 1999 resulted in an increase in mean age since fewer age-4 fish are recruiting to the spawning population. Historical data from the 1950s that are directly comparable to the current monitoring location are not available. Thus, an interim restoration target for the stock (1.45) is based on the 1980s data; currently the stock exceeds this target. 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. On

the basis of 1980s and current catch rates, the present status of the Rappahannock River stock is stable with recent evidence of increasing abundance.

## Appendix II

### Potomac River Assessment Approaches and Results

Contributors: Kristen A. Delano, John E. Olney and Rob Latour (Virginia Institute of Marine Science) and Bob Sadzinski (Maryland Department of Natural Resources)

#### Executive Summary

The Potomac River is a major tributary of the Chesapeake Bay, the area of its watershed ranking fourth on the East Coast. The estuary extends 113 miles from its mouth to the head of tide. At Little Falls, a low head dam for water withdrawal has a newly installed fish passage facility that allows American shad to extend their spawning range an additional 10 to 12 miles up stream to Great Falls, a natural barrier to all anadromous species.

Historical records on American shad fisheries of the Potomac date back to the Colonial period. The first recorded mention of shad was in 1612 when it was said, “Shad, great store, of a yard long, and for sweetness and fatness a reasonable food fish.” During the early years of the nineteenth century, shad landings were estimated to range in the tens of millions of pounds annually and exceeded one hundred million pounds several times. The latter part of that century through the early part of the twentieth century saw landings in the 2 to 3 million pound range. By the middle part of the last century landings were generally less than a million pounds and by the 1960s and early 1970s they had dropped to less than one-half million pounds. In 1980 landings had dropped to only 17,000 pounds and the fishery (except for pound net bycatch) was closed.

To assess the status of American shad on the Potomac River, we examined trends in estimates of total mortality, juvenile abundance, catches in a fishery-independent gill net survey, and landings in commercial pound nets. Pound net landings since 1999 (bycatch plus discards) were compared to historic data to judge current status. The gill net index, the pound net index and the juvenile abundance index depict strongly increasing trends in relative abundance. Since 2002, estimates of total mortality are declining. Recent total mortality estimates are within the range of reference values derived from a yield model exercise. From 1944 to 1956, Potomac River landings of American shad were relatively stable, averaging approximately 850,000 pounds annually, and ranging from about 500,000 to 1,300,000 pounds. In the late 1970s, total landings of American shad decreased sharply from 120,000 pounds in 1976 to 16,000 pounds in 1980. A moratorium on the taking of shad was established in 1980. The geometric mean of the 1940s to 1950s pound net landings is 31.1 pounds per net day. The geometric mean of the 1970’s data is 2.9 pounds per net day. The geometric mean of the current data is 13.6 pounds per net day. The mean of the current pound net catch (bycatch plus discard) is well below the 1950’s average (when catches were sustainable), but is greater than the 1970’s average (when landings were not sustainable) and is increasing. A proposed restoration target for American shad in the Potomac River is the geometric mean of pound net landings

reported in Walburg and Sykes (1957) for the years 1944 to 1952. The proposed target is 31.1 pounds per net-day. Among Chesapeake Bay stocks of American shad, the Potomac River population shows the most promising signs of recovery.

## **Appendix III**

### **Assessment of the 2006 Virginia by-catch of American shad and the status of the Virginia stocks – submitted to the Atlantic States Marine Fisheries Commission, December 2006**

John Olney, Kristen Delano and Pat Crewe  
Department of Fisheries Science  
Virginia Institute of Marine Science  
Gloucester Point, VA 23062

#### **Introduction**

In spring 2006, scientists at the Virginia Institute of Marine Science (VIMS) interviewed permitted fishers who had agreed to participate in the required monitoring program and obtained samples of their by-catch. This report: (1) summarizes the results of fishery independent monitoring of the spawning stock in 2006; (2) summarizes the results of 2006 VIMS by-catch monitoring; (3) provides an estimate of the total by-catch (permitted and non-reported) of American shad in all gears in 2006; (4) projects potential by-catch by gill nets in 2007; (5) provides an assessment of the York River stock based on annual monitoring and a newly developed target total mortality rate; and (6) reports the current status of monitoring on the James and Rappahannock rivers.

This report is a companion to a separate report of the 2006 by-catch prepared by the Virginia Marine Resources Commission (VMRC).

#### **Results of the 2006 Fishery-Independent Monitoring Studies**

The strength of the spawning run of American shad in Chesapeake Bay was poor in 2006. Catches of mature American shad in fishery-independent monitoring gear in Virginia and Maryland dropped to record low levels when judged by the time series of data extending to 1998. Catch-per-unit-effort (Potomac River) and catch index values (the area of the curve of catch rate versus day of the year) in Virginia rivers are depicted in Figure 1. Catch index values recorded in the James and York rivers were the lowest values observed in the monitoring time series. Catches in the Potomac and Rappahannock rivers were the lowest observed since 2000.

#### **Biological Characterization of the 2006 Permitted By-Catch in Virginia**

A subsample of the 2006 by-catch of American shad (n= 69 fish, 27.2% of the total reported to VMRC) was obtained from cooperating fishers and processed for length, weight, sex, maturity stage, age, and the presence of hatchery (OTC) marks. VIMS received an additional 12 American shad from the VMRC that were by-catch in non-



permitted gear outside of the permitted by-catch area. These specimens are summarized separately.

Telephone surveys were conducted weekly with eight cooperating fishers who obtained by-catch permits on the James, York, and Rappahannock Rivers (Table 1). Estimates of catch rates were available for a portion of the sample (n=62). Some collections were obtained from multi-mesh nets that lacked data on length of net so these collections are excluded from the summary data.

Catch and effort information are recorded for each date of harvest in Tables 2-3. Based on telephone interviews, catch per trip varied from 1-12 fish and averaged 2.4 fish/trip (standard deviation, 2.5) among all cooperating fishers. Mean catch rate of individual fishers varied from 1-3.4 (Table 2). The overall catch rate calculated from data reported to VMRC was 1.1 fish per trip (254 fish/233 trips).

The by-catch subsample contained 7 males and 62 females. Most of the subsample was harvested in anchored gill nets (n= 66) with only 3 fish taken in staked gill nets. The subsample contained fish captured in the York River (n= 49) and James River (n=20). No specimens were obtained from the Rappahannock River. Most of the sub-sample was taken in 5-inch stretched mesh nets (Figure 2). The subsample ranged in size and age from 364-620 mm TL and 3-10 years (Figure 3). The smallest specimens were taken in the smallest mesh sizes but size frequencies did not differ markedly among the mesh sizes (Figure 4; samples sizes are small, however). The size frequency distribution of the by-catch subsample was generally similar to the size frequency distribution of the monitoring sample (Figure 5). Size frequency distributions were similar in the James and York rivers (Figure 6).

Hatchery-produced American shad were present in the by-catch subsample (21% of all fish in the James River (4 of 19); 2% of all fish in the York River (1 of 45). Sizes and ages of these marked fish were 364-570 mm TL and 3-9 y. All but one hatchery specimen were female.

Six non-permitted American shad were taken by haul seine in the York River and six non-permitted American shad were taken by anchor gill net in the lower Chesapeake Bay. Specimens ranged in size and age from 420-600 mm TL and 3-9 y, respectively.

### **Estimates of the Total 2006 By-Catch in Virginia**

In addition to the by-catch of American shad reported to the VMRC in permitted gill nets within the permitted by-catch areas, we estimated by-catch in other gears throughout the entire Chesapeake Bay in 2006. We examined VMRC trip records for haul seines and pound nets fished in Virginia waters in February-April 2006. Spring pound net trips (n= 439) in 2006 were reported by 26 fishers operating in all areas of the Chesapeake Bay from the Great Wicomico River to the lower Bay, including nets in the Rappahannock River. Spring haul seine trips (n= 46) were reported by 12 fishers

operating from the lower Bay to Pocomoke Sound, including the York, and Poquoson Rivers. We did not include haul seine sets in coastal waters or embayments. We also examined commercial log book records of a single pound net fisher operating three nets off the mouth of the Rappahannock River (Figure 7). These data depict pound net catches (numbers of shad per day) since 2002. We used the 2006 pound net catch records in our analysis (Table 4).

We estimated that approximately 6,000 American shad were taken as by-catch in gill nets, pound nets and haul seines in 2006 in Virginia in-shore waters (Table 4). The analysis suggests that more fish encountered pound nets (~80% of the total) operating outside of the permitted by-catch fishing area than in any other gear.

We readily acknowledge uncertainty in this estimate of total by-catch in non-permitted gears. Pound net catches of American shad are known to vary widely by location of individual nets and there are few reliable records of shad catch by this gear. In addition, we did not estimate the potential catch of gill nets set outside of the permitted area. Additional log book data from gill netters, haul seine and pound net operators would allow refinement of future estimates.

### **Predictions of the 2007 Gill Net By-Catch in Virginia Given Status-Quo Management Provisions of 2006**

To predict the potential by-catch of American shad in a gill net fishery in 2007 (the 'status quo by-catch provisions' as described in the VMRC proposal for 2007), we assumed that the magnitude of the by-catch in 2007 would be proportional to the catch rates observed in the fishery-independent monitoring gear. To render the predictions, we used the maximum, minimum and average estimates of number of shad caught per trip by VIMS monitoring gear (staked gill nets) over the years 1998-2006 in each river (Table 5). These calculations provided a range of by-catch estimates under different run strength conditions that might be experienced in spring 2007. Since by-catch trips permitted in 2007 are likely to be catches in 300-ft gill nets, the catch rates of the monitoring gear (900-ft stake gill nets) were adjusted by a multiplier of 0.33. These adjusted catch rates were multiplied by the number of trips in which shad were reported as by-catch in 2006. We note that the maximum catch rate in monitoring data in the York River (16.6 fish per trip) exceeds the proposed by-catch allotment of 10 fish/trip. To predict by-catch under conditions of peak run size in the York River, we used the allotment value.

Total by-catch of American shad predicted for gill nets in all rivers in 2007, using the number of trips reporting by-catch in 2006 (VMRC data), ranged from 709 to 2,288 fish (Table 6). We note that the lower estimate (709 fish) is more than twice that reported to VMRC in 2006 (254 fish) when run strength was low. The mean catch rate reported to VIMS in phone interviews in 2006 (2.4 fish/trip) is more than twice that rate calculated from the VMRC mandatory reporting data (1.1 fish/trip).

### **Preliminary Assessment of the York River Stock**

During nine years of VIMS monitoring on the York River, the catch index has been variable with higher values ( $>12$ ) in 1998 and 2001 and lower values ( $<9$ ) in all other years. The data suggest a strong trend towards decreasing catch rates during the period of monitoring (Figure 1). In addition, low juvenile production in 1995 and 1997-1999 has reduced recruitment of young fish to the spawning population in recent years (Figure 8).

The average of the historical data during the 1980's on the York River is 3.96 (SE 0.77). The average of the current monitoring data is higher (8.93, SE 1.23), indicating some recovery from the severe declines in the 1980s and early 1990s. Monitoring in 1998-2005 suggests that the York River stock has recovered to a level that is close to its abundance during the 1980s (Figure 9). However, the stock level was low during that period, and incapable of supporting the fishery. The catch index values for the York River stock are currently well below the average of the 1950s data (Figure 10) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann 1963).

A yield-per-recruit model was constructed using gill net data to provide a baseline over-fishing definition (total  $Z$ ) to evaluate the impact of such fisheries. The modeling approach is currently used in the coast-wide stock assessment of American shad in preparation by the stock assessment sub-committee of the American shad and river herring technical committee of the Atlantic State Fisheries Commission.

The partial recruitment vector used in the yield model was adopted from the Hudson River stock assessment and assumes full recruitment to the gear after age 5. Other parameter inputs for the York River yield model are specific to the York River stock (Maki et al. 2001, maturity-at-age; Hyle 2006, fecundity-at-age). Weight-at-age for York River fish was estimated from the best fit length-at-age model (details provided upon request). Table 7 presents yield model inputs including estimates of  $M$  based on the methods of Hoenig (1983). Maximum age of the York River stock is 12 y, corresponding to  $M = 0.35$ . Yield per recruit corresponding to maximum ages of 8, 10 and 12 are depicted in Figure 11.

The target total mortality rate ( $Z_{30}$ ) in the York River is estimated to be 0.62. Current estimates of total mortality ( $Z$ ) for the York River stock using catch-at-age and repeat spawning data are higher (Figure 12). These results suggest that mortality induced by human activity (including by-catch mortality of immature and mature fish) is excessive and may be a cause of the slow recovery of the York River stock.

### **Current Status of James and Rappahannock River stocks**

The average of the historical data during the 1980's on the James River is 8.88 (SE 2.23). The average of the current VIMS monitoring data is lower (5.84, SE 0.81). Although densities of larval shad are often high on the spawning grounds, there is little evidence of recruitment success on the James River, and the stock is dependent on

hatchery inputs. Hatchery cohorts are recruiting in higher proportions to the James River population and the VIMS catch rate is increasing (Figures 1, 13). However, the stock remains at a low level of abundance relative to the historical data and requires continued protection and restoration.

The average of the historical data during the 1980's on the Rappahannock River is 1.76 (SE 0.39) (Figure 14). The average of the current monitoring data is higher (3.90, SE 0.86). Low juvenile production in 1995 and 1997-1999 has resulted in an increase in mean age since fewer young fish are recruiting to the spawning population. There is little evidence of severe stock decline in the Rappahannock River. On the basis of historic and current catch rates, the present status of the Rappahannock River stock is stable with recent evidence of increasing abundance.

Table 1. Summary of telephone surveys conducted by VIMS for American shad bycatch in the Rappahannock, York, and James rivers from 1/30/2006 - 4/21/2006. Numbers are weekly totals of American shad caught by fisherman. Asterisk indicates specimens that were brought back to VIMS laboratory for inspection. Abbreviations are: Rapp, Rappahannock River; AN, anchored gill net; SGN, staked gill net; NF, not fishing. Blank cells are weeks of no interviews.

River	Fisher	Gear	Week											
			1/30	2/6	2/13	2/20	2/27	3/6	3/13	3/20	3/27	4/3	4/10	4/17
Rapp	1	AN				0	0	0	NF	NF	NF	NF	NF	NF
Rapp	2	AN	NF	NF	NF	0	0	0	0	NF	NF	NF	NF	NF
York	3	SGN	*1	0	0	2	0	0	0	NF	NF	NF	NF	NF
York	4	AN	NF	NF	NF	NF	NF	0	*1	NF	NF	NF	NF	NF
York	5	AN				2	0	*5	*2	*1	*6	*21	*6	*6
James	6	AN				0	*1	*6	0	0	NF	NF	NF	NF
James	7	SGN	NF	NF	NF	NF	NF	0	*1	*1	NF	NF	NF	NF
James	8	AN				*1			*1	*7	1		*2	

Table 2. Catch per unit effort (CPUE, kg/m/d and numbers/trip) associated with the subsample (n=62) of by-catch fish processed by VIMS.

River	Fisher	Total trips reporting shad	Total number of shad	Total Weight (kg)	Range of CPUE (kg/m/d)	Mean CPUE (kg/m/d)	Mean CPUE (N/trip)
JA	6	6	7	15.512	0.005-0.024	0.012	1.2
JA	8	5	7	10.409	0.006-0.030	0.019	1.4
YK	4	1	1	2.884	0.016	0.016	1.0
YK	5	14	47	72.165	0.017-0.180	0.060	3.4

Table 3. Catch per unit effort (CPUE) by sampling date for American shad by-catch samples processed at VIMS.

River	DateFished	Fisherman	Gear	Net	Mesh (in)	Net Length (ft)	Number of shad	Sex	Effort (days)	CPUE (N/m/d)	Weight_sum	CPUE_Wt
JA	3/4/2006	6	AGN	1	6	600	1	F	1	0.005	2.073	0.011
JA	3/6/2006	6	AGN	1	6	600	1	F	2	0.003	2.002	0.005
JA	3/6/2006	6	AGN	2	6	600	1	F	2	0.003	2.493	0.007
YK	3/6/2006	5	AGN	1	6	300	1	F	1	0.011	2.934	0.032
JA	3/8/2006	6	AGN	1	6	600	1	F	1	0.005	2.054	0.011
YK	3/8/2006	5	AGN	2	6	150	1	F	1	0.022	1.986	0.043
YK	3/8/2006	5	AGN	1	3.25	300	3	M	1	0.033	1.649	0.018
JA	3/9/2006	6	AGN	1	6	600	2	F	1	0.011	4.455	0.024
JA	3/11/2006	6	AGN	1	6	600	1	F	1	0.005	2.435	0.013
YK	3/13/2006	4	AGN	1	6.5	600	1	F	1	0.005	2.884	0.016
YK	3/13/2006	5	AGN	1	6	300	2	F	1	0.022	4.461	0.049
JA	3/15/2006	8	AGN	1	6	336	1	F	0.958	0.010	2.521	0.026
JA	3/22/2006	8	AGN	1	6	336	1	F	2.042	0.005	1.340	0.006
JA	3/24/2006	8	AGN	1	5	336	1	M	1	0.010	0.899	0.009
JA	3/24/2006	8	AGN	2	5	336	2	M	1	0.020	2.546	0.025
JA	3/24/2006	8	AGN	1	5	336	2	F	1	0.020	3.103	0.030
YK	3/24/2006	5	AGN	3	7	150	1	F	1	0.022	2.455	0.054
YK	3/28/2006	5	AGN	1	5.5	300	4	F	1	0.044	7.210	0.079
YK	3/29/2006	5	AGN	1	5.5	300	2	F	1	0.022	3.058	0.033
YK	4/3/2006	5	AGN	1	5	300	1	M	1	0.011	1.510	0.017
YK	4/3/2006	5	AGN	1	5	300	12	F	1	0.131	16.426	0.180
YK	4/4/2006	5	AGN	1	5	300	8	F	1	0.087	10.632	0.116
YK	4/11/2006	5	AGN	1	5.25	300	5	F	1	0.055	7.520	0.082
YK	4/12/2006	5	AGN	1	5.25	300	1	F	1	0.011	1.515	0.017
YK	4/17/2006	5	AGN	1	5	300	3	F	1	0.033	5.513	0.060
YK	4/18/2006	5	AGN	1	5	300	3	F	1	0.033	5.296	0.058

Table 4. By-catch of American shad in Virginia in 2006 by gear. Gill net data are from mandatory reporting by permitted fishers to the VMRC. Pound net and haul seine estimates are calculated on the basis of the number of reported trips through April 2006. Values used to expand the trip totals to total by-catch were 12.4 shad per trip in pound nets (the average of log book records from three pound nets off the mouth of the Rappahannock River in February-April 2006) and 6 shad per trip (taken from a single haul seine set in the Mobjack Bay in April 2006).

Gear	Trips	Total shad	Total weight (kg)	Total weight (lbs)
Gill nets	233	254	404.2	889
Pound nets	439	5,444	8,642.7	19,054
Haul seines	46	276	439.2	968
Totals		5,974	9,486.1	20,911



Table 5. Minimum, maximum, and mean numbers of shad per trip in 900-ft stake gill nets in the VIMS American shad monitoring in the James, York, and Rappahannock Rivers, 1998-2006.

	<b>James</b>	<b>York</b>	<b>Rappahannock</b>
Minimum	6.1	9.8	7.9
1998-2006	15.8	25.1	11.8
Maximum	26.7	50.4	26.6

Table 6. Predicted by-catch of American shad (numbers) in gill nets in Virginia in 2007, by river. Estimates were generated the number of trips in 2006 that reported shad as by-catch. Trips were multiplied by the number of shad per trip in VIMS staked gill net monitoring, 1998-2006. These estimates were adjusted for the 300-ft nets used in the fishery by applying a correction factor of 0.33 to the data in Table 5. Note that the estimate of the maximum number of shad per trip on the York River exceeds the proposed 2007 by-catch allowance of 10-fish per boat. \* To predict by-catch under conditions of peak run size, we used the proposed allotment value of 10 fish per trip.

<i>James River</i>	<i># shad per trip adjusted for 300-ft net</i>	<i># trips reporting shad in 2006</i>	<i>Total by-catch</i>
	Minimum (2.0)	27	54
	Maximum (8.8)	27	238
	Average (5.2)	27	140

<i>York River</i>	<i># shad per trip adjusted for 300-ft net</i>	<i># trips reporting shad in 2006</i>	<i>Total by-catch</i>
	Minimum (3.2)	198	634
	Maximum (16.6)*	198	1,980
	Average (8.3)	198	1,643

<i>Rappahannock River</i>	<i># shad per trip adjusted for 300-ft net</i>	<i># trips reporting shad in 2006</i>	<i>Total by-catch</i>
	Minimum (2.6)	8	21
	Maximum (8.8)	8	70
	Average (3.9)	8	31

Table 7. York River stock yield model input parameters.

Yield model input parameters for the York River iteroparous stock (females only).

**M - Natural mortality**

Age invariant	
	Maximum age
M	(Hoenig's method <sup>d</sup> )
0.350023244	12
0.420794392	10
0.52716802	8

**F - Fishing mortality**

values run 0.0-0.7

Age	Maturity <sup>a</sup>	Fecundity <sup>b</sup>	Growth <sup>c</sup>		Natural Mortality <sup>d</sup>	Partial Recruitment Vector <sup>e</sup>
	York River values	York River values	York River, VA; weight at age			(vulnerability -at- age to fishery)
			Linear von Bertalanffy Growth mode <sup>e</sup>			
			g	lbs		Hudson River values
1	0		82.100185	0.180837411		0
2	0		363.17308	0.799940701		0
3	0.02	249268.3167	708.70404	1.561022109		0.03
4	0.33	360979.8324	1026.3152	2.260606189		0.64
5	0.68	452682.2325	1287.0377	2.834884846		1
6	0.80	524887.517	1492.3273	3.287064437		1
7	0.999	581546.1433	1653.4155	3.641884374		1
8	1	626905.437	1782.3782	3.925943179		1
9	1	664476.4143	1889.1976	4.161228301		1
10	1	696871.1644	1981.3004	4.36409773		1
11	1	725932.4429	2063.9256	4.54609157		1
12	1	752922.3879	2140.6617	4.715113857		1

a - Maturity, maximum likelihood estimates of proportion mature at age from Maki et al., 2001

b - R. Hyle, unpublished; assumes spawning duration=34 days, spawning frequency=2.9 days, 30 eggs/g

c - Delano et al., unpublished; weight=a\*((498.2+6.1166\*age)\*(1-exp(-0.4568\*(age-0.0735))))\*\*b, where a=0.000056, b=2.752

d - Hoenig, 1983; M=Exp(1.46-1.01\*Ln(max age))

e- K. Hattala's recruitment vector for the Hudson River stock

Figure 1. Results of experimental gill net (Potomac River) and staked gill net (Virginia rivers) catches of American shad in 2006 compared to previous years of monitoring.

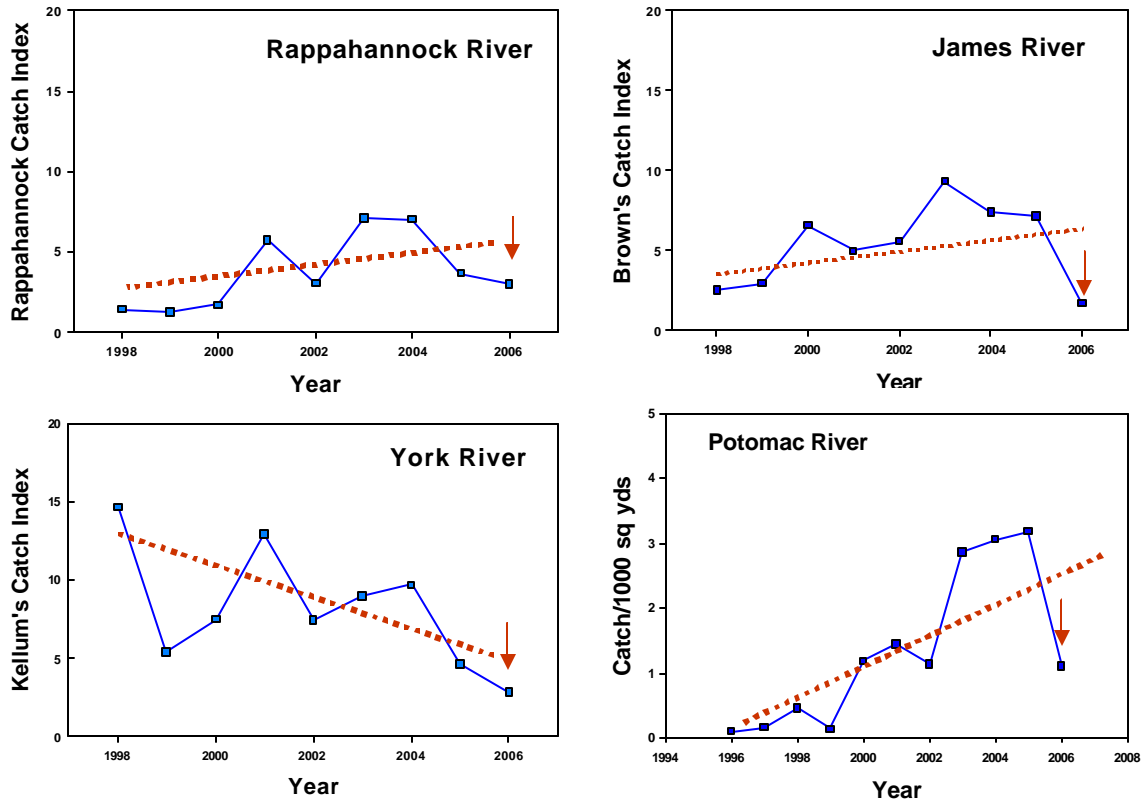


Figure 2. The number of American shad captured by mesh size in the by-catch subsample (n= 69 fish).

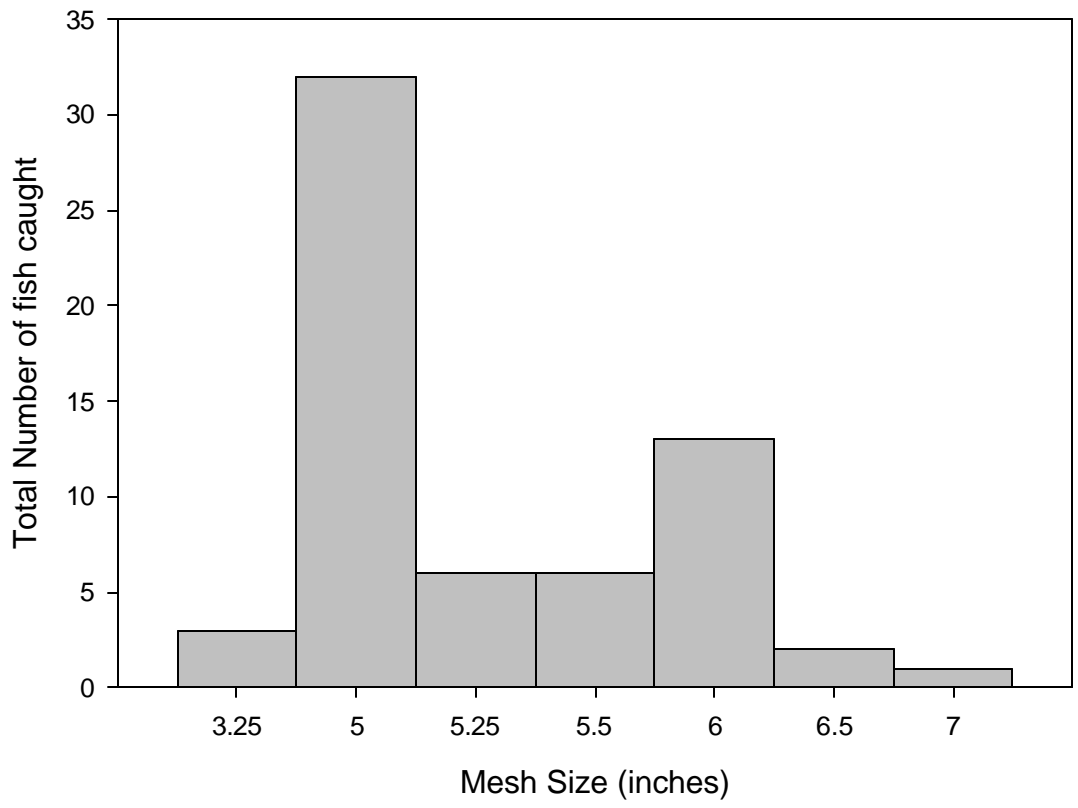


Figure 3. Size (upper panel) and age frequency (lower panel) of the by-catch subsample, 2006 (both sexes). Ages were determined by one reader using the methods of Cating 1953.

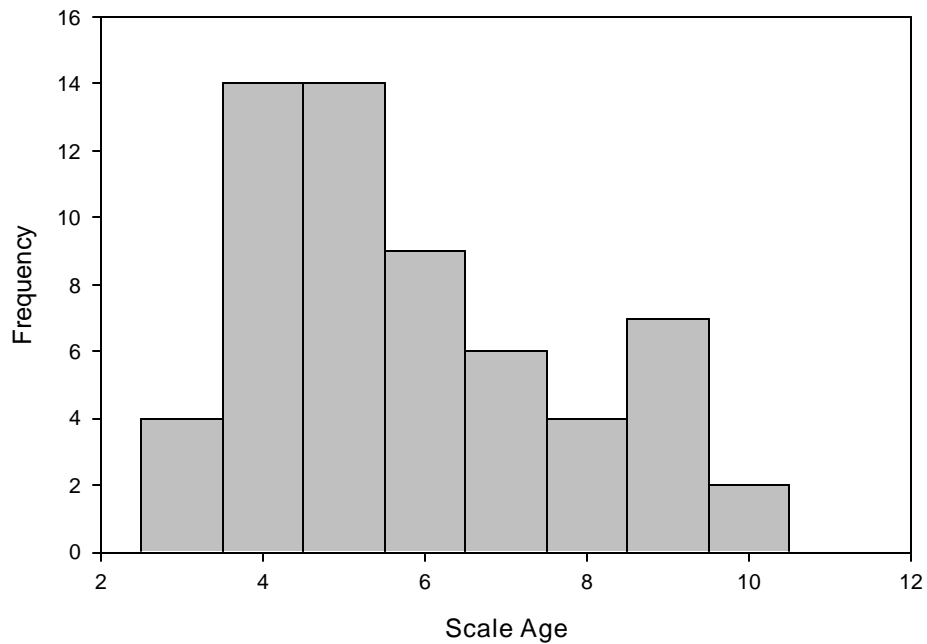
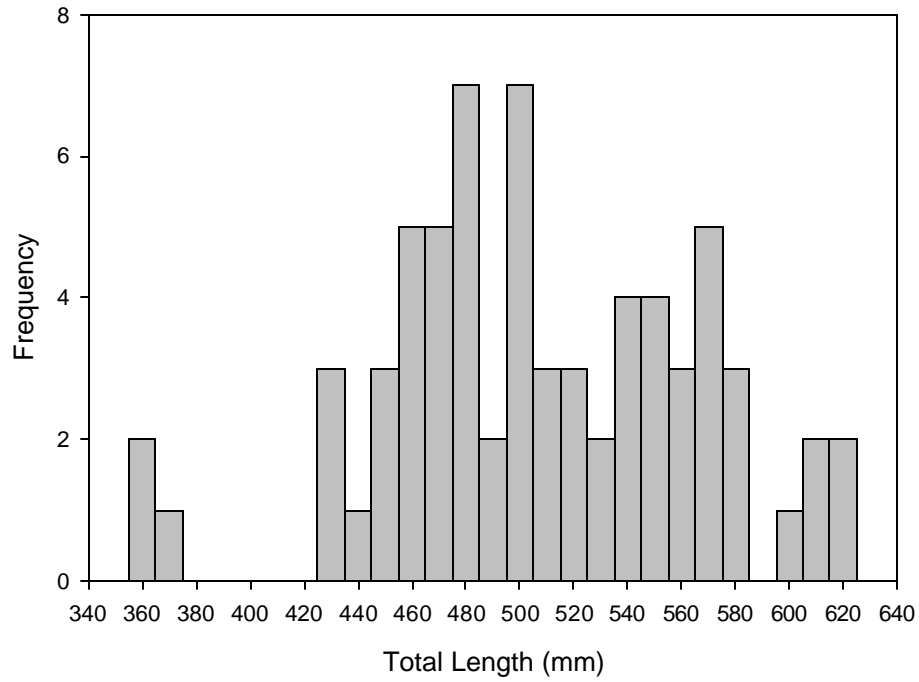


Figure 4. Size frequency of by-catch subsample by mesh size (both sexes).

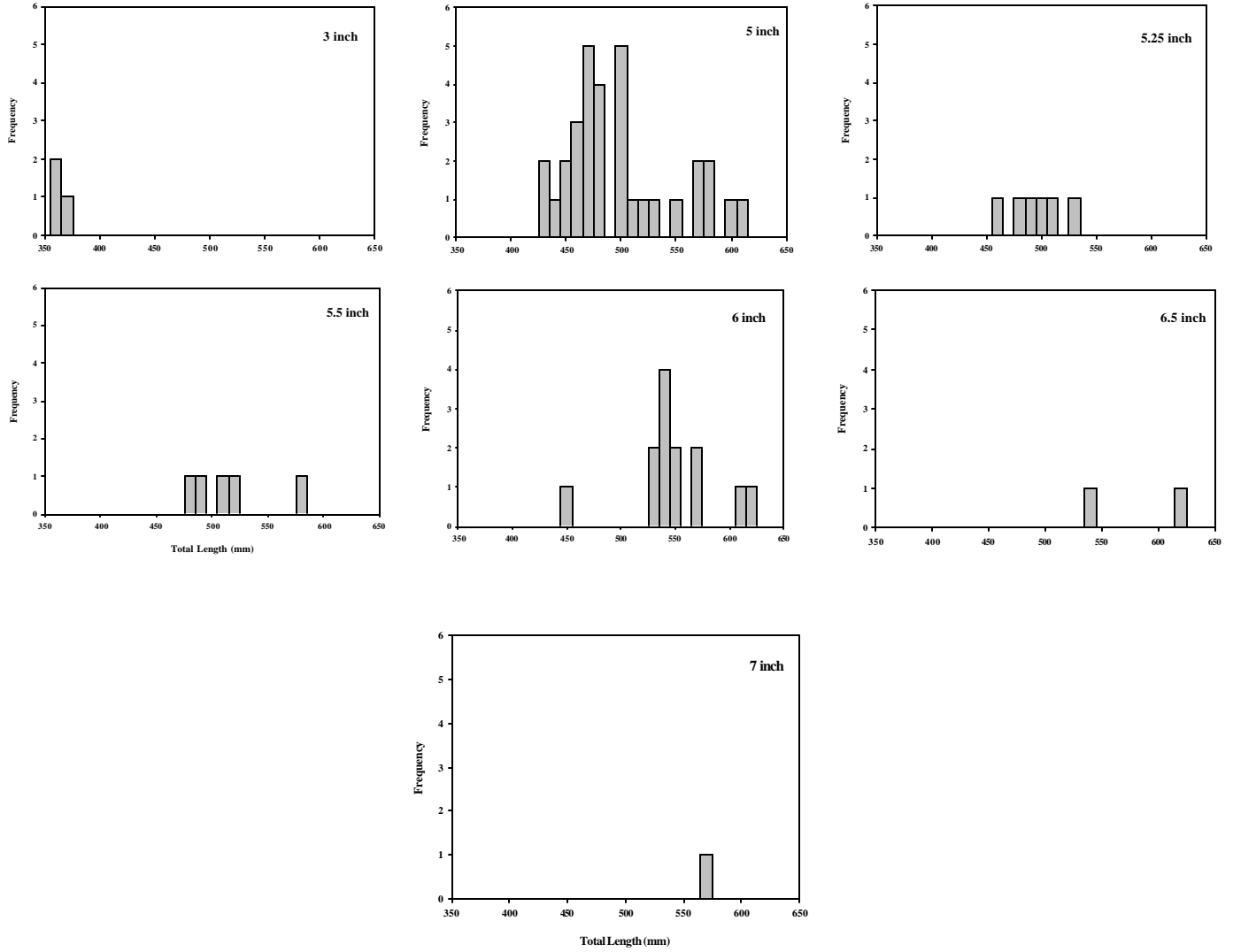


Figure 5. Comparison of size frequencies of the 2006 anchored gill net by-catch and the 2006 fishery-independent, staked gill net monitoring catch in the York 3.25 to 7-inch stretch mesh.

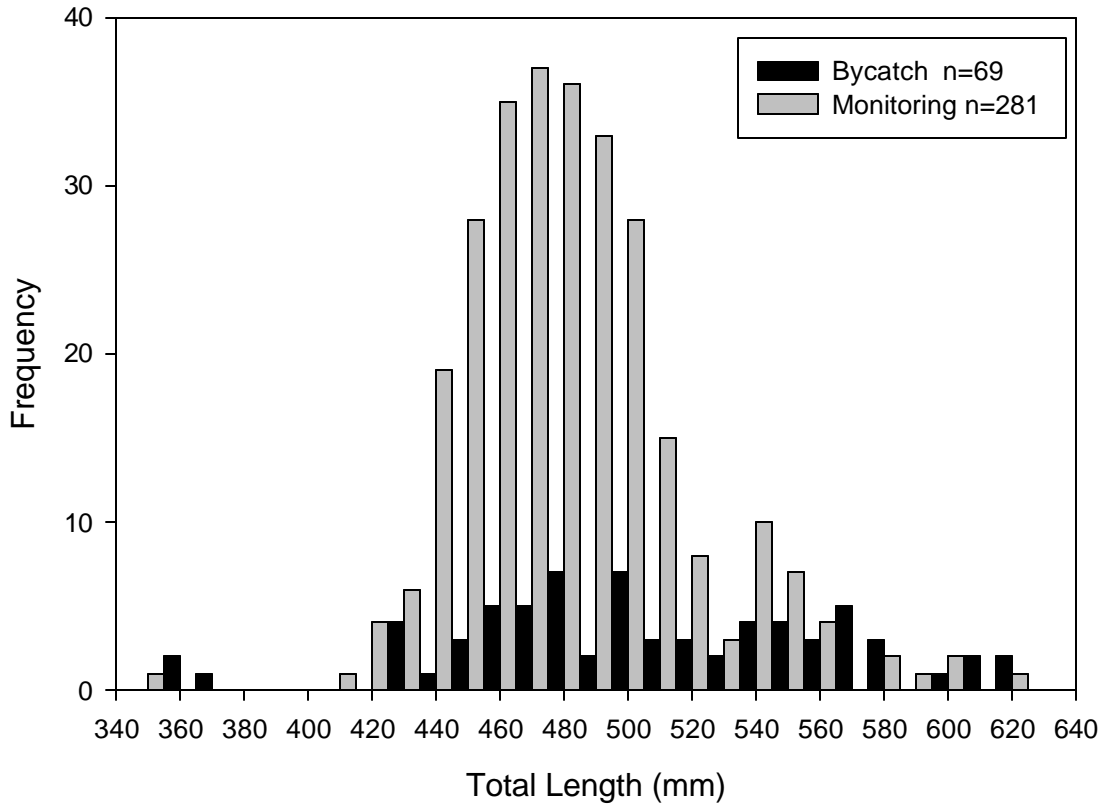




Figure 6. Comparison of size frequency distribution of the by-catch subsample by river.

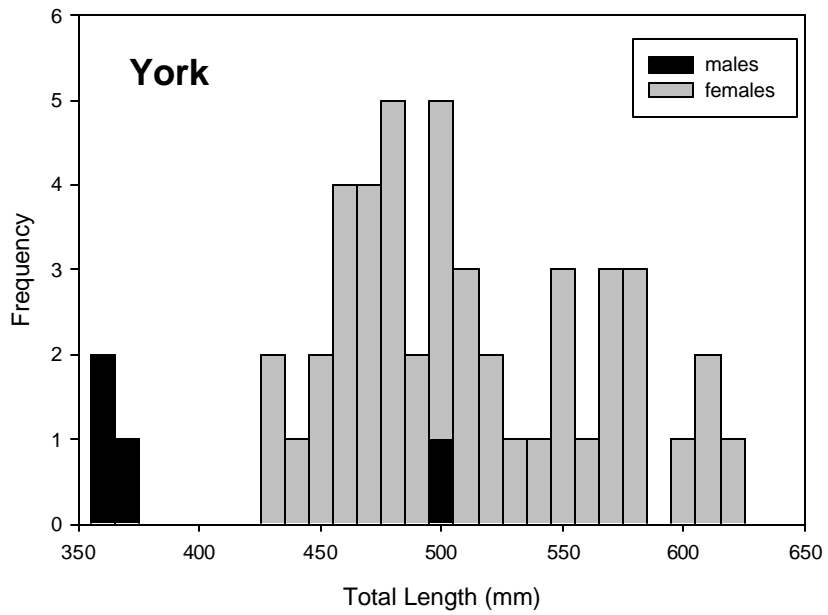
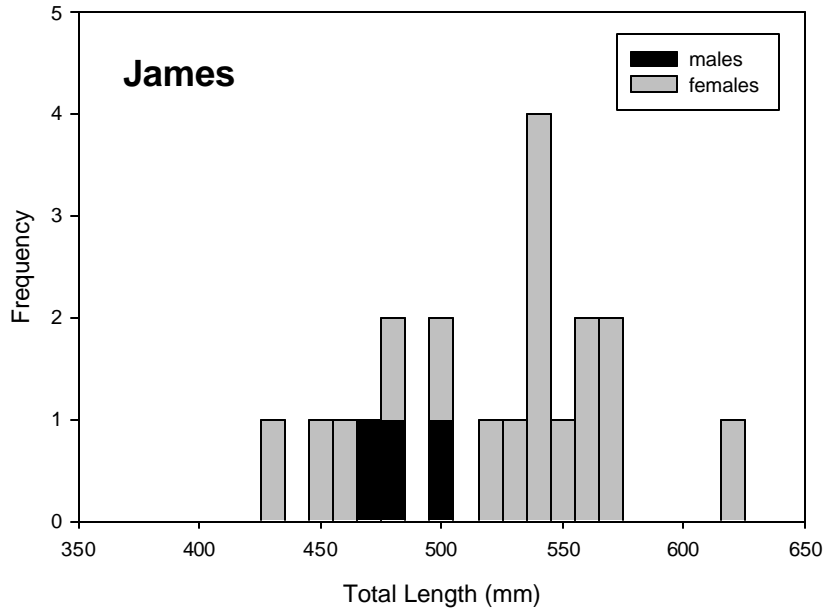


Figure 7. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Great Wicomico River. Data are taken from log books of a single commercial fisher in 2002-2006.

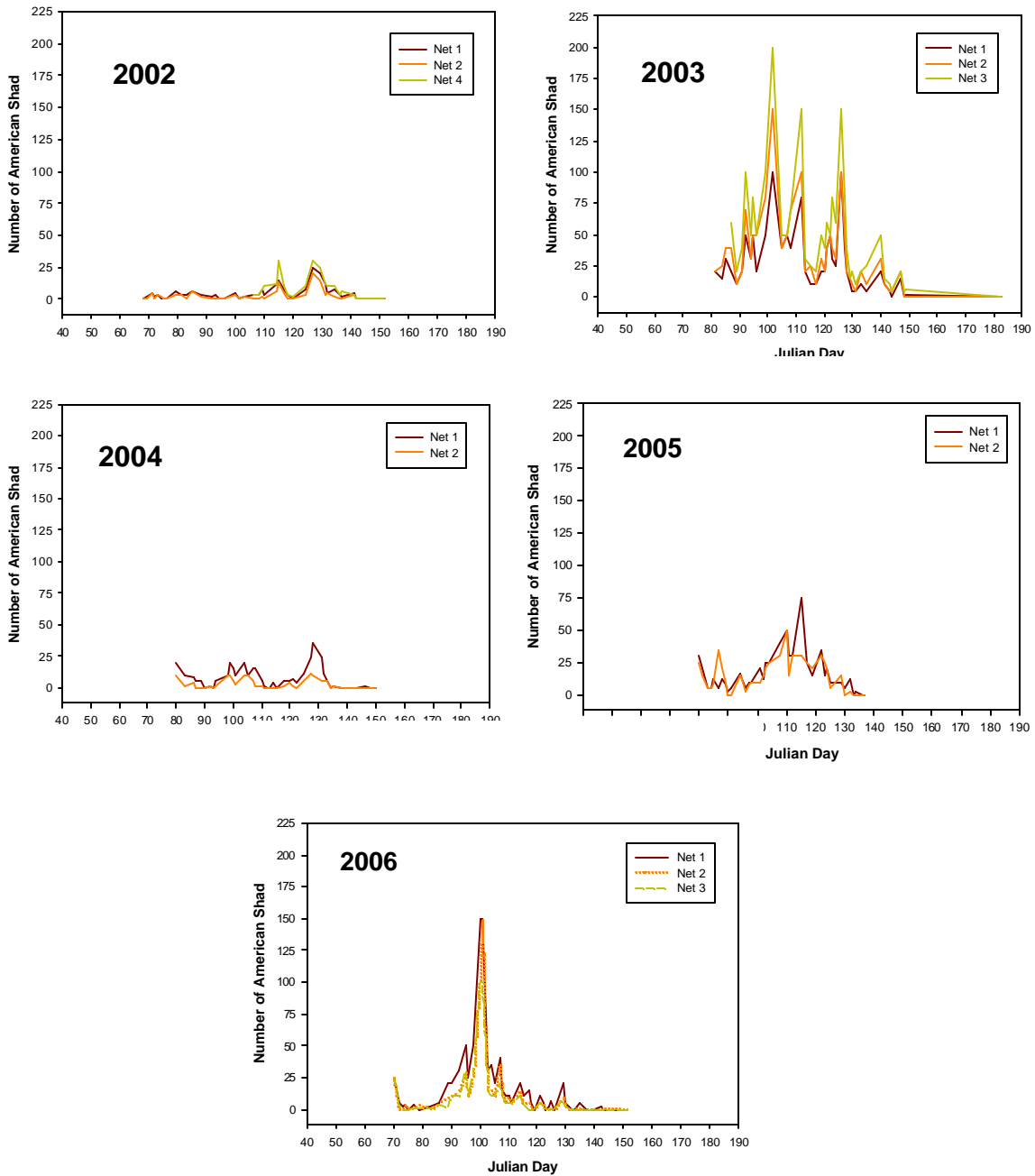


Figure 8. Mean age (based on scales) of females and proportion of age-4 in the York River.

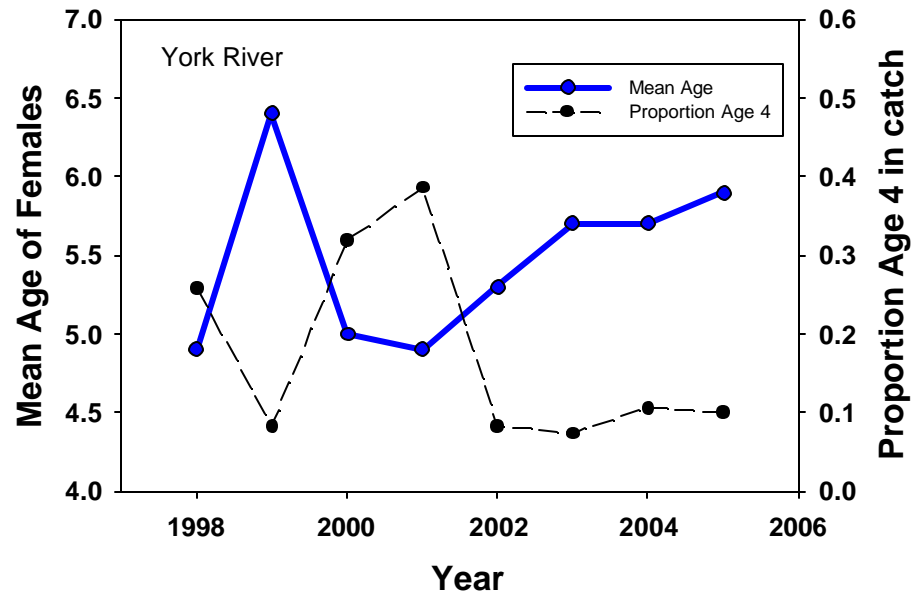


Figure 9. Comparison of recent (1998-2006) and historic (1980-1992) catch index values of American shad in the York River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. Current monitoring is conducted on two successive days in each week from late February to the end of the run each year.

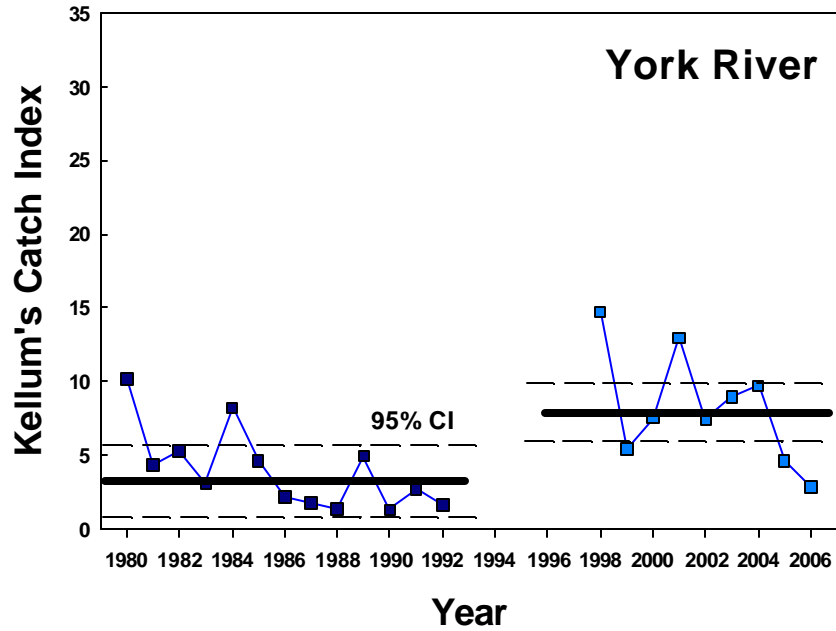


Figure 10. Comparison of recent (1998-2006) and historic (1953-1957, 1980-1992) catch index values of American shad in the York River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. 1950s data are adjusted to account for gear differences (Maki et al. 2006). Current monitoring is conducted on two successive days in each week from late February to the end of the run each year.

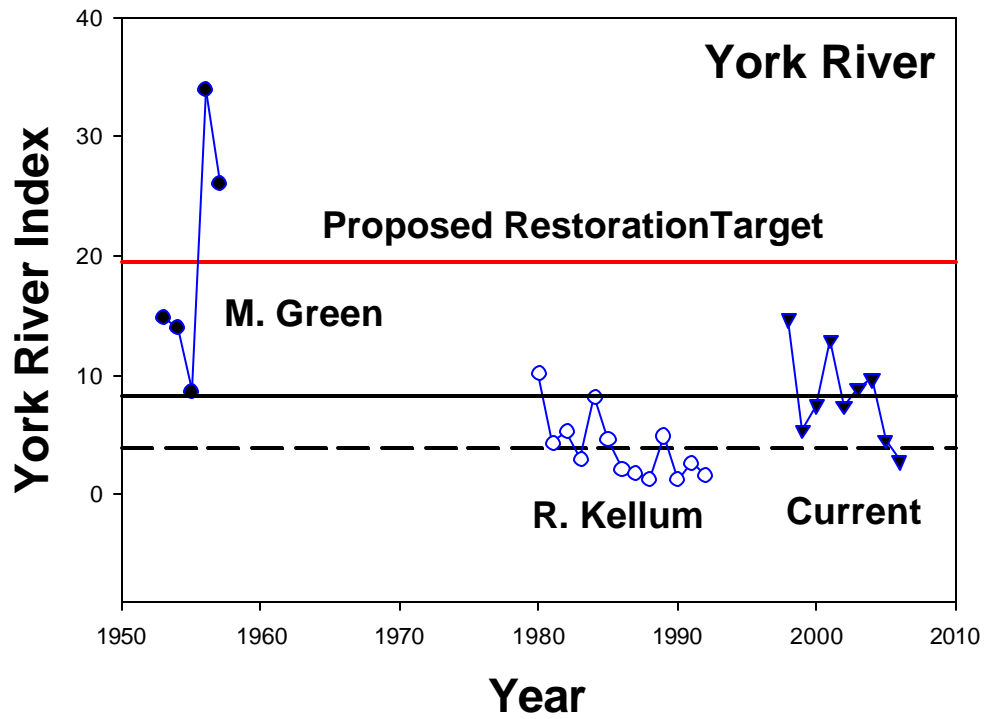


Figure 11. Yield model results for the York River stock.

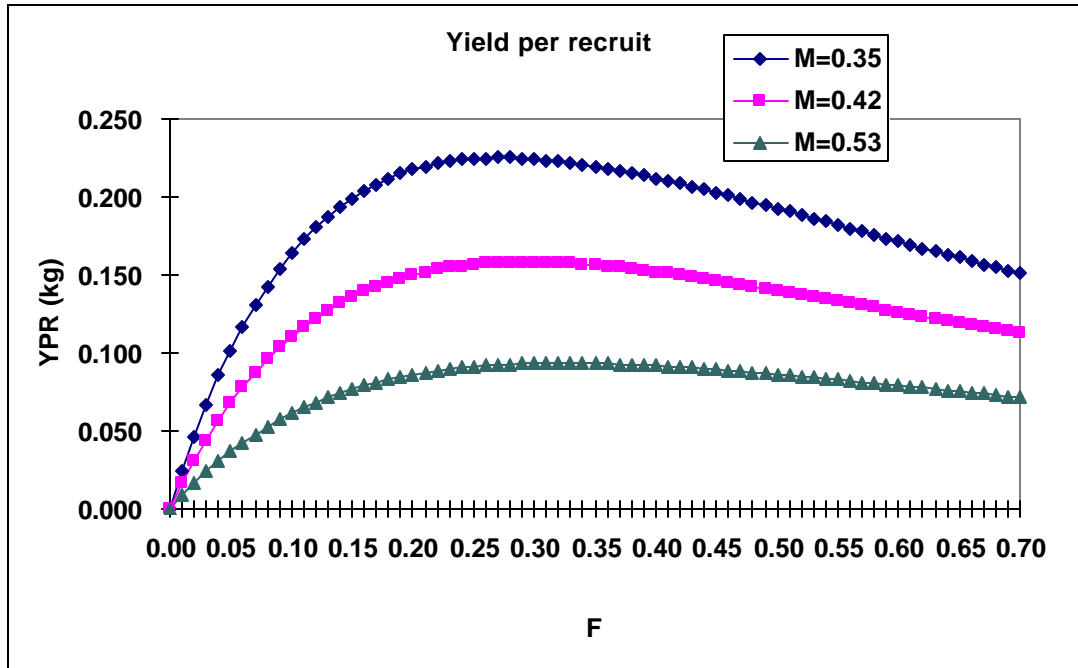


Figure 12. Estimates of total mortality ( $Z$ ) of American shad in the York River. Estimates are derived from linear regressions in the declines of log-transformed catch-at-age data and numbers of repeat spawners.

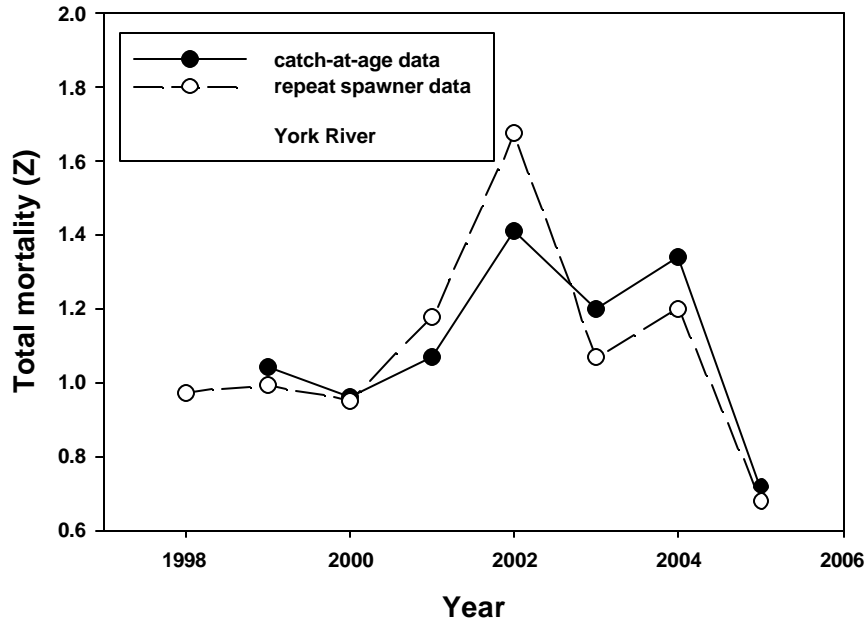


Figure 13. Comparison of recent (1998-2006) and historic (1980-1992) catch index values of American shad in the James River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. Current monitoring is conducted on two successive days in each week from late February to the end of the run each year.

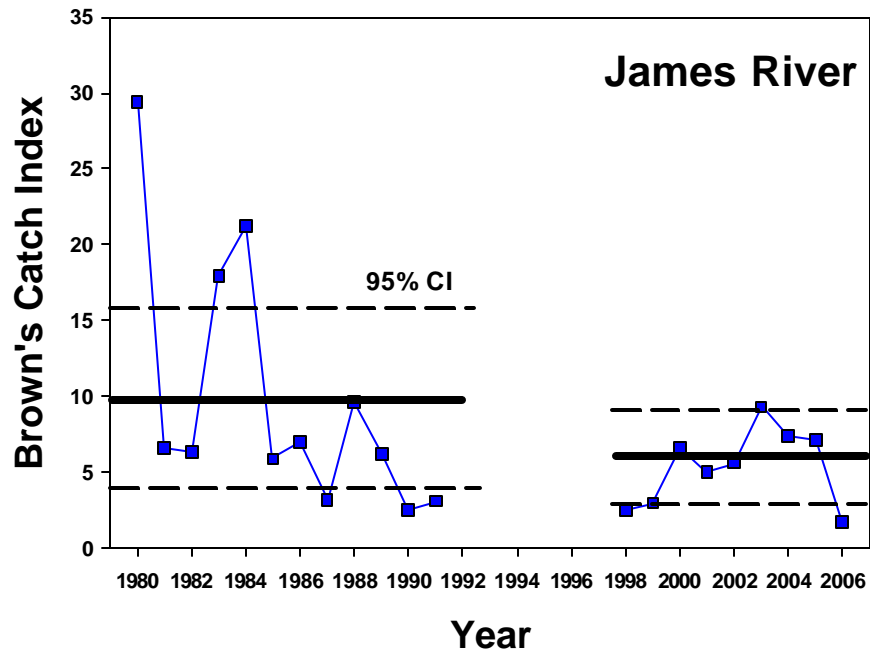




Figure 14. Comparison of recent (1998-2006) and historic (1980-1992) catch index values of American shad in the Rappahannock River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. Current monitoring is conducted on two successive days in each week from late February to the end of the run each year

