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

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Leonard S. Machut
Mary C. Fabrizio

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

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EXECUTIVE SUMMARY

The 2010 striped bass juvenile abundance index is 9.07 and is not significantly different from the historic average of 7.59. Additional methods of calculating the regional index support this conclusion. Although the James and York river catches were numerically higher, and the Rappahannock River catches were lower than historic averages, they were not significantly so. Young-of-year striped bass catches at auxiliary stations provide greater spatial coverage of the nursery grounds and suggest that juvenile striped bass occupied upstream sites in higher abundances during 2010 than in recent years.

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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 2010 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. Declines in commercial harvest mirrored declines in juvenile recruitment (Goodyear 1985). Because the tributaries of 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 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.

In 1967, well before the FMP requirement, Virginia began monitoring the annual recruitment of juvenile striped bass 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 2010 program were to:

1. estimate the relative abundance of the 2010 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 periods from 12 July through 16 September 2010. During each round, seine hauls were conducted at 18 historical 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 approximately 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 placed into water-filled buckets. All striped bass were measured to the nearest mm fork length and a sub-sample of up to 25 individuals was measured to the nearest mm fork length (or total length if appropriate) for all other species. At index stations, fish collected during the first haul were held until the second haul was completed. All captured fish, 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 2010 (Table1). 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 P55 during July and early August (rounds 1, 2 and 3) due to high water levels and limited hydrilla obstruction. As hydrilla beds grew and expanded during the summer, seine hauls could no longer be performed (rounds 4 and 5) at these sites. Although station M52 was sampled during all rounds, hauls were performed within a narrow band of water between shore and dense hydrilla beds which limited haul depths to less than 0.8 m. During late August (round 4), strong, persistent easterly winds increased water levels and reduced the availability of beaches necessary for proper retrieval of the seine at R60 and R65 in the Rappahannock River. During this time, catch efficiencies were likely reduced at other auxiliary sites (e.g., R69) within the Rappahannock River although we are not able to directly quantify changes in efficiency. In the York River, Y21 was not sampled in early July (round 1) due to vessel mechanical problems.

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

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 (i.e. index stations). Catch data from auxiliary stations are not included in the calculation of the annual indices. The index of relative abundance for young-of-year 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 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 – 2010 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 2010, 1,721 young-of-year striped bass were collected from 180 seine hauls at index stations and 723 individuals were collected from 100 hauls at auxiliary stations (Table 1). Using data from both hauls at index stations, the estimated index for 2010 is 9.07 (LCI = 7.14, UCI = 11.40; Table 2), which is not significantly different from the historic index of 7.59 (LCI = 7.28, UCI = 7.90; Figure 2). The "historic index" refers to the mean estimated from catch data for all survey years since 1967. Recruitment failure in tributaries of Virginia, as defined by Addendum II of the FMP (ASMFC 2010), did not occur in 2010.

Even with a 30-minute interlude between sampling at index stations, second hauls are not independent samples and their use violates 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), a result which artificially lowers the geometric mean when data from second hauls are included in the index computation. Using only the first haul at each index station, the annual and historic indices were recalculated. In 2010, 994 young-of-year striped bass were collected resulting in an index estimate of 10.83 (LCI = 7.78, UCI = 14.82, Table 3), which is not significantly different from the recomputed first-haul historic index of 8.28 (LCI = 7.83, UCI = 8.76). 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 2010 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 recruitment during the post-recovery period (1990 – Present) provides additional information on the pattern of striped bass annual recruitment. The 2010 Virginia-wide index of 10.83 (LCI = 7.78, UCI = 14.82) is not significantly different from the mean index for the post-recovery period (index = 11.93; LCI = 11.15, UCI = 12.74) suggesting that 2010 was an average recruitment year.

As a whole, striped bass recruitment success in the Virginia portion of Chesapeake Bay is variable among years and among nursery areas within years. No significant differences were apparent when comparing the 2010 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 to present day). This suggests that striped bass from the Virginia portion of Chesapeake Bay exhibited average recruitment in 2010. 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 2006 and 2007, and average recruitment in 2008 and 2009. Thus, a year of average recruitment is not uncommon. The distribution of juvenile striped bass within the nursery area was similar to previous years with greater numbers of juveniles found in the James River than in the Rappahannock and York River watersheds.

Continued monitoring of regional recruitment success will be an important factor in identifying management strategies to protect the spawning stock of Chesapeake Bay striped bass. Research suggests that a Chesapeake Bay-wide index, computed from Virginia and Maryland data combined, will provide a more robust estimate of young-of-year recruitment strength and may provide a better predictor of subsequent adult striped bass abundance within the Bay (Woodward 2009). This may be particularly appropriate in years when individual state indices provide divergent estimates of year-class strength; patterns which 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 2010 (Table 1). The 2010 index for the James River drainage is 13.92 (LCI = 9.80, UCI = 19.43), which is not significantly different than the historic drainage index of 10.02 (LCI = 9.36, UCI = 10.72; Table 4). Although the annual index is higher than the historic index, there is considerable overlap in confidence intervals of these estimates. Examination of river specific JAI values shows no significant differences either. The 2010 James River main stem (excluding the Chickahominy River) index is 11.39 (LCI = 7.09, UCI = 17.66) compared with the historic index of 9.31 (LCI = 8.57, UCI = 10.10). Similarly, the 2010 Chickahominy River index is 20.45 (LCI = 12.62, UCI = 32.38) compared with the historic index of 11.62 (LCI = 10.31, UCI = 13.07). Catches at Chickahominy River stations were comparable to those made during 2009, greater than those made during 2008, but were less than those observed in 2007 showing annual variability in catches.

Throughout the James River watershed, four of six index sites had average or higher than average index values when compared with their respective historic means, the exceptions being the index stations J29 and J36 in the lower James River (Table 5). Although this may have been the result of a shift in the nursery area (see *Striped Bass Collections from Auxiliary Stations*), the catches observed at J36 may have been impacted by the need to move the sampling location downstream by approximately 50 m due to the construction of a new breakwater (Figure 3). It is unclear how this shift in sampling location, and presumed altered hydrological flows, may impact localized fish distribution in the future and the relationship of current and past catches at this location.

Catches at the Chickahominy River stations were variable throughout the sampling season. Collections at C1 were highest in early July but declined through subsequent weeks (Table 1). This contrasts with catches at C3 which peaked during late July and early August (rounds 2 and 3). Over 60% of all young-of-year striped bass captured from James River index stations was from stations C1 and J46. Although C1 and C3 annually alternate in relative importance, J46 remains the most productive James River index station. In total number of striped bass caught, J46 was the second most productive index site sampled during 2010 in Virginia waters and consistently ranks among the most productive index sites.

Although higher than in recent years, the 2010 JAI value for the York River drainage is 7.49 (LCI = 5.35, UCI = 10.23), which is not significantly different from the historic index of 5.80 (LCI = 5.43, UCI = 6.18), suggesting an average year for this watershed. This represents a potential reversal of the continued index decline observed from 2004 to 2009 (Figure 4). 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 striped bass in the York River during 2010 can be related to increased catches from the Pamunkey River. The 2010 Pamunkey River index of 11.97 (LCI = 8.10, UCI = 17.28) is significantly greater than the historic index of 6.80 (LCI = 6.13, UCI = 7.52) and continues an increasing trend in striped bass recruitment from a low observed in 2008 (Machut and Fabrizio 2009). For the third straight year, the 2010 Mattaponi River index (5.08; LCI = 2.97, UCI = 8.05) is not statistically different from the historic average (5.12; LCI = 4.71, UCI = 5.57) suggesting an average year of recruitment in the Mattaponi River.

Within the York River watershed, catches were concentrated primarily at upper-river sections; 62% of young-of-year striped bass were collected at either P50 or M44. Catch rates in 2010 were roughly similar between stations with peak catches observed in July (Table 1). Only P42 saw an increase in young-of-year striped bass in September. Excluding early July (round 1), fewer young-of-year striped bass were collected at lower index sites (M33 and P42) than at upper index sites in both rivers.

Although the Rappahannock River has the lowest drainage-specific index observed in 2010 (Figure 4), the index of 6.87 (LCI = 3.60, UCI = 11.94) is not statistically different from the historic average of 7.69 (LCI = 7.08, UCI = 8.33). Catches in 2010 were greatest at the two uppermost index sites (R50 and R55; Table 1). Approximately 70% of the total catch in the Rappahannock River drainage in 2010 was collected from R55 alone. Although catches from R50 and R55 have dominated the catches in this drainage for several years, the contrast was more dramatic this year as only 3% of the catches were made from the remaining three downriver index stations.

Although the James River had the highest, and the Rappahannock River the lowest, annual index value, we found that no watershed index is significantly different from its' historic average, a finding consistent with what we reported last year. Another year of average recruitment throughout Virginia waters contrasts with the recently reported lower-than-average recruitment in the Maryland portion of the Chesapeake Bay (Durell and Weedon 2010). The lower than average 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 better 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 change. 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 2010 with increased catches at upriver stations when compared with catches from auxiliary stations in recent years (Figures 5 – 8).

Within the James River, the 2010 nursery area extended farther upstream than in previous years; geometric means at the three upper auxiliary sites were roughly three times higher than historic averages. 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 has proven to be an appropriate alternative because young-of-year striped bass have been detected at this location since 2007 (Hewitt et al. 2008, Machut and Fabrizio 2009). The 2010 catch of 57 young-of-year striped bass represents the largest annual catch in this site's short history. With the exception of 2008, when one striped bass was collected, no young-of-year striped bass have been collected at J12 since 2005 (Table 1).

All stations in the main stem York River are auxiliary. Unlike what we observed in the James River, juvenile striped bass were regularly collected at the lower York River auxiliary sites in 2010. Although not detected at Y15 in 2008 and 2009, juvenile striped bass were captured at this site in 2010; fish had been collected at this location from 2003 – 2007. Young-of-year striped bass were collected during all rounds from Y21, however, only one juvenile striped bass was collected from Y28 in September (rounds 5; Table 1). With the exception of Y28, catches at all auxiliary sites on the main stem of the York River were higher than historic averages (Table 5).

No striped bass were captured in the uppermost Pamunkey River auxiliary site (P55) in 2010. No fish have been captured at this site since 2007. It has been suggested that the lack of striped bass detected at P55 may have been due to the inability to accurately sample in dense hydrilla vegetation (Hewitt et al. 2009, Machut and Fabrizio 2010). During 2010, seine hauls were made during the first three rounds of sampling in limited areas available between the shore and the denser hydrilla beds found farther offshore. No fish were detected during these three hauls, however, given the altered state of habitat at these sites, it remains unclear whether striped bass were present in this general location. Striped bass may be preferentially using the new hydrilla habitat. Alternatively, striped bass may have been present within the upstream portions of these rivers, but may have been forced into deeper waters at P55 by the dense hydrilla beds. Although hydrilla was also present at M52, enough open space was available to deploy and retrieve the seine during all rounds. For the first time since 2007, juvenile striped bass were collected from early July through late August (rounds 1 – 4) at M52. Similar to the James River, this suggests that the striped bass nursery may have occupied sites further upstream in 2010. The continued sampling difficulties at P55, in addition to the catch of striped bass at M52, suggest a need to examine alternative sites or alternative collection methodologies within this region to determine the abundance of juvenile striped bass in the presence of hydrilla.

As in 2007 and 2008 (Hewitt et al. 2008, Machut and Fabrizio 2009), few fish were collected at the lower auxiliary stations in the Rappahannock River; none were detected at R10, and only four fish were captured during July (rounds 1 – 2; Table 1) at R21. Since 1999, few fish have been collected at either site with the exception of 2001 and 2003 (Austin et al. 2002, 2004), years of high recruitment within the Rappahannock River and the entire Virginia portion of Chesapeake Bay. These sites have favorable substrate and no potential seine obstructions which imply 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 in the

Rappahannock River were reasonably productive in 2010. Annual index values were similar to, or greater than, historic averages for 3 of 4 upriver stations (Table 5). Station R75, added in 2006 to replace R76, exhibited the highest catch rates ever recorded: 15 young-of-year striped bass were collected throughout the 2010 sampling season at this site. This further supports the premise that R75 is a suitable auxiliary station for monitoring the upstream limits of juvenile striped bass nursery areas.

Comparisons Between Index and Auxiliary Sites

Whereas the overall increase in catches from upriver index and auxiliary sites generally suggests an upstream shift in the nursery grounds for 2010, direct comparisons between auxiliary and index sites are problematic due to different sampling methods. Figures 5 through 8 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 5 through 8 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 2010, catches were greatest in early July (round 1) when 597 young-of-year striped bass were collected (Table 6). Catches in late July (round 2) decreased by 38%, and catches in early August (round 3) decreased by a further 5% relative to late July. This is consistent with historic trends (Table 6). However, a considerable decrease in catches was observed during late August (round 4; 46%) compared with the historic average (11.9%). Contrary to the historic average, during early September 2010 (round 5), catches increased by 16% relative to late August. 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 by the seine. The increase observed during September 2010 was most likely due to the acute decline in catch during late August since seasonal declines observed in 2010 from July to September were similar to those observed with all years combined.

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 2010 are presented in Tables 7, 8, and 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.

As in previous years, a well defined pattern of high water temperatures during mid-summer which declined as the sampling season progressed was evident (Table 7). Unlike 2007 or 2008 (Hewitt et al. 2008, Machut and Fabrizio 2009) when temperatures were elevated during September (no temperatures below 25.0^{o}C), 2010 temperatures were more similar to those observed in 2005, 2006, and 2009. During September (round

5), 18 of 38 sampled sites (47%) were below 25.0°C. Catch rates in 2010 followed the historic pattern with respect to water temperature: most fish (98%) were captured in waters between 25.0 and 34.9°C (Table 10). The effects of these events on site-specific striped bass abundances cannot 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 2010, as in the past, we observed greater catches of young-of-year striped bass at sites exhibiting lower salinities within the primary nursery area (Table 11). No index station exceeded 12.9 ppt salinity although salinity was as high as 20.3 ppt at auxiliary sites (Table 8). Table 5 shows the relationship between salinity and juvenile striped bass catches. In 2010, the percentage of catch observed in low salinities (0.0 – 4.9 ppt) was the same as that observed historically (93% in 2010 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 2010 vs. 7% all years). Compared to historic averages, salinities in 2010 were on average 1.9 ppt higher at individual stations and our catches reflected this increase. Although juvenile striped bass were captured at downstream auxiliary sites in areas with average salinities up to 19.4 ppt, catches were distinctly lower than those observed in upstream, lower salinity sites. For example, in 2009, only 7 striped bass were captured in the uppermost auxiliary stations of all rivers combined, but 85 striped bass were captured during 2010 in these uppermost auxiliary locations.

No dissolved oxygen (DO) levels measured during the survey in 2010 are considered hypoxic (less than 2-3 mg/L; Table 9). Within the primary nursery area, only 39 samples (21% of 190 measurements) exhibited DO levels that were more than one standard deviation (SD) less than the site's historic average. Lower than average values occurred inconsistently through time and across our sampling sites. Dissolved oxygen measured at the time of sampling does not seem to have a direct effect on detection of fish because DO values more than one SD less than the mean at a given station (shaded values in Table 9) do not necessarily correspond with low catches at that station. For example, although J68 regularly exhibited DO values considered low between late July and September (round 2 -5), striped bass catch rates were extremely high with a mean index value of 33.9 compared with the historic average of 6.7.

Striped bass recruitment variability may be partially explained by climate patterns during the winter and spring preceding our sampling (Wood 2000). Data from the National Climate Data Center (NCDC 2011) indicated that whereas winter (December 2009 through February 2010) precipitation was "much above normal", spring (March through May 2010) was characterized by "near normal" precipitation rates. Summer rainfall (June through August 2010) was "below normal" and salinities were above historic averages during this time (Table 5). Precipitation within the Maryland portion of Chesapeake Bay matched that of Virginia in 2010 (NCDC 2010). Similarly, air temperatures for both states were "much above normal" and "record warmest" during the spring and summer of 2010. Although broad-scale climatic variables are similar between these states, the reported 2010 annual Maryland JAI is significantly lower than its historic average whereas Virginia's annual JAI is not. It is unclear whether finer-scale climatic patterns are important or whether other factors exert effects that may be of greater magnitude. Further research in this area is clearly warranted.

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 2010, nearly 49,000 individuals comprising 66 species were collected (Table 12). The four most common species were white perch (*Morone americana*), Atlantic menhaden (*Brevoortia tyrannus*), spottail shiner (*Notropis hudsonius*) and hogchoker (*Trinectes maculatus*). Young-of -year striped bass were the 9th-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 reported to the ASMFC to fulfill compliance requirements for species of management importance are presently derived from the seine survey. These species include American shad (Watkins et al. 2010) and Atlantic menhaden (VMRC 2010). 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; these include: spottail shiner (Table 13), Atlantic silverside (*Menidia menidia*; Table 14), inland silverside (*Menidia beryllina*; Table 15), and banded killifish (*Fundulus* *diaphanous*; Table 16). The 2010 indices for spottail shiner, Atlantic silverside, and inland silverside are not significantly different from the historic average for these species. Similar to 2009, the 2010 banded killifish index is significantly higher than the historic average (Table 16). The high catches of banded killifish continue a trend of higher than average abundance since 2004, and suggest a sustained increase in the abundance of banded killifish populations. The recently reported average to above-average indices for these species suggest there is a stable population of forage fishes in Virginia waters for commercially and recreationally important fishes.

We will continue to evaluate abundance indices from the seine survey during 2011. Where appropriate, we will compare our survey-derived indices with those calculated from the VIMS trawl survey.

CONCLUSION

The 2010 juvenile abundance index (JAI) for striped bass (9.07) is not significantly different from the historic average (7.59). Abundance indices from individual rivers showed no deviation from their respective historic averages except for the Pamunkey River which had significantly higher recruitment when compared with the historic average. 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 2010. Additional methods of calculating the regional index support this conclusion. Continued calculation 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 may serve as an early warning to managers of potential future declines in standing stock biomass.

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Table 1. Catch of young-of-year striped bass per seine haul in 2010. 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		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Round Total
JAMES	Round	1	0	7	4/2	2/11	11	59/32	7/4	55/60	15	21/19	79	23	48	459
		2	0	6	3/0	0/7	15	25/11	33/20	19/37	51	16/18	32	39	0	332
		3	0	13	2/0	1/1	10	23/4	26/4	27/17	31	4/4	4	30	0	201
		4	0	2	1/0	1/2	7	3/1	7/3	5/20	14	11/7	3	1	9	97
		5	0	7	1/1	1/1	10	3/3	9/7	17/17	21	1/8	1	16	0	124
														James Total		**1213**

Drainage		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55	Round Total
YORK	Round	1	16	ns	0	9	8/12	4/2	25/32	0	108
		2	7	5	0	6	5/0	4/1	34/15	0	77
		3	2	1	0	6	5/2	7/6	15/11	0	55
		4	2	8	0	7	6/1	2/2	6/9	ns	43
		5	0	1	1	1	7/2	1/2	9/5	ns	29

Drainage		Station	**M33**	M37	**M41**	**M44**	**M47**	M52	Round Total
YORK	Round	1	29/5	34	4/0	34/9	12/14	3	144
		2	0/0	6	2/0	21/9	0/2	4	44
		3	0/0	10	1/0	12/5	1/1	5	35
		4	3/6	10	1/0	4/7	0/2	1	34
		5	1/1	4	1/1	6/3	0/0	0	17
								York Total	**586**

Drainage		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	Round Total
RAPPAHANNOCK	Round	1	0	2	0/0	0/0	7	3/0	9/24	57/38	14	3	1	4	162
		2	0	2	5/0	0/0	6	0/0	13/1	51/17	2	5	0	5	107
		3	0	0	5/0	0/0	2	0/0	19/11	77/58	0	0	4	1	177
		4	0	0	0/0	0/0	2	2/0	29/16	10/21	ns	ns	1	5	86
		5	0	0	1/1	0/0	3	0/0	17/14	39/38	0	0	0	0	113
												Rappahannock Total			**645**
												2010 Catch			**2444**

ns = no sample

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	0.98	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	1.80-3.84	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	228	0.74	0.90	2.52	1.68-3.53	89
1981	165	0.52	0.69	1.57	1.10-2.09	116
1982	323	0.78	0.97	2.71	1.85-3.74	106
1983	296	0.91	0.83	3.40	2.53-4.42	102
1984	597	1.09	1.06	4.47	3.22-6.02	106
1985	322	0.72	0.86	2.41	1.78-3.14	142
1986	669	1.12	1.04	4.74	3.62-6.06	144
1987	2191	2.07	1.23	15.74	12.4-19.8	144
1988	1348	1.47	1.13	7.64	6.10-9.45	180
1989	1978	1.78	1.12	11.23	9.15-13.7	180
1990	1249	1.44	1.10	7.34	5.89-9.05	180
1991	667	0.97	0.95	3.76	2.96-4.68	180
1992	1769	1.44	1.25	7.32	5.69-9.28	180
1993	2323	2.19	0.98	18.12	15.4-21.3	180
1994	1510	1.72	1.03	10.48	8.66-12.6	180
1995	926	1.22	1.05	5.45	4.33-6.75	180
1996	3759	2.41	1.23	23.00	18.8-28.1	180
1997	1484	1.63	1.10	9.35	7.59-11.4	180
1998	2084	1.92	1.14	13.25	10.8-16.1	180
1999	442	0.80	0.86	2.80	2.19-3.50	180
2000	2741	2.09	1.24	16.18	13.06-19.92	180
2001	2624	1.98	1.27	14.17	11.33-17.60	180
2002	813	1.01	1.09	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
2010	1721	1.61	1.25	9.07	7.14-11.40	180
Overall (1967-2010)	46748	1.47	1.19	7.59	7.28-7.90	5649

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
2010	994	1.75	1.26	10.83	7.78-14.82	90
Overall (1967-2010)	29229	1.53	1.23	8.28	7.83-8.76	3133
Overall (1990-2010)	22441	1.83	1.21	11.93	11.15-12.74	1890

Table 4. Catch of young-of-year striped bass per seine haul in the primary nursery area in 2010 summarized by drainage and river.

	2010				All Years Combined (1967-2010)			
Drainage River	Total Fish	Index	C.I. (±2 SE)	N (hauls)	Total Fish	Index	C.I. (±2 SE)	N (hauls)
JAMES	708	13.92	9.80 – 19.43	60	18927	10.02	9.36 – 10.72	1878
James	424	11.39	7.09 – 17.66	40	11450	9.31	8.57 – 10.10	1260
Chickahominy	284	20.45	12.62 – 32.38	20	7477	11.62	10.31 – 13.07	618
YORK	437	7.49	5.35 – 10.23	70	13221	5.80	5.43 – 6.18	2152
Pamunkey	240	11.97	8.10 – 17.28	30	6769	6.80	6.13 – 7.52	916
Mattaponi	197	5.08	2.97 – 8.05	40	6452	5.12	4.71 – 5.57	1236
RAPPAHANNOCK	576	6.87	3.60 – 11.94	50	14600	7.69	7.08 – 8.33	1619
OVERALL	1721	9.07	7.14 – 11.40	180	46748	7.59	7.28 – 7.90	5649

Table 5. Striped bass indices recorded at all survey stations in 2010 compared to historic (1967 – 2010) 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*
	1967-2010	Avg. Sal.	14.6	7.9	5.1	2.6	1.8	1.5	1.3	0.6	0.3	0.2	0.2	0.1	0.2
		Index	2.0	14.7	7.1	12.5	12.1	15.5	7.9	20.0	15.8	6.0	8.5	6.7	1.4
	2010	Avg. Sal.	18.7	12.1	8.9	5.8	3.7	4.2	3.8	1.8	0.9	0.4	0.2	0.2	0.2
		Index	0.0	14.0	2.4	4.1	23.5	20.4	20.5	51.5	53.5	19.4	20.8	33.9	5.6
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1967-2010	Avg. Sal.	16.7	13.8	11.0	4.4	1.9	0.8	0.4	0.3					
		Index	1.1	1.7	4.4	9.7	3.8	8.8	12.4	4.8					
	2010	Avg. Sal.	19.4	17.6	14.8	9.1	5.5	2.6	1.5	0.6					
		Index	7.2	6.5	0.3	11.4	8.2	6.1	30.6	0.0					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2010	Avg. Sal.				4.7	2.5	1.3	0.5	0.3	0.1				
		Index				5.8	8.0	6.1	4.9	4.4	1.4				
	2010	Avg. Sal.				9.8	6.6	3.2	1.3	1.1	0.2				
		Index				3.9	22.4	1.7	19.6	3.3	4.5				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	1967-2010	Avg. Sal.	14.3	13.0	10.2	5.5	3.3	2.0	0.9	0.6	0.2	0.2	0.1	0.1	
		Index	0.6	0.8	2.4	3.3	5.2	7.9	11.8	40.8	6.1	4.1	2.9	1.9	
	2010	Avg. Sal.	15.7	14.5	12.3	8.0	6.1	4.0	2.3	1.5	0.5	0.3	0.1	0.1	
		Index	0.0	1.3	1.5	0.0	8.2	0.6	28.9	79.9	3.6	2.8	1.9	5.1	

* = new station in 2006

Table 6. Catch of young-of-year striped bass in the primary nursery areas of Virginia in 2010 summarized by sampling round and month.

	2010					All Years Combined (1967-2010)				
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	597	17.95	10.70 – 29.24		1178	14460	11.63	10.66 – 12.69	
(2nd)	36	369	9.19	4.93 – 15.99	38.2%	1189	11199	8.68	7.94 – 9.49	22.6%
Aug. (3rd)	36	349	8.50	4.75 – 14.26	5.4 %	1181	8364	7.00	6.41 – 7.64	25.3%
(4th)	36	188	6.41	3.93 – 9.88	46.1%	1045	7367	6.52	5.92 – 7.17	11.9%
Sept. (5th)	36	218	6.39	3.79 – 10.12	-16.0%	919	5153	5.66	5.11 – 6.24	30.1%

Table 7. Water temperature (^{o}C) recorded at seine survey stations in 2010. 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	32.5	33.7	31.1	27.7	31.9	29.8	29.4	31.0	28.8	28.5	29.8	30.5	30.5
		2	28.7	29.0	32.7	27.4	31.1	29.4	29.7	32.2	30.1	30.1	30.6	32.5	31.4
		3	31.5	30.2	30.9	29.0	29.9	29.6	30.0	31.0	29.1	28.5	30.3	32.0	30.7
		4	29.4	30.0	29.0	27.0	28.0	27.1	27.4	28.6	27.6	26.9	28.6	29.5	29.2
		5	27.4	26.0	26.3	23.5	25.0	24.4	23.8	26.7	26.1	24.6	26.1	28.5	28.2
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	29.1	ns	28.9	29.2	30.6	30.7	31.0	32.9					
		2	26.8	26.9	27.9	29.9	30.0	30.5	30.8	33.0					
		3	27.7	27.9	28.0	29.3	29.6	30.0	30.1	28.8					
		4	27.6	27.9	26.6	28.4	28.8	29.2	29.7	ns					
		5	24.4	23.8	23.7	24.6	25.1	26.2	25.8	ns					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				29.6	29.7	29.8	30.1	32.0	31.5				
		2				28.7	29.0	28.5	28.6	28.8	28.5				
		3				28.6	28.7	28.7	29.5	30.1	30.4				
		4				28.1	28.1	27.9	28.7	29.5	30.9				
		5				24.6	25.2	24.4	25.0	26.1	27.4				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	Round	1	30.0	29.1	27.7	28.8	28.1	28.6	29.6	29.7	29.6	29.5	30.2	30.4	
		2	31.8	30.1	28.1	29.0	30.3	30.4	30.6	31.2	31.4	31.4	32.5	32.4	
		3	32.6	31.2	29.1	29.2	30.9	32.0	28.7	29.4	29.5	29.8	30.5	32.2	
		4	29.5	28.0	25.4	25.5	27.0	27.0	27.0	27.5	ns	ns	28.6	29.0	
		5	24.0	23.8	21.4	22.9	22.8	24.0	26.3	26.6	26.8	26.1	27.6	28.7	

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

Table 8. Salinity (ppt) recorded at seine survey stations in 2010. 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	16.8	9.6	7.3	4.3	2.6	2.6	2.2	0.7	0.4	0.1	0.2	0.2	0.2
		2	18.7	12.4	7.4	4.7	3.0	3.3	2.8	1.2	0.5	0.2	0.2	0.2	0.2
		3	19.8	12.7	9.0	5.8	4.0	4.2	3.9	1.7	0.7	0.3	0.2	0.2	0.1
		4	18.7	12.2	10.4	6.7	4.2	5.1	4.6	2.0	1.8	0.7	0.3	0.2	0.2
		5	19.6	13.5	10.6	7.7	4.9	5.7	5.3	3.3	1.1	0.6	0.3	0.2	0.2
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	17.1	ns	13.8	7.7	3.9	1.2	0.5	0.3					
		2	19.8	17.2	13.6	7.4	4.2	1.7	0.9	0.6					
		3	20.3	17.3	15.7	11.0	6.8	3.2	1.6	1.0					
		4	19.8	17.6	15.1	8.4	5.1	2.4	1.8	ns					
		5	20.2	18.1	15.9	11.1	7.6	4.3	2.5	ns					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				7.4	3.9	1.4	0.4	0.4	0.1				
		2				9.6	6.4	2.7	1.1	0.9	0.1				
		3				11.2	7.9	3.6	1.5	1.2	0.2				
		4				9.8	7.0	3.2	1.4	1.1	0.2				
		5				11.2	8.0	5.3	2.2	1.7	0.4				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*	
	Round	1	14.4	13.5	11.5	7.0	4.0	2.8	1.1	0.5	0.2	0.1	0.1	0.1	
		2	15.5	14.4	11.9	7.3	8.6	3.3	1.7	0.9	0.3	0.2	0.1	0.1	
		3	16.1	14.8	12.7	7.9	5.4	4.0	2.4	1.6	0.5	0.3	0.1	0.1	
		4	16.2	15.0	12.9	8.7	6.0	4.9	2.9	2.0	ns	ns	0.2	0.1	
		5	16.5	15.0	12.5	9.1	6.3	5.1	3.5	2.5	1.0	0.7	0.2	0.1	

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

Table 9. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2010. 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 2010. Index stations are indicated by bold font.

Drainage		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77*
JAMES	Round	1	11.6	10.3	8.0	4.8	7.6	5.3	5.0	5.5	5.8	6.4	8.9	6.1	4.8
		2	10.4	7.5	7.5	7.2	6.5	7.0	6.1	5.5	5.4	5.9	6.9	3.8	4.2
		3	7.1	7.2	6.9	5.7	6.5	5.7	5.1	5.1	4.2	6.8	6.8	4.6	4.3
		4	6.7	7.4	6.5	5.1	7.3	6.1	5.2	4.2	4.4	5.9	6.1	5.1	4.5
		5	6.4	7.9	6.7	6.2	6.7	6.1	5.7	5.3	5.6	5.4	4.9	3.8	3.9

Drainage		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55
YORK	Round	1	6.9	ns	5.1	3.6	4.9	5.2	5.2	5.3
		2	5.0	5.4	6.1	5.7	5.5	6.7	6.0	7.7
		3	5.7	5.6	4.1	3.3	--	4.9	5.0	6.4
		4	4.7	4.7	4.2	3.6	4.7	5.0	4.8	ns
		5	6.5	5.9	6.2	4.8	4.7	6.1	5.6	ns

		Station	**M33**	M37	**M41**	**M44**	**M47**	M52
	Round	1	4.6	5.4	5.6	5.4	4.5	4.9
		2	4.3	4.5	5.2	5.7	5.9	5.8
		3	3.6	3.5	4.2	4.8	5.8	5.1
		4	4.1	4.5	4.0	5.3	5.8	5.7
		5	4.5	5.1	5.5	5.5	6.6	7.9

Drainage		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75*
RAPPAHANNOCK	Round	1	5.9	5.8	8.1	6.0	7.5	6.3	6.0	7.2	6.8	9.0	7.6	6.8
		2	8.0	5.9	4.6	6.2	7.0	6.8	6.5	7.1	5.5	7.1	5.1	6.7
		3	7.6	5.5	5.2	4.7	6.9	6.3	6.1	7.5	5.4	6.1	4.5	4.0
		4	6.8	6.4	5.7	5.6	6.9	5.9	5.7	6.8	ns	ns	5.7	5.5
		5	7.3	7.8	6.5	5.9	7.6	7.0	5.8	6.2	5.8	7.0	4.9	4.7

ns = no sample taken, * = new station in 2006, -- = faulty DO measurement recorded

Table 10. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2010 summarized by water temperature.

	2010				All Years Combined (1967-2010)			
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	39	3.14	1.56 – 5.38	18	2650	3.55	3.13 – 4.00	707
25.0 - 29.9	1058	8.47	6.24 – 11.28	116	35884	8.50	8.11 – 8.92	4004
30.0 - 34.9	624	15.12	9.68 – 23.03	46	7745	9.03	8.10–10.03	809
Overall	1721	9.07	7.14 – 11.40	180	46748	7.59	7.28 – 7.90	5649

Table 11. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2010 summarized by salinity.

	2010				All Years Combined (1967-2010)			
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	1592	15.58	12.00 – 20.06	118	43231	8.80	8.42 – 9.19	4660
5.0 - 9.9	112	3.08	1.89 – 4.61	44	3122	4.24	3.76 – 4.74	721
10.0 - 14.9	17	1.36	0.48 – 2.52	18	393	2.01	1.62 – 2.45	239
15.0 - 19.9	N/A			0	2	0.11	0.00 – 0.28	29
Overall	1721	9.07	7.14 – 11.40	180	46748	7.59	7.28 – 7.90	5649

Table 12. Species collected during the 2010 survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Morone americana	white perch	8701
Brevoortia tyrannus	Atlantic menhaden	8354
Notropis hudsonius	spottail shiner	4759
Trinectes maculatus	hogchoker	3759
Leiostomus xanthurus	spot	3535
Fundulus heteroclitus	mummichog	3003
Menidia menidia	Atlantic silverside	2647
Fundulus diaphanus	banded killifish	2513
Morone saxatilis	striped bass	2444
Menidia beryllina	inland silverside	1826
Anchoa mitchilli	bay anchovy	1551
Membras martinica	rough silverside	1441
Hybognathus regius	eastern silvery minnow	627
Fundulus majalis	striped killifish	618
Notropis analostanus	satinfin shiner	372
Alosa aestivalis	blueback herring	335
Alosa sapidissima	American shad	330
Ictalurus furcatus	blue catfish	296
Dorosoma cepedianum	gizzard shad	259
Bairdiella chrysoura	silver perch	215
Cyprinodon variegatus	sheepshead minnow	127
Alosa pseudoharengus	alewife	124
Micropogonias undulatus	Atlantic croaker	122
Etheostoma olmstedi	tessellated darter	94
Menticirrhus saxatilis	northern kingfish	86
Mugil curema	white mullet	77
Cynoscion regalis	weakfish	66
Mugil cephalus	striped mullet	57
Ictalurus punctatus	channel catfish	50
Lepomis gibbosus	pumpkinseed	46
Alosa mediocris	hickory shad	43
Anchoa hepsetus	striped anchovy	37
Perca flavescens	yellow perch	36
Lepomis macrochirus	bluegill	34
Enneacanthus gloriosus	bluespotted sunfish	26
Dorosoma petenense	threadfin shad	25
Cynoscion nebulosus	spotted seatrout	21
Gambusia affinis	mosquitofish	19
Ictalurus catus	white catfish	19
Anguilla rostrata	American eel	17
Micropterus salmoides	largemouth bass	17
Lepomis auritus	redbreast sunfish	17

Table 12 (cont'd.)

Scientific Name	Common Name	Total Caught
Morone saxatilis age 1+	striped bass - age 1+	17
Strongylura marina	Atlantic needlefish	16
Peprilus alepidotus	harvestfish	15
Symphurus plagiusa	blackcheek tonguefish	13
Syngnathus fuscus	northern pipefish	10
Pomatomus saltatrix	bluefish	9
Notemigonus crysoleucas	golden shiner	8
Paralichthys dentatus	summer flounder	8
Chaetodipterus faber	Atlantic spadefish	7
Lepisosteus osseus	longnose gar	6
Cyprinus carpio	common carp	5
Gobiosoma bosci	naked goby	4
Micropterus punctulatus	spotted bass	4
Ictalurus nebulosus	brown bullhead	3
Sphoeroides maculatus	northern puffer	3
Gobiesox strumosus	skilletfish	3
Chasmodes bosquianus	striped blenny	3
Micropterus dolomieui	smallmouth bass	2
Pomoxis nigromaculatus	black crappie	1
Hypsoblennius hentzi	feather blenny	1
Gobiidae spp	gobies	1
Synodus foetens	inshore lizardfish	1
Elops saurus	ladyfish	1
Lepomis spp	Lepomis spp	1
Hippocampus erectus	lined seahorse	1
Menticirrhus americanus	southern kingfish	1
	Total	**48889**

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	2.64	1.15	12.99	10.34-16.25	121
1990	2068	2.12	1.30	7.35	5.62-9.54	124
1991	1429	1.87	1.24	5.49	4.17-7.14	119
1992	2357	2.02	1.40	6.50	4.83-8.65	123
1993	1713	1.96	1.27	6.13	4.65-8.01	118
1994	2498	2.29	1.34	8.91	6.77-11.66	120
1995	2216	2.10	1.36	7.16	5.37-9.46	120
1996	2280	2.28	1.27	8.74	6.72-11.29	119
1997	3605	2.17	1.53	7.77	5.67-10.53	125
1998	2092	2.12	1.32	7.36	5.53-9.72	114
1999	1252	1.48	1.30	3.38	2.48-4.52	126
2000	4882	2.73	1.43	14.39	10.92-18.86	125
2001	2848	2.39	1.33	9.92	7.64-12.82	128
2002	1541	1.30	1.40	2.67	1.86-3.70	128
2003	2972	2.42	1.40	10.21	7.76-13.34	129
2004	5113	3.25	1.13	24.72	19.98-30.54	123
2005	3585	2.63	1.40	12.85	9.71-16.91	119
2006	3451	2.47	1.51	10.85	7.96-14.68	117
2007	3823	2.58	1.47	12.22	9.09-16.33	118
2008	2152	1.97	1.46	6.16	4.51-8.31	124
2009	3033	2.21	1.54	8.10	5.89-11.02	122
2010	3983	2.38	1.54	9.79	7.16-13.26	121
Overall (1989-2010)	61833	2.24	1.43	8.41	7.91-8.95	2683

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	1.11	1.50	2.02	1.15-3.24	78
1990	1461	1.17	1.42	2.23	1.35-3.43	80
1991	2618	2.05	1.78	6.76	4.15-10.69	75
1992	5564	2.16	2.19	7.66	4.31-13.15	80
1993	2258	1.84	1.78	5.28	3.21-8.37	79
1994	2179	1.51	1.72	3.52	2.08-5.64	80
1995	2973	2.06	1.88	6.82	4.13-10.92	79
1996	4668	1.89	2.15	5.61	3.07-9.73	79
1997	1108	1.48	1.55	3.39	2.09-5.23	78
1998	2297	2.19	1.71	7.93	5.08-12.11	79
1999	6832	3.02	1.66	19.41	12.94-28.89	76
2000	3119	2.27	1.88	8.71	5.34-13.87	78
2001	3586	2.39	1.84	9.92	6.28-15.39	82
2002	5264	3.24	1.61	24.48	16.77-35.52	80
2003	3470	1.62	2.08	4.03	2.16-7.02	80
2004	1473	1.32	1.73	2.73	1.53-4.49	80
2005	2163	2.17	1.63	7.80	5.14-11.61	82
2006	2660	2.12	1.75	7.33	4.67-11.22	83
2007	2118	2.25	1.62	8.52	5.57-12.78	77
2008	3211	1.63	1.79	4.12	2.45-6.58	83
2009	2693	2.27	1.79	8.64	5.51-13.29	83
2010	1490	2.07	1.40	6.91	4.84-9.73	84
Overall (1989-2010)	64086	1.99	1.82	6.32	5.71-6.98	1755

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	1.15	0.96	2.17	1.63-2.81	107
1990	574	1.09	1.14	1.97	1.39-2.70	110
1991	285	0.86	0.87	1.37	1.00-1.81	105
1992	326	0.67	0.90	0.96	0.65-1.33	110
1993	368	0.76	0.97	1.14	0.77-1.59	106
1994	166	0.53	0.76	0.70	0.46-0.97	106
1995	104	0.44	0.62	0.56	0.38-0.75	107
1996	772	0.82	1.13	1.27	0.83-1.83	107
1997	175	0.54	0.76	0.71	0.48-0.98	110
1998	204	0.69	0.80	0.99	0.70-1.33	104
1999	298	0.72	0.93	1.06	0.73-1.45	113
2000	718	1.06	1.19	1.89	1.31-2.62	113
2001	626	0.96	1.15	1.61	1.10-2.24	115
2002	447	0.78	1.04	1.18	0.80-1.66	114
2003	545	1.21	0.99	2.37	1.80-3.06	113
2004	753	1.23	1.17	2.44	1.75-3.29	113
2005	368	0.93	0.94	1.53	1.11-2.03	110
2006	1161	1.32	1.32	2.73	1.90-3.79	112
2007	807	1.06	1.20	1.88	1.29-2.62	111
2008	658	1.15	1.11	2.14	1.56-2.87	114
2009	1691	1.88	1.29	5.56	4.16-7.35	114
2010	908	1.19	1.30	2.29	1.57-3.21	111
Overall (1989-2010)	12425	0.96	1.09	1.62	1.50-1.73	2425

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	231	0.56	0.82	0.75	0.49 - 1.05	106
1990	235	0.65	0.88	0.92	0.63 - 1.28	109
1991	247	0.59	0.93	0.80	0.50 - 1.16	104
1992	153	0.46	0.77	0.59	0.37 - 0.84	108
1993	258	0.59	0.95	0.80	0.49 - 1.17	103
1994	200	0.53	0.84	0.70	0.44 - 1.01	105
1995	287	0.66	1.01	0.93	0.59 - 1.35	105
1996	600	1.14	1.20	2.12	1.46 - 2.94	104
1997	365	0.88	1.00	1.41	0.99 - 1.92	110
1998	304	0.92	0.94	1.52	1.07 - 2.05	95
1999	335	0.79	1.01	1.20	0.81 - 1.68	107
2000	312	0.81	0.95	1.24	0.86 - 1.69	105
2001	374	0.99	0.95	1.68	1.23 - 2.22	108
2002	478	0.82	1.12	1.26	0.83 - 1.80	109
2003	841	1.16	1.24	2.18	1.50 - 3.03	109
2004	1388	1.79	1.31	5.00	3.63 - 6.77	103
2005	721	1.29	1.22	2.64	1.86 - 3.65	100
2006	498	0.93	1.18	1.53	0.99 - 2.21	97
2007	677	1.32	1.18	2.73	1.94 - 3.74	98
2008	1017	1.62	1.19	4.05	3.00 - 5.37	105
2009	1202	1.74	1.29	4.72	3.43 - 6.39	102
2010	1927	2.15	1.37	7.63	5.57 - 10.34	101
Overall (1989-2010)	12650	1.01	1.16	1.75	1.62-1.89	2293

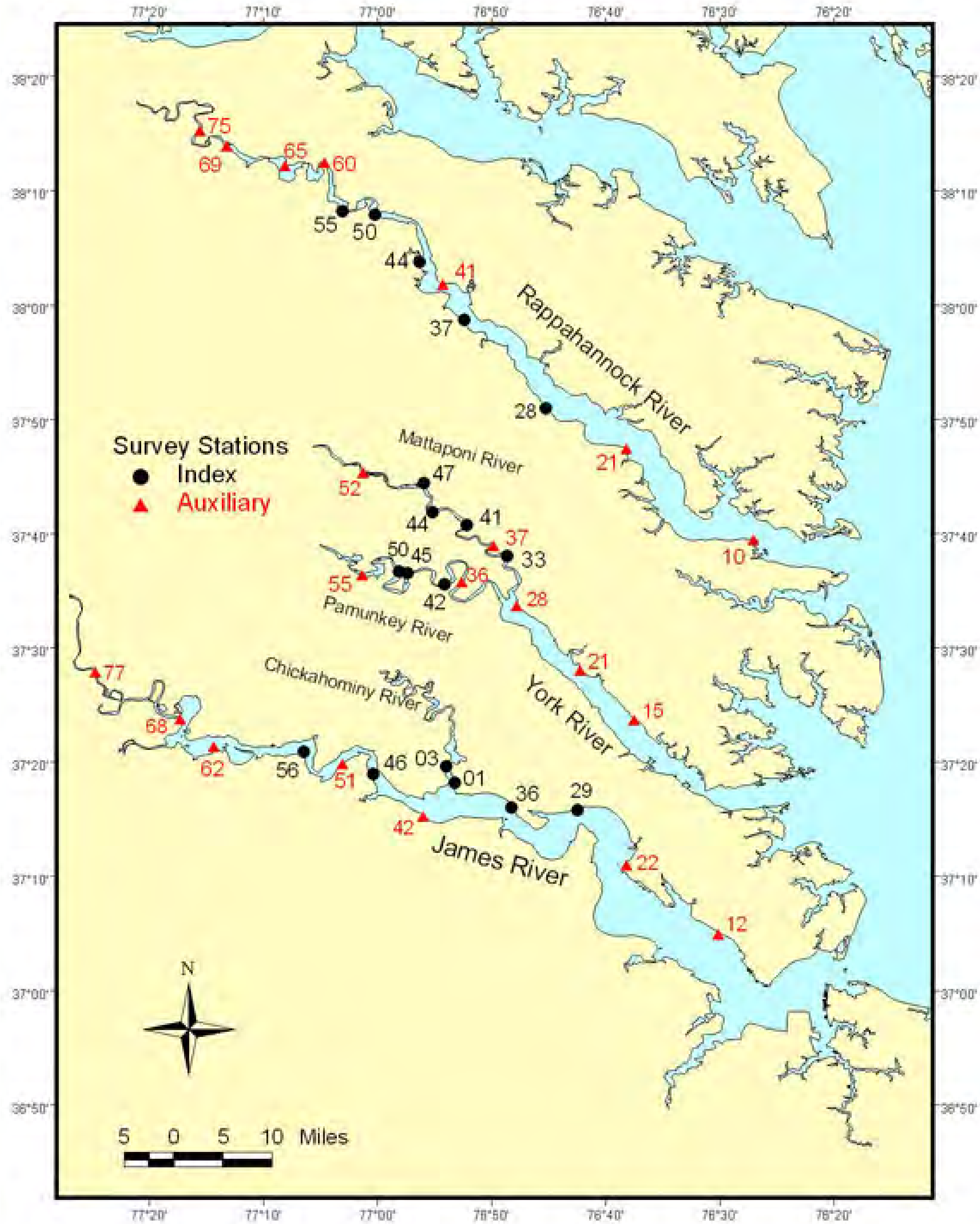

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designation indicates river mile from mouth. Auxiliary stations R75 (Rappahannock) and J77 (James) are new in 2006, replacing R76 and J74/J78, respectively.

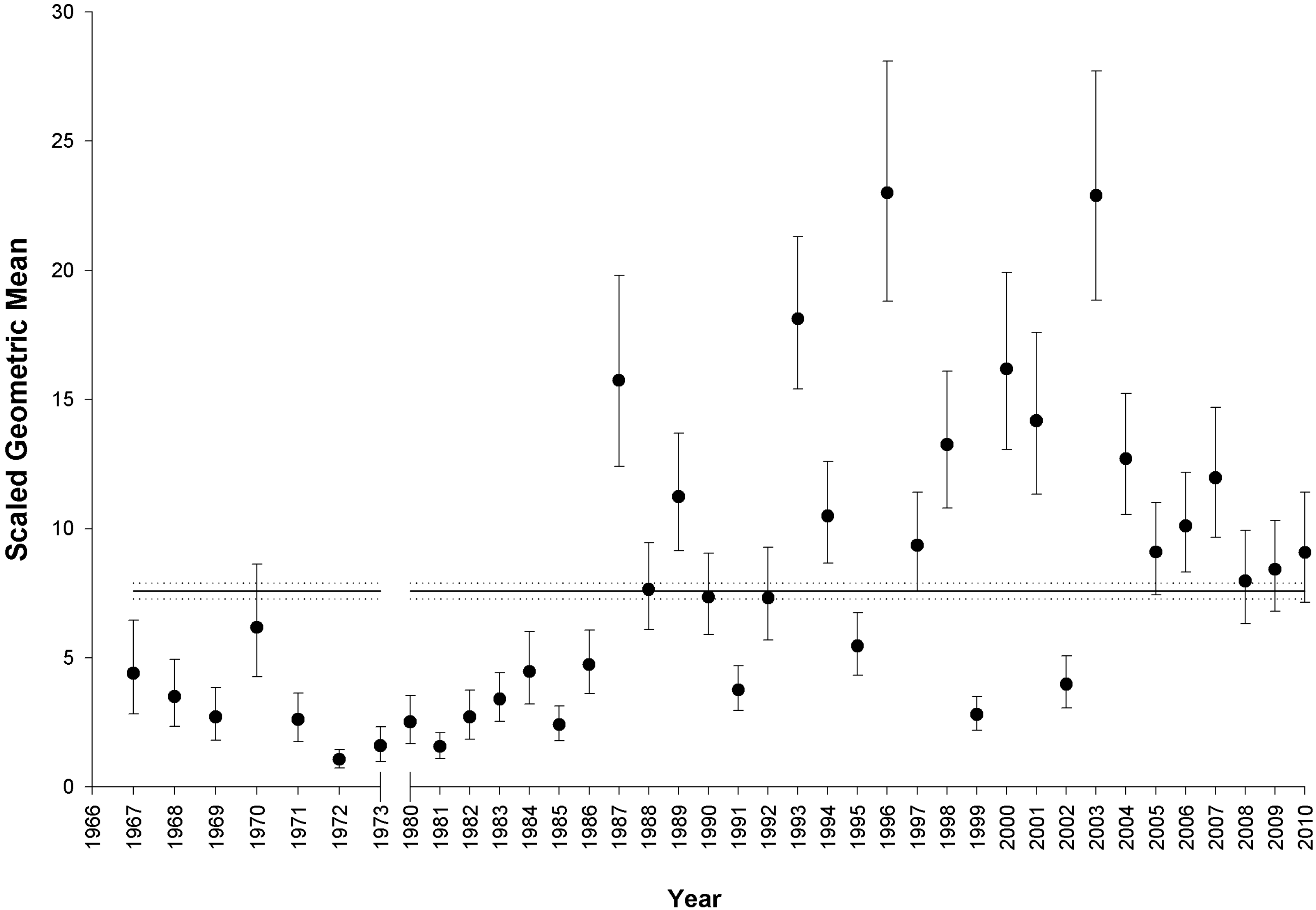

Figure 2. Scaled geometric mean of young-of-the-year striped bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by $\pm$ 2 standard errors of the mean. Horizontal lines indicate historical geometric mean (solid) and confidence intervals (dotted) for 1967-2010.

Figure 3. New breakwater constructed at J36. For 2010, the seine haul location was moved approximately 50m downstream to accommodate for the breakwater placed directly over the historic index station.

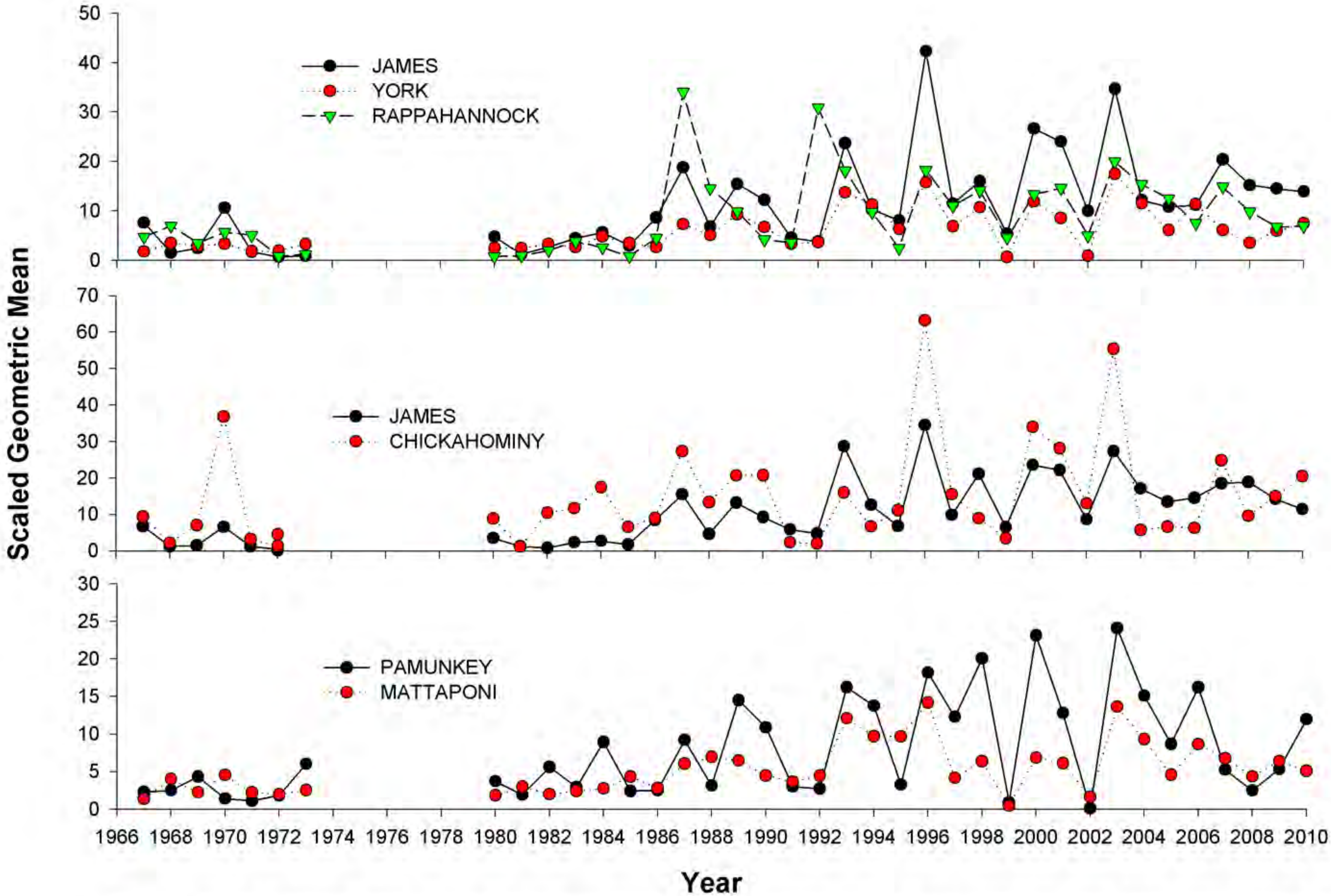

Figure 4. Scaled geometric mean of young-of-the-year striped bass in the primary nursery areas of Virginia (index stations) by drainage and river.

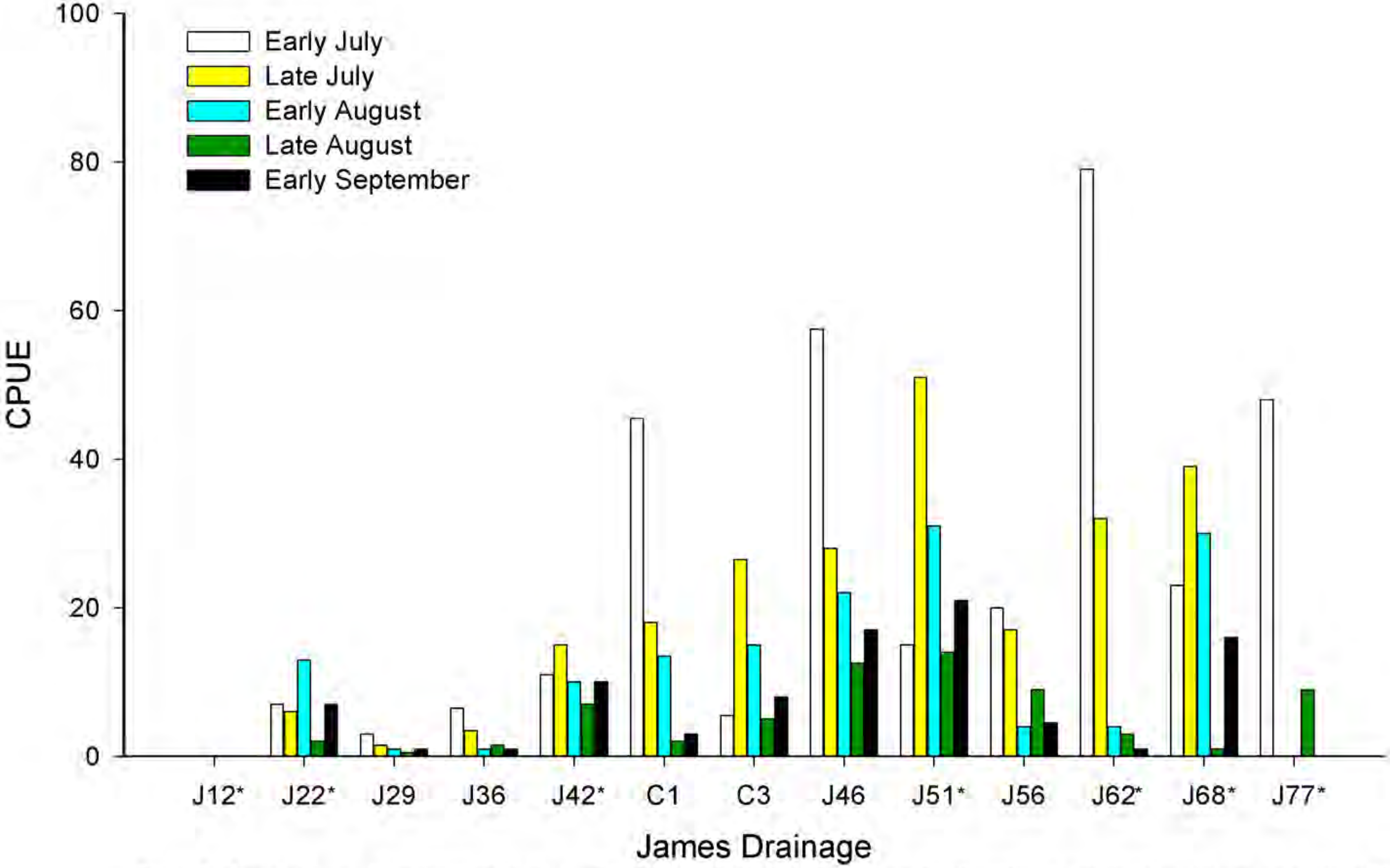

Figure 5. Catch of young-of-year striped bass by station in the James River drainage in 2010. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul.

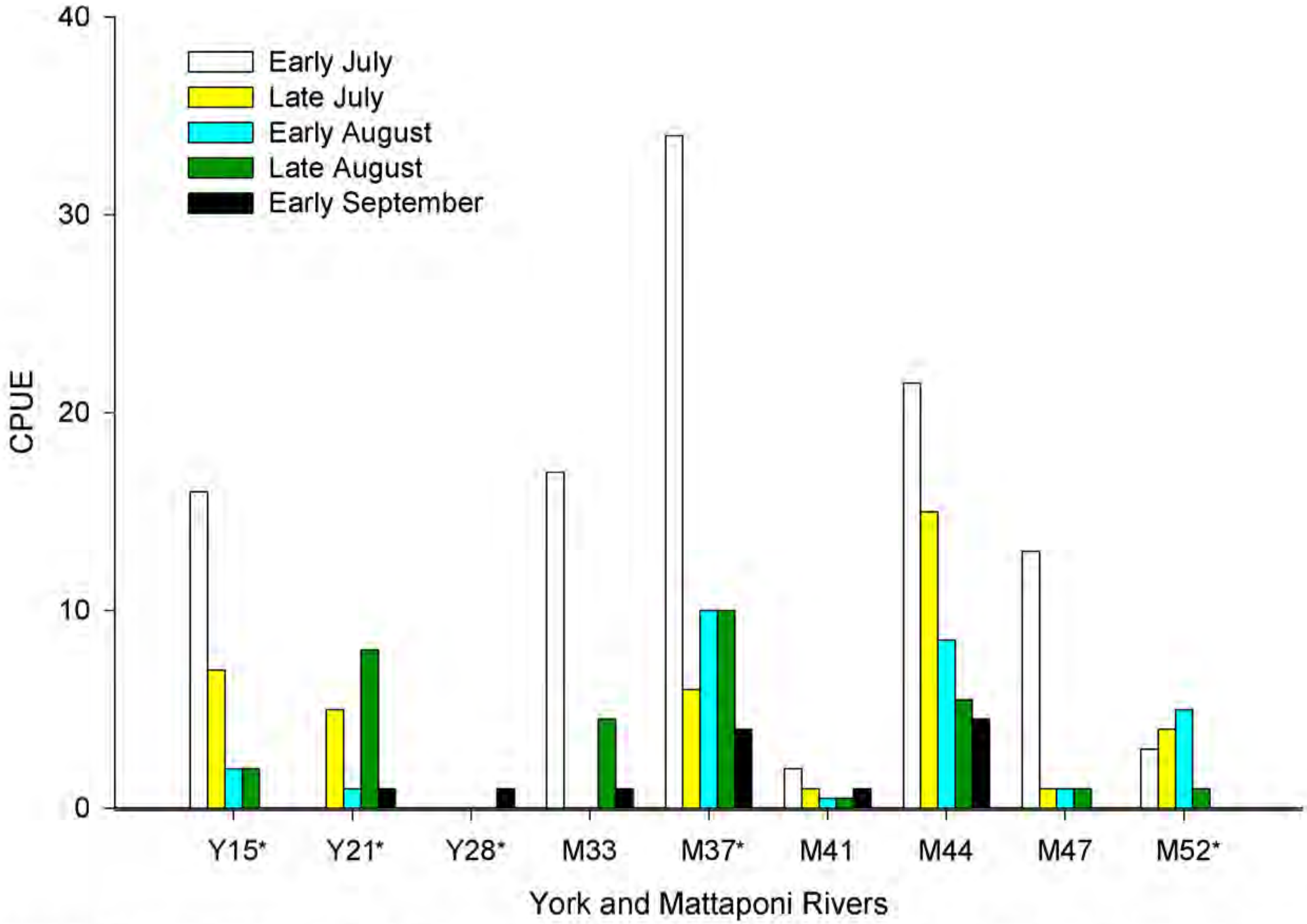

Figure 6. Catch of young-of-year striped bass by station in the York and Mattaponi rivers in 2010. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at Y21 during early July.

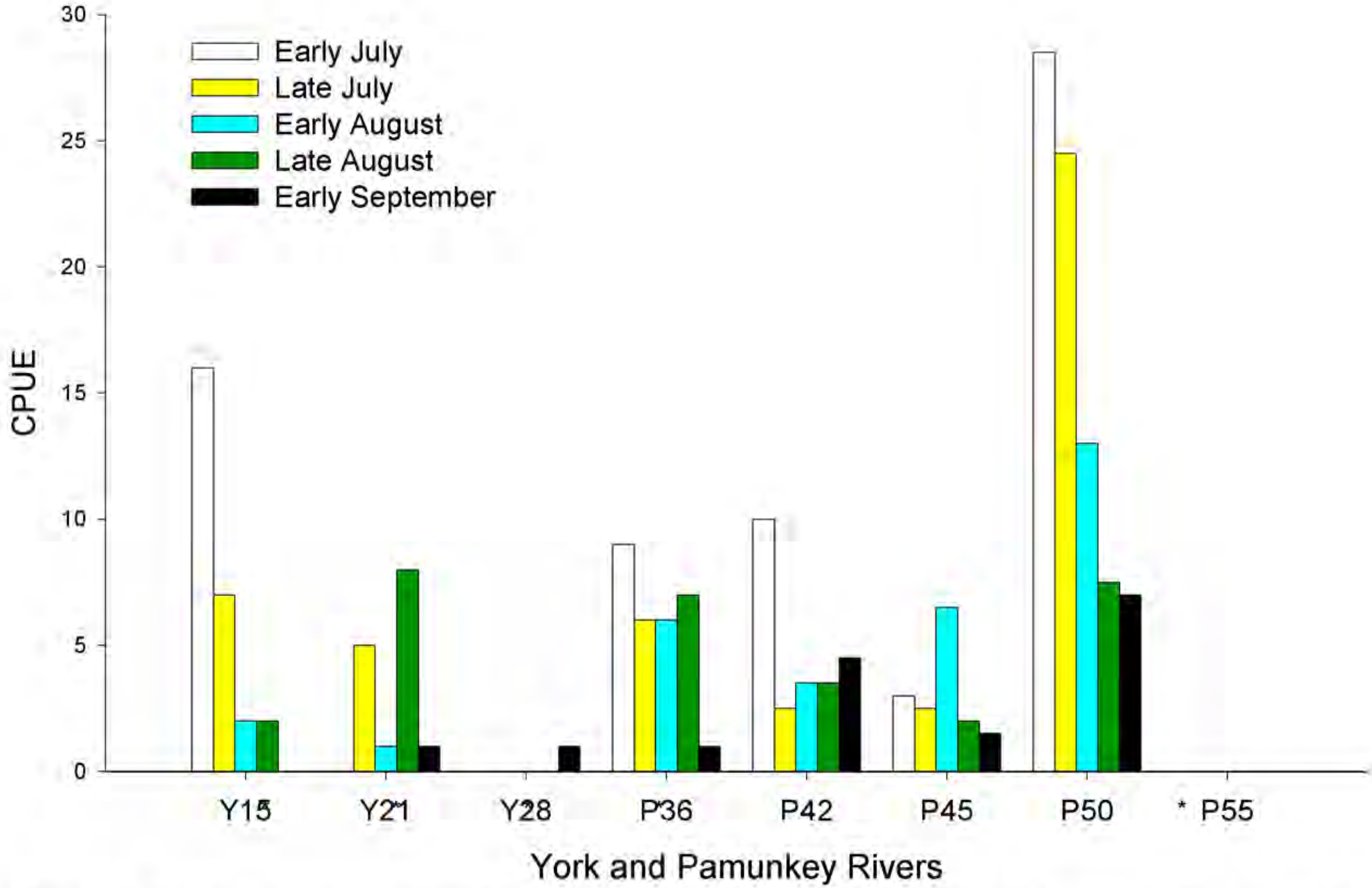

Figure 7. Catch of young-of-year striped bass by station in the York and Pamunkey rivers in 2010. Iindex station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at Y21 during early July or at P55 during late August and early September.

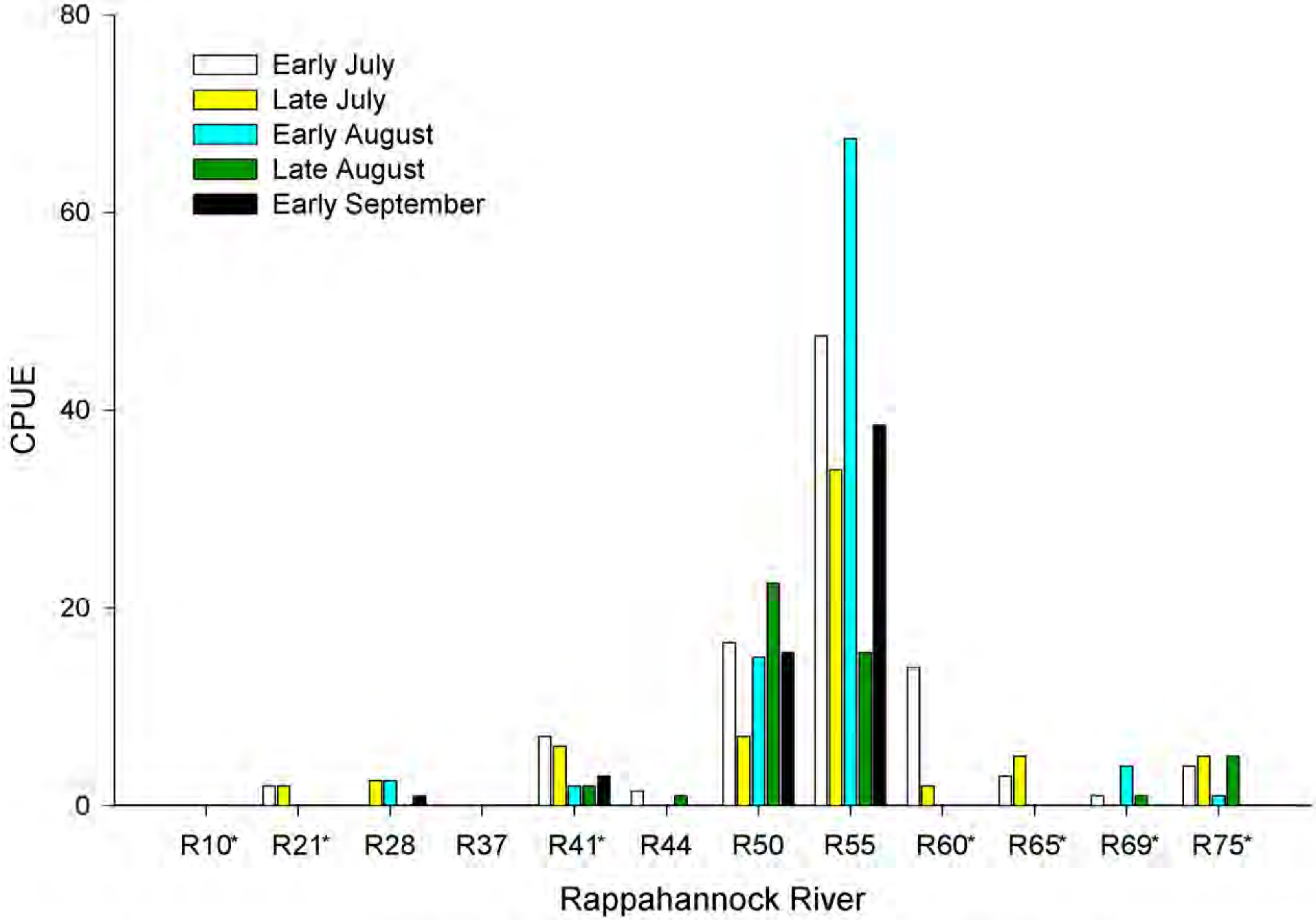

Figure 8. Catch of young-of-year striped bass by station in the Rappahannock River in 2010. Index station catch represent an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at R60 or R6 during late August.