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Evaluation of Striped Bass Stocks in Virginia: Monitoring and Tagging Studies, 1999-2003

Annual Report

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Preface

This report presents the results of striped bass (*Morone saxatilis*) tagging and monitoring activities in Virginia during the period 1 August 2002 through 31 August 2003. It includes an assessment of the biological characteristics of striped bass taken from the 2003 spring spawning run, estimates of annual survival based on annual spring tagging, and the results of the fall 2002 directed mortality study that is cooperative with the Maryland Department of Natural Resources. The information contained in this report is required by the Atlantic States Marine Fisheries Commission and is used to implement a coordinated management plan for striped bass in Virginia, and along the eastern seaboard.

Striped bass have historically supported one of the most important recreational and commercial fisheries along the Atlantic coast. In colonial times, striped bass were abundant in most coastal rivers from New Brunswick to Georgia ,but overfishing, pollution and reduction of spawning habitat have resulted in periodic crashes in stocks and an overall reduction of biomass (Merriman 1941, Pearson 1938). Striped bass populations at the northern and southern extremes of the Atlantic are apparently non-migratory (Raney 1957). Presently, important sources of striped bass in their native range are found in the Roanoke, Delaware and Hudson rivers and the major tributaries of Chesapeake Bay (Lewis 1957) with the Chesapeake Bay and Hudson River being the primary sources of the coastal migratory population (Dorazio *et al.* 1994).

Examination of meristic characteristics indicate that the coastal migratory population consists of distinct sub-populations from the Hudson River, James River, Rappahannock - York rivers, and upper Chesapeake Bay (Raney 1957). The Roanoke River striped bass may represent another distinct sub-population (Raney 1957). The relative contribution of each area to the coastal population varies. Berggren and Lieberman (1978) concluded from a morphological study that Chesapeake Bay striped bass were the major contributor (90.8%) to the Atlantic coast fisheries, and the Hudson River and Roanoke River stocks were minor contributors. However, they estimated that the exceptionally strong 1970 year class constituted 40% of their total sample. Van Winkle *et al.* (1988) estimated that the Hudson River stock constituted 40% - 50% of the striped bass caught in the Atlantic coastal fishery in 1965. Regardless of the exact proportion, management of striped bass is a multi-jurisdictional concern as spawning success in one area probably influences fishing success in many areas. Furthermore, recent evidence suggests the presence of divergent migratory behavior at intra-population levels (Secor 1999). The extent to which these levels of behavioral complexity impact management strategies in Chesapeake Bay and other stocks is unknown.

Concern about the decline in striped bass landings along the Atlantic coast since the mid-1970s prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Management Program (ASMFC 1981). Federal legislation was enacted in 1984 (Public Law 98-613, the Atlantic Striped Bass Conservation Act) which enables Federal imposition of a moratorium for an indefinite period in those states that fail to comply with the coast-wide plan. To be in compliance with the plan, coastal states have imposed restrictions on their commercial and recreational striped bass fisheries ranging from combinations of catch quotas, size limits and time-limited to year-round moratoriums. Due to an improvement in spawning success, as judged by increases in annual values of the Maryland juvenile index, a limited fishery was established in fall, 1990. This transitional fishery existed until 1995 when spawning stock biomass reached sufficiently healthy levels (Field 1997). ASMFC subsequently declared Chesapeake Bay stocks to have reached benchmark levels and adopted Amendment 5 to the original FMP that allowed expanded state fisheries.

To document continued compliance with Federal law, the Virginia Institute of Marine Science (VIMS) has monitored the size and age composition, sex ratio and maturity schedules of the spawning striped bass stock in the Rappahannock River since December 1981 utilizing commercial pound nets and, since 1991, variable-mesh experimental gill nets. Spawning stock assessment was expanded to include the James River in 1994 utilizing commercial fyke nets and variable-mesh experimental gill nets. An experimental fyke net was established in the James River to assess its potential as a source of tagable striped bass. The use of fyke nets had been discontinued after 1997. In conjunction with the monitoring studies, tagging programs have been conducted in the James and Rappahannock rivers since 1987 . These studies were established to document the migration and relative contribution of these Chesapeake Bay stocks to the coastal population and to provide a means to estimate inter-year survival rates (S). With the re-establishment of fall recreational fisheries in 1993, the tagging studies were expanded to include the York River and western Chesapeake Bay to provide a direct estimation of the resultant fishing mortality (F).

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We are deeply indebted to many people for their participation and/or contributions to the striped bass tagging and spawning stock assessment program. These include: the Anadromous Fishes Program staff and Fisheries Department students of the Virginia Institute of Marine Science; Chip Cotton, Pat Crewe, Susan Denny, Wes Dowd, Julia Ellis, Jim Goins, Donna Grusha, Joel Hoffman, Gail Holloman, Kristin Maki, Todd Mathes, Jason Romine, John Walter and Brian Watkins; the cooperating commercial fishermen; Allan Ingraham, Raymond Kellum, Steve Kellum, Neil Leatherwood, Dale Mitchum, Stanley Oliff, Jamie Saunders, Wade Self and Greg Swift; Beth Rodgers of Maryland Department of Natural Resources (MDNR).

Executive Summary

I. Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2003.

Catch Summaries:

1. In 2003, 470 striped bass were sampled between 3 April and 1 May from three commercial pound nets in the Rappahannock River. The samples were predominantly male (60.2%) and young (45.3% ages 3-5). Females dominated the age eight and older age classes (88.2%). The mean age on the male striped bass was 5.2 years. The mean age of the female striped bass was 9.5 years.

2. During the 30 March - 3 May period, the 1998 and 1999 year classes were the most abundant and were 94.7% male. The contribution of age six and older males was only 17.4% of the total catch. Age eight and older females, presumably repeat spawners, were 35.1% of the total catch but represented 88.2% of all females caught.

3. In 2003, 525 striped bass were sampled between 31 March and 1 May in two experimental anchor gill nets in the Rappahannock River. The samples were predominantly male (93.9%) and young (76.6% ages 2-5). Females were slightly prevalent in the age eight and older age classes (54.3%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 8.0 years.

4. During the 30 March - 3 May period, the 1998 and 1999 year classes were the most abundant and were 98.3% male. The contribution of age six and older males was only 18.1% of the total catch. Age eight and older females, presumably repeat spawners, were 3.6% of the total catch but were 61.3% of the total females caught.

5. In 2003, 639 striped bass were sampled between 2 April and 1 May in two experimental anchor gill nets (mile 62) in the James River. Males dominated the 1998-2000 year classes (82.8%). Females dominated the 1999-1994 year classes (93.3%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 7.6 years. In addition, 232 striped bass were sampled from identical gill nets set at river mile 45. Males dominated the total catch (91.8%). The lack of adequate female representation precluded use of these data in this years analysis.

6. During the 30 March - 3 May period, the 1998 and 1999 year classes were the most abundant and were 95.2% male. The contribution of age six and older males was only 12.4% of the total catch. Age eight and older females, presumably repeat spawners, were 2.8% of the total catch but represented 43.9% of all females caught.

Spawning Stock Biomass Indexes (SSBI)

7. The Spawning Stock Biomass Index from the Rappahannock River pound nets was 22.8 kg/day for male striped bass and 53.6 kg/day for female striped bass. The male index was the fifth highest and the female indexe was the highest in the 1991-2003 time series and well above the 13-year average.

8. The SSBI for the Rappahannock River gill nets was 97.3 kg/day for male striped bass and 20.7 kg/day for female striped bass. The male index was the third highest in the 1991-2003 time series and was well above the 13-year average. The female index was 20.7 kg/day, which was the seventh highest in the 1991-2003 time series and was well below the 13-year average.

9. The SSBI for the James River gill nets was 145.7 kg/day for male striped bass and 35.2 kg/day for female striped bass. The male index was the fourth highest in the time series and well above the 10-year average. The female index was the second lowest to date, and was well below the average index value.

Egg Production Potential Indexes (EPPI)

10. An index of potential egg production was derived from laboratory estimates of weight- and length-specific numbers of oocytes in the ovaries of mature females. The Egg Production Potential Index (millions of eggs/day) for the Rappahannock River pound nets was 9.8 million eggs/day almost 2.5 times greater than the 2002 index. Older (8+ years) female stripers were responsible for 95.4% of the index.

11. The EPPI for the Rappahannock River gill nets was 3.7 million eggs/day and was lower than the 2002 index. Older (8+years) female striped bass were responsible for 80.0% of the index.

12. The EPPI for the James River gill nets was 6.0 million eggs/day and was 13.2 % greater than the 2002 index. Older (8+ years) female striped bass were responsible for 73.4% of the index.

Estimates of Annual Survival (S) based on age-specific catch rates

13. The cumulative catch rate (sexes combined) from the Rappahannock River pound nets (15.65 fish/day) was the sixth highest in 1991-2003 time series. There was an increase in every year class, except 1997, from the 2002 values. The cumulative catch rate of male striped bass (9.42 fish/day) was the third lowest in the time series but more than double the rate in 2002. The cumulative catch rate of female striped bass (6.24 fish/day) was the third highest in the time series and was the highest since 1993.

14. Year class-specific estimates of annual survival (S) for pound net data varied widely between years. The geometric mean S of the 1983-1995 year classes varied from 0.516-0.834 (mean = 0.666). The geometric mean survival rates differed greatly between sexes. Mean survival rates for male stripers (1985-1995 year classes) varied from 0.317-0.517 (mean = 0.421) but mean survival rates of female stripers (1983-1991 year classes) varied from 0.587-0.849 (mean = 0.670).

15. The cumulative catch rate (sexes combined) from Rappahannock River gill nets (52.5 fish/day) was the median value in the 1991-2003 time series, but still 62.5% higher than in 2002. Cumulative catch rate of male stripers (49.3 fish/day) was the fifth highest in the time series and near double the rate in 2002. The cumulative catch rates of female striped bass (3.2 fish/day) was the fifth lowest in the time series and the lowest since 1998.

16. Year class-specific estimates of annual survival for gill net data varied widely between years. The geometric mean S of the 1984-1996 year classes varied from 0.408-0.672 (mean = 0.527). The mean survival rates for male stripers (1987-1996) varied from 0.150-0.635 (mean = 0.388). The mean survival rates for female stripers (1984-1990) varied from 0.501-0.781 (mean = 0.603).

17. The cumulative catch rate (sexes combined) from James River (mile 62) gill nets (91.28 fish/day) was almost identical the rate in 2002, but was the third straight year of decline since peaking in 2000. The cumulative catch rates for male striped bass (85.14 fish/day) was the third highest of the 1994-2003 time series and was slightly higher than in 2002. However, the cumulative catch rate of female striped bass (6.14 fish/day) was 40% lower than in 2002 and the second lowest in the time series.

18. Year class-specific estimates of annual survival varied widely between years. The geometric mean S of the 1985-1994 year classes varied from 0.440-0.710 (mean = 0.564). The mean survival rates of male stripers (1988-1993 year classes) varied from 0.286-0.575 (mean = 0.469). The mean survival rates of female stripers (1985-1995 year classes) varied from 0.440-0.706 (mean = 0.583).

Catch rate histories of the 1987-1994 year classes

19. Plots of year class-specific catch rates from 1991-2003 showed a consistent trend of a peak in the abundance of male striped bass followed by a steep decline. There was also a secondary peak of (mostly) female striped bass, usually around age 10.

20. The plots illustrate strong year classes in 1988, 1992 and 1993 and weak year classes in 1990 and 1991.

21. Since 1997, there has been a persistent lack of 590-710 mm TL striped bass in the pound net samples. This trend was not evident from the 1991-1996 samples.

Age determinations using scales and otoliths

21. A total of 249 specimens from 11 size ranges were aged by reading both scales and otoliths. The mean age of the otolith-aged striped bass was 0.22 years older than from the scale-aged striped bass. The two methodologies agreed on the age of the striped bass on 34.5% of the specimens.

22. Tests of symmetry applied to the age matrix indicated that the two ageing methodologies were not interchangeable (p= 0.0027). The age at which the divergence in ages became apparent was determined to be age six.

23. Otoliths were 1.22 times more likely to give an older age than the scale from the same specimen. The otoliths were 3.15 times more likely to produce an age difference of two years or greater. A symmetry test concluded that the otolith ages were older than the scale ages to a significant degree (p= 0.0021)

24. A two-tailed t-test of the mean ages produced by the respective ageing methodologies found that the difference in the mean ages (0.22 years) was not significant (p= 0.4168).

25. A paired t-test of the mean of the age differences produced by the two ageing methodologies found that the mean difference was significantly different from zero (p= 0.0064).

26. A Kolmogorov-Smirnov test of the age structures produced by the two ageing methodologies also found a significant difference, indicating that the two resultant age structures represented different populations.

II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2002-2003.

1. A total of 799 striped bass were tagged and released from pound nets in the Rappahannock River between 3 April and 6 May, 2003. Of this total, 440 were between 457-710 mm total length and considered to be predominantly resident striped bass and 359 were considered to be predominantly migrant striped bass (>710 mm TL). The median date of the tag releases was 22 April for the migrant stripers and 2 May, 2003 for the resident striped bass.

2. A total of 10 migratory striped bass (>710 mm TL), tagged during spring 2002, were recaptured between 19 April, 2002 and 27 April, 2003 (the respective midpoints of the two spring release periods). Recaptures were from New York (3), Massachusetts (2), Chesapeake Bay (2), Rhode Island (1) and New Jersey (1).

3. ASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber models. Twelve of these models were applied to the recapture matrix, each reflecting a different parameterization of time. Models that allowed parameters to be both time-specific and constant across time were specified. The model averaged estimates of the bias-adjusted survival rates ranged from 0.594-0.628 over the time series. Survival was highest during the transitional fishery and decreased slightly thereafter. This trend was the result of a higher proportion of annual tag recoveries being released back into the population in the early 1990's relative to more recent years. The corresponding estimates of F_i ranged from 0.15-0.35 and only infrequently, and by slight margins, exceeded the transitional and full fisheries target values. Both the survival and fishing mortality estimates were relatively constant.

4. Elements of the Rappahannock River tag-recovery matrix did not allow these models to adequately fit the data. The low total number of tagged striped bass and resultant recaptures reported from the 1994 and 1996 cohorts (e.g. five from the 1996 cohort) relative to other years may account for the poor fit of the time-specific models. Unfortunately, numerical complications resulting from low sample size caused some of the more biologically reasonable models to not fit the Rappahannock River data well.

III. Fishing mortality estimates of the fall 2002 resident striped bass fishery in the Chesapeake Bay, Virginia.

1. The fall 2002 striped bass recreational season (1 June - 31 Nov in Maryland, 4 Oct - 31 Dec in Virginia) in Chesapeake Bay was divided in seven rounds in Maryland and three rounds in Virginia (16-26 September, 21-31 October and 20-26 November). Each recovery round was of approximately 30 days in duration.

2. Striped bass were tagged and released during ten-day intervals prior to the start of each recovery round and the recaptures that occurred within that round were used for analysis. Adjustments were made for tag loss, mortality and for mixing of the newly tagged fish into the population.

3. A total of 2,891 striped bass were tagged in Virginia. The number of stripers tagged and released were 672, 1,402 and 817 for the three tagging rounds. The striped bass tagged in all three rounds were predominantly from the 1998 and 1999 year classes.

4. A total of 102 striped bass tagged in Virginia were recaptured by 31 December. Of these recaptures, 79 were recaptured within their round of release. Most recaptures occurred in their area of release, but recaptures were also recovered from Maryland, the Potomac River and the coastal Atlantic Ocean.

5. The Chesapeake Bay estimate of total fishing mortality (F) was 0.22. This is the sum of non-harvest (0.10) and harvest (0.12) mortality estimates. The target F for Chesapeake Bay is 0.28.

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I. Assessment of spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2003.

Introduction

Every year, striped bass migrate along the US east coast from offshore and coastal waters and enter brackish or fresh water to spawn. Historically, the principal spawning areas in the northeastern US have been the Hudson, Delaware and Chesapeake estuarine systems (Hardy 1998). The importance of the Chesapeake Bay spawning grounds to these stocks has long been recognized (Merriman 1941, Raney 1952). In the Virginia tributaries of Chesapeake Bay, peak spawning activity is usually observed in April and is associated with rapidly rising water temperatures in the range of 13-19^0 C (Grant and Olney 1991). Spawning is often completed by mid-May, but may continue until June (Chapoton and Sykes 1961). Spawning grounds have been associated with rock-strewn coastal rivers characterized by rapids and strong currents on the Roanoke and the Susquehanna rivers (Pearson 1938). In Virginia, spawning occurs over the first 40 km of tidal freshwater portions of the James, Rappahannock, Pamunkey and Mattaponi rivers (Grant and Olney 1991; Olney et al. 1991; McGovern and Olney 1996).

The Atlantic States Marine Fisheries Commission (ASMFC) declared that the Chesapeake Bay spawning stocks were fully recovered in 1995 after a period of very low stock abundance in the 1980's. This statement of recovered status was based on estimated levels of spawning stock biomass that were found in 1995 to be equal or greater than the average levels of the 1960-72 period (Rugulo et al. 1994). Thus, continued assessment of spawning stock abundance is an important component of ASMFC mandated monitoring programs. To this end, the Virginia Institute of Marine Science (VIMS) began development of spawning indexes that depict annual changes in catch rates of striped bass on the spawning grounds of the James and the Rappahannock rivers. These rivers represent the major contributors to the Chesapeake bay stocks that originate from Virginia waters.

Materials and Methods

Samples of striped bass for biological characterization of the spring spawning stocks were obtained from the Rappahannock and James rivers between 31 March - 1 May, 2003. Samples (the entire catch of striped bass from each gear) were taken twice-weekly (Monday and Thursday) from a set of three commercial pound nets (river miles 45, 46 and 47) on the Rappahannock River. Pound nets are fixed commercial gears that have been the historically predominant gear type used in the river and are presumed to be non size-selective in their catches of striped bass. The established protocol (Sadler *et al.* 1999) was to alternate the choice of the net sampled but weather constraints often dictated whether that net could be sampled. In addition, data from pound nets sampled in 1991 and 1992 were included to expand the time series. These samples were consistent in every respect to the 1993-2001 samples with the following exceptions in 1991: two samples (3 and 17 April) came from a pound net at river mile 25 and samples were obtained weekly vs. twice weekly.

In addition to the pound nets, samples were also obtained twice-weekly from variable-mesh experimental anchored gill nets (two each at river mile 48 on the Rappahannock River and river mile 47 on the James River, Figures 1-2). The gill nets in the James River were set in a different location than in 2000-2002, or from1994-1999, and were set and fished by a different waterman. To facilitate a comparison with the previous three years of data, gill nets were also set in the old location, but only once per week from 2-16 April, then twice per week thereafter after preliminary results from the new location indicated that the catches were insufficient to assess the spawning stock.

The variable-mesh gill nets deployed on both rivers were constructed of ten panels, each measuring 30 feet (9.14 m) in length, and 10 feet (3.05 m) in depth. The ten stretched-mesh sizes (in inches) were 3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0, 10.0. These mesh sizes correspond to those used for spawning stock assessment by the Maryland Department of Natural Resources. The order of the panels was determined by a randomized stratification scheme. The mesh sizes were divided into two groups, the five smallest and the five largest mesh sizes. One of the two groups was randomly chosen as the first group, and one mesh size from that group was randomly chosen as the first panel in the net. The second panel was randomly chosen from the second group, the third from the first group, and so forth, until the order was complete. The order of the panels in the first net was (in inches) 8.0, 5.25, 9.0, 3.75, 7.0, 4.5, 6.5, 6.0, 10.0, and 3.0, and the order was (in inches) 8.0, 3.0, 10.0, 5.25, 9.0, 6.0, 6.5, 3.75, 7.0, and 4.5 in the second net.

Striped bass 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 records lengths (FL and TL) to the nearest mm, receives weight (g) input from the balance, and allows manual input of sex and gonad maturity into a data file for subsequent analysis. Gonad weight (g) was taken for all female striped bass sampled. Three subsections, randomly chosen from a 10-section grid, were extracted from ovaries in the hydrated state, as described by Barbieri and Barbieri (1993). Each 4-5 gram subsample was washed through a 30 micron screen and stored in 2% formalin. The oocytes were then counted under a dissecting scope. The count was then gravimetrically expanded to estimate the total for the ovary set. Scales were collected from between the spinous and soft dorsal fins above the lateral line for subsequent aging, using the method established by Merriman (1941), except that impressions made in acetate sheets replaced the glass slide and acetone. Otoliths were extracted from a subsample of the striped bass, processed for aging, then compared to their scale-derived ages.

The otolith subsample was from ten striped bass from each of the following size ranges (fork length in mm): 166-309, 310-419, 420-495, 496-574, 575-659, 660-724, 725-779, 780-829, 830-879 and 880-900. All striped bass greater than 900 mm fork length were sampled. The size ranges roughly correspond to age classes based on previous (scale-aged) data.

The otoliths were cleansed of external tissue material by soaking in bleach for 12-24 hours and rinsing in deionized water. The otoliths were prepared for ageing by placing the left sagittae on melted crystal bond and sectioned to a one millimeter thickness on a Buehler isomet saw. The section were then polished on a Metaserv 2000 grinder. The polished section was immersed in a drop of mineral oil and viewed through an Olympus BX60 compound scope at 4-20x. Each otolith was aged twice at different times by the same reader using the methods described by Wischniowski and Bobko (1998). If these ages differed a third reading was made to make a final determination.

All readable scales were aged using the microcomputer program DISBCAL of Frie (1982), in conjunction with a sonic digitizer-microcomputer complex (Loesch et al. 1985). Growth increments were measured from the focus to the posterior edge of each annulus. In order to be consistent with ageing techniques of other agencies, all striped bass were considered to be one year older on 1 January of each year. Scale ages were used exclusively except when a comparison with its companion otolith age was made.

The spawning stock biomass index (SSBI) for striped bass was defined (Sadler et al. 1999) as the 30 Mar - 3 May mean CPUE (kg/net day) of mature males (age-3 years and older), females (age-4 years and older) and the combined sample (males and females of the specified ages). An alternative index, based on the fecundity potential of the female striped bass sampled, was investigated and the results compared with the index based on mean female biomass.

To determine fecundity, the geometric mean of the egg counts of the gonad subsamples for each female striped bass was calculated. A non-linear regression curve was fitted to data of total oocytes versus fork length. The resultant equation was then applied to the fork lengths of all mature (4+ years old) females from the pound net and gill net samples and the Egg Production Potential Index (EPPI) was defined as the mean number of eggs potentially produced per day of effort of the mature female striped bass sampled from 30 March - 3 May.

Estimates of survival (S, the fraction surviving after becoming fully recruited to the stock) were calculated by dividing the catch rate (number/day) of a year class in year a+1 by the catch rate (number/day) of a year class in year a. If the survival estimate between successive years was >1, the estimate was derived by interpolating to the following year. The geometric mean of S was used to estimate survival over periods exceeding one year (Ricker 1975). Separate estimates of survival were made for male and female striped bass, as well as the sexes combined.

Analysis of the differences in the ages estimated by reading the scales and otoliths from the same specimen were made using tests of symmetry (Evans and Hoenig 1998, Hoenig et al. 1995). Differences in the resultant mean ages from the two methods were tested using both two-tailed paired and unpaired t-tests (Zar 1999). The age class distributions resulting from the two ageing methods were compared using the non-parametric Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981).

Results

Catch Summaries

Rappahannock River

Pound nets: Striped bass (n= 470) were sampled between 3 April and 1 May, 2003 from the pound nets in the Rappahannock River. The sampling scheduled for 31 March was missed due to extreme weather conditions. The number of striped bass sampled was more than twice that from 2002 (n= 170) and was near the 13-year average. Total catches varied by only 25-49 striped bass, except for much higher catches on 14 and 24 April and on 1 May (Table 1). Surface water temperature was 15 °C on 3 April, decreased to 11 °C on 10 April, then increased slowly through most of the rest of the sampling season, reaching 16 °C on 28 April and finishing at 21 °C on 6 May. Frequent and heavy rains occurred throughout April, resulting in higher river flows than had been present since 1996. Catches of female striped bass peaked on 14 and 24 April, but were generally higher after 10 April. Males made up 60.2% of the total catch, but were much less prevalent than the 13-year average (78.3%). The 1995-1998 year classes comprised 44.3% of the total catch. Males dominated the 1999-2001 year classes (98.2%) and the 1995-1998 year classes (77.9%), but females dominated the 1987-1994 year classes (93.9%).

Biomass catch rates (g/day) of male and female striped bass were highest on 14 and 24 April (Table 2). The catch rate of females exceeded that of males on every sampling date (by 6.3:1 on 17 April). The mean ages of male striped bass varied from 4.7-5.8 years by sampling date, with the youngest mean ages occurring on the first and last sampling date. The mean ages of females varied from 9.2-10.2 years, but the oldest were concentrated from 10-28 April.

There was a prevalence of striped bass between 460-589 mm total length in the pound net samples (Table 3). This size range accounted for 36.9% of the total sampled. However, the striped bass from 590-719 mm total length accounted for only 5.3% of the total sample. In contrast, the striped bass from 840-939 mm total length accounted for 21.3 % of the total sample. The total contribution of striped bass greater than 710 mm total length was 52.2%.

During the 30 March - 3 May period, the 1998 (21.2%) and 1999 (19.1%) year classes were the most abundant (Table 4). These year classes were 94.7% male. The contribution of males age six and older (the pre-1998 year classes) was 17.0% of the total aged catch . These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 37.2% of the total aged catch, but was also 93.6% of the total females captured. The catch rate (fish/day) of male striped bass was 37.3% below the 11-year average (Table 5). The catch rate of female striped bass was the second highest of the 11-year time series. The mean ages of both sexes were well above the 11-year averages.

Experimental gill nets: Striped bass (n= 525) were also sampled between 31 March and 1 May, 2003 from two multi-mesh experimental gill nets in the Rappahannock River. The total catch was 62.5% greater than in 2002. Total catches peaked sharply on 31 March and on 7 April, due to the large number of three to six year old males (Table 6). Female striped bass were generally caught only in low numbers throughout the sampling period. Males made up 93.9% of the total catch. Males dominated the 1999-2001 year classes (99.6%) and the 1995-1998 year classes (93.0%), but the 1987-1994 year classes were 78.9% female. The 580-719 mm total length size group accounted for 13.6% of the total sampled.

Biomass catch rates (g/day) of male striped bass were highest on 31 March and on 7 April (Table 7). The catch rates of female striped bass were highest from 21-24 April. The catch rate of males exceeded that of females from 31 March -17 April and again from 28 April - 1 May. The mean ages of male striped bass varied from 3.3-5.3 years by sampling date, with the oldest males (five-eight years) being prevalent from 10-14 April. The mean ages of females varied from 5.0-11.5 years, with the oldest females (age nine and older) being prevalent from 10-14 April.

There was a prevalence of 460-579 mm total length striped bass in the gill net samples (Table 8). This size range accounted for 45.9% of the total sampled. In contrast to the pound net samples, the total contribution of striped bass 840-939 mm total length was 3.3%. The total contribution of striped bass greater than 710 mm total length was 15.7%.

During the 30 March - 3 May period, the 1999 (30.5%) and 1998 (24.0%) year classes were prevalent (Table 9). These year classes were 98.3% male. The contribution of males age six and older (the pre-1998 year classes) was only 18.5% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 4.4% of the total aged catch but was 74.2% of the total females captured. The catch rate (fish/day) of male striped bass was above the 11-year average (Table 10), but the catch rate of female striped bass was less than half that from 2002 and was 42.2% below the 11-year average. The striped bass of both sexes were older, and therefore larger, than the average so that the CPUE (g/day) of the male striped bass was second only to 1997, but the CPUE of female striped bass was still 32.2% below the 11-year average.

James River

Experimental gill nets: Striped bass (n=232) were sampled between 2 April and 1 May, 2003 from the two multi-mesh experimental gill nets at mile 47 in the James River. Total catches peaked on 28 April and 1 May, due to a large catch of male striped bass, after generally low catches throughout April (Table 11a). Catches of female striped bass were consistent, although small (0-4). Males dominated the 1999-2001 year classes (99.1%) and the 1995-1998 year classes (87.9%), but the 1987-1994 year classes were exclusively female. Striped bass (n=639) were also sampled from two identical gill nets at mile 62 on the James River. Total catches peaked on 16 and 30 April, due to large catches of male striped bass (Table 11b). Catches of female striped bass peaked on 23 April. The 1999-2001 year classes were exclusively male. Males also dominated the 1995-1998 year classes (90.0%). Females dominated the 1989-1994 year classes (93.3%).

Biomass catch rates (g/day) of male striped bass peaked strongly on 16 April and on 30 April (Table 12). The catch rates of female striped bass were highest on 16 and on 23 April. The catch rate of females exceeded that of males only on 10 and 17 April. Catch rates of males greatly exceeded that for females from 28 April (22.9:1) through 1 May (20.0:1). The mean ages of male striped bass varied from 3.0-5.2 years by date, but varied from only 4.2-4.8 years from 21 April - 1 May. The mean ages of females varied from 4.7-11.0 years by date, but varied from only 6.5-8.4 years from 19-23 April and from 4.7-6.0 years from 24 April - 1 May.

There was a prevalence of striped bass 450- 579 mm total length in the gill net samples (Table 13). This size range accounted for 55.1% of the striped bass sampled. In contrast to the samples from the gill nets and pound nets from the Rappahannock River, striped bass from 590-719 mm total length accounted for 19.1% and those from 840-939 mm total length accounted for 1.4% of the total sampled The total contribution of striped bass greater than 710 mm total length was 7.5%.

During the 30 March - 3 May period, the 1999 (34.9%) and 1998 (33.2%) year classes were the most abundant in the gill nets at mile 45 (Table 14a). These year classes were 94.9% male. The contribution of males age six and older (the pre-1998 year classes) was only 13.9% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was only 3.9% of the total aged catch. In comparison, the 1999 (34.3%) and 1998 (31.6%) year classes were also the most abundant in the gill nets at mile 62 (Table 14b). These classes were 95.2% male. The contribution of males age six and older was 12.4% of the total aged catch. The contribution of females age seven and older was 3.1%

There was a large difference in the catch rates between the experimental gill nets set at mile 45 and the ones set at mile 62 (Table 15). The catch rate (fish/day) of males at mile 62 was 5.6 times the catch rate at mile 45 and the catch rate of females was 4.1 times greater. The mean age of the male stripers were similar, but the mean age of the females captured at mile 62 was about one year older than at mile 45. The catch rate (fish/day) of male stripers from the nets at mile 62 was the second highest of the nine-year time series (Table 15) and twice the overall average. However, the catch rate of females was 17.9% below the average.

Spawning Stock Biomass Indexes

Rappahannock River

Pound nets: The Spawning Stock Biomass Index (SSBI) for spring 2003 was 22.8 kg/day for male striped bass and 53.6 kg/day for female striped bass. The index for male striped bass was more than triple the index for 2002 and was 11.8% above the 13-year average (Table 16). The magnitude of the index for male striped bass was largely determined by the 1996 (30.3%) and 1998 (24.4%) year classes. The index for female striped bass was the highest of the 13-year average (Table 16). The magnitude of the index for the females was largely determined by the 1991-1993 year classes (67.7%).

Experimental gill nets: The Spawning Stock Biomass Index for spring 2003 was 97.3 kg/day for male striped bass and 20.7 kg/day for female striped bass. The index for male striped bass was 82.2% higher than in 2002, and was 27.7% above the 13-year average (Table 16). The 1998-1999 year classes contributed 48.1% of the biomass in the male index. However, the index for female striped bass was about half that from 2002, and was 38.2% below the 13-year average. The 1993-1994 year classes contributed 59.9% of the biomass in the female index.

James River

Experimental gill nets: The Spawning Stock Biomass Index for spring 2003 (mile 62) was 145.74 kg/day for male striped bass and 35.20 kg/day for female striped bass. Although the male index was lower than in 2002, it was 50.7% above the 10-year average (Table 17). The 1998 and 1999 year classes contributed 63.8% of the biomass in the male index. The female index was 26.0% lower than the 2002 index, and was 38.5% lower than the 10-year average. The 1993-1995 year classes accounted for 45.6% of the biomass in the female index. The indexes from the nets set at mile 45 were less than one third the values derived from the nets at mile 62.

Egg Production Potential Indexes

The number of gonads sampled, especially of the larger females, was insufficient to produce separate length-egg production estimates for each river. The pooled data produce a fork length-oocyte count relationship as follows:

$$(\qquad N_o = 0.00114 \times FL^{3.1168})$$

Where N_o is the total number of oocytes and FL is the fork length (>400) in millimeters. Using this relationship, the predicted egg production was 147,000 oocytes for a 400-mm female and 4,279,000 oocytes for a 1180-mm female striped bass (Table 18). The 2003 Egg Production Potential Indexes (EPPI, Table 13) for the Rappahannock River were 9.829 (pound nets) and 3.724 (gill nets). The 2003 EPPI for the James River was 6.037. The indexes for the Rappahannock River were heavily dependent on the egg production potential of the older (8+ years) females (95.4% in the pound nets, 80.0% in the gill nets), while the James River index was more evenly distributed among age groups (Table 19). Previous values for the EPPI for 2001 and 2002 from the Rappahannock River were 3.992 and 1.764 (pound nets) and 4.039 and 6.070 (gill nets). Previous values for The EPPI for 2001 and 2002 from the James River were 5.286 and 6.709 (Sadler et al 2001,2002). Modest changes in the methodology in the 2001-2003 indexes preclude direct comparison with the 1999 and 2000 indexes.

Estimates of Annual Survival (S) based on catch-per-unit-effort

Rappahannock River
Pound nets: Numeric catch rates (fish/day) of individual years classes from 1991-2003 are presented in Tables 20-22. The cumulative annual catch rate for 2003 was the sixth highest in the time series and was triple the catch rate for 2002 (Table 20a,b). The increase was the result of higher catch rates of every year class except for 1997. The catch rate of males was dominated by four and five year old (1998 and 1999 year classes) males (Table 21a,b). These two age classes have contributed more than 50% of the total male catches in every year except 1995 and 1996. Using the maximum catch rate of the resident males as an indicator, the 1995-1997 year classes were strongest and the 1990 and 1991 year classes were the weakest. No pre-1993 year class males were captured. The cumulative catch rate of female stripers was the third highest of the time series and was more than triple the cath rate in 2002 (Table 22a,b). The increase in the cumulative catch rate of female striped bass reversed what had been a general decline from 1993-2002. No pre-1987 year class females were captured in 2003.

The range of overall ages was unchanged from 1991-2003, consisting of 2-10 year old males and 4-15 year old females, but sex-specific changes in the age-structure have occurred. The age at which abundance peaked for males has decreased from age five (1992-1994) to age four (1997-2002). The catch rate of four and five year olds were near equal in 2003. There has been an even more significant change in the age composition of the female spawning stock. From 1991-1996, the cumulative proportion of females age eight and older ranged from 0.167-0.446 (mean = 0.290) as their cumulative catch rate ranged from 0.75-2.08 fish/day (mean = 1.21). From 1997-2001 the range in the cumulative proportion of females age eight and older increased to 0.720-0.853 (mean = 0.789) as cumulative catch rates ranged from 1.44-4.25 fish/day (mean = 2.73). In 2002, the cumulative proportion of female striped bass age eight and older decreased to 0.508. In 2003, the cumulative catch rate of females age eight and older rebounded to 0.875 (the highest of the time series).

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 23-25. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rates (1991-2003) of the 1983-1995 year classes (sexes combined) varied from 0.516-0.834 (Table 23a,b) with an overall mean survival rate of 0.666. These year classes have survival estimates across a minimum of four years. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1991-2003) of the 1985-1996 year classes of males varied from 0.317-0.517 (Table 24a,b) with an overall mean survival rate of 0.423. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2003) of the 1983-1991 year classes of females varied from 0.587-0.849 (Table 25a,b) with an overall mean survival rate of 0.670. The high catch rates of 1992-1996 year class females precluded estimation of survival rates for these stripers in 2003.

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1991-2003 are presented in Tables 26-28. The cumulative annual catch rate (sexes combined) for 2003 from the gill nets was the median value in the time series and 62.5% higher than in 2002 (Table 26a,b). The increase was the result of much higher catch rates of three and four year old males (Table 27a,b). The cumulative catch rate was driven by the catch rates of the1998-2000 year classes of striped bass. The age of peak abundance was four years old. The age of peak abundance had changed from age five (1992-1996, 2002) to age four (1997, 1998, 2000, 2001 and 2003) and age three (1999). In contrast to the pound net catches, the cumulative catch rate of female striped bass was the lowest since 2000 and was 61.1% lower than the cumulative catch rate in 2002 (Table 28a,b).

The overall age structure from 1991-2003 consisted of 2-12 year old males (Table 27a,b) and 2-14 year old females (Table 28a,b), but the 2003 catches contained no males older than age nine. The proportion of males age six and older was 0.2 in 2002 and 2003 after being 0.03-0.06 from 1997-2001. The proportion of females age eight and older increased from 0.148-0.652 from 1991-1996, declined from 0.652-0.347 from 1996-1999, then rebounded to 0.707 in 2001 and 0.594 in 2003, but was 0.286 in 2002.

The cumulative catch rate of male striped bass rebounded in 2003, but was still well below the peak values found from 1997-1999 (Table 27a,b). Using the maximum catch rate of the resident males as an indicator, the 1993, 1994 and 1997 year classes were the strongest and the 1990, 1991 and 2000 year classes the weakest. Catch rates of the male striped bass declined rapidly after ages five or six. These year classes are the primary target of the recreational and commercial fisheries.

The 2003 cumulative catch rate of female striped bass was less than half the 2002 catch rate and was comparable to the low values found from 1997-1999 (Table 28a,b). The increased catch rates for 8-10 year-old females gave evidence of secondary peak of abundance across several year classes. This bimodal distribution of abundance with age had been noted for the pound net catches, but had not been evident in the gill net catches.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in Tables 29-31. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1991-2003) of the 1984-1996 year classes (sexes combined) varied from 0.408-0.672 (Table 29a,b) with an overall mean survival of 0.527. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1991-2003) of the 1987-1996 year classes of males varied from 0.150-0.635 (Table 30a,b) with an overall mean survival of 0.388. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2003) of the 1984-1990 year classes of females varied from 0.501-0.781 (Table 31a,b) with an overall mean survival rate of 0.603. The survival estimates of both sexes of striped bass were lower than those calculated from the pound nets. The estimate of female survival rates was based on fewer years than the estimate from the pound nets due the rareness of the oldest females in the samples.

James River

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1994-2003 are presented in Tables 32-34. The cumulative annual catch rate for 2003 was the fourth highest of the time series, was almost identical to the catch rate for 2002 and was the third consecutive year of decline since the peak in 2000 (Table 32). The cumulative catch rate was driven by high catch rates for the three to five year old (1998-2000 year classes), mostly male striped bass. Most previous years have been driven by high catch rates for three to five year old striped bass.

The overall age structure of the samples remained stable throughout the time series, starting at age two or three , and ranging up to11-14 years (Table 32).The age structure of male striped bass has expanded from three to six years in 1994, to two to10 years by 2003 (Table 33). The age structure of female striped bass was stable from 1994-2003, consisting of three-14 year old females (Table 34). The cumulative proportion of males age six and older has varied from 0.091-0.137 in 2000-2003 after peaking at 0.201-0.299 from 1996-1998. The cumulative proportion of females age eight and older, which had decreased from 0.531-0.266 from 1997-1999, which had decreased to 0.239 in 2002 after increasing to 0.426 in 2001, rebounded to 0.415 in 2003..

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 2003 catch rate, being the third highest overall, but 4.7% higher than the cumulative catch rate for 2002 (Table 33). Using the maximum catch rate of the resident males as an indicator, the 1995-1997 year classes were strongest and the 1992 and 1993 year classes the weakest. Male catch rates declined rapidly after ages five or six, but not as rapidly as on the Rappahannock River. In contrast, the 2003 cumulative catch rate of female striped bass was 39.9% lower than in 2002, and was the second lowest in the time series, but was less than one third the peak cumulative catch rate for 1999 (Table 34). There was a secondary peak in catch rates of females 1988-1991 year classes similar to that noted in the Rappahannock River data.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 35-37. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1994-2003) of the 1985 - 1994 year classes (sexes combined) varied from 0.440-0.710 (Table 35), with an overall mean survival rate of 0.564. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1994-2003) of the 1988-1993 year classes of males varied from 0.286-0.575 (Table 36) with an overall mean survival rate of 0.469. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1994-2003) of the 1985-1995 year classes of females varied from 0.440-0.706 (Table 37) with an overall mean survival rate of 0.583.

Catch rate histories of the 1987-1994 year classes

The catch rate histories of the 1987-1994 year classes from each sampling gear (sampling on the James River commenced in 1993) are depicted in figures three - ten. Consistent among the year classes are a peak of male striped bass at age four or five followed by a rapid decline in the catch rate and a secondary peak of mostly female striped bass around age 10. This secondary peak is best defined from the pound net data. The gill nets appear to be less efficient at catching larger, therefore older, striped bass.

The magnitudes of the (gear-specific) catch rates illustrate the relative strength of each year class. The strongest year classes from the pound nets, based on the relative peaks of young males and older females were in 1988, 1992 and 1993. Conversely the weakest year classes were in 1990 and 1991. The relative lack of the secondary peak in the gill nets make the patterns harder to interpret.

Numeric catch rates for male striped bass decreased rapidly subsequent to their peak of abundance at age four or five in both gears. These fish are the primary target for the commercial and recreational fisheries within Chesapeake Bay. Catch rates of female striped bass also show a steep decline after their initial peak in abundance, presumably due to their migratory behavior, but also exhibit a secondary peak in the catch rates of 9-11 year old females that was persistent across several year classes. This secondary peak is due to the relative lack of intermediate sized (590-710 mm TL) striped bass in the samples (Fig. 11). This pattern was not evident in the catches from 1991-1996 but has been persistent thereafter.

Age determinations using scales and otoliths

A total of 249 striped bass from 11 size ranges were aged by reading both their scales and otoliths. Scale and otolith ages from the same specimen were in agreement 34.5% (86/ 249) of the time and within one year 78.3% (195/249) of the time. Differences between the two age determination methods were first analyzed utilizing tests of symmetry. A chi-square test was performed to test the hypothesis that an *m* x *m* contingency table (Table 38) consisting of two classifications of a sample into categories is symmetric about the main diagonal. The test statistic is

$$X^2 = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \frac{\left(n_{ij} - n_{ji}\right)^2}{n_{ij} + n_{ji}}$$

where n_{ij} = the observed frequency in the *i*th row and *j*th column and n_{ji} = the observed frequency in the *j*th row and *i*th column (Hoenig et al., 1995).

A test of symmetry that is significant indicates that there is a systematic difference between the aging methods. The number of degrees of freedom is equal to the number of non-zero age pair comparisons (here = 31). We tested the hypothesis that the observed age differences were randomly distributed along the main table diagonal (Table 38). The hypothesis was rejected (p= 0.0027), indicating non-random differences between the two ageing methodologies.

Differences between the scale and otolith age from the same specimen ranged from zero to four years (Figure 12). The otolith age exceeded the scale age 36.1% of the time (55.2% of the non-zero differences). When the difference in ages as greater than one year, the otolith age was even more likely to be the older age (73.6%). A test of symmetry that compared the negative and positive differences of the same magnitude (i.e. -4 and 4, -3 and 3, etc., Evans and Hoenig, 1998) rejected the hypothesis that these differences were random ($X^2 = 16.94$, df = 4, p= 0.0021). This indicates that there was a systematic difference with otolith ages predominantly older, especially in specimens where the age difference exceeded one year.

Following the extension of the symmetry test outlined by Hoenig et al. (1995), the point at which the asymmetry begins can be determined by repeatedly collapsing the data to form a "plus" group. The resulting chi-square test is then performed sequentially until the result is no longer significant. Non-random differences between otolith and scale ages occurred in striped bass age six and older. The otolith-ages seven year-old class was the largest contributor to the variability. The comparable scale ages ranged from four to nine so no pattern to the differences was apparent. In striped bass aged 12 and older using otoliths (n= 20), the otolith age was older 90% of the time and included every four-year difference.

Next, t-tests of the resultant means of the two ageing methods were performed. A two-tailed paired t-test was made to test the null hypothesis that differences in the mean ages determined by the two methods were random. The mean age of the sample (n=249) determined by reading the otoliths was greater than the mean age determined by reading the scales (0.22 years, Table 39). The t-tail results were:

$$\bar{A}ge_{otolith} = 7.91 \qquad \bar{A}ge_{scale} = 7.69$$

$$S_{otolith} = 3.13 \qquad S_{scale} = 3.04$$

$$t = 0.81$$

$$df = 496$$

$$p = .4168$$

Therefore the null hypothesis was accepted.

A paired t-test was also performed on the ages determined for each specimen by the two methodologies. The null hypothesis tested was that the mean of the difference resultant from the two methods was not different from zero. The paired t-test results were highly significant ($t=2.749$, $df=248$, $p=.0064$) and the null hypothesis was rejected.

To determine whether the distribution of age classes that resulted from the two ageing methodologies were representative of the same population, a Kolmogorov- Smirnov test was performed on the relative proportion that each assigned age class contributed to the total sample (Table 39). This compares the maximum difference in the relative proportions that an age class contributes to the test statistic ($K_{.05}$):

$$D_{max} = 0.1240 \qquad K_{.05} = 1.3581$$

$$D_{.05} = 1.3581\sqrt{\frac{250+250}{250^2}} = 0.1215$$

The maximum difference exceeded the test statistic, so the null hypothesis, that the age structures derived by the two ageing methods represent the same population, was rejected.

Discussion

Striped bass stocks recovered sufficiently by 1993 to allow the re-establishment of limited commercial and recreational fisheries in Virginia. The monitoring efforts summarized in this report were intended to document changes in the abundance and age composition of spawning stocks in the James and Rappahannock rivers during the period of managed harvest by these fisheries.

The main advantage of pound nets is that the gear provides large catches (often in excess of 100 fish per day) that are presumably not sex or size-biased. However, each pound net has a different fishing characteristic, and our sampling methods (in use since 1993) may have introduced additional variability. The down-river net (mile 44) was set in a shallow, flat-bottomed portion of the river with a leader that extended farther into the bay. The upriver net (mile 47) was set in a constricted portion of the river that abutted the channel, and had a leader that extended almost to the shoreline. Ideally, each net was scheduled to be sampled weekly, but uncontrollable factors (especially tide, weather and market conditions) affected this schedule. During spring 2002, and again in 2003, the down-river net was not set and was replaced by a net across the river at mile 45. This net had been utilized since 1997 as a source for tagging striped bass, but had been excluded from the spawning stock assessment in order to keep the sampling methodology as consistent as possible with the 1991-1996 data. Weekly sampling occurred each Monday and Thursday, a schedule that translated to fishing efforts of 96 hrs (Thursday through Monday) or 72 hrs (Monday through Thursday).

In past years, duration of the pound net set was as low as 24 hrs. and as large as 196 hrs. if the fisherman was unable to fish the scheduled net on the scheduled sampling date. Although these events were uncommon, we were unable to assess whether varying effort influenced estimates of catch rate. The 1997 and 1998 data include a pound net at mile 46 that had an orientation and catch characteristics similar to the net at mile 47. This net was also sampled on one date (7 April) in 2003. The 1991 data included samples taken from a pound net at river mile 25 and were weekly vs. twice-weekly samples, but with similar total effort. While this net is far enough within the Rappahannock to preclude significant contamination from stocks from other rivers, it does not meet the criteria established in 1993, restricting sampling to gears located within the designated spawning grounds (above river mile 37). The catches from these other nets were similar in sex and age composition to the nets presently used and their exclusion would adversely affect our ability to assess the status of the spawning stocks in those years.

Variable-mesh gill nets were set by commercial fishermen and fished by scientists after 24 hours on designated sampling days. As a result, there were fewer instances of sampling inconsistencies. The two nets were set approximately 300 meters apart and along the same depth contours on both rivers. Although the down-river net did not always contain the greater catches, removal by one net may have affected the catch rates of its companion. On one date (17 April) in 2003 only one of the two nets were sampled in the Rappahannock River after one end broke free of its anchor.

The gill net captured proportionally more males than did the pound nets. Anecdotal information from commercial fishermen suggests that spawning males are attracted to con-specifics that have become gilled in the net meshes. Thrashing of gilled fish may emulate spawning behavior (termed "rock fights" by local fishermen) and enhance catches of males. The pound net catches contained a greater relative proportion of older female striped bass than did the catches from the gill nets. This trend has been persistent over several years. Thus, given the presence of large females in the spawning run, it is clear that the gill nets do not adequately sample large (900+ mm FL) striped bass.

Due to problems in obtaining the services of a reliable fisherman to set the gill nets in their usual position at mile 62 in the James River, we experimented with a new fisherman, located further downriver, to attempt setting the gear at a new location (mile 45). To facilitate a comparison of the two sites, gill nets were set at mile 62 by another new fisherman on an as-available basis. Catches from the site at mile 45 were low in general and contained almost no females, so that their use in spawning stock assessment was rejected.

The biological characterization of the spawning stock of striped bass in the Rappahannock River changed dramatically from 1991-2003. There was a steady decrease in the relative abundance of five to seven year-old striped bass from 1991-2001, but these ages were proportionally more abundant in 2002 and 2003. The males in these age classes had been the target of the recreational and commercial fisheries, but with the increase in the availability of larger striped bass in recent years, the younger striped bass may be under less fishing pressure. Current regulations protect females from harvest during their annual migration by higher minimum lengths in the coastal fishery (711 mm TL vs. 458 mm TL within Chesapeake Bay) and the closure of the fishery in the bay during the April spawning run. The result has been a general increase in the abundance of older females throughout the period. The catches of older females from the pound nets was again higher after decreasing in 2002. This pattern was also noted after low catches in 1992 and in 1996. However, the catches of older females in the Rappahannock River gill nets was historically low.

Of note in the 2003 samples was the relative abundance of 1992 year class (11 year old) male and female stripers. The catch/effort of this year class at age nine was second only to the 1989 year class and indicates that the strength of the 1992 year class may have been previously underestimated. In spring 1996, when the maximum catch/effort of four year old males would have been expected, the weather was abnormally cold and wet and catches across all year classes were down from the previous year (Sadler *et al.* 1998).

The 2003 values of the Spawning Stock Biomass Index (SSBI) for the Rappahannock River were higher than in 2002 for male striped bass from both gears and for female striped bass from the pound nets only. The SSBI for female striped bass captured in the pound nets was the highest in the 1991-2003 time series. The increase was due to increased numbers across almost every age class when compared to 2002. In contrast, the decrease in the SSBI for female striped bass in the gill nets was due to lower catches of virtually every age class when compared to 2002.

The 1991-2003 values of the SSBI in the Rappahannock River were not consistent between pound nets and gill nets. In the pound nets, male biomass peaked in 1993 due to strong 1988 and 1989 year classes, and again in 1999 and 2000 due to strong 1996 and 1997 year classes. The value in 2003 was driven by increased catches of 1998 and 1999 year class males, but the values were well below the historical peaks. The female biomass from pound nets showed no reliance upon any age groups but rather a increase in catches across all ages. The male biomass from the gill nets is driven by the number of "super catches", when the net is literally filled by males seeking to spawn, that occur differentially among the years (most notably in 1997 and 1994). The female SSBI was highest from 1992-1996 due to catches of four-seven year old stripers. Due to the highly selective nature of the gill nets (significantly fewer large females), the female SSBI from these nets is less reliable. The low biomass values from both gears of both sexes in 1992 and 1996 are probably an underestimate of spawning stock strength since water temperatures were below normal in those years. Local fishermen that low temperatures alter the catchability of striped bass. It is also possible that the spawning migration continued past the end of sampling in those years. Weather conditions may have played a roll in the catches in 2003, with heavy rainfall ending a three-year drought and producing more turbid water and high river flows.

The 2003 values of the SSBI in the James River were lower than in 2002, especially for females. The male index was driven by large catches of the 1998-2000 year classes while the female index was driven by a large catch of the 1998 year class with a smaller secondary peak of the 1993 year class. Because of the changes in location and in the methodology utilized by the new fisherman starting in 2000, the values are not directly comparable with those of previous years. The below normal river flow conditions noted for the Rappahannock River apply to the James River as well and may be partially responsible for the decrease in catches. The relative scarcity of larger, predominantly female, striped bass from the gill nets in the James River (compared to pound net catches) implies a similar limitation in fishing power as shown in the Rappahannock River but comparative data are not available since there are no commercial pound nets on the James River.

The Egg Production Potential Index (EPPI) is an attempt to better define the reproductive potential of the spawning stocks, especially as they become more heavily dependent on fewer, but larger, female striped bass. For example, in the 2001 Rappahannock River pound net data the contribution of 8+ year old females was 75.2% of the total number of mature females (the basis of our index prior to 1998), 94.1% of the mature female biomass (the basis of the current index) and 94.3% of the calculated egg potential. As noted previously, the catches in 2002 were less reliant on older fish than in the preceding years so that the contribution of 8+ year old females was 46% of the total number of mature females, but still 69.1% of the female biomass and 68.4% of the potential egg production. In 2003, the contribution of 8+ year old females was 87.7% of the total number, 95.5% of the biomass and 95.5% of the calculated egg potential. It should be noted that our fecundity estimates are well below those reported by Setzler et al. (1980). Our methodology differs from the previous studies but the relative contribution in potential egg production of the older females may be underestimated at present.

In our analysis of pound net catch rates, we observed a distinctive bimodal distribution of female striped bass in the 1987-1992 year classes. These striped bass appeared in greatest abundance at age five or six (especially males), at lower abundance at age six to eight (both sexes), and then higher abundance at ages nine to12 (especially females). Also, prior to 1995, the peak catch rates of male and female striped bass (ages four and five) were similar. The catches of these age classes are now almost exclusively male. Thus, the 1990-1992 year classes actually showed greater abundance at ages nine to 12 years than at any other age. Age estimation of larger striped bass by scales is problematic because re-absorption or erosion of outer margins of scales may cause under-estimation of age. Under-ageing errors might tend to lump catches of old fish (>12 years) into younger categories (nine to 12 years). However, ignoring age, we also observed a bimodal size distribution, one group from 470-590 mm fork length, presumably young, and the second group of 850-1200 mm fork length, presumably older. This trend became increasingly apparent in the 1997-2003 data and its significance has not been determined.

The time series of the catch rates by age class and by year class indicate that the age of peak abundance in the rivers has changed from five or six years in 1992-1994 to three to four years in 2000-2002. Changes in the annual catch rates by year class in the Rappahannock River indicated that strong year classes occurred in 1988, 1989, 1996 and 1997, and weak year classes occurred in 1990 and 1991. The relative abundance of ten-year old, 1992 year class, striped bass of both sexes in both 2001 and 2002, indicate that the 1992 year class was also strong. Likewise, the data for the James River indicated that strong year classes occurred in 1989, 1993, 1994 and 1996, and weak year classes occurred in 1990 and 1991.

The time series allows estimates of the instantaneous rates of survival of the year classes using catch curves, especially for the 1983-1994 year classes that were captured for four or five years subsequent to their peak in abundance at age four or five. The survival estimates of female striped bass of these year classes in the Rappahannock River were approximately 0.63 in pound nets and 0.58 in gill nets. The lower capture rates of larger (older) females in the gill nets resulted in lower estimates. The survival estimates of male striped bass were approximately 0.39 in pound nets and 0.31 in gill nets. The high survival estimates for the females may be the result of their differential maturation rates. These differences cause lower peaks in abundance (usually at age five) as only fractions of each year class mature and are depicted in their lower peak abundance values. The large differences between the sexes also reflect a management strategy that targets males. Similarly, survival estimates for these year classes in the James River were approximately 0.34 for male striped bass and approximately 0.51 for females.

The ages of striped bass determined by reading both their scales and otoliths were found to differ by as much as four years. The age difference determined for the largest, and oldest, specimen was four years (16 years by reading the scale vs 20 years by reading the otolith). Agreement between the two ageing methodologies was only 34.5% and was similar to the results from 2002. When there was a non-random disagreement between methodologies, the otolith age was 1.22 times more likely to have been aged older than the respective scale-derived age and 3.15 times as likely to produce a difference of two or more years older. The overall differences were found to be of statistical significance (except for the sample mean ages derived by the two methodologies), especially for striped bass age six and older. Thus, by using otoliths to age the striped bass, the age structure extends back to the 1983 year class, while scale ageing limits the age structure to the 1987 year class. Previous ageing method comparison studies (Secor, et al. 1995, Welch, et al. 1993) concluded that otlith-based and scale-based ages of striped bass became increasingly divergent, with otolith ages being older, especially after 900 mm in size or 10-12 years in age. We plan to continue these comparisons in future years.

Literature Cited

Berggren, T. J. and J. T. Lieberman. 1978. Relative contribution of Hudson, Chesapeake and Roanoke striped bass, *Morone saxatilis*, stocks to the Atlantic coast fishery. U. S.Fish. Bull. 76(2): 335-345.

Barbieri, S. K. and L. R. Barbieri. 1993. A new method of oocyte separation and preservation for fish reproduction studies. U. S. Fish. Bull. 91: 165-170.

Chapoton, R. B. and J. E. Sykes. 1961. Atlantic coast migration of large striped bass as evidenced by fisheries and tagging. Trans. Amer. Fish. Soc. 90(1):13-20.

Dorazio, R. M., K. A. Hattala, C. B. McCollough and J. E. Skjeveland. 1994. Tag recovery estimates of migration of striped bass from spawning areas of the Chesapeake Bay. Trans. Amer. Fish. Soc. 123: 950-963.

Evans, G. T. and J. M. Hoenig. 1998. Testing and viewing symmetry in contingency tables, with application to readers of fish ages. Biometrics 54: 620-629.

Field, J. D. 1997. Atlantic striped bass management: where did we go right? Fisheries 22(7): 6-8.

Frie, R. V. 1982. Measurement of fish scales and back-calculation of body lengths using a digitizing pad and microcomputer. Fisheries 7(5): 5-8.

Grant, G. C. and J. E. Olney. 1991. Distribution of striped bass *Morone saxatilis* (Walbaum) eggs and larvae in major Virginia rivers. U. S. Fish. Bull. 89:187-193.

Hardy, J.D. Jr. 1978. Development of fishes of the mid-Atlantic bight. Vol 111, Aphrederidae through Rachycentridae. U. S. Fish Wildl. Serv. FWS/OBS-78/12.

Hoenig, J. M., M. J. Morgan and C. A. Brown. 1995. Analysing differences between two age determination methods by tests of symmetry. Can. J. Fish. Aquat. Sci. 52: 354-368.

Lewis, R. M. 1957. Comparative study of populations of the striped bass. U. S. Fish and Wildlife Service Spec. Rep. Fisheries 204:1-54.

Loesch, J. G., W. H. Kriete, Jr., and S. M. Atran. 1985. Sonic digitizers "go fishing": fish scales reveal age by sound. Sea Tech., February 1985: 3-31.

Mansueti, R. J. 1961. Age, growth, and movements of the striped bass, *Roccus saxatilis*, taken in size selective fishing gear in Maryland. ......: 9-36.

McGovern, J. C. and J. E. Olney. 1996. Factors affecting survival of early life stages and subsequent recruitment of striped bass on the Pamunkey River, Virginia. Can. J. Fish. Aquat. Sci. 53: 1713-1726.

Merriman, D. 1937. Notes on the life history of the striped bass (*Roccus lineatus*). Copeia 1: 15-36.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. Fish. Bull. U.S. Fish Wildl. Serv. 50(35):1-77.

Olney, J. E., J. D. Field, and J.C. McGovern. 1991. Striped bass egg mortality, production and female biomass in Virginia rivers, 1980-1989. Trans. Amer. Fish. Soc. 120: 354-367.

Pearson, J. C. 1938. The life history of the striped bass, or rockfish, *Roccus saxatilis* (Walbaum). U. S. Fish. Bull. 49: 825-851.

Raney, E. C. 1957. Subpopulations of the striped bass *Roccus saxatilis* (Walbaum), in tributaries in Chesapeake Bay. U. S. Fish Wildl. Serv., Spec. Sci. Fish. 208: 85-107.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd. Can. Bull. 191: 382 p.

Rugolo, L. J., P. W. Jones, R. K. Schaefer, K. S. Knotts, H. T. Hornick and J. L. Markham. 1994. Estimation of Chesapeake Bay-wide exploitation rate and population abundance for the 1993 striped bass stock. Manuscript, Maryland Department of Natural Resources, Annapolis, Md.

Sadler, P. W., Harris, R. E., Romine, J. and J. E. Olney. 1998. Evaluation of striped bass stocks in Virginia: monitoring studies, 1993-1998. Completion Report, Virginia Institute of Marine Science. 99 p.

Sadler, P. W., Latour, R. J., Harris, R. E. and J. E. Olney. 2001. Evaluation of striped bass stocks in Virginia: monitoring and tagging studies, 1999-2003. Annual Report, Virginia Institute of Marine Science: 93 p.

Sadler, P. W., Latour, R. J., Harris, R. E., Maki, K. L. and J. E. Olney. 2002. Evaluation of striped bass stocks in Virginia: monitoring and tagging studies, 1999-2003. Annual Report, Virginia Institute of Marine Science: 102 p.

Secor, D.H. 1999. Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fisheries research 43: 13-34.

Secor, D.H., T. M. Trice and H. T. Hornick. 1995. Validation of otolith-based ageing and a comparison of oolith and scale-based ageing in mark-recaptured Chesapeake Bay striped bass, *Morone saxatilis*. Fish. Bull. 93:186-190.

Setzler, E.M., W.R. Boyton, K.V. Wood, H.H. Zion, L. Lubbers, N.K. Montford, P. Frere, L. Tucker and J.A. Mihursky. 1980. Synopsis of biological data on striped bass, *Morone saxatilis* (Walbaum). NOAA Tech. Rept. NMFS 433.

Shepherd, G. and H. Lazar (eds). 1998. Source document to Amendment 5 to the Interstate Fishery Management Plan for striped bass. ASMFC Rep. No. 34.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry. W. H. Freeman Co. 859 p.

Van Winkle, W., K. D. Kumar, and D. S. Vaughan. 1988. Relative contributions of Hudson River and Chesapeake Bay striped bass stocks to the Atlantic Coast population. Amer. Fish. Soc. Mono. 4: 255-266.

Welch, T. J., M.J. Van Den Avyle, R.K. Betsill and E.M. Driebe. 1993. Precision and relative accuracy of striped bass age estimates from otoliths, scales, anal fin rays and spines. N. Amer. J. Fish. Mgmt. 13:616-620.

Wischniowski, W. and S. Bobko. 1998. Age and growth laboratory manual. Final report Old Dominion Univ. Center for Quantitive Fisheries Ecology.

Zar, J. H. 1999. Biostatistical Analysis, Fourth Edition. Prentis Hall Press. 663 pp.

Table 1. Numbers of striped bass in three age categories (year classes 1999-2001, 1995-1998 and 1987-1994) from pound nets in the Rappahannock River, by sampling date, in spring 2003.

Date	n	Year Class							
		1999 - 2001		1995 - 1998		1987 - 1994		Not aged	
		M	F	M	F	M	F	M	F
3 April	28	8	0	10	2	1	7	0	0
7 April	25	4	0	11	2	1	7	0	0
10 April	25	8	0	12	0	0	5	0	0
14 April	104	35	0	31	6	4	28	0	0
17 April	31	3	2	7	3	1	15	0	0
21 April	28	6	0	5	5	0	12	0	0
24 April	87	11	0	37	14	1	24	0	0
28 April	49	7	0	16	5	1	20	0	0
1 May	93	29	0	34	8	0	22	0	0
Total	**470**	**111**	**2**	**163**	**45**	**9**	**140**	**0**	**0**

Table 2. Net-specific summary of catch rates and ages of striped bass (n= 470) in pound nets on the Rappahannock River, spring 2003. Values in bold are grand means for each column.

Date	Net ID	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
3 April	S454	28	9.5	4.5	21,020.9	36,089.1	5.0	9.3
7 April	S462	25	4.0	2.3	12,172.7	17,529.1	5.8	9.2
10 April	S473	25	6.7	1.7	15,875.1	15,884.3	5.1	10.2
14 April	S454	104	17.5	8.5	43,635.1	81,025.6	5.1	9.8
17 April	S473	31	3.7	6.6	9,306.2	59,058.3	5.5	9.4
21 April	S454	28	2.8	4.3	7,911.0	36,178.0	5.2	9.6
24 April	S473	87	16.3	12.7	46,835.8	104,659.0	5.7	9.3
28 April	S454	49	6.0	6.3	16,023.1	58,577.0	5.4	9.7
1 May	S473	93	21.0	10.0	35,319.5	74,201.4	4.7	9.2
Totals	S454	209	8.9	6.1	22,308.4	55,378.6	5.2	9.7
	S462	25	4.0	2.3	12,172.7	17,529.1	5.8	9.2
	S473	236	11.9	7.8	26,834.2	63,450.7	5.1	9.3
Season		**52.2**	**9.4**	**6.2**	**22,767.3**	**53,560.9**	**5.2**	**9.5**

Table 3. Length frequencies (TL in mm) of striped bass sampled from the pound nets in the Rappahannock River, spring 2003.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	0	460-	11	620-	0	780-	7	940-	8	1100-	0
310-	0	470-	14	630-	1	790-	10	950-	5	1110-	1
320-	0	480-	8	640-	1	800-	7	960-	9	1120-	2
330-	0	490-	12	650-	1	810-	7	970-	5	1130-	0
340-	0	500-	10	660-	3	820-	6	980-	4	1140-	1
350-	1	510-	21	670-	1	830-	5	990-	9	1150-	0
360-	2	520-	9	680-	2	840-	10	1000-	4	1160-	0
370-	1	530-	17	690-	1	850-	6	1010-	4	1170-	0
380-	2	540-	20	700-	0	860-	13	1020-	1	1180-	0
390-	0	550-	18	710-	1	870-	9	1030-	2	1190-	0
400-	1	560-	16	720-	2	880-	9	1040-	0	1200-	0
410-	2	570-	6	730-	9	890-	8	1050-	3	1210-	0
420-	4	580-	11	740-	9	900-	10	1060-	1	1220-	0
430-	7	590-	6	750-	3	910-	14	1070-	1	1230-	0
440-	4	600-	6	760-	8	920-	10	1080-	2	1240-	0
450-	3	610-	2	770-	7	930-	11	1090-	1	1250-	1

Table 4. Mean fork length (mm), weight (g), standard deviation (SD) and CPUE (fish per day; weight per day), of striped bass from pound nets in the Rappahannock River, 30 March - 3 May 2003.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2000	male	23	383.4	28.5	716.7	155.9	0.8	549.5
1999	male	88	458.5	21.2	1,171.0	191.8	2.9	3,435.0
	female	2	442.0	8.5	1,143.9	29.8	0.1	76.3
1998	male	92	521.5	21.2	1,810.1	284.7	3.1	5,551.1
	female	8	514.0	14.6	1,799.1	244.8	0.3	479.7
1997	male	9	627.7	30.5	3,158.1	466.8	0.3	947.4
	female	2	604.5	43.1	3,103.4	1,222.4	0.1	206.9
1996	male	45	713.3	23.8	4,596.5	571.0	1.5	6,894.7
	female	10	718.1	28.3	4,920.2	616.0	0.3	1,640.1
1995	male	17	774.2	31.1	5,814.7	832.5	0.6	3,295.0
	female	25	777.2	22.6	6,355.7	824.3	0.8	5,114.3
1994	male	7	794.1	27.1	6,485.4	600.9	0.2	1,513.3
	female	44	837.1	21.0	7,935.7	972.3	1.5	11,639.0
1993	male	2	862.0	17.0	8,719.5	789.3	0.1	581.3
	female	41	873.6	25.8	9,225.4	1,170.3	1.4	12,608.1
1992	female	34	911.1	34.6	10,610.1	1,479.3	1.1	12,024.8
1991	female	10	954.0	33.1	11,791.4	2,139.1	0.3	3,930.5
1990	female	8	1,017.9	35.0	14,966.4	2,778.8	0.3	3,991.1
1989	female	2	1,065.0	21.2	14,935.7	593.2	0.1	995.7
1987	female	1	1,215.0		20,167.8		0.0	672.3

Table 5. Summary of the season mean (30 March - 3 May) catch rates and ages, by sex, from the pound nets in the Rappahannock River, 30 March - 3 May, 1993-2003.

Year	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2003	470	9.4	6.2	22,767.3	53,560.9	5.2	9.5
2002	170	3.5	1.8	7,057.2	11,422.9	4.6	7.8
2001	577	15.2	3.4	24,193.2	26,298.6	4.3	9.1
2000	1,508	37.4	1.9	42,233.1	14,704.5	3.7	8.8
1999	836	27.7	2.1	31,370.7	16,821.7	3.7	9.9
1998	401	10.3	4.0	15,598.6	32,930.6	4.0	9.5
1997	406	14.4	5.9	22,400.0	49,700.0	4.0	9.2
1996	430	10.1	2.2	14,300.0	9,400.0	3.9	7.9
1995	363	11.2	3.3	13,500.0	20,000.0	3.3	7.2
1994	375	8.4	5.4	17,400.0	30,900.0	4.5	7.2
1993	565	14.4	7.3	31,400.0	37,500.0	4.6	6.9
Mean	**554.6**	**15.0**	**3.8**	**22,173.2**	**26,248.9**	**4.0**	**8.4**

Table 6. Numbers of striped bass in three age categories (year classes 1999-2001, 1995-1998 and 1987-1994) from gill nets in the Rappahannock River, by sampling date, in spring 2003.

Date	n	Year Class							
		1999 - 2001		1995 - 1998		1987 - 1994		Not aged	
		M	F	M	F	M	F	M	F
31 March	164	88	0	74	1	0	1	0	0
3 April	24	14	0	9	0	1	0	0	0
7 April	111	52	0	52	5	1	1	0	0
10 April	20	8	0	9	0	1	2	0	0
14 April	11	3	0	6	0	0	2	0	0
18 April	61	49	1	8	1	1	0	1	0
21 April	11	3	0	3	2	0	3	0	0
24 April	26	10	0	10	3	0	3	0	0
28 April	37	14	0	19	3	0	1	0	0
1 May	60	33	0	24	1	0	2	0	0
Total	525	274	1	214	16	4	15	1	0

Table 7. Summary of catch rates and mean ages of striped bass (n=525) from the two gill nets in the Rappahannock River, spring 2003. Values in bold are grand means for each column.

Date	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
31 March	164	162.0	2.0	314,504.8	11,556.4	4.6	7.5
3 April	24	24.0	0.0	57,040.6	0.0	4.8	
7 April	111	105.0	6.0	239,165.7	36,344.4	4.8	7.5
10 April	20	18.0	2.0	48,623.6	20,225.2	5.3	11.5
14 April	11	9.0	2.0	23,776.0	15,662.1	5.0	9.5
17 April	61	93.8	4.1	91,082.7	8,864.5	3.3	5.0
21 April	11	6.0	5.0	14,333.4	37,738.5	5.2	8.6
24 April	26	20.0	6.0	37,349.8	37,431.8	4.6	7.8
28 April	37	33.0	4.0	59,370.7	14,853.8	4.7	6.0
1 May	60	57.0	3.0	82,613.5	20,146.6	4.3	8.3
Season	**525**	**52.8**	**3.4**	**96,786.1**	**20,282.3**	**4.5**	**7.8**

Note: net 1 was not fished on 17 April. CPUEs were adjusted increased by 1.59 (males) and 2.1 (females).

Table 8. Length frequencies (TL in mm) of striped bass sampled from the experimental gill nets in the Rappahannock River, spring 2003.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	2	460-	10	620-	6	780-	7	940-	1	1100-	0
310-	5	470-	12	630-	7	790-	7	950-	0	1110-	0
320-	8	480-	13	640-	7	800-	10	960-	1	1120-	0
330-	15	490-	29	650-	6	810-	0	970-	0	1130-	0
340-	12	500-	21	660-	9	820-	1	980-	0	1140-	0
350-	13	510-	32	670-	0	830-	1	990-	0	1150-	0
360-	5	520-	27	680-	2	840-	0	1000-	0	1160-	0
370-	12	530-	31	690-	0	850-	1	1010-	0	1170-	0
380-	4	540-	21	700-	4	860-	1	1020-	0	1180-	0
390-	6	550-	20	710-	1	870-	4	1030-	0	1190-	0
400-	10	560-	13	720-	4	880-	3	1040-	0	1200-	0
410-	6	570-	11	730-	6	890-	2	1050-	0	1210-	0
420-	2	580-	9	740-	3	900-	1	1060-	0	1220-	0
430-	10	590-	9	750-	6	910-	1	1070-	0	1230-	0
440-	8	600-	12	760-	6	920-	1	1080-	0	1240-	0
450-	4	610-	8	770-	10	930-	3	1090-	1	1250-	0

Table 9. Mean fork length (mm), weight (g), standard deviations (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the Rappahannock River, 30 March - 3 May, 2003.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2001	male	27	302.8	13.0	349.0	52.6	2.7	942.3
2000	male	88	354.0	33.6	582.5	184.2	8.8	5,126.0
1999	male	160	463.8	21.1	1,308.2	186.9	16.0	20,931.1
1998	male	121	525.0	27.8	1,945.7	393.5	12.1	23,543.0
	female	5	540.0	24.1	2,228.9	441.1	0.3	586.6
1997	male	43	615.8	39.3	3,218.3	646.1	4.3	13,838.7
	female	3	612.3	19.6	2,932.5	395.5	0.3	879.8
1996	male	38	720.9	22.2	5,018.2	512.9	3.8	19,069.2
	female	4	710.8	24.6	5,004.4	617.8	0.4	2,001.8
1995	male	12	748.4	28.3	5,851.5	735.5	1.2	7,021.8
	female	4	766.7	34.4	6,289.1	1,294.3	0.4	2,515.6
1994	male	4	808.8	13.7	7,331.3	1,485.8	0.4	2,932.5
	female	9	848.8	17.5	8,494.1	398.2	0.9	7,644.7
1993	female	5	870.0	38.2	8,301.6	1,328.3	0.5	4,150.8
1990	female	1	1,028.0		13,738.3		0.1	1,373.8
N/A	male	1	471.0		1,396.5		0.1	139.7

N/A: not ageable

Table 10. Summary of the season mean (30 March - 3 May) catch rates and ages, by sex, from the experimental gill nets in the Rappahannock River, 1997-2003.

Year	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2003	525	52.0	3.3	98,466.7	20,716.8	4.5	8.0
2002	323	24.5	7.8	53,606.9	40,727.5	4.8	7.0
2001	622	58.1	4.1	86,827.2	31,011.3	4.3	8.3
2000	493	47.8	3.1	64,955.7	18,196.0	3.8	7.5
1999	671	64.8	2.3	55,997.3	13,331.0	3.3	7.2
1998	603	57.1	2.9	65,500.0	12,200.0	3.9	7.3
1997	824	80.6	1.8	103,600.0	14,100.0	4.0	7.8
1996	498	45.2	4.6	54,300.0	26,600.0	3.6	6.6
1995	226	15.6	7.0	45,600.0	47,700.0	4.7	7.0
1994	516	41.5	10.1	82,700.0	54,900.0	4.7	6.9
1993	527	36.6	16.0	66,900.0	56,500.0	4.9	6.3
Mean	**529.8**	**47.6**	**5.7**	**70,768.5**	**30,543.9**	**4.1**	**7.0**

Table 11a. Numbers of striped bass in three age categories (year classes 1999-2001, 1995-1998 and 1987-1994) in gill nets in the James River (mile 45) by sampling date in spring 2003.

Date	n	Year Class							
		1999 - 2001		1995 - 1998		1987 - 1994		Not aged	
		M	F	M	F	M	F	M	F
2 April	15	6	0	6	1	0	2	0	0
3 April	3	1	0	1	0	0	0	1	0
7 April	15	4	0	8	3	0	0	0	0
10 April	1	0	0	0	0	0	1	0	0
14 April	1	1	0	0	0	0	0	0	0
17 April	4	0	0	2	2	0	0	0	0
21 April	24	7	0	13	3	0	1	0	0
28 April	84	41	1	39	2	0	0	1	0
1 May	85	49	0	33	3	0	0	0	0
Total	**232**	**109**	**1**	**102**	**14**	**0**	**4**	**2**	**0**

Table 11b. Numbers of striped bass in three age categories (year classes 1999-2001, 1995-1998 and 1987-1994) in gill nets in the James River (mile 62) by sampling date in spring 2003.

Date	n	Year Class 1999 - 2001		1995 - 1998		1987 - 1994		Not aged	
		M	F	M	F	M	F	M	F
2 April	14	8	0	5	0	0	1	0	0
9 April	10	3	0	7	0	0	0	0	0
16 April	155	71	0	74	4	0	6	0	0
23 April	80	27	0	31	13	1	7	1	0
24 April	96	48	0	42	6	0	0	0	0
30 April	176	110	0	61	4	0	0	1	0
1 May	108	66	0	40	2	0	0	0	0
Total	**639**	**333**	**0**	**260**	**29**	**1**	**14**	**2**	**0**

Table 12. Summary of catch rates and mean ages of striped bass (n=871) from the gill nets in the James River, spring 2003. Values in bold are grand means for each column.

Date	mile	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
2 April	45	15	12.0	3.0	33,148.1	21,908.3	5.0	8.3
	62	14	38.6	2.6	67,786.4	26,066.6	4.3	10.0
3 April	45	3	3.0	0.0	5,673.9	0.0	4.5	
7 April	45	15	12.0	3.0	29,212.6	10,874.3	5.0	6.3
9 April	62	10	29.7	0.0	24,103.9	0.0	5.2	
10 April	45	1	0.0	1.0	0.0	13,350.3		11.0
14 April	45	1	1.0	0.0	363.3	0.0	3.0	
16 April	62	155	430.7	26.1	863,315.1	194,293.6	4.7	8.4
17 April	45	4	2.0	2.0	4,704.2	8,460.7	5.0	6.5
21 April	45	24	20.0	4.0	42,751.5	18,410.7	4.8	6.8
23 April	62	80	60.0	20.0	115,414.5	125,281.1	4.7	7.5
24 April	62	96	90.0	6.0	159,874.5	20,327.6	4.5	5.7
28 April	45	84	81.0	3.0	143,973.7	6,279.9	4.5	4.7
30 April	62	176	172.0	4.0	259,115.9	12,725.3	4.2	5.8
1 May	45	85	82.0	3.0	133,235.4	10,647.5	4.4	6.0
	62	108	106.0	2.0	150,179.0	3,607.9	4.2	5.0
Totals	**45**	**232**	**23.7**	**2.1**	**43,673.6**	**9,992.4**	**4.6**	**6.7**
	62	**639**	**132.4**	**8.7**	**234,255.6**	**55,043.2**	**4.5**	**7.6**

Note: net 4 was not fished 2-16 April at mile 62. CPUEs were adjusted by 2.97 (males) and 2.61 (females).

Table 13. Length frequencies (TL in mm) of striped bass sampled from the Experimental gill nets nets in the James River, spring 2003.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	2	460-	21	620-	16	780-	5	940-	0	1100-	0
310-	2	470-	30	630-	18	790-	5	950-	0	1110-	0
320-	2	480-	49	640-	13	800-	3	960-	1	1120-	0
330-	9	490-	45	650-	13	810-	0	970-	1	1130-	0
340-	7	500-	38	660-	11	820-	4	980-	1	1140-	0
350-	6	510-	39	670-	9	830-	2	990-	0	1150-	0
360-	6	520-	47	680-	5	840-	0	1000-	0	1160-	0
370-	5	530-	42	690-	2	850-	1	1010-	1	1170-	0
380-	5	540-	25	700-	1	860-	3	1020-	0	1180-	0
390-	13	550-	39	710-	9	870-	1	1030-	0	1190-	0
400-	21	560-	36	720-	2	880-	2	1040-	2	1200-	0
410-	18	570-	38	730-	2	890-	0	1050-	1	1210-	0
420-	14	580-	27	740-	2	900-	1	1060-	1	1220-	0
430-	21	590-	26	750-	4	910-	2	1070-	0	1230-	0
440-	10	600-	27	760-	3	920-	0	1080-	0	1240-	0
450-	30	610-	16	770-	3	930-	3	1090-	0	1250-	0

Table 14a. Mean fork length (mm), weight (g), standard deviations (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the James River (mile 45), 30 March - 3 May, 2003.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2001	male	3	298.7	3.1	355.8	29.9	0.3	118.6
2000	male	26	377.2	27.7	745.1	172.5	2.9	2,152.5
1999	male	80	464.5	22.0	1,357.6	214.6	8.9	12,067.6
	female	1	460.0		1,260.2		0.1	51.1
1998	male	70	533.1	26.1	2,064.9	304.4	7.8	16,060.3
	female	7	552.1	32.8	2,315.0	341.6	0.8	1,800.6
1997	male	23	609.2	32.9	3,086.3	449.5	2.6	7,887.2
	female	2	608.0	25.5	2,987.1	67.8	0.2	663.8
1996	male	5	670.2	90.0	4,103.7	1,428.0	0.6	2,279.8
	female	3	702.7	34.5	4,656.7	221.8	0.3	1,552.2
1995	male	4	752.5	24.1	5,986.1	612.1	0.4	2,660.5
	female	2	778.0	21.2	6,519.7	686.8	0.2	1,448.8
1994	female	2	797.5	24.7	7,185.4	31.3	0.2	1,596.8
1993	female	1	915.0		11,761.7		0.1	1,306.9
1992	female	1	952.0		13,350.3		0.1	1,483.4
N/A	male	2	525.0	72.1	2,013.3	731.6	0.2	447.4

N/A: not ageable

Table 14b. Mean fork length (mm), weight (g), standard deviations (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the James River (mile 62), 30 March - 3 May, 2003.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2001	male	6	299.5	13.6	340.7	56.5	0.9	292.0
2000	male	108	373.0	31.5	711.6	184.6	15.4	10,979.0
1999	male	219	455.9	22.1	1,282.0	196.7	31.3	40,108.3
1998	male	182	530.8	27.9	2,026.5	327.1	26.0	31,266.0
	female	20	540.4	22.7	2,266.9	322.3	2.9	6,476.9
1997	male	53	605.3	32.6	3,065.0	478.8	7.6	23,206.4
	female	3	631.7	25.4	3,364.3	798.6	0.4	1,441.8
1996	male	18	686.6	35.4	4,404.4	664.3	2.6	11,325.6
	female	2	724.0	28.3	4,894.8	876.1	0.3	1,398.5
1995	male	7	747.9	16.3	5,794.4	567.6	1.0	5,794.4
	female	4	780.5	32.1	6,977.8	891.6	0.6	3,986.9
1994	female	4	843.5	28.0	8,923.8	981.9	0.6	5,099.3
1993	male	1	838.0		8,494.9		0.1	1,213.6
	female	5	874.2	35.1	9,742.8	1,706.5	0.7	6,959.1
1992	female	2	946.5	43.1	12,016.3	1,872.6	0.3	3,433.2
1991	female	1	990.0		14,559.8		0.1	2,080.0
1990	female	1	977.0		13,833.6		0.1	1,976.2
1989	female	1	1,010.0		16,405.3		0.1	2,343.6
N/A	male	2	475.0	24.0	1,467.5	263.8	0.3	419.3

N/A: not ageable

Table 15. Summary of the season mean (30 March - 3 May) catch rates and ages, by sex, from the experimental gill nets in the James River, 1995-2003.

Year	mile	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
2003	45	232	23.7	2.1	43,673.6	9,992.4	4.6	6.7
	62	639	132.4	8.7	234,255.6	55,043.2	4.5	7.6
2002	62	824	81.4	10.1	173,663.8	47,591.2	4.7	6.4
2001	62	1,050	98.1	6.9	181,512.7	41,347.7	4.4	7.2
2000	62	1,437	139.6	4.1	241,966.4	20,396.6	4.3	6.7
1999	55	482	25.3	22.9	45,886.4	103,362.7	4.3	6.3
1998	55	199	14.9	7.2	33,000.0	46,500.0	4.7	7.5
1997	55	160	11.1	6.7	23,900.0	44,600.0	4.9	7.8
1996	55	183	10.9	7.4	23,800.0	43,500.0	4.8	7.4
1995	55	419	24.0	22.6	52,400.0	125,300.0	4.4	6.7
Mean		**599.2**	**59.7**	**10.7**	**112,265.0**	**58,626.8**	**4.5**	**6.7**

Table 16. Values of the spawning stock biomass index (SSBI) for male and female striped bass by gear in the Rappahannock River, 30 March - 3 May, 1991-2003.

	Pound nets					Gill nets				
	N		SSBI (kg/day)			N		SSBI (kg/day)		
Year	M	F	M	F	M+F	M	F	M	F	M+F
2003	283	187	22.8	53.6	76.4	467	31	97.3	20.7	118.0
2002	113	57	7.1	11.4	18.5	240	78	53.4	40.7	94.1
2001	470	105	24.2	27.6	51.8	572	41	88.6	30.9	119.5
2000	1,436	71	42.7	14.6	57.3	452	27	65.3	16.5	81.8
1999	738	61	30.5	19.8	50.3	532	21	51.4	13.2	64.6
1998	273	113	14.8	36.4	51.2	485	27	81.5	18.5	100.0
1997	277	115	22.2	49.6	71.7	801	18	177.8	19.1	197.0
1996	334	73	14.1	9.3	23.4	433	46	63.7	30.2	93.9
1995	207	76	12.4	19.8	32.2	162	69	43.9	56.7	100.6
1994	195	141	17.1	30.9	48.0	391	100	101.6	64.7	166.3
1993	357	188	31.2	37.5	68.7	361	160	85.6	74.1	159.6
1992	51	100	5.4	19.4	24.8	61	74	15.0	32.2	47.2
1991	153	70	21.3	21.5	42.8	406	47	65.0	17.8	83.8
Mean	**376**	**104**	**20.4**	**27.0**	**47.4**	**412**	**57**	**76.2**	**33.5**	**109.7**

Table 17. Values of the spawning stock biomass index (SSBI) calculated from gill net catches of male and female striped bass in the James River, 30 March - 3 May, 1994-2003. The 1994 data consisted of one gill net (GN # 1) and were adjusted by the proportion of the biomass that gill net # 2 captured in 1995-1998 (1.8 x GN #1 for males; 1.9 x GN #1 for females).

Year	River Mile	n		SSBI (kg/day)		
		Male	Female	Male	Female	Combined
2003	45	210	19	43.56	9.99	53.55
	62	590	43	145.74	35.20	180.94
2002	62	728	92	173.51	47.59	221.10
2001	62	978	68	181.40	41.31	222.71
2000	62	1,381	40	241.41	21.18	262.59
1999	55	251	211	45.81	101.98	147.79
1998	55	134	65	32.97	46.48	79.45
1997	55	100	60	23.89	44.59	68.48
1996	55	108	74	23.70	43.35	67.05
1995	55	210	202	52.10	125.15	177.25
1994	55	119	64	46.27	65.74	112.01
Mean*		**450**	**92**	**96.68**	**57.26**	**153.93**

1. Mean values exclude the 2003 values from mile 45.

Table 18. Predicted values of fecundity (in millions of eggs) of female striped bass with increasing fork length (mm), James and Rappahannock rivers combined, spring 2003.

FL	Fecundity	FL	Fecundity	FL	Fecundity	FL	Fecundity
400	0.147	600	0.520	800	1.274	1000	2.554
420	0.171	620	0.576	820	1.376	1020	2.717
440	0.198	640	0.636	840	1.484	1040	2.887
460	0.227	660	0.700	860	1.596	1060	3.063
480	0.259	680	0.768	880	1.715	1080	3.247
500	0.294	700	0.840	900	1.839	1100	3.438
520	0.333	720	0.918	920	1.970	1120	3.637
540	0.374	740	0.999	940	2.106	1140	3.843
560	0.419	760	1.086	960	2.249	1160	4.057
580	0.468	780	1.178	980	2.399	1180	4.279

Table 19. Total, age-specific, estimated total egg potential (E, in millions of eggs/day) mature (ages 4 and older) female striped bass, by river and gear type, 30 March - 3 May 2003. The Egg Production Potential Indexes (millions of eggs/day) are in bold.

Age	Rappahannock River						James River		
	Pound Nets			Gill Nets			Gill Nets		
	n	E	%	n	E	%	n	E	%
4	2	0.013	0.1%	0	0.000	0.0%	0	0.000	0.0%
5	8	0.086	0.9%	5	0.199	5.3%	20	1.078	17.8%
6	2	0.036	0.4%	3	0.175	4.7%	3	0.262	4.3%
7	10	0.305	3.1%	4	0.372	10.0%	2	0.267	4.4%
8	24	0.936	9.5%	3	0.356	9.6%	4	0.677	11.2%
9	44	2.157	21.9%	9	1.454	39.0%	4	0.861	14.3%
10	41	2.297	23.4%	5	0.875	23.5%	5	1.205	20.0%
11	34	2.176	22.1%	0	0.000	0.0%	2	0.617	10.2%
12	10	0.738	7.5%	0	0.000	0.0%	1	0.354	5.9%
13	8	0.722	7.3%	1	0.293	7.9%	1	0.339	5.6%
14	2	0.207	2.1%				1	0.376	6.2%
15	0	0.000	0.0%						
16	1	0.156	1.6%						
Total	186	**9.829**	100.0%	30	**3.724**	100.0%	43	**6.037**	100.0%

Table 20a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1998										0.03
1997									0.79	**15.61**
1996								0.19	11.54	**18.13**
1995							0.60	2.15	**11.50**	3.34
1994					0.04	0.51	3.90	**6.33**	2.79	0.11
1993					3.04	3.97	**8.10**	1.48	0.11	0.50
1992			0.12	1.44	**4.80**	2.86	1.25	0.04	0.50	0.50
1991		0.20	0.57	0.48	1.00	**1.63**	0.05	0.52	0.43	0.40
1990	0.42	0.50	1.04	1.33	**2.24**	1.26	0.70	0.70	0.32	0.29
1989	0.33	0.60	3.58	**4.59**	0.68	0.89	0.80	0.78	0.36	0.37
1988	3.58	1.60	**9.54**	2.22	0.60	0.37	1.50	0.89	0.39	0.05
1987	**8.00**	2.75	3.65	1.15	0.68	0.37	1.00	0.89	0.43	0.05
1986	**2.67**	1.15	0.65	0.59	0.40	0.09	1.00	0.22	0.04	0.00
1985	**1.67**	0.30	0.42	0.52	0.08	0.00	0.35	0.15	0.11	0.00
1984	0.50	0.40	**0.58**	0.33	0.28	0.00	0.35	0.07	0.04	0.00
1983	0.25	0.20	**0.46**	0.33	0.08	0.03	0.20	0.00	0.00	
>1983	**0.75**	0.45	0.73	0.33	0.00	0.00				
N/A	0.58	0.30	0.38	0.56	0.60	0.32	0.50	0.44	0.54	0.32
Total	18.75	8.45	21.72	13.87	14.52	12.30	20.30	14.85	29.89	39.70

Table 20b. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)		
	2001	**2002**	**2003**
2000			0.76
1999	0.07	0.51	**3.00**
1998	2.74	1.44	**3.33**
1997	7.49	1.38	0.37
1996	4.29	0.25	1.83
1995	0.10	0.68	1.40
1994	0.58	0.41	1.70
1993	0.87	0.28	1.43
1992	0.87	0.19	1.13
1991	0.81	0.06	0.33
1990	0.45	0.00	0.27
1989	0.26	0.00	0.07
1988	0.10	0.00	0.00
1987	0.00	0.03	0.03
N/A	0.00	0.00	0.00
Total	**18.63**	**5.23**	**15.65**

Table 21a. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1998										0.03
1997									0.79	**15.61**
1996								0.19	11.54	**18.11**
1995							0.55	2.15	**11.46**	3.21
1994					0.04	0.51	3.80	**6.19**	2.68	0.08
1993					2.88	3.83	**7.50**	1.37	0.07	0.26
1992			0.12	1.22	**4.68**	2.66	1.15	0.00	0.36	0.11
1991		0.15	0.54	0.48	0.92	**1.34**	0.05	0.30	0.21	0.05
1990	0.17	0.35	0.96	1.30	**2.00**	0.94	0.35	0.11	0.00	0.03
1989	0.17	0.40	3.46	**3.52**	0.08	0.43	0.55	0.04	0.04	0.03
1988	3.25	0.90	**7.54**	1.11	0.12	0.03	0.20	0.00	0.00	0.00
1987	**6.08**	0.65	1.23	0.22	0.00	0.09	0.00	0.00		
1986	**2.58**	0.30	0.15	0.11	0.04	0.00	0.00			
1985	**0.50**	0.05	0.04	0.04	0.00	0.00				
1984	0.08	**0.15**	0.08	0.00	0.00					
<1984	0.00	0.00	0.00	0.04	0.00					
N/A	0.25	0.10	0.27	0.41	0.44	0.23	0.25	0.33	0.54	0.32
Total	**13.08**	**3.05**	**14.39**	**8.45**	**11.20**	**10.06**	**14.40**	**10.68**	**27.69**	**37.84**

Table 21b. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)		
	2001	2002	2003
2000			**0.76**
1999	0.07	0.44	**2.93**
1998	2.74	1.38	**3.07**
1997	7.42	1.25	0.30
1996	4.03	0.25	1.50
1995	0.10	0.16	0.56
1994	0.39	0.03	0.23
1993	0.16	0.03	0.07
1992	0.19	0.00	0.00
1991	0.13	0.00	0.00
1990	0.00	0.00	
N/A	0.00	0.00	
Total	**15.23**	**3.54**	**9.42**

Table 22a. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1997										
1996										0.03
1995							0.05	0.00	0.04	0.13
1994							0.10	0.15	0.11	0.03
1993					0.16	0.14	0.60	0.11	0.04	0.24
1992				0.22	0.12	0.20	0.10	0.04	0.14	0.40
1991		0.05	0.04	0.00	0.08	0.29	0.00	0.22	0.21	0.34
1990	0.25	0.15	0.08	0.04	0.24	0.31	0.35	**0.59**	0.32	0.26
1989	0.17	0.20	0.12	**1.07**	0.60	0.46	0.25	0.74	0.32	0.34
1988	0.33	0.70	**2.00**	1.11	0.48	0.34	1.30	0.89	0.39	0.05
1987	1.92	2.10	**2.42**	0.93	0.68	0.29	1.00	0.89	0.43	0.05
1986	**1.08**	0.85	0.50	0.48	0.36	0.09	1.00	0.22	0.04	0.00
1985	**1.17**	0.25	0.39	0.48	0.08	0.00	0.35	0.15	0.11	0.00
1984	0.42	0.25	**0.50**	0.33	0.28	0.00	0.35	0.07	0.04	0.00
1983	0.25	0.20	**0.46**	0.33	0.08	0.03	0.20	0.00	0.00	
>1983	0.58	0.45	**0.73**	0.26	0.00	0.00	0.00			
N/A	0.25	0.20	0.12	0.15	0.16	0.09	0.25	0.11	0.00	0.00
Total	**6.42**	**5.40**	**7.36**	**5.40**	**3.32**	**2.24**	**5.90**	**4.18**	**2.19**	**1.87**

Table 22b. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)		
	2001	2002	2003
2000			
1999		0.06	**0.07**
1998		0.06	**0.27**
1997	0.07	**0.13**	0.07
1996	0.26	0.00	**0.37**
1995	0.00	0.63	**0.80**
1994	0.19	0.38	**1.47**
1993	0.71	0.25	**1.37**
1992	0.68	0.19	**1.13**
1991	**0.68**	0.06	0.33
1990	0.45	0.00	0.26
1989	0.26	0.00	0.07
1988	0.10	0.00	0.00
1987	0.00	0.03	0.03
N/A	0.00	0.00	0.00
Total	**3.40**	**1.79**	**6.24**

Table 23a. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
2001										
2000										
1999										
1998										
1997										0.480
1996										0.237
1995									0.290	0.748
1994								0.441	0.884	0.884
1993							0.183	0.993	0.993	0.993
1992					0.596	0.437	0.983	0.983	0.983	0.983
1991						0.869	0.869	0.869	0.869	0.869
1990					0.563	0.745	0.745	0.863	0.863	0.863
1989				0.440	0.440	0.899	0.975	0.689	0.689	0.703
1988			0.233	0.877	0.877	0.877	0.593	0.438	0.506	0.506
1987	0.675	0.675	0.315	0.954	0.954	0.954	0.890	0.483	0.116	0.843
1986	0.431	0.972	0.972	0.972	0.972	0.972	0.220	0.182	0.000	------
1985	0.678	0.678	0.678	0.876	0.876	0.876	0.429	0.733	0.000	------
1984			0.881	0.881	0.881	0.881	0.200	0.571	0.000	------
1983			0.717	0.846	0.846	0.846	0.000	------	------	------

Table 23b. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)		
	01-02	02-03	Mean
1998	------	------	------
1997	0.184	0.268	0.287
1996	0.653	0.653	0.466
1995	0.748	0.748	0.590
1994	0.884	0.884	0.769
1993	0.993	0.993	0.749
1992	0.983	0.983	0.834
1991	0.638	0.638	0.796
1990	0.775	0.775	0.768
1989	0.519	0.519	0.628
1988	0.000	------	0.516
1987	0.843	0.843	0.627
1986	------		0.581
1985	------		0.621
1984	------		0.571
1983	------		0.610

Table 24a. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
2001										
2000										
1999										
1998										
1997										0.475
1996										0.223
1995									0.280	0.559
1994								0.433	0.381	0.381
1993							0.183	0.436	0.436	0.615
1992					0.568	0.432	0.560	0.560	0.726	0.726
1991						0.473	0.473	0.700	0.787	0.787
1990					0.470	0.372	0.314	0.522	0.522	0.000
1989				0.539	0.539	0.539	0.270	0.270	0.750	0.000
1988			0.147	0.565	0.565	0.565	0.000	------	------	------
1987	0.450	0.450	0.179	0.640	0.640	0.000	------	------	------	------
1986	0.116	0.500	0.733	0.364	0.000	------	------	------	------	------
1985	0.100	0.894	0.894	0.000	------	------	------	------	------	------
1984		0.533	0.000	------	------	- -----	------	------	------	------

Table 24b. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)		
	01-02	02-03	Mean
2001	------	------	------
2000	------	------	------
1999	------	------	------
1998	------	------	------
1997	0.168	0.240	0.268
1996	0.610	0.610	0.436
1995	0.559	0.559	0.470
1994	0.768	0.768	0.517
1993	0.661	0.661	0.459
1992	0.000	------	0.490
1991	0.000	------	0.508
1990	0.000	------	0.353
1989	------		0.395
1988	------		0.345
1987	------		0.372
1986	------		0.317
1985	------		0.409
1984	------		0.238

Table 25a. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1998										
1997										
1996										
1995										
1994										
1993										
1992										
1991										
1990								0.914	0.914	0.914
1989				0.912	0.912	0.912	0.912	0.678	0.678	0.765
1988			0.898	0.898	0.898	0.898	0.685	0.438	0.506	0.506
1987			0.802	0.802	0.802	0.802	0.890	0.483	0.116	0.843
1986	0.987	0.987	0.987	0.987	0.987	0.987	0.220	0.181	0.000	------
1985	0.743	0.743	0.743	0.900	0.900	0.900	0.429	0.733	0.000	------
1984			0.914	0.914	0.914	0.914	0.200	0.571	0.000	------
1983			0.717	0.846	0.846	0.846	0.000	------	------	------

Table 25b. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)		
	01-02	02-03	Mean
1998	------	------	------
1997	------	0.538	0.538
1996	------	------	------
1995	------	------	------
1994	------	------	------
1993	------	------	------
1992	------	------	------
1991	0.697	0.697	0.697
1990	0.760	0.760	0.849
1989	0.519	0.519	0.739
1988	0.000	0.000	0.606
1987	0.843	0.843	0.644
1986	------		0.646
1985	------		0.649
1984	------		0.587
1983	------		0.610

Table 26a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
2000										
1999										
1998										1.47
1997									11.70	18.11
1996								0.11	**35.80**	21.26
1995							0.83	**11.67**	10.60	5.79
1994						1.90	29.50	**32.78**	3.20	1.79
1993					4.50	20.00	**83.00**	7.00	0.80	2.00
1992				2.78	7.00	11.40	**14.33**	0.78	1.20	0.63
1991			0.50	2.56	1.88	**5.70**	2.83	1.33	0.50	0.32
1990	0.12	0.56	1.50	**8.22**	7.75	3.50	2.17	0.33	0.10	0.21
1989	1.41	0.78	8.60	**27.56**	4.50	2.50	0.67	0.33	0.20	0.11
1988	9.53	1.89	**25.40**	8.22	2.88	1.50	1.17	0.33	0.20	0.11
1987	**23.65**	5.89	10.40	2.11	1.75	1.60	0.50	0.11	0.10	0.00
1986	**11.18**	3.33	1.60	0.44	1.38	0.30	0.00	0.22	0.00	0.00
1985	**4.12**	1.22	0.40	1.67	0.75	0.20	0.00	0.00	0.20	0.00
1984	**1.64**	0.78	0.40	0.67	0.25	0.00	0.00			
1983	0.35	0.11	**1.30**	0.56	0.13	0.00	0.00			
>1983	0.47	0.44	0.60	0.22	0.00	0.00				
N/A	0.82	0.00	1.10	2.33	1.00	1.20	2.50	2.00	2.50	0.11
Total	**53.29**	**15.00**	**51.80**	**57.34**	**33.77**	**49.80**	**137.50**	**57.00**	**67.10**	**51.91**

Table 26b. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)		
	2001	2002	2003
2001			**2.70**
2000		0.50	**8.80**
1999	0.90	1.10	**16.00**
1998	9.50	8.80	**12.60**
1997	**27.00**	10.20	4.60
1996	17.70	4.60	4.20
1995	2.10	3.50	1.60
1994	1.50	1.20	1.30
1993	1.00	1.00	0.50
1992	1.10	0.30	0.00
1991	0.90	0.30	0.00
1990	0.10	0.00	0.10
1989	0.10	0.00	0.00
1988	0.00	0.00	0.00
1987	0.10	0.00	0.00
1986	0.00	0.00	0.00
1985	0.20	0.00	0.00
N/A	0.20	0.80	0.10
Total	**62.40**	**32.30**	**52.50**

Table 27a. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
2000										
1999										
1998										1.47
1997									11.60	18.11
1996								0.11	**35.70**	20.95
1995							0.83	**11.67**	10.60	5.68
1994						1.90	29.50	**32.56**	2.60	1.26
1993					4.50	20.00	**82.67**	6.44	0.60	1.37
1992				2.78	6.88	11.30	**14.00**	0.56	0.90	0.11
1991			0.50	2.56	1.75	**5.60**	2.50	0.67	0.30	0.00
1990	0.12	0.44	1.50	**8.22**	7.00	3.20	1.83	0.22	0.00	0.00
1989	1.29	0.78	8.30	**25.33**	2.63	1.40	0.50	0.00	0.00	0.00
1988	9.41	1.33	**20.30**	4.89	1.13	0.50	0.17	0.00	0.10	0.00
1987	**22.82**	2.78	4.20	0.33	0.13	0.10	0.00	0.00	0.10	0.00
1986	**10.23**	1.22	0.90	0.11	0.00	0.00	0.00	0.00	0.00	
1985	**2.35**	0.11	0.00	0.33	0.00	0.00				
1984	**0.71**	0.11	0.10	0.11	0.00	0.00				
<1984	0.00	0.00	0.10	0.00						
N/A	0.82	0.00	0.80	1.56	0.88	1.20	2.50	1.78	2.30	0.11
Total	**47.75**	**6.77**	**36.70**	**46.22**	**24.90**	**45.20**	**134.50**	**54.00**	**64.80**	**49.06**

Table 27b. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)		
	2001	2002	2003
2001			**2.70**
2000		0.50	**8.80**
1999	0.90	**1.10**	**15.90**
1998	9.40	8.70	**12.10**
1997	**27.00**	8.80	4.30
1996	17.00	3.30	3.80
1995	1.90	1.40	1.20
1994	1.30	0.20	0.40
1993	0.40	0.20	0.00
1992	0.00	0.00	
1991	0.00		
1990			
1989			
N/A	0.20	0.80	0.10
Total	**58.10**	**25.00**	**49.30**

Table 28a. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
2000										
1999										
1998										
1997									0.10	0.00
1996									0.10	0.32
1995									0.00	0.11
1994								0.22	0.60	0.53
1993							0.33	0.56	0.20	0.63
1992					0.25	0.10	0.33	0.22	0.30	0.53
1991					0.13	0.10	0.33	0.67	0.20	0.32
1990		0.11	0.00	0.00	**0.75**	0.30	0.33	0.11	0.10	0.21
1989	0.12	0.00	0.30	**2.22**	1.88	1.10	0.17	0.33	0.20	0.11
1988	0.12	0.56	**5.10**	3.33	1.75	1.00	1.00	0.33	0.10	0.11
1987	0.82	3.11	**6.20**	1.78	1.63	1.50	0.50	0.11	0.00	0.00
1986	0.94	**2.11**	1.70	0.33	1.38	0.30	0.00	0.22	0.00	0.00
1985	**1.76**	1.11	0.40	1.33	0.75	0.20	0.00	0.00	0.20	0.00
1984	**0.94**	0.67	0.30	0.56	0.25	0.00	0.00			
1983	0.35	0.11	**1.30**	0.56	0.13	0.00	0.00			
>1983	0.47	0.44	**0.50**	0.22	0.00	0.00				
N/A	0.00	0.00	0.30	0.78	0.13	0.00	0.00	0.22	0.20	0.00
Total	**5.52**	**8.22**	**16.10**	**11.11**	**9.03**	**4.60**	**3.00**	**3.00**	**2.30**	**2.87**

Table 28b. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)		
	2001	2002	2003
2000			
1999			**0.10**
1998	0.10	0.10	**0.50**
1997	0.00	**1.40**	0.30
1996	0.70	**1.60**	0.40
1995	0.20	**2.10**	0.40
1994	0.20	**1.00**	0.90
1993	0.60	**0.80**	0.50
1992	**1.10**	0.30	0.00
1991	**0.90**	0.30	0.00
1990	0.10	0.00	0.10
1989	0.10	0.00	0.00
1988	0.00	0.00	0.00
1987	0.10	0.00	0.00
N/A	0.00	0.80	0.00
Total	**4.10**	**8.40**	**3.20**

Table 29a. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1999										
1998										
1997										
1996									0.594	0.833
1995								0.908	0.546	0.777
1994								0.098	0.559	0.838
1993							0.084	0.535	0.535	0.707
1992							0.289	0.289	0.957	0.957
1991						0.496	0.470	0.878	0.878	0.878
1990				0.943	0.452	0.620	0.152	0.798	0.798	0.781
1989				0.163	0.556	0.268	0.500	0.606	0.550	0.909
1988			0.324	0.350	0.521	0.780	0.282	0.606	0.550	0.000
1987	0.663	0.663	0.203	0.829	0.914	0.313	0.220	0.969	0.969	0.969
1986	0.298	0.480	0.928	0.928	0.217	0.856	0.856	0.000	------	------
1985	0.740	0.740	0.740	0.449	0.802	0.802	0.802	0.802	0.802	0.802
1984	0.476	0.927	0.927	0.373	0.000	------	------	------	------	------
1983			0.431	0.232	0.000	------	------	------	------	------

Table 29b. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)		
	01-02	02-03	Mean
1999	------	------	------
1998	------	------	------
1997	0.378	0.451	0.413
1996	0.260	0.913	0.586
1995	0.777	0.457	0.672
1994	0.931	0.931	0.525
1993	0.707	0.500	0.426
1992	0.273	0.000	0.417
1991	0.333	0.000	0.528
1990	0.781	0.781	0.613
1989	0.000	------	0.418
1988	------	------	0.408
1987	0.000	------	0.570
1986			0.530
1985			0.659
1984			0.497
1983			0.208

Table 30a. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1998										
1997										
1996									0.587	0.811
1995								0.908	0.536	0.335
1994								0.080	0.707	0.707
1993							0.078	0.461	0.461	0.292
1992							0.254	0.254	0.122	0.000
1991						0.446	0.268	0.448	0.000	------
1990				0.852	0.457	0.572	0.120	0.000	------	------
1989				0.104	0.532	0.357	0.000	------	------	------
1988			0.241	0.231	0.442	0.340	0.767	0.767	0.000	------
1987	0.429	0.429	0.079	0.394	0.937	0.937	0.937	0.937	0.000	------
1986	0.119	0.738	0.122	0.000	0.000	------	------	------	------	------
1985	0.520	0.520	0.520	0.000	------	------	------	------	------	------
1984	0.537	0.537	0.537	0.000	------	------	------	------	------	------

Table 30b. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)		
	01-02	02-03	Mean
1999			------
1998			
1997	0.326	0.489	0.399
1996	0.473	0.473	0.571
1995	0.737	0.857	0.635
1994	0.555	0.555	0.477
1993	0.500	0.000	0.283
1992	0.000		0.150
1991			0.276
1990			0.366
1989			0.231
1988			0.373
1987			0.520
1986			0.215
1985			0.369
1984			0.382

Table 31a. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1998										
1997										
1996										
1995										
1994										
1993										
1992										
1991										
1990					0.663	0.663	0.860	0.860	0.860	0.781
1989				0.847	0.585	0.548	0.548	0.606	0.550	0.909
1988			0.654	0.526	0.756	0.756	0.330	0.577	0.577	0.000
1987			0.287	0.916	0.920	0.333	0.220	0.969	0.969	0.969
1986		0.806	0.901	0.901	0.217	0.856	0.856	0.000	------	------
1985	0.911	0.911	0.911	0.564	0.719	0.719	0.719	0.719	0.000	------
1984	0.713	0.914	0.914	0.446	0.000	------	------	------	------	------
1983			0.431	0.232	0.000	------	------	------	------	------
1982		0.431	0.232	0.000	------	------	------	------	------	------

Table 31b. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2003.

Year Class	Survival (S)		
	01-02	02-33	Mean
1999			------
1998			------
1997		0.214	0.214
1996		0.250	0.250
1995		0.190	0.190
1994		0.900	0.900
1993		0.625	0.625
1992	0.273	0.000	0.128
1991	0.333	0.000	0.155
1990	0.781	0.781	0.781
1989	0.000		0.550
1988	0.000		0.501
1987	0.000		0.572
1986			0.604
1985			0.659
1984			0.554
1983			0.208
1982			0.200

Table 32. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
2001										**0.86**
2000									0.44	**15.43**
1999								0.40	3.78	**31.29**
1998							1.58	13.50	**29.67**	28.86
1997						0.20	21.58	**42.40**	39.33	8.00
1996						9.10	**73.26**	32.60	11.00	2.86
1995					1.22	10.30	**38.32**	8.40	2.56	1.57
1994			0.10	1.55	7.11	**11.70**	11.05	2.60	1.11	0.57
1993		0.67	1.70	4.44	5.22	**6.10**	2.10	1.60	0.89	0.86
1992		**4.33**	2.90	3.33	3.00	2.90	1.37	1.00	0.89	0.28
1991	2.40	**9.00**	4.50	2.00	1.67	2.20	0.63	1.50	0.22	0.14
1990	**12.40**	11.11	3.10	2.00	0.78	1.40	0.42	0.50	0.11	0.14
1989	**12.00**	9.78	2.60	0.89	1.11	1.20	0.11	0.00	0.00	0.14
1988	**3.20**	2.67	1.00	1.44	0.78	0.40	0.11	0.00	0.00	0.00
1987	0.80	**2.67**	1.00	1.11	0.67	1.00	0.00	0.00		
1986	0.80	**1.78**	0.80	0.33	0.11	0.30	0.00	0.00		
1985	0.80	**1.22**	0.30	0.22	0.11	0.10	0.00	0.00		
1984	**1.20**	0.78	0.20	0.11	0.00	0.00				
>1984	**1.20**	0.56	0.00	0.00						
N/A	0.80	2.00	0.20	0.33	0.33	1.30	0.74	0.50	1.56	0.28
Total	35.60	46.56	18.40	17.78	22.11	48.20	151.27	105.00	91.56	91.28

Table 33. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
2001										**0.86**
2000									0.44	**15.43**
1999								0.30	3.78	**31.29**
1998							1.58	13.50	**28.89**	26.00
1997						0.20	21.47	**41.90**	35.56	7.57
1996						7.30	**72.74**	31.00	8.33	2.57
1995					1.22	8.00	**37.05**	7.60	2.00	1.00
1994			0.10	1.56	6.78	5.20	**10.53**	1.70	0.67	0.00
1993		0.67	1.70	**3.89**	3.78	2.50	1.68	1.10	0.11	0.14
1992		**4.22**	2.80	2.33	1.67	1.10	1.16	0.20	0.00	0.00
1991	2.40	**7.89**	3.60	1.44	1.00	0.10	0.00	0.40	0.00	0.00
1990	**10.60**	6.33	1.50	1.33	0.22	0.30	0.00	0.00		
1989	**8.00**	2.33	0.70	0.44	0.00	0.00	0.00	0.00		
1988	**1.40**	0.56	0.30	0.11	0.11	0.10	0.00	0.00		
1987	0.00	**0.44**	0.10	0.00	0.00	0.00				
1986	0.00	**0.11**	0.00	0.00						
N/A	0.80	1.44	0.10	0.00	0.11	0.50	0.74	0.40	1.56	0.28
Total	23.20	24.00	10.90	11.11	14.89	25.30	146.95	98.10	81.33	85.14

Table 34. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2003. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)									
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
2000										
1999								**0.10**	0.00	0.00
1998								0.00	0.78	**2.86**
1997							0.11	0.50	**3.78**	0.43
1996						1.80	0.53	1.60	**2.67**	0.28
1995						**2.30**	1.26	0.80	0.56	0.57
1994					0.33	**6.50**	0.53	0.90	0.44	0.57
1993				0.56	1.44	**3.60**	0.42	0.50	0.78	0.71
1992		0.11	0.10	1.00	1.33	**1.80**	0.21	0.80	0.89	0.28
1991		1.11	0.90	0.56	0.67	**2.10**	0.63	1.10	0.22	0.14
1990	1.80	**4.78**	1.60	0.67	0.56	1.10	0.42	0.50	0.11	0.14
1989	4.00	**7.44**	1.90	0.44	1.11	1.20	0.11	0.00	0.00	0.14
1988	**2.20**	2.11	0.70	1.33	0.67	0.30	0.11	0.00	0.00	0.00
1987	0.80	**2.22**	0.90	1.11	0.67	1.00	0.00	0.00		
1986	0.80	**1.67**	0.80	0.33	0.11	0.30	0.00	0.00		
1985	0.40	**1.22**	0.30	0.22	0.11	0.10	0.00	0.00		
1984	**1.20**	0.78	0.20	0.11	0.00	0.00				
1983	**0.80**	0.33	0.00	0.00						
1982	**0.40**	0.22	0.00	0.00						
N/A	0.00	0.56	0.10	0.33	0.22	0.80	0.00	0.10	0.00	0.00
Total	12.40	22.56	7.50	6.67	7.22	22.90	4.33	6.90	10.22	6.14

Table 35. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2003.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	Mean
1999										------
1998									0.973	0.973
1997								0.928	0.203	0.434
1996							0.445	0.337	0.260	0.339
1995							0.219	0.305	0.613	0.345
1994						0.944	0.235	0.427	0.514	0.470
1993						0.344	0.762	0.556	0.966	0.613
1992		0.877	0.877	0.901	0.967	0.472	0.730	0.890	0.315	0.710
1991		0.500	0.788	0.788	0.788	0.826	0.826	0.147	0.636	0.595
1990	0.896	0.279	0.645	0.837	0.837	0.598	0.598	0.529	0.529	0.608
1989	0.815	0.266	0.773	0.773	0.773	0.584	0.584	0.584	0.584	0.610
1988	0.834	0.734	0.734	0.542	0.513	0.275	0.000			0.491
1987	------	0.645	0.645	0.948	0.948	0.000				0.593
1986	------	0.449	0.413	0.953	0.953	0.000				0.508
1985	------	0.245	0.733	0.500	0.909	0.000				0.440
1984	0.650	0.256	0.550	0.000						0.339
1983	0.413	0.000								0.189
1982	0.555	0.000								0.245

Table 36. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2003.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	Mean
1999										------
1998									0.900	0.900
1997								0.849	0.213	0.425
1996							0.426	0.269	0.309	0.328
1995							0.205	0.263	0.500	0.300
1994							0.161	0.394	0.000	0.174
1993				0.971	0.662	0.672	0.655	0.357	0.357	0.575
1992		0.663	0.833	0.717	0.833	0.833	0.172	0.000		0.541
1991		0.456	0.401	0.694	0.737	0.737	0.737	0.000		0.513
1990	0.597	0.237	0.887	0.474	0.474	0.000				0.417
1989	0.292	0.300	0.629	0.000						0.286
1988	0.400	0.535	0.606	0.606	0.909	0.000				0.482
1987		0.227	0.000							0.108
1986		0.000								0.000

Table 37. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2003.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	Mean
1999										------
1998										------
1997									0.114	0.114
1996									0.105	0.105
1995						0.548	0.635	0.844	0.844	0.706
1994						0.372	0.372	0.796	0.796	0.544
1993						0.601	0.601	0.601	0.910	0.667
1992						0.791	0.791	0.791	0.315	0.628
1991						0.724	0.724	0.200	0.636	0.508
1990		0.335	0.883	0.883	0.883	0.674	0.674	0.529	0.529	0.643
1989		0.255	0.858	0.858	0.858	0.613	0.613	0.613	0.613	0.623
1988	0.960	0.795	0.795	0.504	0.448	0.367	0.000			0.520
1987	------	0.707	0.707	0.949	0.949	0.000				0.617
1986	------	0.479	0.413	0.953	0.953	0.000				0.515
1985	------	0.245	0.733	0.500	0.909	0.000				0.440
1984	0.650	0.286	0.550	0.000						0.347
1983	0.413	0.000								0.189
1982	0.550	0.000								0.245

Table 38. Data matrix comparing scale (SA) and otolith ages for chi-square test of symmetry. Values are the number of respective readings of each age by ageing method.

SA	Otolith age																	
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**18**	**19**	**20**
2	**5**	1																
3	0	**16**	2															
4		3	**3**	1		5												
5			9	**8**	7	16												
6				1	**6**	10												
7			0	0	4	**12**	8	2										
8						11	**6**	5	3	0								
9						2	8	**9**	9	2								
10							2	11	**13**	4	0	0						
11							1	3	8	**5**	1	1	1	1				
12									2	2	**2**	0	2	1	1			
13									1	2	2	**0**	0	1	0			
14										1	0	0	**1**	1	2			
15										0	0	0	0	**0**	0		1	
16											0	0	0	0	**0**	1	0	1
18															0	**0**	0	0
19														0	0	0	**0**	0
20															0	0	0	**0**

Table 39. Relative contributions of striped bass age classes as determined by ageing specimens (n = 250) by reading both their scales and ooliths.

Age	scale		otolith	
	n	prop.	n	.prop
2	6	.0240	5	.0200
3	18	.0720	20	.0800
4	12	.0480	14	.0560
5	40	.1600	10	.0400
6	16	.0640	17	.0680
7	26	.1040	57	.2280
8	26	.1040	25	.1000
9	30	.1200	30	.1200
10	30	.1200	36	.1440
11	21	.0840	16	.0640
12	10	.0400	5	.0200
13	6	.0240	1	.0040
14	5	.0200	4	.0160
15	1	.0040	4	.0160
16	2	.0080	3	.0120
17	0	.0000	0	.0000
18	0	.0000	1	.0040
19	0	.0000	1	.0040
20	0	.0000	1	.0040
	$\overline{Age} = 7.66$		$\overline{Age} = 7.91$	

Figure 1. Locations of commercial pound nets and experimental gill nets sampled in spring spawning stock assessments of striped bass in the Rappahannock River, 1991-2003.

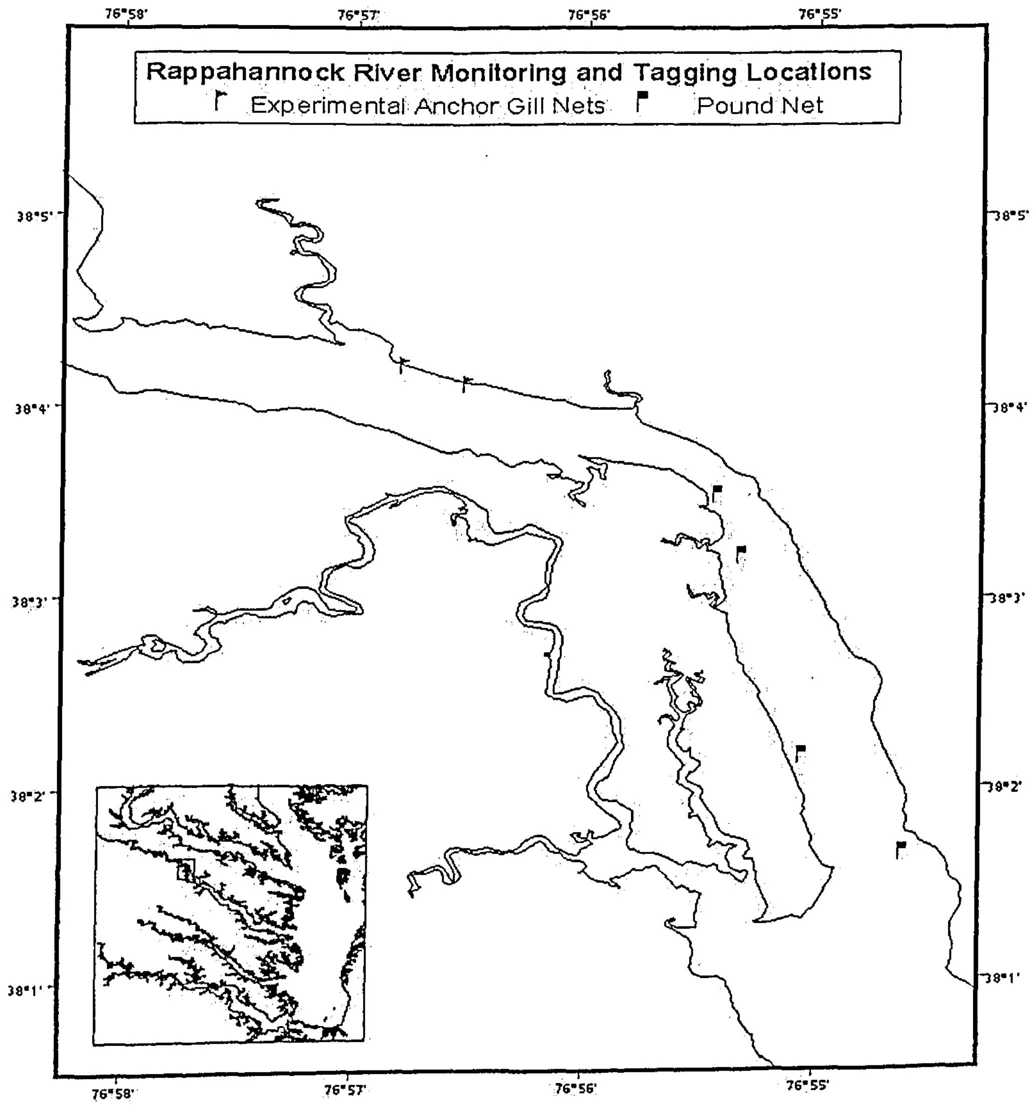


Figure 2. Locations of experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, spring 2003.

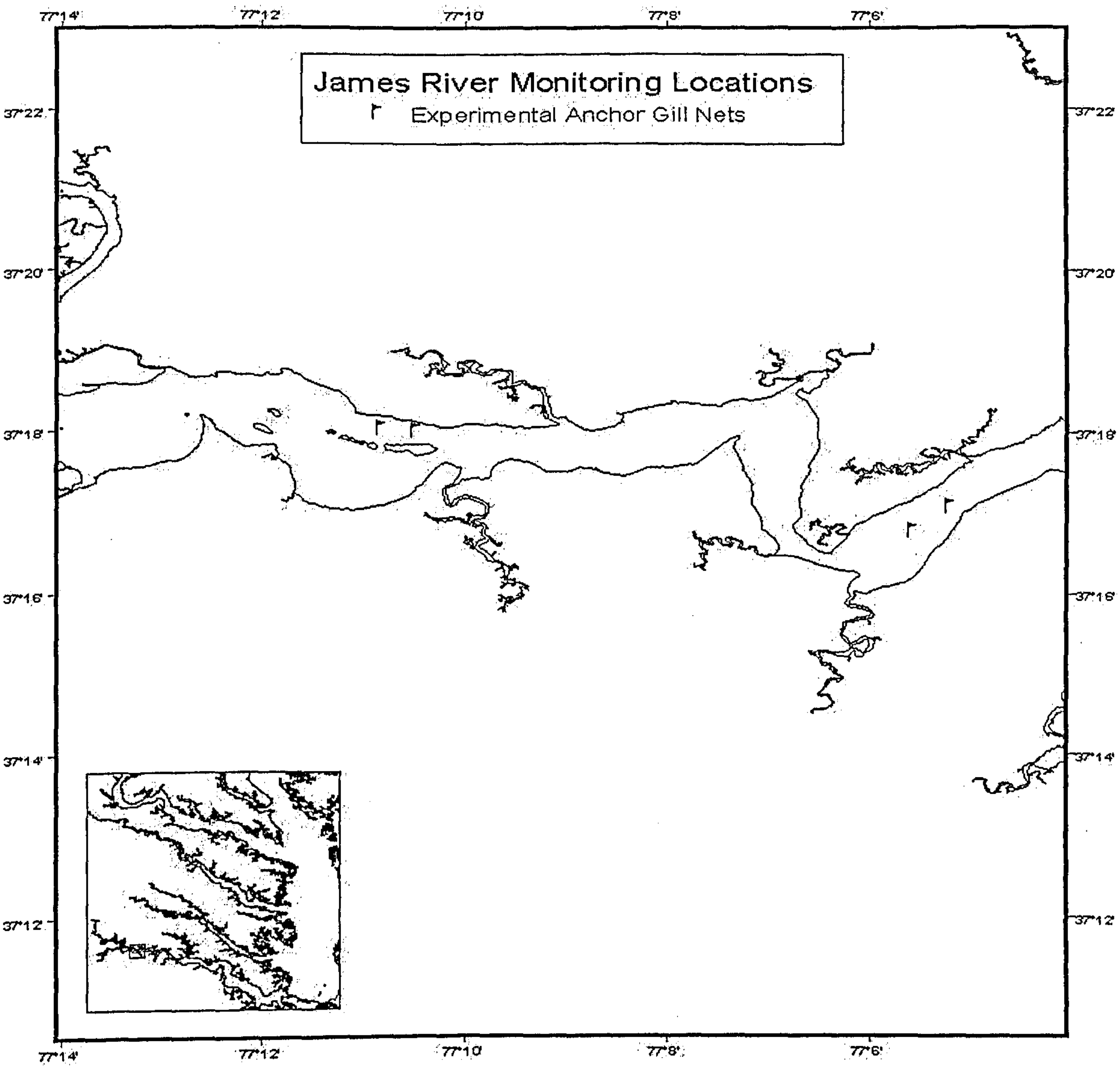


Figure 3. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1987 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

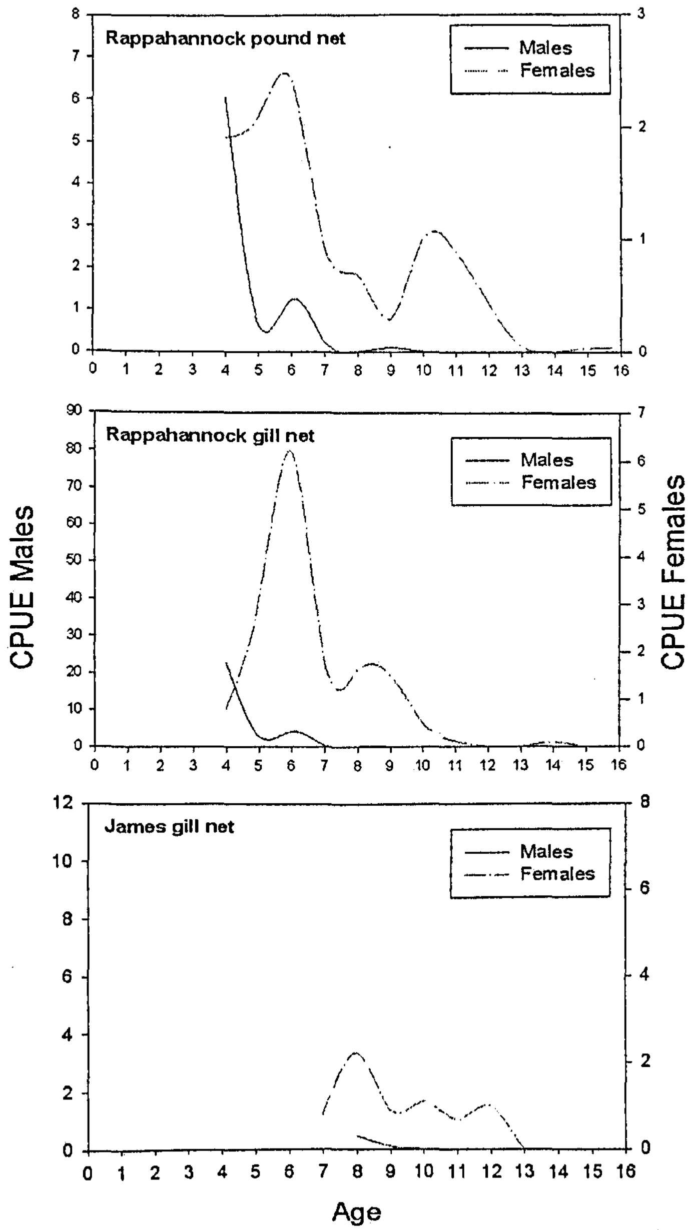


Figure 4. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1988 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

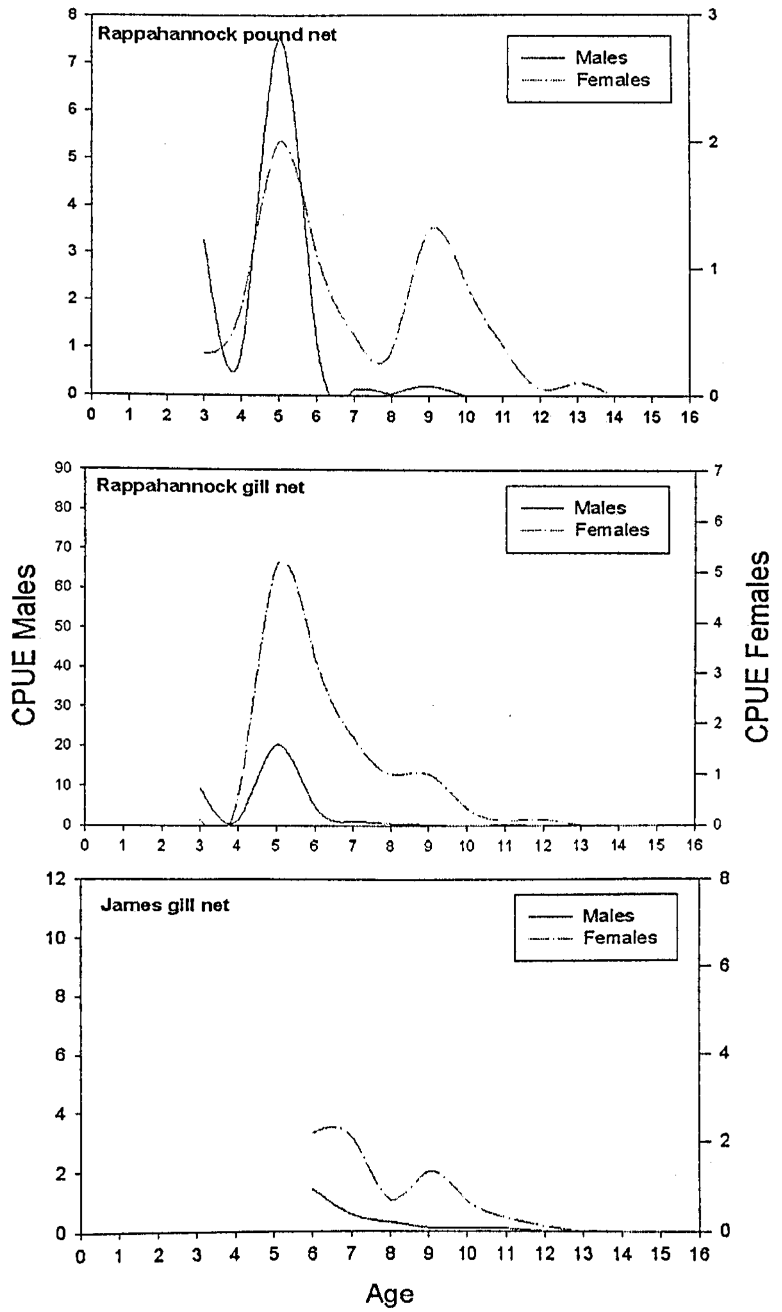


Figure 5. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1989 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

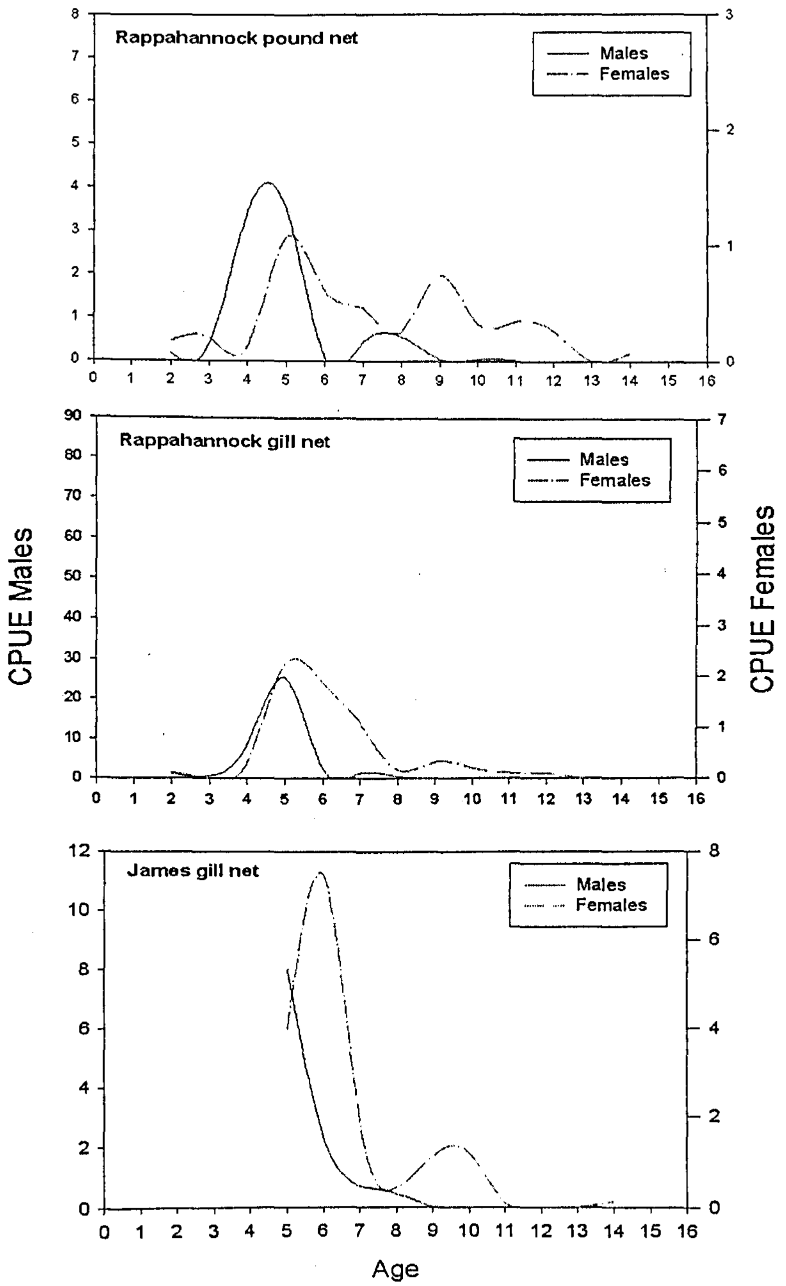


Figure 6. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1990 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

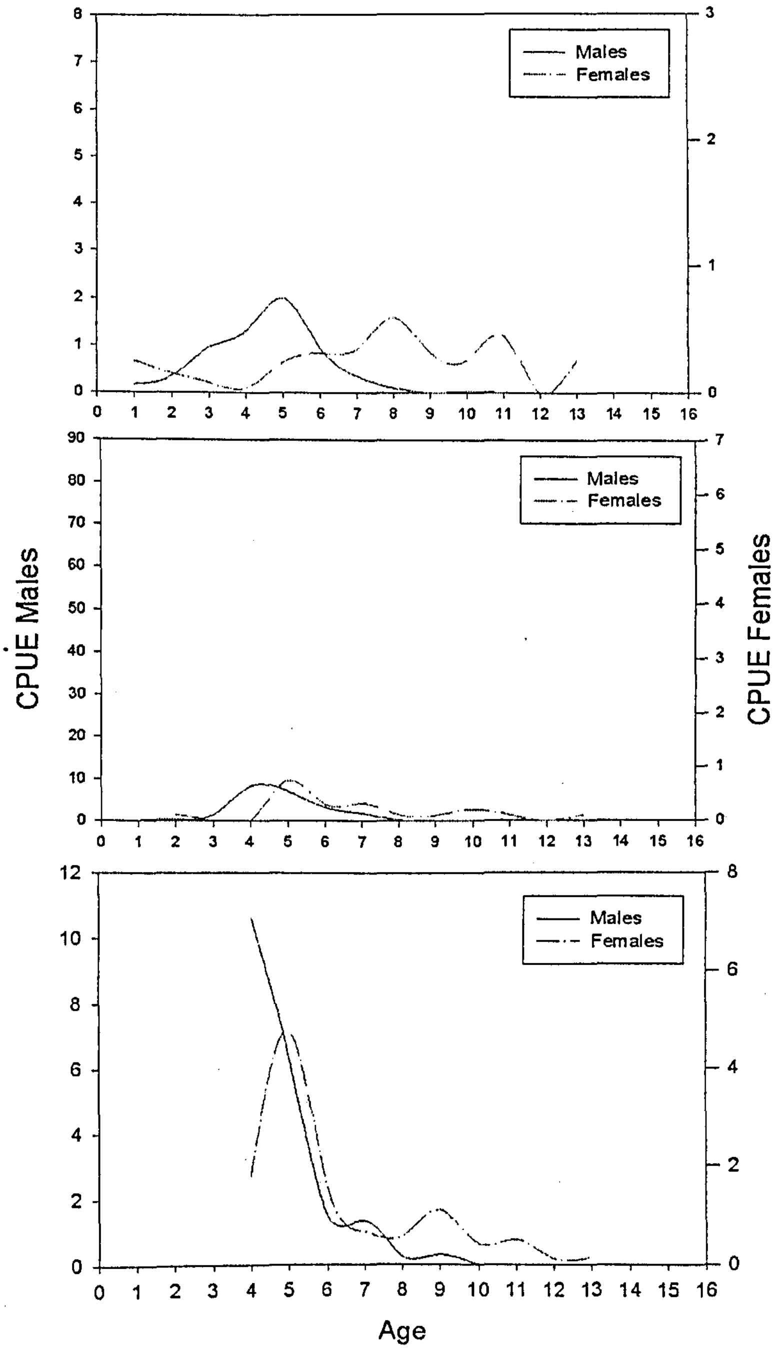


Figure 7. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1991 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

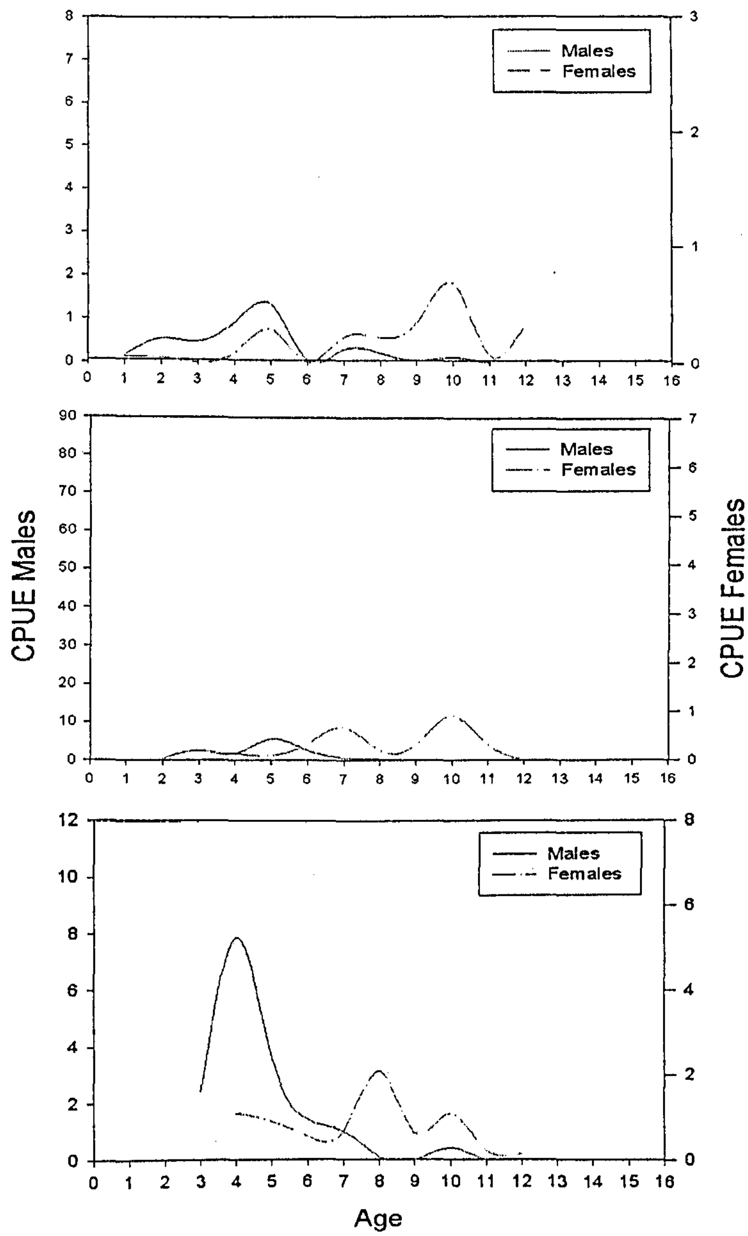


Figure 8. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1992 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

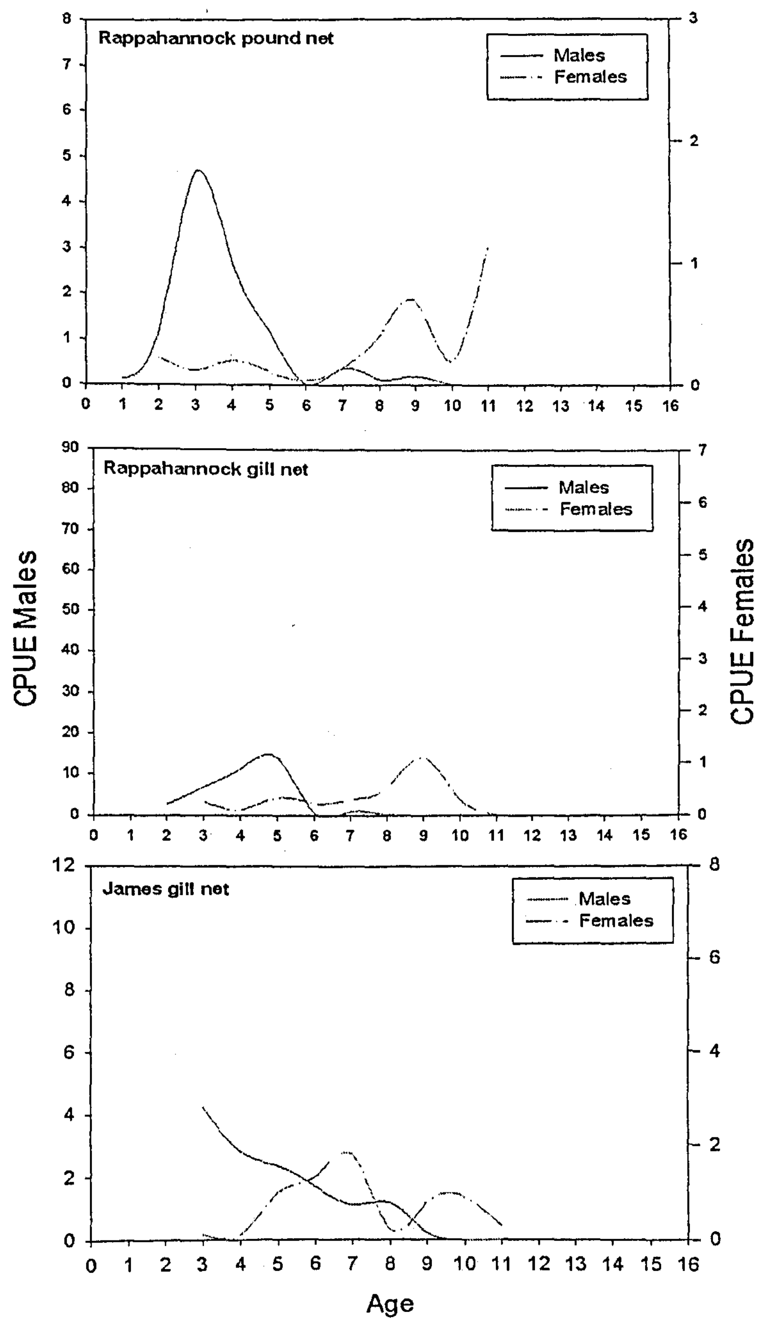


Figure 9. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1993 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

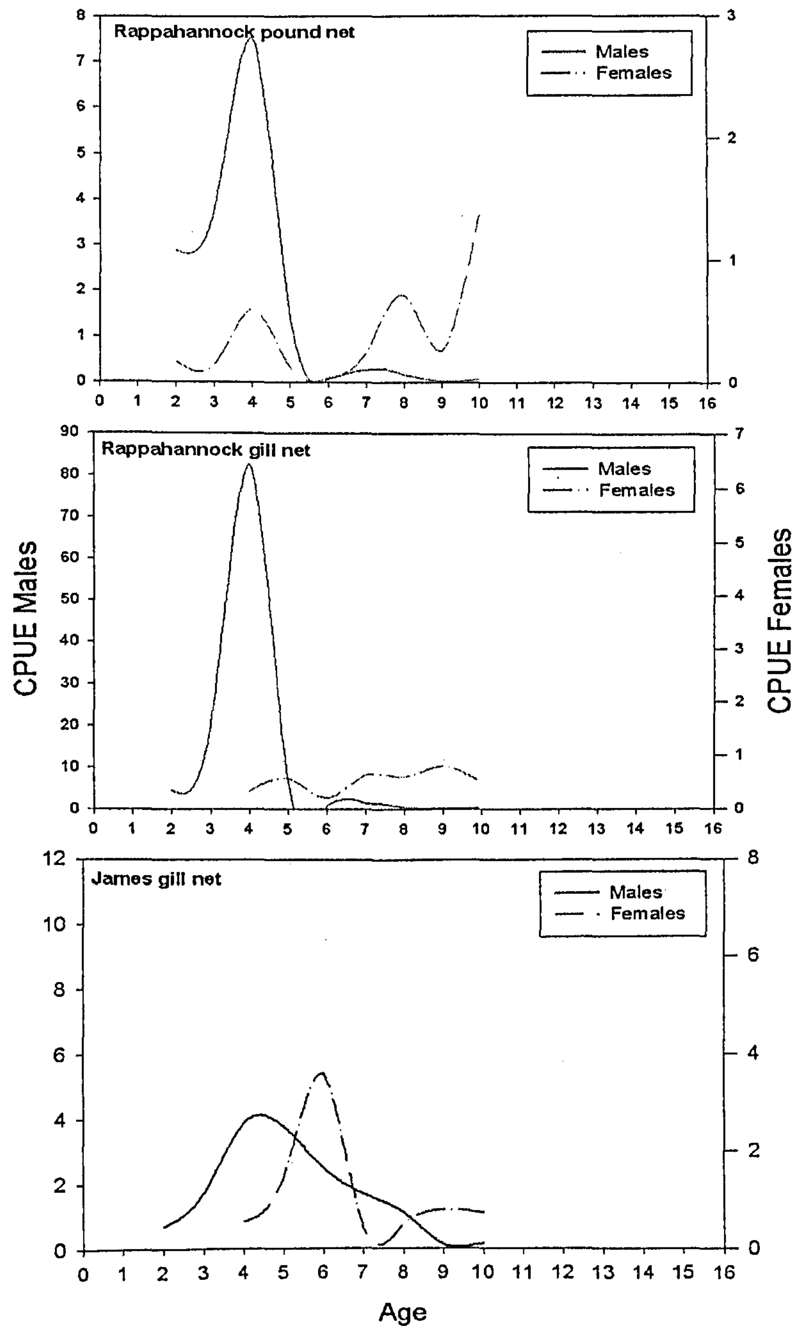


Figure 10. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1994 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) Rivers, springs 1991-2003.

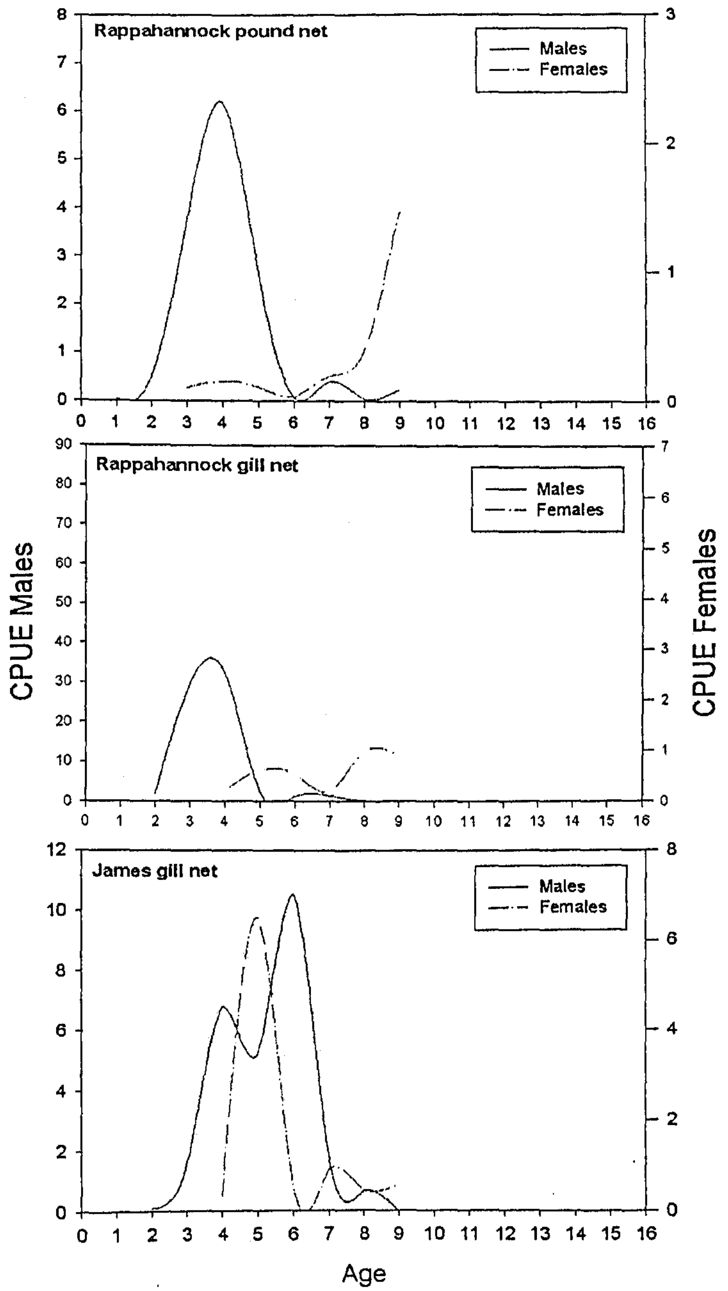


Figure 11. Frequency distribution of striped bass, in 10 mm increments, by total length, sampled from pound nets in the Rappahannock River, springs 1991-2003.

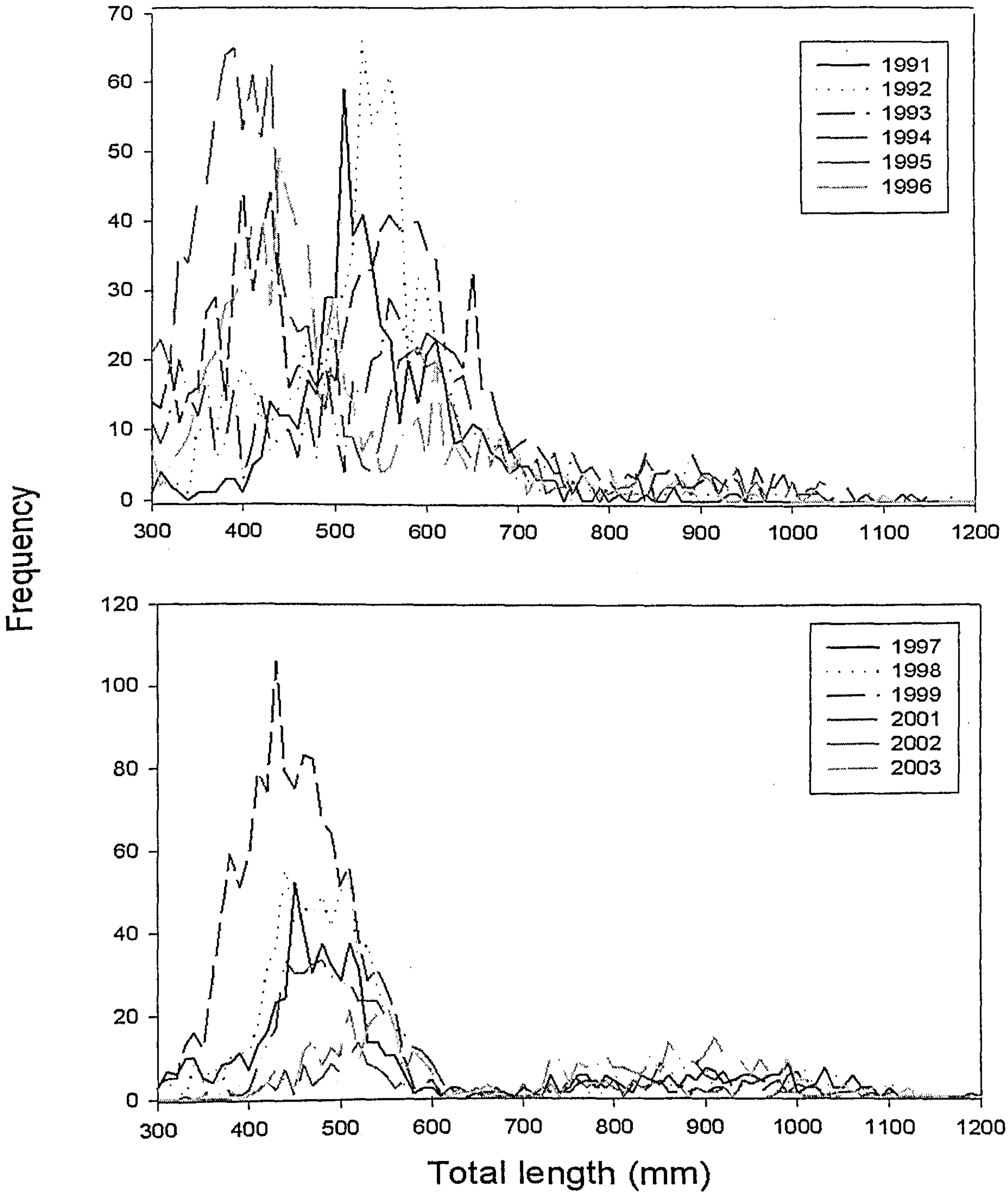
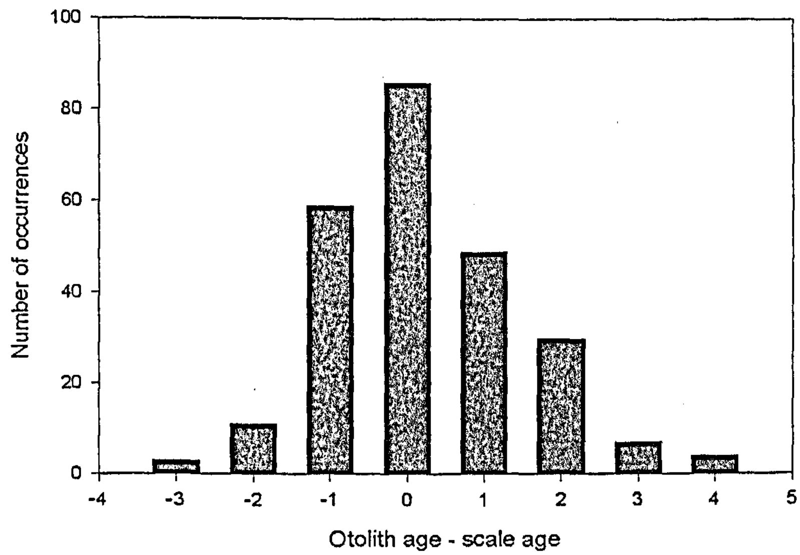


Figure 12. Magnitude of the age differences resulting from ageing specimens of striped bass (n=249) by reading both their scales and otoliths.



II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2002-2003

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Introduction

Striped bass (*Morone saxatilis*) have historically supported one of the most important recreational and commercial fisheries along the Atlantic coast. The species is one of the most important economical and social components of finfish catches in the Chesapeake Bay area. From 1965 to 1972, annual commercial landings of striped bass in Virginia fluctuated from about 554 to 1,271 metric tons (MT). Recreational harvests, although not well documented, may have reached equivalent levels (Field 1997). Beginning in 1973, a dramatic decrease in catches occurred, and during the period 1978 through 1985, annual commercial landings in Virginia averaged about 162 MT. This decline in Virginia's striped bass landings was reflected in similar catch statistics from Maine to North Carolina.

Concern about the decline in striped bass landings along the Atlantic coast since the mid-1970's prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Commission (ASMFC) as part of their Interstate Fisheries Management Program (ASMFC 1981). Federal legislation was enacted in 1984 (Public Law 98-613, The Atlantic Striped Bass Conservation Act), which enables Federal imposition of a moratorium for an indefinite period in those states that fail to comply with the coastwise plan. To be in compliance with the plan, coastal states have imposed restrictions on their commercial and recreational striped bass fisheries ranging from combinations of catch quotas, size limits, and time-limited moratoriums to year-round moratoriums. The FMP was modified three times from 1984-1985 to further restrict fishing (Weaver *et al.* 1986). The first two amendments emphasized the need to reduce fishing mortality and to set target mortality rates. The third amendment was directed specifically at Chesapeake Bay stocks and focused on ensuring success of the 1982 and later year classes by recommending that states protect 95% of those females until they had the opportunity to spawn at least once.

Due to an improvement in spawning success, as judged by increases in annual values of the Maryland juvenile index, a fourth amendment to the FMP established a limited fishery in fall 1990. This transitional fishery existed until 1995 when spawning stock biomass in the Chesapeake Bay reached extremely healthy levels (Field 1997). The ASMFC subsequently declared Chesapeake stocks to have reached benchmark levels and the states adopted a fifth amendment to the original FMP in order to allow expanded state fisheries.

The Anadromous Fishes Program of the Virginia Institute of Marine Science (VIMS) has monitored the size and age composition, sex ratio and maturity schedules of the spawning striped bass stock in the Rappahannock River since 1981. In conjunction with the monitoring studies, VIMS established a tagging program in 1988 to provide information on the migration, relative contribution to the coastal population, and annual survival of striped bass that spawn in the Rappahannock River. This program is part of an active cooperative tagging study that currently involves 15 state and federal agencies along the Atlantic coast. The U.S. Fish and Wildlife Service manages the coast-wide tagging database. Hence, commercial and recreational anglers that target striped bass are encouraged to report all recovered tags to that agency. The analysis protocol, as established by the ASFMC Striped Bass Tagging Subcommittee, involves fitting a suite of reformulated Brownie models (Brownie et al. 1985; White and Burnham 1999) to the tag return data.

Although the initial purpose of the coast-wide tagging study was to evaluate efforts to restore Atlantic striped bass stocks (Wooley *et al.* 1990), tagging data are now being collected to monitor striped bass mortality rates in a recovered fishery. Thus far, these extensive data have not been formally summarized.

In this section, we present a comprehensive analysis of the Rappahannock River striped bass tagging data. We begin with a detailed description of the ASFMC analysis protocol and present annual survival (S) estimates derived from tag-recovery models developed by Seber (1970) as well as estimates on instantaneous fishing mortality (F) that followed when S was partitioned into its components using auxiliary information.

Multi-year Tagging Models

Tag return data is generally represented by constructing an upper triangular matrix of tag recoveries, where each cell of the matrix contains the number of tag returns from a particular year of tagging and recovery. For example, a study with I years of tagging and J years of recovery would yield the following data matrix

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1J} \\ - & r_{22} & \cdots & r_{2J} \\ \vdots & \vdots & \ddots & \vdots \\ - & - & - & r_{IJ} \end{bmatrix}, \tag{1}$$

where r_{ij} is the number of tags recovered in year j that were released in year i (note, $J \geq I$). Tagging periods do not necessarily have to be yearly intervals; however, data analysis is easiest if all periods are the same length and all tagging events are conducted at the beginning of each period.

Application of tagging models involves constructing an upper triangular matrix of expected values and comparing them to the observed data. Since the data are known to follow a multinomial distribution, the method of maximum likelihood can be used to obtain parameter estimates. Analytical solutions for the maximum likelihood parameter estimates are generally not available. Hence, several software packages that numerically maximize a product multinomial likelihood function have been developed for application of tagging models. They include programs SURVIV (White 1983), MARK (White and Burnham 1999), and AVOCADO (Hoenig et al. in prep.).

Seber (1970) models: White and Burnham (1999) reformulated the original Brownie et al. (1985) models to create a consistent framework for modeling mark-recapture data (Smith et al. 2000). This framework served as the foundation for program MARK, which is a comprehensive software package for the application of capture-recapture models. For time-specific parameterization of the Seber models, the matrix of expected values associated to equation (1) would be

$$E(R) = \begin{bmatrix} N_1(1-S_1)r_1 & N_1S_1(1-S_2)r_2 & \cdots & N_1S_1\cdots S_{J-1}(1-S_J)r_J \\ - & N_2(1-S_2)r_2 & \cdots & N_2S_2\cdots S_{J-1}(1-S_J)r_J \\ \vdots & \vdots & \ddots & \vdots \\ - & - & - & N_I(1-S_I)r_I \end{bmatrix}. \qquad (2)$$

where N_i is the number tagged in year i, S_i is the survival rate in year i and r_i is the probability at which tags are reported from killed fish regardless of the source of mortality.

The Seber models are simple and robust, but they do not yield direct information about exploitation (u) or instantaneous rates of mortality ($Z = F + M$), which are often of interest to fisheries managers. Estimates S can be converted to Z via the equation (Ricker 1975)

$$S = e^{-Z} \qquad (3)$$

and if information about M is available, then estimates of F can be recovered. Given estimates of the instantaneous rates, it is possible to recover estimates of u if the timing of the fishery (Type I or Type II) is known (Ricker 1975).

Instantaneous rate models: Hoenig et al. (1998) modified the Brownie et al. (1985) models to allow for the estimation of instantaneous rates of fishing and natural mortality. This extension showed how information on fishing effort could be used as an auxiliary variable and also discussed generalizing the pattern of fishing within the year. The matrix of expected values corresponding to equation (1) for a model that assumes time-specific fishing mortality rates and a constant natural mortality rate would be

$$E(r)=\begin{bmatrix} N_1\phi\lambda u_1(F_1,M) & N_1\phi\lambda u_2(F_2,M)e^{-(F_1+M)} & \cdots & N_1\phi\lambda u_J(F_J,M)e^{-(\sum_{k=1}^{J-1}F_k+(J-1)M)} \\ - & N_2\phi\lambda u_2(F_2,M) & \cdots & N_2\phi\lambda u_J(F_J,M)e^{-(\sum_{k=2}^{J-1}F_k+(J-2)M)} \\ \vdots & \vdots & \ddots & \vdots \\ - & - & - & N_I\phi\lambda u_J(F_J,M) \end{bmatrix}, \qquad (4)$$

where $\phi\lambda$ is the probability of surviving being tagged and retaining the tag in the short-term, l is the tag-reporting rate, and $u_k(F_k,M)$ is the exploitation rate in year k which, as mentioned above, depends on whether the fishery is Type I or Type II.

These models are not as simple as the Seber models, but they do yield direct estimates of F and, depending on the information available, either M or $\phi\lambda$. Also, they can be parameterized to allow for non-mixing of newly and previously tagged animals (Hoenig *et al.* 1998). If the goal of a particular tagging study is to estimate F and M, then auxiliary information on the tag reporting and tag-induced mortality/handling rate is required to apply the instantaneous rates formulation. However, if M is known, perhaps from a study that related it to life history characteristics (Beverton and Holt 1959; Pauly 1980; Hoenig 1983; Roff 1984; Gunderson and Dygert 1988), then these models can be used to estimate F and $\phi\lambda$.

In either case, the auxiliary information needed (i.e., $\phi\lambda$ or M) can often be difficult to obtain in practice, and since F, M and $\phi\lambda$ are related functionally in the models, the reliability of the parameters being estimated is directly related to the accuracy of the estimated auxiliary parameter (Latour et al. 2001a).

Material and Methods

Capture and Tagging Protocol

Each year from 1991 to 2003, during the months of March, April and May, VIMS scientists obtained samples of mature striped bass on the spawning grounds of the Rappahannock River. Samples were taken twice-weekly from pound nets owned and operated by cooperating commercial fishermen. The pound net is a fixed trap that is presumed to be non-size selective in its catch of striped bass and has been historically used by commercial fishermen in the Rappahannock River.

All captured striped bass were removed from each pound net and placed into a floating holding pocket (1.2m x 2.4m x 1.2m deep, with 25.4mm mesh and a capacity of approximately

200 fish) anchored adjacent to the gear. Fish were dip-netted from the holding pocket and examined for tagging. Fork length (FL) and total length (TL) measurements were taken and whenever possible the sex of each fish was determined. Striped bass not previously marked and larger than 458 mm TL were tagged with sequentially numbered internal anchor tags (Floy Tag and Manufacturing, Inc.). Each internal anchor tag was applied through a small incision in the abdominal cavity of the fish. A small sample of scales adjacent to the dorsal fin on the left side was removed and used to estimate age. Each fish was released at the site of capture immediately after receiving a tag.

Analysis protocol

ASMFC: ASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber (1970) models. The protocol is used by each state and federal agency participating in the cooperative tagging study. Tag recoveries from striped bass that were > 711 mm total length (TL) at the time of tagging are analyzed since those fish are believed to be fully recruited to the fishery and also because they constitute the coastal migratory population (Smith *et al.* 2000).

The protocol consists of six steps. First, prior to data analysis, a set of biologically reasonable candidate models is identified. Characteristics of the stock being studied (i.e., Chesapeake Bay, Hudson River, Delaware Bay, etc.) and time are used as factors in determining the parameterizations of the candidate models. These models are then fit to the tagging data, and Akaike's Information Criterion (AIC) (Akaike 1973; Burnham and Anderson 1992), quasi-likelihood AIC (QAIC) (Akaike 1985), and goodness-of-fit (GOF) diagnostics are used to evaluate their fit (Burnham et al. 1995). The overall estimates of survival are calculated as a weighted average of survival from the best fitting models, where the weight is related to the model fit (i.e., the better the fit, the higher the weight) (Buckland et al. 1997; Burnham and Anderson 1998). The candidate models for striped bass survival (S) and tag reporting (r) rates are:

S(.)r(.)	Survival and tag-reporting rates are constant.
S(t)r(t)	Survival and tag-reporting rates are time-specific.
S(.)r(t)	Survival rate is constant and tag-reporting rates are time-specific.
S(p_1)r(t)	Survival rates vary by regulatory periods (p_1=constant 1990-1994 and 1995-2002) and tag reporting rates are time-specific.
S(p_1)r(p_1)	Survival and tar-reporting rates vary by regulatory period.
S(.)r(p_1)	Survival rate is constant and tag-reporting rates vary by regulatory periods.
S(t)r(p_1)	Survival rates are time-specific and tag-reporting vary by regulatory periods.
S(p_2)r(p_1)	Survival and tag-reporting rates vary over different regulatory periods (p_2 = constant 1990-1994,1995-2001 and 2002).
S(p_3)r(p_1)	Survival and tag-reporting rates vary over different regulatory periods (p_3 = constant 1990-1994, 1995-2000, 2001 and 2002).

$S(Tp_1)r(Tp_1)$ Survival and tag-reporting rates have linear trends within regulatory periods.

$S(Tp_1)r(p_1)$ Survival rates have a linear trend within regulatory periods and tag-reporting rates vary by regulatory period.

$S(Tp_1)r(t)$ Survival rates have a linear trend within regulatory periods and tag-reporting rates are time-specific.

$S(p_4)r(p_4)$ Survival and tag-reporting rates vary over regulatory periods (p_4 = constant 1990-1992,1993-1994 and 1995-2002).

The striped bass tagging data contains a large number of tag-recoveries reflecting catch-and-release practices (i.e. the tag of a captured fish is clipped of for the reward and the fish released back into the population). Analysis utilizing these data leads to biased survival estimates. The fifth step applies a correction term (Smith *et al.* 2000) to offset the rerelease-without-tag bias assuming a tag reporting rate of 0.43 (D. Kahn, Delaware Division of Fish and Wildlife, personal communication). The sixth step converts estimates of S_i to F_i via equation (3), assuming that M is 0.15 (Smith *et al.* 2000).

Dunning et al. (1987) quantified the rates of tag-induced mortality and tag retention for Hudson River striped bass. They found retention of internal anchor tags placed into the body cavity via an incision midway between the vent and the posterior tip of the pelvic fin was 98% for fish kept in outdoor holding pools for 180 days. Their holding experiment revealed that the survival rates of both tagged and control fish were not significantly different over a 24-hour period. A similar study conducted on resident striped bass within the York River, Virginia yielded tag-induced mortality and short-term tag retention rates each in excess of 98% (Latour and Olney, Fall 2000 Chesapeake Bay Directed *F* Study). Hence, no attempts were made to adjust for bias due to these sources. Based on these results, the ASMFC analysis protocol specifies making no attempts to adjust for the presence of short-term induced mortality or acute tag-loss.

Results

Spring 2003

Tag release summary: A total of 799 striped bass were tagged and released from the pound nets in the Rappahannock River between 3 April and 6 May, 2003 (Table 1). There were 440 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (98.0%), but the female stripers were larger on average. The median date of these tag releases, to be used as the beginning of the 2003-2004 recapture interval, was 2 May. There were 359 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly female (64.6%) and their average size was larger than the male striped bass. The median date of these tag releases was 22 April.

Mortality estimates, 2002-2003

Tag recapture summary: A total of 76 tagged Rappahannock River striped bass (>458 mm TL) were recaptured between 19 April, 2002 and 27 April, 2003 (the respective midpoints of the two tag release totals, Table 2). Of this total, 53.9% were recaptured within Chesapeake Bay (34.2% in Virginia, 19.7% in Maryland). Other recaptures came from New York (18.4%), Massachusetts (11.8%), New Jersey (6.6%), Rhode Island (3.9%), Connecticut and North Carolina (2.6% each).

A total of 10 migratory striped bass (>710 mm total length), tagged during spring 2002, were recaptured between 19 April, 2002 and 27 April, 2003. Seven of these recaptures were harvested (70.0%), and the remainder were re-released into the population (Table 3). Sport fishermen accounted for all of the harvest. The proportion harvested for the time series varied from 0.493-0.938 (mean = 0.649). Only two of the tagged striped bass were recaptured within Chesapeake Bay (20.0%), with one of those in Virginia and one in Maryland. Other recaptures came from New York (30.0%), Massachusetts (20.0%), Rhode Island (10%), New Jersey (10%) and Connecticut (10%). Thirty one migratory striped bass tagged striped bass tagged prior to spring, 2002 were also recaptured during the 2002 recovery interval and were included in the survival data matrix (Table 3).

ASMFC protocol: Survival estimates were made utilizing the mark-recapture data for the Rappahannock River from 1990-2003. The suite of Seber (1970) models consisted of 13 models that each reflected a different parameterization of time. Models that allowed parameters to be both time-specific and constant across time were specified. Since Atlantic striped bass have been subjected to a variety of harvest regulations since 1990, it was hypothesized that these harvest regulations would influence survival and catch rates. Hence, models that allowed parameters to be constant for the time periods coinciding with coast-wide harvest regulations were also specified.

Survival estimates for striped bass greater than 457 mm (18") total length were suspect. Only one model (S(t) R(t)) fit the data and the results over time had spikes in survival that were not possible (i.e. > 1.0). The results were thus excluded from further analysis pending review into the cause(s) of the problem.

Survival estimates were obtained for striped bass greater than 710 mm (28") total length. Of the 13 proposed models, eight had ΔAICc values less than 7.0 (Table 4). Of those eight models, the calculated weight of the regulatory period-based (i.e., S(p_1) r(p_1)) and the constant survival and tag reporting model (i.e., S(.)r(.)) were larger than that of the other models. The constant survival, regulatory-based reporting model (S(.) R(p_1)) was also heavily weighted. Models that reflected more general time-specific parameterizations tended to not fit the data well. An alternative analysis was performed by the Striped Bass Tagging Subcommittee (Gamble et al. 2003). In this analysis the S(p_3) r(p_1) had the greatest weight, with significant input from the three aforementioned models. The results are contrasted in Table 5.

The VIMS model averaged estimates of the bias-adjusted survival rates ranged from 0.60-0.74 over the time series (Table 6a). Survival was highest during the transitional fishery and decreased slightly during the recovered fishery. This trend was the result of a higher proportion of annual tag recoveries being released back into the population in the early 1990's relative to more recent years. The corresponding estimates of F_i ranged from 0.15-0.35 and only infrequently, and by slight margins, exceeded the transitional and full fisheries target values. Both the survival and fishing mortality estimates were relatively constant. This was to be expected with calculated QAIC weights of the S(.)r(.), S(p_3)r(p_1), S(.)r(p_1) and the S(p_1)r(p_1) models were a combined 0.79.

The SBTC model averaged estimates of the bias-adjusted survival rates ranged from 0.61-0.74 over the time series (Table 6b). Survival was highest during the transitional fishery and decreased slightly during the recovered fishery. The corresponding estimates of F_i ranged from 0.16-0.36 and only infrequently, and by slight margins, exceeded the transitional and full fisheries target values. Both the survival and fishing mortality estimates were relatively constant. This was to be expected with calculated QAIC weights of the S(.)r(.), S(p_3)r(p_1), S(.)r(p_1) and the S(p_1)r(p_1) models were a combined 0.74.

Model evaluation

Latour et al. (2001b) proposed a series of diagnostics that can be used in conjunction with AIC and GOF measures to assess the performance of tag-recovery models. In essence, they suggested that the fit of a model could be critically evaluated by analyzing model residuals and that patterns would be evident if particular assumptions were violated.

For the time-specific Seber (1970) model, Latour et al. (2002) proved the existence of several characteristics about the residuals. Specifically, they showed that row and column sums of the residuals matrix must total zero, and further, they showed that the residuals associated with the "never seen again" category must also always be zero. Latour et al. (2001c) also scrutinized the residuals associated with the instantaneous rates model and found the residual matrix of this model possessed fewer constraints than the time-specific Seber model. Although the row sums in the "never seen again" category must total zero, the column sums and the associated residuals can assume any value.

ASMFC protocol: The sum of residuals associated with the "never seen again" category (rows 4-7) from the S(t)r(t) model for the Rappahannock River were not zero. Inspection of the parameter estimates revealed that the tag reporting estimates in 1993 (r_4) and 1995 (r_6) were 1.0. This would mean that all fishermen reported all recaptures and that there was no mortality or loss of tag in those recaptures returned to the population (highly unlikely if not theoretically impossible). Hand calculation of the estimates of r_4 and r_6 using the analytical formula developed by Seber (1970) yielded values greater than 1.0 which implies that the estimates from program MARK resulted from constraints imposed to satisfy the condition that r_4 and r_6 be probabilities.

Given that management regulations applied to striped bass during the 1990s have specified a wide variety of harvest restrictions, it would be reasonable to assume that the time-specific models (e,g. S(t)r(t), S(p_1)r(t), S(t)r(p_1), etc.) were most appropriate for data analysis. However, elements of the Rappahannock River tag-recovery matrix did not allow these models to adequately fit the data. The low total number tagged striped bass releases resultant recaptures reported from the 1994 and 1996 cohorts (e.g. five from the 1996 cohort) relative to other years may result in the poor fit of the time-specific models. Unfortunately, numerical complications resulting from low sample size caused some of the more biologically reasonable models to not fit the Rappahannock River data well.

Discussion

The decline and subsequent recovery of Atlantic striped bass stocks that has transpired over the past several decades has been well documented (see Richards and Rago, 1999 for a comprehensive historical review of the decline and the science, management and legislation that led to the recovery of Atlantic striped bass stocks). The scale of the management efforts by the ASMFC, with the support of federal legislation, employed to reverse the decline in striped bass abundance were formidable and have proven successful. Those efforts synthesized scientific information from fishery-independent juvenile surveys, tagging studies to determine migration patterns and determine annual survival rates, assessment of spawning stocks and an expanded fishery-dependent monitoring that yielded improved fishery statistics and biological characterization of landings into an inter-jurisdictional cooperative plan. Although the coast-wide tag-recovery study that was initiated constitutes only a small part of the wealth of scientific information acquired by the ASMFC, it has served to provide valuable insight on the annual survival rates of several striped bass stocks.

The presence of recaptured striped bass that are released back into the population after removing the tag streamer in the data base was shown to bias the resultant analyses. Evaluation of the ASMFC (Seber) and the instantaneous rates (Hoenig *et al.*) models determined the ASMFC analysis protocol to be the more reliable. The use of chop variables within the instantaneous rates model to reduce bias was investigated, but parameter estimates based beyond the main diagonal of the tag-recovery matrix were still biased. However, the magnitude of the bias was small and not likely to be severe enough to drastically change the respective estimates of mortality and the qualitative assessment of the status of striped bass stocks in Chesapeake Bay. The results of the Seber models suggest that mortality levels of striped bass are not extreme and that current management regulation practices, allowing full and open fisheries along the Atlantic coast, are sufficient.

We can offer no explanation as to what procedures were done by the Striped Bass Tagging Subcommittee to produce their alternative results. The analysis was performed without the knowledge, consent or review by VIMS personnel. Although the altered results of survival vary only slightly from those provided to the committee by VIMS, the weighting of the candidate models differed greatly. We have no way of validating the new values or the rationale for their analysis and thus object to their use pending thorough review.

Literature Cited

Akaike, H. 1973. Information theory as an extension of the maximum likelihood principle. In Second International Symposium on Information Theory. Edited by B.N. Petrov and F. Csaki. Budapest: Akademiai Kiado.

Akaike, H. 1985. Prediction and entropy. In A Celebration of Statistics. Edited by A.C. Atkinson and S.E. Fienberg. New York: Springer.

Beverton, R.J.H., and S.J. Holt. 1959. A review of the lifespans and mortality rates of fish in nature, and their relation to growth and other physiological characteristics. Ciba Found. Colloq. Ageing 5:142-177.

Brownie, C., D.R. Anderson, K.P. Burhnam, and D.R. Robson. 1985. Statistical inference from band recovery data: a handbook, 2nd ed., U.S. Fish and Wildl. Serv. Resour. Publ. No. 156.

Buckland, S.T., K.P. Burnham, and N.H. Augustin. 1997. Model selection: an integral part of inference. Biometrics 53:603-618.

Burnham, K.P. and D.R. Anderson. 1992. Data-based selection of an appropriate biological model: The key to modern data analysis. In Wildlife 2001: Populations. Edited by D.R. McCullough and R.H. Barrett. London: Elsevier Science Publishers.

Burnham, K.P. and D.R. Anderson. 1998. Model selection and inference: a practical information theoretical approach. Springer-Verlag, New York.

Burnham, K.P., G.C. White, and D.R. Anderson. 1995. Model selection strategy in the analysis of capture-recapture data. Biometrics 51:888-898.

Dunning, D.J., Q.E. Ross, J.F. Waldman, and M.T. Mattson. 1987. Tag retention by, and tagging mortality of, Hudson River striped bass. N. Am J. Fish. Manage. 7:535-538.

Field, J.D. 1997. Atlantic striped bass management: where did we go right? Fisheries 22(7):6-8.

Gamble, M. et al. 2003. Striped bass tagging report for 2002. Revised summary of U.S.F.W.S. cooperative tagging program results. Report No. SB Tag 2003-1. 35pp.

Gunderson, D.R., and P.H. Dygert. 1988. Reproductive effort as a predictor of natural mortality rate. J. Cons. int. Explor. Mer 44:200-209.

Hoenig, J.M. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 81:898-903.

Hoenig, J.M., N.J. Barrowman, W.S. Hearn, and K.H. Pollock. 1998. Multiyear tagging studies incorporating fishing effort data. Can. J. Fish. Aquat. Sci. 55:1466-1476.

Latour, R.J., K.H. Pollock, C.A. Wenner, and J.M. Hoenig. 2001a. Estimates of fishing and natural mortality for red drum (Sciaenops ocellatus) in South Carolina waters. N. Am. J.Fish. Manage. 21: 733-744.

Latour, R.J., J.M. Hoenig, J.E. Olney, and K.H. Pollock. 2001b. Diagnostics for multi-year tagging models with application to Atlantic striped bass (*Morone saxatilis*). Can. J. Fish. Aquat. Sci. 5: 1716-1726.

Latour, R.J., J.M. Hoenig and K.H. Pollock. 2001c. Properties of the residuals from two tag-recovery models. Fish. Bull. In review.

Latour, R.J., J.M. Hoenig and K.H. Pollock.2002. Properties of the residuals from two tag-recovery models. Fish. Bull. In press.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer. 39(2):175-192.

Ricker, W.E. 1975. Computation and Interpretation of Biological Statistics of Fish Populations.Bull. Fish. Res. Board Can. No 191.

Roff, D.A. 1984. The evolution of life history parameters in teleosts. Can. J. Fish. Aquat. Sci. 41:989-1000.

Smith, D.R., K.P. Burnham, D.M. Kahn, X. He, C.J. Goshorn, K.A. Hattala, and A.W. Kahnle. 2000. Bias in survival estimates from tag-recovery models where catch-and-release is common, with an example from Atlantic striped bass (Morone saxatilis). Can. J. Fish. Aquat. Sci. 57:886-897.

Weaver, J.E., R.B. Fairbanks and C. M. Wooley. 1986. Interstate management of Atlantic coastal migratory striped bass. MRFSS 11: 71-85.

White, G.C. 1983. Numerical estimation of survival rates from band-recovery and biotelemetry data. J. Wildl. Manage. 47:716-728.

White, G.C. and K. P. Burnham. 1999. Program MARK–survival estimation from populations of marked animals. Bird Study 46:120-138.

Wooley, C.M., N.C. Parker, B.M. Florence and R.W. Miller. 1990. Striped bass restoration along the Atlantic Coast: a multistate and federal cooperative hatchery and tagging program. Am. Fish. Soc. Symp. 7: 775-781.

Table 1. Summary data of striped bass tagged and released from pound nets in the Rappahannock River, spring 2003.

Date	total tagged	457 - 710 mm TL				> 710 mm TL			
		males		females		males		females	
		n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$
3 April	12	5	476.4	0		1	753.0	6	869.7
7 April	4	3	533.0	0		0		1	911.0
10 April	65	27	512.3	2	520.5	21	745.5	15	839.1
14 April	131	71	483.4	2	560.5	23	751.8	35	876.7
17 April	66	15	489.7	0		7	744.6	44	858.0
21 April	39	7	486.4	0		19	759.3	13	854.8
24 April	65	13	492.4	0		17	731.8	35	843.9
28 April	116	56	497.4	1	543.0	17	741.1	42	845.8
1 May	80	48	495.6	1	560.0	13	728.8	18	842.6
6 May	221	186	489.4	3	523.0	9	740.0	23	884.7
Total	799	431	491.8	9	537.1	127	744.2	232	857.1

Table 2. Location of striped bass recaptured in 2002 that were originally tagged and released in the Rappahannock River during springs 1988-2002.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
Massachusetts	0	0	0	0	2	4	2	1	0	0	0	0	9
Rhode Island	0	0	0	0	0	0	1	0	2	0	0	0	3
Connecticut	0	0	0	0	2	0	0	0	0	0	0	0	2
New York	0	0	0	0	3	4	2	0	2	2	1	0	14
New Jersey	0	0	0	0	3	1	0	0	0	1	0	0	5
Maryland	1	0	0	1	2	4	4	0	1	0	2	0	15
Virginia	1	2	3	3	1	2	3	0	0	5	2	4	26
North Carolina	0	0	0	0	0	0	0	0	0	0	0	2	2
Total	2	2	3	4	13	15	12	1	5	8	5	6	76

Table 3. Recapture matrix of striped bass (>710 m TL) that were tagged and released in the Rappahannock River, springs 1990-2002. The second (bottom) number is the number of those recaptures that were killed.

		recaptures												
Year	n	90	91	92	93	94	95	96	97	98	99	00	01	02
1990	301	26 11	9 1	15 7	2 2	4 3	6 6	1 1	0 0	2 1	1 1	1 0	0 0	0 0
1991	390	---	41 21	24 11	16 12	11 9	3 2	2 2	2 2	1 0	2 2	0 0	0 0	0 0
1992	40	---	---	4 2	3 2	2 1	2 2	0 0	0 0	0 0	1 1	0 0	0 0	0 0
1993	212	---	---	---	22 12	18 11	7 6	4 4	7 5	0 0	0 0	1 1	0 0	0 0
1994	123	---	---	---	---	9 5	7 6	5 5	1 1	2 1	0 0	0 0	0 0	0 0
1995	209	---	---	---	---	---	28 22	10 8	8 5	3 2	3 3	2 1	3 3	0 0
1996	66	---	---	---	---	---	---	1 0	3 3	1 1	0 0	0 0	0 0	0 0
1997	212	---	---	---	---	---	---	----	15 13	13 12	8 6	3 1	0 0	1 1
1998	158	---	---	---	---	---	---	----	----	24 18	13 9	2 0	3 3	2 1
1999	162	---	---	---	---	---	---	----	----	----	17 14	5 2	2 2	3 2
2000	365	---	---	---	---	---	---	----	----	----	----	27 13	19 12	12 6
2001	269	---	---	---	---	---	---	----	----	----	----	----	19 12	14 8
2002	359													10 7

Table 4. Performance statistics, based on quasi-likelihood Akaike Information Criterions (QAIC), used to assess the Seber (1970) models utilized in the ASMFC analysis protocol. Model notations: S (f) and r (f) indicate that survival (S) and tag-reporting rate (r) are functions (f) of the factors within the parenthesis; constant parameters across time (.); parameters constant from 1990-1994 and 1995-2002 (p_1); parameters vary in 2002 (p_2), otherwise the same as p_1; parameters vary in 2001 and 2002 (p_3), otherwise the same as p_1; parameters constant from 1990-1992, 1993-1994 and 1995-2002 (p_4); assumption of linear trends from 1990-1994 and 1995-2002 (Tp_1); and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight	number of parameters
S(p_1)r(p_1)	3739.89	0.00	0.24799	4
S(.)r(.)	3739.90	0.01	0.24653	2
S(.)r(p_1)	3740.20	0.31	0.21257	3
S(p_2)r(p_1)	3741.83	1.94	0.09408	5
S(p_3)r(p_1)	3742.03	2.14	0.08508	6
S(p_4)r(p_4)	3742.51	2.62	0.06678	6
S(Tp_1)r(Tp_1)	3744.49	4.60	0.02490	8
S(.)r(t)	3745.80	5.91	0.01294	14
S(p_1)r(t)	3747.33	7.44	0.00601	15
S(t)r(p_1)	3749.83	9.94	0.00172	15
S(Tp_1)r(t)	3750.25	10.37	0.00139	17
S(Tp_1)r(p_1)	3811.26	71.37	0.00000	6

Table 5. Comparison of the model weighting assigned to the candidate models by VIMS and by the Striped Bass Tagging Subcommittee (SBTS) for 2002-2003.

Model	relative weighting	
	VIMS	SBTS
S(p_1) r(p_1)	0.2480	0.2088
S(.) r(.)	0.2465	0.1632
S(.) r(p_1)	0.2126	0.1558
S(p_2) r(p_1)	0.0941	0.0795
S(p_3) r(p_1)	0.0851	0.2141
S(p_4) r(p_4)	0.0668	0.0611
S(Tp_1) r(Tp_1)	0.0249	0.0258
S(.) r(t)	0.0129	0.0255
S(p_1) r(t)	0.0060	0.0122
S(t) r(p_1)	0.0017	0.0030
S(Tp_1) r(t)	0.0014	0.0030
S(Tp_1) r(p_1)	0.0000	0.0467
S(t) r(t)	excluded	0.0014

(.) Parameters constant across time

(p_1) Parameters constant from 1990-1994 and 1995-2002

(p_2) Parameters constant in 2002, otherwise same as (p_1)

(p_3) Parameters constant in 2001 and 2002, otherwise same as (p_1)

(p_4) Parameters constant in 1990-1992, 1993-1994, and 1995-2002

(Tp_1) Parameters linear from 1990-1994 and 1995-2002

(t) Parameters time-specific

Table 6a. Seber (1970) model estimates (VIMS) of unadjusted survival ($\hat{S}$) rates and adjusted rates of survival ($\hat{S}_{adj}$) and fishing mortality ($\hat{F}$) of striped bass (> 711 mm FL) derived from the proportion of recaptures released alive (P_L) in the Rappahannock River, 1990-2002.

Year	$\hat{S}$	SE ($\hat{S}$)	P_L	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI $\hat{F}$
1990	0.620	0.028	0.583	-0.13	0.710	0.190	0.11, 0.29
1991	0.621	0.027	0.527	-0.12	0.710	0.190	0.11, 0.29
1992	0.622	0.027	0.489	-0.16	0.740	0.150	0.07, 0.24
1993	0.628	0.031	0.341	-0.09	0.690	0.220	0.13, 0.32
1994	0.628	0.032	0.304	-0.07	0.670	0.240	0.15, 0.35
1995	0.594	0.028	0.190	-0.07	0.640	0.300	0.21, 0.39
1996	0.595	0.028	0.130	-0.02	0.600	0.350	0.27, 0.45
1997	0.594	0.027	0.162	-0.04	0.620	0.330	0.25, 0.43
1998	0.594	0.027	0.213	-0.09	0.650	0.270	0.19, 0.37
1999	0.594	0.028	0.200	-0.06	0.630	0.310	0.22, 0.41
2000	0.594	0.028	0.341	-0.07	0.640	0.300	0.21, 0.40
2001	0.601	0.033	0.298	-0.06	0.640	0.300	0.20, 0.42
2002	0.602	0.038	0.286	-0.06	0.640	0.290	0.18, 0.43

Table 6b. Seber (1970) model estimates (SBTC) of unadjusted survival ($\hat{S}$) rates and adjusted rates of survival ($\hat{S}_{adj}$) and fishing mortality ($\hat{F}$) of striped bass (> 711 mm FL) derived from the proportion of recaptures released alive (P_L) in the Rappahannock River, 1990-2002.

Year	$\hat{S}$	SE ($\hat{S}$)	P_L	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI $\hat{F}$
1990	0.623	0.028	0.583	-0.12	0.707	0.196	0.11, 0.29
1991	0.624	0.027	0.527	-0.12	0.706	0.199	0.12, 0.29
1992	0.624	0.027	0.489	-0.15	0.737	0.156	0.08, 0.25
1993	0.630	0.031	0.341	-0.09	0.689	0.222	0.14, 0.32
1994	0.630	0.032	0.304	-0.06	0.673	0.246	0.16, 0.35
1995	0.590	0.028	0.189	-0.07	0.632	0.310	0.22, 0.41
1996	0.591	0.028	0.130	-0.01	0.599	0.362	0.28, 0.46
1997	0.591	0.027	0.162	-0.03	0.611	0.343	0.26, 0.44
1998	0.592	0.027	0.213	-0.08	0.646	0.286	0.20, 0.38
1999	0.592	0.028	0.200	-0.07	0.626	0.318	0.23, 0.42
2000	0.593	0.028	0.341	-0.07	0.634	0.305	0.22, 0.41
2001	0.610	0.033	0.298	-0.05	0.644	0.291	0.17, 0.44
2002	0.612	0.038	0.286	-0.06	0.649	0.282	0.15, 0.44

III. Fishing mortality estimates of the fall 2002 resident striped bass fishery in the Chesapeake Bay, Virginia.

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Introduction

In contrast to the highly migratory, mostly female, coastal striped bass population, the Chesapeake Bay and its tributaries maintain a resident population of mature male striped bass in addition to pre-migrant (<2 years old), immature striped bass. These striped bass evidently exhibit little movement during the summer and early fall, remaining stationary in areas of abundant forage (Merrimen 1941, Vladykov and Wallace 1938, Mansueti 1961). In late fall, in response to falling water temperatures and movement of the schools of baitfish, resident striped bass migrate downriver to deeper parts of the tributaries and generally southward along the western side of Chesapeake Bay to over-winter in deeper portions of the bay (Vladykov and Wallace 1938, Mansueti 1961). These striped bass, supplemented by an infusion of southward migrating coastal fish in late November and December, form the basis of the historic annual fall recreational and commercial fisheries.

In 1993, the rebound in striped bass abundance allowed for a lifting of the moratorium on the recreational fishery. The Atlantic States Marine Fisheries Commission (ASMFC) established a target fishing mortality rate (F) of 0.25, which was further relaxed to a rate of 0.30 in 1995 in response to evidence of continued stock recovery (Field 1997). To document compliance with the ASMFC regulations, the VIMS Anadromous Program modified its fall tagging methodology, begun in 1987, to collaborate with the Maryland Department of Natural Resources (Md DNR) to estimate the recreational fishing mortality rate for Chesapeake Bay.

Materials and Methods

Experimental design

Commencing in 1995, a stratified tag release program was instituted in collaboration with Maryland DNR. The Virginia portion of the Chesapeake Bay was divided into the York, James and Rappahannock rivers and (western) main-stem Chesapeake Bay (Fig. 1). Multiple short-duration (< 10 days) tag release periods, synchronized with the Maryland DNR effort and separated by 3-4 weeks, were executed with the first tagging round occurring prior to the start of each fall recreational season (4 Oct in 2002). The multiple-release protocol minimized the effects of immigration and emigration to the analysis. Optimal tagging quotas, proportionally based on historic catch data, were allotted to each area to facilitate the defusion of tagged fish throughout Chesapeake Bay. From 1995-1998, striped bass were tagged from commercial pound nets, drift gill nets, fyke nets and haul seines at multiple sites within each system. In 2002, an experimental fyke net was constructed at river mile 40 on the James River for evaluation. The use of fyke nets had been discontinued after 1998, due to a drastic decline in their use by commercial fishermen. Also in 2002, variable-mesh anchor gill nets were utilized in the James River in response to the decreasing availability of suitable commercial gears. The meshes used were 4 ½ , 4 7/8 , 5 1/4 and 6 inches. These meshes caught striped bass in the same size ranges as the pound nets and haul seines used elsewhere.

General protocols for tagging follow those described in previous mark-recovery studies (Rugulo et al. 1994, Shaefer and Rugulo 1996, Herbert et al. 1997). A Floy internal tag, with cylindrical dimensions of 5 mm x 15 mm with an 85 mm external tube was used. Tags were inserted into the peritoneal cavity posterior to the pectoral fin on the left side of the fish. Lengths (FL, TL) were recorded for each striped bass and a scale sample was taken from between the two dorsal fins and above the lateral line for subsequent aging of the fish (Merrimen 1941). Only striped bass greater than 458 mm total length (18 inches) were tagged. Physical parameters (time, air and surface water temperatures, tidal stage and surface salinity) were recorded at each tagging location.

Analytical methods

Commencing in 1997, the bay-wide estimate of fishing mortality for resident striped bass has been based on pooled data from the coordinated multiple-release tagging study in addition to harvest statistics from both states from the spring of the subsequent year. The bay-wide estimates are annual mortality rates, however, they pertain to a 12-month period that begins and ends in the late spring of each year (1 June - 31 May).

For purposes of tag release, the natural boundary between Maryland and Virginia was used to stratify the Bay into two management jurisdictions. Despite having separate management jurisdictions, tagging efforts were synchronized during times when the fishing seasons on the two states overlapped. In all years, the first release in each jurisdiction began approximately one week prior to the start of the recreational season. The recovery interval began the day after at least one half of the stripers were tagged on a bay-wide basis in each release interval and continued up to the start of the next interval.

All tagging studies require making the assumption that the tagging process does not affect the behavior or the survival of the tagged fish and that there is no (measurable) tag loss. Assessment of short-term tag-induced mortality were done in Maryland (1995) and Virginia (2000) and produced tagging mortality rates of 1.3% and 1.5% respectively (Latour *et al.* 2001). Determination of the reporting rate of recaptured tagged striped bass was done in 1999 by comparing the observed reporting rate with that of a subset of high-reward tags released simultaneously. The resulting tag reporting rates were 0.64 and 0.55 depending on the recovery interval specified (Rogers *et al.* 2000).

Tag recovery data were provided to the Maryland DNR for estimations of instantaneous exploitation rate (U) and fishing mortality (F). Estimates were calculated utilizing a logistic regression model based on reported tag recoveries that occurred between the midpoints (the date after which 50% of tag releases occurred) of consecutive tagging rounds. The proportion of the number of tags recovered to the number of tags released was the response variable and the explanatory variables consisted of one categorical variable (interval number) and two binary variables (disposition of the recapture and angler type). Tag release and recovery data for input into the model were adjusted to eliminate the following tag recoveries: those that occurred between the start of the tagging round but prior to the day after the midpoint of tag releases for that round; from stripers found dead or if only a tag was recovered (as opposed to a tagged striper, Goshorn, *et al.* 1999). The calculation of the recreational exploitation rate used only tag returns from striped bass harvested by recreational and charter fishermen. A detailed review of the analysis protocol is currently under way (Latour *et al.* 2001).

Results

Tag release summary 2002

In fall 2002, a total of 2,891 striped bass were tagged and released among three tagging rounds (Table 1). The high variability of tag releases among the three rounds reflect the seasonal availability of striped bass to the commercial gears utilized in each sampling area.

Tagging round 5, 16-25 September: The 672 striped bass tagged and released came primarily (87.8%) from two locations (Table 2). The number of striped bass tagged and released met or exceeded the desired quotas only in the Rappahannock River and the middle section of Chesapeake Bay. This overall lack of spatial diversity is typical of previous tagging rounds in September. Water temperatures during the tagging round were 21-24 °C. As water temperatures drop during October, the striped bass form large schools and migrate towards the deeper, open waters in the lower rivers and Chesapeake Bay and are more susceptible to capture in commercial gears.

The majority of the striped bass tagged and released were from the 1999 (55.0%) and 1998 (36.5%) year classes (Table 3). The mean ages of the striped bass varied from 3.27 years (Rappahannock River) to 3.72 years (James River). The mean size (FL) of the striped bass tagged and released varied from 471.5 mm (York and Rappahannock Rivers) to 509.6 mm (James River). The midpoint of the tagging round was 18 September.

Tagging round 6, 21 October - 30 October: The 1,402 striped bass tagged and released reflect the dramatic increase in availability relative to September (Table 4). Water temperatures during the tagging round were 14-18 °C. The number of striped bass tagged and released exceeded the desired quotas in every region except the James and York Rivers.

The majority of the striped bass tagged and released were from the 1999 (49.5%) and 1998 (45.6%) year classes (Table 5). The mean ages of the striped bass varied from 3.39 years (middle Chesapeake Bay) to 3.90 years (James River). The mean sizes (FL) of the striped bass tagged and released varied from 484.0 mm (middle Chesapeake Bay) to 526.4 mm (James River). The midpoint of the tagging round was 23 October.

Tagging round 7, 20-26 November: The 817 striped bass tagged and released reflect a different strategy relative to the previous tagging rounds. First, the Thanksgiving holidays (27-29 November) reduced the number of tagging days available. In addition a strong northeaster on 21

November was followed by unusually cold weather through the rest of the tagging round. Striped bass, usually abundant at all tagging locations, evidently moved into deeper waters away from our commercial gears and resulted in a failure to reach the desired release quotas in all areas except the York River (Table 6). Water temperatures during the tagging round ranged from 10-12 °C.

The majority of the striped bass tagged and released were from the 1999 (59.4%) and 1998 (35.4%) year classes (Table 7). The mean ages of the striped bass varied from 3.21 years (upper Chesapeake Bay) to 4.30 years (James River). The mean sizes of the striped bass tagged and released varied from 470.4 mm (middle Chesapeake Bay) to 557.0 mm (James River). The midpoint of the tagging round was 21 November.

Tag recapture summary

A total of 102 tagged striped bass were recaptured from 16 September - 31 December, 2002 (Table 8). The overall proportion of recapture was 0.035 and varied from 0.007 (James River) to 0.069 (Rappahannock River). Excepting the single recapture from the James River, the proportion of striped bass recaptured within the same area as they were tagged was highest in the Rappahannock River (0.968) and lowest in the upper Chesapeake Bay (0.000). Striped bass tagged in the Virginia part of Chesapeake Bay were predominantly (0.951) recaptured there, but there were five recaptures elsewhere (two in Maryland, two in the Potomac River and one in the Atlantic Ocean off North Carolina). The striped bass recaptured from middle Chesapeake Bay releases were slightly larger and older than the striped bass recaptured from the other areas.

Recapture interval 5, 19 September - 23 October: A total of 53 striped bass (7.9%) tagged in the fifth tagging round were recaptured by 31 December (0.07% per day). Of these, 79.2% of the recaptures occurred within the fifth recapture interval (Table 9). Sport fishermen (recreational and charter anglers) accounted for only 4.8% of the recaptures during the recapture interval. These anglers harvested both recaptured tagged striped bass. The two recaptured striped bass harvested by sport fishermen are the data included in the computation of fishing mortality. There was no commercial harvest of recaptured striped bass during the recovery interval. The "other" category consisted mainly of recaptured striped bass encountered by VIMS tagging personnel at our research pound net in the York River or at the nets of cooperating fishermen at our tagging locations. These fish were re-released unharmed if deemed robust by the chief scientist in each tagging party.

Recapture interval 6, 24 October - 20 November: A total of 41 striped bass (2.9%) tagged in the sixth tagging round were recaptured by 31 December (0.04% per day). However, only 66.7% of these recaptures occurred within the sixth recovery interval (Table 10). Sport fishermen accounted for 14.3% of the recaptures during the recapture interval. Again, more recaptured striped bass were harvested rather than released. The four recaptured striped bass harvested by sport fishermen are the data included in the computation of fishing mortality. There was no reported commercial harvest of recaptured striped bass during the recovery interval.

Recapture interval 7, 21 November - 31 December: A total of 8 striped bass (1.0%) tagged in the seventh tagging round were recaptured by 31 December (0.02% per day). All the recaptures occurred within the recovery interval (Table 11). Sport fisherman accounted for 87.5% of the recaptures during the recapture interval and released more than they harvested. The two recaptured striped bass harvested by sport fishermen are the data included in the computation of fishing mortality.

Several factors during the recapture interval account for the low number of recaptures. Unusually harsh weather during the third tagging round reduced the targeted output of tagged striped bass by almost half. Also, most pound nets, including our research net in the York River, cease operations by Thanksgiving. Other commercial fishing for striped bass, mostly anchor gill nets, also decreases as fishermen expend their quota of striped bass tags for the year. Hence, there were no commercial recaptures during the final recapture interval. In, addition, an unusually prolonged and severe stretch of harsh winter weather persisted throughout late November through December which presumedly reduced the recreational effort.

Estimation of fishing mortality (F):

To obtain an estimate of a fishing mortality rate, the tag-recovery rate f_i must first be converted to a finite exploitation rate (Pollock *et al.* 1991):

$$u_i = \frac{f_i}{\lambda_R}$$

where u_i is the fall recreational/ charter exploitation rate in interval i and λ_R is the probability a recreational angler will report a tag recapture. Since the recovery interval was of short duration (20-40 days), natural mortality was deemed negligible and a type I (pulse) fishery to exist. The fishing mortality rate was then calculated as (Ricker 1975):

$$F = \sum_{i=1}^{L} - \log(1 - u_i)$$

where L is the total number of intervals.

Recreational fishing also occurs in the spring when tagging of the resident striped bass is not conducted. Hence, derivation of an overall resident fishing mortality rate was adjusted by:

$$F_r = F + (FP_s)$$

where F_r is the overall recreational/ charter fishing mortality rate and P_s is the proportion of the number of resident striped bass in the spring harvest relative to the total recreational harvest. Harvest statistics were obtained from the Marine Fisheries Statistics Survey (MRFSS).

The estimate of the Chesapeake Bay fishing mortality rate for 2002 was 0.12. A non-harvest mortality rate of 0.10 was added to produce the final estimate of a recreational/ charter fishing mortality of 0.22 (Hornick *et al.* 2003).

Discussion

The number of striped bass tagged during the three tagging rounds in Virginia are a reflection of their areal and seasonal availability. In September, striped bass are generally scattered in small schools and are structure oriented. Striped bass are reliably captured in quantity from the pound nets of our cooperating fisherman in the upper Rappahannock River and occasionally from haul seines in some shallow bays in the middle James River, but are scarce and sporadic elsewhere. By late October falling water temperatures and the first fall storms apparently initiate a schooling and feeding response in striped bass and they become available to commercial gears throughout western Chesapeake Bay. This trend generally continues through Thanksgiving, but most poundnetters start removing their nets in early November in response to changing conditions in the general fisheries and to reduce exposing excess capacity to potential damage to coastal storms. Unusually harsh weather conditions in late November, 2002 reduced the number of striped bass released below expectations. For the second consecutive year, a haul seine fisherman could not be contracted to relocate to the James River. The one fyke net constructed did not provide suitable numbers of striped bass for tagging. Gill nets were deployed to supplement the numbers, but the total number of striped bass tagged and released on the James River was insufficient to measure the recreational fishery there.

Both pound nets and haul seines are non size-selective but the legal-sized (>458 mm FL) striped bass captured for tagging were overwhelmingly three and four year-old fish. Larger resident male striped bass are encountered in the spring tagging and spawning stock assessment studies, so their omission may create a size-bias in the estimation of fishing mortality of the resident population. Larger fish are generally targeted by recreational anglers and are less likely to be released when captured.

The high incidence of recapture of tagged striped bass within the same general geographic area in which they were released (86.2%) in the first two tagging rounds (rounds five and six) indicate that the early fall migrations of the resident population is limited in scope (see Figure 1 for the areal breakdown). The prevalence of same-area recapture was highest in Rappahannock River (96.8%). The prevalence of same-area recapture was also very high in the York river (83.3%). However, striped bass tagged from our middle and upper Chesapeake Bay locations did show a wider pattern of dispersal. Striped bass tagged there were recaptured in the Chesapeake Bay (Maryland) and the Potomac River (all north and west of the release site), plus off Virginia

Beach (south and east) and outside of Chesapeake Bay (North Carolina). The migration pattern may change towards the end of the tagging season. Recaptures of tagged striped bass from the mouth of Chesapeake Bay and from North Carolina occurred between 24 November and 31 December.

The Chesapeake Bay-wide estimate of resident striped bass fishing mortality was 0.22. This was the sum of the estimate of both non-harvest (0.10) and harvest (0.12) mortalities. Non harvest mortalities include natural deaths and handling-induced mortalities. In our fall 2002 study 89.9% of the recaptures were released alive (46.7% of sport recaptures and 100% of research recaptures). The fishing mortality estimate was below the target rate desired for Chesapeake Bay established by the Atlantic States Marine Fisheries Commission (ASMFC).

Literature Cited

Brownie, C., D. R. Anderson, K. P. Burnam and D. S. Robson. 1985. Statistical inference from band recovery data: a handbook. Second Ed., U.S. Fish and Wildlife Service Resource Pub. 156 pp.

Dorazio, R. M. 1993. Prerelease stratification in tag-recovery models with time dependence. Can. J. Fish. Aquat. Sci. 50: 535-541.

Dorazio, R. M., Hattala, K. A., McCollough and J. E. Skjeveland. 1994. Tag recovery estimates of migration of striped bass from spawning areas of the Chesapeake Bay. Trans. Amer. Fish. Soc. 123: 950-963.

Dorazio, R. M. 1995. Mortality estimates of striped bass caught in Albemarle Sound and Roanoke River, North Carolina. N. Amer. J Fisheries Management 15: 290-299.

Field, J. D. 1997. Atlantic striped bass management: where did we go right? Fisheries 22(7): 6-8.

Goshorn, C. J., B. A. Rogers and R. E. Harris, Jr. 1999. Estimate of the 1998 striped bass rate of fishing mortality in Chesapeake Bay. Manuscript. Maryland Department of Natural Resources Annapolis, Maryland.

Hebert, K. P., D. R. Smith and P. W. Jones. 1997. Estimates of the 1995 striped bass rate of fishing mortality in Chesapeake Bay. Manuscript, Maryland Department of Natural Resources, Annapolis, Md.

Hornick, H. T., B. A. Rogers and R. E. Harris. 2003. Estimate of the 2002 striped bass rate of fishing mortality in Chesapeake Bay. Manuscript, Maryland Department of Natural Resources, Annapolis, Md. 12 pp.

Latour, R. J., K. H. Pollock, C. A. Wenner and J. M. Hoenig. 2001. Estimates of fishing and natural mortality for red drum, *Sciaenops ocellatus* in South Carolina waters. N. Am. J. Fish. Mgmt. In press.

Latour, R. J., C. J. Goshorn, B. A. Rogers, H. T. Hornick, J. E. Olney, R. E. Harris and P. W. Jones. Estimates of fishing mortality for striped bass resident to Chesapeake Bay. In preparation.

Mansueti, R. J. 1961. Age, growth, and movements of the striped bass, *Roccus saxatilis*, taken in size selective fishing gear in Maryland. ......: 9-36.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. Fish. Bull. U.S. Fish Wildl. Serv. 50(35):1-77.

Pollock, K. H., J. Hoenig and C. Jones. 1991. Estimation of fishing and natural mortality when a tagging study is combined with a creel survey or port sampling. Am. Fish. Soc. Symp. 12:423-434.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull Fish. Res. Board Can. No. 191.

Rugolo, L. J., P. W. Jones, R. K. Schaefer, K. S. Knotts, H. T. Hornick and J. L. Markham. 1994. Estimation of Chesapeake Bay-wide exploitation rate and population abundance for the 1993 striped bass stock. Manuscript, Maryland Department of Natural Resources, Annapolis, Md.

Schaefer, R. K. and L. J. Rugulo. 1996. Estimation of Chesapeake Bay-wide exploitation rate and population abundance for the 1994 striped bass stock. Manuscript, Maryland Department of Natural Resources, Annapolis, Md.

Vladykov, V. D. and D. H. Wallace. 1938. Is the striped bass (*Roccus lineatus*) of Chesapeake Bay a migratory fish. Trans. Amer. Fish. Soc. 67: 67-86.

Merriman, D. 1941. Studies on the striped bass (*Roccus saxatilis*) of the Atlantic Coast. Fish. Bull. U.S. Fish Wildl. Serv. 50(35):1-77.

Pollock, K. H., J. Hoenig and C. Jones. 1991. Estimation of fishing and natural mortality when a tagging study is combined with a creel survey or port sampling. Am. Fish. Soc. Symp. 12:423-434.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull Fish. Res. Board Can. No. 191.

Rugolo, L. J., P. W. Jones, R. K. Schaefer, K. S. Knotts, H. T. Hornick and J. L. Markham. 1994. Estimation of Chesapeake Bay-wide exploitation rate and population abundance for the 1993 striped bass stock. Manuscript, Maryland Department of Natural Resources, Annapolis, Md.

Schaefer, R. K. and L. J. Rugulo. 1996. Estimation of Chesapeake Bay-wide exploitation rate and population abundance for the 1994 striped bass stock. Manuscript, Maryland Department of Natural Resources, Annapolis, Md.

Vladykov, V. D. and D. H. Wallace. 1938. Is the striped bass (*Roccus lineatus*) of Chesapeake Bay a migratory fish. Trans. Amer. Fish. Soc. 67: 67-86.

Table 1. Striped bass tag release round dates, proposed tag release quotas and number of striped bass tagged and released in Chesapeake Bay, Virginia, fall 2002. Note: tagging rounds 1-4 were in Maryland only.

Tagging round	Dates	Location	Quota	Releases
5	16-25 Sep.	Chesapeake Bay - upper	150	37
		Chesapeake Bay - middle	150	215
		Rappahannock River	350	375
		York River	100	8
		James River	250	37
		Subtotal	1,000	672
6	21-30 Oct.	Chesapeake Bay - upper	300	432
		Chesapeake Bay - middle	200	425
		Rappahannock River	300	392
		York River	100	76
		James River	300	77
		Subtotal	1,200	1,402
7	20-26 Nov.	Chesapeake Bay - upper	300	194
		Chesapeake Bay - middle	200	62
		Rappahannock River	200	137
		York River	100	404
		James River	200	20
		Subtotal	1,000	817

Table 2. Daily striped bass tag release totals, by area, during round 5 (16-26 September) of the fall 2002 fishing mortality (F) study.

Tag release area	16 Sep	17 Sep	18 Sep	19 Sep	20 Sep	21 Sep	22 Sep	23 Sep	24 Sep	25 Sep
Chesapeake Bay (upper region)										37
Chesapeake Bay (middle region)			110			26				79
Rappahannock River (upper region)	264			111						
York River (middle region)								3		5
James River (middle region)			6		3			6	13	9
totals	264	0	116	111	3	26		9	13	130

Table 3. Age structure, by year class (YC), and mean fork length (FL, in mm) of striped bass tagged and released at each location during round 5 (16-25 September) of the fall 2002 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm) YC	mean FL (mm) total	mean age
Chesapeake Bay (middle region)	1999	81	37.7	469.3	502.5	3.66
	1998	125	58.1	521.6		
	1997	8	3.7	601.9		
	n/aged	1	0.5			
Chesapeake Bay (upper region)	1999	16	43.2	471.6	503.9	3.57
	1998	21	56.8	528.6		
Rappahannock River	1999	271	72.3	456.9	471.5	3.27
	1998	98	26.1	509.0		
	1997	2	0.5	620.0		
	n/aged	4	1.1			
York River	1999	4	50.0	459.8	471.5	3.50
	1998	4	50.0	514.3		
	n/aged	0	0.0			
James River (middle section)	1999	14	37.8	469.0	509.6	3.72
	1998	18	48.6	525.2		
	1997	4	10.8	581.8		
	n/aged	1	2.7			

Table 4. Daily striped bass tag release totals, by area, during round 6 (21-30 October) of the fall 2002 fishing mortality (F) study.

Tag release area	21 Oct	22 Oct	23 Oct	24 Oct	25 Oct	26 Oct	27 Oct	28 Oct	39 Oct	30 Oct
Chesapeake Bay (upper region)			195					236		
Chesapeake Bay (middle region)			287			139				
Rappahannock River	290			102						
York River		27			26				23	7
James River (middle region)	15	13		1				41		
totals	305	40	482	103	26	139		277	23	7

Table 5. Age structure, by year class (YC), and mean fork length (FL, in mm) of striped bass tagged and released at each location during round 6 (21-30 October) of the fall 2002 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm)		mean age
				YC	total	
Chesapeake Bay (upper region)	1999	209	48.5	461.9	491.8	3.54
	1998	208	48.3	517.2		
	1997	12	2.8	595.4		
	1996	1	0.2	697.0		
	n/aged	1	0.2			
Chesapeake Bay (middle region)	1999	262	61.5	462.3	484.0	3.39
	1998	153	35.9	521.4		
	1997	9	2.1	584.1		
	n/aged	2	0.5			
Rappahannock River	1999	175	44.6	460.4	503.0	3.61
	1998	186	47.5	528.5		
	1997	22	5.6	594.1		
	1996	1	0.3	703.0		
	1993	1	0.3	920.0		
	n/aged	7	1.8			
York River	1999	33	43.4	475.0	494.9	3.58
	1998	35	46.1	518.0		
	1997	33	3.9	626.7		
	n/aged	5	6.6			

James River (middle section)	1999	15	19.5	466.0	526.4	3.90
	1998	58	75.3	533.3		
	1997	3	3.9	599.7		
	1994	1	1.3	816.0		

Table 6. Daily striped bass tag release totals, by area, during round 7 (20-26 November) of the fall 2002 fishing mortality (F) study.

Tag release area	20 Nov	21 Nov	22 Nov	23 Nov	24 Nov	25 Nov	26 Nov
Chesapeake Bay (upper region)	72		47			75	
Chesapeake Bay (middle region)		56				6	
Rappahannock River		134				3	
York River	404						
James River (middle region)		14				1	5
totals	476	204	47	0	0	85	5

Table 7. Age structure, by year class (YC), and mean fork length (FL, in mm) of striped bass tagged and released at each location during round 7 (20-26 November) of the fall 2002 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm)		mean age
				YC	total	
Chesapeake Bay (upper region)	1999	154	79.4	457.9	471.2	3.21
	1998	35	18.0	516.8		
	1997	1	0.5	615.0		
	1996	0	0.0			
	1995	1	0.5	786.0		
	n/aged	3	1.5			
Chesapeake Bay (middle region)	1999	49	79.0	455.5	470.4	3.26
	1998	11	17.7	509.0		
	1997	1	1.6	528.0		
	1996	1	1.6	717.0		
	n/aged	0	0.0			
Rappahannock River	1999	82	59.9	461.6	492.5	3.52
	1998	47	34.3	521.8		
	1997	7	5.1	609.6		
	1994	1	0.7	825.0		
	n/aged	0	0.0			
York River	1999	196	48.5	461.2	493.1	3.54
	1998	187	46.3	516.7		
	1997	16	4.0	605.4		
	n/aged	5	1.2			

James River (middle region)	1999	4	20.0	466.0	557.0	4.30
	1998	9	45.0	535.0		
	1997	6	30.0	610.7		
	1994	1	5.0	796.0		

Table 8. Number, location, mean fork length (FL in mm) and mean age of recaptured striped bass, by release location, 16 September - 31 December, 2002.

Release location	Chesapeake Bay (Va.) recaptures*								
		location						mean	
		river			Chesapeake Bay			FL	age
	total	Rap.	York	James	upper	middle	lower		
Rappahannock River	62	60	0	0	0	0	2	478.5	3.4
York River	18	0	15	1	0	0	2	489.0	3.4
James River	1	0	0	1	0	0	0	549.0	4.0
Chesapeake Bay (upper)	9	0	0	0	2	0	3	472.7	3.2
Chesapeake Bay (middle)	12	0	1	0	0	8	2	504.8	3.8

*Other recaptures:	(tagging location)	(recapture location)
	Chesapeake Bay (middle)	1 Potomac River
	Chesapeake Bay (upper)	1 North Carolina
		1 Potomac River
		2 Chesapeake Bay (Maryland)

Table 9. Summary of the disposition of striped bass tagged during round 5 (16-26 September) and subsequently recaptured prior to 31 December, with emphasis on the fifth recapture interval(19 September - 23 October, 2002).

Release location	recaptures								
		16 Sep - 18 Sep	19 Sep - 23 Oct						24 Oct - 31 Dec
			commercial		sport		other		
	total		R	H	R	H	R	H	
Rappahannock River	50	0	0	0	0	2	37	0	11
York River	0	0	0	0	0	0	0	0	0
James River	0	0	0	0	0	0	0	0	0
Chesapeake Bay (upper)	0	0	0	0	0	0	0	0	0
Chesapeake Bay (middle)	3	0	0	0	0	0	3	0	0

R: released alive
H: harvested

Table 10. Summary of the disposition striped bass tagged during round 6 (21-31 October) and subsequently recaptured prior to 31 December, with emphasis on the sixth recapture interval (24 October - 20 November, 2002).

Release location	recaptures								
	total	21 Oct - 23 Oct	24 Oct - 20 Nov						21 Nov - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	12	0	0	0	0	3	4	0	5
York River	13	0	0	0	0	0	12	0	1
James River	1	0	0	0	0	0	0	0	1
Chesapeake Bay (upper)	6	0	0	0	1	0	0	0	5
Chesapeake Bay (middle)	9	0	0	0	1	1	7	0	2

R: released alive
H: harvested

Table 11. Summary of the disposition of striped bass tagged during round 7 (20-26 November) and subsequently recaptured prior to 31 December, 2002.

Release location	recaptures								
	total	20 Nov	21 Nov - 31 Dec						
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	0	0	0	0	0	0	0	0	
York River	5	0	0	0	4	1	0	0	
James River	0	0	0	0	0	0	0	0	
Chesapeake Bay (upper)	3	0	0	0	1	1	1	0	
Chesapeake Bay (middle)	0	0	0	0	0	0	0	0	

R: released alive
H: harvested

Figure 1. Delineation of western Chesapeake Bay, Virginia into tagging jurisdictions and location of tagging sites during fall, 2002.