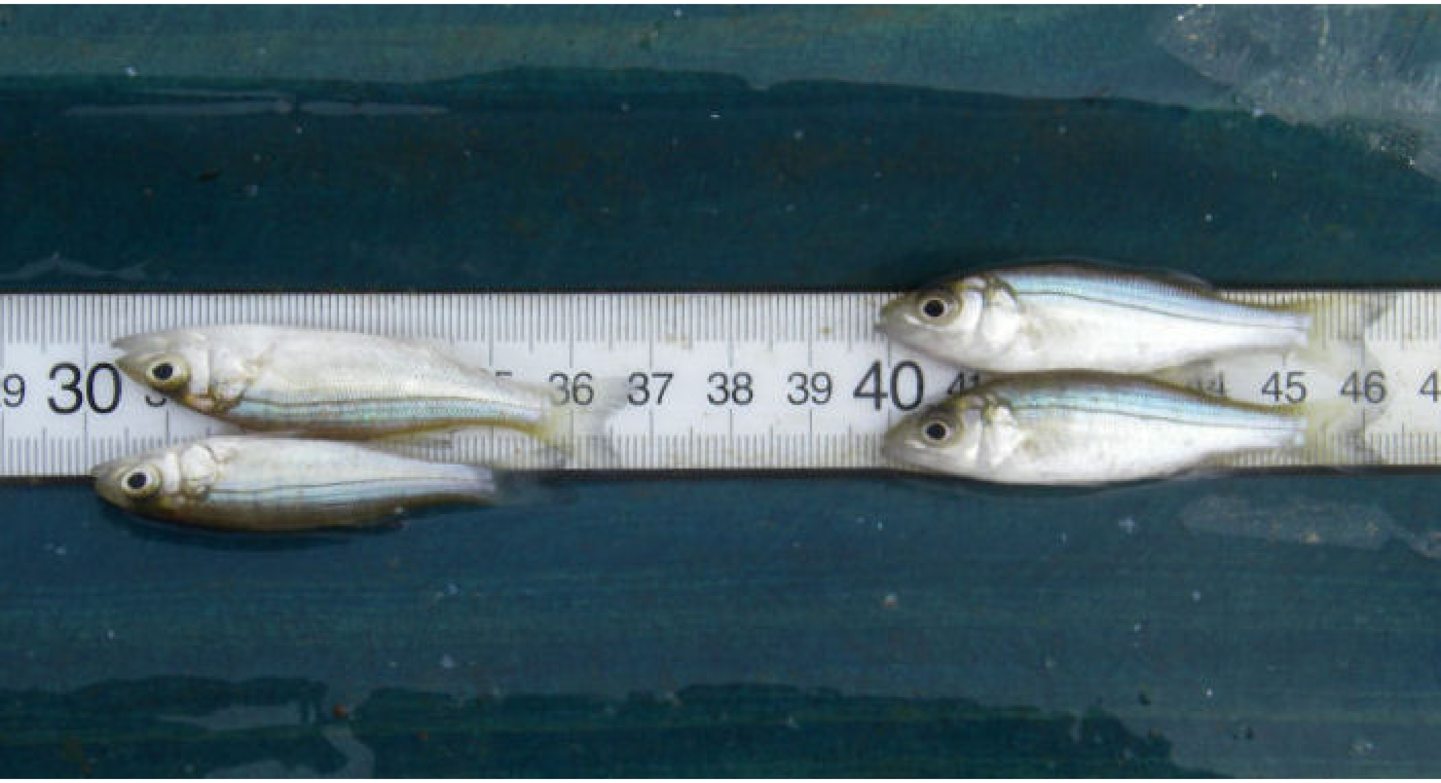
ANNUAL PROGRESS REPORT

Estimation of Juvenile Striped Bass Relative Abundance in the Virginia Portion of Chesapeake Bay

January 2009-December 2009

Leonard S. Machut
Mary C. Fabrizio

Department of Fisheries Science
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia



U.S. Fish and Wildlife Service Sportfish Restoration Project F87R21
Submitted to Virginia Marine Resources Commission March 2010

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 2009 striped bass juvenile abundance index is 8.42 and is not significantly different from the historic average of 7.54. Additional methods of calculating the regional index support this conclusion. Catches in the York River were nearly identical to its historic average. Although the James River catches were higher and the Rappahannock River catches were lower than historic averages, they were not significantly so. Striped bass catches at auxiliary stations provide greater spatial coverage of the nursery grounds and suggest that juvenile striped bass were broadly distributed throughout the sampling area in 2009.

LIST OF TABLES

LIST OF FIGURES

PREFACE

The primary objective of the Virginia Institute of Marine Science juvenile striped bass survey is to monitor the relative annual recruitment success of juvenile striped bass in the major Virginia nursery areas of lower Chesapeake Bay. The U.S. Fish and Wildlife Service initially funded the survey from 1967 to 1973. Beginning in 1980, funds were provided by the National Marine Fisheries Service under the Emergency Striped Bass Study program. Commencing with the 1989 annual survey, the work was jointly supported by Wallop-Breaux funds (Sport Fish Restoration Act), administered through the U.S. Fish and Wildlife Service, and the Virginia Marine Resources Commission. This report summarizes the results of the 2009 sampling period and compares these results with previous years.

INTRODUCTION

Striped bass (*Morone saxatilis*) is one of the most commercially and recreationally sought-after fish species on the east coast of the United States. Decreases in the commercial harvest of striped bass in the 1970s paralleled the steady decline in abundance of striped bass along the east coast; Chesapeake Bay stock abundances were particularly depressed. Because the tributaries of the Chesapeake Bay had been identified as primary spawning and nursery areas, fishery managers enacted regulations intended to halt and reverse the decline of striped bass in the Chesapeake Bay and elsewhere within its native range (ASMFC 2003).

In 1981, the Atlantic States Marine Fisheries Commission (ASMFC) developed the Atlantic Coast Striped Bass Interstate Fisheries Management Plan (FMP), which included recommendations aimed to improve the stock status. The Virginia Marine Resources Commission (VMRC) adopted this plan in March 1982 (Regulation 450-01-0034), but the ASMFC did not have regulatory authority for fisheries management in individual states at that time. As striped bass populations continued to decline, Congress passed the Atlantic Striped Bass Conservation Act (PL 98-613) in 1984, which required states to either follow and enforce management measures in the FMP or face a moratorium on striped bass harvests. Since 1981 the FMP has been amended six times to address changes in the management of the stocks. Amendment VI to the plan, adopted in February 2003, requires "producing states" (i.e., Virginia, Maryland, Delaware and New York) to develop and support programs monitoring striped bass recruitment.

Well before the FMP requirement, Virginia began monitoring the annual recruitment of juvenile striped bass in 1967 using funding from the Commercial Fisheries

Development Act of 1965 (PL88-309). This monitoring continued until 1973 when funding was discontinued. Monitoring of striped bass recruitment was re-instituted in 1980 with Emergency Striped Bass Study funds (PL 96-118, 16 U.S.C. 767g, the "Chafee Amendment"), and since 1989 has been funded by the Wallop-Breaux expansion of the Sport Fish Restoration and Enhancement Act of 1988 (PL 100-448, "the Dingle-Johnson Act"). These funds are administered through the VMRC.

Initially, the Virginia program used a 6 ft x 100 ft x 0.25 in mesh (2 m x 30.5 m x 6.4 mm) bag seine, but comparison tows with Maryland gear (4 ft x 100 ft x 0.25 in mesh; 1.2 m x 30.5 m x 6.4 mm mesh) showed virtually no statistical differences in catch, and Virginia adopted the "Maryland seine" after 1987 (Colvocoresses 1987). The gear comparison study aimed to standardize methods thereby allowing a baywide examination of recruitment success (Colvocoresses and Austin 1987). This was never realized due to remaining differences in data analysis (MD: arithmetic index, VA: geometric index). A baywide index using a geometric mean weighted by river spawning area was finally developed in 1993 (Austin et al. 1993) but has not been regularly computed. Recent computations of a baywide index using the geometric mean were used to correlate young-of-year recruitment to fishery-independent monitoring (Woodward 2009).

Objectives for the 2009 program were to:

1. estimate the relative abundance of the 2009 year class of striped bass in the James, York and Rappahannock river systems,
2. quantify environmental conditions at the time of collection, and

3. examine relationships between juvenile striped bass abundance and environmental and biological data.

METHODS

Field sampling was conducted during five biweekly sampling periods from July through mid-September 2009. During each sampling round, the seine was hauled at 18 historically sampled sites (index stations) and 21 auxiliary stations within the James, York and Rappahannock river systems (Figure 1). Auxiliary sites were added in 1989 to provide better geographic coverage, increase sample sizes within each river system, and to permit monitoring of trends in juvenile abundance within each river system. Such monitoring was desirable in light of increases in stock size and nursery ground expansion.

Collections were made by deploying a 100 ft (30.5 m) long, 4 ft (1.2 m) deep, 0.25 in (6.4 mm) mesh minnow seine perpendicular to the shoreline until either the net was fully extended or a depth of about 4 ft (1.2 m) was encountered and then pulling the offshore end down-current and back to the shore. During each round a single haul was made at each auxiliary station and duplicate hauls, with a 30-minute interlude, were made at each index station. Every fish collected during a haul was removed from the net, and held in water-filled buckets until after the second haul was completed. Individual striped bass were measured to the nearest mm fork length. For all other species, a sub-sample of up to 25 individuals was measured to the nearest mm fork length (or total length if appropriate). All fish captured, except those preserved for life history studies, were returned to the water at the conclusion of sampling.

Collection efficiency was limited at several sites in 2009 (Table1). Electrofishing activities of the Virginia Department of Game and Inland Fisheries (VDGIF) during late

August prevented sampling at R60 in round 4. The invasive aquatic weed hydrilla (*Hydrilla verticillata*) limited sampling at two upper auxiliary sites in the York River drainage (P55 and M52). Seine hauls of limited efficiency were completed at P52 during early July and September (rounds 1 and 5) because of high water levels and the presence of hydrilla. Station M52 was not sampled during late August and September (rounds 4 and 5) due to weather conditions. During September, successive rainstorms increased water levels and reduced the availability of beaches necessary for proper deployment of the seine at numerous sites. For instance, at M37, sampling could not be performed in September because the beach was inundated. Catch efficiencies were likely reduced at these sites although we could not directly quantify changes in efficiency.

At each sampling location salinity, water temperature and dissolved oxygen concentrations were measured after the first haul using a YSI water quality sampler. Sampling time, tidal stage and weather conditions were recorded for each haul.

In this report, comparisons of recruitment indices with prior years are made for the “primary nursery” area only (Colvocoresses 1984) by using data collected from months and areas sampled during all years (index stations). Thus, data from auxiliary stations are not included in the calculation of the annual indices. The index of relative abundance for striped bass is calculated as the adjusted overall mean catch per seine haul such that

$$Index = (\exp(\ln(totnum + 1)) - 1) \times 2.28$$

where *totnum* is the total number of striped bass collected per seine haul. Because the frequency distribution of the catch is skewed and approximates a negative binomial distribution (Colvocoresses 1984), a logarithmic transformation (ln(*totnum*+1)) was applied to the data prior to analysis (Sokal and Rohlf 1981). Mean values are back-transformed and scaled up arithmetically ($\times$ 2.28) to allow for comparisons with Maryland data. Thus, a "scaled" index refers to an index that is directly comparable with the Maryland index.

In accordance with suggestions made by Rago et al. (1995), the Virginia juvenile striped bass index has also been recomputed using only the first haul at each index station. Additionally, due to the rehabilitation of Chesapeake Bay striped bass stocks, and subsequent relaxation of commercial and recreational fisheries regulations in the Chesapeake Bay in 1990 (ASMFC 2003), the seine survey dataset can be separated into three distinct periods:

- 1967 – 1973: an early period of monitoring;
- 1980 – 1989: a decade reflecting severe population depression during which temporary fishing moratoria were in place; and,
- 1990 – Present: a period of post-recovery and regulation targeting the development of a sustainable fishery.

An average index value for the 1990 – 2009 time period was calculated using only the first haul at each index site and was compared with the annual index value to provide a benchmark for interpreting recruitment strength during the post-recovery period.

Throughout this report mean catch rates are compared using 95% confidence intervals. Reference to "significant" differences between geometric means in this context will be restricted to cases of non-overlapping confidence intervals. Because standard errors are calculated from transformed (logarithmic) values, confidence intervals on the back-transformed and scaled indices are non-symmetrical.

RESULTS AND DISCUSSION

Virginia Regional Juvenile Index of Abundance

In 2009, 1,408 young-of-year striped bass were collected from 180 seine hauls at index stations and 390 individuals were collected from 101 hauls at the auxiliary stations (Table 1). Using data from both hauls at index stations, the estimated index for 2009 is 8.42 (LCI = 6.80, UCI = 10.32; Table 2), which is not significantly different from the historic average index of 7.54 (LCI = 7.23, UCI = 7.86; Figure 2). The "historic index" refers to a summation of all survey years from 1967 to the present.

However, even with a 30-minute interlude between sampling at index stations, second hauls are not independent samples and violate a key assumption necessary for making inferences from a sample mean (Rago et al. 1995). Previous reports have noted fewer catches in the second haul (e.g. Hewitt et al. 2007, 2008) which may artificially lower the geometric mean when data from second hauls are included in the computation of the index. Using only the first haul at each index station, the annual and historic indices were recalculated. In 2009, 861 young-of-year striped bass were collected resulting in an index estimate of 10.47 (LCI = 7.81, UCI = 13.83, Table 3) which is not significantly different from the recomputed first-haul historic index of 8.21 (LCI = 7.76, UCI = 8.69). It is important to note that all annual striped bass estimates in Table 3 have been adjusted to account for single hauls. By developing a 2009 index based solely on the first haul a more robust estimate of juvenile abundance can be determined for Virginia waters.

The inclusion of a comparison between the present year's annual recruitment and a post-recovery period index (1990 – Present) provides additional information on the pattern of striped bass annual recruitment in relation to a more recent average that reflects the current status of the stock. The 2009 Virginia-wide index of 10.47 (LCI = 7.81, UCI = 13.83) is not significantly different from the mean index for the post-recovery period (index = 11.98; LCI = 11.19, UCI = 12.82) suggesting that 2009 was an average year.

As a whole, striped bass recruitment success in the Virginia portion of the Chesapeake Bay is variable among years and among nursery areas within years. No significant differences were apparent when comparing the 2009 annual index against any of the three measures of striped bass relative recruitment (traditional historic index, first-haul only index, and mean index from 1990 through present day). This suggests that striped bass from the Virginia portion of the Chesapeake Bay exhibited an average recruitment in 2009. Young-of-year abundance was low in 1999 and 2002, but strong year classes were observed in 2000, 2001, 2003 and 2004. This was followed by average recruitment in 2005, above average recruitment in both 2006 and 2007, and average recruitment in 2008. Thus, a year of average recruitment is not uncommon, and rather is instead expected. The size of the nursery area was generally similar to previous years with greater numbers of juvenile fish found in the James River than in the Rappahannock and York River watersheds.

Continued monitoring of regional recruitment success will be an important factor for identifying management strategies to protect the spawning stock of Chesapeake Bay striped bass. Ongoing research at VIMS suggests that a Chesapeake Bay-wide index, computed from Virginia and Maryland data combined, could provide a more complete and robust estimate of young-of-year recruitment strength for Chesapeake Bay striped bass (Woodward 2009). This may be particularly appropriate to consider in years when individual state indices provide divergent estimates of year-class strength because such a pattern may simply reflect annual changes in the spatial distribution and contribution of nursery areas throughout the bay, rather than overall changes in the abundance of recruits to the Chesapeake Bay stock.

Individual Watershed Juvenile Index of Abundance

Juvenile striped bass were widely distributed in the James River in 2009 (Table 1). The 2009 index for the James drainage is 14.50 (LCI = 10.31, UCI = 20.09), which is not significantly different than the historic James drainage index of 9.91 (LCI = 9.25, UCI = 10.62; Table 4). Although the annual index is nearly 50% higher than the historic index, the lack of significant difference is difference is due to overlapping confidence intervals in both the James River system and within the individual rivers. The 2009 James River main stem (excluding the Chickahominy River) index is 14.27 (LCI = 9.66, UCI = 20.67) compared to the historic index of 9.25 (LCI = 8.50, UCI = 10.05). Similarly, the Chickahominy River 2009 index was 14.9 (LCI = 7.43, UCI = 28.36) compared to the historic index of 11.40 (LCI = 10.08, UCI = 12.85). Catches at Chickahominy River index stations were greater than those made during 2008 but were less than those observed in 2007 showing variability in yearly catches. Throughout the James River watershed five of six index sites had average or higher index averages than their respective historic averages, the lone exception being J56 (Table 5).

Catches at the Chickahominy River stations were variable throughout the sampling season. Collections at C3 were highest in early July but declined sharply in subsequent weeks (Table 1). This contrasts with catches at C1 which were stable through late August before decreasing in September. (Increased water levels during September limited beach availability for hauling-out and several fish may have been lost during sampling.) Roughly 40% of all young-of-year striped bass captured in the James drainage were from stations C3 and J46. While this represents higher catches at C3 when compared to 2005, 2006, and 2008; catches at J46 were notably lower than those made in 2007 and 2008. However, in total number of striped bass caught, J46 remained the second most productive index site sampled during 2009 in Virginia waters. Since 1990, J46 has consistently ranked among the top three productive index stations.

Although having the lowest drainage-specific index observed in 2009 (Figure 3), at 5.92 (LCI = 4.30, UCI = 7.94) the 2009 index for the York drainage is not significantly different from the historic index of 5.74 (LCI = 5.37, UCI = 6.14) suggesting an average year for this watershed. This represents a potential reversal of the continued index decline from 2005 – 2008 (Figure 3). No index sites are located on the main stem of the York River although three auxiliary stations are present; the watershed index is compiled from sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. The increased catches of young-of-year fishes in 2009 can be related to increased collections made from the Pamunkey River. The 2009 Pamunkey River index of 5.33 (LCI = 3.24, UCI = 8.21) is not significantly different from the historic index of 6.66 (LCI = 5.99, UCI = 7.39) marking a significant increase over 2008, the lowest index value reported in any river since 2002 (Machut and Fabrizio 2009). For the third straight year, the 2009 Mattaponi River index (6.40; LCI = 4.13, UCI = 9.47) is not statistically different from the historic average (5.13; LCI = 4.70, UCI = 5.58).

Within the York River watershed, catches were well distributed through the mid- and upper-river sections: M41, M44, M47, P45, and P50. Catch rates in 2009 were roughly similar with peak catches in July decreasing through August and September. Only M50 saw an increase in young-of-year striped bass in September. Fewer young-of-year striped bass were collected at the lower index sites for each river (M33 and P42). Catches at the lower Pamunkey and Mattaponi index sites were variable with catches fluctuating throughout the sampling season (Table 1).

The 2009 index for the Rappahannock River is 6.76 (LCI = 4.24, UCI = 10.26), which although lower than previous years is not statistically different from the historic average of 7.72 (LCI = 7.10, UCI = 8.37). Catches in 2009 were greatest at the two uppermost index sites (R50 and R55) with R55 being the most productive site (Table 1). Approximately 60% of the total catch in the Rappahannock River drainage in 2009 was collected from R55. Catches from R50 and R55 have dominated this drainage for several years.

Although the James River had the highest annual index value, and the York River the lowest, unlike recent previous years no drainage index, or individual river index, is significantly different from its' historic average. This is noteworthy as significant annual fluctuations in catches of YOY striped bass have been reported for individual rivers since 1997. Even in years with average recruitment (1988, 1990, 1992, 2005, 2008), abundance of YOY fish in at least one river was either significantly higher or lower than its' historic average. Additionally, the production of another year of average recruitment throughout Virginia contrasts with the recently reported lower-than-average catches in the Maryland portion of the Chesapeake Bay (Durell and Weedon 2009). The low JAI values observed in Maryland have increased concerns about the productivity of the bay stock at the regional level. Similarly, the impacts of disease (i.e., mycobacteriosis, Gauthier et al. 2009) and other stressors may have consequences for stock health that are likely to be manifested as declines in recruitment.

Striped Bass Collections from Auxiliary Stations

The 1989 addition of auxiliary stations has provided better overall spatial coverage for the James, York and Rappahannock drainages as upriver and downriver auxiliary sites allow for a more detailed delineation of the upper and lower limits of the nursery range. These auxiliary stations reveal that in years of low or high river flow, the spatial extent of nursery areas can change relative to river flow. Additionally, in years of high juvenile abundance the nursery area generally expands both up and down-river. This interannual flux in the collection of young-of-year striped bass at auxiliary sites is evident in 2009.

Similar to 2005 - 2007, no young-of-year striped bass were collected from J12 (Table 1); one had been collected in 2008. In 2006, when J77 replaced J74 and J78 (which could no longer be seined) as the uppermost James River sampling station, no striped bass were collected (see Hewitt et al. 2007). However, J77 was proven to be an appropriate alternative auxiliary site because fish were detected at this site in 2007 (Hewitt et al. 2008) and 2008 (Machut and Fabrizio 2009). This has continued into 2009 with a single fish collected during round 5. Catches at the upstream and downstream auxiliary sites suggest juvenile striped bass were broadly distributed throughout the James River nursery in 2009. However, fewer young-of-year striped bass were collected at the uppermost and lowermost auxiliary sites than in either 2007 or 2008.

All stations in the main stem York River are auxiliary. Similar to 2008, no juvenile striped bass were captured at Y15 during 2009, although young-of-year fish had been collected at this location from 2003 – 2007. Young-of-year striped bass were collected in 2009 from Y21 during late July (round 2) and from Y28 in late July and September (Rounds 2 and 5; Table 1). Catches in all auxiliary sites on the main stem of the York River were lower than historic averages (Table 5).

No striped bass were caught in the uppermost auxiliary sites in the Pamunkey and Mattaponi rivers. No fish have been caught at these sites since 2007. The lack of fish at P55 may have been due to the inability to accurately sample in dense hydrilla (*Hydrilla verticillata*) vegetation using a 100-ft seine. Although hydrilla was also present at M52, enough open space was available to deploy and retrieve the seine from July through early August (weather precluded sampling in later rounds.) However, no striped bass were collected. Given the altered state of habitat at these sites in recent history, it is unclear whether striped bass were present in this general location during the sampling season. Striped bass may be preferentially using the new hydrilla habitat (that is, perhaps juvenile striped bass were present but were not detected). Alternatively, striped bass may have been present within the upstream portions of these rivers, but may have been forced into deeper waters by the dense hydrilla beds. Or, the striped bass nursery may indeed have been located further downstream. If continued sampling difficulties persist, it may prove worthwhile to examine alternative sites or alter collection methodologies within this region to determine the presence/absence of juvenile striped bass.

As in 2007 and 2008 (Hewitt et al. 2008, Machut and Fabrizio 2009), few fish were collected at R10 and none at R21 (Table 1). Since 1999, few fish have been collected at either site save for 2001 and 2003 (Austin et al. 2002, 2004) which were years of high recruitment within both the Rappahannock River and the entire Virginia portion of the Chesapeake Bay. These sites have favorable substrate and no potential seine obstructions which suggest that these sites may have lower value as nursery areas due to consistently high salinities during average discharge years. Although few fish were collected at lower auxiliary sites, upriver auxiliary stations were reasonably productive in 2009. Annual index values were similar to or greater than historic averages for 3 of 4 upriver stations (Table 5), the lone exception being R69. R75, added in 2006 to replace R76, was comparatively productive as six young-of-year striped bass were collected throughout the 2009 sampling season; no fish were collected in 2006, only two in 2007, and ten in 2008. This suggests that this site is a suitable auxiliary station for monitoring upstream limits of juvenile striped bass.

Comparisons Between Index and Auxiliary Sites

Direct comparisons between auxiliary and index sites are problematic due to different sampling methods. Figures 4 through 7 show catch rates at all stations with index station catches reported as an average of two hauls. Past analyses demonstrated that catches are consistently greater in the first haul of any given set of seine hauls. Because only one haul is made at the auxiliary sites, the figures may overemphasize the contribution of the auxiliary sites relative to the index sites. Figures 4 through 7 are included only to demonstrate the spatial distribution of the year class in the river systems. Catches from auxiliary sites are important because they allow us to detect a shift in the spatial distribution that may partially explain variation in catch rates at the index sites. Reducing hauls at index sites to one per site and including some of the auxiliary sites in the index may lead to a more precise and robust estimate of relative year-class strength (Rago et al. 1995).

Sampling Round Comparison

In 2009, our catches were greatest in early July (round 1) when 491 young-of-year striped bass were collected (Table 6). Catches in late July (round 2) decreased by 21%, and catches in early August (round 3) decreased by 28% relative to late July. This is relatively consistent with historic trends (Table 6). However, a considerable decrease in catches were observed during round 4 in late August (49%) compared to the historic average (10.4%). A decrease in round 5 catches during early September 2009 (26%) was roughly similar the historic average (31.3%). Generally, raw catch values are highest during July and early August (rounds 1, 2, and 3) and taper off in late August and September (rounds 4 and 5) because fish disperse to deeper water and are large enough to effectively avoid capture. Additionally, adversely high September water levels reduced or precluded accessibility to beachheads necessary to properly deploy and retrieve seine hauls. Many sites (e.g. C1, C3, M41, M44, R65) had limited beachheads and fish may have been lost while retrieving the seine; while a few (M37, M52) could not be sampled at all.

Environmental Conditions and Potential Relationships to Juvenile Striped Bass Abundance

The distribution of juveniles within the nursery may be affected by water quality parameters during sampling. Pertinent environmental variables recorded at the time of each collection in 2009 are presented in Tables 7 through 9. Direct round-by-round comparisons of environmental and water quality parameters are difficult because of local site conditions and variations, so we examined this on a broader scale.

Striped bass recruitment variability is partially explained by temperature and precipitation in the winter and spring preceding sampling (Wood 2000). Data from the National Climate Data Center (NCDC 2010) indicated that whereas winter (December 2008 through February 2009) precipitation was "below normal", spring (March through May 2009) was characterized by "above normal" precipitation rates. Summer rainfall (June through August 2009) was characterized as "normal" and while salinities were generally slightly above historic averages during this time (Table 5) they were below those reported in 2008 when precipitation was "below normal" (Machut and Fabrizio 2009). Precipitation within the Maryland portion of the Chesapeake Bay was similar to that of Virginia in 2009 (NCDC 2010).

As in previous years, the pattern of high water temperatures in the mid summer and declining temperatures during the late summer was well defined in 2009 (Table 7). Unlike 2007 or 2008 (Hewitt et al. 2008, Machut and Fabrizio 2009) when temperatures were elevated (no temperatures below 25.0^{o}C) during September, 2009 temperatures were more similar to temperatures in preceding years (2005 and 2006). During September (round 5), 24 of 38 sampled sites (63%) were below 25.0^{o}C. Catch rates in 2009 followed the historic pattern with respect to water temperature: most fish (96%) were captured in waters between 25.0 and 34.9 ^{o}C (Table 10). The effects of these events on site-specific striped bass abundances can not be easily assessed. Water temperatures in these systems reflect the long-term weather patterns of summer, but also exhibit significant day-to-day and river-to-river variation. Sampling takes place at shallow shoreline areas that are easily affected by local events such as thunderstorms and by small-scale spatial and temporal variations associated with time of sampling (e.g.

morning versus afternoon or tidal stage). As noted in previous reports, this relationship is considered to be largely the result of a coincident downward progression of both catch rates and temperature as the survey season progresses (beyond early August) rather than any direct effect of water temperature on juvenile fish distribution.

In 2009, as in the past, we observed greater catches of young-of-year striped bass at lower salinities within the primary nursery area (Table 11). No index station exceeded 11.3 ppt salinity although salinity was as high as 19.6 ppt at the farthest downstream auxiliary sites (Table 8). Table 5 shows the relationship of juvenile striped bass catches with respect to historic and 2009 salinity gradients within each river system. In 2009, the percentage of catch observed in low salinities (0.0 – 4.9 ppt) was the same as observed historically (92% in 2009 vs. 92% all years; Table 11). Similarly, the catch in mid-range salinities (5.0 – 9.9 ppt) was the same as the historic average (7% in 2009 vs. 7% all years). In 2008, salinities ranges were generally higher at index stations, and catches reflected this (Table 11 in Machut and Fabrizio 2009). Juvenile striped bass were captured at downstream auxiliary sites during early rounds of the 2009 survey in areas with salinities ranging from 6.8 ppt to over 13.8 ppt, although catches were lower than those observed in lower salinity, upstream sites. Salinity is not the only factor affecting the spatial distribution of striped bass in 2009.

None of the dissolved oxygen (DO) levels measured during the survey in 2009 are considered hypoxic (less than 2-3 mg/L; Table 9). Approximately half of the sampling sites in the primary nursery area had at least one DO measurement that was more than one standard deviation (SD) less than the mean DO recorded from 1989 to the present at each station (Table 9). Lower than average values occurred inconsistently temporally and spatially. Dissolved oxygen measured at the time of sampling does not seem to have a direct effect on detection because DO values more than one SD less than the mean at a station (shaded values in Table 9) do not necessarily correspond with low catches at that station.

Additional Abundance Indices Calculated from the Seine Survey

Due to a sampling regime that spans from euryhaline to freshwater zones, a variety of species are collected by the juvenile striped bass seine survey annually. In 2009, over 45,000 individuals comprising 62 species were collected (Table 12). The four most common species were white perch (*Morone americana*), bay anchovy (*Anchoa mitchilli*), Atlantic silverside (*Menidia menidia*), and spottail shiner (*Notropis hudsonius*). Young-of -year striped bass were the 11th-most common species. Several common species occupying the nearshore zone are collected at high enough frequencies to allow for the calculation of abundance indices.

Several annual indices for species of management importance are presently reported to the ASMFC to fulfill compliance requirements including American shad (Watkins et al. 2009) and menhaden (VMRC 2009). Abundance estimates for juvenile American shad from the seine survey were highly correlated with those from push-net sampling (Wilhite et al. 2003), providing validation for this seine survey-based index.

Additional indices have been computed as supplementary information for the VMRC; these include: spottail shiner (Table 13), Atlantic silverside (Table 14), inland silverside (*Menidia beryllina*; Table 15), and banded killifish (*Fundulus diaphanous*; Table 16). The 2009 indices for spottail shiner and for Atlantic silverside are not significantly different from the historic average for these two species (Tables 13, 14).

Both inland silverside and banded killifish indices in 2009 are significantly higher than the historic average for these species (Table 15, 16). Although only a preliminary index, the high catches of banded killifish in 2009 continue the trend of higher than average abundance since 2004, and suggest a sustained increase in the abundance of banded killifish populations.

We will continue to evaluate abundance indices from the seine survey during 2010. Where appropriate, we will compare our survey-derived indices with those calculated from the VIMS trawl survey.

CONLCUSION

The 2009 juvenile abundance index (JAI) for striped bass (8.42) is not significantly different from the historic average (7.54); and, abundance indices from individual rivers showed no deviation from their respective historic averages. This observation suggests that striped bass spawning success was synchronous across the broad spatial scale of sampling in Virginia waters and that production in Virginia waters was average in 2009. Additional methods of calculating the regional index support this conclusion as well. Continued computations of the JAI is critical for predicting future recruitment to the commercial and recreational striped bass fisheries, and for identifying years of recruitment failure which serve as an early warning to managers of potential future declines in standing stock biomass.

ACKNOWLEDGMENTS

We are deeply indebted to the many landowners on the tributaries of the Chesapeake Bay that have graciously allowed us to conduct sampling on their property. We thank the Mariners' Museum, Jamestown 4-H Camp, June Parker Marina, Chickahominy Riverfront Park, and the United States Army at Fort Eustis for their permission to sample. Additional thanks go to Jordan Point Marina, June Parker Marina and Chickahominy Riverfront Park for use of their boat ramps. We would also like to thank the students who assisted in the field sampling and data compilation of this report, especially Pat McGrath and Branson Williams. Summer technicians were Zenia Sherman, Patrick Link, Alison Deary, and Matthew Norwood.

Funding was provided by a grant from the United States Fish and Wildlife Service Sport Fish Restoration Project (F87R21) through the Virginia Marine Resources Commission to the Virginia Institute of Marine Science.

LITERATURE CITED

ASMFC (Atlantic States Marine Fisheries Commission). 2003. Amendment #6 to the Interstate Fishery Management Plan for Atlantic Striped Bass. Fisheries Management Report 41. Atlantic States Marine Fisheries Commission, Washington, D.C. 63 p.

Austin, H.M., J.A. Colvocoresses and T.A. Mosca III. 1993. Develop a Chesapeake Bay-wide young-of-the-year striped bass index. Final Report, CBSAC Cooperative Agreement NA16FUO393-01, 59 p. + 2 app.

Austin, H.M., A.D. Estes and D.M. Seaver. 2002. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2001. Virginia Institute of Marine Science, Gloucester Point, VA. 33 p.

Austin, H.M., A.D. Estes, D.M. Seaver and A.H. Hewitt. 2004. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2003. Virginia Institute of Marine Science, Gloucester Point, VA. 33 p.

Colvocoresses, J. A. 1984. Striped bass research, Virginia. Part I: Juvenile striped bass seining program. Annual Report 1987-88. Virginia Institute of Marine Science, Gloucester Point, Virginia. 64 p.

Colvocoresses, J. A. 1987. Intercalibration and refinement of estimates of abundance of Chesapeake Bay juvenile striped bass. NOAA Tech. Rept. TRS-SAC-91-010, 28 p.

Colvocoresses, J.A. and H.M. Austin. 1987. Development of an index of juvenile striped bass abundance for the Chesapeake Bay System: I. An evaluation of present measures and recommendations for future studies. Special Science Report 120. Virginia Institute of Marine Science, Gloucester Point, VA. 108 p.

Durell, E.Q., and C. Weedon. 2009. Striped bass seine survey juvenile index web page. http://www.dnr.state.md.us/fisheries/juvindex/index.html. Maryland Department of Natural Resources, Fisheries Service. Site accessed March 2010.

Gauthier, D. T., R. J. Latour, D. M. Heisey, C. F. Bonzek, J. Gartland, E. J. Burge, and W. K. Vogelbein. 2008. Mycobacteriosis-associated mortality in wild striped bass (*Morone saxatilis*) from Chesapeake Bay, USA. Ecological Applications 18: 1718 - 1727.

Hewitt, A. H., J.K. Ellis and M.C. Fabrizio. 2007. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2006. Virginia Institute of Marine Science, Gloucester Point, VA. 31 p.

Hewitt, A. H., L. S. Machut and M.C. Fabrizio. 2008. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2007. Virginia Institute of Marine Science, Gloucester Point, VA. 28 p.

Machut, L. S., and M.C. Fabrizio. 2009. Estimation of juvenile striped bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2008. Virginia Institute of Marine Science, Gloucester Point, VA. 34 p.

NCDC (National Climate Data Center). 2010. http://www.ncdc.noaa.gov/oa/ncdc.html. Site accessed March 2010.

Rago, P., D. Stephan, and H. Austin. 1995. ASMFC Special Report 48. Report of the juvenile indices abundance workshop, January 1992, Kent Island, MD. 83 p.

Sokal, R.R. and F.J Rohlf. 1981. Biometry. W.H. Freeman and Co., San Francisco, CA. 851 p.

Watkins, B, J. Olney, and R. O'Reilly. 2009. A summary of Virginia's American shad fisheries in 2008 and results of monitoring and restoration programs: annual compliance report to the Atlantic States Marine Fisheries Commission American Shad Technical Committee, Virginia Institute of Marine Sciences, Gloucester Point, VA.43 pp.

Wilhite, M. L., K. L. Maki, J. M. Hoenig, and J. E. Olney. 2003. Towards validation of a juvenile index of abundance for American shad in the York River, Virginia. Pages 285 - 294 *in* K. E. Limburg and J. A. Waldman (eds.) Biodiversity Status and Conservation of the World's Shads. American Fisheries Society Symposium 35, Bethesda, MD.

Wood, R.J. 2000. Synoptic scale climatic forcing of multispecies fish recruitment patterns in Chesapeake Bay. Ph.D. Dissertation. College of William and Mary, Williamsburg, VA.

Woodward, J. R. 2009. Investigating the relationships between recruitment indices and estimates of adult abundance for striped bass, weakfish, and Atlantic croaker. Masters thesis. College of William and Mary, Williamsburg, VA.

VMRC (Virginia Marine Resources Commission). 2009. Atlantic menhaden compliance report for Virginia: Report to the Atlantic States Marine Fisheries Commission. Fisheries Management Division, Newport News, VA. 14 pp.

Table 1. Catch of young-of-year striped bass per seine haul in 2009. Two hauls were made per sampling round at each of the index stations (bold). Rounds 1 and 2 were completed in July, while Rounds 3 and 4 were completed in August, and Round 5 in September.

Drainage																Round
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Total
	Round	1	0	6	17/6	29/25	25	7/18	89/0	7/26	18	2/4	9	2	0	290
		2	0	2	2/3	16/4	52	11/18	57/12	28/51	37	5/3	0	2	0	303
		3	0	10	1/22	15/11	24	13/9	14/2	22/22	3	8/0	6	5	0	187
		4	0	11	7/2	6/9	28	7/17	10/1	11/16	2	0/0	3	10	0	140
		5	0	1	5/4	8/4	3	0/0	3/1	9/5	3	1/0	1	3	1	52
															James Total	972
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	0	0	0	6	4/4	19/6	14/1	0						54
		2	0	1	1	1	0/1	6/1	17/2	ns						30
		3	0	0	0	6	1/2	6/0	5/7	ns						27
		4	0	0	0	0	1/2	3/0	5/5	ns						16
		5	0	0	1	0	2/0	1/0	0/2	0						6
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				3/1	11	57/3	6/15	4/20	0					120
		2				4/2	7	5/0	2/9	8/9	0					46
		3				2/1	7	1/0	7/4	2/6	0					30
		4				0/0	1	0/0	3/0	3/4	ns					11
		5				0/2	ns	3/1	2/3	14/8	ns					33
															York Total	373
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75		
	Round	1	5	0	2/2	5/1	8	4/1	21/12	32/24	7	2	2	0		128
		2	0	0	3/0	1/0	17	2/1	7/4	58/35	4	4	0	2		138
		3	0	0	6/0	2/3	8	2/2	6/4	48/24	5	1	0	3		114
		4	0	0	0/2	1/0	5	0/1	2/1	20/5	ns	2	1	1		41
		5	0	0	0/2	0/0	0	0/1	1/1	18/5	3	1	0	0		32
															Rappahannock Total	453

ns = no sample

2008 Catch	1798

Table 2. Catch of young-of-year striped bass in the primary nursery areas of Virginia (index stations) summarized by year, where x = total fish, Index = $(\exp(\ln(x+1))-1)\times 2.28$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1967	209	1.07	0.977	4.40	2.82-6.45	53
1968	208	0.93	0.900	3.50	2.35-4.94	66
1969	207	0.78	0.890	2.71	1.80-3.84	77
1970	463	1.31	1.113	6.15	4.27-8.57	78
1971	178	0.75	0.855	2.56	1.72-3.58	81
1972	96	0.38	0.578	1.05	0.71-1.42	118
1973	139	0.51	0.782	1.52	0.94-2.22	87
1980	228	0.74	0.900	2.52	1.68-3.53	89
1981	165	0.52	0.691	1.57	1.10-2.09	116
1982	323	0.78	0.967	2.71	1.85-3.74	106
1983	296	0.91	0.833	3.40	2.53-4.42	102
1984	597	1.09	1.059	4.47	3.22-6.02	106
1985	322	0.72	0.859	2.41	1.78-3.14	142
1986	669	1.12	1.036	4.74	3.62-6.06	144
1987	2191	2.07	1.228	15.74	12.4-19.8	144
1988	1348	1.47	1.127	7.64	6.10-9.45	180
1989	1978	1.78	1.119	11.23	9.15-13.7	180
1990	1249	1.44	1.096	7.34	5.89-9.05	180
1991	667	0.97	0.951	3.76	2.96-4.68	180
1992	1769	1.44	1.247	7.32	5.69-9.28	180
1993	2323	2.19	0.975	18.12	15.4-21.3	180
1994	1510	1.72	1.034	10.48	8.66-12.6	180
1995	926	1.22	1.045	5.45	4.33-6.75	180
1996	3759	2.41	1.227	23.00	18.8-28.1	180
1997	1484	1.63	1.097	9.35	7.59-11.4	180
1998	2084	1.92	1.139	13.25	10.8-16.1	180
1999	442	0.80	0.862	2.80	2.19-3.50	180
2000	2741	2.09	1.240	16.18	13.06-19.92	180
2001	2624	1.98	1.271	14.17	11.33-17.60	180
2002	813	1.01	1.085	3.98	3.05-5.08	180
2003	3406	2.40	1.18	22.89	18.84-27.71	180
2004	1928	1.88	1.04	12.70	10.54-15.22	180
2005	1352	1.61	1.05	9.09	7.45-11.02	180
2006	1408	1.69	1.04	10.10	8.31-12.18	180
2007	1999	1.83	1.18	11.96	9.66-14.70	180
2008	1518	1.50	1.17	7.97	6.33-9.93	180
2009	1408	1.55	1.10	8.42	6.80-10.32	180
Overall (1967-2009)	45027	1.46	1.19	7.54	7.23-7.86	5469

Table 3. Catch of young-of-year striped bass in the primary nursery areas of Virginia (index stations) using only the 1st haul (Rago et al. 1995) summarized by year, where x = total fish, Index $=(\exp(\ln(x+1))-1)\times 2.28$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1967	209	1.07	0.98	4.40	2.82-6.45	53
1968	208	0.93	0.90	3.50	2.35-4.94	66
1969	207	0.78	0.89	2.71	1.8-3.84	77
1970	463	1.31	1.11	6.15	4.27-8.57	78
1971	178	0.75	0.86	2.56	1.72-3.58	81
1972	96	0.38	0.58	1.05	0.71-1.42	118
1973	139	0.51	0.78	1.52	0.94-2.22	87
1980	216	0.82	0.96	2.90	1.85-4.21	72
1981	112	0.64	0.74	2.05	1.28-2.99	58
1982	172	0.86	0.96	3.10	1.86-4.71	54
1983	185	0.99	0.94	3.86	2.44-5.71	51
1984	377	1.27	1.09	5.81	3.72-8.63	53
1985	216	0.94	0.92	3.54	2.4-4.97	71
1986	449	1.35	1.07	6.53	4.56-9.06	72
1987	1314	2.27	1.22	19.77	14.25-27.13	72
1988	820	1.57	1.21	8.66	6.2-11.85	90
1989	1427	2.06	1.18	15.68	11.71-20.77	90
1990	720	1.58	1.12	8.76	6.44-11.7	90
1991	462	1.17	1.05	5.04	3.59-6.85	90
1992	1143	1.65	1.31	9.63	6.76-13.41	90
1993	1241	2.34	0.89	21.36	17.31-26.25	90
1994	969	1.93	1.09	13.37	10.17-17.4	90
1995	559	1.37	1.07	6.71	4.89-8.99	90
1996	2326	2.60	1.27	28.29	21.11-37.69	90
1997	931	1.83	1.14	11.92	8.9-15.76	90
1998	1365	2.12	1.22	16.66	12.35-22.23	90
1999	274	0.92	0.91	3.43	2.43-4.64	90
2000	1528	2.22	1.23	18.70	13.91-24.9	90
2001	1671	2.16	1.32	17.52	12.7-23.89	90
2002	486	1.17	1.13	5.03	3.48-7.01	90
2003	2042	2.50	1.26	25.61	19.09-34.13	90
2004	1129	2.07	1.04	15.75	12.19-20.19	90
2005	835	1.79	1.07	11.42	8.64-14.9	90
2006	767	1.76	1.06	11.02	8.34-14.36	90
2007	1271	2.09	1.21	16.07	11.95-21.39	90
2008	867	1.70	1.11	10.15	7.56-13.42	90
2009	861	1.72	1.11	10.47	7.81-13.83	90
Overall (1967-2009)	28235	1.53	1.23	8.21	7.76-8.69	3043
Overall (1990-2009)	21447	1.83	1.21	11.98	11.19-12.82	1800

Table 4. Catch of young-of-year striped bass per seine haul in the primary nursery area in 2009 summarized by drainage and river.

Drainage / River	2009 Total Fish	2009 Scaled Mean	2009 C.I. (±2 SE)	2009 N (hauls)	All Years Combined (1967-2009) Total Fish	All Years Combined (1967-2009) Scaled Mean	All Years Combined (1967-2009) C.I. (±2 SE)	All Years Combined (1967-2009) N (hauls)
JAMES	705	14.50	10.31 - 20.09	60	18219	9.91	9.25 - 10.62	1818
James	416	14.27	9.66 - 20.67	40	11026	9.25	8.50 - 10.05	1220
Chickahominy	289	14.97	7.43 - 28.36	20	7193	11.40	10.08 - 12.85	598
YORK	331	5.92	4.30 - 7.94	70	12784	5.74	5.37 - 6.14	2082
Pamunkey	117	5.33	3.24 - 8.21	30	6529	6.66	5.99 - 7.39	886
Mattaponi	214	6.40	4.13 - 9.47	40	6255	5.13	4.70 - 5.58	1196
RAPPAHANNOCK	372	6.76	4.24 - 10.26	50	14024	7.72	7.10 - 8.37	1569
OVERALL	1408	8.42	6.80 - 10.32	180	45027	7.54	7.23 - 7.86	5469

Table 5. Striped bass indices recorded at all survey stations in 2009 compared to historic (1967 – 2009) values with corresponding annual and historic average salinities (Avg. Sal., ppt). The York drainage includes Pamunkey and Mattaponi rivers. Index stations are indicated by bold font.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
	1967-2009	Avg. Sal.	14.4	7.7	4.9	2.5	1.5	1.4	1.2	0.5	0.3	0.2	0.2	0.1	0.2
		Index	2.2	14.9	7.3	12.9	11.1	15.3	7.6	19.3	14.9	5.7	8.1	6.1	0.7
	2009	Avg. Sal.	16.8	9.5	6.5	3.4	1.4	1.7	1.5	0.6	0.2	0.1	0.2	0.2	0.2
		Index	0.0	10.5	11.4	23.9	45.4	15.2	14.7	36.7	16.2	3.2	5.8	8.5	0.3
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1967-2009	Avg. Sal.	16.6	13.6	10.8	4.2	1.7	0.7	0.4	0.3					
		Index	1.0	1.6	4.6	9.6	3.7	8.9	11.9	5.0					
	2009	Avg. Sal.	18.2	15.3	12.5	5.8	2.6	0.8	0.3	0.2					
		Index	0.0	0.3	0.7	3.4	3.1	5.0	9.0	0.0					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2009	Avg. Sal.				4.5	2.3	1.2	0.5	0.3	0.1				
		Index				5.8	7.6	6.3	4.6	4.4	1.2				
	2009	Avg. Sal.				6.1	2.1	1.1	0.3	0.2	0.0				
		Index				2.6	12.0	3.9	8.7	14.7	0.0				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	1967-2009	Avg. Sal.	14.2	12.9	10.1	5.4	3.1	1.9	0.8	0.5	0.2	0.2	0.1	0.1	
		Index	0.6	0.8	2.5	3.4	5.0	8.3	11.5	39.6	6.2	4.3	3.0	1.0	
	2009	Avg. Sal.	15.7	13.8	9.9	5.8	3.0	1.7	0.7	0.3	0.1	0.1	0.1	0.1	
		Index	1.0	0.0	2.7	2.0	11.7	2.6	9.1	48.6	10.4	4.2	1.0	2.0	

*= new station in 2006

Table 6. Catch of young-of-year striped bass in the primary nursery areas of Virginia in 2009 summarized by sampling round and month.

	2009					All Years Combined (1967-2009)				
Month (Round)	N (hauls)	Total Fish	Scaled Mean	C.I. (± 2 SE)	Decrease From Previous Round	N (hauls)	Total Fish	Scaled Mean	C.I. (± 2 SE)	Decrease From Previous Round
July (1st)	36	491	17.03	11.24 - 25.30		1142	13863	11.47	10.49 - 12.52	
(2nd)	36	387	11.37	7.00 - 17.79	21.2%	1153	10830	8.67	7.91 - 9.48	21.9%
Aug. (3rd)	36	280	9.93	6.42 - 14.88	27.6%	1145	8015	6.96	6.37 - 7.60	26.0%
(4th)	36	144	4.85	2.86 - 7.61	48.6%	1009	7179	6.52	5.91 - 7.18	10.4%
Sept. (5th)	36	106	3.82	2.30 - 5.86	26.4%	883	4935	5.63	5.08 - 6.22	31.3%

Table 7. Water temperature (^{o}C) recorded at seine survey stations in 2009. The York drainage includes the Pamunkey and Mattaponi rivers. Index stations are indicated by bold font. Red colors denote temperatures over 30^{o}C; blue colors denote temperatures below 25^{o}C.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
	Round	1	27.9	27.7	28.3	25.7	27.3	26.9	27.2	28.5	26.9	26.3	28.2	29.4	28.4
		2	31.2	30.0	29.7	26.6	28.9	28.1	27.8	28.5	26.9	26.6	27.9	29.2	28.6
		3	29.6	29.1	29.8	26.1	28.4	27.8	28.0	28.8	28.6	27.7	29.4	31.7	30.3
		4	30.7	30.4	30.7	27.2	29.2	28.9	28.6	29.9	28.9	28.6	29.7	31.3	30.5
		5	23.1	21.0	25.5	25.0	24.3	24.6	24.5	25.1	25.8	23.9	24.0	26.7	26.7
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	26.2	25.6	25.0	26.3	26.6	27.5	27.2	27.6					
		2	28.1	27.3	27.0	28.1	28.4	28.8	29.2	30.3					
		3	27.7	28.4	27.1	28.7	29.5	29.8	30.1	30.8					
		4	27.8	28.1	27.3	28.5	28.6	30.0	29.5	29.4					
		5	21.1	21.6	23.0	24.1	24.2	24.9	24.7	26.2					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				26.8	26.9	27.0	27.4	28.0	30.0				
		2				27.8	28.2	27.4	28.9	30.3	32.4				
		3				29.0	29.2	28.9	29.7	30.6	32.5				
		4				28.9	29.0	28.6	29.3	30.6	ns				
		5				24.2	ns	24.4	24.0	24.2	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	Round	1	29.2	27.8	24.7	25.2	27.1	27.9	25.9	27.4	26.4	27.0	27.5	27.7	
		2	29.5	27.9	26.7	26.5	27.6	30.1	26.8	27.3	27.2	27.6	28.4	28.9	
		3	29.5	29.2	27.9	27.6	27.7	28.1	28.5	29.4	29.4	32.4	31.1	31.6	
		4	30.2	29.9	26.8	27.7	30.4	30.1	29.2	29.9	ns	28.6	30.4	30.5	
		5	25.5	24.2	22.1	23.5	23.7	23.8	26.1	25.9	26.0	24.6	26.8	27.5	

ns = no sample taken, *= new station in 2006

Table 8. Salinity (ppt) recorded at seine survey stations in 2009. The York drainage includes the Pamunkey and Mattaponi rivers. Index stations are indicated by bold font.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
	Round	1	15.5	6.8	4.1	1.2	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
		2	16.4	7.2	5.3	2.0	1.1	0.9	0.7	0.2	0.1	0.1	0.1	0.1	0.2
		3	16.9	9.4	5.4	2.3	0.9	1.1	1.0	0.3	0.1	0.1	0.1	0.2	0.2
		4	17.9	10.4	7.0	4.4	2.0	2.8	2.4	0.7	0.3	0.2	0.2	0.2	0.2
		5	17.2	13.5	10.7	6.9	2.6	3.6	3.2	1.6	0.5	0.2	0.3	0.2	0.1
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	16.7	13.1	11.0	3.6	0.8	0.1	0.1	0.1					
		2	16.3	13.7	11.2	5.3	2.0	0.4	0.2	0.1					
		3	19.4	16.0	12.3	4.3	1.8	0.5	0.2	0.2					
		4	19.1	15.9	13.3	7.0	3.5	1.2	0.5	0.2					
		5	19.6	17.7	14.8	8.9	5.0	2.0	0.7	0.5					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				5.2	1.4	0.2	0.1	0.1	0.0				
		2				5.3	2.2	1.2	0.2	0.1	0.0				
		3				5.6	2.5	1.2	0.3	0.2	0.1				
		4				4.9	2.2	1.1	0.2	0.2	ns				
		5				9.5	ns	1.8	0.5	0.3	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	Round	1	13.8	12.5	10.6	5.8	2.0	0.6	0.1	0.1	0.1	0.1	0.1	0.1	
		2	15.4	13.9	11.2	5.8	3.3	1.6	0.4	0.1	0.1	0.1	0.1	0.1	
		3	16.4	13.9	5.3	5.3	2.4	1.7	0.4	0.3	0.1	0.1	0.1	0.1	
		4	16.2	14.7	11.3	4.7	3.7	2.2	1.0	0.5	ns	0.1	0.1	0.1	
		5	16.5	13.9	11.3	7.2	3.8	2.5	1.5	0.7	0.2	0.1	0.1	0.1	

ns = no sample taken; *new station in 2006

Table 9. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2009. The York drainage includes the Pamunkey and Mattaponi rivers. Shaded values are more than one standard deviation (SD) less than the mean dissolved oxygen concentrations recorded at that station from 1989 to 2009. Index stations are indicated by bold font.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
	Round	1	6.9	6.9	7.9	5.7	8.1	6.7	6.2	7.1	5.6	7.4	10.0	5.4	5.6
		2	8.6	6.8	7.0	6.6	7.4	6.8	6.2	4.7	4.0	5.0	7.6	6.0	4.9
		3	6.0	5.7	6.8	5.5	8.1	6.9	5.7	5.0	4.7	5.0	8.9	6.3	5.6
		4	8.3	6.5	7.7	5.4	6.5	6.4	5.5	5.8	5.2	6.1	8.2	5.3	5.5
		5	6.3	7.3	5.9	5.6	7.0	5.9	5.8	5.5	5.4	6.8	7.7	5.7	5.2
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	6.1	6.2	4.7	4.4	5.3	6.2	4.9	6.6					
		2	6.1	5.6	4.7	4.4	5.3	5.2	5.0	5.3					
		3	4.2	4.6	4.7	4.5	5.4	5.7	5.5	5.9					
		4	5.7	4.9	5.0	4.6	4.3	6.0	5.0	6.0					
		5	6.3	5.6	5.1	4.6	4.9	5.3	5.4	8.6					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				4.4	4.1	4.1	4.5	4.8	6.2				
		2				3.2	4.2	3.9	4.4	5.3	6.4				
		3				3.4	4.0	4.1	4.7	5.0	6.2				
		4				3.9	4.5	3.5	4.1	5.3	ns				
		5				3.9	ns	4.3	5.5	5.5	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	Round	1	8.0	6.8	6.5	10.8	6.9	7.3	6.8	7.6	5.8	5.9	6.3	5.0	
		2	6.9	5.5	5.7	4.7	6.0	6.4	4.5	5.4	4.5	7.2	7.6	6.7	
		3	6.3	5.6	10.5	4.4	5.5	7.2	6.3	6.4	5.8	5.8	6.6	7.1	
		4	7.2	6.8	5.8	7.0	6.7	7.4	6.0	6.4	ns	5.4	5.4	5.6	
		5	6.8	6.8	6.1	5.1	6.3	6.3	5.8	6.6	5.1	6.5	6.2	5.8	

ns = no sample taken, *= new station in 2006

Table 10. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2009 summarized by water temperature.

	2009				All Years Combined (1967-2009)			
Temp. (°C)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)
15.0 - 19.9	N/A			0	79	2.85	1.40 - 4.86	30
20.0 - 24.9	51	2.41	1.32 - 3.83	29	2612	3.56	3.14 - 4.02	690
25.0 - 29.9	1297	10.81	8.52 - 13.58	135	34825	8.50	8.10 - 8.92	3888
30.0 - 34.9	60	6.44	3.77 - 10.28	16	7121	8.74	7.82 - 9.74	763
Overall	1408	8.42	6.80 - 10.32	180	45027	7.54	7.23 - 7.86	5470

Table 11. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2009 summarized by salinity.

	2009				All Years Combined (1967-2009)			
Salinity (ppt)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)	Total Fish	Scaled Mean	C.I. (± 2 SE)	N (sites)
0.0 - 4.9	1304	10.03	7.89 - 12.61	142	41639	8.66	8.28 - 9.05	4543
5.0 - 9.9	84	4.30	2.63 - 6.55	28	3010	4.32	3.82 - 4.85	677
10.0 - 14.9	20	3.43	1.44 - 6.48	10	376	2.07	1.65 - 2.54	221
15.0 - 19.9	N/A			0	2	0.11	0.00 - 0.28	29
Overall	1408	8.42	6.80 - 10.32	180	45027	7.54	7.23 - 7.86	5470

Table 12. Species collected during the 2009 survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Morone americana	white perch	9054
Anchoa mitchilli	bay anchovy	4178
Menidia menidia	Atlantic silverside	3879
Notropis hudsonius	spottail shiner	3530
Dorosoma petenense	threadfin shad	3124
Trinectes maculatus	hogchoker	3013
Micropogonias undulatus	Atlantic croaker	2381
Menidia beryllina	inland silverside	2270
Brevoortia tyrannus	Atlantic menhaden	2200
Dorosoma cepedianum	gizzard shad	1949
Morone saxatilis	striped bass	1798
Fundulus diaphanus	banded killifish	1676
Leiostomus xanthurus	spot	1498
Fundulus majalis	striped killifish	1325
Fundulus heteroclitus	mummichog	1040
Notropis analostanus	satinfin shiner	422
Alosa aestivalis	blueback herring	323
Ictalurus furcatus	blue catfish	267
Menticirrhus saxatilis	northern kingfish	182
Bairdiella chrysoura	silver perch	152
Etheostoma olmstedi	tessellated darter	143
Anchoa hepsetus	striped anchovy	141
Lepomis gibbosus	pumpkinseed	109
Hybognathus regius	eastern silvery minnow	102
Perca flavescens	yellow perch	94
Membras martinica	rough silverside	69
Lepomis macrochirus	bluegill	65
Ictalurus punctatus	channel catfish	51
Cynoscion regalis	weakfish	37
Micropterus salmoides	largemouth bass	37
Anguilla rostrata	American eel	35
Gambusia affinis	mosquitofish	34
Symphurus plagiusa	blackcheek tonguefish	34
Mugil cephalus	striped mullet	32
Alosa pseudoharengus	alewife	27
Enneacanthus gloriosus	bluespotted sunfish	22
Morone saxatilis age 1+	striped bass age 1+	20
Ictalurus catus	white catfish	16
Strongylura marina	Atlantic needlefish	16
Notemigonus crysoleucas	golden shiner	15
Syngnathus fuscus	northern pipefish	15
Menticirrhus americanus	southern kingfish	14

Table 12 (cont'd.)

Scientific Name	Common Name	Total Caught
Alosa sapidissima	American shad	12
Lepomis auritus	redbreast sunfish	10
Pomatomus saltatrix	bluefish	9
Cynoscion nebulosus	spotted seatrout	9
Mugil curema	white mullet	9
Micropterus dolomieui	smallmouth bass	9
Micropterus punctulatus	spotted bass	9
Paralichthys dentatus	summer flounder	7
Gobiosoma bosci	naked goby	7
Lepisosteus osseus	longnose gar	5
Ictalurus nebulosus	brown bullhead	4
Peprilus alepidotus	harvestfish	3
Cyprinus carpio	common carp	3
Gobiesox strumosus	skilletfish	3
Carpiodes cyprinus	quillback	2
Synodus foetens	inshore lizardfish	2
Sphoeroides maculatus	northern puffer	1
Moxostoma macrolepidotum	shorthead redhorse	1
Hippocampus erectus	lined seahorse	1
Elops saurus	ladyfish	1
Paralichthys lethostigma	southern flounder	1
	Total	45497

Table 13. Preliminary catch of spottail shiner from select juvenile striped bass seine survey stations using only the 1st haul (Rago et al. 1995) summarized by year, where x = total fish, Index = $(\exp(\ln(x+1))-1)$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1989	2940	2.63807	1.15228	12.99	10.34-16.25	121
1990	2068	2.12259	1.29601	7.35	5.62-9.54	124
1991	1429	1.87	1.23605	5.49	4.17-7.14	119
1992	2357	2.015	1.3984	6.5	4.83-8.65	123
1993	1713	1.96459	1.26693	6.13	4.65-8.01	118
1994	2498	2.29397	1.33781	8.91	6.77-11.66	120
1995	2216	2.09947	1.35987	7.16	5.37-9.46	120
1996	2280	2.27637	1.26594	8.74	6.72-11.29	119
1997	3605	2.17176	1.52948	7.77	5.67-10.53	125
1998	2092	2.12388	1.32285	7.36	5.53-9.72	114
1999	1252	1.47682	1.29656	3.38	2.48-4.52	126
2000	4882	2.7335	1.42587	14.39	10.92-18.86	125
2001	2848	2.391	1.32817	9.92	7.64-12.82	128
2002	1541	1.29968	1.40332	2.67	1.86-3.7	128
2003	2972	2.4169	1.39978	10.21	7.76-13.34	129
2004	5113	3.24738	1.13139	24.72	19.98-30.54	123
2005	3585	2.6282	1.40333	12.85	9.71-16.91	119
2006	3451	2.47264	1.51421	10.85	7.96-14.68	117
2007	3823	2.58185	1.46999	12.22	9.09-16.33	118
2008	2152	1.96877	1.46292	6.16	4.51-8.31	124
2009	3057	2.21082	1.54228	8.12	5.9-11.06	122
Overall (1989-2009)	57874	2.23585	1.42240	8.35	7.87-8.90	2562

Table 14. Preliminary catch of Atlantic silverside from select juvenile striped bass seine survey stations using only the 1st haul (Rago et al. 1995) summarized by year, where x = total fish, Index $= (\exp(\ln(x+1)) - 1)$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1989	881	1.1051	1.50119	2.02	1.15-3.24	78
1990	1461	1.17127	1.41896	2.23	1.35-3.43	80
1991	2618	2.04904	1.77581	6.76	4.15-10.69	75
1992	5564	2.15905	2.19294	7.66	4.31-13.15	80
1993	2258	1.83756	1.77961	5.28	3.21-8.37	79
1994	2179	1.50913	1.71828	3.52	2.08-5.64	80
1995	2973	2.05617	1.87555	6.82	4.13-10.92	79
1996	4668	1.88795	2.15424	5.61	3.07-9.73	79
1997	1108	1.47831	1.54771	3.39	2.09-5.23	78
1998	2297	2.18908	1.70737	7.93	5.08-12.11	79
1999	6832	3.01594	1.66273	19.41	12.94-28.89	76
2000	3119	2.27328	1.88175	8.71	5.34-13.87	78
2001	3586	2.39064	1.83703	9.92	6.28-15.39	82
2002	5264	3.23784	1.61034	24.48	16.77-35.52	80
2003	3470	1.61637	2.08233	4.03	2.16-7.02	80
2004	1473	1.31635	1.72808	2.73	1.53-4.49	80
2005	2163	2.1748	1.62921	7.8	5.14-11.61	82
2006	2660	2.11936	1.74685	7.33	4.67-11.22	83
2007	2118	2.25324	1.62428	8.52	5.57-12.78	77
2008	3211	1.63278	1.79165	4.12	2.45-6.58	83
2009	2614	2.25054	1.7757	8.49	5.43-13.02	83
Overall (1989-2009)	62517	1.98581	1.84066	6.28	5.66-6.97	1671

Table 15. Preliminary catch of inland silverside from select juvenile striped bass seine survey stations using only the 1st haul (Rago et al. 1995) summarized by year, where x = total fish, Index $= (\exp(\ln(x+1)) - 1)$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1989	471	1.15243	0.9603	2.17	1.63-2.81	107
1990	574	1.08967	1.14123	1.97	1.39-2.7	110
1991	285	0.86355	0.86956	1.37	1.00-1.81	105
1992	326	0.67407	0.9007	0.96	0.65-1.33	110
1993	368	0.76098	0.97236	1.14	0.77-1.59	106
1994	166	0.52888	0.75896	0.7	0.46-0.97	106
1995	104	0.44168	0.61769	0.56	0.38-0.75	107
1996	772	0.82161	1.13019	1.27	0.83-1.83	107
1997	175	0.53677	0.7631	0.71	0.48-0.98	110
1998	204	0.68634	0.80286	0.99	0.7-1.33	104
1999	298	0.72175	0.93048	1.06	0.73-1.45	113
2000	718	1.06247	1.18843	1.89	1.31-2.62	113
2001	626	0.95942	1.15439	1.61	1.1-2.24	115
2002	447	0.7813	1.0447	1.18	0.8-1.66	114
2003	545	1.21473	0.98658	2.37	1.8-3.06	113
2004	753	1.23417	1.17461	2.44	1.75-3.29	113
2005	368	0.92792	0.94336	1.53	1.11-2.03	110
2006	1161	1.31615	1.32256	2.73	1.9-3.79	112
2007	807	1.05754	1.20408	1.88	1.29-2.62	111
2008	658	1.14575	1.10641	2.14	1.56-2.87	114
2009	1690	1.87628	1.28929	5.53	4.13-7.31	114
Overall (1989-2009)	11516	0.95049	1.07698	1.59	1.47-1.71	2314

Table 16. Preliminary catch of banded killifish from select juvenile striped bass seine survey stations using only the 1st haul (Rago et al. 1995) summarized by year, where x = total fish, Index $= (\exp(\ln(x+1)) - 1)$, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean 1n (x+1)	SD	Index	C.I. (± 2 SE)	N (hauls)
1989	223	0.54	0.83	0.72	0.46-1.03	102
1990	213	0.62	0.85	0.86	0.57-1.20	105
1991	217	0.54	0.89	0.71	0.43-1.04	101
1992	110	0.39	0.68	0.48	0.29-0.69	104
1993	230	0.57	0.92	0.77	0.47-1.13	100
1994	163	0.48	0.78	0.61	0.38-0.89	101
1995	233	0.60	0.94	0.82	0.51-1.19	102
1996	535	1.06	1.18	1.89	1.29-2.66	101
1997	296	0.82	0.95	1.27	0.88-1.73	105
1998	228	0.83	0.88	1.30	0.92-1.76	93
1999	205	0.61	0.87	0.83	0.54-1.18	101
2000	210	0.67	0.84	0.95	0.65-1.31	101
2001	275	0.88	0.88	1.41	1.03-1.87	104
2002	312	0.70	1.00	1.01	0.65-1.44	104
2003	499	0.92	1.10	1.52	1.03-2.13	104
2004	1287	1.66	1.34	4.28	3.04-5.89	101
2005	701	1.22	1.23	2.39	1.66-3.34	101
2006	498	0.88	1.16	1.42	0.92-2.04	102
2007	686	1.28	1.18	2.58	1.84-3.52	103
2008	995	1.55	1.21	3.71	2.72-4.97	105
2009	1251	1.69	1.33	4.41	3.18-6.00	107
Overall (1989-2009)	9367	0.88381	1.08562	1.42	1.31-1.54	2147

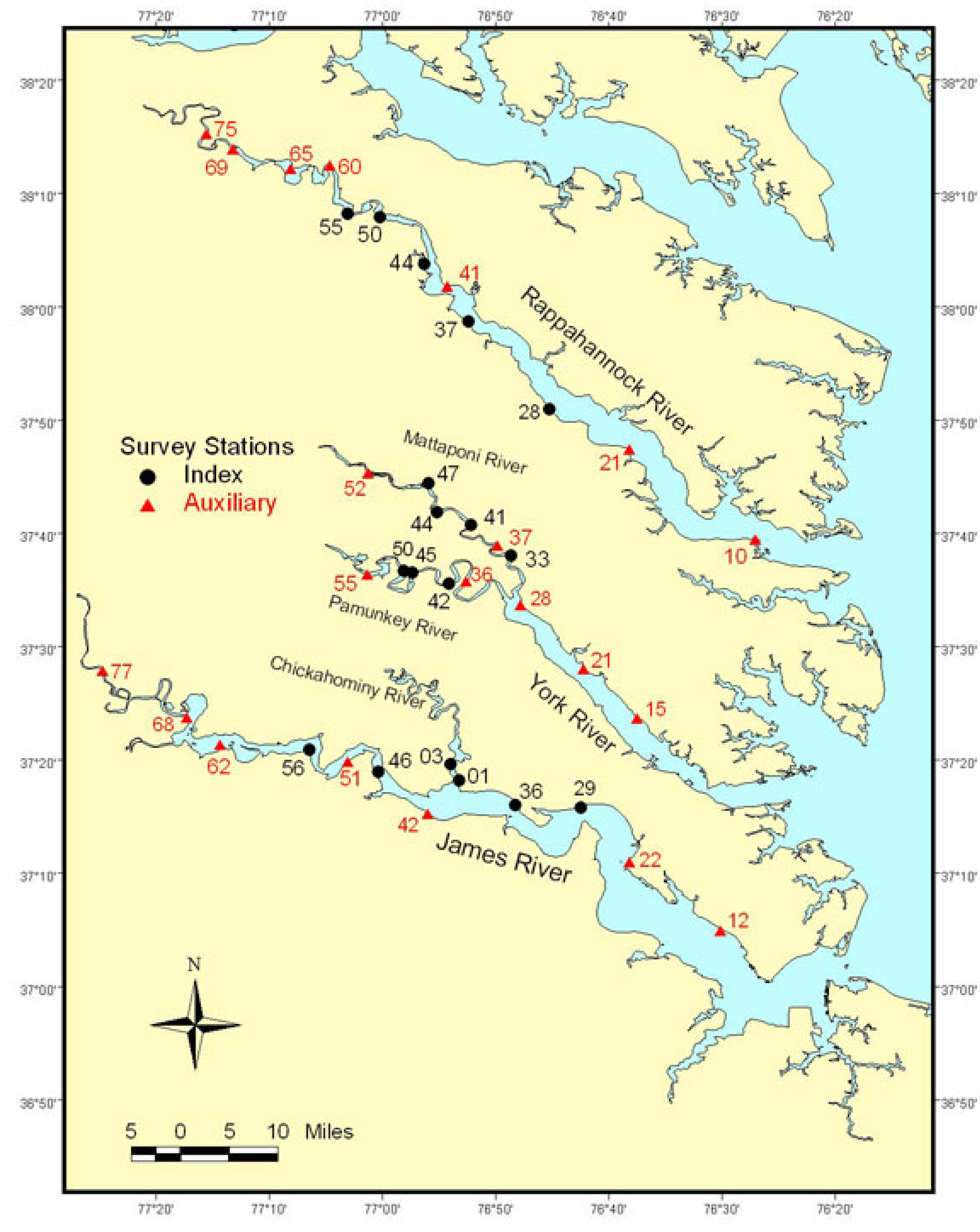


Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designation indicates river mile from mouth. Auxiliary stations R75 (Rappahannock) and J77 (James) are new in 2006, replacing R76 and J74/J78, respectively.

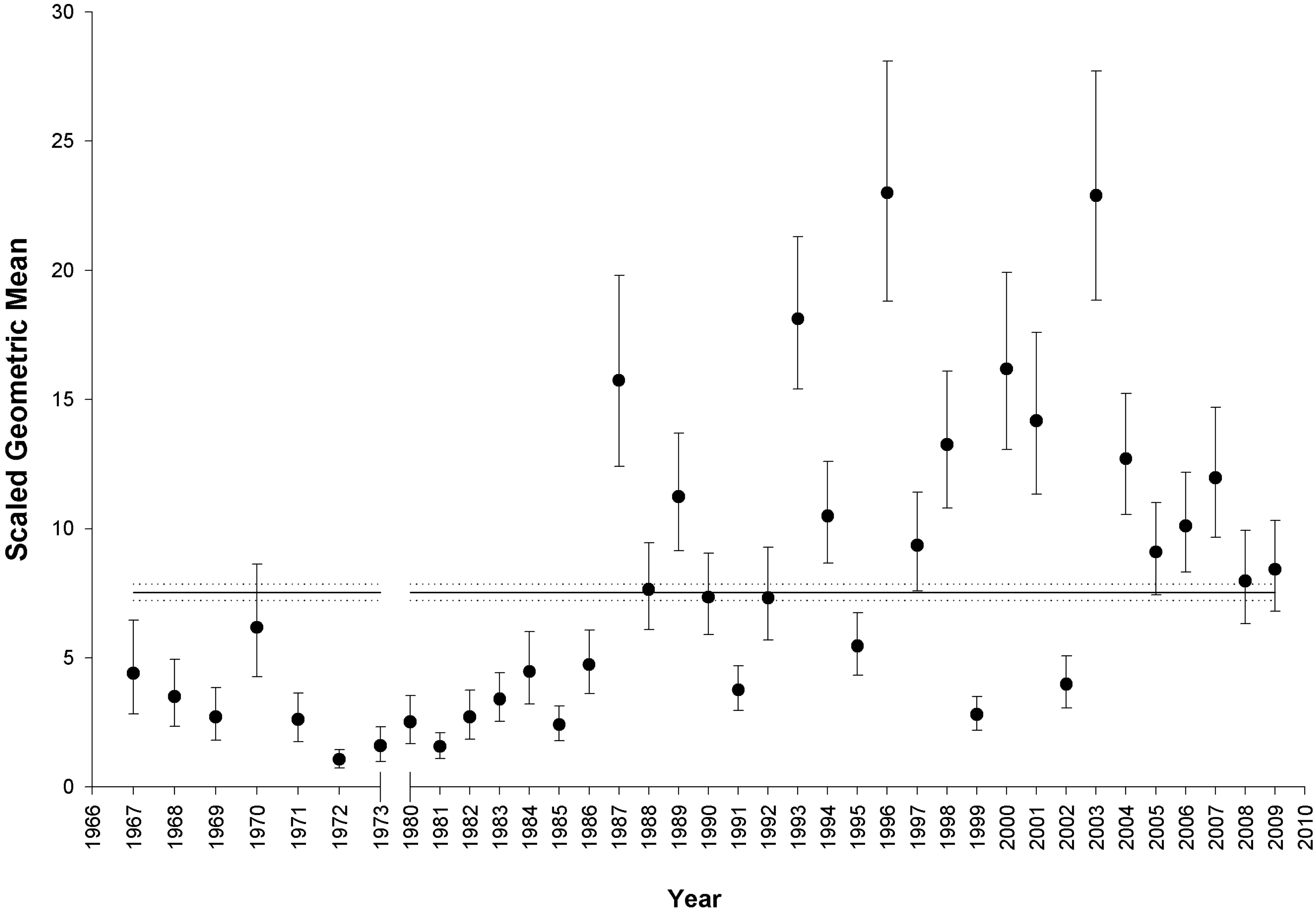


Figure 2. Scaled geometric mean of young-of-the-year striped bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate historical geometric mean (solid) and confidence intervals (dotted) for 1967-2009.

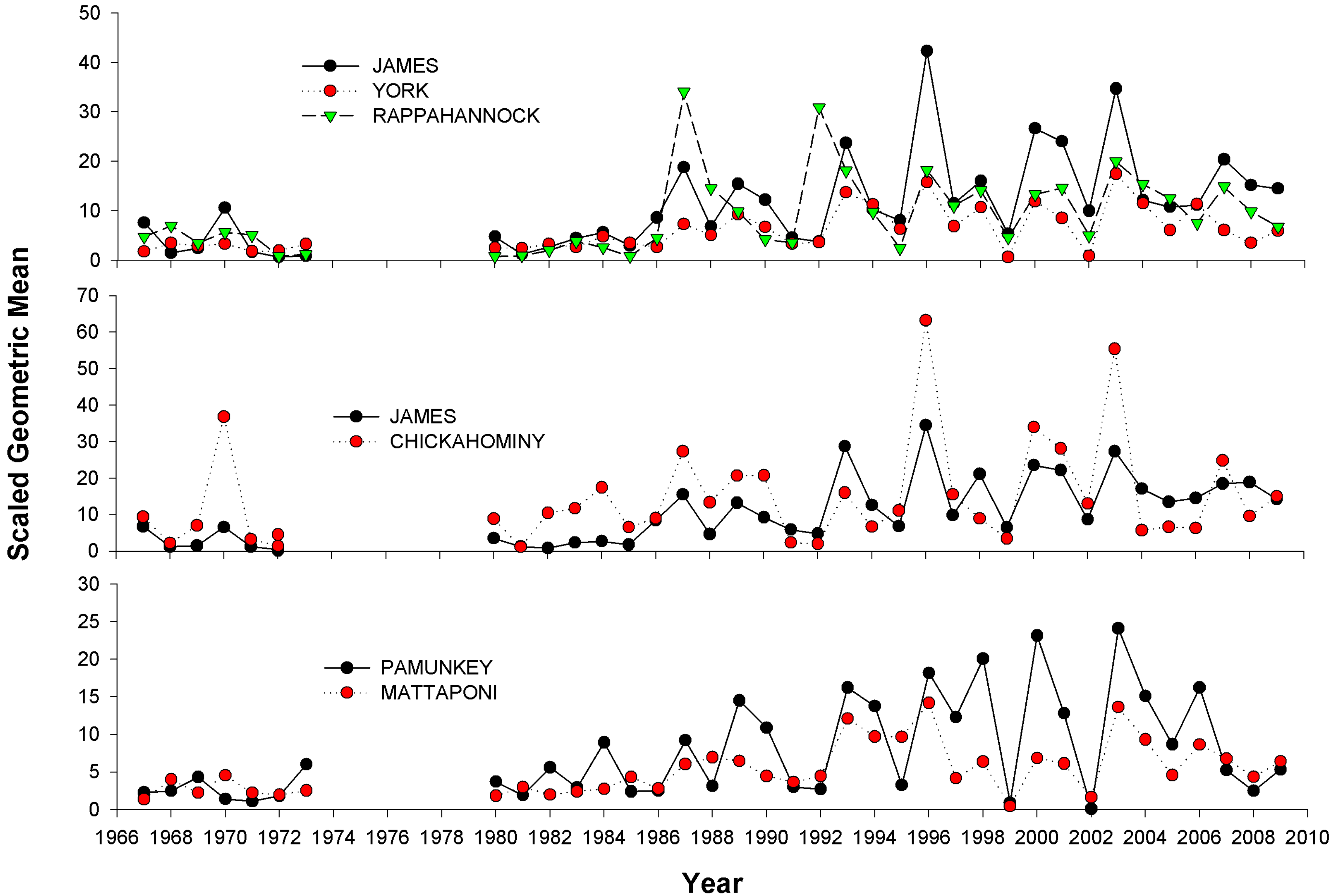


Figure 3. Scaled geometric mean of young-of-the-year striped bass in the primary nursery areas of Virginia (index stations) by drainage and river.

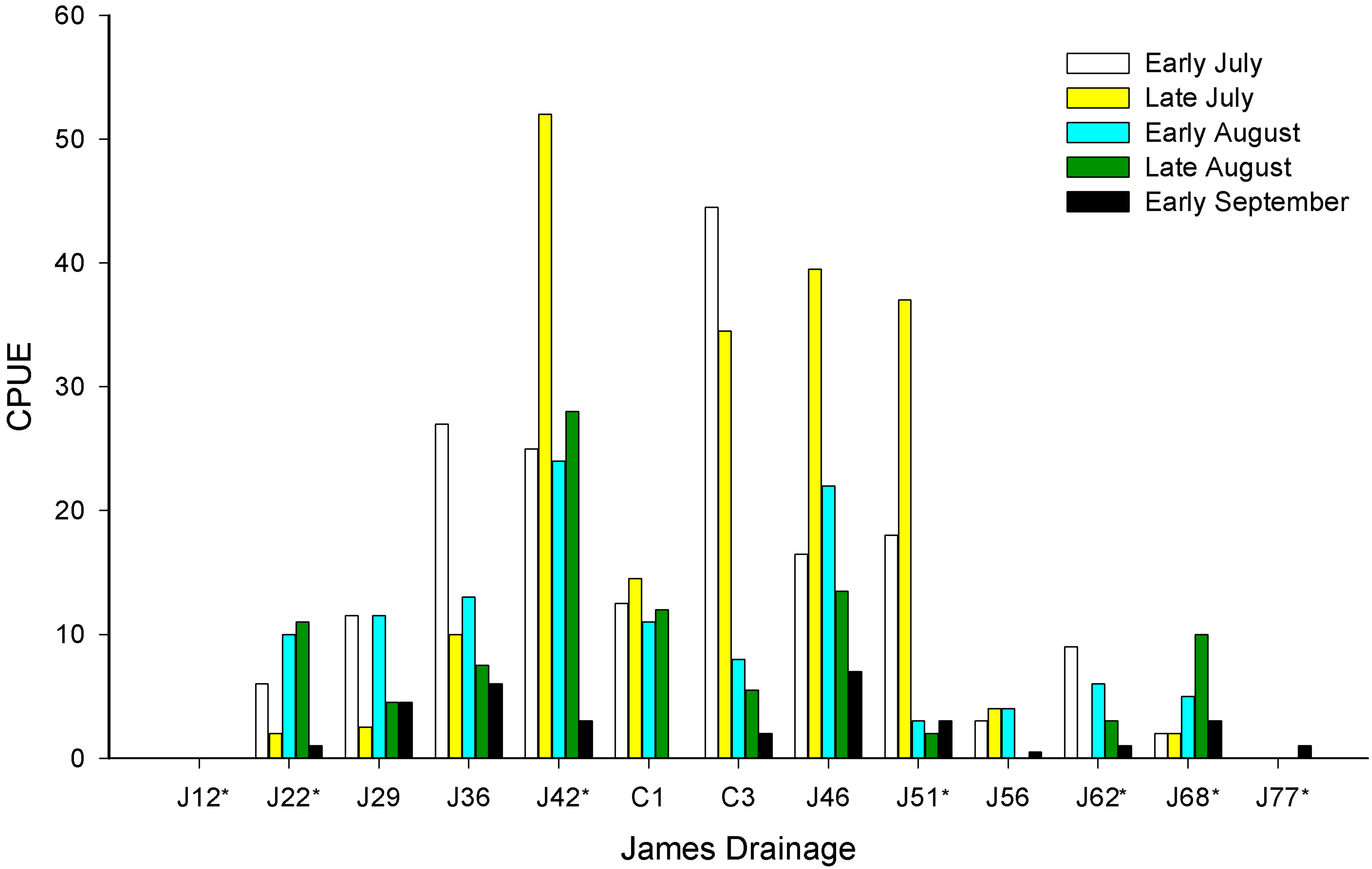


Figure 4. Catch of young-of-year striped bass by station in the James River drainage in 2009. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

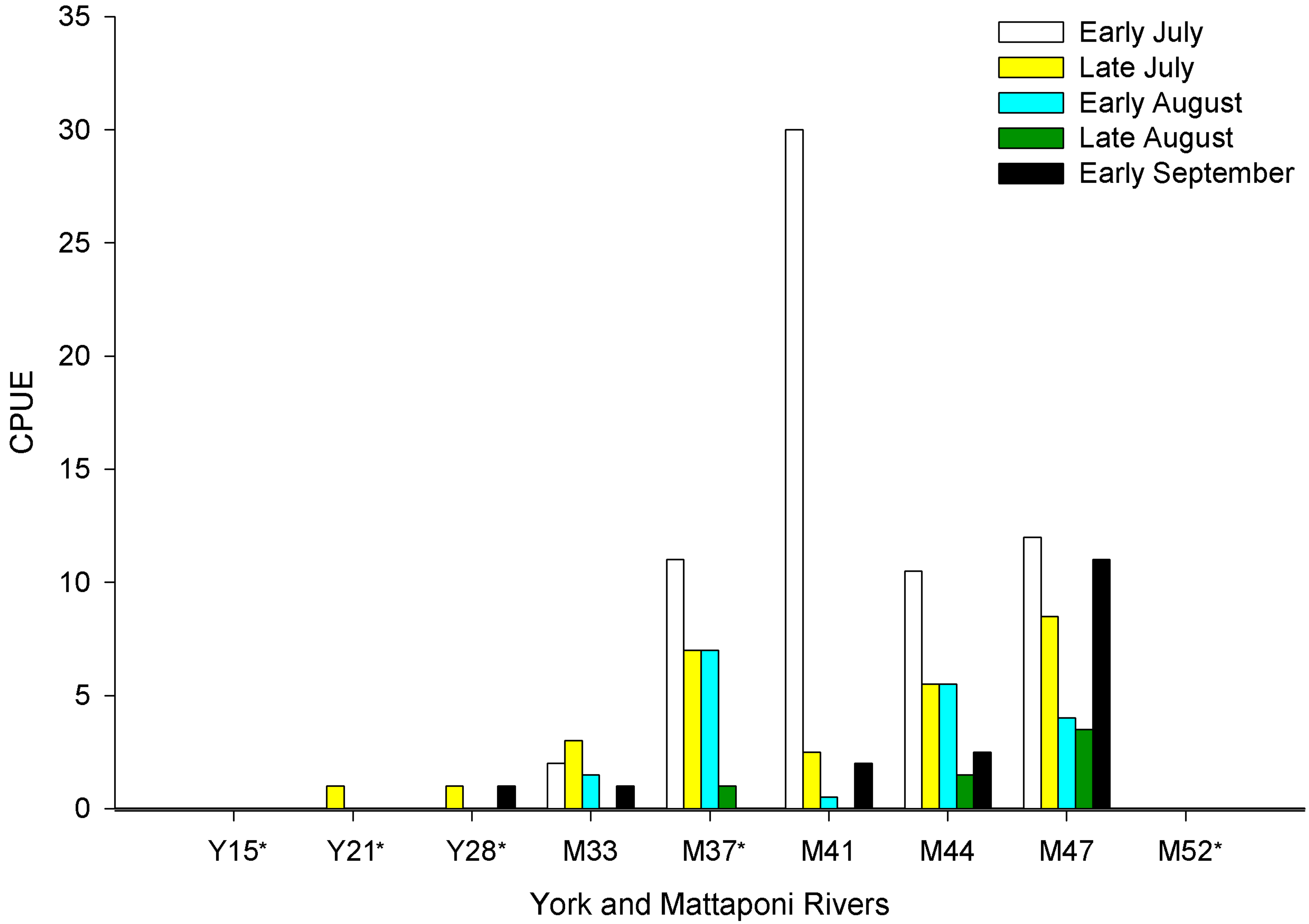


Figure 5. Catch of young-of-year striped bass by station in the York and Mattaponi rivers in 2009. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

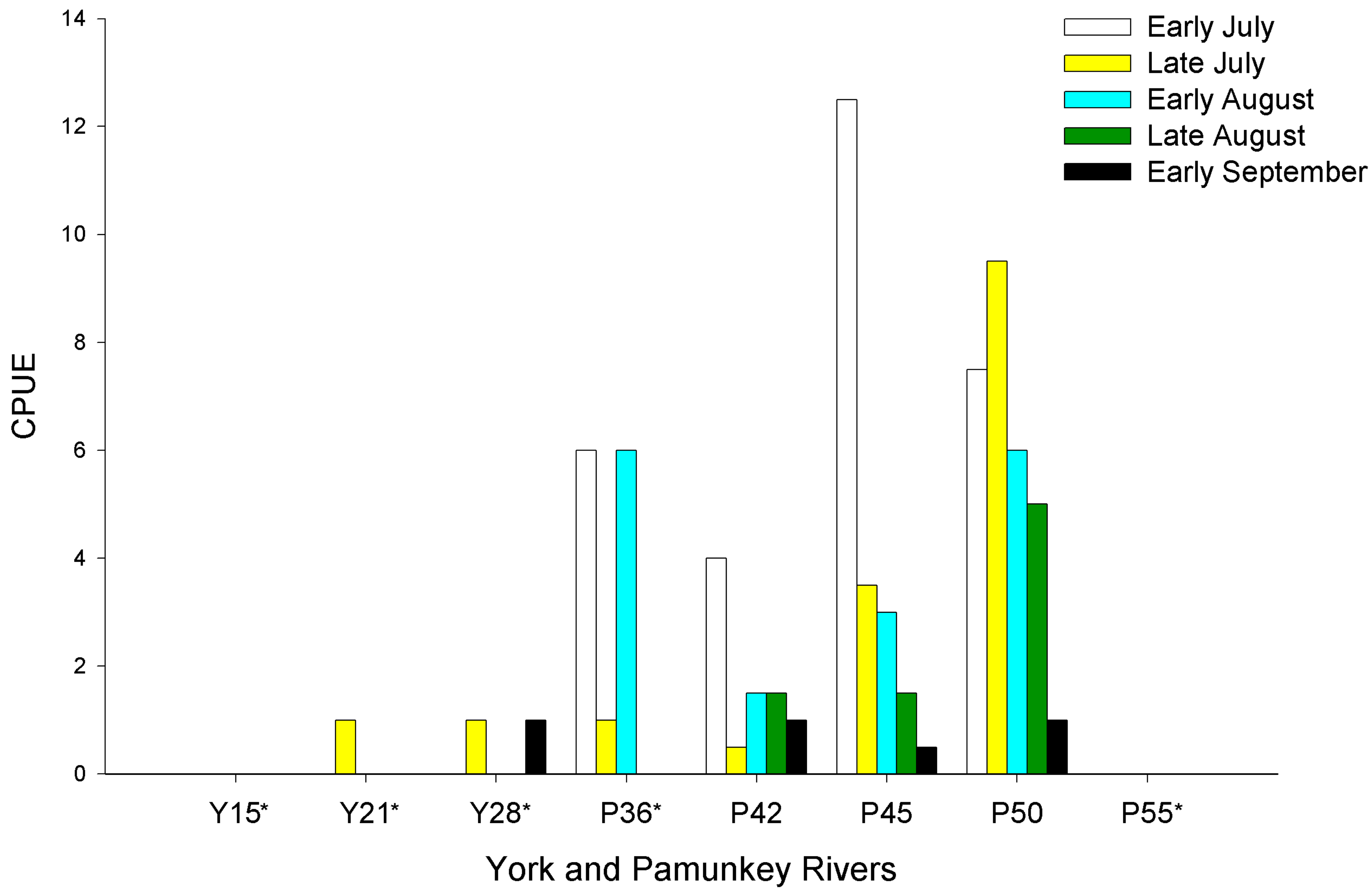


Figure 6. Catch of young-of-year striped bass by station in the York and Pamunkey rivers in 2009. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.

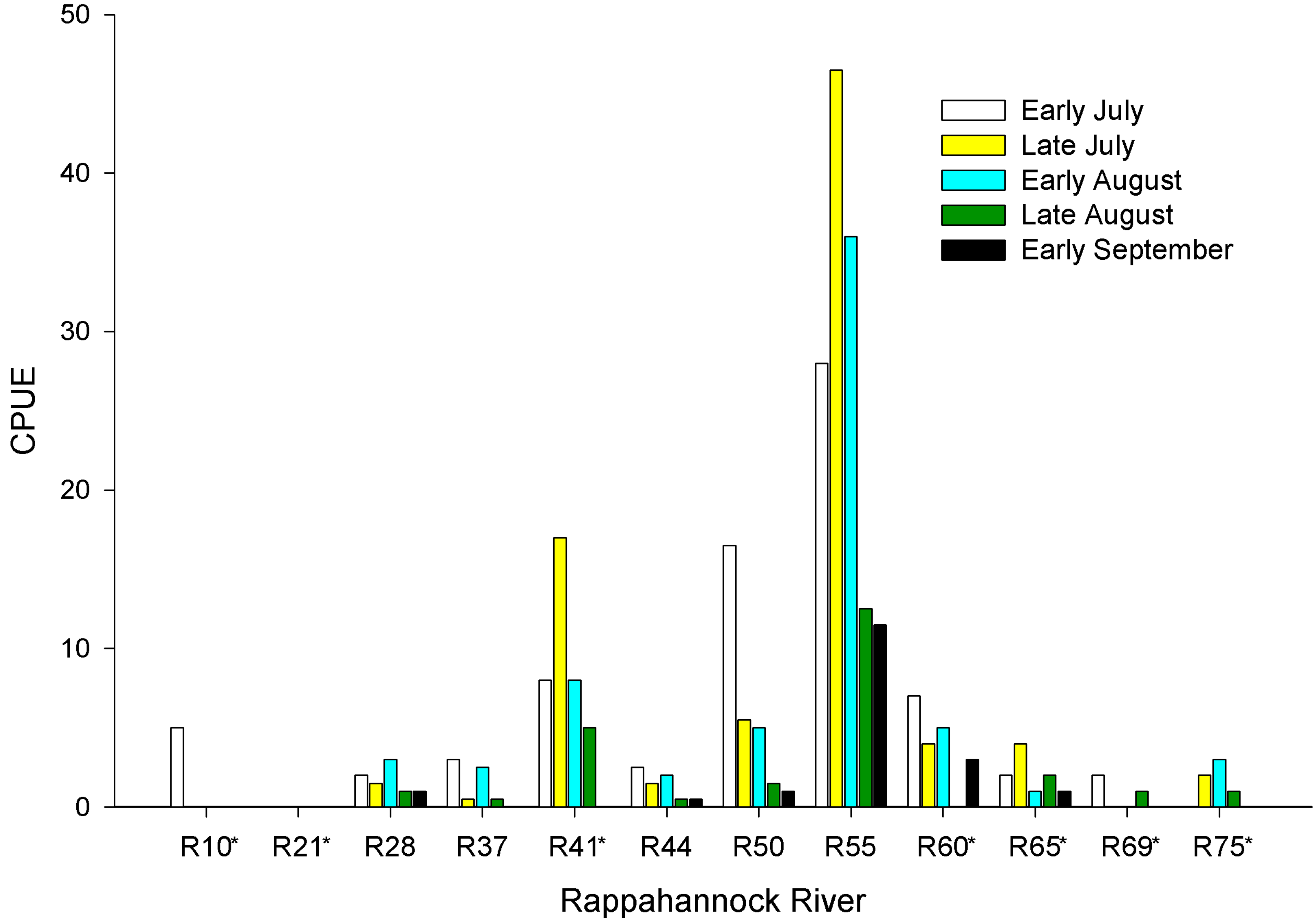


Figure 7. Catch of young-of-year striped bass by station in the Rappahannock River in 2009. Catch at index stations (non-starred) is an average of two hauls. Auxiliary station (starred) catch represents one haul.