12-16-2002

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Recommended Citation
Sadler, P. W., Latour, R. J., Harris, R. E., Maki, K. L., & Olney, J. E. (2002) Evaluation of striped bass stocks in Virginia, monitoring and tagging studies, 1999-2003 Annual report, 1 September 2001 - 31 October 2002. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/dvnk-x588

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

Annual Report

Contract Number: F-77-R-15

Project Period: 1 September 2001 - 31 October 2002

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Submitted To:

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16 December 2002

Preface

This report presents the results of striped bass (*Morone saxatilis*) tagging and monitoring activities in Virginia during the period 1 September 2001 through 31 October 2002. It includes an assessment of the biological characteristics of striped bass taken from the 2002 spring spawning run, estimates of annual survival based on annual spring tagging, and the results of the fall 2001 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. The use of fyke nets was 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).

Acknowledgments

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; Pat Crewe, Susan Denny, Jim Goins, Gail Holloman, Todd Mathes, Jason Romine, John Walter and Brian Watkins; the cooperating commercial fishermen; Bobby Brown, Mark Brown, Allan Ingraham, Raymond Kellum, Randy Kirby, Dale Mitchum, Stanley Oliff, Jamie Saunders 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 2002.

Catch Summaries:

1. In 2002, 170 striped bass were sampled between 1 April and 2 May from three commercial pound nets in the Rappahannock River. The samples were predominantly male (66.5%) and young (62.4% ages 3-5). Females dominated the age eight and older age classes (93.5%). The mean age on the male striped bass was 4.6 years. The mean age of the female striped bass was 7.8 years.

2. During the 30 March - 3 May period, the 1997 and 1998 year classes were the most abundant and were 93.3% male. The contribution of age six and older males was only 8.8% of the total catch. Age seven and older females, presumably repeat spawners, were 28.8% of the total catch but represented 86.0% of all females caught.

3. In 2002, 323 striped bass were sampled between 1 April and 2 May in two experimental anchor gill nets in the Rappahannock River. The samples were predominantly male (75.9%) and young (63.8% ages 2-5). Females dominated the age eight and older age classes (85.7%). The mean age of the male striped bass was 4.8 years. The mean age of the female striped bass was 7.0 years.

4. During the 30 March - 3 May period, the 1997 and 1998 year classes were the most abundant and were 92.1% male. The contribution of age six and older males was only 14.9% of the total catch. Age seven and older females, presumably repeat spawners, were 14.2% of the total catch but were 60.2% of the total females caught.

5. In 2002, 824 striped bass were sampled between 1 April and 2 May in two experimental anchor gill nets in the James River. Males dominated the 1997-2000 year classes (93.8%). Females dominated the 1990-1993 year classes (94.7%). The mean age of the male striped bass was 4.7 years. The mean age of the female striped bass was 6.4 years.

6. During the 30 March - 3 May period, the 1997 and 1998 year classes were the most abundant and were 93.4% male. The contribution of age six and older males was only 12.1% of the total catch. Age seven and older females, presumably repeat spawners, were 3.3% of the total catch but represented 29.3% of all females caught.

Spawning Stock Biomass Indexes (SSBI)

7. The Spawning Stock Biomass Index from the Rappahannock River pound nets was 7.1 kg/day for male striped bass and 11.4 kg/day for female striped bass. The male and female indexes were the second lowest in the 1991-2002 time series and well below the 12-year average.

8. The SSBI for the Rappahannock River gill nets was 53.4 kg/day for male striped bass and 40.7 kg/day for female striped bass. The male index was the third lowest in the 1991-2002 time series and was below the 12-year average. The female index was the highest since 1995 and was above the 12-year average.

9. The SSBI for the James River gill nets was 173.5 kg/day for male striped bass and 47.6 kg/day for female striped bass. The male index was the third highest in the time series and well above the nine-year average. The female index was the fourth highest to date, but was 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 1.76 and was less than one half the 2001 index. Older (8+ years) female stripers were responsible for 68.4% of the index.

11. The EPPI for the Rappahannock River gill nets was 6.07 and was higher than the 2001 index. Older (8+years) female striped bass were responsible for 48.7% of the index.

12. The EPPI for the James River gill nets was 6.71 and was higher than the 2001 index. Older (8+ years) female striped bass were responsible for 51.7% 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 (5.14 fish/day) was the lowest in 1991-2002 time series. The cumulative catch rate of male striped bass (3.16 fish/day) and female striped bass (1.79 fish/day) were both the second lowest values in the time series.

14. Year class-specific estimates of annual survival (S) for pound net data varied widely between years. The geometric mean S of the 1983-1994 year classes varied from 0.504-0.632 (mean = 0.577). The geometric mean survival rates differed greatly between sexes. Mean survival rates for male stripers (1985-1994 year classes) varied from 0.263-0.508 (mean = 0.378) but mean survival rates of female stripers (1983-1990 year classes) varied from 0.587-0.690 (mean = 0.629).

15. The cumulative catch rate (sexes combined) from Rappahannock River gill nets (32.3 fish/day) was the lowest in the 1991-2002 time series. Cumulative catch rates of male stripers (23.9 fish/day) were the second lowest since 1992. Cumulative catch rates of female striped bass (8.4 fish/day) were the highest since 1995.

16. Year class-specific estimates of annual survival for gill net data varied widely between years. The geometric mean S of the 1984-1995 year classes varied from 0.408-0.740 (mean = 0.512). The mean survival rates for male stripers (1984-1995) varied from 0.153-0.589 (mean = 0.332). The mean survival rates for female stripers (1984-1990) varied from 0.501-0.664 (mean = 0.582).

17. The cumulative catch rate (sexes combined) from James River gill nets (91.6 fish/day) was lower than 2001, but was the third highest of the 1994-2002 time series. The cumulative catch rates for male striped bass (81.3 fish/day) and female striped bass (10.2 fish/day) were both the third highest values in the time series.

18. Year class-specific estimates of annual survival varied widely between years. The geometric mean S of the 1984-1992 year classes varied from 0.329-0.798 (mean = 0.525). The mean survival rates of male stripers (1988-1992 year classes) varied from 0.281-0.538 (mean = 0.454). The mean survival rates of female stripers (1984-1990 year classes) varied from 0.340-0.617 (mean = 0.490).

Age determinations using scales and otoliths

19. A total of 145 specimens from 11 size ranges were aged by reading both scales and otoliths. The mean age of the otolith-aged striped bass was 0.25 years older than from the scale-aged striped bass. The two methodologies agreed on the age of the striped bass on 37.2% of the specimens.

20. Tests of symmetry applied to the age matrix indicated that the two ageing methodologies were interchangeable, but only to a marginally significant degree (p=0.0531). The age at which the divergence in ages became apparent was determined to be age six.

21. A two-tailed t-test of the mean ages produced by the respective ageing methodologies found that the difference in the mean ages (0.25 years) was not significant.

22. A Kolmogorov-Smirnov test of the age structures produced by the two ageing methodologies also found no significant difference indicating that both age structures represented the same population.

II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2001-2002.

1. A total of 313 striped bass were tagged and released from pound nets in the Rappahannock River between 1 April and 2 May, 2002. Of this total, 191 were between 457-710 mm total length and considered to be predominantly resident striped bass and 122 were considered to be predominantly migrant striped bass (>710 mm TL). The median date of the tag releases was 11 April 2002.

2. A total of 264 striped bass were tagged and released from a research pound net in the York River between 26 February and 16 May, 2002. Of this total, 229 were resident striped bass (457-710 mm TL) and 35 were migrant striped bass (>710 mm TL). The median date of the tag releases was 7 May 2002.

3. A total of 19 migratory striped bass (>710 mm TL), tagged during spring 2001, were recaptured between 10 April, 2001 and 11 April, 2002 (the respective midpoints of the two spring release periods).

4. 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 0.61-0.76 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 0.13-0.35 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.

5. 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 2001 resident striped bass fishery in the Chesapeake Bay, Virginia.

1. The fall 2001 striped bass recreational season (1 June - 31 Nov in Maryland, 6 Oct - 31 Dec in Virginia) in Chesapeake Bay was divided in seven rounds in Maryland and three rounds in Virginia (17-26 September, 22 October- 1 November and 19-29 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 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 3,010 striped bass were tagged in Virginia. The number of stripers tagged and released were 838, 1,616 and 545 for the three tagging rounds. The striped bass tagged in all three rounds were predominantly from the 1997 and 1998 year classes.

4. A total of 89 striped bass tagged in Virginia were recaptured by 31 December. Of these recaptures, 54 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 0.23. This is the sum of non-harvest (0.10) and harvest (0.13) mortality estimates. The target F for Chesapeake Bay is 0.28.

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I. Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2002.

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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 1 April - 2 May, 2002. 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. On two sampling dates (4 and 18 April) large striped bass (>710 mm total length) were tagged and released after recording their lengths and determining their sex. This data was included in the monitoring sample for that date with a weight determined by a sex-specific, length-weight non-linear regression. 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 59 on the James River, Figures 1-2). The gill nets in the James River were in a different location than in 1994-1999 and were set and fished by a different waterman.

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 subsequent aging and comparison with the age determined by reading the scales.

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 880-919. All striped bass greater than 920 mm fork length were sampled. The size ranges roughly correspond to age classes based on previous (scale-aged) data.

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)

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 a two-tailed t-test (Zar 1999). Age distributions resulting from ageing methods were compared using the non-parametric Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981).

Results

Catch Summary

Rappahannock River

Pound nets: Striped bass (n= 170) were sampled between 1 April and 2 May, 2002 from the pound nets in the Rappahannock River. The number of striped bass sampled was the lowest since twice-weekly sampling began in 1993. Total catches varied by only 14-33 striped bass between 1-22 April, then rapidly diminished (Table 1). Catches of female striped bass were highest from 4-15 April, but were scarce after 22 April. Males made up 66.5% of the total catch, but were much less prevalent than in previous years. Males dominated the 1998-2000 year classes (93.5%) and the 1994-1997 year classes (60.0%), but females dominated the 1987-1993 year classes (94.1%).

Eighteen large (>710 mm total length) striped bass from two monitoring samples (14 from 4 April and four from 18 April) were tagged and released rather than returned to the lab for analysis. The weight of each specimen was estimated by non-linear regression to be:

$$\text{males} \quad w = .000028 FL^{2.8957}$$

$$\text{females} \quad w = .00003 FL^{2.8872}$$

where w is the weight in grams and FL is the forklength in millimeters.

Biomass catch rates (g/day) of male striped bass were highest on 1,5 and 22 April (Table 2). The catch rates of female striped bass were highest on 5 and 15 April. The catch rate of males greatly exceeded that of females from 22-29 April. Catch rates of females exceeded that for males from 5-18 April (6:1 on 15 April). The mean ages of male striped bass varied from 3.9-5.3 years with the youngest mean ages occurring during the middle of the sampling period. The mean ages of females varied from 4.0-8.9 years, but varied from only 7.6-8.9 years from 5-15 April.

During the 30 March - 3 May period, the 1998 (27.1%) and 1997 (25.9%) year classes were the most abundant (Table 3). These year classes were 93.3% male. The contribution of males age six and older (the pre-1997 year classes) was 8.8% 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 28.8% of the total aged catch but was also 86.0% of the total females captured.

Experimental gill nets: Striped bass (n= 323) were also sampled between 1 April and 2 May, 2002 from two multi-mesh experimental gill nets in the Rappahannock River. Total catches peaked sharply on 18 April, due to the large number of five to eight year old males (Table 4). Catches of female striped bass were highest from 1-8 April, and were generally caught only in low numbers throughout the remainder of the sampling period. Males made up 75.9% of the total catch. Males dominated the 1998-2000 year classes (99.0%) and the 1994-1997 year classes (68.9%), but the 1984-1993 year classes were 87.5% female.

Biomass catch rates (g/day) of male striped bass were highest on 18 April (Table 5). The catch rates of female striped bass were highest from 1-4 April. The catch rate of females exceeded that of males from 1-11 April and again on 22 April. The mean ages of male striped bass varied from 4.3-5.5 years with the oldest males (five- eight years) being prevalent from 1-18 April. The mean ages of females varied from 6.0-7.4 years, with the oldest females (age nine and older) being prevalent from 1-11 April.

During the 30 March - 3 May period, the 1997 (31.6%) and 1998 (27.2%) year classes were prevalent (Table 6). These year classes were 91.2% male. The contribution of males age six and older (the pre-1997 year classes) was only 15.1% 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 14.2% of the total aged catch but was 60.2% of the total females captured.

James River

Experimental gill nets: Striped bass (n= 824) were sampled between 1 April and 2 May, 2002 from the two multi-mesh experimental gill nets in the James River. Total catches peaked on 15 April, due to a large catch of male striped bass, then declined thereafter (Table 7). Catches of female striped bass were consistent, although small, from 1-18 April. Males dominated the 1998-2000 year classes (97.7%) and the 1994-1997 year classes (86.6%), but females were prevalent in the 1987-1993 year classes (94.7%).

Biomass catch rates (g/day) of male striped bass were highest from 1-4 April and on 15 April (Table 8). The catch rates of female striped bass were highest from 1-15 April, peaking on 1 April. The catch rate of females exceeded that of males only on 25 and 29 April. Catch rates of males greatly exceeded that for females on 15 April (5.6:1) and from 1-4 April (4.5-4.8:1). The mean ages of male striped bass varied from 3.9-5.0 years, but varied from only 4.6-5.0 years from 1-18 April. The mean ages of females varied from 5.6-7.4 years, but varied from only 6.3-7.4 years from 1-11 April and from 5.6-6.7 years from 15-29 April.

During the 30 March - 3 May period, the 1997 (43.0%) and 1998 (32.4%) year classes were the most abundant (Table 9). These year classes were 93.4% male. The contribution of males age six and older (the pre-1997 year classes) was only 12.3% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. In contrast to previous years, younger (four to six years old) females were prevalent (70.7% of all females captured). The contribution of females age seven and older, presumably repeat spawners, was only 3.3% of the total aged catch.

Spawning Stock Biomass Indexes

Rappahannock River

Pound nets: The Spawning Stock Biomass Index (SSBI) for spring 2002 was 7.1 kg/day for male striped bass and 11.4 kg/day for female striped bass. The index for male striped bass was lowest since 1992 and was 65.0% below the 12-year average (Table 10). The magnitude of the index for male striped bass was largely determined by the 1997 and 1998 year classes (65.%). The index for female striped bass was the lowest since 1996 and was less than half of the 12-year average (Table 10). The magnitude of the index for the females was largely the result of the pre-1996 year classes (96.7%).

Experimental gill nets: The Spawning Stock Biomass Index for spring 2002 was 53.4 kg/day for male striped bass and 40.7 kg/day for female striped bass. The index for male striped bass was 39.7% lower than in 2001, and was 28.2% below the 12-year average (Table 10). The 1996-1998 year classes contributed 78.2% of the biomass in the male index. The index for female striped bass was the highest since 1995, and was 17.6% above the 12-year average. However, the increases in the index in 2001 and 2002 did reverse a trend of declining indexes that occurred from1993-1999. The pre-1996 year classes contributed 67.1% of the biomass in the female index.

James River

Experimental gill nets: The Spawning Stock Biomass Index for spring 2002 was 173.5 kg/day for male striped bass and 47.6 kg/day for female striped bass. Although the male index was lower than in 2001, it was 90.2% above the nine-year average (Table 11). The 1997 and 1998 year classes contributed 70.1% of the biomass in the male index. In contrast, the female index was 151.2% higher than the 2001 index, but was 20.3% below the nine-year average. The pre-1996 year classes accounted for 46.2% of the biomass in the female index.

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:

$$(\qquad N_o = 0.00183 \times FL^{3.0227})$$

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 134,000 oocytes for a 400-mm female and 3,530,000 oocytes for a 1180-mm female striped bass (Table 12). The 2002 Egg Production Potential Indexes (EPPI, Table 13) for the Rappahannock River were 1.764 (pound nets) and 6.070 (gill nets). The

2002 EPPI for the James River was 6.709. The indexes for the Rappahannock River were heavily dependent on the egg production potential of the older (8+ years) females (68.4% in the pound nets, 48.7% in the gill nets), while the James River index was more evenly distributed among age groups. Modest changes in the methodology in the 2001 and 2002 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 1991-2002 are presented in Tables 14-16. The cumulative annual catch rate for 2002 was the lowest in the time series and was 72.4% lower than the catch rate for 2001 (Table 14). The reduction was the result of much lower catch rates of three and four year old (1998 and 1999 year classes) males (Table 15). These age classes have increasingly dominated the total catches in recent years (21.1% in 1994, 89.2% in 2000). Using the maximum catch rate of the resident males as an indicator, the 1997and 1998 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 second lowest of the time series and was 47.4% lower than in 2001 (Table 16). Cumulative catch rates of female striped bass have generally declined since peaking in 1993.

The range of overall ages was unchanged from 1991-2002, 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). 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.

Numeric catch rates for male striped bass decreased rapidly subsequent to their peak of abundance at age four or five (Figure 3). Catch rates of female striped bass also show a steep decline after their initial peak in abundance, but also exhibit a secondary peak in the catch rates of 9-11 year old females that was persistent across several year classes.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 17-19. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1991-2002) of the 1983-1994 year classes (sexes combined) varied from 0.504-0.632 (Table 17) with an overall mean survival rate of 0.577. 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 (1991-2002) of the 1985-1994 year classes of males varied from 0.263-0.508 (Table 18) with an overall mean survival rate of 0.378. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2002) of the 1983-1990 year classes of females varied from 0.587-0.690 (Table 19) with an overall mean survival rate of 0.629.

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1991-2002 are presented in Tables 20-22. The cumulative annual catch rate (sexes combined) for 2002 from the gill nets was the second lowest in the time series and 48.1% lower than in 2001 (Table 20). The reduction was the result of much lower catch rates of three and four year old males (Table 21). The cumulative catch rate was driven by the catch rates of the1997 and 1998 year classes of striped bass. The age of peak abundance was five years old for the first time since 1996. The age of peak abundance had changed from age five (1992-1996) to age four (1997, 1998, 2000 and 2001) and age three (1999). In contrast to the pound net catches, the cumulative catch rate of female striped bass was the highest since 1995 and was double the cumulative catch rate in 2001 (Table 22).

The overall age structure from 1991-2002 consisted of 2-12 year old males (Table 21) and 2-14 year old females (Table 22), but the 2002 catches contained no males older than age nine. The age of peak male abundance was age five for the first time since 1995. 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, but fell again to 0.286 in 2002.

The cumulative catch rate of male striped bass decreased sharply in 2002 and continued a general decline in catch rates since peaking in 1997 (Table 21). Using the maximum catch rate of the resident males as an indicator, the 1993, 1994 and 1996 year classes were the strongest and the 1990 and 1991 year classes the weakest. Catch rates of the male striped bass declined rapidly after ages five or six (Figure 4). These year classes are the primary target of the recreational and commercial fisheries.

The 2002 cumulative catch rate of female striped bass was double the 2001 catch rate and was the third consecutive year of increases after declining from 1993-1999 (Table 22). The increased catch rates for 8-10 year-old females gave evidence of secondary peak of abundance in several year classes (Figure 4). 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 23-25. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1991-2002) of the 1984-1995 year classes (sexes combined) varied from 0.408-0.740 (Table 23) with an overall mean survival of 0.512. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1991-2002) of the 1984-1995 year classes of males varied from 0.153-0.589 (Table 24) with an overall mean survival of 0.346. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2002) of the 1984-1990 year classes of females varied from 0.501-0.664 (Table 25) with an overall mean survival rate of 0.582. 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 1994-2002 are presented in Tables 26-28. The cumulative annual catch rate for 2002 was the third highest of the time series, but was 12.8% (lower) than the catch rate for 2001 and was the third consecutive year of decline (Table 26). The cumulative catch rate was driven by high catch rates for the four to six year old (1996-1998 year classes), mostly male striped bass. Previous years had 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, ranging from two or three years up to 11-14 years (Table 26).The age structure of male striped bass has expanded from three to six years in 1994 to two to nine years in 2002 (Table 27). The age structure of female striped bass was stable from 1994-2002, consisting of 2-14 year old females (Table 28). The cumulative proportion of females age eight and older, which had decreased from 0.531-0.266 from 1997-1999, decreased to 0.239 in 2002 after increasing to 0.426 in 2001.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 2002 catch rate, being the third highest overall, but 17.1% lower than the cumulative catch rate for 2001 (Table 27). 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 (Figure 5). In contrast, the 2002 cumulative catch rate of female striped bass 50.3% higher than in 2001, and was the third highest in the time series, but was less than one half the cumulative catch rates for 1999 (Table 28). There was a secondary peak in catch rates of females 1988-1991 year classes (Figure 5) 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 29-31. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1994-2002) of the 1984 - 1992 year classes (sexes combined) varied from 0.329-0.798 (Table 29), with an overall mean survival rate of 0.525. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1994-2002) of the 1988-1993 year classes of males varied from 0.281-0.538 (Table 30) with an overall mean survival rate of 0.454. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1994-2002) of the 1984-1990 year classes of females varied from 0.340-0.617 (Table 31) with an overall mean survival rate of 0.490.

Age determinations using scales and otoliths

A total of 145 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 37.2% (54/ 145) of the time. Differences between the two age determination methods were analyzed utilizing tests of symmetry. A chi-square test was performed to test the hypothesis that an *m* x *m* contingency table (Table 32) 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 comparisons (here = 23). We tested the hypothesis that the observed age differences were randomly distributed along the main table diagonal (Table 32). The hypothesis was not rejected, but at a marginal level of probability ($p= 0.053$).

Differences between the scale and otolith age from the same specimen ranged from zero to four years (Figure 6). The otolith age exceeded the scale age 59.3% of the time. 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 ($X^2 = 10.4931$, df = 4, $p= 0.329$). 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.

A two-tailed 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 determined by reading the otoliths was greater than the mean age determined by reading the scales (0.25 years, Table 33). The t-tail results were:

$$\overline{X}_s = 6.78 \qquad \overline{X}_o = 7.08$$

$$SS_s = 846.031 \qquad SS_o = 947.008$$

$$S^2_{s+o} = \frac{846.031+947.008}{144+144} = 6.226$$

$$S_{\overline{X}_s-\overline{X}_o} = \sqrt{\frac{6.226}{145}x2} = 0.293$$

$$t = \frac{7.08-6.83}{0.293} = 0.853$$

$t_{.05,288} = 1.968$ The t value did not exceed the test statistic ($t_{.05,288}$). Therefore the null hypothesis was accepted.

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 33). This compares the maximum difference in the relative proportions that an age class contributes to the test statistic ($K_{.05}$):

$$D_{\max} = 0.1173 \qquad K_{.05} = 1.3581$$

$$D_{.05} = 1.3581\sqrt{\frac{145+145}{145^2}} = 0.1595$$

The maximum difference did not exceed the test statistic, so the null hypothesis, that the age structures derived by the two methods represent the same population, was accepted.

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, 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. 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. The gill net sample scheduled for 2 May from the James River was lost due to an accident.

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 (1000+ mm FL) striped bass.

The biological characterization of the spawning stock of striped bass in the Rappahannock River changed dramatically from 1991-2002. 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. 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. However in 2002, the relative contribution of virgin spawners (four through seven years) increased over previous years.

Of note in the 2002 samples was the relative abundance of 1992 year class (ten 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 2002 values of the Spawning Stock Biomass Index (SSBI) for the Rappahannock River were lower than in 2001 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 lowest in the 1991-2002 time series. The increase in the SSBI for female striped bass captured in the gill nets was due to increased numbers of six to eight year olds (1994-1996 year classes). This reversed a trend where the SSBI for female striped bass had been becoming increasingly dependant upon older striped bass.

The 1991-2002 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. These year classes were much less abundant in the 2002 catches. The female biomass from pound nets showed no reliance upon any age groups but rather a decrease 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 poor catches in 2002. A multi-year drought had increased salinities in the Rappahannock River sampling area (usually in fresh waters), which was coupled with temperatures that were above 90°F (33°C) on 11-15 April, followed by sub-freezing temperatures on 17-19 April, then a return to 90°F temperatures on 21 April. Total catches in both gears decreased rapidly over this period and virtually all females captured after 18 April were in the "spent" condition.

The 2002 values of the SSBI in the James River were the third highest for males and fourth highest for females since the survey began in 1994. The male index was driven by large catches of the 1996-1998 year classes while the female index had a bimodal distribution, peaking first with the 1996 and 1997 age classes, then again with the 1992 and 1993 age classes. 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 water temperatures noted for the Rappahannock River in 1996 apply to the James River as well and probably produced a similar under-estimation of spawning stock abundance. The sampling site in the James River was in fresh water despite the drought, but showed the same rapid decline in catches after 15 April after the unusually variable weather. The scarcity of larger, predominantly female, striped bass from the gill nets in the James River 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. The egg-size relationship for 2002 is limited by small sample size, especially females over 1000 mm fork length with ovaries at the proper maturation state. 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. We will continue to evaluate and refine this new approach.

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 1997-2001 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. However, the age difference determined for the largest, and oldest, specimen was only one year (15 years by reading the scale vs 16 years by reading the otolith). Agreement between the two ageing methodologies was 37.2%. When there was a non-random disagreement between methodologies, the otolith age was 1.46 times more likely to have been aged older than the respective scale-derived age and 3.0 times as likely to produce a difference of two or more years older. This overall difference was found to be of marginal statistical significance, especially for striped bass age six and older. 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.

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Table 1. Numbers of striped bass in three age categories (year classes 1998-2000, 1994-1997 and 1984-1993) in pound nets in the Rappahannock River by sampling date in spring 2002.

Date	n	Year Class							
		1998 - 2000		1994 - 1997		1987 - 1993		Not aged	
		M	F	M	F	M	F	M	F
1 April	33	14	1	12	5	0	1	0	0
4 April	26	6	0	8	9	0	3	0	0
8 April	21	8	0	8	3	0	2	0	0
11 April	14	6	0	1	6	0	1	0	0
15 April	25	8	0	3	7	0	7	0	0
18 April	15	7	2	1	3	0	1	0	0
22 April	24	4	0	15	3	1	1	0	0
25 April	9	3	1	5	0	0	0	0	0
29 April	3	2	0	1	0	0	0	0	0
Total	**170**	**58**	**4**	**54**	**36**	**1**	**16**	**0**	**0**

Table 2. Net-specific summary of catch rates and ages of striped bass (n= 170) in pound nets on the Rappahannock River, spring 2002. 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
1 April	S462	33	6.5	1.8	12,145.3	8,326.2	4.3	7.0
5 April	S462	26	4.7	4.0	10,519.2	27,065.0	4.9	7.9
8 April	S473	21	4.0	1.3	7,779.8	8,968.4	4.6	8.0
11 April	S473	14	2.3	2.3	3,247.2	14,137.0	3.9	7.6
15 April	S473	25	2.8	3.5	4,890.0	29,196.7	4.2	8.9
18 April	S473	15	2.7	2.3	3,579.2	11,558.5	4.0	6.7
22 April	S473	24	5.0	1.0	13,619.0	4,961.4	5.3	6.8
25 April	S473	9	2.7	0.3	5,382.9	480.3	4.9	4.0
29 April	S473	3	0.8	0.0	1,121.2	0.0	4.3	
Totals	S462	59	5.7	2.7	11,448.5	16,357.1	4.5	7.6
	S473	111	2.9	1.5	5,850.7	10,041.3	4.6	7.8
Season		**170**	**3.5**	**1.8**	**7,075.2**	**11,422.9**	**4.6**	**7.8**

Table 3. 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 2002.

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
1999	male	14	403.4	13.7	924.3	124.4	0.4	404.4
	female	2	402.5	9.2	1,027.0	42.3	0.1	64.2
1998	male	44	463.1	19.5	1,408.1	231.6	1.4	1,936.2
	female	2	443.0	18.4	1,223.3	307.9	0.1	76.5
1997	male	40	521.2	28.8	2,134.1	361.7	1.3	2,667.6
	female	4	527.5	32.1	2,354.6	500.2	0.1	294.3
1996	male	8	626.1	28.1	3,313.1	391.0	0.3	828.3
1995	male	5	723.6	12.9	5,089.4	331.2	0.2	795.2
	female	20	724.5	27.8	5,024.0	472.2	0.6	3,140.0
1994	male	1	751.0		5,945.0		0.0	185.5
	female	12	790.3	18.0	6,766.7	604.7	0.4	2,537.5
1993	male	1	865.0		8,249.9		0.0	257.8
	female	8	829.0	22.4	7,771.8	714.5	0.3	1,942.9
1992	female	6	894.8	20.1	10,705.3	745.1	0.2	2,007.2
1991	female	2	937.5	0.8	11,777.1	475.3	0.1	736.1
1987	female	1	1,181.0		19,974.8		0.0	624.2

Table 4. Numbers of striped bass in three age categories (year classes 1998-2000, 1994-1997 and 1984-1993) in gill nets in the Rappahannock River by sampling date in spring 2002.

Date	n	Year Class							
		1998 - 2000		1994 - 1997		1984 - 1993		Not aged	
		M	F	M	F	M	F	M	F
1 April	42	5	0	17	13	0	6	0	1
4 April	36	3	0	11	18	1	3	0	0
8 April	44	12	1	16	11	0	4	0	0
11 April	16	4	0	6	5	0	1	0	0
15 April	28	13	0	8	4	0	0	3	0
18 April	129	57	0	63	4	1	0	3	1
22 April	12	3	0	5	4	0	0	0	0
25 April	6	1	0	4	1	0	0	0	0
29 April	4	1	0	2	1	0	0	0	0
2 May	6	3	0	3	0	0	0	0	0
Total	**323**	**102**	**1**	**135**	**61**	**2**	**14**	**6**	**2**

Table 5. Summary of catch rates and mean ages of striped bass (n=323) from the two gill nets in the Rappahannock River, spring 2002. 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
1 April	42	22.0	20.0	70,993.8	117,329.5	5.5	7.4
4 April	36	15.0	21.0	45,357.8	109,250.3	5.4	6.8
8 April	44	28.0	16.0	61,763.5	77,006.7	4.7	7.0
11 April	16	10.0	6.0	29,012.7	32,001.2	5.1	7.2
15 April	28	24.0	4.0	41,353.7	22,021.5	4.5	7.0
18 April	129	124.0	5.0	240,390.8	21,852.1	4.6	6.7
22 April	12	8.0	4.0	14,490.2	18,350.6	4.5	6.5
25 April	6	5.0	1.0	15,155.9	3,463.2	5.4	6.0
29 April	4	3.0	1.0	4,574.3	6,000.0	4.3	8.0
2 May	6	6.0	0.0	12,976.7	0.0	4.8	
Season	**323**	**24.5**	**7.8**	**53,606.9**	**40,727.5**	**4.8**	**7.0**

Table 6. 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, 2002.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2000	male	5	293.0	7.6	348.9	30.7	0.5	174.5
1999	male	11	385.6	31.3	788.6	196.5	1.1	867.4
1998	male	87	463.7	19.3	1,398.1	213.0	8.7	12,163.3
	female	1	474.0		1,601.0		0.1	160.1
1997	male	88	532.4	25.3	2,197.0	351.1	8.8	19,333.6
	female	14	553.6	26.2	2,702.4	398.6	1.4	3,783.3
1996	male	30	619.8	32.6	3,420.3	608.3	3.0	10,261.0
	female	16	639.8	32.5	3,671.5	409.8	1.6	5,874.5
1995	male	14	698.0	25.4	4,796.7	635.3	1.4	6,715.4
	female	21	723.9	24.2	5,129.3	568.5	2.1	10,771.5
1994	male	2	771.0	41.0	6,824.5	560.5	0.2	1,364.9
	female	10	792.1	18.7	6,433.4	935.3	1.0	6,433.4
1993	male	2	822.5	38.9	8,101.1	461.0	0.2	1,620.2
	female	8	811.1	57.9	8,090.6	1,610.0	0.8	6,472.5
1992	female	3	882.7	20.8	8,992.8	865.4	0.3	2,697.8
1991	female	3	936.7	18.6	12,082.9	1,057.9	0.3	3,624.8
N/A	male	6	499.2	61.2	1,843.9	725.2	0.6	1,106.3
	female	2	685.0	32.5	4,547.6	894.1	0.2	909.6

N/A: not ageable

Table 7. Numbers of striped bass in three age categories (year classes 1998-2000, 1994-1997 and 1985-1993) in gill nets in the James River by sampling date in spring 2002.

Date	n	Year Class							
		1998 - 2000		1994 - 1997		1987 - 1993		Not aged	
		M	F	M	F	M	F	M	F
1 April	155	41	0	95	7	0	5	7	0
4 April	146	40	0	89	6	0	4	7	0
8 April	78	35	4	30	5	1	3	0	0
11 April	120	39	0	68	10	0	3	0	0
15 April	226	108	1	97	18	0	2	0	0
18 April	65	26	1	27	11	0	0	0	0
22 April	10	6	1	2	1	0	0	0	0
25 April	7	1	0	3	3	0	0	0	0
29 April	17	2	0	9	5	0	1	0	0
Total	**824**	**298**	**7**	**421**	**65**	**1**	**18**	**14**	**0**

Table 8. Summary of catch rates and mean ages of striped bass (n=824) from the two gill nets in the James River, spring 2002. 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
1 April	155	143.0	12.0	345,586.8	76,000.5	5.0	7.4
4 April	146	136.0	10.0	319,983.6	66,766.6	4.9	7.4
8 April	78	66.0	12.0	133,740.7	63,591.5	4.6	6.3
11 April	120	107.0	13.0	237,378.5	59,739.5	4.8	6.4
15 April	226	206.0	20.0	385,249.6	68,479.1	4.5	5.6
18 April	65	53.0	12.0	101,415.8	43,959.8	4.6	5.9
22 April	10	10.0	0.0	12,035.8	0.0	3.9	
25 April	7	1.0	6.0	2,071.0	26,014.3	5.0	6.2
29 April	17	11.0	6.0	22,243.3	27,147.2	4.9	6.7
Totals	**824**	**81.4**	**10.1**	**173,664.8**	**47,591.2**	**4.7**	**6.4**

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 James River, 30 March - 3 May, 2002.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2000	male	4	306.0	3.4	394.0	28.4	0.4	175.1
1999	male	34	389.3	23.7	831.3	146.9	3.8	3,140.5
1998	male	260	464.2	21.4	1,486.2	227.5	28.9	42,935.6
	female	7	461.6	23.0	1,442.1	165.7	0.8	1,121.6
1997	male	320	527.8	25.0	2,214.2	351.9	35.6	78,726.1
	female	34	544.6	25.9	2,557.1	415.3	3.8	9,660.0
1996	male	75	615.8	26.5	3,442.4	457.5	8.3	28,686.4
	female	24	617.1	24.6	3,556.7	459.3	2.7	9,484.4
1995	male	18	694.2	25.7	4,952.6	591.4	2.0	9,905.2
	female	5	723.2	29.3	6,090.9	999.2	0.6	3,923.8
1994	male	6	774.0	35.9	6,760.8	968.3	0.7	4,507.2
	female	4	791.5	22.5	7,053.9	381.3	0.4	3,135.0
1993	male	1	835.0		7,628.1		0.1	847.6
	female	7	854.4	11.4	9,089.0	1,002.1	0.8	7,069.3
1992	female	8	891.1	23.7	10,183.1	1,197.8	0.9	9,051.7
1991	female	2	926.5	6.4	11,962.2	657.8	0.2	2,658.2
1990	female	1	1,003.0		15,980.3		0.1	1,775.6
N/A	male	14	575.8	45.8	2,806.5	860.9	1.6	4,365.7

N/A: not ageable

Table 10. Values of the spawning stock biomass index (SSBI) for male and female striped bass by gear in the Rappahannock River, 30 March - 3 May, 1991-2002.

Year	Pound nets					Gill nets				
	N		SSBI (kg/day)			N		SSBI (kg/day)		
	M	F	M	F	M+F	M	F	M	F	M+F
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	**384**	**98**	**20.3**	**24.8**	**45.1**	**408**	**59**	**74.4**	**34.6**	**109.0**

Table 11. 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, 1994-2002. 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
2002	60	728	92	173.51	47.59	221.10
2001	60	978	68	181.40	41.31	222.71
2000	60	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		**434**	**97**	**91.22**	**59.71**	**150.94**

Table 12. Predicted values of fecundity (in millions of eggs) of female striped bass with increasing fork length (mm), James and Rappahannock rivers combined, spring 2002.

FL	Fecundity	FL	Fecundity	FL	Fecundity	FL	Fecundity
400	0.134	600	0.457	800	1.090	1000	2.141
420	0.156	620	0.505	820	1.175	1020	2.273
440	0.179	640	0.556	840	1.264	1040	2.410
460	0.205	660	0.610	860	1.357	1060	2.553
480	0.233	680	0.667	880	1.455	1080	2.701
500	0.263	700	0.728	900	1.557	1100	2.855
520	0.297	720	0.793	920	1.664	1120	3.015
540	0.332	740	0.862	940	1.776	1140	3.181
560	0.371	760	0.934	960	1.892	1160	3.353
580	0.413	780	1.010	980	2.014	1180	3.530

Table 13. 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 2002. 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	0.011	0.6%	1	0.022	0.4%	7	0.162	2.4%
5	4	0.039	2.2%	14	0.505	8.3%	34	1.297	19.3%
6	0	0.000	0.0%	16	0.895	14.7%	24	1.333	19.9%
7	20	0.507	28.7%	21	1.698	28.0%	5	0.448	6.7%
8	12	0.395	22.4%	10	1.060	17.5%	4	0.470	7.0%
9	8	0.304	17.2%	8	0.922	15.2%	7	1.035	15.4%
10	6	0.287	16.3%	3	0.441	7.3%	8	1.346	20.1%
11	1	0.110	6.2%	3	0.527	8.7%	2	0.378	5.6%
12	0	0.000	0.0%	0			1	0.240	3.6%
13	0	0.000	0.0%	0			0		
14	0	0.000	0.0%	0			0		
15	1	0.111	6.3%	0			0		
Total	54	**1.764**	100.0%	76	**6.070**	100.0%	67	**6.709**	100.0%

Table 14. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2002. 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	2001	2002
2000												
1999											0.07	**0.51**
1998										0.03	**2.74**	1.44
1997									0.79	**15.61**	7.49	1.38
1996								0.19	11.54	**18.13**	4.29	0.25
1995							0.60	2.15	**11.50**	3.34	0.10	0.68
1994					0.04	0.51	3.90	**6.33**	2.79	0.11	0.58	0.41
1993					3.04	3.97	**8.10**	1.48	0.11	0.50	0.87	0.28
1992			0.12	1.44	**4.80**	2.86	1.25	0.04	0.50	0.50	0.87	0.19
1991		0.20	0.68	0.48	1.00	**1.63**	0.05	0.52	0.43	0.40	0.81	0.06
1990	0.42	0.50	1.04	1.33	**2.24**	1.26	0.70	0.70	0.32	0.29	0.45	0.00
1989	0.33	0.60	3.58	**4.59**	0.68	0.89	0.80	0.78	0.36	0.37	0.26	0.00
1988	3.50	1.60	**9.54**	2.22	0.60	0.37	1.50	0.89	0.39	0.05	0.10	0.00
1987	**8.00**	2.75	3.65	1.15	0.68	0.37	1.00	0.89	0.43	0.05	0.00	0.03
1986	**2.67**	1.15	0.65	0.59	0.40	0.09	1.00	0.22	0.04	0.00	0.00	
1985	**1.67**	0.30	0.42	0.52	0.08	0.00	0.35	0.15	0.11	0.00	0.00	
1984	0.50	0.40	**0.58**	0.33	0.28	0.00	0.35	0.07	0.04	0.00	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	0.34	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	0.00	0.00
Total	**18.75**	**8.45**	**21.83**	**13.89**	**14.52**	**12.29**	**20.30**	**14.85**	**29.88**	**39.69**	**18.63**	**5.14**

Table 15. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2002. 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	2001	2002
2000												
1999											0.07	**0.44**
1998										0.03	**2.74**	1.38
1997									0.79	**15.61**	7.42	1.25
1996								0.19	11.36	**18.11**	4.03	0.25
1995							0.55	2.15	**11.46**	3.21	0.10	0.16
1994					0.04	0.51	3.80	**6.19**	2.68	0.08	0.39	0.03
1993					2.88	3.83	**7.50**	1.37	0.07	0.26	0.16	0.03
1992			0.12	1.22	**4.68**	2.66	1.15	0.00	0.36	0.11	0.19	0.00
1991		0.15	0.54	0.48	0.92	**1.34**	0.05	0.30	0.21	0.05	0.13	0.00
1990	0.17	0.35	0.96	1.30	**2.00**	0.94	0.35	0.11	0.00	0.03	0.00	0.00
1989	0.17	0.40	3.46	**3.52**	0.08	0.43	0.55	0.04	0.04	0.03	0.00	0.00
1988	3.25	0.90	**7.54**	1.11	0.12	0.03	0.20	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							
N/A	0.25	0.10	0.27	0.41	0.44	0.23	0.25	0.33	0.54	0.32	0.00	0.00
Total	**13.08**	**3.05**	**14.38**	**8.44**	**11.20**	**9.98**	**14.40**	**10.68**	**27.52**	**37.82**	**15.23**	**3.16**

Table 16. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2002. 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	2001	2002
2000												
1999												**0.06**
1998												**0.06**
1997											0.07	**0.13**
1996										0.03	**0.26**	0.00
1995							0.05	0.00	0.04	0.13	0.00	**0.63**
1994							0.10	0.15	0.11	0.03	0.19	**0.38**
1993					0.16	0.14	0.60	0.11	0.04	0.24	**0.71**	0.25
1992				0.22	0.12	0.20	0.10	0.04	0.14	0.40	**0.68**	0.19
1991		0.05	0.04	0.00	0.08	0.29	0.00	0.22	0.21	0.34	**0.68**	0.06
1990	0.25	0.15	0.08	0.04	0.24	0.31	0.35	**0.59**	0.32	0.26	0.45	0.00
1989	0.17	0.20	0.12	**1.07**	0.60	0.46	0.25	0.74	0.32	0.34	0.26	0.00
1988	0.33	0.70	**2.00**	1.11	0.48	0.34	1.30	0.89	0.39	0.05	0.10	0.00
1987	1.92	2.10	**2.42**	0.93	0.68	0.29	1.00	0.89	0.43	0.05	0.00	0.03
1986	**1.08**	0.85	0.50	0.48	0.36	0.09	1.00	0.22	0.04	0.00	0.00	
1985	**1.17**	0.25	0.39	0.48	0.08	0.00	0.35	0.15	0.11	0.00	0.00	
1984	0.42	0.25	**0.50**	0.33	0.28	0.00	0.35	0.07	0.04	0.00	0.00	
1983	0.25	0.20	**0.46**	0.33	0.08	0.03	0.20	0.00	0.00			
>1983	0.58	0.15	**0.42**	0.15	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	0.00	0.00
Total	**6.59**	**5.40**	**7.35**	**5.44**	**3.32**	**2.23**	**5.90**	**4.19**	**2.18**	**1.87**	**3.40**	**1.79**

Table 17. Estimated annual and geometric mean (GM) survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2002.

Year Class	Survival (S)											
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	GM
1998											0.526	0.526
1997										0.480	0.184	0.297
1996										0.237	0.058	0.117
1995									0.290	0.451	0.451	0.389
1994								0.440	0.456	0.456	0.707	0.504
1993							0.183	0.838	0.838	0.838	0.322	0.511
1992					0.596	0.437	0.913	0.913	0.913	0.913	0.218	0.630
1991						0.869	0.869	0.869	0.869	0.869	0.074	0.576
1990					0.563	0.745	0.745	0.863	0.863	0.863	0.000	0.632
1989				0.440	0.440	0.899	0.975	0.689	0.689	0.703	0.000	0.575
1988			0.232	0.877	0.877	0.877	0.593	0.438	0.506	0.506	0.000	0.516
1987	0.675	0.675	0.315	0.954	0.954	0.954	0.890	0.483	0.116	0.775	0.775	0.601
1986	0.430	0.972	0.972	0.972	0.972	0.972	0.220	0.181	0.000	------	------	0.580
1985	0.678	0.678	0.678	0.876	0.876	0.876	0.429	0.733	0.000	------	------	0.621
1984			0.881	0.881	0.881	0.881	0.200	0.571	0.000	------	------	0.571
1983			0.717	0.846	0.846	0.846	0.000	------	------	------	------	0.610

Table 18. Estimated annual and geometric mean (GM) survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2002.

Year Class	Survival (S)											
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	GM
1998											0.504	0.504
1997										0.480	0.168	0.284
1996										0.223	0.062	0.118
1995									0.280	0.223	0.223	0.241
1994								0.433	0.381	0.381	0.077	0.263
1993							0.183	0.435	0.435	0.615	0.188	0.332
1992					0.568	0.432	0.560	0.560	0.726	0.726	0.000	0.490
1991						0.473	0.473	0.700	0.787	0.787	0.000	0.508
1990					0.470	0.372	0.314	0.522	0.522	0.000	------	0.353
1989				0.538	0.538	0.538	0.270	0.270	0.750	0.000	------	0.395
1988			0.147	0.564	0.564	0.564	0.000	------	------	------	------	0.344
1987	0.450	0.450	0.179	0.640	0.640	0.000	------	------	------	------	------	0.372
1986	0.116	0.500	0.733	0.364	0.000	------	------	------	------	------	------	0.317
1985	0.100	0.894	0.894	0.000	------	------	------	------	------	------	------	0.409
1984		0.533	0.000	------	------	------	------	------	------	------	------	0.238

Table 19. 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, 1991-2002.

Year Class	Survival (S)											
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	GM
1998												------
1997												------
1996												------
1995												------
1994												------
1993											0.352	0.352
1992											0.279	0.279
1991											0.088	0.088
1990								0.914	0.914	0.914	0.000	0.627
1989				0.912	0.912	0.912	0.912	0.678	0.678	0.765	0.000	0.690
1988			0.899	0.899	0.899	0.899	0.685	0.438	0.506	0.506	0.000	0.607
1987			0.801	0.801	0.801	0.801	0.890	0.483	0.116	0.775	0.775	0.614
1986	0.987	0.987	0.987	0.987	0.987	0.987	0.220	0.182	0.000	------	------	0.646
1985	0.743	0.743	0.743	0.900	0.900	0.900	0.429	0.733	0.000	------	------	0.649
1984			0.915	0.915	0.915	0.915	0.200	0.571	0.000	------	------	0.587
1983			0.717	0.846	0.846	0.846	0.000	------	------	------	------	0.610

Table 20. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2002. 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	2001	2002
2000												**0.50**
1999											0.90	**1.10**
1998										1.47	**9.50**	8.80
1997									11.70	18.11	**27.00**	10.20
1996								0.11	**35.70**	21.26	17.70	4.60
1995							0.83	**11.67**	10.60	5.79	2.10	3.50
1994						1.90	29.50	**32.78**	3.20	1.79	1.50	1.20
1993					4.50	20.00	**83.00**	7.00	0.80	2.00	1.00	1.00
1992				2.78	7.00	11.40	**14.33**	0.78	1.20	0.63	1.10	0.30
1991			0.50	2.56	1.88	**5.70**	2.83	1.33	0.50	0.32	0.90	0.30
1990	0.11	0.56	1.50	**8.22**	7.75	3.50	2.17	0.33	0.10	0.21	0.10	0.00
1989	1.33	0.78	8.60	**27.56**	4.50	2.50	0.67	0.33	0.20	0.11	0.10	0.00
1988	9.00	1.89	**25.40**	8.22	2.88	1.50	1.17	0.33	0.20	0.11	0.00	0.00
1987	**23.44**	5.89	10.40	2.11	1.75	1.60	0.50	0.11	0.10	0.00	0.10	0.00
1986	**10.56**	3.33	1.60	0.44	1.38	0.30	0.00	0.22	0.00	0.00		
1985	**3.89**	1.22	0.40	1.67	0.75	0.20	0.00	0.00	0.20	0.00		
1984	**1.56**	0.78	0.40	0.67	0.25	0.00	0.00					
1983	0.33	0.11	**1.30**	0.56	0.13	0.00	0.00					
>1983	0.44	0.44	0.60	0.22	0.00	0.00						
N/A	0.78	0.00	1.10	0.78	1.00	1.20	2.50	2.00	2.50	0.11	0.20	0.80
Total	**50.33**	**15.00**	**52.80**	**55.78**	**33.75**	**49.80**	**137.50**	**57.00**	**64.50**	**51.90**	**62.20**	**32.30**

Table 21. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2002. 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	2001	2002
2000												**0.50**
1999											0.90	**1.10**
1998										1.47	**9.40**	8.70
1997									11.60	18.11	**27.00**	8.80
1996								0.11	**35.70**	20.95	17.00	3.30
1995							0.83	**11.67**	10.60	5.68	1.90	1.40
1994						1.90	29.50	**32.56**	2.60	1.26	1.30	0.20
1993					4.50	20.00	**82.50**	6.44	0.60	1.37	0.40	0.20
1992				2.78	6.75	11.30	**14.00**	0.56	0.90	0.11	0.00	0.00
1991			0.50	2.56	1.75	**5.60**	2.50	0.67	0.30	0.00	0.00	
1990	0.11	0.44	1.50	**8.22**	7.00	3.20	1.83	0.22	0.00	0.00		
1989	1.22	0.78	8.20	**25.33**	2.63	1.40	0.50	0.00	0.00	0.00		
1988	8.89	1.33	**20.30**	4.89	1.13	0.50	1.17	0.00	0.10	0.00		
1987	**21.56**	2.78	4.20	0.33	0.13	0.10	0.00	0.00	0.10	0.00		
1986	**9.67**	1.22	0.90	0.11	0.04	0.00	0.00					
1985	**2.22**	0.11	0.00	0.33	0.00	0.00						
1984	**0.67**	0.11	0.10	0.11	0.00	0.00						
N/A	0.78	0.00	0.80	1.56	0.88	1.20	2.50	1.78	2.30	0.11	0.20	0.80
Total	**45.11**	**6.78**	**36.60**	**46.22**	**24.75**	**45.20**	**134.33**	**54.00**	**64.80**	**49.06**	**58.10**	**23.00**

Table 22. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2002. 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	2001	2002
2000												
1999												
1998											**0.10**	0.10
1997									0.10	0.00	0.00	**1.40**
1996									0.10	0.32	0.70	**1.60**
1995									0.00	0.11	0.20	**2.10**
1994								0.22	0.60	0.53	0.20	**1.00**
1993							0.33	0.56	0.20	0.63	0.60	**0.80**
1992					0.13	0.10	0.33	0.22	0.30	0.53	**1.10**	0.30
1991					0.13	0.10	0.33	0.67	0.20	0.32	**0.90**	0.30
1990		0.11	0.00	0.00	**0.63**	0.30	0.33	0.11	0.10	0.21	0.10	0.00
1989	0.11	0.00	0.30	**2.22**	1.88	1.10	0.17	0.33	0.20	0.11	0.10	0.00
1988	0.11	0.56	**5.10**	3.33	1.75	1.00	1.00	0.33	0.10	0.11	0.00	0.00
1987	0.87	3.11	**6.10**	1.78	1.63	1.50	0.50	0.11	0.00	0.00	0.10	0.00
1986	0.89	**2.11**	1.70	0.33	1.38	0.30	0.00	0.22	0.00	0.00		
1985	**1.67**	1.11	0.40	1.33	0.75	0.20	0.00	0.00	0.20	0.00		
1984	**0.89**	0.67	0.30	0.56	0.25	0.00	0.00					
1983	0.33	0.11	**1.30**	0.56	0.13	0.00	0.00					
>1983	0.44	0.44	**0.50**	0.22	0.00	0.00						
N/A	0.00	0.00	0.30	0.79	0.13	0.00	0.00	0.22	0.20	0.00	0.00	0.80
Total	**5.22**	**8.22**	**16.00**	**11.11**	**8.75**	**4.60**	**3.00**	**2.78**	**2.30**	**2.84**	**4.10**	**8.40**

Table 23. Estimated annual and geometric mean (GM) survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2002.

Year Class	Survival (S)											
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	GM
1998											0.926	0.926
1997											0.378	0.378
1996									0.595	0.833	0.260	0.505
1995								0.908	0.546	0.777	0.777	0.740
1994								0.098	0.559	0.838	0.800	0.438
1993							0.084	0.534	0.534	0.707	0.707	0.413
1992							0.289	0.289	0.957	0.957	0.273	0.461
1991						0.496	0.470	0.878	0.878	0.878	0.333	0.612
1990				0.943	0.452	0.620	0.152	0.798	0.798	0.476	0.000	0.496
1989				0.163	0.556	0.268	0.493	0.606	0.550	0.909	0.000	0.417
1988			0.324	0.350	0.521	0.780	0.282	0.606	0.550	0.000	------	0.408
1987	0.444	0.444	0.203	0.829	0.914	0.313	0.220	0.969	0.969	0.969	0.000	0.530
1986	0.315	0.480	0.929	0.929	0.217	0.856	0.856	0.000	------	------	------	0.533
1985	0.754	0.754	0.754	0.449	0.719	0.719	0.719	0.719	0.000	------	------	0.599
1984	0.449	0.927	0.927	0.373	0.000	------	------	------	------	------	------	0.492
1983			0.431	0.232	0.000	------	------	------	------	------	------	0.208

Table 24. Estimated annual and geometric mean (GM) survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2002.

Year Class	Survival (S)											
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	GM
1998											0.926	0.926
1997											0.326	0.326
1996									0.587	0.811	0.194	0.452
1995								0.908	0.536	0.335	0.737	0.589
1994								0.080	0.707	0.707	0.154	0.280
1993							0.078	0.461	0.461	0.292	0.500	0.300
1992							0.254	0.254	0.122	0.000	------	0.153
1991						0.446	0.268	0.448	0.000	------	------	0.276
1990				0.852	0.457	0.572	0.120	0.000	------	------	------	0.366
1989				0.104	0.532	0.357	0.000	------	------	------	------	0.231
1988			0.241	0.621	0.621	0.621	0.292	0.292	0.000	------	------	0.365
1987	0.441	0.441	0.079	0.394	0.937	0.937	0.937	0.937	0.000	------	------	0.523
1986	0.126	0.738	0.122	0.364	0.000	------	------	------	------	------	------	0.245
1985	0.530	0.530	0.530	0.000	------	------	------	------	------	------	------	0.376
1984	0.637	0.637	0.637	0.000	------	------	------	------	------	------	------	0.447

Table 25. 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, 1991-2002.

Year Class	Survival (S)											
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	GM
1998												------
1997												------
1996												------
1995												------
1994												------
1993												------
1992											0.273	0.273
1991											0.333	0.333
1990					0.724	0.724	0.860	0.860	0.860	0.476	0.000	0.612
1989				0.847	0.585	0.548	0.548	0.667	0.550	0.909	0.000	0.557
1988			0.654	0.526	0.756	0.756	0.330	0.577	0.577	0.000	------	0.501
1987			0.292	0.916	0.920	0.333	0.220	0.969	0.969	0.969	0.000	0.573
1986		0.806	0.901	0.901	0.217	0.856	0.856	0.000	------	------	------	0.604
1985	0.927	0.927	0.927	0.564	0.719	0.719	0.719	0.719	0.000	------	------	0.664
1984	0.753	0.914	0.914	0.446	0.000	------	------	------	------	------	------	0.562
1983			0.431	0.232	0.000	------	------	------	------	------	------	0.208

Table 26. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the James River, 30 March - 3 May, 1994-2002. Maximum catch rate for any year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)								
	1994	1995	1996	1997	1998	1999	2000	2001	2002
2000									**0.44**
1999								0.40	**3.78**
1998							1.50	13.50	**29.67**
1997						0.20	20.50	**42.40**	39.33
1996						9.10	**69.60**	32.60	11.00
1995					1.22	10.30	**36.40**	8.40	2.56
1994			0.10	1.55	7.11	**11.70**	10.50	2.60	1.11
1993		0.67	1.60	4.44	5.22	**6.10**	2.00	1.60	0.89
1992		**4.33**	2.90	3.33	3.00	2.90	1.30	1.00	0.89
1991	2.40	**8.89**	4.50	2.00	1.67	2.20	0.60	1.50	0.22
1990	**12.40**	11.11	3.10	2.00	0.78	1.40	0.40	0.50	0.11
1989	**12.20**	9.78	2.70	0.89	1.11	1.20	0.10	0.00	0.00
1988	**3.60**	2.67	1.00	1.44	0.78	0.40	0.10	0.00	0.00
1987	0.80	**2.67**	1.00	1.11	0.67	1.00	0.00	0.00	
1986	0.80	**1.89**	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	0.10	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	0.80	2.00	0.20	0.33	0.33	1.30	1.40	0.50	1.56
Total	**35.80**	**44.56**	**18.30**	**17.78**	**22.11**	**48.20**	**143.70**	**105.00**	**91.56**

N/A: not ageable

Table 27. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2002. Maximum catch rate for any year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)								
	1994	1995	1996	1997	1998	1999	2000	2001	2002
2000									**0.44**
1999								0.30	**3.78**
1998							1.50	13.50	**28.89**
1997						0.20	20.40	**41.90**	35.56
1996						7.30	**69.10**	31.00	8.33
1995					1.22	8.00	**35.20**	7.60	2.00
1994			0.10	1.56	6.78	5.20	**10.00**	1.70	0.67
1993		0.67	1.60	**3.89**	3.78	2.50	1.60	1.10	0.11
1992		**4.22**	2.80	2.33	1.67	1.10	1.10	0.20	0.00
1991	2.40	**7.89**	3.60	1.44	1.33	0.10	0.00	0.40	0.00
1990	**10.60**	6.33	1.50	1.33	0.22	0.30	0.00	0.00	
1989	**8.00**	2.33	0.80	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				
1986	0.00	**0.11**	0.00	0.00					
N/A	0.80	1.44	0.10	0.00	0.11	0.50	0.70	0.40	1.56
Total	**23.20**	**23.99**	**10.90**	**11.10**	**15.22**	**25.30**	**139.60**	**98.10**	**81.33**

N/A: not ageable

Table 28. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2002. Maximum catch rate for any year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)								
	1994	1995	1996	1997	1998	1999	2000	2001	2002
2000									
1999								**0.10**	0.00
1998								0.00	**0.78**
1997							0.10	0.50	**3.78**
1996						1.80	0.50	1.60	**2.67**
1995						**2.30**	1.20	0.80	0.56
1994					0.33	**6.50**	0.50	0.90	0.44
1993				0.56	1.44	**3.60**	0.40	0.50	0.78
1992		0.11	0.10	1.00	1.33	**1.80**	0.20	0.80	0.89
1991		1.00	0.90	0.56	0.67	**2.10**	0.60	1.10	0.22
1990	1.80	**4.78**	1.50	0.67	0.56	1.10	0.40	0.50	0.11
1989	4.00	**7.44**	1.90	0.44	1.11	1.20	0.10	0.00	0.00
1988	**2.20**	2.11	0.70	1.33	0.67	0.30	0.10	0.00	0.00
1987	0.80	**2.22**	0.90	1.11	0.67	1.00	0.00	0.00	
1986	0.80	**1.78**	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
Total	12.40	22.56	7.40	6.67	7.22	22.90	4.10	6.80	10.22

N/A: not ageable

Table 29. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the James River, 30 March - 3 May, 1994-2002.

Year Class	Survival (S)								
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	Mean
1997								0.928	0.928
1996							0.468	0.337	0.397
1995							0.231	0.305	0.265
1994						0.897	0.248	0.427	0.456
1993						0.328	0.800	0.556	0.526
1992		0.877	0.877	0.901	0.967	0.448	0.769	0.890	0.798
1991		0.506	0.788	0.788	0.788	0.826	0.826	0.147	0.590
1990	0.896	0.279	0.645	0.837	0.837	0.598	0.598	0.220	0.554
1989	0.801	0.276	0.763	0.763	0.763	0.044	0.000	------	0.445
1988	0.741	0.734	0.734	0.542	0.513	0.250	0.000	------	0.476
1987		0.645	0.645	0.948	0.948	0.000	------	------	0.593
1986		0.423	0.413	0.953	0.953	0.000	------	------	0.503
1985		0.245	0.733	0.500	0.909	0.000	------	------	0.439
1984	0.650	0.376	0.376	0.000	------	------	------	------	0.329
1983	0.416	0.000	------	------	------	------	------	------	0.190
1982	0.555	0.000	------	------	------	------	------	------	0.247

Table 30. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2002.

Year Class	Survival (S)								
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	Mean
1997								0.849	0.849
1996							0.449	0.269	0.348
1995							0.216	0.263	0.238
1994							0.170	0.394	0.259
1993				0.971	0.662	0.640	0.688	0.100	0.490
1992		0.663	0.833	0.717	0.812	0.812	0.182	0.000	0.538
1991		0.456	0.401	0.923	0.670	0.670	0.670	0.000	0.514
1990	0.597	0.237	0.887	0.474	0.474	0.000	------	------	0.417
1989	0.292	0.342	0.555	0.000	------	------	------	------	0.281
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 31. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2002.

Year Class	Survival (S)								
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	Mean
1995						0.522	0.667	0.700	0.625
1994						0.372	0.372	0.489	0.408
1993						0.601	0.601	0.601	0.601
1992						0.791	0.791	0.791	0.791
1991						0.724	0.724	0.200	0.472
1990		0.314	0.902	0.902	0.902	0.674	0.674	0.220	0.584
1989		0.255	0.836	0.836	0.836	0.083	0.000	------	0.426
1988	0.960	0.795	0.795	0.500	0.450	0.333	0.000	------	0.515
1987		0.707	0.707	0.949	0.949	0.000	------	------	0.617
1986		0.450	0.416	0.949	0.949	0.000	------	------	0.508
1985		0.245	0.740	0.500	0.901	0.000	------	------	0.439
1984	0.648	0.257	0.555	0.000	------	------	------	------	0.340
1983	0.416	0.000	------	------	------	------	------	------	0.190
1982	0.555	0.000	------	------	------	------	------	------	0.247

Table 32. 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. Value pairs with the same subscript are contrasted by the test.

SA	Otolith age														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	3	2_{1}													
3	2_{1}	5	1_{2}	1_{12}											
4		0_{2}	4	0_{3}	2_{13}										
5		0_{12}	2_{3}	9	8_{4}	6_{14}									
6			0_{13}	2_{4}	13	5_{5}	2_{15}								
7				0_{14}	16_{5}	8	2_{6}	2_{16}	1_{21}						
8					0_{15}	0_{6}	1	6_{7}	1_{17}						
9						2_{16}	4_{7}	5	2_{8}	3_{18}		1_{23}			
10						1_{21}	1_{17}	2_{8}	6	2_{9}	3_{19}	1_{22}			
11								4_{18}	0_{9}	0	1_{10}	1_{20}			
12									0_{19}	1_{10}	0				
13								0_{23}	0_{22}	0_{20}		0			
14													0		
15														0	1_{11}
16														0_{11}	0

Table 33. Relative contributions of striped as determined by ageing specimens by reading both their scales and ooliths.

Age	scale		otolith	
	n	prop.	n	.prop
2	5	.0344	5	.0344
3	9	.0621	7	.0483
4	6	.0414	7	.0483
5	25	.1724	12	.0829
6	22	.1517	39	.2690
7	29	.2000	22	.1517
8	8	.0552	10	.0690
9	17	.1172	19	.1310
10	16	.1103	10	.0690
11	6	.0414	6	.0414
12	1	.0069	4	.0276
13	0	.0000	3	.0207
14	0	.0000	0	.0000
15	1	.0069	0	.0000
16	0	.0000	1	.0069
	$\overline{Age} = 6.83$		$\overline{Age} = 7.08$	

Figure 1. Locations of commercial pound nets and experimental gill nets sampled in spring spawning stock assessments of striped bass in the Rappahannock River, 1991-2002.

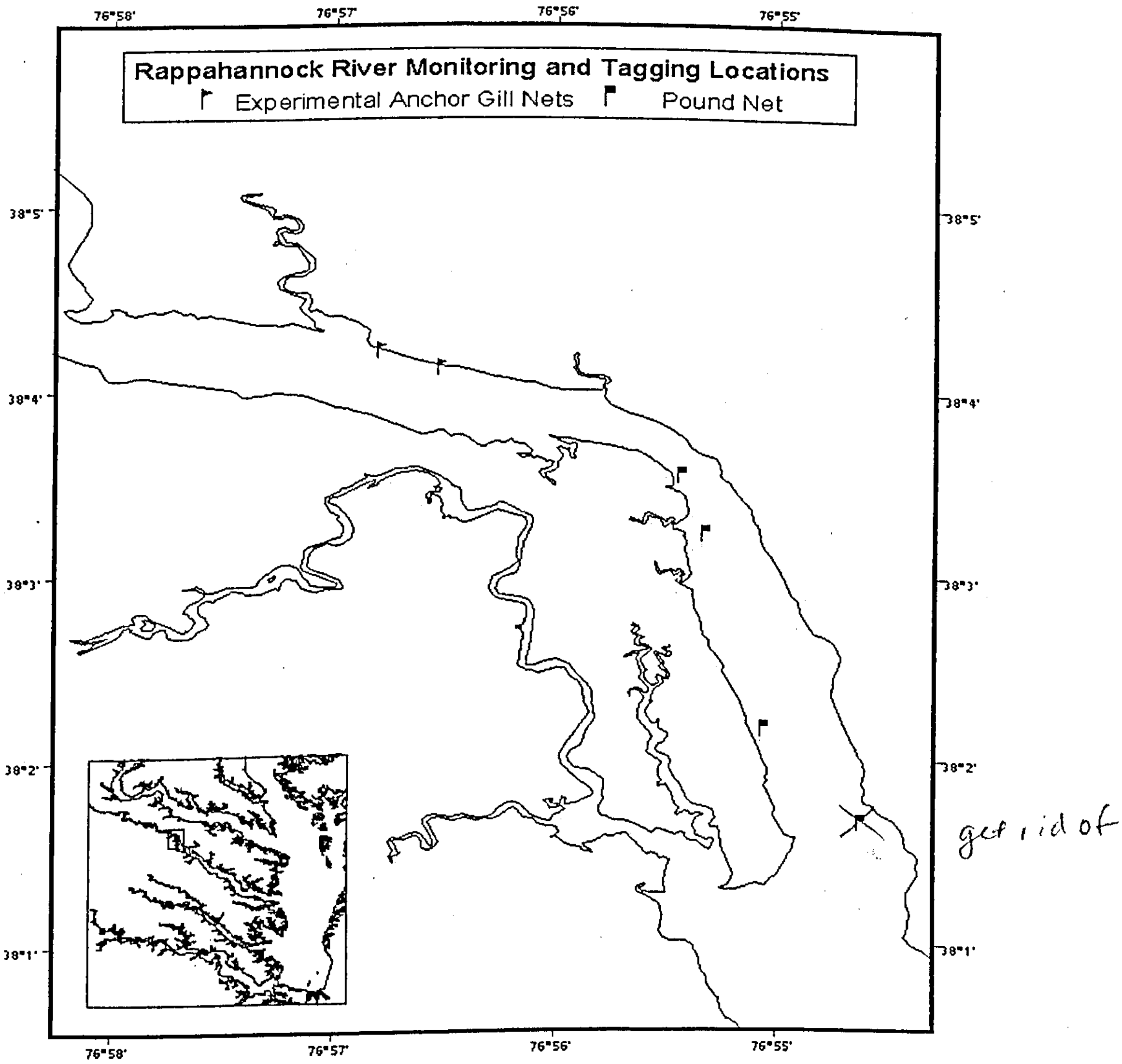


Figure 2. Locations of experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, spring 2002.

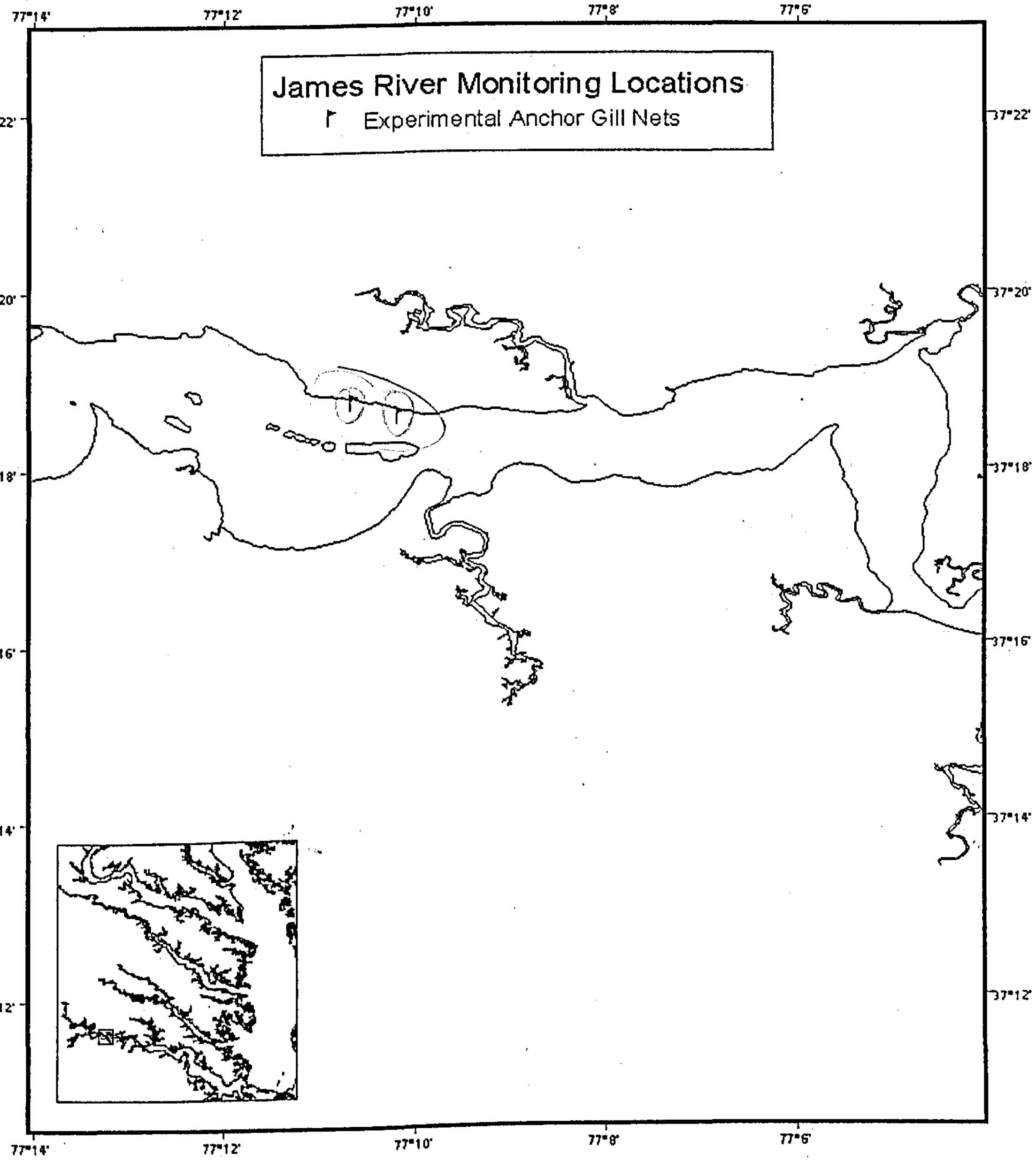


Figure 3. Catch rates (number of fish/day) of eight year classes (1987-1994) of male and female striped bass in pound nets in the Rappahannock River, 30 March - 3 May, 1991-2002.

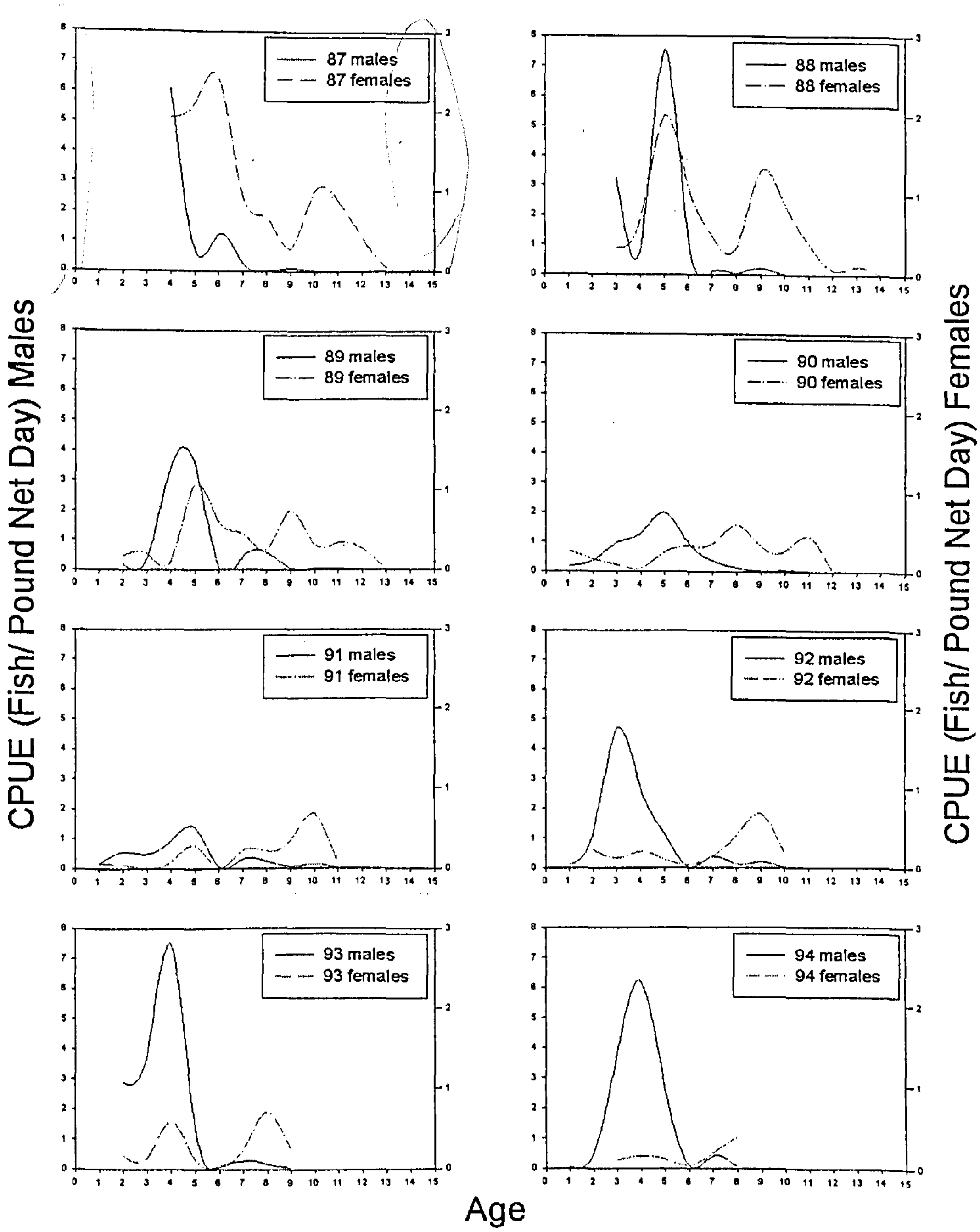


Figure 4. Catch rates (number of fish/day) of eight year classes (1987-1994) of male and female striped bass in experimental gill nets in the Rappahannock River, 30 March - 3 May, 1991-2002.

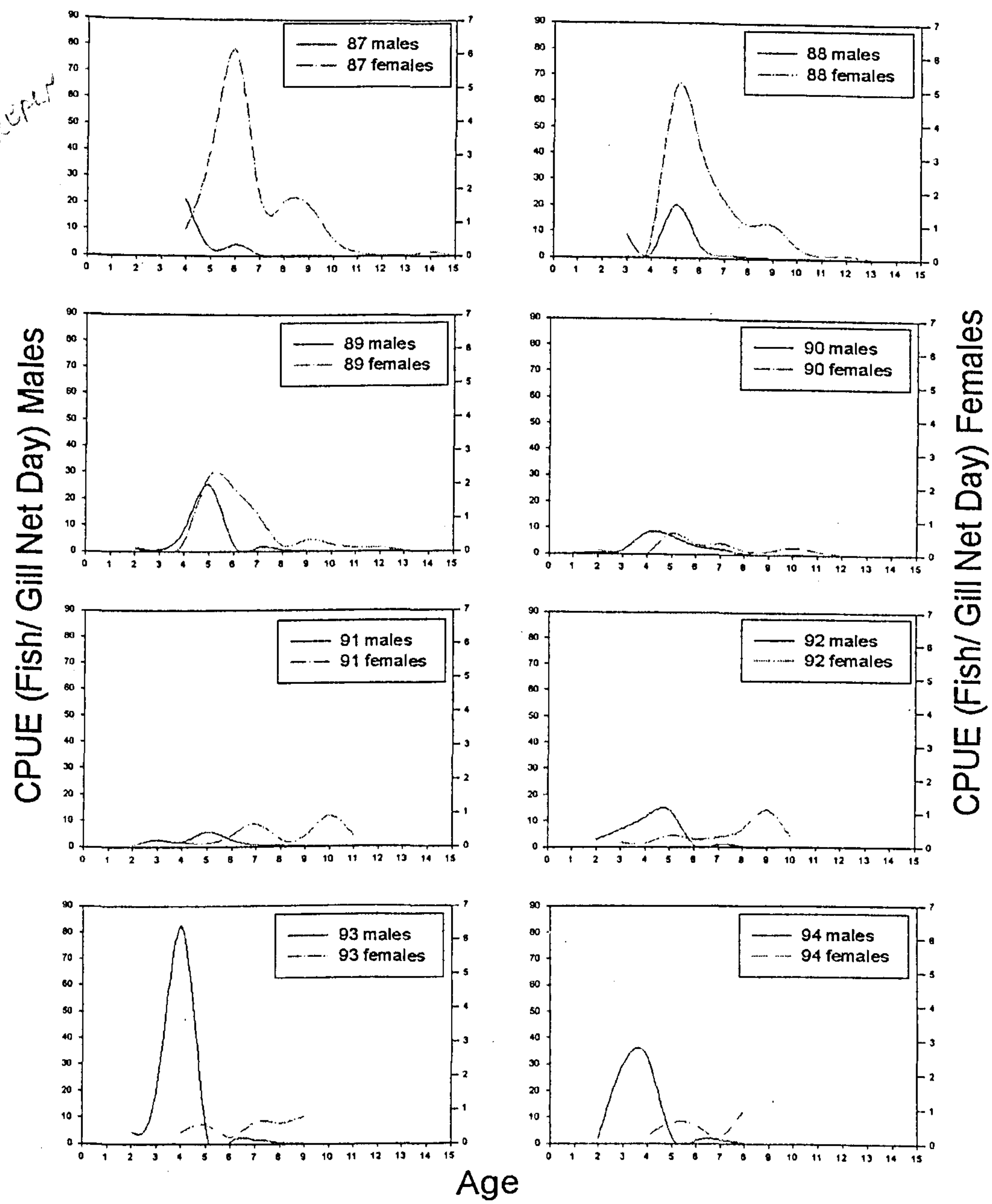


Figure 5. Catch rates (number of fish/day) of eight year classes (1987-1994) of male and female striped bass in experimental gill nets in the James River, 30 March - 3 May, 1994-2002.

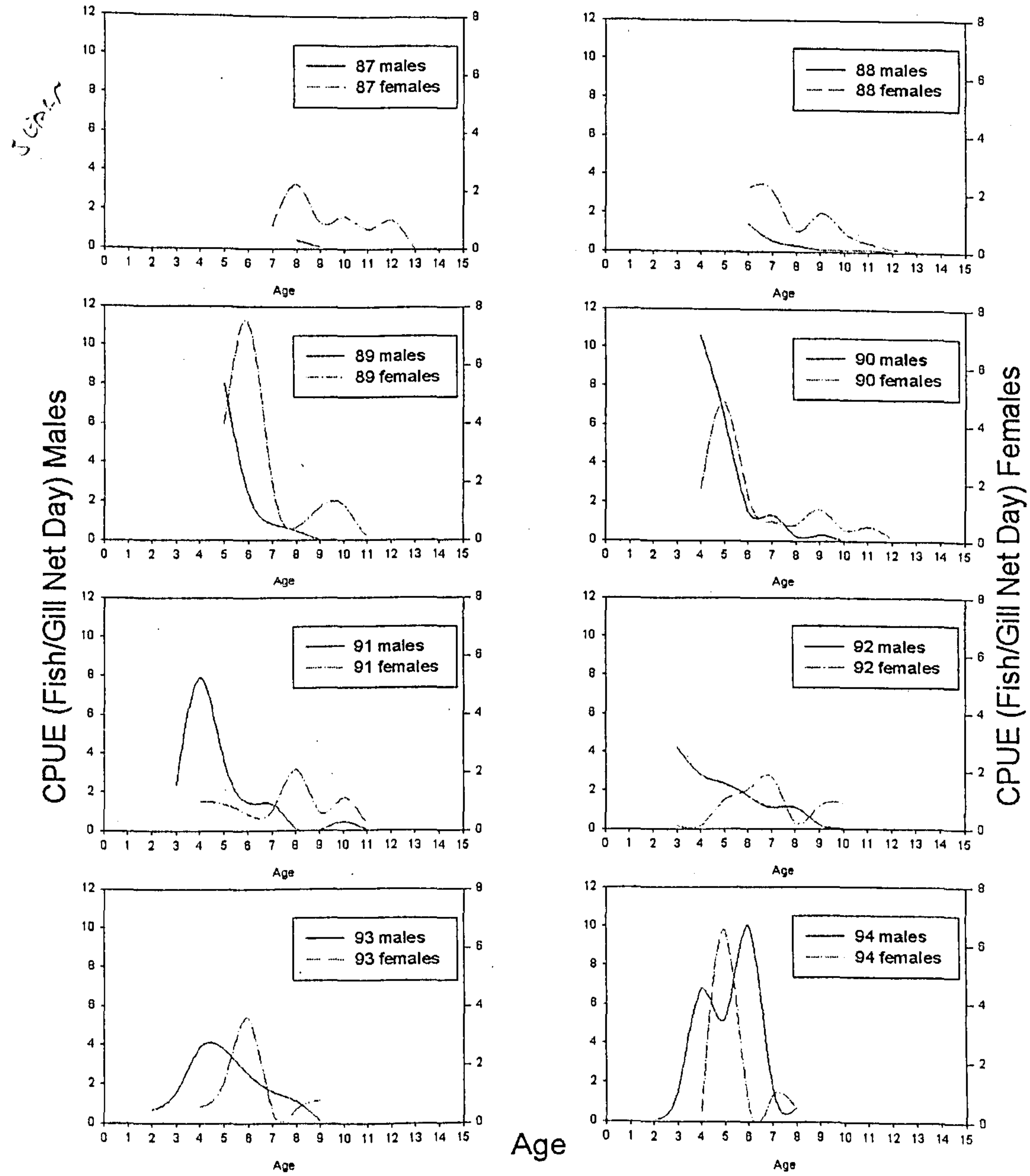
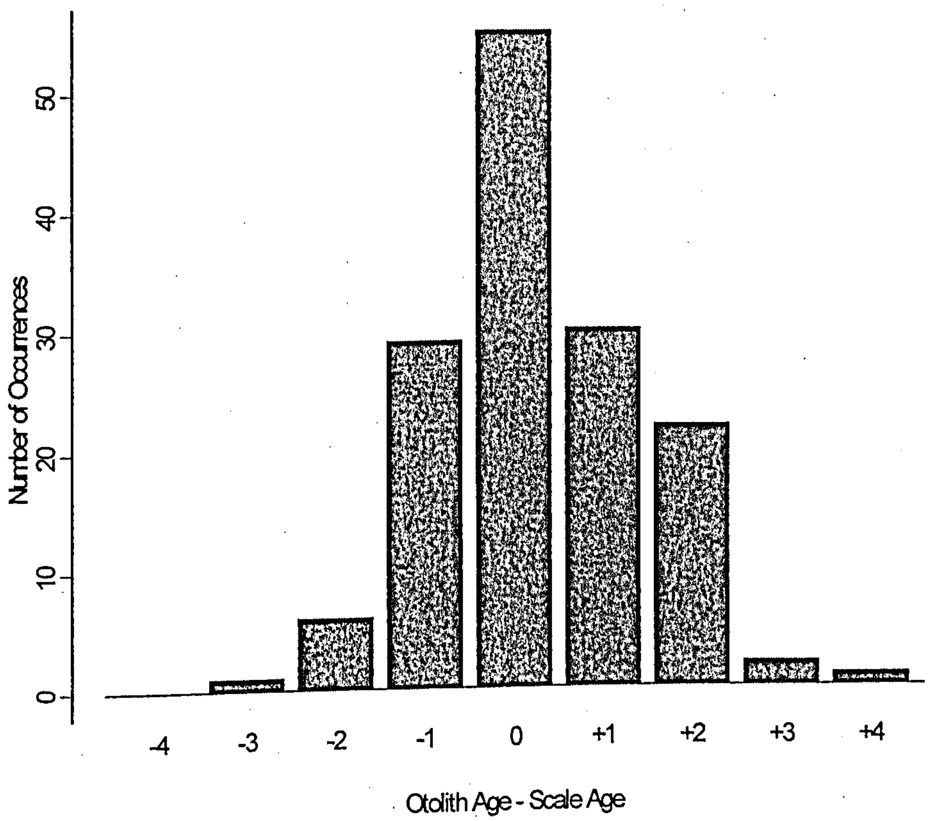


Figure 6. Magnitude of the age differences resulting from ageing specimens of striped bass (n=145) by reading both their scales and otoliths.



II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2001-2002

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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.

For the purposes of comparison and model validation, we follow the reformulated Brownie results with estimates of instantaneous fishing (F) and natural (M) mortality. These parameter estimates were obtained by applying the recently developed instantaneous rates formulation of the Brownie models (Hoenig et al. 1998a). The results from both methods were thoroughly examined and a discussion pertaining to the performance of the models and the reliability of the subsequent parameter estimates is included.

Multiyear 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

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

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)

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

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. (1998a) 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.

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

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 b). 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 1990 to 2001, 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. Striped Bass were also tagged and released from a research pound net located at river mile 13 in the York River from late February into middle May.

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 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 1995-2001) 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 1990-1994,1995-2000 and 2001).

$S(p_3)r(p_1)$ Survival and tag-reporting rates vary over different regulatory periods (p_3 = constant 1990-1994, 1995-1999, 2000 and 2001).

$S(Tp_1)r(Tp_1)$ 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 1995-2001).

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.

Instantaneous rates model: In applying the Hoenig *et al.* (1998) models to the striped bass data, two cases were considered. First, a time-specific parameterization was utilized with a supplied $\phi\lambda$ value of 0.43 and calculated values of F_i and M (model 1). Consistent with the ASMFC protocol, no adjustments for short-term tag-induced mortality or acute tag-loss. Second, the value of M was fixed at 0.15 and estimates of F_i and $\phi\lambda$ were calculated (model 2). These analyses provided additional estimates of F_i and allowed an indirect test of the assumptions of M = 0.15 and a tag reporting rate of 0.43 inherent in the ASMFC protocol.

The presence of tag-recoveries where the tag of a recaptured is clipped off and the fish is released back into the population can be interpreted as chronic tag-loss. As with the Seber models, analysis of these data with the Hoenig *et al.* models result in biased parameter estimates. No post-analysis correction term has been developed for the instantaneous rates models, therefore, a chop variable was applied to mitigate the bias (Latour *et al.* 2001a). The chop variable specified how many diagonals in the upper right corner of the recovery matrix should be ignored in the analysis. With chronic tag-loss, the number of tag recoveries in cells in the upper right corner would be lower than expected, since those recoveries correspond to the tagged cohorts that have experienced several years of tag-loss. By treating the data in those diagonals as part of the "never seen again" category (one of the possible fates in a multinomial distribution), the resulting parameter estimates were not based on those data and the effects of chronic tag-loss were mitigated. The use of chop variables yields parameter estimates that are less precise, but this penalty was accepted in an effort to gain accuracy.

Results

Spring 2002

Tag release summary: A total of 313 striped bass were tagged and released from the pound nets in the Rappahannock River between 1 April and 2 May, 2002 (Table 1). There were 191 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (99.0%), but the female stripers were larger on average. The median date of these tag releases, to be used as the beginning of the 2001-2002 recapture interval, was 11 April. There were 122 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly female (90.2%) and their average size was larger than the male striped bass. The median date of these tag releases was also 11 April.

A total of 264 striped bass were tagged and released from the VIMS research pound net in the York River between 26 February and 16 May, 2002 (Table 2). There were 229 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (92.1%), but the female stripers were larger on average. The median date of these tag releases was 7 May. There were 35 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly (94.3%) female. It is problematic whether the number of striped bass tagged and released in the York River will be insufficient to produce a reliable mortality estimate.

Mortality estimates, 2001-2002

Tag recapture summary: A total of 19 migratory striped bass (>710 mm total length), tagged during spring 2001, were recaptured between 10 April, 2000 and 18 April, 2001 (the respective midpoints of the two spring tag release totals). Twelve of these recaptures were harvested (62.2%), and the remainder were re-released into the population (Table 3). The proportion harvested for the time series varied from 0.493-0.938 (mean = 0.636). Only seven of the tagged striped bass were recaptured within Chesapeake Bay (0.368), with six of those in Virginia and one in Maryland. Other recaptures came from Massachusetts (4 = 0.211), Rhode Island (3 = 0.158), New York (2 = 0.105), New Jersey (2 = 0.105) and Connecticut (1=0.053).

ASMFC protocol: Survival estimates were made utilizing the mark-recapture data for the Rappahannock River from 1990-2001. The time series for the York River is too short to generate a reliable estimate. The suite of Seber (1970) models consisted of 12 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 coastwide harvest regulations were also specified.

Of the 12 proposed models, seven had ΔAICc values less than 7.0 (Table 4). Of those 7 models, the calculated weight of the constant survival and tag reporting model (i.e., S(.)r(.)) was larger than that of the other models. Comparatively, the weight values associated with the models that reflected the various period-specific parameterizations of S and/or r were the next largest and all similar in relative magnitude. Models that reflected more general time-specific parameterizations tended to not fit the data well.

The model averaged estimates of the bias-adjusted survival rates ranged from 0.61-0.76 over the time series (Table 5). 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 0.13-0.35 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 0.75.

Instantaneous rates models: All parameter estimates using Hoenig *et al.* models for Rappahannock River striped bass were based on a chop variable of 10 diagonals (note that 10 diagonals is the maximum number that could be eliminated since at least two diagonals of data are needed to derive parameter estimates).

The expected trends in mortality associated with the various regulatory periods were evident in the model 1 estimates of F_i (Table 6). From 1990-1994, the fishing mortality estimates ranged from 0.26-0.34 while from 1995-2001, the estimates ranged from 0.18-0.39. However, the 2000 and 2001 estimates of F (0.22) were lower than those for the previous years. The low estimate for F resulted mainly from a lower than average recapture rate (0.07 vs. .010 for 1990-1999).

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. (2001b) 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.

Instantaneous rates model: Since the chop variable was fixed at 10 diagonals for the Rappahannock River data analyses, the data from only two diagonals were used to derive parameter estimates under the parameterizations inherent to models 1 and 2. This characteristic rendered it impossible to examine the residual matrixes for all possible patters, leaving each row and column of the matrix with only four and three values, respectively. Hence, it was only possible to examine the residuals matrixes for the pattern associated for non-mixing (predominantly negative and positive residuals along the respective main and super diagonals). This pattern was not evident in either residuals matrix, which is consistent with previous analyses designed to detect the presence of non-mixing in the striped bass tag-recovery data from Chesapeake Bay (Latour et al. 2001 b,c).

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 both the Seber and the Hoenig *et al.* 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.

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Table 1. Summary data of striped bass tagged and released from pound nets in the Rappahannock River, spring 2002.

Date	total tagged	457 - 710 mm TL				> 710 mm TL			
		males		females		males		females	
		n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$
1 April	51	37	577.6	1	625.0	3	696.0	10	885.0
5 April	53	25	479.0	0		2	726.5	26	811.8
8 April	35	19	486.1	0		2	777.0	14	758.6
11 April	39	18	498.8	0		1	728.0	20	787.1
15 April	44	14	525.3	0		2	736.5	28	772.0
18 April	40	31	483.6	0		1	702.0	8	788.5
22 April	21	18	533.9	0		1	669.0	2	856.0
25 April	29	26	504.5	1	550.0	0		2	777.5
2 May	1	1	491.0	0		0		0	
Total	313	189	513.9	2	587.5	12	722.3	110	795.5

Table 2. Summary data of striped bass tagged and released the VIMS research pound net in the York River, spring 2002.

Date	total tagged	457 - 710 mm TL				> 710 mm TL			
		males		females		males		females	
		n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$
26 Feb.	2	1	581.0	0		0		1	778.0
28 Feb.	6	5	538.6	0		0		1	850.0
5 March	4	3	512.3	0		0		1	726.0
12 March	2	1	630.0	0		0		1	742.0
19 March	3	1	490.0	1	621.0	0		1	721.0
28 March	2	0		0		0		2	716.0
4 April	5	1	654.0	0		0		4	727.0
11 April	2	0		0		0		2	735.5
18 April	4	0		2	633.0	0		2	740.5
25 April	15	9	492.8	3	632.0	0		3	729.3
30 April	44	29	508.4	8	580.5	0		7	774.3
2 May	28	24	507.7	1	645.0	1	686.0	2	785.5
7 May	46	38	490.5	2	552.0	1	686.0	5	732.8
9 May	16	14	508.7	1	629.0	0		1	685.0
14 May	43	43	503.6	0		0		0	
16 May	42	42	500.2	0		0		0	
Total	264	211	504.1	18	600.3	2	686.0	33	746.6

Table 3. Recapture matrix of striped bass (>710 m TL) that were tagged and released in the Rappahannock River, springs 1990-2001. The second (bottom) number is the number of those recaptures that were killed.

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

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 1995-2001 (p_1); parameters vary in 2001 (p_2), otherwise the same as p_1; parameters vary in 1999, 2000 and 2001 (p_3), otherwise the same as p_1; parameters constant from 1990-1992, 1993-1994 and 1995-2001 (p_4); assumption of linear trends from 1990-1994 and 1995-2001 (Tp_1); and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ **weight**	**number of parameters**
S(.)r(.)	2061.99	0.00	0.32	2
S(p_3)r(p_1)	2062.51	0.52	0.25	5
S(.)r(p_1)	2063.15	1.16	0.18	3
S(p_1)r(p_1)	2063.95	1.97	0.12	4
S(p_2)r(p_1)	2064.61	2.63	0.09	5
S(p_4)r(p_4)	2067.17	5.19	0.02	6
S(Tp_1)r(p_1)	2067.17	5.49	0.02	6
S(Tp_1)r(Tp_1)	2069.34	7.35	0.01	8
S(.)r(t)	2073.76	11.77	0.00	13
S(p_1)r(t)	2075.52	13.53	0.00	14
S(t)r(p_1)	2076.85	14.87	0.00	14
S(Tp_1)r(t)	2078.48	16.49	0.00	16
S(t)r(t)	2084.76	22.77	0.00	23

Table 5. Seber (1970) model estimates 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, 1990-2001.

Year	$\hat{S}$	SE ($\hat{S}$)	P_L	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI $\hat{F}$
1990	0.62	0.03	0.58	-0.12	0.71	0.20	0.11, 0.30
1991	0.62	0.03	0.56	-0.13	0.72	0.18	0.10, 0.28
1992	0.62	0.03	0.53	-0.18	0.76	0.13	0.04, 0.23
1993	0.62	0.03	0.35	-0.09	0.69	0.22	0.14, 0.32
1994	0.72	0.03	0.32	-0.07	0.67	0.25	0.15, 0.35
1995	0.60	0.03	0.19	-0.07	0.65	0.28	0.17, 0.41
1996	0.60	0.04	0.13	-0.01	0.61	0.34	0.23, 0.46
1997	0.60	0.04	0.17	-0.04	0.63	0.32	0.21, 0.44
1998	0.60	0.04	0.22	-0.09	0.66	0.26	0.15, 0.38
1999	0.60	0.04	0.20	-0.06	0.64	0.29	0.17, 0.43
2000	0.63	0.05	0.34	-0.07	0.67	0.29	0.17, 0.42
2001	0.64	0.06	0.30	-0.56	0.67	0.24	0.08, 0.45

Table 6. Instantaneous rates model estimates of: fishing ($\hat{F}$) and natural ($\hat{M}$) mortality, when tag reporting rate ($\phi\lambda$) is assumed to be 0.43, for striped bass (>711 mm FL) in the Rappahannock River, 1990-2001.

Year	$\phi\lambda = 0.43$	
	$\hat{F}_i$ (SE)	$\hat{M}$ (SE)
1990	0.27 (0.06)	0.24 (0.12)
1991	0.26 (0.06)	
1992	0.31 (0.10)	
1993	0.31 (0.07)	
1994	0.34 (0.09)	
1995	0.38 (0.09)	
1996	0.18 (0.08)	
1997	0.21 (0.06)	
1998	0.39 (0.09)	
1999	0.39 (0.09)	
2000	0.22 (0.05)	
2001	0.22 (0.06)	

N/a: standard errors not currently available for the instantaneous rates models.

III. Fishing mortality estimates of the fall 2001 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 (6 Oct in 2001). 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. Use of fyke nets were discontinued after 1998 due to a drastic decline in their use by commercial fishermen. In 2001, 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.

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 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. 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 2001

In fall 2001, a total of 3,010 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, 17-26 September: The 838 striped bass tagged and released came primarily (98.6%) 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 1998 (55.6%) and 1997 (40.2%) year classes (Table 3). The mean age of the striped bass varied from 3.41 years (Rappahannock River) to 3.83 years (York River). The mean size (FL) of the striped bass tagged and released varied from 481.9 mm (Rappahannock River) to 507.8 mm (lower James River). The midpoint of the tagging round was 20 September.

Tagging round 6, 22 October - 1 November: The 1,616 striped bass tagged and released reflect the dramatic increase in availability relative to September (Table 4). Water temperatures during the tagging round were 16-19 °C. The number of striped bass tagged and released exceeded the desired quotas in every region except the Rappahannock River.

The majority of the striped bass tagged and released were from the 1998 (57.7%) and 1997 (40.0%) year classes (Table 5). The mean age of the striped bass varied from 3.31 years (middle Chesapeake Bay) to 3.79 years (middle James River). The mean size (FL) of the striped bass tagged and released varied from 474.6 mm (middle Chesapeake Bay) to 494.7 mm (middle James River). The midpoint of the tagging round was 27 October.

Tagging round 7, 19-29 November: The 545 striped bass tagged and released reflect a different strategy relative to the previous tagging rounds. First, the Thanksgiving holidays (22-25 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 1998 (55.0%) and 1997 (19.1%) year classes (Table 7). The mean age of the striped bass varied from 3.40 years (Rappahannock River) to 4.36 years (middle Chesapeake Bay). The mean size of the striped bass tagged and released varied from 475.2 mm (Rappahannock River) to 544.7 mm (middle Chesapeake Bay). The midpoint of the tagging round was 27 November.

Tag recapture summary

A total of 89 tagged striped bass were recaptured from 17 September - 31 December, 2001 (Table 8). The overall proportion of recapture was 0.040 and varied from 0.014 (upper Bay) to 0.056 (Rappahannock River). The proportion of striped bass recaptured within the same area as they were tagged was highest in the Rappahannock River (0.980) and lowest in the middle Chesapeake Bay (0.000). Striped bass tagged in the Virginia part of Chesapeake Bay were predominantly (0.966) recaptured there, but there were three recaptures elsewhere (one in Maryland, one in the Potomac River and one in the Atlantic Ocean). 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, 20 September - 26 October: A total of 55 striped bass (6.6%) tagged in the fifth tagging round were recaptured by 31 December (0.06% per day). However, only 60.0% of these recaptures occurred within the fifth recapture interval (Table 9). Sport fishermen (recreational and charter anglers) accounted for only 15.2% of the recaptures during the recapture interval. These anglers released more tagged striped bass than they harvested. The two recaptured striped bass harvested by sport fishermen are the data included in the computation of fishing mortality. Commercial harvest accounted for 1.8% of the 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, 27 October - 26 November: A total of 28 striped bass (1.7%) tagged in the sixth tagging round were recaptured by 31 December (0.03% per day). However, only 53.6% of these recaptures occurred within the sixth recovery interval (Table 10). One tagged striped bass (3.6%) was recaptured between the beginning of the tagging round and the beginning of the recovery interval and 12 tagged striped bass (42.9%) were recaptured after the recovery interval. Sport fishermen accounted for 66.7% of the recaptures during the recapture interval. Again, more recaptured striped bass were released rather than harvested. 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, 27 November - 31 December: A total of 6 striped bass (1.1%) tagged in the seventh tagging round were recaptured by 31 December (0.03% per day). All the recaptures occurred within the recovery interval (Table 11). Sport fisherman accounted for 50.0% of the recaptures during the recapture interval and harvested more than they released. 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 tagging round reduced the targeted output of tagged striped bass by more than 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 2001 was 0.23. A non-harvest mortality rate of 0.10 was added to produce the final estimate of a recreational/ charter fishing mortality of 0.13 (Hornick *et al.* 2002).

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, 2001 greatly reduced the number of striped bass released.

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 (81.9%) 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 (98%). The prevalence of same-area recapture was also very high (>90%) in the James and York rivers. However, striped bass tagged from our middle Chesapeake Bay location did show a wide pattern of dispersal. Striped bass tagged there were recaptured in the Chesapeake Bay (Maryland),Potomac River and the Piankatank River (all north and west of the release site), plus off Hampton and Norfolk (south and west) and at Cape Charles (south and east). The migration pattern may change towards the end of the tagging season. Recaptures of tagged striped bass from Cape Charles to Cape Henry (both at the mouth of Chesapeake Bay) occurred between 6-31 December.

The Chesapeake Bay-wide estimate of resident striped bass fishing mortality was 0.23. This was the sum of the estimate of both non-harvest (0.10) and harvest (0.13) mortalities. Non harvest mortalities include natural deaths and handling-induced mortalities. In our fall 2001 study

71.9% of the recaptures were released alive (97.0% of commercial recaptures, 41.5% 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).

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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 2001. Note: tagging rounds 1-4 were in Maryland only.

Tagging round	Dates	Location	Quota	Releases
5	17-26 Sep.	Chesapeake Bay - upper	150	0
		Chesapeake Bay - middle	150	353
		Rappahannock River	350	473
		York River	100	7
		James River	250	5
		Subtotal	1,000	838
6	22-31 Oct.	Chesapeake Bay - upper	300	313
		Chesapeake Bay - middle	200	374
		Rappahannock River	300	280
		York River	100	343
		James River	300	306
		Subtotal	1,200	1,616
7	20-29 Nov.	Chesapeake Bay - upper	300	186
		Chesapeake Bay - middle	200	28
		Rappahannock River	200	103
		York River	100	121
		James River	200	118
		Subtotal	1,000	556

Table 2. Daily striped bass tag release totals, by area, during round 5 (17-26 September) of the fall 2001 fishing mortality (F) study.

Tag release area	17 Sep	18 Sep	19 Sep	20 Sep	21 Sep	22 Sep	23 Sep	24 Sep	25 Sep	26 Sep
Chesapeake Bay (upper region)			0		0				0	
Chesapeake Bay (middle region)		221						132		
Rappahannock River (upper region)	284			189						
Rappahannock River (middle region)										
York River (middle region)								6		1
James River (middle region)										
James River (lower region)			2		3			0		
totals	284	221	2	189	3			138	0	1

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 (17-26 September) of the fall 2001 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm)		mean age
				YC	total	
Chesapeake Bay (middle region)	1998	192	54.4	465.3	491.1	3.48
	1997	151	42.8	517.4		
	1996	8	2.3	612.1		
	n/aged	2	0.6			
Rappahannock River	1998	279	59.0	455.7	481.9	3.41
	1997	179	37.8	518.7		
	1996	6	1.3	598.5		
	n/aged	9	1.9			
York River	1998	2	28.6	443.5	485.3	3.83
	1997	3	42.9	486.3		
	1996	1	14.3	566.0		
	n/aged	1	14.3			
James River (lower section)	1998	1	20.0	445.0	507.8	3.80
	1997	4	80.0	523.5		
	1996	0	0.0			

Table 4. Daily striped bass tag release totals, by area, during round 6 (22-31 October) of the fall 2001 fishing mortality (F) study.

Tag release area	22 Oct	23 Oct	24 Oct	25 Oct	26 Oct	27 Oct	28 Oct	29 Oct	30 Oct	31 Oct
Chesapeake Bay (upper region)								113		200
Chesapeake Bay (middle region)			224						150	
Rappahannock River	190									90
York River		33			57				253	
James River (middle region)	199		58	20						
James River (lower region)		13						16		
totals	389	46	282	20	57			129	403	290

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 (22-31 October) of the fall 2001 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm) YC	mean FL (mm) total	mean age
Chesapeake Bay (upper region)	1998	184	58.8	461.2	485.9	3.42
	1997	125	39.9	518.9		
	1996	4	1.3	591.5		
Chesapeake Bay (middle region)	1998	281	75.1	459.2	474.6	3.31
	1997	86	23.0	518.6		
	1996	4	1.1	607.5		
	n/aged	3	0.8			
Rappahannock River	1998	151	53.9	458.1	486.3	3.46
	1997	123	43.9	518.7		
	1996	2	0.1	620.0		
	n/aged	4	0.1			
York River	1998	171	49.9	464.6	491.9	3.54
	1997	160	46.6	513.2		
	1996	8	2.3	594.3		
	1990	1	0.3	962.0		
	n/aged	3	0.9			
James River (middle section)	1998	130	46.9	457.8	494.7	3.79
	1997	141	50.9	524.4		
	1996	6	2.2	597.5		

James River (lower section)	1998	15	51.7	460.0		
	1997	12	41.3	520.7		
	1996	2	6.9	590.0	494.1	3.55

Table 6. Daily striped bass tag release totals, by area, during round 7 (19-29 November) of the fall 2001 fishing mortality (F) study.

Tag release area	19 Nov	20 Nov	21 Nov	22 Nov	23 Nov	24 Nov	25 Nov	26 Nov	27 Nov	28 Nov	29 Nov
Chesapeake Bay (upper region)	88		50					48			
Chesapeake Bay (middle region)											28
Rappahannock River									103		
York River		86								35	
James River (middle region)	51								34		
James River (lower region)								18	15		
totals	139	86	50					66	152	35	28

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 (19-29 November) of the fall 2001 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm) YC	mean FL (mm) total	mean age
Chesapeake Bay (upper region)	1998	158	84.9	452.2	480.6	3.41
	1997	16	8.6	510.5		
	1996	2	1.1	605.5		
	1993	5	2.7	807.6		
	1992	3	1.6	877.0		
	1991	1	0.5	891.0		
	1990	1	0.5	1003.0		
Chesapeake Bay (middle region)	1998	18	64.3	442.8	544.7	4.36
	1997	1	3.6	492.0		
	1996	2	7.1	624.0		
	1995	4	14.3	692.8		
	1993	1	3.6	837.0		
	1991	1	3.6	892.0		
	1989	1	3.6	1042.0		
Rappahannock River	1998	62	60.2	456.6	475.2	3.40
	1997	38	36.9	502.6		
	1996	1	1.0	581.0		
	n/aged	2	1.9			

York River	1998	68	56.2	465.0	486.3	3.45
	1997	51	42.1	510.2		
	1996	1	0.8	716.0		
	n/aged	1	0.8			
James River (middle region)	1998	30	34.9	465.3	498.2	3.73
	1997	50	58.1	525.1		
	1996	4	4.7	589.0		
	1994	1	1.2	779.0		
James River (lower region)	1998	19	57.6	466.5	488.8	3.34
	1997	10	30.3	531.1		
	n/aged	4	12.1			

Table 8. Number, location, mean fork length (FL in mm) and mean age of recaptured striped bass, by release location, 17 September - 31 December, 2001.

Release location	Chesapeake Bay (Va.) recaptures*								
		location						mean	
		river			Chesapeake Bay			FL	age
	total	Rap.	York	James	upper	middle	lower		
Rappahannock River	49	48	0	0	0	0	1	484.2	3.4
York River	11	0	10	1	0	0	0	493.5	3.5
James River	11	0	0	10	0	0	1	492.6	3.6
Chesapeake Bay (upper)	7	0	1	0	4	0	2	492.9	3.4
Chesapeake Bay (middle)	11	1	0	0	0	0	5	500.5	3.6

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

Table 9. Summary of the disposition of striped bass tagged during round 5 (17-26 September) and subsequently recaptured prior to 31 December, with emphasis on the fifth recapture interval(20 September - 26 October, 2001).

Release location	recaptures								
	total	17 Sep - 19 Sep	20 Sep - 26 Oct						27 Oct - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	45	0	24	0	2	2	3	0	14
York River	1	0	0	0	0	0	0	0	1
James River	1	0	0	0	0	0	0	0	1
Chesapeake Bay (upper)	0	0	0	0	0	0	0	0	0
Chesapeake Bay (middle)	8	0	0	1	1	0	0	0	6

R: released alive
H: harvested

Table 10. Summary of the disposition striped bass tagged during round 6 (22 October - 1 November) and subsequently recaptured prior to 31 December, with emphasis on the sixth recapture interval (27 October - 26 November, 2001).

Release location	recaptures								
	total	22 Oct - 26 Oct	27 Oct - 26 Nov						27 Nov - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	4	0	0	0	2	2	0	0	0
York River	10	0	0	0	0	0	4	0	6
James River	8	1	1	0	3	2	0	0	1
Chesapeake Bay (upper)	3	0	0	0	0	0	0	0	3
Chesapeake Bay (middle)	3	0	0	0	1	0	0	0	2

R: released alive
H: harvested

Table 11. Summary of the disposition of striped bass tagged during round 7 (19-29 November) and subsequently recaptured prior to 31 December 2001.

Release location	recaptures								
			27 Nov - 31 Dec						
			commercial		sport		other		
	total	19 Nov - 26 Nov	R	H	R	H	R	H	
Rappahannock River	0	0	0	0	0	0	0	0	
York River	0	0	0	0	0	0	0	0	
James River	2	0	0	0	0	2	0	0	
Chesapeake Bay (upper)	4	0	0	0	1	0	3	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, 2001.