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Evaluation of striped bass stocks in Virginia, monitoring and tagging studies, 1999-2003 annual report, 1 September 1998 - 31 October 1999

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

Annual Report

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Preface

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

Examination of meristic characteristics indicate that the coastal migratory population consists of distinct subpopulations from the Hudson River, James River, Rappahannock - York rivers, and upper Chesapeake Bay (Raney 1957). The Roanoke River striped bass may represent another distinct subpopulation (Raney 1957). The relative contribution of each area to the coastal population varies. Berggren and Lieberman (1978) concluded from a morphological study that Chesapeake Bay striped bass were the major contributor (90.8%) to the Atlantic coast fisheries, and the Hudson River and Roanoke River stocks were minor contributors. However, they estimated that the exceptionally strong 1970 year class constituted 40% of their total sample. Van Winkle *et al.* (1988) estimated that the Hudson River stock constituted 40% - 50% of the striped bass caught in the Atlantic coastal fishery in 1965. Regardless of the exact proportion, management of striped bass is truly a multi-jurisdiction concern as spawning success in one area certainly influences fishing success in many areas.

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 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 to year-round moratoriums. Due to an improvement in spawning success, as judged by increases in annual values of the Maryland juvenile index, a limited fishery was established in fall, 1990. This transitional fishery existed until 1995 when spawning stock biomass reached sufficiently healthy levels (Field 1997). ASMFC subsequently declared Chesapeake Bay stocks to have reached benchmark levels and adopted Amendment 5 to the original FMP that allowed expanded state fisheries.

To document continued compliance with Federal law, the Anadromous Fishes Program of the Virginia Institute of Marine Science (VIMS) has monitored the size and age composition, sex ratio and maturity schedules of the spawning striped bass stock in the Rappahannock River since

December 1981 utilizing commercial pound nets and, since 1993, variable-mesh experimental gill nets. Spawning stock assessment was expanded to include the James River in 1994 utilizing commercial fyke nets and variable-mesh experimental gill nets. The use of fyke nets was discontinued after 1997. In conjunction with the monitoring studies, tagging programs have been conducted in the James and Rappahannock rivers since 1987 . These studies were established to document the migration and relative contribution of these Chesapeake Bay stocks to the coastal population and to provide a mean to estimate inter-year survival rates (S). With the re-establishment of fall recreational fisheries in 1993, the tagging studies were expanded to the York River and western Chesapeake Bay to provide a direct estimation of the resultant fishing mortality (F).

This document reports the results of our tagging and monitoring activities during the period 1 September 1998 through 31 October 1999. It includes an assessment of the biological characteristics of striped bass taken the 1999 spring spawning run, estimates of annual survival based on annual spring tagging (Appendix A), and the results of the fall 1998 directed mortality study that is cooperative with the Maryland Department of Natural Resources (Appendix B). The information contained in this report is required by the ASMFC and is used to implement a coordinated management plan for striped bass in Virginia, and along the eastern seaboard.

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We are deeply indebted to numerous parties for their participation and/or contributions to the striped bass tagging and spawning stock assessment program. These include, but are not limited to: the support personnel from the Virginia Institute of Marine Science; Mary Lynn Aiken, Pat Crewe, Susan Denny, Brett Falterman, John Foster, Jim Goins, Dean Grubbs, Beth Hinchey, Gail Holloman, Curtis Leigh, Kristin Maki, Todd Mathes, John Walter and Brian Watkins; the cooperating commercial fishermen; Bobby Brown, Russell Gaskins, Donnie Green, Joe Hinson, Allan Ingraham, Raymond Kellum, Stanley Oliff, Shelton Rowe and Charles Tench; Cynthia Goshorn and Beth Rodgers of Maryland Department of Natural Resources (MDNR) and David Smith of the U.S. Geological Survey.

Executive Summary

Catch Summaries:

1. In 1999, 1,370 striped bass were sampled from four commercial pound nets in the Rappahannock River. The samples were predominantly male (94.5%) and young (83.8% ages 2 - 4). Females dominated the age-nine and older age classes (98.0%).

2. Maximum catch rates of male striped bass in the pound net samples occurred from 25 March - 1 April. The maximum catch rates of female striped bass occurred from 19 - 26 April.

3. During the 30 March - 3 May period, the 1995 and 1996 year classes were the most abundant and were 99.8% male. The contribution of age five and older males was only 2.3% of the total catch. Age eight and older females, presumably repeat spawners, were 6.3% of the total catch but represented 85.2% of all females caught.

4. In 1999, 921 striped bass were sampled in two variable-mesh anchor gill nets in the Rappahannock River. The samples were predominantly male (96.4%) and young (86.6% ages 2-4). Old females (pre-1985 year classes) were absent in gill net catches, although present in pound net samples.

5. Maximum catch rates of male striped bass occurred from 5 - 8 April. The catches of female striped bass were low throughout the sampling period.

6. During the 30 March - 3 May period, the 1995 - 1997 year classes were the most abundant and were 99.7% male. The contribution of age five and older males was only 7.1%. Age eight and older females were 1.2% of the total catch and 34.8% of the total females caught.

7. In 1999, 534 striped bass were sampled from two variable-mesh gill nets in the James River. The sex ratio was less male-dominated than those from the Rappahannock (53.7% male). Males dominated the 1995 - 1997 year classes (80.4%) but females were more numerous in the 1991 - 1994 year classes and dominated the catch of the 1984 - 1990 year classes (93.5%).

8. Maximum catch rates of male striped bass occurred from 26 - 29 April. Maximum catch rates of female stripers occurred from 15 - 22 April. In contrast to the Rappahannock River, the catch rates of female striped bass exceeded those of male striped bass for most of the sampling period.

9. During the 30 March - 3 May period, the 1994 and 1995 year classes were the most abundant and were 60.0% male. The contribution of age five and older males was only 8.7% of the total catch. Age eight and older females, presumably repeat spawners, were 12.7% of the total catch but represented only 26.6% of all females caught.

Spawning Stock Biomass Indexes (SSBI)

10. The Spawning Stock Biomass Index from the Rappahannock River pound nets was 30.5 kg/day for male striped bass and 19.8 kg/day for female striped bass. Relative to the time series, the 1999 male index was exceeded only by the 1993 index and was 50.2% above the seven-year average. The female index was the lowest since 1993 and was 31.7% below the average index value.

11. The SSBI for the Rappahannock River gill nets was 48.7 kg/day for male striped bass and 11.8 kg/day for female striped bass. Relative to the time series, the male index was the second lowest since 1993 (43.3% below the seven-year average) and the female index was the lowest since 1993 (70.0% below the average index value).

12. The 1999 SSBI for the James River gill nets 45.8 kg/day for male striped bass and 102.0 kg/day for female striped bass. Relative to the time series, the male index was the highest since 1995 (22.2% above the six-year average). The female index was exceeded by the 1995 value and was 58.2% above the average index value.

Egg Production Potential Indexes (EPPI)

13. A new index of potential egg production was derived from laboratory estimates of weight- and length-specific numbers of oocytes in the ovaries of mature females. The Egg Production Potential Index (millions of eggs/day) for the Rappahannock River pound nets was 2.22. Older (8+ years) female stripers were responsible for 92.5% of the index.

14. The EPPI for the Rappahannock River gill nets was 1.40. Older female striped bass were responsible for 60.7% of the index.

15. The EPPI for the James River gill nets was 12.29. Younger (4 - 8 years) were responsible for 64.8% of the index.

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

16. The 1999 cumulative catch rate from the Rappahannock River pound nets (29.9 fish/day) was the highest in the 1993-1999 time series and double the cumulative catch rate in 1998. This was the result of very high catch rates of 1995 and 1996 year class (3 and 4 year old) stripers while the catch rates of most other year classes declined from those in 1998.

17. Year class-specific estimates of annual survival (S) for pound net data varied widely between years. The geometric mean S of the 1983-1992 year classes varied from 0.57 - 0.73. The geometric mean survival rates differed greatly between sexes. Mean survival rates for male stripers (1987-1992 year classes) varied from 0.28 - 0.53 but mean survival rates of female stripers (1983-1992 year classes) varied from 0.61 - 0.92.

18. The 1999 cumulative catch rate from Rappahannock River gill nets (64.5 fish/day) was second only to that for 1997 and 13.2% greater than in 1998. Catch rates were very high for the 1995-1997 year classes (2 - 4 year old) and catch rates for most other year classes declined from the 1998 catch rates.

19. Year class-specific estimates of annual survival for gill net data varied widely between years. The geometric mean S of the 1985-1991 year classes varied from 0.37 - 0.66. The mean survival rates for male stripers varied from 0.24 - 0.54. The mean survival rates for female stripers varied from 0.41 - 0.68.

20. The 1999 cumulative catch rate from James River gill nets (48.2 fish/day) was the highest of the 1994-1999 time series. In contrast to the Rappahannock River data, catch rates were higher for most every year class compared to the 1998 catch rates.

21. Year class-specific estimates of annual survival varied widely between years. The geometric mean S of the 1984-1992 year classes varied from 0.33 - 0.91. The geometric mean S for the 1985-1991 year classes varied from only 0.54 - 0.78. The mean survival rates of male stripers (1988-1992 year classes) varied from 0.24 - 0.71. The mean survival rates of female stripers varied from 0.34 - 0.82.

Results of Tagging:

22. In spring 1998, 158 striped bass were tagged and released from the four pound nets within the spawning grounds of the Rappahannock River. Recapture information during the period 1988-1998 were used as input for Program MARK. Model averaging of the estimates from nine models were used to estimate annual survival. These results have been previously reported as a memorandum to the Striped Bass Tagging Committee (J. Olney, B. Harris and P. Sadler, authors), and are included as Appendix A.

23. In fall 1999, 8,536 striped bass were tagged and released in various locations throughout the Chesapeake Bay and its tributaries by VIMS and MDNR personnel. A total of 59 tags were recaptured during the specified recovery period Recapture data were used to calculate a Chesapeake Bay-wide estimate of fishing mortality (F). The preliminary bay-wide estimate was 0.20 which was below the 1998 target fishing rate of 0.28. These results were previously reported as a draft final report (Goshorn et al. 1999), and are included as Appendix B.

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Assessment of the spawning stocks of striped bass in the Rappahannock and James rivers, Virginia, spring 1999.

Introduction

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

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

Materials and Methods

Samples of striped bass for biological characterization of the spring spawning stocks were obtained from the Rappahannock and James rivers in between 30 March - 3 May, 1999. Samples (the entire catch of striped bass from each gear) were taken twice-weekly (usually Monday and Thursday) from a set of two commercial pound nets (river miles 44 and 47) on the Rappahannock River. The established protocol (Sadler *et al.* 1999) was to alternate the choice of the net sampled but weather constraints often dictated whether that net could be sampled. In addition to the pound nets, samples were obtained from variable-mesh experimental anchored gill nets (two each at river mile 48 on the Rappahannock River and river mile 55 on the James River (Figures 1-2). Pound nets are fixed commercial gears that have been historically predominant gear types used in the river and are presumed to be non size-selective in their catches of striped bass.

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

Striped bass collected from the monitoring sites were measured and weighed on a Limnoterra FMB IV electronic fish measuring board interfaced with a Mettler PM 30000-K electronic balance. The board records lengths (FL and TL) to the nearest mm, receives weight input from the balance, and allows manual input of sex and gonad maturity into a data file for subsequent analysis. Gonad weight was taken for all female striped bass sampled, and two or three subsections extracted as described by Barbieri and Barbieri (1993). A 2-3 gram subsample was taken, weighed and washed through a 30 micron screen and stored in 2% formalin for subsequent counting. Scales were collected from between the spinous and soft dorsal fins above the lateral line for subsequent aging, using the method established by Merriman (1941), except that impressions made in acetate sheets replaced the glass slide and acetone.

All readable scales were aged using the microcomputer program DISBCAL of Frie (1982), in conjunction with a sonic digitizer-microcomputer complex (Loesch et al. 1985). Growth increments were measured from the focus to the posterior edge of each annulus. In order to be consistent with ageing techniques of other agencies, all striped bass were considered to be one year older on 1 January of each year. Mean age was determined by the sum of the relative contribution of each age class to the total (aged) catch.

The spawning stock biomass index (SSBI) for striped bass was defined as the spring 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.

Each ovary subsample was mixed in 500 ml of water and stirred until a homogenous suspension resulted. A two-milliliter aliquot was extracted and the contents counted under a dissecting scope. The resultant count was then extrapolated to account for the entire subsample. The geometric mean of the subsamples for each fish was calculated. Values of greater than 10 eggs/gram of ovary, representing gonads that were in an early stage of development, were found to give equally low fecundity estimates across a wide range of sizes when compared to estimates from more mature samples and were excluded from further analysis. A non-linear regression curve was fitted to data of total oocytes verses fork length. The resultant equation was then applied to the fork lengths of all mature (4+ years old) females from the pound net and gill net samples and the Egg Production Potential Index (EPPI) was defined as the mean number of eggs potentially produced per day of effort of the mature female striped bas sampled from 30 March - 3 May.

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

Results

Catch Summary

Rappahannock River

Pound nets: Striped bass (n= 1,370) were sampled between 18 March and 6 May, 1999 from the four pound nets in the Rappahannock River. Total catches peaked from 18 - 25 March and again from 26 April - 3 May, due to large numbers of young (2 - 4 year old) males (Table 1). Catches of female striped bass were highest on 26 April but were generally available throughout April and early May. Males made up 94.5% of the total catch. Males dominated the 1995-1997 year classes (99.4%) and the 1991-1994 year classes (86.0%), but females dominated the 1984-1990 year classes (96.0%).

Catch rates (g/day) of male striped bass were highest from 25 March - 1 April (Table 2). The catch rates of female striped bass were highest from 19 - 26 April. The catch rate of males greatly exceeded that of females from 18 March - 5 April (155.8 : 1 on 22 March) and again from 26 April - 6 May. Catch rates of females exceeded that for males on 8 April and from 19-22 April (3.1 : 1 on 19 April). The mean ages of male striped bass varied from 3.1 - 4.4 years with the youngest males being prevalent from 18 - 22 March. The mean ages of females varied from 3.0 - 12.0 years, but during the 30 March - 3 May sampling window varied only from 8.7 - 12.0 years.

During the 30 March - 3 May period, the 1996 (38.6%) and 1995 (38.5%) year classes were the most abundant (Table 3). These year classes were 99.8% male. The contribution of males age-5 and older (the pre-1994 year classes) was only 2.3% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age-8 and older, presumably repeat spawners, was

6.3% of the total aged catch but was also 85.2% of the total females captured.

Experimental gill nets: Striped bass (n= 921) were also sampled between 18 March and 6 May, 1999 from two multi-mesh experimental gill nets in the Rappahannock River. Total catches peaked sharply from 5 - 8 April, due to large numbers of young (2 - 4 year old) males (Table 4). Catches of female striped bass were highest on 15 April, but were generally available only in low numbers throughout the sampling period. Males made up 96.4% of the total catch. Males dominated the 1995-1997 year classes (99.7%) and the 1991-1994 year classes (74.3%), but females dominated the 1984-1990 year classes (80.0%).

Catch rates (g/day) of male striped bass were highest from 5 - 8 April (Table 5). The catch rates of female striped bass were highest on 15 April. The catch rate of males exceeded that of females except on 15 April and on 6 May. The mean ages of male striped bass varied from 3.1 - 4.7 years with the youngest males (2 - 3 years) being prevalent throughout the sampling period. The mean ages of females varied from 5.5 - 13.0 years but these means were based on very low total catches.

The mean age of the female striped bass captured from the gill nets was two years younger than that estimated for those captured in the pound nets, illustrating a relative scarcity of older (age-8+) females in gill-net catches. Only eight age-8+ females were captured in gill nets, and seven of these were taken from 25 March - 15 April.

During the 30 March - 3 May period, the 1996 (53.2%) year class was prevalent, followed by the 1997 (17.4%) and 1995 (15.8%) year classes (Table 6). These year classes were 99.7% male. The contribution of males age-5 and older (the pre-1994 year classes) was only 7.1% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age-8 and older, presumably repeat spawners, was 1.2% of the total aged catch but was 34.8% of the total females captured.

James River

Experimental gill nets: Striped bass (n= 534) were sampled between 18 March and 6 May, 1999 from the two multi-mesh experimental gill nets in the James River. Total catches peaked from 19 - 29 April (Table 7). The 1995 -1997 year classes were prevalent (41.0% of the total catch), but in contrast to the catches from the Rappahannock River, females comprised almost half (46.3%) of the total catch. Catches of female striped bass were highest on 19 April but were generally available throughout April and early May. Males dominated the 1995-1997 year classes (80.4%), but females were more numerous in the 1991-1994 year classes (59.8%), and dominated the 1984-1990 year classes (93.5%).

Catch rates (g/day) of male striped bass were highest from 26 - 29 April (Table 8). The catch rates of female striped bass were highest from 15 - 22 April. The catch rate of males exceeded that of females only from 18 - 25 March and from 26 April - 6 May. Catch rates of females greatly exceeded that for males from 29 March - 22 April (26.3 : 1 on 15 April). The mean ages of male striped bass varied from 3.5 - 4.9 years. The mean ages of females varied from 5.0 - 9.3 years, but during the 30 March - 3 May sampling window varied only from 5.6 - 7.3 years.

During the 30 March - 3 May period, the 1994 (24.3%) and 1995 (21.4%) year classes were the most abundant (Table 9). These year classes were 60.0% male. The contribution of males age-5 and older (the pre-1994 year classes) was only 8.7% of the total aged catch. These year classes were most vulnerable to commercial and recreational exploitation within Chesapeake Bay. The contribution of females age-8 and older, presumably repeat spawners, was 12.7% of the total aged catch but was also 26.6% of the total females captured. Females ages 4 - 7, scarce in Rappahannock River samples, were 29.5% of the total catch from the James River.

Spawning Stock Biomass Indexes

Rappahannock River

Pound nets: The Spawning Stock Biomass Index (SSBI) for spring 1999 was 30.5 kg/day for male striped bass and 19.8 kg/day for female striped bass. The index for male striped bass was second in magnitude only to the 1993 male index and was 50.2% above the seven-year average (Table 10). The magnitude of the index for male striped was largely determined by the 1995 and 1996 year classes (72.2%). The index for female striped bass was the second lowest since 1993 and was 31.7% below the average (Table 10). The magnitude of the index for the females was largely the result of the pre-1992 year classes (94.4%).

Experimental gill nets: The Spawning Stock Biomass Index for spring 1999 was 48.7 kg/day for male striped bass and 11.8 kg/day for female striped bass. The index for male striped bass was the second lowest since 1993 and 43.4% below the seven-year average (Table 10). The 1995 and 1996 year classes contained 67.1% of the biomass in the male index. The index for female striped bass was the lowest since 1993, 70% below the average, and continues a trend of declining indexes throughout the time series. The pre-1992 year classes contained 70.3% of the biomass in the female index.

James River

Experimental gill nets: The Spawning Stock Biomass Index for spring 1999 was 45.8 kg/day for male striped bass and 102.0 kg/day for female striped bass. The male index was the highest since 1995, and was 22.2% above the six-year average (Table 11). The female index was second only to the 1995 index and was 58.2% above the six-year average. In contrast to the Rappahannock River, there was no concentration of biomass within any age group.

Egg Production Potential Indexes

The number of gonads sampled, especially of the larger females, was insufficient to produce separate estimates for each river. The number of oocytes increased with increasing size (Figure 3). The pooled data produce a fork length - oocyte count relationship as follows:

$$N_o = 1.07 \times FL^{2.033}$$

Where N_o is the total number of oocytes and FL is the fork length (>400) in millimeters. Thus, the predicted egg production increased from 276,000 for a 400 mm female to 2,182,000 for a 1180 mm female striped bass (Table 12). The Egg Production Potential Indexes (EPPI, Table 13) for the Rappahannock River were 2.22 (pound nets) and 1.401 (gill nets). The EPPI for the James River was 12.286. The indexes for the Rappahannock River were heavily dependent on the egg production potential of the older (8+ years) females (92.5% in the pound nets, 60.7% in the gill nets), while the James River index was more dependent on younger (4 - 8 years) females (64.8%).

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

Rappahannock River

Pound nets: Catch rates (number of fish/day) of individual years classes from 1993-1999 are presented in Tables 14 - 16. The cumulative annual catch rate for 1999 was greater than for any of the previous years and double the catch rate for 1998 (Table 14). However, the cumulative catch rate was driven by high catch rates of 1995 and 1996 year class (3 and 4 year old) stripers and the catch rates of most other year classes actually declined from 1998. The age of peak abundance for each year has declined from ages 5 - 6 in 1993 to ages 3 - 4 in 1999.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 1999 catch rate being the overall highest and double that for 1998 (Table 15). Using the maximum catch rate of the resident males as an indicator, the 1988 and the 1993-1996 year classes were strongest and the 1990 and 1991 year classes were the weakest. Male catch rates decline rapidly after age five or six. The 1999 cumulative catch rate of female striped bass was the lowest in the time series and was less than half the 1998 cumulative catch rate (Table 16). This trend was true for every year class (except the 1992 year class) captured in 1999. The overall age structure was unchanged from 1993-1999, consisting of 2 - 10 year old males and 4 - 15 year old females. The rapid decline in male catch rates for the 1987-1994 year classes are illustrated in Figure 4. These graphs also illustrate another persistent phenomenon; a secondary peak in the catch rates of 9 - 11 year old females across several year classes.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in tables 17 - 19. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1993-1999) of the 1983 - 1992 year classes (sexes combined) varied from 0.568 - 0.729 (Table 17) with an overall mean survival of 0.628. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1993-1999) of the 1987-1992 year classes of males varied from 0.277 - 0.527 (Table 18) with an overall mean survival of 0.391. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1993-1999) of the 1983-1992 year classes of females varied from 0.609 - 0.916 for those year classes with three or more annual estimates (Table 19) with an overall mean survival of 0.758.

Experimental gill nets: Catch rates (number of fish/day) of individual years classes from 1993-1999 are presented in Tables 20 - 22. The cumulative annual catch rate for 1999 was second only to that for 1997, but only 13.2% greater than the catch rate for 1998 (Table 20). The cumulative catch rate was driven by high catch rates of 1995 - 1997 year classes (2 - 4 year old) of striped bass and the catch rates of most other year classes actually declined from 1998. The age of peak abundance for each year has declined from ages 5 - 6 in 1993 to ages 2 - 4 in 1999.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 1999 catch rate being the second overall highest and 20% higher than that for 1998 (Table 21). Using the maximum catch rate of the resident males as an indicator, the 1988, 1989, 1994 and 1996 year classes were strongest and the 1990 and 1991 year classes the weakest. Male catch rates decline rapidly after ages five or six. The 1999 cumulative catch rate of female striped bass was the lowest in the time series, but was similar to cumulative catch rates for 1997 and 1998 (Table 22). Catch rates for every year class (except the 1985 and 1992 year classes) captured in 1999 were lower than in 1998. The overall age structure was unchanged from 1993-1999, consisting of 2 - 12 year old males and 2 - 14 year old females. The rapid decline in male catch rates for the 1987-1994 year classes are illustrated in Figure 5. but the secondary peak of older females found in the pound nets was not evident in the gill nets.

Estimates of annual survival (S) for the individual year classes and their overall geometric means are presented in Tables 23 - 25. While annual survival estimates varied widely among years, due to strong or weak overall catches, the geometric mean survival rate (1993-1999) of the 1985 - 1991 year classes (sexes combined) varied from 0.373 - 0.655 (Table 23) with an overall mean survival of 0.467. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1993-1999) of the 1987-1991 year classes of males varied from 0.239 - 0.536 (Table 24) with an overall mean survival of 0.369. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1993-1999) of the 1985-1990 year classes of females varied from 0.407 - 0.684 (Table 25) with an overall mean survival of 0.563. The survival estimates of the male striped bass were similar to those calculated from the pound nets. The survival estimates of the female striped bass were lower in the gill nets due to the greater abundance of older female striped bass in the pound net samples. This scarcity of older female stripers, and the greater proportion of males in the gill nets produced the lower combined survival estimate.

James River

Experimental gill nets: Catch rates (number of fish/day) of individual years classes from 1994-1999 are presented in Tables 26 - 28. The cumulative annual catch rate for 1999 was the highest of the time series, and was more than double the catch rate for 1998 (Table 26). The cumulative catch rate was driven by higher catch rates for most every year class. The age of peak abundance for each year has been ages 4 - 5 in each year.

The cumulative catch rate of male striped bass mirrored the trends of the combined data with the 1999 catch rate being the highest overall and 65.7% higher than that for 1998 (Table 27). Using the maximum catch rate of the resident males as an indicator, the 1989 - 1991, 1995 and 1996 year classes were strongest and the 1992 and 1993 year classes the weakest. Male catch rates decline rapidly after ages five or six but not as rapidly as on the Rappahannock River. The 1999 cumulative catch rate of female striped bass was the highest in the time series, slightly greater than in 1995, and was triple the catch rates for 1996 - 1998 (Table 28). Catch rates for every year class (except the 1985 and 1988 year classes) captured in 1999 were higher than in 1998. The age structure of male striped bass changed from 3 - 6 years in 1994 to 2 - 11 years in 1999. The age structure of female striped bass was unchanged from 1993-1999, consisting of 2 - 14 year old females. The changes in catch rates for the 1987-1994 year classes are illustrated in Figure 6. The secondary peak of older females found in the pound nets was not evident in the gill nets.

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 (1993-1999) of the 1984 - 1992 year classes (sexes combined) varied from 0.330 - 0.905 (Table 29), but only varied from 0.535 - 0.782 for the 1985-1991 year classes, with an overall mean survival of 0.624. There were widely divergent estimates of annual survival of male and female striped bass. The geometric mean survival rate (1993-1999) of the 1988-1992 year classes of males varied from 0.236 - 0.714 (Table 30) with an overall mean survival of 0.489. These year classes have been the major target of the fall recreational and commercial fisheries that reopened in 1993. The geometric mean survival rate (1993-1999) of the 1984-1990 year classes of females varied from 0.340 - 0.819 (Table 31) with an overall mean survival of 0.598.

Estimates of Annual Survival, 1988-1998

The release and recovery matrix of spring tagging data (striped bass >28 inches in total length) were used as input for Program MARK to estimate annual survival. These results have been previously reported as a memorandum to the Striped Bass Tagging Committee (J. Olney, B. Harris and P. Sadler, authors), and are appended (Appendix A).

Fall Directed F Cooperative Tagging Study

In fall 1999, 8,536 striped bass were tagged and released in various locations throughout the Chesapeake Bay and its tributaries by VIMS and MDNR personnel. A total of 59 tags were recaptured during the specified recovery period Recapture data were used to calculate a Chesapeake Bay-wide estimate of fishing mortality (F). The preliminary bay-wide estimate was 0.20 which was below the 1998 target fishing rate of 0.28. These results were previously reported as a draft final report (Goshorn et al. 1999), and are appended (Appendix B). The reader should note that the Goshorn et al. (1999) report is in revision (personal communication, C. Goshorn, 21 January 2000).

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 selective harvest by these fisheries.

The main advantage of pound nets is that the gear provides large catches (often in excess of 100 fish per day) that are presumably not sex- or size-biased. However, each pound net has a different fishing characteristic, and our sampling methods, established in 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 sampled weekly, but uncontrollable factors (especially tide, weather and market conditions) affected this schedule. In addition, weekly sampling occurred each Monday and Thursday, a schedule that translated to fishing efforts of 96 hrs (Thursday through Monday) or 72 hrs (Monday through Thursday). However, on two occasions, 19 and 22 April, the effort was only 24 hours and in past years the effort could be extended up to 196 hours if the fisherman was unable to fish the scheduled net for that sampling date. Although these events were uncommon, we were unable to assess whether or not they influenced estimates of catch rate.

Variable-mesh gill nets were set by commercial fishermen and fished by scientists after 24 hours on designated sampling days. As a result, there were fewer instances of sampling inconsistencies. The two nets were set approximately 100 meters apart and along the same depth contours on both rivers. Although the down-river net did not always contain the greater catches, removal by one net may have affected the catch rates of its companion.

The gill net captured proportionally more males than did the pound nets. Anecdotal information from commercial fishermen suggests that spawning males are attracted to con-specifics that have become gilled in the net meshes. Thrashing of gilled fish may emulate spawning behavior (termed “rock fights” by local fishermen) and enhance catches of males.

The pound net catches contained a greater relative proportion of older female striped bass than did the catches from the gill nets. Thus, given the presence of large females in the spawning run, it is clear that the gill nets do not adequately sample large (1000+ mm FL) striped bass.

The biological characterization of the spawning stock of striped bass in the Rappahannock River changed dramatically from 1993-1999. There was a steady decrease in the relative abundance of five to seven year-old males. These age classes are targeted by the recreational and commercial fisheries. Current regulations protect females from harvest during their annual migration by higher minimum lengths in the coastal fishery (711 mm TL vs. 458 mm TL within Chesapeake Bay) and the closure of the fishery in the bay during the April spawning run. Our monitoring data depict increasing abundance of female striped bass >10 years old throughout the period.

The 1999 values of the Spawning Stock Biomass Index (SSBI) for the Rappahannock River were below the 1993 - 1999 average for female striped bass in both pound nets and gill nets. The proportion of older (greater than eight years) females was similar to 1997 and 1998 so the decrease in the value was attributable to fewer females of all age classes. Two very large catches of very young male stripers produced an above average SSBI for males in the pound nets, but the male SSBI in the gill nets was below the average.

The 1993 - 1999 values of the SSBI in the Rappahannock River were not consistent between pound nets and gill nets. Based on pound net catches, the highest values of male and female biomass were in 1993 and 1997, respectively. For the gill net data, the highest value of male biomass was in 1997. Due to the highly selective nature of the gill nets (significantly fewer large females), the female SSBI from these nets is less reliable. Female biomass rebounded in the pound nets in 1997 and 1998. The high values in 1993 and 1997 were such that most of the other values were below the six-year mean. The low values in 1996 are probably an underestimate of spawning stock strength since water temperatures were below normal in that year, and the spawning migration probably continued past the end of sampling.

The values of the SSBI in the James River were highest in 1995 and have slowly increased from the lowest values that were estimated for 1996. The below normal water temperatures noted for the Rappahannock River in 1996 apply to the James River as well and probably produced a similar under-estimation of spawning stock abundance. The scarcity of larger striped bass from the gill nets in the James River implies a similar limitation in fishing power as shown in the Rappahannock River but comparative data are not available since there are no commercial pound nets on the James River.

The new 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 the larger female striped bass. For example, in the Rappahannock River the contribution of 8+

year old females was 85.2% of the total number of mature females (the basis of our index prior to 1998), 94.4% of the mature female biomass (the basis of the current index) and 92.5% of the calculated egg potential. It should be noted the egg-size relationship from the current study produced fecundity estimates well below those reported by other authors (Setzler et al. 1980), so the relative contribution in potential egg production of the older females may be underestimated at present. We will continue to evaluate and refine this new approach.

In our analysis of catch rates, we observed a distinctive bimodal distribution in the 1987-1989 year classes. These striped bass appeared in greatest abundance at age five or six, at lower abundance at age six to eight, and then higher abundance at ages nine to12. 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. Thus, 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 1997-1999 data and its significance has not been determined.

The time series of the catch rates by age class and by year class indicate that the age of peak abundance in the rivers has changed from five or six years in 1993 and 1994 to three to five years in 1999. Changes in the annual catch rates by year class in the Rappahannock River indicated that strong year classes occurred in 1988, 1989, 1993-1996, and weak year classes occurred in1990 and 1991. Likewise the data for the James River indicated that strong year classes occurred in 1988-1990, and weak year classes occurred in 1991 and 1992.

The time series allows estimates of survival of the year classes using catch curves, especially for the 1987-1991 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 0.75 in pound nets and 0.56 in gill nets. The lower capture rates of larger (older) females in the gill nets resulted in lower estimates. The survival estimates of male striped bass were approximately 0.39 in pound nets and 0.36 in gill nets. The large differences between the sexes may reflect a management strategy that targets males. The high survival estimates for the females may be the result of their differential maturation rates. These differences may cause lower peaks in abundance (usually at age five) as only fractions of each year class mature. Similarly, survival estimates for these year classes in the James River were highly variable, ranging from 0.49-0.74 for females and from 0.28-0.53 for male striped bass.

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Table 1. Numbers of striped bass in three age categories (year classes 1995-1997, 1991-1994 and 1984-1990) in pound nets in the Rappahannock River by sampling date in spring 1999.

Date	n	Year Class							
		1995 - 1997		1991 - 1994		1984 - 1990		Not aged	
		M	F	M	F	M	F	M	F
18 March	148	139	2	7	0	0	0	0	0
22 March	148	144	1	2	0	0	0	1	0
25 March	128	114	2	9	2	0	0	1	0
29 March	69	64	0	3	0	0	1	1	0
1 April	85	48	1	28	1	0	5	2	0
5 April	42	39	0	1	0	0	1	1	0
8 April	34	23	0	4	2	0	4	1	0
12 April	80	59	0	10	2	0	9	0	0
15 April	39	35	0	2	0	0	2	0	0
19 April	17	12	0	1	1	0	3	0	0
22 April	23	14	0	1	0	1	7	0	0
26 April	180	150	1	11	4	0	12	2	0
29 April	92	75	0	12	1	0	1	3	0
3 May	244	209	0	24	2	0	2	7	0
6 May	41	23	0	8	5	0	2	3	0
Total	**1370**	**1148**	**7**	**123**	**20**	**1**	**49**	**22**	**0**

Table 2. Net-specific summary of catch rates and ages of striped bass (n= 1,370) in four pound nets on the Rappahannock River, spring 1999. Values in bold are grand means for each column.

Date	Net ID	n	CPUE (fish/day)		CPUE (g/day)		Mean age	
			M	F	M	F	M	F
18 March	S462	148	20.9	0.3	20,574.3	289.8	3.3	3.5
22 March	S473	148	36.8	0.3	31,259.5	200.6	3.1	3.0
25 March	S462	128	124.0	4.0	122,279.2	9,930.2	3.4	5.0
29 March	S473	69	68.0	1.0	58,904.2	11,380.0	3.4	5.0
1 April	S454	85	78.0	7.0	135,299.5	55,019.7	4.4	8.7
5 April	S473	42	10.3	0.3	10,165.5	2,835.9	3.6	12.0
8 April	S441	34	9.3	2.0	12,324.1	18,597.0	3.7	10.1
12 April	S473	80	17.3	2.8	26,279.6	23,542.3	4.1	9.9
15 April	S441	39	12.3	0.3	10,933.4	7,626.2	3.4	12.0
19 April	S473	17	13.0	4.0	14,700.8	45,496.7	3.8	11.0
22 April	S441	23	16.0	7.0	24,559.3	71,381.8	4.1	10.7
26 April	S473	180	40.8	4.3	41,403.3	38,099.7	3.6	9.8
29 April	S441	92	30.0	0.7	29,815.7	5,156.2	3.7	9.5
3 May	S473	244	60.0	1.0	58,319.4	7,764.8	3.5	9.0
6 May	S441	41	11.3	2.3	13,134.2	12,507.7	4.0	7.1
Totals	S441	229	15.5	1.8	17,167.8	15,618.7	3.5	9.4
	S454	85	79.0	6.0	135,299.5	55,019.7	4.4	8.7
	S462	276	34.0	0.5	33,287.4	1,494.9	3.3	5.0
	S473	780	33.7	1.6	33,787.0	15,756.8	3.5	9.7
Season		**1370**	**29.4**	**1.7**	**31,093.1**	**14,015.3**	**3.5**	**9.2**

Table 3. Mean fork length (mm), weight (g), standard deviation (SD) and CPUE (fish per day; weight per day), of striped bass from pound nets in the Rappahannock River, 30 March - 3 May 1999.

Year Class	Sex	n	Fork Length Mean	Fork Length SD	Weight Mean	Weight SD	CPUE F/day	CPUE W/day
1997	male	22	295.6	23.4	322.3	72.8	0.8	253.3
1996	male	323	383.2	26.3	702.1	146.9	11.5	8,099.6
1995	male	321	455.1	21.2	1,215.6	215.5	11.5	13,936.1
	female	1	494.0		1,862.6		0.0	66.5
1994	male	75	515.1	21.3	1,835.9	272.4	2.7	4,917.6
	female	3	534.7	8.1	1,974.6	213.5	0.1	211.6
1993	male	2	643.5	44.6	3,648.3	493.0	0.1	260.6
	female	1	625.0		3,313.0		0.0	118.3
1992	male	10	707.3	37.6	4,714.6	733.8	0.4	1,683.8
	female	4	721.3	22.3	5,008.5	740.5	0.1	715.5
1991	male	6	763.3	22.9	6,016.1	923.1	0.2	1,289.2
	female	6	776.8	29.7	6,389.2	777.9	0.2	1,369.1
1990	female	9	826.8	26.5	8,109.8	1,285.8	0.3	2,606.7
1989	male	1	890.0		8,353.5		0.0	298.3
	female	9	887.7	33.6	9,195.9	482.7	0.3	2,955.8
1988	female	11	929.1	18.2	10,505.9	751.2	0.4	4,127.3
1987	female	12	955.9	30.0	11,544.7	1,001.9	0.4	4,947.7
1986	female	1	1,000.0		14,779.1		0.0	527.8
1985	female	3	1,038.7	15.5	14,191.0	939.5	0.1	1,520.5
1984	female	1	1,144.0		17,934.0		0.0	640.5
N/A	male	15	440.7	69.5	1,185.0	509.7	0.5	634.8

N/A- not aged

Table 4. Numbers of striped bass in three age categories (year classes 1995-1997, 1991-1994 and 1984-1990) in gill nets in the Rappahannock River by sampling date in spring 1999.

Date	n	Year Class							
		1995 - 1997		1991 - 1994		1985 - 1990		Not aged	
		M	F	M	F	M	F	M	F
18 March	73	68	0	3	0	0	0	2	0
22 March	80	72	0	2	4	0	0	2	0
25 March	42	37	0	4	0	0	1	0	0
29 March	39	35	0	4	0	0	0	0	0
1 April	43	35	1	4	1	0	1	0	1
5 April	265	239	0	8	1	1	1	15	0
8 April	176	167	0	8	0	0	0	1	0
12 April	20	14	0	2	2	0	1	1	0
15 April	27	19	0	2	5	0	1	0	0
19 April	3	2	0	1	0	0	0	0	0
22 April	33	19	0	4	2	1	0	6	1
26 April	40	31	1	5	1	0	2	0	0
29 April	51	44	0	5	1	0	0	1	0
3 May	13	7	0	6	0	0	0	0	0
6 May	16	8	0	3	4	0	1	0	0
Total	**921**	**797**	**2**	**61**	**21**	**2**	**8**	**28**	**2**

Table 5. Summary of catch rates and mean ages of striped bass (n=921) from the two gill nets in the Rappahannock River, spring 1999. 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
18 March	73	73.0	0.0	73,263.1	0.0	3.4	
22 March	80	76.0	4.0	70,546.5	11,603.8	3.2	5.8
25 March	42	41.0	1.0	46,512.7	18,750.0	3.4	13.0
29 March	39	39.0	0.0	37,397.1		3.3	
1 April	43	39.0	4.0	47,581.2	19,614.6	3.6	6.3
5 April	265	263.0	2.0	191,269.8	22,989.9	3.0	11.0
8 April	176	176.0	0.0	132,891.5		3.1	
12 April	20	17.0	3.0	16,700.9	13,025.1	3.4	6.7
15 April	27	21.0	6.0	25,918.8	36,123.4	3.5	7.5
19 April	3	3.0	0.0	5,233.9		4.7	
22 April	33	30.0	3.0	44,813.5	13,767.4	4.1	5.5
26 April	40	36.0	4.0	31,983.9	21,526.9	3.4	7.0
29 April	51	50.0	1.0	42,663.1	6,262.9	3.3	7.0
3 May	13	13.0	0.0	21,005.9		4.3	
6 May	16	11.0	5.0	14,530.1	20,852.9	3.8	6.4
Season	**921**	**59.2**	**2.2**	**53,487.5**	**12,301.1**	**3.3**	**7.2**

Table 6. Mean fork length (mm), weight (g), standard deviations (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the Rappahannock River, 30 March - 3 May, 1999.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
1997	male	116	309.2	10.9	397.4	47.3	11.6	4,610.2
	female	1	290.0		331.6		0.1	33.2
1996	male	357	357.0	28.9	597.8	148.4	35.7	21,280.5
	female	1	420.0		1,029.3		0.1	102.9
1995	male	106	454.4	21.6	1,246.2	215.9	10.6	13,209.4
1994	male	26	534.3	28.3	2,059.3	356.4	2.6	5,354.1
	female	6	558.8	25.9	2,691.9	376.6	0.6	1,615.1
1993	male	6	609.8	39.1	3,178.4	624.5	0.6	1,907.0
	female	2	600.0	39.6	3,390.7	471.6	0.2	678.1
1992	male	9	695.9	49.3	4,684.1	835.1	0.9	4,215.7
	female	3	723.7	30.2	5,437.5	935.1	0.3	1,631.2
1991	male	3	760.0	12.3	6,327.9	408.1	0.3	1,898.4
	female	2	792.0	26.9	6,964.6	644.0	0.2	1,392.9
1990	female	1	840.0		8,252.5		0.1	825.3
1989	female	2	835.0	7.1	8,378.8	285.5	0.2	1,675.8
1988	male	1	860.0		8,606.6		0.1	860.7
	female	1	900.0		10,119.6		0.1	1,012.0
1987	male	1	950.0		11,762.5		0.1	1,176.3
1985	female	2	1,046.0	19.8	15,015.2	784.5	0.2	3,003.0
Not Aged	male	23	362.3	53.1	649.6	334.1	2.3	1,494.1
	female	2	821.5	75.7	6,807.5	1,268.1	0.2	1,361.5

Table 7. Numbers of striped bass in three age categories (year classes 1995-1997, 1991-1994 and 1984-1990) in gill nets in the James River by sampling date in spring 1999.

Date	n	Year Class							
		1995 - 1997		1991 - 1994		1985 - 1990		Not aged	
		M	F	M	F	M	F	M	F
18 March	19	9	1	5	4	0	0	0	0
22 March	9	4	0	4	1	0	0	0	0
25 March	7	3	0	3	1	0	0	0	0
29 March	8	4	0	0	2	0	2	0	0
1 April	18	1	1	4	10	0	2	0	0
5 April	26	2	1	4	14	0	4	1	0
8 April	27	6	2	3	13	0	3	0	0
12 April	32	14	2	6	7	0	3	0	0
15 April	45	2	8	2	22	0	10	0	1
19 April	70	13	8	9	33	0	7	0	0
22 April	52	11	11	5	17	0	6	0	2
26 April	84	33	6	25	14	1	2	1	2
29 April	113	64	3	26	8	2	4	3	3
3 May	15	8	0	5	2	0	0	0	0
6 May	9	2	0	2	5	0	0	0	0
Total	534	176	43	103	153	3	43	5	8

Table 8. Summary of catch rates and mean ages of striped bass (n=534) from the two gill nets in the James River, spring 1999. 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
18 March	19	14.0	5.0	25,324.1	15,890.0	4.0	5.4
22 March	9	8.0	1.0	17,356.1	3,602.1	4.9	6.0
25 March	7	6.0	1.0	14,410.9	2,741.0	4.8	5.0
29 March	8	4.0	4.0	4,374.9	31,466.6	3.5	9.3
1 April	18	5.0	13.0	14,737.4	66,828.2	5.4	6.8
5 April	26	7.0	19.0	18,286.4	102,691.0	5.2	7.0
8 April	27	9.0	18.0	11,816.8	82,777.9	4.0	6.3
12 April	32	20.0	12.0	33,257.4	65,457.1	4.1	7.3
15 April	45	4.0	41.0	7,436.2	195,892.7	4.5	6.7
19 April	70	22.0	48.0	39,145.3	208,978.5	4.3	6.2
22 April	52	17.0	35.0	30,508.4	131,010.4	4.0	5.7
26 April	84	60.0	24.0	112,106.7	90,735.4	4.4	5.6
29 April	113	96.0	17.0	168,805.6	82,338.0	4.3	6.5
3 May	15	13.0	2.0	22,763.8	6,917.8	4.4	5.5
6 May	9	4.0	5.0	6,561.8	23,585.7	4.0	6.6
Totals	**534**	**19.3**	**16.3**	**35,126.1**	**74,060.8**	**4.3**	**6.4**

Table 9. Mean fork length (mm), weight (g), standard deviations (SD) and CPUE (number per day; weight per day) of striped bass from gill nets in the James River, 30 March - 3 May, 1999.

Year Class	Sex	n	Fork Length		Weight		CPUE	
			Mean	SD	Mean	SD	F/day	W/day
1997	male	2	295.0	21.2	352.5	83.9	0.2	70.5
1996	male	73	383.5	25.0	816.7	153.7	7.3	5,961.6
	female	18	380.9	21.1	765.5	237.7	1.8	1,377.9
1995	male	80	458.4	22.8	1,378.9	238.4	8.0	11,030.9
	female	23	474.4	18.5	1,654.2	226.3	2.3	3,639.3
1994	male	52	543.6	28.9	2,345.1	393.4	5.2	11,960.1
	female	65	552.6	26.5	2,654.7	451.7	6.5	17,255.9
1993	male	25	605.0	23.2	3,217.0	443.9	2.5	8,042.6
	female	36	616.7	25.1	3,700.8	462.5	3.6	13,322.8
1992	male	11	671.6	29.9	4,199.7	440.6	1.1	4,619.6
	female	18	694.2	37.9	4,961.6	762.5	1.8	8,930.8
1991	male	1	724.0		5,413.9		0.1	541.4
	female	21	778.0	28.3	6,843.1	998.0	2.1	14,370.5
1990	male	3	811.3	27.6	6,999.2	948.1	0.3	2,099.8
	female	11	835.5	17.5	7,930.1	1,236.1	1.1	8,723.1
1989	female	12	868.8	17.1	9,102.8	804.7	1.2	10,923.4
1988	male	1	892.0		9,099.5		0.1	910.0
	female	3	920.3	10.0	10,705.6	1,166.5	0.3	3,211.7
1987	female	10	948.4	31.5	12,466.8	1,145.1	1.0	12,466.8
1986	female	3	980.0	10.0	12,177.1	2,679.5	0.3	3,653.1
1985	female	1	1,039.0		14,000.0		0.1	1,400.0

Table 10. Values of the spawning stock biomass index (SSBI) for male and female striped bass by gear in the Rappahannock River, 30 March - 3 May, 1993-1999.

	Pound nets					Gill nets				
	N		SSBI (kg/day)			N		SSBI (kg/day)		
Year	M	F	M	F	M+F	M	F	M	F	M+F
1999	738	61	30.5	19.8	50.3	532	21	51.4	13.2	64.6
1998	273	113	14.8	36.4	51.2	485	27	81.5	18.5	100.0
1997	277	115	22.2	49.6	71.7	801	18	177.8	19.1	197.0
1996	334	73	14.1	9.3	23.4	433	46	63.7	30.2	93.9
1995	207	76	12.4	19.8	32.2	162	69	43.9	56.7	100.6
1994	195	141	17.1	30.9	48.0	391	100	101.6	64.7	166.3
1993	357	188	31.2	37.5	68.7	361	160	85.6	74.1	159.6
Mean	**340**	**110**	**20.3**	**29.0**	**49.4**	**452**	**63**	**86.5**	**39.5**	**126.0**

Table 11. Values of the spawning stock biomass index (SSBI) calculated from gill net catches of male and female striped bass in the James River, 30 March - 3 May, 1994-1999. The 1994 data consisted of one gill net (GN # 1) and were adjusted by the proportion of the biomass that gill net # 2 captured in 1995-1998 (1.8 x GN #1 for males; 1.9 x GN #1 for females.

Year	n		SSBI (kg/day)		
	Male	Female	Male	Female	Combined
1999	251	211	45.81	101.98	147.79
1998	134	65	32.97	46.48	79.45
1997	100	60	23.89	44.59	68.48
1996	108	74	23.70	43.35	67.05
1995	210	202	52.10	125.15	177.25
1994*	119	64	46.27	65.74	112.01
Mean	**154**	**113**	**37.46**	**71.22**	**108.67**

Table 12. Predicted values of fecundity (in millions of eggs) of female striped bass with increasing fork length (mm), James and Rappahannock rivers combined, spring 1999.

FL	Fecundity	FL	Fecundity	FL	Fecundity	FL	Fecundity
400	0.209	**600**	0.476	**800**	0.854	**1000**	1.344
420	0.230	**620**	0.509	**820**	0.898	**1020**	1.399
440	0.253	**640**	0.542	**840**	0.943	**1040**	1.456
460	0.277	**660**	0.577	**860**	0.989	**1060**	1.513
480	0.302	**680**	0.614	**880**	1.036	**1080**	1.572
500	0.328	**700**	0.651	**900**	1.084	**1100**	1.631
520	0.355	**720**	0.689	**920**	1.134	**1120**	1.692
540	0.384	**740**	0.729	**940**	1.185	**1140**	1.754
560	0.413	**760**	0.769	**960**	1.237	**1160**	1.817
580	0.444	**780**	0.811	**980**	1.290	**1180**	1.882

Table 13. Total, age-specific, estimated total egg potential (E, in millions of eggs/day) mature (ages 4 and older) female striped bass, by river and gear type, 30 March - 3 May 1999. The Egg Production Potential Indexes (millions of eggs/day) are in bold.

Age	Rappahannock River						James River		
	Pound Nets			Gill Nets			Gill Nets		
	n	E	%	n	E	%	n	E	%
4	1	0.011	0.5%	0			23	0.680	5.5%
5	3	0.040	1.8%	6	0.247	17.6%	65	2.622	21.3%
6	1	0.018	0.8%	2	0.095	6.8%	36	1.814	14.8%
7	4	0.099	4.4%	3	0.209	14.9%	18	1.155	9.4%
8	6	0.173	7.8%	2	0.167	12.0%	21	1.696	13.8%
9	9	0.294	13.2%	1	0.094	6.7%	11	1.026	8.4%
10	9	0.340	15.3%	2	0.186	13.3%	12	1.212	9.9%
11	11	0.454	20.5%	1	0.108	7.7%	3	0.341	2.8%
12	12	0.526	23.7%	0			10	1.208	9.8%
13	1	0.048	2.2%	0			3	0.387	3.1%
14	3	0.156	7.0%	2	0.295	21.0%	1	0.145	1.2%
15	1	0.063	2.8%	0			0		
Total	61	**2.222**	100.0%	19	**1.401**	100.0%	203	**12.286**	100.0%

Table 14. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1993-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)						
	1993	1994	1995	1996	1997	1998	1999
1997							(2) **0.786**
1996						(2) 0.185	(3) **11.536**
1995					(2) 0.600	(3) 2.148	(4) **11.500**
1994			(1) 0.040	(2) 0.514	(3) 3.900	(4) **6.333**	(5) 2.786
1993			(2) 3.040	(3) 3.972	(4) **8.100**	(5) 1.481	(6) 0.107
1992	(1) 0.115	(2) 1.444	(3) **4.800**	(4) 2.857	(5) 1.250	(6) 0.037	(7) 0.500
1991	(2) .0676	(3) 0.481	(4) 1.000	(5) **1.629**	(6) 0.050	(7) 0.518	(8) 0.429
1990	(3) 1.039	(4) 1.333	(5) **2.240**	(6) 1.257	(7) 0.700	(8) 0.704	(9) 0.321
1989	(4) 3.577	(5) **4.593**	(6) 0.680	(7) 0.886	(8) 0.800	(9) 0.778	(10) 0.357
1988	(5) **9.538**	(6) 2.222	(7) 0.600	(8) 0.372	(9) 1.500	(10) 0.889	(11) 0.393
1987	(6) **3.654**	(7) 1.148	(8) 0.680	(9) 0.372	(10) 1.000	(11) 0.889	(12) 0.429
1986	(7) 0.654	(8) 0.592	(9) 0.400	(10) 0.086	(11) **1.000**	(12) 0.222	(13) 0.036
1985	(8) 0.423	(9) **0.518**	(10) 0.080	(11) 0.00	(12) 0.350	(13) 0.148	(14) 0.107
1984	(9) **0.577**	(10) 0.333	(11) 0.280	(12) 0.000	(13) 0.350	(14) 0.074	(15) 0.036
1983	(10) **0.462**	(11) 0.333	(12) 0.080	(13) 0.029	(14) 0.200		
1982	(11) **0.308**	(12) 0.185					
1981	(12) **0.269**	(13) 0.074					
1980	(13) 0.154	(14) 0.037					
1979		(15) **0.037**					
N/aged	0.384	0.555	0.600	0.315	.0500	0.444	0.536
Total	21.830	13.885	14.520	12.289	20.300	20.300	29.857

Table 15. Catch rates (fish/day) of year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1993-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)						
	1993	1994	1995	1996	1997	1998	1999
1997							(2) **0.786**
1996						(2) 0.185	(3) **11.357**
1995					(2) 0.550	(3) 2.148	(4) **11.464**
1994			(1) 0.040	(2) 0.514	(3) 3.800	(4) **6.185**	(5) 2.679
1993			(2) 2.880	(3) 3.829	(4) **7.500**	(5) 1.370	(6) 0.071
1992	(1) 0.115	(2) 1.222	(3) **4.680**	(4) 2.657	(5) 1.150	(6) 0.000	(7) 0.357
1991	(2) 0.538	(3) 0.481	(4) 0.920	(5) **1.343**	(6) 0.050	(7) 0.296	(8) 0.214
1990	(3) 0.962	(4) 1.296	(5) **2.000**	(6) 0.943	(7) 0.350	(8) 0.111	(9) 0.000
1989	(4) 3.462	(5) **3.519**	(6) 0.080	(7) 0.429	(8) 0.550	(9) 0.037	(10) 0.036
1988	(5) **7.538**	(6) 1.111	(7) 0.120	(8) 0.029	(9) .0200		
1987	(6) **1.231**	(7) 0.222	(8) 0.000	(9) 0.086			
1986	(7) **0.154**	(8) 0.111	(9) 0.040				
1985	(8) **0.038**	(9) 0.037					
1984	(9) **0.077**	(10) 0.000					
1983		(11) 0.000					
1982		(12) **0.037**					
1981							
1980							
1979							
N/aged	0.269	0.407	0.440	0.229	0.250	0.333	0.536
Total	14.384	8.443	11.200	9.982	14.400	14.400	27.524

Table 16. Catch rates (fish/day) of year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1993-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)						
	1993	1994	1995	1996	1997	1998	1999
1997							
1996							
1995					(2) **0.050**		(4) 0.036
1994					(3) 0.100	(4) **0.148**	(5) 0.107
1993			(2) 0.160	(3) 0.143	(4) **0.600**	(5) 0.111	(6) 0.036
1992		(2) **0.222**	(3) 0.120	(4) 0.200	(5) 0.100	(6) 0.037	(7) 0.143
1991	(2) 0.038	(3) 0.000	(4) 0.080	(5) **0.286**	(6) 0.000	(7) 0.222	(8) 0.214
1990	(3) 0.077	(4) 0.037	(5) 0.240	(6) 0.314	(7) 0.350	(8) **0.593**	(9) 0.321
1989	(4) 0.115	(5) **1.074**	(6) 0.600	(7) 0.457	(8) 0.250	(9) 0.741	(10) 0.321
1988	(5) **2.000**	(6) 1.111	(7) 0.480	(8) 0.343	(9) 1.300	(10) 0.889	(11) 0.393
1987	(6) **2.423**	(7) 0.926	(8) 0.680	(9) 0.286	(10) 1.000	(11) 0.889	(12) 0.429
1986	(7) **0.500**	(8) 0.481	(9) 0.360	(10) 0.086	(11) 1.000	(12) 0.222	(13) 0.036
1985	(8) 0.385	(9) **0.481**	(10) 0.080	(11) 0.000	(12) 0.350	(13) 0.148	(14) 0.107
1984	(9) **0.500**	(10) 0.333	(11) 0.280	(12) 0.000	(13) 0.350	(14) 0.074	(15) 0.036
1983	(10) **0.462**	(11) 0.333	(12) 0.080	(13) 0.029	(14) 0.200		
1982	(11) **0.308**	(12) 0.148					
1981	(12) **0.269**	(13) 0.074					
1980	(13) **0.154**	(14) 0.037					
1979		(15) **0.037**					
N/aged	0.115	0.148	0.160	0.086	0.250	0.111	0.000
Total	7.346	5.442	3.320	2.230	5.900	4.185	1.786

Table 17. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1993-1999.

Year Class	93-94 S	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1997							
1996						------	------
1995					------	------	------
1994				------	------	0.440	0.440
1993			------	------	0.183	0.072	0.114
1992	------	------	0.595	0.438	0.632	0.632	0.568
1991	------	------	------	0.564	0.564	0.828	0.641
1990	------	------	0.561	0.748	0.748	0.456	0.615
1989	------	0.439	0.439	0.903	0.978	0.459	0.601
1988	0.233	0.877	0.877	0.877	0.593	0.442	0.588
1987	0.314	0.955	0.955	0.955	0.889	0.472	0.697
1986	0.795	0.676	0.822	0.822	0.822	0.162	0.603
1985	------	0.877	0.877	0.877	0.423	0.723	0.729
1984	0.884	0.884	0.884	0.884	0.211	0.486	0.630
1983	0.721	0.843	0.843	0.843	0.000		0.609
1982	0.601	0.00					0.265
1981	0.275	0.00					0.129
1980	0.241	0.00					0.114

Table 18. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1993-1999.

Year Class	93-94 S	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1997						------	------
1996						------	------
1995					------	------	------
1994				------	------	0.433	0.433
1993			------	------	0.183	0.052	0.098
1992		------	0.568	0.438	0.557	0.557	0.527
1991	------	------	------	0.467	0.467	0.723	0.540
1990	------	------	0.472	0.371	0.317	0.000	0.277
1989	------	0.539	0.539	0.539	0.256	0.256	0.400
1988	0.147	0.565	0.565	0.565	0.000		0.345
1987	0.180	0.622	0.622	0.000			0.327
1986	0.721	0.216	0.000				0.279

Table 19. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from pound nets in the Rappahannock River, 30 March - 3 May, 1993-1999.

Year Class	93-94 S	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1997						------	------
1996					------	------	------
1995				------	0.849	0.849	0.849
1994			------	------	------	0.723	0.723
1993		------	------	------	0.185	0.324	0.245
1992	------	0.949	0.949	0.894	0.894	0.894	0.916
1991	------	------	------	0.881	0.881	0.964	0.908
1990	------	------	------	------	------	0.541	0.541
1989	------	0.911	0.911	0.911	0.911	0.433	0.785
1988	0.898	0.898	0.898	0.898	0.684	0.442	0.763
1987	0.802	0.802	0.802	0.802	0.889	0.483	0.750
1986	------	------	------	------	0.222	0.162	0.190
1985	------	0.899	0.899	0.899	0.429	0.723	0.742
1984	0.915	0.915	0.915	0.915	0.211	0.486	0.645
1983	0.721	0.843	0.843	0.843	0.000		0.609
1982	0.481	0.000					0.217
1981	0.275	0.000					0.129
1980	0.240	0.000					0.114

Table 20. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1993-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)						
	1993	1994	1995	1996	1997	1998	1999
1997							(2) **11.700**
1996						(2) 0.111	(3) **35.700**
1995					(2) 0.833	(3) **11.667**	(4) 10.600
1994				(2) 1.900	(3) 29.500	(4) **32.778**	(5) 3.200
1993			(2) 4.500	(3) 20.000	(4) **83.000**	(5) 7.000	(6) 0.800
1992		(2) 2.778	(3) 7.000	(4) 11.400	(5) **14.333**	(6) 0.778	(7) 1.200
1991	(2) 0.500	(3) 2.556	(4) 1.875	(5) **5.700**	(6) 2.833	(7) 1.333	(8) 0.500
1990	(3) 1.500	(4) **8.222**	(5) 7.750	(6) 3.500	(7) 2.167	(8) 0.333	(9) 0.100
1989	(4) 8.600	(5) **27.556**	(6) 4.500	(7) 2.500	(8) 0.667	(9) 0.333	(10) 0.200
1988	(5) **25.400**	(6) 8.222	(7) 2.875	(8) 1.500	(9) 1.167	(10) 0.333	(11) 0.200
1987	(6) **10.400**	(7) 2.111	(8) 1.750	(9) 1.600	(10) 0.500	(11) 0.111	(12) 0.100
1986	(7) **2.600**	(8) 0.444	(9) 1.375	(10) 0.300		(12) 0.222	(13) 0.000
1985	(8) 0.400	(9) **1.667**	(10) 0.750	(11) 0.200			(14) 0.200
1984	(9) 0.400	(10) **0.667**	(11) 0.250				
1983	(10) **1.300**	(11) 0.556	(12) 0.125				
1982	(11) **0.400**	(12) 0.222					
1981	(12) 0.000						
1980	(13) **0.200**						
1979							
N/aged	1.100	0.778	1.000	1.200	2.500	2.000	2.500
Total	**52.800**	**55.779**	**33.750**	**49.800**	**137.500**	**56.999**	**64.500**

Table 21. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1993-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)						
	1993	1994	1995	1996	1997	1998	1999
1997							(2) **11.600**
1996						(2) 0.111	(3) **35.700**
1995					(2) 0.833	(3) **11.667**	(4) 10.600
1994				(2) 1.900	(3) 29.500	(4) **32.556**	(5) 2.600
1993			(2) 4.500	(3) 20.000	(4) **82.500**	(5) 6.444	(6) 0.600
1992		(2) 2.778	(3) 6.750	(4) 11.300	(5) **14.000**	(6) 0.556	(7) 0.900
1991	(2) 0.500	(3) 2.556	(4) 1.750	(5) **5.600**	(6) 2.500	(7) 0.667	(8) 0.300
1990	(3) 1.500	(4) **8.222**	(5) 7.000	(6) 3.200	(7) 1.833	(8) 0.222	(9) 0.000
1989	(4) 8.200	(5) **25.333**	(6) 2.625	(7) 1.400	(8) 0.500		(10) 0.000
1988	(5) **20.300**	(6) 4.889	(7) 1.125	(8) 0.500	(9) 0.167		(11) 0.100
1987	(6) **4.200**	(7) 0.333	(8) 0.125	(9) 0.100			(12) 0.100
1986	(7) **0.900**	(8) 0.111					
1985	(8) 0.000	(9) **0.333**					
1984	(9) 0.100	(10) **0.111**					
1983	(10) 0.000						
1982	(11) **0.100**						
1981							
1980							
1979							
N/aged	0.800	1.556	0.875	1.200	2.500	1.778	2.300
Total	36.600	46.222	24.750	24.750	134.333	54.001	64.800

Table 22. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1993-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)						
	1993	1994	1995	1996	1997	1998	1999
1997							(2) **0.100**
1996							(3) **0.100**
1995							(4) 0.000
1994						(4) 0.222	(5) **0.600**
1993					(4) 0.333	(5) **0.556**	(6) 0.200
1992			(3) 0.125	(4) 0.100	(5) **0.333**	(6) 0.222	(7) 0.300
1991			(4) 0.125	(5) 0.100	(6) 0.333	(7) **0.667**	(8) 0.200
1990			(5) **0.625**	(6) 0.300	(7) 0.333	(8) 0.111	(9) 0.100
1989	(4) 0.300	(5) **2.222**	(6) 1.875	(7) 1.100	(8) 0.167	(9) 0.333	(10) 0.200
1988	(5) **5.100**	(6) 3.333	(7) 1.750	(8) 1.000	(9) 1.000	(10) 0.333	(11) 0.100
1987	(6) **6.100**	(7) 1.778	(8) 1.625	(9) 1.500	(10) 0.500	(11) 0.111	(12) 0.000
1986	(7) **1.700**	(8) 0.333	(9) 1.375	(10) 0.300		(12) 0.222	(13) 0.000
1985	(8) 0.400	(9) **1.333**	(10) 0.750	(11) 0.200			(14) 0.200
1984	(9) 0.300	(10) **0.556**	(11) 0.250				
1983	(10) **1.300**	(11) 0.556	(12) 0.125				
1982	(11) **0.300**	(12) 0.222					
1981	(12) 0.000						
1980	(13) **0.200**						
1979							
N/aged	0.300	0.778	0.125	0.000	0.000	0.222	0.200
Total	16.000	11.111	8.750	4.600	2.999	2.778	2.300

Table 23. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1993-1999.

Year Class	93-94 S	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1997						------	
1996						------	
1995					------	0.909	0.909
1994				------	------	0.098	0.098
1993			------	------	0.084	0.024	0.045
1992		------	------	------	0.289	0.289	0.289
1991	------	------	------	0.497	0.471	0.375	0.444
1990	------	0.943	0.452	0.619	0.154	0.300	0.414
1989	------	0.163	0.555	0.267	0.500	0.600	0.373
1988	0.324	0.350	0.522	0.778	0.285	0.600	0.446
1987	0.203	0.829	0.914	0.313	0.222	0.901	0.461
1986	0.727	0.727	0.218	0.860	0.860	0.000	0.524
1985	------	0.450	0.719	0.719	0.719	0.719	0.655
1984	------	0.374	0.000				0.172
1983	0.428	0.225	0.000				0.205
1982	0.555	0.000					0.247

Table 24. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1993-1999.

Year Class	93-94 S	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1997						------	------
1996						------	------
1995					------	0.909	0.909
1994				------	------	0.080	0.080
1993			------	------	0.078	0.093	0.085
1992		------	------	------	0.254	0.254	0.254
1991	------	------	------	0.446	0.267	0.450	0.377
1990	------	0.851	0.457	0.573	0.028	0.000	0.343
1989	------	0.104	0.571	0.357	0.000		0.239
1988	0.241	0.230	0.444	0.334	0.774	0.774	0.412
1987	0.079	0.375	0.945	0.945	0.945	0.945	0.536
1986	0.123	0.000					0.060

Table 25. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the Rappahannock River, 30 March - 3 May, 1993-1999.

Year Class	93-94 S	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1997						------	------
1996					------	------	------
1995				------	------	------	------
1994			------	------	------	------	------
1993		------	------	------	------	0.360	0.360
1992	------	------	------	------	0.949	0.949	0.949
1991	------	------	------	------	------	0.300	0.300
1990	------	------	0.730	0.730	0.333	0.901	0.632
1989	------	0.844	0.533	0.550	0.550	0.601	0.606
1988	0.641	0.525	0.756	0.756	0.333	0.300	0.518
1987	0.293	0.913	0.923	0.333	0.222	0.000	0.407
1986	0.917	0.917	0.218	0.860	0.860	0.000	0.579
1985	------	0.562	0.719	0.719	0.719	0.719	0.684
1984	------	0.450	0.000				0.204
1983	0.463	0.225	0.000				0.215
1982	0.740	0.000					0.319

Table 26. Catch rates (fish/day) of year classes of striped bass (sexes combined) sampled from gill nets in the James River, 30 March - 3 May, 1994-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)					
	1994	1995	1996	1997	1998	1999
1997						(2) **0.200**
1996						(3) **9.100**
1995					(3) 1.222	(4) **10.300**
1994			(2) 0.100	(3) 1.556	(4) 7.111	(5) **11.700**
1994		(2) 0.667	(3) 1.600	(4) 4.444	(5) 5.222	(6) **6.100**
1992		(3) **4.333**	(4) 2.900	(5) 3.333	(6) 3.000	(7) 2.900
1991	(3) 2.400	(4) **8.889**	(5) 4.500	(6) 2.000	(7) 1.667	(8) 2.200
1990	(4) **12.400**	(5) 11.111	(6) 3.100	(7) 2.000	(8) 0.778	(9) 1.400
1989	(5) **12.200**	(6) 9.778	(7) 2.700	(8) 0.889	(9) 1.111	(10) 1.200
1988	(6) **3.600**	(7) 2.667	(8) 1.000	(9) 1.444	(10) 0.778	(11) 0.400
1987	(7) 0.800	(8) **2.667**	(9) 1.000	(10) 1.111	(11) 0.667	(12) 1.000
1986	(8) 0.800	(9) **1.889**	(10) 0.800	(11) 0.333	(12) 0.111	(13) 0.300
1985	(9) 0.800	(10) **1.222**	(11) 0.300	(12) 0.222	(13) 0.111	(14) 0.100
1984	(10) **1.200**	(11) 0.778	(12) 0.100	(13) 0.111		
1983	(11) **0.800**	(12) 0.333				
1982	(12) **0.400**	(13) 0.222				
N/aged	0.800	2.000	0.200	0.333	0.333	1.300
Total	35.800	44.556	18.300	17.778	22.112	48.200

Table 27. Catch rates (fish/day) of year classes of male striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)					
	1994	1995	1996	1997	1998	1999
1997						(2) **0.200**
1996						(3) **7.300**
1995					(3) 1.222	(4) **8.000**
1994			(2) 0.100	(3) 1.556	(4) **6.778**	(5) 5.200
1994		(2) 0.667	(3) 1.600	(4) **3.889**	(5) 3.778	(6) 2.500
1992		(3) **4.222**	(4) 2.800	(5) 2.333	(6) 1.667	(7) 1.100
1991	(3) 2.400	(4) **7.889**	(5) 3.600	(6) 1.444	(7) 1.333	(8) 0.100
1990	(4) **10.600**	(5) 6.333	(6) 1.500	(7) 1.333	(8) 0.222	(9) 0.300
1989	(5) **8.000**	(6) 2.333	(7) 0.800	(8) 0.444	(9) 0.000	(10) 0.000
1988	(6) **1.400**	(7) 0.556	(8) 0.300	(9) 0.111	(10) 0.111	(11) 0.100
1987		(8) **0.444**	(9) 0.100			
1986		(9) **0.111**				
N/aged	0.800	1.444	0.100	0.000	0.111	0.500
Total	**23.200**	**24.000**	**10.900**	**11.110**	**15.222**	**25.300**

Table 28. Catch rates (fish/day) of year classes of female striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-1999. Maximum catch rate for any year class during the sampling period is in bold type. The small number in parentheses is the age of each year class during that year.

Year Class	CPUE (fish/day)					
	1994	1995	1996	1997	1998	1999
1996						(3) **1.800**
1995						(4) **2.300**
1994					(4) 0.333	(5) **6.500**
1993				(4) 0.556	(5) 1.444	(6) **3.600**
1992		(3) 0.111	(4) 0.100	(5) 1.000	(6) 1.333	(7) **1.800**
1991		(4) 1.000	(5) 0.900	(6) 0.556	(7) 0.667	(8) **2.100**
1990	(4) 1.800	(5) **4.778**	(6) 1.500	(7) 0.667	(8) 0.556	(9) 1.100
1989	(5) 4.000	(6) **7.444**	(7) 1.900	(8) 0.444	(9) 1.111	(10) 1.200
1988	(6) **2.200**	(7) 2.111	(8) 0.700	(9) 1.333	(10) 0.667	(11) 0.300
1987	(7) 0.800	(8) **2.222**	(9) 0.900	(10) 1.111	(11) 0.667	(12) 1.000
1986	(8) 0.800	(9) **1.778**	(10) 0.800	(11) 0.333	(12) 0.111	(13) 0.300
1985	(9) 0.400	(10) **1.222**	(11) 0.300	(12) 0.222	(13) 0.111	(14) 0.100
1984	(10) **1.200**	(11) 0.778	(12) 0.200	(13) 0.111		
1983	(11) **0.800**	(12) 0.333				
1982	(12) **0.400**	(13) 0.222				
N/aged	0.000	0.556	0.100	0.333	0.222	0.800
Total	12.400	22.556	7.400	6.667	7.222	22.900

Table 29. Estimated annual and geometric mean survival (S) rates for year classes of striped bass (sexes combined) sampled from gill nets in the James River, 30 March - 3 May, 1994-1999.

Year Class	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1995					------	------
1994				------	------	------
1993			------	------	------	------
1992		0.877	0.877	0.900	0.967	0.905
1991	------	0.506	0.788	0.788	0.788	0.699
1990	0.896	0.279	0.767	0.767	0.767	0.646
1989	0.801	0.276	0.763	0.763	0.763	0.629
1988	0.741	0.736	0.736	0.539	0.514	0.645
1987	------	0.645	0.645	0.948	0.948	0.782
1986	------	0.423	0.417	0.949	0.949	0.631
1985	------	0.245	0.740	0.500	0.901	0.535
1984	0.648	0.378	0.378	0.000		0.330
1983	0.416	0.000				0.190
1982	0.555	0.000				0.247

Table 30. Estimated annual and geometric mean survival (S) rates for year classes of male striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-1999.

Year Class	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1995					-------	------
1994			------	------	0.767	0.767
1993		------	------	0.971	0.662	0.802
1992		0.663	0.833	0.715	0.660	0.714
1991	------	0.456	0.401	0.923	0.075	0.236
1990	0.597	0.237	0.889	0.474	0.474	0.490
1989	0.292	0.342	0.555	0.000		0.281
1988	0.397	0.540	0.608	0.608	0.901	0.590
1987	------	0.444	0.100	0.000		0.107
1986	------	0.000				0.000

Table 31. Estimated annual and geometric mean survival (S) rates for year classes of female striped bass sampled from gill nets in the James River, 30 March - 3 May, 1994-1999.

Year Class	94-95 S	95-96 S	96-97 S	97-98 S	98-99 S	Mean S
1994					------	------
1993				------	------	------
1992			------	------	------	------
1991			------	------	------	------
1990	------	0.314	0.902	0.902	0.902	0.693
1989	------	0.255	0.836	0.836	0.836	0.621
1988	0.960	0.795	0.795	0.500	0.450	0.671
1987	------	0.707	0.707	0.949	0.949	0.819
1986	------	0.450	0.416	0.949	0.949	0.641
1985	------	0.245	0.740	0.500	0.901	0.535
1984	0.648	0.257	0.555	0.000		0.340
1983	0.416	0.000				0.190
1982	0.555	0.000				0.247

Figure 1. Locations of commercial pound nets and experimental gill nets sampled in spring spawning stock assessments of striped bass in the Rappahannock River, 1993-1999.

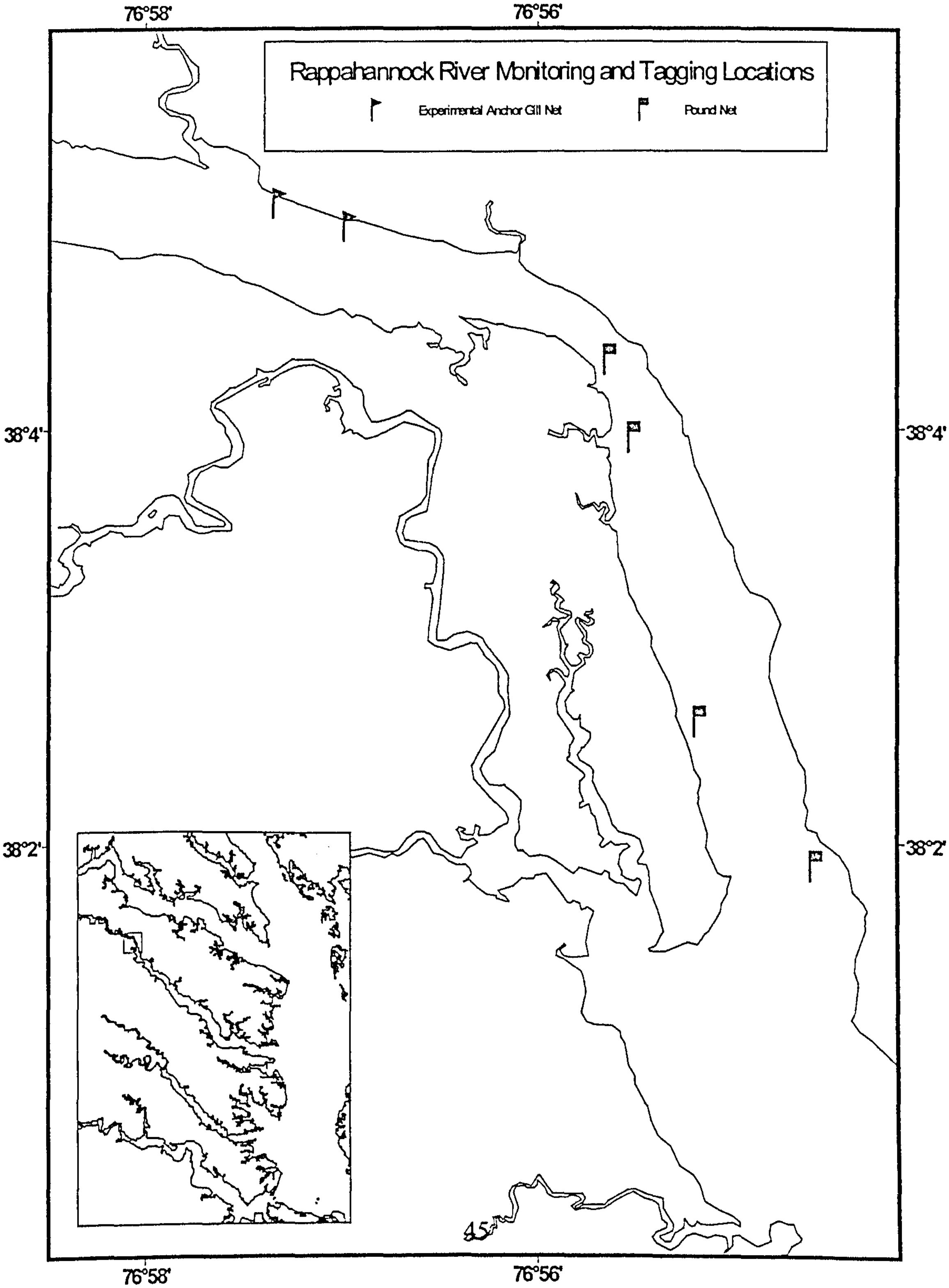


Figure 2. Locations of experimental anchor gill nets sampled in spring spawning stock assessments of striped bass in the James River, 1994-1999.

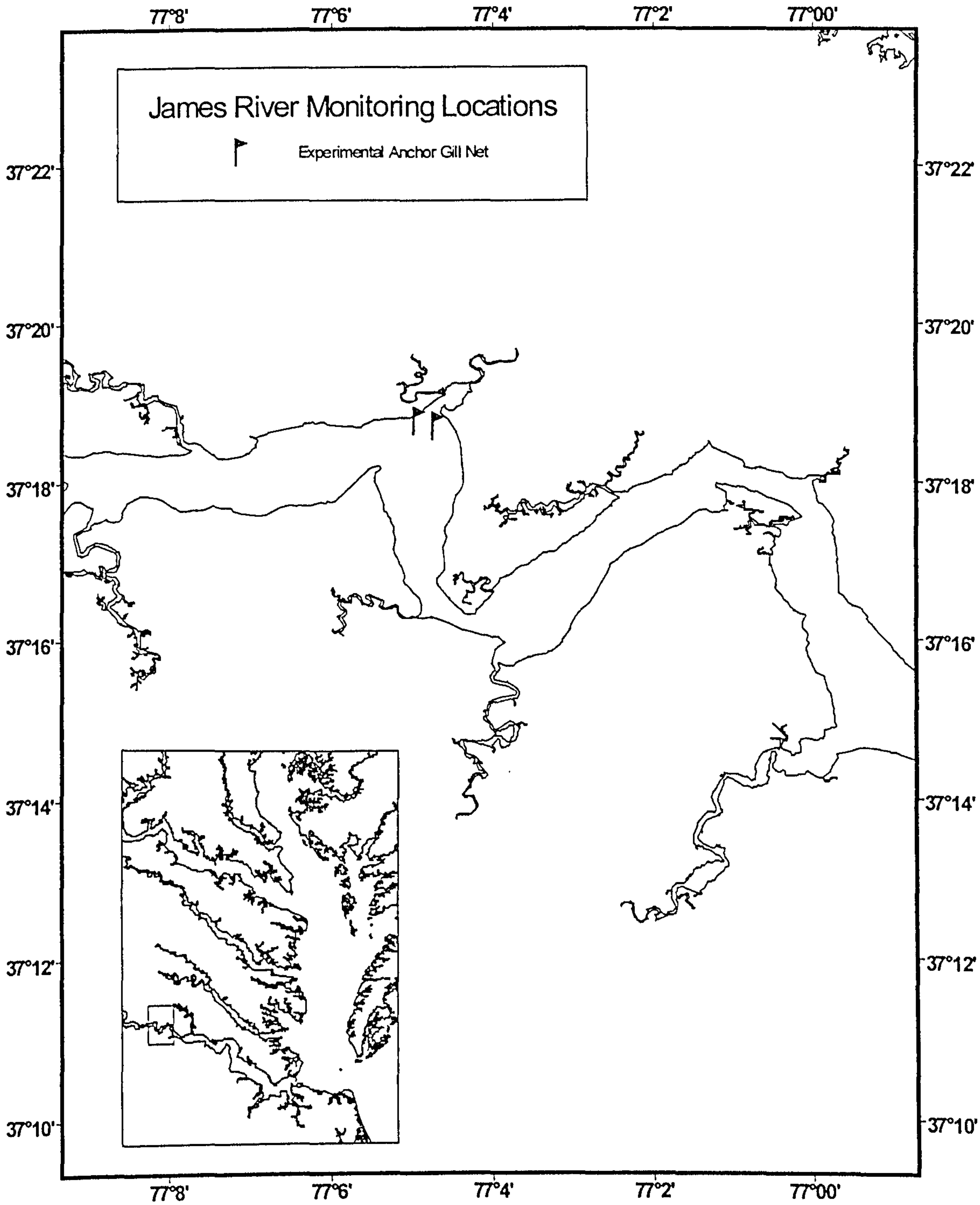


Figure 3. The relationship between geometric mean oocyte count and fork length of female striped bass in the James and Rappahannock rivers, spring 1999.

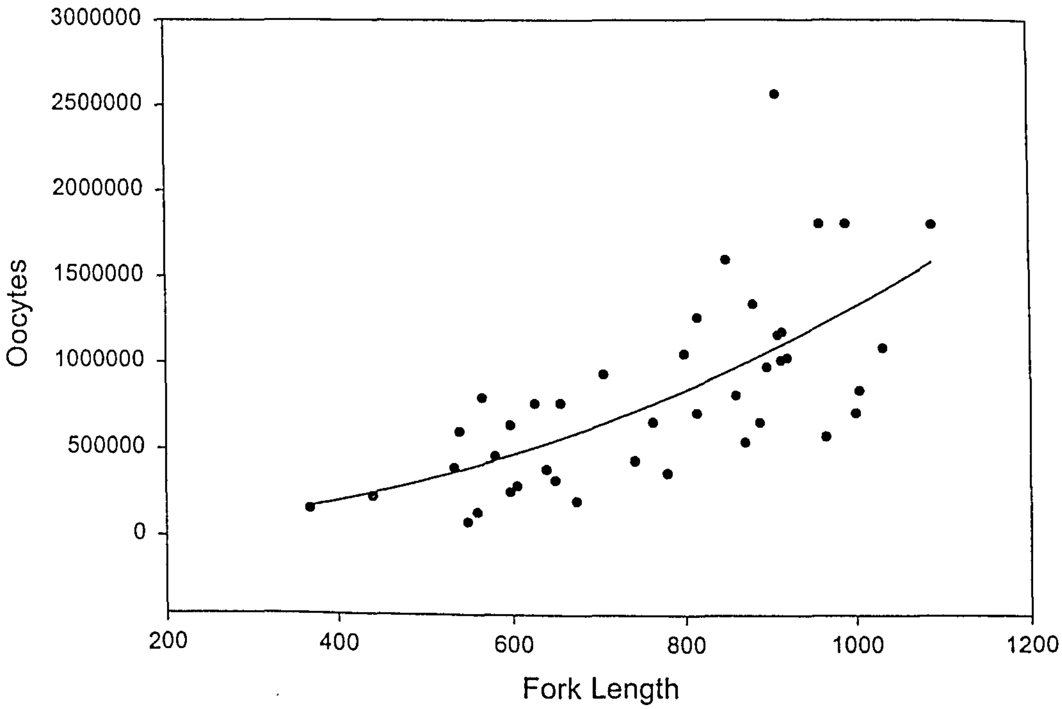


Figure 4. Catch rates (number of fish per day) of eight year classes (1987-1994) of male and female striped bass in pound nets in the Rappahannock River, 30 March-May 3, 1993-1999

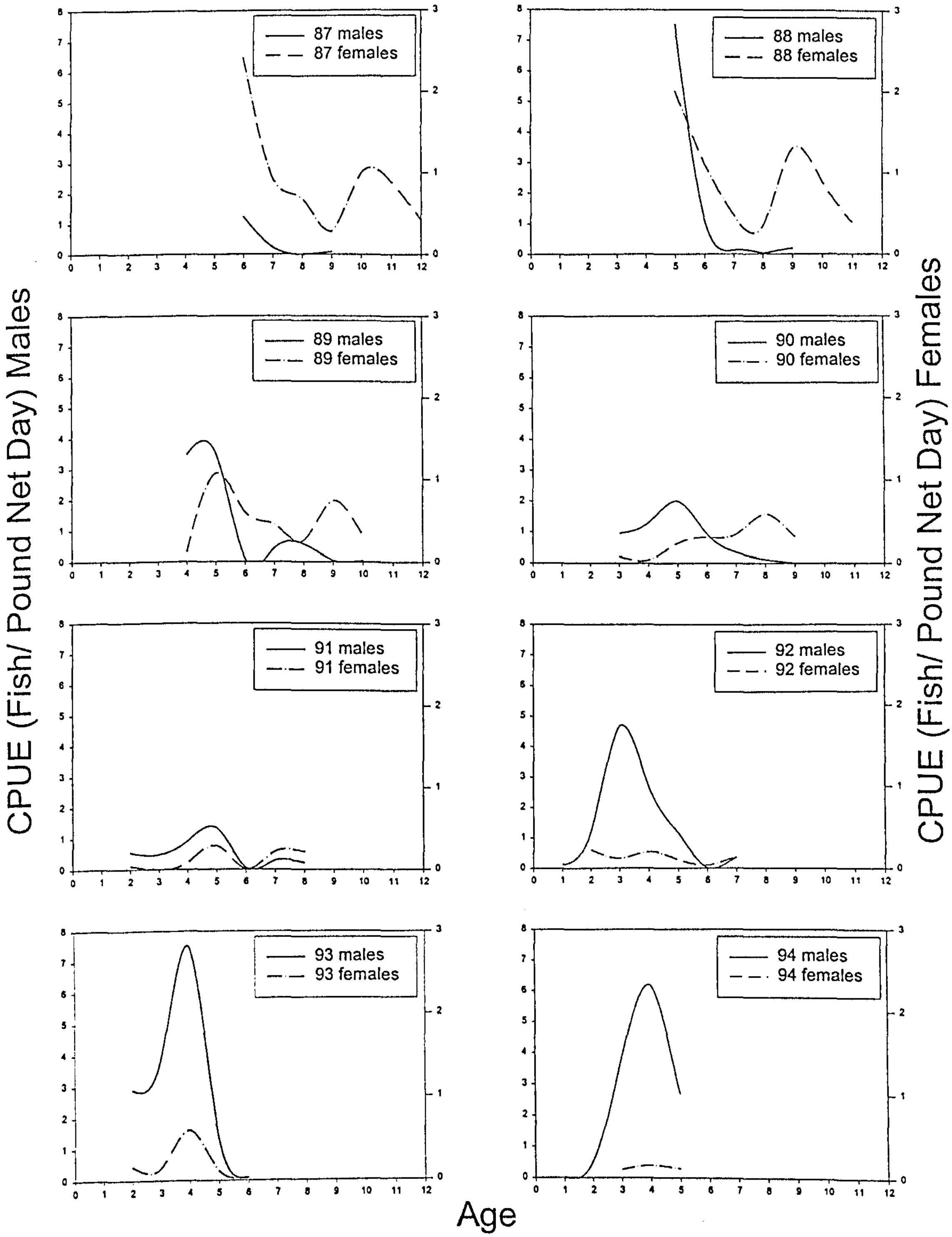


Figure 5. Catch rates (number of fish per day) of eight year classes (1987-1994) of male and female striped bass in variable mesh gill nets in the Rappahannock River, 30 March-3 May, 1993-1999.

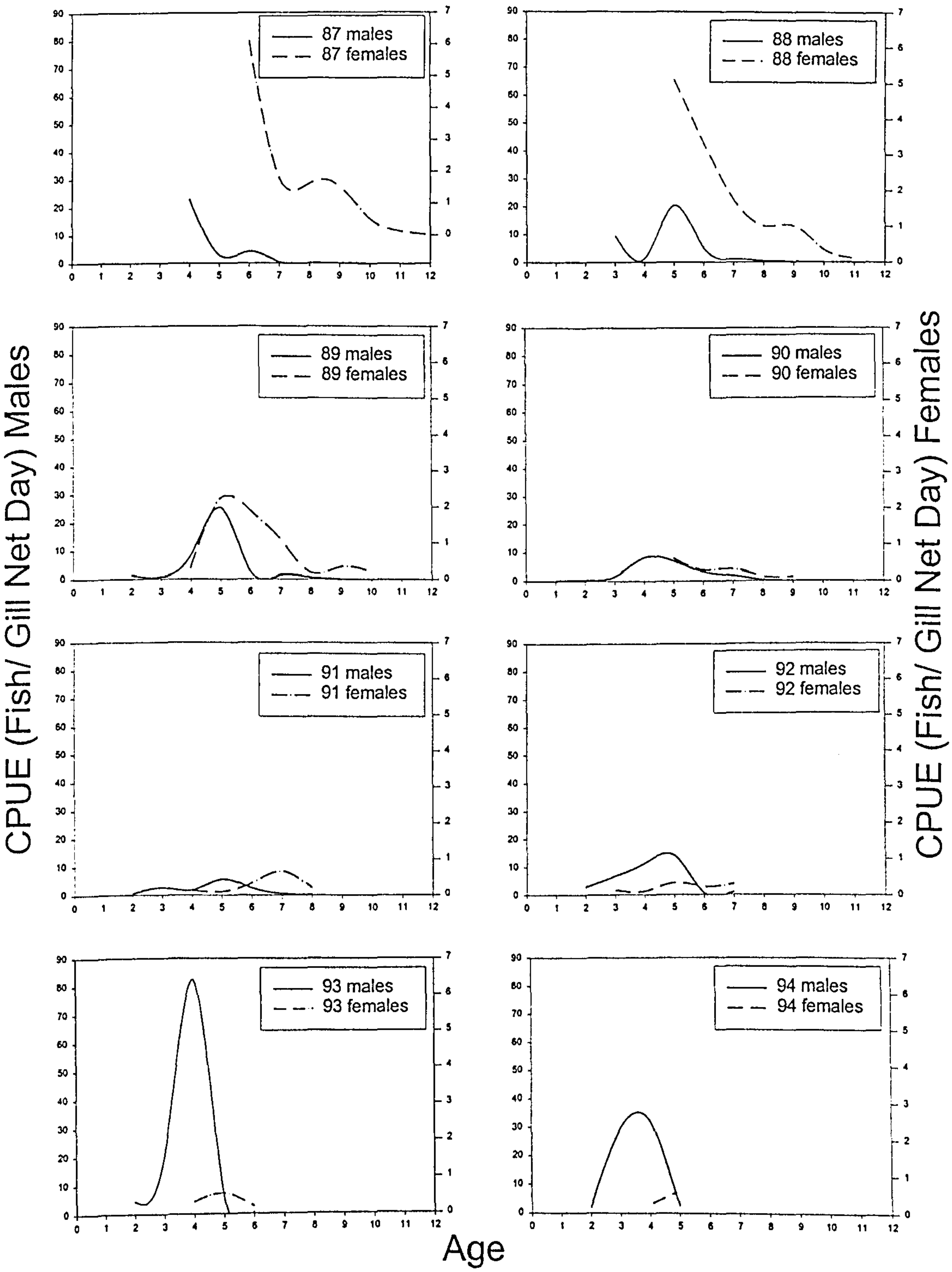
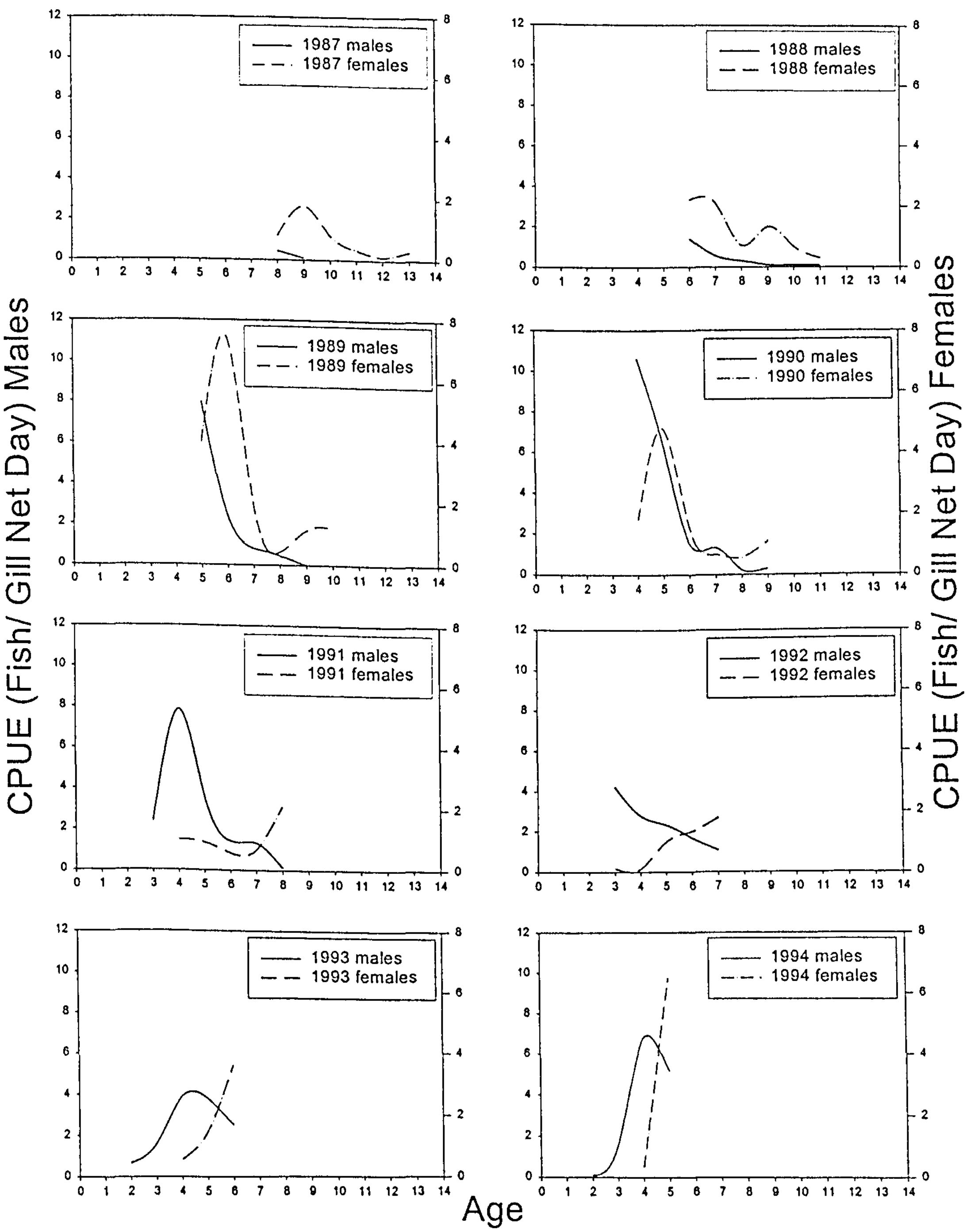


Figure 6. Catch rates (number of fish per day) of eight year classes (1987-1994) of male and female striped bass in variable mesh gill nets in the James River, 30 March-3 May, 1994-1999.



Appendix A

Memorandum to the Striped Bass Tagging Committee

By J.E. Olney, R.H. Harris, Jr and P.Sadler

Memorandum

To: Striped Bass Tagging Committee
Copies: Bob Beal (ASMFC), Rob O'Reilly (VMRC)
From: John Olney, Bobby Harris and Phil Sadler (VIMS)
Date: 2 July 1999
Subject: revised Annual survival estimates for Virginia, 1988-1998

In this revised memorandum, we present release data for striped bass >28 inches in total length (Table 1), the release and recovery matrix used as input for Program MARK (Table 2), nine models of the ten chosen for the initial analysis (Table 3), estimates of annual survival rates for the Rappahannock River, Virginia during 1988 to 1998 (Table 4), and weighted survival estimates for each year (Table 5). The numbers of annual releases were variable and usually <300 individuals. The fewest tagged fish were released in 1988, 1992 and 1996 (Table 2). Thus, small sample size may be one important source of bias. We selected models that have been applied to tag/release data from other producer areas, but did not include group effects (sex was not consistently determined throughout the period). Period effects (denoted in model designations by the letter 'p', Models 2,3,4 and 7) were related to regulatory changes, specifically the moratorium (88-89), Amendment 4 (90-94), and Amendment 5 (95-98). Models 4 and 6 estimated parameters (denoted by 'd') in four time periods, (88-89, 90-94, 95-96 and 97-98) based on regulatory actions that were made along the New England coast, specific to Massachusetts. Model 5 estimated parameters (denoted by 'va') in four time periods, (88-89, 90-92, 93-94 and 95-98) based on regulatory actions that were specific to Virginia. In this case, the fishing season was shorter in 93-94 than in 90-92.

Model 1 (with the smallest ΔQAIC value) was the most general model. Models 1-9 had ΔQAIC values <=7, and were used to tabulate survival estimates (Table 4). Model averaging is shown in Table 5. The time series depicted by Models 2, 4 and 7 show a decreasing trend in survival through the period. This trend (Figure 1),(as well as the absolute values of the estimated survival rates) is similar to those reported by Dave Smith and others for the Chesapeake Bay and Hudson River producer areas.

This is the first step in our analysis of spring tagging data. We thank Cynthia Goshorn and Beth Rodgers (Maryland DNR), and Dave Smith (USGS) for their help. Vic Vecchio (New York DEC) created the template for use in the model averaging. Recovery data were provided by Tina McCrobie (USFWS).

Table 1. Inclusive dates of release for striped bass > 28 inches total length for the Rappahannock River, Virginia producer area from 1988 to 1998. The interval value is that used in the MARK analysis.

Year	Date of first release	Date of last release	Interval value (yrs)
1988	4/18	5/23	1.025
1989	4/20	5/25	0.989
1990	3/12	5/2	1.085
1991	3/13	4/29	1.107
1992	4/8	5/7	1.030
1993	4/1	5/6	1.036
1994	4/7	4/28	1.030
1995	3/14	5/17	1.118
1996	3/25	5/7	1.055
1997	3/17	4/21	1.063
1998	3/16	4/16	1.093

Table 2. Release and recapture matrix of striped bass for the Rappahannock River, Virginia producer area from 1988 to 1998. Total length of all fish was 28 inches or greater.

Year of release	Number Released	1988 (4/28/88-4/27/89)	1989 (4/28/89-4/16/90)	1990 (4/17/90-4/12/91	1991 (4/13/91-4/20/92	1992 (4/21/92-4/19/93)	1993 (4/20/93-4/14/94)	1994 (4/15/94-4/18/95)	1995 (4/19/95-4/25/96)	1996 (4/26/96-4/14/97)	1997 (4/15/97-4/9/98)	1998 (4/10/98-4/19/99)
1988	56	9	7	6	2	0	2	0	0	0	1	0
1989	101		4	4	3	3	0	2	0	0	0	1
1990	300			26	9	15	2	3	7	1	0	2
1991	390				41	24	16	11	3	2	2	1
1992	40					4	3	2	2	0	0	0
1993	212						22	18	7	5	6	0
1994	123							9	7	5	1	2
1995	209								28	10	8	3
1996	66									1	3	1
1997	212										15	13
1998	158											24

Table 3. Models used in the analysis, Delta QAIC >= 7. The notations used are the same as those used in MARK. QAIC is the Akaike information criteria value.

Model Number	Designation	QAIC	ΔQAIC	AIC Weight	Number of Parameters
1	{S(.)R(.)}	3093.946	0.00	0.532404	2
2	{S(p)R(p)}	3096.845	2.90	0.124949	6
3	{S(.)R(p)}	3097.039	3.09	0.113398	4
4	{S(d)R(p)}	3098.412	4.47	0.057077	7
5	{S(va)R(va)}	3098.765	4.82	0.047842	8
6	{S(.)R(d)}	3099.012	5.07	0.042284	5
7	{S(p)R(t}	3099.056	5.11	0.041364	14
8	{S(.)R(t}	3100.087	6.14	0.024702	12
9	{S(t)R(t)}	3100.958	7.01	0.015981	21

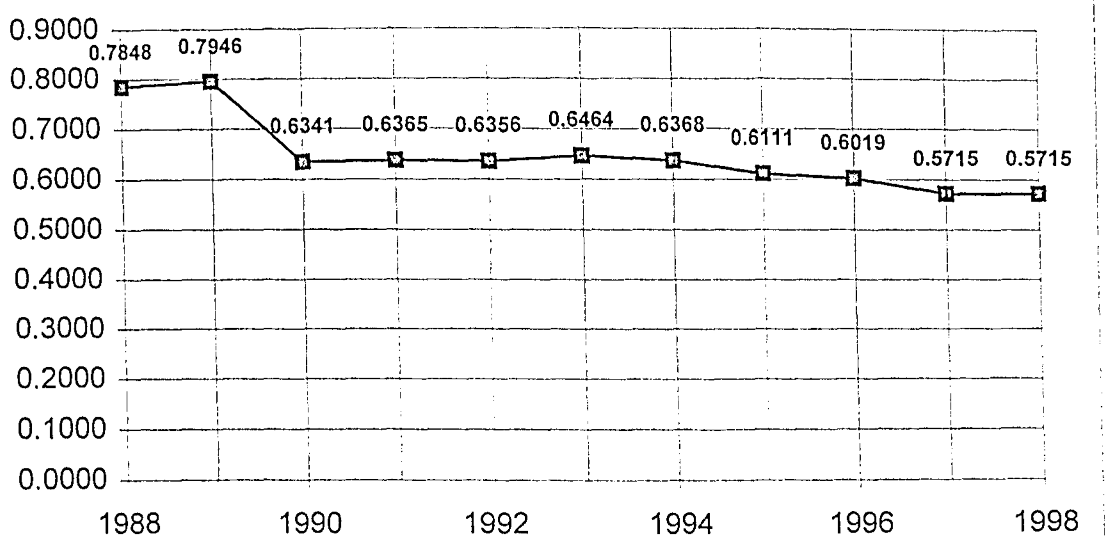
Table 4. Estimated annual survival rates from the nine models used in the analysis of a release recapture matrix of striped bass >28 inches total length in the Rappahannock River, 1988-1998.

Year	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
1988	0.637775	0.823987	0.641048	0.823065	0.854982	0.641207	0.828668	0.636700	0.842880
1989	0.637775	0.823987	0.641048	0.823065	0.854982	0.641207	0.828668	0.636700	0.746032
1990	0.637775	0.638201	0.641048	0.641463	0.607302	0.641207	0.622082	0.636700	0.531017
1991	0.637775	0.638201	0.641048	0.641463	0.607302	0.641207	0.622082	0.636700	0.627734
1992	0.637775	0.638201	0.641048	0.641463	0.607302	0.641207	0.622082	0.636700	0.590234
1993	0.637775	0.638201	0.641048	0.641463	0.681720	0.641207	0.622082	0.636700	0.884564
1994	0.637775	0.638201	0.641048	0.641463	0.681720	0.641207	0.622082	0.636700	0.495107
1995	0.637775	0.595454	0.641048	0.594207	0.591052	0.641207	0.616069	0.636700	0.893724
1996	0.637775	0.595454	0.641048	0.594207	0.591052	0.641207	0.616069	0.636700	0.518379
1997	0.637775	0.595454	0.641048	0.544414	0.591052	0.641207	0.616069	0.636700	0.361403
1998	0.637775	0.595454	0.641048	0.544414	0.591052	0.641207	0.616069	0.636700	0.361403

Table 5. Weighted annual survival rates using the nine models used in the analysis of a release recapture matrix of striped bass >28 inches total length in the Rappahannock River, 1988-1998.

Year	Survival	s.e.(S)	LCL	UCL
1988	0.7848	0.1400	0.4202	0.9483
1989	0.7946	0.1542	0.3801	0.9606
1990	0.6341	0.0278	0.5783	0.6865
1991	0.6365	0.0284	0.5796	0.6898
1992	0.6356	0.0288	0.5779	0.6897
1993	0.6464	0.0351	0.5755	0.7115
1994	0.6368	0.0303	0.5760	0.6936
1995	0.6111	0.0502	0.5100	0.7036
1996	0.6019	0.0526	0.4963	0.6987
1997	0.5715	0.0808	0.4121	0.7173
1998	0.5715	0.0808	0.4121	0.7173

Figure 1. Annual Survival Estimates, striped bass gt 28 inches
1988 - 1998, Rappahannock River, VA



Appendix B

Estimate of the 1998 striped bass rate of fishing mortality in Chesapeake Bay

C.J. Goshorn, B.A. Rodgers and R.E. Harris, 1999

Estimate of the 1998 Striped Bass Rate of Fishing Mortality in Chesapeake Bay

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INTRODUCTION

All Atlantic Coast states participating in the harvest of striped bass have been required to fish at a target fishing mortality rate (F) determined by the Atlantic States Marine Fisheries Commission (ASMFC) since the lifting of the striped bass moratorium in 1990. The annual target (interim) for Chesapeake Bay was set at F=0.25 from 1990 to 1994, F=0.30 from 1995 to 1996, and F=0.28 for 1997 to present. Estimates of F for Chesapeake Bay from 1990 - 1992 were inferred from data collected in coastwide tagging studies. A pilot mark-recapture study was completed by the Maryland Department of Natural Resources (MDNR) in Maryland's portion of the Bay in 1992, and since 1993, mark-recapture studies conducted in Maryland, Potomac River and Virginia have been used to estimate F in Chesapeake Bay.

Each year from 1992-94, single release (prior to the opening of fall recreational season) mark-recapture studies were used to produce estimates of F for resident Chesapeake Bay fish (Rugolo and Lange 1993, Rugolo et. al. 1994, Schaefer and Rugolo 1996). However, starting in fall 1995, with the greatly expanded fall recreational season in the Chesapeake Bay, a multiple release study was conducted to produce a bay-wide estimate of fishing mortality rate. A multiple release study was chosen because the design minimizes the effects of in-season migration (Hebert et al, 1997) and the multiple release design can accommodate low numbers of fish available for tagging prior to the earlier opening of the recreational fishery. The multiple release design used in the 1995 study was repeated for the 1996 and 1997 estimates of fishing mortality; however, no fish were tagged in the Potomac in 1998. As in 1996 and 1997, the objective of the 1998 study was to estimate the bay-wide rate of total fishing mortality for the resident Chesapeake Bay striped bass stock.

METHODS

Experimental Design

Chesapeake Bay was stratified into two management jurisdictions for purposes of tag release: Maryland and Virginia (Table 1 and Appendix A, Figure 1). The 1998 recreational season for Maryland and Virginia ran from August 15 through November 30 and October 4 through December 31, respectively. The first release interval within each jurisdiction began approximately one week prior to the recreational fishery opening in that jurisdiction. Throughout the study, tag release periods within each jurisdiction remained coordinated among jurisdictions. Bay-wide, the first and second release involved only Maryland, the third release was the first for Virginia and the third for Maryland, and so on. This produced a total of five synchronized and discrete Chesapeake Bay-wide release periods, of approximately five to six days, which spanned the Bay-wide recreational/charter fishery season and which were separated by an average of 19 days (Table 1). The shorter the release interval in a multiple release study of relatively short recovery periods (recovery days compared to a year) the better the design. When feasible, release intervals were completed in as short a time frame as possible. Individually, four release intervals took place in Maryland and three release intervals took place in Virginia.

Table 1. Fall 1998 bay-wide release interval dates and release jurisdictions.

	Release Interval				
	1	2	3	4	5
Release Dates	8/8/98- 8/14/98	8/29/98- 9/4/98	9/28/98- 10/3/98	10/26/98- 10/3098	11/18/98- 11/23/98
Jurisdictions of release	MD	MD	MD VA	MD VA	VA

The initial target number of tag releases bay-wide was at least 7400 or at least 600-800 in each jurisdiction during each release period. Only legal size fish (≥ 18 inches or 457mm TL) were tagged and released for use in the analysis. To provide a uniform spatial distribution of tag releases, each jurisdiction was further subdivided into areas. Maryland waters of Chesapeake Bay were divided into Upper Bay, Middle Bay and Lower Bay, and Virginia was divided into James River, Rappahannock River, York River and Main Bay (Appendix A, Figure 1). Target numbers of tag releases in each area were based on proportions of tags released in previous studies (Schaefer and Rugolo, 1996, and Hebert et. al., 1997, Goshorn et.al., 1998 and 1999), but were altered while the study was in progress to accommodate availability of fish.

All tag recoveries were handled and recorded mainly by the USFWS and to some extent by each management jurisdiction. As tags were reported, staff would ask the angler when, how and where the fish was caught, whether it was caught recreationally or commercially, and whether the fish was released or harvested. A complete record of all reported tag returns from fish released in Maryland, Potomac River and Virginia during the study period was obtained from the USFWS

Annapolis Fisheries Office. A recovery round in this study began the day after at least 50% of the fish were tagged on a bay-wide basis during a specific release round and recovery rounds were not specific to each jurisdiction as in 1996 (Goshorn et. al., 1998 and 1999). Tag recoveries were assigned a recovery round based on the above definition (Table 2) with the exception of round four and five. The 1998 study was originally designed to be analyzed on a jurisdiction level as was done in 1996. However, in order to analyze the data on a bay-wide basis, as in the updated 1997 report, round four recovery interval was extended to November 30, 1998, to included the end of the Maryland recreational season (Goshorn et. al., 1999). The final recovery day for round five was the closing day of Virginia's recreational season.

Table 2. Fall 1998 bay-wide recovery interval dates.

Recovery Interval				
1	2	3	4	5
8/15/98- 9/2/98	9/3/98- 10/1/98	10/2/98- 10/27/98	10/28/98- 11/30/98	12/1/98- 12/31/98

As in the 1995, 1996, and 1997 studies, recoveries were only used from fish harvested during the recovery interval that directly followed the release. Similar to the 1997 study, recoveries from harvested striped bass were not limited to the jurisdiction of release. Recoveries included in the analysis could have been from striped bass harvested and recovered in any Chesapeake Bay jurisdiction. For example, to be included in the analysis as a third interval recovery, a fish released in Maryland during release interval three must have been reported as harvested within the Chesapeake Bay during recovery interval three. As long as the recovery was obtained within the Chesapeake Bay, the jurisdiction of recovery was irrelevant. By not restricting the jurisdiction of recovery, we were able to account for tagged striped bass harvested and reported by recreational fishermen anywhere within the Chesapeake Bay and mitigate concerns of fish movement across jurisdictional boundaries within the bay during the study.

Field Procedures

All tagging was done cooperatively with local commercial watermen (Appendix A, Figures 2-6). Study fish were caught in pound nets in Maryland. A combination of pound nets, fyke nets and haul seines were used to capture fish in Virginia. In most cases fish tagging was performed either onboard a MDNR or Virginia Institute of Marine Science (VIMS) research vessel. However, on occasion, fish were tagged and released onboard the waterman's fishing vessel.

Maryland Specific Fish Handling Techniques

Prior to receiving fish onboard sampling boats , a 1200 liter (312 gallon) fiberglass cylindrical holding tank was partially filled with water from Chesapeake Bay and mixed with approximately 20 ml of defoaming reagent, 1 liter of table salt, and several bags of ice cubes to minimize stress to the fish. Aeration was continuously supplied by bottled oxygen connected to air diffusers submerged in the tank. Salinity (parts per thousand) and temperatures (C°) for water and air were measured at each net.

Fish were transferred from pound nets with dip nets lifted by hand or electric winch and were either placed on the deck of the boat and transferred to the holding tank or placed directly into the holding tank. Striped bass were sorted so that only legal sized fish were retained. On occasion, fish were directly transferred to the tank without sorting. Once the tank was full (approximately 100 fish), the research vessel motored several hundred meters away from the commercial net and tagging began.

Virginia Specific Fish Handling Techniques

In Virginia, a floating holding pocket (1.2m x 2.4m x 1.2m deep, with 25.4 mm mesh and a capacity of approximately 200 fish) was used to contain the fish prior to tagging upon removal from pound nets. In both haul seines and fyke nets, holding pockets were not used and the fish were transferred directly from the commercial gear to research vessels for processing.
Striped bass were removed from commercial gear with dip nets lifted by hand or hydraulic winch, placed onto the deck of the commercial boat (in the case of the pound nets), and culled from the catch. At pound nets, the holding pockets containing untagged fish were tied to a pole at the head of the net. When currents were strong, tagging was accomplished at the pound net head adjacent to gear but not near the pound net leader where fish would be easily recaptured. When currents were light, the holding pocket was tethered to the research vessel which often floated several hundred meters away from the pound net during tagging.

Tagging Procedures

Handling was minimized during tagging. Fish were removed by hand or dip net from the holding tank or pocket. In Maryland, fish were examined for presence of an implanted coded wire tag (CWT) with a CWT detection wand. CWT positive fish were not tagged, but were sacrificed to obtain CWT tag and otoliths for age determination. Each fish was then measured for total length (TL in millimeters) with caudal fin fully extended and a sub-sample was sampled for scales to determine age. Internal anchor tags with external streamers supplied by USFWS were inserted into the left ventral area just behind and below the pectoral fin through an incision made with a surgical scalpel. The incision was sprayed with an iodine-based antiseptic solution and the fish was released overboard.

Statistical Analysis

Assumptions

Modeling of tag recovery data requires several assumptions. The important ones for this particular study are:

1.) the sample is representative of the target population,

2.) there is no tag loss,

3.) survival is not affected by tagging itself, and

4.) the fate of each tagged fish is independent.

Modeling

A logistic model was applied to tag recovery and release data. Logistic models linearly relate a dichotomous or ordinal response variable to explanatory variables by transforming data using a logit function. We used the SAS Logistic Procedure (SAS, 1989), which fits linear logistic regression models to ordinal response data and calculates Maximum Likelihood Estimates (MLE) of model parameters (Appendix B).

In the model, the proportion of the number of recovered tags to the number of tags released was the response variable and the explanatory variables consisted of one categorical variable (interval number, which accounted for unequal interval lengths), and two binary variables (disposition and angler type). The following model was used for analysis of recovery data for each release/recovery interval:

$$\ln\left[\frac{r_{ijk}/m_i}{1-r_{ijk}/m_i}\right]=b_0+\boldsymbol{b}'\boldsymbol{x} \qquad (1)$$

Where,

m_i = number of fish tagged and released for each recovery interval (i), adjusted for tag-induced mortality of 1.3% (Rugolo and Lange, 1993),
r_{ijk} = number recovered tags during recovery interval (i) from angler type (j) and fish disposition (k),
b′ and b_0 = regression parameters, and
x = variables which indicate the interval, fish disposition, angler type, and their interactions.

The SAS Logistic Procedure partitioned out an estimate of the recreational/charter recovery rate (f_{iR}), or the proportion of fish caught and kept by recreational/charter anglers for each interval (i) during the fishing season by using the ratio:

$$f_{iR} = \frac{\exp(b_0 + \boldsymbol{b}'\boldsymbol{x})}{1 + \exp(b_0 + \boldsymbol{b}'\boldsymbol{x})} \qquad (2)$$

Since all harvested fish with tags are not reported, the finite exploitation rate (U_{iR}) was then determined for the recreational/charter component of the fishery for each interval (i) using the following equation:

$$U_{iR} = \frac{f_{iR}}{\lambda} \qquad (3)$$

Where λ = recreational/charter reporting rate of 0.751 and is assumed to be constant. This value of the reporting rate was determined during a previous study which utilized tags containing $100 rewards when reported (Rugolo et al., 1994).

The commercial exploitation rate could not be derived without an estimate of the commercial reporting rate which is not known. Therefore, commercial estimates of the fishing mortality rate were indirectly calculated from recreational estimates based on weighting of proportional harvest.

Instantaneous Rate of Fishing Mortality

The conversion from rate of exploitation (U_{iR}) to instantaneous rate of fishing mortality (F_R) was then made as follows:

(4)

$$F_R=\sum_{i=1}^{L} -\ln(1-U_{iR})$$

Where,

F_R = directed fishing mortality rate in the recreational/charter fishery, and
L = number of intervals.

To include recreational/charter fishing which occurred in the spring of 1998, the spring resident stock harvest component was added to the recreational/charter estimate of fishing mortality:

(5)

$$F_R^{\prime}=F_R+[F_R*(P_S)]$$

Where,

F'_R = directed fishing mortality rate in the recreational and charter fishery for fall 1998 and spring 1999, and
P_S = proportion of number of striped bass in spring resident stock harvest to number of striped bass in recreational/charter harvest during fall 1998 to spring 1999. Harvest numbers were obtained from the Marine Recreational Fisheries Statistics Survey (MRFSS).

Estimates of the rate of fishing mortality attributed to the commercial component was determined by the following equation:

(6)
$$F_C = F_R' * P_C$$

Where,

P_C = proportion of the number of striped bass in the commercial harvest to the number of striped bass in recreational/charter harvest (fall 1998+spring 1999). The recreational/charter harvest was obtained from MRFSS; and the commercial harvest was obtained from monitoring programs from Chesapeake Bay jurisdictions, and

F_C = the directed instantaneous commercial fishing mortality rate.

The overall 1998 fishing mortality rate (F_{BAY}) was determined by summing recreational/charter and commercial components:

(7)
$$F_{BAY} = F_R' + F_C$$

Estimation of Variance

To estimate the variance we assume that: 1) the recovery rate estimates are independent between intervals, 2) the reporting rate is constant across time, and 3) harvest statistics are known and not estimated.

An approximate variance of U_{iR} is derived from the delta method (Mood et. al., 1974) and is shown as follows:

(8)
$$var(U_{iR}) \cong U_{iR}^2 \left(\frac{var(f_{iR})}{f_{iR}^2} + \frac{var(\lambda)}{\lambda^2} \right)$$

Where,
f_{iR} = recovery rates for recreational/charter anglers in the i^{th} interval,
U_{iR} = finite exploitation rates for the recreational/charter fisheries in the i^{th} interval, and
λ = recreational/charter reporting rate of 0.751 which is assumed to be constant.

Because the estimate of fall-instantaneous-recreational/charter fishing mortality (F_R) is a transformation of U_{iR} , we used the delta method to approximate the variance of F_{iR} (per interval) and the assumption of independence of estimates between intervals to compute variance of F_R. Thus, we have

(9a)
$$var\left(F_{iR}\right) \cong \frac{var\left(U_{iR}\right)}{1 - var\left(U_{iR}\right)^2}$$

and

(9b)
$$var\left(F_R\right) \cong \sum_{i=1}^{L} var\left(F_{iR}\right)$$

The variance estimate for total fishing mortality (F_{BAY}) can then be written as a function of F_R , the proportion of spring to fall harvest P_S , and the proportion of commercial to fall harvest (P_C). Assuming the proportional harvest statistics are known:

(10) $$var\left(F_{BAY}\right) = \sum_{i=1}^{L} var\left(F_R\right)\left(1+P_C+P_S*P_C\right)^2$$

We also estimated the variance associated with the reporting rate (0.751) from the previously reported lower and upper 95% confidence bounds of that rate and included that in the estimate of variance around F. The confidence bounds of the reporting rate were 60.4% and 99.2% (Rugolo et al, 1994). From these bounds, the largest half-width (.241) was used to approximate the variance associated with the reporting rate. Given that a 95% confidence interval is determined by using $1.96*\sigma=0.241$, the standard deviation (σ) of 0.123 was estimated by dividing 0.241 by 1.96. The standard deviation was then squared to obtain a variance of 0.015 around the reporting rate of 0.751 and was incorporated into the calculation of overall variance for F_{BAY} to account for a portion of the variance.

RESULTS

Tag Releases and Recoveries

Tag releases were sometimes less than target numbers due to inclement weather and lack of fish (Table 3 and Appendix A, Figures 2-6). In other cases, more tags were released than proposed because fish were available and more releases would increase the precision of the fishing mortality estimate. Although round five releases fell just short of the targeted 1000 releases per jurisdiction per round, overall the bay-wide release target of 7500 was exceeded (Table 3). Fish recovered prior to start of a recovery interval, on the day of the release, or reported as an accidental death, found dead, or tag found only, were removed from the analysis entirely.

Table 3. Release numbers (adjusted for tag-induced mortality of 1.3%) of tagged striped bass used to estimate the instantaneous annual rate of fishing mortality in Chesapeake Bay for fall 1998.

Release Interval					
1	2	3	4	5	TOTAL
1486	1307	2037	2718	987	8536

In these tagging experiments, tag recoveries are differentiated from tag recaptures. Tag recoveries are tags retrieved from animals which are harvested or permanently removed from a population, whereas tag recaptures occur when a tag is retrieved, information collected, and the animal is immediately returned to the population. In our calculation of the exploitation rate, we only used tag recoveries reported by recreational/charter anglers within the Chesapeake Bay because the disposition of interest was that of fish harvested by recreational anglers (Table 4). Additionally, only fish with complete recovery dates (d/m/y) were used in the analysis.

Table 4. Number of tagged striped bass released and subsequently harvested (recovered) by recreational/charter anglers within the Chesapeake Bay during specified recovery interval of the fall 1998 recreational fishery. Recoveries are only included from fish released during corresponding release interval.

Recovery interval					
1	2	3	4	5	TOTAL
2	4	20	31	2	59

Instantaneous Rate of Fishing Mortality and Associated Variance

Estimates of the rate of exploitation (*U*) were directly derived from modeling of tag recovery data from fish harvested by recreational anglers and were determined for the recreational/charter fishery (Tables 4 & 5). This method of estimation assumes 0.751 to be the reporting rate of recovered tags (Rugolo et al, 1994). Estimates of exploitation for the recreational/charter season were converted to instantaneous rates (F_{Ri}) for each round and summed across intervals to determine F_R for recreational/charter anglers (Table 5). This estimate was then adjusted to include the resident portion of the commercial and recreational fisheries that occurred during winter 1998-99 and during spring and summer of 1999, respectively (Table 6). This resulted in the bay-wide F (F_{BAY}) of 0.10 (Table 5). Non-harvest mortality (0.10) was added to the point estimate of 0.10 to obtain the final estimate of bay-wide fishing mortality of 0.20 for 1998. The variance of 0.00030 (Table 5) converts to a Coefficient of Variation of 17%.

Table 5. Preliminary estimates of fishing mortality rate for 1998 fall recreational/charter (F_R) and commercial (F_C) components of Chesapeake Bay striped bass fisheries and combined bay-wide fishing mortality (F_{BAY}) in 1998.

	F_R	var (F_R)	F_C	F_{BAY}	var (F_{BAY})	CV
BAY	0.03704	0.00004	0.06790	0.10494	0.00030	0.16515

Table 6. Resident striped bass harvest (in numbers) in Chesapeake Bay for a twelve month period beginning with the initiation of the 1998 recreational season in Maryland (August 15, 1998). Harvest numbers were obtained from Marine Recreational Fisheries Statistics Survey (MRFSS) and monitoring program from respective jurisdictions.

Fishery Component	Maryland	Potomac River	Virginia	Total
Fall recreational/charter *1	254,277	----	207,394	461,671
Spring/Summer Recreational *2	239,857	0	25,141	264,998
Commercial *3	633,067	73,743	139,426	846,236
TOTAL	1,127,201	73,743	371,961	1,572,905

*1 Potomac fall recreational harvest is included within Maryland and Virginia numbers
*2 MD and VA Spring/summer harvest numbers are preliminary and based on last years harvest numbers
*3 Commercial harvest numbers are preliminary because commercial seasons are currently open and final numbers will not be available until after August 15, 1999.

CONCLUSIONS

The final bay-wide F estimate of 0.20 is below the 1998 target fishing rate of 0.28 for the Chesapeake Bay and indicates a continued decrease in fishing mortality from the 1997 estimate of F = 0.25 and the 1996 estimate of F = 0.33. Although bay wide harvest numbers for the twelve month period which began on August 15, 1998, are not final, it appears that there was decrease in the total number of fish harvested within the Chesapeake Bay for that time period.

The multiple release approach remains the most appropriate design for the estimation of F during the more extended fall recreational seasons in the Chesapeake Bay. The estimate produced by the logistic analysis best uses the recovery data of fish harvested by recreational fishers and addresses the issue of possible migration of striped bass across jurisdictional boundaries within the Chesapeake Bay during the recreational seasons (Schaefer and Rugolo, 1996).

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APPENDIX A

Locations of management jurisdictions, areas and sites of tag releases used for the fall 1998 striped bass rate of fishing mortality study on Chesapeake Bay.

Figure 1. Management jurisdiction and area designations used for tag release during fall 1998 striped bass fishing mortality study in Chesapeake Bay.

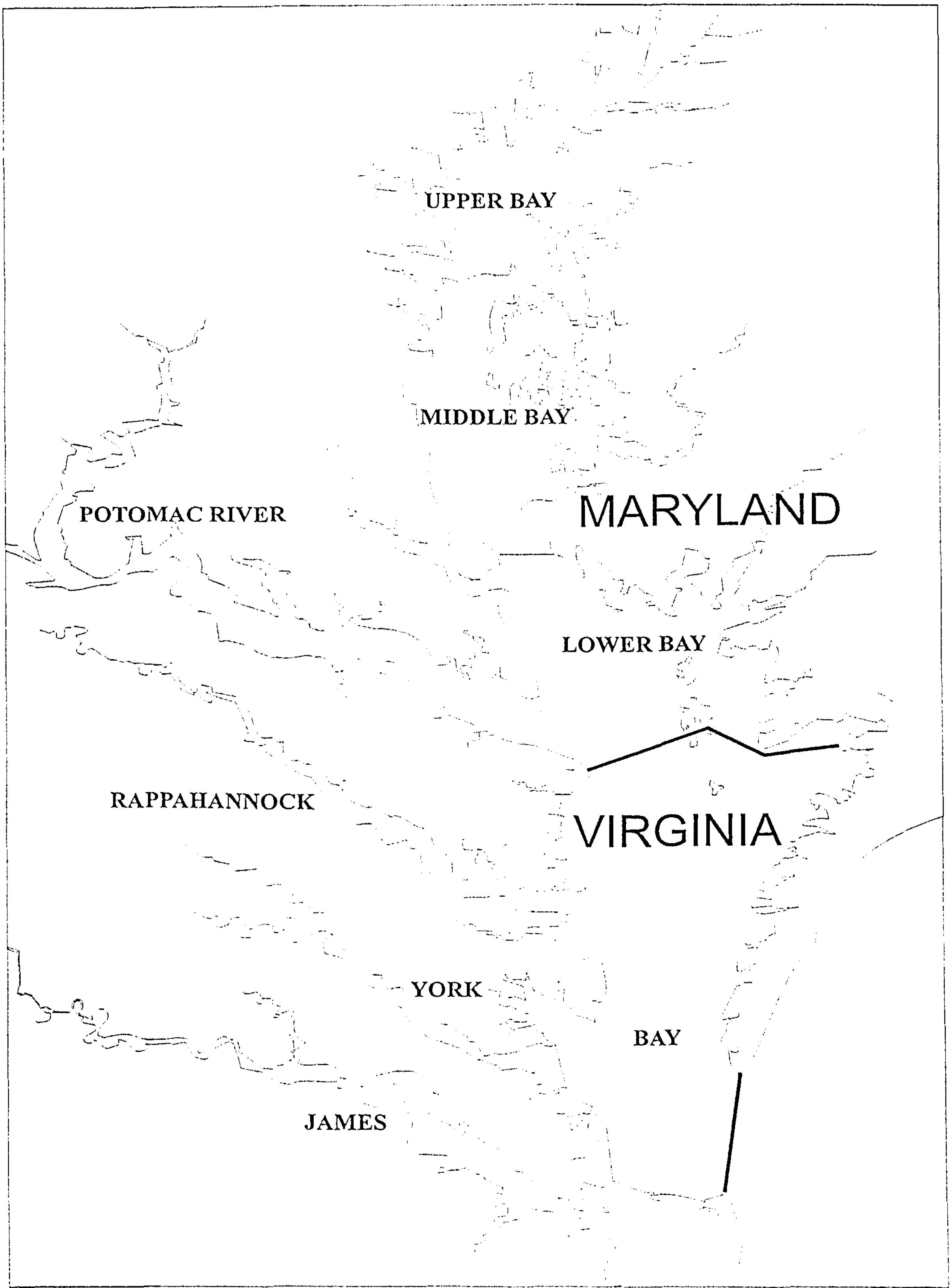


Figure 2. Numbers (unadjusted) of tags released during interval one of the 1998 fishing mortality study in Chesapeake Bay. Circles represent approximate locations of release sites. Black lines designate management jurisdictions for purposes of this study.

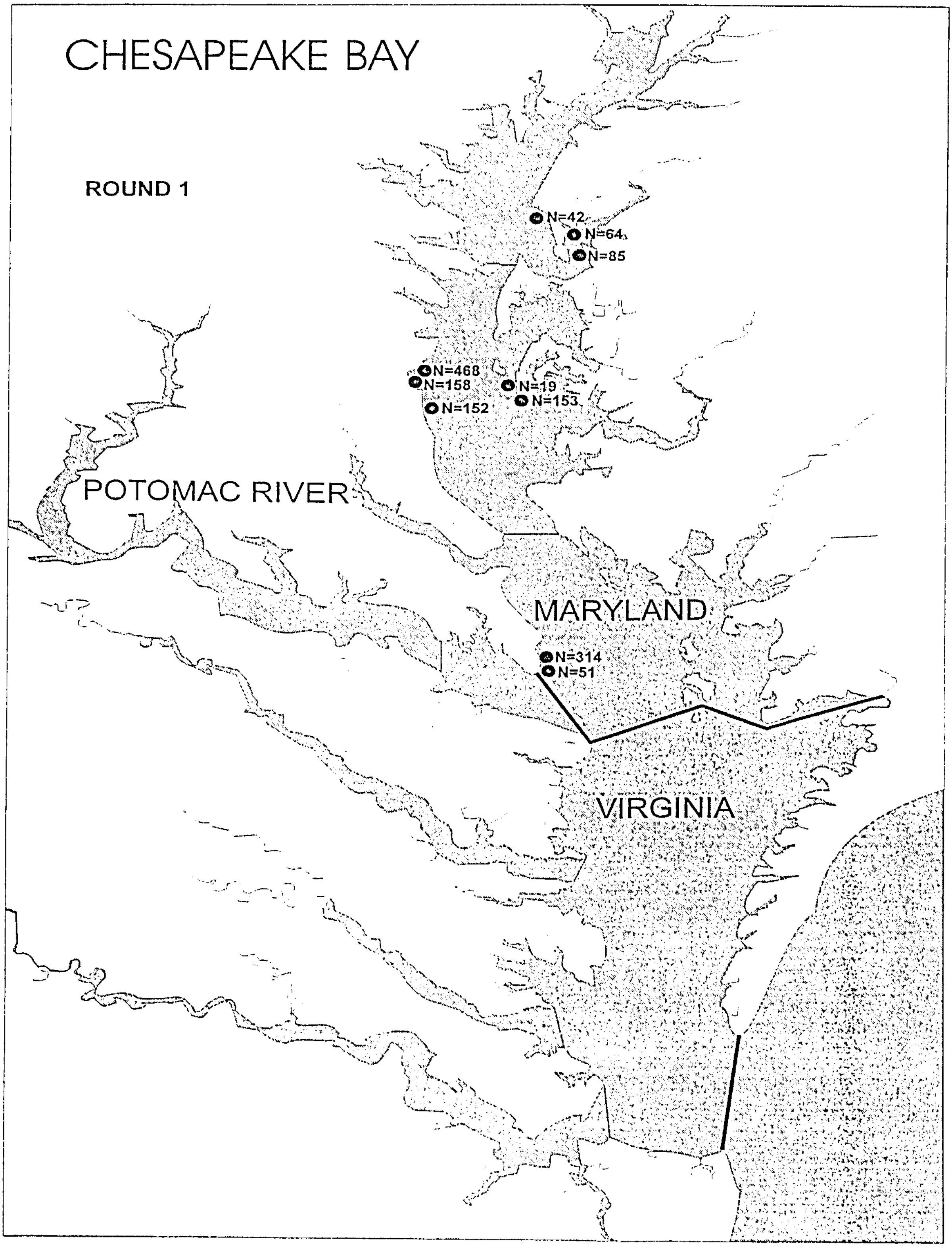


Figure 3. Numbers (unadjusted) of tags released during interval two of the 1998 fishing mortality study in Chesapeake Bay. Circles represent approximate locations of release sites. Black lines designate management jurisdictions for purposes of this study.

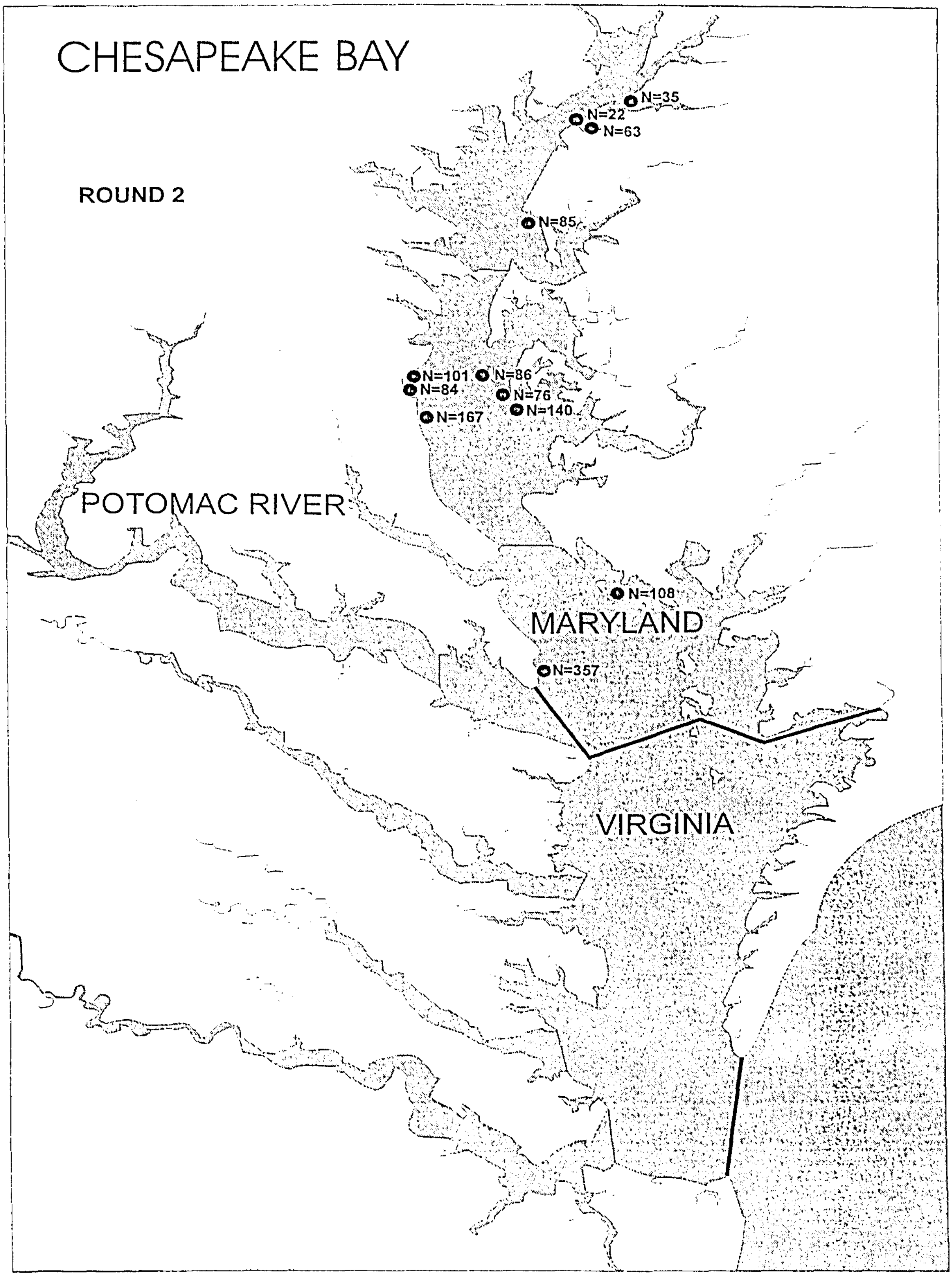


Figure 4. Numbers (unadjusted) of tags released during interval three of the 1998 fishing mortality study in Chesapeake Bay. Circles represent approximate locations of release sites. Black lines designate management jurisdictions for purposes of this study.

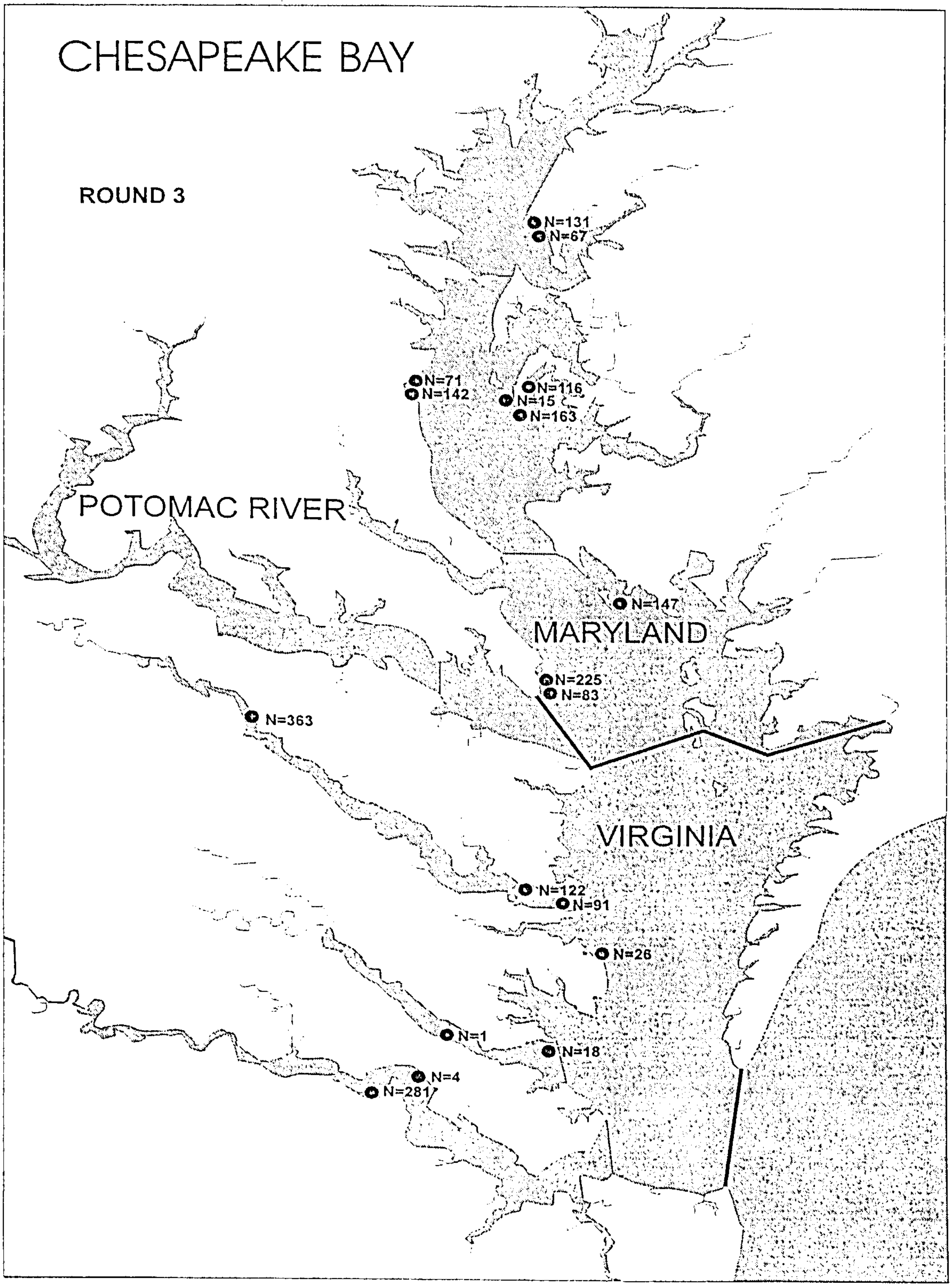


Figure 5. Numbers (unadjusted) of tags released during interval four of the 1998 fishing mortality study in Chesapeake Bay. Circles represent approximate locations of release sites. Black lines designate management jurisdictions for purposes of this study.

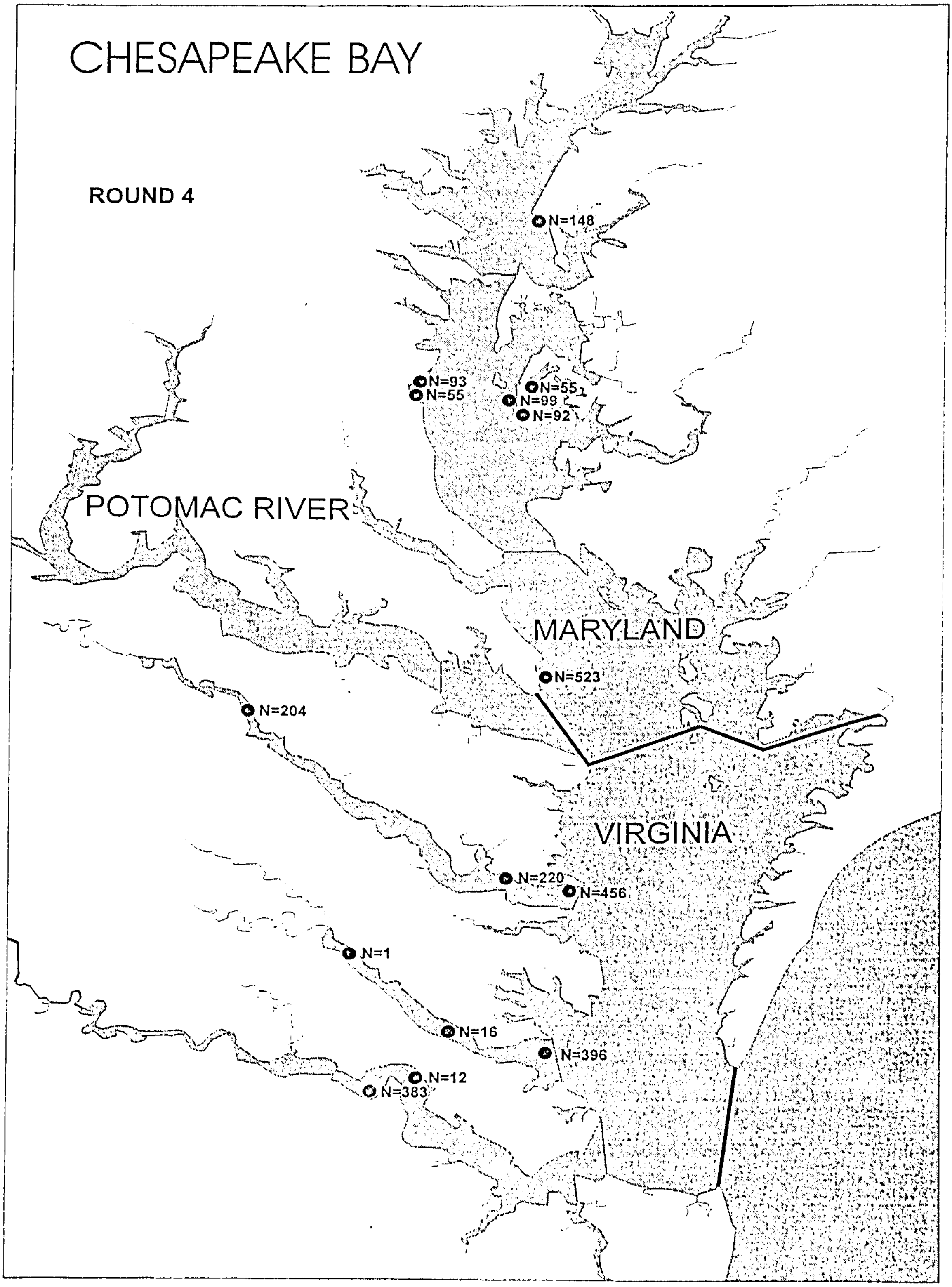
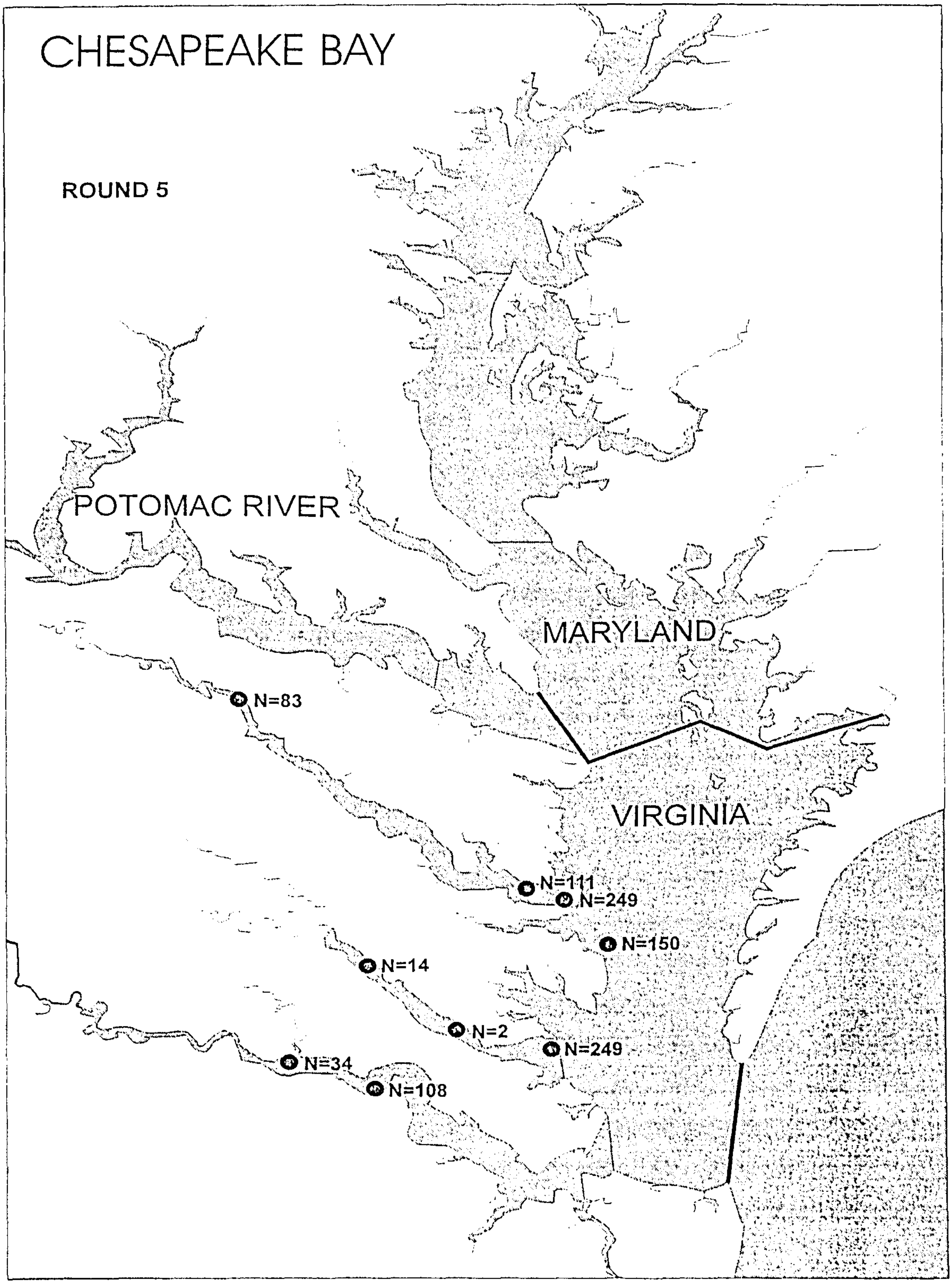


Figure 6. Numbers (unadjusted) of tags released during interval five of the 1998 fishing mortality study in Chesapeake Bay. Circles represent approximate locations of release sites. Black lines designate management jurisdictions for purposes of this study.



APPENDIX B

Statistical Analysis Program (SAS) used to compute the updated 1998 bay-wide estimate of F and associated variance.

```
* FOR 1998 FALL DIRECTED FISHING MORTALITY ESTIMATE;
/*************************************************;
*DF98BAY.SAS   BAYWIDE ROUNDS;
/**********************************************
 *                                      *
 *  THIS PROGRAM USES LOGISTIC MODELS TO ESTIMATE  *
 *  RECOVERY RATE.  THE FOLLOWING CODES PERTAIN:   *
 *                                      *
 *  STATE:    MD, POT, VA                     *
 *  FISHER:   0 = commercial,  1 = recreational    *
 *  RECOVERY: 0 = harvested,   1 = not harvested   *
 *                                      *
 ***********************************************/
data recovery;
input count recovery fisher m state $ interval;
if fisher=1 and recovery=0 then recharv =1;
else recharv=0;
if interval eq 1 then i1=1;
else i1=0;
if interval eq 2 then i2=1;
else i2=0;
if interval eq 3 then i3=1;
else i3=0;
if interval eq 4 then i4=1;
else i4=0;
if interval eq 5 then i5=1;
else i5=0;

inter1=i1*recharv;
inter2=i2*recharv;
inter3=i3*recharv;
inter4=i4*recharv;
inter5=i5*recharv;
cards;

 2 0 1 1486 BAY 1   /*   BAY1  RHARV    */

 4 0 1 1307 BAY 2   /*   BAY2  RHARV    */

20 0 1 2037 BAY 3   /*   BAY3  RHARV    */

31 0 1 2718 BAY 4   /*   BAY4  RHARV    */

 2  0 1  987 BAY 5  /*   BAY5  RHARV    */
;
```

```
data BAY;
set recovery;
if state='BAY';
hn=1;

proc logistic data=BAY;
model count/m = recharv i1 i2 i3 i4 i5 inter1 inter2 inter3 inter4 inter5;
output out=rmest1 pred=rmest stdxbeta=stdxbeta xbeta=xbeta;
run;


data bayest;
set rmest1;
if recharv = 1;
rmest2=1/(1+exp(-xbeta));
rmest3=count/m;
rmvar=(rmest*(1-rmest))/m;
rmvar2=(stdxbeta**2)*(exp(-xbeta)/(1+exp(-xbeta))**2)**2;
keep interval state hn rmest rmvar rmest2 rmest3 rmvar2;

proc print;

proc sort data=bayest;
by hn interval;

proc print;


data fbayest;
set bayest;
retain F var_F;
by hn interval;
lambda=.751;
varlam=0.015;          /*variance*/
Psf1=264998/461671;         /* BAY sprg res/rec&chtr */
Pcr1=846236/(461671+264998); /* BAY comm/ rec&chtr+sprg res */

if first.hn then do;
F=0; var_F=0;
end;
U=rmest/lambda;
Fi=-log(1-U);
var_U=U**2*(rmvar/rmest**2+varlam/lambda**2);
var_Fi=var_u/(1-U)**2;
F=F+Fi;
```

```
var_F=var_F+var_Fi;
if last.hn and state='BAY' then do;
fc=f*(1+psf1)*pcr1;
ft=f*(1+pcr1+psf1*pcr1);
varft=var_f*(1+pcr1+psf1*pcr1)**2;
cv=sqrt(varft)/ft;
output;
end;
keep state f var_f fc ft varft cv;
run;

TITLE1 '1998 DIRECTED F ESTIMATE';
TITLE2 'run 7/8/99 with most recent harvest numbers';
proc print;
run;
```