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

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EXECUTIVE SUMMARY

The 2011 striped bass juvenile abundance index is 27.09 and is significantly higher than the historic average of 7.92. Unlike previous years, the 2011 York River index was the highest among Virginia watersheds with high recruitment in both the Pamunkey and Mattaponi rivers. All individual river JAI values were significantly higher than their respective historic averages except for the Chickahominy River which was not significantly different from its historic average. This suggests a strong year class was produced in the Virginia portion of Chesapeake Bay in 2011. Sampling of auxiliary stations provides greater spatial coverage of the nursery grounds and suggests that juvenile striped bass occupied upstream sites in higher abundances during 2011 compared with these sites historic averages.

Several important changes were incorporated into the 2011 annual report. Samples collected within the currently established sampling season (early-July through mid-September) were used to estimate annual recruitment indices for 1967 – 1973; we omitted samples taken outside the established sampling time frame to improve our ability to compare contemporary indices with those from the late 1960s to early 1970s. In addition, the historic average is now properly calculated as the geometric mean of annual juvenile abundance estimates. Previously, the historic average was simply the mean over all stations sampled over time; the previous method therefore weighted the mean by the number of stations sampled in any given year and because the survey sampled fewer stations prior to 1988, the previous (incorrect) historic average was biased by recent abundance estimates. A juvenile white perch recruitment index has been developed for each major Virginia tributary to Chesapeake Bay.

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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 2011 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 the manner in which the catch data were analyzed (MD: arithmetic index, VA: geometric index). A baywide index using a geometric mean weighted by river spawning area was developed and proposed 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 2011 program were to:

1. estimate the relative abundance of the 2011 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 (rounds) from 29 June through 6 September 2011. During each round, seine hauls were conducted at 18 index stations and 21 auxiliary stations in the James, York and Rappahannock river systems (Figure 1). Auxiliary sites were added to the survey in 1989 to provide better geographic coverage and increase sample sizes within each river system. Such monitoring was desirable in light of increases in stock size during the 1980s and hypothesized expansion of the nursery ground.

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

Collection efficiency was limited at several sites in 2011 (Table 1). The invasive aquatic weed hydrilla (*Hydrilla verticillata*) restricted sampling at two upper auxiliary sites in the York River drainage (P55 and M52). A seine haul of limited efficiency was completed at P55 during early July (round 1) due to hydrilla obstruction. Hydrilla beds grew and expanded quickly during the summer, and precluded seine hauls from late July through September (rounds 2, 3, 4, and 5) at this site. Station M52 was sampled during all rounds except September (round 5) when severe weather prevented sampling. However, at this site, hauls were performed only within a narrow band of water between the shore and dense hydrilla beds and were restricted to depths less than 0.8 m. Several other sites were not sampled due to severe weather: P45 during early July (round 1) and R75 during late August (round 4). Flood pulses subsequent to Hurricane Irene and Tropical Storm Lee delayed sampling during September (round 5), triggered a landslide that buried our sampling site at R60, and precluded sampling at M37 and M52. J77 was not sampled in early July (round 1) due to vessel mechanical problems.

In this report, comparisons of recruitment indices with prior years are made for the “primary nursery” area only (Colvocoresses 1984) 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 per seine haul (includes catches from the first and second seine haul at each station). 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 (× 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, the rehabilitation of Chesapeake Bay striped bass stocks, and subsequent relaxation of commercial and recreational fisheries regulations in Chesapeake Bay in 1990 (ASMFC 2003) allows us to examine the recruitment of striped bass during 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 1990 – 2011 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.

In previous reports we calculated the historic average as the geometric mean across all stations. However, survey effort has not been equal through time. The number of hauls completed annually has ranged from 42 (1967) to 180 (post-1988) resulting in an estimate of the historic average that is biased by recruitments during years of higher effort. The historic average should be calculated as the mean of annual abundance estimates (n = 39). Equal weight is thus given to years of lower sampling effort, which in this time series happen to be years of low abundance, and years with higher sampling effort, which tended to occur during the latter part of the time series and represent years of higher abundance.

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 2011, 4,189 young-of-year striped bass were collected from 178 seine hauls at index stations and 4,685 individuals were collected from 96 hauls at auxiliary stations (Table 1). Using index-station data from both hauls, the estimated striped bass recruitment index in 2011 is 27.09 (LCI = 22.30, UCI = 32.80; Table 2), which is significantly greater than the newly estimated historic average of 7.11 (LCI = 5.57, UCI = 8.94; Figure 2). Numerically, the 2011 index represents the largest index value ever recorded by the Seine Survey and indicates that a strong year class was produced in 2011. Recruitment failure, as defined by Addendum II of the FMP (ASMFC 2010), did not occur in 2011.

Previously, annual recruitment indices were derived from all collections made during a sampling year, including those made outside of the currently established sampling season (early-July through mid-September). From 1967 to 1973, seine sampling extended into October and occasionally into December (1973). Current sampling concludes in mid-September because sampling efficiency decreases as fish grow and move to deeper waters. Indices calculated by including samples collected after mid-September will therefore be biased low. To uniformly compare annual recruitment indices, only those fish collected during the currently established sampling season are included in the calculation of the recruitment index (Tables 2 – 4). This change resulted in elevated indices from 1967 to 1973 compared with the indices reported for these years in previous reports.

Even with a 30-minute interlude between hauls 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 consistently documented 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. Thus, the annual and historic indices were recalculated using only the first haul at each index station. In 2011, 2,397 young-of-year striped bass were collected resulting in a (first-haul) index of 31.69 (LCI = 24.29, UCI = 41.16, Table 3), which is significantly greater than the recomputed first-haul historic index of 8.45 (LCI = 6.59, UCI = 10.71). It is important to note that all annual striped bass estimates in Table 3 have been adjusted to reflect the index based on single hauls. By developing a 2011 index based solely on the first haul, a more robust (and statistically valid) estimate of juvenile abundance can be determined for Virginia waters. The 2011 Virginia-wide index of 31.69 (LCI = 24.29, UCI = 41.16) is significantly greater than the mean index estimated for the post-recovery period (index = 12.50; LCI = 9.84, UCI = 15.75) further supporting our conclusion that a strong year class was produced in 2011.

As a whole, striped bass recruitment success in the Virginia portion of Chesapeake Bay is generally variable among years and among nursery areas within years. Weak year classes were observed in 1999 and 2002 (Figure 2), but strong year classes were observed in 2000, 2001, 2003 and 2004. This was followed by average recruitment in 2005 and 2006, a strong year class in 2007, and average recruitment from 2008 through 2010. Collections made during 2011 indicate a strong year class was produced regardless of which recruitment measure is used (historic index, first-haul only index, and mean index from 1990 to present day). Since the ASMFC declared striped bass stocks recovered, exceptionally strong year classes have been observed approximately every decade (1993 and 2003); thus, a year of strong recruitment as evidenced in 2011 is not unexpected.

Continued monitoring of regional recruitment success will be important 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; Fabrizio et al. in review.). This may be particularly appropriate in years when individual state indices provide divergent estimates of year-class strength; such divergences may arise due to annual changes in the spatial distribution and contribution of nursery areas throughout the Chesapeake Bay.

Individual Watershed Juvenile Index of Abundance

Recruitment indices observed in 2011 in the three Virginia watersheds were an order of magnitude greater than their respective historic averages. The 2011 index for the James River drainage is 24.25 (LCI = 16.43, UCI = 35.33), compared with the historic James River index of 9.03 (LCI = 6.80, UCI = 11.80; Table 4). The 2011 JAI value for the York River drainage is 32.03 (LCI = 24.86, UCI = 41.08), compared with the historic York River index of 5.37 (LCI = 4.12, UCI = 6.86). And, the 2011 JAI value for the Rappahannock River is 24.44 (LCI = 16.43, UCI = 35.88), compared with the historic Rappahannock River index of 7.31 (LCI = 5.45, UCI = 9.63).

Examination of river-specific JAI values shows some variation between rivers within the same watershed, as evidenced by differences between the James and Chickahominy rivers. The 2011 James River main stem index of 29.94 (LCI = 18.94, UCI = 46.62) is significantly greater than the historic index of 10.18 (LCI = 9.38, UCI = 11.03); however, the 2011 Chickahominy River index of 15.89 (LCI = 7.59, UCI = 31.16) is not significantly different from the historic index of 12.09 (LCI = 10.76, UCI = 13.57). The Chickahominy River represents the only river within the Virginia nursery area which did not exhibit significantly higher abundance of young-of-year striped bass in 2011 compared with the historic average. Catches at Chickahominy River stations were comparable to those observed in 2009 and 2010, and greater than those observed in 2008. Striped bass were predominately captured at C1, located near the confluence of the Chickahominy and James rivers.

Throughout the James River watershed, four of six index sites were characterized by greater- than-average relative abundances compared with their respective historic means, the exceptions being stations J29 and C3 (Table 5). In 2011, catches at C3 were consistently poor; fewer striped bass were captured at this location than from any other index station in the James River drainage. Catches at the Chickahominy River stations were variable throughout the sampling season. Collections at C1 were highest in early July but as expected, declined through time (Table 1), whereas at C3 captures increased during September (round 5). Nearly 70% of all young-of-year striped bass captured from James River index stations were 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 most productive index site sampled in 2011 from Virginia waters.

Catches observed at J36 may have been affected by the need sample upstream of the traditional site by approximately 100 m due to the construction of a private breakwater in 2011 (Figure 3). It is unclear how this small change in sampling location, and presumed altered hydrological flows, may have affected fish distribution at this site; also unclear is the relationship of current and past catches at this location. During 2011 higher-than-average catches were observed at J36 and at 8 other index stations in the James River drainage (13 index stations were sampled in this drainage).

Continuing the trend of higher catches in recent years, the 2011 York River drainage JAI represents a reversal of the decline in the York River index observed between 2004 and 2008 (Figure 4). The JAI for the York River was the highest index of all drainages sampled in 2011 (Table 4). No index sites are located along the main stem of the York River although three auxiliary stations are sampled; the watershed JAI is compiled from sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. The 2011 Pamunkey River JAI of 41.09 (LCI = 32.33, UCI = 52.06) is significantly greater than the historic index of 7.38 (LCI = 6.66, UCI = 8.15) and continues an increasing trend in striped bass recruitment from the low observed in 2008 (Machut and Fabrizio 2009). The 2011 Mattaponi River index (26.66; LCI = 17.86, UCI = 39.31) is significantly higher than the historic average (5.53; LCI = 5.08, UCI = 6.01). The confidence intervals for the 2011 York River drainage JAI do not overlap with those of any previous annual estimates implying that the 2011 year class was the strongest produced within the York River since the inception of the seine survey.

Unlike recent years, catches within the York River watershed were not concentrated primarily at upper-river sections but were evenly distributed throughout the watershed. Catch rates in 2011 were roughly similar between most stations with peak catches observed in July (Table 1). Only M33 and P50 exhibited increases in catch of young-of-year striped bass in the later part of the sampling season (August, September).

Similar to other Virginia nursery grounds, the 2011 Rappahannock River index of 24.44 (LCI = 22.30, UCI = 32.80) is significantly greater than the historic average of 7.31 (LCI = 5.45, UCI = 9.63). Catches in 2011 were greatest at the two uppermost index sites (R50 and R55; Table 1); R50 and R55 have dominated the catches in this drainage for several years. More than 75% of the total catch in the Rappahannock River drainage in 2011 was taken from these two stations.

Unlike recent years in which no individual watershed index values were significantly different from their historic averages, catches from the primary striped bass nursery areas in Virginia during 2011 indicate a broadly distributed and consistently high level of recruitment throughout Virginia waters. This indicates a strong year class was produced in Virginia; a strong recruitment year in the Maryland portion of Chesapeake Bay has also been reported for 2011 (Durell and Weedon 2012). Since 2003, the seine survey has estimated either average or above-average years of recruitment implying that recruitment failure is not presently of concern.

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 changes. 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 2011 with increased catches at upriver stations compared with catches from these same auxiliary stations in recent years (Figures 5 – 8).

Within the James River, upstream sections of the 2011 nursery area contributed more juveniles than in previous years; geometric means at the three upper auxiliary sites were more than five times higher than the historic average for these sites (Table 5). 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 observed (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). The 2011 catch of 80 young-of-year striped bass, over 4 sampling rounds, represents the largest annual catch in this site's short history (6 years). The nursery grounds also extended farther downstream than in previous years with higher-than-average catches at J22 (Table 5). For the first time since 2008, a single striped bass was collected at J12 (Table 1).

All stations in the main stem York River are auxiliary stations. Catches at all York River auxiliary sites were higher than historic averages for these sites (Table 5). Although not detected at Y15 in 2008 and 2009, juvenile striped bass were captured at this site in 2010 and 2011; and, striped bass were captured in greater prevalence as auxiliary stations progressed upriver (Y15, Y28, and P36). Station P36 was particularly productive; more than 2,500 juvenile striped bass were collected during early July (round 1; Figure 7). This is noteworthy as the previous highest catch in one seine haul at this site was 243 individuals. As an auxiliary station, this sampling event is not a component of the JAI computation but further supports our conclusion of strong recruitment for 2011.

We previously suggested that the lack of striped bass at station P55 may have been due to the inability to accurately sample in dense hydrilla vegetation (Hewitt et al. 2009, Machut and Fabrizio 2010). During early July 2011, a single seine haul of limited area between dense hydrilla beds yielded a catch of one fish (Table 1). Given the alteration of habitat observed at P55, it remains difficult to estimate relative abundance at this location. Although hydrilla was also present at M52, enough open space was available inside of the observed hydrilla beds to deploy and retrieve the seine from July through August (rounds 1 through 4); weather precluded September sampling (round 5). Although the area sampled was shallow (haul depths less than 0.8 m), eleven striped bass were collected over four rounds. Striped bass were plentiful at other up-river locations within the James and Rappahannock rivers. It is plausible that in an unaltered state, catches at P55, and to a lesser extent M52, could have been considerably higher. 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. Alternatively, striped bass may be preferentially using the new hydrilla habitat and unavailable to the sampling gear. The continued sampling difficulties at P55, in addition to the catch of striped bass at M52, suggest a need to examine alternative collection methodologies within this region to determine the abundance of juvenile striped bass in nearshore areas of the river where hydrilla is present.

As in recent years, few fish were collected at the lower auxiliary stations in the Rappahannock River. Juvenile striped bass were detected only during early July at R10, and only four fish were captured during early July and early August at R21 (Table 1). Since 1999, few fish were captured at either site. These sites have favorable substrate and no seine obstructions; the consistent low capture rates at R10 and R21 suggest these sites may have lower value as nursery areas in the Rappahannock River. Although few fish were collected at lower auxiliary sites, upriver auxiliary stations in the Rappahannock River were productive in 2011. Annual relative abundance at upriver auxiliary stations were greater than the historic averages for these sites (Table 5). Station R75, added in 2006 to replace R76, exhibited the highest catch rates ever recorded at this site: 43 young-of-year striped bass were collected over four rounds during the 2011 sampling season.

Striped bass occupied auxiliary sites further upstream and in higher abundances during 2011 than in recent years. The broad spatial scale and high catch rates at auxiliary stations provide further evidence that a strong year class was produced in 2011 throughout the Virginia portions of Chesapeake Bay. However, direct comparisons between auxiliary and index sites are problematic due to slightly different sampling protocols (index station catches are reported as an average of two hauls, whereas only a single haul is made at auxiliary stations). Past analyses demonstrate that catches are consistently greater in the first of two hauls at a given site. Because only one haul is made at the auxiliary sites, the figures may overestimate relative abundance at the auxiliary sites relative to the index sites.

Sampling Round Comparison

Considerably more young-of-year striped bass were collected during each round in 2011 than in comparable rounds dating back to 2003. 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. In early July 2011, we collected 1,256 young-of-year striped bass (round 1; Table 6). Typically, catches decrease by 20% between early and late July, but catches in late July of 2011 (round 2) increased slightly (1,275 young-of-year striped bass). Catches in early August (round 3) decreased by nearly 40% relative to late July; although a greater decrease than the historic average decrease between rounds 2 and 3 (Table 6), the magnitude of the 2011 decrease is likely due to the exceptionally high catches observed in late July. A further decrease in catches was observed in late August (round 4; 35% decrease) compared with the historic average decrease of 13.9%. During early September 2011 (round 5), catches decreased 24% relative to late August. Expected decreases in catch rates between late August and early September (Table 6) suggest that high flows from Hurricane Irene and Tropical Storm Lee did not have noticeable changes on the distribution and abundance of young-of-year striped bass.

Environmental Conditions and Potential Relationships to Juvenile Striped Bass Abundance

The distribution of juveniles within the nursery area may be affected by water quality parameters. Although variation in local site conditions preclude direct round-by-round comparisons of environmental and water quality parameters, broad scale patterns can be discussed.

Historically, a well-defined pattern exists with high water temperatures observed during July and temperatures declining as the sampling season progresses. In 2011, water temperatures increased during July to peak in early August (round 3, Table 7). Temperatures during 2011 were more similar to those observed in 2007 and 2008 (Hewitt et al. 2008, Machut and Fabrizio 2009). During September 2011 (round 5), 10% (4 of 38) sampled sites exhibited water temperatures below 25.0^{o}C; in 2010, approximately 50% of sites exhibited temperatures below 25^{o}C in September. Catch rates in 2011 followed the historic pattern with respect to water temperature: most fish (99%) were captured in waters between 25.0 and 34.9^{o}C (Table 8). Water temperature in tidal tributaries reflects not only long-term climate patterns, but also significant day-to-day and river-to-river variation. Shallow shoreline areas 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, the relationship between declining catches and decreasing temperature is considered to be largely the result of a coincident downward progression of both catch rates and water temperature as the survey season progresses (beyond early August) rather than any direct effect of water temperature on juvenile fish distribution.

In 2011, 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 9). No index station exceeded 9.7 ppt salinity although salinity was as high as 17.6 ppt at auxiliary sites (Table 10). This was lower than previous years when salinity approached or exceeded 20 ppt at downstream sites. Table 5 shows the relationship between salinity and juvenile striped bass catches. In 2011, the percentage of catch observed in low salinities (0.0 – 4.9 ppt) was similar to that observed historically (97% in 2011 vs. 93% all years; Table 9). Similarly, the catch in mid-range salinities (5.0 – 9.9 ppt) was similar to the historic average (3% in 2011 vs. 6% all years). Although juvenile striped bass were captured at downstream auxiliary sites in areas with average salinities of 15.4 ppt, catches were distinctly lower than those observed in upstream, lower salinity areas.

No dissolved oxygen (DO) levels measured during the 2011 survey were considered hypoxic (less than 2-3 mg/L; Table 11). Within the primary nursery area, approximately 30% of measurements (52 of 171 measurements) exhibited DO levels that were more than one standard error (SE) less than the site's historic average. Lower-than-average values generally occurred inconsistently through time and across sampling sites.

All DO values at Rappahannock River stations from R50 upriver during September (round 5) were more than one SE below their respective historic averages. This was likely the result of the Tropical Storm Lee flood pulse that delayed sampling and which increased turbidity and deposited significant debris into the nearshore zone. 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 SE less than the mean at a given station (shaded values) do not necessarily correspond with low catches at that station (Table 1). For example, although DO concentrations during early September (round 5) were more than one SE below the historic average at station P50, striped bass catches at this site were similar to those observed in earlier rounds.

Striped bass recruitment variability may be partially explained by climate patterns during winter and spring preceding our sampling (Wood 2000). Winter (December - February 2011) and spring (March - May 2011) precipitation was characterized as “above normal” (NCDC 2012); summer rainfall (June - August 2011) was “near normal” and salinities were similar to or below historic averages (Table 5). In previous years, at least one season was classified as “below normal” (Machut and Fabrizio 2009, 2010, 2011). Appropriate climatological conditions may have provided suitable environmental conditions for a strong year class in 2011. Striped bass abundance has been positively associated with high flows during the preceding winter (Wingate and Secor 2008). It is unclear if finer-scale climatic patterns are important or if other factors exert effects that may be of greater magnitude on variations in recruitment of juvenile striped bass. 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 2011, nearly 86,000 individuals comprising 69 species were collected (Table 12). This represents a 76% increase in the number of fish observed relative to 2010 collections. The four most common species were white perch (*Morone americana*), striped bass, spottail shiner (*Notropis hudsonius*) and Atlantic silverside (*Menidia menidia*). Consistent collection of several common species occupying the nearshore zone allows for the calculation of additional abundance indices.

Several annual indices reported to the ASMFC to fulfill compliance requirements for species of management importance are presently derived from data collected by 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.

One of the most commonly captured species by the seine survey is the white perch, which supports important recreational and commercial fisheries in Chesapeake Bay (Murdy et al. 1997, NMFS 2012). The general overlap in spawning times and use of nursery grounds by white perch and striped bass suggest that the seine survey may adequately sample juvenile white perch and that calculation of a recruitment index for this species is appropriate. Examination of raw data suggests high annual variability in white perch catches. In years of low abundance (e.g., 1985) the proportion of hauls containing white perch may be as low as 40%; whereas in years of high abundance (e.g., 2011), white perch can be found in 95% of hauls. A delta-lognormal index was developed to address this variation and to accommodate data with a high proportion of zero hauls. We used Cox's method (Fletcher 2008) to estimate the mean abundance based on the delta-lognormal distribution, and calculated 95% confidence intervals from 1,000 bootstrap samples as described by Fletcher (2008). This approach remains under development, so we report only the means here.

From early July through September 2011, 24,086 juvenile white perch were collected from 30 sampling stations. Because migration of white perch between Virginia tributaries is unlikely (Mulligan and Chapman 1989), we assumed each tributary supported an individual stock and reported indices of abundance for each river (Figures 9 - 12). Generally, river-specific indices suggest a strong year class of white perch was produced throughout Virginia in 2011. Numerically, the highest annual JAI values for white perch were observed in the James, Mattaponi, and Rappahannock rivers in 2011. The Pamunkey River index was the highest recorded since 1996. At present, the river specific indices developed for white perch should be considered preliminary and will be revised in subsequent reports. Alternative approaches for estimating confidence intervals will be examined. The white perch JAI developed by the seine survey compliments the juvenile white perch index currently reported by the Juvenile Fish Trawl Survey (Tuckey and Fabrizio 2011); unlike the index reported by the trawl survey, the seine survey index is based on catches from both tidal brackish and freshwater zones.

Additional indices have been computed as supplementary information; these include spottail shiner (Table 13), Atlantic silverside (Table 14), inland silverside (*Menidia beryllina*; Table 15), and banded killifish (*Fundulus diaphanous*; Table 16).

The 2011 indices for spottail shiner, inland silverside, and banded killifish are significantly higher than the historic averages for these species. There was no significant difference between the 2011 Atlantic silverside index and the historic average. 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. Higher-than-average indices for striped bass, spottail shiner, inland silverside, and banded killifish suggest that conditions present in Virginia tidal tributaries were broadly beneficial to a wide range of species in 2011. 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 2012. Where appropriate, we will compare our survey-derived indices with those calculated from the VIMS trawl survey.

CONCLUSION

The 2011 juvenile abundance index (JAI) for striped bass (27.09) is significantly higher than the historic average (7.11) for Virginia waters. Abundance indices from all individual rivers were significantly higher than their respective historic averages except for the Chickahominy River which was not significantly different from the historic average. This suggests that striped bass in Virginia waters produced a strong year class in 2011 and spawning success was consistent across broad spatial scales. 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. During 2012, alternative approaches for estimating confidence intervals for the white perch index will be examined. Additionally, the examination of juvenile striped bass relative condition, from weight measurements started in 2009, is underway with the goal of including annual estimates of relative condition in the 2012 annual report.

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Table 1. Catch of young-of-year striped bass per seine haul in 2011. Two hauls were completed at each index station (bold). Sampling was completed in July (rounds 1 and 2), August (rounds 3 and 4), and September (round 5).

Drainage															Round
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Total
	Round	1	1	2	4/1	16/20	46	102/94	3/0	66/107	38	10/13	154	8	ns*	685
		2	0	34	14/6	58/65	38	72/19	2/0	27/73	56	20/33	39	9	27	592
		3	0	2	0/0	8/3	10	15/15	2/2	89/81	34	19/4	153	44	40	521
		4	0	18	3/ns	47/16	13	14/12	1/3	106/19	20	17/2	49	26	10	376
		5	0	11	6/12	3/2	16	2/7	8/7	48/36	59	4/2	12	26	3	264
															James Total	**2438**
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	18	4	66	2533	15/16	43/ns	27/20	1						2743
		2	2	0	27	132	20/20	19/15	35/23	ns						293
		3	0	0	14	189	20/19	25/15	35/25	ns						342
		4	0	1	16	60	21/16	10/3	45/36	ns						208
		5	0	3	13	72	11/5	5/7	41/21	ns						178
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				68/56	10	64/31	50/10	2/13	6					310
		2				11/2	16	208/154	14/35	12/7	4					463
		3				24/14	19	3/6	44/9	2/7	0					128
		4				6/1	3	4/3	16/13	6/1	1					54
		5				49/11	ns	12/8	10/2	8/4	ns					104
															York Total	**4823**
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75		
	Round	1	2	1	9/6	15/14	156	21/22	76/38	139/65	2	18	7	35		626
		2	0	0	16/4	5/1	115	12/15	44/66	60/88	6	11	4	6		453
		3	0	3	7/7	3/13	64	21/23	12/23	107/72	14	3	9	0		381
		4	0	0	6/5	1/2	5	8/10	10/5	27/8	1	0	5	ns		93
		5	0	0	1/1	1/0	2	0/0	8/8	17/14	ns	0	6	2		60
															Rappahannock Total	**1613**
ns = not sampled															2011 Catch	**8874**

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	191	1.18	1.00	5.17	3.20-7.86	42
1968	184	1.04	0.92	4.15	2.68-6.06	50
1969	193	0.97	0.94	3.73	2.39-5.46	55
1970	345	1.39	1.11	6.88	4.52-10.06	56
1971	165	0.90	0.90	3.34	2.17-4.81	60
1972	84	0.45	0.59	1.28	0.87-1.75	90
1973	133	0.60	0.82	1.86	1.12-2.76	70
1980	228	0.74	0.90	2.52	1.68-3.53	89
1981	165	0.52	0.69	1.56	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	12.40-19.80	144
1988	1348	1.47	1.13	7.64	6.10-9.45	180
1989	1978	1.78	1.12	11.23	9.15-13.70	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	1.24	7.35	5.72-9.31	180
1993	2323	2.19	0.98	18.11	15.35-21.30	180
1994	1510	1.72	1.03	10.48	8.66-12.60	180
1995	926	1.22	1.05	5.45	4.33-6.75	180
1996	3759	2.41	1.23	23.00	18.80-28.10	180
1997	1484	1.63	1.10	9.35	7.59-11.40	180
1998	2084	1.92	1.14	13.25	10.80-16.10	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
2011	4189	2.56	1.19	27.09	22.30-32.80	178
Overall (1967-2011)	50732	1.41	0.56	7.11	5.57-8.94	39

Table 3. Catch of young-of-year striped bass in the primary nursery areas of Virginia using only the 1st haul (Rago et al. 1995) summarized by year, 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	191	1.18	1.00	5.17	3.20-7.86	42
1968	184	1.04	0.92	4.15	2.68-6.06	50
1969	193	0.97	0.94	3.73	2.39-5.46	55
1970	345	1.39	1.11	6.88	4.52-10.06	56
1971	165	0.90	0.90	3.34	2.17-4.81	60
1972	84	0.45	0.59	1.28	0.87-1.75	90
1973	133	0.60	0.82	1.86	1.12-2.76	70
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
2011	2397	2.70	1.17	31.69	24.29-41.16	90
Overall (1967-2011)	31421	1.55	0.60	8.45	6.59-10.71	39
Overall (1990-2011)	24838	1.87	0.47	12.50	9.84-15.75	22

Table 4. Catch of young-of-year striped bass per seine haul in the primary nursery area in 2011 summarized by drainage and river.

	2011				All Years Combined (1967-2011)			
Drainage River	Total Fish	Index	C.I. (±2 SE)	N (hauls)	Total Fish	Index	C.I. (±2 SE)	N (hauls)
JAMES	1440	24.25	16.43 – 35.33	59	20304	9.03	6.80 – 11.80	39
James	1060	29.94	18.94 – 46.62	39	12487	10.18	9.38 – 11.03	39
Chickahominy	380	15.89	7.59 – 31.16	20	7817	12.09	10.76 – 13.57	39
YORK	1613	32.03	24.86 – 41.08	69	14745	5.37	4.12 – 6.86	39
Pamunkey	613	41.09	32.33 – 52.06	29	7366	7.38	6.66 – 8.15	39
Mattaponi	1000	26.66	17.86 – 39.31	40	7379	5.53	5.08 – 6.01	39
RAPPAHANNOCK	1136	24.44	16.43 – 35.88	50	15683	7.31	5.45 – 9.63	39
Overall	4189	27.09	22.30 – 32.80	178	50732	7.11	5.57 – 8.94	39

Table 5. Striped bass indices recorded at all survey stations in 2011 compared to historic (1967 – 2011) 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.	14.5	7.9	4.8	2.5	1.8	1.5	1.4	0.6	0.3	0.2	0.2	0.1	0.2
		Index	1.9	14.9	7.3	12.9	14.0	17.1	7.7	21.4	17.2	6.3	9.8	7.3	2.8
	2011	Avg. Sal.	12.5	8.3	5.5	3.0	1.6	1.8	1.6	0.5	0.3	0.2	0.2	0.2	0.2
		Index	0.3	19.1	7.2	31.4	47.2	45.7	4.6	129.9	88.1	20.3	128.5	42.6	31.9
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1967-2010	Avg. Sal.	16.6	13.8	10.7	4.2	1.7	0.7	0.4	0.3					
		Index	1.3	1.8	5.1	11.9	4.3	9.1	13.2	4.8					
	2011	Avg. Sal.	15.4	12.8	10.4	4.7	2.3	0.7	0.3	0.6*					
		Index	2.8	2.5	50.6	443.3	35.0	27.9	67.8	2.3					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2010	Avg. Sal.				4.5	2.4	1.2	0.4	0.3	0.1				
		Index				6.2	8.6	6.7	5.4	4.5	1.5				
	2011	Avg. Sal.				3.2	1.6	0.7	0.1	0.1	0.1				
		Index				31.1	22.9	39.6	34.1	11.5	4.3				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	1967-2010	Avg. Sal.	14.2	12.9	9.9	5.4	3.2	2.0	1.0	0.6	0.2	0.2	0.1	0.1	
		Index	0.6	0.8	2.7	3.5	5.9	8.4	13.1	42.2	6.2	4.2	3.2	2.8	
	2011	Avg. Sal.	12.4	11.1	8.3	3.6	1.6	0.8	0.3	0.2	0.2	0.1	0.1	0.1	
		Index	0.6	1.2	11.5	7.4	64.4	19.2	45.1	97.9	9.1	6.6	13.7	9.7	

* - only sampled during early July (round 1)

Table 6. Catch of young-of-year striped bass in the primary nursery areas of Virginia in 2011 summarized by sampling round and month.

	2011					All Years Combined (1967-2011)				
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)	35	1256	46.94	30.69 – 71.19		39	15716	11.27	8.73 – 14.40	
(2nd)	36	1275	43.40	28.38 – 65.80	-1.5 %	39	12474	8.36	6.39 – 10.78	20.6%
Aug. (3rd)	36	774	26.65	17.44 – 40.17	39.3%	39	9138	6.58	5.04 – 8.44	26.7%
(4th)	35	503	18.80	12.78 – 27.22	35.0%	35	7870	6.20	4.71 – 8.01	13.9%
Sept. (5th)	36	381	13.73	9.04 – 20.37	24.3%	32	5534	5.07	3.89 – 6.48	29.7%

Table 7. Water temperature (°C) recorded at seine survey stations in 2011. The York drainage includes the Pamunkey and Mattaponi rivers. Index stations are indicated by bold font. Red colors denote temperatures over 30°C; blue colors denote temperatures below 25°C.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77
	Round	1	33.2	35.0	31.4	27.1	33.0	29.4	29.1	31.1	27.8	27.0	28.8	30.2	ns
		2	33.5	33.5	31.4	27.4	30.6	29.9	29.3	30.5	29.1	28.5	29.0	30.8	30.9
		3	32.7	32.5	32.5	29.5	32.4	31.8	31.6	33.1	31.7	30.8	32.7	34.3	34.2
		4	29.5	27.3	31.0	27.5	29.4	28.4	28.8	30.2	29.2	28.0	29.7	31.2	29.9
		5	26.3	27.9	27.1	25.4	27.2	26.8	26.6	27.3	26.0	25.7	28.0	28.7	28.8
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	32.4	30.6	27.8	28.9	29.0	29.7	29.6	30.5					
		2	30.6	30.7	29.3	29.9	30.6	31.2	31.1	ns					
		3	30.4	30.2	29.4	30.9	31.2	32.1	31.9	ns					
		4	26.9	26.3	27.7	29.1	29.2	30.1	29.2	ns					
		5	25.9	27.1	25.3	25.6	24.8	25.2	25.3	ns					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				28.7	29.1	28.2	29.6	31.1	30.6				
		2				30.5	30.7	29.6	31.9	32.5	33.0				
		3				32.0	31.8	31.7	32.2	33.7	34.6				
		4				29.0	29.1	28.1	29.1	31.2	30.1				
		5				25.9	ns	25.6	25.8	25.9	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	Round	1	30.5	28.8	26.4	27.6	28.2	29.5	27.9	28.5	28.7	27.6	28.0	28.6	
		2	31.5	29.4	26.6	28.9	31.8	30.6	29.3	30.1	30.2	30.4	30.6	31.1	
		3	31.2	31.3	30.3	30.3	30.9	32.0	33.1	34.2	32.6	34.1	33.4	34.1	
		4	30.8	30.0	26.9	28.1	29.1	30.0	28.8	29.7	28.9	28.3	29.9	ns	
		5	28.6	27.8	25.2	26.7	27.4	28.6	24.4	25.1	ns	25.8	24.6	24.6	

ns = no sample taken

Table 8. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2011 summarized by water temperature.

	2011				All Years Combined (1967-2011)			
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	54	2.30	0.66 – 4.85	20
20.0 - 24.9	32	17.64	12.70 – 24.22	4	2585	3.96	3.48 – 4.47	637
25.0 - 29.9	2527	25.89	19.80 – 33.67	105	38343	8.81	8.40 – 9.24	4091
30.0 - 34.9	1630	29.71	22.15 – 39.62	69	9375	9.99	9.01 –11.05	878
Overall	4189	27.09	22.30 – 32.80	178	50732	8.18	7.85 – 8.52	5690

Table 9. Catch of young-of-year striped bass per seine haul in the primary nursery areas of Virginia in 2011 summarized by salinity.

	2011				All Years Combined (1967-2011)			
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	4063	30.29	24.75 – 36.96	159	47100	9.49	9.08 – 9.91	4712
5.0 - 9.9	126	10.07	5.83 – 16.53	19	3240	4.47	3.98 – 5.00	723
10.0 - 14.9	N/A			0	390	2.11	1.69 – 2.57	228
15.0 - 19.9	N/A			0	2	0.12	0.00 – 0.29	28
Overall	4189	27.09	22.30 – 32.80	178	50732	8.18	7.85 – 8.52	5691

Table 10. Salinity (ppt) recorded at seine survey stations in 2011. 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	13.3	6.4	5.8	2.6	1.4	1.6	1.3	0.5	0.3	0.4	0.5	0.4	ns
		2	13.1	6.6	3.2	1.2	0.5	0.7	0.6	0.2	0.1	0.1	0.1	0.1	0.1
		3	15.2	10.0	6.8	3.3	1.9	1.8	1.6	0.4	0.2	0.1	0.2	0.2	0.1
		4	16.0	10.1	6.9	4.6	2.6	3.0	2.6	1.0	0.5	0.2	0.2	0.2	0.2
		5	5.0*	8.6	5.7	3.1	1.7	2.1	1.8	0.6	0.3	0.2	0.2	0.2	0.2
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	14.8	13.3	12.2	4.8	2.1	0.8	0.6	0.6					
		2	14.0	11.3	8.4	2.7	1.2	0.3	0.1	ns					
		3	16.9	14.6	12.7	7.3	3.5	1.1	0.3	ns					
		4	17.6	15.1	12.9	6.3	3.6	1.1	0.6	ns					
		5	13.9	9.8	5.9	2.2	0.9	0.3	0.1	ns					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				3.1	0.8	0.9	0.3	0.3	0.2				
		2				2.3	0.7	0.3	0.1	0.1	0.0				
		3				5.6	2.6	1.1	0.1	0.1	0.0				
		4				4.8	2.3	1.1	0.2	0.1	0.0				
		5				0.1	ns	0.0	0.0	0.0	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	Round	1	11.4	11.1	8.4	3.9	0.8	0.4	0.1	0.1	0.1	0.1	0.1	0.1	
		2	11.5	10.5	7.3	3.0	1.2	0.7	0.3	0.3	0.3	0.2	0.3	0.1	
		3	12.8	11.8	9.7	4.6	2.6	1.2	0.3	0.1	0.1	0.1	0.1	0.1	
		4	13.5	12.0	9.4	4.6	2.4	1.5	0.6	0.3	0.1	0.1	0.1	ns	
		5	12.6	10.1	6.6	1.7	1.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0	

ns = no sample taken; * = sampling site directly downstream from Lake Maury outflow after heavy rain event

Table 11. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2011. The York drainage includes the Pamunkey and Mattaponi rivers. Shaded values are more than one standard error (SE) less than the mean dissolved oxygen concentrations recorded at that station from 1989 to 2011. 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	--	--	--	--	--	--	--	--	6.3	7.0	8.4	6.4	ns
		2	7.0	7.1	6.0	6.2	7.0	7.9	5.5	6.4	6.2	6.8	8.5	7.1	5.2
		3	7.2	7.4	6.3	5.7	6.3	6.2	5.7	8.4	6.2	6.4	--	6.6	5.2
		4	7.8	7.2	7.7	5.6	7.0	7.2	5.4	6.1	5.2	7.5	10.5	6.4	5.7
		5	6.7	7.1	7.3	6.1	7.7	6.8	6.0	6.6	5.1	7.1	10.8	6.1	5.9
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	--	6.9	5.0	5.3	6.1	6.4	5.1	7.6					
		2	5.6	5.5	5.4	5.7	6.5	6.5	5.5	ns					
		3	6.2	4.8	5.4	3.5	4.2	5.5	5.0	ns					
		4	4.6	5.5	5.4	4.6	5.5	6.4	5.6	ns					
		5	6.1	7.0	6.1	5.3	5.6	4.8	3.8	ns					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				3.9	4.5	4.0	5.2	5.7	5.8				
		2				4.0	4.1	4.5	5.4	5.7	6.4				
		3				4.4	4.6	5.5	6.0	6.3	8.2				
		4				4.5	5.0	4.9	5.5	6.6	6.5				
		5				3.5	ns	6.9	5.0	5.1	ns				
RAPPAHANNOCK		Station	R10	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	Round	1	8.7	6.4	5.4	6.1	8.3	7.7	6.4	7.0	4.7	7.4	7.8	6.1	
		2	8.2	7.0	5.4	6.8	5.9	8.2	6.3	6.8	6.2	7.1	8.6	--	
		3	6.6	7.2	5.5	5.5	6.3	8.7	7.6	6.2	--	--	--	--	
		4	7.5	7.2	6.6	7.0	8.1	8.7	7.1	7.6	6.3	7.8	6.4	ns	
		5	8.2	7.4	7.1	6.7	8.2	7.8	5.0	5.1	ns	5.2	3.7	4.4	

ns = no sample taken, -- = YSI probe inoperable

Table 12. Species collected during the 2011 survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Morone americana	white perch	32082
Morone saxatilis	striped bass	8874
Notropis hudsonius	spottail shiner	8365
Menidia menidia	Atlantic silverside	4831
Fundulus heteroclitus	mummichog	4566
Anchoa mitchilli	bay anchovy	3548
Alosa aestivalis	blueback herring	3534
Hybognathus regius	eastern silvery minnow	3119
Trinectes maculatus	hogchoker	2613
Fundulus diaphanus	banded killifish	2426
Membras martinica	rough silverside	2284
Brevoortia tyrannus	Atlantic menhaden	2044
Menidia beryllina	inland silverside	1768
Dorosoma cepedianum	gizzard shad	1160
Alosa sapidissima	American shad	828
Ictalurus furcatus	blue catfish	808
Leiostomus xanthurus	spot	754
Alosa pseudoharengus	alewife	398
Fundulus majalis	striped killifish	363
Mugil curema	white mullet	211
Dorosoma petenense	threadfin shad	184
Notropis analostanus	satinfin shiner	164
Etheostoma olmstedi	tessellated darter	125
Lepomis macrochirus	bluegill	119
Ictalurus punctatus	channel catfish	108
Perca flavescens	yellow perch	76
Bairdiella chrysoura	silver perch	75
Strongylura marina	Atlantic needlefish	65
Micropogonias undulatus	Atlantic croaker	60
Alosa mediocris	hickory shad	51
Lepomis gibbosus	pumpkinseed	47
Gambusia affinis	mosquitofish	43
Menticirrhus saxatilis	northern kingfish	42
Anchoa hepsetus	striped anchovy	28
Cynoscion regalis	weakfish	26
Morone saxatilis age 1+	striped bass - age 1+	25
Anguilla rostrata	American eel	24

Table 12 (cont'd.)

Scientific Name	Common Name	Total Caught
Micropterus salmoides	largemouth bass	20
Mugil cephalus	striped mullet	20
Micropterus punctulatus	spotted bass	13
Notemigonus crysoleucas	golden shiner	12
Lepomis auritus	redbreast sunfish	10
Enneacanthus gloriosus	bluespotted sunfish	9
Lepisosteus osseus	longnose gar	7
Carpiodes cyprinus	quillback	7
Ictalurus catus	white catfish	7
Syngnathus fuscus	northern pipefish	5
Gobiosoma bosci	naked goby	4
Micropterus dolomieui	smallmouth bass	4
Scomberomorus maculatus	Spanish mackerel	4
Ictalurus nebulosus	brown bullhead	3
Peprilus alepidotus	harvestfish	3
Synodus foetens	inshore lizardfish	3
Elops saurus	ladyfish	3
Paralichthys dentatus	summer flounder	3
Symphurus plagiusa	blackcheek tonguefish	2
Pomatomus saltatrix	bluefish	2
Sphoeroides maculatus	northern puffer	2
Cyprinodon variegatus	sheepshead minnow	2
Moxostoma macrolepidotum	shorthead redhorse	2
Lepomis spp	Lepomis spp	2
Pomoxis nigromaculatus	black crappie	1
Esox niger	chain pickerel	1
Cyprinus carpio	common carp	1
Rhinoptera bonasus	cownose ray	1
Caranx hippos	crevalle jack	1
Trachinotus carolinus	Florida pompano	1
Gobiidae spp	gobies	1
Cynoscion nebulosus	spotted seatrout	1
Noturus gyrinus	tadpole madtom	1
	Total	**85996**

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
2011	6194	3.20	1.41	23.50	17.84-30.85	117
Overall (1989-2011)	68027	2.29	0.45	8.84	7.14-10.89	23

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	1.49	1.57	3.42	1.93-5.68	58
1990	1430	1.47	1.46	3.33	1.97-5.31	60
1991	2532	2.53	1.71	11.51	6.89-18.84	55
1992	5564	2.88	2.08	16.79	9.39-29.45	60
1993	2166	2.21	1.80	8.12	4.71-13.56	59
1994	2174	1.98	1.73	6.26	3.64-10.35	60
1995	2701	2.43	1.81	10.39	6.11-17.26	59
1996	4666	2.50	2.17	11.24	5.96-20.52	59
1997	973	1.83	1.48	5.26	3.24-8.23	58
1998	2182	2.61	1.60	12.64	8.02-19.64	60
1999	6227	3.37	1.50	28.03	18.49-42.23	57
2000	2936	2.83	1.72	15.99	9.81-25.71	58
2001	3487	2.92	1.69	17.48	11.02-27.41	62
2002	4582	3.48	1.53	31.38	20.82-47.04	60
2003	3470	2.16	2.15	7.63	3.95-14.04	60
2004	1473	1.76	1.79	4.78	2.64-8.19	60
2005	1843	2.48	1.50	10.97	7.18-16.52	62
2006	2613	2.56	1.68	11.96	7.52-18.72	64
2007	2021	2.68	1.51	13.61	8.84-20.70	58
2008	3107	2.04	1.78	6.71	3.93-11.06	63
2009	2618	2.76	1.68	14.80	9.35-23.13	63
2010	1347	2.38	1.26	9.78	6.87-13.78	64
2011	2953	2.63	1.80	12.94	7.87-20.92	63
Overall (1989-2011)	63946	2.43	0.52	10.40	8.18-13.17	23

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
2011	1334	1.32	1.27	2.76	1.95-3.79	110
Overall (1989-2011)	13759	0.97	0.33	1.65	1.31-2.03	23

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
2011	1920	1.95	1.95	6.00	4.25-8.32	97
Overall (1989-2011)	14570	1.06	0.49	1.88	1.34-2.54	23

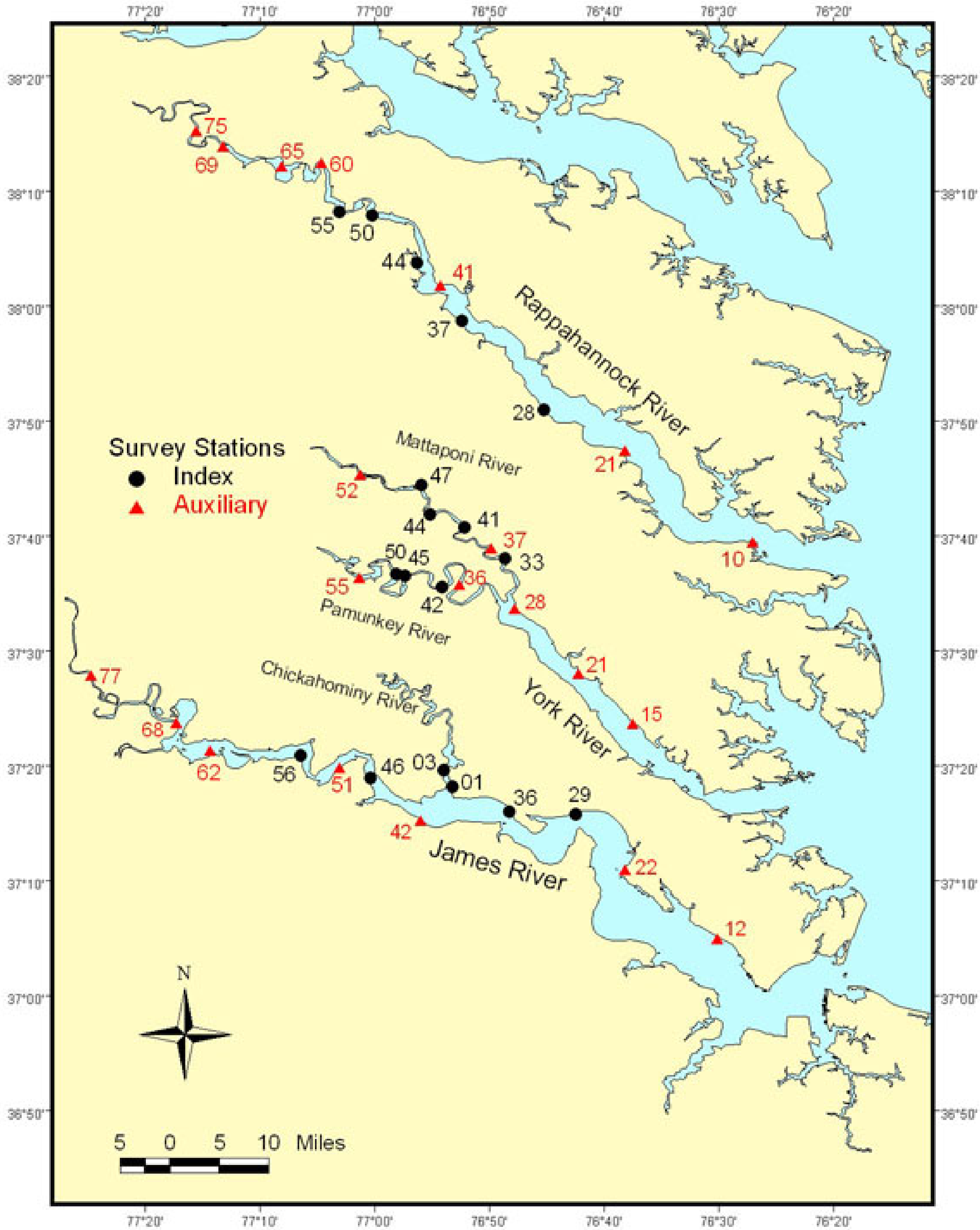

Figure 1. Juvenile striped bass seine survey stations. Numeric portion of station designation indicates approximate river mile from mouth.

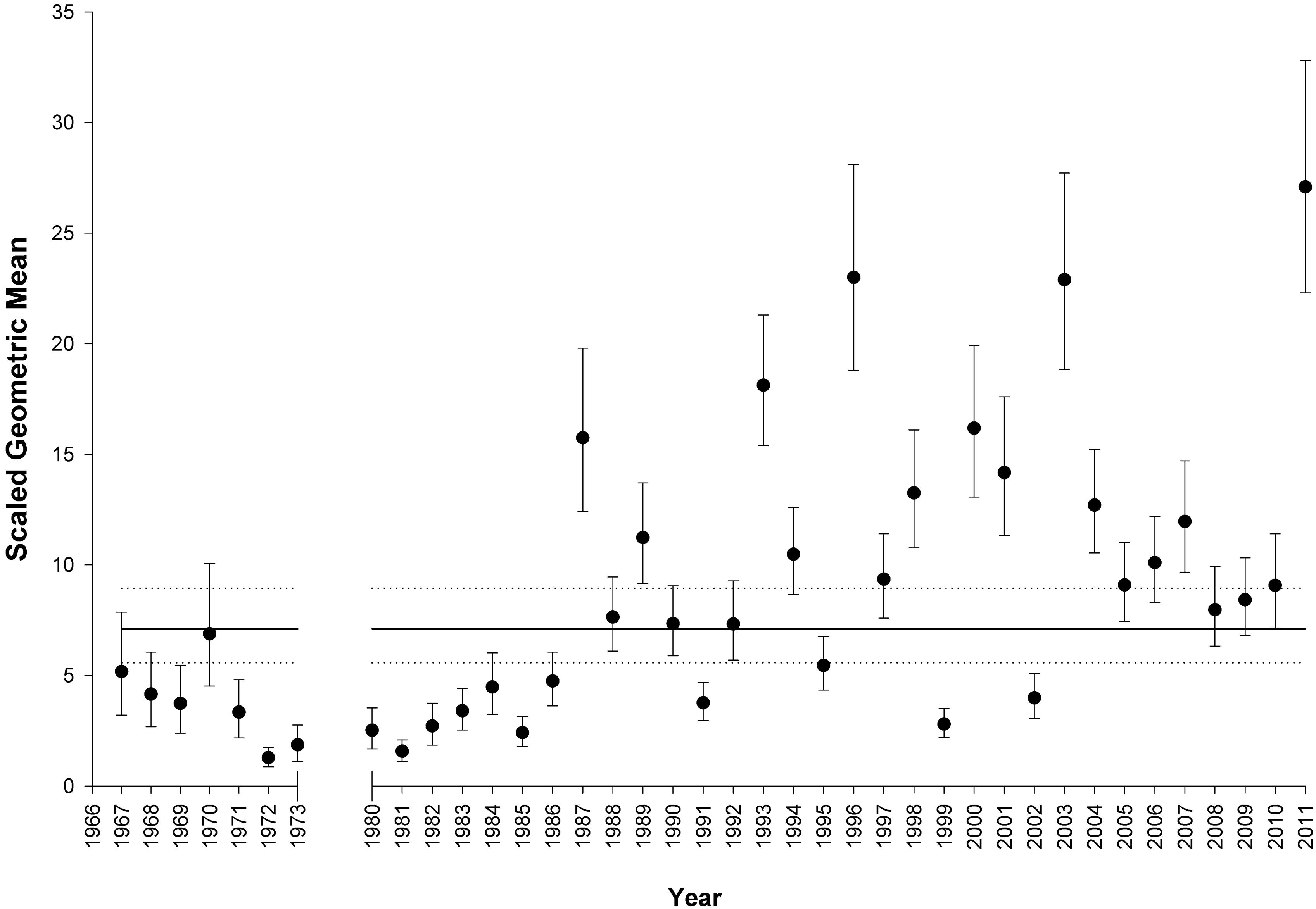

Figure 2. Scaled geometric mean of young-of-year striped bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by + 2 standard errors of the mean. Horizontal lines indicate the historical geometric mean (solid) and confidence intervals (dotted) for 1967-2011.

Figure 3. New breakwater constructed at J36 on the James River overlaying the historic sampling location. For 2011, the seine location was moved approximately 100m upstream (just beyond the dock in the right background).

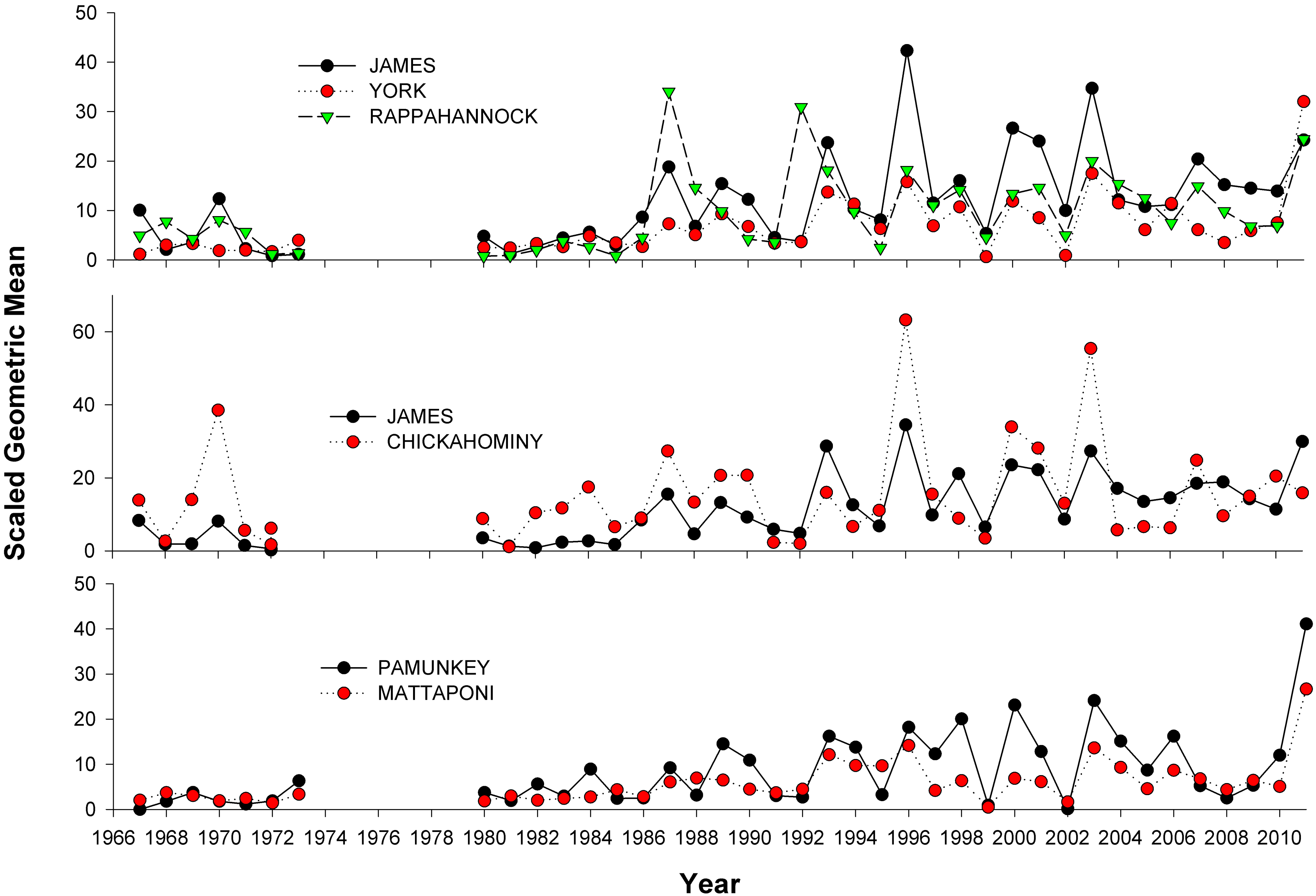

Figure 4. Scaled geometric mean of young-of-year striped bass in the primary nursery areas of Virginia (index stations) by drainage and river.

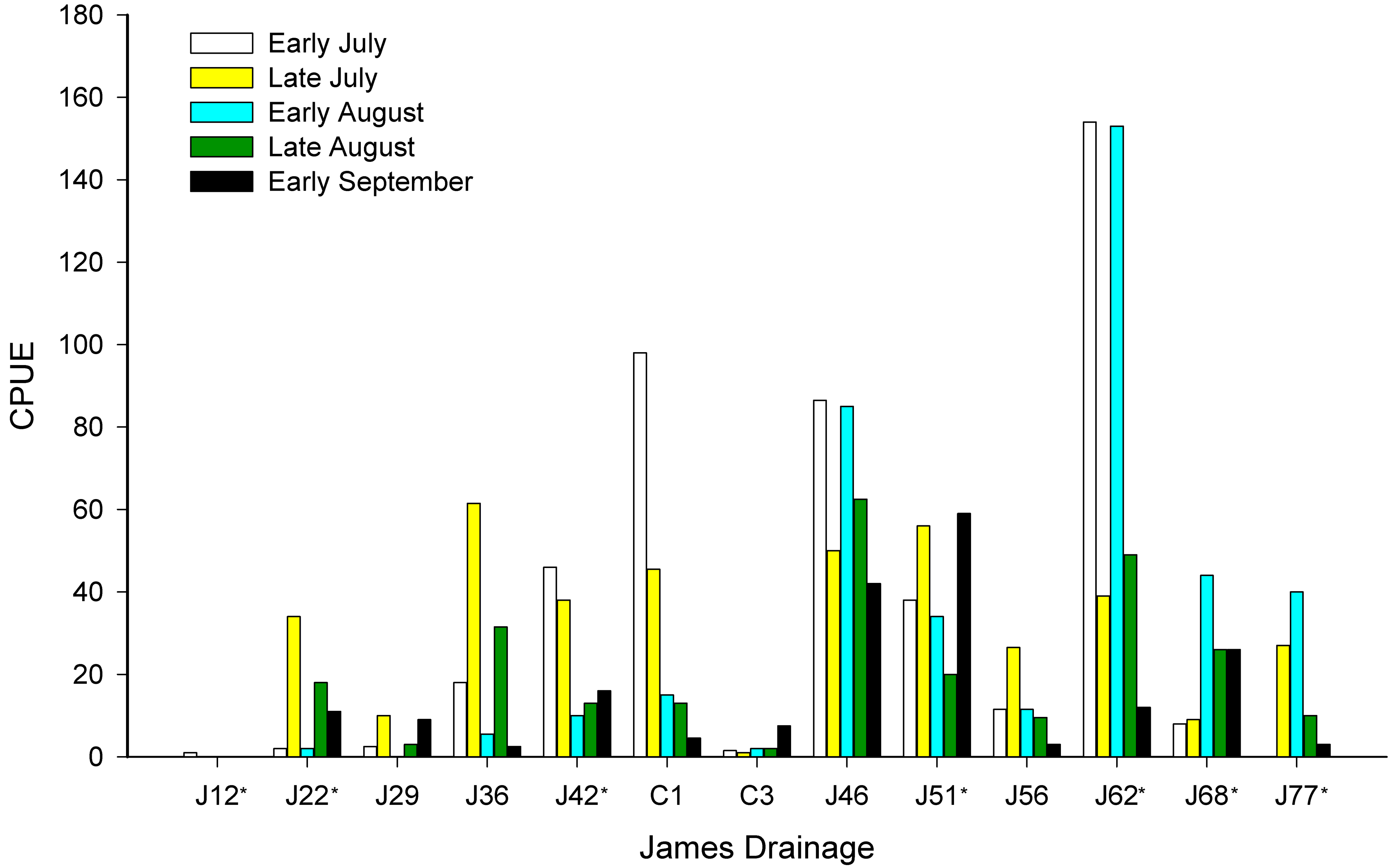

Figure 5. Catch of young-of-year striped bass by station in the James River drainage in 2011. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at J77 during early July.

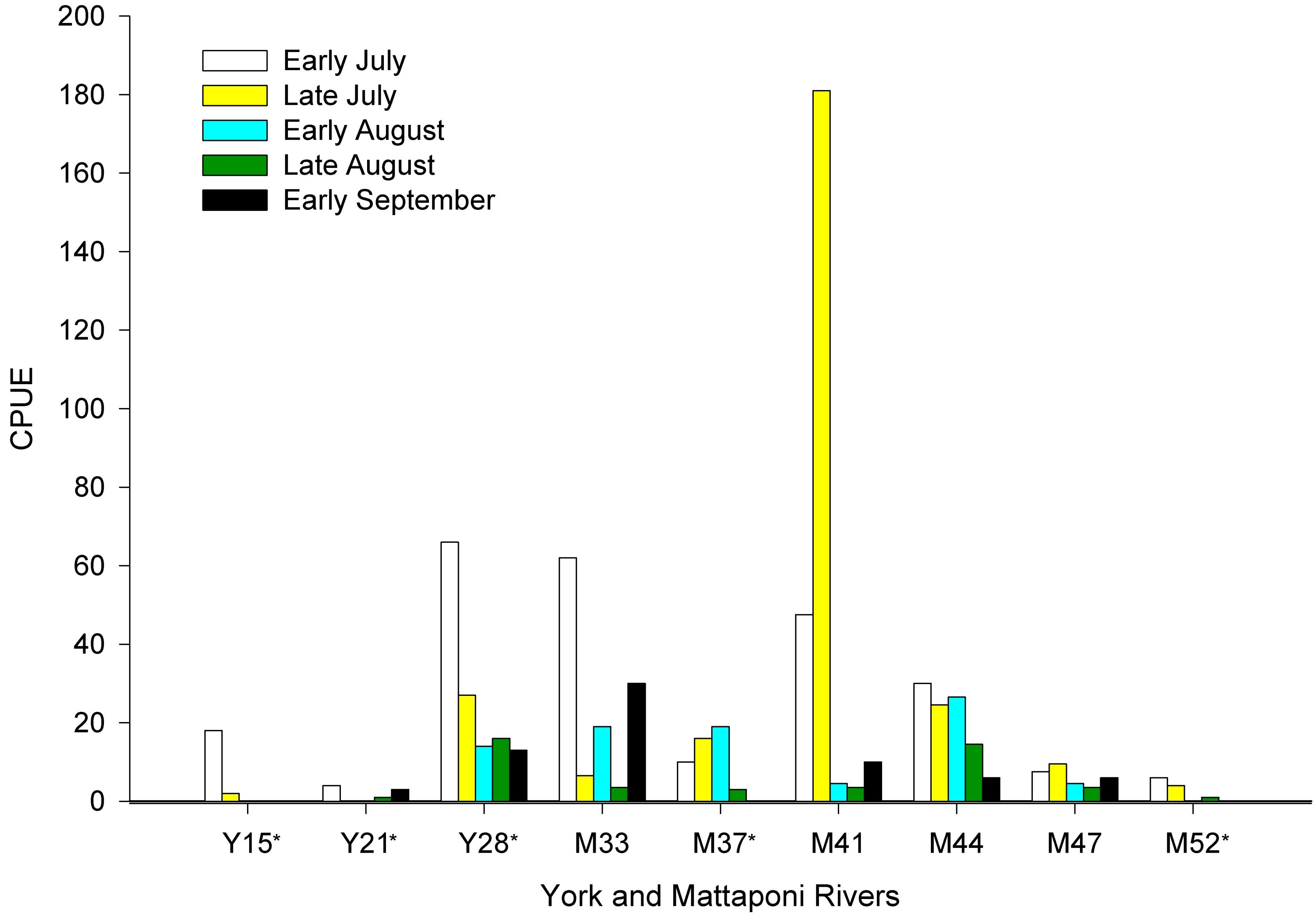

Figure 6. Catch of young-of-year striped bass by station in the York and Mattaponi rivers in 2011. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at M37 and M52 during early September.

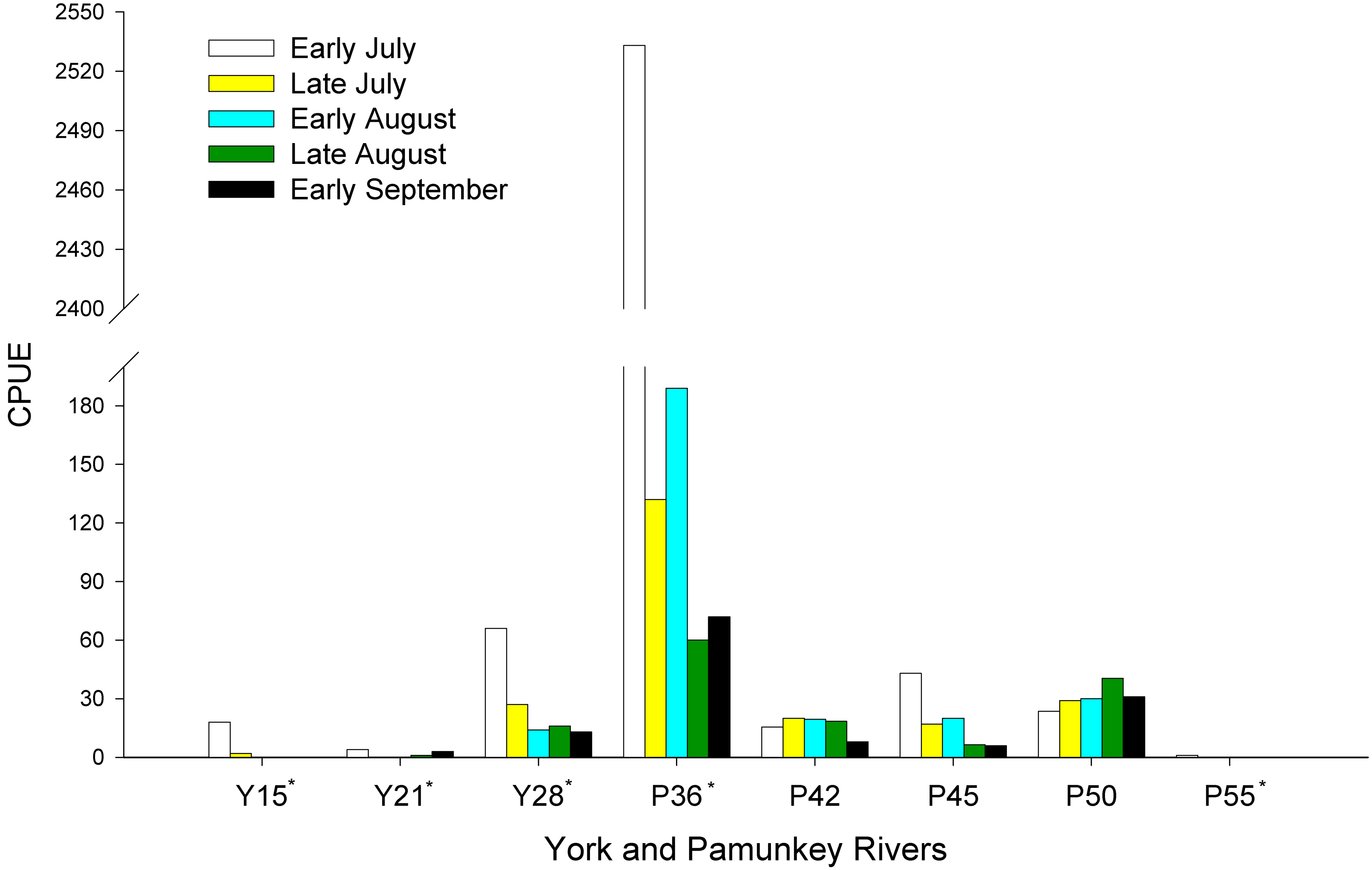

Figure 7. Catch of young-of-year striped bass by station in the York and Pamunkey rivers in 2011. Iindex station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at P55 after early July.

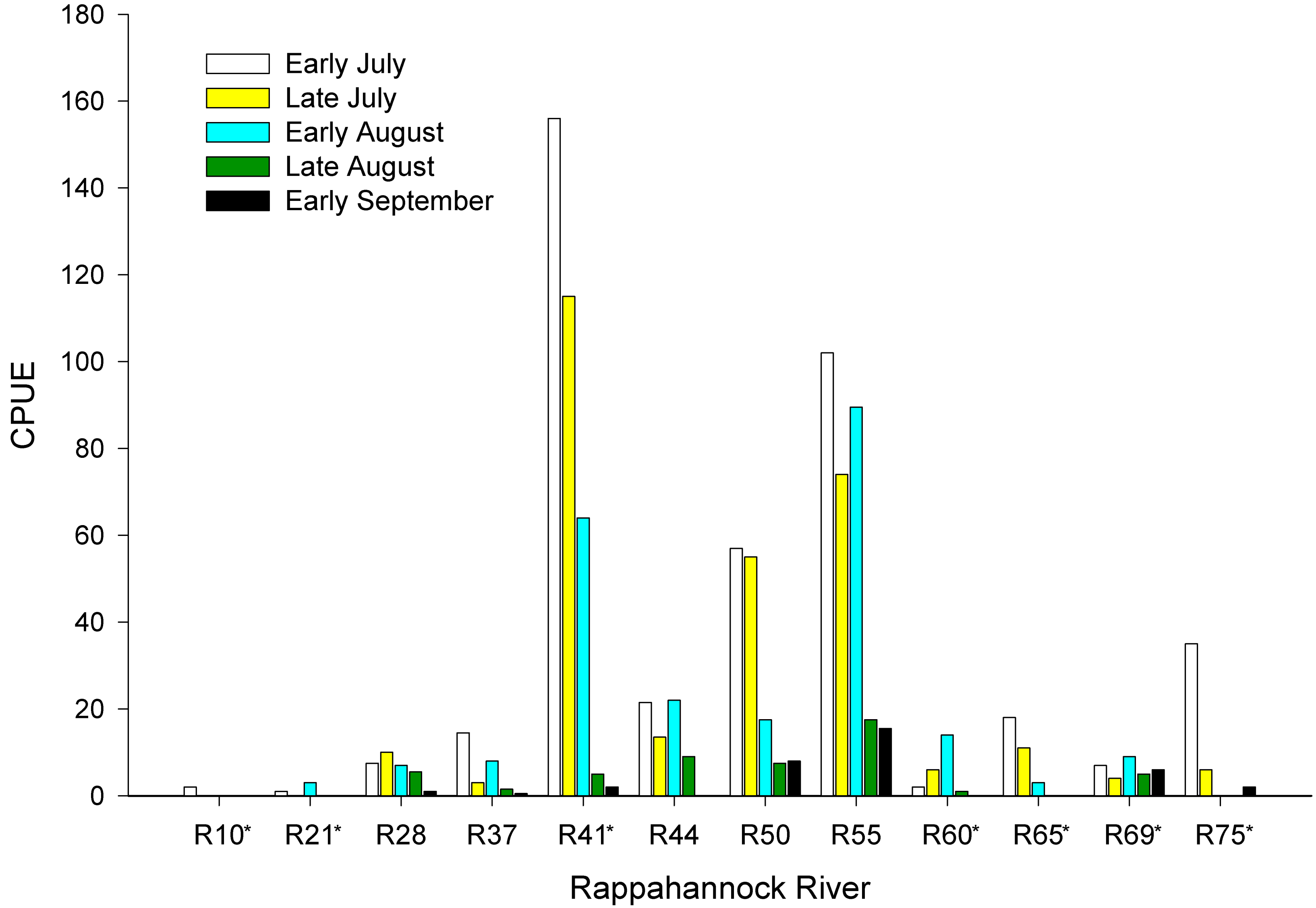

Figure 8. Catch of young-of-year striped bass by station in the Rappahannock River in 2011. Index station catch represent an average of two hauls; auxiliary station (starred) catch represents one haul. No sampling occured at R75 during late August or at R60 during September.

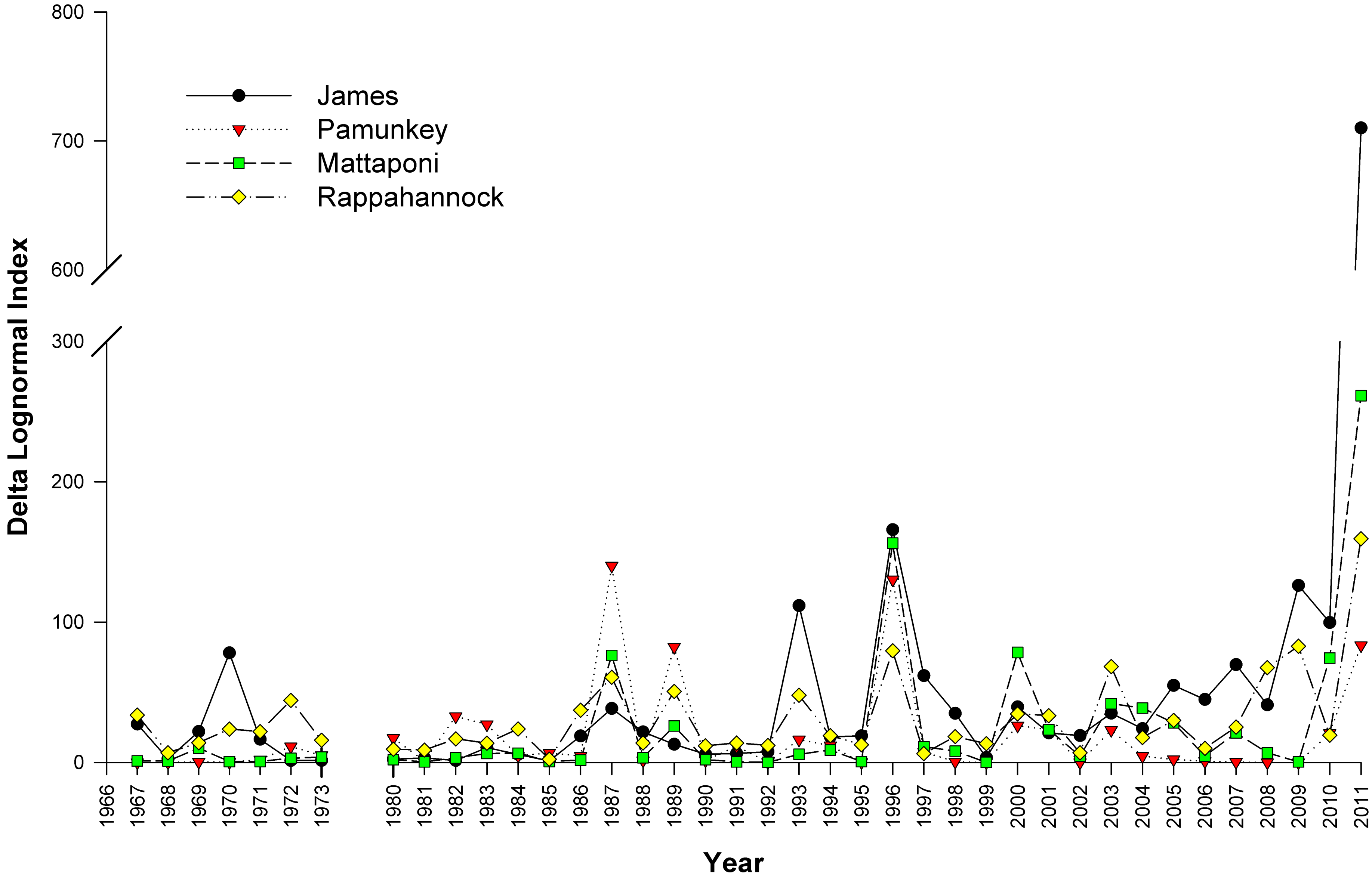

Figure 9. Delta-lognormal mean of young-of-year white perch from select seine survey stations by river and year.

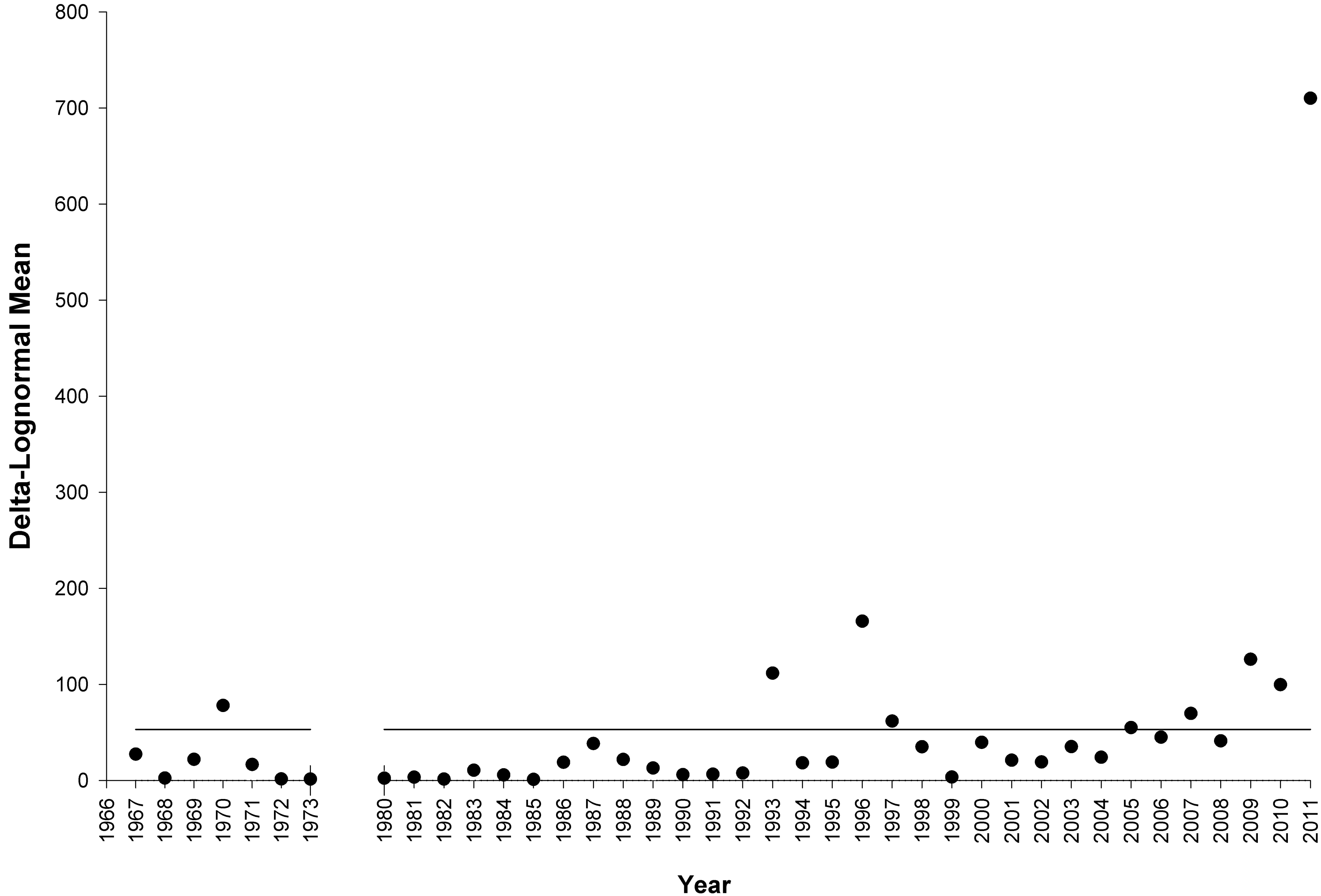

Figure 10. Delta-lognormal mean of young-of-year white perch from the James River nursery area by year. The horizontal line indicates the historical mean for 1967-2011.

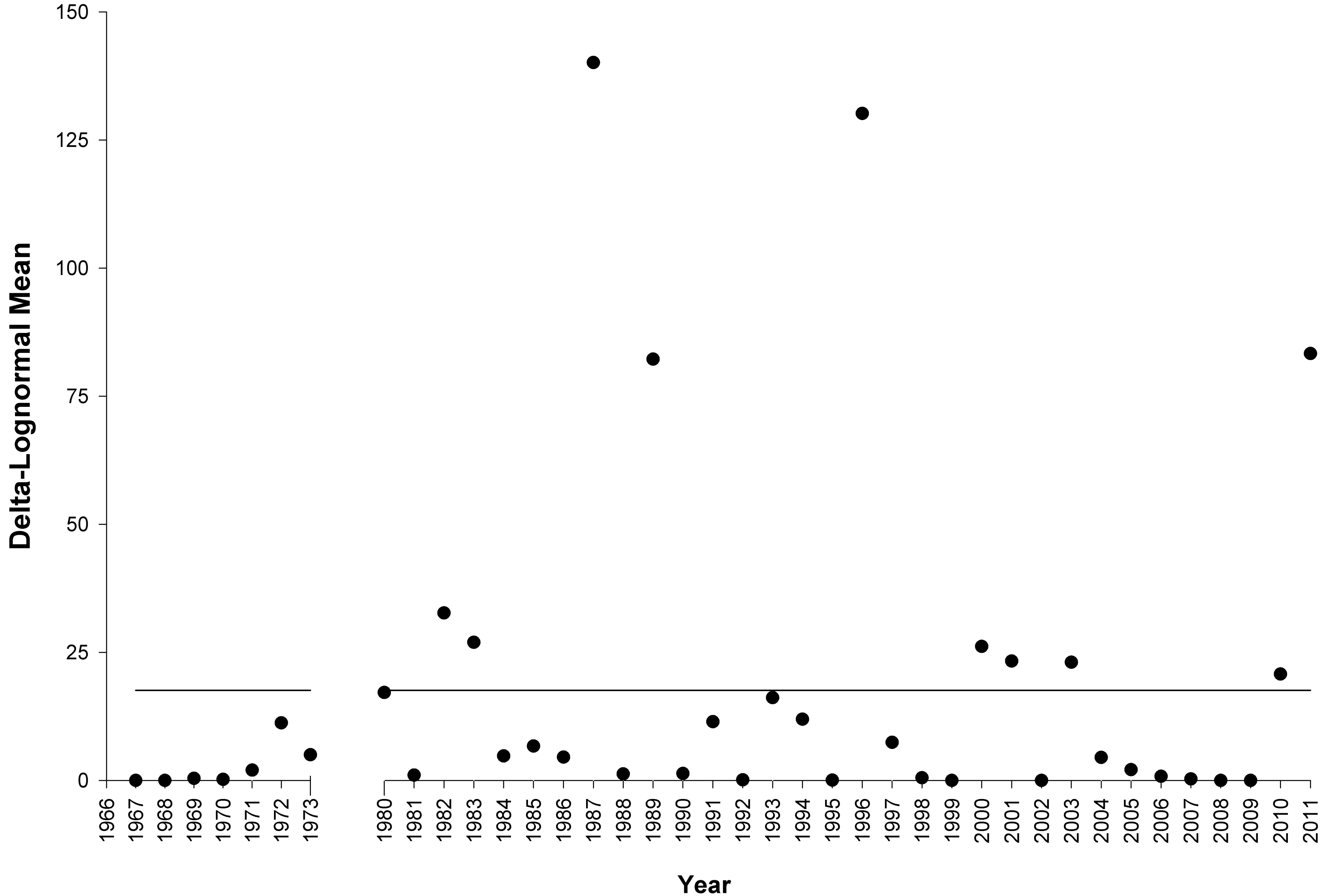

Figure 11. Delta-lognormal mean of young-of-year white perch from the Pamunkey River nursery area by year. The horizontal line indicates the historical mean for 1967-2011.

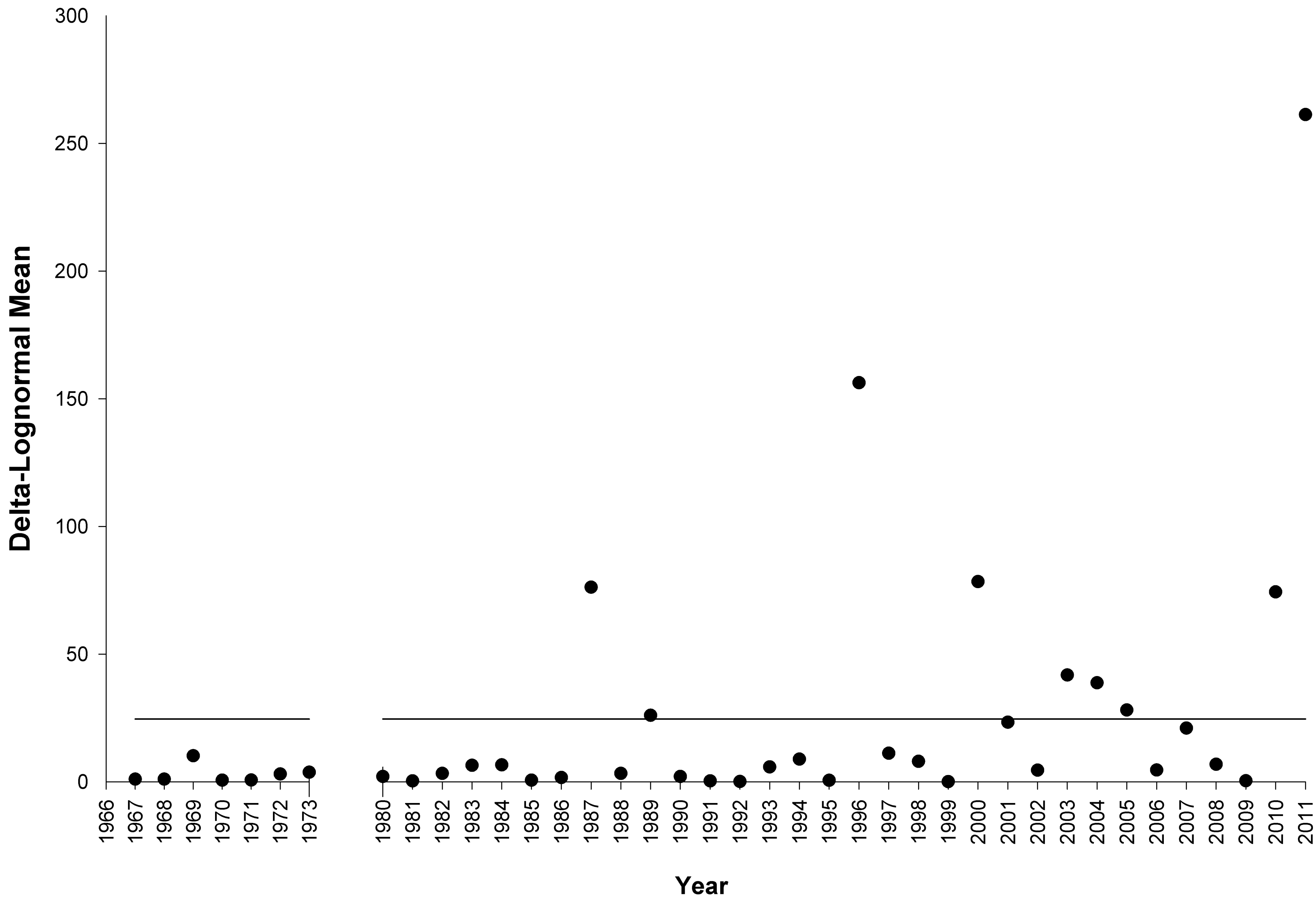

Figure 12. Delta-lognormal mean of young-of-year white perch from the Mattaponi River nursery area by year. The horizontal line indicates the historical mean for 1967-2011.

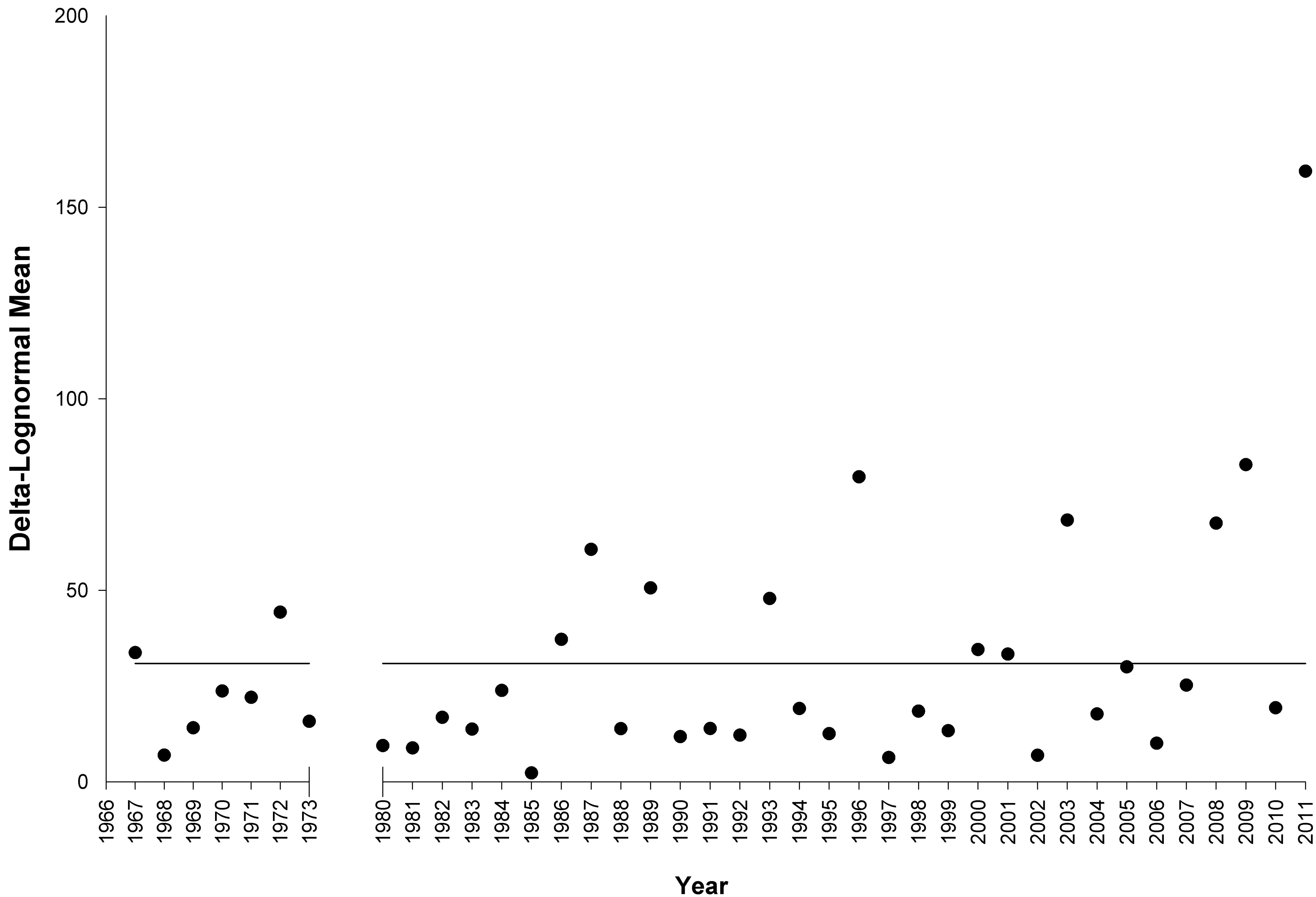

Figure 13. Delta-lognormal mean of young-of-year white perch from the Rappahannock River nursery area by year. The horizontal line indicates the historical mean for 1967-2011.