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Evaluation of Striped Bass Stocks in Virginia: Monitoring and Tagging Studies, 2004-2008

Annual Report

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Preface

This report presents the results of striped bass (*Morone saxatilis*) tagging and monitoring activities in Virginia during the period 1 September 2004 through 31 August 2005. It includes an assessment of the biological characteristics of striped bass taken from the 2005 spring spawning run, estimates of annual survival based on annual spring tagging, and the results of the fall 2004 directed mortality study that is a collaborative effort with the Maryland Department of Natural Resources. The information contained in this report is required by the Atlantic States Marine Fisheries Commission and is used to implement a coordinated management plan for striped bass in Virginia, and along the eastern seaboard.

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

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

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

To document continued compliance with Federal law, the Virginia Institute of Marine Science (VIMS) has monitored the size and age composition, sex ratio and maturity schedules of the spawning striped bass stock in the Rappahannock River since December 1981 utilizing commercial pound nets and, since 1991, variable-mesh experimental gill nets. Spawning stock assessment was expanded to include the James River in 1994 utilizing commercial fyke nets and variable-mesh experimental gill nets. An experimental fyke net was established in the James River to assess its potential as a source for tagging striped bass. 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 annual 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; Fisheries Department students of the Virginia Institute of Marine Science Aaron Aunin, Chip Cotton, Donna Grusha, Patrick McGrath, Sarah Muffleman, Jason Romine, Vince Saba, Troy Tuckey and John Walter; the cooperating commercial fishermen Allan Ingraham, Ernest George, Joe Hinson, Raymond Kellum, Kevin Morris, Stanley Oliff, and Greg Swift; Jim Goins of the Virginia Institute of Marine Science and Harry Hornick and Beth Versak of Maryland Department of Natural Resources (Md DNR).

Executive Summary

New Features:

Sections IV and V, evaluating the pound net based Spawning Stock Biomass Index and its potential as an appropriate input model for the Virtual Population Analysis, and section VI, evaluating the striped bass by-catch from staked gill nets used for American shad monitoring in the James and Rappahannock rivers, are new in 2005. The life history chapter in section I was expanded to include the 1997 year class.

I. Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2005.

Catch Summaries:

1. In 2005, 617 striped bass were sampled between 30 March and 3 May from two commercial pound nets in the Rappahannock River. The samples were predominantly male (72.1%) and young (56.9% ages 3-5). Females dominated the age nine and older age classes (85.8%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 9.7 years.

2. During the 30 March - 3 May period, the 2000 and 2001 year classes were the most abundant in the Rappahannock River pound net samples and were 96.2% male. The contribution of age eight and older males was only 9.2% of the total catch. Age eight and older females, presumably repeat spawners, were 25.1% of the total catch but represented 87.6% of all females caught.

3. In 2005, 322 striped bass were sampled between 30 March and 3 May in two experimental anchor gill nets in the Rappahannock River. The samples were predominantly male (91.6%) and young (89.8% ages 3-5). Females dominated the age nine and older age classes (66.7%). The mean age of the male striped bass was 4.3 years. The mean age of the female striped bass was 7.4 years.

4. During the 30 March - 3 May period, the 2000 and 2001 year classes were the most abundant in the Rappahannock River gill net samples and were 99.5% male. The contribution of age eight and older males was only 7.1% of the total catch. Age eight and older females, presumably repeat spawners, were 6.8% of the total catch but were 71.0% of the total females caught.

5. In 2005, 820 striped bass were sampled between 30 March and 3 May in two experimental anchor gill nets (mile 62) in the James River. The samples were predominantly male (96.3%) and young (75.7% ages 3-5). Females dominated the age ten and older age classes (68.8%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 6.9 years.

6. During the 30 March - 3 May period, the 2000-2003 year classes were the most abundant in the James River gill net samples and were 99.2% male. The contribution of age eight and older males was only 4.3% of the total catch. Age eight and older females, presumably repeat spawners, were 3.4% of the total catch but represented 70.0% of all females caught.

Spawning Stock Biomass Indexes (SSBI)

7. The Spawning Stock Biomass Index (SSBI) from the Rappahannock River pound nets was 26.4 kg/day for male striped bass and 39.0 kg/day for female striped bass. The male index was the fifth highest in the 1991-2005 time series and above the 15-year average. However, the 2005 index was less than the index for 2004. The female index was also the fifth highest in the time series and above the 15-year average, but was lower than the indexes for 2003 or 2004.

8. The SSBI for the Rappahannock River gill nets was 55.6 kg/day for male striped bass and 19.9 kg/day for female striped bass. The male index was the fifth lowest in the 1991-2005 time series and well below the 15-year average. The female index was the sixth lowest in the 1991-2005 time series and was also well below the 15-year average.

9. The SSBI for the James River gill nets was 147.7 kg/day for male striped bass and 21.6 kg/day for female striped bass. The male index was the fifth highest in the 1994-2005 time series, and was above the 12-year average. The female index was the lowest in the 12-year time series and was the third consecutive year of decline.

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 2005 Egg Production Potential Index (EPPI, millions of eggs/day) for the Rappahannock River pound nets was 6.3 million eggs/day. This was the median EPPI of the 2001-2005 time series. Older (8+ years) female stripers were responsible for 93.2% of the index.

11. The 2005 EPPI for the Rappahannock River gill nets was 3.1 million eggs/day. This was the lowest EPPI of the 2001-2005 time series and was half the 2003 maximum index. Older (8+years) female striped bass were responsible for 90.3% of the index.

12. The 2005 EPPI for the James River gill nets was 3.2 million eggs/day. This was the lowest EPPI of the 2001-2005 time series and was less than half the 2003 maximum index. Older (8+ years) female striped bass were responsible for 88.3% of the index.

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

13. The cumulative catch rate (all age classes, sexes combined) from the Rappahannock River pound nets (17.6 fish/day) was the median in the1991-2005 time series. There was a decrease in the 1989-2000 year classes from the 2004 values. The cumulative catch rate of male striped bass (12.7 fish/day) was the median in the time series but was almost half the rate in 2004. The cumulative catch rate of female striped bass (5.0 fish/day) was also the median in the 1991-2005 time series but less than half the rate in 2004.

14. Year class-specific estimates of annual survival (S) for pound net data varied widely between years. The geometric mean S of the 1983-1997 year classes varied from 0.501-0.757 (mean = 0.643). The geometric mean survival rates differed greatly between sexes. Mean survival rates for male stripers (1985-1997 year classes) varied from 0.317-0.577 (mean = 0.446) but mean survival rates of female stripers (1983-1991 year classes) varied from 0.587-0.723 (mean = 0.659).

15. The cumulative catch rate (all age classes, sexes combined) from Rappahannock River gill nets (32.2 fish/day) was the second lowest value in the 1991-2005 time series, and 63.0% lower than in 2004. Cumulative catch rate of male stripers (29.5 fish/day) was also the second lowest in the time series and 62.8% lower than the rate in 2004. The cumulative catch rate of female striped bass (2.7 fish/day) was the lowest in the time series less than half the catch rate in 2004.

16. Year class-specific estimates of annual survival for gill net data varied widely between years. The geometric mean S of the 1984-1997 year classes varied from 0.408-0.659 (mean = 0.520). The mean survival rates for male stripers (1987-1997) varied from 0.150-0.520 (mean = 0.376). The mean survival rates for female stripers (1984-1990) varied from 0.501-0.669 (mean = 0.582).

17. The cumulative catch rate (all age classes, sexes combined) from James River (mile 62) gill nets (82.0 fish/day) was the seventh highest catch rate in the 1994-2005 time series, but was the lowest index since 1999. The catch rate was 37.7% lower than the rate in 2004. The cumulative catch rate for male striped bass (79.0 fish/day) was also the seventh highest of the 1994-2005 time series, but was 37.8% lower than the rate in 2004. The cumulative catch rate of female striped bass (3.0 fish/day) was 34.2% lower than the rate in 2004 and was the lowest in the time series.

18. Year class-specific estimates of annual survival in the James River varied widely between years. The geometric mean S of the 1984-1997 year classes varied from 0.347-0.686 (mean = 0.537). The mean survival rates of male stripers (1988-1997 year classes) varied from 0.286-0.562 (mean = 0.421). The mean survival rates of female stripers (1984-1995 year classes) varied from 0.347-0.775 (mean = 0.562).

Catch rate histories of the 1987-1997 year classes

19. Plots of year class-specific catch rates vs. year in the James and Rappahannock rivers from 1991-2004 showed a consistent trend of a peak in the abundance of male striped bass followed by a steep decline. There was also a secondary peak of (mostly) female striped bass, usually around age 10.

20. The areas under the catch curves indicate that the 1987-1989, 1993 and 1996 year classes were the strongest, and the 1990 and 1991 year classes the weakest in the Rappahannock River from 1987-1997. In the James River, the 1995-1997 year classes were the strongest and 1987 and 1988 year classes the weakest.

Growth rate of striped bass derived from annuli measurements

21. The scales of 246 striped bass were digitally measured and the increments between annuli were used to determine their growth history.

22. On average, striped bass grow about 141 mm fork length in their first year. The growth rate decreases with age to about 50 mm per year by age 10.

23. Striped bass were estimated to reach the minimum legal length for the resident fishery (18 in. total length) at age 3.5 and reach the minimum length for the coastal fishery (28 in. total length) at age seven.

Age determinations using scales and otoliths

24. A total of 247 specimens from 11 size ranges were aged by reading both scales and otoliths. The mean age of the otolith-aged striped bass was 0.15 years older than from the scale-aged striped bass. The two methodologies agreed on the age of the striped bass on 42.1% of the specimens and within one year 81.8% of the time.

25. Tests of symmetry applied to the age matrix indicated that the two ageing methodologies were not interchangeable (p= 0.0048). The age at which the divergence in ages became apparent was determined to be age seven.

26. Otoliths were 1.47 times more likely to give an older age than the scale from the same specimen. The otoliths were 2.46 times more likely to produce a higher age difference of two or more years than to produce a lower age.

27. A paired t-test of the mean of the age differences produced by the two ageing methodologies found that the mean difference was significantly different from zero (p= 0.0027).

28. A Kolmogorov-Smirnov test of the age structures produced by the two ageing methodologies also indicated an overall significant difference, indicating that the two resultant age structures did not represent an equivalent population. The differential ageing between the two methodologies on the age-nine striped bass was the source of the significant difference.

II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring 2004-2005.

1. A total of 921 striped bass were tagged and released from pound nets in the Rappahannock River between 28 March and 16 May, 2005. Of this total, 637 were between 457-710 mm total length and considered to be predominantly resident striped bass and 284 were considered to be predominantly migrant striped bass (>710 mm TL). The median date of the tag releases was 28 April for both the resident and the migrant striped bass.

2. A total of 80 (out of 1,447) resident striped bass (>457 mm TL), tagged during spring 2004, were recaptured between 19 April, 2004 and 27 April, 2005 (the respective midpoints of the two tag release totals), and were used to estimate mortality. Forty-five of these recaptures were harvested (56.3%) and the rest were re-released into the population. In addition, 62 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. Most recaptures (59.9%) were caught within Chesapeake Bay (41.5% in Virginia, 18.3% in Maryland). However, other recaptures came from New York (12.7%), Massachusetts (11.3%), New Jersey (4.2%), Rhode Island and North Carolina (3.5 % each), Delaware (2.8%), Connecticut (1.4%) and New Hampshire (0.4%).

3. A total of 39 (out of 686) migratory striped bass (>710 mm total length), tagged during spring 2004, were recaptured between 19 April, 2004 and 27 April, 2005, and were used to estimate the mortality. Twenty-one of these recaptures were harvested (53.8%), and the rest were re-released into the population. In addition, 39 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. Most recaptures (30.8%) came from Chesapeake Bay (24.4%in Virginia, 6.4% in Maryland). Other recaptures came from New York (23.1%), Massachusetts (20.5%), New Jersey and Rhode Island (6.4% each), North Carolina (5.1%), Delaware (3.8%), Connecticut (2.6%) and New Hampshire (1.3%).

4. The ASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber models. Thirteen of these models were applied to the recapture matrix, each reflecting a different parameterization over 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 for migrant striped bass ranged from 0.606-0.658 over the time series. The 2004 survival rate was the highest overall, otherwise 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 fishing mortality (assuming natural mortality is 0.15) ranged from 0.115-0.335 and only infrequently, and by slight margins, exceeded the fisheries target values.

5. Elements of the Rappahannock River tag-recovery matrix for resident striped bass 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 in the fall, 2004, resident striped bass fishery in Chesapeake Bay, Virginia.

1. The fall 2004 striped bass recreational season (1 June - 31 November in Maryland, 4 October - 31 December in Virginia) in Chesapeake Bay was divided into six rounds in Maryland and three rounds in Virginia (20-29 September, 18-27 October and 18-26 November). Each recovery round was approximately 30 days in duration.

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

3. A total of 3,434 striped bass were tagged in Virginia. The number of stripers tagged and released were 899, 1,383 and 1,152 respectively for the three tagging rounds. The striped bass tagged in all three rounds were predominantly from the 2000 and 2001 year classes.

4. A total of 145 striped bass tagged in Virginia were recaptured by 31 December. Of these recaptures, 93 were recaptured within their round of release. Most recaptures occurred in their area of release, but recaptures were also recovered from the Chesapeake Bay in Maryland, Potomac River and in the Atlantic Ocean.

5. The Chesapeake Bay estimate of total fishing mortality (F) was 0.16. This is the sum of non-harvest (0.10) and harvest (0.06) mortality estimates. The target F for Chesapeake Bay is 0.28.

IV. Striped bass spawning stock assessment in the Rappahannock River, Virginia: evaluation of the pound net-based Spawning Stock Biomass Index.

1. Pound nets in the Rappahannock River have been the sample source for striped bass spawning stock assessment since 1991. Pound nets are considered to be non-size or sex selective.

2. The pound nets are fixed gear and are privately owned and operated for commercial purposes. Thus, while we have an excellent working relationship with the fisherman, we do not have absolute control over when or how the gear is fished.

3. A total of 7,426 striped bass have been sampled from among four pound nets within the striped bass spawning grounds in the Rappahannock River between 30 March and 3 May, 1991-2004. The resultant Spawning Stock Biomass Indexes (SSBI) ranged from 18.5 (2002) to 123.9 (2004) with a mean of 52.9. In most years the female biomass exceeded the male biomass.

4. Age and sex-specific catch per unit effort data reliably tracked strong and weak year classes and provided estimates of annual survival.

5. Each pound net sample consisted of the total catch of striped bass from that net so no estimates of variance are made.

Comparison of the temporal window with full seasonal data

6. The 30 March – 3 May temporal window resulted from variability in the beginning and ending of sampling prior to 1999. The sampling season had begun as early as 9 March (1998) and as late as 7 April (1994). The season had ended as early as 21 April and as late as 3 May.

7. Pound net samples from March were male dominated (7.7:1) relative to the 30 March – 3 May temporal window (3.2:1). Hence, the window corresponded to the period of increased abundance of female striped bass in the spawning areas, and differentially including March samples would greatly affect the value of the seasonal female CPUE and compromise its use as an index.

Comparison of VIMS pound net index data with VIMS juvenile index data

8. No definitive relationship between river flow and the SSBI was apparent. In 1992 and 1996, weather conditions were persistently wetter and cooler than normal. The fishermen reported that the striped bass spawning area was displaced well below our sampling sites. In both these years catches across all age classes were lower than in the previous year. In 2002, a persistent drought produced a similar pattern.

9. The strength of the spawning stock was not an indicator of the strength of that year's juvenile index. However, years with high mean flows or high peak flows had higher juvenile indexes while years with low mean or peak flows had low juvenile indexes.

10. Plots of the abundance of 11 and 12 year-old striped bass most closely correlated with their respective Rappahannock River juvenile indexes (eg., the abundance of 1994 year class striped bass in 2005 verses the 1994 juvenile index). The correlations of younger age classes produced weaker results

Comparison of the Rappahannock River and Virginia juvenile indexes

11. The juvenile indexes for the Rappahannock River generally tracked the comprehensive Virginia juvenile index. However, in 1987 and 1992, the juvenile indexes indicated exceptionally strong year classes in the Rappahannock River, but only moderately strong year classes in Virginia. The two year classes have been major contributors to the Spawning Stock Biomass Index and would not be expected to correlate highly to the Virginia juvenile index.

12. The Rappahannock River is the smallest component in the comprehensive Virginia juvenile index (York River, 37.9%, James River, 33.2% and Rappahannock River, 28.9%).

Comparison of the Rappahannock River SSBI and the Maryland juvenile indexes

13. The 1987 and 1992 Maryland juvenile indexes were also weaker relative to the strength of the Rappahannock River juvenile indexes. In fact there were no major peaks in the Maryland juvenile index from 1980-1992. Thus there is no expectation that the SSBI would correlate to the Maryland juvenile index during that period.

14. From 1993 to present the juvenile indexes from the Rappahannock River, Virginia and Maryland have indicated repeated strong year classes, most notably in 1993, 1996 and 2003. Thus potential correlation among the indexes is possible in future years.

V. Comparison of the catches of the Rappahannock River pound nets, and the correlation of the Virginia Spawning Stock Biomass Indexes to the Maryland gill net indexes.

1. From 1991 to 1996 there were only two pound nets (S441 and S473) available for obtaining striped bass monitoring samples from the spawning grounds in the Rappahannock River. A third net (S462) was added in 1997 and the fourth net (S454) began operation 1999. In 2001, the fisherman discontinued fishing one net (S441).

Comparison of the contributions of the four Rappahannock River pound nets to the Spawning Stock Biomass Index.

2. Catches of both male and female striped bass were generally highest from net S473 and lowest from net S441. Although nets S454 and S462 were ampled much less frequently, their catches were similar to net S473.

3. There was no consistent difference among the mean ages of the males or the female striped bass captured from the four pound nets.

4. To maximize the available data, the catches of the nets when fished on the same date, but used as a source for tagging striped bass were used to compare to the net used for monitoring. The catches of net S473 (the net with the longest, most consistent catch record) were then correlated to the catches of each of the other three nets when fished on the same date.

5. The catches of male striped bass from the other three nets had a positive correlation to the catches of net S473. The values of R^2 ranged from 0.58-0.64. The narrow range of the R^2 values indicates that, over time, substituting these nets for each other would yield similar results if scaled for the lower catch rates of net S441.

6. The catches of female striped bass from the other three nets also had a positive correlation to the catches of net S474. The values of R^2 ranged from 0.47-0.57 While these values are lower than for male striped bass, the narrow range indicates that substituting these nets for each other would still yield similar results if properly scaled.

Correlation of the Rappahannock River Spawning Stock Biomass Index with the Maryland gill net spawning stock index.

7. There was a negative correlation between the female pound net Rappahannock River Spawning Stock Biomass Index and the Maryland female gill net spawning stock biomass index. Although the low values of the Rappahannock River index in 1996 and 2002 were probably the result of extreme environmental conditions, there was little similarity in the temporal distribution between the two indexes.

Assessment of the Rappahannock River Spawning Stock Biomass Index as input in the VPA model.

8. Although there have been changes in the set of pound nets sampled over time, there is a notable correlation among the catches of the different nets, suggesting that the various nets are tracking the same population and the signal to noise ratio is high.

9. The lack of relationship between the Virginia and Maryland indexes suggest that the Virginia (actually Rappahannock River) and Maryland populations are different. Hence, both sets of data may be needed to get a representative picture of striped bass dynamics in Chesapeake Bay.

VI. Evaluation of the 2000-2004 striped bass by-catch from the American shad staked gill net stock assessment survey in the James and Rappahannock rivers as an alternative index of abundance.

1. Stake gill nets have been used to assess American shad stocks in the James, York and Rappahannock rivers since 1998. The staked gill net in the James River is located at river mile 10 and is 900 feet in length (30 30-foot panels) of 4.88 inch monofilament. The staked gill net in the Rappahannock River is located at river mile 37 and is 912 feet in length (19 48-foot panels) of 5.0 inch monofilament. These stands are remnants of the now dormant American shad fishery and are among the nets used to provide historical catch records to the Virginia Institute of Marine Science (VIMS).

2. The striped bass by-catch in the nets has been enumerated and the whole or a subsample from randomly chosen panels was brought to VIMS for biological work-up. Data recorded include total length (mm), weight (g), sex and age as determined from reading the scales from impressions made into acetate sheets. The length data are investigated in this report as an alternative index of abundance in comparison with experimental, multi-mesh anchor gill nets used for striped bass spawning stock assessment in the James and Rappahannock rivers.

3. Catch rates (fish/day) of striped bass by one inch total length increments (18-24 inches) were compared and plotted. The correlation equation of the data pairs was calculated and the R^2 value determined.

4. For the James River, the 18, 19 and 20 inch correlations between the two gears were positive, but were inconsistent, alternating between positive and negative values for the 21-24 inch striped bass. The R^2 values were 0.60, 0.72 and 0.26 for striped bass of 18, 19 and 20 inches respectively.

5. For the Rappahannock River, only the 23 inch striped bass had more than slightly positive correlation between the catch rates of the two gears. These results do not support the idea that the two gears are tracking the same population.

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Introduction

Every year, striped bass migrate along the US east coast from offshore and coastal waters and then 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 the tidal freshwater portions of the James, Rappahannock, Pamunkey and Mattaponi rivers (Grant and Olney 1991; Olney et al. 1991; McGovern and Olney 1996).

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

Materials and Methods

Samples of striped bass for biological characterization of the spring spawning stocks were obtained from the Rappahannock River between 31 March - and 2 May, 2005. Samples (the entire catch of striped bass from each gear) were taken twice-weekly (Monday and Thursday) from a pair of commercial pound nets (river miles 45 and 46) in the Rappahannock River. A third pound net located at river mile 47 was damaged by a commercial vessel and was not available for sampling. Pound nets are fixed commercial gears that have been the historically predominant gear type used in the river and are presumed to be non size-selective in their catches of striped bass. The established protocol (Sadler *et al.* 1999) was to alternate the choice of the net sampled but weather constraints often dictated whether that net could be sampled. In addition, data from pound nets sampled in 1991 and 1992 were included to expand the time series. These samples were consistent in every respect to the 1993-2001 samples with the following exceptions in 1991: two samples (3 and 17 April) came from a pound net at river mile 25 and samples were obtained weekly vs. twice weekly.

In addition to the pound nets, samples were also obtained twice-weekly from variable-mesh experimental anchored gill nets (two at river mile 48 on the Rappahannock River and two at river mile 62 on the James River, Figures 1-2). 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, and 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 in the second net 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 2004, a manufacturing error resulted in two nets of the first configuration being utilized.

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. Scales were collected from between the spinous and soft dorsal fins above the lateral line for subsequent aging, using the method established by Merriman (1941), except that impressions made in acetate sheets replaced the glass slide and acetone. Otoliths were extracted from a stratified subsample of the striped bass, processed for aging, and compared to their scale-derived ages.

The otolith subsample was the first 10 striped bass of each sex sampled from each of the following size ranges (fork length, in mm): 166-309, 310-419, 420-495, 496-574, 575-659, 660-724, 725-779, 780-829, 830-879 and 880-900. All striped bass greater than 900 mm fork length were sampled. The size ranges roughly correspond to age classes based on previous (scale-aged) data.

The otoliths were cleansed of external tissue material by soaking in bleach for 12-24 hours and rinsing in de-ionized water. The otoliths were prepared for ageing by placing the left sagitta on melted crystal bond and sectioned to a one millimeter thickness on a Buehler isomet saw. The sections were then polished on a Metaserv 2000 grinder. The polished section was immersed in a drop of mineral oil and viewed through an Olympus BX60 compound microscope at 4-20x. Each otolith was aged at least twice at different times by each of two readers using the methods described by Wischniowski and Bobko (1998).

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

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

To determine fecundity, the geometric mean of the egg counts of the gonad subsamples for each ripe female striped bass collected in 2001-2003 was calculated. A non-linear regression 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 fishing effort by the mature female (age 4+) 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 the same year class in year a. If the survival estimate between successive years was >1, the estimate was derived by interpolating to the following year. The geometric mean of S was used to estimate survival over periods exceeding one year (Ricker 1975). Separate estimates of survival were made for male and female striped bass, as well as the sexes combined.

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

Results

Catch Summaries

Rappahannock River:

Pound nets: Striped bass (n= 617) were sampled between 31 March and 2 May, 2005, from the pound nets in the Rappahannock River. The number of striped bass sampled was less than was sampled in 2004 (n= 951) but was 18.4% above the 15-year average. Total catches varied from 13-122 striped bass, with peak catches on 31 March and 4 April (Table 1). Surface water temperature increased steadily from 9.6 EC on 31 March to 17.7 EC on 21 April, then varied between 15-17 EC through 2 May. Dry weather again persisted throughout April, resulting in lower river flows than had been present in 2001-2003. Catches of female striped bass peaked on 21 April, but were generally high from 21-28 April. Males made up 72.1% of the total catch, but this was slightly below the 15-year average (77.2%). The 2001-2003 year classes comprised 41.5% of the total catch. Males dominated the 2001-2003 year classes (99.6%) and the 1997-2000 year classes (78.9%), but females dominated the 1987-1996 year classes (85.8%).

Biomass catch rates (g/day) of male striped bass peaked on 31 March and female striped bass were highest on 21 April (Table 2). The numeric catch rate of females exceeded that of males only on 21 April. However, the biomass catch rates for female striped bass exceeded that for males overall (1.47:1), peaking on 21 April (4.33:1). The mean ages of male striped bass varied from 3.7-5.8 years by sampling date, with the oldest mean ages occurring from 25-28 April. The mean ages of females varied from 9.0-10.6 years by sampling date, but only varied from 9.4-9.8 years from 18 April – 2 May.

There was a peak in abundance of striped bass (mostly male) between 450-500 mm total length in the pound net samples (Table 3). This size range accounted for 21.1% of the total sampled. There was a secondary peak in abundance of striped bass between 810-860 mm total length, accounting for 11.7% of the total sampled. However, the striped bass from 630-740 mm total length accounted for only 3.4% of the total sample. The total contribution of striped bass greater than 710 mm total length (the minimum total length for the coastal fishery) was 36.8%.

During the 30 March - 3 May period, the 2001 (30.8%) and 2000 (15.7%) year classes were the most abundant (Table 4). These year classes were 96.2% male. The contribution of males age six and older (the pre-2000 year classes) was 15.9% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 26.6% of the total aged catch, but was also 92.7% of the total females captured. The catch rate (fish/day) of male striped bass was 12.7, which is 16.4% below the 13-year average (Table 5). The catch rate of female striped bass (4.9 fish/day) was 11.4% above the 13-year average, but was less than in 2003 or 2004. The biomass catch rates (kg/day) of both sexes were above the average of the 13-year time series. The mean ages (30 March – 3 May) of both sexes were above the 13-year averages.

Experimental gill nets: Striped bass (n= 322) were also sampled between 30 March and 3 May, 2005 from two multi-mesh experimental gill nets in the Rappahannock River. The total catch was 61.1% less than in 2004. Total catches peaked on 18 and 21 April, due to the large number of three to six year old males (Table 6). Female striped bass were generally caught in low numbers throughout the sampling period. Males made up 91.6% of the total catch. Males dominated the 2001-2003 year classes (100%) and the 1997-2000 year classes (93.8%), but the 1987-1996 year classes were 67.9% female

Biomass catch rates (g/day) of male striped bass were highest on 21 April (Table 7). The catch rates of female striped bass were highest on 18 and 25 April. The catch rate of males exceeded that of females on every sampling occasion. The mean ages of male striped bass varied from 4.3-5.9 years by sampling date (excluding the one male captured on 2 May), with the oldest males (five - nine years) being most abundant from 25-28 April. The mean ages of females varied from 8.0-11.0 years by sampling date, with the oldest females (age nine and older) being most abundant from 14-25 April.

There was a peak in the distribution of length frequencies of striped bass in the gill net samples between 440-550 mm TL (Table 8). In previous years, there was a distinct secondary peak of larger striped bass, but this was less apparent in 2005. In contrast to the pound net samples, the total contribution of striped bass greater than 850 mm total length was 5.9% vs. 20.3% in the pound nets. The total contribution of striped bass greater than 710 mm total length was 14.9% in the gill nets.

During the 30 March - 3 May period, the 2001 (36.6%) and 2000 (20.5%) year classes were most abundant (Table 9). These year classes were 99.5% male. The contribution of males age six and older (the pre-2000 year classes) was 20.1% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 7.5% of the total aged catch but was 88.9% of the total females captured. The catch rate (fish/day) of male striped bass was the third lowest in the 13-year time series and was 41.0% below the average (Table 10). The catch rate of female striped bass was also the third lowest in the time series and was 54.2% below the 13-year average. The biomass catch rates (g/day) for both sexes were also among the lowest in the time series.

James River:

Experimental gill nets: Striped bass (n= 820) were sampled between 30 March and 3 May, 2005, from two multi-mesh experimental gill nets at mile 62 in the James River. Total catches peaked first on 31 March and again on 2 May. Young, male striped bass were primarily responsible for the peak catches (Table 11). Catches of female striped bass were consistent, although small. Males dominated the 2001-2003 year classes (99.5%) and the 1997-2000 year classes (96.1%), but the 1987-1996 year classes were nearly equal by sex (53.1% male).

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Biomass catch rates (g/day) of male striped bass peaked strongly on 7 April and on 2 May, but were high throughout the sampling season (Table 12). The catch rates of female striped bass were highest on 21 April. The biomass catch rate of males exceeded that of females on every sampling date (6.9:1 for the season). The mean ages of male striped bass varied from 4.3-5.2 years by sampling date. The mean ages of females varied from 6.0-11.3 years by sampling date, but varied from only 8.0-11.3 years from 31 March -21 April.

There was a broad peak of striped bass 430- 640 mm total length in the gill net length frequencies (Table 13). This size range accounted for 71.0% of the striped bass sampled. In contrast to the samples from the pound nets (19.9%) from the Rappahannock River, striped bass greater than 850 mm total length accounted for only 3.8% of the total sampled. The total contribution of striped bass greater than 710 mm total length was 11.8%.

During the 30 March - 3 May period, the 2001 (45.4%), 2000 (24.3%) and 2002 (17.9%) year classes were the most abundant in the gill nets (Table 14). These year classes were 99.2%

male. The contribution of males age six and older (the pre-2000 year classes) was only 18.7% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was only 2.9% of the total aged catch.

The catch rate (fish/day) of male striped bass was lower than for 2004, but was 16.9% above the 11-year average (Table 15). However, the catch rate of female striped bass was the lowest of the time series and was 68.8% below the 11-year average. Likewise, the biomass catch rate (g/day) of male striped bass was lower than 2004, but was 19.2% above the average while the biomass catch rate of female striped bass was lower than in 2004, and was 59.1% below the 11-year average. The mean age of male striped bass varied from only 4.3-4.9 years by sampling year, while the mean age of female striped bass varied from 6.3-8.6 years.

Spawning Stock Biomass Indexes

Rappahannock River:

Pound nets: The Spawning Stock Biomass Index (SSBI) for spring 2005 was 26.4 kg/day for male striped bass and 39.0 kg/day for female striped bass. The index for male striped bass was the fifth highest in the 15-year time series, although 54.9% less than the index for 2004, and 12.8% above the 15-year average (Table 16). The magnitude of the index for male striped bass was largely determined by the 2001 (23.9%) and 1997 (20.7%) year classes. The index for female striped bass was the fourth highest of the 15-year time series, although 40.4% below the index for 2004, and 21.6% above the average (Table 16). The magnitude of the index for the females was largely determined by the 1993-1996 year classes (77.9%).

Experimental gill nets: The Spawning Stock Biomass Index for spring 2005 was 55.6 kg/day for male striped bass and 19.9 kg/day for female striped bass. The index for male striped bass was the fifth lowest of the time series, 67.7% below the 2004 index, and was 31.5% below the 15-year average (Table 16). The 2000-2001 year classes contributed 46.9% of the biomass in the male index. Likewise, the index for female striped bass was 61.7% below the 2004 index, and was 41.1% below the 15-year average. The 1994-1996 year classes contributed 57.1% of the biomass in the female index.

James River:

Experimental gill nets: The Spawning Stock Biomass Index for spring 2005 was 147.7 kg/day for male striped bass and 21.6 kg/day for female striped bass. The male index was the fifth highest in the 12-year time series, although 28.7% lower than the 2004 index, and was 34.1% above the average (Table 17). The 2000 and 2001 year classes contributed 50.4% of the biomass in the male index. The female index was the lowest since 2000, 30.9% lower than the 2004 index, and was 58.6% lower than the 12-year average. The 1995-1997 year classes accounted for 53.0% 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 (2001-2003) produce a fork length-oocyte count relationship as follows:

$$N_o = 0.000857 \times FL^{3.1373}$$

where N_0 is the total number of oocytes and FL is the fork length (>400) in millimeters. Using this relationship, the predicted egg production was 125,000 oocytes for a 400-mm female and 3,719,000 oocytes for a 1180-mm female striped bass (Table 18). The 2005 Egg Production Potential Indexes (EPPI, Table 19) for the Rappahannock River were 6.30 (pound nets) and 3.06 (gill nets). The 2005 EPPI for the James River was 3.24. The indexes for the Rappahannock River were heavily dependent on the egg production potential of the older (8+ years) females (93.2% in the pound nets, 90.3% in the gill nets). The James River index was also dependent on these older females (88.3%). Previous values for the EPPI for 2001-2004 from the Rappahannock River were 3.992, 1.764, 9.829 and 10.55 (pound nets) and 4.039, 6.070, 3.724 and 8.432 (gill nets). Previous values for the EPPI for 2001-2004 from the James River were 5.286, 6.709, 6.037 and 4.922 respectively (Sadler et al 2001, 2002, 2003, 2004). Modest changes in the methodology (utilizing fully mature ovaries solely rather than ovaries in various states of maturation) in the 2001-2005 indexes preclude direct comparison with the 1999 and 2000 indexes.

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

Rappahannock River:

Pound nets: Numeric catch rates (fish/day) of individual year classes from the 1991-2005 samples are presented in Tables 20-22. The cumulative annual catch rate of all year classes for 2005 was the eighth highest in the time series and was 44.4% lower than the cumulative catch rate for 2004 (Tables 20a,b). The decrease was the result of lower catch rates in all except the 2000 year class. The catch rate of males was dominated by four and five year-olds (2000 and 2001 year classes, Tables 21a,b). These two age classes contributed 62.3% on the total catch. Previously, these two age classes had contributed more than 50% of the total male catches in every year except 1995, 1996 and 2004. Using the maximum catch rate of the resident males as an indicator, the 1995-1997 year classes were strongest and the 1990 and 1991 year classes were the weakest. No pre-1994 year class males were captured. The cumulative catch rate of female stripers was also the eigth highest of the time series, and was 39.7% lower than the catch rate in 2004 (Tables 22a,b). The decrease in the cumulative catch rate of female striped bass reversed an increase in the capture of female striped bass after a general decline from 1993-2002. No pre-1985 year class females were captured in 2005.

The range of overall ages was unchanged from 1991-2005, consisting of 2-10 year old males and 4-16 year old females (except for one 18 and one 20 year-old female), but sex-specific changes in the age-structure have occurred. The age at which abundance peaked for males has decreased from age five (1992-1994) to age four (1997-2002). The catch rate of four and five year olds were near equal in 2003 and 2004, but the peak was age four in 2005. 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 0.134-0.468 (mean = 0.294) as their cumulative catch rate ranged from 0.75-2.08 fish/day (mean = 1.32). From 1997-2001 the range in the cumulative proportion of females age eight and older increased to 0.770-0.872 (mean = 0.825) as cumulative catch rates ranged from 1.44-4.45 fish/day (mean = 2.84). In 2002, the cumulative proportion of female striped bass age eight and older decreased to 0.508. The cumulative proportion of the catch rate of females age eight and older rebounded to 0.875, 0.903 in 2004 (the highest of the time series) and 0.883 in 2005.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 23-25. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rates (1991-2005) of the 1983-1997 year classes (sexes combined) varied from 0.501-0.757 (Tables 23a,b) with an overall mean survival rate of 0.643. 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 (1991-2005) of the 1985-1997 year classes of males varied from 0.317-0.577 (Tables 24a,b) with an overall mean survival rate of 0.446. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2005) of the 1983-1991 year classes of females varied from 0.587-0.723 (Tables 25a,b) with an overall mean survival rate of 0.659. The high catch rates of 1992-1998 year class females in 2003 precluded estimation of survival rates for these stripers in 2005.

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1991-2005 are presented in Tables 26-28. The cumulative annual catch rate (all age classes, sexes combined) for 2005 from the gill nets was the second lowest in the time series and 63.0% lower than in 2004 (Tables 26a,b). The decrease was the result lower catch rates of virtually every age class. The cumulative catch rate was driven by the catch rates of the 2000 and 2001 year classes of striped bass. The age of peak abundance was four years old. The age of peak abundance had changed from age five (1992-1996, 2002) to age four (1997, 1998, 2000, 2001 and 2003) and age three (1999 and 2004). The cumulative catch rate of male striped bass was the fourth lowest in the time series and was 62.8% less than in 2004 (Tables 27 a,b). The cumulative catch rate of female striped bass was the second lowest of the time series, and was 64.6% less than the cumulative catch rate in 2004 (Tables 28a,b).

The overall age structure from 1991-2005 consisted of 2-12 year old males (Tables 27a,b) and 2-14 year old females (Tables 28a,b), although only one male older than 10 years was captured in 2005. The proportion of males age six and older (0.21) was less than in 2004 (0.33). The proportion of males age six and older was also 0.2 in 2002 and 2003 after being 0.03-0.06 from 1997-2001. The proportion of female striped bass age eight and older was 0.44 in 2005.

The proportion of females age eight and older increased from 0.148 to 0.652 from 1991 to 1996, declined from 0.652 to 0.315 from 1996 to 2002 (except 0.707 in 2001), then rebounded to 0.594 in 2003 and 0.843 in 2004.

The cumulative catch rate (all age classes) of male striped bass declined in 2005, and was the lowest value since 1995 (Tables 27a,b). Using the maximum catch rate of the resident males as an indicator, the 1993, 1994 and 1997 year classes were the strongest and the 1990, 1991 and 2000 year classes the weakest. The catch rates of male striped bass declined rapidly after ages five or six. These year classes are the primary target of the recreational and commercial fisheries.

The 2005 cumulative catch (all age classes) rate of female striped bass was less than half the 2004 catch rate and was comparable to the values found from 1997-2000 (Tables 28a,b). In 2004, the increased catch rates for 8-14 year-old females gave evidence of secondary peak of abundance across several year classes. This was not evident from the catches in 2005. This bimodal distribution of abundance with age had been noted for the pound net catches, but has not been evident in the gill net catches.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in Tables 29-31. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1991-2005) of the 1984-1997 year classes (sexes combined) varied from 0.408-0.659 (Tables 29a,b) with an overall mean survival of 0.520. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1991-2005) of the 1987-1997 year classes of males varied from 0.150-0.520 (Tables 30a,b) with an overall mean survival of 0.376. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2005) of the 1984-1990 and 1992 year classes of females varied from 0.501-0.669 (Tables 31a,b) with an overall mean survival rate of 0.582. The survival estimates of both sexes of striped bass were lower than those calculated from the pound nets. The estimate of female survival rates was based on fewer years than the estimate from the pound nets due the rareness of the oldest females in the samples.

James River:

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1984-2005 are presented in Tables 32-34. The cumulative annual catch rate (all age classes, sexes combined) for 2005 was the sixth highest of the time series, but was a 37.7% below the catch rate for 2004 and the lowest value since 1999. It reestablished a trend of decline from the peak in 2000 that was interrupted in 2004 (Tables 32a,b). The cumulative catch rate was driven by high catch rates for the three to five year old (2000-2002 year classes), mostly male striped bass.

The overall age structure of the samples has remained stable throughout the time series, starting at age two or three, and ranging up to 11-14 years (Tables 32a,b).The age structure of male striped bass has expanded from three to six years in 1994, to two to11 years by 2005 (Tables 33a,b). The age structure of female striped bass was stable from 1994-2005, consisting of three to14 year old females (Tables 34a,b). The cumulative proportion of males age six and older has varied from 0.091-0.191 in 2000-2005 after peaking at 0.201-0.299 from 1996-1998.

The cumulative proportion of females age eight and older, which had decreased from 0.531-0.266 from 1997-1999, rebounded to 0.426 in 2001 and was 0.700 in 2005.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 2005 catch rate being the sixth highest overall, but 37.8% lower than the cumulative catch rate for 2004 and the lowest value since 1999 (Tables 33a,b). Using the maximum catch rate of the resident males as an indicator, the 1995-1997 and the 2000 year classes were strongest and the 1992 and 1993 year classes the weakest. Male catch rates declined after ages five or six, but not as rapidly as on the Rappahannock River. In contrast, the 2005 cumulative catch rate of female striped bass was 34.2% lower than in 2004, and was the lowest in the time series (Tables 34a,b). There was no secondary peak in catch rates of females 1988-1994 year classes similar to that noted in the Rappahannock River pound net data.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 35-37. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1994-2005) of the 1984 -1997 year classes (sexes combined) varied from 0.347-0.686 (Table 35), with an overall mean survival rate of 0.537. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1994-2005) of the 1988-1997 year classes of males varied from 0.286-0.562 (Table 36) with an overall mean survival rate of 0.421. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1994-2005) of the 1984-1995 year classes of females varied from 0.347-0.775 (Table 37) with an overall mean survival rate of 0.562.

Catch rate histories of the 1987-1997 year classes

The catch rate histories of the 1987-1997 year classes from each sampling gear (sampling on the James River commenced in 1993) are depicted in Figures 3-13. Consistent among the year classes are a peak of male striped bass at age four or five followed by a rapid decline in the catch rate and a secondary peak of mostly female striped bass around age 10. This secondary peak is best defined from the pound net data. The gill nets appear to be less efficient at catching larger, therefore older, striped bass. In both gears the catch rates of male striped bass was an order of magnitude greater than the catch rates of female striped bass.

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

1987 Year class: The catch history of the 1987 year class commences at age four from the Rappahannock River and age seven from the James River. Peak abundance of male striped bass occurred at age four and the peak abundance of female striped bass occurred at age six in the Rappahannock River (Figure 3). Abundances of both sexes declined rapidly with age, although there was a distinctive secondary peak in the abundance of female striped bass captured from the pound nets. Using the calculated area under the catch curve (CCA) at age eight (the oldest year comparable among the 11 year classes) as an indicator of year class strength, the 1987 year class was near the mean for the 1987-1997 year classes (Table 38) in the pound net samples. However, the 1987 year class was below the mean in the gill net samples in the Rappahannock River (Table 39). Since the time series does not include catches at ages two and three, the values of the catch curve area are underestimated.

1988 Year class: The catch history of the 1988 year class commences at age three from the Rappahannock River and age six from the James River. Age three was the apparent age of full recruitment to both sampling gears. Peak abundance of both male and female striped bass occurred at age five (Figure 4). Abundances decreased rapidly with age, although the pound net samples again had a secondary peak of female striped bass at age nine. The 1988 year class was above the mean CCA in the pound net samples (Table 38), but slightly below the mean from the gill net samples in the Rappahannock River (Table 39).

1989 Year class: The catch history of the 1989 year class, fully recruited to the gears in the Rappahannock River, commenced at age five in the James River samples. Peak abundance of male striped bass occurred at age four (pound nets) and five (gill nets in both rivers, Figure 5). Peak abundance of female striped bass occurred at five in the Rappahannock River (both gears) and age six in the James River. There was a secondary peak in abundance of female striped bass at age nine in the pound net samples. The CCA from both gears in the Rappahannock River was below the mean (Tables 38, 39).

1990 Year class: The catch history of the 1990 year class commenced at age four in the James River. Peak abundance of male striped bass occurred at age four (gill nets) and five (pound nets) in the Rappahannock River and age four in the James River (Figure 6). The peak abundance of female striped bass occurred at age five in the gill net samples from both rivers, but was age eight in the pound net samples. The CCA was the second lowest of the time series from both gears in the Rappahannock River (Tables 38, 39). The CCA for the James River, though lacking values for ages two and three, was also below the mean (Table 40).

1991 Year class: The catch history of the 1991 year class commenced at age three in the James River and was fully recruited to the sampling gear. Peak abundance of male striped bass occurred at age four in the James River and at age five in the Rappahannock River (both gears, Figure 7). Peak abundance of female striped bass occurred at age eight in the James River and at age 10 in the Rappahannock River. It is interesting to note that age five and six female striped bass were not caught in the same relative abundance as in the 1987-1990 year classes. The CCA was the lowest of the year classes compared in the Rappahannock River in both sampling gears (Tables 38, 39) and well below the mean in the James River (Table 40).

1992 Year class: Peak abundance of male striped bass occurred at age three in the pound nets in the Rappahannock River and in the gill nets in the James River, but occurred at age five in the gill nets in the Rappahannock River (Figure 8). Peak abundance of female striped bass occurred at age seven in the James River but occurred at age nine (gill nets) and age eleven (pound nets) in the Rappahannock River. Again, there were relatively few ages five and six female striped bass captured in the Rappahannock River. Thus, what had been a secondary peak of abundance for the 1987-1989 years classes has been the primary peak in the 1990-1992 year classes. The CCA was higher than for the 1990 and 1991 year classes, but was still below the mean in the Rappahannock River (Tables 38, 39), and was the lowest value for the James River (Table 40).

1993 Year class: Peak abundance of male striped bass occurred at age four in the Rappahannock (both gears) and the James rivers (Figure 9). Peak abundance of female striped bass occurred at age six on the James River, but not until ages nine (gill nets) and age ten (pound nets) in the Rappahannock River. Again, there were relatively few ages five and six female striped bass captured in the Rappahannock River. The CCA was the highest of all the year classes from the gill net samples, but was only near the mean from the pound net samples in the Rappahannock River (Tables 38, 39). The CCA for the James River was well below the mean (Table 40).

1994 Year class: Peak abundance of male striped bass occurred at age four in the Rappahannock River (both gears) and at age six in the James River (Figure 10). Peak abundance of female striped bass occurred at age five on the James River, but not until age ten in the Rappahannock River (both gears). Again, there were relatively few ages five and six female striped bass captured in the Rappahannock River. The CCA was below the mean from the pound net samples but well above the mean from the gill net samples in the Rappahannock River (Tables 38, 39). The CCA for the James River was higher than for the 1991-1993 year classes bur was still below the mean (Table 40).

1995 Year class: Peak abundance of male striped bass occurred at age three (gill nets) and four (pound nets) in the Rappahannock River and occurred at age five in the James River (Figure 11). Peak abundance of female striped bass occurred at age four in the James River but not until age nine in the Rappahannock River (both gears). Again, there were relatively few ages five and six female striped bass captured in the Rappahannock River. The CCA was above the mean in the Rappahannock River pound nets (Table 38), but below the mean in the gill nets (Table 39). The CCA was above the mean in the James River (Table 40). The 1993-1995 year classes were characterized as having a primary peak of young, males striped bass and a secondary peak of older, female striped bass.

1996 Year class: Peak abundance of male striped bass occurred at age three (gill nets) and four (pound nets) in the Rappahannock River and occurred at age four in the James River (Figure 12). Peak abundance of female striped bass occurred at age six in the James River and at age eight in the Rappahannock River (both gears). Again, there were relatively few ages five and six female striped bass captured in the Rappahannock River. The CCA was the highest amongst the year classes from the pound samples in the Rappahannock River (Table 38) and well above the mean in the gill net samples (Table 39). The CCA for the James River was by far the highest of any of the year classes (Table 40).

1997 Year class: Peak abundance of male striped bass occurred at three (pound nets) and age four (gill nets) in the Rappahannock River and occurred at age four in the James River (Figure 13). Age eight females showed an increase in abundance in the Rappahannock River pound nets and James River gill nets but were rare in the Rappahannock River gill nets. The CCA was the second highest in the Rappahannock River pound nets (Table 38) and James River gill nets (Table 40), and the third highest in the Rappahannock River gill nets (Table 39).

Growth rate of striped bass derived from annuli measurements

The scales of 246 striped bass were digitally measured and the increments between annuli were used to determine their growth history. The back-calculated length-at-age of striped bass was 141mm at age one (Table 41a). The rate of growth was about 100 mm in their second year and decreased gradually with age to about 80 mm in their fifth year and to about 50 mm in their 10^{th} year (Tables 41a,b). Interestingly, the growth rates of the most recent year classes were the highest, although the growth rate of the oldest year classes were based on very few specimens. Based on these growth estimates, an 18 inch (457 mm) total length striped bass would be 3.5 years of age during the fall recreational fishery in Chesapeake Bay. These striped bass reach the 28 inch (711 mm) total length minimum for the coastal fishery at age seven.

Age determinations using scales and otoliths

A total of 247 striped bass from 11 size ranges were aged by reading both their scales and otoliths. Scale and otolith ages from the same specimen were in agreement 42.1% (104/ 247) of the time and within one year 81.8% (202/247) of the time. Differences between the two age determination methods were first analyzed utilizing tests of symmetry. A chi-square test was performed to test the hypothesis that an *m* x *m* contingency table (Table 42) consisting of two classifications of a sample into categories is symmetric about the main diagonal. The test statistic is

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

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

A test of symmetry that is significant indicates that there is a systematic difference between the aging methods. The number of degrees of freedom is equal to the number of non-zero age pair comparisons (here = 30). We tested the hypothesis that the observed age differences were symetrically distributed about the main table diagonal (Table 42). The hypothesis was rejected (χ^2 = 53.863, p= 0.0048, indicating non-random differences between the two ageing methodologies.

Following the extension of the symmetry test outlined by Hoenig et al. (1995), the point at which the asymmetry begins can be determined by repeatedly collapsing the data to form a Aplus@ group. The resulting chi-square test is then performed sequentially until the result is no longer significant. Non-random differences between otolith and scale ages occurred in striped bass age seven and older. The otolith-aged eight year-old class was the largest contributor to the variability. In the striped bass aged 11 and older using otoliths (n = 57), the otolith age was equal to (n =16) or older (n =41) than the scale age 71.9% of the time.

Differences between the scale and otolith age from the same specimen ranged from zero to six years (Figure 13). The otolith-derived age exceeded the scale age 34.4% of the total examined (59.4% of the non-zero differences). When the differences in ages were greater than one year, the otolith age was even more likely to be the older age (71.1%). Another test of symmetry that compared the negative and positive differences of the same magnitude (i.e. -4 and 4, -3 and 3, etc., Evans and Hoenig, 1998) failed to reject the hypothesis that these differences were random (X^2 = 9.768, df = 5, p= 0.0856). This test has far fewer degrees of freedom than did the previous test of symmetry. Thus, the results indicate that the second test has less power to resolve questions of symmetry rather than contradicting the first test.

Next, t-tests of the resultant means of the two ageing methods were performed. A two-tailed t-test was made to test the null hypothesis that the mean ages determined by the two methods were not different. The mean age of the sample (n=247) determined by reading the otoliths was greater than the mean age determined by reading the scales (by 0.15 years, Table 43). The test results were:

$$\bar{A}ge_{otolith} = 8.75 \qquad \bar{A}ge_{scale} = 8.53$$

$$S_{otolith} = 3.28 \qquad S_{scale} = 3.38$$

$$t = 0.795$$
$$df = 492$$
$$p = .4273$$

Therefore the null hypothesis was not rejected.

A paired t-test was also performed on the ages determined for each specimen by the two methodologies. The null hypothesis tested was that the mean of the difference resultant from the two methods was not different from zero. The paired t-test results were highly significant (t=3.032, df=246, p=.0027) and the null hypothesis was rejected.

To determine whether the distribution of age classes that resulted from the two ageing methodologies were representative of the same population, a Kolmogorov- Smirnov test was performed on the relative proportion that each assigned age class contributed to the total sample (Table 43). This compares the maximum difference in the relative proportions that an age class contributes to the test statistic ($K_{.05}$):

$$D_{\max} = 0.1255 \qquad K_{.05} = 1.3581$$

$$D_{.05} = 1.3581\sqrt{\frac{247+247}{247^2}} = 0.1222$$

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

Discussion

Striped bass stocks had 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 (due to differences in depth, bottom, fetch, nearness to shoals or channels, etc.), 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. Since spring 2002 the down-river net has not been set and was replaced by a net across the river at mile 45. This net had been utilized since 1997 as a source for tagging striped bass, but had been excluded from the spawning stock assessment in order to keep the sampling methodology as consistent as possible with the 1991-1996 data. Weekly sampling occurred each Monday and Thursday, a schedule that translated to fishing efforts of 96 hrs (Thursday through Monday) or 72 hrs (Monday through Thursday).

In past years, duration of the pound net set was as low as 24 hrs., and as large as 196 hrs., if the fisherman was unable to fish the scheduled net on the scheduled sampling date. Although these events were uncommon, we were unable to assess whether varying effort influenced estimates of catch rate. The 1997 and 1998 data include a pound net at mile 46 that had an orientation and catch characteristics similar to the net at mile 47. This net was also sampled on one date (7 April) in 2003. In 2005 this net was substituted entirely for the net at mile 47 due to extensive damage to the net at mile 47 in a maritime accident. 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, although in 2004, a manufacturing error resulted in two nets of the number one configuration being fished on both rivers. The two nets were set approximately 300 meters apart and along the same depth contours on both rivers. Although the down-river net did not always contain the greater catches, removal by one net may have affected the catch rates of its companion.

The gill nets 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 Arock fights@ by local fishermen) and enhance catches of males. The pound net catches contained a greater relative proportion of older female striped bass than did the catches from the gill nets. This trend has been persistent over several years. Thus, given the presence of large females in the spawning run, it is clear that the gill nets do not adequately sample large (900+ mm FL) striped bass.

The biological characterization of the spawning stock of striped bass in the Rappahannock River changed dramatically from 1991-2005. There was a steady decrease in the relative abundance of five to seven year-old striped bass from 1991-2001, but these ages were proportionally more abundant in 2002-2005. The males in these age classes had been the target of the recreational and commercial fisheries, but with the increase in the availability of larger striped bass in recent years, the younger striped bass may be under less fishing pressure. Current regulations protect females from harvest during their annual migration by higher minimum lengths in the coastal fishery (711 mm TL vs. 458 mm TL within Chesapeake Bay) and the closure of the fishery in the bay during the April spawning run. The result has been a general increase in the abundance of older females throughout the period. The catches of older females from the pound nets were somewhat lower in 2005. They had increased dramatically in 2003 and 2004, after having decreased in 2002. This pattern was also noted after low catches in 1992 and in 1996. However, catches of the older females in the Rappahannock River gill nets was historically low.

Of note in the 2005 samples was the relative abundance of 1996 year class (nine year old) male and female stripers. This year class has been above-average in abundance since recruiting to the gears at age three, which indicates that it is a very strong year class. The 1992 year class (13 years old) also showed increased abundance relative to previous year classes at that age. 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 2005 values of the Spawning Stock Biomass Index (SSBI) for the Rappahannock River were lower than in 2004 for both male and female striped bass and from both gears. The SSBI for male and female striped bass captured in the pound nets were above the mean in the 1991-2005 time series. The decrease in the SSBI was due to decreased numbers across almost every age class when compared to 2004. In contrast, the decrease in the SSBI resulted in values below the mean for both male and female striped bass in the gill nets. In fact, the catch rate for female striped bass was the lowest since 2000, especially for the larger, older specimens.

The 1991-2005 values of the SSBI in the Rappahannock River were not consistent between pound nets and gill nets. In the pound nets, male biomass peaked in 1993 due to strong 1988 and 1989 year classes, and again in 1999 and 2000 due to strong 1996 and 1997 year classes. The value in 2005 was driven by decreased catches of 1998-2000 year classes of males, after strong catches in 2004. The female biomass from pound nets showed no reliance upon any age groups. The male biomass from the gill nets is driven by the number of Asuper catches@, when the net is literally filled by males, seeking to spawn, that occur differentially among the years (most notably in 1994, 1997 and 2004). Due to the highly selective nature of the gill nets (significantly fewer large females), the female SSBI from these nets is less reliable. The low biomass values from both gears of both sexes in 1992 and 1996 are probably an underestimate of spawning stock strength since water temperatures were below normal in those years. Local fishermen that low temperatures alter the catchability of striped bass. It is also possible that the spawning migration continued past the end of sampling in those years.

The 2005 values of the SSBI in the James River were also lower than in 2004 for both male and female striped bass. The male index was driven by large catches of the 2000-2002 year classes while the female index had low catch rates across all year classes. Because of the changes in location and in the methodology utilized by the new fisherman starting in 2000, the values are not directly comparable with those of previous years. The below normal river flow conditions noted for the Rappahannock River, apply to the James River as well. The relative scarcity of larger, predominantly female, striped bass from the gill nets in the James River (compared to pound net catches) implies a similar limitation in fishing power as shown in the Rappahannock River but comparative data are not available since there are no commercial pound nets on the James River.

The Egg Production Potential Index (EPPI) is an attempt to better define the reproductive potential of the spawning stocks, especially as they become more heavily dependent on fewer, but larger, female striped bass. For example, in the 2001 Rappahannock River pound net data the contribution of 8+ year old females was 75.2% of the total number of mature females (the basis of our index prior to 1998), 94.1% of the mature female biomass (the basis of the current index) and 94.3% of the calculated egg potential. As noted previously, the catches in 2002 were less reliant on older fish than in the preceding years so that the contribution of 8+ year old females was 46% of the total number of mature females, but still 69.1% of the female biomass and 68.4% of the potential egg production. In 2005, the contribution of 8+ year old females was 87.6% of the total number, 94.8% of the biomass and 95.6% of the calculated egg potential. It should be noted that our fecundity estimates for individual striped bass are well below those reported by Setzler et al. (1980). Our methodology differs from the previous studies, but the relative contribution in potential egg production of the older females may be underestimated at present.

In our analysis of pound net catch rates, we observed a distinctive bimodal distribution of female striped bass in the 1987-1996 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 1991-1995 year classes actually showed greater abundance at ages nine to 12 years than at any other age. Age estimation of larger striped bass by scales is problematic because re-absorption or erosion of outer margins of scales may cause under-estimation of age. Under-ageing errors might tend to lump catches of old fish (>12 years) into younger categories (nine to 12 years). However, ignoring age, we also observed a bimodal size distribution, one group from 470-590 mm fork length, presumably young, and the second group of 850-1200 mm fork length, presumably older. This trend became increasingly apparent in the 1997-2003 data and its significance has not been determined. In 2004 and 2005, the second group was expanded to 750-1200 mm as the strong 1996 and 1997 year classes were caught in abundance.

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

The time series allows estimates of the instantaneous rates of survival of the year classes using catch curves, especially for the 1983-1997 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 0.66 in pound nets and 0.58 in gill nets. The lower capture rates of larger (older) females in the gill nets resulted in lower estimates. The survival estimates of male striped bass were approximately 0.45 in pound nets and 0.38 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 0.42 for male striped bass and approximately 0.56 for female striped bass.

The catch histories of the 1987-1997 year classes in the Rappahannock River show two distinct patterns. The 1987-1990 year classes had initial peaks of abundance of both sexes at ages four or five and a secondary peak in the abundance of female striped bass after age eight. Subsequent year classes did not have the initial peak in abundance of female striped bass, but only what was the secondary peak of eight to 12 year-olds. Since catches of larger, thus older, striped bass was less consistent in the gill net catches, this pattern was less apparent in that data set. Using the area under the catch curve as an indicator of year class strength, the 1993 and 1996 year classes were the strongest and the 1990 and 1991 year classes were the weakest.

Back-calculation of the growth based on measurements between scale annuli indicated that striped bass grow about 140 mm (fork length) in their first year. Growth averaged 115 mm in their second year and decreased gradually to about 50 mm by age 10. Thus, striped bass reach the 18 in. (457 mm) minimum total length for the Chesapeake Bay resident fishery at 3.5 years of age (the 2001 year class in 2004) and the 28 in. (711 mm) minimum total length for the coastal fishery at age seven.

The ages of striped bass determined by reading both their scales and otoliths were found to differ by as much as six years (though only for a single specimen). The age difference determined for the largest, and oldest, specimens was 0-6 years (13-20 years by reading the scale vs 13-22 years by reading the otolith). The maximum age determined by reading scales has generally remained constant at 16 years since 1991 (although a single 20 year-old was aged in 2005), while there has been an annual progression in the maximum age determined by reading otoliths. Agreement between the two ageing methodologies was only 42.1% and was slightly higher than the results from 2004. When there was disagreement between methodologies, the otolith age was 1.47 times more likely to have been aged older than the respective scale-derived age and 2.5 times as likely to produce a difference of two or more years older. The differences were found to be statistically non-random and different from zero. The age at which the divergence became significant was age seven. However, the relative contributions of the age classes and their overall mean age were marginally statistically different between the two methodologies. Thus, by using otoliths to age the striped bass, the age structure extends back to the 1983 year class, while scale ageing limits the age structure to the 1985 year class. Previous ageing method comparison studies (Secor, et al. 1995, Welch, et al. 1993) concluded that otolith-based and scale-based ages of striped bass became increasingly divergent, with otolith ages being older, especially after 900 mm in size or 10-12 years in age. We plan to continue these comparisons in future years.

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Table 1. Numbers of striped bass in three age categories (year classes 2001-2003, 1997-2000 and 1987-1996) from pound nets in the Rappahannock River, by sampling date, spring, 2005. M = males, F = females.

Date	n	Year Class							
		2001 - 2003		1997 - 2000		1987 - 1996		Not aged	
		M	F	M	F	M	F	M	F
31 March	122	97	0	16	2	1	6	0	0
4 April	91	35	0	28	5	4	18	1	0
7 April	51	35	0	4	1	2	8	1	0
11 April	25	7	1	0	3	0	14	0	0
14 April	13	4	0	3	3	0	3	0	0
18 April	36	9	0	12	3	1	11	0	0
21 April	62	9	0	17	11	1	23	1	0
25 April	79	14	0	35	6	5	19	0	0
28 April	74	24	0	20	8	5	16	1	0
2 May	64	21	0	30	2	2	9	0	0
Total	**617**	**255**	**1**	**165**	**44**	**21**	**127**	**4**	**0**

Table 2. Net-specific summary of catch rates and mean ages of striped bass (n= 617) in pound nets on the Rappahannock River, spring, 2005. Values in bold are grand means for each column. M = male, F = female.

Date	Net ID	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
31 March	S462	122	38.0	2.7	51,895.1	23,673.4	4.0	9.5
4 April	S454	91	17.0	5.8	40,416.2	43,189.5	5.2	9.6
7 April	S462	51	14.0	3.0	21,656.4	29.266.7	4.1	10.6
11 April	S454	25	1.8	4.5	1,630.2	35,986.9	3.7	9.8
14 April	S462	13	2.3	2.0	3,483.3	14,150.0	4.3	9.0
18 April	S454	36	5.5	3.5	14,258.9	29,548.4	5.4	9.4
21 April	S462	62	9.0	11.7	20,583.3	89,166.7	5.2	9.8
25 April	S454	79	13.5	6.3	39,525.0	43,525.0	5.8	9.2
28 April	S462	74	17.0	7.7	42,483.3	66,550.0	5.5	9.7
2 May	S454	64	13.3	2.8	30,646.7	21,562.5	5.2	9.6
Totals	S454	295	10.2	4.6	25,295.4	34,762.5	5.4	9.5
	S462	322	16.1	5.4	28,020.3	44,561.4	4.0	9.8
Season		617	**12.7**	**4.9**	**26,463.2**	**38,962.0**	**4.5**	**9.7**

Table 3. Length frequencies (TL in mm) of striped bass sampled from the pound nets in the Rappahannock River, spring, 2005.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	1	**460-**	22	**620-**	6	**780-**	5	**940-**	4	**1100-**	0
310-	0	**470-**	32	**630-**	3	**790-**	7	**950-**	8	**1110-**	0
320-	1	**480-**	31	**640-**	4	**800-**	9	**960-**	2	**1120-**	1
330-	1	**490-**	20	**650-**	2	**810-**	16	**970-**	4	**1130-**	0
340-	2	**500-**	17	**660-**	2	**820-**	12	**980-**	2	**1140-**	1
350-	2	**510-**	13	**670-**	3	**830-**	19	**990-**	1	**1150-**	0
360-	2	**520-**	17	**680-**	0	**840-**	11	**1000-**	2	**1160-**	0
370-	2	**530-**	14	**690-**	0	**850-**	14	**1010-**	2	**1170-**	1
380-	3	**540-**	13	**700-**	2	**860-**	7	**1020-**	3	**1180-**	0
390-	1	**550-**	8	**710-**	0	**870-**	9	**1030-**	0	**1190-**	0
400-	7	**560-**	11	**720-**	3	**880-**	16	**1040-**	2	**1200-**	0
410-	13	**570-**	13	**730-**	2	**890-**	8	**1050-**	2	**1210-**	0
420-	17	**580-**	16	**740-**	6	**900-**	10	**1060-**	0	**1220-**	0
430-	19	**590-**	14	**750-**	3	**910-**	10	**1070-**	2	**1230-**	0
440-	12	**600-**	9	**760-**	4	**920-**	4	**1080-**	0	**1240-**	1
450-	25	**610-**	6	**770-**	6	**930-**	8	**1090-**	1	**1250-**	0

Table 4. Mean fork length (mm), weight (g), standard deviation (SD) and CPUE (fish per day; weight per day), of striped bass from pound nets in the Rappahannock River, 30 March - 3 May, 2005 (n/a: unageable).

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
2003	male	2	283.0	28.3	293.2	95.7	0.1	16.8
2002	male	64	384.3	26.1	721.7	149.3	1.8	1,319.7
2001	male	189	448.0	26.6	1,170.5	243.4	5.4	6,320.7
	female	1	450.0		1,347.5		0.0	38.5
2000	male	87	526.0	27.3	1,922.7	278.8	2.5	4,779.3
	female	10	543.7	31.2	2,174.1	378.6	0.3	621.2
1999	male	23	578.8	26.3	2,625.3	553.3	0.7	1,725.2
	female	2	626.0	11.3	2,850.1	70.9	0.1	162.9
1998	male	18	692.1	42.8	4,574.6	863.9	0.5	2,352.7
	female	9	728.8	27.3	5,133.3	418.3	0.3	1,320.0
1997	male	35	757.6	29.4	5,454.3	764.9	1.0	5,454.3
	female	24	776.4	24.1	6,092.6	817.7	0.7	4,177.8
1996	male	15	794.0	29.0	6,269.6	661.6	0.4	1,687.0
	female	44	812.9	31.3	7,326.1	1,380.1	1.3	9,210.0
1995	male	3	787.7	29.1	6,466.7	1,072.8	0.1	92.0
	female	30	854.8	24.0	8,413.2	1,000.8	0.9	7,211.3
1994	male	3	806.3	110.9	7,333.3	3,651.8	0.1	313.0
	female	21	878.3	29.1	8,945.0	1,283.4	0.6	7700.4
1993	male	1	810.0		6,100.0		0.0	174.3
	female	19	918.5	53.7	11,525.2	3,010.5	0.5	6,256.5
1992	female	10	955.2	30.7	12,296.6	2,079.1	0.3	3,513.3
1991	female	3	1,005.0	37.4	13,783.3	340.3	0.1	1,181.4
1990	female	1	1,010.0		13,800.0		0.0	394.3
1989	female	1	1,062.0		18,950.0		0.0	541.4
1987	female	1	1,120.0		18,850.0		0.0	538.6
1985	female	1	1,182.0		26,000.0		0.0	742.9

Table 5. Summary of the season mean (30 March - 3 May) catch rates and ages, by sex, from the pound nets in the Rappahannock River, 30 March - 3 May, 1993-2005. M = male, F = female.

Year	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2005	617	12.7	4.9	26,463.2	38,962.0	4.5	9.7
2004	951	23.5	8.3	58,561.9	65,437.0	5.3	9.4
2003	470	9.4	6.2	22,767.3	53,560.9	5.2	9.5
2002	170	3.5	1.8	7,057.2	11,422.9	4.6	7.8
2001	577	15.2	3.4	24,193.2	26,298.6	4.3	9.1
2000	1,508	37.4	1.9	42,233.1	14,704.5	3.7	8.8
1999	836	27.7	2.1	31,370.7	16,821.7	3.7	9.9
1998	401	10.3	4.0	15,598.6	32,930.6	4.0	9.5
1997	406	14.4	5.9	22,400.0	49,700.0	4.0	9.2
1996	430	10.1	2.2	14,300.0	9,400.0	3.9	7.9
1995	363	11.2	3.3	13,500.0	20,000.0	3.3	7.2
1994	375	8.4	5.4	17,400.0	30,900.0	4.5	7.2
1993	565	14.4	7.3	31,400.0	37,500.0	4.6	6.9
Mean	**589.9**	**15.2**	**4.4**	**25,172.7**	**31,356.8**	**4.3**	**8.6**

Table 6. Numbers of striped bass in three age categories (year classes 2001-2003, 1997-2000 and 1987-1996) from gill nets in the Rappahannock River, by sampling date, spring, 2005. M = male, F = female.

Date	n	Year Class							
		2001 - 2003		1997 - 2000		1987 - 1996		Not aged	
		M	F	M	F	M	F	M	F
31 March	25	15	0	8	1	1	0	0	0
4 April	27	9	0	14	0	2	2	0	0
7 April	34	21	0	6	2	2	1	2	0
11 April	14	5	0	6	0	0	3	0	0
14 April	37	20	0	13	1	1	2	0	0
18 April	53	33	0	15	2	0	3	0	0
21 April	77	45	0	26	0	2	2	2	0
25 April	21	4	0	11	0	1	5	0	0
28 April	33	10	0	20	2	0	1	0	0
2 May	1	0	0	1	0	0	0	0	0
Total	**322**	**162**	**0**	**120**	**8**	**9**	**19**	**4**	**0**

Table 7. Summary of catch rates and mean ages of striped bass (n=322) from the two gill nets in the Rappahannock River, spring 2005. Values in bold are grand means for each column.

Date	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
31 March	25	24.0	1.0	39,269.8	5,834.2	4.6	8.0
4 April	27	25.0	2.0	59,897.5	16,350.3	5.4	9.5
7 April	34	31.0	3.0	55,397.2	16,189.4	4.3	8.0
11 April	14	11.0	3.0	25,030.7	24,075.1	5.0	9.0
14 April	37	34.0	3.0	72,650.0	27,850.0	4.8	10.1
18 April	53	48.0	5.0	71,591.7	35,893.3	4.3	9.0
21 April	77	75.0	2.0	115,438.3	16,102.7	4.6	11.0
25 April	21	16.0	5.0	44,800.7	34,622.1	5.9	9.6
28 April	33	30.0	3.0	67,469.0	21,655.9	5.2	8.7
2 May	1	1.0	0.0	5,200.0	0.0	8.0	
Season	322	**29.7**	**2.7**	**55,674.5**	**19,857.3**	**4.8**	**9.2**

Table 8. Length frequencies (TL in mm) of striped bass sampled from the experimental gill nets in the Rappahannock River, spring, 2005.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	2	460-	13	620-	5	780-	1	940-	0	1100-	0
310-	2	470-	18	630-	5	790-	4	950-	2	1110-	0
320-	1	480-	13	640-	4	800-	6	960-	0	1120-	0
330-	0	490-	10	650-	7	810-	2	970-	1	1130-	0
340-	5	500-	20	660-	5	820-	6	980-	0	1140-	0
350-	1	510-	18	670-	7	830-	1	990-	1	1150-	0
360-	6	520-	13	680-	3	840-	2	1000-	0	1160-	0
370-	5	530-	12	690-	2	850-	1	1010-	0	1170-	0
380-	2	540-	12	700-	2	860-	5	1020-	0	1180-	0
390-	0	550-	9	710-	0	870-	1	1030-	0	1190-	0
400-	3	560-	7	720-	1	880-	2	1040-	0	1200-	0
410-	4	570-	7	730-	1	890-	0	1050-	0	1210-	0
420-	5	580-	4	740-	1	900-	2	1060-	0	1220-	0
430-	4	590-	6	750-	0	910-	1	1070-	0	1230-	0
440-	10	600-	3	760-	2	920-	2	1080-	0	1240-	0
450-	15	610-	4	770-	2	930-	1	1090-	0	1250-	0

Table 9. Mean fork length (mm), weight (g), standard deviations (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the Rappahannock River, 30 March - 3 May, 2005.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2003	male	4	286.5	11.0	289.7	31.4	0.4	115.9
2002	male	40	367.4	36.3	627.7	193.1	4.0	2,510.9
2001	male	118	454.4	25.7	1,224.8	223.8	11.8	14,207.7
2000	male	65	514.2	29.6	1,826.4	339.0	6.5	11,872.5
	female	1	501.0		1,911.6		0.1	181.2
1999	male	24	597.8	23.5	3,027.5	463.7	2.4	7,267.0
	female	2	623.5	26.1	3,473.7	494.6	0.2	694.7
1998	male	17	648.7	50.0	3,783.4	959.0	1.7	6,431.7
	female	2	738.5	10.6	5,461.8	336.9	0.2	1,092.4
1997	male	14	735.3	52.7	5,303.9	948.5	1.4	7,425.4
	female	4	786.3	38.6	6,453.7	989.2	0.4	2,581.5
1996	male	7	724.0	58.8	5,217.2	1,095.2	0.7	3,652.0
	female	8	802.8	38.8	7,073.3	1,639.7	0.8	5,658.5
1995	male	1	834.0		8,050.0		0.1	805.0
	female	3	852.0	27.6	8,546,6	1,075.7	0.3	2,562.8
1994	male	1	707.0		4,515.1		0.1	451.5
	female	3	888.7	28.0	10,488.3	1,286.7	0.3	3,146.5
1993	female	3	854.7	66.1	8,999.0	2,815.2	0.3	2,699.7
1992	female	1	933.0		12,300.0		0.1	1,230.0
N/A	male	4	491.8	140.2	1,909.1	1,583.3	0.1	763.6

N/A: not ageable

Table 10. Summary of the season mean (30 March - 3 May) catch rates and mean ages, by sex, from the experimental gill nets in the Rappahannock River, 1993-2005. M = male, F = female.

Year	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2005	322	29.7	2.7	55,674.5	19,857.3	4.8	9.2
2004	827	79.3	7.8	170,528.8	58,098.9	4.8	8.7
2003	525	52.0	3.3	98,466.7	20,716.8	4.5	8.0
2002	323	24.5	7.8	53,606.9	40,727.5	4.8	7.0
2001	622	58.1	4.1	86,827.2	31,011.3	4.3	8.3
2000	493	47.8	3.1	64,955.7	18,196.0	3.8	7.5
1999	671	64.8	2.3	55,997.3	13,331.0	3.3	7.2
1998	603	57.1	2.9	65,500.0	12,200.0	3.9	7.3
1997	824	80.6	1.8	103,600.0	14,100.0	4.0	7.8
1996	498	45.2	4.6	54,300.0	26,600.0	3.6	6.6
1995	226	15.6	7.0	45,600.0	47,700.0	4.7	7.0
1994	516	41.5	10.1	82,700.0	54,900.0	4.7	6.9
1993	527	36.6	16.0	66,900.0	56,500.0	4.9	6.3
Mean	**554.6**	**50.3**	**5.9**	**79,081.9**	**32,840.1**	**4.3**	**7.4**

Table 11. Numbers of striped bass in three age categories (year classes 2001-2003, 1997-2000 and 1987-1996) from gill nets in the James River by sampling date, spring, 2005. M = male, F = female.

Date	n	Year Class							
		2001 - 2003		1997 - 2000		1987 - 1996		Not aged	
		M	F	M	F	M	F	M	F
31 March	120	71	0	46	1	1	0	1	0
4 April	52	30	0	16	0	1	3	2	0
7 April	116	46	0	59	1	4	2	4	0
11 April	88	42	0	37	2	2	3	2	0
14 April	49	24	0	20	1	3	1	0	0
18 April	60	32	0	26	1	0	1	0	0
21 April	99	55	1	34	2	2	4	1	0
25 April	24	6	0	15	1	1	0	1	0
28 April	25	12	1	9	3	0	0	0	0
2 May	187	120	0	59	1	3	1	3	0
Total	**820**	**438**	**2**	**321**	**13**	**17**	**15**	**14**	**0**

Table 12. Summary of catch rates and mean ages of striped bass (n=820) from the gill nets in the James River, spring 2005. Values in bold are grand means for each column. M = males, F = female.

Date	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
31 March	120	119.0	1.0	214,099.5	7,494.7	4.3	8.0
4 April	52	49.0	3.0	117,079.0	38,418.3	5.0	11.3
7 April	116	113.0	3.0	254,628.9	27,236.8	5.0	9.7
11 April	88	83.0	5.0	174,341.1	38,025.5	4.7	9.4
14 April	49	47.0	2.0	93,638.8	16,454.9	4.7	8.5
18 April	60	58.0	2.0	102,109.5	15,455.1	4.4	8.0
21 April	99	92.0	7.0	157,829.9	43,459.1	4.5	8.1
25 April	24	23.0	1.0	51,230.5	2,971.1	5.2	6.0
28 April	25	21.0	4.0	38,052.2	14,526.1	4.8	6.3
2 May	187	185.0	2.0	276,617.7	11,817.3	4.4	8.5
Total	**820**	**79.0**	**3.0**	**147,962.7**	**21,585.9**	**4.6**	**8.5**

Table 13. Length frequencies (TL in mm) of striped bass sampled from the experimental gill nets in the James River, spring 2005.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	4	**460-**	39	**620-**	11	**780-**	5	**940-**	2	**1100-**	1
310-	3	**470-**	44	**630-**	22	**790-**	7	**950-**	2	**1110-**	1
320-	2	**480-**	27	**640-**	9	**800-**	4	**960-**	0	**1120-**	0
330-	4	**490-**	19	**650-**	6	**810-**	2	**970-**	0	**1130-**	0
340-	7	**500-**	26	**660-**	15	**820-**	3	**980-**	0	**1140-**	0
350-	3	**510-**	31	**670-**	10	**830-**	4	**990-**	0	**1150-**	0
360-	3	**520-**	26	**680-**	7	**840-**	3	**1000-**	1	**1160-**	0
370-	6	**530-**	23	**690-**	5	**850-**	2	**1010-**	0	**1170-**	0
380-	6	**540-**	28	**700-**	5	**860-**	0	**1020-**	0	**1180-**	0
390-	13	**550-**	32	**710-**	4	**870-**	1	**1030-**	0	**1190-**	0
400-	12	**560-**	24	**720-**	5	**880-**	1	**1040-**	1x	**1200-**	0
410-	34	**570-**	28	**730-**	3	**890-**	2	**1050-**	0	**1210-**	0
420-	20	**580-**	32	**740-**	0	**900-**	3	**1060-**	0	**1220-**	0
430-	37	**590-**	24	**750-**	2	**910-**	0	**1070-**	0	**1230-**	0
440-	31	**600-**	18	**760-**	2	**920-**	2	**1080-**	0	**1240-**	0
450-	40	**610-**	20	**770-**	2	**930-**	0	**1090-**	0	**1250-**	0

Table 14. 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, 2005.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
2003	male	9	295.3	12.2	339.6	60.5	0.9	305.6
2002	male	147	383.0	30.2	766.9	183.1	14.7	11,273.6
2001	male	273	448.5	27.6	1,241.5	262.7	27.3	33,892.6
	female	2	484.5	4.9	1,670.6	132.3	0.2	334.1
2000	male	196	540.9	30.5	2,065.3	346.1	19.6	40,480.6
	female	3	552.7	28.2	2,414.5	510.6	0.3	724.4
1999	male	75	588.6	30.5	2,916.6	532.2	7.5	21,874.7
	female	2	618.5	36.1	3,496.8	743.4	0.2	699.4
1998	male	49	648.9	48.7	3,943.6	881.0	4.9	19,323.4
	female	2	675.0	7.1	4,540.1	171.7	0.2	908.0
1997	male	10	733.6	62.7	5,776.5	1,279.6	1.0	5,776.5
	female	6	770.0	30.8	6,476.4	985.3	0.6	3.885.8
1996	male	12	742.7	47.5	5,866.6	1,158.2	1.2	7,039.9
	female	4	820.8	24.6	7,721.6	879.0	0.4	3,088.6
1995	male	1	754.0		6,353.8		0.1	635.4
	female	5	857.4	40.9	8,936.6	1,530.5	0.5	4,468.3
1994	male	3	827.3	58.5	7,849.9	2,443,7	0.3	2,355.0
	female	2	876.5	16.2	9,822.5	1,299.0	0.2	1,964.5
1993	male	1	902.0		9050.0		0.1	905.0
	female	2	898.5	61.5	11,338.4	3,260.4	0.2	2,267.4
1992	female	1	1,040.0		17,474.0		0.1	1,747.4
1991	female	1	1,044.0		15,018.6		0.1	1,501.9
N/A	male	14	572.1	91.1	2,428.4	1,361.3	1.4	4,099.7

N/A: not ageable

Table 15. Summary of the season mean (30 March - 3 May) catch rates and ages, by sex, from experimental gill nets in the James River, 1995-2005.

Year	mile	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
2005	62	820	79.0	3.0	147,962.7	21,585.9	4.6	8.5
2004	62	1,447	127.0	4.5	207,183.6	31,237.6	4.4	8.6
2003	62	639	132.4	8.7	234,255.6	55,043.2	4.5	7.6
2002	62	824	81.4	10.1	173,663.8	47,591.2	4.7	6.4
2001	62	1,050	98.1	6.9	181,512.7	41,347.7	4.4	7.2
2000	62	1,437	139.6	4.1	241,966.4	20,396.6	4.3	6.7
1999	55	482	25.3	22.9	45,886.4	103,362.7	4.3	6.3
1998	55	199	14.9	7.2	33,000.0	46,500.0	4.7	7.5
1997	55	160	11.1	6.7	23,900.0	44,600.0	4.9	7.8
1996	55	183	10.9	7.4	23,800.0	43,500.0	4.8	7.4
1995	55	419	24.0	22.6	52,400.0	125,300.0	4.4	6.7
Mean		**696.4**	**67.6**	**9.6**	**124,139.2**	**52,769.5**	**4.5**	**6.9**

Table 16. Values of the spawning stock biomass index (SSBI) for male and female striped bass, by gear, in the Rappahannock River, 30 March - 3 May, 1991-2005.

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
2005	438	177	26.4	39.0	65.4	291	27	55.6	19.9	75.4
2004	703	247	58.5	65.4	123.9	714	74	171.9	52.0	223.9
2003	283	187	22.8	53.6	76.4	467	31	97.3	20.7	118.0
2002	113	57	7.1	11.4	18.5	240	78	53.4	40.7	94.1
2001	470	105	24.2	27.6	51.8	572	41	88.6	30.9	119.5
2000	1,436	71	42.7	14.6	57.3	452	27	65.3	16.5	81.8
1999	738	61	30.5	19.8	50.3	532	21	51.4	13.2	64.6
1998	273	113	14.8	36.4	51.2	485	27	81.5	18.5	100.0
1997	277	115	22.2	49.6	71.7	801	18	177.8	19.1	197.0
1996	334	73	14.1	9.3	23.4	433	46	63.7	30.2	93.9
1995	207	76	12.4	19.8	32.2	162	69	43.9	56.7	100.6
1994	195	141	17.1	30.9	48.0	391	100	101.6	64.7	166.3
1993	357	188	31.2	37.5	68.7	361	160	85.6	74.1	159.6
1992	51	100	5.4	19.4	24.8	61	74	15.0	32.2	47.2
1991	153	70	21.3	21.5	42.8	406	47	65.0	17.8	83.8
Mean	**402**	**119**	**23.4**	**30.4**	**53.8**	**425**	**58**	**81.2**	**33.8**	**115.0**

Table 17. Values of the spawning stock biomass index (SSBI) calculated from gill net catches of male and female striped bass in the James River, 30 March - 3 May, 1994-2005. 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
2005	**62**	781	30	147.66	21.59	169.25
2004	**62**	1,393	50	207.04	31.24	238.28
2003	**62**	590	43	145.74	35.20	180.94
2002	**62**	728	92	173.51	47.59	221.10
2001	**62**	978	68	181.40	41.31	222.71
2000	**62**	1,381	40	241.41	21.18	262.59
1999	**55**	251	211	45.81	101.98	147.79
1998	**55**	134	65	32.97	46.48	79.45
1997	**55**	100	60	23.89	44.59	68.48
1996	**55**	108	74	23.70	43.35	67.05
1995	**55**	210	202	52.10	125.15	177.25
1994	**55**	119	64	46.27	65.74	112.01
Mean		**564**	**83**	**110.13**	**52.12**	**162.25**

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

FL	Fecundity	FL	Fecundity	FL	Fecundity	FL	Fecundity
400	0.125	**600**	0.446	**800**	1.099	**1000**	2.212
420	0.146	**620**	0.494	**820**	1.187	**1020**	2.354
440	0.168	**640**	0.546	**840**	1.280	**1040**	2.502
460	0.194	**660**	0.601	**860**	1.378	**1060**	2.656
480	0.221	**680**	0.660	**880**	1.482	**1080**	2.817
500	0.251	**700**	0.723	**900**	1.590	**1100**	2.984
520	0.284	**720**	0.789	**920**	1.703	**1120**	3.157
540	0.320	**740**	0.860	**940**	1.822	**1140**	3.337
560	0.359	**760**	0.935	**960**	1.947	**1160**	3.525
580	0.401	**780**	1.015	**980**	2.077	**1180**	3.719

Table 19. Total, age-specific, estimated total egg potential (E, in millions of eggs/day) from mature (ages 4 and older) female striped bass, by river and gear type, 30 March - 3 May 2005. 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	1	0.005	0.08	0	0.000	0.00	2	0.046	1.42
5	10	0.094	1.49	1	0.025	0.82	3	0.104	3.21
6	2	0.029	0.46	2	0.101	3.30	2	0.099	3.05
7	9	0.212	3.36	2	0.171	5.59	2	0.129	3.98
8	24	0.688	10.92	3	0.290	9.49	6	0.587	18.10
9	44	1.459	23.16	8	0.893	29.21	4	0.477	14.71
10	30	1.162	18.44	3	0.402	13.15	5	0.686	21.15
11	21	0.887	14.08	4	0.587	19.20	2	0.293	9.03
12	14	0.685	10.87	3	0.410	13.41	2	0.319	9.84
13	10	0.549	8.71	1	0.178	5.82	1	0.250	7.71
14	3	0.193	3.06	0	0.000	0.00	1	0.253	7.80
15	1	0.065	1.03	0	0.000	0.00	0	0.000	0.00
16	1	0.076	1.21	0	0.000	0.00	0	0.000	0.00
17	0	0.000	0.00	0	0.000	0.00	0	0.000	0.00
18	1	0.090	1.43	0	0.000	0.00	0	0.000	0.00
19	0	0.000	0.00	0	0.000	0.00	0	0.000	0.00
20	1	0.107	1.70	0	0.000	0.00	0	0.000	0.00
Total	172	**6.301**	100.00	27	**3.057**	100.00	30	**3.243**	100.00

Table 20a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 20b. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)				
	2001	**2002**	**2003**	**2004**	**2005**
2002					1.83
2001				3.47	5.43
2000			0.76	**5.57**	2.77
1999	0.07	0.51	3.00	**5.90**	0.71
1998	2.74	1.44	3.33	**3.50**	0.77
1997	7.49	1.38	0.37	2.23	1.69
1996	4.29	0.25	1.83	4.16	1.69
1995	0.10	0.68	1.40	2.33	0.94
1994	0.58	0.41	1.70	1.67	0.69
1993	0.87	0.28	1.43	1.00	0.57
1992	0.87	0.19	1.13	1.10	0.29
1991	0.81	0.06	0.33	0.17	0.09
1990	0.45	0.00	0.27	0.07	0.03
1989	0.26	0.00	0.07	0.07	0.03
1988	0.10	0.00	0.00	0.00	0.00
1987	0.00	0.03	0.03	0.00	0.03
N/A	0.00	0.00	0.00	0.40	0.49
Total	**18.63**	**5.23**	**15.65**	**31.71**	**17.63**

Table 21a. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 21b. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)				
	2001	**2002**	**2003**	**2004**	**2005**
2002					1.83
2001				3.47	**5.40**
2000			0.76	**5.47**	2.49
1999	0.07	0.44	2.93	**5.67**	0.66
1998	2.74	1.38	3.07	**3.37**	0.51
1997	7.42	1.25	0.30	1.93	1.00
1996	4.03	0.25	1.50	2.23	0.43
1995	0.10	0.16	0.56	0.53	0.09
1994	0.39	0.03	0.23	0.20	0.09
1993	0.16	0.03	0.07	0.10	0.00
1992	0.19	0.00	0.00	0.07	0.00
1991	0.13	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00
N/A	0.00	0.00	0.00	0.40	0.46
Total	**15.23**	**3.54**	**9.42**	**23.44**	**12.66**

Table 22a. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 22b. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	**CPUE (fish/day)**				
	2001	**2002**	**2003**	**2004**	**2005**
2001					0.03
2000				0.10	0.29
1999		0.06	0.07	**0.23**	0.06
1998		0.06	**0.27**	0.17	0.26
1997	0.07	0.13	0.07	0.30	**0.69**
1996	0.26	0.00	0.37	**1.93**	1.26
1995	0.00	0.63	0.80	**1.80**	0.86
1994	0.19	0.38	**1.47**	**1.47**	0.60
1993	0.71	0.25	**1.37**	0.90	0.54
1992	0.68	0.19	**1.13**	1.03	0.29
1991	**0.68**	0.06	0.33	0.17	0.09
1990	0.45	0.00	0.26	0.07	0.03
1989	0.26	0.00	0.07	0.07	0.03
1988	0.10	0.00	0.00	0.00	0.00
1987	0.00	0.03	0.03	0.00	0.03
N/A	0.00	0.00	0.00	0.00	0.03
Total	**3.40**	**1.79**	**6.24**	**8.24**	**4.97**

Table 23a. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
2001										
2000										
1999										
1998										
1997										0.480
1996										0.237
1995									0.290	0.914
1994								0.441	0.884	0.884
1993							0.183	0.993	0.993	0.993
1992					0.596	0.437	0.983	0.983	0.983	0.983
1991						0.869	0.869	0.869	0.869	0.869
1990					0.563	0.745	0.745	0.863	0.863	0.863
1989				0.440	0.440	0.899	0.975	0.689	0.689	0.703
1988			0.233	0.877	0.877	0.877	0.593	0.438	0.506	0.506
1987	0.675	0.675	0.315	0.954	0.954	0.954	0.890	0.483	0.116	0.902
1986	0.431	0.972	0.972	0.972	0.972	0.972	0.220	0.182	0.000	------
1985	0.678	0.678	0.678	0.876	0.876	0.876	0.429	0.733	0.000	------
1984			0.881	0.881	0.881	0.881	0.200	0.571	0.000	------
1983			0.717	0.846	0.846	0.846	0.000	------	------	------

Table 23b. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)				
	01-02	02-03	03-04	04-05	Mean
2000			------	0.497	0.497
1999			------	0.120	0.120
1998			------	0.408	0.408
1997	0.668	0.668	0.688	0.220	0.501
1996	0.990	0.990	0.990	0.758	0.705
1995	0.914	0.914	0.914	0.403	0.659
1994	0.884	0.884	0.982	0.413	0.729
1993	0.993	0.993	0.699	0.570	0.718
1992	0.983	0.983	0.973	0.264	0.757
1991	0.638	0.638	0.515	0.529	0.724
1990	0.775	0.775	0.259	0.429	0.650
1989	0.646	0.646	0.646	0.429	0.633
1988	0.000	------	------	------	0.516
1987	0.902	0.902	0.902	0.902	0.670
1986	------	------	------	------	0.581
1985	------	------	------	------	0.621
1984	------	------	------	------	0.571
1983	------	------	------	------	0.610

Table 24a. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

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

Table 24b. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)				
	01-02	02-03	03-04	04-05	Mean
2001			------	------	------
2000			------	0.455	0.455
1999			------	0.116	0.116
1998			------	0.151	0.151
1997	0.638	0.638	0.638	0.518	0.577
1996	0.821	0.821	0.821	0.193	0.474
1995	0.559	0.559	0.946	0.170	0.446
1994	0.768	0.768	0.870	0.450	0.546
1993	0.855	0.855	0.855	0.000	0.496
1992	0.716	0.716	0.716	0.000	0.554
1991	------	------	------	------	0.508
1990	------	------	------	------	0.353
1989	------	------	------	------	0.395
1988	------	------	------	------	0.345
1987	------	------	------	------	0.372
1986	------	------	------	------	0.317
1985	------	------	------	------	0.409
1984	------	------	------	------	0.238

Table 25a. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1998										
1997										
1996										
1995										
1994										
1993										
1992										
1991										
1990								0.914	0.914	0.914
1989				0.912	0.912	0.912	0.912	0.678	0.678	0.765
1988			0.898	0.898	0.898	0.898	0.685	0.438	0.506	0.506
1987			0.802	0.802	0.802	0.802	0.890	0.483	0.116	0.902
1986	0.987	0.987	0.987	0.987	0.987	0.987	0.220	0.181	0.000	------
1985	0.743	0.743	0.743	0.900	0.900	0.900	0.429	0.733	0.000	------
1984			0.914	0.914	0.914	0.914	0.200	0.571	0.000	------
1983			0.717	0.846	0.846	0.846	0.000	------	------	------

Table 25b. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)				
	01-02	02-03	03-04	04-05	Mean
1998	------	------	0.981	0.981	0.981
1997	------	------	------	------	-------
1996	------	------	------	0.653	0.653
1995	------	------	------	0.477	0.477
1994	------	------	-----	0.408	0.408
1993	------	------	0.657	0.600	0.628
1992	------	------	0.919	0.282	0.509
1991	0.697	0.697	0.515	0.529	0.603
1990	0.760	0.760	0.269	0.429	0.653
1989	0.646	0.646	0.646	0.429	0.723
1988	0.000	------	-------	-------	0.607
1987	0.902	0.902	0.902	0.902	0.693
1986	------	------	------	------	0.646
1985	------	------	------	------	0.649
1984	------	------	------	------	0.587
1983	------	------	------	------	0.610

Table 26a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 26b. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)				
	2001	**2002**	**2003**	**2004**	**2005**
2003					0.40
2002				4.10	4.00
2001			2.70	**21.78**	11.80
2000		0.50	8.80	**16.22**	6.60
1999	0.90	1.10	**16.00**	10.74	2.40
1998	9.50	8.80	**12.60**	10.00	1.90
1997	**27.00**	10.20	4.60	10.32	1.40
1996	17.70	4.60	4.20	7.58	1.30
1995	2.10	3.50	1.60	2.74	0.20
1994	1.50	1.20	1.30	1.68	0.30
1993	1.00	1.00	0.50	0.64	0.10
1992	1.10	0.30	0.00	0.42	0.10
1991	0.90	0.30	0.00	0.00	0.00
1990	0.10	0.00	0.10	0.00	0.00
1989	0.10	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00
1987	0.10	0.00	0.00	0.00	0.00
1986	0.00	0.00	0.00	0.00	0.00
1985	0.20	0.00	0.00	0.00	0.00
N/A	0.20	0.80	0.10	0.84	0.40
Total	**62.40**	**32.30**	**52.50**	**87.06**	**32.20**

Table 27a. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 27b. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)				
	2001	**2002**	**2003**	**2004**	**2005**
2003					0.40
2002				4.10	4.00
2001			2.70	**21.78**	11.80
2000		0.50	8.80	**16.00**	6.50
1999	0.90	1.10	**15.90**	10.52	2.40
1998	9.40	8.70	**12.10**	9.68	1.70
1997	**27.00**	8.80	4.30	9.68	1.30
1996	17.00	3.30	3.80	5.68	0.70
1995	1.90	1.40	1.20	0.64	0.10
1994	1.30	0.20	0.40	0.32	0.10
1993	0.40	0.20	0.00	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00
N/A	0.20	0.80	0.10	0.84	0.40
Total	**58.10**	**25.00**	**49.30**	**79.24**	**29.50**

Table 28a. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 28b. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)				
	2001	**2002**	**2003**	**2004**	**2005**
2000				**0.22**	0.10
1999			0.10	**0.22**	0.00
1998	0.10	0.10	**0.50**	0.32	0.20
1997	0.00	**1.40**	0.30	0.64	0.10
1996	0.70	1.60	0.40	**1.90**	0.60
1995	0.20	2.10	0.40	**2.10**	0.10
1994	0.20	1.00	0.90	**1.36**	0.20
1993	0.60	**0.80**	0.50	0.64	0.10
1992	**1.10**	0.30	0.00	0.42	0.10
1991	**0.90**	0.30	0.00	0.00	0.00
1990	0.10	0.00	0.10	0.00	0.00
1989	0.10	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00	0.00
1987	0.10	0.00	0.00	0.00	0.00
N/A	0.00	0.80	0.00	0.00	0.00
Total	**4.10**	**8.40**	**3.20**	**7.62**	**2.70**

Table 29a. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)									
	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1999										
1998										
1997										
1996									0.594	0.833
1995								0.908	0.546	0.777
1994								0.098	0.559	0.984
1993							0.084	0.535	0.535	0.707
1992							0.289	0.289	0.957	0.957
1991						0.496	0.470	0.878	0.878	0.878
1990				0.943	0.452	0.620	0.152	0.798	0.798	0.781
1989				0.163	0.556	0.268	0.500	0.606	0.550	0.909
1988			0.324	0.350	0.521	0.780	0.282	0.606	0.550	0.000
1987	0.663	0.663	0.203	0.829	0.914	0.313	0.220	0.969	0.969	0.969
1986	0.298	0.480	0.928	0.928	0.217	0.856	0.856	0.000	------	------
1985	0.740	0.740	0.740	0.449	0.802	0.802	0.802	0.802	0.802	0.802
1984	0.476	0.927	0.927	0.373	0.000	------	------	------	------	------
1983			0.431	0.232	0.000	------	------	------	------	------

Table 29b. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)				
	01-02	02-03	03-04	04-05	Mean
2001	------	------	------	0.542	0.542
2000	------	------	------	0.407	0.407
1999	------	------	0.671	0.223	0.387
1998	------	------	0.794	0.190	0.388
1997	0.726	0.726	0.726	0.136	0.478
1996	0.754	0.754	0.754	0.172	0.576
1995	0.777	0.884	0.884	0.073	0.559
1994	0.984	0.984	0.984	0.179	0.512
1993	0.707	0.800	0.800	0.156	0.431
1992	0.725	0.725	0.725	0.238	0.537
1991	0.333	0.000	------	------	0.528
1990	0.781	0.781	0.000	------	0.579
1989	0.000	------	------	------	0.418
1988	------	------	------	------	0.408
1987	0.000	------	------	------	0.570
1986	------	------	------	------	0.529
1985	0.000	------	------	------	0.659
1984	------	------	------	------	0.497
1983	------	------	------	------	0.208

Table 30a. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

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

Table 30b. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)				
	01-02	02-03	03-04	04-05	Mean
2002	------	------	------	0.976	0.976
2001	------	------	------	0.542	0.542
2000	------	------	------	0.406	0.406
1999	------	------	0.701	0.228	0.400
1998	------	------	0.800	0.176	0.375
1997	0.710	0.710	0.710	0.134	0.468
1996	0.694	0.694	0.694	0.123	0.519
1995	0.737	0.857	0.533	0.156	0.507
1994	0.555	0.555	0.800	0.313	0.438
1993	0.500	0.000	------	------	0.283
1992	0.000	------	------	------	0.150
1991	------	------	------	------	0.276
1990	------	------	------	------	0.366
1989	------	------	------	------	0.231
1988	------	------	------	------	0.373
1987	------	------	------	------	0.520
1986	------	------	------	------	0.215
1985	------	------	------	------	0.369
1984	------	------	------	------	0.382

Table 31a. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

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

Table 31b. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1991-2005.

Year Class	Survival (S)				
	01-02	02-03	03-04	04-05	Mean
2000				0.455	0.455
1999				0.000	0.000
1998	------	------	0.640	0.625	0.632
1997		0.457	0.457	0.156	0.319
1996	------	------	------	0.316	0.316
1995	------	------	------	0.048	0.048
1994	------	------	------	0.147	0.147
1993	------	0.894	0.894	0.156	0.500
1992	0.725	0.725	0.725	0.238	0.549
1991	0.333	0.000	------	------	0.155
1990	0.781	0.781	0.000	------	0.669
1989	0.000	------	------	------	0.550
1988	0.000	------	------	------	0.501
1987	0.000	------	------	------	0.572
1986	------	------	------	------	0.604
1985	------	------	------	------	0.659
1984	------	------	------	------	0.554
1983	------	------	------	------	0.208
1982	------	------	------	------	0.200

Table 32a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the James River, 30 March - 3 May, 1994-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 32b. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the James River, 30 March - 3 May, 1994-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)	
	2004	2005
2003		**0.90**
2002	0.36	14.70
2001	**30.54**	27.50
2000	**48.00**	19.90
1999	28.00	7.70
1998	11.82	5.10
1997	4.08	1.60
1996	3.56	1.60
1995	1.36	0.60
1994	1.00	0.50
1993	0.28	0.30
1992	0.38	0.10
1991	0.00	0.10
1990	0.00	0.00
1989	0.00	0.00
1988	0.00	0.00
1987	0.00	0.00
N/A	2.36	1.40
Total	131.56	82.00

Table 33a. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 33b. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)	
	2004	**2005**
2003		**0.90**
2002	0.36	14.70
2001	**30.54**	27.30
2000	**47.82**	19.60
1999	27.64	7.50
1998	10.46	4.90
1997	3.90	1.00
1996	2.28	1.20
1995	0.54	0.10
1994	1.00	0.30
1993	0.00	0.10
1992	0.10	0.00
1991	0.00	0.00
1990	0.00	0.00
1989	0.00	0.00
1988	0.00	0.00
N/A	2.36	1.40
Total	**127.00**	**79.00**

Table 34a. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2005. Maximum catch rate for each year class during the sampling period is in bold type.

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

Table 34b. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-2005. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)	
	2004	**2005**
2001		0.20
2000	0.18	0.30
1999	0.18	0.20
1998	0.36	0.20
1997	0.18	0.60
1996	1.28	0.40
1995	0.82	0.50
1994	1.00	0.20
1993	0.28	0.20
1992	0.28	0.10
1991	0.00	0.10
1990	0.00	0.00
1989	0.00	0.00
1988	0.00	0.00
1987	0.00	0.00
1986	0.00	0.00
N/A	0.00	0.00
Total	**4.56**	**3.00**

Table 35a. 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, 1994-2005.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
1999										0.970
1998									0.973	0.410
1997								0.928	0.203	0.510
1996							0.445	0.751	0.751	0.751
1995							0.219	0.305	0.613	0.866
1994						0.944	0.235	0.427	0.949	0.949
1993						0.344	0.762	0.556	0.966	0.591
1992		0.877	0.877	0.901	0.967	0.472	0.730	0.890	0.653	0.653
1991		0.500	0.788	0.788	0.788	0.826	0.826	0.147	0.636	0.845
1990	0.896	0.279	0.645	0.837	0.837	0.598	0.598	0.529	0.529	0.000
1989	0.815	0.266	0.773	0.773	0.773	0.584	0.584	0.584	0.584	0.000
1988				0.834	0.734	0.734	0.542	0.513	0.275	0.000
1987					------	0.645	0.645	0.948	0.948	0.000
1986					------	0.449	0.413	0.953	0.953	0.000
1985					------	0.245	0.733	0.500	0.909	0.000
1984							0.650	0.256	0.550	0.000
1983									0.413	0.000
1982									0.555	0.000

Table 35b. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2005.

Year Class	Survival (S)	
	04-05	Mean
2001	0.900	0.900
2000	0.415	0.415
1999	0.275	0.516
1998	0.431	0.556
1997	0.466	0.460
1996	0.449	0.610
1995	0.441	0.435
1994	0.500	0.591
1993	0.591	0.607
1992	0.263	0.686
1991	0.845	0.638
1990	------	0.551
1989	------	0.551
1988	------	0.491
1987	------	0.593
1986	------	0.508
1985	------	0.440
1984	------	0.347

Table 36a. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2004.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
1999										0.883
1998									0.900	0.402
1997								0.849	0.213	0.515
1996							0.426	0.269	0.309	0.887
1995							0.205	0.263	0.500	0.540
1994							0.161	0.843	0.843	0.843
1993				0.971	0.662	0.672	0.655	0.357	0.357	0.591
1992		0.663	0.833	0.717	0.833	0.833	0.172	0.794	0.794	0.794
1991				0.456	0.401	0.694	0.737	0.737	0.737	0.000
1990					0.597	0.237	0.887	0.474	0.474	0.000
1989							0.292	0.300	0.629	0.000
1988					0.400	0.535	0.606	0.606	0.909	0.000
1987									0.227	0.000
1986										0.000

Table 36b. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2005.

Year Class	Survival (S)	
	04-05	Mean
2001	0.542	0.542
2000	0.406	0.406
1999	0.228	0.449
1998	0.176	0.399
1997	0.134	0.334
1996	0.123	0.329
1995	0.156	0.296
1994	0.313	0.497
1993	------	0.495
1992	------	0.562
1991	------	0.513
1990	------	0.417
1989	------	0.286
1988	------	0.482
1987	------	0.108
1986	------	0.000

Table 37a. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2005.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
1999										------
1998										0.126
1997									0.608	0.608
1996									0.692	0.692
1995						0.548	0.898	0.898	0.898	0.898
1994						0.688	0.688	0.688	0.688	0.688
1993						0.601	0.601	0.601	0.910	0.394
1992						0.791	0.791	0.791	0.561	0.561
1991						0.724	0.724	0.200	0.636	0.845
1990		0.335	0.883	0.883	0.883	0.674	0.674	0.529	0.529	0.000
1989		0.255	0.858	0.858	0.858	0.613	0.613	0.613	0.613	0.000
1988				0.960	0.795	0.795	0.504	0.448	0.367	0.000
1987					------	0.707	0.707	0.949	0.949	0.000
1986					------	0.479	0.413	0.953	0.953	0.000
1985					------	0.245	0.733	0.500	0.909	0.000
1984							0.650	0.286	0.550	0.000
1983									0.413	0.000
1982									0.550	0.000

Table 37b. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets (mile 62) in the James River, 30 March - 3 May, 1994-2005.

Year Class	Survival (S)	
	04-05	Mean
1999	------	------
1998	0.556	0.514
1997	0.608	0.608
1996	0.313	0.531
1995	0.610	0.775
1994	0.200	0.560
1993	0.714	0.618
1992	0.357	0.618
1991	0.845	0.602
1990	------	0.571
1989	------	0.559
1988	------	0.520
1987	------	0.617
1986	------	0.515
1985	------	0.440
1984	------	0.347
1983	------	0.189
1982	------	0.245

Table 38a. Comparison of the area under the catch curve (fish/ day) of the 1987-2003 year classes of striped bass from pound nets in the Rappahannock River, 1991-2005.

age	year class										
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	
2			0.2	0.3	0.3	0.7	1.5	0.3	0.3	0.1	
3		3.6	0.8	1.3	0.8	5.5	5.5	4.2	2.5	11.6	
4	8.0	5.2	4.4	2.6	1.8	8.4	13.6	10.5	14.0	29.8	
5	10.8	14.7	8.9	4.9	3.4	9.6	15.1	13.3	17.3	34.1	
6	14.4	16.9	9.6	6.1	3.5	9.7	15.2	13.4	17.4	34.3	
7	15.6	17.5	10.5	6.8	4.0	10.2	15.7	14.0	18.1	36.1	
8	16.2	17.9	11.3	7.5	4.4	10.7	16.6	14.4	19.5	40.3	
9	16.6	19.4	12.1	7.8	4.8	11.5	16.8	16.1	21.8	42.0	
10	17.6	20.3	12.5	8.1	5.7	11.7	18.3	17.8	22.7		
11	18.5	20.7	12.8	8.6	5.9	12.9	19.3	18.4			
12	18.9	20.7	13.1	8.6	7.0	14.0	19.8				
13	19.0	20.8	13.1	8.9	8.1	14.3					
14	19.0	20.8	13.2	8.9	8.4						
15	19.0	20.8	13.2	9.0							
16	19.0	20.8	13.3								
17	19.0	20.8									
18	19.1										
19											
20											
area	**19.1**	**20.8**	**13.3**	**9.0**	**8.4**	**14.3**	**19.8**	**18.4**	**22.7**	**42.0**	

Table 38b. Comparison of the area under the catch curve (fish/ day) of the 1987-2003 year classes of striped bass from pound nets in the Rappahannock River, 1991-2005.

age	year class										mean
	1997	1998	1999	2000	2001	2002	2003				
2	0.4	0.0	0.0	0.0	0.0	0.0	0.0				0.3
3	16.0	2.7	0.6	0.8	3.5	1.8					4.1
4	23.5	4.2	3.6	6.3	8.9						9.8
5	24.9	7.5	9.5	9.1							13.1
6	25.3	11.0	10.2								14.1
7	27.5	11.8									15.1
8	29.2										16.2
9											17.2
10											18.1
11											18.7
12											19.2
13											19.5
14											19.6
15											19.6
16											19.6
17											19.6
18											19.6
19											
20											
area	29.2	11.8	10.2	9.1	8.9	1.8	0.0				19.6

Table 39a. Comparison of the area under the catch curve (fish/ day) of the 1987-2003 year classes of striped bass from gill nets in the Rappahannock River, 1991-2005.

age	year class										
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	
2			0.7	0.3	0.3	1.4	2.3	1.0	0.4	0.1	
3		9.5	1.5	1.8	2.8	8.4	22.3	30.5	12.1	35.9	
4	23.7	11.4	10.1	10.0	4.7	19.8	105.3	63.2	22.7	57.1	
5	29.5	36.8	37.7	17.8	10.4	34.1	112.3	66.4	28.5	74.8	
6	39.9	45.0	42.2	21.3	13.2	34.9	113.1	68.2	30.6	79.4	
7	42.1	47.9	44.7	23.4	14.6	36.1	115.1	69.7	34.1	83.6	
8	43.8	49.4	45.3	23.8	15.1	36.7	116.1	70.9	35.7	91.2	
9	45.4	50.6	45.7	23.9	15.4	37.8	117.1	72.2	38.4	92.5	
10	45.9	50.9	45.9	24.1	16.3	38.1	117.6	73.9	38.6		
11	46.0	51.1	46.0	24.2	16.6	38.1	118.2	74.2			
12	46.1	51.2	46.1	24.2	16.6	38.6	118.3				
13	46.1	51.2	46.1	24.3	16.6	38.7					
14	46.2	51.2	46.1	24.3	16.6						
15	46.2	51.2	46.1	24.3							
16	46.2	51.2	46.1								
17	46.2	51.2									
18	46.2										
19											
20											
area	**46.2**	**51.2**	**46.1**	**24.3**	**16.6**	**38.7**	**118.3**	**74.2**	**38.6**	**92.5**	

Table 39b. Comparison of the area under the catch curve (fish/ day) of the 1987-2003 year classes of striped bass from gill nets in the Rappahannock River, 1991-2005.

age	year class										mean
	1997	1998	1999	2000	2001	2002	2003				
2	5.9	0.7	0.5	0.3	1.4	2.1	0.2				**1.2**
3	24.0	10.2	1.6	9.1	23.1	6.1					**13.3**
4	51.0	19.0	17.6	25.3	34.9						**32.7**
5	61.2	31.6	28.3	31.9							**43.4**
6	65.8	41.6	30.7								**47.8**
7	76.1	43.5									**50.8**
8	77.5										**52.4**
9											**53.5**
10											**54.0**
11											**54.2**
12											**54.3**
13											**54.3**
14											**54.3**
15											**54.3**
16											**54.3**
17											**54.3**
18											**54.3**
19											
20											
area	**77.5**	**43.5**	**30.7**	**31.9**	**34.9**	**6.1**	**0.2**				**54.3**

Table 40a. Comparison of the area under the catch curve (fish/ day) of the 1987-2003 year classes of striped bass from gill nets in the James River, 1994-2005.

age	**year class**										
	1987	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	
2						0.0	0.3	0.1	0.0	0.0	
3					2.4	4.3	2.0	1.6	1.2	9.1	
4				12.4	11.4	7.2	6.5	8.7	11.5	82.4	
5			12.0	23.5	15.9	10.6	11.7	20.4	49.8	115.0	
6		3.2	21.8	26.6	17.9	13.6	17.8	31.5	58.2	126.0	
7	0.8	5.9	24.4	28.6	19.6	16.5	19.9	34.1	60.8	128.8	
8	3.5	6.9	25.3	29.4	21.8	17.8	21.5	35.2	62.4	132.4	
9	4.5	8.3	26.4	30.8	22.4	18.8	22.4	35.7	63.7	134.0	
10	5.6	9.1	27.6	31.2	23.9	19.7	23.2	36.7	64.3		
11	6.3	9.5	27.7	31.7	24.1	20.0	23.5	37.2			
12	7.3	9.6	27.7	31.8	24.3	20.4	23.8				
13	7.3	9.6	27.7	32.0	24.3	20.5					
14	7.3	9.6	27.8	32.0	24.4						
15	7.3	9.6	27.8	32.0							
16	7.3	9.6	27.8								
17	7.3	9.6									
18	7.3										
19											
20											
area	**7.3**	**9.6**	**27.8**	**32.0**	**24.4**	**20.5**	**23.8**	**37.2**	**64.3**	**134.0**	

Table 40b. Comparison of the area under the catch curve (fish/ day) of the 1987-2003 year classes of striped bass from gill nets in the James River, 1991-2005.

age	year class										mean
	1997	1998	1999	2000	2001	2002	2003				
2	0.1	0.8	0.2	0.2	0.4	0.2	0.5				**0.2**
3	21.7	14.3	4.0	15.7	31.0	14.9					**10.2**
4	64.1	44.0	35.3	63.7	58.5						**35.1**
5	103.4	72.8	63.3	83.6							**54.7**
6	111.4	84.6	71.0								**61.5**
7	115.5	89.7									**64.2**
8	117.1										**65.9**
9											**66.9**
10											**67.8**
11											**68.3**
12											**68.6**
13											**68.7**
14											**68.7**
15											**68.7**
16											**68.7**
17											**68.7**
18											**68.7**
19											
20											
area	**117.1**	**89.7**	**71.0**	**83.6**	**58.5**	**15.1**	**0.5**				**68.7**

Table 41a. Back-calculated length-at-age (FL, in mm) for striped bass sampled from the James and Rappahannock rivers during spring, 2005.

Year Class	n	length-at-age (FL, in mm)							
		1	2	3	4	5	6	7	8
2003	8	155.7							
2002	9	149.9	274.2						
2001	16	148.4	261.2	360.5					
2000	19	142.6	256.8	364.7	452.2				
1999	7	144.2	261.2	377.5	468.0	540.0			
1998	23	128.6	229.5	325.1	414.6	491.7	556.1		
1997	24	139.4	246.9	349.0	448.1	540.8	622.7	689.7	
1996	47	138.0	245.3	344.3	438.4	525.8	604.4	674.0	735.6
1995	34	148.0	252.8	354.9	450.8	540.1	621.3	699.9	765.6
1994	26	137.1	234.2	327.1	413.3	496.4	577.1	649.7	716.7
1993	15	142.9	243.4	335.4	422.2	500.9	575.2	643.2	708.2
1992	10	135.4	229.8	325.2	411.2	493.6	571.0	640.9	703.0
1991	2	155.1	261.0	351.8	447.6	532.4	611.1	694.4	763.3
1990	1	128.7	210.5	294.7	368.7	459.5	526.6	592.4	648.3
1989	5	139.8	225.3	315.2	398.0	481.7	554.5	612.1	675.5
all	246	141.1	246.1	344.1	434.4	517.7	594.3	670.9	731.7

Table 41b. Back-calculated length-at-age (FL, in mm) for striped bass sampled from the James and Rappahannock rivers during spring, 2005.

Year Class	n	length-at-age (FL, in mm)							
		9	10	11	12	13	14	15	16
2003	8								
2002	9								
2001	16								
2000	19								
1999	7								
1998	23								
1997	24								
1996	47								
1995	34	819.1							
1994	26	772.3	824.1						
1993	15	771.1	829.1	873.9					
1992	10	765.4	824.2	857.2	919.1				
1991	2	818.6	875.9	927.4	969.4	1007.2			
1990	1	703.5	753.9	806.1	862.0	913.6	963.0		
1989	5	737.5	795.1	846.2	891.0	931.4	969.6	999.7	
all	246	786.8	823.5	871.3	913.8	948.1	968.5	999.7	

Table 42. Data matrix comparing scale (SA) and otolith ages for chi-square test of symetry. Values are the number of the respective readings of each combination of ages. Values along the main diagonal (methods agree) are highlighted for reference.

SA	Otolith age																			
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
2	**8**																			
3	3	**3**	3																	
4		1	**10**	5																
5			9	**6**	2	2														
6				2	**2**	2		1												
7					1	**7**	6	8	1											
8						1	**4**	15	4											
9						1	1	**38**	5	2	2									
10							1	12	**10**	3	4	1	1							
11							1	6	6	**4**	8									
12									2	3	**6**	3				1				
13									1		5	**4**								
14													**0**	1	1					
15												1		**0**						
16															**2**		2			1
17																**0**				
18																	**0**		1	
19																		**0**		
20																		1	**0**	
21																				**0**

Table 43. Relative contributions of striped bass age classes as determined by ageing specimens (n = 247) by reading both their scales and ooliths.

Age	scale		otolith	
	n	prop.	n	.prop
2	8	.0323	11	.0445
3	9	.0364	4	.0162
4	16	.0648	22	.0891
5	19	.0769	13	.0526
6	7	.0283	5	.0202
7	23	.0931	13	.0526
8	24	.0972	13	.0526
9	49	.1984	80	.3239
10	32	.1286	29	.1174
11	25	.1012	12	.0486
12	15	.0607	25	.1012
13	10	.0405	9	.0364
14	2	.0081	1	.0040
15	1	.0040	1	.0040
16	5	.0202	3	.0121
17	0	.0000	1	.0040
18	1	.0040	2	.0081
19	0	.0000	1	.0040
20	1	.0040	1	.0040
21	0	.0000	0	.0000
22	0	.0000	1	.0040
	$\overline{Age} = 8.52$		$\overline{Age} = 8.67$	

Figure 1. Locations of the commercial pound nets and experimental gill nets sampled in spring spawning stock assessments of striped bass in the Rappahannock River, 1991-2005.

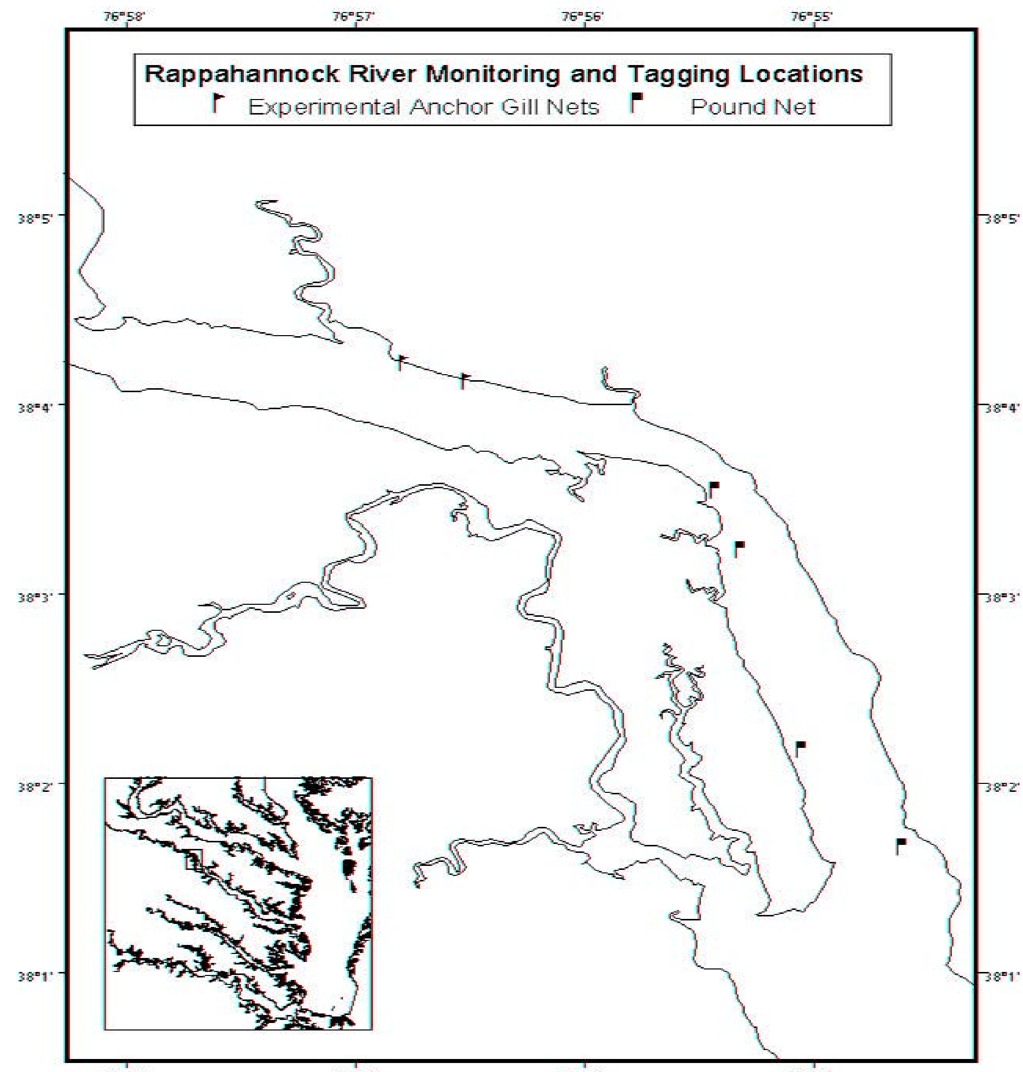


Figure 2. Locations of the experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, springs 2003-2005.

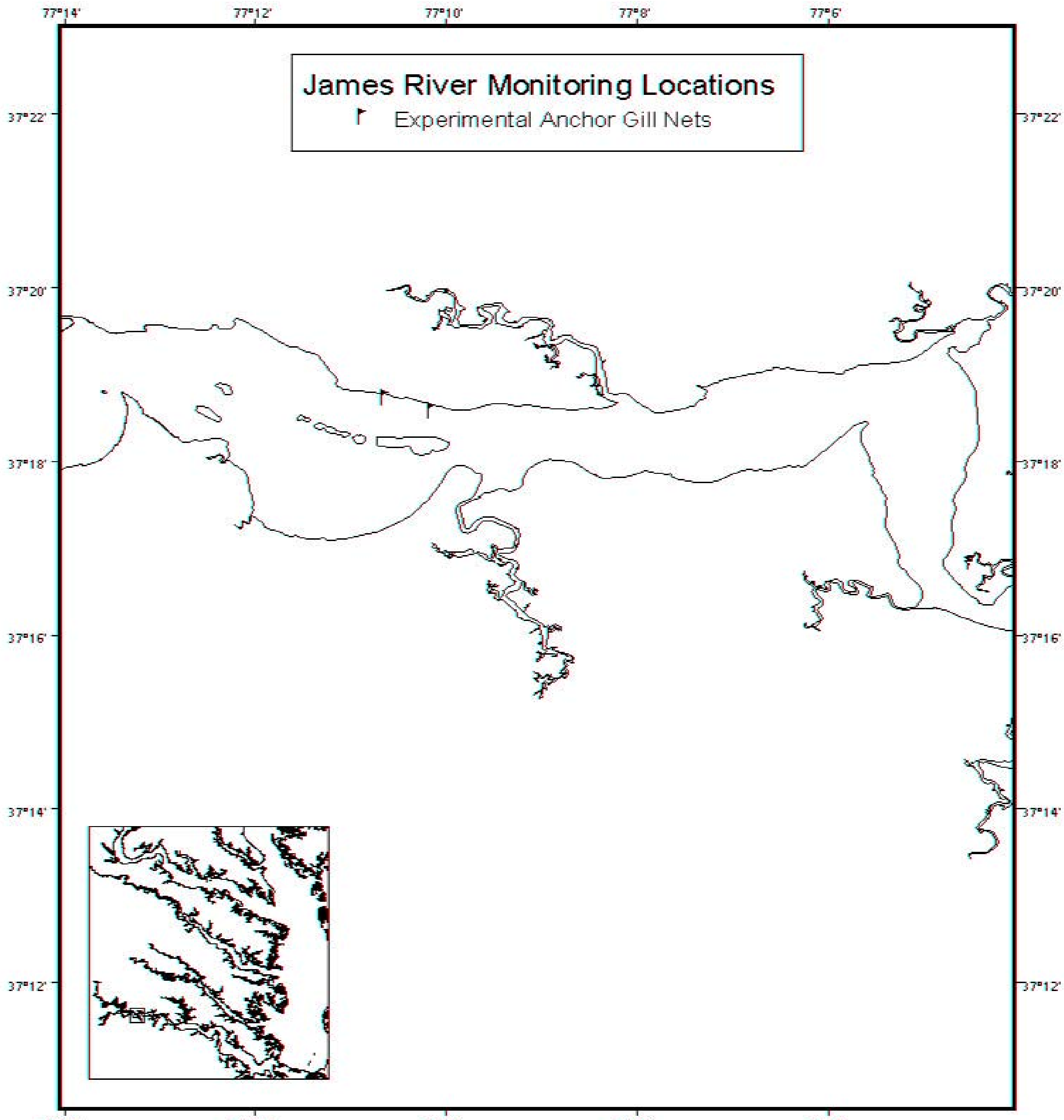


Figure 3. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1987 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

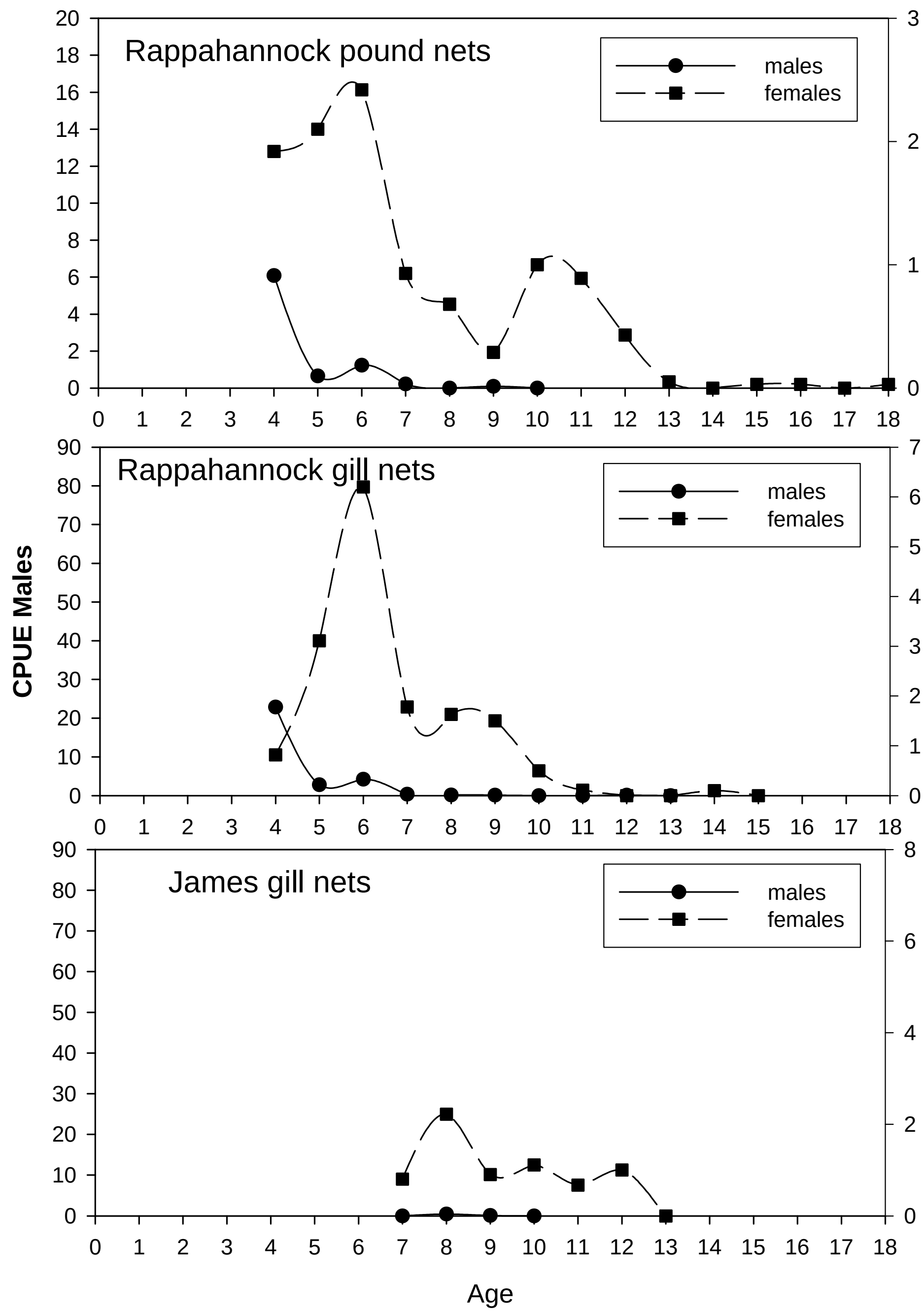


Figure 4. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1988 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

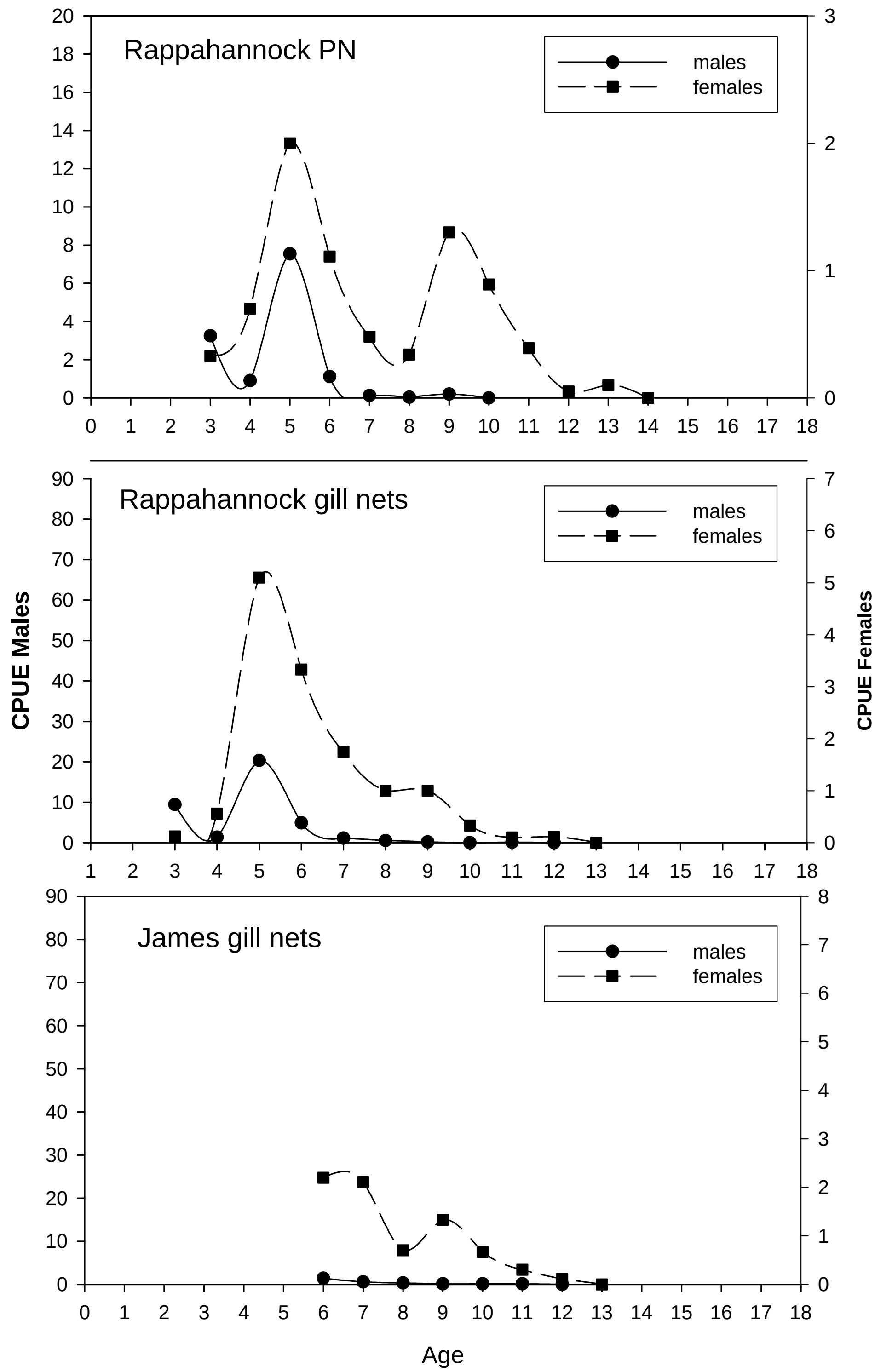


Figure 5. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1989 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

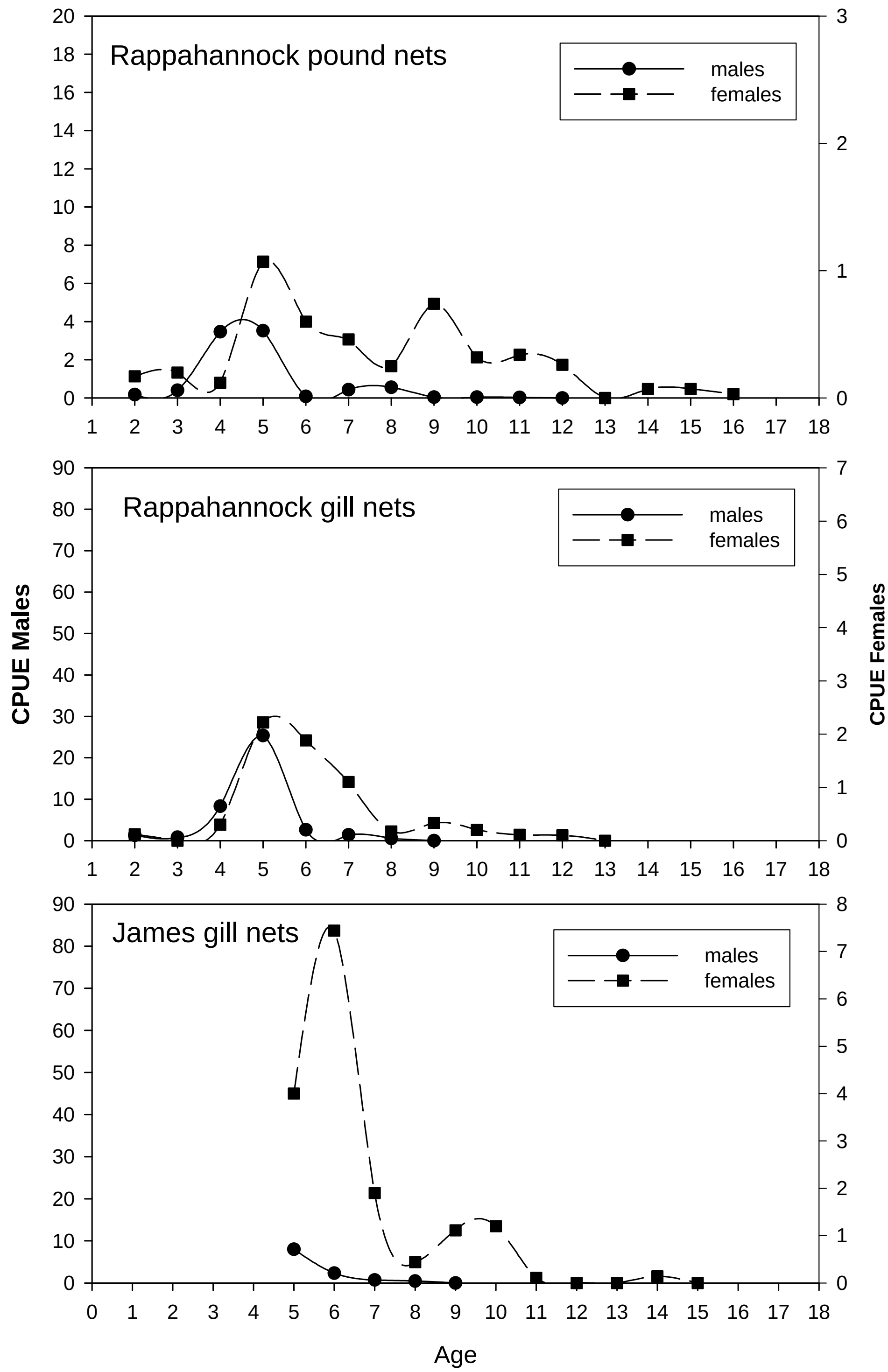


Figure 6. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1990 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

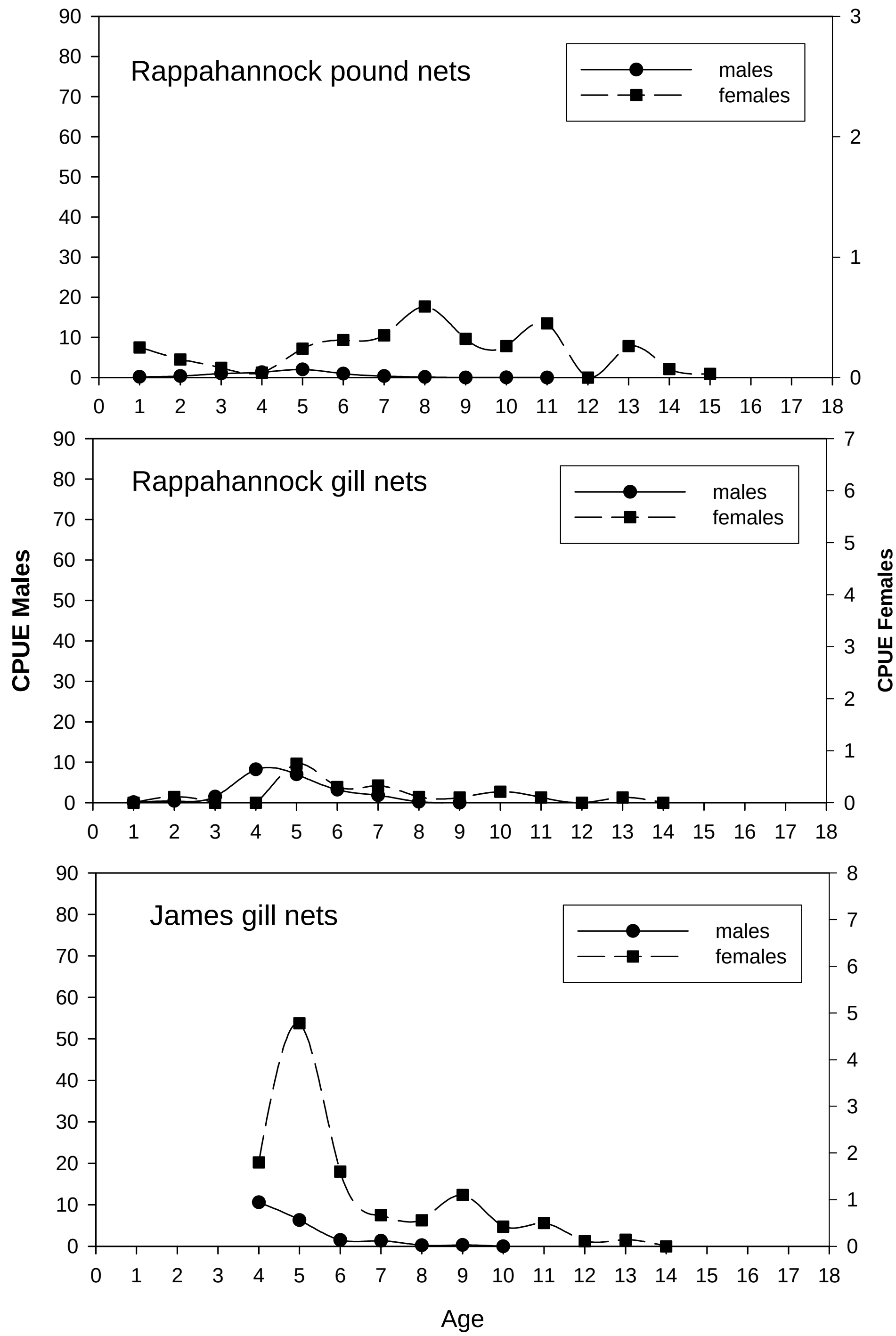


Figure 7. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1991 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

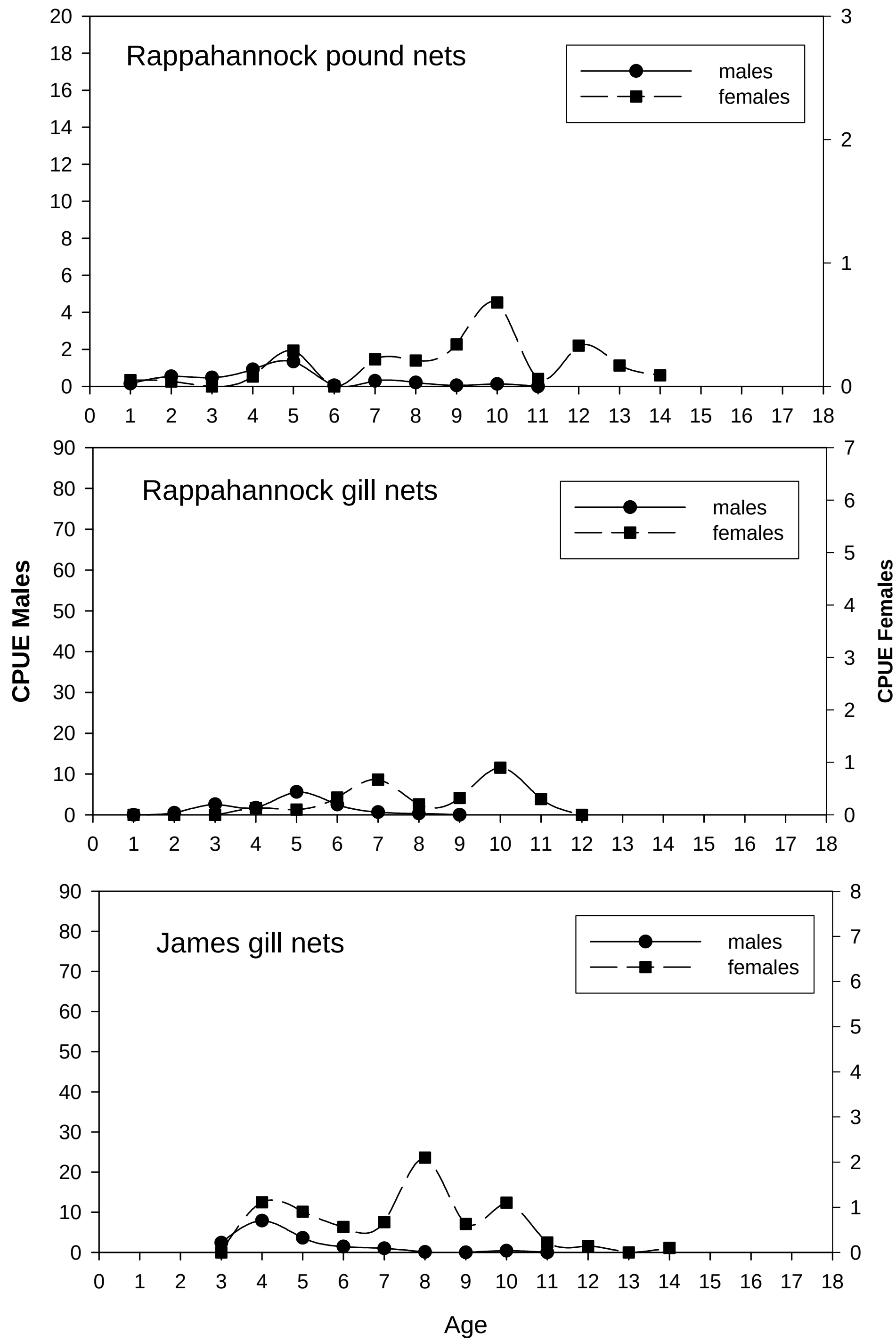


Figure 8. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1992 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

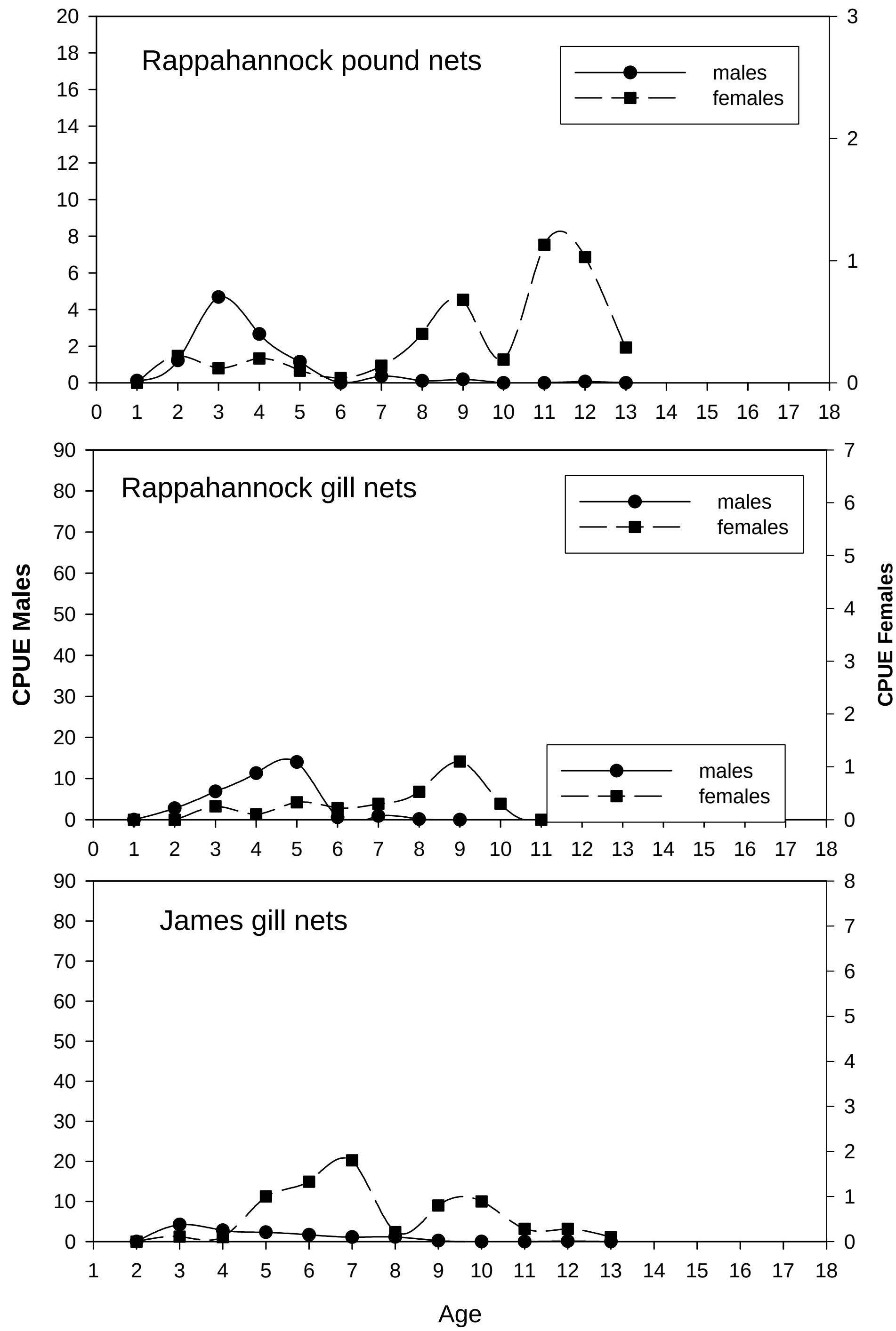


Figure 9. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1993 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

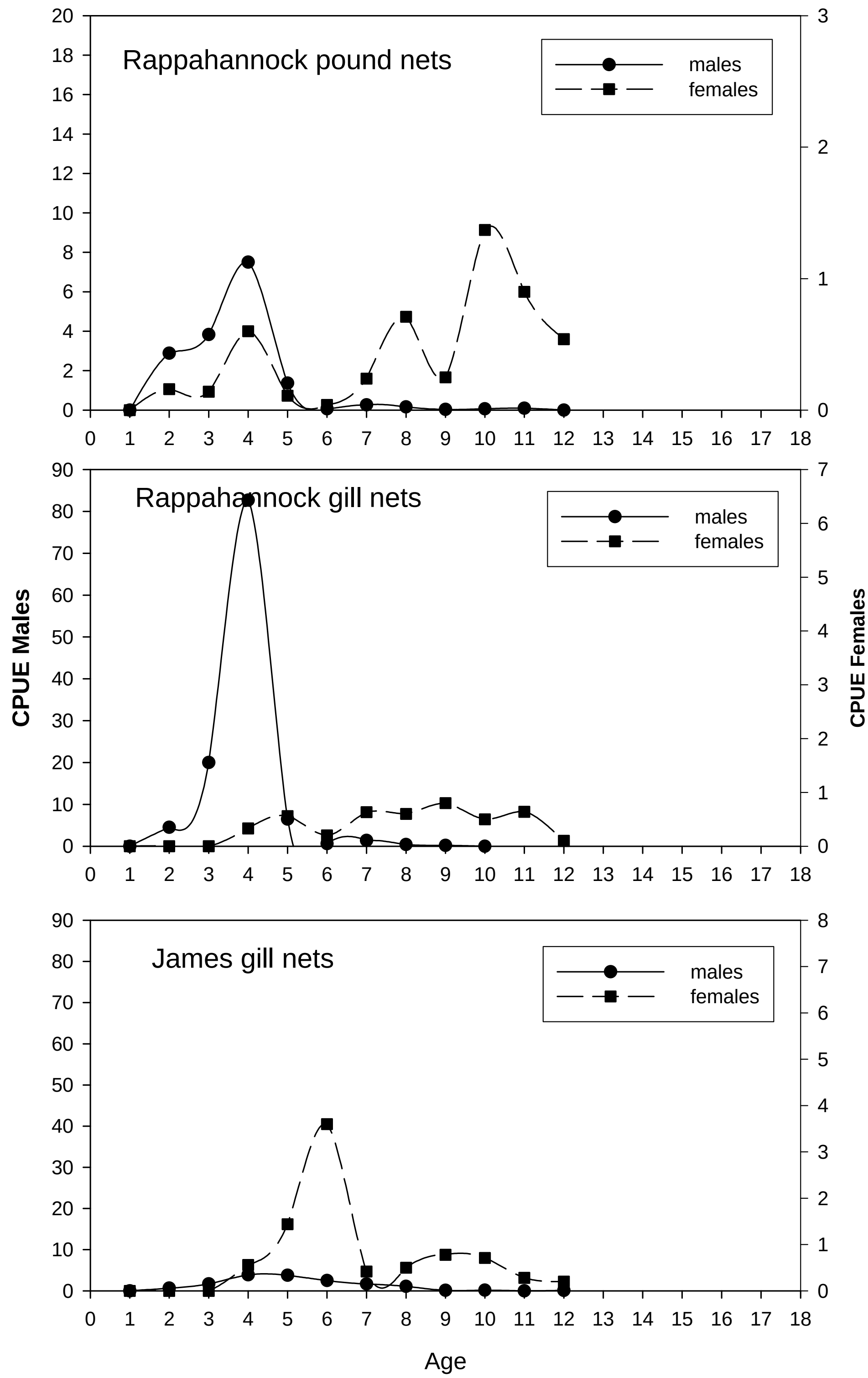


Figure 10. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1994 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

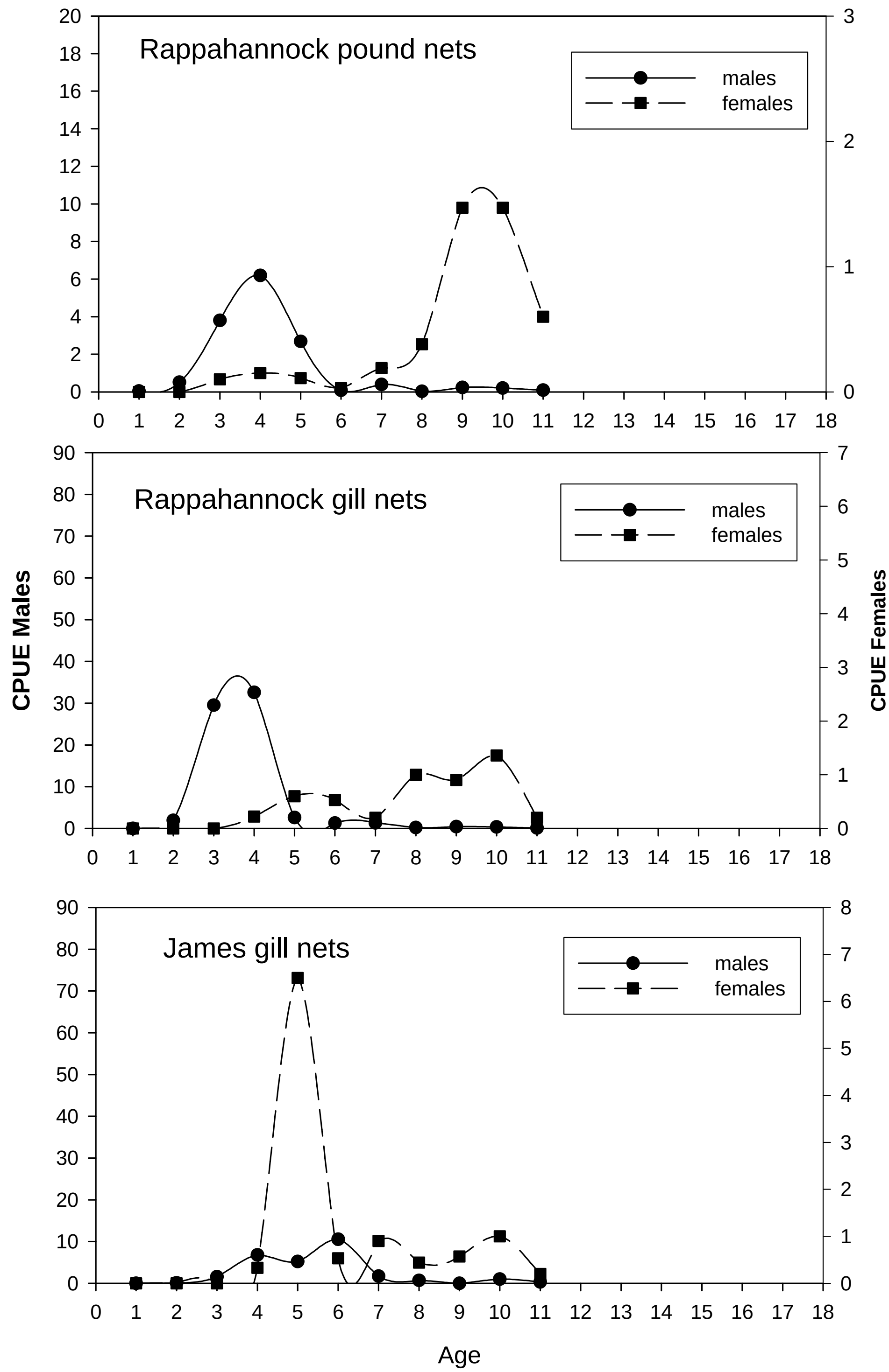


Figure 11. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1995 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

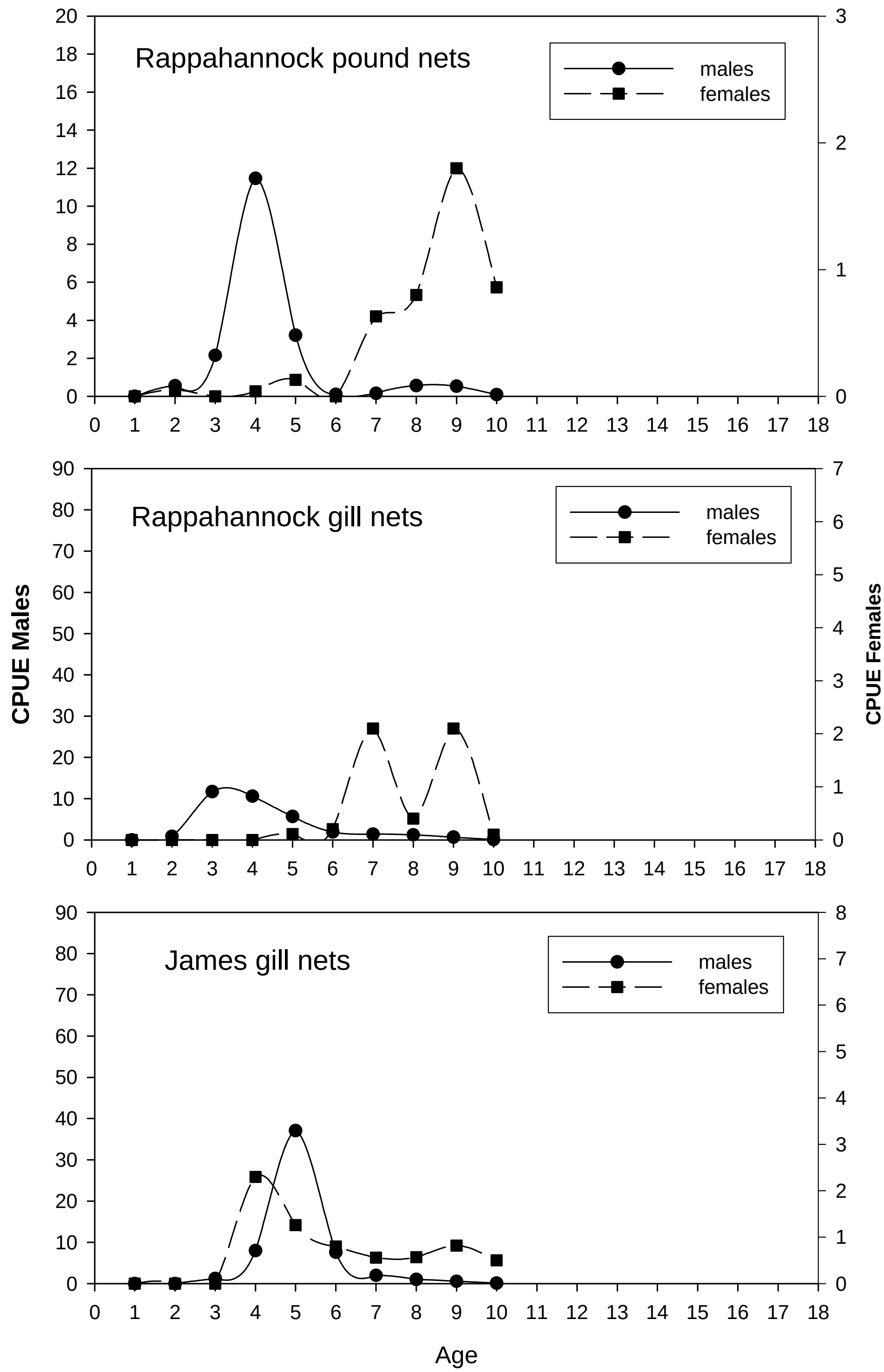


Figure 12. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1996 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

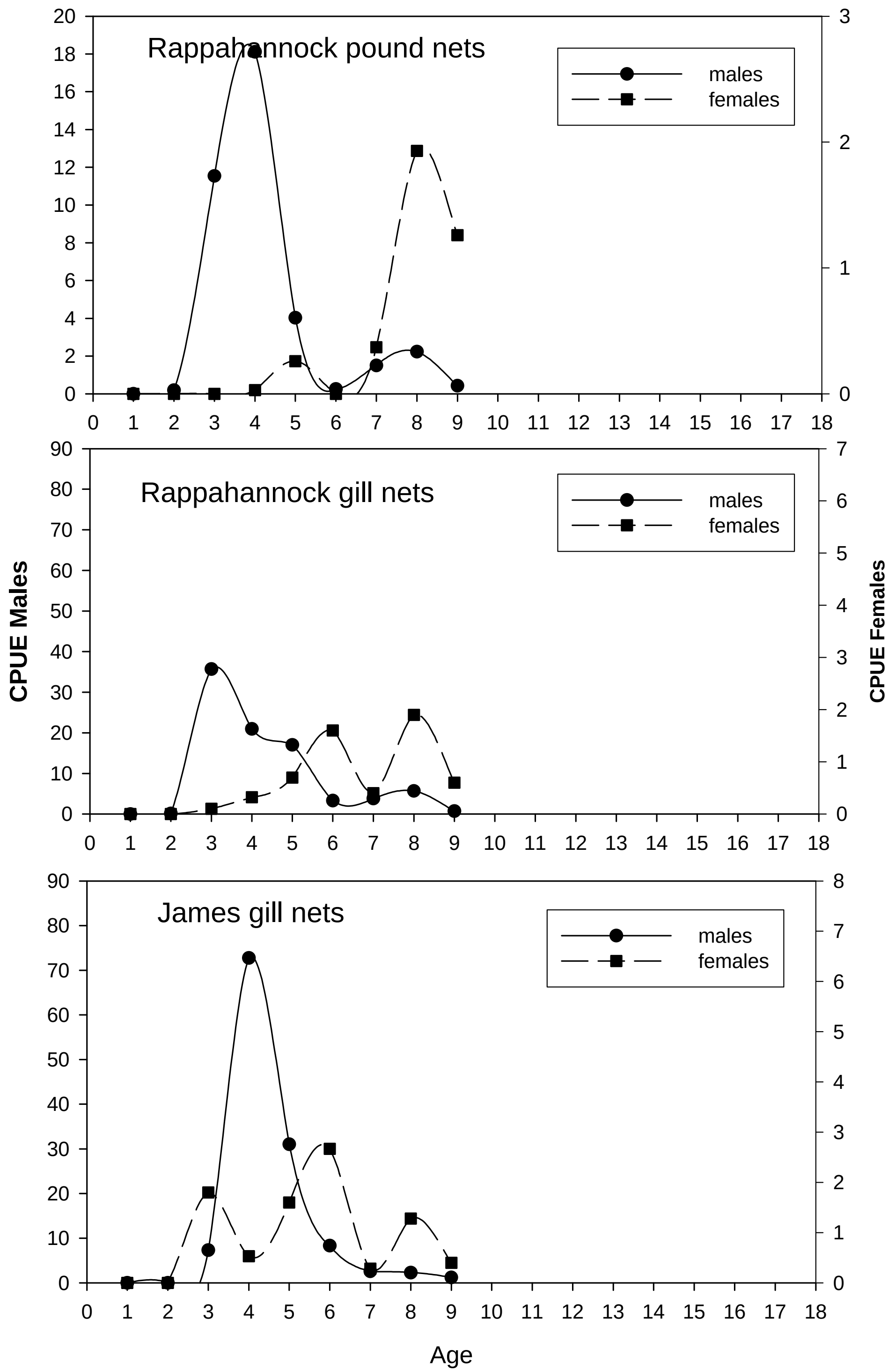


Figure 13. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1997 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2005.

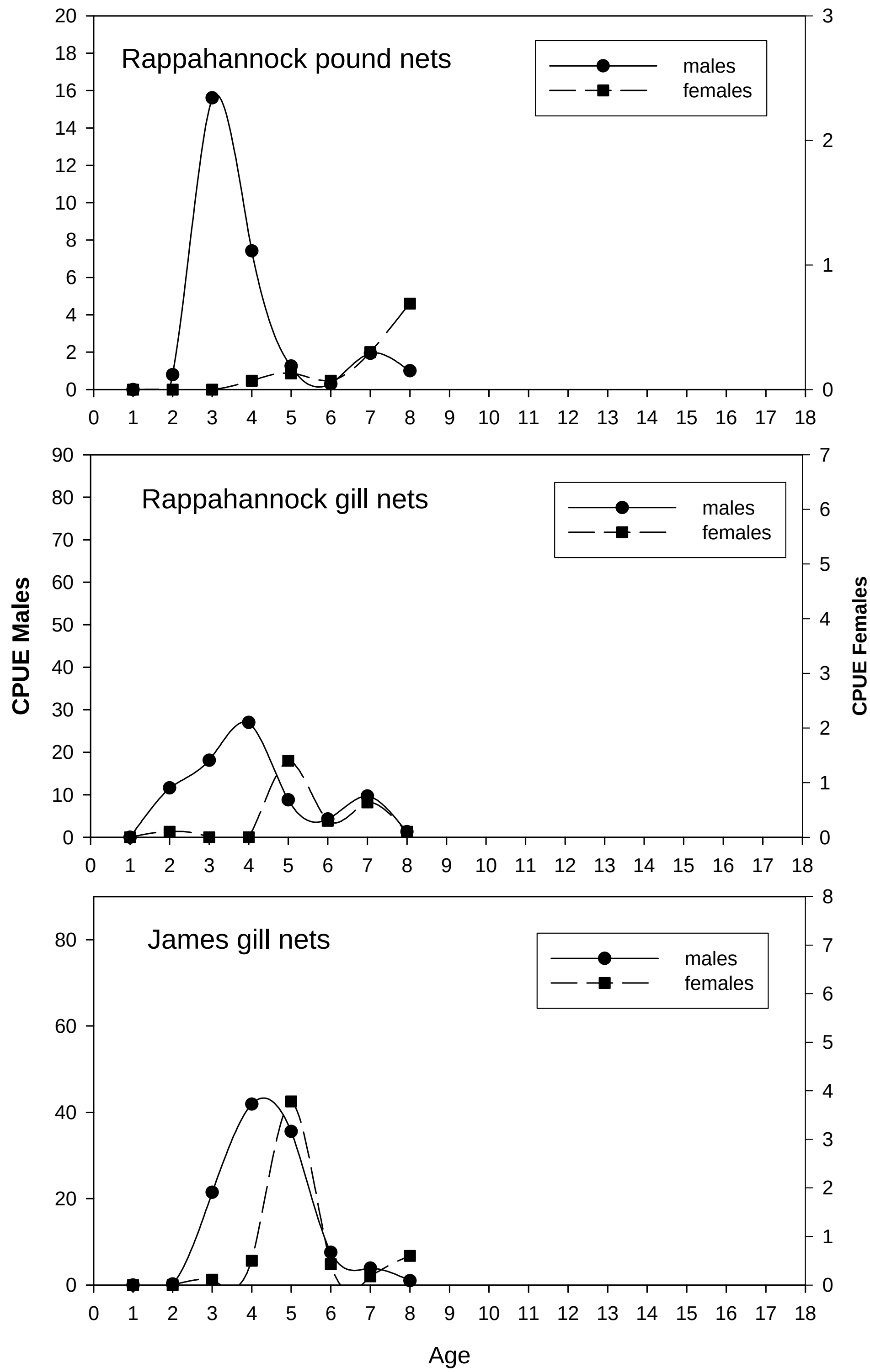
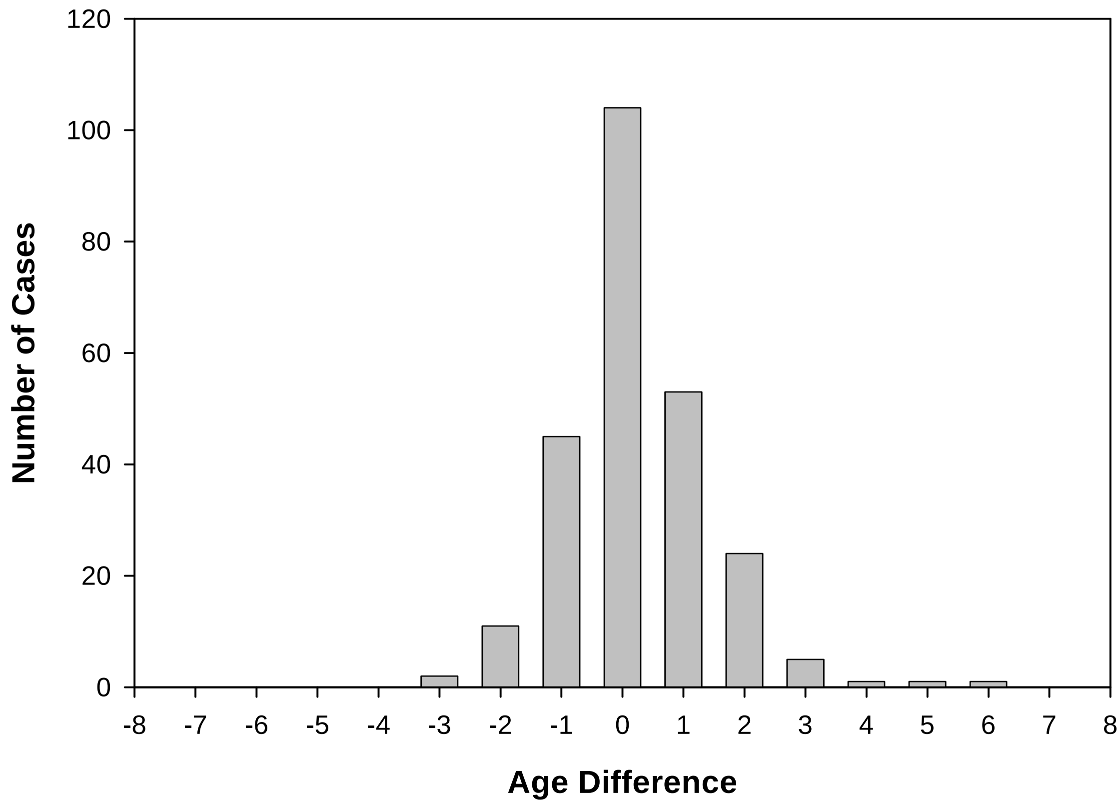


Figure 14. Magnitude of the age differences (otolith age – scale age) resulting from ageing specimens of striped bass (n=247) by reading both their scales and otoliths, spring, 2005.



II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring, 2004-2005

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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 the fall of 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 Striped Bass Program of the Virginia Institute of Marine Science (VIMS) has monitored the size and age composition, sex ratio and maturity schedules of the spawning striped bass stock in the Rappahannock River since 1981. In conjunction with the monitoring studies, VIMS established a tagging program in 1988 to provide information on the migration, relative contribution to the coastal population, and annual survival of striped bass that spawn in the Rappahannock River. This program is part of an active cooperative tagging study that currently involves 15 state and federal agencies along the Atlantic coast. The U.S. Fish and Wildlife

Service manages the coast-wide tagging database. Hence, commercial and recreational anglers that target striped bass are encouraged to report all recovered tags to that agency. The analysis protocol, as established by the ASFMC Striped Bass Tagging Subcommittee, involves fitting a suite of reformulated Brownie models (Brownie et al. 1985; White and Burnham 1999) to the tag return data.

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

This section is an update material provided for this report by Latour (Sadler et al. 2001). He did a comprehensive analysis of the Rappahannock River striped bass tagging data, gave a detailed description of the ASFMC analysis protocol and presented annual survival (S) estimates derived from tag-recovery models developed by Seber (1970) as well as estimates of instantaneous fishing mortality (F) that followed when S was partitioned into its components using auxiliary information.

Multi-year Tagging Models

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

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

where r_{ij} is the number of tags recovered in year j that were released in year i (note, $J \exists I$). 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 can be assumed 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 models: White and Burnham (1999) reformulated the original Brownie et al. (1985) models in the way originally suggested by Seber (1970) 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 with equation (1) would be

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

where N_i is the number tagged in year i, S_i is the survival rate in year i and r_i is the probability a tag is recovered from a 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, which are often of interest to fisheries managers. Estimates S can be converted to the instantaneous mortality rate via the equation (Ricker 1975)

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

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

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

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

where ϕ 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 $\varphi\lambda$. Also, they can be parameterized to allow for non-mixing of newly and previously tagged animals (Hoenig *et al.* 1998b). 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 $\varphi\lambda$.

In either case, the auxiliary information needed (i.e., $\varphi\lambda$ or M) can often be difficult to obtain in practice, and since F, M and $\varphi\lambda$ 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).

Materials and Methods

Capture and Tagging Protocol

Each year from 1991 to 2005, 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 a cooperating commercial fisherman. The pound net is a fixed trap that is presumed to be non-size selective in its catch of striped bass, and has been historically used by commercial fishermen in the Rappahannock River.

All captured striped bass were removed from each pound net and placed into a floating holding pocket (1.2m x 2.4m x 1.2m deep, with 25.4mm mesh and a capacity of approximately 200 fish) anchored adjacent to the gear. Fish were dip-netted from the holding pocket and examined for tagging. Fork length (FL) and total length (TL) measurements were taken and whenever possible the sex of each fish was determined. Striped bass not previously marked and larger than 458 mm TL were tagged with sequentially numbered internal anchor tags (Floy Tag and Manufacturing, Inc.). Each internal anchor tag was applied through a small incision in the abdominal cavity of the fish. A small sample of scales from between the dorsal fins and above the lateral line 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: TheASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber (1970) models. The protocol is used by each state and federal agency participating in the cooperative tagging study. Tag recoveries from striped bass greater than 457 mm total length are analyzed from known producer areas (including Chesapeake Bay). Tag recoveries from striped bass that were greater than 711 mm total length (TL) at the time of tagging are analyzed from all coastal states since those fish are believed to be fully recruited to the fishery and also because they constitute the coastal migratory population (Smith *et al.* 2000).

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

S(.)r(.)	Survival and tag-recovery rates are constant over time.
S(t)r(t)	Survival and tag-recovery rates are time-specific.
S(.)r(t)	Survival rate is constant and tag-recovery rates are time-specific.
S(p_1)r(t)	Survival rates vary by regulatory periods (p_1=constant 1990-1994 and 1995-2004) and tag-recovery rates are time-specific.
S(p_1)r(p_1)	Survival and tag-recovery rates vary by regulatory period.
S(.)r(p_1)	Survival rate is constant and tag-recovery rates vary by regulatory periods.

S(t)r(p_1)	Survival rates are time-specific and tag-recovery varies by regulatory periods.
S(p_2)r(p_1)	Survival and tag-recovery rates vary over different regulatory periods (p_2 = constant 1990-1994, 1995-2003 and 2004).
S(p_3)r(p_1)	Survival and tag-recovery rates vary over different regulatory periods (p_3 = constant 1990-1994, 1995-2002, 2003 and 2004).
S(Tp_1)r(Tp_1)	Survival and tag-recovery rates have linear trends within regulatory periods.
S(Tp_1)r(p_1)	Survival rates have a linear trend within regulatory periods and tag-recovery rates vary by regulatory period.
S(Tp_1)r(t)	Survival rates have a linear trend within regulatory periods and tag-recovery rates are time-specific.
S(p_4)r(p_4)	Survival and tag-recovery rates vary over regulatory periods (p_4 = constant 1990-1992, 1993-1994 and 1995-2004).

The striped bass tagging data contain a large number of tag-recoveries reflecting catch-and-release practices (i.e., the tag of a captured fish is clipped off for the reward and the fish released back into the population). Analysis utilizing these data leads to biased survival estimates if tag recoveries for re-released fish are treated as if the fish were killed. The fifth step applies a correction term (Smith *et al.* 2000) to offset the re-release-without-tag bias assuming a tag reporting rate of 0.43 (D. Kahn, Delaware Division of Fish and Wildlife, personal communication). The sixth step converts estimates of S_i to F_i via equation (3), assuming that $Z = F + M$ and 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 survival in the presence of tagging activity and short-term tag retention rates each in excess of 98% (Sadler et al. 2001). Based on these results, the ASMFC analysis protocol specifies making no attempts to adjust for the presence of short-term tag-induced mortality or acute tag-loss.

Results

Spring 2005 tag release summary

A total of 921 striped bass were tagged and released from the pound nets in the Rappahannock River between 28 March and 16 May, 2005 (Table 1). There were 637 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (95.1%), but the female stripers were larger on average. The median date of these tag releases, to be used as the beginning of the 2005-2006 recapture interval, was 28 April. There were 284 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly female (77.1%) and their average size was larger than for the male striped bass. The median date of these tag releases was 28 April.

Mortality estimates, 2004-2005

Tag recapture summary: A total of 80 (out of 1,447) resident striped bass (>458 mm TL), tagged during spring 2004, were recaptured between 19 April, 2004, and 27 April, 2005 (the respective midpoints of the two tag release totals), and were used to estimate mortality. Forty five of these recaptures were harvested (56.3%) and the rest were re-released into the population (Table 2). The proportion of tagged striped bass recaptured from 1991-2005 in their first year after release varied from 0.055 (80/1,447) to 0.111 (162/1.464). Since 1997, the initial recapture rates have only varied from 0.055-0.077. In addition, 62 striped bass tagged in previous springs were recaptured during the 2004-2005 recovery interval and were used to complete the input data matrix. The largest source of recaptures (59.9%) in the 2004-2005 recovery interval was Chesapeake Bay (41.6% in Virginia, 18.3% in Maryland, Table 3). Other recaptures came from New York (12.7%), Massachusetts (11.3%), New Jersey (4.2%), Rhode Island and North Carolina (3.5 % each), Delaware (2.8%), Connecticut (1.4%) and New Hampshire (0.7%). There was a primary peak of recaptures in May through July and a secondary peak in October through December.

A total of 39 (out of 686) migratory striped bass (>710 mm total length), tagged during spring 2004, were recaptured between 19 April, 2004, and 27 April, 2005 (the 2004-2005 recovery interval) and were used to estimate the mortality of this sub-group. Twenty one of these recaptures were harvested (53.8%), and the rest were re-released into the population (Table 4). The proportion of tagged striped bass recaptured from 1991-2005 in their first year after release varied from 0.015 (1/67) to 0.152 (24/158). In addition, 39 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. Unlike 2004, the largest source (30.8%) of the recaptured tagged striped bass was Chesapeake Bay Virginia (24.4% in Virginia, 6.4% in Maryland, Table 5). Other recaptures came from New York (23.1%), Massachusetts (20.5%), New Jersey and Rhode Island (6.4% each), North Carolina (5.1%), Delaware (3.8%), Connecticut (2.6%) and New Hampshire (1.3%). The peak months for recaptures were May through July, but some migrant striped bass were recaptured from every month except February.

ASMFC protocol: Survival estimates were made utilizing the mark-recapture data for the Rappahannock River from 1990-2004. The suite of Seber (1970) models consisted of 13 models that each reflected a different parameterization over 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 stable coast-wide harvest regulations were also specified.

Prior to 2003, survival estimates from Virginia for striped bass greater than 457 mm (18") total length were suspect and not reported to the Stock Assessment Committee. Only one model (S(t) R(t)) fit the data and the previous results over time had spikes in survival (S) that were not possible (i.e. > 1.0). The 2003 *F* estimate was high (0.62), but this was likely over-estimated due to linear monotonic trend models (Welsh personal comm.). When the additional 2004 data was included, the 2003 *F* estimate was 0.12. In 2004, the S(t) R(t)model was again the only model to fit the data (Table 6). The 2004 *F* estimate was 0.49, the *S* estimate was 0.51, and none of the annual *S* estimates exceeded 1.0 (Table 7).

Survival estimates were obtained for striped bass greater than 710 mm (28") total length. Of the 13 proposed models, eight had ΔAICc values less than 7.0 (Table 8). A ΔAICc of 7.0 receives a weighting of 0.01 and is used as the threshold for inclusion in the analysis. Of the eight models, the calculated weight of the constant survival and two-period regulatory-based tag recovery model (i.e., S(.)r(p_1)) was slightly larger than the other models. Models that reflected more general time-specific parameterizations tended to not fit the data well. The ranking of the models, except for the constant survival and reporting model, was inversely related to the number of associated parameters.

The VIMS model-averaged estimates of the bias-adjusted survival rates for striped bass greater than 710 mm ranged from 0.606-0.658 over the time series (Table 9). The 2004 survival estimate was the highest in the time series. Otherwise, survival was highest during the transitional fishery and decreased slightly during the recovered fishery. This trend was the result of a higher proportion of annual tag recoveries being released back into the population in the early 1990's relative to more recent years. The corresponding estimates of $\hat{F}$ ranged from 0.115-0.335 and only infrequently, and by slight margins, exceeded the transitional and full fisheries target values.

Model evaluation

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

For the time-specific Seber (1970) model, Latour et al. (2002) proved the existence of several characteristics about the residuals. Specifically, they showed that row and column sums of the residuals matrix must total zero, and further, they showed that the residuals associated with the Anever seen again@ category must also always be zero unless parameter estimates fall on a boundary condition. Latour et al. (2001c) also scrutinized the residuals associated with the instantaneous rates model and found the residual matrix of this model possessed fewer constraints than the time-specific Seber model. Although the row sums category must total zero, the column sums and the associated residuals can assume any value.

ASMFC protocol: 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 of striped bass releases, and the resultant low numbers of recaptures reported from the 1994 and 1996 cohorts (e.g. six from the 1996 cohort) relative to other years, may have resulted in the poor fit of the time-specific models. Unfortunately, numerical complications resulting from low sample size may have caused some of the more biologically reasonable models to not fit the Rappahannock River data well.

Discussion

The survival estimate for migrant striped bass for 2004-2005 was 0.658. The survival estimates for 2003 and 2004 are the highest in the time series and have incrementally increased every year since 1995. The estimate of fishing mortality for 2004-2005 was 0.225. The estimates of fishing mortality from 1990-2004 varied from 0.115-0.335 and exceeded the ASMFC threshold of 0.30 only in 1996 and 1997. Prior to 2004, the models that assume constant survival and/or reporting rate and the models that partition the time series into two periods (1990-1994 and 1995-2004) were found to best fit the data and contributed most heavily to the analysis (0.62 in 2003). These are the models that use the fewest parameters to produce the estimates of survival and fishing mortality. However, in 2004 the regulatory-based reporting rate models were the most heavily weighted (0.821).

Our analyses of the resident striped bass are problematic. The 2004-2005 estimates of survival (0.507) and fishing mortality (0.491) were derived after eliminating the time-dependent model (this model does not provide a terminal year estimate). However, in the original analysis this was the only model that the data fit (0.99996 of the weighting). While the new results for survival and fishing mortality, based mainly on the trend model, are plausible, the range of values are extreme, highly variable, and even include negative estimates of fishing mortality for other years. Given the poor fit on the data to the trend model in the original analysis, we have little confidence in the result. We intend to investigate the problems and their causes of these analyses and hopefully provide more credible future estimates.

Recently, we have begun using instantaneous rates models to study mortality rates of resident striped bass as an alternative to the Seber-Brownie models. These models are more efficient in that they require fewer parameters. This provides greater flexibility in modeling mortality over time. Preliminary results suggest that the models provide more reasonable results than the present method and that natural mortality is higher than previously thought and has been increasing over time. If true, then fishing mortality has been lower than previously estimated (Sadler, et al. 2004).

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Table 1. Summary data of striped bass tagged and released from pound nets in the Rappahannock River, spring 2005.

Date	total tagged	457 - 710 mm TL				> 710 mm TL			
		Males		females		males		females	
		n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$	n	$\overline{FL}$
28 March	96	80	511.4	1	612.0	2	792.5	13	883.1
31 March	114	82	528.2	3	624.2	8	803.8	21	901.8
4 April	46	25	539.8	2	631.5	2	821.0	17	907.2
7 April	94	72	497.8	3	552.3	4	794.5	15	899.9
11 April	13	5	510.8	0		0		8	940.3
14 April	17	8	539.5	0		1	796.0	8	939.4
18 April	13	2	577.0	0		0		11	927.9
21 April	30	13	560.8	1	564.0	1	728.0	15	883.9
25 April	63	29	563.9	4	607.5	8	796.0	22	879.1
28 April	108	63	547.7	3	615.0	11	809.1	31	899.1
2 May	51	37	544.1	3	548.0	2	812.5	9	915.0
5 May	58	31	552.6	2	562.5	10	817.2	15	898.2
9 May	116	82	572.9	2	551.5	12	786.9	20	874.8
12 May	63	53	555.0	0		3	783.7	7	866.3
16 May	39	24	571.6	7	610.1	1	725.0	7	823.0
Total	921	606	539.8	31	593.1	65	701.2	219	830.3

Table 2. Recapture matrix of striped bass (>457 mm TL) that were released in the Rappahannock River, springs 1990-2004. The second (bottom) number is the number of those recaptures that were harvested.

Year	n	recaptures														
		90	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**
1990	1,464	162 21	64 20	47 24	25 10	12 8	10 9	3 2	2 0	3 0	1 1	1 1	0 0	0 0	1 1	0 0
1991	2,481		167 48	81 38	53 22	29 14	6 3	5 5	2 2	2 1	4 0	1 0	0 0	0 0	1 1	0 0
1992	130			14 7	8 4	6 1	5 3	1 0	1 0	1 0	1 1	0 0	0 0	0 0	0 0	0 0
1993	621				50 18	37 17	17 12	8 5	9 4	2 1	0 0	1 0	0 0	0 0	0 0	0 0
1994	195					13 6	10 7	5 4	4 1	4 2	0 0	0 0	0 0	0 0	0 0	0 0
1995	698						55 24	30 12	20 9	5 4	4 1	2 1	3 2	0 0	1 1	0 0
1996	376							21 3	18 10	7 3	3 2	1 1	1 1	1 1	0 0	0 0
1997	712								47 26	26 17	14 10	3 2	0 0	1 1	2 1	1 1
1998	784									55 28	26 16	2 1	3 3	3 1	1 0	0 0
1999	853										66 30	23 7	9 4	5 2	3 2	0 0
2000	1,765											122 44	51 23	23 11	16 7	6 4
2001	797												61 32	23 14	16 5	7 7
2002	315													20 10	8 4	15 6
2003	852														58 32	33 20
2004	1,447															80 45

Table 3. Location of striped bass (> 457 mm TL), recaptured in 2005, that were originally tagged and released in the Rappahannock River during springs 1988-2004 and used for mortality analysis.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
N. Hampshire	0	0	0	0	0	1	0	0	0	0	0	0	1
Massachusetts	0	0	0	0	2	3	8	2	1	0	0	0	16
Rhode Island	0	0	0	0	0	1	2	1	1	0	0	0	5
Connecticut	0	0	0	0	0	0	1	0	1	0	0	0	2
New York	0	0	0	0	4	4	2	1	2	3	2	0	18
New Jersey	0	0	0	0	2	1	1	0	0	0	2	0	6
Delaware	0	0	0	0	0	2	0	0	0	1	1	0	4
Maryland	0	0	0	1	5	12	6	0	0	2	0	0	26
Virginia	1	0	4	10	8	9	3	1	0	7	8	8	59
North Carolina	3	0	0	0	0	0	0	0	0	0	0	2	5
Total	4	0	4	11	21	33	23	5	5	13	13	10	142

Table 4. Recapture matrix of striped bass (>710 mm TL) that were released in the Rappahannock River, springs 1990-2004. The second (bottom) number is the number of those recaptures that were harvested.

Year	n	recaptures														
		90	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**
1990	301	26 10	9 2	15 6	2 1	4 3	6 5	1 1	0 0	2 0	1 1	1 1	0 0	0 0	1 1	0 0
1991	390		41 19	24 10	16 12	11 9	3 2	2 1	2 2	1 0	2 2	0 0	0 0	0 0	1 1	0 0
1992	40			4 2	3 1	2 1	2 1	0 0	0 0	0 0	0 0	1 1	0 0	0 0	0 0	0 0
1993	212				22 11	18 11	7 5	4 2	7 3	0 0	0 0	1 0	0 0	0 0	0 0	0 0
1994	123					9 4	7 4	5 4	1 1	2 0	0 0	0 0	0 0	0 0	0 0	0 0
1995	210						29 18	11 6	8 5	3 2	3 1	2 1	3 2	0 0	1 1	0 0
1996	67							1 1	3 3	1 1	0 0	0 0	1 1	0 0	0 0	0 0
1997	212								15 11	13 12	8 6	3 2	0 0	1 1	2 1	1 1
1998	158									24 16	13 9	2 1	3 3	2 1	0 0	0 0
1999	162										17 13	6 2	2 1	3 2	2 1	0 0
2000	365											28 13	19 11	14 6	9 5	4 3
2001	269												19 9	14 8	4 2	6 6
2002	122													10 7	6 3	7 5
2003	400														35 23	21 13
2004	686															39 21

Table 5. Location of striped bass (> 710 mm TL), recaptured in 2005, that were originally tagged and released in the Rappahannock River during springs 1988-2004 and used for mortality analysis.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
N. Hampshire	0	0	0	0	0	1	0	0	0	0	0	0	1
Massachusetts	0	0	0	0	2	3	8	2	1	0	0	0	16
Rhode Island	0	0	0	0	0	1	2	1	1	0	0	0	5
Connecticut	0	0	0	0	0	0	1	0	1	0	0	0	2
New York	0	0	0	0	4	4	2	0	2	4	2	0	18
New Jersey	0	0	0	0	2	1	1	1	0	0	1	0	5
Delaware	0	0	0	0	0	2	0	0	0	0	1	0	3
Maryland	0	0	0	1	3	1	0	0	0	0	0	0	5
Virginia	0	0	1	5	2	4	0	0	0	1	2	4	19
North Carolina	2	0	0	0	0	0	0	0	0	0	0	2	4
Total	2	0	1	6	13	16	14	4	5	5	6	6	78

Table 6. Performance statistics (>457 mm TL), 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 1995-2004 (p_1); parameters vary in 2004 (p_2), otherwise the same as p_1 ; parameters vary in 2003 and 2004 (p_3), otherwise the same as p_1 ; parameters constant from 1990-1992, 1993-1994 and 1995-2004 (p_4); assumption of linear trends from 1990-1994 and 1995-2004 (Tp_1); and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ **weight**	**number of parameters**
S(t)r(t)	10527.18	0.00	0.99996	29
S(p_1 **)r(t)**	10550.04	22.86	0.00001	17
S(p_4 **)r(** p_4 **)**	10551.80	24.61	0.00000	6
S(Tp_1 **)r(** Tp_1 **)**	10551.97	24.67	0.00000	8
S(Tp_1 **)r(t)**	10552.21	25.02	0.00000	19
S(.)r(t)	10552.23	25.04	0.00000	16
S(p_1 **)r(** p_1 **)**	10552.25	25.07	0.00000	4
S(T_{p1} **)r(** p_1 **)**	10552.74	25.55	0.00000	6
S(p_2 **)r(** p_1 **)**	10553.66	26.48	0.00000	5
S(t)r(p_1 **)**	10553.99	26.81	0.00000	17
S(p_3 **)r(** p_1 **)**	10555.15	27.97	0.00000	6
S(.)r(p_1 **)**	10558.00	30.81	0.00000	3
S(.)r(.)	10576.99	49.81	0.00000	2

Table 7. Seber (1970) model estimates (VIMS) of unadjusted survival ($\hat{S}$) rates and adjusted rates of survival ($\hat{S}_{adj}$) and fishing mortality ($\hat{F}$) of striped bass (> 457 mm FL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2004.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI $\hat{F}$
1990	0.816	0.086	0.481	-0.143	0.952	-0.101	-0.23, 0.23
1991	0.276	0.051	0.524	-0.082	0.301	1.051	0.71, 1.44
1992	0.804	0.164	0.408	-0.142	0.938	-0.086	-0.27, 0.75
1993	0.604	0.131	0.456	-0.105	0.675	0.243	-0.06, 0.81
1994	0.573	0.128	0.381	-0.087	0.628	0.316	0.00, 0.88
1995	0.689	0.138	0.262	-0.054	0.728	0.167	-0.08, 0.75
1996	0.623	0.130	0.274	-0.039	0.648	0.273	0.00, 0.84
1997	0.561	0.106	0.330	-0.058	0.595	0.369	0.08, 0.83
1998	0.408	0.078	0.362	-0.060	0.434	0.685	0.36, 1.11
1999	0.373	0.066	0.286	-0.060	0.396	0.776	0.46, 1.16
2000	0.422	0.065	0.436	-0.074	0.456	0.636	0.37, 0.97
2001	0.457	0.101	0.367	-0.069	0.490	0.562	0.21, 1.07
2002	0.647	0.150	0.368	-0.064	0.692	0.219	-0.08, 0.87
2003	0.723	0.157	0.271	-0.048	0.760	0.124	-0.12, 0.82
2004	0.507	0.035	0.267	-0.037	0.527	0.491	0.36, 0.64

Table 8. Performance statistics (>711 mm TL), 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 1995-2004 (p_1); parameters vary in 2004 (p_2), otherwise the same as p_1 ; parameters vary in 2003 and 2004 (p_3), otherwise the same as p_1 ; parameters constant from 1990-1992, 1993-1994 and 1995-2004 (p_4); assumption of linear trends from 1990-1994 and 1995-2004 (Tp_1); and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight	number of parameters
S(.)r(p_1)	4205.92	0.00	0.19132	3
S(p_2)r(p_1)	4205.94	0.02	0.18973	5
S(Tp_1)r(p_1)	4206.12	0.20	0.17307	6
S(p_3)r(p_1)	4206.41	0.49	0.15011	5
S(p_1)r(p_1)	4206.92	1.00	0.11588	4
S(.)r(.)	4207.18	1.26	0.10202	2
S(Tp_1)r(Tp_1)	4208.70	2.78	0.04776	8
S(p_4)r(p_4)	4209.77	3.85	0.02787	6
S(.)r(t)	4216.71	10.79	0.00087	17
S(p_1)r(t)	4217.14	11.22	0.00070	17
S(t)r(p_1)	4217.86	11.94	0.00049	17
S(Tp_1)r(t)	4220.16	14.23	0.00016	19
S(t)r(t)	4224.81	18.88	0.00012	29

Table 9. Seber (1970) model estimates (SBTC) of unadjusted survival ($\hat{S}$) rates and adjusted rates of survival ($\hat{S}_{adj}$) and fishing mortality ($\hat{F}$) of striped bass (> 711 mm FL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2004.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}_{adj}$	$\hat{F}$	95%CI
1990	0.635	0.032	0.577	-0.127	0.727	0.169	0.08, 0.27
1991	0.635	0.028	0.560	-0.131	0.730	0.164	0.08, 0.26
1992	0.635	0.026	0.535	-0.172	0.767	0.115	0.04, 0.20
1993	0.637	0.029	0.349	-0.093	0.702	0.204	0.12, 0.30
1994	0.637	0.033	0.318	-0.070	0.685	0.228	0.14, 0.34
1995	0.603	0.031	0.204	-0.078	0.654	0.275	0.18, 0.38
1996	0.606	0.027	0.125	-0.016	0.616	0.335	0.25, 0.43
1997	0.610	0.024	0.167	-0.037	0.633	0.307	0.23, 0.39
1998	0.613	0.022	0.217	-0.086	0.671	0.250	0.18, 0.33
1999	0.616	0.023	0.200	-0.057	0.654	0.275	0.21, 0.35
2000	0.620	0.025	0.348	-0.072	0.668	0.254	0.18, 0.34
2001	0.623	0.028	0.298	-0.052	0.657	0.270	0.19, 0.36
2002	0.626	0.031	0.295	-0.077	0.678	0.238	0.15, 0.34
2003	0.639	0.041	0.246	-0.057	0.678	0.238	0.13, 0.38
2004	0.658	0.049	0.295	-0.043	0.687	0.225	0.10, 0.38

III. Fishing mortality estimates in the fall, 2004, resident striped bass fishery in 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 consists of a resident population of mature male striped bass in addition to pre-migrant (<2 years old), immature striped bass of both sexes. These resident 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/yr., 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 Fishes 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) upper and middle main-stem Chesapeake Bay (Fig. 1). Multiple, short-duration (< 10 days) tag release periods, synchronized with the Md 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 Virginia). The multiple-release protocol minimized the effects of immigration and emigration in the analysis. Optimal tagging quotas, proportionally based on historic catch data, were allotted to each area to facilitate the diffusion of tagged fish throughout Chesapeake Bay. From 1995-2004, striped bass were tagged from commercial pound nets, drift gill nets, fyke nets and haul seines at multiple sites within each system.

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

The tagging study requires 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 the short-term tag-induced mortality was done in Maryland (1995), and in Virginia (2000), and produced tagging mortality rates of 1.3% and 1.5% respectively (Latour *et al.* in prep). 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 Md DNR for estimation of exploitation rate (U) and instantaneous fishing mortality (F). Estimates were calculated utilizing a logistic regression model based on reported tag recoveries that occurred between the midpoints (the date after which 50% of tag releases occurred) of consecutive tagging rounds. The proportion of the number of tags recovered to the number of tags released was the response variable and the explanatory variables consisted of one categorical variable (interval number) and two binary variables (disposition of the recapture and angler type). Note, however, that this procedure is identical to calculating simple ratios of recaptured to marked individuals. The logistic regression is simply an artifact from an earlier time when the incorporation of additional factors was contemplated. 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.

Results

Tag release summary

In fall 2004, a total of 3,434 striped bass were tagged and released among three tagging rounds in Virginia. The high variability of tag releases among the three rounds normally reflect the seasonal availability of striped bass to the commercial gears utilized in each sampling area.

Tagging round 4, 20-29 September: The 899 striped bass tagged and released came primarily (52.6%) from middle Chesapeake Bay locations (Table 1). Only the two Chesapeake Bay jurisdictions exceeded their desired quotas. This overall lack of spatial diversity is typical of previous tagging rounds in September, but the striped bass normally caught in abundance in the upper Rappahannock River were caught in unusually low numbers. The haul seines in the James River were also less successful than had been the case in previous September tagging rounds. The highest single day tagging total was on 24 September (Table 2) and this date was the midpoint for the fourth tagging round.

Water temperatures during the tagging round were 22-24 EC. 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 2001 (63.6%) and 2000 (29.6%) year classes (Table 3). The mean ages of the striped bass from each jurisdiction varied from only 3.28 years (Rappahannock River) to 3.65 years (York River). The mean size (FL) of the striped bass tagged and released from each jurisdiction varied from 472.9 mm (Rappahannock River) to 504.0 mm (York River).

Tagging round 5, 18-27 October: There was 1,383 striped bass tagged and released during the tagging interval. This reflects the typical increase in availability relative to September or early October (Table 1). Unfortunately, the striped bass catches in the upper Rappahannock River had remained low after the fourth tagging round was completed and the fishermen ceased fishing. However, except for the James River, the other tagging jurisdictions exceeded their quotas. The most successful tagging date was 19 October (Table 4) and this was the midpoint of the fifth tagging round. Water temperatures during the tagging round were 15-18 EC.

The majority of the striped bass tagged and released were from the 2001 (71.2%) and 2000 (27.3%) year classes (Table 5). The mean ages of the striped bass from each jurisdiction varied from only 3.28 years (middle Chesapeake Bay) to 3.48 years (James River). The mean sizes (FL) of the striped bass tagged and released from each jurisdiction varied from 484.7 mm (middle Chesapeake Bay) to 495.7 mm (James River).

Tagging round 6, 17-26 November: There was 1,152 striped bass tagged and released in this tagging interval. This final tagging round used a different strategy relative to the previous tagging rounds. First, the Thanksgiving holidays (24-26 November) reduced the number of tagging days available. In addition, a northeaster on 19 November was followed by unusually cold weather through the rest of the tagging round. Striped bass, usually abundant at most tagging locations, evidently moved into deeper waters away from our commercial gears. This was especially true for the haul seines utilized in the James River, and resulted in a failure to reach the desired release quotas in all jurisdictions except in the middle Chesapeake Bay (Table 1). However, striped bass were abundant in the pound nets near the mouth of the Rappahannock River, so additional fish were tagged there to supplement the loss from the other areas. The most successful tagging date was 18 November and this was the midpoint of the sixth tagging round. Water temperatures during the tagging round ranged from 11-13EC.

The majority of the striped bass tagged and released were from the 2001 (61.7%) and 2000 (31.5%) year classes (Table 7). The mean ages of the striped bass from each jurisdiction varied from 3.09 years (York River) to 3.80 years (James River). The mean sizes of the striped bass tagged and released from each jurisdiction varied from 456.7 mm (York River) to 523.4 mm (James River).

Tag recapture summary

A total of 145 of the striped bass tagged during the fall were recaptured from 20 September - 31 December, 2004 (Table 8). The overall proportion recaptured was 0.042 and varied by jurisdiction from 0.020 (upper Chesapeake Bay) to 0.220 (York River). All recaptures from the James and upper Rappahannock rivers were recaptured within the same area they were tagged. Striped bass tagged in the York River were predominantly recaptured there (0.949), but were also recaptured in the lower Chesapeake Bay. Striped bass tagged near the mouth of the Rappahannock River (middle Chesapeake Bay) were predominantly recaptured in the lower Rappahannock River (0.739), but were also recaptured in the lower Chesapeake Bay (0.109), middle and upper Chesapeake Bay (0.065 each) and the Potomac River (0.022). Striped bass tagged and released in the upper Chesapeake Bay were mostly recaptured there (0.471) but were also recaptured in Maryland (0.176), James River (0.118), middle Chesapeake Bay, lower Chesapeake Bay, Potomac River and the Atlantic Ocean (0.059 each). The striped bass recaptured from James River releases were slightly larger and older than the striped bass recaptured from the other areas.

Recapture interval 4, 25 September-19 October: A total of 78 striped bass (8.7%) that were tagged in the fourth tagging round were recaptured by 31 December (0.08% per day). Forty one of these recaptures occurred within the fourth recapture interval (Table 9). Most (95.1%) recaptures came from the pound nets from which the striped bass were obtained for tagging. Sport fishermen (recreational and charter anglers) accounted for only 4.9% of the recaptures during the fourth recapture interval. These anglers harvested all of these recaptured tagged striped bass. These two recaptured striped bass harvested by sport fishermen were the data used in the computation of fishing mortality. The Aother@ 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 5, 20 October-18 November: A total of 54 striped bass (3.9%) that were tagged in the sixth tagging round were recaptured by 31 December (0.05% per day). Thirty five of these recaptures (64.8%) occurred within the fifth recovery interval, mostly from the pound nets from which they were tagged (Table 10). Sport fishermen accounted for only 20.0% of the recaptures during the fifth recapture interval. Less than half (42.9%) of the recaptured striped bass caught by anglers were harvested. These three recaptured striped bass harvested by sport fishermen were the data used in the computation of fishing mortality.

Recapture interval 6, 19 November - 31 December: A total of 13 striped bass (1.1%) that were tagged in the seventh tagging round were recaptured by 31 December (0.03% per day). By design, all the recaptures occurred within the recovery interval (Table 11). Sport fisherman accounted for 38.5% of the recaptures during the recapture interval and released more than half. The two recaptured striped bass harvested by sport fishermen were the data included in the computation of fishing mortality.

Estimation of fishing mortality (F)

To obtain an estimate of fishing mortality, 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 given that a tagged fish has been caught. Since the recovery interval was of short duration (20-40 days), natural mortality was deemed negligible and a type I (pulse) fishery was presumed to exist. The fishing mortality rate was then calculated as (Ricker 1975):

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

where L is the total number of intervals.

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

$$F_r = F + (FP_S)$$

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

The estimate of the Chesapeake Bay fishing mortality rate for 2004 was 0.06. A non-harvest mortality rate of 0.10 was added to produce the final estimate of a recreational/charter fishing mortality of 0.16 (Hornick *et al.* 2005).

Discussion

The number of striped bass tagged during the three tagging rounds in Virginia is generally a reflection of their areal and seasonal availability. In September, striped bass are generally scattered in small schools and are structure oriented. Usually 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 initiates a schooling and feeding response in striped bass and they become susceptible 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 falling catches in the general fisheries and to reduce exposing nets to potential damage from coastal storms. However, striped bass were less abundant in the middle James and upper Rappahannock rivers in 2004. Therefore the majority of the striped bass were tagged in the two Chesapeake Bay jurisdictions.

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 immigrate from coastal waters into Chesapeake Bay in late November and are generally targeted by recreational anglers. Historically, these striped bass 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 in the first two tagging rounds in Virginia (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 York River and was also very high in the pound nets at the mouth of the Rappahannock River. However, striped bass tagged from our upper Chesapeake Bay locations did show a wider pattern of dispersal. Striped bass tagged there were recaptured throughout the Chesapeake Bay (including Maryland) as well as in the James and Rappahannock rivers.

The Chesapeake Bay-wide estimate of resident striped bass fishing mortality was 0.16. This was the sum of the estimate of both non-harvest (0.10) and harvest (0.06) mortalities. Non harvest mortalities include natural deaths and handling-induced mortalities. In our fall 2004 study, 85.5% of the recaptures were released alive (50.0% of sport recaptures and 100% of research recaptures). The fishing mortality estimate was below the target rate (0.30) 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, 2004. Note: tagging rounds 1-3 were in Maryland only.

Tagging round	Dates	Location	Quota	Releases
4	20-29 Sep.	Chesapeake Bay – upper	150	192
		Chesapeake Bay – middle	150	473
		Rappahannock River	350	90
		York River	100	68
		James River	250	76
		Subtotal	1,000	899
5	18-27 Oct.	Chesapeake Bay - upper	300	632
		Chesapeake Bay - middle	200	553
		Rappahannock River	300	0
		York River	100	145
		James River	300	53
		Subtotal	1,200	1,383
6	17-26 Nov.	Chesapeake Bay - upper	300	137
		Chesapeake Bay - middle	200	955
		Rappahannock River	200	0
		York River	100	55
		James River	200	5
		Subtotal	1,000	1,152

Table 2. Daily striped bass tag release totals, by area, during round four (20-29 September) of the fall, 2004 fishing mortality (F) study.

Tag release area	20 Sep	21 Sep	22 Sep	23 Sep	24 Sep	25 Sep	26 Sep	27 Sep	28 Sep	29 Sep
Chesapeake Bay (upper region)					113			37		42
Chesapeake Bay (middle region)		130			161			81		101
Rappahannock River (upper region)	49							41		
York River (middle region)		14			30				24	
James River (middle region)	1		75							
totals	50	144	75	0	304	0	0	159	24	143

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 four (20-29 September) of the fall, 2004 fishing mortality study.

Tagging location	Year class	n	%	Mean FL (mm)		Mean age
				YC	total	
Chesapeake Bay (upper region)	2001	116	60.4	458.6	482.9	3.43
	2000	69	35.9	515.3		
	1999	7	3.6	567.3		
Chesapeake Bay (middle region)	2001	304	64.3	456.1	478.3	3.37
	2000	146	30.9	514.5		
	1999	12	2.5	554.9		
	1998	1	0.2	677.0		
	n/aged	10	2.1	514.7		
Rappahannock River (upper section)	2001	65	72.2	453.9	472.9	3.28
	2000	21	23.3	520.1		
	1999	2	2.2	596.5		
	n/aged	2	2.2	470.5		
York River (middle section)	2001	33	48.5	454.9	504.0	3.65
	2000	27	39.7	529.9		
	1999	6	8.8	602.2		
	1998	1	1.5	633.0		
	1997	1	1.5	710.0		
James River (middle section)	2001	46	60.5	455.8	483.7	3.43
	2000	26	34.2	519.7		
	1999	3	3.9	608.3		
	n/aged	1	1.3	456.0		

Table 4. Daily striped bass tag release totals, by area, during round five (18-27 October-5) of the fall, 2004 fishing mortality (F) study.

Tag release area	18 Oct	19 Oct	20 Oct	21 Oct	22 Oct	23 Oct	24 Oct	25 Oct	26 Oct	27 Oct
Chesapeake Bay (upper region)	264							386		
Chesapeake Bay (middle region)		553								
Rappahannock River										
York River		102			18				25	
James River (middle region)	36		17							
totals	300	655	17	0	18	0	0	386	25	0

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 five (18-27 October) of the fall, 2004 fishing mortality study.

Tagging location	Year class	n	%	Mean FL (mm) YC	Mean FL (mm) total	Mean age
Chesapeake Bay (upper region)	2001	441	69.8	460.8	478.0	3.29
	2000	166	26.3	518.1		
	1999	6	9.5	587.2		
	n/aged	19	3.0	491.6		
Chesapeake Bay (middle region)	2001	196	35.4	457.4	474.7	3.28
	2000	63	11.4	517.8		
	1999	5	0.9	566.8		
	n/aged	289	52.3	475.5		
York River (middle section)	2001	96	66.2	458.3	480.2	3.35
	2000	44	30.3	517.8		
	1999	3	2.1	624.7		
	n/aged	2	1.4	489.5		
James River (middle section)	2001	30	56.6	465.1	495.7	3.48
	2000	20	37.7	528.2		
	1999	1	1.9	540.0		
	1998	1	1.9	723.0		
	n/aged	1	1.9	493.0		

Table 6. Daily striped bass tag release totals, by area, during round six (17-25 November) of the fall, 2004 fishing mortality (F) study.

Tag release area	17 Nov	18 Nov	19 Nov	20 Nov	21 Nov	22 Nov	23 Nov	24 Nov	25 Nov	26 Nov
Chesapeake Bay (upper region)	137									
Chesapeake Bay (middle region)		539				416				
Rappahannock River (upper region)										
York River (middle region)	43		6							
James River (middle region)	5					6				
totals	185	539	6	0	0	422	0	0	0	0

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 six (17-26 November) of the fall, 2004 fishing mortality study.

Tagging location	Year class	n	%	Mean FL (mm) YC	Mean FL (mm) total	Mean age
Chesapeake Bay (upper region)	2001	118	86.1	454.1	460.2	3.13
	2000	17	12.4	501.5		
	n/aged	2	1.5	472.0		
Chesapeake Bay (middle region)	2001	532	55.7	463.1	499.0	3.54
	2000	334	35.0	528.0		
	1999	62	6.5	603.3		
	1998	13	1.4	662.3		
	1997	1	0.1	720.0		
	1996	1	0.1	782.0		
	n/aged	12	1.3	521.9		
York River (middle section)	2001	51	92.7	447.3	456.7	3.09
	2000	3	5.5	557.0		
	1999	1	1.8	637.0		
James River (middle section)	2001	1	20.0	459.0	523.4	3.8
	2000	4	80.0	539.5		

Table 8. Number, location, mean fork length (FL in mm) and mean age of recaptured striped bass, by release location, 20 September - 31 December, 2004.

Release location	Chesapeake Bay (Va.) recaptures*								
	total	location						mean	
		river			Chesapeake Bay			FL	age
		Rap.	York	James	upper	middle	lower		
Rappahannock River	4	4	0	0	0	0	0	457.0	3.0
York River	59	0	56	0	0	0	3	508.1	3.7
James River	4	0	0	3	0	0	1	544.5	3.8
Chesapeake Bay (upper)	19	0	0	2	7	0	5	493.6	3.6
Chesapeake Bay (middle)	59	1	0	0	4	48	6	484.6	3.4

*Other recaptures	Tagging location	Recapture location
	York River	North Carolina
	Upper Chesapeake Bay	Chesapeake Bay-Maryland (3)
		Potomac River
		Atlantic Ocean-Virginia
	Middle Chesapeake Bay	Potomac River

Table 9. Summary of the disposition of striped bass tagged during round four (20-29 September) and subsequently recaptured prior to 31 December, with emphasis on the fourth recapture interval (25 September – 19 October, 2004).

Release location	recaptures								
	total	20 Sep - 24 Sep	25 Sep – 19 Oct						20 Oct - 31 Dec
			commercial		sport		other		
			R	H	R	H	R	H	
Rappahannock River	4	0	0	0	0	0	2	0	2
York River	25	2	0	0	0	0	14	3	6
James River	0	0	0	0	0	0	0	0	0
Chesapeake Bay (upper)	6	0	0	0	0	0	4	0	2
Chesapeake Bay (middle)	43	12	0	0	0	2	20	0	9

R: released alive
H: harvested

Table 10. Summary of the disposition striped bass tagged during round five (18-27 October) and subsequently recaptured prior to 31 December 2004, with emphasis on the fifth recapture interval (20 October –18 November).

<table>
<tr><th rowspan="4">Release location</th><th colspan="9">recaptures</th></tr>
<tr><th rowspan="3">total</th><th rowspan="3">18 Oct - 19 Oct</th><th colspan="6">20 Oct – 18 Nov</th><th rowspan="3">19 Nov - 31 Dec</th></tr>
<tr><th colspan="2">commercial</th><th colspan="2">sport</th><th colspan="2">other</th></tr>
<tr><th>R</th><th>H</th><th>R</th><th>H</th><th>R</th><th>H</th></tr>
<tr><td>Rappahannock River</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>York River</td><td>30</td><td>0</td><td>0</td><td>0</td><td>1</td><td>1</td><td>19</td><td>0</td><td>9</td></tr>
<tr><td>James River</td><td>3</td><td>0</td><td>0</td><td>0</td><td>3</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Chesapeake Bay (upper)</td><td>12</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>4</td><td>0</td><td>7</td></tr>
<tr><td>Chesapeake Bay (middle)</td><td>9</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>5</td><td>0</td><td>3</td></tr>
</table>

R: released alive
H: harvested

Figure 1. Delineation of western Chesapeake Bay, Virginia into tagging jurisdictions and location of tagging sites during fall, 2004.

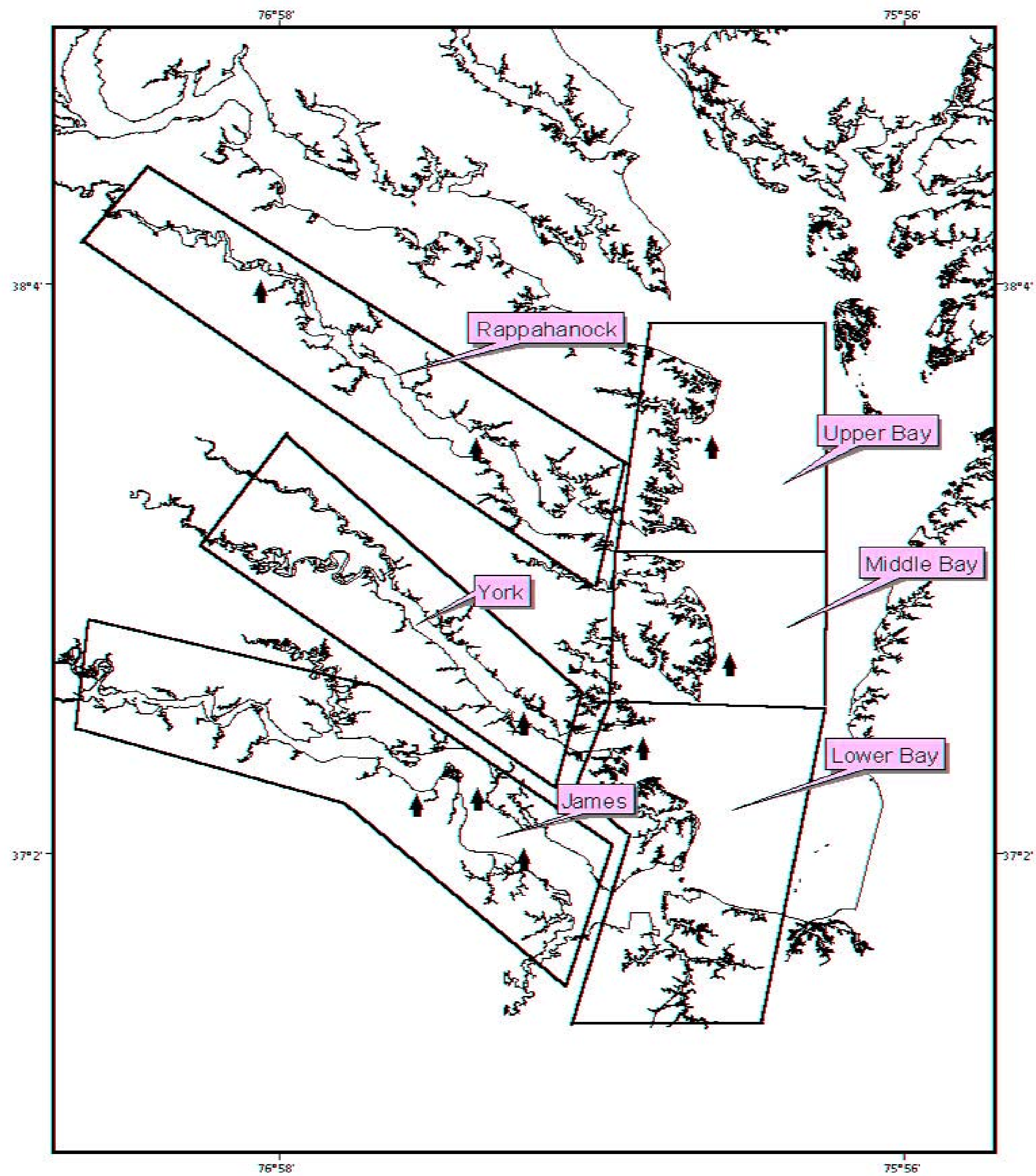
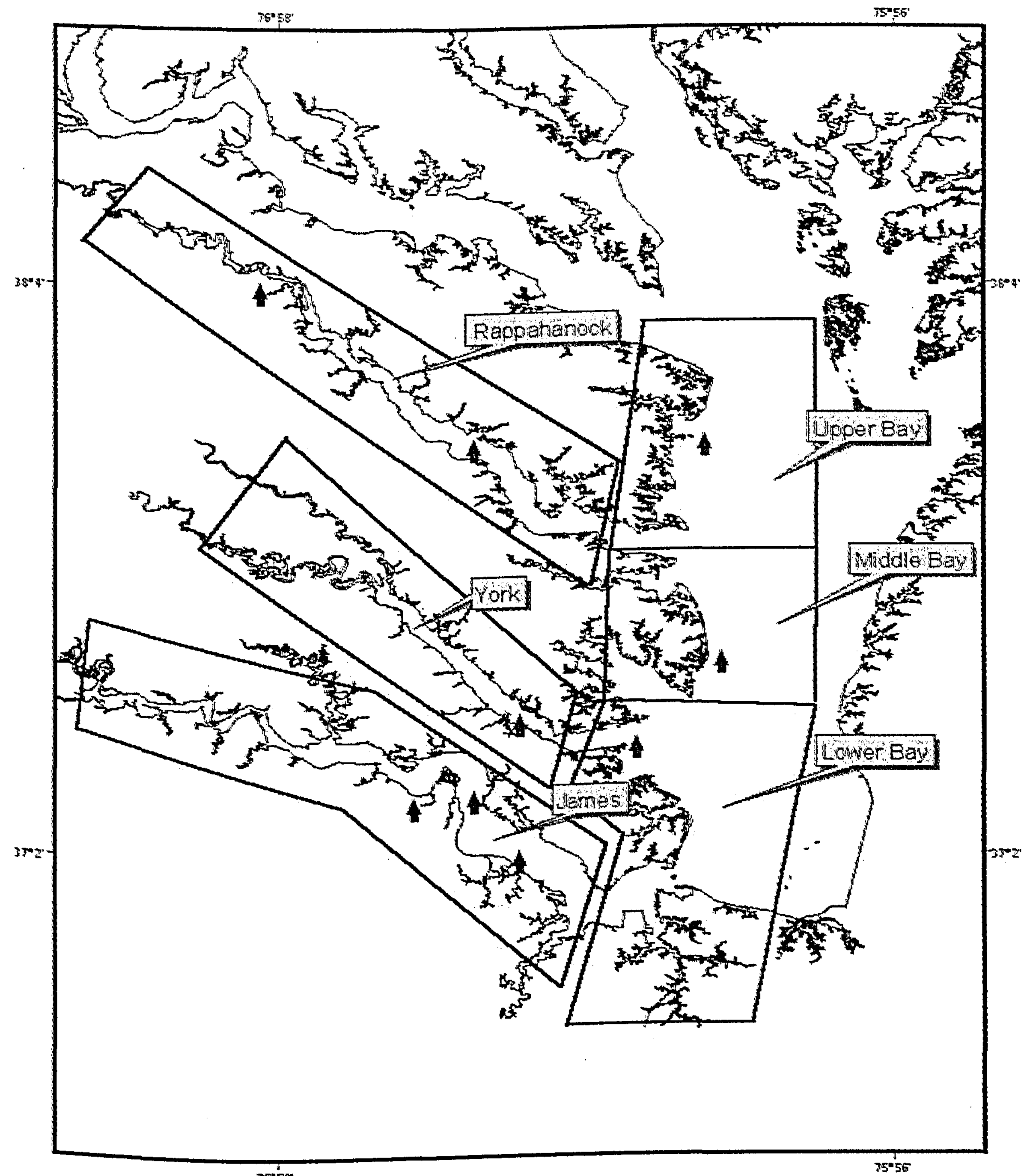


Table 11. Summary of the disposition of striped bass tagged during round six (17-25 November) and subsequently recaptured prior to 31 December, 2004.

Release location	recaptures								
	total	17 Nov - 18 Nov	19 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	1	2	0	
James River	1	0	0	0	1	0	0	0	
Chesapeake Bay (upper)	1	0	0	0	0	1	0	0	
Chesapeake Bay (middle)	7	0	0	0	1	0	6	0	

R: released alive
S: harvested

Figure 1. Delineation of western Chesapeake Bay, Virginia into tagging jurisdictions and location of tagging sites during fall, 2004.



IV. Striped bass spawning stock assessment in the Rappahannock River, Virginia: evaluation of the pound net-based Spawning Stock Biomass Index.

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Striped bass spawning stock assessment in the Rappahannock River, Virginia: evaluation of the pound net-based Spawning Stock Biomass Index.

Introduction

The Virginia Institute of Marine Science (VIMS) has produced abundance and biomass indexes of striped bass using pound nets and multi-mesh anchor gill nets since 1991. The 3 to 4 pound nets that are used to assess the spawning stock are located 6 to 10 river miles above the lower delineation of the striped bass spawning grounds near the brackish/freshwater interface. The gill nets are located 1 to 2 river miles upriver of the pound nets.

Pound nets are considered to be non-size or sex selective and striped bass of 200-1250 mm total length have been captured for our study. In contrast, the gill nets capture a much higher rate of smaller (<711 mm.) striped bass. These striped bass are mostly (> 90%) male. The local lore is that the fighting of gilled striped bass emulates spawning behavior ("rock fights") and attracts additional males. The gill nets under-represent the larger-sized, female-dominated striped bass (when compared to the pound net catches) which are the true basis of the spawning stock (Maryland DNR uses similar gear and has noted the same biases).

The pound nets are privately owned and operated. Although we have an excellent relationship with the fisherman, we do not have absolute control over how the nets are operated. Pound nets are fixed gear, which compromises their usefulness in calculating meaningful variances and other statistical measures that require random sampling. However, in analyzing these data over the years, we believe the results to be of considerable scientific value.

Methods

The three pound nets currently used for the index are located from river miles 45 to 47. A fourth net at river mile 44 was used from 1991-2000. The leaders originate in about three feet of depth and extend to the head in about 12 feet of water. The heads abut the channel and water depths drop rapidly to 30-40 feet.

The pound nets are generally fished on Mondays and Thursdays of each week and the entire catch of striped bass constitutes the sample. Thus the gear fishes continuously, usually for 72 or 96 hours. Deviations do occur, due to weather or fisherman constraints, though we try to minimize these events by sampling a net known to have been fished previously (to avoid gear saturation) or by returning the next day to collect the sample. The gill nets are also fished on Mondays and Thursdays and sample for 24 hours.

The samples are returned to VIMS for laboratory work-up. Each striped bass is measured (FL, TL in mm), weighed (g), its sex and gonadal stage recorded, and a scale sample taken. Since 2002, a sub-sample of the stripers sampled (including all specimens greater than 900 mm TL) also had their otoliths extracted. The scales of the striped bass are mounted and pressed on acetate sheets and an attempt is made to determine the age of all specimens. The spawning stock biomass index (SSBI) was defined (Sadler et al. 1998) as the mean CPUE (kg/day) of male (age 3+) and female (age 4+) striped bass captured between 30 March and 3 May of each year.

The striped bass scales are aged according to the protocol developed by Merriman (1941), except that scale impressions in acetate sheets have replaced scale specimens on glass slides and a microfiche reader has replaced a microscope. The index is then partitioned into age-specific components by CPUE (number of fish/day and kg/day).

Daily mean water flows for March, April and May from 1985 to 2003 were obtained from the United States Geological Service (USGS) and were measured at Fredricksburg. Although Fredricksburg is approximately 50 miles upriver of the sampling location, there are no additional significant freshwater inflows (other than local drainage) between the USGS station and our sampling location.

Results

A total of 7,426 striped bass have been sampled from the Rappahannock River pound nets since 1991 (Sadler *et al.* 2004). Annual totals varied from 151 (1992) to 1, 508 (2000) with a mean of 530.4 (Table 1). The resultant SSBIs (sexes combined) ranged from 18.5 (2002) to 123.9 (2004) with a mean of 52.9. In most years (11 out of 14), the contribution of female striped bass to the index exceeded that for the males. There was no temporal pattern to the index values, other than the two highest values for the females and for the males and females combined occurring in the past two years.

In addition to the biomass-based SSBI, age-specific CPUEs (number fish/day and kg/day) were tabulated (Table 2). These data are useful for demonstrating year class strengths and for estimates of annual survival (S). Striped bass appear fully recruited to the pound nets at age three, although the maximum CPUE is often age four or five due to the influx of first-spawning females. These temporal data also illustrate the increased contribution to the spawning stock of older (age 8+), and therefore larger and more fecund, striped bass during the time series.

These age data were also tabulated on a sex-specific basis (Tables 3 and 4). The cumulative CPUEs over all age classes for both sexes are highly variable and tend to be dominated by the recruitment of strong year classes to the pound nets. This is notable for the 1992, 1993, and especially for the 1996 year classes. These same year classes form the basis for the aforementioned dramatic increase in the abundance of older striped bass of both sexes in 2003 and 2004.

No estimates of variance are made. Since each sample consists of an entire catch from a pound net so there is no sampling variance. The use of fixed, therefore non-random, sampling gear within a restricted temporal window precludes calculating a seasonal variance as a useful measure of sampling adequacy.

Comparison of the temporal window with full seasonal data

The 30 March – 3 May temporal window for the Rappahannock River indexes was established in 1999 after evaluation of the data from 1993-1998 (Sadler *et al.* 1999). The dynamics for establishing the pound nets involve weather constraints (the threat of icing, flooding and dangerous debris conditions) and the market for the fish captured in the pound nets. The fishermen are also active in the gill net fishery that is allowed until 31 March each year. Hence, seasonal sampling of the pound nets began as early as 9 March in 1998 and as late as 7 April in 1994. The terminal end of the season was a combination of the fishermen inactivating their gear in favor of the lucrative blue crab peeler fishery that commences in May, the termination of our spring tagging program after water temperatures exceeded 22 degrees C (due to concerns of increased tagging mortality), and a typical rapid decline in the abundance of striped bass. Hence, the sampling ended as early as 21 April and as late as 3 May. We also evaluated catch data from multi-mesh anchored gill nets that were sampled between one to two miles upriver of the pound nets. The sampling season of the gill nets started as early as 6 March and extended as late as 7 May.

There was a definite trend in the temporal distribution of the catches of female striped bass from 1993-1998 (Figure 1). These catch rates were very low in March compared to the catch rates in April. This trend was not evident for the catches of male striped bass. Re-examining the temporal trends using all the presently available data (1991-2004) did not significantly change the original observations (Figure 2). The temporal trend in the catch rates of striped bass from the gill nets was similar to that from the pound nets.

There were additional differences in the catches of the pre-30 March samples compared to the 30 March – 3 May samples. Samples collected prior to 30 March were younger on average than those collected between 30 March and 3 May (Table 5). The age difference was greater for females than for males, reflecting the timing of the arrival of the larger and predominantly female migratory striped bass. The sex ratios were also different between the two temporal groupings. The 1995-1998 average ratio of males to females from samples prior to 30 March was 7.7:1, but was 3.2:1 from 30 March – 3 May. Thus, the description and assessment of the spawning stock would be greatly influenced by how early and how often samples were acquired in a given year. The restriction of the index to the 30 March – 3 May temporal window allowed for a better inter-annual assessment of the spawning stock.

Influence of river flow on the juvenile and spawning stock indexes

River flows from 1985-2003 (USGS 2004) were compared to the yearly spawning stock biomass indexes (SSBI) and juvenile indexes (JI). River flows could affect the catchability of striped bass by displacing the spawning grounds more upriver or downriver than in less extreme conditions, or by changing turbidity (the fishermen indicate that striped bass respond to rapid increases in turbidity by relocating downriver into clearer, more saline waters). River flows also affect the survival rate of the spawn and can influence year class strength.

No definitive relationship between river flow and the SSBI was apparent (Table 6). The values of the male and female components of the index varied independently through all flow regimes. In 1992 and 1996, both cooler and wetter than normal but not the most extreme flow conditions encountered, the local fishermen indicated that striped bass were spawning well below our sampling site. In both of these years, catches of striped bass in the pound nets were lower for all age classes relative to the previous or the ensuing years. In 2002, at the culmination of a nearly three-year drought, there was extreme short-term variation in air and water temperatures in mid-April (multiple days with air temperatures exceeding 30 °C, followed by sub-freezing temperatures and snow, followed by a second period of air temperatures exceeding 30 °C). Those striped bass present spawned (mostly partially spawned) and immediately left the area and few striped bass entered the area thereafter. The result was another year in which the CPUE of all age classes were lower than the previous or the ensuing years (and in this case a weak JI).

The strength of the spawning stock was not an indicator of the strength of that year's juvenile index (as would be expected since stock-recruitment relationships generally appear weak). However, years with high mean flows or high peak flows (eg. 1987 and 1993) had higher juvenile indexes while years with low mean and peak flows (eg. 1985, 1995 and 1999) had low juvenile indexes (Table 7).

Comparison of VIMS pound net index data with VIMS juvenile index data

Comparisons were made between the VIMS Rappahannock River juvenile index (JI, Austin *et al.* 2004) for a year and the age-specific CPUE of that year class over time (e.g., the 1990 JI with the age three CPUE in 1993, age four CPUE in 1994, etc.). Ideally the CPUEs of ages at which striped bass are fully recruited to the pound nets and at maximum abundance, ages five and six, would correlate with strong and weak year classes as predicted by their juvenile indexes. Unfortunately, plots of the CPUEs of three to five year-old striped bass poorly track their respective juvenile indexes (Figure 3), especially for the very strong indexes for 1992 and 1993 (the central peak in the graphs) and correlations of the juvenile indexes to these age classes were very weak (Figure 4).

The plots of the six to eight year-old striped bass also fail to track their respective juvenile indexes (Figure 5) and give similarly poor correlations (Figure 6). From 1997-2001 striped bass of 580-680 mm fork length were almost completely absent from the pound net (and gill net) samples. The reason for this extended absence is unclear, but cannot be explained by any single environmental factor. These striped bass are mostly six years of age, so again the predicted strong 1992 and 1993 year classes were not tracked well by these age classes from the pound net index during these years. The abundance of six to eight year-olds rapidly increased in the pound net samples after 2001, which corresponds to the predicted strong 1996 and 1997 year classes.

The plots of nine and ten year-old striped bass show a transition towards a closer tracking of their respective juvenile indexes (Figure 7). While the results of the previous age classes were dominated by resident, mostly male, striped bass, these nine and ten year-old striped bass were predominantly migrant female striped bass returning to the Rappahannock River to spawn. Abnormally low catches across all age classes in 2002 resulted in the failure of the nine year-olds to track the strong 1993 year class and the ten year-olds to track the strong 1992 year class. Hence, overall correlations of these two age classes with their respective juvenile indexes were still weak (Figure 8).

The plots of eleven and twelve year-old striped bass more closely paralleled the juvenile indexes (Figure 9). These age classes are almost entirely comprised of fully mature, migrant female striped bass returning to the Rappahannock River to spawn. Unlike any of the other age classes, there was a strong peak of abundance of the 1992 year class striped bass (in 2003 and 2004). Accordingly, the correlation of eleven and twelve year-old striped bass with their respective juvenile indexes was much higher (Figure 10) than in the younger age classes.

Comparison of the Rappahannock River and Virginia Juvenile Indexes

The juvenile indexes for the Rappahannock River generally tracked their corresponding Virginia juvenile indexes, but there were two major exceptions. In 1987 and 1992, the juvenile index indicated exceptionally strong year classes for the Rappahannock River, but only a moderately strong year class in 1987 and a below average year class in 1992 as indicated by the Virginia index (Figure 11). These two strong year classes have been large contributors to the Spawning Stock Biomass Index (the 1987 year class as four to six year-olds and the 1992 year class as 10-12 year-olds) and thus weaken any correlation to the Virginia juvenile index. It should be noted that the Rappahannock River contributed the least of the three river systems to the 1980-2004 Virginia juvenile index (York River 37.9%, James River 33.2%, Rappahannock River 28.9%).

Comparison of the Rappahannock River SSBI and the Maryland Juvenile Indexes

The 1987 and 1992 Maryland juvenile indexes (Durell and Weedom, 2003) were also weaker in relative magnitude than in the Rappahannock River (Table 8). In fact, there were no major peaks in the Maryland juvenile indexes from 1980-1992 (Figure 12). Thus, it would not be expected that the age-specific CPUEs from the Rappahannock River SSBI would correlate with the Maryland JI for the pre-1993 period. From 1993-2004, the juvenile indexes from all rivers in both jurisdictions of Chesapeake Bay have had repeated strong peaks in abundance, most notably in 1993, 1996 and 2003. Similarly the 2002 juvenile index was the lowest since 1993 throughout Chesapeake Bay. However, the low catches of all age classes in 1996 and 2002, coupled with the lack of 580-680 mm fork length striped bass previously described, preclude the Rappahannock SSBI from any relationship with the Maryland juvenile index.

Discussion

The use of the pound nets to describe the spawning stock in the Rappahannock River has several advantages. The pound nets are not size or sex-selective for mature striped bass. By sampling for (usually) 72 or 96 hours, much of the short-term changes in abundance that affect short-duration sampling (trawls, gill nets, electro-shocking, etc.) is smoothed out. In fact, these samples represent continuous sampling of the Rappahannock River spawning grounds for the duration of the sampling season. It also provides a better representation of the larger, older striped bass than the multi-mesh experimental gill nets used to describe the same spawning stock. These older striped bass have increased in prevalence in recent years and, because of their much higher fecundity, have come to dominate both biomass and egg potential-based indexes.

However, because the pound nets are fixed sampling gears, no estimate of variability is possible. There is also the increased likelihood of unmeasurable changes in catchability due to changes in conditions within the spawning zone in response to environmental extremes. Presumedly, the poor catches of all size and age classes that occurred in 1992, 1996 and 2002 were the results of extreme environmental conditions, since these same age classes rebounded the next year (resulting in implausible survival estimates for that year).

It is not clear why there were so few 580-680 mm fork length striped bass caught from 1997-2001. These fish were captured in increasing numbers from 1991-1996 as the large 1987-1989 year classes matured. Although the 1990 and 1991 year classes were much weaker, the very large 1992 and 1993 year classes were missed as they grew through this size range. These two large year classes have been documented as having above-average CPUEs as 11 and 12 year-olds (by both scale and otolith ageing), which validate the high juvenile indexes reported for 1992 and 1993. This size class has increased in abundance since 2001, as the very large 1996 and 1997 year classes matured through this size range.

The below-expected catches in 1992, 1996 and 2002 and the "missing" mid-size striped bass in 1997-2001 make it impossible to correlate the SSBI with the juvenile index and greatly complicate estimating annual survival rates. Environmental extremes and changes in catchability occur periodically and adversely affect most field sampling programs. The correlations of the CPUE of every age class with their respective JI, except one, was positive, suggesting that some relationship exists. At present, only 11 and 12 year-old striped bass show any promise for validating the juvenile index. However, if the 1997-2001 lack of mid-size striped bass is not a recurring phenomenon, then five and six year-old striped bass should begin increasingly correlating with their respective juvenile indexes.

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Table 1. Values of the VIMS Rappahannock River pound net Spawning Stock Biomass Index, 1991-2004.

Year	number of fish	% males	SSBI (kg/day) males	SSBI (kg/day) females	SSBI (kg/day) combined
1991	223	68.6	21.3	21.5	43.8
1992	151	33.8	5.4	19.4	24.8
1993	565	66.7	31.2	37.5	68.7
1994	375	62.4	17.1	30.9	48
1995	363	79.1	12.4	19.8	32.2
1996	430	83	14.1	9.3	23.4
1997	406	71.3	22.2	49.6	71.7
1998	401	71.8	14.8	36.4	51.2
1999	836	92.7	30.5	19.8	50.3
2000	1,508	95	42.7	14.6	57.3
2001	577	81.2	24.2	27.6	51.8
2002	170	67.6	7.1	11.4	18.5
2003	470	67.4	22.8	53.6	76.4
2004	951	74	58.5	65.4	123.9
mean	**530.4**	**72.5**	**23.2**	**29.8**	**52.9**

Table 2. Age-specific CPUE, sexes combined, from the VIMS Rappahannock River pound net spawning stock assessment survey, 30 March – 3 May, 1991-2004 (maximum values in bold).

	CPUE (fish/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.42	0.2	0.12	0	0.04	0	0	0	0	0	0	0	0	0
2	0.33	0.5	0.58	1.44	3.04	0.51	0.6	0.19	0.79	0.03	0.06	0	0	0.03
3	3.58	0.6	1.04	0.48	**4.8**	**3.97**	3.9	2.15	**11.54**	15.61	2.74	0.5	0.77	3.47
4	**8**	1.6	3.58	1.33	1	2.86	**8.1**	**6.33**	**11.5**	**18.13**	**7.48**	**1.44**	3	5.57
5	3.67	**2.75**	**9.54**	**4.59**	2.24	1.63	1.25	1.48	2.79	3.34	4.29	1.38	**3.33**	**5.9**
6	1.67	1.15	3.65	2.22	0.68	1.26	0.05	0.04	0.11	0.11	0.1	0.25	0.37	3.53
7	0.5	0.3	0.65	1.15	0.6	0.89	0.7	0.52	0.5	0.5	0.58	0.78	1.83	2.23
8	0.25	0.4	0.42	0.59	0.68	0.37	0.8	0.7	0.43	0.5	0.87	0.41	1.4	4.17
9	0.17	0.2	0.58	0.52	0.4	0.37	1.5	0.78	0.32	0.39	0.87	0.28	1.7	2.33
10	0.5	0.3	0.46	0.33	0.08	0.09	1	0.89	0.36	0.29	0.81	0.19	1.43	1.67
11	0.08	0.15	0.31	0.33	0.28	0	1	0.89	0.39	0.37	0.45	0.06	1.13	1
12			0.27	0.19	0.08	0	0.35	0.22	0.43	0.05	0.26	0	0.33	1.1
13			0.15	0.07		0.03	0.35	0.15	0.04	0.05	0.1	0	0.27	0.17
14				0.04			0.2	0.07	0.11			0	0.07	0.07
15				0.04					0.04			0.03	0	0.07
16													0.03	
no age	0.58	0.3	0.38	0.56	0.6	0.31	0.5	0.44	0.54	0.32	0	0	0	0.4
Sum	19.75	8.45	21.73	13.88	14.52	12.29	20.3	14.85	29.89	39.69	18.61	5.32	15.66	31.71
	CPUE (kg/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.08	0.03	0.02	0	0	0	0	0	0	0	0	0	0	0
2	0.15	0.24	0.2	0.36	1.12	0.19	0.22	0.06	0.25	0.01	0.03	0	0	0.01
3	3.88	0.59	1.09	0.41	3.85	2.81	3.25	1.55	8.1	12.24	2.15	0.47	0.55	2.61
4	**13.41**	2.78	6.12	2.2	1.6	3.37	10.45	8.1	**14**	**21.02**	**8.84**	2.01	3.51	7.21
5	8.69	**6.85**	**22.99**	**10.72**	**5.69**	3.41	2.26	2.51	5.13	6.28	8.21	2.96	6.03	11.55
6	5.56	3.81	13.41	7.83	2.72	**3.64**	0.18	0.1	0.38	0.36	0.33	0.83	1.15	9.7
7	2.25	1.34	3.48	6.33	3.43	**3.67**	3.34	2.57	2.4	2.65	2.76	**3.94**	8.53	10.15
8	1.58	2.46	3.11	4.36	4.99	2.17	4.63	4.46	2.66	3.29	5.85	2.72	8.59	**23.63**
9	1.29	1.69	4.52	4.23	3.49	2.6	**11.83**	6.02	2.61	3.25	6.82	2.2	**13.15**	16.06
10	4.54	2.83	4.35	3.26	0.91	0.62	9.3	8.22	3.25	2.81	7.35	2.01	**13.19**	14.71
11	0.81	1.67	3.27	3.47	3.39	0	11.12	**10.08**	4.13	3.76	4.92	0.74	12.02	10.32
12			3.3	2.41	0.82	0	4.72	2.94	4.95	0.6	3.15	0	3.93	12.66
13			1.78	0.97		0.49	4.81	2	0.53	0.66	1.4	0	3.99	2.44
14				0.75			2.96	1.31	1.52			0	1	1.08
15				0.62					0.64			0.62	0	1.08
16													0.67	
no age	1.43	0.98	1.27	2.18	1.44	0.67	2.98	1.3	0.63	0.35	0	0	0	0.79
Sum	43.67	25.27	68.91	50.1	33.45	23.64	72.05	51.22	51.18	57.28	51.81	18.5	76.31	124

Table 3. Age-specific CPUE, males only, from the VIMS Rappahannock River pound net spawning stock assessment survey, 30 March – 3 May, 1991-2004 (maximum values in bold).

	CPUE (fish/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.17	0.1	0.12	0	0.04	0	0	0	0	0	0	0	0	0
2	0.17	0.35	0.54	1.22	2.88	0.51	0.55	0.19	0.79	0.03	0.06	0	0	0.03
3	3.25	0.4	0.96	0.48	**4.68**	**3.83**	3.8	2.15	**11.54**	15.61	2.74	0.44	0.77	3.47
4	**6.08**	**0.9**	3.46	1.3	0.92	2.66	**7.5**	**6.19**	**11.46**	**18.11**	**7.42**	**1.38**	2.93	5.47
5	2.58	0.65	**7.54**	**3.52**	2	1.34	1.15	1.37	2.68	3.21	4.03	1.25	**3.07**	**5.67**
6	0.5	0.3	1.23	1.11	0.08	0.94	0.05	0	0.07	0.08	0.1	0.25	0.3	3.37
7	0.08	0.05	0.15	0.22	0.12	0.43	0.35	0.3	0.36	0.26	0.39	0.16	1.5	1.93
8		0.15	0.04	0.11	0	0.03	0.55	0.11	0.21	0.11	0.16	0.03	0.57	2.23
9			0.08	0.04	0.04	0.09	0.2	0.04	0	0.05	0.19	0.03	0.23	0.53
10				0					0.04	0.03	0.13		0.07	0.2
11				0						0.03				0.1
12				0.04										0.07
13														
14														
15														
16														
no age	0.25	0.1	0.27	0.41	0.44	0.23	0.25	0.33	0.54	0.32	0	0	0	0.4
Sum	13.08	3	14.39	8.45	11.2	10.06	14.4	10.68	27.69	37.84	15.22	3.54	9.44	23.47

	CPUE (kg/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.03	0.02	0.02	0	0	0	0	0	0	0	0	0	0	0
2	0.09	0.18	0.19	0.32	1.07	0.19	0.2	0.06	0.25	0.01	0.03	0	0	0.01
3	3.54	0.38	1.01	0.41	3.72	2.71	3.15	1.55	8.1	12.24	2.15	0.4	0.55	2.61
4	**9.71**	**1.42**	5.9	2.14	1.49	**3.06**	**9.48**	**7.84**	**13.94**	**20.99**	**8.74**	1.94	3.44	7.07
5	5.95	**1.43**	**17.71**	**7.77**	**5.01**	2.75	2.07	2.31	4.92	6.02	7.63	**2.67**	5.55	11.06
6	1.46	0.87	4.25	3.43	0.33	2.68	0.18	0	0.26	0.25	0.33	0.83	0.95	9.25
7	0.31	0.24	0.83	1.14	0.65	1.76	1.63	1.57	1.68	1.35	1.81	0.8	**6.89**	8.78
8		0.84	0.27	0.73	0	0.17	3.15	0.68	1.29	0.6	1	0.19	3.3	**12.22**
9			0.65	0.33	0.35	0.65	1.49	0.26	0	0.4	1.39	0.26	1.51	3.38
10				0					0.3	0.21	1.13		0.58	1.63
11				0						0.27				1.05
12				0.51										0.7
13														
14														
15														
16														
no age	0.37	0.26	0.6	1.22	0.85	0.32	1.02	0.6	0.63	0.35	0	0	0	0.79
Sum	21.46	5.64	31.43	18	13.47	14.29	22.37	14.87	31.37	42.69	24.21	7.09	22.77	58.55

Table 4. Age-specific CPUE, females only, from the VIMS Rappahannock River pound net spawning stock assessment survey, 30 March – 3 May 1991-2004 (maximum values in bold).

	CPUE (fish/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.25	0.1	0	0	0	0	0	0	0	0	0	0	0	0
2	0.17	0.15	0.04	0.22	0.16	0	0.05	0	0	0	0	0	0	0
3	0.33	0.2	0.08	0	0.12	0.14	0.1	0	0	0	0	0.06	0	0
4	**1.92**	0.7	0.12	0.04	0.08	0.2	0.6	0.15	0.04	0.03	0.06	0.06	0.07	0.1
5	1.08	**2.1**	2	1.07	0.24	0.29	0.1	0.11	0.11	0.13	0.26	0.13	0.27	0.23
6	1.17	0.85	**2.42**	**1.11**	0.6	0.31	0	0.04	0.04	0.03	0	0	0.07	0.17
7	0.42	0.25	0.5	0.93	0.48	**0.46**	0.35	0.22	0.14	0.24	0.19	**0.63**	0.33	0.3
8	0.25	0.25	0.39	0.48	**0.68**	0.34	0.25	0.59	0.21	**0.4**	**0.71**	0.38	0.83	**1.93**
9	0.17	0.2	0.5	0.48	0.36	0.29	**1.3**	0.74	0.32	0.34	0.68	0.25	**1.47**	1.8
10	0.5	0.3	0.46	0.33	0.08	0.09	1	**0.89**	0.32	0.26	0.68	0.19	1.37	1.47
11	0.08	0.15	0.31	0.33	0.28	0	1	**0.89**	0.39	0.34	0.45	0.06	1.13	0.9
12			0.27	0.15	0.08	0	0.35	0.22	**0.43**	0.05	0.26	0	0.33	1.03
13			0.15	0.07		0.03	0.35	0.15	0.04	0.05	0.1	0	0.27	0.17
14				0.04			0.2	0.07	0.11			0	0.07	0.07
15				0.04					0.04			0.03	0	0.07
16													0.03	
no age	0.33	0.2	0.12	0.15	0.16	0.09	0.25	0.11	0	0	0	0	0	0
Sum	6.67	5.45	7.36	5.44	3.32	2.24	5.9	4.18	2.19	1.87	3.39	1.79	6.24	8.24

	CPUE (kg/day)													
age	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1	0.05	0.01	0	0	0	0	0	0	0	0	0	0	0	0
2	0.07	0.07	0.01	0.04	0.05	0	0.02	0	0	0	0	0	0	0
3	0.34	0.21	0.08	0	0.13	0.1	0.1	0	0	0	0	0.06	0	0
4	3.7	1.37	0.22	0.06	0.11	0.3	0.97	0.26	0.07	0.03	0.1	0.08	0.07	0.14
5	2.74	**5.42**	5.28	2.95	0.68	0.66	0.2	0.2	0.21	0.26	0.58	0.29	0.48	0.49
6	4.09	2.94	**9.16**	4.4	2.39	0.96	0	0.1	0.12	0.11	0	0	0.21	0.45
7	1.94	1.09	2.65	**5.19**	2.78	1.9	1.72	1	0.72	1.31	0.96	**3.14**	1.64	1.37
8	1.58	1.62	2.84	3.63	**4.99**	**2.01**	1.48	3.78	1.37	2.68	4.85	2.54	5.3	11.41
9	1.29	1.69	3.87	3.89	3.14	1.95	10.33	5.75	2.61	2.85	5.43	1.94	11.64	12.68
10	**4.54**	2.83	4.35	3.26	0.91	0.62	9.3	8.22	2.96	2.6	**6.22**	2.01	**12.61**	**13.07**
11	0.81	1.67	3.27	3.47	3.39	0	**11.12**	**10.08**	4.13	**3.5**	4.92	0.74	12.02	9.28
12			3.3	1.91	0.82	0	4.72	2.94	**4.95**	0.6	3.15	0	3.93	11.95
13			1.78	0.97		0.49	4.81	2	0.53	0.66	1.4	0	3.99	2.44
14				0.75			2.96	1.31	1.52			0	1	1.08
15				0.62					0.64			0.62	0	1.08
16													0.67	
no age	1.06	0.72	0.67	0.96	0.58	0.35	1.96	0.71	0	0	0	0	0	0
Sum	22.21	19.64	37.48	32.1	19.97	9.34	49.69	36.35	19.83	14.6	27.61	11.42	53.56	65.44

Table 5. Comparison of catches and mean ages, by sex, of striped bass prior to and within the 30 March – 3 May temporal window, 1993-1998.

	pre-30 March				30 March - 3 May			
	Males		Females		Males		Females	
Year	N	$\overline{Age}$	N	$\overline{Age}$	N	$\overline{Age}$	N	$\overline{Age}$
1993	0		0		372	4.7	191	6.9
1994	0		0		228	4.5	147	7.2
1995	356	3.1	108	5.3	280	3.3	83	7.2
1996	103	3.3	14	6.6	353	4	78	6.8
1997	232	3.7	15	7.6	297	4.1	118	9.2
1998	410	3.5	6	6.5	288	4	101	9.5
95-98	1101	3.4	143	5.7	1218	3.9	380	8.4

Table 6. Comparison of river flows with Spawning Stock Biomass Indexes from pound nets in the Rappahannock River, 30 March – 3 May, 1985-2003 (Red denotes minimum values and blue denotes maximum values).

Year	River flows cf/s/day		VIMS SSBI (pound nets)		
	Mean	Maximum	male	female	combined
1985	837	1320			
1986	1450	4290			
1987	4077	30100			
1988	1035	2450			
1989	1537	9610			
1990	2323	5790			
1991	1974	7970	21.3	21.5	42.8
1992	2216	16700	5.4	19.4	24.8
1993	4999	18100	31.2	37.5	68.7
1994	2923	15800	17.1	30.9	48
1995	829	1440	12.4	19.8	32.2
1996	2981	10500	14.1	9.3	23.4
1997	1835	3700	22.2	49.6	71.7
1998	2827	9490	14.8	36.4	51.2
1999	835	1130	30.5	19.8	50.3
2000	1845	4140	42.7	14.6	57.3
2001	2501	16000	24.2	27.6	51.8
2002	1190	4509	7.1	11.4	18.5
2003	3451	8547	22.8	53.6	76.4
2004			58.5	65.4	123.9
mean	2184	4227	23.2	29.8	52.9

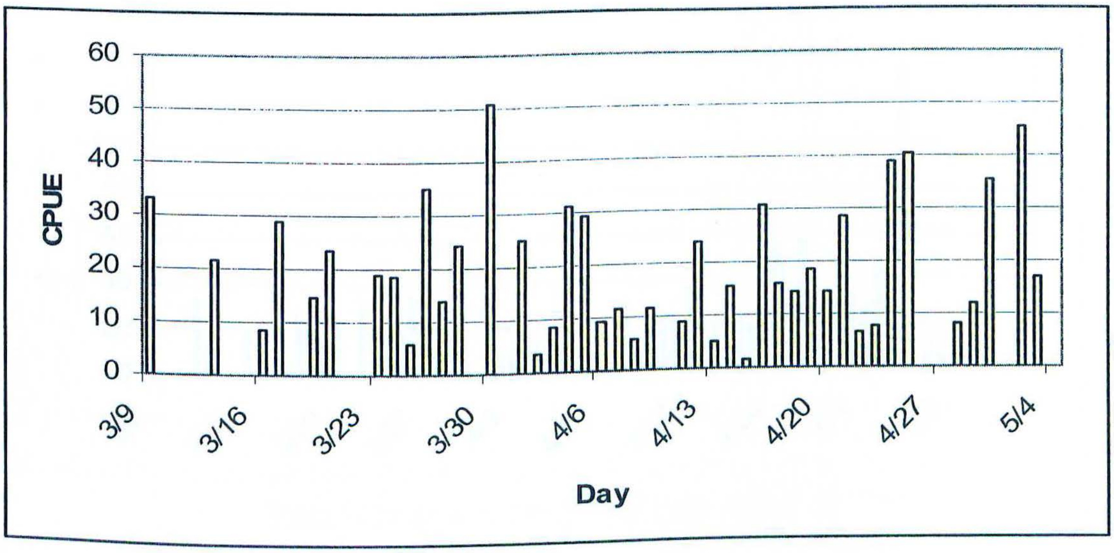
Table 7. Comparison of Rappahannock River flows (30 March – 3 May) with VIMS striped bass juvenile indexes, 1985-2004 (red denotes minimum values and blue denotes maximum values).

VIMS striped bass juvenile indexes					River flow (cf/s)	
Year	James	York	Rappahannock	Combined	Mean	Maximum
1980	4.77	2.51	0.75	2.54		
1981	1.2	2.42	0.88	1.57		
1982	2.71	3.28	1.98	2.71		
1983	4.43	2.63	3.77	3.48		
1984	5.59	4.8	2.57	4.36		
1985	2.94	3.42	0.8	2.41	837	1320
1986	8.63	2.67	4.49	4.75	1450	4290
1987	18.8	7.29	34.03	15.75	4077	30100
1988	6.8	5.06	14.55	7.64	1035	2450
1989	15.4	9.29	9.87	11.23	1537	9610
1990	12.21	6.72	4.18	7.64	2323	5790
1991	4.5	3.37	3.56	3.78	1974	7970
1992	3.71	3.64	30.92	7.32	2216	16700
1993	23.7	13.7	18.1	18.12	4999	18100
1994	10.28	11.29	9.7	10.49	2923	15800
1995	8.8	6.31	2.41	5.45	829	1440
1996	42.62	15.78	18.18	23.05	2981	10500
1997	9.22	6.49	9.52	8.24	1835	3700
1998	16.02	10.84	14.18	13.33	2827	9490
1999	5.33	0.64	4.55	2.8	835	1130
2000	26.64	11.88	13.32	16.18	1845	4140
2001	24.03	8.52	14.6	14.17	2501	16000
2002	9.97	0.9	4.96	3.98	1190	4509
2003	34.55	17.47	19.98	22.85	3451	8547
2004	12.13	11.5	15.36	12.7		
overall	9.23	5.64	7.35	7.21	2184	4227

Table 8. Comparison of the Virginia and Maryland juvenile indexes, by river, 1980-2004 (blue denotes maximum values and red denotes minimum values).

	VIMS striped bass juvenile indexes				Maryland striped bass juvenile indexes					
Year	James	York	Rap.	Mean	Chop.	Bay head	Nanti.	Poto.	Patux.	Mean
1980	4.77	2.51	0.75	2.54	0.60	1.43	0.81	1.04		1.02
1981	1.2	2.42	0.88	1.57	0.84	0.17	1.16	0.68		0.59
1982	2.71	3.28	1.98	2.71	5.68	2.98	3.08	3.50		3.57
1983	4.43	2.63	3.77	3.48	0.64	0.61	0.59	0.62	0.04	0.61
1984	5.59	4.8	2.57	4.36	2.13	2.24	0.81	1.42	0.39	1.64
1985	2.94	3.42	0.8	2.41	1.78	0.19	0.94	1.45	1.95	0.91
1986	8.63	2.67	4.49	4.75	0.32	0.90	1.24	3.09	1.17	1.34
1987	18.8	7.29	34.03	15.75	3.06	0.16	1.36	3.01	0.94	1.46
1988	6.8	5.06	14.55	7.64	0.40	2.25	0.28	0.22	0.40	0.73
1989	15.4	9.29	9.87	11.23	28.10	8.54	1.94	1.15	0.92	4.87
1990	12.21	6.72	4.18	7.64	1.34	2.20	0.56	0.38	0.17	1.03
1991	4.5	3.37	3.56	3.78	4.42	1.99	0.52	0.84	0.53	1.52
1992	3.71	3.64	30.92	7.32	2.07	0.87	1.72	6.00	1.85	2.34
1993	23.7	13.7	18.1	18.12	27.87	15.00	4.56	15.96	47.18	13.97
1994	10.28	11.29	9.7	10.49	7.71	12.88	9.06	2.01	2.82	6.40
1995	8.8	6.31	2.41	5.45	9.96	2.85	3.76	4.48	3.46	4.41
1996	42.62	15.78	18.18	23.05	33.29	15.00	19.13	13.60	58.11	17.61
1997	9.22	6.49	9.52	8.24	3.95	6.15	1.74	3.67	2.72	3.91
1998	16.02	10.84	14.18	13.33	21.10	4.32	2.74	4.42	7.58	5.50
1999	5.33	0.64	4.55	2.8	20.01	1.91	5.52	5.84	5.39	5.34
2000	26.64	11.88	13.32	16.18	12.53	8.84	10.86	3.52	5.03	7.42
2001	24.03	8.52	14.6	14.17	86.71	7.15	20.31	5.01	10.01	12.57
2002	9.97	0.9	4.96	3.98	0.38	1.35	4.89	3.95	0.69	2.20
2003	34.55	17.47	19.98	22.85	20.56	11.89	3.25	12.81	22.17	10.83
2004	12.13	11.5	15.36	12.7	9.52	4.17	9.65	2.36	1.29	4.85
overall	9.23	5.64	7.35	7.21						

Figure 1. Temporal distribution of male (top graph) and female (bottom graph) striped bass catches (kg/day) from pound nets in the Rappahannock River, 1993-1998.



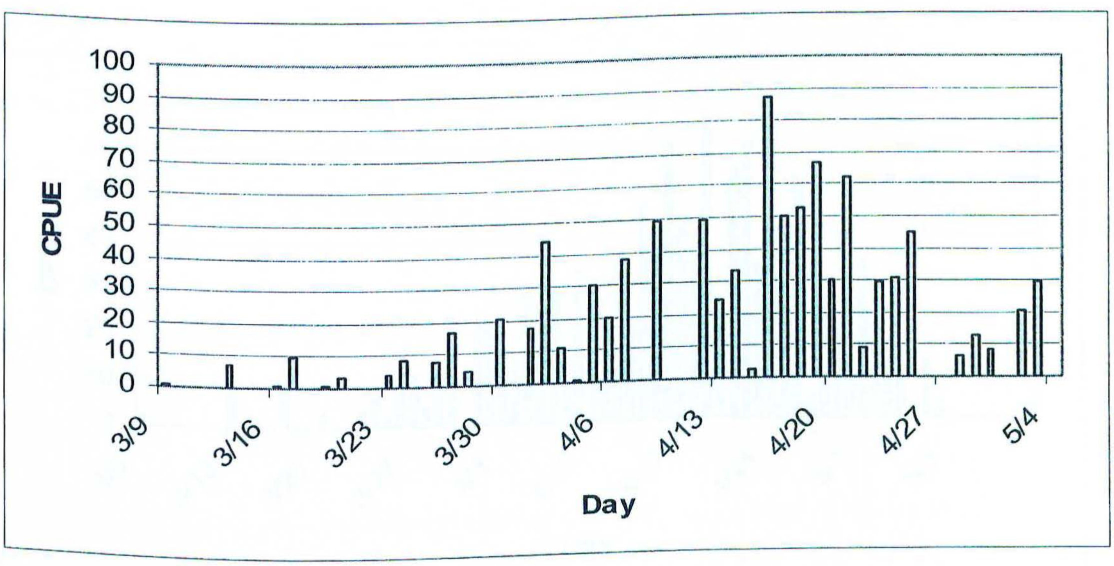
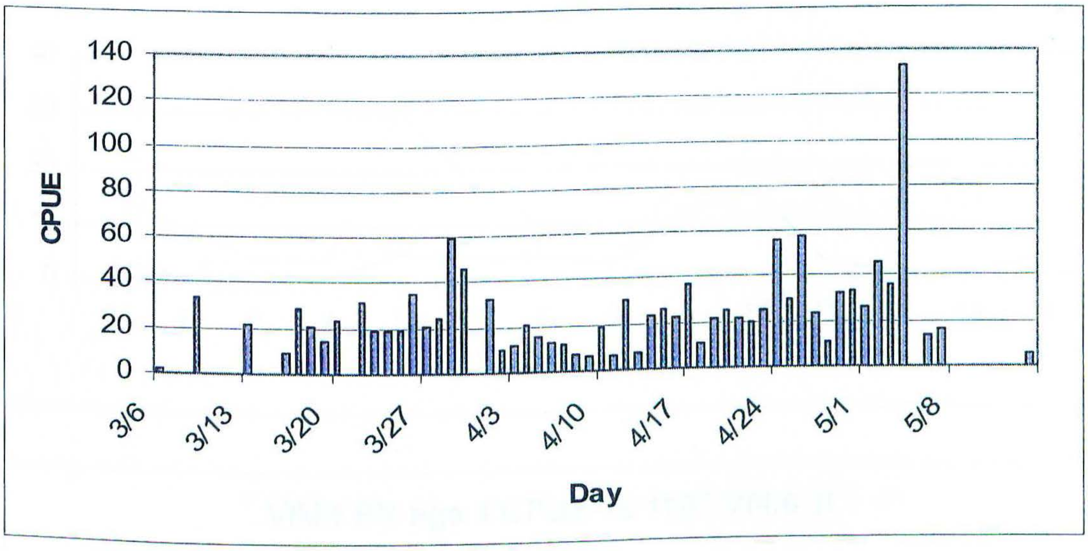


Figure 2. Temporal distribution of male (top graph) and female (bottom graph) striped bass catches (kg/day) from pound nets in the Rappahannock River, 1991-2004.



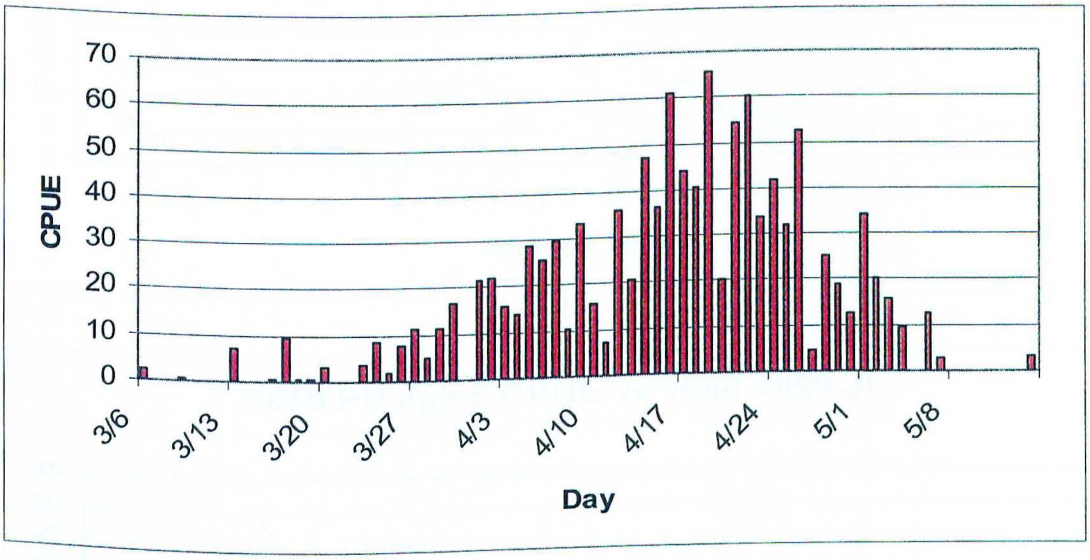
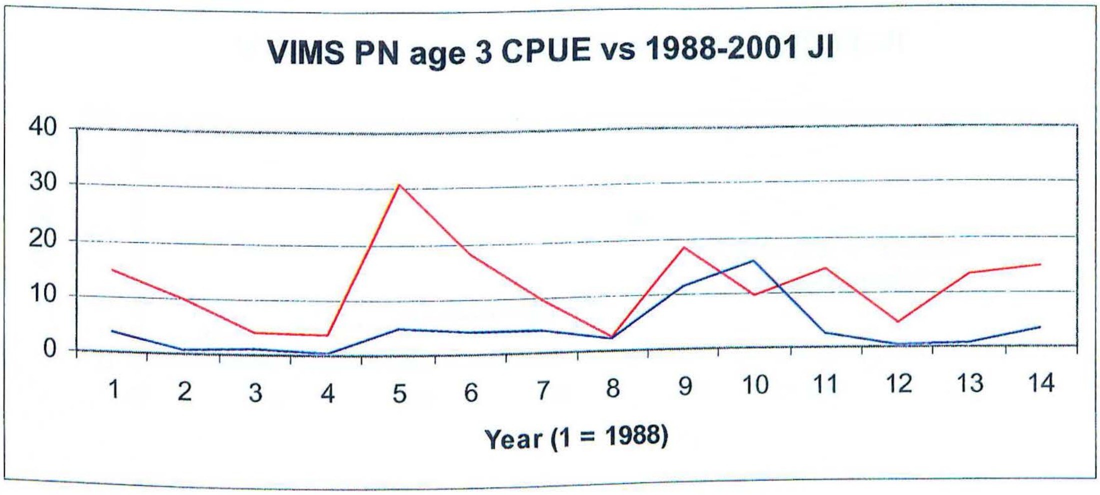
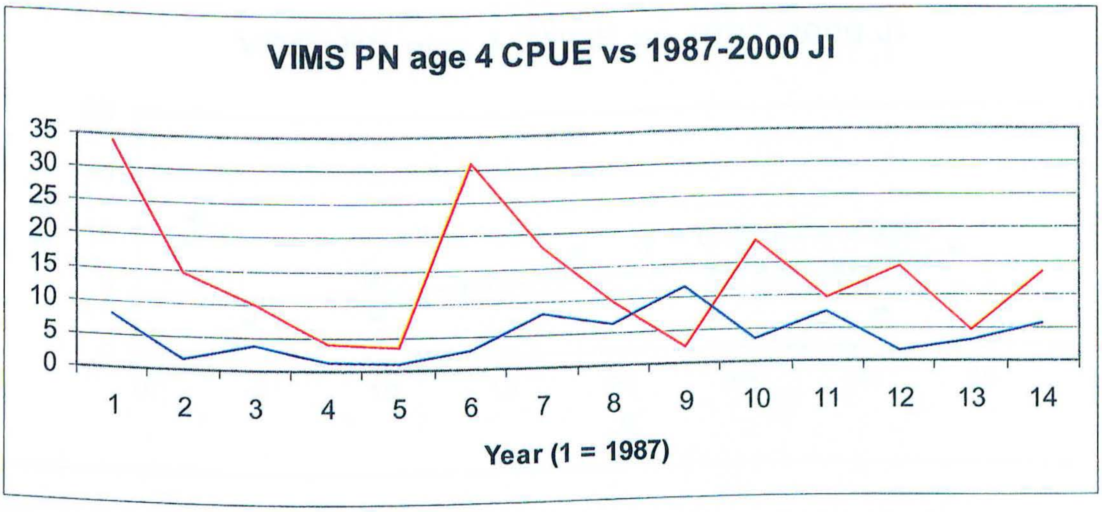


Figure 3. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-three through age-five CPUEs (blue lines) of striped bass from the pound net index.





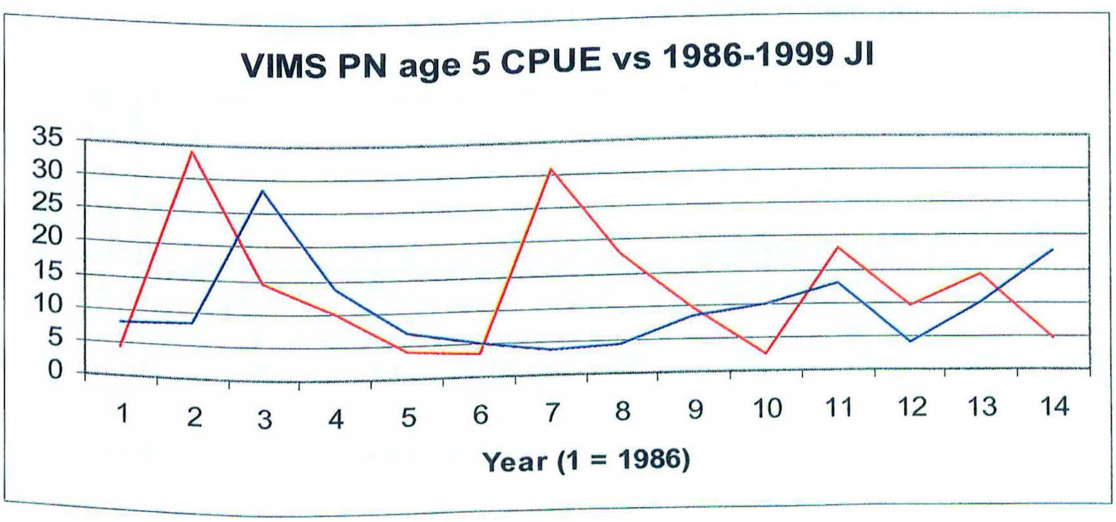
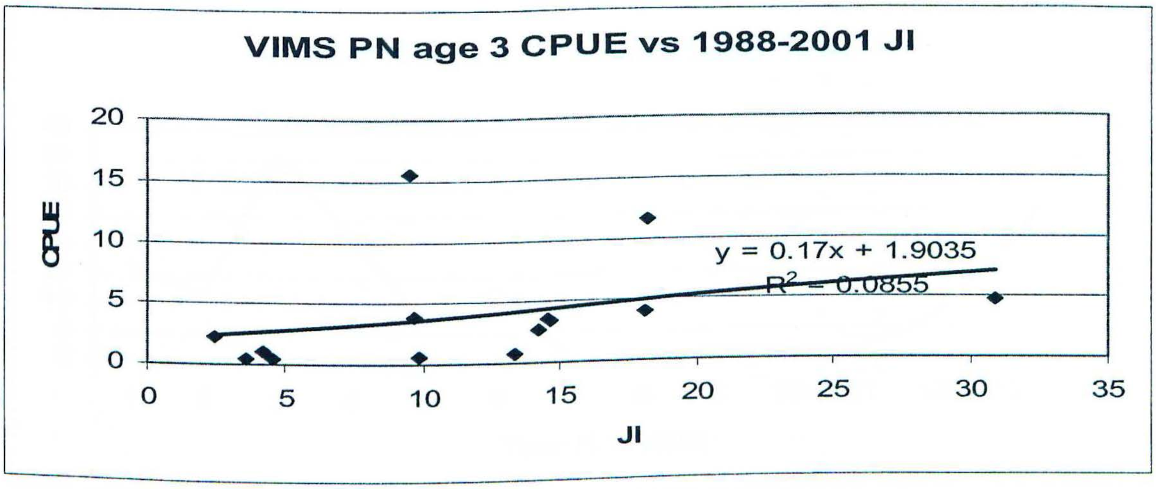
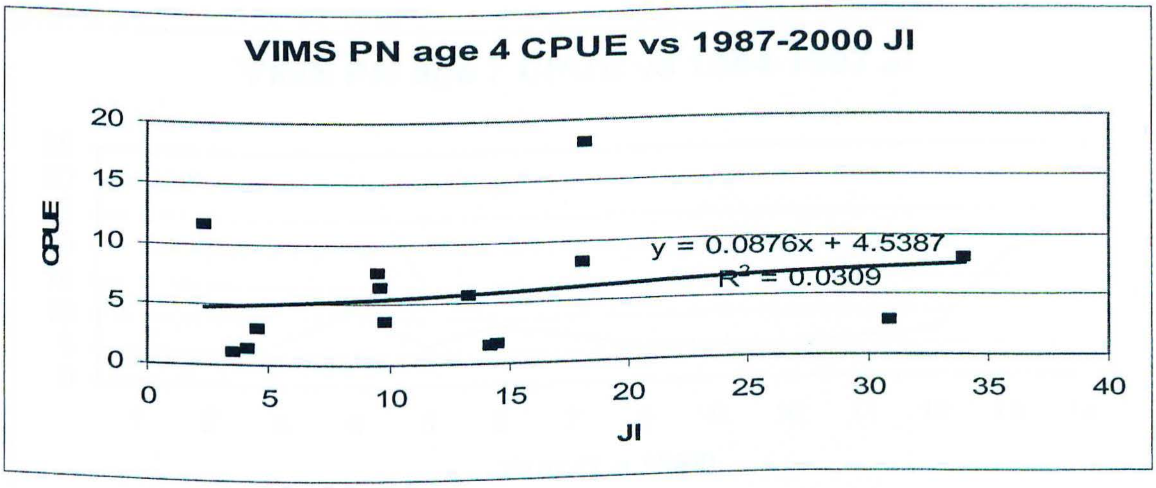


Figure 4. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-three through age-five CPUEs of striped bass from the pound net index.





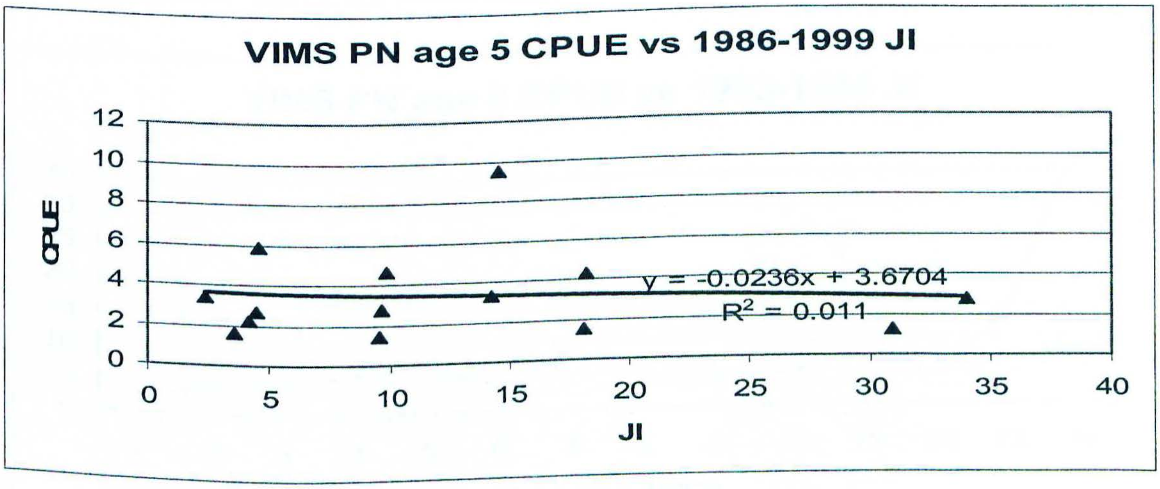
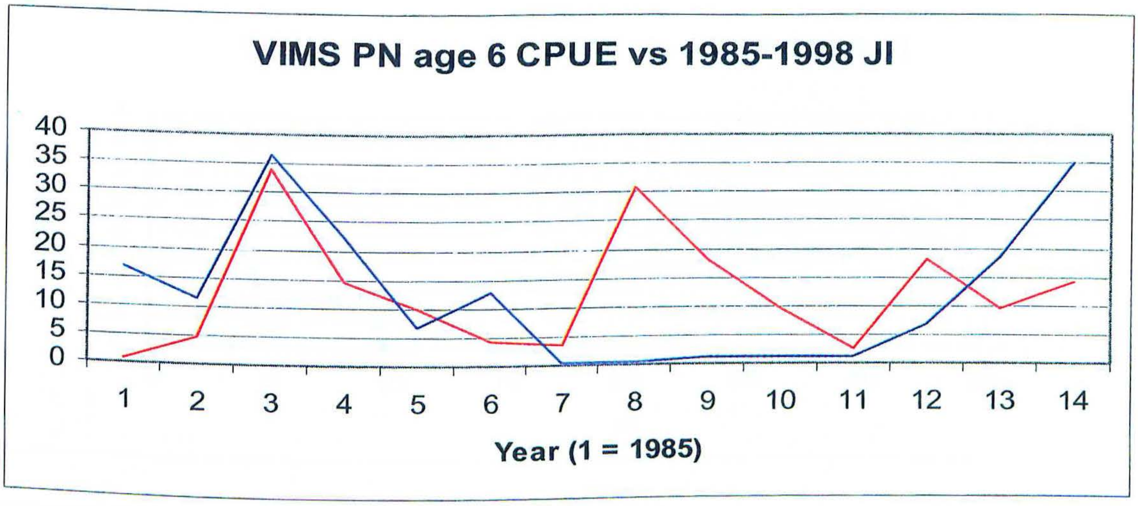
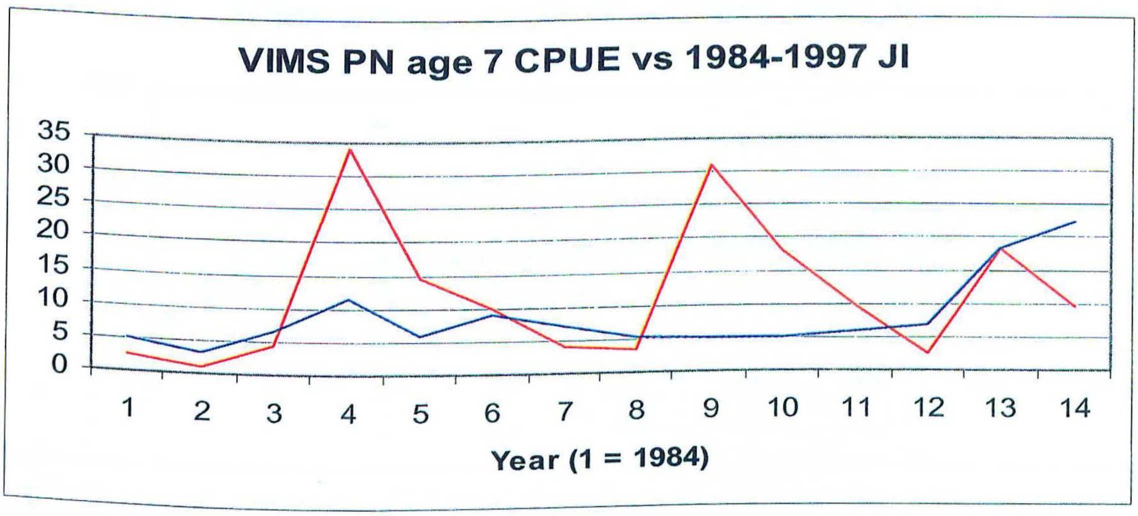


Figure 5. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-six through age-eight CPUEs (blue lines) of striped bass from the pound net index.





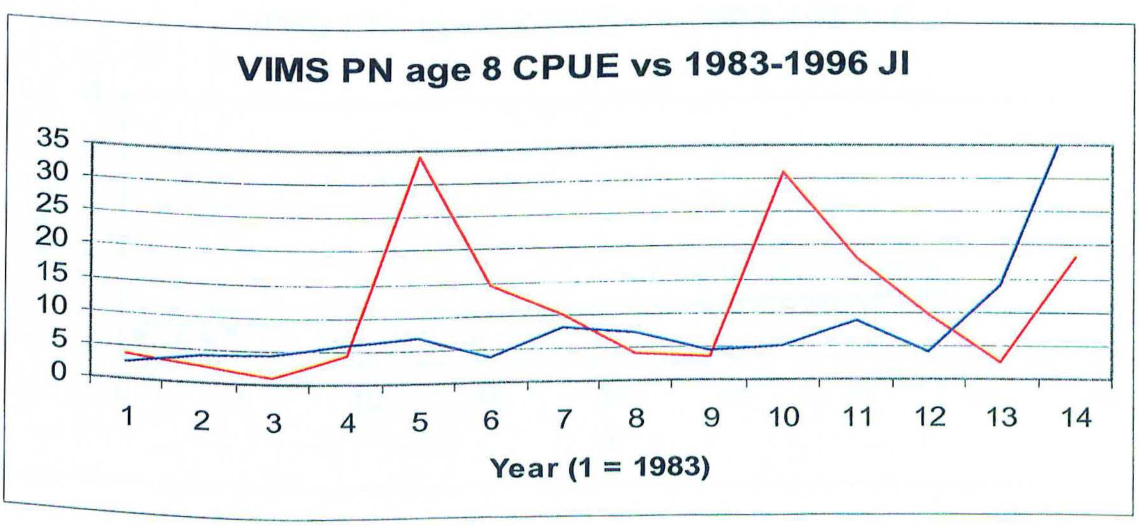
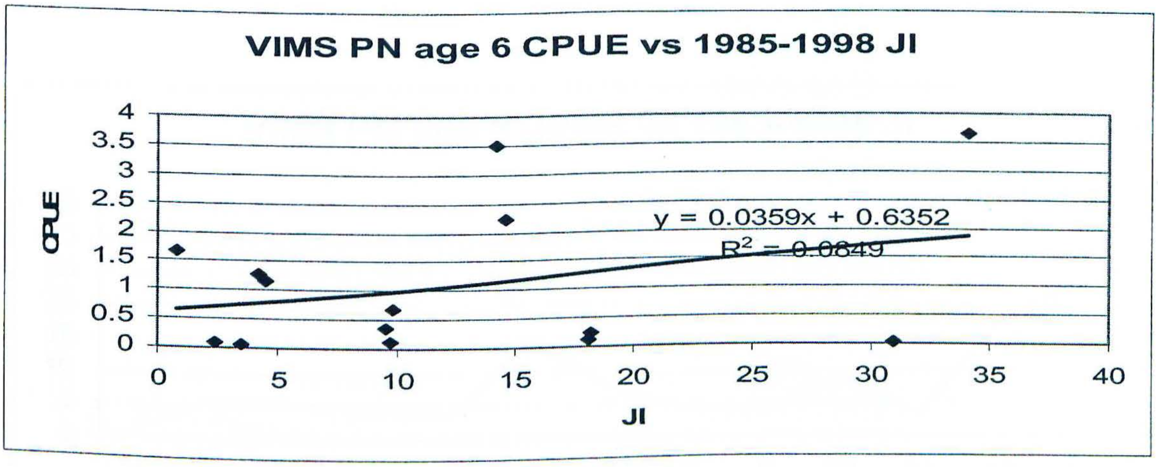
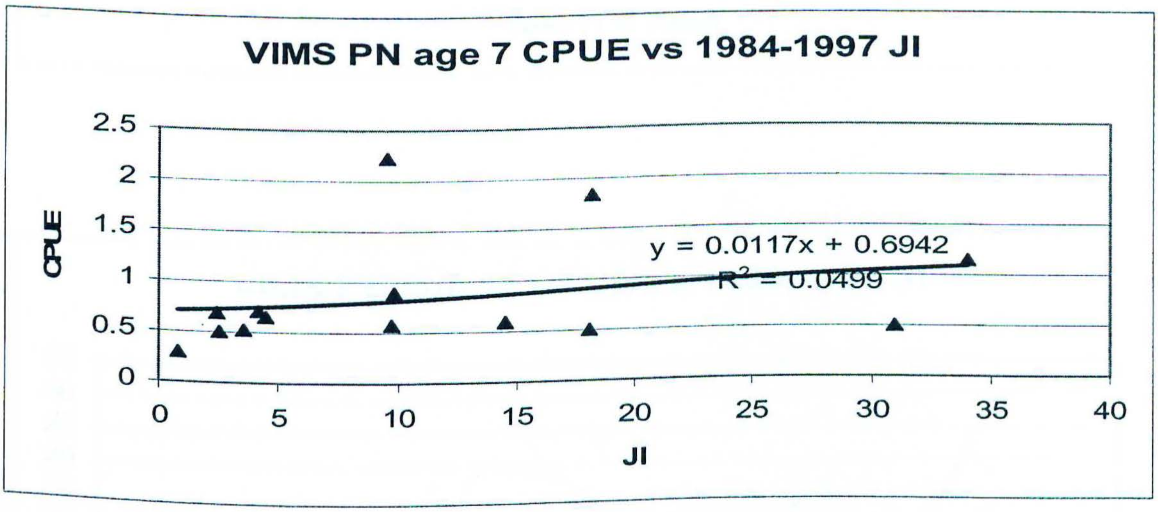


Figure 6. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-six through age-eight CPUEs of striped bass from the pound net index.





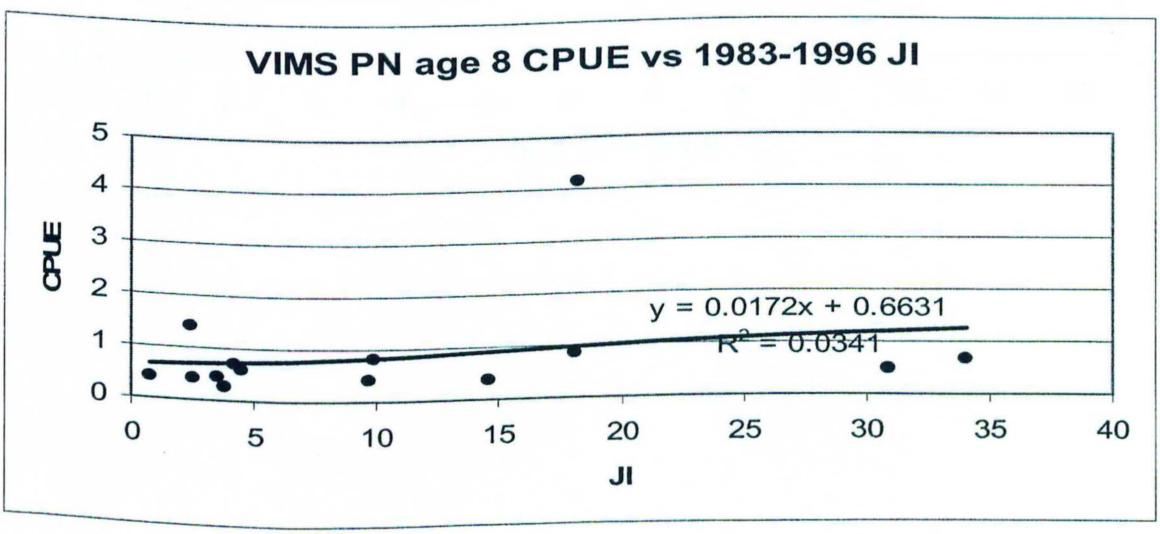
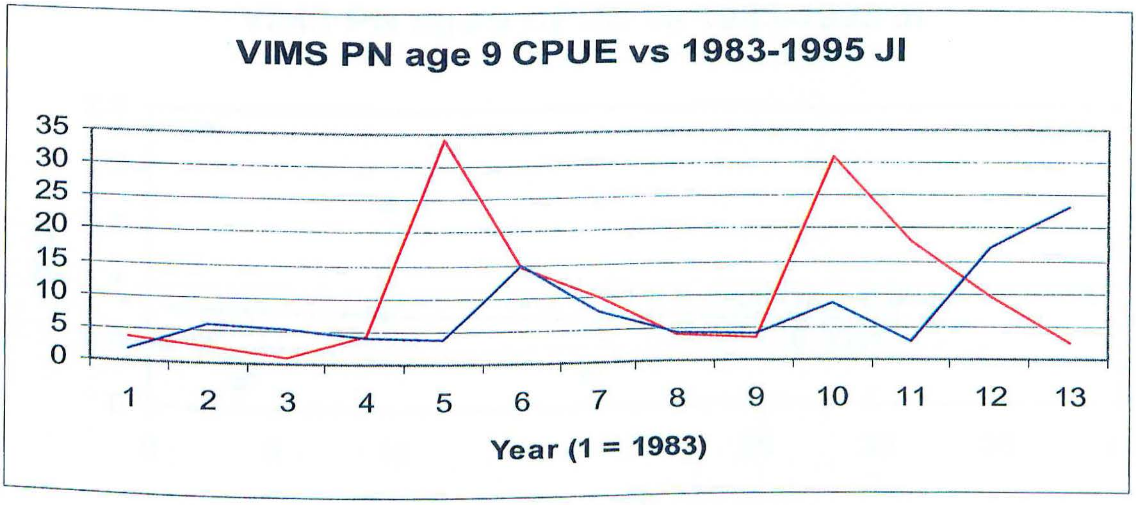


Figure 7. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-nine and age-ten CPUEs (blue lines) of striped bass from the pound net index.



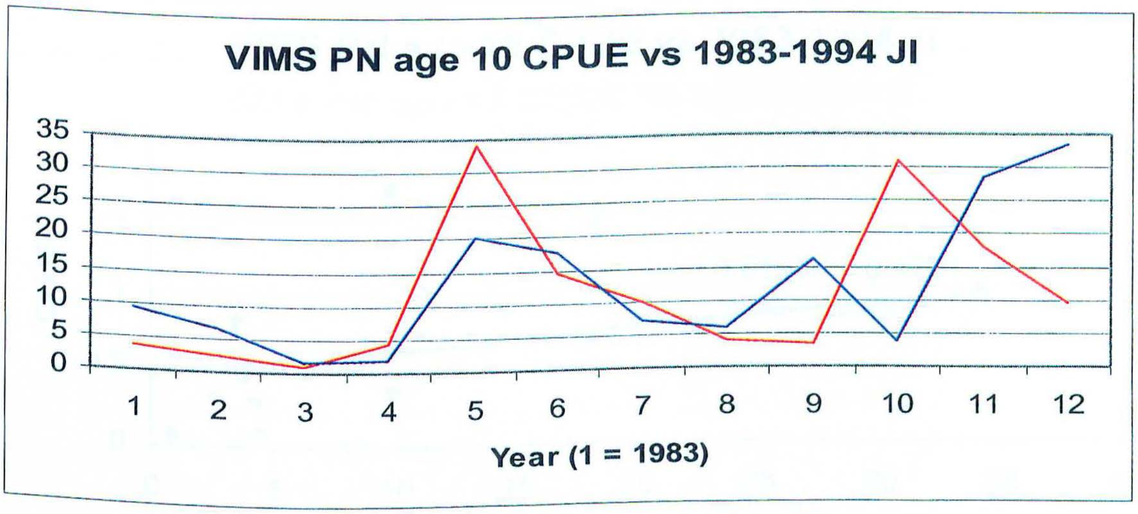
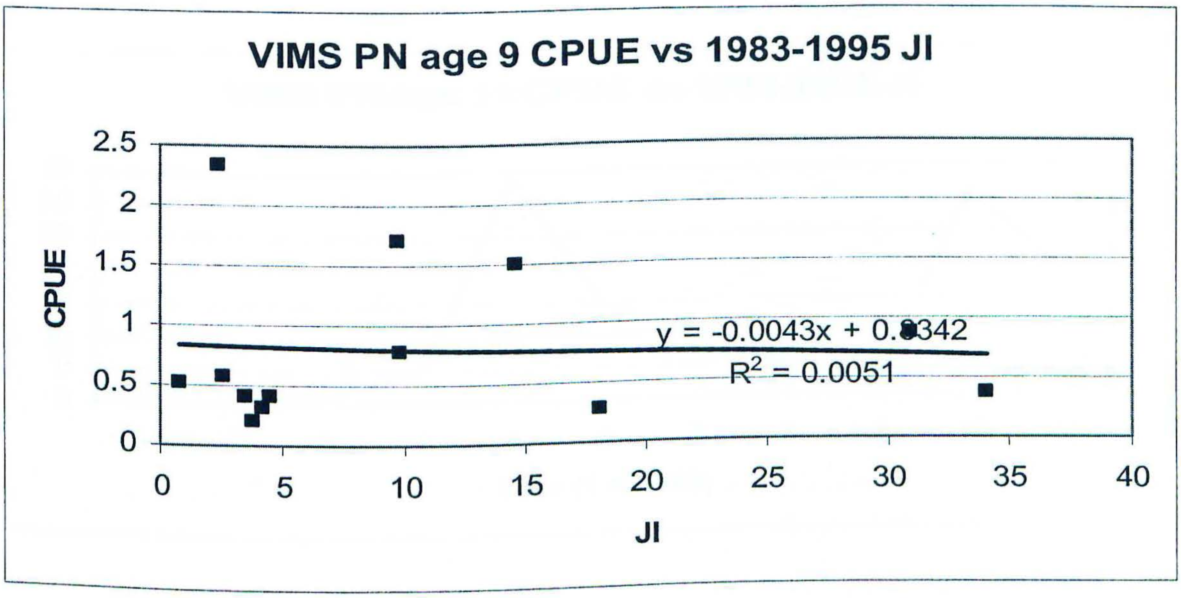


Figure 8. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-nine and age-ten CPUEs of striped bass from the pound net index.



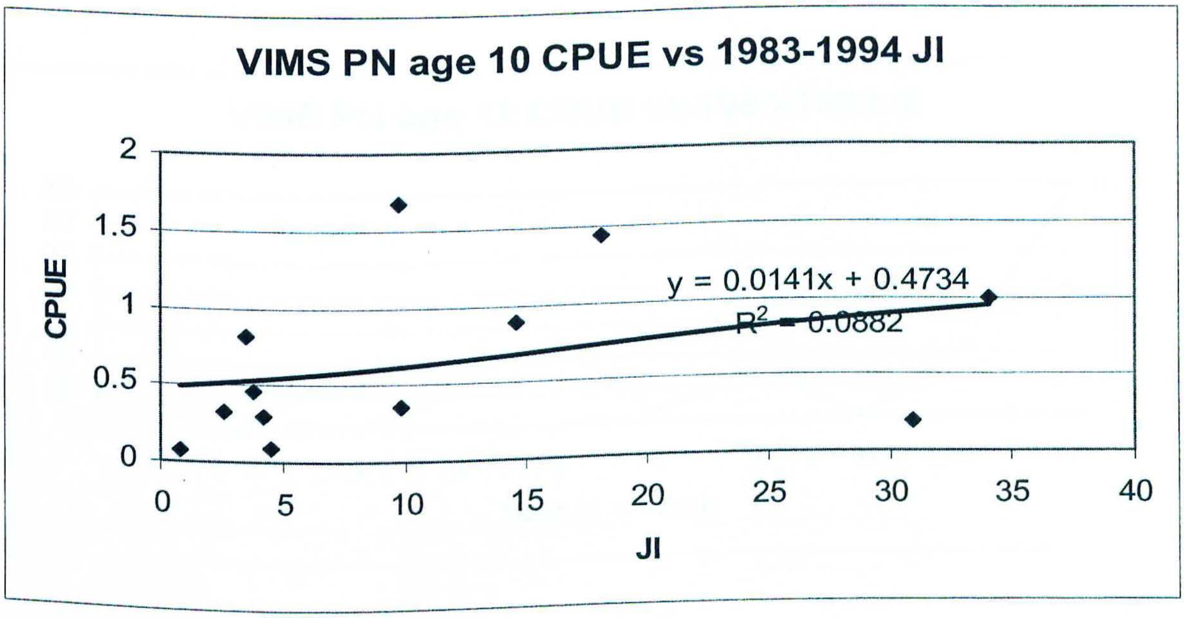
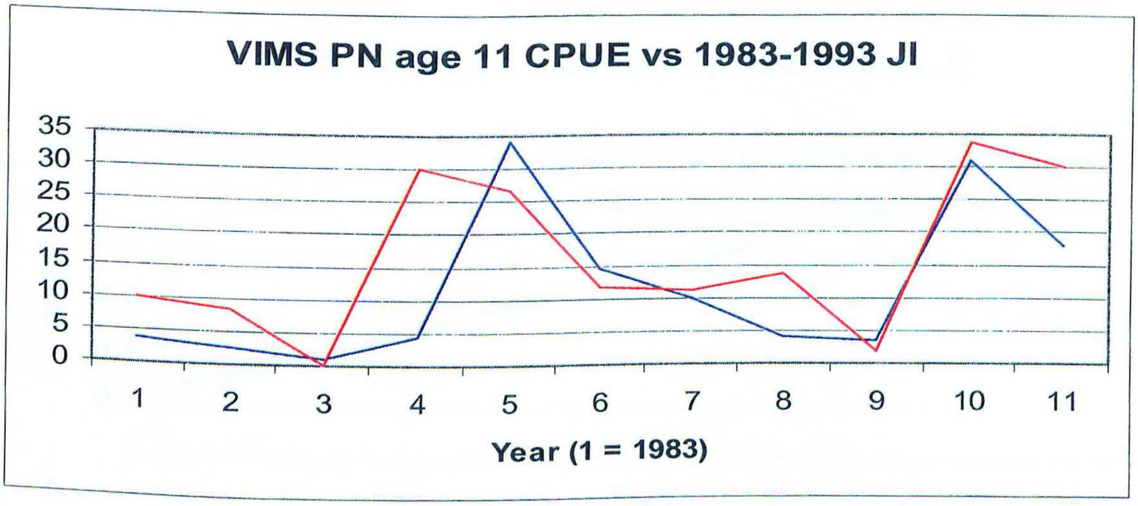


Figure 9. Comparison of the VIMS Rappahannock River juvenile indexes (red lines) with their respective age-eleven and age-twelve CPUEs (blue lines) of striped bass from the pound net index.



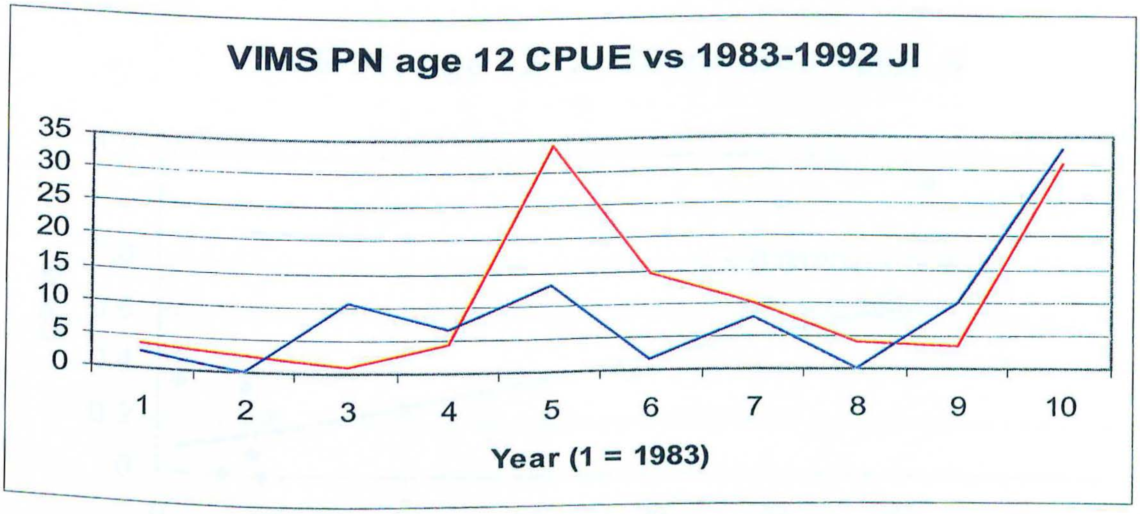
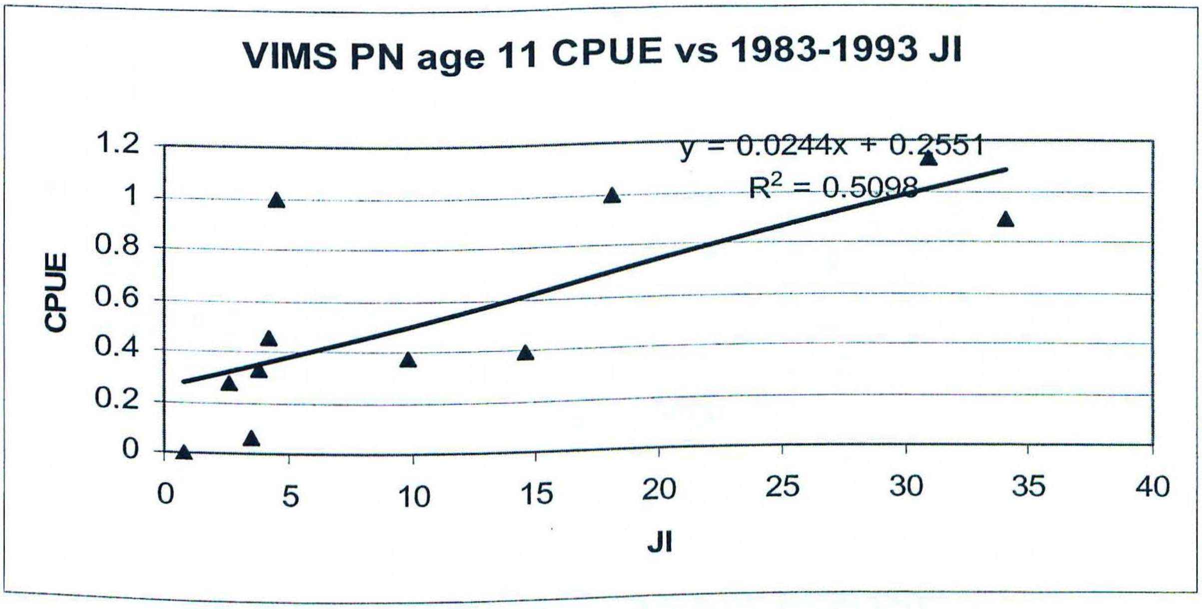


Figure 10. Correlation of the VIMS Rappahannock River juvenile indexes with their respective age-eleven and age-twelve CPUEs of striped bass from the pound net index.



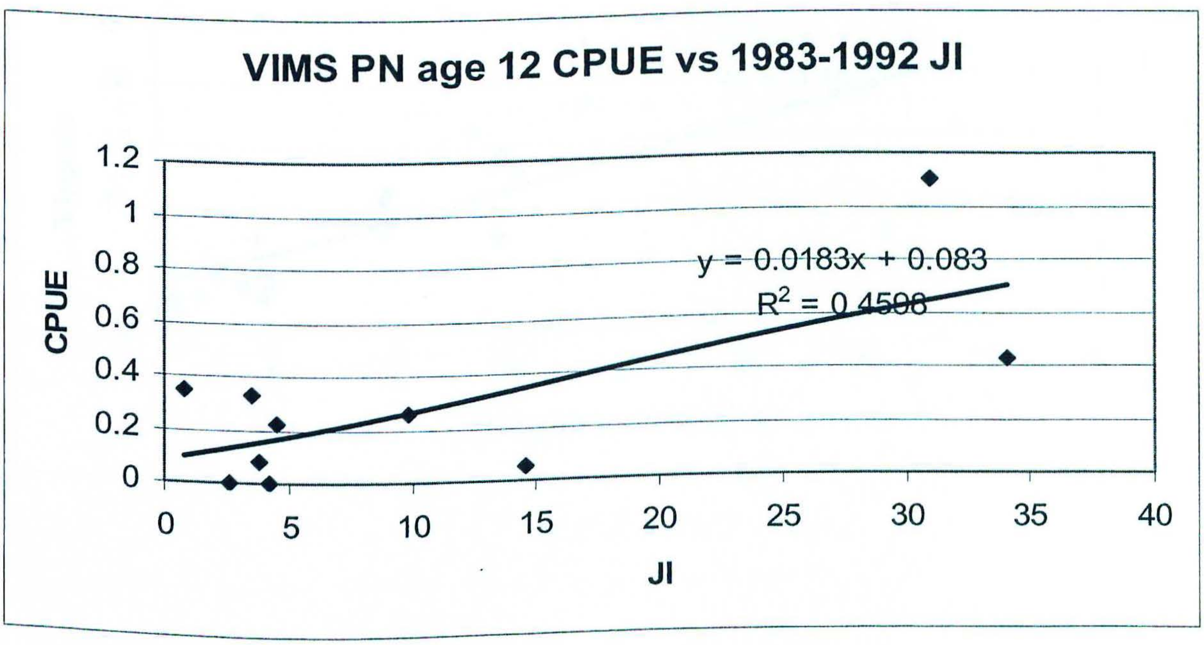
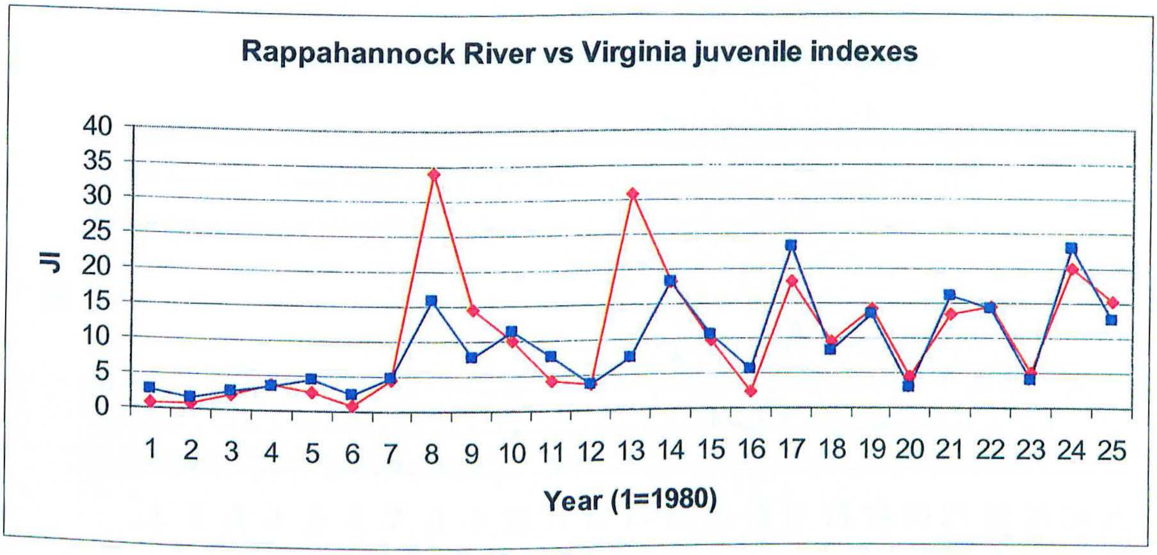


Figure 11. Comparison of the Rappahannock River juvenile index (red line) with the Virginia juvenile index (blue line) and their correlation, 1980-2004.



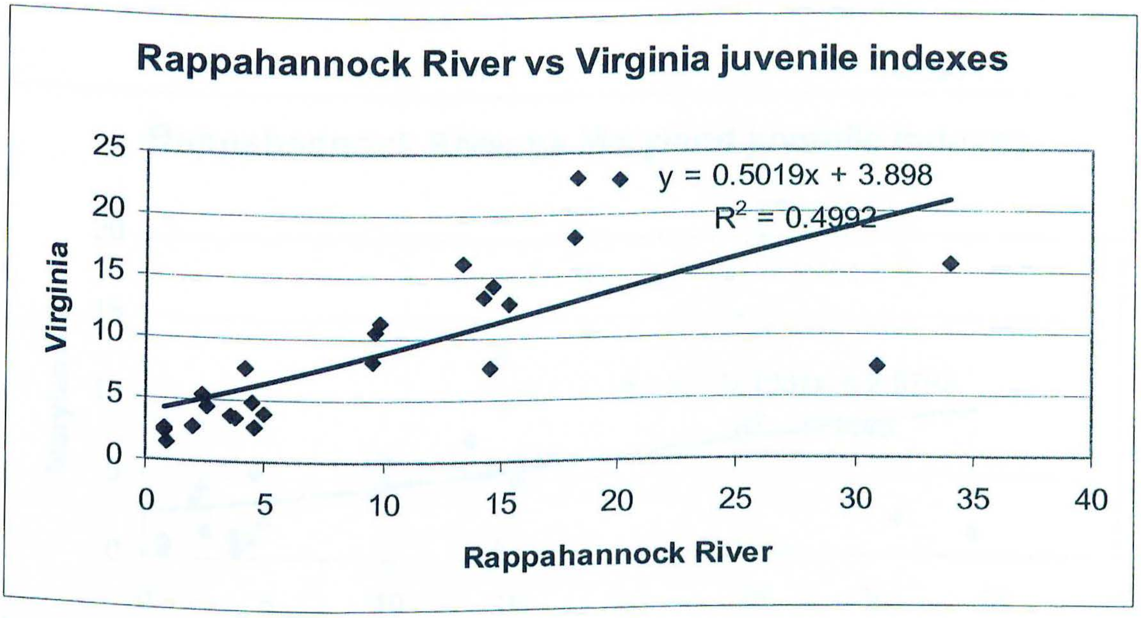
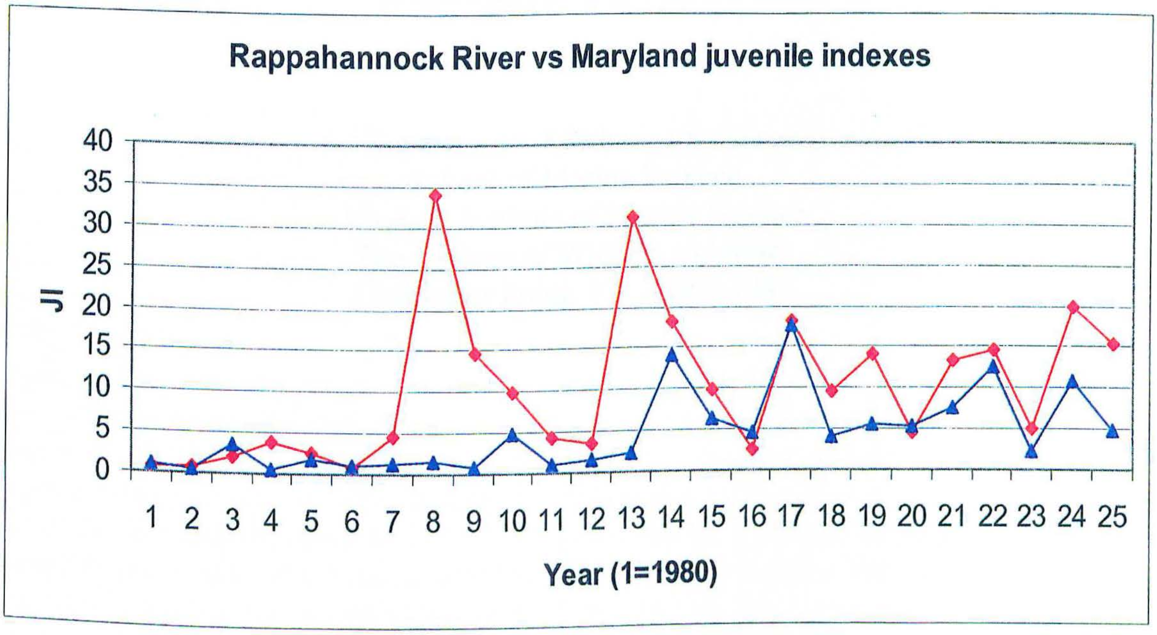
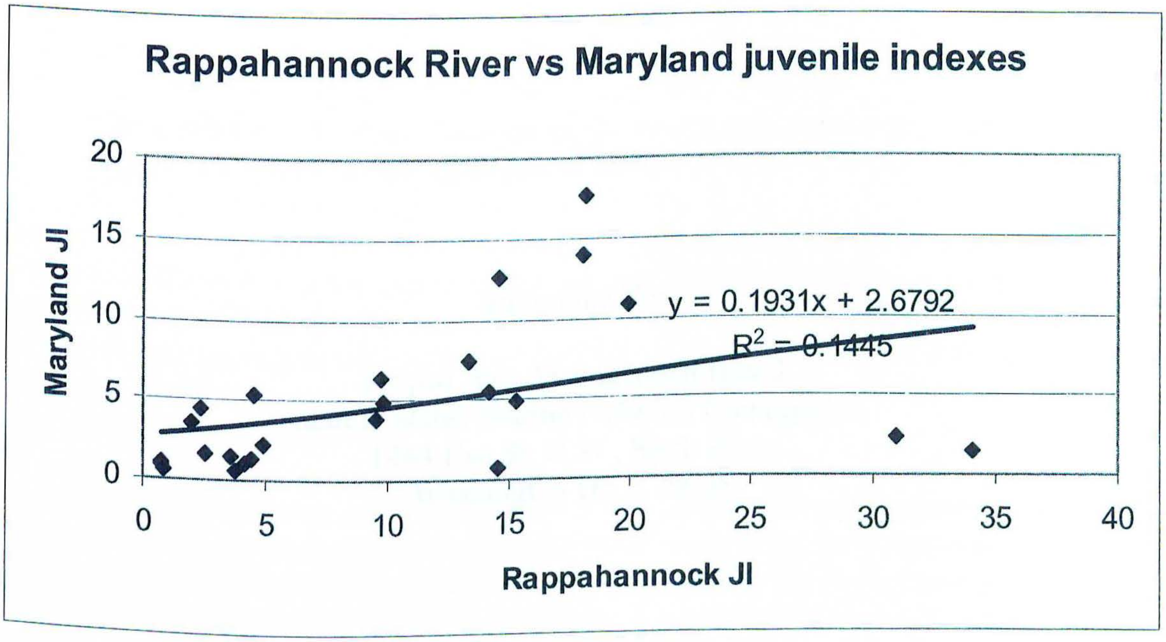


Figure 12. Comparison of the Rappahannock River juvenile index (red line) with the Maryland juvenile index (blue line) and their correlation, 1980-2004.





V. Comparison of the catches of the Rappahannock River pound nets, and the correlation of the Virginia Spawning Stock Biomass Indexes to the Maryland gill net indexes.

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Comparison of the catches of the Rappahannock River pound nets and the correlation of the Virginia Spawning Stock Biomass Indexes to the Maryland gill net indexes.

Introduction

From 1991 to 1996 there were only two pound nets (S441 and S473) available for obtaining striped bass monitoring samples from the spawning grounds in the Rappahannock River. Both nets were of identical size and configuration, but S441 (river mile 44) was located within a shallow bay (one to three meters in depth) while S473 (river mile 47) was located in a narrower section of the river with the head of the net in about four meters of depth and closely abutting the main channel (10+ meters deep). In 1997, a third net was added (S462, river mile 46), about ½ mile below S473, in a similar depth profile, and also closely abutting the channel. In 1999 the fourth net (S454, river mile 45) was added, located 1.5 miles below S462, and with a similar depth profile as nets S462 and S473. Throughout this period, the bay in which net S441 was located experienced continued shoaling and the fisherman discontinued its use after 2001. The use of the nets at river miles 45 and 46 was gradually incorporated into the monitoring sampling protocol after demonstrating that they provided samples that were similar in size, age and sex composition as the original two nets (at first they were used predominantly as a source for tagging striped bass).

Results

Comparison of the contributions of the four Rappahannock River pound nets to the Spawning Stock Biomass Index.

Catch rates. The mean catch rates (fish/day) of striped bass from the four pound nets are compared in Table 1. The catches of both male and female striped bass were generally highest from net S473 and lowest from net S441. Although nets S454 and S462 were sampled for monitoring much less frequently, they produced catch rates that were close to those of net S473. The standard errors to the mean catch rates from the four pound nets were also highest from net S473.

The mean biomass catch rates and their standard deviations (kg/day) of striped bass from the four pound nets showed similar patterns, with net S473 having the highest values and net S441 the lowest (Table 2). The temporal patterns in the mean values between nets S441 and S473 were not consistent. For example, the mean values increased between years from net S473 from 1997-1998, but fell from net S441. Likewise, the mean values increased at net S441 from 1995-1996, 1996-1997 and 1998-1999, but fell from net S473 (Figure 1).

Age. There was no consistent difference among the mean ages of the male or female striped bass captured from the four pound nets (Table 3). Each net showed an increase in the mean ages of both sexes in recent years (Figure 2). Thus, while there was variability in the catch rates among the pound nets, there was no indication of any age (therefore size) bias.

Correlation of catches. To maximize the data available to compare the catches among the four pound nets, the monitoring samples were correlated to the catches of the pound nets that provided striped bass for tagging that were fished on the same date (the monitoring sample was limited to striped bass >457 mm fork length, while the other nets included all tagged striped bass plus any untagged or recaptured striped bass >457 mm fork length). Since net S473 had the longest, most consistent sampling history, its catches were correlated to each of the other nets.

The catches of male striped bass from each of the other three nets had a positive correlation to the catches from net S473 (Figure 3). The values of R^2 ranged from 0.58-0.64. The narrow range of the R^2 values indicates that, over time, substituting these nets for each other would yield similar results if indexed for the lower catch rate from net S441.

The catches of female striped bass from each of the other three nets also had a positive correlation to the catches from net S473 (Figure 4). The values of R^2 ranged from 0.47-0.57. While these values are lower than those for the male striped bass, the narrow range indicates that substituting these nets for each other would yield similar results if indexed for the lower catch rate from net S441.

Correlation of the Rappahannock River Spawning Stock Biomass Index with the Maryland gill net spawning stock index.

The maximum value of the Rappahannock River female Spawning Stock Biomass Index (1991-2002) was 49.6 kg/day in 1997 and the minimum value was 9.3 kg/day in 1996 (Table 4). In contrast, the maximum value of the Maryland gill net female spawning stock biomass index was 547.7 kg/day in 1995 and the minimum value was 87.3 kg/day in 1994. There was a negative correlation between the Rappahannock River and Maryland Indexes (Figure 17). While the low values in the Rappahannock River index in 1996 and 2002 were probably the result of extreme environmental conditions within the river, there was little similarity in the temporal distribution between the two indexes.

Assessment of the Rappahannock River Spawning Stock Biomass Index as input in the VPA model.

Although there have been changes in the set of pound nets sampled over time, there is a notable correlation among the catches of the different nets, suggesting that the various nets are tracking the same population and the signal to noise ratio is high.

The lack of relationship between the Virginia and Maryland indexes suggest that the Virginia (actually Rappahannock River) and Maryland populations being different. Hence, both sets of data may be needed to get a representative picture of striped bass dynamics in Chesapeake Bay.

Table 1. Mean catch rates and standard deviations of male and female striped bass (fish/day) from the four pound nets sampled in the Rappahannock River, 30 March – 3 May, 1993-2004.

Year	CPUE (fish/day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	9.7			24.9	7			8.2
1994	3.5			16.9	1.9			10.8
1995	3.8			23.7	3.2			4.1
1996	8.4			14.9	0.9			6.1
1997	15.9			15.2	6.5			7.2
1998	6.6		10.3	22.7	2.6		5.4	5.5
1999	19.9	26		28.3	2.6	2.3		2.5
2000	31.9	14		45.9	0.7	4.3		2.4
2001	9.6	10.5		16.9	1.9	5.5		4
2002			5.7	2.9			2.9	1.5
2003		8.9	4	11.9		6.1	7.8	7.8
2004		22.1	29	25.6		7.8	9.1	9.1

Year	SD (fish/day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	5.6			19.9	4.3			1.6
1994	1.2			15.6	1.1			1.9
1995	4.1			24.8	1.3			3.7
1996	8.2			10	0.8			3.1
1997	12.8			4.9	10.9			4.5
1998	4.3		3.7	14.3	0.9		0.8	4.2
1999	9.2			21.4	3			1.8
2000	23.9			43	0.9			1.5
2001	9.4			13.6	0.9			2.8
2002			1.3	1.3			1.4	1.2
2003		6.3		8.4		2		4.8
2004		14.9		19.7		5.5		5.3

Note: net S454 was sampled once per year from1999 to 2001 and net S462 was sampled once in 2003 and 2004.

Table 2. Mean catch rates and standard deviations of male and female striped bass (kg/day) from the four pound nets sampled in the Rappahannock River, 30 March – 3 May, 1993-2004.

Year	CPUE (kg/ day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	21.9			52.9	35.9			38
1994	10.2			31.3	11.1			67.8
1995	5.1			27.7	19.1			24.5
1996	10.4			25.6	3.7			25.6
1997	21.6			20.4	49.4			62.5
1998	8.5		14.2	33.1	23.4		44.3	47.7
1999	16.3	45.1		30.2	25.7	18.6		23.5
2000	37.6	18.9		50.1	5.6	38.4		17.8
2001	12	15.1		29.1	15.6	9.8		32.4
2002			11.4	5.9			17.7	10
2003		22.3	12.2	26.8		55.4	17.5	63.5
2004		53.8	60.6	67.3		60.3	67.2	75

Year	SD (kg/day)							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	12.8			40.9	18			15.6
1994	5.1			22.1	6.9			19.9
1995	3.5			25.5	13			21.4
1996	9.6			19.3	3.5			14.8
1997	17.6			15.4	80.1			42.1
1998	4.6		3.6	18.9	9.6		7.4	31
1999	9.9			19.8	31			9.2
2000	29.3			42.7	6.1			11.2
2001	11.6			17.8	5.5			24.9
2002			1.2	4.1			13.3	10
2003		15.3		16.7		25.9		37
2004		34.7		31.6		45.5		43.4

Note: net S454 was sampled once per year from1999 to 2001 and net S462 was sampled once in 2003 and 2004.

Table 3. Mean ages of male and female striped bass from the four pound nets in the Rappahannock River, 30 March – 3 May, 1993-2004.

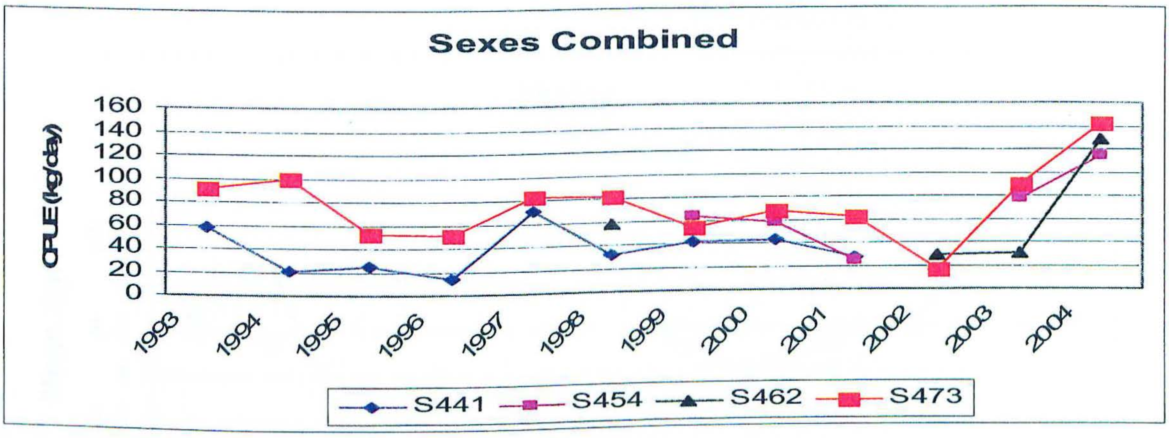
Year	Mean Age							
	Males				Females			
	S441	S454	S462	S473	S441	S454	S462	S473
1993	4.7			4.5	7			6.6
1994	5.2			4.4	7.1			7.1
1995	3.2			3.2	6.2			4.7
1996	3.7			4	6.5			6.1
1997	3.8			3.9	8.7			9.2
1998	3.8		3.8	3.7	9.6		9	9
1999	3.7	4.4		3.6	10.4	8.7		9.9
2000	3.8	4		3.7	8.7	9.8		8.6
2001	4	4.3		4.4	8.8	9.5		9.1
2002			4.5	4.6			7.6	7.8
2003		5.2	5.8	5.1		9.7	9.2	9.3
2004		5.2	4.6	5.4		9.2	9.5	9.7

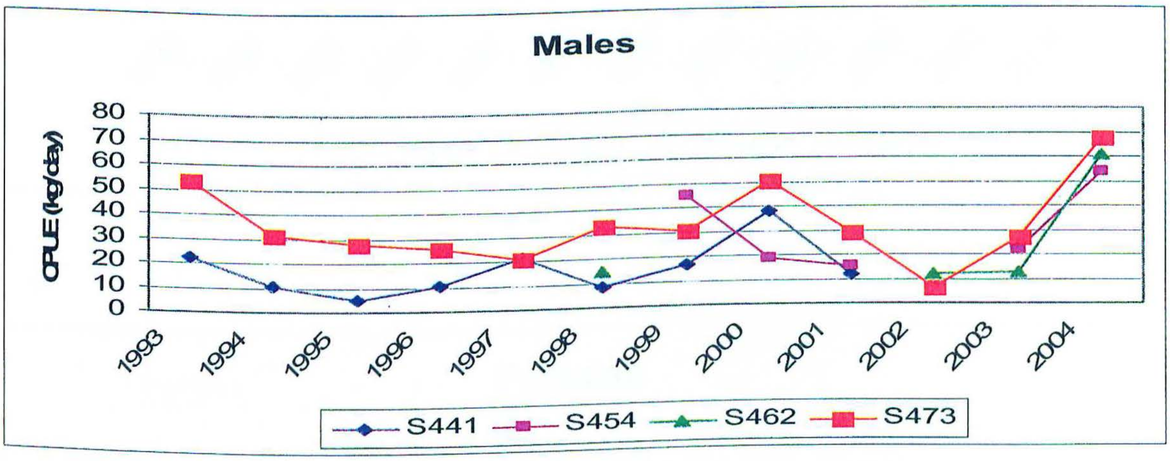
Note: net S454 was sampled once per year from 1999 to 2001 and net S462 was sampled once in 2003 and 2004.

Table 4. Values of the Rappahannock River pound net and the Maryland gill net female Spawning Stock Biomass Indexes (kg/day), 1991-2002.

	female SSBI	
Year	Virginia	Maryland
1991	21.5	109.4
1992	19.4	275
1993	37.5	278.5
1994	30.9	87.3
1995	19.8	547.7
1996	9.3	347.9
1997	49.6	256.9
1998	36.4	157.4
1999	19.8	161.4
2000	14.6	169.9
2001	27.6	490.2
2002	11.4	266.4

Figure 1. Comparison of the mean annual catch rates between the pound nets in the Rappahannock River, 30 March – 3 May, 1993-2004.





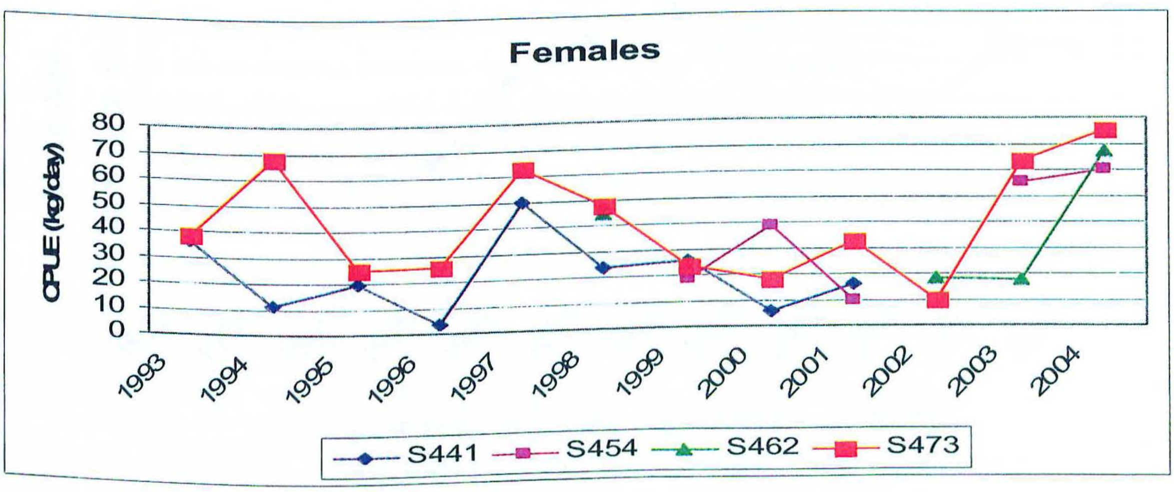
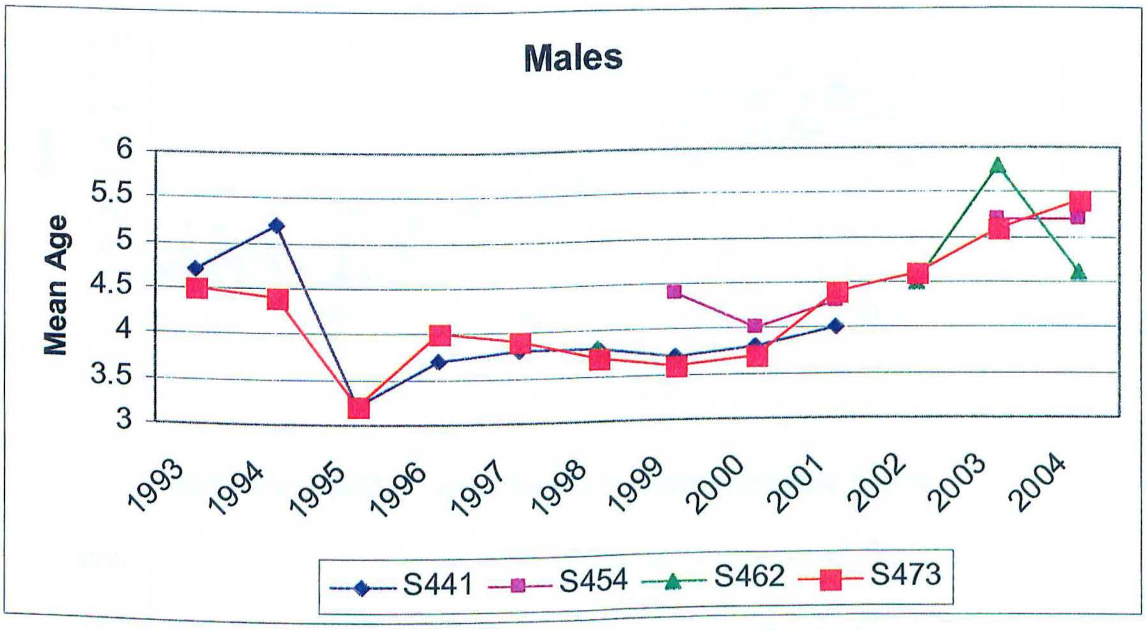


Figure 2. Comparison of the annual mean ages of male and female striped bass from the pound nets in the Rappahannock River, 30 March – 3 May, 1993-2004.



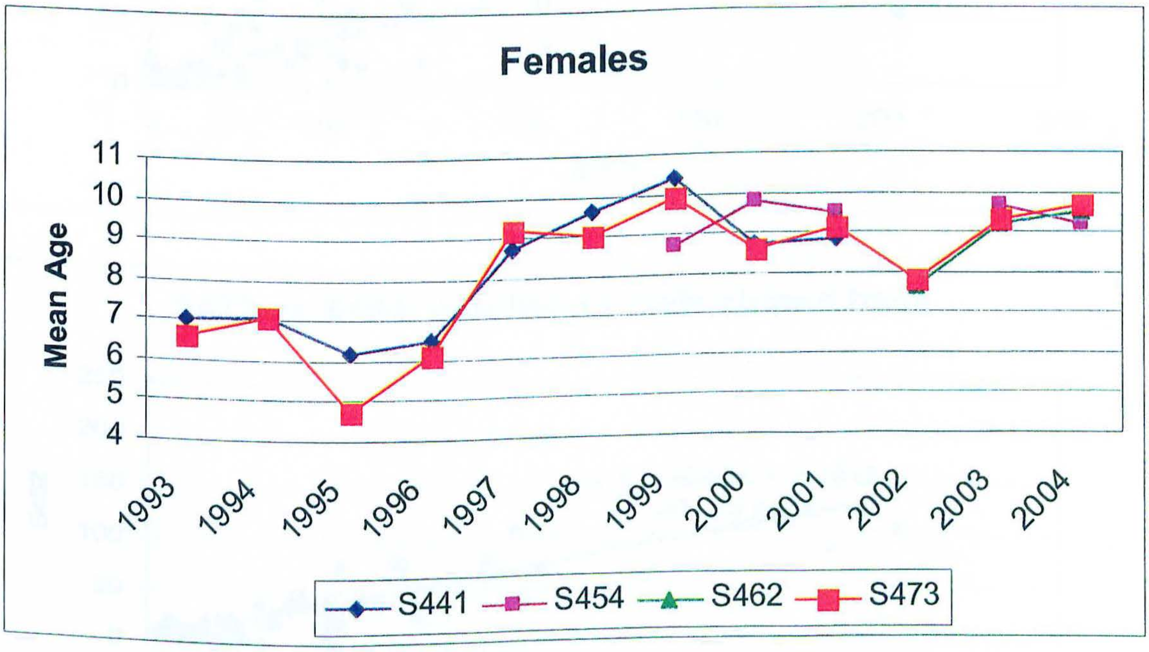


Figure 3. Correlations of the catches of male striped bass from net S473 with those from nets S441 (1993-2001), S454 (1998-2004) and S462 (1997-2004).

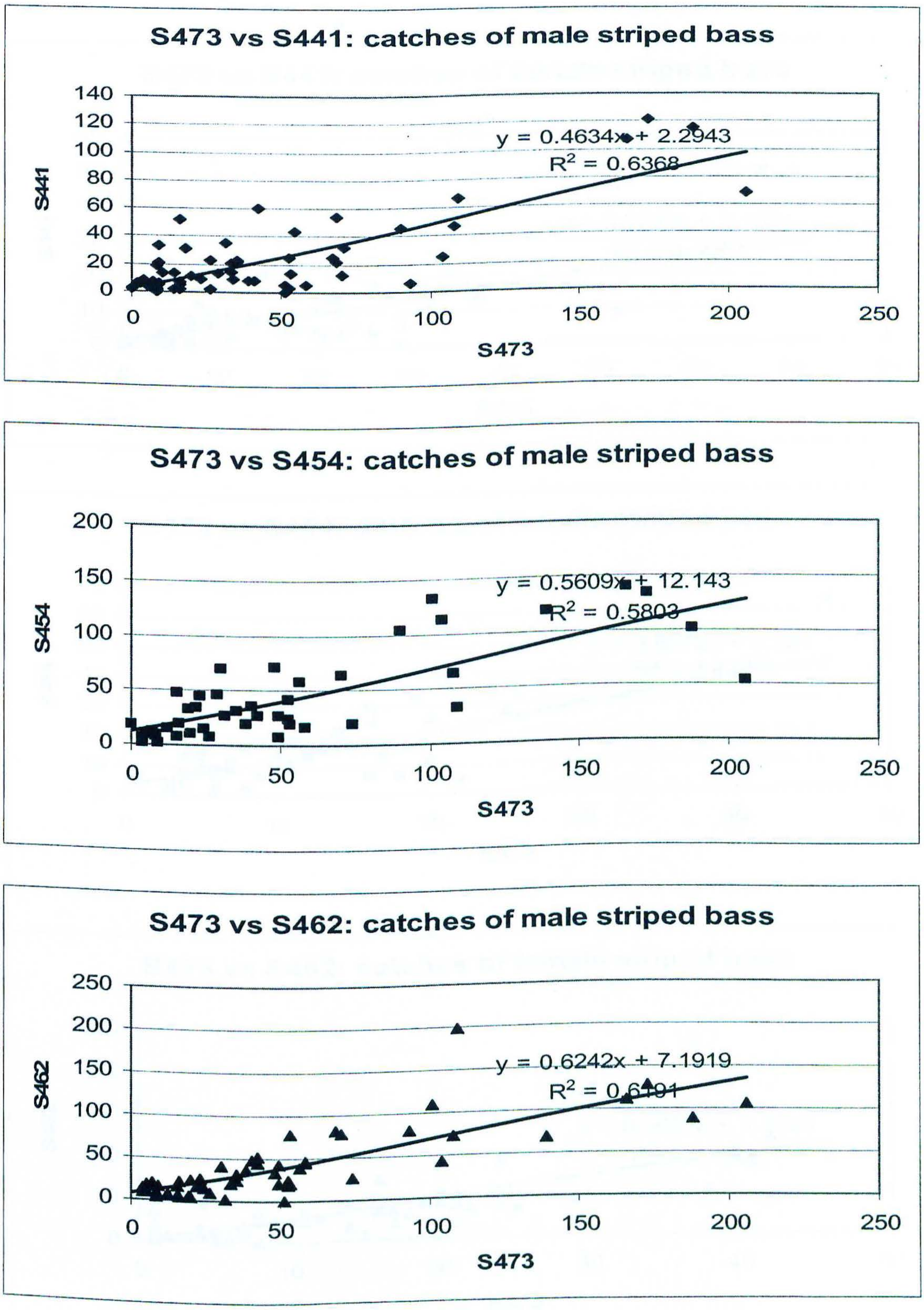
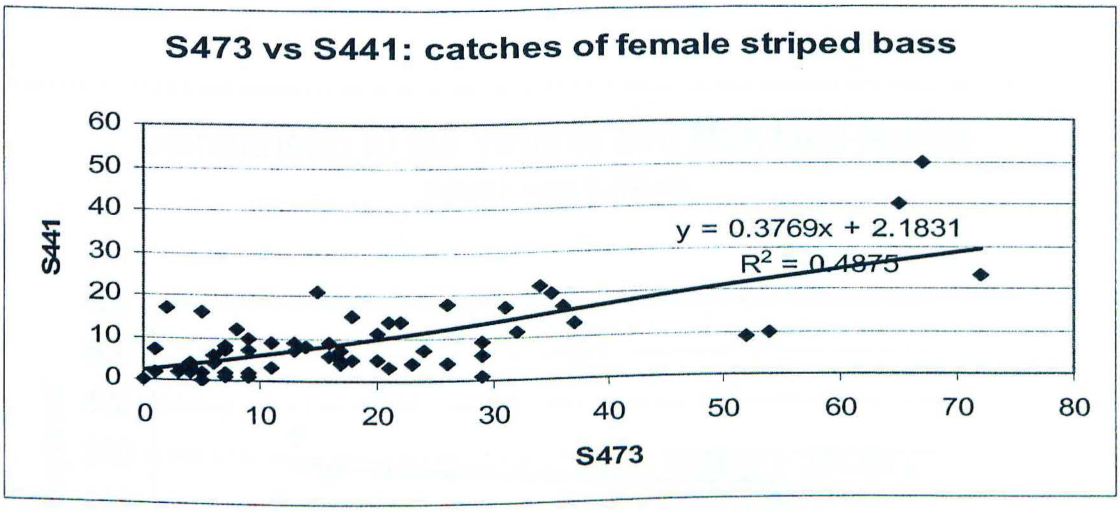
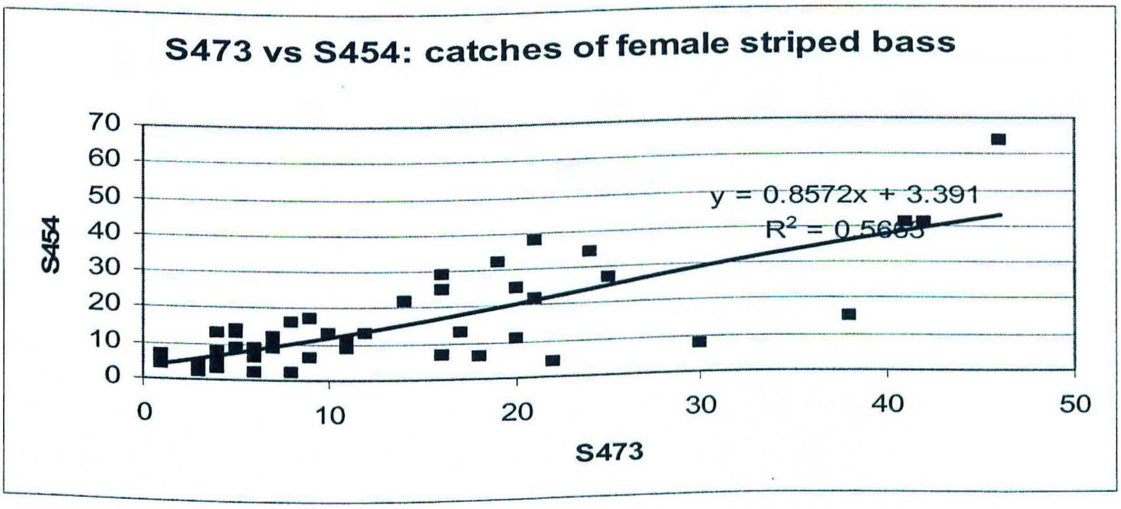


Figure 4. Correlations of the catches of female striped bass from net S473 with those from nets S441 (1993-2001), S454 (1998-2004) and S462 (1997-2004).





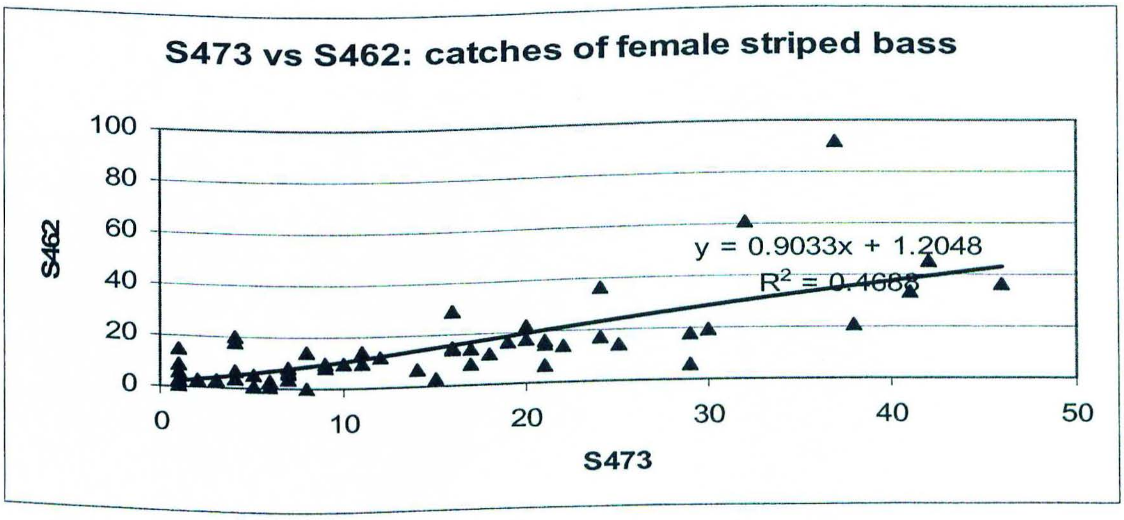
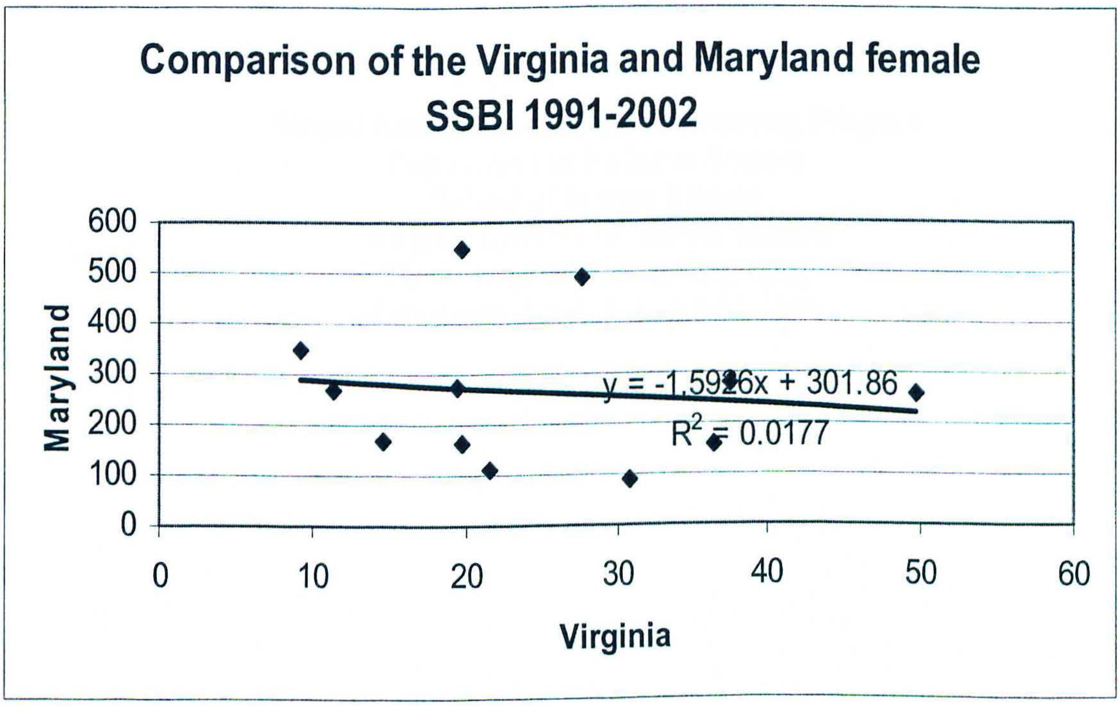


Figure 5. Correlation of the Rappahannock River pound net Spawning Stock Biomass Indexes with the Maryland gill net spawning stock indexes, 1991-2002.



VI. Evaluation of the 2000-2004 striped bass by-catch from the American shad staked gill net stock assessment survey in the James and Rappahannock rivers as an alternative index of abundance.

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Introduction

Historically, American shad (*Alosa sapidissima*) supported large commercial fisheries in Chesapeake Bay and along the U.S. and Canadian east coasts. However, coast-wide landings declined from 50 million pounds in 1900 to 1.5 million pounds in 1993. Commencing in 1994, a total moratorium on shad fishing was established for the Chesapeake Bay and its tributaries in Virginia.

In 1998, the *Alosa* Stock Assessment Task Force was established at the Virginia Institute of Marine Science (VIMS). Staked gill nets were established in the James, York and Rappahannock rivers to monitor relative abundance. Staked gill nets were the predominant commercial gear utilized in the shad fishery in these rivers, and the new program allowed comparison with historic catch rate data recorded in fishers' logbooks. In addition to American shad, these nets also catch significant numbers of striped bass. The potential for utilizing these data as a useful index of striped bass abundance is investigated in this report.

Material and Methods

When the shad moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGN) retained proprietary rights to those sites for all future use. VIMS has historic catch data from staked gill nets in James, York and Rappahannock rivers. One cooperating fishermen on each river was contracted to establish a monitoring staked gill net similar to what was used to provide the previous catch data.

The staked gill net on the James River is located at river mile 10, near the James River Bridge. This net consisted of 30, 30-foot panels (between stakes) of 4.88 inch stretched mesh monofilament nylon netting. The staked gill net on the Rappahannock River iss located at river mile 37, near the Route 360 Bridge at Tappahannock. This net consisted of 19, 48-foot panels of 5.0 inch stretched mesh monofilament nylon netting. The two nets reflect river-specific differences in staked gill nets fished in the James and Rappahannock rivers. Each net is fished twice-weekly (usually on Sunday and Monday). The set time is 24 hours.

The striped bass by-catch was also collected and brought to VIMS for work-up. In periods of extreme abundance, a sub-sample of randomly chosen panels was segregated for work-up, with a target of approximately 50 striped bass per week. A total count of the striped bass caught in the net was made to allow extrapolation of the work-up data. The work-up data consisted of total length (in mm), weight (g) and sex. A scale sample was taken for subsequent ageing from between the two dorsal fins and above the lateral line. A complete description of the collection methods can be found in the American shad stock assessment annual report (Olney 2004). The striped bass ageing methodology was described in section I of this report.

The multi-mesh experimental anchor gill nets are located at river mile 62 on the James River and at river mile 48 on the Rappahannock River. Two 300-foot nets consisting of 10 30-foot sections on differentially sized meshes (3.0, 3.75, 4.5, 5.25, 6.0, 6.5, 7.0, 8.0, 9.0 and 10.0 inches stretched nylon monofilament) are fished twice-weekly (usually on Monday and Thursday) from each river. The set time is 24 hours. All striped bass are brought back to VIMS for biological work-up. The complete methodology is described in Section I of this report.

In order to compare catch rates from the *Alosa* project staked gillnets and the striped bass monitoring program experimental multimesh gillnets, we restrict attention to the catches occurring between 30 March and 3 May of each year. Five years of data are currently available (2000–2004). There are two comparisons that can be made: size-specific catch rates and age-specific catch rates. In this report, we restrict attention to the size-specific catch rates. This comparison is of interest because it does not depend on the reliability of age determinations. In the future, we intend to also compare age-specific catch rates.

It should be noted that the staked gillnets are composed of a single mesh size which means they are selective for a much narrower size range than the experimental multi-mesh gillnets. Catch rates outside the selection range are likely to be low and highly variable because the nets are not efficient for catching very large and very small fish. Consequently, we might anticipate that the catches in the staked gillnets correlate well with the catches in the multi-mesh gillnets only over a limited size range.

Results

In the James and the Rappahannock rivers, catches were highest for striped bass between 18 and 24 inches total length (Figures 1a,b). This range of sizes contributed 80.4% (Rappahannock River) to 83.7% (James River) of the total staked gill net catches and 54.6% (Rappahannock River) and 71.0% of the total experimental gill nets catches. All further analysis was based on the striped bass from this range of total lengths.

Plots of catch per net in the staked gillnets versus catch per net in the experimental multi-mesh nets are shown in Figures 2 (a and b) for the James River and in Figures 3 (a and b) for the Rappahannock River. For the James River, slopes of linear regressions are positive with correlations (R^2) of 0.60, 0.72 and 0.26 for fish of 18, 19, and 20 inches total length, respectively. Above 20 inches, the results were less good: slope is negative for 21 inch fish, positive for 22 inches, negative for 23 inches, and slightly positive for 24 inches.

For the Rappahannock River, the results did not support the idea that the two sampling programs were tracking the same population. Only for fish of length 23 inches was the slope more than slightly positive, with an R^2 of 0.32. For the other sizes the slopes were either negative or just lightly positive.

Discussion

It is encouraging that the two sampling programs in the James River provide correlated catch rates for a series of adjacent size classes. This supports the idea that the two programs are tracking the same population – but only over a narrow size range. Components of the striped bass population appear to segregate spatially, at least at certain times, and these components may exhibit complicated movement patterns in response to environmental factors such as water temperature and in response to stage in the reproductive cycle. The two monitoring programs in the James River take place in different locations (staked gill net at river mile 10, experimental gill net at river mile 62). It appears that when striped bass greater than 21.0 inches are in one place they are not in the other, resulting in a negative correlation.

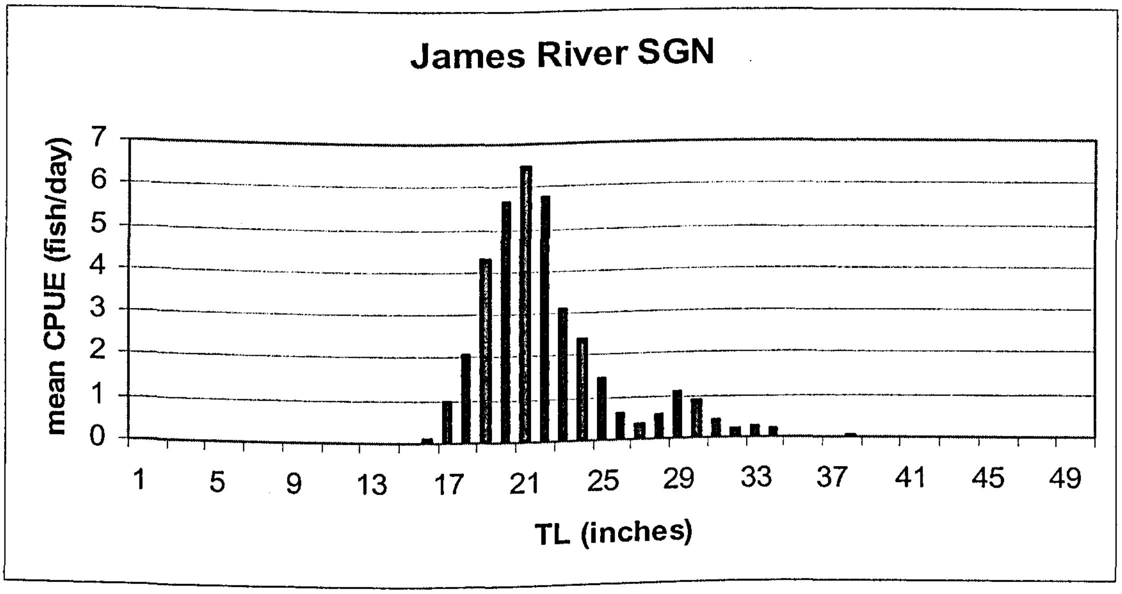
The results for the Rappahannock River are problematic. The two programs appear to be monitoring different populations. This raises the question of which program, if either, is providing a valid index of the stock-wide (but size-specific) abundance. The results suggest that further work is needed to develop and evaluate indices for the Rappahannock River.

It is noteworthy that these comparisons are based on just five data points. A progressively more reliable evaluation will develop as increased data points accrue.

Literature cited

Olney, J.E. 2004. Monitoring Relative Abundance of American Shad in Virginia's Rivers. Annual Report. 83p.

Figure 1a. Comparison of the seasonal mean catch rate (fish/day) frequencies, in inches total length, of the striped bass captured in the staked gill net and multi-mesh experimental gill nets in the James River, 30 March – 3 May, 2000-2004.



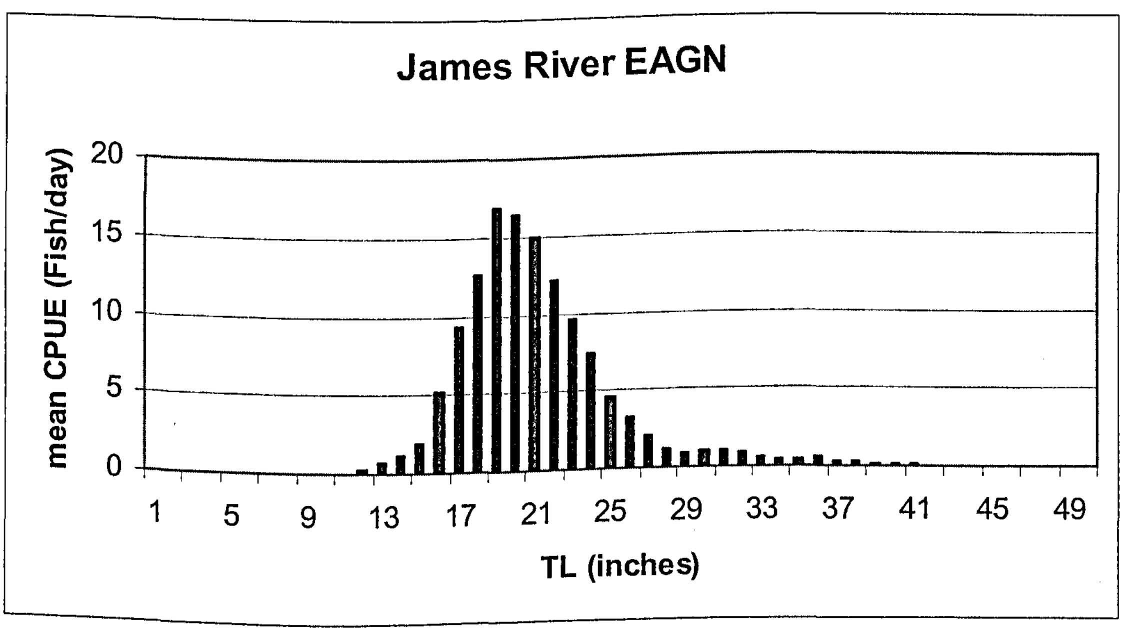
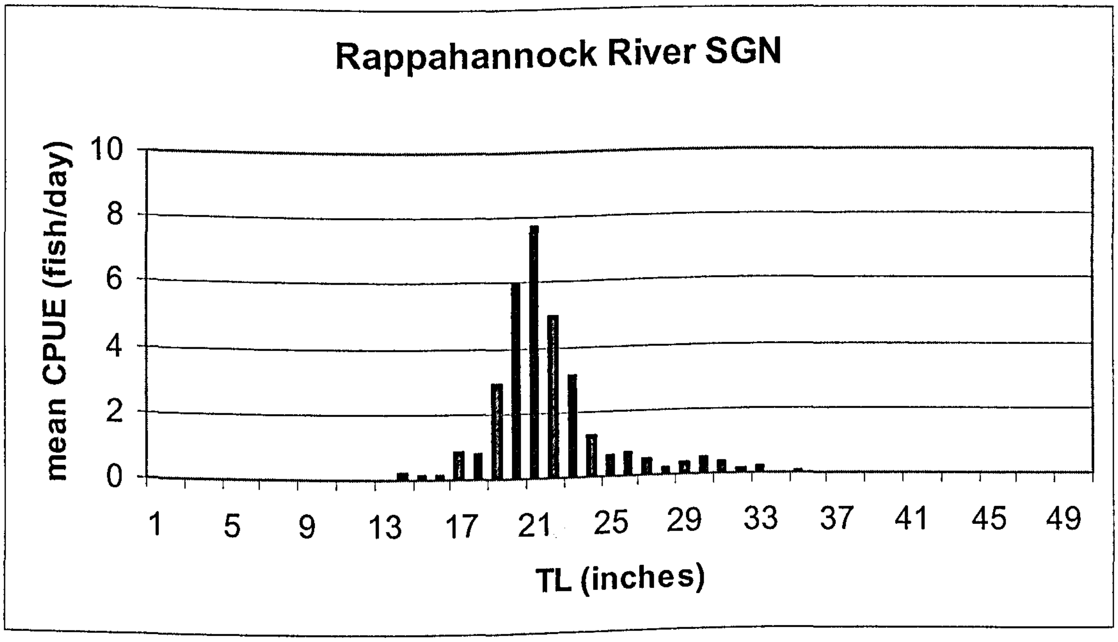


Figure 1b. Comparison of the seasonal mean catch rate (fish/day) frequencies, in inches total length, of the striped bass captured in the staked gill net and the multi-mesh experimental gill nets in the Rappahannock River, 30 March – 3 May, 2000-2004.



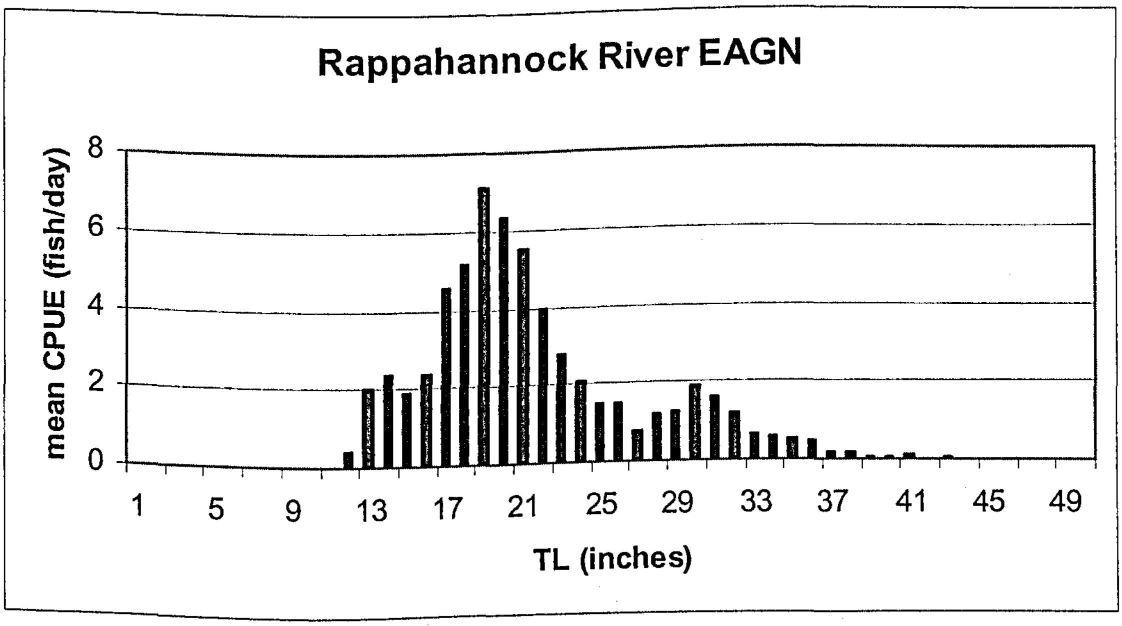


Figure 2a. Correlation of the seasonal mean CPUE (fish/day) of 18-20 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the James River, 30 March – 3 May, 2000-2004.

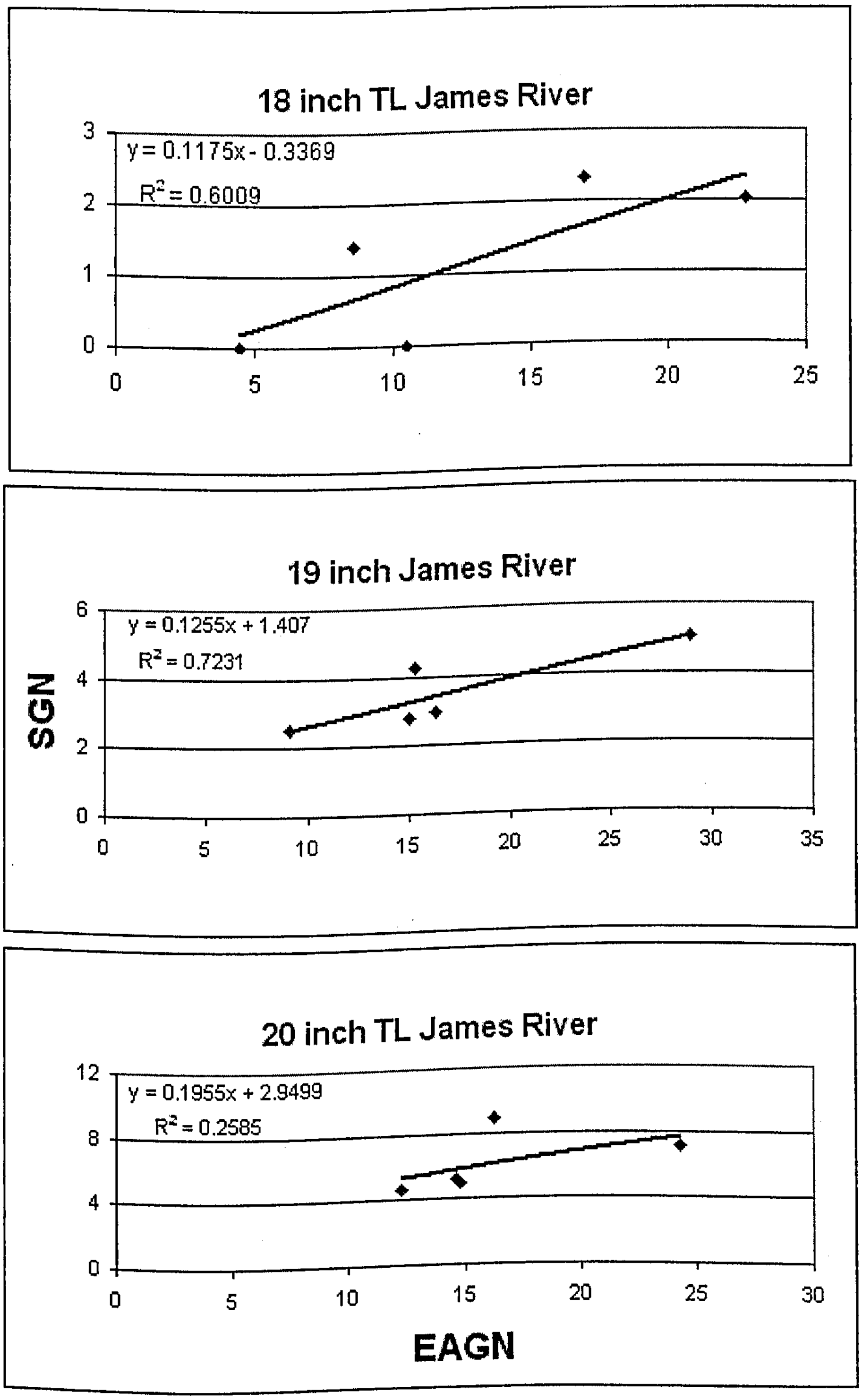


Figure 2b. Correlation of the seasonal mean CPUE (fish/day) of 21-24 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the James River, 30 March – 3 May, 2000-2004.

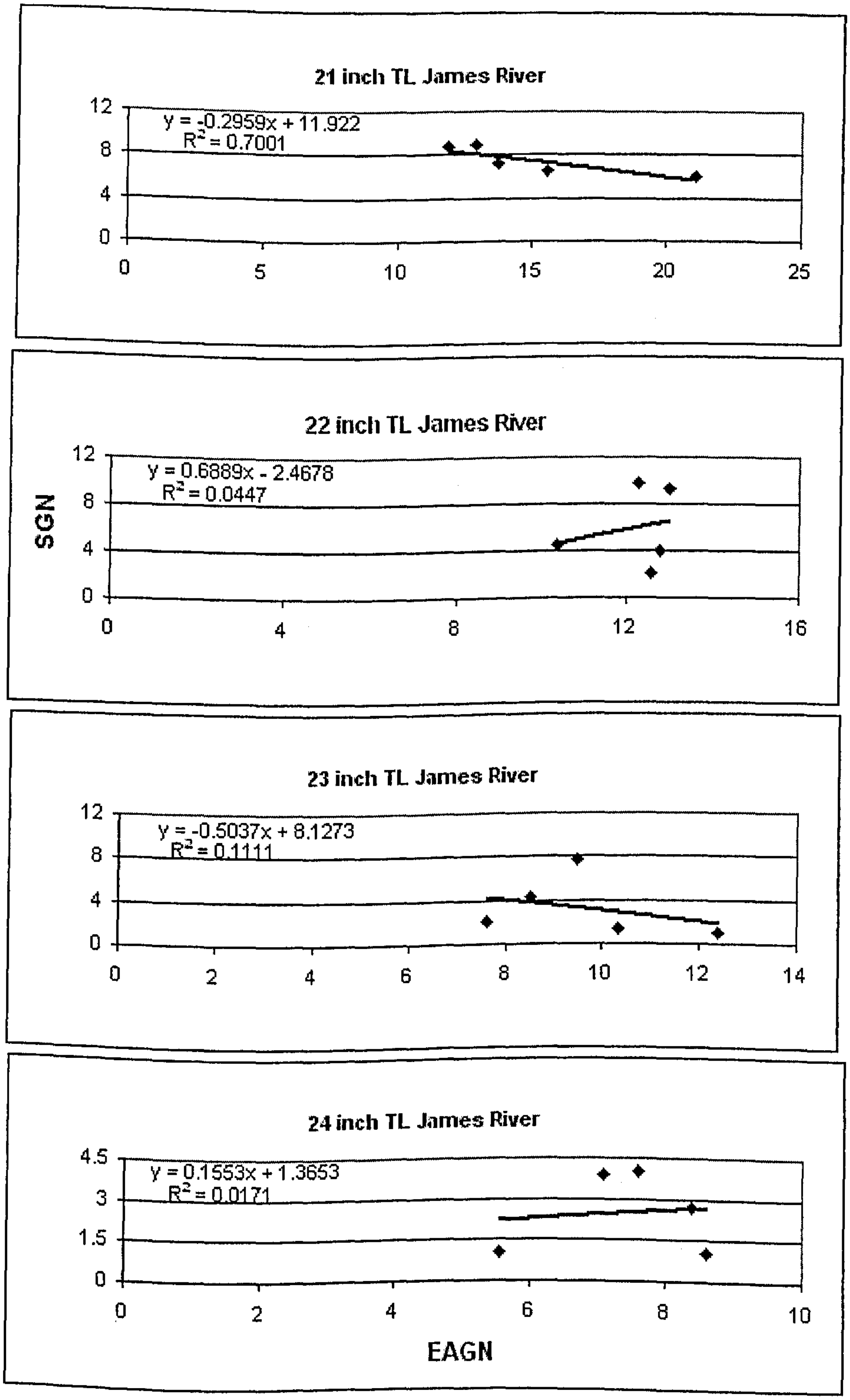


Figure 3a. Correlation of the seasonal mean CPUE (fish/day) of 18-20 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the Rappahannock River, 30 March – 3 May, 2000-2004.

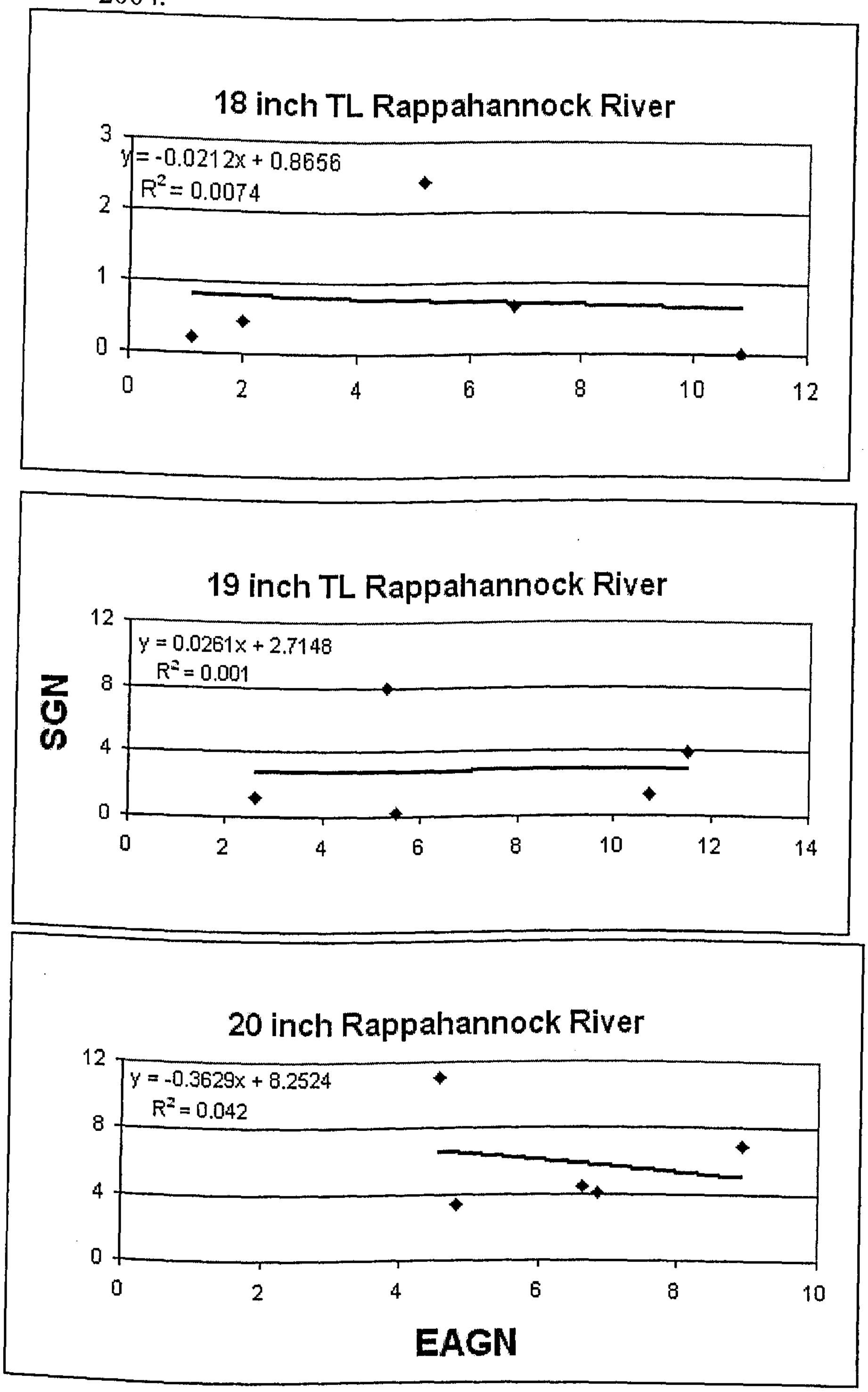


Figure 3b. Correlation of the seasonal mean CPUE (fish/day) of 18-24 inch total length striped bass captured in the multi-mesh, experimental gill nets and staked gill nets in the Rappahannock River, 30 March – 3 May, 2000-2004.