12-27-2001

Evaluation of striped bass stocks in Virginia, monitoring and tagging studies, 1999-2003 Annual report, 1 September 2000 - 31 October 2001

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

Annual Report

Contract Number: F-77-R-14

Project Period: 1 September 2000 - 31 October 2001

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Submitted To:

Virginia Marine Resources Commission
P.O. Box 756
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27 December 2001

Preface

This report presents the results of striped bass (*Morone saxatilis*) tagging and monitoring activities in Virginia during the period 1 September 2000 through 31 October 2001. It includes an assessment of the biological characteristics of striped bass taken from the 2001 spring spawning run, estimates of annual survival based on annual spring tagging, and the results of the fall 2000 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 are limited to 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 truly a multi-jurisdictional concern as spawning success in one area certainly 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 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 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, Dan Hepworth, Gail Holloman, Curtis Leigh, Kristin Maki, Todd Mathes, Jason Romine, John Walter and Brian Watkins; the cooperating commercial fishermen; Bobby Brown, Donnie Green, Allan Ingraham, Raymond Kellum, Randy Kirby, Stanley Oliff, Jamie Saunders and Greg Swift; Cynthia Goshorn and Beth Rodgers of Maryland Department of Natural Resources (MDNR) and David Smith of the U.S. Geological Survey.

Executive Summary

I. Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2001.

Catch Summaries:

1. In 2001, 577 striped bass were sampled between 2 April and 3 May from three commercial pound nets in the Rappahannock River. The samples were predominantly male (81.8%) and young (78.3% ages 2-5). Females dominated the age eight and older age classes (85.6%). The mean age on the male striped bass was 4.3 years. The mean age of the female striped bass was 9.1 years.

2. During the 30 March - 3 May period, the 1996 and 1997 year classes were the most abundant and were 97.2% male. The contribution of age six and older males was only 5.2% of the total catch. Age eight and older females, presumably repeat spawners, were 15.4% of the total catch but represented 84.8% of all females caught.

3. In 2001, 640 striped bass were sampled between 29 March and 3 May in two experimental anchor gill nets in the Rappahannock River. The samples were predominantly male (93.4%) and young (86.1% ages 2-5). All the pre-1993 year class stripers sampled were female. The mean age of the male striped bass was 4.3 years. The mean age of the female striped bass was 8.3 years.

4. During the 30 March - 3 May period, the 1996 and 1997 year classes were the most abundant and were 98.4% male. The contribution of age six and older males was only 5.6%. Age eight and older females, presumably repeat spawners, were 4.5% of the total catch but were 70.7% of the total females caught.

5. In 2001, 1,133 striped bass were sampled between 26 March and 3 May in two experimental anchor gill nets in the James River. Males dominated the 1997-1999 year classes (99.0%) and the 1993-1996 year classes (91.7%). Females dominated the 1985-1992 year classes (80.0%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 7.4 years.

6. During the 30 March - 3 May period, the 1996 and 1997 year classes were the most abundant and were 97.2% male. The contribution of age six and older males was only 3.0% of the total catch. Age eight and older females, presumably repeat spawners, were 2.6% of the total catch but represented 42.6% of all females caught.

Spawning Stock Biomass Indexes (SSBI)

7. The Spawning Stock Biomass Index from the Rappahannock River pound nets was 24.2 kg/day for male striped bass and 27.6 kg/day for female striped bass. The male index was lower than 1999-2000, but slightly above the 11-year average. The female index was the highest since 1998 and was slightly greater than the average index value.

8. The SSBI for the Rappahannock River gill nets was 88.6 kg/day for male striped bass and 30.9 kg/day for female striped bass. The male index was the highest since 1997 and was above the 11-year average. The female index was the highest 1995, but was still below the 11-year average.

9. The SSBI for the James River gill nets was 181.4 kg/day for male striped bass and 41.3 kg/day for female striped bass. The male index was the second highest in the time series and ore than double the eight-year average. The female index was the second lowest to date and was 22.5% 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 3.99. Older (8+ years) female stripers were responsible for 94.3% of the index.

11. The EPPI for the Rappahannock River gill nets was 4.04. Older (8+years) female striped bass were responsible for 89.3% of the index.

12. The EPPI for the James River gill nets was 5.29. Older (8+ years) female striped bass were responsible for 71.1% 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 (18.6 fish/day) was lower than in 1999-2000. This was the result of lower catch rates of three and four-year old, mostly male, stripers, while the catch rates of 8-11 year classes were greater than those from 2000. The cumulative catch rate of male striped bass (15.2 fish/day) was lower than 1999-2000, while the cumulative catch rate of female striped bass (3.4 fish/day) was the highest since 1998.

14. Year class-specific estimates of annual survival (S) for pound net data varied widely between years. The geometric mean S of the 1983-1993 year classes varied from 0.56-0.87 (mean = 0.648). The geometric mean survival rates differed greatly between sexes. Mean survival rates for male stripers (1985-1993 year classes) varied from 0.32-0.63 (mean = 0.412) but mean survival rates of female stripers (1983-1989 year classes) varied from 0.55 - 0.82 (mean = 0.649).

15. The cumulative catch rate (sexes combined) from Rappahannock River gill nets (62.2 fish/day) was19.8% higher than in 2000 and the third highest overall. Catch rates were high for the 1996 and 1997 year classes, but also showed increases in the 1991 and 1992 year classes. Cumulative catch rates of male stripers were higher than 2000 and third highest overall. Cumulative catch rates of female striped bass were the highest since 1996.

16. Year class-specific estimates of annual survival for gill net data varied widely between years. The geometric mean S of the 1984-1992 year classes varied from 0.41 - 0.69 (mean = 0.535). The mean survival rates for male stripers (1984-1991) varied from 0.15-0.39 (mean = 0.304). The mean survival rates for female stripers (1984-1990) varied from 0.50-0.74 (mean = 0.617).

17. The cumulative catch rate (sexes combined) from James River gill nets (105.0 fish/day) lower than 2000, but was the second highest of the 1994-2001 time series. Catch rates were highest for the 1996-1998 year classes, while the catch rates from most other year classes showed a decline from 2000. The cumulative catch rates for male striped bass (98.1 fish/day) was the second highest of the time series, while the cumulative catch rate for female striped bass (6.8 fish/day), although greater than in 2000, was the third lowest 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 0.33-0.78 (mean = 0.534). The mean survival rates of male stripers (1988-1993 year classes) varied from 0.28-0.73 (mean = 0.520). The mean survival rates of female stripers (1984-1990 year classes) varied from 0.34-0.69 (mean = 0.505).

II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2000-2001.

19. A total of 797 striped bass were tagged and released from pound nets in the Rappahannock River between 26 March and 30 April, 2001. Of this total, 528 were resident striped bass (457-710 mm TL) and 269 were migrant striped bass (>710 mm TL). The median date of the tag releases was 10 April 2001.

20. A total of 179 striped bass were tagged and released from a research pound net in the York River between 20 February and 16 May, 2001. Of this total, 160 were resident striped bass (457-710 mm TL) and 19 were migrant striped bass (>710 mm TL). The median date of the tag releases was 2 May 2001.

21. A total of 27 migratory striped bass (>710 mm TL), tagged during spring 2000, were recaptured between 11 April, 2000 and 9 April, 2001 (the respective midpoints of the two spring release periods).

22. 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 0.60-0.72 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 0.13-0.34 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.

23. 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 2000 resident striped bass fishery in the Chesapeake Bay, Virginia.

24. The fall 2000 striped bass recreational season (1 June - 30 Nov in Maryland, 4 Oct - 31 Dec in Virginia) in Chesapeake Bay was divided in seven rounds in Maryland and three rounds in Virginia (20-26 September, 25-31 October and 15-21 November). Each round was of approximately 30 days in duration.

25. Striped bass were tagged and released during six-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.

26. A total of 3,881 striped bass were tagged in Virginia. The number of stripers tagged and released was 715, 2052 and 1,114 for the three tagging rounds. The striped bass tagged in all three rounds were predominantly from the 1996 and 1997 year classes.

27. A total of 178 striped bass tagged in Virginia were recaptured by 31 December. Of these recaptures, 19 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.

28. The Chesapeake Bay estimate of total fishing mortality (F) was 0.28. This is the sum of non-harvest (0.10) and harvest (0.1) 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 2001.

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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 Anadromous Fishes Program at 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 26 March - 3 May, 2001. 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 44, 45 and 47) on the Rappahannock River. Pound nets are fixed commercial gears that have been the historically predominant gear type used in the river and are presumed to be non size-selective in their catches of striped bass. The established protocol (Sadler *et al.* 1999) was to alternate the choice of the net sampled but weather constraints often dictated whether that net could be sampled. In addition 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.

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.

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.

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. Mean age was determined by the sum of the relative contribution of each age class to the total (aged) catch.

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 subsamples for each fish 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)

Results

Catch Summary

Rappahannock River

Pound nets: Striped bass (n= 577) were sampled between 2 April and 3 May, 2001 from the pound nets in the Rappahannock River. Total catches peaked on 23 April and again on 30 April, due to large numbers of males striped bass (Table 1). Catches of female striped bass were highest on 23 April, but were generally available throughout April. Males made up 81.8% of the total catch, but were less prevalent than in 2000 (96%) or in 1999 (94.5%). Males dominated the 1997-1999 year classes (99.4%) and the 1993-1996 year classes (80.1%), but females dominated the 1984-1992 year classes (87.0%).

Biomass catch rates (g/day) of male striped bass were highest on 23 and 30 April (Table 2). The biomass catch rates of female striped bass were highest on 5 April and on 16 April. The catch rate of males greatly exceeded that of females on 2 April and again from 30 April - 3 May (7.4:1 on 30 April). Biomass catch rates of females exceeded that for males only 5-19 April and again on 26 April (19.8:1 on 9 April). The mean ages of male striped bass varied from 3.9-5.8 years with the youngest mean ages occurring at the beginning and at the end of the sampling period. The mean ages of females varied from 6.8-10.0 years, but varied from only 9.0-10.0 years from 16-30 April.

During the 30 March - 3 May period, the 1997 (40.2%) and 1996 (23.5%) year classes were the most abundant (Table 3). These year classes were 97.3% male. The contribution of males age-6 and older (the pre-1996 year classes) was 5.2% of the total aged catch . These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age-8 and older, presumably repeat spawners, was 15.4% of the total aged catch but was also 84.8% of the total females captured.

Experimental gill nets: Striped bass (n= 640) were also sampled between 29 March and 3 May, 2001 from two multi-mesh experimental gill nets in the Rappahannock River. Total catches peaked sharply on 16 April and again on 23 April, due to large numbers of young (2-4 year old) males (Table 4). Catches of female striped bass were highest from 12-16 April, but were generally caught only in low numbers throughout the sampling period. Males made up 93.4% of the total catch. Males dominated the 1997-1999 year classes (99.7%) and the 1993-1996 year classes (92.5%), but the 1984-1992 year classes were exclusively female.

Biomass catch rates (g/day) of male striped bass were highest on 16 April and on 23 April (Table 5). The biomass catch rates of female striped bass were highest from 12-16 April. The catch rate of males exceeded that of females except on 12 and 16 April. The mean ages of male striped bass varied from 3.8-5.6 years with the oldest males (5-8 years) being prevalent from 5-12 April. The mean ages of females varied from 7.6-10.0 years but these means were based on very low total catches.

During the 30 March - 3 May period, the 1997 (42.3%) and 1996 (26.6%) year classes were prevalent (Table 6). These year classes were 98.4% male. The contribution of males age-6 and older (the pre-1996 year classes) was only 5.6% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age-8 and older, presumably repeat spawners, was 4.5% of the total aged catch but was 70.7% of the total females captured.

James River

Experimental gill nets: Striped bass (n= 1,133) were sampled between 26 March and 3 May, 2001 from the two multi-mesh experimental gill nets in the James River. Total catches peaked from 9-12 April and again on 23 April, due to large catches of male striped bass (Table 7). Catches of female striped bass were consistent, although small, peaking on 9 and 23 April. Males dominated the 1997-1999 year classes (99.0%) and the 1993-1996 year classes (91.7%), but females were prevalent in the 1985-1992 year classes (80.0%).

Biomass catch rates (g/day) of male striped bass were highest from 9-12 April and on 23 April (Table 8). The biomass catch rates of female striped bass were highest from 2-9 April, peaking sharply on 9 April. The biomass catch rate of females exceeded that of males only on 2 April. Catch rates of males greatly exceeded that for females on 12 April (13.6:1) and from 23-26 April (8.2-9.1:1). The mean ages of male striped bass varied from 3.9-4.9 years, but varied from only 4.2-4.4 years from 12-30 April. The mean ages of females varied from 5.2-9.8 years, but varied from 8.0-9.8 years from 26 March - 12 April and from 5.2-7.5 years from 16 April - 3 May.

During the 30 March - 3 May period, the 1997 (37.6%) and 1996 (28.9%) year classes were the most abundant (Table 9). These year classes were 97.2% male. The contribution of males age-6 and older (the pre-1995 year classes) was only 3.0% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age-8 and older, presumably repeat spawners, was only 2.6% of the total aged catch but was also 42.6% of the total females captured.

Spawning Stock Biomass Indexes

Rappahannock River

Pound nets: The Spawning Stock Biomass Index (SSBI) for spring 2001 was 24.2 kg/day for male striped bass and 27.6 kg/day for female striped bass. The index for male striped bass lower than 1999-2000 and was slightly greater than the 11-year average (Table 10). The magnitude of the index for male striped bass was largely determined by the 1996 and 1997 year classes (67.7%). The index for female striped bass was the highest since 1998 and was slightly greater than the 11-year average (Table 10). The magnitude of the index for the females was largely the result of the pre-1994 year classes (94.1%).

Experimental gill nets: The Spawning Stock Biomass Index for spring 2001 was 88.6 kg/day for male striped bass and 30.9 kg/day for female striped bass. The index for male striped bass was the highest since 1997, and was 16.1% above the 11-year average (Table 10). The 1997-1998 year classes contributed 74.9% of the biomass in the male index. The index for female striped bass was the highest since 1995, but was still 9.8% below the 11-year average. However, the increase did reverse a trend of declining indexes that occurred from1993-1999. The pre-1994 year classes contributed 88.8% of the biomass in the female index.

James River

Experimental gill nets: The Spawning Stock Biomass Index for spring 2001 was 181.4 kg/day for male striped bass and 41.3 kg/day for female striped bass. Although the male index was lower than in 2000, it was 241.1% above the eight-year average (Table 11). The 1996 and 1997 year classes contributed 71.7% of the biomass in the male index. In contrast, he female index was the second lowest index to date and was 22.5% below the eight-year average. The pre-1994 year classes accounted for 70.0% 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:

$$N_o = 0.0005 \times FL^{3.2}$$

Where N_o is the total number of oocytes and FL is the fork length (>400) in millimeters. Thus, the predicted egg production was 106,000 for a 400-mm female and 3,381,000 for a 1180-mm female striped bass (Table 12). The Egg Production Potential Indexes (EPPI, Table 13) for the

Rappahannock River were 3.992 (pound nets) and 4.039 (gill nets). The EPPI for the James River was 5.286. The indexes for the Rappahannock River were heavily dependent on the egg production potential of the older (8+ years) females (94.3% in the pound nets, 89.3% in the gill nets), while the James River index was more evenly distributed among age groups. Modest changes in the methodology in 2001 preclude direct comparison with the 1999 and 2000 indexes.

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

Rappahannock River

Pound nets: Catch rates (number of fish/day) of individual years classes from 1991-2001 are presented in Tables 14-16. The cumulative annual catch rate for 2001 was 53.1% lower than the catch rate for 2000 (Table 14). The reduction was the result of much lower catch rates of three and four old (1997 and 1998 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 1995-1997 year classes were strongest and the 1990 and 1991 year classes were the weakest.. The cumulative catch rate of female stripers was actually higher than in 2000 and was the first increase between years since 1996-1997 (Table 16).

The range of overall ages was unchanged from 1991-2001, 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 (1997-2001). 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 0.754-0.853 (mean = 0.814) as cumulative catch rates ranged from 1.44-4.45 fish/day (mean = 2.84).

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 (1991-2001) of the 1983-1993 year classes (sexes combined) varied from 0.561-0.869 (Table 17) with an overall mean survival rate of 0.648. 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 (1991-2001) of the 1985-1993 year classes of males varied from 0.317-0.627 (Table 18) with an overall mean survival rate of 0.412. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2001) of the 1983-1989 year classes of females varied from 0.548-0.817 (Table 19) with an overall mean survival rate of 0.649.

Experimental gill nets: Catch rates (number of fish/day) of individual years classes from 1991-2001 are presented in Tables 20-22. In contrast to the pound net catch rates, the cumulative annual catch rate (sexes combined) for 2001 from the gill nets was 19.8% higher than in 2000 and 8.5% above the 11-year average (Table 20). The cumulative catch rate was driven by the catch rates of the1996-1997 year classes (4- 5 year old) of striped bass. The age of peak abundance for each year has declined from age five (1992-1996) to age four (1997, 1998, 2000 and 2001) and age three (1999).

The overall age structure from 1991-2000 consisted of 2-12 year old males (Table 21) and 2-14 year old females (Table 22), but the 2001 catches contained no males older than eight. The age of peak male abundance declined from age five (1993-1995) to age three (1996 and 1999) and age four (1997-1998 and 2000-2001). The proportion of females age eight and older increased from 0.147-0.652 from 1991-1996, declined from 0.652-0.347 from 1996-1999, then rebounded to 0.707 in 2001.

The cumulative catch rate of male striped bass increased for the first year 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 2001 cumulative catch rate of female striped bass was 44.4% higher than the 2000 catch rate and was the second 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 (1991-2001) of the 1984-1992 year classes (sexes combined) varied from 0.408-0.691 (Table 23) with an overall mean survival of 0.535. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1991-2001) of the 1984-1993 year classes of males varied from 0.153-0.388 (Table 24) with an overall mean survival of 0.304. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2001) of the 1984-1990 year classes of females varied from 0.501-0.736 (Table 25) with an overall mean survival rate of 0.617. 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: Catch rates (number of fish/day) of individual years classes from 1994-2001 are presented in Tables 26-28. The cumulative annual catch rate for 2001 was the second highest of the time series, but was 26.9% lower than the catch rate for 2000 (Table 26). The cumulative catch rate was driven by higher catch rates for the 3-5 year old (1996-1998 year classes), mostly male striped bass. The relative contribution of these age classes has increased from 0.492-0.645 (1995-1999) to 0.845-0.880 (2000-2001).

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 3-6 years in 1994 to 2-10 years in 2001 (Table 27). The age structure of female striped bass was stable from 1994-2001, 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, increased for the second consecutive year to 0.426.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 2001 catch rate being the second highest overall, but 29.8% lower than and the cumulative catch rate for 2000 (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 2001 cumulative catch rate of female striped bass 65.9% higher than in 2000, but was the third lowest in the time series, and was less than one third 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 (1994-2001) of the 1984 - 1992 year classes (sexes combined) varied from 0.330-0.783 (Table 29), with an overall mean survival rate of 0.534. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1994-2001) of the 1988-1993 year classes of males varied from 0.281-0.729 (Table 30) with an overall mean survival rate of 0.520. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1994-2001) of the 1984-1990 year classes of females varied from 0.340-0.687 (Table 31) with an overall mean survival rate of 0.505.

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 2001, the down-river net was not set and fished for the first time until 9 April. In addition, on 26 April an intermediate net at river mile 45 was sampled out of necessity. 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). However, on 26 April the effort was only 48 hrs.

In past years efforts as low as 24 hrs. and as large as 196 hrs. were encountered 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 100 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 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 1991-2001. There was a steady decrease in the relative abundance of five to seven year-old striped bass. The males in these age classes are targeted by the recreational and commercial fisheries. 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, the relative contribution of virgin spawners (four through seven years) has decreased.

Of note in the 2001 samples was the relative abundance of 1992 year class (nine 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 2001 values of the Spawning Stock Biomass Index (SSBI) for the Rappahannock River were higher than in 2000 for female striped bass from both gears and for male striped bass from the gill nets only. The increase in the female indexes was due to the influx of strong 1991 and 1992 year classes into the spawning stock. There was also an increase in the number of 10-year and older females in both the pound nets and gill nets as compared to the 2000 data. These oldest stripers had become increasingly abundant from 1991-1999 and have become increasingly responsible for the bulk of the female SSBI.

The 1991-2001 values of the SSBI in the Rappahannock River were not consistent between pound nets and gill nets. In the pound nets, male biomass peaked in 1993 due to strong 1988 and 1989 year classes, and again in 1999 and 2000 due to strong 1996 and 1997 year classes. The female biomass from pound nets, which increased for the first time since 1996-1997, show a trend of increasing reliance on fewer, but older (and heavier) striped bass. 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, which the local fishermen say alters the catchability of the striped bass. It is also possible that the spawning migration continued past the end of sampling in those years.

The 2001 values of the SSBI in the James River were second highest for males and second lowest for females since the survey began in 1994. The male index was driven by large catches of the 1996-1998 year classes. Because of the changes in location and in the methodology utilized by the new waterman 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 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. The egg-size relationship for 2001 is limited by small sample size, especially females over 1000 mm fork length with ovaries at the proper maturation state. It should be noted the egg-size relationship from the current study produced fecundity estimates well below those reported by other authors (Setzler et al. 1980), so 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 2000-2001. 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 nine-year old, 1992 year class, striped bass of both sexes 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 survival of the year classes using catch curves, especially for the 1983-1993 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 0.65 in pound nets and 0.60 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 0.41 in pound nets and 0.30 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 0.30 for male striped bass and approximately 0.62 for females.

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Table 1. Numbers of striped bass in three age categories (year classes 1997-1999, 1993-1996 and 1984-1992) in pound nets in the Rappahannock River by sampling date in spring 2001.

Date	n	Year Class							
		1997 - 1999		1993 - 1996		1984 - 1992		Not aged	
		M	F	M	F	M	F	M	F
2 April	43	31	0	8	3	0	1	0	0
5 April	48	19	0	8	7	0	14	0	0
9 April	8	2	0	0	2	0	4	0	0
12 April	18	8	1	3	2	0	4	0	0
16 April	47	8	0	14	7	5	13	0	0
19 April	43	28	0	6	1	1	7	0	0
23 April	108	32	1	51	7	3	14	0	0
26 April	32	14	0	7	4	0	7	0	0
30 April	169	130	0	35	0	1	3	0	0
3 May	61	45	0	13	3	0	0	0	0
Total	577	**317**	**2**	**145**	**36**	**10**	**67**	**0**	**0**

Table 2. Net-specific summary of catch rates and ages of striped bass (n= 577) in pound nets on the Rappahannock River, spring 2001. 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
2 April	S473	43	9.8	1.0	14,658.7	4,964.4	3.9	6.8
5 April	S473	48	9.0	7.0	13,759.0	61,021.1	4.3	9.2
9 April	S441	8	2.0	6.0	837.6	16,604.2	4.0	8.8
12 April	S473	18	5.5	3.5	10,346.3	25,833.6	4.5	8.4
16 April	S473	47	9.0	6.7	28,989.2	58,487.7	5.8	9.6
19 April	S441	43	11.7	2.7	15,232.5	22,179.2	4.1	9.3
23 April	S474	108	43.0	11.0	48,343.8	42,584.4	5.0	9.0
26 April	S454	32	10.5	5.5	15,128.7	46,732.6	4.3	9.5
30 April	S474	169	41.5	0.8	49,928.0	6,729.4	4.0	10.0
3 May	S441	61	19.3	1.0	23,621.1	6.133.7	4.0	7.7
Totals	S441	112	10.6	1.9	13,230.4	13,475.3	4.0	8.8
	S454	32	10.5	5.5	15,128.7	46,732.6	4.3	9.5
	S473	433	17.8	2.9	30,033.0	27,888.0	4.4	9.1
Season		**577**	**15.2**	**3.4**	**24,193.2**	**26,298.6**	**4.3**	**9.1**

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 2001.

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
1999	male	2	315.0	12.7	390.7	27.8	0.1	25.2
1998	male	85	394.8	21.5	784.9	139.7	2.7	2,152.1
1997	male	230	451.9	22.9	1,178.2	205.1	7.4	8,741.2
	female	2	481.5	12.0	1,563.1	107.7	0.1	100.8
1996	male	125	524.0	22.9	1,891.2	283.7	4.0	7,625.9
	female	8	543.9	31.9	2,247.3	446.3	0.3	580.0
1995	male	3	633.3	52.7	3,391.1	954.7	0.1	328.2
1994	male	12	710.0	18.4	4,663.9	471.8	0.4	1,805.4
	female	6	725.8	26.9	4,936.9	419.0	0.2	955.5
1993	male	5	748.6	20.0	6,211.5	857.5	0.2	1,001.9
	female	22	790.5	21.3	6,831.2	870.2	0.7	4,847.9
1992	male	6	820.8	12.5	7,171.4	645.2	0.2	1,388.0
	female	21	827.2	16.4	8,017.6	760.4	0.7	5,431.3
1991	male	4	870.0	16.3	8,722.4	1,132.3	0.1	1,125.5
	female	21	874.8	24.1	9,182.7	1,216.3	0.7	6,220.6
1990	female	14	935.1	22.1	10,888.3	1,076.0	0.5	4,917.3
1989	female	8	984.0	16.3	12,201.3	1,447.6	0.3	3,148.7
1988	female	3	1,053.7	35.9	14,418.8	1,785.6	0.1	1,395.4

Table 4. Numbers of striped bass in three age categories (year classes 1997-1999, 1993-1996 and 1984-1992) in gill nets in the Rappahannock River by sampling date in spring 2001.

Date	n	Year Class							
		1997 - 1999		1993 - 1996		1984 - 1992		Not aged	
		M	F	M	F	M	F	M	F
29 March	18	14	0	3	0	0	1	0	0
2 April	27	16	0	7	2	0	2	0	0
5 April	26	15	0	9	0	0	2	0	0
9 April	8	2	1	3	1	0	1	0	0
12 April	18	3	0	6	2	0	7	0	0
16 April	216	129	0	72	10	0	5	0	0
19 April	28	22	0	5	0	0	1	0	0
23 April	176	106	0	66	1	0	3	0	0
26 April	30	21	0	5	1	0	2	1	0
30 April	82	50	0	31	0	0	0	1	0
3 May	11	9	0	2	0	0	0	0	0
Total	**640**	**387**	**1**	**209**	**17**	**0**	**24**	**2**	**0**

Table 5. Summary of catch rates and mean ages of striped bass (n=640) from the two gill nets in the Rappahannock River, spring 2001. 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
29 March	18	17.0	1.0	26,377.9	8,273.7	4.1	9.0
2 April	27	23.0	4.0	39,808.5	31,181.9	3.9	9.0
5 April	26	24.0	2.0	44,836.6	17,058.6	4.5	9.5
9 April	8	5.0	3.0	16,516.2	17,612.5	5.6	6.7
12 April	18	9.0	9.0	20,592.6	84,308.6	5.0	9.2
16 April	216	201.0	15.0	294,227.5	100,208.4	4.2	7.6
19 April	28	27.0	1.0	32,100.3	10,090.4	3.8	10.0
23 April	176	172.0	4.0	265,329.8	28,359.7	4.3	8.5
26 April	30	27.0	3.0	33,507.1	20,655.9	4.0	8.0
30 April	82	82.0	0.0	127,880.2	0.0	4.4	
3 May	11	11.0	0.0	14,065.3	0.0	4.2	
Season	**640**	**54.4**	**3.8**	**81,331.8**	**28,944.2**	**4.3**	**8.3**

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, 2001.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
1999	male	9	306.1	9.5	357.3	28.4	0.9	321.5
1998	male	94	378.0	31.9	694.2	168.2	9.4	6,525.3
	female	1	420.0		944.6		0.1	94.5
1997	male	270	458.0	21.5	1,273.4	209.3	27.0	34,382.3
1996	male	170	518.5	22.6	1,880.2	294.0	17.0	31,962.8
	female	7	543.6	32.9	2,431.8	507.2	0.7	1,702.3
1995	male	19	636.3	25.8	3,460.9	525.2	1.9	6,575.6
	female	2	616.0	5.7	3,696.2	282.2	0.2	739.2
1994	male	13	694.8	37.7	4,620.0	814.3	1.3	6,006.1
	female	2	688.5	26.2	5,098.7	535.5	0.2	1,019.7
1993	male	4	762.3	3.6	6,194.0	368.2	0.4	2,477.6
	female	6	794.5	12.6	7,839.0	440.2	0.6	4,703.4
1992	female	11	838.4	17.4	8,749.7	860.3	1.1	9,624.7
1991	female	9	877.3	24.4	10,015.0	1,112.2	0.9	9,013.5
1990	female	1	995.0		14,559.5		0.1	1,456.0
1989	female	1	965.0		12,871.3		0.1	1,287.1
1987	female	1	1,030.0		13,072.0		0.1	1,307.2
N/A	male	2	601.5	170.4	3,176.1	2,363.4	0.2	635.2

N/A: not ageable

Table 7. Numbers of striped bass in three age categories (year classes 1997-1999, 1993-1996 and 1985-1992) in gill nets in the James River by sampling date in spring 2001.

Date	n	Year Class							
		1997 - 1999		1993 - 1996		1985 - 1992		Not aged	
		M	F	M	F	M	F	M	F
26 March	42	22	0	15	1	1	3	0	0
29 March	41	16	0	22	2	0	1	0	0
2 April	30	11	0	13	1	0	5	0	0
5 April	65	30	0	27	1	2	5	0	0
9 April	254	110	0	125	7	1	8	2	1
12 April	182	106	0	71	1	1	2	1	0
16 April	78	39	1	31	5	2	0	0	0
19 April	63	33	0	26	3	0	1	0	0
23 April	230	139	2	78	9	0	2	0	0
26 April	48	24	0	21	3	0	0	0	0
30 April	72	46	2	20	4	0	0	0	0
3 May	28	19	1	2	4	0	1	1	0
Total	**1133**	**595**	**6**	**451**	**41**	**7**	**28**	**4**	**1**

Table 8. Summary of catch rates and mean ages of striped bass (n=1,133) from the two gill nets in the James River, spring 2001. 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
26 March	42	38.0	4.0	77,614.5	39,535.0	4.4	9.3
29 March	41	38.0	3.0	89,195.4	24,179.9	4.9	8.0
2 April	30	24.0	6.0	52,891.3	62,584.1	4.5	9.5
5 April	65	59.0	6.0	129,736.3	66,241.2	4.6	9.8
9 April	254	238.0	16.0	495,441.9	120,092.5	4.7	8.3
12 April	182	179.0	3.0	337,596.6	24,779.8	4.4	8.7
16 April	78	72.0	6.0	141,124.8	28,570.4	4.5	6.5
19 April	63	59.0	4.0	98,721.6	23,691.0	4.3	7.5
23 April	230	217.0	13.0	354,011.2	43,306.9	4.3	5.9
26 April	48	45.0	3.0	77,991.5	8,569.2	4.5	5.3
30 April	72	66.0	6.0	96,898.8	16,611.8	4.2	5.2
3 May	28	22.0	6.0	30,712.6	19,029.8	3.9	5.5
Totals	**1,133**	**88.1**	**6.3**	**165,161.4**	**39,766.0**	**4.5**	**7.4**

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, 2001.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
1999	male	3	311.3	13.3	381.8	78.6	0.3	114.5
	female	1	306.0		391.8		0.1	39.2
1998	male	135	389.8	24.6	830.4	155.9	13.5	11,210.1
1997	male	419	456.5	21.4	1,351.1	222.0	41.9	56,610.0
	female	5	471.0	20.8	1,586.9	340.1	0.5	793.5
1996	male	310	529.6	27.4	2,142.9	392.5	31.0	66,431.4
	female	16	539.6	23.3	2,339.1	303.8	1.6	3,742.6
1995	male	76	613.7	28.2	3,310.3	532.1	7.6	25,158.5
	female	8	599.3	18.8	3,072.7	341.6	0.8	2,458.1
1994	male	17	691.2	39.1	4,726.1	880.1	1.7	8,034.4
	female	9	731.9	31.7	5,716.9	813.7	0.9	5,145.2
1993	male	11	763.6	34.6	6,605.4	876.1	1.1	7,265.9
	female	5	781.2	19.2	6,915.3	969.4	0.5	3,457.6
1992	male	2	846.5	19.1	9,073.1	781.5	0.2	1,814.6
	female	8	835.5	21.5	9,014.8	869.3	0.8	7,211.8
1991	male	4	877.3	25.9	10,027.0	1,128.5	0.4	4,010.8
	female	11	890.2	26.6	10,727.8	1,545.6	1.1	11,800.6
1990	female	5	955.0	27.0	12,927.4	960.8	0.5	6,463.7
N/A	male	4	506.0	153.0	2,157.6	1,851.6	0.4	863.1
	female	1	540.0		2,354.2		0.1	235.4

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, 1991-2001.

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
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	**408**	**101**	**21.4**	**26.0**	**47.4**	**423**	**57**	**76.3**	**34.0**	**110.3**

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, 1994-2001. 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
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		**410**	**98**	**80.94**	**61.22**	**142.17**

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 2001.

FL	Fecundity	FL	Fecundity	FL	Fecundity	FL	Fecundity
400	0.106	600	0.388	800	0.975	1000	1.991
420	0.124	620	0.431	820	1.055	1020	2.121
440	0.144	640	0.477	840	1.139	1040	2.257
460	0.166	660	0.527	860	1.228	1060	2.399
480	0.190	680	0.579	880	1.322	1080	2.546
500	0.217	700	0.636	900	1.421	1100	2.700
520	0.246	720	0.696	920	1.524	1120	2.861
540	0.277	740	0.759	940	1.633	1140	3.027
560	0.311	760	0.827	960	1.747	1160	3.201
580	0.348	780	0.899	980	1.866	1180	3.381

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 2001. The Egg Production Potential Indexes (millions of eggs/day) are in bold.

Age	Rappahannock River						James River		
	Pound Nets			Gill Nets			Gill Nets		
	n	E	%	n	E	%	n	E	%
4	2	0.013	0.3%	0	0.000	0.0%	5	0.091	1.7%
5	8	0.075	1.9%	7	0.202	5.0%	16	0.450	8.5%
6	0	0.000	0.0%	2	0.085	2.1%	8	0.313	5.9%
7	6	0.140	3.5%	2	0.122	3.0%	9	0.670	12.7%
8	22	0.674	16.9%	6	0.578	14.3%	5	0.457	8.6%
9	21	0.743	18.6%	11	1.259	31.2%	8	0.907	17.2%
10	21	0.890	22.3%	9	1.193	29.5%	11	1.528	28.9%
11	14	0.734	18.4%	1	0.198	4.9%	5	0.869	16.4%
12	8	0.493	12.4%	1	0.179	4.4%	0		
13	3	0.231	5.8%	0	0.000	0.0%	0		
14	0			1	0.198	5.5%	0		
15	0			0			0		
Total	**105**	**3.992**	**100.0%**	**40**	**4.039**	**100.0%**	**67**	**5.286**	**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, 1991-2001. 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
1999											**0.07**
1998										0.03	**2.74**
1997									0.79	**15.61**	7.49
1996								0.19	11.54	**18.13**	4.29
1995							0.60	2.15	**11.50**	3.34	0.10
1994					0.04	0.51	3.90	**6.33**	2.79	0.11	0.58
1993					3.04	3.97	**8.10**	1.48	0.11	0.50	0.87
1992			0.12	1.44	**4.80**	2.86	1.25	0.04	0.50	0.50	0.87
1991		0.20	0.68	0.48	1.00	**1.63**	0.05	0.52	0.43	0.40	0.81
1990	0.42	0.50	1.04	1.33	**2.24**	1.26	0.70	0.70	0.32	0.29	0.45
1989	0.33	0.60	3.58	**4.59**	0.68	0.89	0.80	0.78	0.36	0.37	0.26
1988	3.50	1.60	**9.54**	2.22	0.60	0.37	1.50	0.89	0.39	0.05	0.10
1987	**8.00**	2.75	3.65	1.15	0.68	0.37	1.00	0.89	0.43	0.05	0.00
1986	**2.67**	1.15	0.65	0.59	0.40	0.09	1.00	0.22	0.04	0.00	
1985	**1.67**	0.30	0.42	0.52	0.08	0.00	0.35	0.15	0.11	0.00	
1984	0.50	0.40	**0.58**	0.33	0.28	0.00	0.35	0.07	0.04	0.00	
1983	0.25	0.20	**0.46**	0.33	0.08	0.03	0.20	0.00			
>1983	0.75	0.45	0.73	0.34	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
Total	**18.75**	**8.45**	**21.83**	**13.89**	**14.52**	**12.29**	**20.30**	**14.85**	**29.88**	**39.69**	**18.63**

N/A: not aged

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, 1991-2001. 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
1999											**0.07**
1998										0.03	**2.74**
1997									0.79	**15.61**	7.42
1996								0.19	11.36	**18.11**	4.03
1995							0.55	2.15	**11.46**	3.21	0.10
1994					0.04	0.51	3.80	**6.19**	2.68	0.08	0.39
1993					2.88	3.83	**7.50**	1.37	0.07	0.26	0.16
1992			0.12	1.22	**4.68**	2.66	1.15	0.00	0.36	0.11	0.19
1991		0.15	0.54	0.48	0.92	**1.34**	0.05	0.30	0.21	0.05	0.13
1990	0.17	0.35	0.96	1.30	**2.00**	0.94	0.35	0.11	0.00	0.03	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
1988	3.25	0.90	**7 .54**	1.11	0.12	0.03	0.20	0.00			
1987	**6.08**	0.65	1.23	0.22	0.00	0.09	0.00				
1986	**2.58**	0.30	0.15	0.11	0.04	0.00					
1985	**0.50**	0.05	0.04	0.04	0.00						
1984	0.08	**0.15**	0.08	0.00							
1983				0.00							
1982				0.04							
N/A	0.25	0.10	0.27	0.41	0.44	0.23	0.25	0.33	0.54	0.32	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**

N/A: not aged

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, 1991-2001. 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
1998											
1997											**0.07**
1996										0.03	**0.26**
1995							0.05	0.00	0.04	**0.13**	0.00
1994							0.10	0.15	0.11	0.03	**0.19**
1993					0.16	0.14	0.60	0.11	0.04	0.24	**0.71**
1992				0.22	0.12	0.20	0.10	0.04	0.14	0.40	**0.68**
1991		0.05	0.04	0.00	0.08	0.29	0.00	0.22	0.21	0.34	**0.68**
1990	0.25	0.15	0.08	0.04	0.24	0.31	0.35	**0.59**	0.32	0.26	0.45
1989	0.17	0.20	0.12	**1.07**	0.60	0.46	0.25	0.74	0.32	0.34	0.26
1988	0.33	0.70	**2.00**	1.11	0.48	0.34	1.30	0.89	0.39	0.05	0.10
1987	1.92	2.10	**2.42**	0.93	0.68	0.29	1.00	0.89	0.43	0.05	0.00
1986	**1.08**	0.85	0.50	0.48	0.36	0.09	1.00	0.22	0.04	0.00	
1985	**1.17**	0.25	0.39	0.48	0.08	0.00	0.35	0.15	0.11	0.00	
1984	0.42	0.25	**0.50**	0.33	0.28	0.00	0.35	0.07	0.04	0.00	
1983	0.25	0.20	**0.46**	0.33	0.08	0.03	0.20	0.00			
1982	0.17	0.30	**0.31**	0.15	0.00						
>1982	**0.58**	0.15	0.42	0.15	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
Total	**6.59**	**5.40**	**7.35**	**5.44**	**3.32**	**2.23**	**5.90**	**4.19**	**2.18**	**1.87**	**3.40**

N/A: not aged

Table 17. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2001.

Year Class	Survival (S)										
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1998											------
1997										0.480	0.480
1996										0.237	0.237
1995									0.290	0.030	0.093
1994								0.440	0.456	0.456	0.451
1993							0.183	0.838	0.838	0.838	0.573
1992					0.596	0.437	0.913	0.913	0.913	0.913	0.752
1991						0.869	0.869	0.869	0.869	0.869	0.869
1990					0.563	0.745	0.745	0.863	0.863	0.863	0.765
1989				0.440	0.440	0.899	0.975	0.689	0.689	0.703	0.664
1988			0.232	0.877	0.877	0.877	0.593	0.438	0.506	0.506	0.565
1987	0.675	0.675	0.315	0.954	0.954	0.954	0.890	0.483	0.116	0.000	0.561
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 survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2001.

Year Class	Survival (S)										
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1998											------
1997										0.475	0.475
1996										0.223	0.223
1995									0.280	0.031	0.093
1994								0.433	0.381	0.381	0.398
1993							0.183	0.436	0.436	0.615	0.382
1992					0.568	0.432	0.368	0.368	0.726	0.726	0.510
1991						0.473	0.473	0.700	0.786	0.786	0.627
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	0.394
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, 1991-2001.

Year Class	Survival (S)										
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1998											------
1997											------
1996											------
1995											------
1994											------
1993											------
1992											------
1991											------
1990								0.914	0.914	0.914	0.914
1989				0.912	0.912	0.912	0.912	0.678	0.678	0.765	0.817
1988			0.898	0.898	0.898	0.898	0.685	0.438	0.506	0.506	0.688
1987			0.802	0.802	0.802	0.802	0.890	0.483	0.116	0.000	0.548
1986	0.987	0.987	0.987	0.987	0.987	0.987	0.220	0.181	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			0.914	0.914	0.914	0.914	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, 1991-2001. 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
1999											**0.90**
1998										1.47	**9.50**
1997									11.70	18.11	**27.00**
1996								0.11	**35.70**	21.26	17.70
1995							0.83	**11.67**	10.60	5.79	2.10
1994						1.90	29.50	**32.78**	3.20	1.79	1.50
1993					4.50	20.00	**83.00**	7.00	0.80	2.00	1.00
1992				2.78	7.00	11.40	**14.33**	0.78	1.20	0.63	1.10
1991			0.50	2.56	1.88	**5.70**	2.83	1.33	0.50	0.32	0.90
1990	0.11	0.56	1.50	**8.22**	7.75	3.50	2.17	0.33	0.10	0.21	0.10
1989	1.33	0.78	8.60	**27.56**	4.50	2.50	0.67	0.33	0.20	0.11	0.10
1988	9.00	1.89	**25.40**	8.22	2.88	1.50	1.17	0.33	0.20	0.11	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
1986	**10.56**	3.33	2.60	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					
1983	0.33	0.11	**1.30**	0.56	0.13	0.00					
>1983	0.44	0.44	0.60	0.22	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
Total	**50.33**	**15.00**	**52.80**	**55.78**	**33.75**	**49.80**	**137.50**	**57.00**	**64.50**	**51.90**	**62.20**

N/A: not aged

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, 1991-2001. 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
1999											**0.90**
1998										1.47	**9.40**
1997									11.60	18.11	**27.00**
1996								0.11	**35.70**	20.95	17.00
1995							0.83	**11.67**	10.60	5.68	1.90
1994						1.90	29.50	**32.56**	2.60	1.26	1.30
1993					4.50	20.00	**82.50**	6.44	0.60	1.37	0.40
1992				2.78	6.75	11.30	**14.00**	0.56	0.90	0.11	0.00
1991			0.50	2.56	1.75	**5.60**	2.50	0.67	0.30	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	0.17	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					
1985	**2.22**	0.11	0.00	0.33	0.00						
1984	**0.67**	0.11	0.10	0.11	0.00						
1983				0.00							
1982				0.10							
N/A	0.78	0.00	0.80	1.56	0.88	1.20	2.50	1.78	2.30	0.11	0.20
Total	**45.11**	**6.78**	**36.60**	**46.22**	**24.75**	**45.20**	**134.33**	**54.00**	**64.80**	**49.06**	**58.10**

N/A: not aged

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, 1991-2001. 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
1998											**0.10**
1997									0.10	0.00	0.00
1996									0.10	0.32	**0.70**
1995									0.00	0.11	**0.20**
1994								0.22	**0.60**	0.53	0.20
1993							0.33	0.56	0.20	**0.63**	0.60
1992					0.13	0.10	0.33	0.22	0.30	0.53	**1.10**
1991					0.13	0.10	0.33	0.67	0.20	0.32	**0.90**
1990		0.11	0.00	0.00	**0.63**	0.30	0.33	0.11	0.10	0.21	0.10
1989	0.11	0.00	0.30	**2.22**	1.88	1.10	0.17	0.33	0.20	0.11	0.10
1988	0.11	0.56	**5.10**	3.33	1.75	1.00	1.00	0.33	0.10	0.11	0.00
1987	0.78	3.11	**6.10**	1.78	1.63	1.50	0.50	0.11	0.00	0.00	0.10
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					
1983	0.33	0.11	**1.30**	0.56	0.13	0.00					
1982	0.22	**0.44**	0.30	0.22	0.00						
>1982	**0.22**	0.00	0.20	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
Total	**5.22**	**8.22**	**16.00**	**11.11**	**8.75**	**4.60**	**3.00**	**2.78**	**2.30**	**2.84**	**4.10**

N/A: not aged

Table 23. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2001.

Year Class	Survival (S)										
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1998											------
1997											------
1996									0.596	0.833	0.705
1995								0.908	0.546	0.363	0.565
1994								0.098	0.559	0.838	0.358
1993							0.084	0.535	0.535	0.500	0.331
1992							0.289	0.289	0.957	0.957	0.526
1991						0.496	0.470	0.878	0.878	0.878	0.691
1990				0.943	0.452	0.620	0.152	0.798	0.798	0.476	0.533
1989				0.163	0.556	0.268	0.500	0.667	0.550	0.909	0.455
1988			0.324	0.350	0.521	0.780	0.282	0.606	0.550	0.000	0.408
1987	0.666	0.666	0.203	0.829	0.914	0.313	0.220	0.969	0.969	0.969	0.579
1986	0.315	0.781	0.729	0.729	0.217	0.856	0.856	0.000	------	------	0.526
1985	0.754	0.754	0.754	0.449	0.719	0.719	0.719	0.719	0.000	------	0.599
1984	0.500	0.927	0.927	0.373	0.000	------	------	------	------	------	0.502
1983			0.431	0.232	0.000	------	------	------	------	------	0.208

Table 24. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2001.

Year Class	Survival (S)										
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1998											------
1997											------
1996									0.587	0.811	0.690
1995								0.908	0.536	0.335	0.546
1994								0.199	0.707	0.707	0.463
1993							0.078	0.461	0.461	0.292	0.264
1992							0.254	0.254	0.122	0.000	0.153
1991						0.446	0.268	0.448	0.000	------	0.276
1990				0.851	0.457	0.572	0.120	0.000	------	------	0.366
1989				0.104	0.532	0.357	0.000	------	------	------	0.231
1988			0.241	0.231	0.442	0.340	0.767	0.767	0.000	------	0.373
1987	0.441	0.441	0.079	0.949	0.949	0.949	0.949	0.949	0.000	------	0.365
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	0.548	0.548	0.548	0.000	------	------	------	------	------	------	0.388

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, 1991-2001.

Year Class	Survival (S)										
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1998											------
1997											------
1996											------
1995											------
1994									0.883	0.378	0.578
1993										0.952	0.952
1992											------
1991											------
1990					0.724	0.724	0.860	0.860	0.860	0.476	0.736
1989				0.847	0.585	0.548	0.548	0.667	0.550	0.909	0.651
1988			0.653	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	0.598
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
1982		0.682	0.733	0.000	------	------	------	------	------	------	0.428

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, 1994-2001. 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
1999								0.40
1998							1.50	**13.50**
1997						0.20	20.50	**42.40**
1996						9.10	**69.60**	32.60
1995					1.22	10.30	**36.40**	8.40
1994			0.10	1.55	7.11	**11.70**	10.50	2.60
1993		0.67	1.60	4.44	5.22	**6.10**	2.00	1.60
1992		**4.33**	2.90	3.33	3.00	2.90	1.30	1.00
1991	2.40	**8.89**	4.50	2.00	1.67	2.20	0.60	1.50
1990	**12.40**	11.11	3.10	2.00	0.78	1.40	0.40	0.50
1989	**12.20**	9.78	2.70	0.89	1.11	1.20	0.10	0.00
1988	**3.60**	2.67	1.00	1.44	0.78	0.40	0.10	0.00
1987	0.80	**2.67**	1.00	1.11	0.67	1.00	0.00	
1986	0.80	**1.89**	0.80	0.33	0.11	0.30	0.00	
1985	0.80	**1.22**	0.30	0.22	0.11	0.10	0.00	
1984	**1.20**	0.78	0.10	0.11	0.00			
1983	**0.80**	0.33	0.00					
1982	**0.40**	0.22	0.00					
N/A	0.80	2.00	0.20	0.33	0.33	1.30	1.40	0.50
Total	**35.80**	**44.56**	**18.30**	**17.78**	**22.11**	**48.20**	**143.70**	**105.00**

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, 1994-2001. 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
1999								0.30
1998							1.50	**13.50**
1997						0.20	20.40	**41.90**
1996						7.30	**69.10**	31.00
1995					1.22	8.00	**35.20**	7.60
1994			0.10	1.56	6.78	5.20	**10.00**	1.70
1993		0.67	1.60	**3.89**	3.78	2.50	1.60	1.10
1992		**4.22**	2.80	2.33	1.67	1.10	1.10	0.20
1991	2.40	**7.89**	3.60	1.44	1.33	0.10	0.00	0.40
1990	**10.60**	6.33	1.50	1.33	0.22	0.30	0.00	
1989	**8.00**	2.33	0.80	0.44	0.00	0.00	0.00	
1988	**1.40**	0.56	0.30	0.11	0.11	0.10	0.00	
1987		**0.44**	0.10	0.00				
1986		0.11	0.00					
N/A	0.80	1.44	0.10	0.00	0.11	0.50	0.70	0.40
Total	**23.20**	**24.00**	**10.90**	**11.11**	**15.22**	**25.30**	**139.60**	**98.10**

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, 1994-2001. 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
1999								**0.10**
1998								0.00
1997							0.10	0.50
1996						**1.80**	0.50	1.60
1995						**2.30**	1.20	0.80
1994					0.33	**6.50**	0.50	0.90
1993				0.56	1.44	**3.60**	0.40	0.50
1992		0.11	0.10	1.00	1.33	**1.80**	0.20	0.80
1991		1.00	0.90	0.56	0.67	**2.10**	0.60	1.10
1990	1.80	**4.78**	1.50	0.67	0.56	1.10	0.40	0.50
1989	4.00	**7.44**	1.90	0.44	1.11	1.20	0.10	0.00
1988	**2.20**	2.11	0.70	1.33	0.67	0.30	0.10	0.00
1987	0.80	**2.22**	0.90	1.11	0.67	1.00	0.00	
1986	0.80	**1.78**	0.80	0.33	0.11	0.30	0.00	
1985	0.40	**1.22**	0.30	0.22	0.11	0.10	0.00	
1984	**1.20**	0.78	0.20	0.11	0.00			
1983	**0.80**	0.33	0.00					
1982	**0.40**	0.22	0.00					
N/A	0.00	0.56	0.10	0.33	0.22	0.80	0.00	0.10
Total	**12.40**	**22.56**	**7.40**	**6.67**	**7.22**	**22.90**	**4.10**	**6.80**

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, 1994-2001.

Year Class	Survival (S)							
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1996							0.468	0.468
1995							0.231	0.231
1994						0.897	0.248	0.472
1993						0.328	0.800	0.512
1992		0.877	0.877	0.901	0.967	0.448	0.769	0.783
1991		0.506	0.788	0.788	0.788	0.826	0.826	0.744
1990	0.896	0.279	0.645	0.837	0.837	0.598	0.598	0.632
1989	0.801	0.276	0.763	0.763	0.763	0.044	0.000	0.448
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	------	0.363
1985		0.245	0.733	0.500	0.909	0.000	------	0.439
1984	0.650	0.376	0.376	0.000	------	------	------	0.330
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, 1994-2001.

Year Class	Survival (S)							
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1996							0.449	0.449
1995							0.216	0.216
1994							0.170	0.170
1993				0.971	0.662	0.640	0.688	0.729
1992		0.663	0.833	0.717	0.812	0.812	0.182	0.602
1991		0.456	0.401	0.923	0.670	0.670	0.670	0.608
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, 1994-2001.

Year Class	Survival (S)							
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	Mean
1996						0.942	0.942	0.942
1995						0.522	0.667	0.590
1994						0.372	0.372	0.372
1993						0.373	0.373	0.373
1992						0.667	0.667	0.667
1991						0.724	0.724	0.724
1990		0.314	0.902	0.902	0.902	0.674	0.674	0.687
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

Figure 1. Locations of commercial pound nets and experimental gill nets sampled in spring spawning stock assessments of striped bass in the Rappahannock River, 1991-2001.

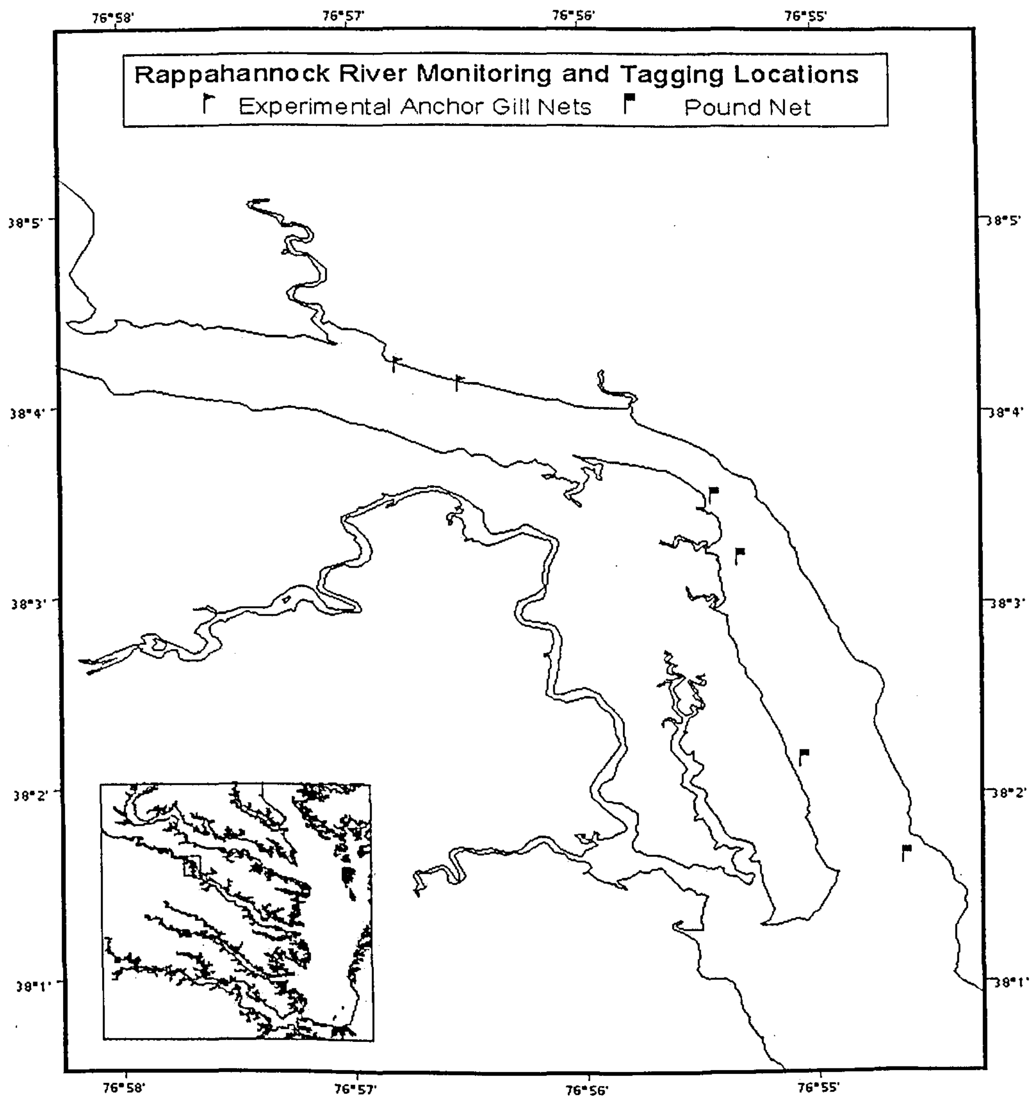


Figure 2. Locations of experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, spring 2001.

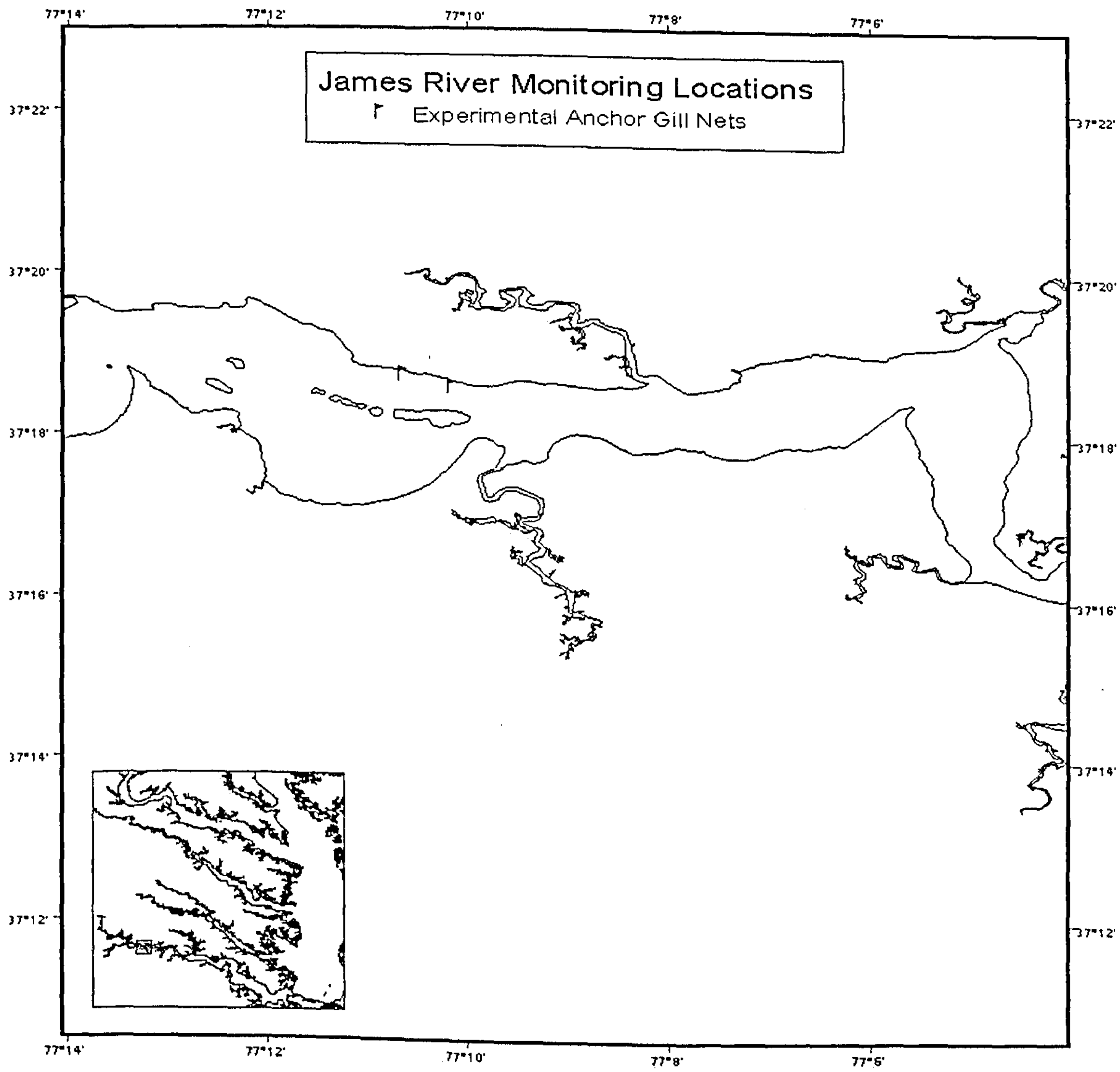


Figure 3. Catch rates (number of fish per day) of eight year classes (1987-1994) of male and female striped bass in pound nets in the Rappahannock River, 30 March - 3 May, 1991-2001.

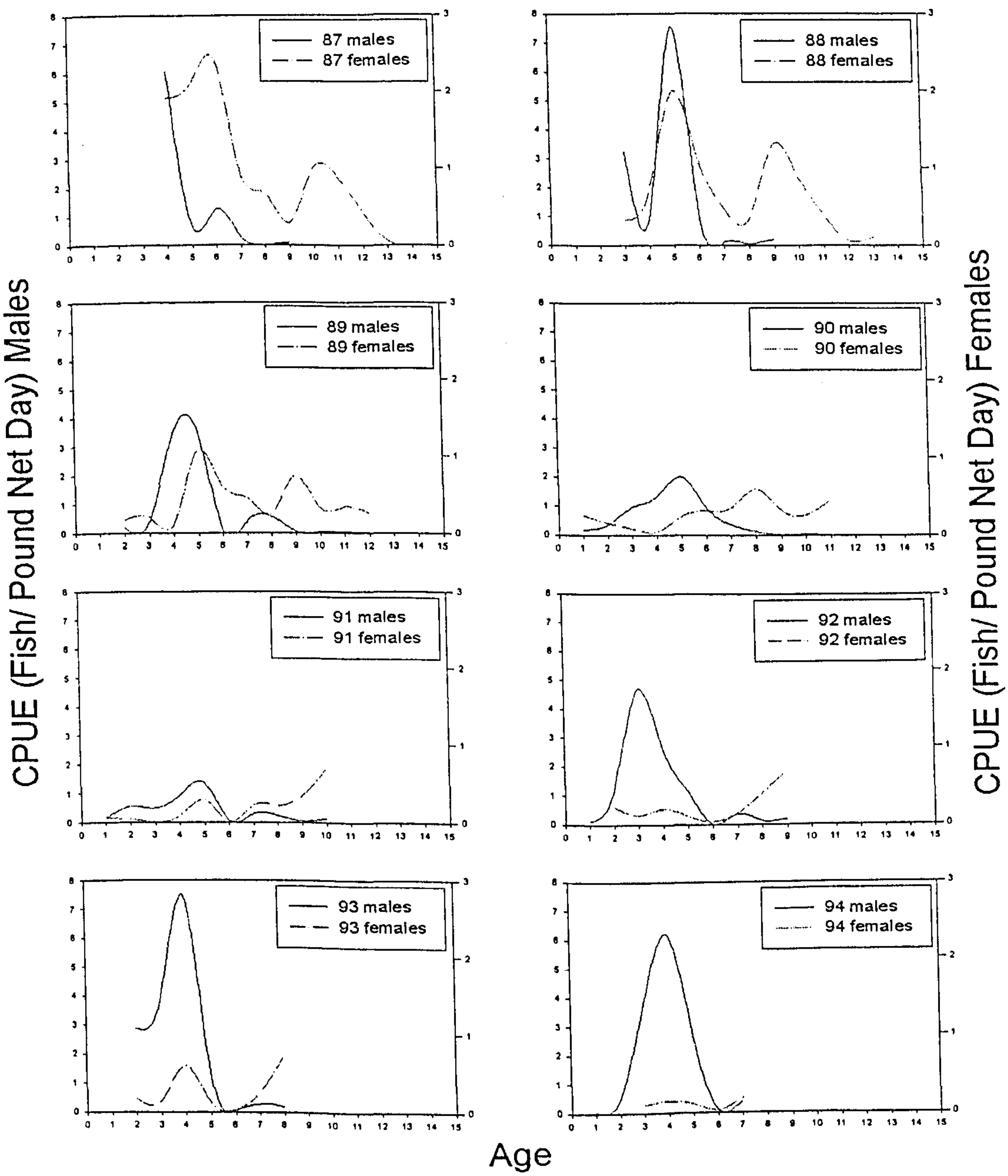


Figure 4. Catch rates (number of fish per day) of eight year classes (1987-1994) of male and female striped bass in experimental gill nets in the Rappahannock River, 30 March - 3 May, 1991-2001.

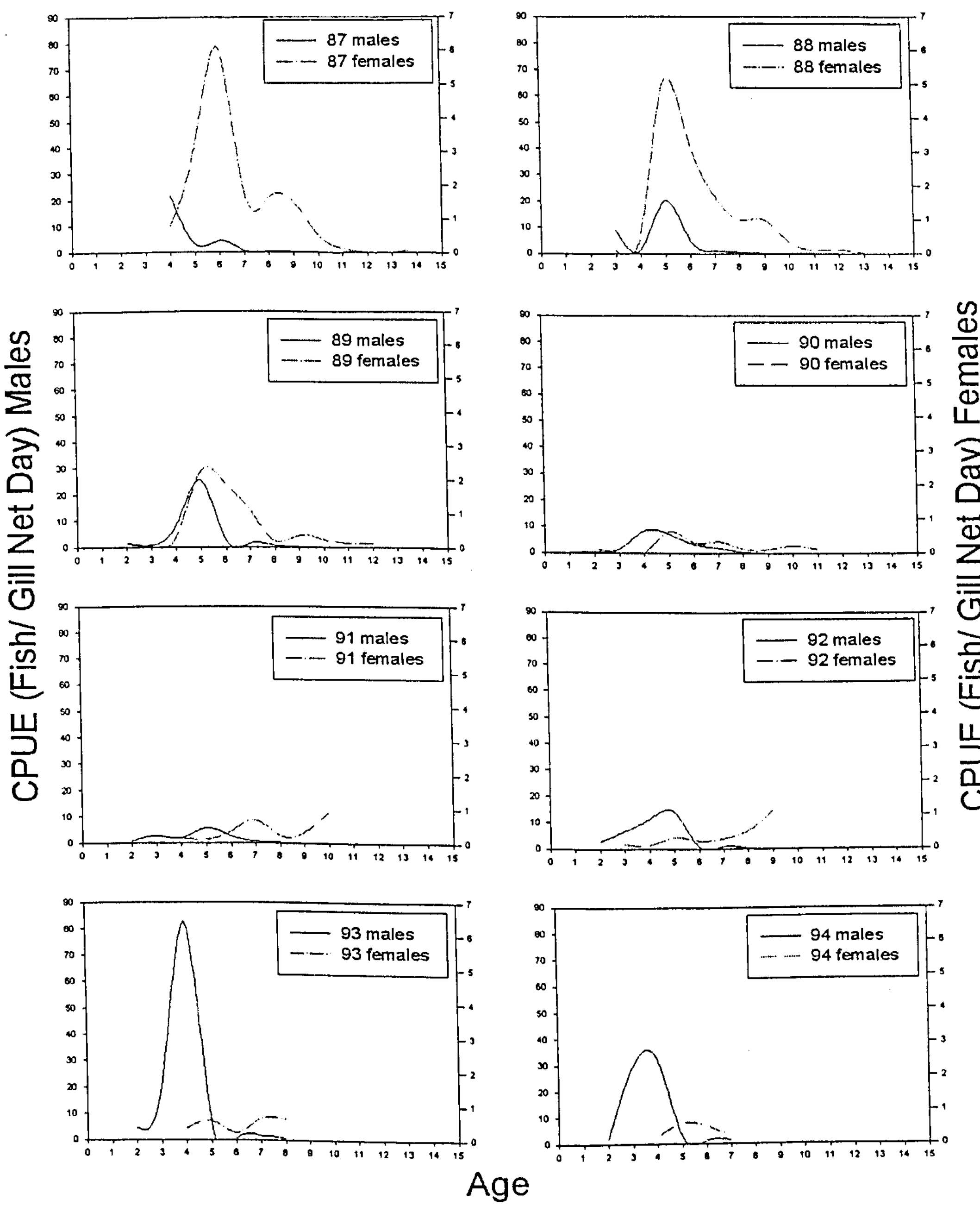
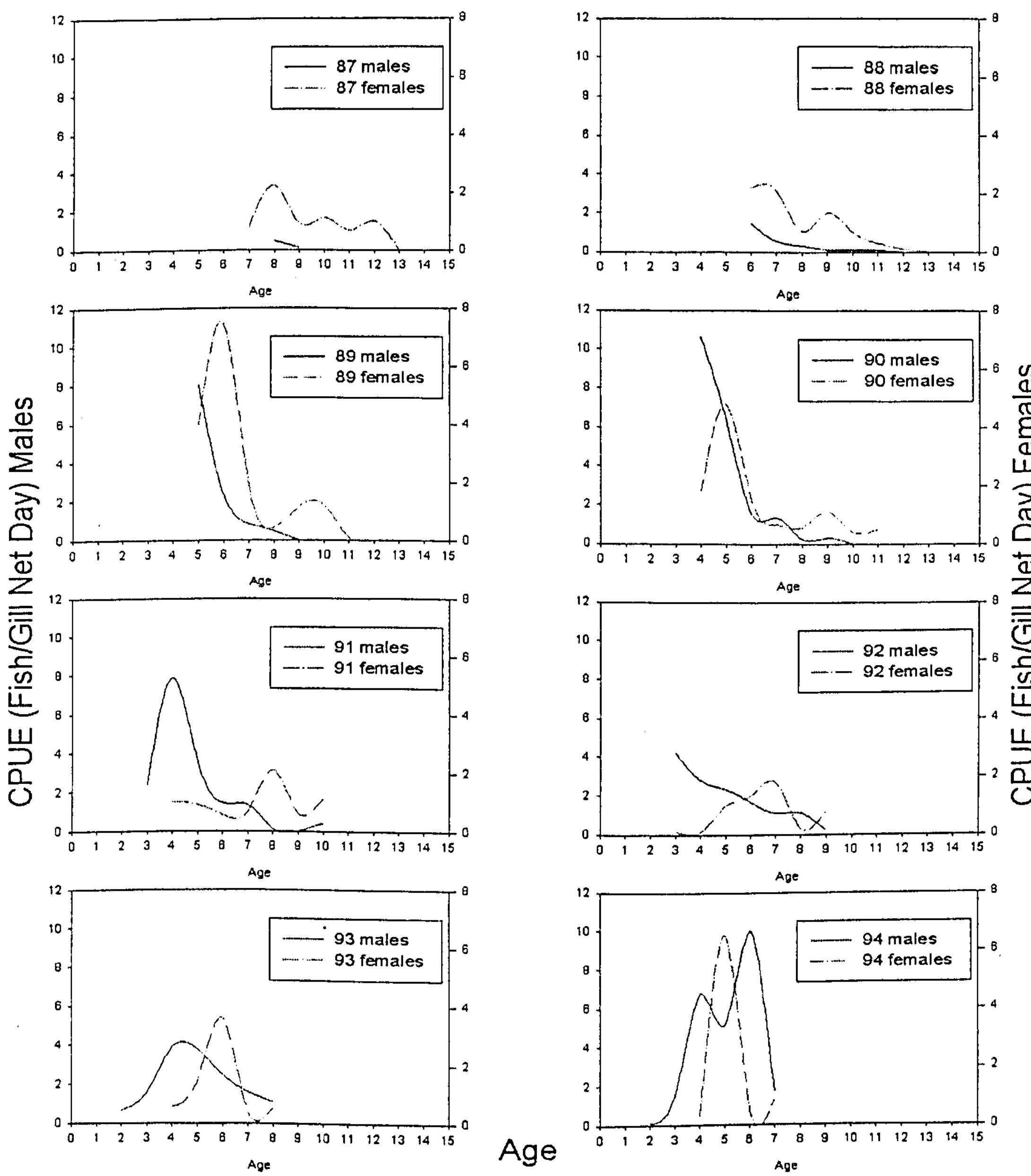


Figure 5. Catch rates (number of fish per day) of eight year classes (1987-1994) of male and female striped bass in experimental gill nets in the James River, 30 March - 3 May, 1991-2001.



II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2000-2001

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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 1987 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

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

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

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

where $\phi\lambda$ is the probability of surviving being tagged and retaining the tag in the short-term, λ 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 dipnetted 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 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 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 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 2001

Tag release summary: A total of 797 striped bass were tagged and released from the pound nets in the Rappahannock River between 26 March and 30 April, 2001 (Table 1). There were 528 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (93.9%), 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 10 April. There were 269 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly female (79.9%) and their average size was larger than the male striped bass. The median date of these tag releases was also 10 April.

A total of 179 striped bass were tagged and released from the VIMS research pound net in the York River between 20 February and 16 May, 2001 (Table 2). There were 160 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (81.9%), but the female stripers were larger on average. The median date of these tag releases was 2 May. There were 19 migrant striped bass (>710 mm TL) tagged and released. These stripers were exclusively female. It is problematic that the number of striped bass tagged and released in the York River will be insufficient to produce a reliable mortality estimate.

Mortality estimates, 2000-2001

Tag recapture summary: A total of 27 migratory striped bass (>710 mm total length), tagged during spring 2000, were recaptured between 11 April, 2000 and 9 April, 2001 (the respective midpoints of the two spring tag release totals). Thirteen of these recaptures were harvested (recapture rate = 0.481), and the remainder were re-released into the population (Table 3). The recapture rate for the time series varied from 0.423-0.867 (mean = 0.612). Only six of the tagged striped bass were recaptured within Chesapeake Bay (0.222). Other recaptures came from Massachusetts (7 = 0.259), New York (4 = 0.148), New Jersey (4 = 0.148), Rhode Island (1 = 0.037), New Hampshire (1 = 0.037), Virginia coast (1 = 0.037), North Carolina (1 = 0.037) and two of indeterminate location.

ASMFC protocol: The suite of Seber 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 significantly larger 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 0.60-0.72 over the time series (Table 5). 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 0.13-0.34 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(.) and the S(p_2)r(p_1) models of 0.41 and 0.18, respectively.

Instantaneous rates models: All parameter estimates using Hoenig *et al.* models for Rappahannock River striped bass were based on a chop variable of eight diagonals. Use of additional diagonals led to numerical difficulties with the estimation process.

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 0.11-0.19 and from 1995-1999, the estimates ranged from 0.17-0.31. However, the 2000 estimate of F (0.06) was the lowest in the time series regardless of regulation period. The low estimate for F resulted mainly from a lower than average recapture rate (0.07 vs. the 11-year average of 0.10).

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. (2001c) 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. The residual matrix of the instantaneous rates model was found to possess fewer constraints than the time-specific Seber model (Latour *et al.* 2001b). 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 eight diagonals for the Rappahannock River data analyses, the data from only three diagonals was 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.

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 was large and has 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. The spring tagging program in the

Rappahannock River provides data valuable to the ASMFC on the annual survival of the striped bass spawning stocks in the Virginia tributaries of the Chesapeake Bay.

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 2001.

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 March	111	84	536.2	7	632.1	3	839.7	17	857.0
29 March	69	53	528.3	3	661.3	4	807.8	9	942.8
2 April	59	45	545.2	4	592.0	2	761.5	8	923.1
5 April	78	39	522.4	1	621.0	10	796.0	28	896.2
9 April	110	44	514.8	7	601.0	7	779.0	52	868.5
12 April	28	10	552.3	1	556.0	1	804.0	16	903.4
16 April	56	16	549.9	5	567.8	3	824.0	32	887.3
19 April	91	61	546.3	1	556.0	7	797.9	22	929.4
23 April	57	35	525.9	2	580.5	5	812.0	15	903.7
26 April	51	31	537.9	1	540.0	8	846.0	11	875.5
30 April	87	31	537.9	1	540.0	8	846.0	11	875.5
Total	797	496	535.1	32	601.8	54	807.1	215	889.9

Table 2. Summary data of striped bass tagged and released the VIMS research pound net in the York River, spring 2001.

Date	total tagged	457 - 710 mm TL				> 710 mm TL			
		males		females		males		females	
		n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$
20 Feb.	1	0		0		0		1	772.0
27 Feb.	1	0		0		0		1	788.0
1 March	1	0		0		0		1	916.0
16 March	7	7	589.7	0		0		0	
20 March	2	0		0		0		2	724.0
23 March	3	2	586.0	0		0		1	713.0
27 March	7	5	538.6	0		0		2	783.5
29 March	3	2	557.0	0		0		1	712.0
3 April	3	0		2	635.5	0		1	776.0
10 April	2	1	563.4	0		0		1	800.0
17 April	6	2	491.0	1	665.0	0		2	739.0
24 April	15	6	579.2	1	690.0	0		5	786.6
1 May	85	69	538.8	15	615.1	0		1	790.0
16 May	43	37	530.8	6	615.1	0		1	790.0
Total	179	131	541.6	29	616.9	0		19	773.3

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

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

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

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight	number of parameters
S(.)r(.)	2014.77	0.00	0.42	2
S(p_2)r(p_1)	2016.31	1.54	0.20	5
S(.)r(p_1)	2016.42	1.65	0.18	3
S(p_1)r(p_1)	2016.45	2.69	0.11	4
S(p_3)r(p_1)	2019.46	4.70	0.04	5
S(p_4)r(p_4)	2020.67	5.91	0.02	6
S(Tp_1)r(p_1)	2021.18	6.42	0.02	6
S(Tp_1)r(Tp_1)	2023.76	9.00	0.01	8
S(.)r(t)	2025.25	10.48	0.00	12
S(p_1)r(t)	2026.97	12.20	0.00	13
S(t)r(p_1)	2028.81	14.05	0.00	13
S(Tp_1)r(t)	2020.58	14.82	0.00	15
S(t)r(t)	2035.00	20.23	0.00	21

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, 1990-2000.

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	0.24	0.17, 0.42

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; fishing ($\hat{F}$) and tag reporting ($\hat{\phi\lambda}$) rates when natural mortality is assumed to be 0.15, for striped bass (>711 mm FL) in the Rappahannock River, 1990-2000.

Year	$\phi\lambda = 0.43$		M = 0.15	
	$\hat{F}_i$ (SE)	$\hat{M}$ (SE)	$\hat{F}_i$ (SE)	$\hat{\phi\lambda}$ (SE)
1990	0.11 (0.05)	0.31 (0.14)	0.32 (N/a)	0.35 (N/a)
1991	0.11 (0.04)		0.30 (N/a)	
1992	0.13 (0.07)		0.38 (N/a)	
1993	0.19 (0.07)		0.38 (N/a)	
1994	0.19 (0.07)		0.41 (N/a)	
1995	0.28 (0.08)		0.42 (N/a)	
1996	0.17 (0.08)		0.25 (N/a)	
1997	0.20 (0.06)		0.29 (Na)	
1998	0.31 (0.09)		0.43 (N/a)	
1999	0.29 (0.10)		0.45 (N/a)	
2000	0.06 (0.05)		0.23 (N/a)	

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

III. Fishing mortality estimates of the fall 2000 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 (< 7 days) tag release periods, synchronized with the Maryland DNR effort and separated by 3-4 weeks, were executed with the first tagging round occurring prior to the start of each fall recreational season (4 Oct in 2000). 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 discontinued after 1998 due to a drastic decline in their use by commercial fishermen.

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.* In preparation).

Results

Tag release summary

In fall 2000, a total of 3,881 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, 20-26 September: The 715 striped bass tagged and released came primarily (70.3%) 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 lack of success 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 1997 (77.9%) and 1996 (20.7%) year classes (Table 3). The mean age of the striped bass varied from 3.11 years (lower Chesapeake Bay) to 3.42 years (James River). The mean size (FL) of the striped bass tagged and released varied from 460.0 mm (lower Chesapeake Bay) to 486.8 mm (James River). The midpoint of the tagging round was 21 September.

Tagging round 6, 25-31 October: The 2,052 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 James River.

The majority of the striped bass tagged and released were from the 1997 (75.2%) and 1996 (23.3%) year classes (Table 5). The mean age of the striped bass varied from 3.11 years (lower Chesapeake Bay) to 3.52 years (James River). The mean size (FL) of the striped bass tagged and released varied from 461.0 mm (lower Chesapeake Bay) to 498.2 mm (James River). The midpoint of the tagging round was 27 October.

Tagging round 7, 15-21 November: The 1,114 striped bass tagged and released reflect a different strategy relative to the previous tagging rounds. Striped bass were abundant at all tagging locations, which allowed the tag releases to be concentrated in the first days of the tagging round (Table 6). This facilitated maximum time for tag dispersal prior to the traditional peak of recreational fishing effort associated with the Thanksgiving holidays. Water temperatures during the tagging round ranged from 11-12 °C. Tagging quotas were met or exceeded in every region except for lower Chesapeake Bay (our cooperating fisherman ceased commercial operations).

The majority of the striped bass tagged and released were from the 1997 (79.7%) and 1996 (19.7%) year classes (Table 7). The mean age of the striped bass varied from 3.1 years (upper Chesapeake Bay) to 3.37 years (James River). The mean size of the striped bass tagged and released varied from 458.5 mm (middle Chesapeake Bay) to 489.2 mm (James River). The midpoint of the tagging round was 16 November.

Tag recapture summary

A total of 178 tagged striped bass were recaptured from 20 September - 31 December, 2000 (Table 8). The overall proportion of recapture was 0.046 and varied from 0.012 (upper Bay) to 0.184 (York River). The proportion of striped bass recaptured within the same area as they were tagged was highest in the lower Chesapeake Bay (0.926) and the York River (0.924) and lowest in the middle Chesapeake Bay (0.278). Striped bass tagged in the Virginia part of Chesapeake Bay were predominantly (0.966) recaptured there, but there were six recaptures elsewhere (three in Maryland, one in the Potomac River and two in the Atlantic Ocean). The striped bass recaptured from James River releases were larger and older than the striped bass recaptured from the other areas, but this was largely the result of one large striper within a small sample size.

Recapture interval 5, 22 September - 27 October: A total of 57 striped bass (8.0%) tagged in the fifth tagging round were recaptured by 31 December (0.08% per day). Only one of these recaptures did not occur within the fifth recapture interval (Table 9). Sport fishermen (recreational and charter anglers) accounted for only 23.2% of the recaptures during the recapture interval. These anglers also released more tagged striped than they harvested. The five harvested recaptured striped bass by sport fishermen are the data included in the computation of fishing mortality. Commercial harvest accounted for 41.1% of the recaptured striped bass during the recovery interval and was concentrated in the pound nets near the mouth of the York River (considered lower Bay nets). 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, 28 October - 16 November: A total of 114 striped bass (5.6%) tagged in the sixth tagging round were recaptured by 31 December (0.09% per day). However, four tagged striped bass were recaptured between the beginning of the tagging round and the beginning of the recovery interval and 14 tagged striped bass were recaptured after the recovery interval (Table 10). Sport fishermen accounted for 13.5% of the recaptures during the recapture interval. In contrast to the fifth recapture interval, 76.9% of these recaptured striped bass were harvested rather than being released. The 10 harvested recaptured striped bass by sport fishermen are the data included in the computation of fishing mortality. Commercial harvest accounted for 19.8% of the recaptured striped bass during the recovery interval and was concentrated in the pound nets in the lower York River.

Recapture interval 7, 17 November - 31 December: A total of seven striped bass (0.6%) tagged in the seventh tagging round were recaptured by 31 December (0.01% per day). All the recaptures occurred within the recovery interval (Table 11). Sport fisherman accounted for 85.7% of the recaptures during the recapture interval and harvested more than they released. The four harvested recaptured striped bass are the data included in the computation of fishing mortality.

Several factors during the recapture interval account for the low number of recaptures. Our cooperating fisherman in the mouth of the York River (five pound nets) ceased commercial operations the first week of November. These nets historically provided large numbers of striped bass for tagging and subsequent recaptures. Most other 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 was only one commercial recapture 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 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 2000 was 0.18. A non-harvest mortality rate of 0.10 was added to produce the final estimate of a recreational/ charter fishing mortality of 0.28 (Hornick *et al.* 2001).

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.

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 (83.1%) 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 the lower and middle York River (>90%). The prevalence of same-area recapture was also very high (>80%) in the James and Rappahannock 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), Rappahannock River, Piankatank River (all north and west of the release site), York River, Mobjack Bay, Back River (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, Cape Henry (both at the mouth of Chesapeake Bay) and from the Atlantic Ocean all occurred between 11-31 December.

The Chesapeake Bay-wide estimate of resident striped bass fishing mortality was 0.28. This was the sum of the estimate of both non-harvest (0.10) and harvest (0.18) mortalities. Non harvest mortalities include natural deaths and handling-induced mortalities. In our fall 2000 study 44.9% of the recaptures were released alive (30.3% of commercial recaptures, 46.7% of sport recaptures and 85.1% of research recaptures). The fishing mortality estimate was equal to 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 2000. Note: tagging rounds 1-4 were in Maryland only.

Tagging round	Dates	Location	Quota	Releases
5	20-26 Sep.	Chesapeake Bay - upper	100	57
		Chesapeake Bay - middle	100	148
		Chesapeake Bay - lower	100	58
		Rappahannock River	350	356
		York River	100	18
		James River	250	79
		Subtotal	1000	716
6	25-31 Oct.	Chesapeake Bay - upper	200	327
		Chesapeake Bay - middle	100	365
		Chesapeake Bay - lower	200	426
		Rappahannock River	300	529
		York River	100	222
		James River	300	182
		Subtotal	1200	2051
7	15-21 Nov.	Chesapeake Bay - upper	200	374
		Chesapeake Bay - middle	100	100
		Chesapeake Bay - lower	200	0
		Rappahannock River	200	297
		York River	100	118
		James River	200	225
		Subtotal	1000	1114

Table 2. Daily striped bass tag release totals, by area, during round 5 (20-26 September) of the fall 2000 fishing mortality (F) study.

Tag release area	20 Sep	21 Sep	22 Sep	23 Sep	24 Sep	25 Sep	26 Sep
Chesapeake Bay (upper region)			57				
Chesapeake Bay (middle region)		147					
Chesapeake Bay (lower region)	29		17				12
Rappahannock River (upper region)		259				61	
Rappahannock River (middle region)	15					21	
York River (middle region)	12					6	
James River (middle region)	16	61					
James River (lower region)	2						
totals	74	467	74			88	12

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 (20-26 September) of the fall 2000 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm)		mean age
				YC	total	
Chesapeake Bay (upper region)	1997	36	63.2	459.7	481.1	3.37
	1996	21	36.8	517.8		
Chesapeake Bay (middle region)	1997	126	85.1	455.8	465.3	3.15
	1996	22	14.9	520.0		
Chesapeake Bay (lower region)	1998	1	1.7	426.0	460.0	3.11
	1997	50	86.2	454.2		
	1996	5	8.6	498.0		
	1995	1	1.7	618.0		
	n/aged	1	1.7	471.0		
Rappahannock River	1997	280	78.7	458.3	471.6	3.22
	1996	72	20.2	517.6		
	1995	2	0.6	575.5		
	1994	1	0.3	692.0		
	n/aged	1	0.3	460.0		
York River	1997	14	77.8	458.1	474.1	3.22
	1996	4	22.2	530.8		
James River	1998	1	1.3	426.0	486.8	3.42
	1997	52	85.8	461.6		
	1996	24	30.4	525.4		
	1994	1	1.3	718.0		
	1993	1	1.3	700.0		

Table 4. Daily striped bass tag release totals, by area, during round 6 (25-31 October) of the fall 2000 fishing mortality (F) study.

Tag release area	25 Oct	26 Oct	27 Oct	28 Oct	29 Oct	30 Oct	31 Oct
Chesapeake Bay (upper region)		89					238
Chesapeake Bay (middle region)		180				185	
Chesapeake Bay (lower region)	134		105			187	
Rappahannock River (upper region)	299					61	
Rappahannock River (middle region)	110						121
York River (middle region)	94					128	
James River (middle region)	169	61					
James River (lower region)	5		8				
totals	811	330	113			561	359

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 (25-31 October) of the fall 2000 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm) YC	mean FL (mm) total	mean age
Chesapeake Bay (upper region)	1997	265	81.0	456.3	469.8	3.20
	1996	59	18.0	522.1		
	1995	1	0.3	591.0		
	1994	1	0.3	730.0		
	n/aged	1	0.3	569.0		
Chesapeake Bay (middle region)	1998	1	0.3	426.0	468.1	3.21
	1997	292	80.0	454.1		
	1996	71	19.5	525.3		
	n/aged	1	0.3	542.0		
Chesapeake Bay (lower region)	1997	379	89.0	453.7	461.0	3.11
	1996	44	10.3	515.2		
	1995	2	0.5	650.5		
	n/aged	1	0.2	480.0		
Rappahannock River	1998	1	0.2	423.0	485.4	3.39
	1997	316	59.7	460.8		
	1996	191	36.1	520.3		
	1995	9	1.7	594.2		
	1994	1	0.2	705.0		
	n/aged	11	2.1	480.9		

York River	1997	166	74.7	460.5	477.3	3.29
	1996	52	23.4	518.9		
	1995	1	0.5	610.0		
	1994	1	0.5	652.0		
	1991	1	0.5	845.0		
	n/aged	1	0.5	435.0		
James River	1997	113	62.1	462.2	498.2	3.52
	1996	57	31.3	526.8		
	1995	3	1.6	630.3		
	1994	3	1.6	696.3		
	1993	3	1.6	764.7		
	1992	2	1.1	838.5		
	n/aged	1	0.6	470.0		

Table 6. Daily striped bass tag release totals, by area, during round 7 (15-21 November) of the fall 2000 fishing mortality (F) study.

Tag release area	15 Nov	16 Nov	17 Nov	18 Nov	19 Nov	20 Nov	21 Nov
Chesapeake Bay (upper region)		374					
Chesapeake Bay (middle region)	100					0	
Chesapeake Bay (lower region)							
Rappahannock River (upper region)	222						
Rappahannock River (middle region)	56					19	
York River (middle region)	83		35				
James River (middle region)	221						
James River (lower region)	4						
totals	686	374	35			19	

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 (15-21 November) of the fall 2000 fishing mortality study.

Tagging location	year class	n	%	mean FL (mm)		mean age
				YC	total	
Chesapeake Bay (upper region)	1997	334	89.3	454.6	459.8	3.10
	1996	37	9.9	506.9		
	n/aged	3	0.8	456.0		
Chesapeake Bay (middle region)	1997	85	85.0	448.6	458.5	3.14
	1996	12	12.0	517.3		
	1995	1	1.0	623.0		
	n/aged	2	2.0	444.5		
Chesapeake Bay (lower region)	not sampled					
Rappahannock River	1997	234	78.8	454.6	470.5	3.23
	1996	58	19.5	522.2		
	1995	3	1.0	618.0		
	1994	1	0.3	755.0		
	n/aged	1	0.3	465.0		
York River	1997	86	72.9	461.9	477.0	3.26
	1996	31	26.2	519.8		
	n/aged	1	0.8	445.0		
James River	1997	141	62.7	464.8	489.2	3.37
	1996	80	35.6	530.6		
	1995	1	0.4	605.0		
	n/aged	3	1.3	497.0		

Table 8. Number, location, mean fork length (FL in mm) and mean age of recaptured striped bass, by release location, 20 September - 31 December, 2000.

Release location	Chesapeake Bay (Va.) recaptures*								
		location						mean	
		river			Chesapeake Bay			FL	age
	total	Rap.	York	James	upper	middle	lower		
Rappahannock River	22	19	0	0	0	0	2	476.5	3.4
York River	66	0	61	1	0	0	4	478.9	3.3
James River	7	0	0	6	0	0	0	535.6	3.9
Chesapeake Bay (upper)	11	0	0	0	7	0	1	457.0	3.1
Chesapeake Bay (middle)	18	6	1	0	0	5	5	465.6	3.2
Chesapeake Bay (lower)	54	1	2	0	0	1	50	454.5	3.0

*Other recaptures:

(tagging location)	(recapture location)
James River	1 Atlantic Ocean
Rappahannock River	1 Atlantic Ocean
Chesapeake Bay (upper)	2 Maryland
	1 Potomac River
Chesapeake Bay (middle)	1 Maryland

Table 9. Summary of the disposition of striped bass tagged during round 5 (20-26 September) and subsequently recaptured prior to 31 December, with emphasis on the fifth recapture interval(22 September - 27 October, 2000).

Release location	recaptures								
	total	20 Sep - 21 Sep	22 Sep - 27 Oct						28 Oct - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	11	0	3	0	1	0	0	7	0
York River	11	0	0	0	0	1	8	1	1
James River	1	0	0	0	1	0	0	0	0
Chesapeake Bay (upper)	2	0	0	0	2	0	0	0	0
Chesapeake Bay (middle)	8	0	1	0	3	4	0	0	0
Chesapeake Bay (lower)	24	0	0	23	1	0	0	0	0

R: released alive
H: harvested

Table 10. Summary of the disposition striped bass tagged during round 6 (25-31 October) and subsequently recaptured prior to 31 December, with emphasis on the sixth recapture interval (28 October - 16 November, 2000).

Release location	recaptures								
	total	25 Oct - 27 Oct	28 Oct - 16 Nov						17 Nov - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	11	0	1	0	1	2	0	0	7
York River	51	0	0	1	0	2	47	1	0
James River	4	0	0	1	0	1	0	0	2
Chesapeake Bay (upper)	8	0	7	0	0	0	0	1	0
Chesapeake Bay (middle)	10	0	5	0	0	3	0	0	2
Chesapeake Bay (upper)	30	4	1	17	2	2	1	0	3

R: released alive
H: harvested

Table 11. Summary of the disposition of striped bass tagged during round 7 (15-21 November) and subsequently recaptured prior to 31 December.

Release location	recaptures								
	total	15 Nov - 16 Nov	17 Nov - 31 Dec						
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	0	0	0	0	0	0	0	0	
York River	4	0	0	0	1	3	0	0	
James River	2	0	0	0	1	1	0	0	
Chesapeake Bay (upper)	1	0	0	1	0	0	0	0	
Chesapeake Bay (middle)	0	0	0	0	0	0	0	0	
Chesapeake Bay (lower)	not sampled								

R: released alive
H: harvested

Figure 1. Delineation of western Chesapeake Bay, Virginia into tagging jurisdictions and location of tagging sites during fall, 2000.