11-27-2007

Evaluation of striped bass stocks in Virginia : monitoring and tagging studies, 2004-2008 - Annual Report 1 September 2006 - 31 August 2007

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Recommended Citation

Sadler, P. W., Hoenig, J. M., Harris, R. E., Wilk, R. J., & Goins, L. M. (2007) Evaluation of striped bass stocks in Virginia : monitoring and tagging studies, 2004-2008 - Annual Report 1 September 2006 - 31 August 2007. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/z114-bg23

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

Annual Report

Contract Number:	**F-77-R-19**
Project Period:	**1 September 2006 - 31 August 2007**
Principal Investigator:	**John M. Hoenig**

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27 November 2007

Preface

This report presents the results of striped bass (*Morone saxatilis*) tagging and monitoring activities in Virginia during the period 1 September 2006 through 31 August 2007. It includes an assessment of the biological characteristics of striped bass taken from the 2007 spring spawning run, estimates of annual survival and fishing mortality based on annual spring tagging, and the preliminary results of the fall 2006 study that documents the prevalence of mycobacterial infections of striped bass in Chesapeake Bay. 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). Commencing in 2005, these estimates of F were estimated from the striped bass tagged during the spring in the Rappahannock River.

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; the Environmental and Aquatic Animal Health staff, Drs. Wolfgang Vogelbein, David Gauthier, and Ashley Haines; Fisheries Department students of the Virginia Institute of Marine Science Aaron Bever, Andre Buchheister, Chip Cotton, Abby Lynch, Patrick Lynch, Christopher Magel, Patrick McGrath, Jason Romine, Troy Tuckey, Sally Upton, and Ana Verissimo; the cooperating commercial fishermen Ernest George, Joe Hinson, Albert and Stanley Oliff, Paul Somers, Clark Trader, and John and Glenn Wyatt; and Maryland Department of Natural Resources (Md DNR) staff Harry Hornick, Beth Versak and Alexi Sharov.

Executive Summary

New Features: This year we began a cooperative effort with Maryland Department of Natural Resources to expand the scope the mycobacterial tagging study to assess the inpact of the disease throughout the Chesapeake Bay. Expected benefits include estimates of disease progression and mortality and their implications for stock management.

I. Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2007.

Catch Summaries:

1. In 2007, 1,104 striped bass were sampled between 30 March and 3 May from three commercial pound nets in the Rappahannock River. The samples were predominantly male (67.8%) and young (35.1% ages 2-4). Females dominated the age nine and older age classes (85.1%). The mean age of the male striped bass was 5.0 years. The mean age of the female striped bass was 10.5 years.

2. During the 30 March - 3 May period, the 2002 and 2003 year classes were the most abundant in the Rappahannock River pound net samples and were 97.1% male. The contribution of age six and older males was only 14.5% of the total aged catch. Age seven and older females, presumably repeat spawners, were 31.2% of the total catch but represented 94% of all females caught.

3. In 2007, 743 striped bass were sampled between 2 April and 3 May in two experimental anchor gill nets in the Rappahannock River. The samples were predominantly male (91.1%) and young (64.1% ages 2-4). Females dominated the age nine and older age classes (63%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 11.1 years.

4. During the 2 April - 3 May period, the 2003 and 2004 year classes were the most abundant in the Rappahannock River gill net samples and were 99.8% male. The contribution of age six and older males was only 18.4% of the total catch. Age seven and older females, presumably repeat spawners, were 7.4% of the total catch but were 83.3% of the total females caught.

5. In 2007, 426 striped bass were sampled between 2 April and 3 May in two experimental anchor gill nets (mile 62) in the James River. The samples were predominantly male (85%) and young (52.1% ages 2-4). Females dominated the age nine and older age classes (85.2%). The mean age of the male striped bass was 4.5 years. The mean age of the female striped bass was 9.8 years.

6. During the 2 April - 3 May period, the 2003 and 2004 year classes were the most abundant in the James River gill net samples and were 99.5% male. The contribution of age six and older males was only 15.2% of the total catch. Age seven and older females, presumably repeat spawners, were 12.4% of the total aged catch, but represented 84.1% of all females caught.

Spawning Stock Biomass Indexes (SSBI)

7. The Spawning Stock Biomass Index (SSBI) from the Rappahannock River pound nets was 47.6 kg/day for male striped bass and 87.6 kg/day for female striped bass. The male index was the second highest in the 1991-2007 time series and 91.2% above the 17-year average. The 2007 index was 84.5% higher than the index for 2006. The female index was by far the highest in the 1991-2007 time series. The 2007 female index was 254.7% higher than the 2006 index and 162.3% higher than the 17-year average.

8. The SSBI for the Rappahannock River gill nets was 134.1 kg/day for male striped bass and 68.0 kg/day for female striped bass. The male index was the third highest in the 1991-2007 time series and 62.7% above the 17-year average. The female index was the highest in the 1991-2007 time series and was 87.8% above the 17-year average.

9. The SSBI for the James River gill nets was 69.7 kg/day for male striped bass and 55.4 kg/day for female striped bass. The male index was near the median in the 1994-2007 time series, and was 41.8% below the 14-year average. The female index was the fifth highest in the 14-year time series and was nearly equal to the 14-year average.

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 2007 Egg Production Potential Index (EPPI, millions of eggs/day) for the Rappahannock River pound nets was 13.79 million eggs/day. This was the highest EPPI of the 2001-2007 time series. Older (8+ years) female stripers were responsible for 93.2% of the index.

11. The 2007 EPPI for the Rappahannock River gill nets was 9.92 million eggs/day. This was the highest EPPI of the 2001-2007 time series. Older (8+years) female striped bass were responsible for 83.3% of the index.

12. The 2007 EPPI for the James River gill nets was 8.40 million eggs/day. This was the second highest EPPI of the 2001-2007 time series. Older (8+ years) female striped bass were responsible for 77.7% 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 (31.52 fish/day) was the second highest in the1991-2007 time series. There was an increase in the 2002 and 2003 year classes from the 2006 values. The cumulative catch rate of male striped bass (21.36 fish/day) was the fourth highest in the time series and was 13.4% higher than the rate in 2006. The cumulative catch rate of female striped bass (10.16 fish/day) was the highest in the 1991-2007 time series and 183.8% higher than the rate in 2006.

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 0.516-0.800 (mean = 0.676). The geometric mean survival rates differed greatly between sexes. Mean survival rates for male stripers (1985-1997 year classes) varied from 0.317-0.586 (mean = 0.445) but mean survival rates of female stripers (1983-1994 year classes) varied from 0.461-0.834 (mean = 0.654).

15. The cumulative catch rate (all age classes, sexes combined) from Rappahannock River gill nets (82.55 fish/day) was the third highest value in the 1991-2007 time series and 146.4% higher than in 2006. Cumulative catch rate of male stripers (75.22 fish/day) was the third highest in the time series and 169.6% higher than the rate in 2006. The cumulative catch rate of female striped bass (7.33 fish/day) was seventh highest in the time series and 30.9% higher than the catch rate in 2006.

16. Year class-specific estimates of annual survival for gill net data varied widely between years. The geometric mean S of the 1984-1998 year classes varied from 0.408-0.723 (mean = 0.604). The mean survival rates for male stripers (1987-1998) varied from 0.153-0.646 (mean = 0.381). The mean survival rates for female stripers (1984-1993, excluding 1991) varied from 0.496-0.965 (mean = 0.674).

17. The cumulative catch rate (all age classes, sexes combined) from James River (mile 62) gill nets (47.24 fish/day) was the sixth lowest catch rate in the 1994-2007 time series. This is the lowest since 1998. The catch rate was 63.2% lower than the rate in 2006. The cumulative catch rate for male striped bass (40.20 fish/day) was also the seventh lowest of the 1994-2007 time series, and was 65.5% lower than the rate in 2006. The cumulative catch rate of female striped bass (6.94 fish/day) was 42.2% lower than the rate in 2006, and was the seventh lowest value in the 1994-2007 time series.

18. Year class-specific estimates of annual survival in the James River varied widely between years. The geometric mean S of the 1984-1999 year classes varied from 0.338-0.730 (mean = 0.566). The mean survival rates of male stripers (1988-1999 year classes) varied from 0.286-0.612 (mean = 0.452). The mean survival rates of female stripers (1984-1995 year classes) varied from 0.339-0.760 (mean = 0.596).

Catch rate histories of the 1987-1999 year classes

19. Plots of year class-specific catch rates vs. year in the James and Rappahannock rivers from 1991-2005 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 1988, 1989, 1996, and1997 year classes were the strongest, and the 1990 and 1991 year classes the weakest in the Rappahannock River from 1987-1999. In the James River, the 1989, 1993, 1994, and 1996 year classes were the strongest and 1990 and 1991 year classes the weakest.

Growth rate of striped bass derived from annuli measurements

21. The scales of 318 striped bass were digitally measured and the increments between annuli were used to determine their growth history.

22. On average, striped bass grow about 159 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 318 specimens from 11 size ranges were aged by reading both scales and otoliths. The mean age of the otolith-aged striped bass was 0.32 years older than from the scale-aged striped bass. The two methodologies agreed on the age of the striped bass on 50.0% of the specimens and within one year 84.0% of the time.

25. Tests of symmetry applied to the age matrix indicated that the differences (higher or lower in age) between the two ageing methodologies were non-random ($p = <.0005$).

26. A paired t-test of the mean of the age differences produced by the two ageing methodologies found that the mean difference were not significantly different from zero ($p< .001$).

27. A Kolmogorov-Smirnov test of the age structures produced by the two ageing methodologies also indicated xxx 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-ten and age-eleven 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 2006-2007.

1. A total of 1,960 striped bass were tagged and released from pound nets in the Rappahannock River between 26 March and 3 May, 2007. Of this total, 1,120 were between 457-710 mm total length and considered to be predominantly resident striped bass and 840 were considered to be predominantly migrant striped bass (>710 mm TL). The median date of both tag releases was 19 April.

2. A total of 48 (out of 668) striped bass (>457 mm TL), tagged during spring 2006, were recaptured between 24 April, 2006 and 18 April, 2007 (the respective midpoints of the two tag release totals), and were used to estimate mortality. Twenty seven of these recaptures were harvested (56.3%) and the rest were re-released into the population. In addition, 47 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. Most recaptures (63.5%) were caught within Chesapeake Bay (44.2% in Virginia, 19.2% in Maryland). However, other recaptures came from Massachusetts (12.5%), New York (20.5), New Jersey (7.7%), North Carolina (4.8 %), and Connecticut (2.9%).

3. A total of 12 (out of 175) migratory striped bass (>710 mm total length), tagged during spring 2006, were recaptured between 14 April, 2006 and 18 April, 2007, and were used to estimate the mortality. Ten of these recaptures were harvested (83.3%), and the rest were re-released into the population. In addition, 26 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. Most recaptures (25.0%) came from Massachusetts. Other recaptures came from Chesapeake Bay (22.7%, 15.9% in Virginia, 6.8% in Maryland), New York (20.5), New Jersey (13.6), North Carolina (11.4%), and Connecticut (6.8%).

4. The ASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber models. Nine 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 0.546-0.761 over the time series. The 2006 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 0.123-0.449 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.

6. After adjusting for tag-induced mortality, reporting rate of recaptured striped bass and hook-and-release mortality, the 2006 estimate of exploitation rate for Virginia was 0.06 and the estimate of fishing mortality was 0.06. When pooled with the Maryland and Potomac River data, the final (after including non-harvest mortality) Chesapeake Bay estimate was 0.18.

III. The role of Mycobacteriosis in elevated Natural Mortality of Chesapeake Bay striped bass: disease progression and developing better models for stock assessment and Management.

1. Mycobacteriosis in striped bass is a chronic disease caused by various species of bacteria in the genus *Mycobacterium*. The disease appears as grey granulomatous nodules in internal organs and externally as ulcerous skin lesions. Mycobacteriosis in captive fishes is generally thought to be fatal, but this has not been established for wild striped bass.

2. The impact of the disease is poorly understood. Fundamental questions, such as mode of transmission, duration of disease stages, effects on fish movements, feeding, reproduction and mortality rates associated with the disease are unknown.

3. A total of 3,710 striped bass were tagged, assessed for external diseases indications, photographed and released from two pound nets in the upper Rappahannock (n=399) and five pound nets in the lower Rappahannock (n=3,311) River during fall, 2006. Only 32.1% of the total tagged were without any external sign of mycobacteriosis.

4. A total of 656 striped bass were tagged, assessed for external diseases indications, photographed and released from five pound nets in the lower Rappahannock (n=656) River during spring, 2007. Only 46.6% of the total tagged were without any external sign of mycobacteriosis.

5. A total of 394 striped bass tagged during fall, 2006 were recaptured prior to 20 September, 2007. Although 32.1% of the releases were assessed as clean and 10.8% were assessed as heavily infected, the recaptures rates were 21.0% for the clean and 18.1 % for the heavily infected striped bass releases.

6. A total of 95 striped bass tagged during spring, 2007 were recaptured prior to 20 September, 2007. Although 46.6% of the releases were assessed as clean and 9.6% were assessed as heavily infected, the recaptures rates were 37.5% for the clean and 8.3 % for the heavily infected striped bass releases.

7. A total of 33 striped bass tagged during fall, 2005 were recaptured prior to 20 September, 2007. While the percentage of moderately and heavily infected striped bass recaptures exceed the percentage of the initial releases during the first year at large, this trend reversed in the second year.

8. A total of 50 striped bass tagged during spring, 2006 were recaptured prior to 20 September, 2007. The relative proportion of the infection index of the recaptures during year two closely mirrored that of their initial release.

9. It must be assumed that all fish have the same tag recovery rate to estimate survival rates, however, the disease severity may affect the movement of individual striped bass. It is therefore necessary to accumulate sufficient tag returns to estimate the relative survival rates.

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I. Assessment of spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 2007.

I. Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring, 2007.

Striped Bass Assessment and Monitoring Program
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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° 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 2 April and 3 May, 2007. Samples (the entire catch of striped bass from each gear) were taken twice-weekly (Monday and Thursday) from among three of commercial pound nets (river miles 45, 46 and 47) in the Rappahannock River. Pound nets are fixed commercial gears that have been the historically predominant gear type used in the river and are presumed to be non size-selective in their catches of striped bass. The established protocol (Sadler *et al.* 1999) was to alternate the choice of the net sampled but weather constraints often dictated whether that net could be sampled. In addition, data from pound nets sampled in 1991 and 1992 were included to expand the time series. These samples were consistent in every respect to the 1993-2001 samples with the following exceptions in 1991: two samples (3 and 17 April) came from a pound net at river mile 25 and samples were obtained weekly vs. twice weekly.

In addition to the pound nets, samples were also obtained twice-weekly from variable-mesh experimental anchored gill nets (two at river mile 48 on the Rappahannock River and two at river mile 62 on the James River, Figures 1 and 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. These 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= 1,104) were sampled between 2 April and 3 May, 2007 from the pound nets in the Rappahannock River. The number of striped bass sampled was higher than was sampled in 2006 (n= 776) and was 73.4% above the 15-year average. Total catches varied from 83-157 striped bass, with peak catches on 19 and 30 April (Table 1). Surface water temperature increased from 12 °C on 26 March to 15 °C on 2 April, decreased gradually to 10.5 °C on 19 April, and then increased rapidly to 19 °C on 3 May. For the fourth consecutive year, dry

weather persisted throughout April, resulting in lower river flows than had been present in 2001-2003. Catches of female striped bass peaked on 5 April and again on 19-26 April, and were dominated by the pre-1998 year classes. Males made up 67.8% of the total catch, which was well below the 15-year average (76.4%). The 2003-2005 year classes comprised only 35.1% of the total catch. In contrast, in 2006 the 2002-2004 year classes comprised 64.8% of the total catch. Males dominated the 2003-2005 year classes (99.0%) and the 1999-2002 year classes (88.8%), but females dominated the 1989-1998 year classes (85.1%).

Biomass catch rates (g/day) of male striped bass peaked on 5 April and again on 30 April, while the catch rate of female striped bass peaked on 5 April (Table 2). The numeric catch rate of males exceeded that of females on every sampling date except on 23 April. Unlike 2006, but consistent with most previous years, the biomass catch rates for female striped bass exceeded that for males overall (1.84:1), peaking on 19 and 23 April (>3.0:1). The mean ages of male striped bass varied from 4.3-6.0 years by sampling date, with the oldest mean age occurring on 26 April. The mean ages of females varied from 9.5-11.1 years by sampling date, but only varied from 10.6-11.1 years from 5-19 April.

There was a peak in abundance of striped bass (mostly male) between 470-570 mm total lengths in the pound net samples (Table 3). This size range accounted for 36.3% of the total sampled. There was a secondary peak in abundance of striped bass between 850-960 mm total lengths, accounting for 25.5% of the total sampled. However, the striped bass from 620-710 mm total length accounted for only 1.4% 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 41.5%.

During the 30 March - 3 May period, the 2003 (27.1%) and 2002 (19.6%) year classes were the most abundant (Table 4). These year classes were 97.1% male. The contribution of males age six and older (the pre-2002 year classes) was 14.5% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was 31.2% of the total aged catch, but was also 94.0% of the total females captured. The catch rate (fish/day) of male striped bass was 21.4, which is 34.6% above the 15-year average (Table 5). The catch rate of female striped bass (13.6 fish/day) was 169.4% above the 15-year average, and was the highest value in the time series. The biomass catch rates (kg/day) of both sexes of striped bass were well above the average of the 15-year time series. The mean age (30 March – 3 May) of the male striped bass was above the 15-year average. The mean age of the female striped bass was the highest value in the time series.

Experimental gill nets: Striped bass (n= 743) were also sampled between 2 April and 3 May, 2007 from two multi-mesh experimental gill nets in the Rappahannock River. The total catch was more than double than in 2006 (335). Total catches peaked on 2 April, due to the large number of three to four year old males (Table 6). Total catches of female striped bass peaked on 5 April and again from 26-30 April. Males made up 91.1% of the total catch. Males dominated the 2003-2005 year classes (99.8%) and the 1999-2002 year classes (92.4%), but the 1989-1998 year classes were 63.0% female.

Biomass catch rate (g/day) of male striped bass was highest on 2 April (Table 7). The catch rate (fish/day) of males exceeded that of females on every sampling occasion. The mean ages of male striped bass varied from 3.4-5.8 years by sampling date, with the oldest males being most abundant from 30 April – 3 May. The biomass catch rate of female striped bass (g/day) peaked sharply on 5 April. The mean ages of females varied from 8.9-14.5 years by sampling date, with the oldest females (age nine and older) being most abundant from 2-12 April.

There was a peak in the distribution of length frequencies of striped bass in the gill net samples between 450-550 mm TL (Table 8). In previous years, there was a distinct secondary peak of larger striped bass, but this was less apparent in 2006 and again in 2007. The total contribution of striped bass greater than 840 mm total length from the gill nets (9.0%) was much lower than from the pound nets (30.6%). The total contribution of striped bass greater than 710 mm total length was 17.5% in the gill nets.

During the 30 March - 3 May period, the 2003 (37.7%) and 2004 (25.0%) year classes were most abundant (Table 9). These year classes were 99.8% male. The contribution of males age six and older (the pre-2002 year classes) was 18.4% 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 7.4% of the total aged catch but was 83.3% of the total females captured. The catch rate (fish/day) of male striped bass was the third highest in the 15-year time series and was 53.2% above the average (Table 10). The catch rate of female striped bass was the fifth highest in the time series and was 25.9% above the 15-year average. The biomass catch rates (g/day) for male striped bass was the second highest in the time series and was 69.3% above the 15-year average. The biomass catch rate for female striped bass was the highest in the time series and was 95.6% above the 15-year average.

James River:

Experimental gill nets: Striped bass (n= 426) were sampled between 2 April and 3 May, 2007, from two multi-mesh experimental gill nets at mile 62 in the James River. Total catches peaked on 2 April. Young, male striped bass were primarily responsible for the peak catches (Table 11). Catches of female striped bass peaked from 2-12 April. Males dominated the 2003-2005 year classes (99.6%) and the 1999-2002 year classes (89.2%), but the 1989-1998 year classes were predominantly female (85.2%).

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Biomass catch rates (g/day) of male striped bass peaked strongly on 2 April, but were high on all but two occasions (Table 12). The catch rates of female striped bass were highest from 23-30 April. The biomass catch rate of males exceeded that of females on every sampling date except for 19 and 26 April (1.3:1 for the season). The mean ages of male striped bass varied from 4.0-5.3 years by sampling date. The mean ages of females varied from 5.3-13.0 years by sampling date, but varied from only 9.5-13.0 years from 2-23 April..

There was a peak of striped bass 390- 510 mm total length in the gill net length frequencies (Table 13). This size range accounted for 45.5% of the total striped bass sampled. In contrast to the samples from Rappahannock River, the striped bass greater than 840 mm total length accounted for 11.7% of the total sampled. The total contribution of striped bass greater than 710 mm total length was 16.9%.

During the 30 March - 3 May period, the 2003 (26.2%) and 2004 (25.8%) year classes were the most abundant in the gill nets (Table 14). These year classes were 99.5% male. The contribution of males age six and older (the pre-2002 year classes) was only 15.2% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age seven and older, presumably repeat spawners, was only 12.4% of the total aged catch, but represented 84.1% of the total females captured..

The catch rate (fish/day) of male striped bass was lower than for 2006, and was 42.3% below the 13-year average (Table 15). Likewise, the catch rate of female striped bass was lower than for 2006 and was 26.3% below the 13-year average. The biomass catch rate (g/day) of male striped bass was 67.3% lower than 2006, and was 45.0% below the average. The biomass catch rate of female striped bass was 44.2% lower than in 2006, but was only 2.0% below the 13-year average. The mean age of male striped bass has varied from only 4.3-4.9 years by sampling year, while the mean age of female striped bass varied from 6.3-9.8 years.

Spawning Stock Biomass Indexes

Rappahannock River:

Pound nets: The Spawning Stock Biomass Index (SSBI) for spring 2007 was 47.6 kg/day for male striped bass and 87.6 kg/day for female striped bass. The index for male striped bass was the second highest in the 17-year time series, almost double the index for 2006, and more than double the 17-year average (Table 16). The magnitude of the index for male striped bass was largely determined by the 2002 (23.8%) and 2003 (23.0%) year classes. The index for female striped bass was by far the highest in the 17-year time series, almost quadruple the index for 2006, and over 2.5 times the 17-year average (Table 16). The magnitude of the index for the females was largely determined by the 1996 and1997 year classes (58.1%).

Experimental gill nets: The Spawning Stock Biomass Index for spring 2007 was 134.1 kg/day for male striped bass and 68.0 kg/day for female striped bass. The index for male striped bass was the third highest of the time series, 272.6% above the 2006 index, and was 62.7% above the 17-year average (Table 16). The 2000-2003 year classes contributed 66.5% of the biomass in the male index. The index for female striped bass was 71.7% above the 2006 index, and was 87.8% above the 17-year average. The 1996 and 1997 year classes contributed 41.4% of the biomass in the female index.

James River:

Experimental gill nets: The Spawning Stock Biomass Index for spring 2007 was 69.7 kg/day for male striped bass and 55.4 kg/day for female striped bass. The male index was near the median in the 14-year time series, 67.3% lower than the 2006 index, and 41.8% below the 14-year average (Table 17). The 2001-2003 year classes contributed 64.9% of the biomass in the male index. The female index was the fifth highest in the time series, but was 44.3% lower than the 2006 index, and was nearly equal to the 14-year average. The 1996 and 1997 year classes accounted for 55.7% 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 2007 Egg Production Potential Indexes (EPPI, Table 19) for the Rappahannock River were 13.79 (pound nets) and 9.92(gill nets). The 2007 EPPI for the James River was 8.40. The indexes for both the Rappahannock and James rivers were heavily dependent on the egg production potential of the 1996 and 1997 year class females (59.5% in the pound nets, 42.7% in the Rappahannock gill nets and 56.3% in the James River gill nets). Previous values for the EPPI for 2001-2006 from the Rappahannock River were 3.992, 1.764, 9.829, 10.55, 6.30 and 4.01 (pound nets) and 4.039, 6.070, 3.724, 8.432, 3.06 and 6.27 (gill nets). Previous values for the EPPI for 2001-2006 from the James River were 5.286, 6.709, 6.037, 4.922, 3.24 and 15.1 respectively (Sadler et al 2001, 2002, 2003, 2004, 2005 and 2006). Thus, the EPPI values for the two gears in the Rappahannock River gave mixed signals as to the status of the spawning stock, while the EPPI value for the James River was its maximum value. 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 1991-2007 samples are presented in Tables 20-22. The cumulative annual catch rate of all year classes for 2007 was the second highest in the time series and was 42.9% higher than the cumulative catch rate for 2006 (Tables 20a,b). The increase was the result of high catch rates for the 2002 and 2003 year classes. The catch rate of males was dominated by four and five year olds (2002 and 2003 year classes, Tables 21a,b). These two age classes contributed 66.8% of the total male catch. 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-1996 year class males were captured. The cumulative catch rate of female stripers was also the highest of the time series, and was almost triple the catch rate in 2006 (Tables 22a,b). The 1996 and 1997

year classes accounted for 57.0% of the total female catch. No pre-1990 year class females were captured in 2007.

The range of overall ages was unchanged from 1991-2007, consisting mainly of 2-10 year old males and 4-16 year old females, but sex-specific changes in the age-structure have occurred. The age at which abundance peaked for males has decreased from age five (1992-1994) to age four (1997-2002, 2006-2007). The catch rate of four and five year olds were near equal in 2003 and 2004, but the peak was age three 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 0.75-2.1 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 1.4-4.5 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 from 2003-2005, decreased back to 0.787 in 2006, but was 0.929 in 2007 (the highest in the time series).

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 23-25. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rates (1991-2007) of the 1983-1997 year classes (sexes combined) varied from 0.516-0.800 (Tables 23a,b) with an overall mean survival rate of 0.676. 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 (1991-2007) of the 1985-1997 year classes of males varied from 0.317-0.586 (Tables 24a,b) with an overall mean survival rate of 0.445. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2007) of the 1983-1994 year classes of females varied from 0.461-0.834 (Tables 25a,b) with an overall mean survival rate of 0.654.

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1991-2007 are presented in Tables 26-28. The cumulative annual catch rate (all age classes, sexes combined) for 2007 from the gill nets was the third highest in the time series and was more than double the cumulative catch rate in 2006 (Tables 26a,b). The cumulative catch rate was driven by the catch rates of the 2003 and 2004 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, 2003 and 2007) and age three (1999, 2004 and 2006). The cumulative catch rate of male striped bass was also the third highest in the time series and was almost triple the catch rate in 2006 (Tables 27 a,b). The cumulative catch rate of female striped bass was the seventh highest of the time series, and was 30.9% higher than the cumulative catch rate in 2006 (Tables 28a,b).

The overall age structure from 1991-2007 consisted of 2-12 year old males (Tables 27a,b) and 2-14 year old females (Tables 28a,b). The proportion of males age six and older (0.20) was consistent with the 2002-2006 values after being 0.03-0.06 from 1997-2001. The proportion of female striped bass age eight and older was 0.83 in 2007. 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 rebounded from a decline in 2006, and was the highest value since 2004 (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 2007 cumulative catch (all age classes) rate of female striped bass was much higher than the 2006 catch rate (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 2005-2007. 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 (1991-2007) of the 1984-1998 year classes (sexes combined) varied from 0.408-0.723 (Tables 29a,b) with an overall mean survival of 0.604. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1991-2007) of the 1987-1998 year classes of males varied from 0.153-0.646 (Tables 30a,b) with an overall mean survival of 0.381. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1991-2007) of the 1984-1993 (excluding 1991) year classes of females varied from 0.496-0.965 (Tables 31a,b) with an overall mean survival rate of 0.674. The overall survival estimate of male striped bass was lower than that calculated from the pound nets. The estimate of female survival rates, although slightly greater than the pound net estimate, was based on fewer year classes than the estimate from the pound nets due to the relative rareness of the oldest females in the samples.

James River:

Experimental gill nets: Numeric catch rates (fish/day) of individual years classes from 1984-2007 are presented in Tables 32-34. The cumulative annual catch rate (all age classes, sexes combined) for 2007 was the lowest since 1998, and was a 63.2% lower than the catch rate for 2006 (Tables 32a,b). The cumulative catch rate was driven by high catch rates for the three to five year old (2002-2004 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, up to two to11 years by 2005 (Tables 33a,b). The age structure of female striped bass was stable from 1994-2007, consisting of three to14 year old females (Tables 34a,b). The cumulative proportion of males age six and older was 0.179, and has varied from 0.091-0.191 in 2000-2007 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 has increased to 0.777 in 2007.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 2007 catch rate being the lowest since 1998, and 65.5% lower than the cumulative catch rate for 2006 (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. The 2007 cumulative catch rate of female striped bass was 42.2% lower than the catch rate in 2006, and was the median 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 (1994-2007) of the 1984 -1999 year classes (sexes combined) varied from 0.338-0.730 (Table 35), with an overall mean survival rate of 0.566. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1994-2007) of the 1988-1999 year classes of males varied from 0.286-0.612 (Table 36) with an overall mean survival rate of 0.452. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1994-2007) of the 1984-1995 year classes of females varied from 0.339-0.760 (Table 37) with an overall mean survival rate of 0.596.

Catch Rate Histories of the 1987-1999 Year Classes

The catch rate histories of the 1987-1999 year classes from each sampling gear (sampling on the James River commenced in 1993) are depicted in Figures 3-15. 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 12 year classes) as an indicator of year class strength, the 1987 year class was near the mean for the 1987-1999 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. No 1987 year class striped bass were captured in 2007.

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). No 1988 year class striped bass were captured in 2007.

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 age 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). Two female 1989 year class striped bass was captured (one each in the James and Rappahannock rivers) in 2007.

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). One female 1990 year class striped bass (in the Rappahannock River) was captured in 2007.

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 to the Rappahannock River in both sampling gears (Tables 38, 39) and well below the mean in the James River (Table 40). No female 1991 year class striped bass were captured in 2007.

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). Fourteen female 1992 year class striped bass (thirteen in the Rappahannock and one in the James) were captured in 2007.

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). Twenty six female 1993 year class striped bass (22 in the Rappahannock and four in the James) were captured in 2007.

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 slightly 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 but was still below the mean (Table 40). Thirty one female 1994 year class striped bass (30 in the Rappahannock and one in the James) were captured in 2007.

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, male striped bass and a secondary peak of older, female striped bass. Twenty eight (all female) 1995 year class striped bass (27 in the Rappahannock and one in the James) were captured in 2007.

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 ten in the James River and at age 11 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 the highest of any of the year classes (Table 40). One hundred seventy (153 female, 13 male and one undetermined) 1996 year class striped bass (153 in the Rappahannock and 17 in the James) were captured in 2007.

1997 Year class: Peak abundance of male striped bass occurred at age three (pound nets) and age four (gill nets) in the Rappahannock River and occurred at age four in the James River (Figure 13). Age ten females showed an increase in abundance in the Rappahannock River (both gears) and the James 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). One hundred thirty (107 female and 23 male) 1997 year class striped bass (112 in the Rappahannock and 18 in the James) were captured in 2007.

1998 Year class: Peak abundance of male striped bass occurred at age five (gill nets) and age six (pound nets) in the Rappahannock River and occurred at age four in the James River (Figure 14). Age nine females showed an increase in abundance verses their abundance in 2006 (at age eight) in both rivers. The CCA was the lowest since the 1992 year class and the fourth lowest overall in the Rappahannock River pound nets (Table 38) and well below average in the gill nets (Table 39). The CCA was above average in the James River (Table 40), but was the lowest since the sampling location was changed in 2003. One hundred one (55 male and 46 female) 1998 year class striped bass (89 in the Rappahannock and 12 in the James) were captured in 2007.

1999 Year class: Peak abundance of male striped bass occurred at age four in the Rappahannock River gill nets and at age five in the pound nets and James River gill nets (Figure 15). The CCA at age eight was the lowest since the 1992 year class in the pound nets (Table 38) and the 1991 year class in the Rappahannock River gill nets (Table 39). The CAA for the James River was the lowest since the 1995 year class. Ninety (65 male and 25 female) 1999 year class striped bass (77 in the Rappahannock and 13 in the James) were captured in 2007.

Growth Rate of Striped Bass Derived from Annuli Measurements

The scales of 318 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 159mm 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

Tests of symmetry: A total of 318 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 50.0% (159/ 318) of the time and within one year 84.0% (267/318) 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 = 25). We tested the hypothesis that the observed age differences were symmetrically distributed about the main table diagonal (Table 42). The hypothesis was rejected ($\chi^2 = 79.15$, p< .0005), indicating non-random differences between the two ageing methodologies. The two ageing methods were also found to be non-random in 2004 and 2005, but not in 2006.

Differences between the scale and otolith age from the same specimen ranged from zero to six years (Figure 16). The otolith-derived age exceeded the scale age 32.4% of the total examined (64.8% 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 (84.3%). 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) rejected the hypothesis that these differences were random (X^2 = 25.2, df = 4, p< 0.005). This test has far fewer degrees of freedom than did the previous test of symmetry.

T-tests: 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=318) determined by reading the otoliths was greater than the mean age determined by reading the scales (by 0.32 years, Table 43). The test results were:

$$\bar{A}ge_{otolith} = 9.58 \qquad \bar{A}ge_{scale} = 9.26$$
$$S_{otolith} = 3.15 \qquad S_{scale} = 3.02$$

$$t = 1.271$$
$$df = 634$$
$$p = .2040$$

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 ($t=4.97$, $df=317$, $p<.001$) and the null hypothesis was rejected.

Kolmogorov-Smirnov test: 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 ($K_{.05}$):

$$D_{\max} = 0.1510 \qquad K_{.05} = 1.3581$$

$$D_{.05} = 1.3581\sqrt{\tfrac{295+295}{295^2}} = 0.1077$$

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

Discussion

Striped bass stocks 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 “rock fights” by local fishermen) and enhance catches of males. The pound net catches contained a greater relative proportion of older female striped bass than did the catches from the gill nets. This trend has been persistent over several years. Thus, given the presence of large females in the spawning run, it is clear that the gill nets do not adequately sample large (900+ mm FL) striped bass. However, in 2007 the two oldest striped bass (1989 year class) were captured in the gill nets.

The biological characterization of the spawning stock of striped bass in the Rappahannock River changed dramatically from 1991-2007. 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 2002-2007. 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 and gill nets were much greater in 2007 than in 2006. 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, there was an increase in the number of older striped bass in the gill nets in the James River.

Of note again in the 2006 samples was the relative abundance of 1996 year class (11 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 2007 value of the Spawning Stock Biomass Index (SSBI) for the Rappahannock River pound nets was the highest since the survey began in 1991. The SSBI for male striped bass captured in the pound nets was more than double the mean of the 1991-2007 time series. The SSBI for female striped bass more than 2.5 times the mean. The huge increase in the SSBI was due to increased numbers across almost every age class when compared to 2006. There was a slightly less dramatic increase in the SSBI for the Rappahannock River gill nets, which was close to double the mean in the 1991-2007 time series, but was second to the 2004 value.

The 1991-2007 values of the SSBI in the Rappahannock River were often inconsistent 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 2007 was driven by increased catches of 1998-2001 year classes of males, after weak catches in 2006. The female biomass from pound nets showed no reliance upon any age groups, although the exceptionally strong 1996 and 1997 year classes continue to contribute highly. The male biomass from the gill nets is driven by the number of "super catches", when the net is literally filled by males, seeking to spawn, that occur differentially among the years (most notably in 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 believe 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.

In contrast to the Rappahannock River, the 2007 values of the SSBI in the James River were much lower than in 2006 for both male and female striped bass. The male index was driven by large catches of the 2002-2004 year classes while the female index had higher catch rates of the 1994-1997 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. 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 2007, the contribution of 8+ year old females was 93.2% of the total number, 95.0% of the biomass and 98.1% 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 1987-1997 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 1991-1996 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

2004-2007, 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 1983-1994 year classes that were captured for four or five years subsequent to their peak in abundance at age four or five. The survival estimates of female striped bass of these year classes in the Rappahannock River were approximately 0.65 in pound nets and 0.54 in gill nets. The lower capture rates of larger (older) females in the gill nets resulted in lower estimates. The survival estimates of 1985-1997 year class 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 0.45 for male striped bass and approximately 0.59 for female striped bass.

The catch histories of the 1987-1998 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 2002 year class in fall 2005) 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 0-4 years (13-19 years by reading the scale vs 13-21 years by reading the otolith). The maximum age determined by reading scales has generally remained constant at 16 years since 1991 (although one 19 year old was aged in 2007), while there has been an annual progression in the maximum age determined by reading otoliths. Agreement between the two ageing methodologies was 50.0% and was higher than the results from 2006. When there was disagreement between methodologies, the otolith age was 1.89 times more likely to have been aged older than the respective scale-derived age and 5.13 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. This was consistent with the results in 2004 and 2005. However, test of symmetry and t-test of the means gave contradictory results in 2006. However, the relative contributions of the age classes and their overall mean age were statistically different between the two methodologies. 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.

Literature Cited

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

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

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

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

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

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

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

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

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

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

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

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

Mansueti, R.J. 1961. Age, growth, and movements of the striped bass, *Roccus saxatilis*, taken in size selective fishing gear in Maryland. Ches. Sci. 2: 9-36.

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

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

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

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

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

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

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

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

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

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

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

Sadler, P.W., R.J. Latour, R.E. Harris, J.K. J.K. Ellis and J.E. Olney. 2003. Evaluation of striped bass stocks in Virginia: monitoring and tagging studies, 1999-2003. Annual Report, Virginia Institute of Marine Science: 131 p.

Sadler, P.W., J.M. Hoenig, R.E. Harris and B.G. Holloman. 2004. Evaluation of striped bass stocks in Virginia: monitoring and tagging studies, 1999-2004. Annual Report, Virginia Institute of Marine Science: 167 p.

Sadler, P.W., J.M. Hoenig, R.E. Harris and B.G. Holloman. 2005. Evaluation of striped bass stocks in Virginia: monitoring and tagging studies, 2005-2009. Annual Report, Virginia Institute of Marine Science: 199 p.

Sadler, P.W., J.M. Hoenig, R.E. Harris, and B.G. Holloman. 2006. Evaluation of striped bass stocks in Virginia: monitoring and tagging studies, 2005-2009. Annual Report, Virginia Institute of Marine Science: 150 p.

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

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

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

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

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

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

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

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

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

Table 1. Numbers of striped bass in three age categories (year classes 2003-2005, 1999-2002 and 1989-1998) from pound nets in the Rappahannock River, by sampling date, spring, 2007. M = males, F = females.

Date	n	Year Class					
		2003-2005		1999-2002		1989-1998	
		M	F	M	F	M	F
2 April	106	50	3	20	5	3	25
5 April	144	46	0	36	4	9	49
9 April	122	62	0	33	2	4	21
12 April	116	68	0	26	2	1	19
19 April	150	36	0	34	7	9	64
23 April	118	25	0	26	6	6	55
26 April	108	22	1	24	8	11	42
30 April	157	35	0	76	4	9	33
3 May	83	40	0	34	1	2	6
Total	**1,104**	**384**	**4**	**309**	**39**	**55**	**313**

Table 2. Net-specific summary of catch rates and mean ages of striped bass (n=1,104) in pound nets on the Rappahannock River, spring, 2007. Values in bold are the 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
2 April	S454	106	18.3	8.3	30,204.7	67,447.1	4.3	9.5
5 April	S462	144	30.3	17.7	71,609.2	166,042.9	5.0	10.6
9 April	S462	122	24.8	5.8	45,368.6	51,106.1	4.5	11.1
12 April	S473	116	31.7	7.0	53,004.7	66,704.9	4.3	10.9
19 April	S454	150	11.3	10.1	26,759.8	92,826.3	5.2	11.0
23 April	S473	118	14.3	15.3	38,784.7	129,082.6	5.4	10.3
26 April	S454	108	19.0	17.0	60,539.9	136,808.8	6.0	10.4
30 April	S462	157	30.0	9.3	79,913.7	70,138.9	5.6	10.1
3 May	S454	83	25.7	2.0	48,397.4	12,929.2	4.8	9.5
Totals	S454	447	16.8	9.5	37,435.0	80,516.9	5.1	10.3
	S462	423	28.2	10.3	65,087.0	89,373.5	5.0	10.6
	S473	234	21.8	11.7	44,879.0	102,349.3	5.0	10.6
Season		**1,104**	**21.4**	**10.2**	**47,614.4**	**87,666.9**	**5.0**	**10.5**

Table 3. Length frequencies (TL in mm) of striped bass sampled from the pound nets in the Rappahannock River, spring, 2007.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	0	**460-**	22	**620-**	8	**780-**	14	**940-**	16	**1100-**	1
310-	1	**470-**	45	**630-**	3	**790-**	5	**950-**	15	**1110-**	1
320-	0	**480-**	30	**640-**	2	**800-**	13	**960-**	23	**1120-**	0
330-	0	**490-**	48	**650-**	0	**810-**	13	**970-**	9	**1130-**	0
340-	0	**500-**	41	**660-**	0	**820-**	12	**980-**	14	**1140-**	0
350-	1	**510-**	33	**670-**	0	**830-**	15	**990-**	10	**1150-**	0
360-	2	**520-**	27	**680-**	0	**840-**	15	**1000-**	6	**1160-**	0
370-	4	**530-**	45	**690-**	0	**850-**	20	**1010-**	1	**1170-**	0
380-	8	**540-**	32	**700-**	2	**860-**	19	**1020-**	2	**1180-**	0
390-	6	**550-**	39	**710-**	1	**870-**	25	**1030-**	6	**1190-**	0
400-	10	**560-**	27	**720-**	6	**880-**	30	**1040-**	0	**1200-**	0
410-	12	**570-**	34	**730-**	3	**890-**	23	**1050-**	2	**1210-**	0
420-	16	**580-**	24	**740-**	8	**900-**	31	**1060-**	0	**1220-**	0
430-	22	**590-**	22	**750-**	6	**910-**	32	**1070-**	2	**1230-**	0
440-	19	**600-**	21	**760-**	7	**920-**	25	**1080-**	2	**1240-**	0
450-	28	**610-**	10	**770-**	2	**930-**	23	**1090-**	0	**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, 2 April – 3 May, 2007.

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
2005	male	1	293.0		329.5		0.0	9.4
2004	male	87	388.2	23.0	775.0	142.0	2.5	1,926.5
	female	1	404.0		863.9		0.0	24.7
2003	male	296	459.9	24.9	1,294.9	234.6	8.5	10,951.0
	female	3	454.3	31.0	1,440.6	388.8	0.1	123.5
2002	male	204	527.0	23.2	1,942.1	275.8	5.8	11,319.6
	female	12	530.4	22.9	2,232.1	242.6	0.3	765.3
2001	male	34	576.9	32.0	2,543.8	493.3	1.0	2,471.1
	female	6	587.2	39.2	2,912.0	618.5	0.2	499.2
2000	male	36	713.4	30.7	4,564.3	584.9	1.0	4,694.7
	female	3	717.7	11.2	5,266.4	305.9	0.1	451.4
1999	male	36	763.3	31.3	5,752.0	799.9	1.0	5,916.4
	female	18	771.7	18.9	6,513.6	585.0	0.5	3,349.9
1998	male	31	787.8	48.6	6,311.2	1,082.5	0.9	5,589.9
	female	35	803.1	25.1	7,255.1	864.5	1.0	7,255.1
1997	male	13	814.4	21.1	7,122.4	770.7	0.4	2,645.5
	female	81	844.8	19.1	8,175.5	866.2	2.3	18,920.5
1996	male	10	816.8	56.0	7,171.6	914.9	0.3	2,049.0
	female	122	877.2	27.5	9,161.1	1,236.1	3.5	31,933.0
1995	female	25	901.0	30.5	10,133.4	1,183.2	0.7	7,238.2
1994	female	25	921.0	31.7	11,306.5	2,106.3	0.7	8,076.1
1993	female	16	946.7	41.9	11,986.8	2,146.8	0.5	5,479.7
1992	female	8	974.3	38.4	13,693.2	1,716.0	0.2	3,129.9
1990	female	1	1,015.0		14,721.2		0.0	420.6

Table 5. Summary of the season mean (2 April – 3 May) catch rates and ages, by sex, from the pound nets in the Rappahannock River, 2 April – 3 May, 1993-2007. M = male, F = female.

Year	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2007	1,104	21.4	13.2	47,614.4	87,666.9	5.0	10.5
2006	776	18.6	3.6	25,798.2	24,752.5	4.0	9.0
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	53,437.0	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	636.6	15.9	4.9	26,710.5	34,662.2	4.3	8.8

Table 6. Numbers of striped bass in three age categories (year classes 2003-2005, 1999-2002 and 1989-1998) from gill nets in the Rappahannock River, by sampling date, spring, 2007. M = male, F = female.

		Year Class					
		2003-2005		1999-2002		1989-1998	
Date	**n**	**M**	**F**	**M**	**F**	**M**	**F**
2 April	228	155	0	57	2	8	6
5 April	161	106	0	30	2	7	16
9 April	18	11	0	1	0	2	4
12 April	23	15	0	1	1	2	4
19 April	8	5	0	0	0	0	3
23 April	115	83	0	28	2	1	1
26 April	114	76	1	21	3	4	9
30 April	68	23	0	30	4	5	6
3 May	8	2	0	3	0	1	2
Total	**743**	**476**	**1**	**171**	**14**	**30**	**51**

Table 7. Summary of catch rates and mean ages of striped bass (n=743) from the two gill nets in the Rappahannock River, spring 2007. 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
2 April	228	220	8	393,685.4	64,463.1	4.5	9.8
5 April	161	143	18	254,592.0	178,761.6	4.4	11.1
9 April	18	14	4	28,511.5	40,317.1	4.8	11
12 April	23	18	5	32,994.9	59,847.3	4.2	12.2
19 April	8	5	3	3,915.1	42,497.5	3.4	14
23 April	115	112	3	170,125.0	26,625.7	4.2	9.3
26 April	114	101	13	145,385.8	88,330.9	4.1	8.9
30 April	68	58	10	163818.3	80,443.5	5.5	9.1
3 May	8	6	2	17,686.0	30,881.9	5.8	14.5
Season	**743**	**75.2**	**7.3**	**134,523.8**	**68,018.7**	**4.5**	**11.1**

Table 8. Length frequencies (TL in mm) of striped bass sampled from the experimental nets in the Rappahannock River, spring, 2007.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
290-	1	**450-**	43	**610-**	6	**770-**	3	**930-**	0	**1090-**	1
300-	3	**460-**	27	**620-**	3	**780-**	6	**940-**	5	**1100-**	0
310-	10	**470-**	37	**630-**	11	**790-**	4	**950-**	3	**1110-**	0
320-	10	**480-**	33	**640-**	7	**800-**	3	**960-**	1	**1120-**	0
330-	8	**490-**	42	**650-**	5	**810-**	5	**970-**	2	**1130-**	0
340-	18	**500-**	24	**660-**	6	**820-**	5	**980-**	0	**1140-**	0
350-	21	**510-**	32	**670-**	4	**830-**	3	**990-**	2	**1150-**	0
360-	19	**520-**	16	**680-**	7	**840-**	7	**1000-**	2	**1160-**	0
370-	20	**530-**	22	**690-**	5	**850-**	7	**1010-**	0	**1170-**	1
380-	16	**540-**	13	**700-**	6	**860-**	5	**1020-**	2	**1180-**	0
390-	9	**550-**	17	**710-**	5	**870-**	3	**1030-**	0	**1190-**	0
400-	7	**560-**	7	**720-**	1	**880-**	4	**1040-**	2	**1200-**	0
410-	14	**570-**	8	**730-**	8	**890-**	8	**1050-**	2	**1210-**	0
420-	11	**580-**	5	**740-**	10	**900-**	3	**1060-**	2	**1220-**	0
430-	29	**590-**	5	**750-**	4	**910-**	1	**1070-**	2	**1230-**	0
440-	15	**600-**	11	**760-**	6	**920-**	2	**1080-**	0	**1240-**	0

Table 9. Mean fork length (mm), weight (g), standard deviation (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the Rappahannock River, 2 April – 3 May, 2007.

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
2005	male	11	293.9	5.6	343.1	25.4	1.2	419.4
2004	male	186	357.0	36.2	610.6	200.4	20.7	12,618.6
2003	male	279	453.0	25.1	1,262.2	231.8	31.0	39,129.8
	female	1	487.0		1,867.5		0.1	207.5
2002	male	64	522.0	23.3	1,975.0	317.7	7.1	14,044.6
	female	7	556.9	25.1	2,560.7	300.4	0.8	1,991.6
2001	male	52	608.3	34.0	3,129.6	579.1	5.8	18,082.4
	female	3	632.3	36.4	3,507.4	518.4	0.3	1,169.1
2000	male	36	686.4	40.9	4,492.9	709.9	4.0	17,971.6
1999	male	19	735.4	45.3	5,403.5	958.4	2.1	11,407.3
	female	4	767.5	33.7	5,930.6	1,045.1	0.4	2,635.8
1998	male	19	757.3	50.8	5,984.8	914.8	2.1	12,634.6
	female	4	801.3	24.6	7,935.0	1,220.4	0.4	3,526.7
1997	male	8	795.9	48.6	6,885.0	900.4	0.9	6,120.0
	female	10	837.5	15.1	8,428.0	749.6	1.1	9,364.4
1996	male	3	774.3	116.4	6,286.9	2,491.0	0.3	2,095.6
	female	18	864.8	36.9	9,382.2	1,123.5	2.0	18,764.5
1995	female	2	848.5	68.6	9,622.8	3,059.2	0.2	2,138.4
1994	female	5	957.0	35.7	13,393.2	2,115.9	0.6	7,440.7
1993	female	6	964.2	28.8	13,454.6	2,023.8	0.7	8,969.7
1992	female	5	1,004.2	10.5	16,991.0	605.0	0.6	9,439.4
1989	female	1	1,115.0		21,329.0		0.1	2,369.9

Table 10. Summary of the season mean (2 April – 3 May) catch rates and mean ages, by sex, from the experimental gill nets in the Rappahannock River, 1993-2007. M = males, F = female.

Year	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2007	743	75.2	7.3	134,524.0	68,017.7	4.5	11.1
2006	335	27.9	5.6	52,966.9	39,531.5	4.7	8.8
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	13,331.3	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	537.0	49.1	5.8	79,476.5	34,765.9	4.4	7.8

Table 11. Numbers of striped bass in three categories (year class 2003-2005, 1999-2002 and 1989-1998) from gill nets in the James River by sampling date, spring 2007. M = male, F = female.

		Year Class					
		2003-2005		1999-2002		1989-1998	
Date	**n**	**M**	**F**	**M**	**F**	**M**	**F**
2 April	94	45	0	37	1	2	9
5 April	72	47	0	18	0	0	7
9 April	45	27	0	14	0	2	2
12 April	35	16	0	17	0	0	2
19 April	4	2	0	0	0	0	2
23 April	40	10	0	16	3	1	10
26 April	22*	3	1	5	4	0	8
30 April	77	48	0	16	5	2	6
3 May	37	24	0	9	3	1	0
Total	**426**	**222**	**1**	**132**	**16**	**8**	**46**

* 1 sex undetermined

Table 12. Summary of catch rates and mean ages of striped bass (n=426) from the gill nets in the James River, spring 2007. Values in bold are grand means for each column. M = male, F = female.

Date	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
		M	F	M	F	M	F
2 April	94	84	10	151,113.0	97,079.1	4.5	11.4
5 April	72	65	7	92,661.7	64,705.6	4.0	11.0
9 April	45	43	2	75,510.9	18,271.1	4.6	10.0
12 April	35	33	2	64,737.8	19,120.8	4.7	11.0
19 April	4	2	2	2,490.6	24,483.1	4.0	13.0
23 April	40	27	13	64,677.9	104,259.6	5.2	9.5
26 April	22*	8	13	19,268.0	85,270.2	5.3	8.8
30 April	77	66	11	104,136.8	78,205.8	4.2	8.6
3 May	37	34	3	52,936.4	7,632.6	4.2	5.3
Season	**426**	**40.2**	**7.0**	**69,725.9**	**55,447.5**	**4.5**	**9.8**

* 1 sex undetermined

Table 13. Length frequencies (TL in mm) of striped bass sampled from the experimental gill nets in the James River, spring 2007.

TL	n	TL	n	TL	n	TL	n	TL	n	TL	n
300-	1	460-	21	620-	3	780-	0	940-	0	1100-	0
310-	3	470-	15	630-	9	790-	5	950-	2	1110-	0
320-	2	480-	12	640-	9	800-	2	960-	0	1120-	1
330-	0	490-	18	650-	3	810-	0	970-	0	1130-	0
340-	1	500-	12	660-	3	820-	3	980-	1	1140-	0
350-	2	510-	3	670-	2	830-	5	990-	2	1150-	0
360-	2	520-	9	680-	3	840-	3	1000-	0	1160-	0
370-	2	530-	6	690-	4	850-	3	1010-	0	1170-	0
380-	4	540-	21	700-	1	860-	2	1020-	0	1180-	0
390-	16	550-	8	710-	2	870-	2	1030-	0	1190-	0
400-	17	560-	12	720-	2	880-	5	1040-	1	1200-	0
410-	17	570-	9	730-	1	890-	9	1050-	0	1210-	0
420-	21	580-	10	740-	0	900-	4	1060-	0	1220-	0
430-	15	590-	10	750-	0	910-	5	1070-	0	1230-	0
440-	15	600-	10	760-	1	920-	3	1080-	0	1240-	0
450-	15	610-	8	770-	1	930-	6	1090-	1	1250-	0

Table 14. Mean fork length (mm), weight (g), standard deviation (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the James River, 2 April – 3 May, 2007.

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
2005	male	1	305.0		364.9		0.1	40.5
2004	male	110	381.5	28.2	765.8	153.6	12.2	9,360.2
2003	male	111	450.1	24.5	1,256.8	214.2	12.3	15,500.5
	female	1	446.0		1,227.9		0.1	136.4
2002	male	75	529.9	25.9	2,036.1	334.3	8.3	16,967.7
	female	6	543.8	22.1	2,390.8	252.8	0.7	1,593.9
2001	male	39	593.5	32.8	2,945.5	510.5	4.3	12,763.8
	female	3	609.0	49.3	3,513.9	1,086.4	0.3	1,171.3
2000	male	8	665.8	40.9	4,200.0	679.9	0.9	3,733.4
	female	4	699.5	66.4	5,143.8	1,042.7	0.4	2,286.1
1999	male	10	742.3	63.6	5,818.7	1,377.7	1.1	6,465.2
	female	3	763.0	19.9	6,237.7	253.2	0.3	2,079.2
1998	male	5	733.4	74.5	5,300.0	1,266.0	0.6	2,944.4
	female	7	809.3	23.6	7,254.2	738.4	0.8	5,642.2
1997	male	2	713.5	137.9	5,169.6	2,812.4	0.2	1,148.8
	female	16	847.8	13.3	8,768.7	869.7	1.8	15,588.9
1996	male	1	791.0		7,212.8		0.1	801.4
	female	15	869.5	24.7	9,176.8	1,132.1	1.7	15,294.7
	unknown	1	865.0		8,629.9		0.1	958.9
1995	female	1	907.0		10,100.3		0.1	1,122.3
1994	female	1	942.0		10,404.8		0.1	1,156.1
1993	female	4	943.0	55.7	12,462.5	2,914.2	0.4	5,538.9
1992	female	1	978.0		15,538.4		0.1	1,726.5
1989	female	1	1,065.0		19,000.0		0.1	2,111.1

Table 15. Summary of season mean (2 April – 3 May) catch rates and ages, by sex, from experimental gill nets in the James River, 1995-2007.

Year	mile	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
2007	62	426*	40.2	7.0	69,725.9	55,447.5	4.5	9.8
2006	62	1,284	116.4	12.0	213,141.3	99,613.1	4.5	9.6
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		720.8	69.3	9.5	126,799.9	56,578.9	4.5	7.7

* 1 sex undetermined

Table 16. Values of the spawning stock biomass index (SSBI) for male and female striped bass, by gear, in the Rappahannock River, 2 April – 3 May, 1991 – 2007.

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
2007	747.0	355.0	47.6	87.6	135.2	666.0	66.0	134.1	68.0	202.1
2006	647.0	122.0	25.8	24.7	50.5	275.0	56.0	49.2	39.6	88.8
2005	438.0	177.0	26.4	39.0	65.4	291.0	27.0	55.6	19.9	75.4
2004	703.0	247.0	58.5	65.4	123.9	714.0	74.0	171.9	52.0	223.9
2003	283.0	187.0	22.8	53.6	76.4	467.0	31.0	97.3	20.7	118.0
2002	113.0	57.0	7.1	11.4	18.5	240.0	78.0	53.4	40.7	94.1
2001	470.0	105.0	24.2	27.6	51.8	572.0	41.0	88.6	30.9	119.5
2000	1,436.0	71.0	42.7	14.6	57.3	452.0	27.0	65.3	16.5	81.8
1999	738.0	61.0	30.5	19.8	50.3	532.0	21.0	51.4	13.2	64.6
1998	273.0	113.0	14.8	36.4	51.2	485.0	27.0	81.5	18.5	100.0
1997	277.0	115.0	22.2	49.6	71.7	801.0	18.0	177.8	19.1	197.0
1996	334.0	73.0	14.1	9.3	23.4	433.0	46.0	63.7	30.2	93.9
1995	207.0	76.0	12.4	19.8	32.2	162.0	69.0	43.9	56.7	100.6
1994	195.0	141.0	17.1	30.9	48.0	391.0	100.0	101.6	64.7	166.3
1993	357.0	188.0	31.2	37.5	68.7	361.0	160.0	85.6	74.1	159.6
1992	51.0	100.0	5.4	19.4	24.8	61.0	74.0	15.0	32.2	47.2
1991	153.0	70.0	21.3	21.5	42.8	406.0	47.0	65.0	17.8	83.8
Mean	**436.6**	**132.8**	**24.9**	**33.4**	**58.4**	**429.9**	**56.6**	**82.4**	**36.2**	**118.6**

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, 2 April – 3 May, 1994-2007. The 1994 catch 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).

	River	n		SSBI (kg/day)		
Year	**Mile**	**Male**	**Female**	**Male**	**Female**	**M+F**
2007	**62**	361	63	69.70	55.40	125.10
2006	**62**	1,159	120	213.14	99.49	312.63
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		**592**	**84**	**114.60**	**55.74**	**170.33**

Table 18. Predicting 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, 2 April – 3 May 2007. 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	3	0.016	0.12	1	0.026	0.26	1	0.020	0.23
5	12	0.104	0.76	7	0.276	2.78	6	0.219	2.61
6	6	0.072	0.52	3	0.176	1.78	3	0.158	1.88
7	3	0.067	0.49	0	0.000	0.00	4	0.327	3.90
8	18	0.506	3.67	4	0.431	4.34	3	0.316	3.77
9	35	1.115	8.09	4	0.492	4.96	7	0.888	10.58
10	81	3.021	21.90	10	1.411	14.23	16	2.344	27.92
11	123	5.189	37.62	18	2.822	28.46	15	2.384	28.40
12	25	1.144	8.29	2	0.297	2.99	1	0.181	2.16
13	25	1.225	8.88	5	1.075	10.84	1	0.204	2.43
14	16	0.857	6.21	6	1.319	13.30	4	0.825	9.83
15	7	0.409	2.96	5	1.246	12.56	1	0.229	2.73
16	0	0.000	0.00	0	0.000	0.00	0	0.000	0.00
17	1	0.066	0.48	0	0.000	0.00	0	0.000	0.00
18	0	0.000	0.00	1	0.346	3.49	1	0.300	3.57
19	0	0.000	0.00	0	0.000	0.00	0	0.000	0.00
20	0	0.000	0.00	0	0.000	0.00	0	0.000	0.00
Total	355	**13.792**	100.00	66	**9.915**	100.00	63	**8.396**	100.00

Table 20a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 2 April – 3 May, 1991-2007. 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, 2 April - 3 May, 1991-2007. 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**	**2006**	**2007**
2005							**0.03**
2004							**2.52**
2003						7.89	**8.55**
2002					1.83	6.40	**6.17**
2001				3.47	**5.43**	3.17	1.14
2000			0.76	**5.57**	2.77	0.14	1.12
1999	0.07	0.51	3.00	**5.90**	0.71	0.51	1.51
1998	2.74	1.44	3.33	**3.50**	0.77	0.91	1.89
1997	7.49	1.38	0.37	2.23	1.69	0.86	2.68
1996	4.29	0.25	1.83	4.16	1.69	1.17	3.80
1995	0.10	0.68	1.40	2.33	0.94	0.23	0.71
1994	0.58	0.41	1.70	1.67	0.69	0.20	0.71
1993	0.87	0.28	1.43	1.00	0.57	0.20	0.46
1992	0.87	0.19	1.13	1.10	0.29	0.11	0.20
1991	0.81	0.06	0.33	0.17	0.09	0.00	0.00
1990	0.45	0.00	0.27	0.07	0.03	0.00	0.03
1989	0.26	0.00	0.07	0.07	0.03	0.00	0.00
1988	0.10	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.03	0.03	0.00	0.03	0.00	0.00
N/A	0.00	0.00	0.00	0.40	0.49	0.26	0.00
Total	**18.63**	**5.23**	**15.65**	**31.64**	**18.05**	**22.05**	**31.52**

Table 21a. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 2 April - 3 May, 1991-2007. 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, 2 April - 3 May, 1991-2007. Maximum catch rate for each year class during the sampling period is in bold type.

Year	CPUE (fish/day)						
Class	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
2005							**0.03**
2004							**2.49**
2003						7.77	**8.46**
2002					1.83	**6.29**	5.83
2001				3.47	**5.40**	2.91	0.97
2000			0.76	**5.47**	2.49	0.09	1.03
1999	0.07	0.44	2.93	**5.67**	0.66	0.20	1.00
1998	2.74	1.38	3.07	**3.37**	0.51	0.57	0.89
1997	7.42	1.25	0.30	1.93	1.00	0.29	0.37
1996	4.03	0.25	1.50	2.23	0.43	0.03	0.29
1995	0.10	0.16	0.56	0.53	0.09	0.00	0.00
1994	0.39	0.03	0.23	0.20	0.09	0.06	0.00
1993	0.16	0.03	0.07	0.10	0.00	0.00	0.00
1992	0.19	0.00	0.00	0.07	0.00	0.00	0.00
1991	0.13	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N/A	0.00	0.00	0.00	0.40	0.46	0.29	0.00
Total	**15.23**	**3.54**	**9.42**	**23.44**	**12.96**	**18.50**	**21.36**

Table 22a. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 2 April - 3 May, 1991-2007. 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, 2 April - 3 May, 1991-2007. 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	2006	2007
2004							**0.03**
2003						**0.11**	0.09
2002						0.11	**0.34**
2001					0.03	**0.26**	0.17
2000				0.10	**0.29**	0.06	0.09
1999		0.06	0.07	0.23	0.06	0.31	**0.51**
1998		0.06	0.27	0.17	0.26	0.34	**1.00**
1997	0.07	0.13	0.07	0.30	0.69	0.57	**2.31**
1996	0.26	0.00	0.37	1.93	1.26	1.14	**3.51**
1995	0.00	0.63	0.80	**1.80**	0.86	0.23	0.71
1994	0.19	0.38	**1.47**	**1.47**	0.60	0.14	0.71
1993	0.71	0.25	**1.37**	0.90	0.54	0.20	0.46
1992	0.68	0.19	**1.13**	1.03	0.29	0.11	0.20
1991	**0.68**	0.06	0.33	0.17	0.09	0.00	0.00
1990	0.45	0.00	0.26	0.07	0.03	0.00	0.03
1989	0.26	0.00	0.07	0.07	0.03	0.00	0.00
1988	0.10	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.00	0.03	0.03	0.00	0.03	0.00	0.00
N/A	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Total	**3.40**	**1.79**	**6.24**	**8.24**	**5.09**	**3.58**	**10.16**

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, 2 April - 3 May, 1991-2007.

Year	Survival (S)									
Class	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	0.456	0.456	0.315	0.954	0.954	0.954	0.890	0.483	0.116	0.903
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, 2 April - 3 May, 1991-2007.

Year	Survival (S)						
Class	01-02	02-03	03-04	04-05	05-06	06-07	Mean
2001	-----	-----	-----	-----	0.584	0.360	0.459
2000	-----	-----	-----	0.497	0.636	0.636	0.586
1999	-----	-----	-----	0.635	0.635	0.635	0.635
1998	-----	-----	-----	0.814	0.814	0.814	0.814
1997	0.843	0.843	0.843	0.843	0.843	0.843	0.778
1996	0.980	0.980	0.980	0.980	0.980	0.980	0.800
1995	0.914	0.914	0.914	0.403	0.869	0.869	0.706
1994	0.884	0.884	0.982	0.752	0.752	0.752	0.784
1993	0.993	0.993	0.699	0.570	0.898	0.898	0.751
1992	0.983	0.983	0.973	0.264	0.830	0.830	0.767
1991	0.869	0.638	0.515	0.529	0.000	-----	0.663
1990	0.863	0.775	0.259	0.754	0.754	0.754	0.724
1989	0.703	0.646	0.646	0.429	0.000	-----	0.584
1988	0.000	-----	-----	-----	-----	-----	0.516
1987	0.903	0.903	0.903	0.903	0.000	-----	0.637
1986	-----	-----	-----	-----	-----	-----	0.621
1985	-----	-----	-----	-----	-----	-----	0.621
1984	-----	-----	-----	-----	-----	-----	0.571
1983	-----	-----	-----	-----	-----	-----	0.620

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, 2 April - 3 May, 1991-2007.

Year	Survival (S)									
Class	**91-92**	**92-93**	**93-94**	**94-95**	**95-96**	**96-97**	**97-98**	**98-99**	**99-00**	**00-01**
2002										
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	0.315	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	0.505	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, 2 April - 3 May, 1991-2007.

Year	Survival (S)						
Class	01-02	02-03	03-04	04-05	05-06	06-07	Mean
2002	-----	-----	-----	-----	-----	0.927	0.927
2001	-----	-----	-----	-----	0.539	0.333	0.424
2000	-----	-----	-----	0.455	0.643	0.643	0.573
1999	-----	-----	-----	0.561	0.561	0.561	0.561
1998	-----	-----	-----	0.642	0.642	0.642	0.642
1997	0.638	0.638	0.638	0.518	0.608	0.608	0.586
1996	0.821	0.821	0.821	0.193	0.821	0.821	0.554
1995	0.559	0.559	0.946	0.170	0.000	-----	0.409
1994	0.768	0.768	0.870	0.450	0.667	0.000	0.500
1993	0.855	0.855	0.855	0.000	-----	-----	0.496
1992	0.717	0.717	0.717	0.000	-----	-----	0.554
1991	0.000	-----	-----	-----	-----	-----	0.508
1990	-----	-----	-----	-----	-----	-----	0.353
1989	-----	-----	-----	-----	-----	-----	0.395
1988	-----	-----	-----	-----	-----	-----	0.335
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, 2 April - 3 May, 1991-2007.

Year	Survival (S)									
Class	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
1999										
1998										
1997										
1996										
1995										
1994										
1993										
1992										
1991										
1990								0.914	0.914	0.914
1989				0.912	0.912	0.912	0.912	0.679	0.679	0.764
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	0.182	0.000	-----
1985	0.743	0.743	0.743	0.900	0.900	0.900	0.429	0.733	0.000	-----
1984			0.915	0.915	0.915	0.915	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, 2 April - 3 May, 1991-2007.

Year Class	Survival (S)						
	01-02	02-03	03-04	04-05	05-06	06-07	Mean
1999	-----	-----	-----	-----	-----	-----	-----
1998	-----	-----	-----	-----	-----	-----	-----
1997	-----	-----	-----	-----	-----	-----	-----
1996	-----	-----	-----	-----	-----	-----	-----
1995	-----	-----	-----	0.478	0.909	0.909	0.734
1994	-----	-----	0.834	0.834	0.834	0.834	0.834
1993	-----	-----	0.657	0.600	0.906	0.906	0.754
1992	-----	-----	0.912	0.282	0.830	0.830	0.649
1991	0.697	0.697	0.515	0.529	0.000	-----	0.461
1990	0.760	0.760	0.269	0.754	0.754	0.754	0.718
1989	0.646	0.646	0.646	0.429	0.000	-----	0.655
1988	0.000	-----	-----	-----	-----	-----	0.607
1987	0.902	0.902	0.902	0.902	0.000	-----	0.675
1986	-----	-----	-----	-----	-----	-----	0.646
1985	-----	-----	-----	-----	-----	-----	0.648
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, 2 April - 3 May, 1991-2007. 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, 2 April - 3 May, 1991-2007. Maximum catch rate for each year class during the sampling period is in bold type.

Year	CPUE (fish/day)						
Class	2001	2002	2003	2004	2005	2006	2007
2005							**1.22**
2004						0.40	**20.67**
2003					0.40	9.20	**31.11**
2002				4.10	4.00	**8.20**	7.89
2001			2.70	**21.78**	11.80	4.90	6.11
2000		0.50	8.80	**16.22**	6.60	2.80	4.00
1999	0.90	1.10	16.00	**10.74**	2.40	1.10	2.55
1998	9.50	8.80	**12.60**	10.00	1.90	1.90	2.55
1997	**27.00**	10.20	4.60	10.32	1.40	1.60	2.00
1996	17.70	4.60	4.20	7.58	1.30	1.80	2.33
1995	2.10	3.50	1.60	2.74	0.20	0.40	0.22
1994	1.50	1.20	1.30	1.68	0.30	0.80	0.56
1993	1.00	1.00	0.50	0.64	0.10	0.20	0.67
1992	1.10	0.30	0.00	0.42	0.10	0.00	0.56
1991	0.90	0.30	0.00	0.00	0.00	0.00	0.00
1990	0.10	0.00	0.10	0.00	0.00	0.00	0.00
1989	0.10	0.00	0.00	0.00	0.00	0.00	0.11
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.10	0.00	0.00	0.00	0.00	0.00	0.00
1985	0.20	0.00	0.00	0.00	0.00	0.00	0.00
N/A	0.20	0.80	0.10	0.84	0.40	0.20	0.00
Total	**62.40**	**32.30**	**52.50**	**87.06**	**30.90**	**33.50**	**82.55**

Table 27a. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 2 April - 3 May, 1991-2007. 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, 2 April - 3 May, 1991-2007. 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	2006	2007
2005							**1.22**
2004						0.40	**20.67**
2003					0.40	9.20	**31.00**
2002				4.10	4.00	**7.90**	7.11
2001			2.70	**21.78**	11.80	4.60	5.78
2000		0.50	8.80	**16.00**	6.50	2.30	4.00
1999	0.90	1.10	15.90	**10.52**	2.40	1.00	2.11
1998	9.40	8.70	**12.10**	9.68	1.70	0.80	2.11
1997	**27.00**	8.80	4.30	9.68	1.30	0.70	0.89
1996	17.00	3.30	3.80	5.68	0.70	0.60	0.33
1995	1.90	1.40	1.20	0.64	0.10	0.10	0.00
1994	1.30	0.20	0.40	0.32	0.10	0.10	0.00
1993	0.40	0.20	0.00	0.00	0.00	0.00	0.00
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1991	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N/A	0.20	0.80	0.10	0.84	0.40	0.20	0.00
Total	**58.10**	**25.00**	**49.30**	**79.24**	**29.40**	**27.90**	**75.22**

Table 28a. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 2 April - 3 May, 1991-2007. 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, 2 April - 3 May, 1991-2007. 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**	**2006**	**2007**
2003							0.11
2002						0.30	**0.78**
2001						0.30	**0.33**
2000				0.22	0.10	**0.50**	0.00
1999			0.10	0.22	0.00	0.10	**0.44**
1998	0.10	0.10	0.50	0.32	0.20	**1.10**	0.44
1997	0.00	**1.40**	0.30	0.64	0.10	0.90	1.11
1996	0.70	1.60	0.40	1.90	0.60	1.20	**2.00**
1995	0.20	**2.10**	0.40	**2.10**	0.10	0.30	0.22
1994	0.20	1.00	0.90	**1.36**	0.20	0.70	0.56
1993	0.60	**0.80**	0.50	0.64	0.10	0.20	0.67
1992	**1.10**	0.30	0.00	0.42	0.10	0.00	0.56
1991	**0.90**	0.30	0.00	0.00	0.00	0.00	0.00
1990	0.10	0.00	0.10	0.00	0.00	0.00	0.00
1989	0.10	0.00	0.00	0.00	0.00	0.00	0.11
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1987	0.10	0.00	0.00	0.00	0.00	0.00	0.00
N/A	0.00	0.80	0.00	0.00	0.00	0.00	0.00
Total	**4.10**	**8.40**	**3.20**	**7.82**	**1.50**	**5.60**	**7.33**

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, 2 April - 3 May, 1991-2007.

Year	Survival (S)									
Class	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
2002										
2001										
2000										
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	0.495	0.606	0.928	0.928
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	0.929	0.929	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	0.456	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, 2 April - 3 May, 1991-2007.

Year	Survival (S)						
Class	01-02	02-03	03-04	04-05	05-06	06-07	Mean
2002	-----	-----	-----	-----	-----	0.962	0.962
2001	-----	-----	-----	0.542	0.720	0.720	0.655
2000	-----	-----	-----	0.407	0.778	0.778	0.627
1999	-----	-----	-----	0.619	0.619	0.619	0.619
1998	-----	-----	0.794	0.634	0.634	0.634	0.671
1997	0.726	0.726	0.726	0.579	0.579	0.579	0.648
1996	0.754	0.754	0.754	0.675	0.675	0.675	0.711
1995	0.777	0.885	0.885	0.382	0.382	0.550	0.643
1994	0.984	0.984	0.984	0.690	0.690	0.700	0.636
1993	0.707	0.923	0.923	0.923	0.923	0.923	0.617
1992	0.894	0.894	0.894	0.894	0.894	0.894	0.723
1991	0.333	0.000	-----	-----	-----	-----	0.527
1990	0.781	0.781	0.000	-----	-----	-----	0.579
1989	0.928	0.928	0.928	0.928	0.928	0.928	0.654
1988	-----	-----	-----	-----	-----	-----	0.408
1987	0.000	-----	-----	-----	-----	-----	0.569
1986	-----	-----	-----	-----	-----	-----	0.529
1985	0.000	-----	-----	-----	-----	-----	0.659
1984	-----	-----	-----	-----	-----	-----	0.493
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, 2 April - 3 May, 1991-2007.

Year	Survival (S)									
Class	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
2002										
2001										
2000										
1999										
1998										
1997										
1996									0.567	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	0.769	0.000	-----	-----	-----	-----
1986	0.119	0.738	0.122	0.000	-----	-----	-----	-----	-----	-----
1985	0.520	0.520	0.520	0.000	-----	-----	-----	-----	-----	-----
1984	0.537	0.537	0.537	0.000	-----	-----	-----	-----	-----	-----
1983	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

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, 2 April - 3 May, 1991-2007.

Year Class	Survival (S)						
	01-02	02-03	03-04	04-05	05-06	06-07	Mean
2002	-----	-----	-----	-----	-----	0.900	0.900
2001	-----	-----	-----	0.542	0.670	0.670	0.624
2000	-----	-----	-----	0.406	0.784	0.784	0.630
1999	-----	-----	-----	0.228	0.938	0.938	0.585
1998	-----	-----	0.800	0.602	0.602	0.602	0.646
1997	0.710	0.710	0.710	0.134	0.827	0.827	0.566
1996	0.694	0.694	0.694	0.123	0.857	0.550	0.554
1995	0.737	0.857	0.533	0.395	0.395	0.000	0.496
1994	0.555	0.555	0.800	0.565	0.565	0.000	0.477
1993	0.500	0.000	-----	-----	-----	-----	0.283
1992	-----	-----	-----	-----	-----	-----	0.153
1991	-----	-----	-----	-----	-----	-----	0.276
1990	-----	-----	-----	-----	-----	-----	0.369
1989	-----	-----	-----	-----	-----	-----	0.231
1988	-----	-----	-----	-----	-----	-----	0.373
1987	-----	-----	-----	-----	-----	-----	0.326
1986	-----	-----	-----	-----	-----	-----	0.215
1985	-----	-----	-----	-----	-----	-----	0.369
1984	-----	-----	-----	-----	-----	-----	0.380
1983	-----	-----	-----	-----	-----	-----	-----

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, 2 April - 3 May, 1991-2007.

Year	Survival (S)									
Class	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01
2002										
2001										
2000										
1999										
1998										
1997										
1996										
1995										
1994										
1993										
1992										
1991										
1990					0.663	0.663	0.860	0.860	0.860	0.476
1989				0.847	0.585	0.548	0.548	0.606	0.928	0.928
1988			0.653	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	0.567	0.719	0.719	0.719	0.719	0.000	-----
1984	0.713	0.914	0.914	0.446	0.000	-----	-----	-----	-----	-----
1983			0.430	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, 2 April - 3 May, 1991-2007.

Year Class	Survival (S) 01-02	02-03	03-04	04-05	05-06	06-07	Mean
2002	-----	-----	-----	-----	-----	-----	-----
2001	-----	-----	-----	-----	-----	-----	-----
2000	-----	-----	-----	-----	-----	0.000	0.000
1999	-----	-----	-----	-----	-----	-----	-----
1998	-----	-----	-----	-----	-----	0.400	0.400
1997	-----	0.955	0.955	0.955	0.955	0.955	0.955
1996	-----	-----	-----	-----	-----	-----	-----
1995	-----	-----	-----	0.378	0.378	0.733	0.471
1994	-----	-----	-----	0.717	0.717	0.800	0.744
1993	-----	0.965	0.965	0.965	0.965	0.965	0.965
1992	0.894	0.894	0.894	0.894	0.894	0.894	0.894
1991	0.333	0.000	-----	-----	-----	-----	0.155
1990	0.000	-----	-----	-----	-----	-----	0.595
1989	0.928	0.928	0.928	0.928	0.928	0.928	0.794
1988	-----	-----	-----	-----	-----	-----	0.501
1987	0.000	-----	-----	-----	-----	-----	0.496
1986	-----	-----	-----	-----	-----	-----	0.605
1985	-----	-----	-----	-----	-----	-----	0.660
1984	-----	-----	-----	-----	-----	-----	0.555
1983	-----	-----	-----	-----	-----	-----	0.207

Table 32a. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets (mile 62) in the James River, 2 April - 3 May, 1994-2007. 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 (mile 62) in the James River, 2 April - 3 May, 1994-2007. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)			
	2004	2005	2006	2007
2005				0.11
2004			0.50	**12.22**
2003		0.90	**27.60**	12.44
2002	0.36	14.70	**37.00**	9.00
2001	30.54	27.50	**33.70**	4.66
2000	**48.00**	19.90	9.80	1.33
1999	28.00	7.70	3.90	1.44
1998	11.82	5.10	2.60	1.34
1997	4.08	1.60	2.90	2.00
1996	3.56	1.60	3.90	1.90
1995	1.36	0.60	1.00	0.10
1994	1.00	0.50	1.00	0.10
1993	0.28	0.30	1.10	0.40
1992	0.38	0.10	0.10	0.10
1991	0.00	0.10	0.40	0.00
1990	0.00	0.00	0.40	0.00
1989	0.00	0.00	0.00	0.10
1988	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00
N/A	2.36	1.40	2.40	0.00
Total	**131.74**	**82.00**	**128.30**	**47.24**

Table 33a. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets (mile 62) in the James River, 2 April - 3 May, 1994-2007. 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 (mile 62) in the James River, 2 April - 3 May, 1994-2007. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)			
	2004	**2005**	**2006**	**2007**
2005				**0.11**
2004			0.50	**12.22**
2003		0.90	**27.60**	12.33
2002	0.36	14.70	**36.90**	8.33
2001	30.54	27.30	**32.30**	4.33
2000	**47.82**	19.60	8.70	0.89
1999	27.64	7.50	3.50	1.11
1998	10.46	4.90	2.20	0.56
1997	3.90	1.00	1.40	0.22
1996	2.28	1.20	0.60	0.10
1995	0.54	0.10	0.10	0.00
1994	1.00	0.30	0.10	0.00
1993	0.00	0.10	0.00	0.00
1992	0.10	0.00	0.00	0.00
1991	0.00	0.00	0.10	0.00
1990	0.00	0.00	0.00	0.00
1989	0.00	0.00	0.00	0.00
1988	0.00	0.00	0.00	0.00
N/A	2.36	1.40	2.40	0.00
Total	**127.00**	**79.00**	**116.40**	**40.20**

Table 34a. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets (mile 62) in the James River, 2 April - 3 May, 1994-2007. 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 (mile 62) in the James River, 2 April - 3 May, 1994-2007. Maximum catch rate for each year class during the sampling period is in bold type.

Year Class	CPUE (fish/day)			
	2004	**2005**	**2006**	**2007**
2003				**0.11**
2002			0.10	**0.67**
2001		0.20	**1.40**	0.33
2000	0.18	0.30	**1.10**	0.44
1999	0.18	0.20	**0.40**	0.33
1998	0.36	0.20	0.40	0.78
1997	0.18	0.60	1.50	1.78
1996	1.28	0.40	3.30	1.70
1995	0.82	0.50	0.90	0.10
1994	1.00	0.20	0.90	0.10
1993	0.28	0.20	1.10	0.40
1992	0.28	0.10	0.10	0.10
1991	0.00	0.10	0.30	0.00
1990	0.00	0.00	0.40	0.00
1989	0.00	0.00	0.10	0.10
1988	0.00	0.00	0.00	0.00
1987	0.00	0.00	0.00	0.00
N/A	0.00	0.00	0.00	0.00
Total	**4.56**	**3.00**	**12.00**	**6.94**

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, 2 April - 3 May, 1994-2007.

Year	Survival (S)									
Class	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
2003										
2002										
2001										
2000										
1999										0.895
1998									0.973	0.410
1997								0.928	0.203	0.510
1996							0.445	0.337	0.772	0.772
1995							0.219	0.305	0.613	0.866
1994						0.944	0.235	0.427	0.974	0.974
1993						0.344	0.762	0.928	0.928	0.928
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	0.768	0.768	0.768
1990	0.896	0.279	0.645	0.837	0.837	0.598	0.598	0.956	0.956	0.956
1989	0.815	0.266	0.773	0.773	0.773	0.584	0.584	0.584	0.584	0.919
1988	0.834	0.734	0.734	0.542	0.513	0.275	0.000	-----	-----	-----
1987		0.645	0.645	0.949	0.949	0.000	-----	-----	-----	-----
1986		0.449	0.413	0.953	0.953	0.000	-----	-----	-----	-----
1985		0.246	0.733	0.500	0.909	0.000	-----	-----	-----	-----
1984	0.650	0.256	0.550	0.000	-----	-----	-----	-----	-----	-----

Table 35b. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the James River, 2 April - 3 May, 1994-2007.

Year	Survival (S)			
Class	**04-05**	**05-06**	**06-07**	**Mean**
2003	-----	-----	0.451	0.451
2002	-----	-----	0.243	0.243
2001	-----	-----	0.138	0.138
2000	0.415	0.492	0.136	0.303
1999	0.275	0.506	0.369	0.463
1998	0.431	0.510	0.515	0.538
1997	0.843	0.843	0.690	0.601
1996	0.772	0.772	0.487	0.594
1995	0.857	0.857	0.100	0.427
1994	0.974	0.974	0.100	0.551
1993	0.928	0.928	0.364	0.711
1992	0.641	0.641	0.641	0.730
1991	0.768	0.768	0.000	0.677
1990	0.956	0.956	0.000	0.699
1989	0.919	0.919	0.919	0.692
1988	-----	-----	-----	0.491
1987	-----	-----	-----	0.593
1986	-----	-----	-----	0.508
1985	-----	-----	-----	0.440
1984	-----	-----	-----	0.338

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, 2 April - 3 May, 1994-2007.

Year Class	Survival (S)									
	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
2003										
2002										
2001										
2000										
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	0.838	0.838	0.838
1993				0.972	0.661	0.672	0.655	0.357	0.357	0.845
1992		0.664	0.832	0.717	0.833	0.833	0.172	0.794	0.794	0.794
1991		0.456	0.400	0.694	0.736	0.736	0.736	0.758	0.758	0.758
1990	0.597	0.237	0.887	0.475	0.475	0.000	-----	-----	-----	-----
1989	0.291	0.300	0.629	0.000	-----	-----	-----	-----	-----	-----
1988	0.400	0.536	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, 2 April - 3 May, 1994-2007.

Year Class	Survival (S)			
	04-05	05-06	06-07	Mean
2003	-----	-----	0.447	0.447
2002	-----	-----	0.226	0.226
2001	-----	-----	0.134	0.134
2000	0.410	0.444	0.102	0.265
1999	0.271	0.467	0.317	0.434
1998	0.468	0.449	0.255	0.454
1997	0.599	0.599	0.157	0.417
1996	0.526	0.500	0.167	0.390
1995	0.430	0.430	0.000	0.326
1994	0.300	0.333	0.000	0.434
1993	0.845	0.000	-----	0.566
1992	0.000	-----	-----	0.612
1991	0.758	0.758	0.000	0.610
1990	-----	-----	-----	0.417
1989	-----	-----	-----	0.286
1988	-----	-----	-----	0.481
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, 2 April - 3 May, 1994-2007.

Year	Survival (S)									
Class	94-95	95-96	96-97	97-98	98-99	99-00	00-01	01-02	02-03	03-04
2002										
2001										
2000										
1999										
1998										0.723
1997									0.860	0.860
1996									-----	-----
1995						0.548	0.945	0.945	0.945	0.945
1994						0.688	0.688	0.688	0.688	0.688
1993						0.844	0.844	0.844	0.844	0.844
1992						0.791	0.791	0.791	0.561	0.561
1991						0.724	0.724	0.771	0.771	0.771
1990		0.335	0.883	0.883	0.883	0.674	0.674	0.956	0.956	0.956
1989		0.255	0.858	0.858	0.858	0.584	0.584	0.584	0.584	0.894
1988	0.959	0.794	0.794	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		0.246	0.733	0.500	0.909	0.000	-----	-----	-----	-----
1984	0.650	0.258	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, 2 April - 3 May, 1994-2007.

Year Class	Survival (S)			
	04-05	05-06	06-07	Mean
2002	-----	-----	-----	-----
2001	-----	-----	0.236	0.236
2000	-----	-----	0.400	0.400
1999	-----	-----	0.825	0.825
1998	0.723	0.723	0.723	0.723
1997	0.860	0.860	0.860	0.860
1996	-----	-----	0.515	0.515
1995	0.945	0.945	0.111	0.675
1994	0.949	0.949	0.111	0.594
1993	0.844	0.844	0.364	0.760
1992	0.709	0.709	0.709	0.697
1991	0.771	0.771	0.000	0.638
1990	0.956	0.956	0.000	0.729
1989	0.894	0.894	0.000	0.627
1988	-----	-----	-----	0.520
1987	-----	-----	-----	0.617
1986	-----	-----	-----	0.515
1985	-----	-----	-----	0.440
1984	-----	-----	-----	0.339
1983	-----	-----	-----	0.189
1982	-----	-----	-----	0.245

Table 38a. Comparison of the area under the catch curve (fish/ day) of the 1987-2005 year classes of striped bass from pound nets in the Rappahannock River, 1991-2007.

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	43.2	
11	18.5	20.7	12.8	8.6	5.9	12.9	19.3	18.4	22.9	47.0	
12	18.9	20.7	13.1	8.6	7.0	14.0	19.8	18.6	23.6		
13	19.0	20.8	13.1	8.9	8.1	14.3	20.0	19.3			
14	19.0	20.8	13.2	8.9	8.4	14.4	20.5				
15	19.0	20.8	13.2	9.0	8.4	14.6					
16	19.0	20.8	13.3	9.0	8.4						
17	19.0	20.8	13.3	9.0							
18	19.1	20.8	13.3								
19	19.1	20.8									
20	19.1										
area	**19.1**	**20.8**	**13.3**	**9.0**	**8.4**	**14.6**	**20.5**	**19.3**	**23.6**	**47.0**	

Table 38b. Comparison of the area under the catch curve (fish/ day) of the 1987-2005 year classes of striped bass from pound nets in the Rappahannock River, 1991-2007.

age	year class										mean
	1997	1998	1999	2000	2001	2002	2003	2004	2005		
2	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0		**0.2**
3	16.0	2.7	0.6	0.8	3.5	1.8	7.9	2.6			**4.2**
4	23.5	4.2	3.6	6.3	8.9	8.2	16.5				**10.1**
5	24.9	7.5	9.5	9.1	12.1	14.3					**13.7**
6	25.3	11.0	10.2	9.2	13.3						**14.7**
7	27.5	11.8	10.7	10.3							**15.6**
8	29.2	12.7	12.2								**16.7**
9	30.1	14.6									**17.8**
10	32.8										**18.9**
11											**19.8**
12											**20.3**
13											**20.7**
14											**20.9**
15											**20.9**
16											**20.9**
17											**20.9**
18											**20.9**
19											**20.9**
20											
area	**32.8**	**14.6**	**12.2**	**10.3**	**13.3**	**14.3**	**16.5**	**2.6**	**0.0**		**20.9**

Table 39a. Comparison of the area under the catch curve (fish/ day) of the 1987-2005 year classes of striped bass from gill nets in the Rappahannock River, 1991-2007.

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	94.3	
11	46.0	51.1	46.0	24.2	16.6	38.1	118.2	74.2	39.0	96.6	
12	46.1	51.2	46.1	24.2	16.6	38.6	118.3	75.0	39.2		
13	46.1	51.2	46.1	24.3	16.6	38.7	118.5	75.6			
14	46.2	51.2	46.1	24.3	16.6	38.7	119.2				
15	46.2	51.2	46.1	24.3	16.6	39.3					
16	46.2	51.2	46.1	24.3	16.6						
17	46.2	51.2	46.1	24.3							
18	46.2	51.2	46.2								
19	46.2	51.2									
20	46.2										
area	**46.2**	**51.2**	**46.2**	**24.3**	**16.6**	**39.3**	**119.2**	**75.6**	**39.2**	**96.6**	

Table 39b. Comparison of the area under the catch curve (fish/ day) of the 1987-2005 year classes of striped bass from gill nets in the Rappahannock River, 1991-2007.

age	year class										mean
	1997	1998	1999	2000	2001	2002	2003	2004	2005		
2	5.9	0.7	0.5	0.3	1.4	2.1	0.2	0.4	1.2		1.1
3	24.0	10.2	1.6	9.1	23.1	6.1	9.4	21.1			20.1
4	51.0	19.0	17.6	25.3	34.9	14.3	40.5				30.3
5	61.2	31.6	28.3	31.9	39.8	22.2					34.4
6	65.8	41.6	30.7	34.7	45.9						37.1
7	76.1	43.5	31.8	38.7							38.7
8	77.5	45.4	34.3								39.9
9	79.1	47.9									40.6
10	81.1										41.0
11											42.2
12											42.3
13											42.4
14											42.5
15											42.5
16											42.5
17											42.5
18											42.5
19											42.5
20											
area	81.1	47.9	34.3	38.7	45.9	22.2	40.5	21.1	1.2		42.5

Table 40a. Comparison of the area under the catch curve (fish/ day) of the 1987-2005 year classes of striped bass from gill nets in the James River, 1994-2007.

age	year class										
	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	
2						0	0.3	0.1	0	0	
3					2.4	4.3	2	1.6	1.2	9.1	
4				12.4	11.4	7.2	6.5	8.7	11.5	82.4	
5			12	23.5	15.9	10.6	11.7	20.4	49.8	115	
6		3.2	21.8	26.6	17.9	13.6	17.8	31.5	58.2	126	
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	
10	5.6	9.1	27.6	31.2	23.9	19.7	23.2	36.7	64.3	137.9	
11	6.3	9.5	27.7	31.7	24.1	20	23.5	37.2	65.3	139.8	
12	7.3	9.6	27.7	31.8	24.3	20.4	23.8	38.2	65.4		
13	7.3	9.6	27.7	32	24.3	20.5	24.9	38.3			
14	7.3	9.6	27.8	32	24.4	20.6	25.3				
15	7.3	9.6	27.8	32	24.8	20.7					
16	7.3	9.6	27.8	32.4	24.8						
17	7.3	9.6	27.9	32.4							
18	7.3	9.6	28								
19	7.3	9.6									
20	7.3										
area	**7.3**	**9.6**	**28**	**32.4**	**24.8**	**20.7**	**25.3**	**38.3**	**65.4**	**139.8**	

Table 40b. Comparison of the area under the catch curve (fish/ day) of the 1987-2005 year classes of striped bass from gill nets in the James River, 1991-2007.

age	year class										mean
	1997	1998	1999	2000	2001	2002	2003	2004	2005		
2	0.1	0.8	0.2	0.2	0.4	0.2	0.5	0.5	0.1		**0.2**
3	21.7	14.3	4	15.7	31	14.9	28.1	12.7			**11.5**
4	64.1	44	35.3	63.7	58.5	51.9	40.5				**35.2**
5	103.4	72.8	63.3	83.6	92.2	60.9					**54.2**
6	111.4	84.6	71	93.4	96.8						**61.1**
7	115.5	89.7	74.9	94.7							**63.7**
8	117.1	92.3	76.3								**65.3**
9	120	93.7									**66.4**
10	122										**67.7**
11											**68.1**
12											**68.4**
13											**68.6**
14											**68.6**
15											**68.7**
16											**68.7**
17											**68.7**
18											**68.7**
19											**68.7**
20											
area	**122**	**93.7**	**76.3**	**94.7**	**96.8**	**60.9**	**40.5**	**12.7**	**0.1**		**68.7**

Table 41a. Back-calculated length-at-age (FL, in mm) for striped bass sampled from the James and Rappahannock rivers during spring, 2007.

Year Class	n	length-at-age (FL, in mm)							
		1	2	3	4	5	6	7	8
2005	1	195.0							
2004	13	179.3	289.2						
2003	19	171.2	285.0	382.5					
2002	20	165.0	275.7	381.9	472.2				
2001	19	156.6	270.7	381.0	483.2	562.2			
2000	16	161.8	273.3	377.2	479.8	573.7	648.4		
1999	16	157.0	260.8	359.5	457.0	548.1	635.4	703.5	
1998	25	155.7	255.9	351.9	445.1	535.0	616.8	686.7	743.2
1997	34	154.4	251.7	346.2	436.9	523.5	606.5	684.3	752.5
1996	94	157.6	251.5	340.6	429.4	513.6	591.3	663.6	731.1
1995	38	156.9	247.3	334.5	419.2	504.9	581.4	653.1	722.8
1994	14	156.1	242.2	334.7	419.0	507.3	586.2	653.8	720.6
1993	5	162.0	254.9	332.2	411.6	494.1	563.2	633.3	696.3
1992	3	162.0	250.7	329.9	419.8	486.2	551.6	618.0	678.6
1991	1	149.7	241.1	326.0	410.9	489.3	561.1	639.5	691.7
all	318	159.4	258.8	351.6	440.3	523.7	599.6	668.3	732.0

Table 41b. Back-calculated length-at-age (FL, in mm) for striped bass sampled from the James and Rappahannock rivers during spring, 2007.

Year Class	n	length-at-age (FL, in mm)							
		9	10	11	12	13	14	15	16
2005	1								
2004	13								
2003	19								
2002	20								
2001	19								
2000	16								
1999	16								
1998	25								
1997	34	807.6							
1996	94	793.6	846.5						
1995	38	786.9	844.3	891.2					
1994	14	779.8	837.9	890.4	930.1				
1993	5	752.3	813.4	871.6	928.1	970.2			
1992	3	736.5	791.3	843.0	890.3	929.6	965.2		
1991	1	753.7	802.7	851.7	894.1	930.1	962.7	1,001.9	
all	318	791.6	842.7	886.4	922.9	952.2	964.6	1,001.9	

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.

S	Otolith Age																					
A	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2	**1**																					
3		**8**	4	1																		
4		1	**18**	0																		
5			9	**5**	4	2																
6			1	2	**8**	7	1															
7					2	**8**	3	1	0	0	1	1										
8						3	**2**	4	5	2	0	0										
9						1	0	**11**	1	11	1	0										
10								3	**4**	24	3	1										
11								2	1	**77**	8	1	3									
12										22	**7**	3	5									
13										2	3	**6**	2	1								
14										2	0	0	**2**	1								
15													1	**2**								
16													0	0	**0**			1				
17																**0**		0				
18																	**0**	0				
19																		**0**		1		
20																			**0**	0		
21																				**0**		
22																					**0**	
23																						**0**

Table 43. Relative contributions of striped bass age classes as determined by ageing specimens (n = 318) by reading both their scales and otoliths.

Age	scale		otolith	
	n	prop	n	prop
2	1	0.0031	1	0.0031
3	13	0.0409	9	0.0283
4	19	0.0597	32	0.1006
5	20	0.0629	8	0.0252
6	19	0.0597	14	0.0440
7	16	0.0503	21	0.0660
8	16	0.0503	6	0.0189
9	25	0.0786	21	0.0660
10	35	0.1101	11	0.0346
11	92	0.2893	140	0.4403
12	38	0.1195	23	0.0723
13	14	0.0440	12	0.0377
14	5	0.0157	13	0.0409
15	3	0.0094	5	0.0157
16	1	0.0031	0	0.0000
17	0	0.0000	0	0.0000
18	0	0.0000	0	0.0000
19	1	0.0031	0	0.0000
20	0	0.0000	1	0.0031
21	0	0.0000	1	0.0031
22	0	0.0000	0	0.0000
	Age = 9.26		Age = 9.58	

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, 1991-2007.

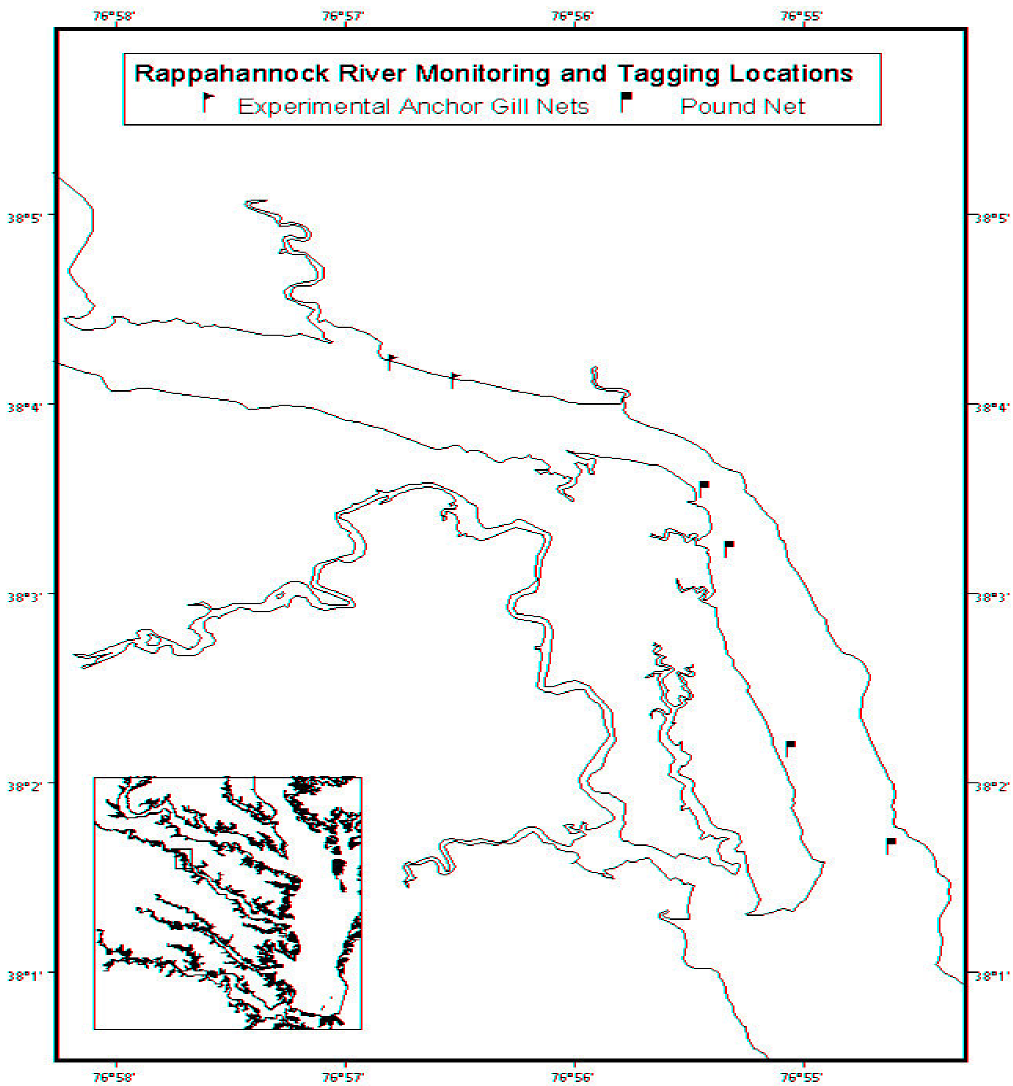


Figure 2. Locations of the experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, springs 2003-2007.

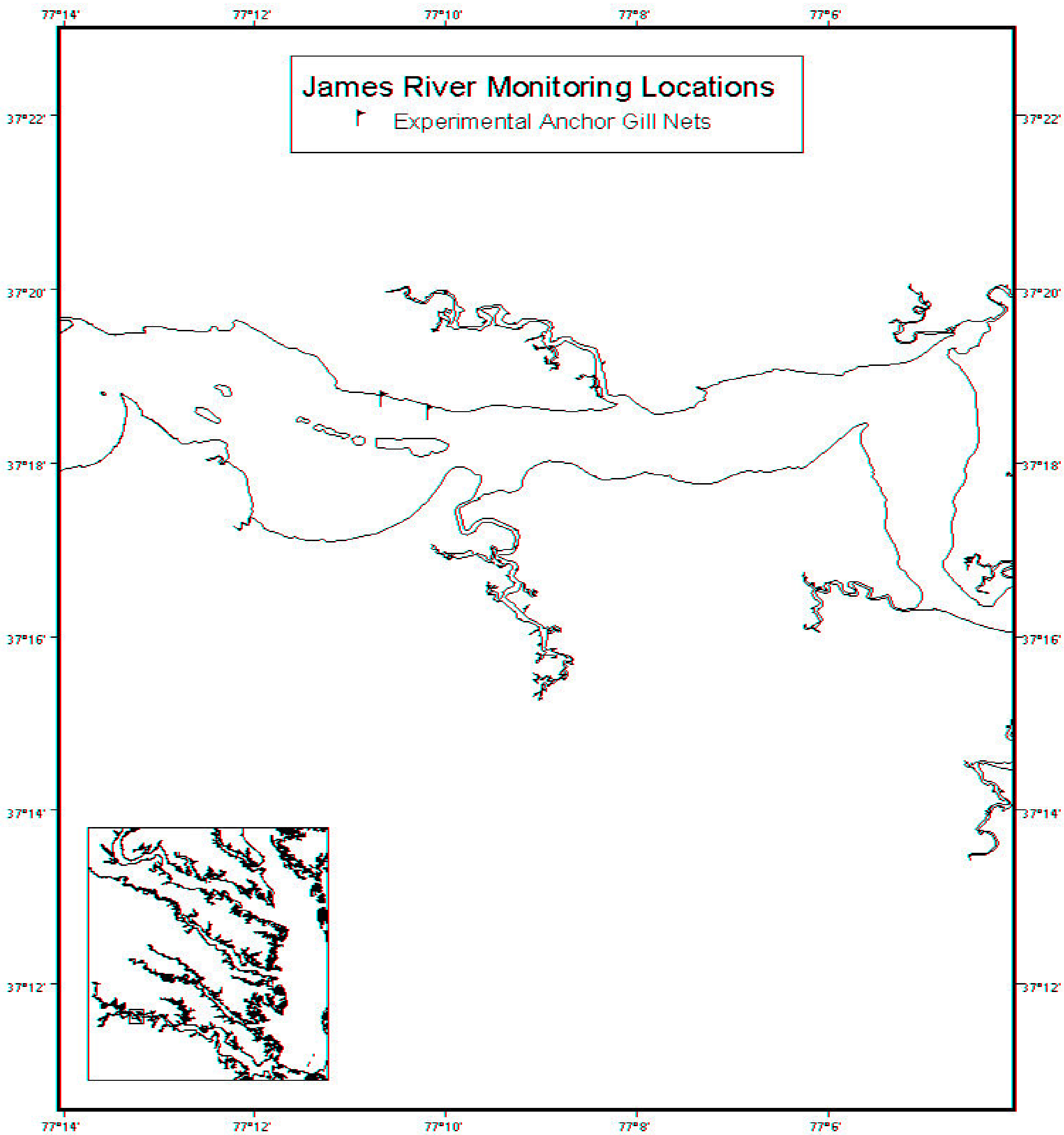


Figure 3. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1987 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2007.

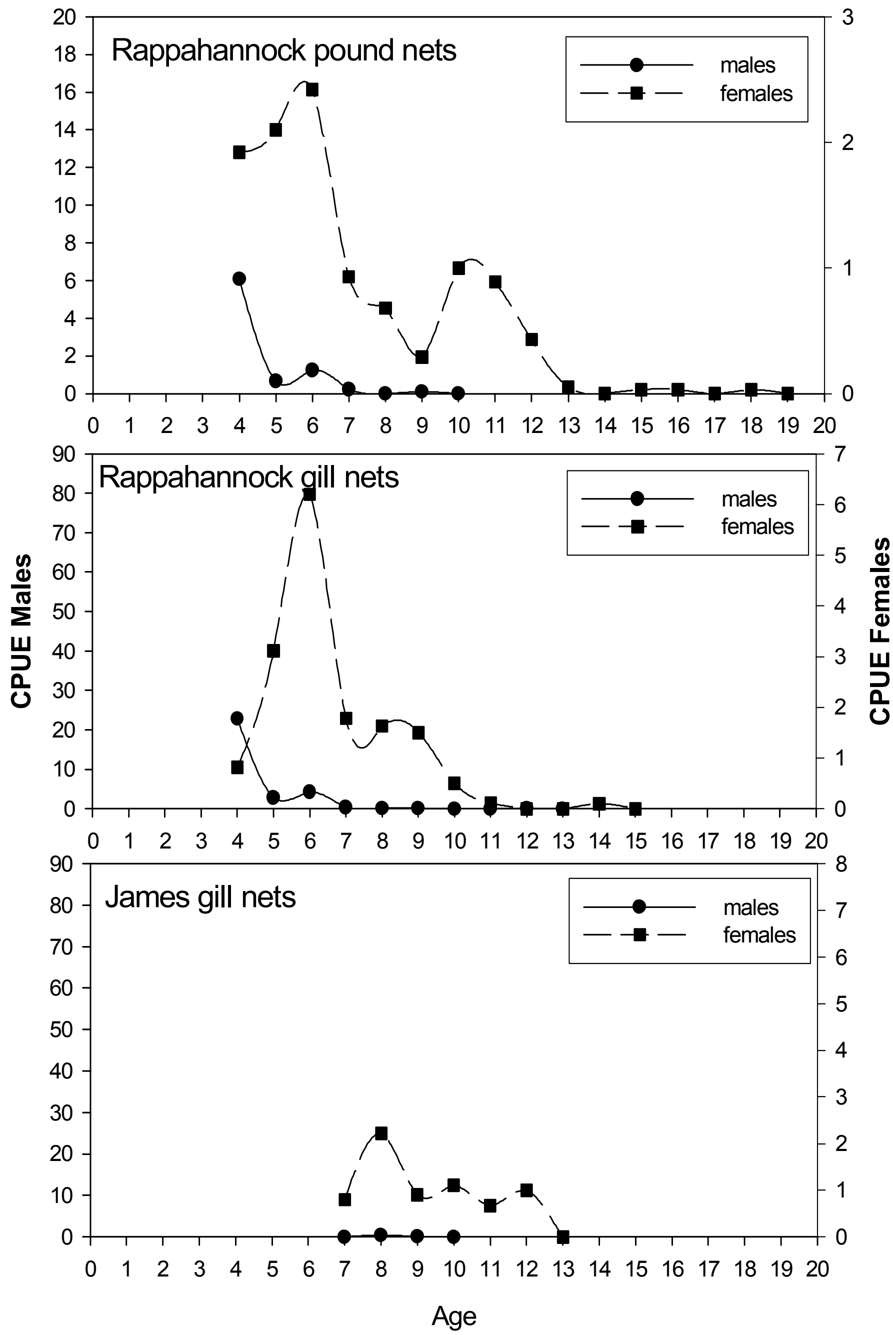


Figure 4. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1988 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2007.

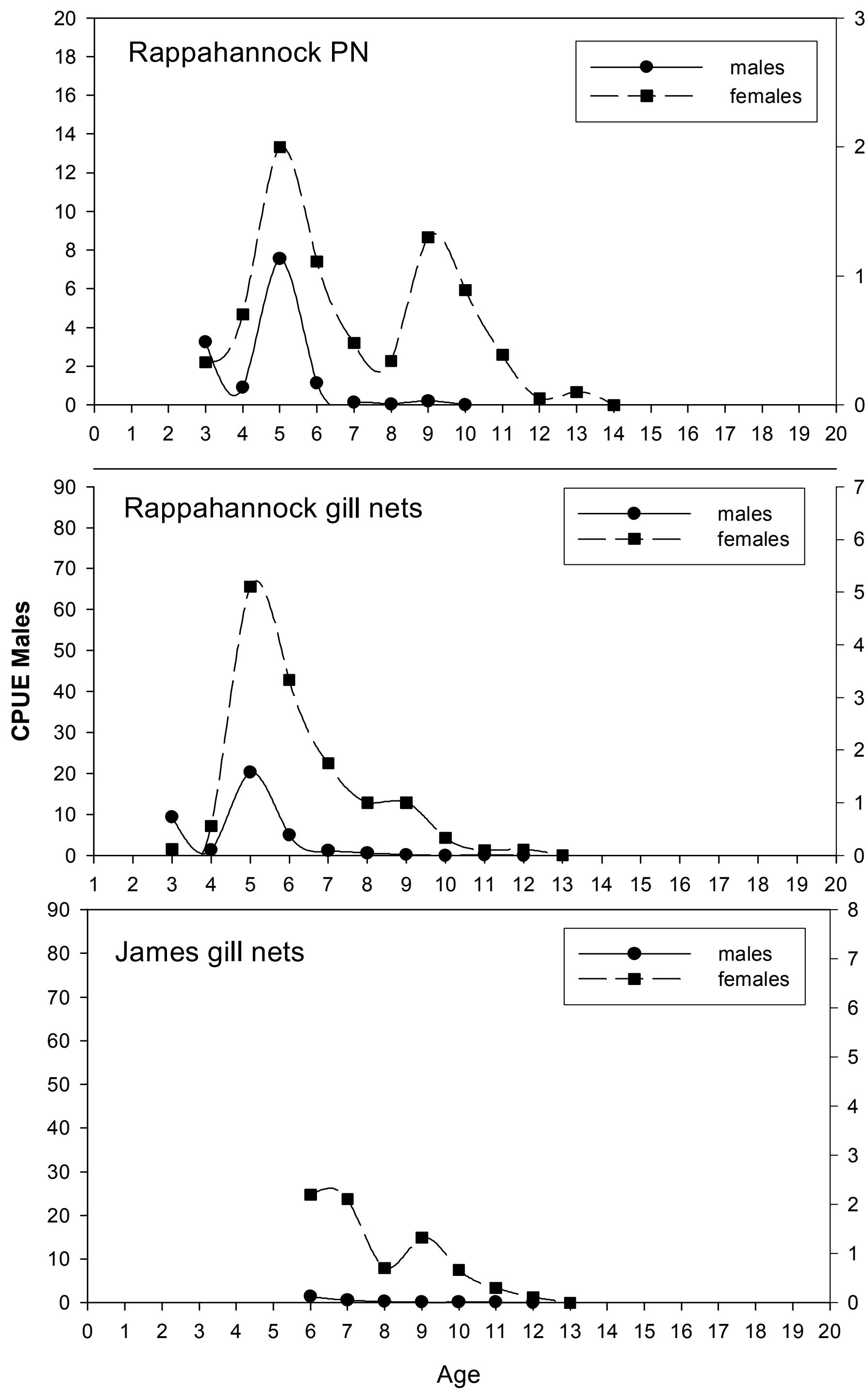


Figure 5. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1989 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2007.

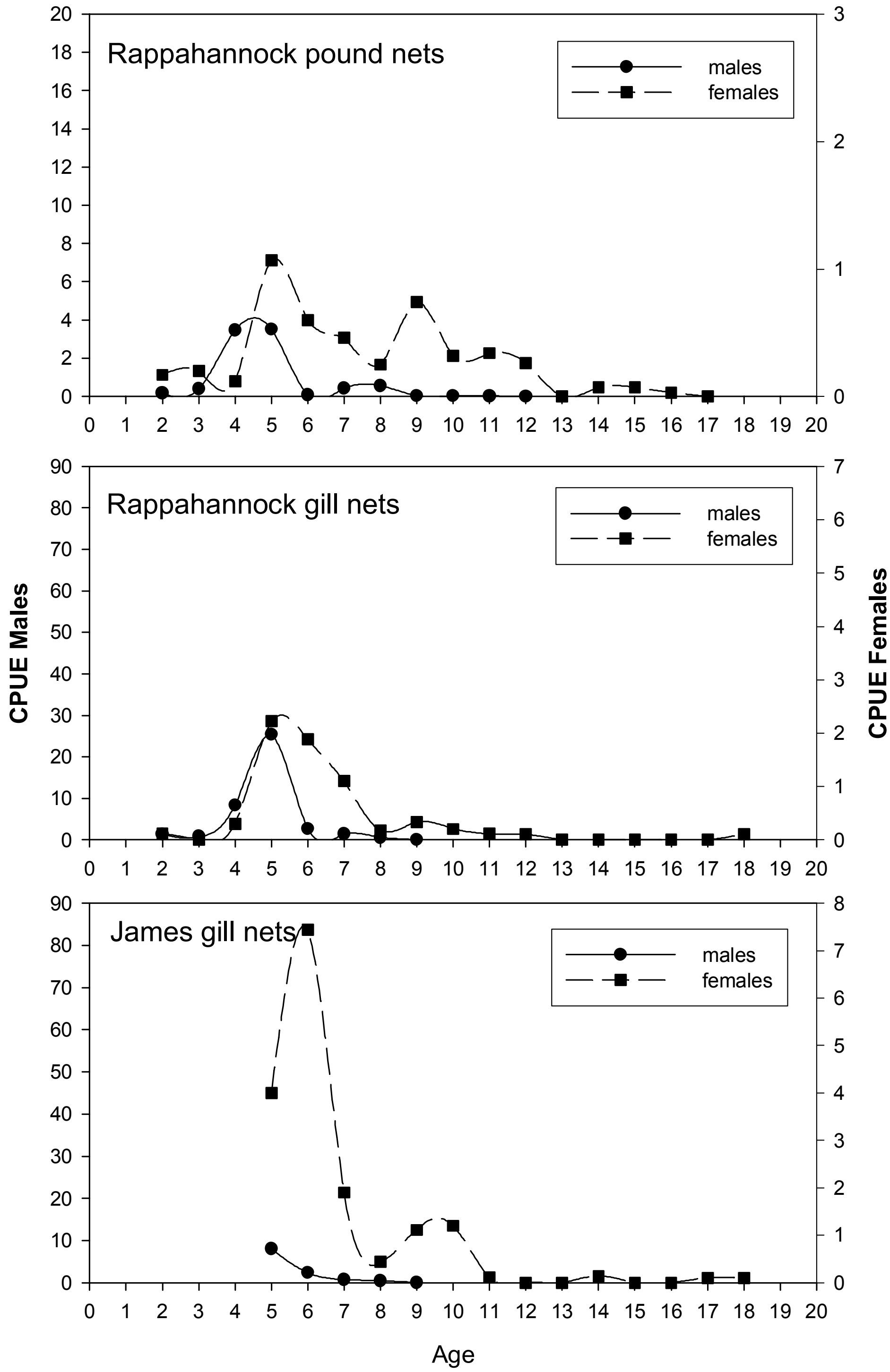


Figure 6. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1990 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1991-2007.

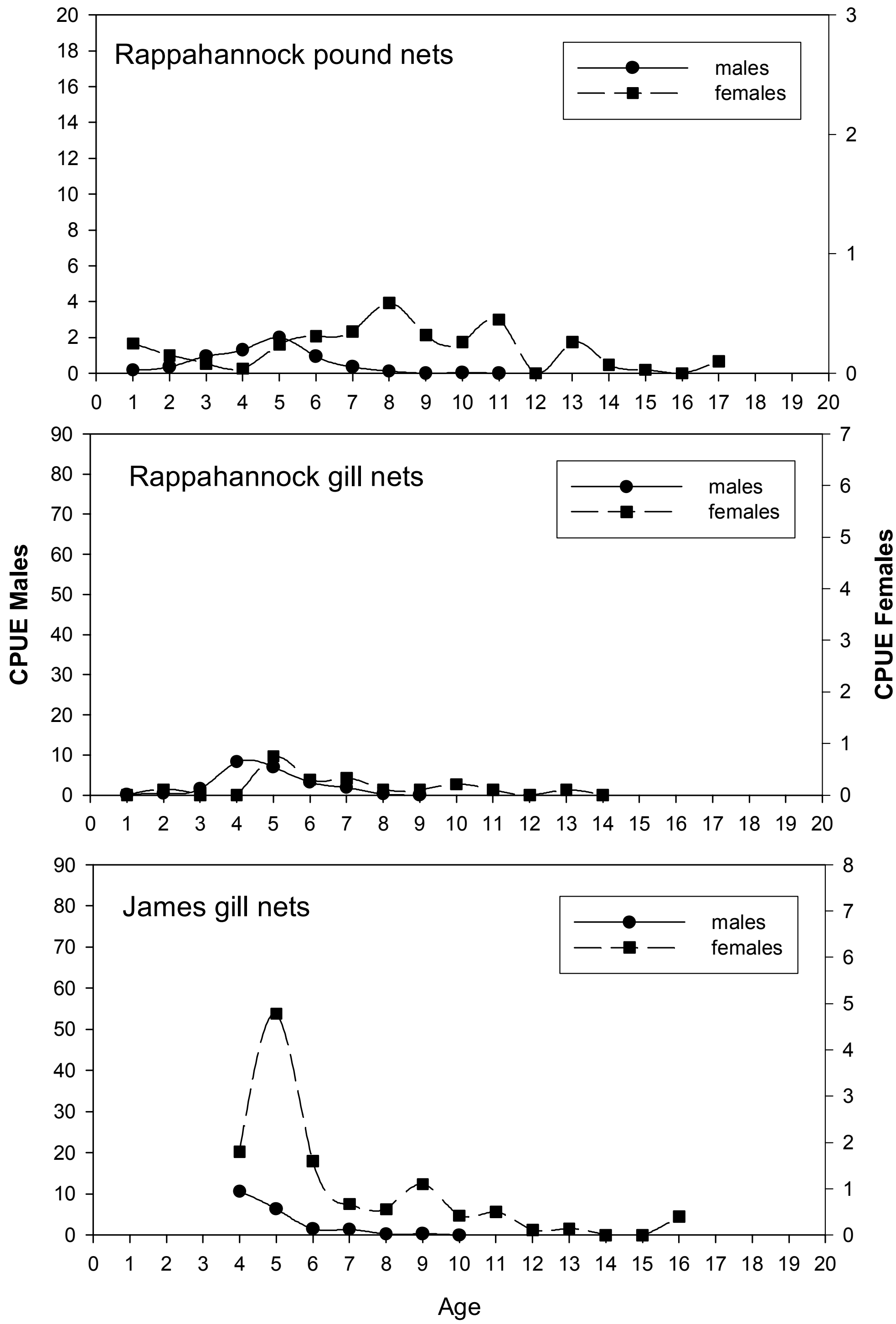


Figure 7. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1991 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1992-2007.

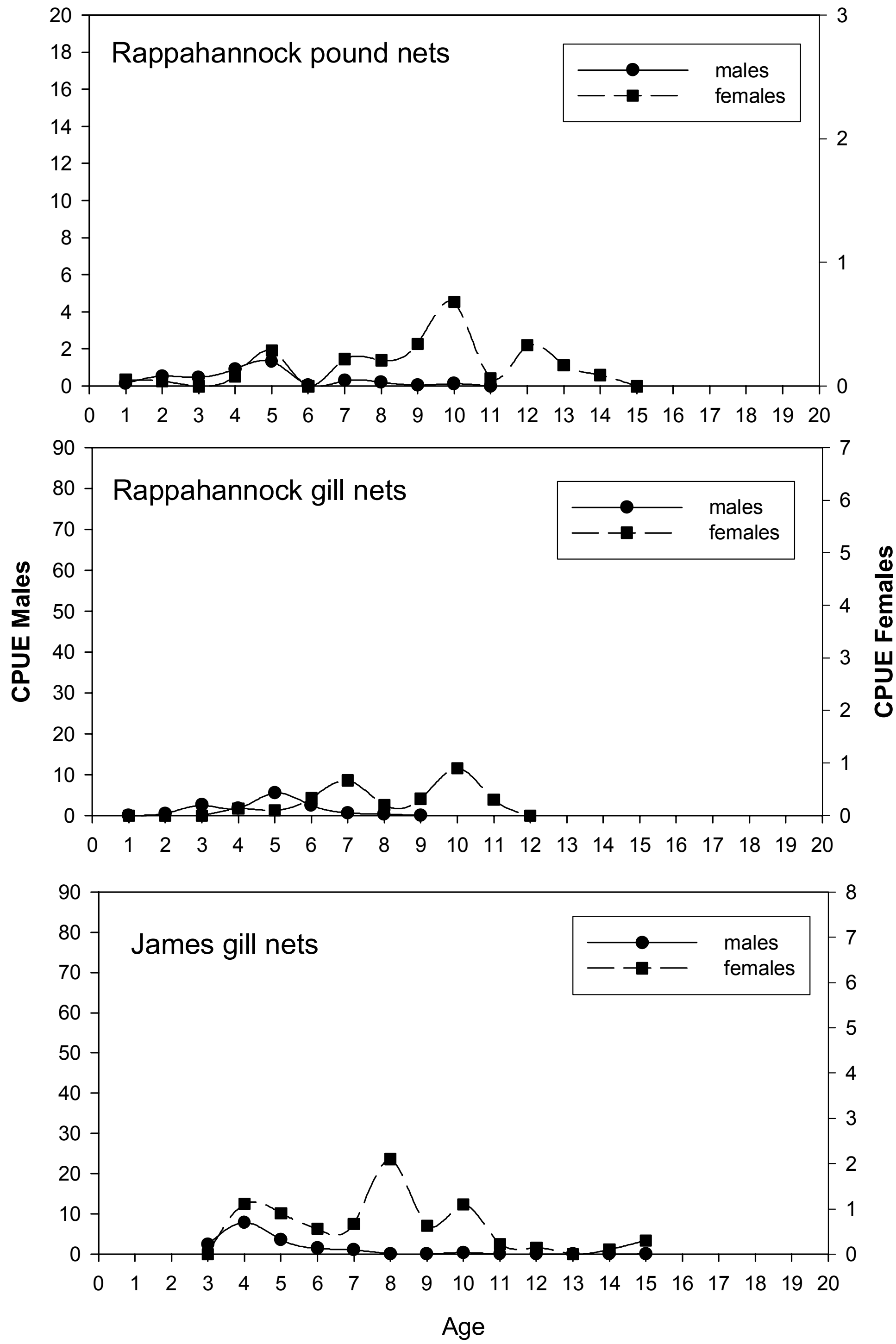


Figure 8. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1992 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1993-2007.

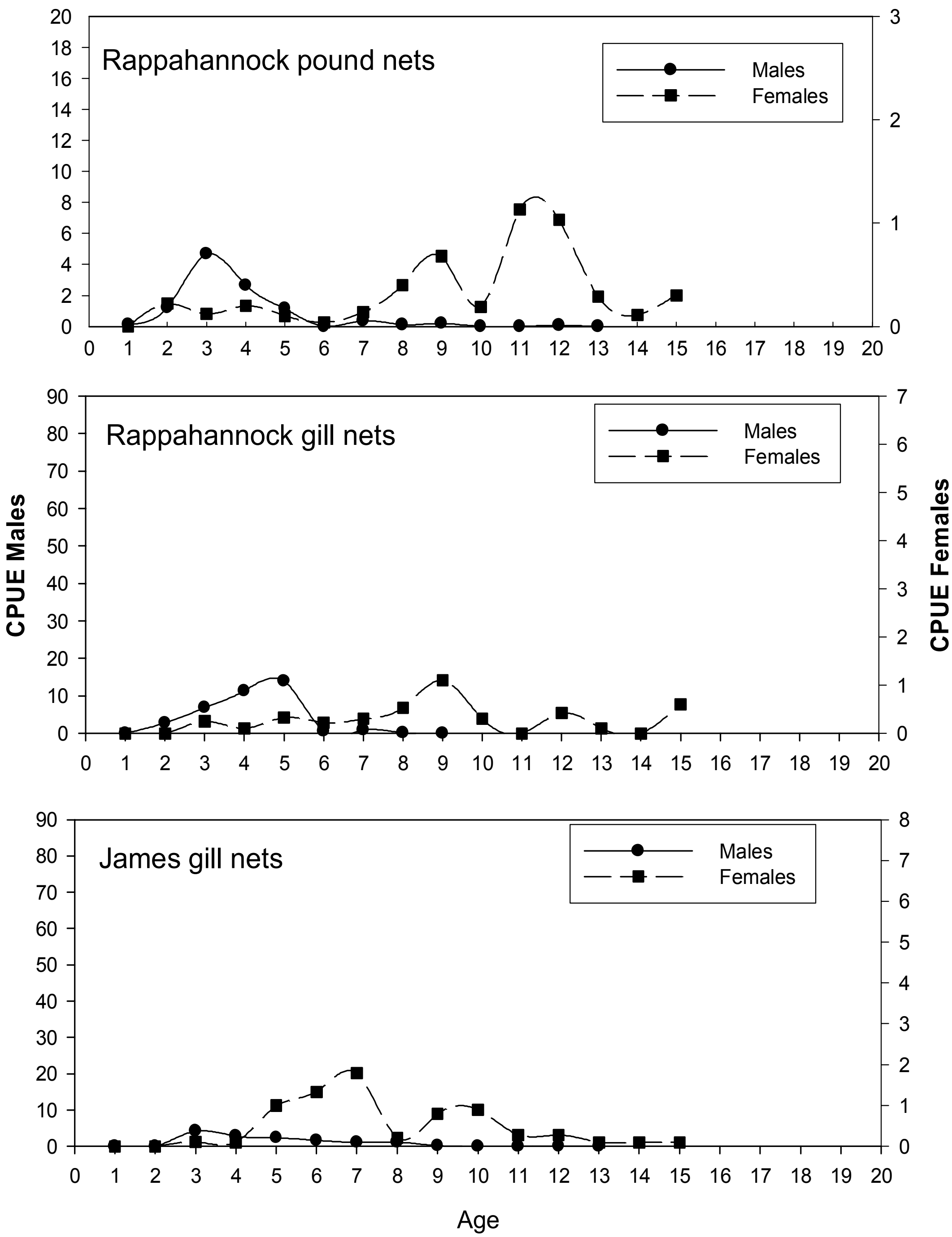


Figure 9. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1993 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1994-2007.

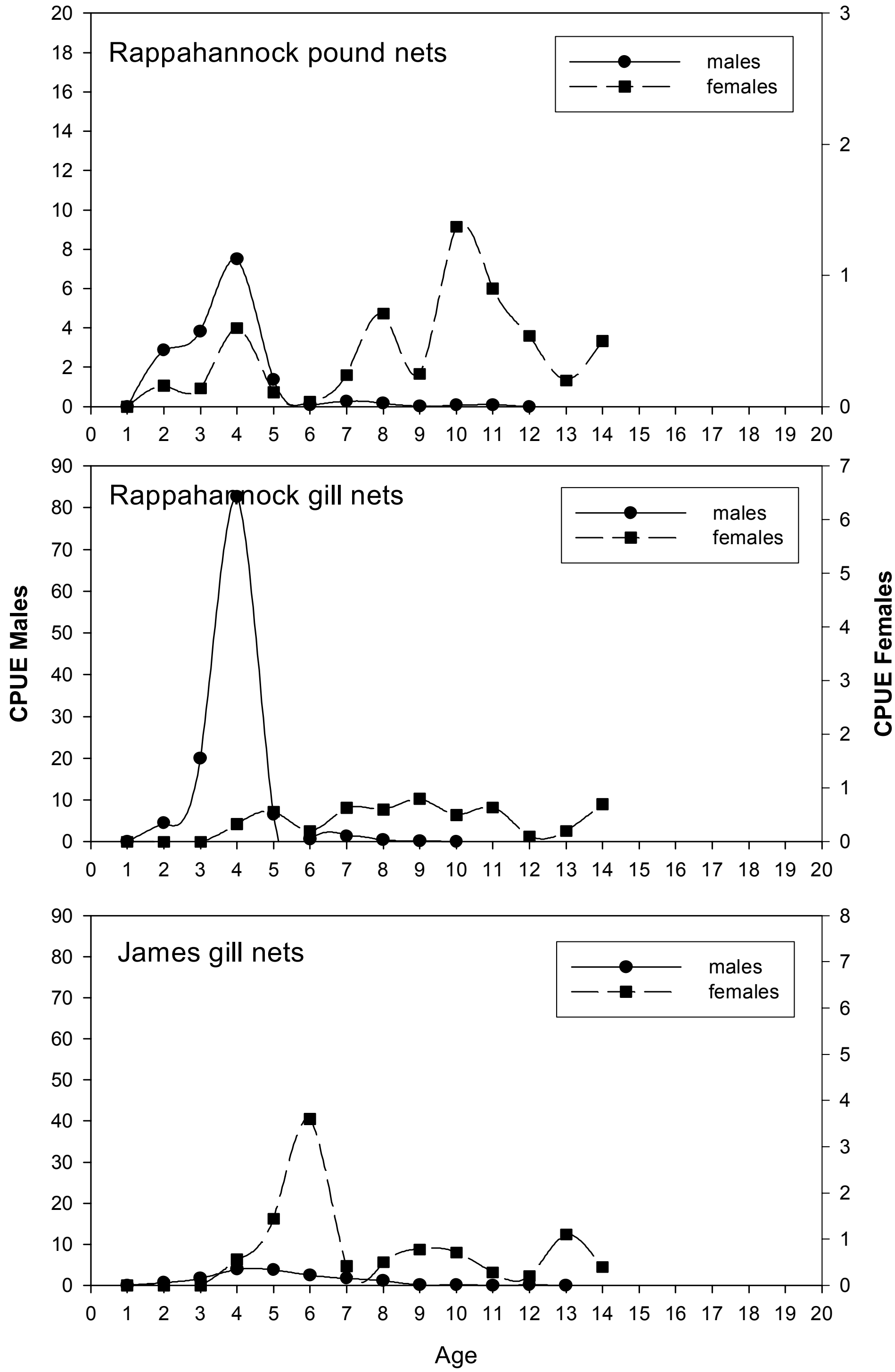


Figure 10. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1994 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1995-2007.

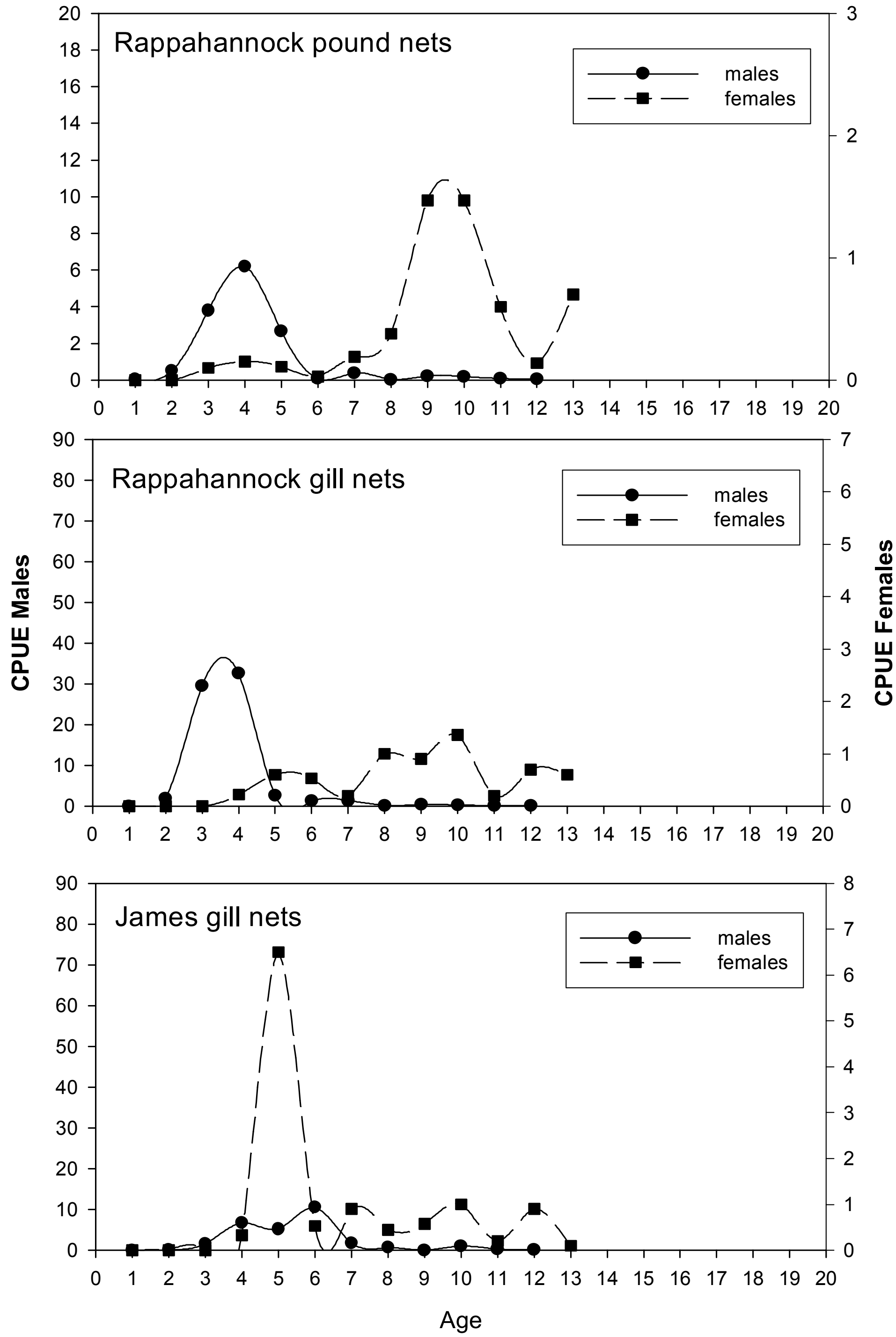


Figure 11. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1995 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1996-2007.

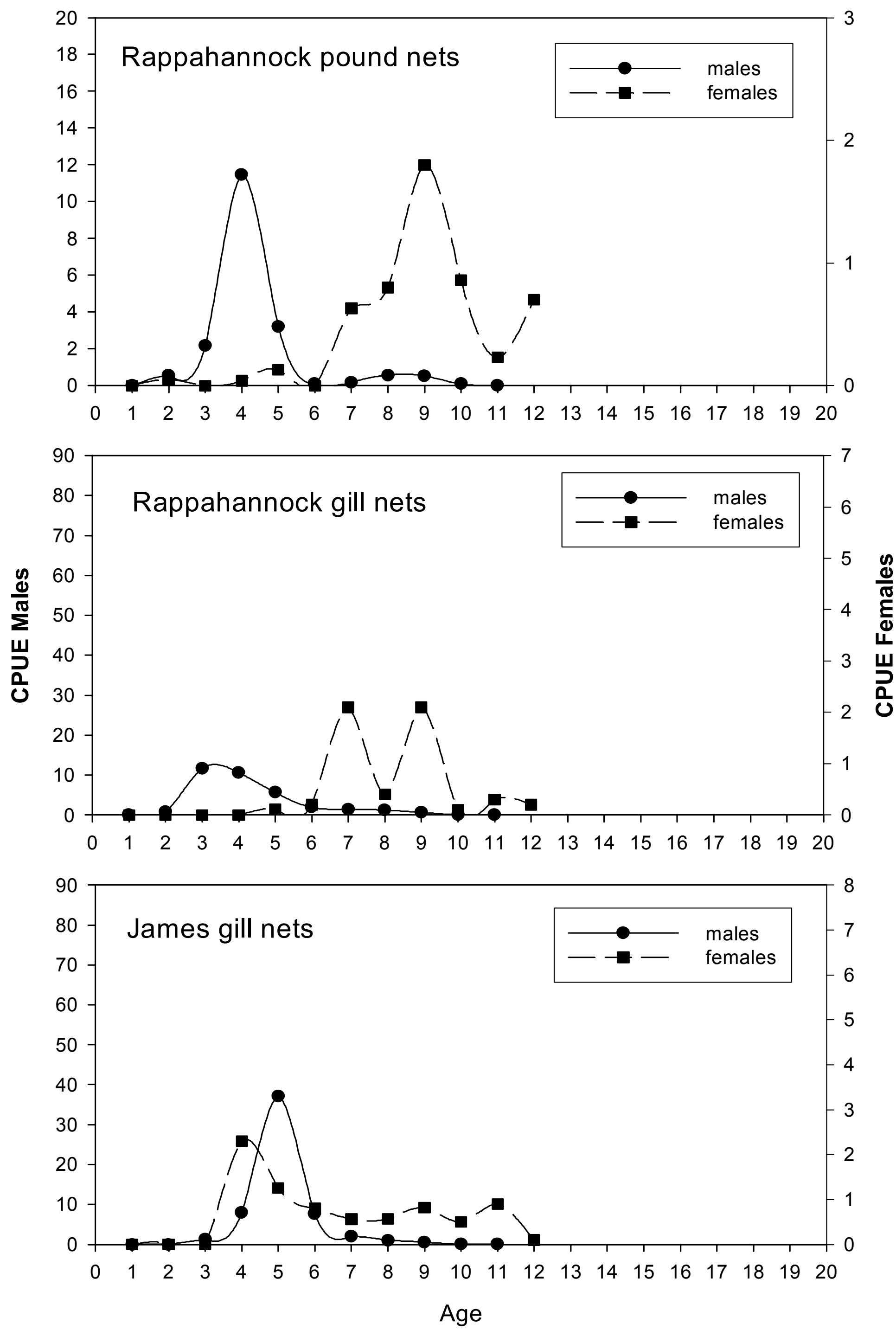


Figure 12. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1996 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1997-2007.

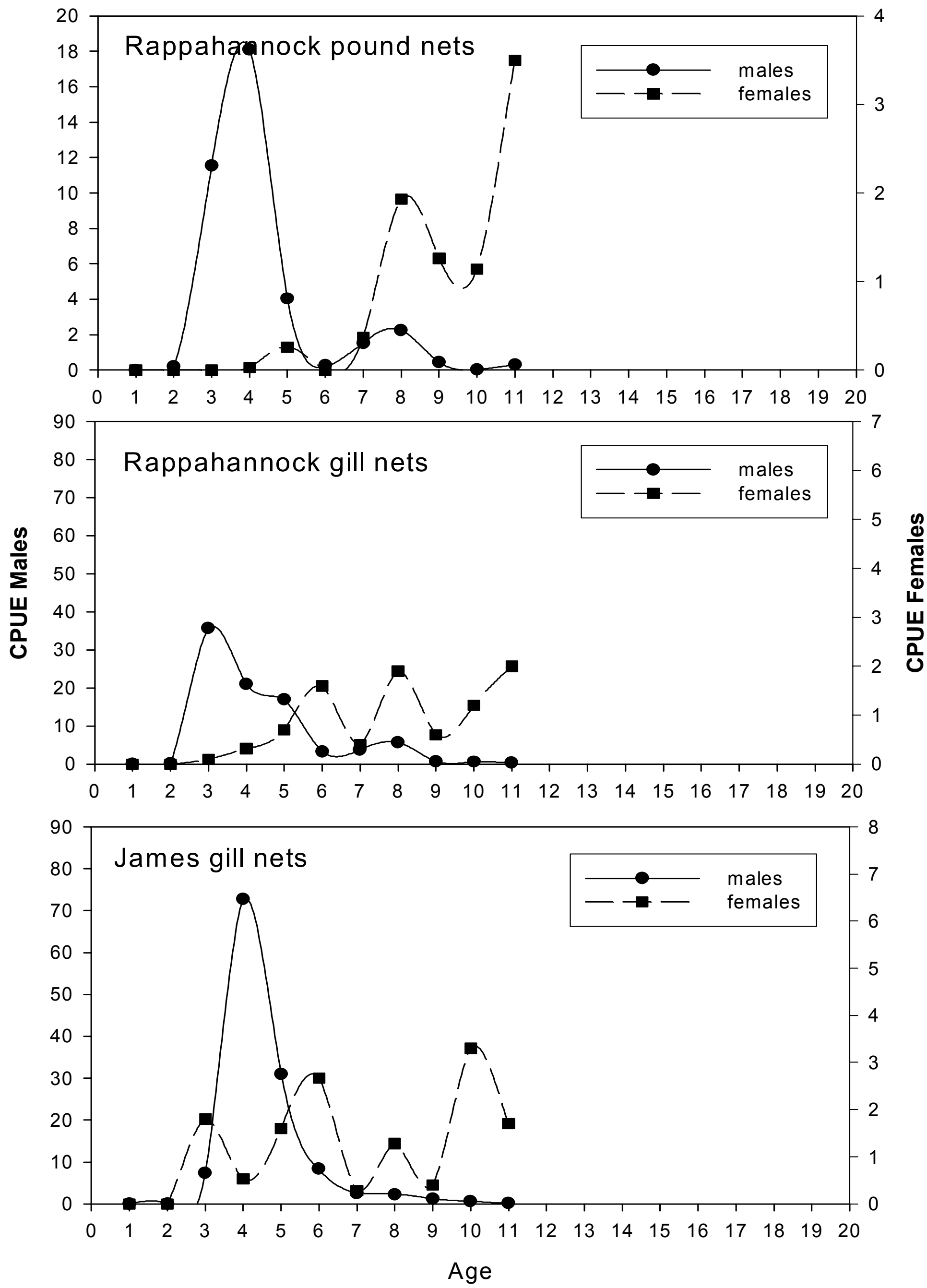


Figure 13. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1997 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1998-2007.

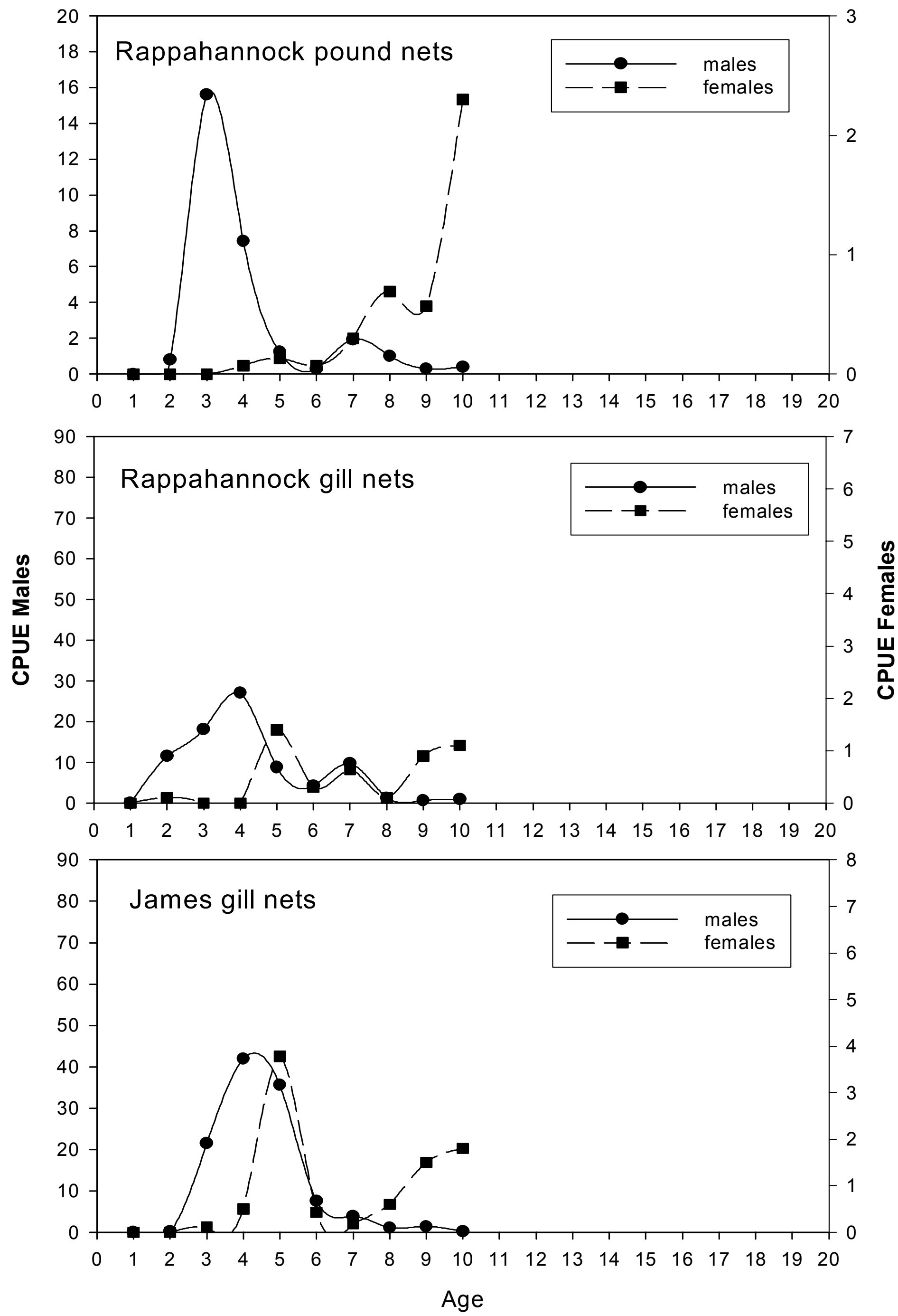


Figure 14. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1998 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1999-2007.

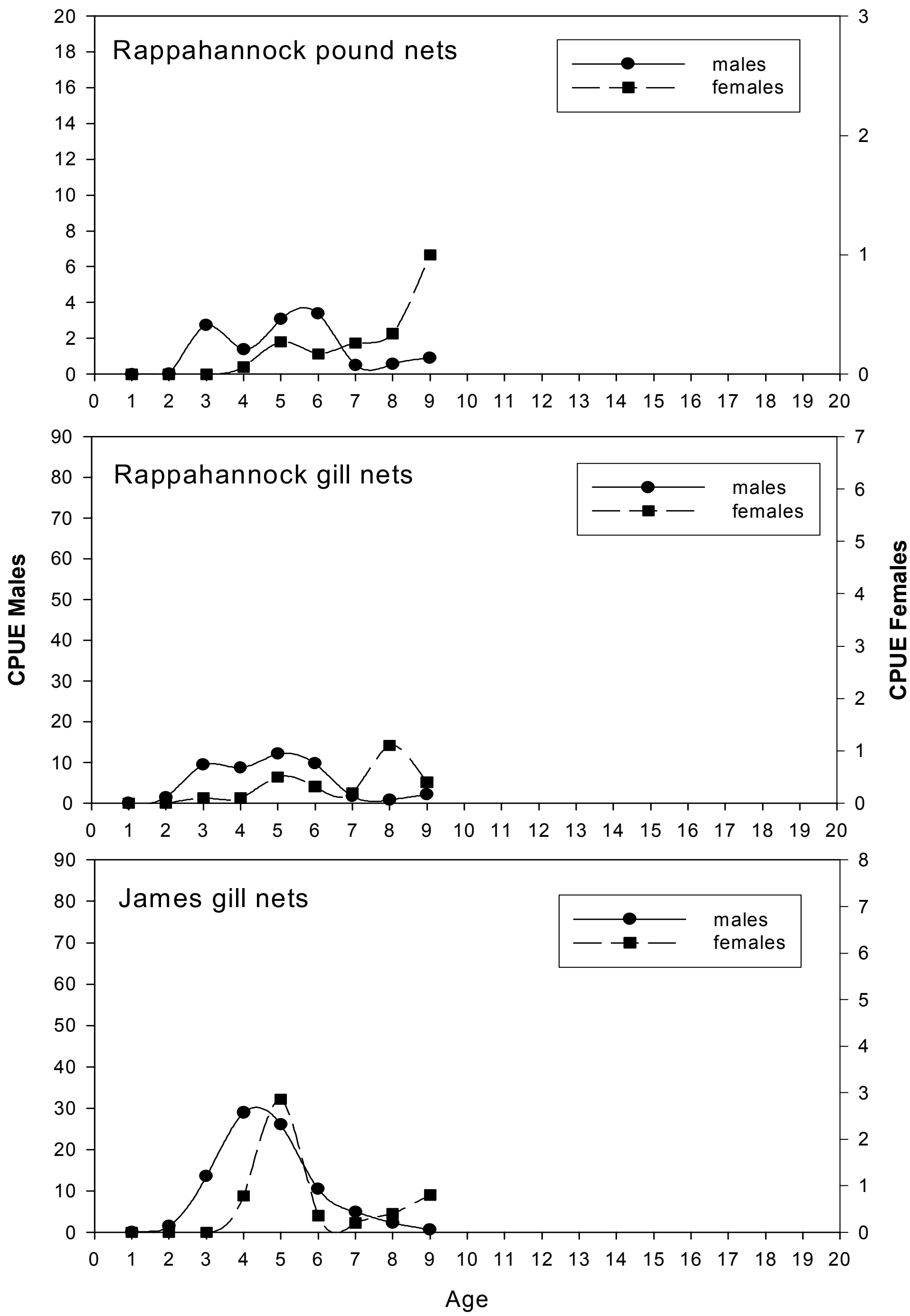


Figure 15. Age-specific catch-per-unit-effort (CPUE, fish/day) of the 1999 year class of striped bass from the Rappahannock (pound nets and experimental gill nets) and James (experimental gill nets) rivers, spring, 1999-2007.

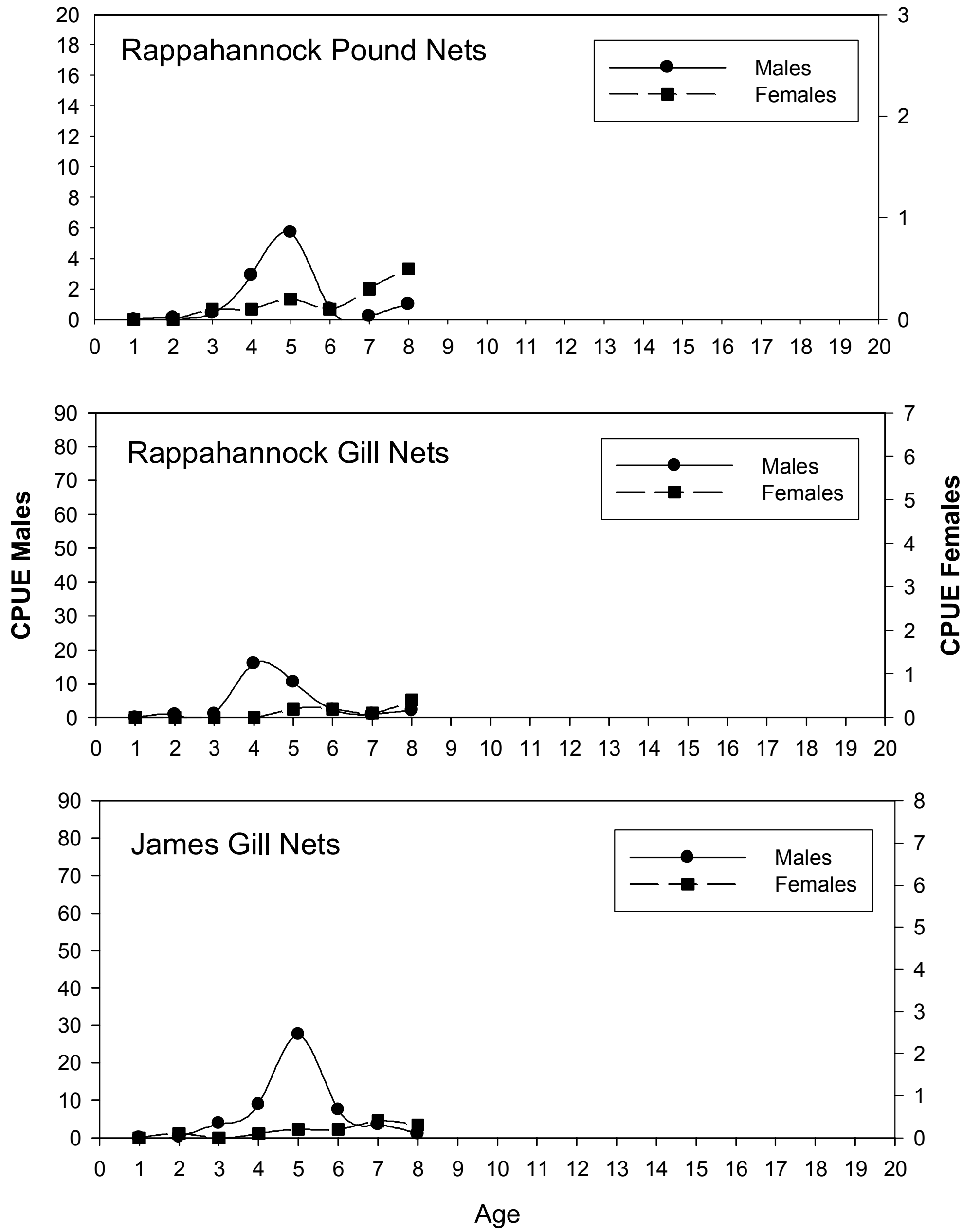
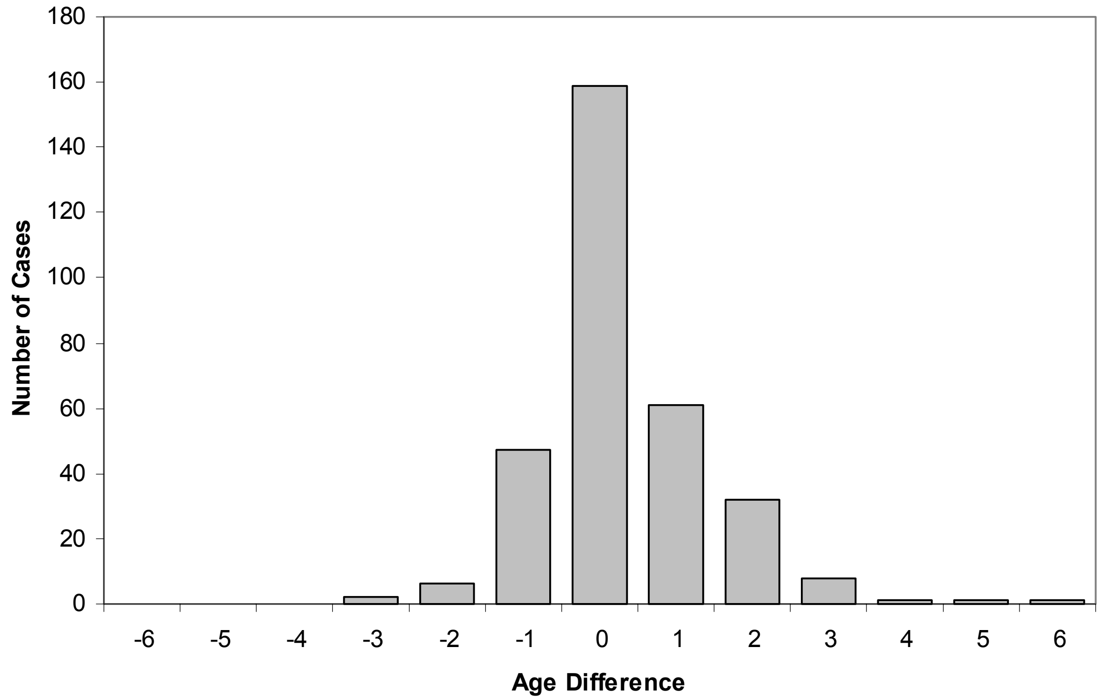


Figure 16. Magnitude of the age differences (otolith age – scale age) resulting from ageing specimens of striped bass (n=318) by reading both their scales and otoliths, spring, 2007.



II. Mortality estimates of striped bass (*Morone saxatilis*) that spawn in the Rappahannock River, Virginia, spring, 2006-2007.

Striped Bass Assessment and Monitoring Program
Department of Fisheries Science
School of Marine Science
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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.

This section is an update to material provided by Sadler et al. (2001). They 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, $J \geq I$). Tagging periods do not necessarily have to be yearly intervals; however, data analysis is easiest if all periods are the same length and all tagging events are conducted at the beginning of each period.

Application of tagging models involves constructing an upper triangular matrix of expected values and comparing them to the observed data. Since the recovery data over time for each year's batch of tagged fish 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. For the 2006 estimates the updated version of MARK (version 4.3) replaced the version used in previous years (version 4.2).

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

$$Z = -\log_e(S) \qquad (3)$$

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. For striped bass, a Type II (continuous) fishery is assumed. Note that ϕ and λ are considered constant over time.

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 handling mortality 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 (e.g., 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 2007, 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 pound net. 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: The ASFMC Striped Bass Tagging Subcommittee established a data analysis protocol that involves deriving survival estimates from a suite of Seber (1970) models. The protocol is used by each state and federal agency participating in the cooperative tagging study. Tag recoveries from striped bass 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). For the 2006 analysis, the last regulatory period (2000-present in previous years), was redefined as two periods (2000-2002 and 2003-present) to reflect the adoption of the latest amendment to the Federal Management Plan (FMP). 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)r(t)	Survival rates vary by regulatory periods (p=constant 1990-1994, 1995-1999, 2000-2002 and 2003-2006) and tag-recovery rates are time-specific.
S(p)r(p)	Survival and tag-recovery rates vary by regulatory period.
S(.)r(p)	Survival rate is constant and tag-recovery rates vary by regulatory periods.

S(t)r(p) Survival rates are time-specific and tag-recovery varies by regulatory periods.

S(d)r(p) Survival and tag-recovery rates vary over different regulatory periods (d= constant 1990-1994, 1995-1999, 2000-2002, 2003-2005 and 2006).

S(v)r(p) Survival and tag-recovery rates vary over different regulatory periods (v= constant 1990-1994, 1995-1999, 2000-2002, 2003-2004, 2005 and 2006).

The following models were eliminated from the analyses this year after an evaluation by the Tagging Subcommittee found that they were not producing meaningful results:

S(Tp)r(Tp) Survival and tag-recovery rates have linear trends within regulatory periods.

S(Tp)r(p) Survival rates have a linear trend within regulatory periods and tag-recovery rates vary by regulatory period.

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

S(p_1)r(p_1) Survival and tag-recovery rates vary over regulatory periods (p_1= constant 1990-1992, 1993-1994 and 1995-2006).

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.

Estimates of Exploitation and Fishing mortality rates of resident striped bass

Exploitation rate (R/M) method: Estimates of the exploitation rate (μ) are calculated by the recapture rate adjusted for the reporting rate:

$$\mu = R_k + R_r * 0.08 / (\lambda M)$$

where R_k is the number or recaptures kept with tags, R_r is the number of fish released with tags, λ is the reporting rate (0.64) and M is the number of tagged striped bass released. The exploitation rate is then used to calculate the estimate of fishing mortality (F) by solving the following equation for *F*:

$$\mu = F / (F + M) * (1 - \exp(-M - F))$$

where natural mortality (M) is assumed to be 0.15. Other adjustments are made for tag-induced mortality (0.013) and hook-and-release mortality (0.08).

Catch equation method: Fishing and natural mortality can be estimated from the tagging data using the above described relationship between exploitation rate, fishing mortality and natural mortality. This can be rewritten as:

$$F = \mu / (S-1) * \ln(S)$$

Survival (S) is estimated from the tagging data using the MARK models used with the estimate of μ to determine F.

Instantaneous rates method: This method (defined in the multi-year tagging methods section) allows the estimate of natural mortality to be constant, or to vary by periods. Three scenarios were analyzed, based of the ASMFC tagging subcommittee recommendations: Constant natural mortality, two periods of differing natural mortality (1988-1997 and1998-2006) and three periods (1988-1996, 1998-2000 and 2001-2006).

Results

Spring 2007 Tag Release summary

A total of 1,960 striped bass were tagged and released from the pound nets in the Rappahannock River between 26 March and 3 May, 2007 (Table 1). There were 1,120 resident striped bass (457-710 mm TL) tagged and released. These stripers were predominantly male (96.2%), but the female stripers were larger on average. The median date of these tag releases, to be used as the beginning of the 2006-2007 recapture interval, was 19 April. There were 840 migrant striped bass (>710 mm TL) tagged and released. These stripers were predominantly female (71.0%) and their average size was larger than for the male striped bass. The median date of these tag releases was 19 April.

Mortality Estimates, 2006-2007

Tag recapture summary: A total of 48 (out of 668) striped bass (>458 mm TL), tagged during spring 2006, were recaptured between 24 April, 2006, and 18 April, 2006 (the respective midpoints of the two tag release totals), and were used to estimate mortality. Twenty seven 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 1991-2007 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, 47 striped bass tagged in previous springs were recaptured during the 2006-2007 recovery interval and were used to complete the input data matrix. The largest source of recaptures (63.5%) in the 2006-2007 recovery interval was Chesapeake Bay (44.2% in Virginia, 19.2% in Maryland, Table 3). Other recaptures came from Massachusetts (12.5%), New York (8.7%), New Jersey (7.7%), North Carolina (4.8 %), and Connecticut (2.9%). There were no recaptures from Rhode Island, Delaware or Maine. The primary peak of recaptures was in May through July, with a secondary peak from October through December. However, there were recaptures in every month of the year.

A total of 12 (out of 175) migratory striped bass (>710 mm total length), tagged during spring 2006, were recaptured between 14 April, 2006, and 18 April, 2006 (the 2006-2007 recovery interval) and were used to estimate the mortality of this sub-group. Ten of these recaptures were harvested (83.3%), and the rest were re-released into the population (Table 4). The proportion of tagged striped bass recaptured from 1991-2007 in their first year after release varied from 0.015 (1/67) to 0.152 (24/158). In addition, 26 striped bass tagged in previous springs were recaptured during the recovery interval and were used to complete the input data matrix. The largest source (25.0%) of the recaptured tagged striped bass was Massachusetts (Table 5), followed by Chesapeake Bay (22.7%, 15.9% in Virginia and 6.8% in Maryland). Other recaptures came from New York (20.5%), New Jersey (13.6%), North Carolina (11.4%), and Connecticut (6.8%). The peak month for recaptures was July, but some migrant striped bass were recaptured from every month of the year.

ASMFC protocol: Survival estimates were made utilizing the mark-recapture data for the Rappahannock River from 1990-2006. The suite of Seber (1970) models consisted of nine 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. Models that allowed trends within periods and Virginia-specific models for the transition from a partial to an open fishery were eliminated for the 2006 analyses after the ASMFC tagging subcommittee determined that they only poorly evaluated the data and carried no weight in the model averaging for multiple years.

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.). However, in 2004-2006, the S(t) R(t) was the only model to fit the data (Table 6). The 2006 *F* estimate was 0.45, the *S* estimate was 0.55, 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 nine proposed models, only four, the S(v)r(p), S(p)r(p), S(d)r(p) and the S(.)r(p) 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. In contrast, in the 2004 analysis, eight models fit this criterium. 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 0.546-0.761 over the time series (Table 9). The 2006 survival estimate (0.66) was slightly higher than the estimate for 2005. 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 0.123-0.449 and only infrequently exceeded the transitional and full fisheries target values.

Four periods vs. three periods models: The redefinition of the terminal period from 2000-present to 2000-2002 and 2003-present greatly affected the estimates of survival and fishing mortality. Both the ranking and the relative weights of the models were greatly affected (Table 10). For example, in 2006 both MARK analyses ranked the S(v)r(p) the highest, but the relative weighting varied (0.675 for the four regulatory period vs. 0.978 for the three regulatory period versions) while using the same input data matrix. Since the four period analyses were adopted by the tagging subcommittee as the standard, this resulted in very different estimates of S and F than has been reported in previous years (Table 11). This had little effect on the 2006 estimates, but the new analysis resulted in F estimates that greatly exceeded the target value of 0.30 for the years 2003 and 2004. A reanalysis of the data through 2005, using both regulatory criteria, both resulted in the same model being ranked highest (S(d)r(p)), but also had significant differences in the overall rankings and weightings of the models (Table 10) and in the estimates of survival and fishing mortality (Table 11). It will be necessary to further evaluate the two versions before the reasons and significance of the results can be resolved.

Estimates of Exploitation and Fishing Mortality of resident striped bass

Tag recapture summary: There were 33 recaptures (of 461 tagged) of resident striped bass (males, 457-711 mm TL) recaptured within Chesapeake Bay between 1 April, 2006 and 31 March, 2007. An additional 19 recaptures from striped bass tagged during springs 1990-2005 were recaptured. Twenty seven of these recaptures were harvested (81.8%). These data were provided to Maryland Department of Natural Resources to produce separate (Virginia and Maryland) and combined estimates of F (Sharov, 2007).

MARK method: These data were input into the MARK input matrix (Table 12) and M is assumed to be 0.15. The MARK results of the nine models gave 100% of the weight to the S(t)r(t) model (Table 13). This gave an estimate of F for 2006 of 2.8 (Table 12).

Catch equation method: The S estimates from the MARK output and estimates of exploitation produced F estimates that ranged from 0.06-0.26 (Table 14). Excepting the 1992 value the range was 0.06-0.21. The estimates of M ranged from 0.00-2.84.

R/M method: The estimates of F ranged from 0.00-0.18 (Table 15). It should be noted that the 1992 value resulted from a very low release total (31) and is suspect. The range for all other years is 0.00-0.09. Natural mortality is assumed to be 0.15 in this analytical approach.

Instantaneous rates method: The three approaches (constant M, two separate and three separate periods of constant M) all produced estimates of F that ranged from 0.00-0.10 (Table 15) but produced quite different estimates of M. The constant M approach produced an intermediate, averaged estimate of 0.58. The two periods approach produced M estimates that rose from 0.35 prior to 1997 and 0.90 thereafter. However, the three periods approach produced post-1997 estimates that rose to 0.99 from 1997-2000, but then fell back to 0.81 thereafter.

Model Evaluations

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

For the time-specific Seber (1970) model, Latour et al. (2002) proved the existence of several characteristics about the residuals. Specifically, they showed that row and column sums of the residuals matrix must total zero, and further, they showed that the residuals associated with the “never seen again” category must also always be zero 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)r(t), S(t)r(p), 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 2006-2007 was 0.659. The survival estimate for 2006 is lower than estimated for 2005, but was near the median (0.661) of the 17 year time series. The estimate of fishing mortality for 2006-2007 was 0.266, was also near the median (0.269) in the time series. The estimates of fishing mortality from 1990-2006 varied from 0.123-0.456 and, prior to the new analyses this year, had exceeded the ASMFC threshold of 0.30 only in 1996 and 1997. The adoption of a redefined final regulatory period into two separate regimes resulted in fishing mortality estimates of 0.449 and 0.456 for 2003 and 2004 respectively. These estimates are far greater than previous estimates for these years. Since the four regulatory period based analyses were newly adopted this year, they have not been fully evaluated and these values should be viewed cautiously until validated. We intend to further investigate these models in the coming year.

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. In 2005 and 2006 specialized variants of the regulatory models, creating a separate period for the final (d model) or each of the final two (v model) years received the highest weighting.

Our analyses of the resident striped bass are problematic. The 2006-2007 estimates of survival (0.551) and fishing mortality (0.445) 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 (1.000 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 of the trend model to the data in the original analysis, we have little confidence in the result. We intend to investigate the problems in the analyses and their causes 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, and they can be used to obtain estimates of current mortality rates. 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).

The estimate of the exploitation rate for Chesapeake Bay in Virginia was 0.06 and the corresponding fishing mortality was 0.06. When combined with the Maryland and Potomac River data, the bay-wide value was 0.08. When non-harvest mortality is considered the estimate for 2006 is 0.18. The instantaneous rates models and the catch equation model gave estimates of F that ranged from 0.15-0.25. These are all below the target of 0.27 set by the ASMFC.

Literature Cited

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Hoenig, J.M., N.J. Barrowman, K.H. Pollock, E.N. Brooks, W.S. Hearn and T. Polacheck. 1998b. Models for Tagging Data that Allow for Incomplete Mixing of Newly Tagged Animals. Can. J. Fish. Aquat. Sci. 55:1477-1483.

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

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

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

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

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

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

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

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

Seber, G.A.F. 1970. Estimating time-specific survival and reporting rates for adult birds from band returns. Biometrika, 57: 313-318.

Sharov, A. and P.W. Jones. 2003. Estimation of the fishing mortality rate of resident striped bass in the Chesapeake Bay using spring tagging data. Report to the Atlantic States Marine Fisheries Stock Assessment Committee. 9pp.

Sharov, A. 2007. Estimation of Striped Bass Fishing mortality in Chesapeake Bay. Report to the Atlantic States Marine Fisheries Stock Assessment Committee. 15pp.

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

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

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

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

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

Table 1. Summary data of striped bass tagged and released from pound nets in the Rappahannock River, spring 2007.

Date	Total Tagged	457 - 711 mm TL				>711 mm TL			
		males		females		males		females	
		n	*TL*	n	*TL*	n	*TL*	n	*TL*
26 March	159	143	507.5	1	519.0	5	802.8	10	924.5
29 March	121	89	508.0	0		8	834.9	24	927.3
2 April	89	58	521.8	2	520.0	13	807.0	16	904.9
5 April	71	30	536.2	1	633.0	11	809.5	29	929.6
9 April	227	121	522.5	1	604.0	25	831.6	80	938.3
12 April	179	97	530.5	2	522.5	26	837.0	54	938.6
19 April	297	142	541.0	7	573.0	35	803.7	113	931.3
23 April	90	31	514.2	6	562.3	14	823.6	39	917.7
26 April	216	64	527.3	10	563.0	23	800.2	119	922.1
30 April	358	198	543.6	11	569.2	59	827.1	90	923.5
3 May	153	104	530.7	2	586.0	25	848.5	22	1,258.1
Total	1,960	1,077	525.8	43	565.2	244	820.5	596	956.0

Table 2. Recapture matrix of striped bass (>457 mm TL) that were released in the Rappahannock River, springs 1990-2006. 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	05	06
1990		162	64	47	25	12	10	3	2	3	1	1	0	0	1	0	0	0
	1,464	21	20	24	10	8	9	2	0	0	1	1			1			
1991			167	81	53	29	6	5	2	2	4	1	0	0	1	0	0	0
	2,481		48	38	22	14	3	1	2	1	4	0			1			
1992				14	8	6	5	1	1	1	1	0	0	0	0	0	0	0
	130			7	4	1	3	0	0	0	1							
1993					50	37	17	8	9	2	0	1	0	0	0	0	0	0
	621				18	17	12	5	4	1		0						
1994						13	10	5	4	4	0	0	0	0	0	0	0	0
	195					6	7	4	1	2								
1995							55	30	20	5	4	2	3	0	1	0	1	0
	698						24	12	9	4	1	1	2		1		0	
1996								21	18	7	3	1	1	1	0	0	1	0
	376							3	10	3	2	1	1	1			1	
1997									47	26	14	3	0	1	2	1	0	0
	712								26	17	10	2		1	1	1		
1998										55	26	2	3	3	1	0	0	0
	784									28	16	1	3	1	0			
1999											66	23	9	5	3	0	0	0
	853										30	7	4	2	2			
2000												122	51	23	16	6	5	1
	1,765											44	23	11	7	4	5	1
2001													61	23	16	7	2	2
	797												32	14	5	7	1	0
2002														20	8	15	1	1
	315													10	4	6	1	1
2003															58	37	9	4
	852														32	20	5	3
2004																80	21	13
	1,477															45	14	8
2005																	42	26
	921																27	17
2006																		48
	668																	27

Table 3. Location of striped bass (> 457 mm TL), recaptured in 2007, that were originally tagged and released in the Rappahannock River during springs 1988-2006 and used for mortality analysis.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
Massachusetts	0	0	0	0	1	4	3	3	1	1	0	0	13
Connecticut	0	0	0	0	1	1	1	0	0	0	0	0	3
New York	0	0	0	0	4	2	0	1	1	1	0	0	9
New Jersey	0	0	0	0	1	6	0	0	0	1	0	0	8
Maryland	0	0	0	1	2	7	3	2	3	2	0	0	20
Virginia	2	2	0	5	3	1	3	0	3	8	6	13	46
North Carolina	3	0	1	0	0	0	0	0	0	0	1	0	5
Total	5	2	1	6	12	21	10	6	8	13	7	13	104

Table 4. Recapture matrix of striped bass (>710 mm TL) that were released in the Rappahannock River, springs 1990-2006. The second (bottom) number is the number of those recaptures that were harvested.

		Recaptures																
Year	**n**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**	**05**	**06**
1990		26	9	15	2	4	6	1	0	2	1	1	0	0	1	0	0	0
	301	10	1	6	1	3	5	1		0	1	1			1			
1991			41	24	16	11	3	2	2	1	2	0	0	0	1	0	0	0
	390		19	10	12	9	2	1	2	0	2				1			
1992				4	3	2	2	0	0	0	1	0	0	0	0	0	0	0
	40			2	1	1	1				1							
1993					22	18	7	4	7	0	0	1	0	0	0	0	0	0
	212				11	11	5	2	3			0						
1994						9	7	5	1	2	0	0	0	0	0	0	0	0
	123					4	4	4	1	0								
1995							29	11	8	3	3	2	3	0	1	0	1	0
	210						18	6	5	2	1	1	2		1		0	
1996								1	3	1	0	0	1	0	0	0	0	0
	67							0	3	1			1					
1997									15	13	8	3	0	1	2	1	0	0
	212								11	12	6	2		1	1	1		
1998										24	13	2	3	2	0	0	0	0
	158									16	9	1	3	1				
1999											17	6	2	3	2	0	0	0
	162										13	2	1	2	1			
2000												28	19	14	9	4	3	0
	365											13	11	6	5	3	3	
2001													19	14	4	6	2	1
	269												9	8	2	6	1	0
2002														10	6	7	1	0
	122													7	3	5	1	
2003															35	24	7	1
	400														23	13	3	1
2004																39	12	13
	686															21	8	8
2005																	16	11
	284																12	7
2006																		12
	175																	10

Table 5. Location of striped bass (> 710 mm TL), recaptured in 2007, that were originally tagged and released in the Rappahannock River during springs 1988-2006 and used for mortality analysis.

State	Month												total
	J	F	M	A	M	J	J	A	S	O	N	D	
Massachusetts	0	0	0	0	1	4	3	1	1	1	0	0	11
Connecticut	0	0	0	0	1	1	1	0	0	0	0	0	3
New York	0	0	0	0	4	2	0	1	1	1	0	0	9
New Jersey	0	0	0	0	1	4	0	0	0	1	0	0	6
Maryland	0	0	0	1	1	1	0	0	0	0	0	0	3
Virginia	1	2	0	2	0	0	0	0	0	0	0	2	7
North Carolina	3	0	1	0	0	0	0	0	0	0	1	0	5
Total	4	2	1	3	8	12	4	2	2	3	1	2	44

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, 1995-1999, 2000-2002, and 2003-2006 (p); parameters vary in 2006 (d), otherwise the same as p; parameters vary in 2005 and 2006 (v), otherwise the same as p; and parameters are time-specific (t).

Model	$QAIC_c$	Δ $QAIC_c$	$QAIC_c$ weight	number of parameters
S(t)r(t)	10,788.50	0.00	1.00000	33
S(v)r(p)	10,815.31	26.81	0.00000	9
S(p)r(t)	10,815.76	27.26	0.00000	21
S(.)r(t)	10,816.10	27.60	0.00000	18
S(p)r(p)	10,817.23	28.72	0.00000	8
S(d)r(p)	10,818.99	30.48	0.00000	9
S(t)r(p)	10,819.95	31.45	0.00000	21
S(.)r(p)	10,820.28	31.78	0.00000	5
S(.)r(.)	10,864.51	76.01	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 TL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2006.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}_{adj}$	$\hat{F}$	95% CI $\hat{F}$
1990	0.816	0.090	0.481	-0.143	0.952	-0.101	-0.24, 0.25
1991	0.276	0.053	0.524	-0.082	0.301	1.051	0.70, 1.45
1992	0.805	0.171	0.408	-0.142	0.938	-0.086	-0.27, 0.81
1993	0.604	0.136	0.456	-0.105	0.675	0.243	-0.07, 0.84
1994	0.568	0.132	0.381	-0.087	0.623	0.324	-0.01, 0.92
1995	0.684	0.141	0.262	-0.054	0.723	0.174	-0.08, 0.77
1996	0.639	0.138	0.274	-0.040	0.666	0.257	-0.03, 0.85
1997	0.567	0.111	0.330	-0.057	0.601	0.359	0.06, 0.84
1998	0.413	0.082	0.362	-0.059	0.439	0.673	0.34, 1.11
1999	0.369	0.067	0.286	-0.059	0.392	0.786	0.47, 1.18
2000	0.431	0.068	0.436	-0.074	0.466	0.614	0.34, 0.96
2001	0.478	0.106	0.367	-0.068	0.512	0.519	0.17, 1.04
2002	0.617	0.140	0.368	-0.061	0.657	0.269	-0.04, 0.88
2003	0.764	0.143	0.271	-0.048	0.802	0.070	-0.14, 0.70
2004	0.308	0.071	0.281	-0.039	0.321	0.988	0.58, 1.48
2005	0.374	0.102	0.280	-0.033	0.387	0.799	0.35, 1.41
2006	0.515	0.090	0.358	-0.067	0.551	0.445	0.16, 0.85

Table 8. Performance statistics (>710 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, 1995-1999, 2000-2002, and 2003-2006 (p); parameters vary in 2006 (d), otherwise the same as p; parameters vary in 2005 and 2006 (v), otherwise the same as p; and parameters are time-specific (t).

Model	$QAIC_c$	Δ $QAIC_c$	$QAIC_c$ weight	number of parameters
S(v)r(p)	5,271.81	0.00	0.67478	9
S(p)r(p)	5,274.13	2.32	0.21165	8
S(d)r(p)	5,276.11	4.30	0.07872	9
S(.)r(p)	5,278.29	6.48	0.02645	5
S(.)r(t)	5,280.83	9.02	0.00744	18
S(p)r(t)	5,285.77	13.95	0.00063	21
S(t)r(t)	5,288.00	16.18	0.00021	33
S(t)r(p)	5,288.91	17.09	0.00013	21
S(.)r(.)	5,305.69	33.88	0.00000	2

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 (> 710 mm TL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2006.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}_{adj}$	$\hat{F}$	95% CI
1990	0.630	0.026	0.578	-0.127	0.721	0.177	0.11, 0.26
1991	0.630	0.026	0.560	-0.131	0.725	0.172	0.10, 0.26
1992	0.630	0.026	0.535	-0.172	0.761	0.123	0.05, 0.21
1993	0.630	0.026	0.349	-0.093	0.694	0.215	0.14, 0.30
1994	0.630	0.026	0.318	-0.070	0.678	0.239	0.16, 0.33
1995	0.587	0.029	0.204	-0.079	0.637	0.301	0.21, 0.40
1996	0.587	0.029	0.125	-0.016	0.596	0.367	0.28, 0.47
1997	0.587	0.029	0.167	-0.036	0.609	0.346	0.26, 0.45
1998	0.587	0.029	0.217	-0.084	0.641	0.295	0.20, 0.40
1999	0.587	0.029	0.200	-0.057	0.622	0.325	0.23, 0.43
2000	0.668	0.044	0.349	-0.072	0.720	0.179	0.07, 0.33
2001	0.668	0.044	0.298	-0.053	0.705	0.199	0.09, 0.35
2002	0.668	0.044	0.295	-0.073	0.721	0.178	0.06, 0.32
2003	0.518	0.062	0.246	-0.058	0.549	0.449	0.24, 0.71
2004	0.518	0.062	0.321	-0.051	0.546	0.456	0.25, 0.72
2005	0.624	0.119	0.238	-0.036	0.647	0.285	0.01, 0.78
2006	0.625	0.122	0.289	-0.052	0.659	0.266	-0.01, 0.78

Table 10. Comparison of the model ranking and weighting of three regulatory periods (1990-1994, 1995-1999 and 2000-present) and four regulatory periods (1990-1994, 1995-1999, 2000-2002 and 2003-present) MARK analyses for 1990-2005 and 1990-2006.

1990-2005				1990-2006			
3 period		4 period		3 period		4 period	
model	weight	model	weight	model	weight	model	weight
S(d)r(3p)	0.7043	S(d)r(4p)	0.8733	S(v)r(3p)	0.9782	S(v)r(4p)	0.6748
S(v)r(3p)	0.2752	S(.)r(4p)	0.0641	S(.)r(3p)	0.0090	S(4p)r(4p)	0.2117
S(.)r(3p)	0.0153	S(4p)r(4p)	0.0329	S(.)r(t)	0.0054	S(d)r(4p)	0.0787
S(3p)r(3p)	0.0031	S(v)r(4p)	0.0138	S(d)r(3p)	0.0044	S(.)r(4p)	0.0265
S(.)r(t)	0.0015	S(.)r(t)	0.0128	S(3p)r(3p)	0.0019	S(.)r(t)	0.0074
S(3p)r(t)	0.0004	S(4p)r(t)	0.0018	S(3p)r(t)	0.0008	S(4p)r(t)	0.0006
S(t)r(3p)	0.0001	S(t)r(t)	0.0008	S(t)r(t)	0.0002	S(t)r(t)	0.0002
S(t)r(t)	0.0001	S(t)r(4p)	0.0005	S(t)r(3p)	0.0001	S(t)r(4p)	0.0001
S(.)r(.)	0.0000	S(.)r(.)	0.0000	S(.)r(.)	0.0000	S(.)r(.)	0.0000

Table 11. Comparison of the model-averaged estimates of survival (S) and fishing mortality (F) from the three regulatory period and four regulatory period MARK analyses for 1990-2005 and 1990-2006.

Year	1990-2005				1990-2006			
	3 period		4 period		3 period		4 period	
	S	F	S	F	S	F	S	F
1990	0.72	0.19	0.72	0.18	0.72	0.18	0.72	0.18
1991	0.72	0.18	0.72	0.17	0.72	0.17	0.72	0.17
1992	0.76	0.13	0.76	0.12	0.76	0.12	0.76	0.12
1993	0.69	0.22	0.69	0.21	0.69	0.21	0.69	0.21
1994	0.67	0.24	0.68	0.24	0.68	0.24	0.68	0.24
1995	0.67	0.25	0.64	0.30	0.64	0.29	0.64	0.30
1996	0.63	0.31	0.60	0.36	0.60	0.36	0.60	0.37
1997	0.64	0.29	0.61	0.34	0.61	0.34	0.61	0.35
1998	0.68	0.24	0.64	0.29	0.64	0.29	0.64	0.29
1999	0.66	0.27	0.62	0.32	0.63	0.32	0.62	0.32
2000	0.67	0.26	0.71	0.19	0.67	0.25	0.72	0.18
2001	0.65	0.28	0.69	0.22	0.66	0.27	0.71	0.20
2002	0.67	0.25	0.71	0.19	0.67	0.25	0.71	0.18
2003	0.66	0.27	0.71	0.19	0.66	0.26	0.55	0.45
2004	0.66	0.27	0.71	0.20	0.66	0.27	0.55	0.46
2005	0.81	0.06	0.83	0.04	0.68	0.22	0.65	0.29
2006					0.83	0.03	0.66	0.27

Table 12. Recapture matrix of male striped bass (457-710 mm TL) that were released in the Rappahannock River, springs 1990-2005. 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	05	06
1990	189	20 1	7 1	2 0	1 0	0	1 1	0	0	0	0	0	0	0	0	0	0	0
1991	107		18 3	6 5	2 0	1 0	1 0	0	0	0	0	0	0	0	0	0	0	0
1992	31			4 3	0	2 0	1 1	0	0	0	0	0	0	0	0	0	0	0
1993	166				12 2	8 3	3 3	1 1	1 0	1 0	0	0	0	0	0	0	0	0
1994	38					1 0	3 3	0	0	0	0	0	0	0	0	0	0	0
1995	361						37 6	10 5	10 3	2 2	0	0	0	0	0	0	0	0
1996	258							20 2	12 6	4 2	3 2	0	0	0	0	0	0	0
1997	458								27 12	9 5	4 3	0	0	0	0	0	0	0
1998	601									26 11	12 7	0	0	1 0	1 0	0	0	0
1999	666										48 16	15 4	6 3	2 0	1 1	0	0	0
2000	1352											113 29	30 12	7 5	7 2	1 0	1 1	0
2001	496												50 22	8 6	9 1	0	0	1 0
2002	189													12 3	2 1	7 1	0	1 1
2003	443														24 8	11 7	2 2	2 2
2004	757															38 22	6 5	0
2005	597																26 14	15 10
2006	461																	33 14

Table 13. Performance statistics (males 457-710 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, 1995-1999, 2000-2002, and 2003-2006 (p); parameters vary in 2006 (d), otherwise the same as p; parameters vary in 2005 and 2006 (v), otherwise the same as p; and parameters are time-specific (t).

Model	$QAIC_c$	$\Delta\ QAIC_c$	$QAIC_c$ weight	number of parameters
S(t)r(t)	9,256.70	0.00	1.00000	33
S(t)r(p)	9,297.52	40.82	0.00000	21
S(p)r(t)	9,317.63	60.93	0.00000	21
S(.)r(t)	9,318.32	61.62	0.00000	18
S(d)r(p)	9,340.99	84.29	0.00000	9
S(v)r(p)	9,341.63	84.94	0.00000	9
S(p)r(p)	9,342.95	86.25	0.00000	8
S(.)r(p)	9,348.43	91.73	0.00000	5
S(.)r(.)	9,391.01	134.31	0.00000	2

Table 14. 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 (males 457-710 mm TL) derived from the proportion of recaptures released alive (P_l) in the Rappahannock River, 1990-2006.

Year	$\hat{S}$	SE ($\hat{S}$)	P_l	bias	$\hat{S}$ adj	$\hat{F}$	95% CI $\hat{F}$
1990	0.222	0.060	0.450	-0.128	0.255	1.216	0.73, 1.78
1991	0.416	0.144	0.520	-0.250	0.554	0.440	-0.07, 1.27
1992	0.618	0.228	0.167	-0.067	0.662	0.262	-0.13, 1.41
1993	0.850	0.364	0.533	-0.090	0.934	-0.082	-0.24, 3.64
1994	0.322	0.138	0.583	-0.075	0.348	0.905	0.25, 1.89
1995	0.381	0.077	0.587	-0.161	0.454	0.640	0.29, 1.08
1996	0.892	0.177	0.258	-0.050	0.940	-0.088	-0.20, 1.49
1997	0.413	0.093	0.420	-0.064	0.442	0.668	0.30, 1.17
1998	0.205	0.043	0.429	-0.047	0.215	1.386	1.00, 1.82
1999	0.257	0.045	0.313	-0.065	0.275	1.142	0.82, 1.50
2000	0.264	0.037	0.383	-0.082	0.288	1.095	0.83, 1.39
2001	0.367	0.079	0.360	-0.092	0.405	0.755	0.39, 1.23
2002	0.672	0.154	0.467	-0.067	0.720	0.178	-0.10, 0.85
2003	0.563	0.120	0.341	-0.048	0.591	0.376	0.06, 0.91
2004	0.157	0.042	0.228	-0.027	0.162	1.673	1.18, 2.21
2005	0.338	0.080	0.286	-0.032	0.349	0.904	0.50, 1.42
2006	0.047	0.163	0.385	-0.071	0.051	2.827	-0.21, 9.87

Table 15. Estimates of fishing mortality (F) and natural mortality (M) of the catch equation, exploitation rate (R/M, where M is the number of marked striped bass), and instantaneous rate (IRCR) analytical approaches.

Year	IRCR constant M		IRCR 2 period M		IRCR 3 period M		Catch Equation		R/M assumed M	
	F	M	F	M	F	M	F	M	F	M
1988	0.01	0.58	0.01	0.35	0.01	0.35			0.01	0.15
1989	0.00	0.58	0.00	0.35	0.00	0.35			0.00	0.15
1990	0.06	0.58	0.04	0.35	0.04	0.35	0.06	1.36	0.01	0.15
1991	0.06	0.58	0.04	0.35	0.04	0.35	0.18	0.52	0.06	0.15
1992	0.17	0.58	0.10	0.35	0.10	0.35	0.26	0.18	0.18	0.15
1993	0.06	0.58	0.04	0.35	0.04	0.35	0.10	0.00	0.02	0.15
1994	0.05	0.58	0.03	0.35	0.03	0.35	0.21	0.87	0.00	0.15
1995	0.09	0.58	0.06	0.35	0.06	0.35	0.12	0.74	0.03	0.15
1996	0.04	0.58	0.03	0.35	0.03	0.35	0.08	0.00	0.02	0.15
1997	0.07	0.58	0.07	0.90	0.07	0.99	0.11	0.73	0.05	0.15
1998	0.05	0.58	0.06	0.90	0.06	0.99	0.10	1.45	0.03	0.15
1999	0.05	0.58	0.07	0.90	0.08	0.99	0.11	1.21	0.04	0.15
2000	0.04	0.58	0.05	0.90	0.05	0.99	0.11	1.17	0.04	0.15
2001	0.06	0.58	0.09	0.90	0.09	0.81	0.15	0.79	0.09	0.15
2002	0.03	0.58	0.06	0.90	0.06	0.81	0.07	0.29	0.03	0.15
2003	0.03	0.58	0.05	0.90	0.05	0.81	0.09	0.45	0.04	0.15
2004	0.05	0.58	0.08	0.90	0.07	0.81	0.13	1.71	0.05	0.15
2005	0.04	0.58	0.06	0.90	0.06	0.81	0.11	0.96	0.04	0.15
2006	0.06	0.58	0.09	0.90	0.08	0.81	0.16	2.84	0.06	0.15

III. The role of Mycobacteriosis in elevated Natural Mortality of Chesapeake Bay striped bass: disease progression and developing better models for stock assessment and management.

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Introduction

During the late 1990s concern emerged among recreational and commercial fishermen about perceived declining condition in striped bass (*Morone saxatilis*). Emaciation and ulcerative skin lesions were commonly reported and associated with a bacterial disease called mycobacteriosis. The disease is now epizootic throughout the Bay with more than 70% of striped bass in some tributaries affected. Several hypotheses have been presented to explain this emerging problem. These include stress associated with loss of food forage base due to recent declines in menhaden stocks (starvation), overcrowding, and loss of summer thermal refuges as a result of hypoxia and high temperature. Recent tag-recapture analyses indicate that striped bass survival has declined significantly (~20%) over the last 10 to 15 years. This troubling decline is attributable to an increase in natural mortality and corresponds roughly with the Bay-wide outbreak of mycobacteriosis in striped bass. Current fishery management strategies do not account for changes in natural mortality over time, especially during infectious disease epizootics. Thus, the overall aim of the current study is to determine the contribution of mycobacteriosis to natural mortality in the striped bass, and thus the potential for adverse impacts by the disease on the stock.

Mycobacteriosis in fish is a chronic disease caused by various species of bacteria in the genus *Mycobacterium*. Mycobacterial disease occurs in a wide range of species of fish worldwide and is an important problem in aquacultural operations. The disease appears as grey granulomatous nodules in internal organs, especially the spleen and kidney (Figure 1b), and can also manifest itself as ulcerous skin lesions (Figure 1a). Fish with ulcerous dermal lesions in the wild sometimes have an extremely emaciated appearance.

Mycobacteriosis was first reported from Chesapeake Bay striped bass in 1997 (Vogelbein et al. 1999; Rhodes et al. 2002, 2003, 2004). Since then, the disease has spread throughout the Bay and the prevalence has risen to as high as 70 – 80% (Cardinal 2001; Vogelbein et al. 1999; this project, unpublished observations). Several species of *Mycobacterium* have been isolated from Chesapeake Bay striped bass, including several new species, but it is not yet clear which species are involved in disease processes. Indeed, there may be more than one pathogenic species.

Mycobacteria are slow-growing, aerobic bacteria common in terrestrial and aquatic habitats. Most are saprophytes, but certain species infect both endo- and poikilothermic animals. Mycobacterial infections are common in wild and captive fish stocks world-wide. Mycobacteriosis in fishes is a chronic, systemic disease that can result in degradation of body condition and ultimately in death (Colorni 1992). Clinical signs are nonspecific and may include scale loss, skin ulceration, emaciation, exophthalmia, pigmentation changes and spinal defects (Nigrelli & Vogel 1963; Bruno et al. 1998). Granulomatous inflammation, a host cellular response comprised largely of phagocytic cells of the immune system called macrophages, is a characteristic of the disease. In an attempt to sequester, kill and degrade mycobacteria, these macrophages encapsulate bacteria, forming nodular structures called granulomas. Skin ulceration in most fishes is uncommon and usually represents the endstage of the disease process, as captive fish with skin lesions generally do not recover and die quickly. Hence, the presence of skin lesions is particularly alarming, as it may indicate that the fish are progressing from chronic, covert infection to active, lethal disease.

The impact of the disease on the population ecology of striped bass is poorly understood. Fundamental questions, such as mode of transmission, duration of disease stages, effects of disease on fish movements, feeding and reproduction, and mortality rates associated with disease, remain unanswered. Nonetheless, there are indications the disease may be having a significant impact on Chesapeake striped bass populations. Jiang et al. (in press) analyzed striped bass tagging data from Maryland and found a significant increase in natural mortality rate at about the time when mycobacteriosis was first being detected in Chesapeake Bay striped bass. A similar analysis of Rappahannock River, Virginia, striped bass tagging data from this project also reveals an increase in natural mortality rate in recent years (see Table 1): natural mortality rate for fish age 2 and above was estimated to increase from M = .231 during the period 1990 – 1996 to M=.407 during the period 1997-2004. In addition, R. Latour and D. Gauthier (VIMS, pers. com.) used force-of-infection models to examine the epizootiology of mycobacteriosis in Chesapeake Bay striped bass from 2003-2005. The results of this analysis indicated that the probability a disease negative fish becomes disease positive depends on age; the inclusion of sex and season as covariates significantly improved model fit; and that there is evidence of disease associated mortality.

Mycobacteriosis in fishes is generally thought to be fatal, but this has not been established for wild striped bass. Three possible distinct disease outcomes in the case of striped bass are: 1) death, 2) recovery or reversion to a non-disease state, or 3) movement of infected fish to another location. Because of the uncertainty about the fate of the infected fish, the impact of the disease on striped bass populations is unknown. If mycobacteriosis in striped bass is ultimately fatal, the potential for significant impacts on the productivity and the quality of the Atlantic coastal migratory stock is high. Researchers, fisheries managers and commercial and recreational fishermen are therefore becoming gravely concerned. At a recent symposium entitled "*Management Issues of the Restored Stock of Striped Bass in the Chesapeake Bay: Diseases, Nutrition, Forage Base and Survival*", Kahn (2004) reported that both Maryland and Virginia striped bass tag-recaptures have declined in recent years. This suggests that survival has declined significantly, from 60-70% in the early-mid 1990's to 40-50% during the late 1990's and early 2000's. Kahn (2004) and Crecco (2003) both concluded that the 20% decline in striped bass survival was not caused by fishing mortality, but rather, by an increase in natural mortality. These analyses, however, are predicated on the assumption that tag reporting rate has not changed over time. No data are currently available to evaluate this assumption. Hypotheses presented at the Symposium to explain the decline in striped bass survival included the possible role of mycobacteriosis (May et al., 2004; Vogelbein et al., 2004). However, Jacobs et al. (2004) found that decline in striped bass nutritional status during the fall was independent of disease. Uphoff (2004) reported that abundance of forage-sized menhaden, a primary food source of striped bass, declined to near historic lows during the mid 1990's. Similar studies indicated that as the striped bass population has increased during the 1990’s, predatory demand increased coincident with a decline in menhaden populations (Hartman, 2004; Garrison et al., 2004).

Striped bass are presently managed by attempting to control fishing mortality. Fishing mortality is determined in three ways, and each method uses a value for natural mortality rate based on the assumption that natural mortality does not change over time. (This is done because of the difficulty in estimating natural mortality rate). If natural mortality has increased over time, and if these increases have not been quantified, then estimates of fishing mortality will be too high (when they are obtained from a Virtual Population Analysis or from a Brownie-type tagging model). Thus, there is the real potential of restricting the fishery because the fishing mortality appears too high when the actual situation is that the natural mortality has risen. This is not just of theoretical concern – for the last several years the Atlantic States Marine Fisheries Commission’s Striped Bass Technical Committee and Subcommittees have struggled with the problem that the total mortality rate appears to have gone up despite the fact that the fishing regulations have been stable. But information on whether diseases may be elevating the natural mortality rate is scarce and largely circumstantial (indirect) or anecdotal. To date, no one has quantified the effects of the disease on striped bass survival rate. Indeed, to our knowledge, quantitative estimates of infectious disease impacts on population dynamics have not been incorporated in the management plan of any marine finfish species.

Materials and Methods

Capture and Tagging Protocol

Striped bass for tagging were obtained from two pound nets in the upper Rappahannock River (river miles 45 and 46) and from five pound nets in the lower Rappahannock River (river miles 0-3). 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 pound net. 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. These tags are identical to the tags issued by the U. S. Fish and Wildlife Service except that they are lime green in color and have REWARD and a VIMS phone number imprinted into them. The rewards offered were $5 for recapture information and $20 for donating the entire specimen, on ice, to VIMS personnel.

Mycobacteriosis Assessment

Each tagged striped bass is given a complete external disease assessment and is photographed with a digital Cannon 30 camera. Overview and close-up photos are made for each side to document the initial assessment and to provide a basis for comparison when project personnel obtain recaptured striped bass. We identify 4 discrete lesion categories:

SD: Scale Damage: Includes one or more of the following features. (Fig. 2a)

- Loss of a single or multiple adjacent scales without significant erosion of underlying tissue. Hemorrhage or discoloration may be apparent
- Hemorrhagic foci underlying intact, scaled skin
- Scales which are present, but appear incomplete or eroded along a margin. Hemorrhage present or absent.

PF: Pigmented focus: ~1mm^2 pale to dark brown focus (Fig. 2b)

U: Ulceration: Loss of multiple adjacent scales with erosion/excavation of underlying tissue. Hemorrhage present or absent. Pigmentation present or absent. (Fig. 2c,d)

- scale damage or extensive loss
- range of severity: single small ulcers to multi-focal, coalescing ulcers occupying large portions of the body.

H: Putative Healing: Hyper-pigmented, (may not be apparent in ventral lesions). Scales present, but incomplete or abnormally organized. (Fig. 2e)

Within the categories U and PF we assign a severity number from 1 to 3 (PF) or 4 (U) according to the number of pigmented foci or the number and/or size of lesions.

A skin pathology diagnostic allows distinction between diseased and healthy fish in the context of the tagging program. By this approach, the impacts of the disease will be evaluated through differential tag return rates. Survival rates of fish with pathognomonic skin pathology will be compared to survival rates of fish without skin pathology. In addition, survival rates of fish with visceral lesions (as predicted by the diagnostic) will be compared to survival rates of fish without visceral lesions. This will provide better estimates of components of natural mortality (M) and provide inputs for future multi-species modeling efforts.

Analytical Approach:

If mycobacteriosis has no impact on the fate of fish, and if tag return rate is not affected by the presence of lesions, then we would expect to recover equal proportions of tags from fish with and without external lesions. In contrast, if externally ulcerous fish have higher mortality, we might expect to see a lower tag return rate in this group. (We discuss the necessary assumptions below.) Thus, we may estimate the impact of the lesions in terms of the relative survival (or relative risk) or in terms of the odds ratio. The results of the tagging experiment can be displayed in a 2x2 contingency table, as follows:

	recovered	not recovered
lesions	*a*	*b*
no lesions	*c*	*d*

The relative survival (with lesions : without lesions) is computed as

$$relative\ survival = \frac{a/(a+b)}{c/(c+d)} = \frac{a(c+d)}{c(a+b)}$$

Thus, if 8% of the tags are recovered from fish with lesions while 16% are recovered from fish without external lesions, the relative survival is 0.5, i.e., fish with external lesions survive half as well as fish without. The odds ratio is computed as

$$odds\ ratio = ad/(bc)$$

(see, e.g., Rosner 1990). The odds of obtaining a tag return from a fish with lesions is a/b; the odds ratio is simply the ratio of the odds for the two groups (fish with and without external lesions). Thus, odds ratio = $(a/b)/(c/d) = ad/bc$. The odds ratio can take on values between 0 and infinity. In the above example, the odds ratio would be 0.46. A value less than one indicates that fish with lesions have lower survival than fish without lesions. It is of interest to examine whether the ratio of survival changes over time. If the ratio of survival is constant over time, then a plot of log(ratio of recaptures) will be a linear function of time at liberty with slope equal to the difference in instantaneous mortality rates (i.e., exp(slope) estimates the ratio of survival rates). Note, that for this analysis to be valid, it is necessary to assume that the *ratio* of tag reporting rates for the two groups remains constant over time but *not* that the reporting rates for the two groups are equal nor that the rates are unchanging. Departures from a linear relationship indicate that the ratio of survival rates or the ratio of reporting rates is changing over time (or both are changing). This model is a logistic model; consequently, standard methods are available for fitting and examining the model (see, e.g., Hoenig et al. 1990).

These analyses can be further refined by sub-dividing the group that has external lesions into categories that reflect the relative progression in severity (infection index). These categories are:

Clean:	no external sign of infection.
Light:	PF1 and/or U1 on at least one side
Moderate:	PF2 and/or U2 on at least one side
Heavy:	PF3 and/or U3 or 4 on at least one side
Other:	all H, but without any PF or U

Relative return rates and spatial differentiation refine our knowledge of the effects of the disease on striped bass stocks. Comparison of the disease index (and accompanying photos) with the infection index of recaptures returned to VIMS provides a measure of disease progression (or remission) of these striped bass.

In subsequent reports, because tagged fish will be released at two times (one year apart), it will also be possible to fit Brownie tagging models (Brownie et al. 1985) or instantaneous rates models (Hoenig et al. 1998a,b) to the data. These models allow one to estimate annual survival rate. Thus, one can compare the survival of fish tagged with and without external signs of mycobacteriosis. Two assumptions of the model are worth noting. First, tag reporting rate need not be 100%, need not be known, and need not be constant over time. However, previously tagged and newly tagged fish are assumed to have the same reporting rate. This assumption may be violated if, for example, disease severity increases in a tagged cohort over time. In this case previously tagged fish may look less appealing than newly tagged fish, thus affecting reporting rate differentially. Second, the Brownie models are based on the assumption that the population is homogeneous, i.e., that all animals have the same probability of survival. To the extent that survival is a function of the severity of the disease, there may be some heterogeneity within the defined categories of those with and without external signs of disease. Biases that may arise due to failures of these assumptions will be studied by sensitivity analysis. Information on disease progression from the holding studies and from examination of recaptured fish from the pound nets, and information on disease prevalence from periodic examination of samples from the pound net, will be used to guide the sensitivity analyses.

There are other potential problems to this analysis. If ulcerous fish exhibit different movement patterns than fish that do not have the skin disease, this could influence disease dynamics. This will be tested by gathering information on the location of recaptures and evaluating the spatial distribution of recaptures for the two groups of fish.

Results

Tag Release Summary

Fall 2006: A total of 3,710 striped bass were tagged, assessed for external disease indications, photographed and released from two pound nets in the upper Rappahannock (n = 399) and five pound nets in the lower Rappahannock (n = 3,311) River during fall, 2006 (Table 2). The striped bass tagged upriver were mostly 430-480 mm in fork length

(Figure 3). There was a trend towards a higher prevalence of infection with size. There was a much broader range in size at the lower river nets, peaking at around 490 mm (Figure 4). The striped bass tagged in the lower Rappahannock River also showed a trend of an increasing prevalence of infection with size. Combined, only 32.1% (1,192/3,710) of the total that were tagged were without any external sign of mycobacteriosis. The lightly-infected group (39.9%) had the highest prevalence, while 10.8% were heavily infected. The striped bass tagged upriver had a lower prevalence of infected striped bass (52.9% vs.69.7%). These prevalences were lower than was found in the 2005 tag releases (74.8% vs. 77.9% respectively).

Spring 2007: A total of 656 striped bass were tagged, assessed, photographed and released from the pound nets in the lower Rappahannock River during late spring, 2007 (Table 3). The striped bass tagged in the upper Rappahannock River were similar in size to the fall releases there (Figure 5) and showed the same trend towards an increasing prevalence of infection with size. However, the striped bass tagged from the nets in the lower Rappahannock River, had a much greater range of sizes than in the fall (Figure 6), due the presence of the larger, mature spawning-size fish that were exiting the rivers in route to the coastal, oceanic waters where they spend the rest of the year. These larger striped bass had a very low prevalence of infection relative to the smaller, resident Chesapeake Bay striped bass. Although greater than for the fall releases, only 46.6% (306/656) of the total that were tagged were without any external sign of mycobacteriosis. The lightly-infected group was 30.8% of the releases, while 9.6% were heavily infected. Interestingly, the prevalences of both the non-infected and the heavily infected striped bass were greater than the striped bass tagged in spring 2006.

Tag Recapture Summary

Fall 2006 releases: A total of 394 striped bass tagged during fall 2006 were recaptured prior to 20 September, 2007 (Table 4). Many (35.0%) of these stripers were recaptured within 7 days of release, usually from the same or nearby pound net from which they were released. These immediately-recaptured stripers had a somewhat different disease index distribution than did the releases. While 32.1% of the releases were clean, only 21.0% of the immediate recaptures were. Also, 10.8% of the releases were heavily infected while 18.1% of the immediate recaptures were. Furthermore, by the end of summer, 2007, 28.7% of the recaptures were clean while 17.3% were assessed as heavy. Overall, 11.1% of the striped bass tagged from the lower Rappahannock River pound nets and 6.3% of the striped bass tagged from the upper Rappahannock River pound nets were recaptured by the end of summer, 2007. Striped bass tagged from the lower Rappahannock River pound nets were recaptured throughout both the Virginia and Maryland portions of the Chesapeake Bay (Table 5), while the striped bass tagged from the upper Rappahannock River pound nets (much fewer in number) were recaptured only within the Rappahannock River.

Spring 2007 releases: A total of 95 striped bass tagged and released during spring 2007 were recaptured prior to 20 September 2007 (Table 6). The incidence of immediate recapture (25.3%) was lower than for the fall 2006 releases. Although 46.6% of the spring releases were assessed as clean, only 37.5% on the immediate recaptures were. Also, 9.6% of the spring releases were heavily infected and 8.3% of the immediate recaptures were. By 20 September, 26.3% of the recaptures were clean and 11.6% of the recaptures were heavily infected. Recaptures of striped bass released from the lower Rappahannock River pound nets occurred in Rappahannock River, Potomac River and most sections of Chesapeake Bay (Virginia and Maryland, Table 7). Interestingly, there were more recaptures from Maryland waters than from within Virginia (excluding the immediate release area).

Fall 2005 releases: A total of 33 striped bass tagged and released during fall 2005 were recaptured between 21 September, 2006 and 20 September, 2007 (year two at large, Table 8). Most of these recaptures (46.9%) were in the subsequent fall of their release with a consistent, low, incidence of recapture thereafter. Even after being at large for one full year, 46.9% were recaptured back within their release area and another 25% were recaptured within the Rappahannock River (Table 9). The rate of recapture in year two was higher from the upper Rappahannock releases (5.6%) than for the lower Rappahannock releases (1.1%). While the percentage of moderately and heavily infected striped bass recaptures exceed the percentage of the initial releases during the first year at large, this trend reversed in the second year.

Spring 2006 releases: A total of 50 striped bass tagged in spring 2006 were recaptured between 21 September, 2006 and September 20, 2007 (0.5-1.5 years at large, Table 11). While most of the recaptures (60.0%) were caught the following fall, there was a second peak (30%) the next spring. Again, most recaptures (56.0%) were caught in the area of release and the Rappahannock River (14.0%), but there was at least one recapture reported from each section of Chesapeake Bay (Table 12). In contrast to the fall releases, the rate of recapture from the lower Rappahannock River releases (9.6%) exceeded the rate from the upper river (2.9%) during the second year. Also in contrast to the results from the fall releases, the relative proportion of the infection index of the recaptures during year two closely mirrored that of their initial release (Table 13). It should be noted that the number of striped bass tagged in the fall greatly exceeded the spring total.

Estimation of survival rates and relative survival rates

In theory, an estimate of the relative survival rate of fish in two disease categories can be obtained from the tagging data by looking at ratios of recaptures. It is necessary to assume that all fish have the same tag recovery rate, which implies that the fish in the two disease categories are well mixed and behave the same. It can be seen in Table 14, however, that the rate of recapture in the first 7 days increases with disease severity. Thus, for the fall 2005 releases, the recovery rate for clean, lightly, moderately and heavily diseased fish are 0.035, 0.054, 0.067, and 0.085, respectively. A similar trend occurs for the fall 2006 releases. This suggests that disease status may affect movement. Consequently, it may not be possible to estimate the relative survival rate from the short term tag recoveries. The number of tag returns drops off sharply with time as the fish move away from the pound net. It is therefore necessary to accumulate sufficient tag returns to estimate the relative survival rates.

If newly tagged animals mix with previously tagged animals before the start of the fishing season, then it is possible to estimate the annual survival rate from two years of recapture data for a pair of cohorts tagged a year apart (Brownie et al. 1985). If, however, mixing of the cohorts is delayed, then it is necessary to accumulate a third year of data and use a model that allows for delayed mixing (Hoenig et al. 1998). The tagging on the Rappahannock in the fall occurs concurrently with commercial fishing. Thus, it is not reasonable to assume that the newly tagged fish have the same spatial distribution as fish tagged the year before. Examination of the tagging data for the two years of tagging reveal that the vast majority of the recaptures occur during the first seven days after the fish are released. Thus, a delayed mixing model appears necessary. This will necessitate having another year's data.

Discussion

The results so far establish some important points. First, we are obtaining excellent cooperation from commercial and sport fishers so that our rate of return of tags (about 10% of releases), and of tagged carcasses, is encouraging. Since we doubled the number of releases this year we have a greater quantity of data to evaluate the population consequences of the mycobacterial infection. Second, if diseased fish are less able to withstand the stress of capture and tagging than lightly diseased or non-diseased fish, then we could have an artifact of tagging whereby an appreciable fraction of the diseased fish experience an abnormal mortality associated with the tagging process. The fact that we did not obtain more tag returns from fish without signs of disease than from diseased fish indicates that this is not a problem. In fact, we obtained slightly higher tag return rates from diseased fish than from fish without signs of disease. Third, it is possible that diseased fish may differ in their ability to swim and migrate from fish without signs of the disease. Thus, it will be necessary to investigate the spatial pattern of the tag returns by disease category. Fortunately, we are able to obtain detailed recapture locations from almost all fish.

The prevalence of heavily-infected striped bass remained stable from fall 2005 to fall 2006 (11.7% and 10.8% respectively) although the proportion of the striped bass examined as non-infected rose from 25-30%. We have recapture information from striped bass released as heavily-infected more than one year after their release, so the disease is not 100% fatal within this time frame. However, the necropsies performed on returned carcasses do indicate that the disease is progressive, but we currently do not have enough data to determine the rate of progression or to determine the population consequences.

The lower prevalence of mycobacterial infections in the larger, migrant striped bass indicates that resident population is most at risk. Since the resident striped bass form the basis of both the recreational and commercial fisheries in Virginia, the results of this study will be increasingly important.

The striped bass tagged for this study do not appear to mix throughout the resident population during their first year after release. The short-term recaptures (the most numerous) have a disproportionate prevalence of the most heavily infected striped bass when compared to all the subsequent recaptures. Thus, the use of Brownie models will be deferred until next year when there will be two years of releases at large greater than one year.

Literature Cited

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

Bruno DW, J Griffiths, CG Mitchell, BP Wood, ZJ Fletcher, FA Drobniewski, and TS Hastings. 1998. Pathology attributed to *Mycobacteria chelonae* infection among farmed and laboratory - infected Atlantic salmon (*Salmo salar*). *Dis Aquat Org.* 33:101-109

Cardinal JL. 2001. Mycobacteriosis in striped bass, *Morone saxatilis*, from Virginia waters of Chesapeake Bay. Master's Thesis. School of Marine Science, Virginia Institute of Marine Science. Pp.83.

Colorni A. 1992. A systemic mycobacteriosis in the European sea bass *Dicentrarchus labrax* cultured in Eilat (Red Sea). *Bamidgeh – Isr J Aquacult* 44:75-81

Crecco, V. 2003. Methods of estimating fishing (F) and natural (M) mortality rates from total mortality (Z) and exploitation (u) rates for striped bass. Final Report. Connecticut Marine Fisheries Division. 40 pp.

Garrison, LP, JS Link and G White. 2004. A multispecies modeling approach to evaluate interactions between Atlantic menhaden and its predators. Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

Hartman, KJ 2004. Increases in coastal striped bass predatory demand and implications of declines in Atlantic menhaden populations. Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

Hoenig JM, NJ Barrowman, WS Hearn, and KH Pollock. 1998. Multiyear Tagging Studies Incorporating Fishing Effort Data. *Can. J. Fish. Aquat. Sci*. 55:1466-1476.

Hoenig JM, NJ Barrowman, KH Pollock, EN Brooks, WS Hearn and T Polacheck. 1998. Models for Tagging Data that Allow for Incomplete Mixing of Newly Tagged Animals. *Can. J. Fish. Aquat. Sci*. 55:1477-1483.

Hoenig JM, P Pepin, and WD Lawing. 1990. Estimating Relative Survival Rate for Two Groups of Larval Fishes from Field Data: Do Older Larvae Survive Better than Young? *Fish. Bull*. 88:485-491.

Jacobs JM, HL Rogers, WF Van Heukelem, B Coakley, C Gieseker and M Matsche. 2004. Nutritional health of Chesapeake Bay striped bass *Morone saxatilis* in relation to disease. Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

Kahn, DM. 2004. Tag-recapture data from Chesapeake Bay resident striped bass indicate that survival has declined. Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

May, EB, V Pernell Lewis, AM Overton, J Jacobs and L Alade. 2004. Potential impacts of mycobacteriosis in striped bass on Chesapeake and Atlantic coastal stocks. Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

Nigrelli RF and H Vogel. 1963. Spontaneous tuberculosis in fish and other coldblooded vertebrates with special reference to *Mycobacterium fortuitum* from fish and human lesions. *Zoologica* 48:131-144.

Rhodes MW, H Kator, S Kotob, P van Berkum, I Kaattari, WK Vogelbein, F Quinn, MM Floyd, WR Butler and CA Ottinger. 2003. *Mycobacterium shottsii* sp. nov., a slow growing species isolated from Chesapeake Bay striped bass (*Morone saxatilis*). *Int. J. Syst. Evol. Micro.* 53:1-5.

Rhodes MW, H Kator, S Kotob, P van Berkum, I Kaattari, WK Vogelbein, F Quinn, MM Floyd, WR Butler, CA Ottinger. 2002. *Mycobacterium shottsii* sp. nov., a slow growing species isolated from Chesapeake Bay striped bass, (*Morone saxatilis*). Int. J. System. Environ. Microbiol. 53:421-424.

Rhodes, MW, H Kator, I Kaattari, D Gauthier, WK Vogelbein, & C Ottinger. 2004. Isolation and characterization of *Mycobacterium* spp. from striped bass, *Morone saxatilis*, from the Chesapeake Bay. *Dis. Aquat. Org*. 61:41-51.

Rosner, B. 1990. Fundamentals of Biostatistics, 3rd edition. PWS-Kent Publishing Company, Boston.

Uphoff, JH Jr. 2004. Striped bass and Atlantic menhaden: Is there a predator-prey imbalance in Chesapeake Bay? Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

Vogelbein WK, DE Zwerner, H Kator, MW Rhodes and J Cardinal. 1999. Mycobacteriosis of striped bass from Chesapeake Bay. pages 53-58. In J.E. Olney (ed.), *Research on Recreational Fishes and Fisheries*, VIMS Spec. Sci. Rept. 139, 82 pp.

Vogelbein WK, DT Gauthier, MW Rhodes, H Kator, R Latour, C Bonzek and C Ottinger. 2004. Mycobacteriosis in striped bass (*Morone saxatilis*) from Chesapeake Bay. Abstract: 60th Annual Northeast Fish and Wildlife Conference. 25-28 April, 2004. Ocean City, Maryland.

Table 1. Parameter estimates and standard errors (SE) from fitting two models to the Virginia striped bass spring tagging data (age 2 and greater). In model (a), estimates are obtained for year-specific fishing mortality rates for killed fish in year xx, Fk(xx), for fishing mortality associated with released fish experiencing hooking mortality, Fr(xx), and for natural mortality rate in two time periods (1990-1996 and 1997-2004). In model (b), the same parameters are estimated but, in addition, the tag reporting rates for kept (lambdaK) and released (lambdaR) fish are estimated instead of being fixed at 0.43.

	(a)		(b)	
parameter	estimate	SE	estimate	SE
Fk(90)	0.122	0.023	0.182	0.057
Fk(91)	0.165	0.021	0.259	0.067
Fk(92)	0.236	0.032	0.360	0.091
Fk(93)	0.227	0.032	0.347	0.086
Fk(94)	0.263	0.043	0.428	0.107
Fk(95)	0.274	0.042	0.469	0.116
Fk(96)	0.195	0.035	0.416	0.111
Fk(97)	0.199	0.039	0.370	0.105
Fk(98)	0.306	0.058	0.645	0.179
Fk(99)	0.240	0.034	0.578	0.163
Fk(00)	0.114	0.023	0.196	0.065
Fk(01)	0.111	0.024	0.145	0.047
Fk(02)	0.252	0.057	0.286	0.084
Fr(90)	0.135	0.025	0.159	0.145
Fr(91)	0.153	0.020	0.184	0.164
Fr(92)	0.166	0.027	0.193	0.172
Fr(93)	0.209	0.031	0.241	0.218
Fr(94)	0.199	0.037	0.246	0.237
Fr(95)	0.073	0.020	0.097	0.095
Fr(96)	0.083	0.022	0.127	0.117
Fr(97)	0.101	0.027	0.137	0.125
Fr(98)	0.076	0.027	0.113	0.106
Fr(99)	0.103	0.022	0.165	0.153
Fr(00)	0.055	0.016	0.076	0.073
Fr(01)	0.064	0.018	0.069	0.065
Fr(02)	0.114	0.035	0.107	0.098
Fk(03)	0.427	0.140	0.362	0.129
Fr(03)	0.242	0.088	0.168	0.164
Fk(04)	0.924	0.556	0.684	0.329
Fr(04)	0.449	0.276	0.245	0.280
M90-96	0.231	0.019	0.083	0.177
M97-04	0.407	0.037	0.168	0.125
lambdaK	0.430	0.000	0.250	0.057
lambdaR	0.430	0.000	0.347	0.312

Table 2. Tag release totals and mycobacteria infection index, by date, of striped bass in the upper and lower Rappahannock River sites, fall, 2006.

Date	release area	n	infection index				
			clean	light	moderate	heavy	other
25 September	upper	130	67	19	33	7	4
28 September	upper	43	13	19	6	4	1
29 September	lower	95	33	39	14	8	1
02 October	upper	81	41	27	7	2	4
03 October	lower	151	57	49	19	25	0
05 October	upper	22	6	9	3	3	1
09 October	upper	123	61	37	11	6	8
10 October	lower	305	76	127	60	40	2
13 October	lower	265	59	132	52	21	1
17 October	lower	170	40	64	30	34	2
24 October	lower	161	47	65	26	23	0
27 October	lower	225	73	97	34	20	1
30 October	lower	98	29	42	23	3	1
31 October	lower	227	66	88	32	40	1
03 November	lower	176	64	70	27	13	2
07 November	lower	202	80	62	32	25	3
10 November	lower	197	66	90	24	14	3
14 November	lower	192	74	61	37	19	1
17 November	lower	214	52	108	29	22	3
20 November	lower	215	64	106	27	8	0
27 November	lower	149	43	70	27	8	0
30 November	lower	64	20	23	9	11	0
07 December	lower	205	61	77	31	36	0
totals	upper	399	188	111	60	22	18
	lower	3,311	1,004	1,370	533	380	21
	both	3,710	1,192	1,481	593	402	39

Table 3. Tag release totals and mycobacteria infection index, by date, of striped bass in the upper and lower Rappahannock River sites, spring, 2007.

Date	release area	n	infection index				
			clean	light	moderate	heavy	other
08 May	lower	194	120	45	15	12	2
11 May	lower	209	102	63	21	19	3
14 May	lower	114	36	43	19	12	3
18 May	lower	88	31	29	12	14	2
22 May	lower	51	17	22	5	6	1
totals	lower	656	306	202	72	63	11

Table 4. Seasonal recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during fall, 2006.

Date	release area	n	infection index				
			clean	light	moderate	heavy	other
0-7 days	upper	5	1	2	0	1	1
	lower	133	28	52	25	24	4
Fall 2006 (>7 days)	upper	16	7	7	1	1	0
	lower	91	25	29	18	19	0
Winter 2007	upper	0	0	0	0	0	0
	lower	26	12	6	6	2	0
Spring 2007	upper	1	1	0	0	0	0
	lower	77	29	24	8	14	2
Summer 2007	upper	3	0	1	0	0	2
	lower	33	5	14	7	6	1
totals	upper	25	9	10	2	1	3
	lower	369	104	127	64	67	7
	both	394	113	137	66	68	10

Table 5. Spatial recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during fall, 2006 (five striped bass were recaptured outside of Chesapeake Bay).

recapture area	release area	n	infection index				
			clean	light	moderate	heavy	other
release area	upper	10	4	3	0	2	1
	lower	226	66	75	40	44	1
Rappahannock River	upper	16	6	8	1	0	1
	lower	14	8	2	2	1	1
upper Bay (Md)	upper	0	0	0	0	0	0
	lower	13	4	6	2	1	0
lower Bay (Md)	upper	0	0	0	0	0	0
	lower	30	5	14	5	5	1
Potomac River	upper	0	0	0	0	0	0
	lower	4	1	1	1	1	0
upper Bay (Va)	upper	0	0	0	0	0	0
	lower	35	8	9	8	9	1
lower Bay (Va)	upper	0	0	0	0	0	0
	lower	22	5	7	5	5	0
totals	upper	26	10	11	1	2	2
	lower	344	97	114	63	66	4
	both	370	107	125	64	68	6

Table 6. Seasonal recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during spring, 2007.

Date	release area	n	infection index: clean	light	moderate	heavy	other
0-7 days	lower	24	9	9	1	2	3
Spring 2007 (>7days)	lower	49	11	20	12	6	0
Summer 2007	lower	22	5	6	7	3	1
totals	lower	95	25	35	20	11	4

Table 7. Spatial recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during spring, 2007.

recapture area	release area	n	infection index				
			clean	light	moderate	heavy	other
release area	lower	80	21	28	18	10	3
Rappahannock River	lower	2	0	0	1	1	0
upper Bay (Md)	lower	2	2	1	0	0	0
lower Bay (Md)	lower	3	0	1	1	0	1
Potomac River	lower	4	2	2	0	0	0
upper Bay (Va)	lower	2	1	1	0	0	0
lower Bay (Va)	lower	0	0	0	0	0	0
totals	lower	93	26	33	20	11	4

Table 8. Seasonal recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during fall, 2005 and recaptured from fall 2006 through summer 2007.

Date	release area	n	infection index: clean	light	moderate	heavy	other
Fall 2006	upper	9	2	6	1	0	0
	lower	15	2	9	1	3	0
Winter 2007	upper	1	0	1	0	0	0
	lower	2	0	1	0	1	0
Spring 2007	upper	1	0	1	0	0	0
	lower	2	0	2	0	0	0
Summer 2007	upper	1	0	0	1	0	0
	lower	2	1	1	0	0	0
totals	upper	12	2	8	2	0	0
	lower	21	3	13	1	4	0
	both	33	5	21	3	4	0

Table 9. Spatial recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during fall, 2005 and recaptured from fall 2006 through summer 2007.

recapture area	release area	n	infection index				
			clean	light	moderate	heavy	other
release area	upper	6	2	3	1	0	0
	lower	9	3	5	1	0	0
Rappahannock River	upper	7	1	6	0	0	0
	lower	1	0	1	0	0	0
upper Bay (Md)	upper	1	0	0	1	0	0
	lower	1	1	0	0	0	0
lower Bay (Md)	upper	0	0	0	0	0	0
	lower	0	0	0	0	0	0
Potomac River	upper	0	0	0	0	0	0
	lower	0	0	0	0	0	0
upper Bay (Va)	upper	0	0	0	0	0	0
	lower	4	0	3	0	1	0
lower Bay (Va)	upper	0	0	0	0	0	0
	lower	3	0	1	1	1	0
totals	upper	14	3	9	2	0	0
	lower	18	4	10	2	2	0
	both	32	7	19	4	2	0

Table 10. Seasonal recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during spring, 2006 and recaptured from fall 2006 through summer 2007.

Date	release area	n	infection index				
			clean	light	moderate	heavy	other
Fall 2006	upper	2	1	0	1	0	0
	lower	28	11	14	2	1	0
Winter 2007	upper	0	0	0	0	0	0
	lower	3	1	2	0	0	0
Spring 2007	upper	0	0	0	0	0	0
	lower	15	4	6	2	2	1
Summer 2007	upper	0	0	0	0	0	0
	lower	2	0	2	0	0	0
totals	upper	2	1	0	1	0	0
	lower	48	16	24	4	3	1
	both	50	17	24	5	3	1

Table 11. Spatial recapture summary, by mycobacteria infection index and release area, of striped bass tagged and released in the upper and lower Rappahannock River sites during spring, 2006 and recaptured from fall 2006 through summer 2007.

recapture area	release area	n	infection index				
			clean	light	moderate	heavy	other
release area	upper	0	0	0	0	0	0
	lower	28	9	15	2	1	1
Rappahannock River	upper	1	1	0	0	0	0
	lower	6	3	1	1	1	0
upper Bay (Md)	upper	1	0	0	1	0	0
	lower	0	0	0	0	0	0
lower Bay (Md)	upper	0	0	0	0	0	0
	lower	1	0	1	0	0	0
Potomac River	upper	0	0	0	0	0	0
	lower	3	1	2	0	0	0
upper Bay (Va)	upper	0	0	0	0	0	0
	lower	4	1	2	0	1	0
lower Bay (Va)	upper	0	0	0	0	0	0
	lower	6	2	3	1	0	0
totals	upper	2	1	0	1	0	0
	lower	48	16	24	4	3	1
	both	50	17	24	5	3	1

Table 12. Temporal change in the release disease index of subsequent recaptures of striped bass tagged during fall 2005.

Area	Disease Index	Release Condition	Release condition of recaptures			
			0-7 Days	rest of Fall 2005	Winter 05-06 -Summer 06	Fall 2006-Summer 07
Upper	Clean	0.2680	0.1429	0.1111	0.4000	0.1667
	Light	0.4320	0.7143	0.3333	0.4000	0.6667
	Medium	0.1920	0.0000	0.3333	0.1000	0.1667
	Heavy	0.0960	0.1429	0.2222	0.1000	0.0000
	Other	0.0120	0.0000	0.0000	0.0000	0.0000
Lower	Clean	0.2548	0.1591	0.1333	0.1364	0.1429
	Light	0.4170	0.3977	0.4000	0.5000	0.6190
	Medium	0.1999	0.2386	0.3333	0.2727	0.0476
	Heavy	0.1201	0.1818	0.2667	0.0909	0.0000
	Other	0.0064	0.0114	0.0000	0.0000	0.0000

Table 13. Temporal change in the release disease index of subsequent recaptures of striped bass tagged during spring, 2006.

Area	Disease Index	Release Condition	Release condition of recaptures			
			0-7 Days	rest of Spring 2006	Summer 2006	Fall 2006- Summer 07
Upper	Clean	.3676	.0000	.6667	1.0000	.5000
	Light	.4706	.0000	.3333	.0000	.0000
	Medium	.1324	.0000	.0000	.0000	.5000
	Heavy	.0000	.0000	.0000	.0000	.0000
	Other	.0294	.0000	.0000	.0000	.0000
Lower	Clean	.3327	.1724	.1818	.3889	.3333
	Light	.4622	.6207	.5000	.3333	.5000
	Medium	.1215	.1379	.2727	.2222	.0833
	Heavy	.0757	.0690	.0455	.0556	.0625
	Other	.0060	.0000	.0000	.0000	.0208

Table 14. Recapture summary, by release assessment and season, of striped bass tagged and released in the upper and lower Rappahannock River sites during fall 2005 and spring 2006.

	Release Assessment	n	Recaptures										
			0-7 days	Fall 2005	Winter 2006	Spring 2006	Summ 2006	Fall 2006	Winter 2007	Spring 2007	Summ 2007	Fall 2007	Sum
Fall 2005	Clean	399	14	2	1	1	1	2	0	0	1	0	22
	Light	653	35	6	2	4	5	9	1	2	1	0	65
	Moderate	313	21	3	1	4	1	1	0	0	0	0	31
	Heavy	188	16	4	0	2	0	3	1	0	0	0	26
	Other	10	1	0	0	0	0	0	0	0	0	0	1
	No Assess.	3	1	0	0	0	0	0	0	0	0	0	1
Spring 2006	Clean	1,004	28	-----	-----	-----	-----	25	12	29	5	7	106
	Light	1,370	52	-----	-----	-----	-----	29	6	24	14	4	129
	Moderate	533	25	-----	-----	-----	-----	18	6	8	7	2	66
	Heavy	380	24	-----	-----	-----	-----	19	2	14	6	0	67
	Other	21	4	-----	-----	-----	-----	0	0	2	1	0	7
	No Assess.	3	0	-----	-----	-----	-----	0	0	0	0	0	0
Total	Fall 2005	1,566	88	15	4	11	7	15	2	2	2	0	146
	Spring 2006	3,311	133	-----	-----	-----	-----	91	26	77	33	13	375
	Both	4,877	221	15	4	11	7	106	28	79	35	13	521

Figure 1. Gross clinical signs of mycobacteriosis in Chesapeake Bay striped bass. A) severe ulcerative dermatitis. Note shallow, rough textured hemorrhagic and hyper-pigmented (dorsal lesions) ulcers. B) Multi-focal pale gray nodules within the spleen.

Figure 2. A spectrum of gross skin lesions attributable to mycobacteriosis in the striped bass, *Morone saxatilis.* a) mild scale damage and scale loss (arrows). b) pigmented foci (arrows). Inset: higher magnification of a pigmented focus showing pin-point erosion through an overlying scale (arrow). c) early ulceration exhibiting focal loss of scales, mild pin-point multifocal pigmentation and underlying exposed dermis. d) large advanced shallow roughly textured ulceration exhibiting hyper-pigmentation and hemorrhage. e) late stage healing lesion exhibiting hyper-pigmentation, reformation of scales and re-epithelialization and closure of the ulcer. f) Ziehl Neelsen stain of a histologic section of a skin lesion exhibiting granulomatous inflammation and acid-fast rod-shaped mycobacteria (staining red). g) histologic section showing normal healthy skin composed of epidermis (Ep), scales (Sc), dermis (D) and underlying skeletal muscle. h) histologic section through a skin ulcer showing loss of epidermis and scales and extensive granuloma formation (G).

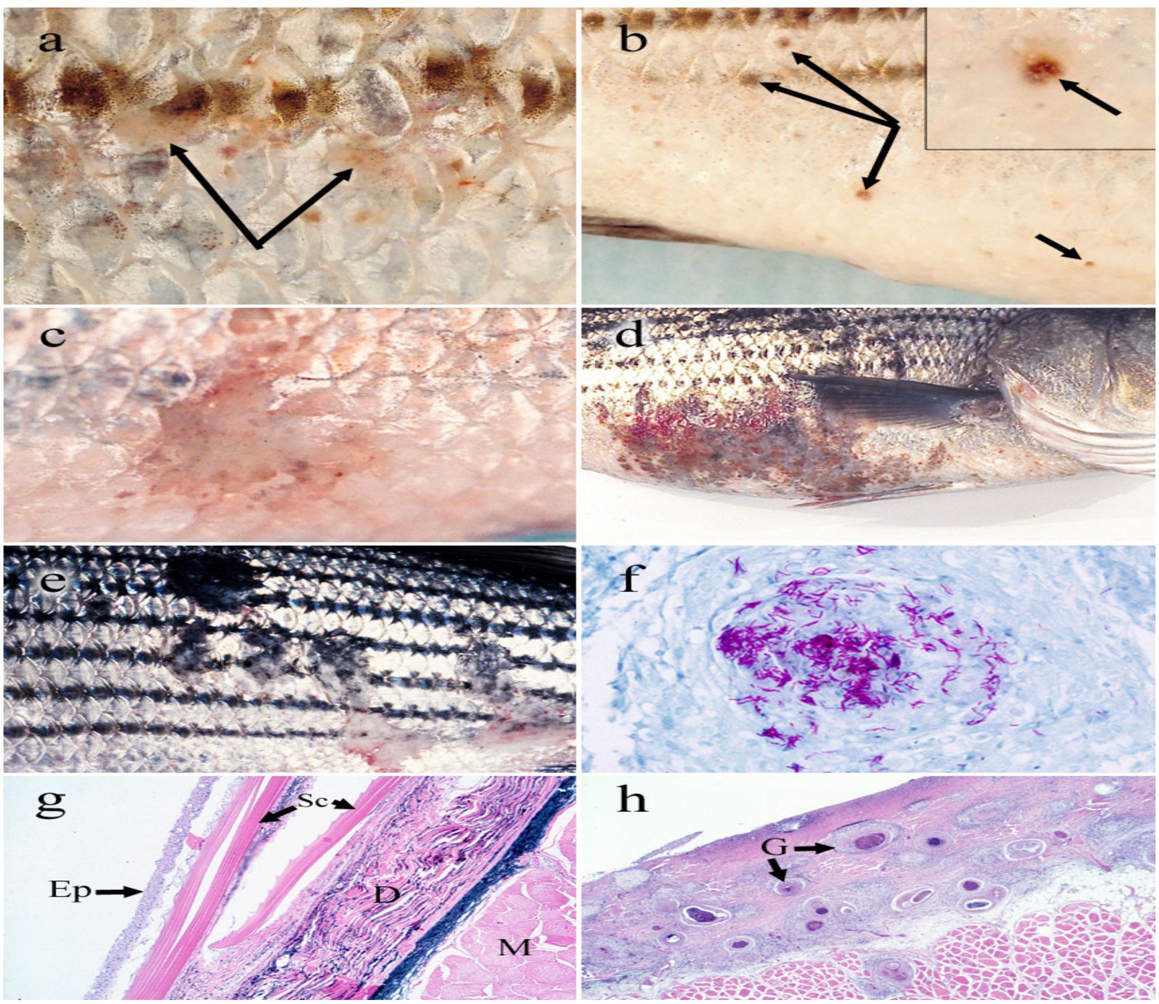
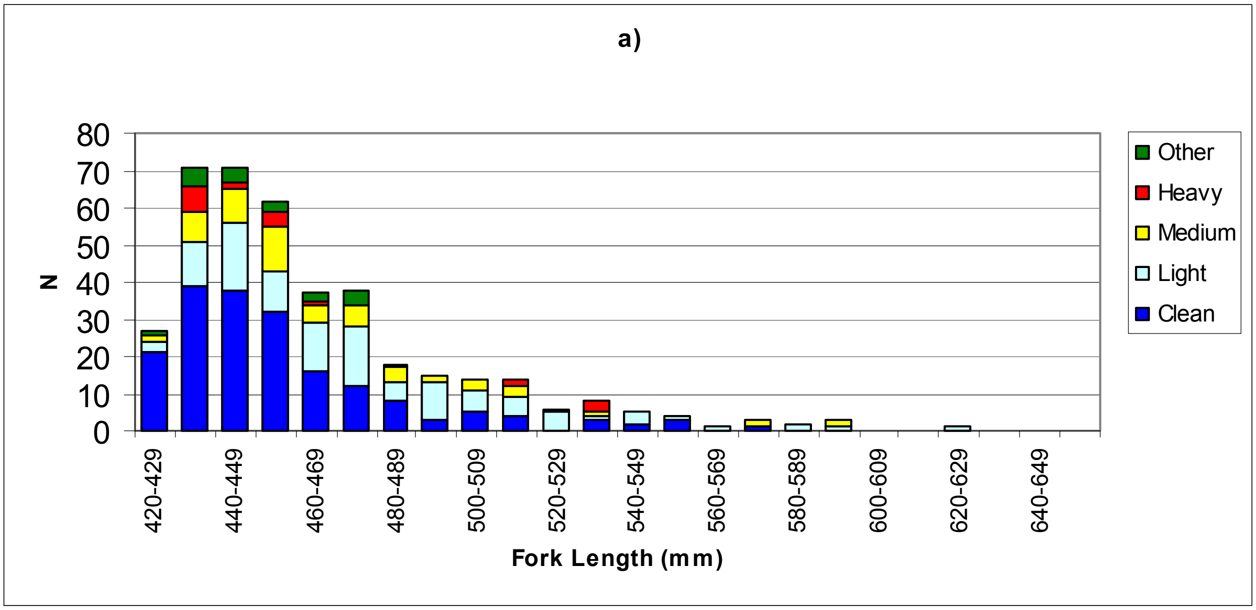


Figure 3. a) Size distribution (fork length in mm), by infection index, of striped bass tag releases from the upper Rappahannock River, fall 2006. b) Relative proportion of each infection index, by fork length, of the tag releases.



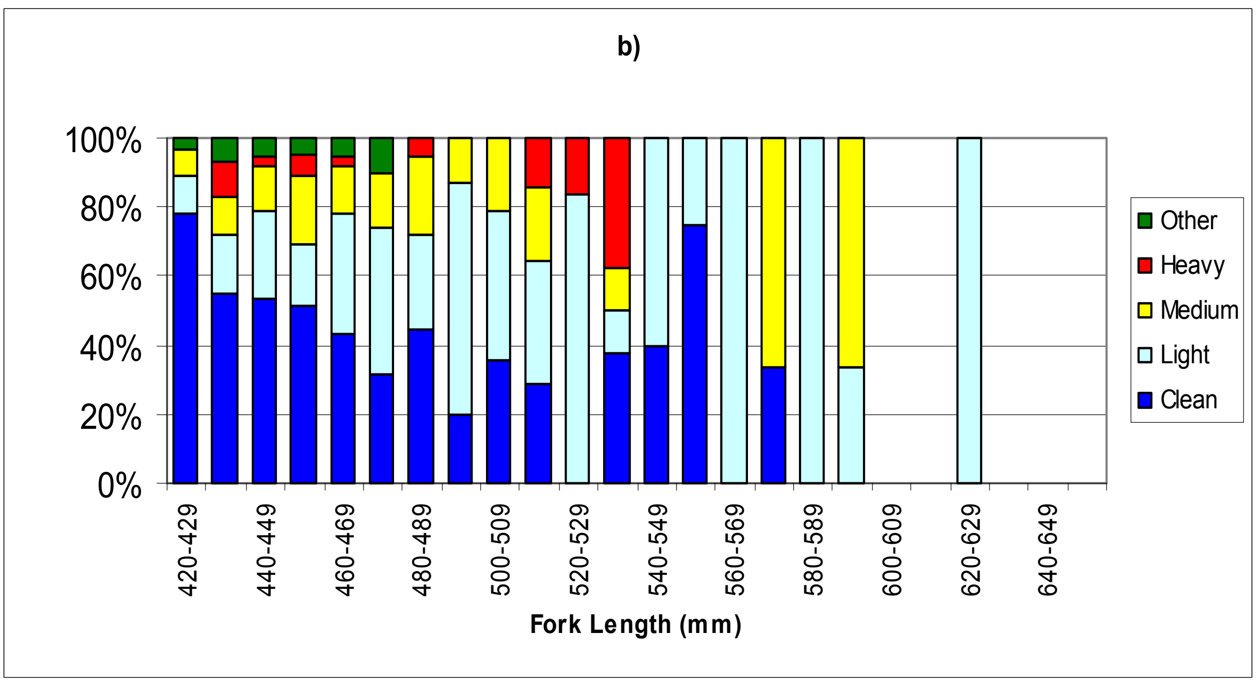
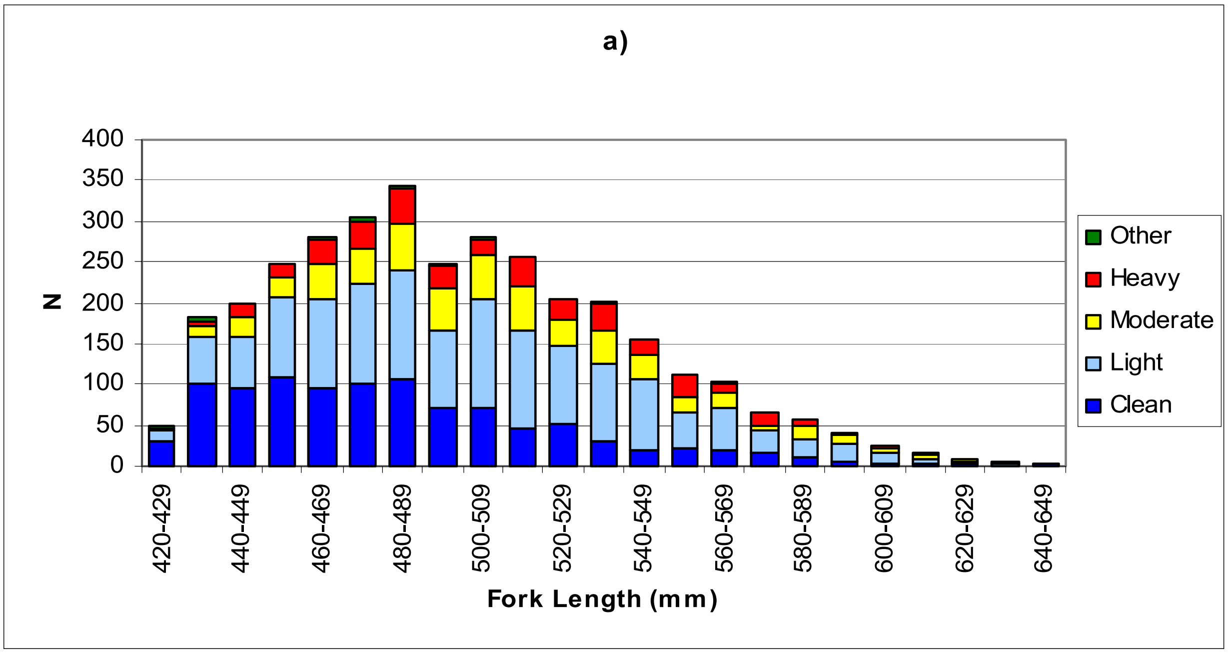


Figure 4. a) Size distribution (fork length in mm), by infection index, of striped bass tag releases from the lower Rappahannock River, fall 2006. b) Relative proportion of each infection index, by fork length, of the tag releases.



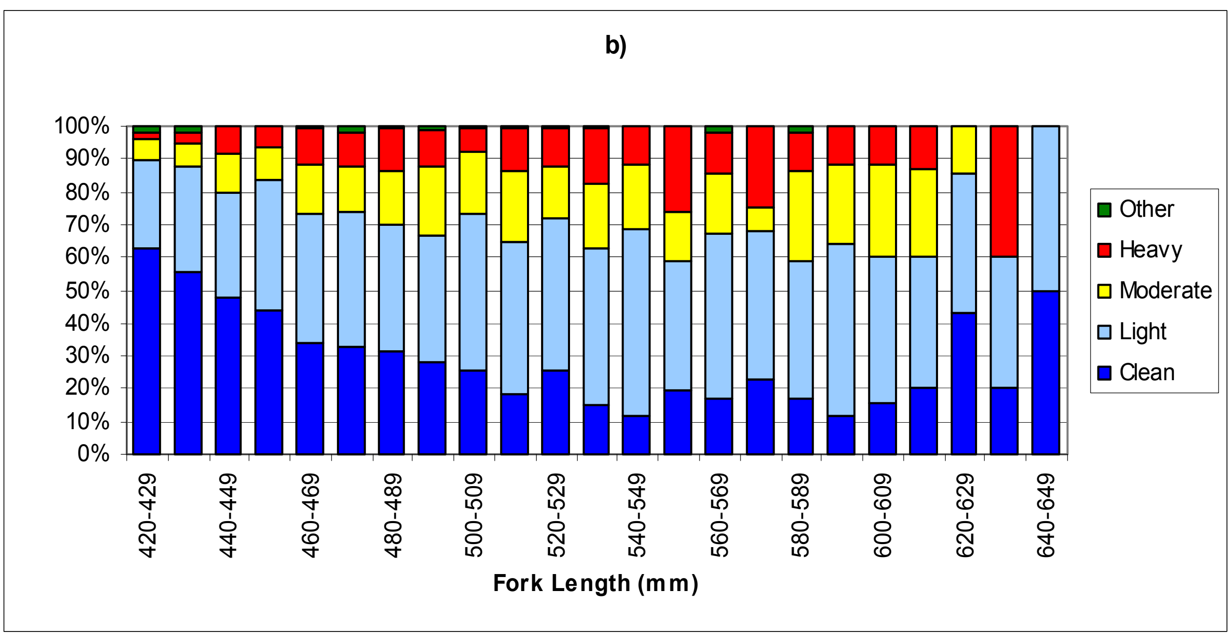
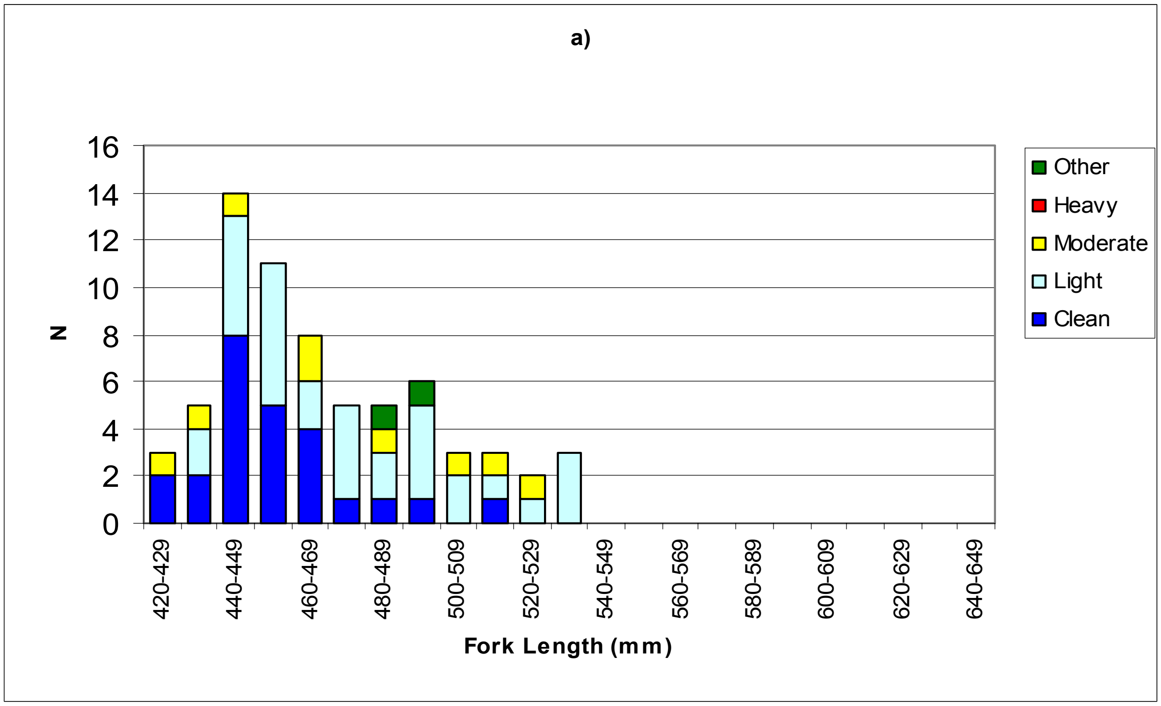


Figure 5. a) Size distribution (fork length in mm), by infection index, of striped bass tag releases from the upper Rappahannock River, spring 2007. b) Relative proportion of each infection index, by fork length, of the tag releases.



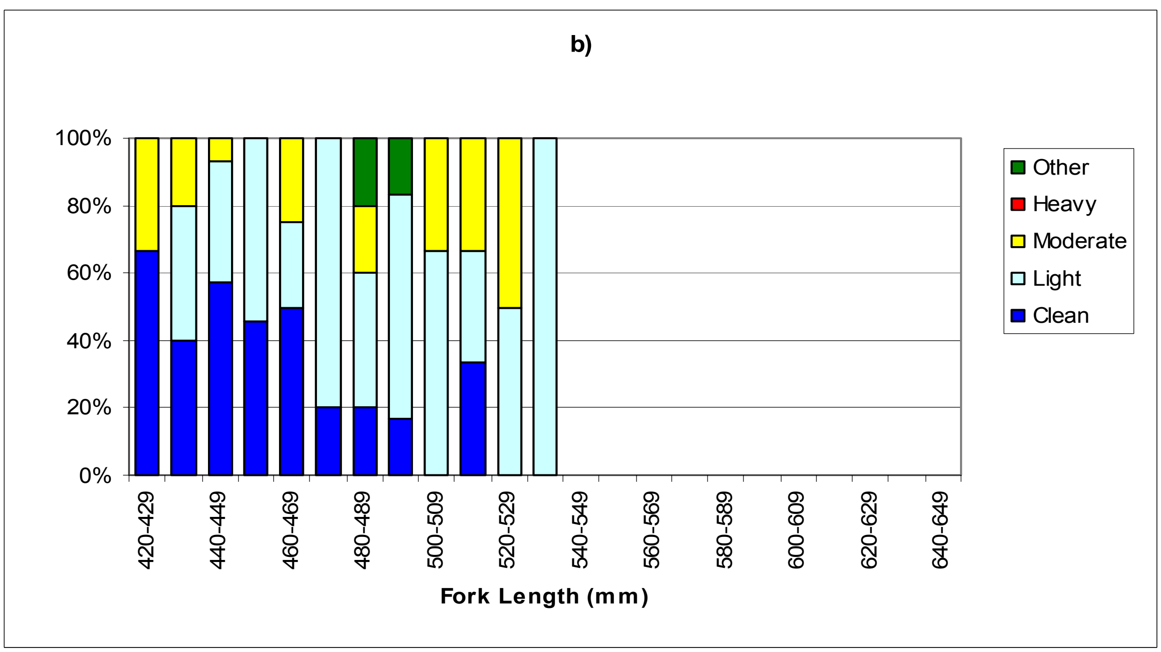


Figure 6. a) Size distribution (fork length in mm), by infection index, of striped bass tag releases from the lower Rappahannock River, spring 2007. b) Relative proportion of each infection index, by fork length, of the tag releases.