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

ANNUAL PROGRESS REPORT: 2015 - 2016

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EXECUTIVE SUMMARY

The 2015 Striped Bass juvenile abundance index was 12.00 and was not significantly greater than the historic average of 8.63. Compared with their respective historic averages abundance indices from individual rivers in 2015 varied, such that significantly higher recruitment was observed in the Rappahannock River and average recruitment was observed in the James and York rivers. Relatively higher catches of young-of-the-year Striped Bass at upriver and downriver auxiliary sites suggest expansion of Striped Bass nursery grounds in 2015. Unlike Striped Bass in Virginia waters, juvenile White Perch abundance indices in 2015 were significantly greater than the historic average for this species. Another below-average year class for Atlantic Croaker appears to have occurred in 2015. In contrast, American Shad, Alewife, and Blueback Herring abundance indices were above average in Virginia waters in 2015. Average to above-average indices for many forage fishes suggest adequate production of key prey resources for populations of commercial and recreational piscivores in Virginia waters.

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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 of juvenile Striped Bass in the principal Virginia nursery areas of Chesapeake Bay. The U.S. Fish and Wildlife Service initially funded the survey from 1967 to 1973 with funds from the Commercial Fisheries Development Act of 1965 (PL88-309). Beginning in 1980, funds were provided by the National Marine Fisheries Service under the Emergency Striped Bass Study program (PL96-118, 16 U.S.C. 767g, the "Chafee Amendment." Commencing with the 1989 annual survey, the work was jointly supported by Wallop-Breaux funds (Sport Fish Restoration and Enhancement Act of 1988 PL100-488, the "Dingell-Johnson Act"), administered through the U.S. Fish and Wildlife Service, and the Virginia Marine Resources Commission. This report summarizes the results of the 2015 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 harvests mirrored declines in juvenile recruitment (Goodyear 1985). Because the tributaries of Chesapeake Bay were 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 the plan in March 1982 (Regulation 450-01-0034). As Striped Bass populations continued to decline, Congress passed the Atlantic Striped Bass Conservation Act (PL 98-613) in 1984, which required states to 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 that monitor Striped Bass recruitment.

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 hauls with Maryland gear (4 ft. x 100 ft. x 0.25 in. mesh; 1.2m x 30.5m x 6.4mm 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 and promote a bay-wide recruitment estimate (Colvocoresses and Austin 1987). This was never realized due to remaining differences in the methods of estimation of means (MD: arithmetic index; VA: geometric index). A bay-wide index using a geometric mean weighted by spawning area in each river was proposed in 1993 (Austin et al. 1993) but has not been implemented. Recent computations of a bay-wide geometric mean juvenile abundance index (JAI) were found to be correlated with abundance estimates of adult fish from fishery-independent monitoring (Woodward 2009).

Objectives for the 2015 program were to:

1. estimate the relative abundance of the 2015 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 to 8 September 2015. 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 in years of high recruitment.

Collections were made by deploying a 100 ft. (30.5 m) long, 4 ft. (1.2 m) deep, and 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 (FL), and for all other species, a sub-sample of up to 25 individuals was measured to the nearest mm FL (or total length if appropriate). At index stations, fish collected during the first haul were held in a water-filled bucket 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. Sampling time, tidal stage, and weather conditions were recorded at each sampling location.

Salinity, water temperature, and dissolved oxygen concentrations were measured after the first haul using a YSI water quality sampler.

In this report, comparisons of Striped Bass 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-the-year Striped Bass is calculated as the adjusted overall mean catch per seine haul such that

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

where *totnum* is the total number of Striped Bass per seine haul; catches from the first and second seine haul at each index station are considered in this calculation. Because the frequency distribution of the catch is skewed (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 arithmetically ($\times 2.28$) to allow comparisons with Maryland indices. Thus, a "scaled" index refers to an index that is directly comparable with the Maryland index.

Even with a 30-minute interlude between hauls at index stations, second hauls cannot be considered 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 lower catches on average in the second haul (e.g. Hewitt et al. 2007, 2008), a result which artificially lowers the geometric mean when data from both hauls are included in the index computation. 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) allow examination of 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 – 2014 was calculated using both hauls and only the first haul at each index site to provide a benchmark for interpreting recruitment strength during the post-recovery period and was compared with the 2015 annual index. The historic average is calculated as the mean of the individual annual abundance estimates (one estimate per year).

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 for the back-transformed and scaled indices are non-symmetrical.

RESULTS AND DISCUSSION

Juvenile Index of Abundance for Virginia

We collected 1,884 young-of-the-year Striped Bass in 2015 from 180 seine hauls at index stations and 1,192 individuals from 105 hauls at auxiliary stations (Table 1). Using index-station catches from both hauls, the estimated Striped Bass recruitment index in 2015 was 12.00 (LCI = 9.79, UCI = 14.62; Table 2), which was not significantly different from the historic average of 8.63 (LCI = 6.95, UCI = 10.30; Figure 2). Using index station catches from only the first haul in 2015, 993 young-of-the-year Striped Bass were collected, resulting in an index of 13.35 (LCI = 10.16, UCI = 17.37, Table 3), which is not significantly different from the first-haul historic index of 10.43 (LCI = 8.46, UCI =12.52), and is similar to the mean index estimated for the post-recovery period (post-recovery index = 13.58; LCI = 11.05, UCI = 16.12).

Prior to 2011, annual recruitment indices were calculated from all collections made during a sampling year including samples taken before July and after mid-September. In particular from 1967 to 1973, seine sampling extended into October and occasionally into December (1973). Current protocols conclude sampling in mid-September because after this time, sampling efficiency decreases due to increased avoidance of the sampling gear and dispersal of juveniles into deeper waters. Indices calculated from data that include catches after mid-September are therefore biased low. Starting in 2011, recruitment calculations were made using catch data from the currently established sampling season (July through mid-September) to permit uniform comparisons of annual recruitment (Tables 2– 4).

Striped Bass recruitment success in the Virginia portion of Chesapeake Bay is variable among years and among nursery areas within years. Since the termination of the Striped Bass fishing moratorium in 1990, strong year classes have been observed approximately every decade (1993, 2003, and 2011). The highest recruitment index observed by the Virginia seine survey occurred in 2011. Average to above-average recruitment years occurred between 2003 and 2011, and in 2013-2015 (Figure 2). Below-average year classes were observed in 1991, 1999, 2002, and 2012 (Figure 2). In the past decade, recruitment has been above-average or average in all but one year (2012), indicating production has been relatively consistent in Virginia nurseries during this time. Under current ASMFC regulations (ASMFC 2010), management action is triggered after three consecutive years of below-average recruitment in producing states.

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 better estimate of recruitment strength and serve as a better predictor of subsequent adult Striped Bass abundance within the Bay (Woodward 2009). This may be particularly appropriate in years when individual state JAIs provide divergent estimates of year-class strength (such as 2015 when Maryland reported above-average recruitment for striped bass); such differences may arise due to annual changes in the spatial distribution and contribution of nursery areas throughout Chesapeake Bay.

Juvenile Index of Abundance for Individual Watersheds

Using index-station catches from both hauls, the estimated Striped Bass recruitment indices observed in the three Virginia watersheds during 2015 were considered average (James and York rivers) or significantly above-average (Rappahannock River) compared with their respective historic means (Table 4). The 2015 JAI for the James River drainage was 13.98 (LCI = 11.04, UCI = 17.57), compared with the historic James River index of 8.95 (LCI = 6.86, UCI = 11.53; Table 4). The 2015 JAI value for the York River drainage was 7.94 (LCI = 5.47, UCI = 11.20), compared with the historic York River index of 5.47 (LCI = 4.25, UCI = 6.91; Table 4). The 2015 JAI value for the Rappahannock River was 17.14 (LCI = 10.97, UCI = 26.18), compared with the historic Rappahannock River index of 7.30 (LCI = 5.51, UCI = 9.51; Table 4).

Similar to what has been observed in the past (Machut and Fabrizio 2011, 2012), mid-river index stations contributed a greater proportion of the catches: in the James River system, 46% of all young-of-the-year Striped Bass occurred in the core nursery zone in 2015 (C1, C3, and J46; Table 1). The remaining striped bass were captured at upriver (29%) and downriver sites (25%; Table 1).

The 2015 York River JAI of 7.94 (LCI = 5.47, UCI = 11.20) was not significantly different than the historic average of 5.47 (LCI = 4.25, UCI = 6.91; Table 4; Figure 3). No index sites are located along the main stem of the York River, thus, the watershed JAI is compiled from sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. The 2015 Pamunkey River JAI of 11.13 (LCI = 6.28, UCI = 18.74) was not significantly higher than the historic index of 6.23 (LCI = 4.49, UCI =

8.42), and the 2015 Mattaponi River index of 6.01 (LCI = 3.64, UCI = 9.33) was also not significantly different from the historic average of 4.94 (LCI = 3.96, UCI = 6.09). About 22% of York River system Striped Bass were collected from the Pamunkey River and 31% from the Mattaponi River; the remainder (47%) were from the York River auxiliary stations (Table 1).

Unlike the James and York River systems, the Rappahannock River yielded an index of 17.14 (LCI = 10.97, UCI = 26.18) in 2015 which was significantly higher than the historic average of 7.30 (LCI = 5.51, UCI = 9.51; Table 4). In 2015, 77% of the total Rappahannock River catch was taken from the three uppermost index sites (R44, R50, R55; Table 1); these three sites have dominated the catches in this drainage for several years.

Striped Bass Collections from Auxiliary Stations

Figures 4 – 7 illustrate the spatial distribution of the 2015 year class throughout the nursery areas sampled by this survey. Note that the scaling of the y-axes is not constant across the figures. The 1989 addition of auxiliary stations provided increased spatial coverage in the James, York and Rappahannock drainages, and the upriver and downriver auxiliary sites allowed delineation of the upper and lower limits of the nursery. These auxiliary stations reveal spatial changes in the nursery areas that occur due to annual changes in river flow. Additionally, in years of low or high juvenile abundance, the nursery area may contract or expand spatially. We observed relatively large catches of young-of-the-year Striped Bass at upriver and downriver auxiliary sites in 2015, which we interpret as expansion of the nursery area.

Juvenile Striped Bass were captured at all auxiliary stations in the James River during 2015, although catches were lowest at the upper- and lower-most stations (Table 1; Figure 4). Striped Bass were collected from all auxiliary sites in the Pamunkey and Mattaponi rivers in 2015 (Tables 1 and 5; Figures 5 and 6). Additionally, Striped Bass were collected from all three auxiliary stations within the York River watershed (Table 1). The greatest number of Striped Bass captured in a single haul in the York River system in 2015 was at YK28, an auxiliary station where 40% of the total York River catch, occurred (Table 5).

We previously suggested that the lack of Striped Bass at auxiliary stations in the York River watershed may have been due to the inability to accurately sample in the dense *Hydrilla* vegetation that typically occurs at these sites (Machut and Fabrizio 2010). In 2015, we detected juvenile Striped Bass at the three York River auxiliary sites (Table 1), but not all fish may have been detected due to low capture efficiencies associated with hauling a seine net through dense aquatic vegetation. Furthermore, recent catches at P55, and to a lesser extent at M52, may have been affected by the altered state of the near-shore zone at these sites. Striped Bass may have been forced into deeper waters by the dense *Hydrilla* beds; alternatively, Striped Bass may preferentially use *Hydrilla* habitats but remain unavailable to the sampling gear. The continued sampling difficulties at these stations suggest a need to examine alternative collection methods within this region to determine the abundance of juvenile Striped Bass in near-shore areas where *Hydrilla* is present.

Striped Bass were collected at all upriver Rappahannock River auxiliary stations during 2015. In recent years, few fish have been collected at the lower auxiliary stations in the Rappahannock River (R12, R21) even though these sites have favorable substrate and no obstructions to compromise seining. The consistent low capture rates at R12 and R21 suggest these sites may have lower value as nursery areas in the Rappahannock River. The same is not true for upstream auxiliary locations. Historic JAI values at auxiliary stations upstream of Tappahannock (near R37) appear comparable to JAIs at index stations R28, R37, and R44 (Table 5).

Comparison among Sampling Rounds

The largest number of young-of-the-year Striped Bass were collected during rounds 1 and 2 in 2015, with fewer recorded in subsequent rounds (Table 6). Historically, 31% of the Striped Bass captured within the primary nursery areas of Virginia occur in the first round of sampling, however in 2015, we observed 44% of Striped Bass in round 1 sampling; this resulted in a higher percent change between rounds compared with historic patterns, with the exception of round 5 (Table 6).

Environmental Conditions and Potential Relationships to Juvenile Striped Bass Abundance

In Virginia tidal tributaries, water temperatures follow a well-defined pattern of high temperatures in July followed by declining temperatures towards the end of the sampling season in mid-September. In 2015, this pattern was significantly altered: water temperatures peaked during late July into early August (rounds 2 and 3), and remained above 25^{o}C throughout August and into early September (rounds 4 and 5;

Table 7). A more traditional temperature pattern occurred in 2009 and 2010 (Machut and Fabrizio 2010, 2011) when temperatures in September were below 25^{o}C. In September 2015 (round 5), no sites exhibited water temperatures below 25^{o}C compared with about 50% of sites in 2010. Statewide average air temperatures from July-September of 2015 were "above average" in Maryland and Virginia (NCDC 2015). The altered pattern in water temperatures in Striped Bass nursery areas has now occurred in consecutive years with similar water temperatures observed in 2013 and 2014. This temperature pattern did not seem to affect catches, however. Catch rates in 2015 followed the historic pattern with respect to water temperature: most fish (99%) were captured at temperatures between 25.0 and 34.9^{o}C (Table 8). Water temperatures in tidal tributaries reflect not only long-term, regional climate patterns, but also significant day-to-day and local variation. Shallow shoreline areas are easily affected by local events such as thunderstorms and small-scale spatial and temporal variations associated with time of sampling (e.g., morning versus afternoon, riparian shading, 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 decline in catch rates and water temperatures as the season progresses (beyond early August) rather than any direct effect of water temperature on juvenile fish distribution.

In 2015, average salinity at all stations was equal to or lower than that observed historically except for R12 (Table 5). As observed in the past, greater catches of young-of-the-year Striped Bass in 2015 were obtained at sites exhibiting low salinities within the primary nursery area (Table 9). Only one index station exceeded 10.0 ppt salinity,

although salinity as high as 17.9 ppt was observed at one auxiliary site in the James River (Table 10). In 2015, the percentage of catch observed in low salinities (0.0 – 4.9 ppt) was slightly higher than that observed historically (95.4% in 2015 vs. 93% all years; Table 9). Conversely, the catch in mid-range salinities (5.0 – 9.9 ppt) was slightly below the historic average (4.6% in 2015 vs. 6%, all years). Although juvenile Striped Bass were captured at downstream sites with average salinities up to 15 ppt, catches were distinctly lower at such sites compared with catches in lower salinity areas.

Dissolved oxygen (DO) concentrations were lower in 2015 at many sites compared with the historic average (Table 11). Within the nursery area, 40% of the measurements (75 of 190 measurements) exhibited DO levels that were more than one standard error (SE) less than the site's historic average (Table 11). Nine DO measurements from seven sites exhibited particularly low levels (< 3.8 mg O_2/L) during 2015 (all occurring in the York River system). Relationships between DO and juvenile Striped Bass catches are difficult to ascertain. Lower-than-average values occurred inconsistently through time and across sampling sites. DO values less than one SE below the mean at a given station (shaded values in Table 11) did not necessarily correspond with low catches at that station (Table 1). High seasonal catches at index stations occurred during periods when DO was more than one SE below the historic average and when DO measures were within one SE of the historic average.

Striped Bass recruitment variability may be partially explained by regional climate patterns during winter and spring (Wood 2000). For example, abundance of young Striped Bass has been positively associated with high river flows during the

preceding winter (Wingate and Secor 2008). One of the strongest Striped Bass year classes was produced in 2011, which was characterized by above normal precipitation in winter and spring (Machut and Fabrizio 2012). Precipitation in the winter and spring of 2015 (December 2014 - May 2015) was "near average" in Maryland and Virginia (NCDC 2015). Although these regional precipitation conditions were 'near average,' salinities were generally below the historic averages at most Virginia seine sites (Table 5). Clearly, other factors, in addition to regional climate patterns, influence variation in recruitment of juvenile Striped Bass.

Additional Abundance Indices Calculated from the Seine Survey

A variety of species are collected by the juvenile Striped Bass seine survey annually due to a sampling regime that spans the euryhaline to freshwater zone. The five most common species encountered in 2015 were Atlantic Silverside (*Menidia menidia*), White Perch (*Morone americana*), Spottail Shiner (*Notropis hudsonius*), Blueback Herring (*Alosa aestivalis*), and Striped Bass (*Morone saxatilis;* Table 12). In 2015, more than 48,000 individuals comprising 65 species were collected (Table 12).

One of the most common species captured annually by the seine survey, White Perch, supports important recreational and commercial fisheries in Chesapeake Bay (Murdy et al. 1997, NMFS 2012). The general overlap in spawning time 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. Colvocoresses (1988) found a strong correlation between a young-of-the-year White Perch index (geometric mean) calculated from seine survey

data and an index obtained for harvest-sized White Perch from a trawl survey. In years of low abundance (e.g., 1985) the proportion of seine hauls containing White Perch may be as low as 40%; whereas in years of high abundance (e.g., 2011), White Perch may be found in 95% of seine hauls. A delta-lognormal index was developed to address this inter-annual 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 July through September 2015, 4,182 young-of-the-year White Perch were collected from 140 sampling stations during five sampling rounds. Because White Perch movement among Virginia tributaries is unlikely (Mulligan and Chapman 1989), we presume each tributary supports a distinct stock and report juvenile abundance for each river separately (Table 13; Figures 8 - 12). Generally, 2015 river-specific JAIs for White Perch suggest average to above-average recruitment for this species throughout Virginia. At present, development of river-specific indices for White Perch is incomplete. Although we feel confident in the estimation of annual mean relative abundance, alternative approaches for estimating confidence intervals need to be examined. The White Perch JAI developed by the seine survey compliments the juvenile White Perch index currently reported by the VIMS Juvenile Fish Trawl Survey (Tuckey and Fabrizio 2012); however, unlike the index reported by the trawl survey, the seine survey index is based on catches from tidal brackish and freshwater zones.

Atlantic Croaker (*Micropogonias undulatus*) is another commercially and recreationally important fish (Murdy et al. 1997, NMFS 2012) regularly collected by the seine survey. Young-of-the-year Atlantic Croaker are collected at predominately mesohaline sampling sites during July and early August (rounds 1, 2, and 3) before fish are able to avoid the net (Williams and Fabrizio 2011). Murdy et al. (1997) report peak spawning of Atlantic Croaker from August – October; thus, young-of-the-year fish collected during 2015 were spawned during the fall of 2014. Similar to White Perch, Atlantic Croaker raw catch data exhibit high annual variability in the proportion of non-zero hauls. To address this variation and accommodate data with a high proportion of zero hauls we developed a delta-lognormal index for Atlantic Croaker. Estimation of confidence intervals for the mean of the delta-lognormal distribution remains under development, so only the means are reported here.

From July through early August 2015, we encountered at total of 7 young-of-the-year Atlantic Croaker (one other fish was age 1+) and these fish were observed at two sampling locations (Table 14; Figure 13). Because Atlantic Croaker are coastal shelf spawners with larval migration into Chesapeake Bay, we report a Virginia-wide estimate of juvenile abundance (Table 14; Figure 13). Periods of strong recruitment from 1992 – 1995, 1997 – 1998, and 2007 – 2009 correspond with patterns observed by the VIMS Juvenile Fish Trawl Survey (Tuckey and Fabrizio 2012). However, an extremely weak year class for Atlantic Croaker appears to have occurred during 2015.

Spot (*Leiostomus xanthurus*), like Atlantic Croaker, is another commercially and recreationally important fish that is collected by the seine survey and reported as a

Virginia-wide estimate of juvenile abundance (Table 15; Figure 14). From July through early August 2015, 43 young-of-the-year Spot were collected from 6 sampling locations. Using the delta-lognormal approach, we observed a below-average year class for Spot in 2015 (Table 15; Figure 14).

Indices of abundance for common forage species within the tidal near-shore zone were computed for: Spottail Shiner (*Notropis hudsonius*; Table 16), Atlantic Silverside (*Menidia menidia*; Table 17), Inland Silverside (*Menidia beryllina*; Table 18), and Banded Killifish (*Fundulus diaphanus*; Table 19). The 2015 Spottail Shiner delta-lognormal mean of 33.8 was similar to the historic average of 24.3 (Table 16). The 2015 Atlantic Silverside delta-lognormal mean of 104.0 was substantially higher than the historic average of 44.5 (Table 17). The 2015 Inland Silverside abundance index of 9.9 was also higher than the historic average of 4.5 (Table 18). The 2015 Banded Killifish delta-lognormal mean of 5.5 was similar to the historic average of 4.6 (Table 19). Average to above-average indices for all four of these species in 2015 suggest that a robust population of forage fishes was available for commercially and recreationally important piscivores in Virginia waters.

Indices of abundance derived from seine survey collections are reported for species of management importance to fulfill commonwealth compliance requirements to the ASMFC; these species include America Shad (Watkins et al. 2011), Alewife, Blueback Herring, 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 support for the seine survey-based

index. These indices are provided to VMRC when requested and are also reported here. Alosines greatly contribute to the dynamics of freshwater, estuarine, and marine habitats serving as prey for many large, predatory fishes and consuming large amounts of plankton. Many stocks of alosine species are currently at record lows or of unknown status because of a lack of data to assess populations accurately especially within riverine environments. Data collected on American Shad, Alewife, and Blueback Herring from the seine survey are critical for assessing stocks in the James, York, and Rappahannock rivers. The 2015 geometric mean abundances for American shad in the James, York, and Rappahannock rivers exhibit an increasing trend over the past two years after nearly a decade of low recruitment (Figure 15). Indices of abundance for American Shad also increased in the Chickahominy, as well as the Pamunkey, and Mattaponi rivers (Figure 15). The 2015 geometric mean abundance indices for Alewife also increased in the three rivers (Figure 16). Most notably, the index of abundance for the Rappahannock River was the highest observed since surveys began in 1989 (Figure 16). The 2015 geometric mean abundance indices for Blueback Herring increased in the James, York, and Rappahannock rivers over the past two years. In particular, the Rappahannock River index of abundance was the highest observed since 1984. The increased abundances of these three alosine species appears encouraging.

CONCLUSION

The 2015 juvenile abundance index (JAI) for Striped Bass (12.00) was not significantly greater than the historic average (8.63) for Virginia waters. Compared with historic averages, we observed significantly higher recruitment in the Rappahannock River, but average recruitment in the James and York rivers. Continued evaluation of juvenile Striped Bass abundance is important in predicting recruitment to the commercial and recreational Striped Bass fisheries in the Chesapeake Bay and along the Atlantic coast. A critical characteristic of the long-term annual seine survey conducted in the Chesapeake Bay is the ability to identify years of below-average recruitment which, if persistent, serve as an early warning to managers of potential declines in Striped Bass standing stock biomass. Juvenile White Perch abundance indices in 2015 were average to above-average compared with the historic average for this species. Forage fish abundance index values were average or above average in 2015. Abundance indices for three alosine species increased throughout Virginia waters in 2015 relative to index values in previous years.

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Table 1. Catch of young-of-the-year Striped Bass per seine haul in 2015. 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	J78	Total
	Round	1	7	3	4/4	5/14	4	42/25	23/15	8/9	10	9/5	35	13	2	237
		2	0	1	6/11	11/7	1	7/2	10/1	1/0	7	2/6	39	3	0	115
		3	0	3	6/7	10/4	0	17/32	2/1	3/11	6	9/4	5	1	0	121
		4	0	0	10/12	9/2	0	7/5	4/5	16/4	0	7/1	1	1	0	84
		5	0	1	8/12	0/2	3	3/6	19/5	12/9	3	6/6	2	5	0	102
														James Total		**659**
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	9	20	142	4	20/25	33/12	47/31	9						352
		2	6	2	175	0	10/15	13/0	8/8	2						239
		3	2	25	153	2	0/18	1/1	14/9	0						225
		4	2	2	32	0	3/6	0/5	2/11	0						63
		5	5	26	80	1	0/1	0/3	2/0	0						118
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				44/27	92	10/5	28/19	3/7	0					235
		2				9/3	48	10/2	6/4	2/0	1					85
		3				1/2	27	0/1	3/0	3/2	0					39
		4				2/0	4	1/2	11/0	4/0	2					26
		5				6/5	52	1/0	1/0	0/1	0					66
														York Total		**1,448**
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Round	1	1	0	5/7	13/14	10	61/69	39/43	63/44	1	2	0	5		377
		2	0	0	8/7	20/16	29	19/16	34/72	51/54	17	4	1	6		354
		3	0	0	2/1	7/6	6	31/19	11/48	13/14	4	4	2	0		168
		4	0	0	1/0	1/3	4	1/0	5/4	3/1	2	0	0	0		25
		5	0	0	0/0	2/1	10	0/0	8/14	6/1	0	2	1	0		45
														Rappahannock Total		**969**
														2015 Catch		**3,076**

Table 2. Catch of young-of-the-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 ln (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
2012	408	0.78	0.83	2.68	2.10-3.33	179
2013	1620	1.76	1.08	10.94	8.97-13.25	180
2014	2293	1.78	1.26	11.30	8.98-14.09	180
2015	1884	1.83	0.08	12.00	9.79-14.62	180
Overall (1967-2014)	55053	1.42	0.55	8.63	6.95-10.30	42 (years)

Table 3. Catch of young-of-the-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 ln (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
2012	265	0.92	0.87	3.47	2.50-4.63	90
2013	877	1.82	1.10	11.85	8.92-15.54	90
2014	1401	2.01	1.24	14.81	10.87-19.93	90
2015	993	1.93	1.09	13.35	10.16-17.37	90
(1967-2014)	33964	1.55	0.59	10.43	8.46-12.52	42 (years)
(1990-2014)	27381	1.84	0.48	13.58	11.05-16.12	25 (years)

Table 4. Catch of young-of-the-year Striped Bass per seine haul in the primary nursery area in 2015 summarized by drainage and river.

	2015				All Years Combined (1967-2014)			
Drainage River	Total Fish	Index	C.I. (±2 SE)	N (hauls)	Total Fish	Index	C.I. (±2 SE)	N (years)
JAMES	503	13.98	11.04 – 17.57	60	21697	8.95	6.86 – 11.53	42
James	272	12.61	9.72 – 16.20	40	13120	8.08	5.98 – 10.72	42
Chickahominy	231	17.11	10.55 – 27.01	20	8577	11.34	8.57 – 14.82	42
YORK	518	7.94	5.47 – 11.20	70	16064	5.47	4.25 – 6.91	42
Pamunkey	298	11.13	6.28 – 18.74	30	8040	6.23	4.49 – 8.42	42
Mattaponi	220	6.01	3.64 – 9.33	40	8024	4.94	3.96 – 6.09	42
RAPPAHANNOCK	858	17.14	10.97 – 26.18	50	17292	7.30	5.51 – 9.51	42
Overall	1884	12.00	9.79-14.62	180	55053	8.63	6.95 – 10.30	42

Table 5. Site specific Striped Bass indices and average site salinity during 2015 compared to historic (1967 – 2014) index values with corresponding 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
	1967-2014	Avg. Sal.	14.3	7.8	4.7	2.5	1.5	1.4	1.3	0.6	0.3	0.2	0.2	0.1	0.2
		Index	1.8	14.3	7.2	12.4	13.6	17.2	7.5	19.2	17.4	6.4	11.0	6.3	2.6
	2015	Avg. Sal.	13.4	7.0	4.1	1.9	0.8	0.9	0.8	0.2	0.1	0.1	0.1	0.1	0.1
		Index	1.2	2.96	17.1	10.9	2.5	22.3	13.0	12.0	8.6	11.1	17.7	7.4	0.6
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1967-2014	Avg. Sal.	16.5	13.8	10.6	4.1	1.7	0.7	0.4	0.3					
		Index	1.3	1.9	5.8	12.5	4.4	9.1	12.6	4.3					
	2015	Avg. Sal.	15.6	12.8	9.4	3.0	1.1	0.3	0.1	0.1					
		Index	9.6	21.9	227.3	2.2	12.1	6.3	17.2	2.2					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2014	Avg. Sal.				4.5	2.4	1.1	0.4	0.3	0.1				
		Index				6.1	8.1	6.8	5.6	4.6	1.4				
	2015	Avg. Sal.				3.8	1.4	0.4	0.1	0.1	0.0				
		Index				10.8	70.8	4.0	7.4	3.5	1.0				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	1967-2014	Avg. Sal.	14.1	12.8	10.0	5.3	3.1	2.0	0.9	0.6	0.2	0.2	0.1	0.1	
		Index	0.5	0.7	2.8	3.2	5.7	8.2	13.6	38.9	6.0	4.1	3.0	2.6	
	2015	Avg. Sal.	14.2	12.6	9.6	3.8	1.6	1.0	0.2	0.1	0.0	0.1	0.1	0.1	
		Index	0.3	0.0	4.3	13.2	21.6	17.0	43.5	28.4	5.7	4.5	1.5	1.9	

Table 6. Catch of young-of-the-year Striped Bass in the primary nursery areas of Virginia in 2015 summarized by sampling round and month.

	2015					All Years Combined (1967-2014)				
Month (Round)	N (hauls)	Total Fish	Scaled Mean	C.I. (± 2 SE)	Change From Previous Round	N (years)	Total Fish	Scaled Mean	C.I. (± 2 SE)	Change From Previous Round
July (1st)	39	827	39.05	28.92 – 52.47		42	17079	11.37	8.91 – 14.36	
(2nd)	39	451	15.95	10.48 – 23.76	-45.8%	42	13798	8.49	6.57 – 10.84	-19.2%
Aug. (3rd)	39	313	11.10	7.18 – 16.64	-30.6%	42	9961	6.61	5.14 – 8.37	-27.8%
(4th)	39	148	6.25	4.17 – 8.99	-52.7%	38	8359	6.16	4.74 – 7.86	-16.1%
Sept. (5th)	39	140	4.86	2.88 – 7.60	-5.4%	35	5856	4.93	3.84 – 6.23	-29.9%

Table 7. Water temperature (°C) recorded at seine survey stations in 2015. 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	J78
	Round	1	30.0	31.3	28.7	27.1	27.9	26.5	28.0	28.5	27.8	26.4	29.0	28.1	27.2
		2	29.6	29.3	29.7	26.3	28.5	28.1	27.4	30.0	28.0	27.0	28.9	29.4	27.7
		3	28.4	29.3	31.5	27.2	30.4	29.0	29.2	30.7	29.0	28.2	30.1	31.1	30.0
		4	28.8	28.1	30.4	26.8	30.5	29.1	29.0	29.4	27.4	25.9	29.4	30.4	28.5
		5	28.7	29.2	29.2	26.4	29.2	28.1	27.4	28.2	26.9	26.7	26.9	28.7	27.2
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	27.7	27.3	27.0	27.6	28.2	28.2	27.5	29.9					
		2	27.8	26.6	27.7	28.5	29.2	29.5	29.6	30.7					
		3	27.3	28.1	29.3	28.8	29.2	29.9	29.8	29.8					
		4	27.8	26.5	27.0	28.2	28.5	28.9	28.5	29.3					
		5	26.4	26.5	25.6	27.2	27.4	27.9	28.5	28.7					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				27.7	27.6	27.8	28.8	31.9	28.4				
		2				28.8	28.9	29.4	29.9	30.5	30.7				
		3				29.0	28.9	29.6	30.4	31.1	30.2				
		4				27.6	27.8	28.1	28.6	29.5	29.1				
		5				27.2	27.3	27.4	28.0	29.5	29.1				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	Round	1	29.9	28.3	26.0	27.0	28.1	29.0	26.9	27.3	27.4	27.8	25.8	25.4	
		2	28.7	28.0	25.3	25.3	27.7	27.6	28.0	28.2	27.5	28.2	28.1	26.6	
		3	31.3	29.8	26.9	29.0	29.2	29.4	28.8	29.2	29.0	29.4	29.3	29.3	
		4	30.6	30.0	26.9	30.1	30.2	30.9	26.8	27.3	26.8	26.2	27.9	28.5	
		5	28.8	28.3	25.0	25.7	27.0	28.7	25.0	27.1	27.2	26.9	27.9	28.2	

Table 8. Catch of young-of-the-year Striped Bass per seine haul in the primary nursery areas of Virginia in 2015 summarized by water temperature.

	2015				All Years Combined (1967-2014)			
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	4	4.17	0.94 – 10.62	2	2,664	3.96	3.49 – 4.47	651
25.0 - 29.9	1,809	13.12	10.57 – 16.18	160	42,295	8.72	8.33 – 9.11	4,558
30.0 - 34.9	71	5.76	3.01 – 9.94	18	9,665	9.53	8.62 – 10.52	937
Overall	1,884	12.00	9.79 – 14.62	180	55,053	8.63	6.95 – 10.30	6,231

Table 9. Catch of young-of-the-year Striped Bass per seine haul in the primary nursery areas of Virginia in 2015 summarized by salinity.

	2015				All Years Combined (1967-2014)			
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	1,797	12.66	10.18 – 15.62	164	51,307	9.38	9.00 – 9.78	5,186
5.0 - 9.9	87	9.22	5.46 – 14.80	16	3,322	4.30	3.85 – 4.79	773
10.0 - 14.9	N/A			0	422	2.16	1.75 – 2.61	244
15.0 - 19.9	N/A			0	2	0.12	-0.04 – 0.29	28
Overall	1,884	12.00	9.79 – 14.62	180	55,053	8.63	6.95 – 10.30	6,231

Table 10. Salinity (ppt) recorded at seine survey stations in 2015. 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	J78
	Round	1	6.3	4.7	2.3	0.4	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
		2	13.0	4.9	2.5	0.6	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
		3	14.0	6.8	4.1	1.9	0.6	0.6	0.5	0.1	0.1	0.1	0.1	0.1	0.1
		4	15.6	7.9	5.1	2.6	0.9	1.1	1.0	0.2	0.1	0.1	0.1	0.1	0.1
		5	17.9	10.8	6.7	3.8	2.1	2.2	2.1	0.6	0.3	0.1	0.2	0.2	0.2
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	13.5	9.4	7.1	0.8	0.1	0.1	0.0	0.1					
		2	13.9	11.4	7.1	1.2	0.2	0.1	0.1	0.1					
		3	16.1	12.9	10.0	3.0	0.9	0.2	0.1	0.1					
		4	17.1	13.9	10.6	3.7	1.3	0.3	0.1	0.0					
		5	17.6	16.6	12.4	6.3	3.0	1.0	0.3	0.2					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				1.2	0.1	0.0	0.0	0.0	0.0				
		2				2.2	0.2	0.1	0.0	0.0	0.0				
		3				3.0	0.8	0.1	0.0	0.0	0.0				
		4				4.1	1.4	0.2	0.1	0.1	0.0				
		5				8.4	4.7	1.3	0.3	0.3	0.1				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	Round	1	14.3	12.7	9.2	3.0	0.4	0.3	0.1	0.1	0.1	0.1	0.0	0.0	
		2	14.0	11.6	7.9	1.5	0.3	0.2	0.1	0.1	0.0	0.0	0.1	0.1	
		3	13.6	12.3	9.9	4.6	1.4	0.6	0.1	0.1	0.0	0.0	0.0	0.1	
		4	14.5	12.8	9.8	4.6	2.5	1.4	0.3	0.1	0.0	0.1	0.1	0.1	
		5	14.7	13.5	11.4	5.1	3.2	2.3	0.5	0.3	0.1	0.1	0.1	0.1	

Table 11. Dissolved oxygen concentrations (mg/L) at seine survey stations in 2015. The York drainage includes the Pamunkey and Mattaponi rivers. Blue shaded values are more than one standard error (SE) less than the mean dissolved oxygen concentrations recorded at that station from 1989 to 2014. Yellow shaded values denote particularly low dissolved oxygen values (also more than 1 SE below the long-term mean). Index stations are indicated by bold font.

Drainage															
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J78
	Round	1	6.3	8.0	6.6	6.0	7.1	6.5	6.0	8.5	6.5	6.3	7.9	6.4	5.9
		2	6.2	6.6	7.4	6.1	9.1	7.5	6.9	8.6	8.2	8.0	10.1	6.3	6.4
		3	6.3	7.8	6.9	6.0	8.4	6.8	5.9	6.4	6.4	6.3	8.7	6.5	5.4
		4	6.2	6.8	7.2	6.1	8.0	8.5	6.4	8.0	6.9	6.9	10.6	7.5	6.8
		5	6.6	7.8	6.9	5.4	8.0	7.1	5.8	4.9	5.6	5.9	5.6	5.8	6.3
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	Round	1	5.7	5.8	3.8	4.0	5.3	4.4	3.8	6.3					
		2	5.1	5.1	4.8	4.1	4.8	5.2	4.3	5.1					
		3	4.9	4.9	6.3	5.0	6.0	5.5	5.6	5.5					
		4	4.9	4.9	4.2	5.9	6.2	6.5	6.2	7.7					
		5	4.9	4.1	4.1	3.6	5.1	5.9	5.1	5.7					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	Round	1				3.5	4.3	3.8	3.8	6.8	4.4				
		2				4.2	3.6	3.8	4.3	5.5	4.8				
		3				4.7	5.0	4.6	4.9	6.1	5.1				
		4				7.8	4.6	5.0	5.8	8.4	5.0				
		5				3.4	4.2	4.1	4.2	5.6	4.4				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	Round	1	7.1	6.2	5.4	5.5	6.7	5.9	6.9	7.3	6.5	7.2	4.3	4.6	
		2	7.4	7.4	7.0	7.1	7.4	7.9	7.2	7.4	7.4	9.0	4.7	4.4	
		3	7.3	7.1	5.6	6.1	7.8	8.7	6.1	4.9	5.3	7.1	5.4	6.2	
		4	8.4	6.8	6.5	7.4	6.4	8.3	8.0	7.9	6.5	6.3	7.7	6.4	
		5	7.1	7.3	5.4	5.0	5.9	7.5	6.6	6.4	6.2	6.7	6.3	6.4	

Table 12. Species collected during the 2015 seine survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Menidia menidia	Atlantic Silverside	8,987
Morone americana	White Perch	8,173
Notropis hudsonius	Spottail Shiner	5,999
Alosa aestivalis	Blueback Herring	5,905
Morone saxatilis	Striped Bass	3,093
Anchoa mitchilli	Bay Anchovy	2,470
Trinectes maculatus	Hogchoker	2,267
Menidia beryllina	Inland Silverside	2,231
Alosa sapidissima	American Shad	1,412
Fundulus heteroclitus	Mummichog	1,382
Fundulus diaphanus	Banded Killifish	1,243
Fundulus majalis	Striped Killifish	1,035
Dorosoma cepedianum	Gizzard Shad	799
Hybognathus regius	Eastern Silvery Minnow	704
Ictalurus furcatus	Blue Catfish	302
Bairdiella chrysoura	Silver Perch	298
Etheostoma olmstedi	Tessellated Darter	258
Brevoortia tyrannus	Atlantic Menhaden	246
Notropis analostanus	Satinfin Shiner	223
Alosa pseudoharengus	Alewife	220
Menticirrhus americanus	Southern Kingfish	208
Lepomis macrochirus	Bluegill	137
Mugil curema	White Mullet	128
Perca flavescens	Yellow Perch	95
Cynoscion regalis	Weakfish	73
Membras martinica	Rough Silverside	67
Leiostomus xanthurus	Spot	55
Notemigonus crysoleucas	Golden Shiner	48
Anchoa hepsetus	Striped Anchovy	37
Ictalurus catus	White Catfish	33
Strongylura marina	Atlantic Needlefish	33
Alosa mediocris	Hickory Shad	29
Dorosoma petenense	Threadfin Shad	29
Ictalurus punctatus	Channel Catfish	28
Lepomis gibbosus	Pumpkinseed	27
Enneacanthus gloriosus	Bluespotted Sunfish	26
Anguilla rostrata	American Eel	21

Table 12. (cont'd.)

Scientific Name	Common Name	Total Caught
Lepomis auritus	Redbreast Sunfish	19
Mugil cephalus	Striped Mullet	15
Pogonias chromis	Black Drum	14
Micropterus salmoides	Largemouth Bass	14
Micropterus punctulatus	Spotted Bass	9
Micropogonias undulatus	Atlantic Croaker	8
Gambusia affinis	Mosquitofish	8
Moxostoma macrolepidotum	Shorthead Redhorse	7
Peprilus alepidotus	Harvestfish	6
Carpiodes cyprinus	Quillback	6
Syngnathus fuscus	Northern Pipefish	6
Hemiramphus brasiliensis	Ballyhoo	5
Lepisosteus osseus	Longnose Gar	4
Ictalurus nebulosus	Brown Bullhead	4
Gobiosoma bosc	Naked Goby	4
Lagodon rhomboides	Pinfish	4
Cyprinus carpio	Carp	4
Paralichthys dentatus	Summer Flounder	3
Scomberomorus maculatus	Spanish Mackerel	3
Pomatomus saltatrix	Bluefish	3
Chaetodipterus faber	Atlantic Spadefish	2
Lepomis microlophus	Redear Sunfish	2
Lepomis cyanellus	Green Sunfish	2
Sphoeroides maculatus	Northern Puffer	1
Notorus gyrinus	Tadpole Madtom	1
Pomoxis nigromaculatus	Black Crappie	1
Gobiesox strumosus	Skilletfish	1
Amia calva	Bowfin	1
	Total	48,478

Table13. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by river and year.

Year	James River		York River		Rappahannock River		N
	# of Fish	Delta Mean	# of Fish	Delta Mean	# of Fish	Delta Mean	(hauls)
1967	275	26.3	6	0.7	256	34.4	26
1968	47	2.4	10	0.7	125	6.9	19
1969	324	21.7	106	7.4	242	13.9	39
1970	1138	79.4	7	0.5	267	24	48
1971	280	16.7	17	1.5	311	23.2	44
1972	36	1.4	247	7.1	392	44.7	57
1973	29	1.4	71	4.1	296	15.7	53
1980	56	2.3	211	15.6	145	9.4	34
1981	89	3.1	22	0.6	133	8.9	45
1982	2	1.4	292	20.2	126	16.9	28
1983	111	10.7	175	9.9	128	13.7	39
1984	64	5.7	100	5.4	156	25.6	44
1985	12	1	88	3.2	31	2.3	25
1986	280	18.9	79	2.9	336	40	49
1987	267	38.5	880	63.2	1177	60.8	63
1988	129	21.5	69	2.2	287	13.9	61
1989	391	12.9	807	28.2	1349	48.8	104
1990	216	5.9	70	1.7	487	11.7	84
1991	231	6.4	169	4.2	387	13.1	91
1992	257	7.7	4	0.1	395	11.9	67
1993	3174	115.8	344	7.6	1177	46.4	113
1994	437	18	420	9.4	655	19.1	125
1995	584	19.1	17	0.3	418	12.5	93
1996	2882	163.7	1654	66.5	2294	79.5	126
1997	812	60.8	305	8.3	248	6.3	102
1998	1145	35.1	195	4.7	457	18.5	108
1999	135	3.4	1	0.0	486	13.3	67
2000	1397	38.3	1363	40.0	1184	34.4	121
2001	698	20.9	799	21.1	1126	32.1	123
2002	603	19.3	129	2.7	275	7.1	83
2003	1089	35.5	1132	27.8	1849	69.3	120
2004	890	24.2	799	22.0	670	17.8	130
2005	1167	54.6	579	15.3	834	28	122
2006	1509	45.2	95	2.8	388	10	99
2007	2278	69.3	417	22.7	830	24.2	113
2008	1318	40.6	184	4.1	1512	71	107
2009	2880	124.5	10	0.2	1813	79	90
2010	2058	99.1	1632	43.6	728	19.2	130
2011	12992	697.4	4112	132.6	4169	163.1	140
2012	1021	24.6	47	1.0	338	8.7	99
2013	1141	43.3	433	10.4	623	17.8	119
2014	1430	71.1	2373	62.0	841	22.1	120
2015	892	32.8	1621	53.5	1017	25.6	140

Table 14. Delta-lognormal mean of young-of-the-year Atlantic Croaker from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Delta Mean	N (hauls)
1980	167	5.3	20
1981	0	0.0	0
1982	52	1.1	5
1983	114	5.4	10
1984	17	0.5	4
1985	129	4.1	14
1986	9	0.7	4
1987	46	1.9	9
1988	10	0.6	4
1989	112	1.5	16
1990	20	0.3	2
1991	636	10.0	48
1992	717	11.6	41
1993	1115	24.9	47
1994	862	16.8	39
1995	598	14.0	36
1996	18	0.4	3
1997	955	27.4	48
1998	840	14.7	43
1999	519	9.3	38
2000	21	0.3	10
2001	35	0.8	11
2002	146	2.2	29
2003	8	0.1	4
2004	185	4.8	20
2005	177	6.7	24
2006	399	6.6	37
2007	329	16.2	21
2008	1306	77.3	52
2009	1724	50.1	46
2010	76	2.1	13
2011	36	0.5	10
2012	953	22.7	49
2013	749	16.2	36
2014	9	0.2	2
2015	7	0.1	2

Table 15. Delta-lognormal mean of young-of-the-year Spot from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Delta Mean	N (hauls)
1967	73	2.3	14
1968	655	11.6	38
1969	528	9.6	50
1970	57	0.6	25
1971	704	11.8	58
1972	443	2.6	54
1973	2306	49.0	72
1980	2174	25.0	72
1981	829	14.5	43
1982	631	91.7	18
1983	129	5.6	16
1984	899	30.5	19
1985	406	12.0	26
1986	1338	59.8	33
1987	161	5.1	15
1988	943	21.0	37
1989	1319	20.9	52
1990	1050	11.1	62
1991	1069	12.8	74
1992	525	6.0	65
1993	961	11.1	74
1994	990	10.0	60
1995	237	2.3	40
1996	728	11.3	44
1997	1900	25.4	78
1998	881	15.8	55
1999	887	11.3	77
2000	465	6.2	46
2001	484	6.6	53
2002	185	1.7	44
2003	470	5.9	27
2004	581	6.1	51
2005	2711	27.6	87
2006	471	5.0	66
2007	977	16.9	77
2008	906	9.7	84
2009	1208	14.1	73
2010	2801	30.7	87
2011	669	12.8	60
2012	581	6.6	66
2013	635	11.8	58
2014	591	13.1	48
2015	44	0.4	11

Table 16. Delta-lognormal mean of Spottail Shiner from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Delta Mean	N (hauls)
1989	2843	22.3	115
1990	2019	15.3	104
1991	1394	10.8	94
1992	2313	17.5	99
1993	1708	12.8	99
1994	2286	18.6	110
1995	2212	18.0	105
1996	2182	18.4	109
1997	3568	25.9	105
1998	2100	16.3	101
1999	1149	8.3	81
2000	4857	40.2	113
2001	2721	21.7	113
2002	1381	9.9	71
2003	3070	23.4	126
2004	5133	42.0	127
2005	3597	30.6	112
2006	3464	29.2	107
2007	3837	33.7	111
2008	2147	17.9	95
2009	3035	24.1	101
2010	3989	27.0	105
2011	6284	58.5	122
2012	4022	30.8	103
2013	4325	33.7	109
2014	3401	24.8	125
2015	4463	33.8	131
Overall (1989-2014)	83,500	24.3	26 (years)

Table 17. Delta-lognormal mean of Atlantic Silverside from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Index	N (hauls)
1989	1089	10.8	27
1990	2917	51.0	51
1991	2855	39.9	68
1992	6087	125.8	58
1993	2364	31.8	59
1994	2305	34.1	52
1995	3079	41.4	59
1996	4871	85.3	52
1997	1160	13.2	55
1998	2434	26.0	66
1999	6822	68.2	88
2000	3778	44.0	65
2001	4015	54.7	73
2002	5387	67.0	96
2003	3351	53.9	35
2004	1503	20.9	39
2005	1979	22.1	69
2006	2847	31.1	67
2007	2067	29.2	68
2008	3454	36.5	58
2009	2916	37.6	72
2010	1723	18.6	86
2011	3585	47.5	75
2012	1381	14.2	68
2013	6814	92.4	59
2014	4966	65.4	70
2015	7542	104.0	74
Overall (1989-2014)	93,291	44.5	26 (years)

Table 18. Delta-lognormal mean of Inland Silverside from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Index	N (hauls)
1989	495	3.0	86
1990	591	3.8	76
1991	286	1.8	66
1992	339	1.8	60
1993	385	2.3	59
1994	171	1.0	49
1995	109	0.7	48
1996	807	5.4	60
1997	201	1.2	57
1998	213	1.4	61
1999	307	1.9	58
2000	729	5.1	77
2001	660	4.1	66
2002	498	3.0	67
2003	574	3.4	98
2004	1125	6.6	84
2005	419	2.5	78
2006	1184	7.5	88
2007	861	5.4	78
2008	704	3.9	92
2009	1751	9.8	113
2010	1507	8.8	78
2011	1476	7.6	89
2012	962	5.2	111
2013	1658	10.3	109
2014	1849	10.7	107
2015	1618	9.9	108
Overall (1989-2014)	21,479	4.5	26 (years)

Table 19. Delta-lognormal mean of Banded Killifish from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish (x)	Index	N (hauls)
1989	236	1.6	47
1990	238	1.6	50
1991	263	1.9	42
1992	153	1.1	35
1993	264	2.0	41
1994	203	1.4	43
1995	287	2.1	38
1996	654	4.9	64
1997	365	2.6	60
1998	311	2.2	61
1999	297	2.2	49
2000	252	1.7	54
2001	355	2.3	70
2002	364	2.6	49
2003	802	5.7	68
2004	1383	9.6	89
2005	715	5.6	68
2006	498	4.0	48
2007	692	5.0	75
2008	1025	6.8	87
2009	1208	9.0	85
2010	1965	14.8	97
2011	1958	13.9	88
2012	1865	13.3	97
2013	638	4.5	70
2014	715	4.6	87
2015	885	5.5	94
Overall (1989-2014)	18,591	4.6	26 (years)

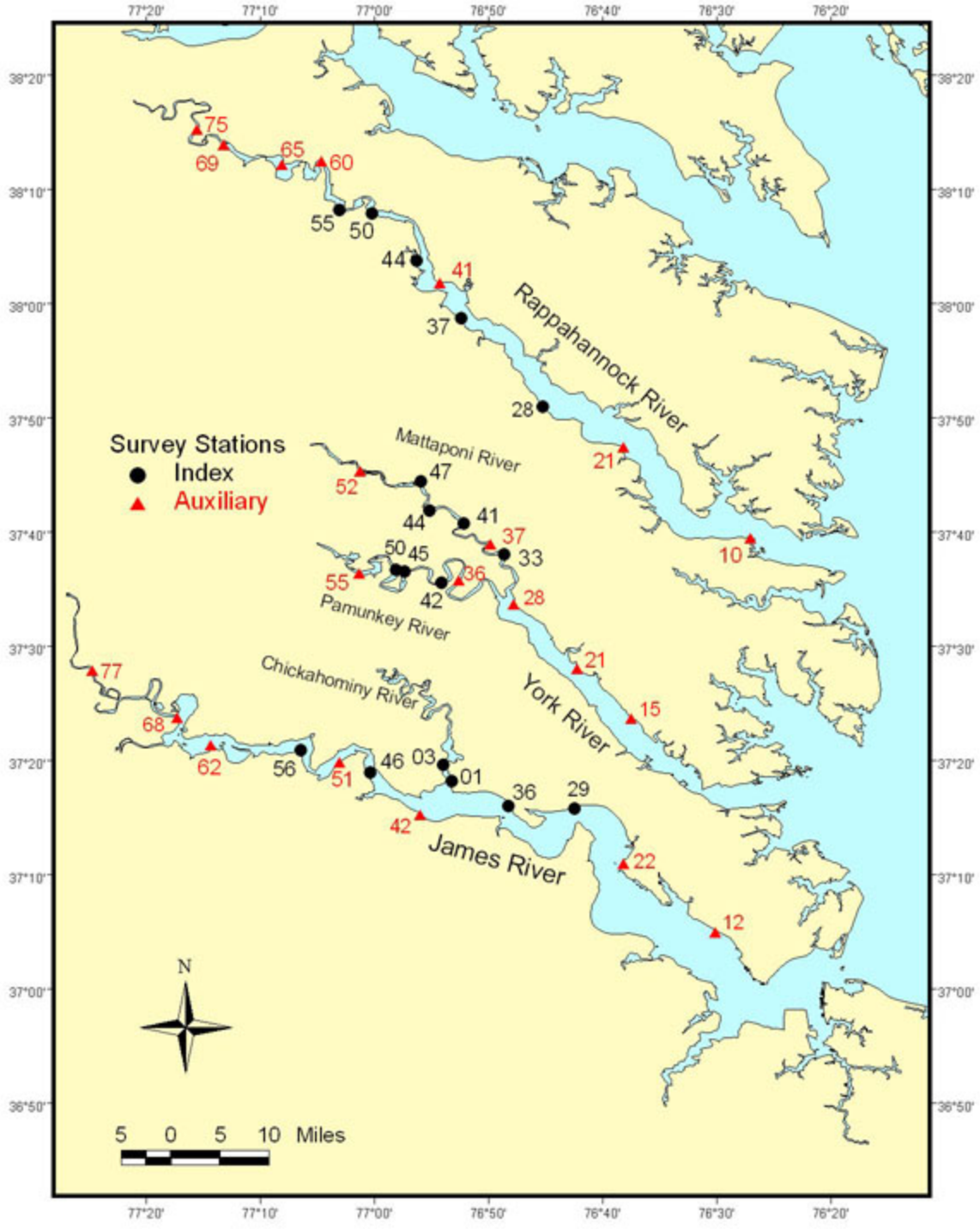

Figure 1. Juvenile Striped Bass seine survey stations. Numeric portion of station designation indicates approximate mile from mouth of river.

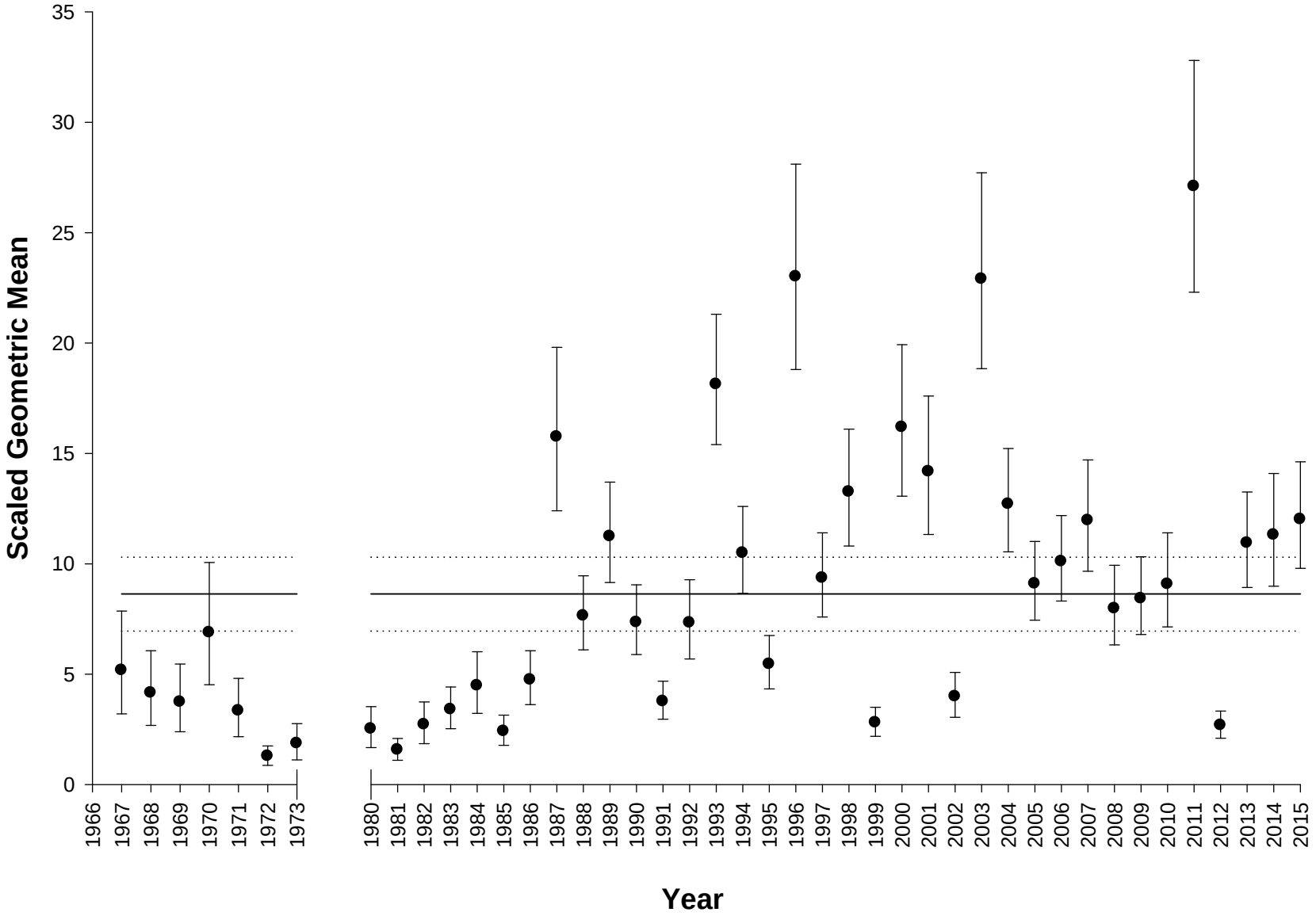

Figure 2. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate the historical arithmetic mean (solid) and confidence intervals (dotted) for 1967-2014.

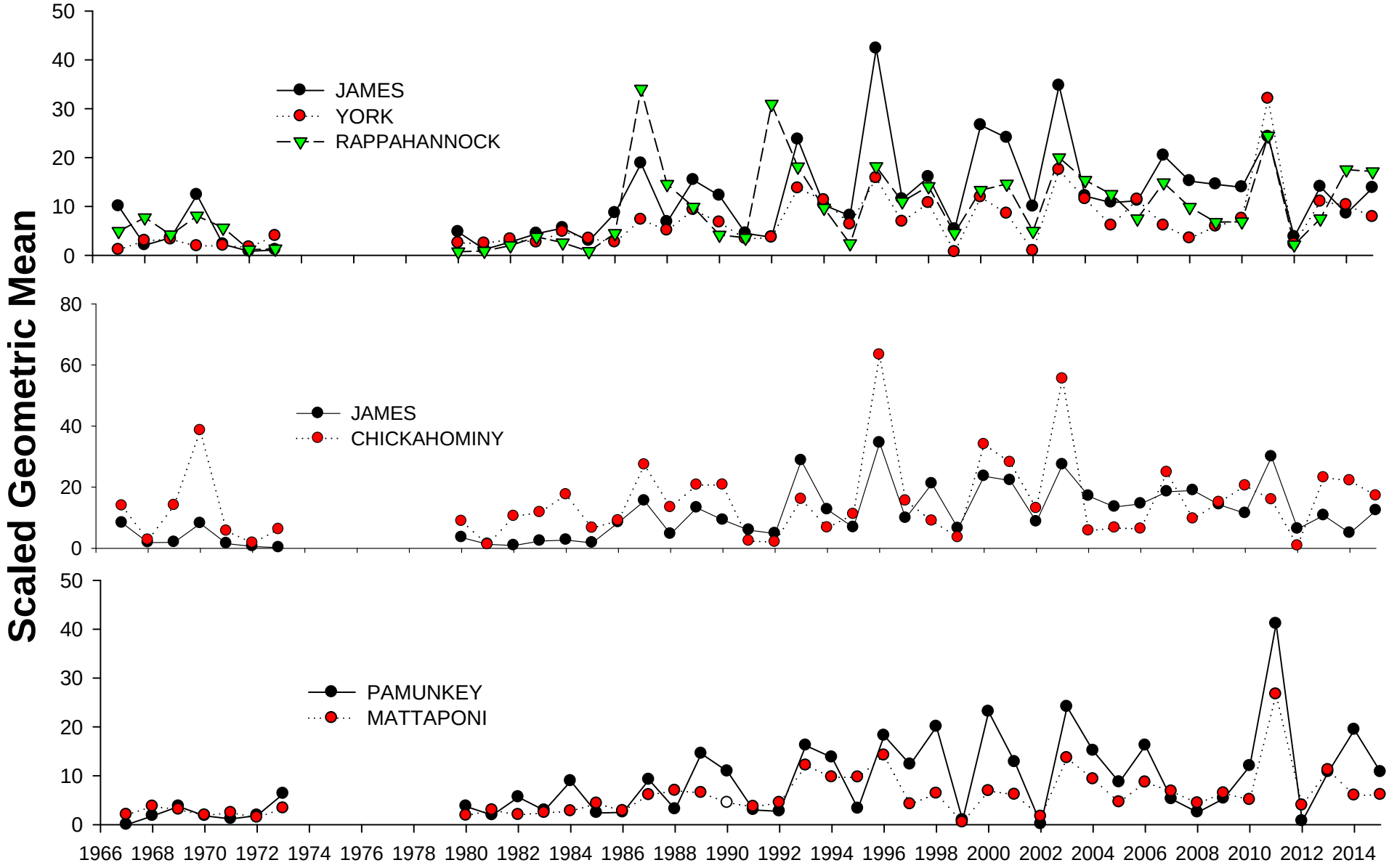

Figure 3. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by drainage and river.

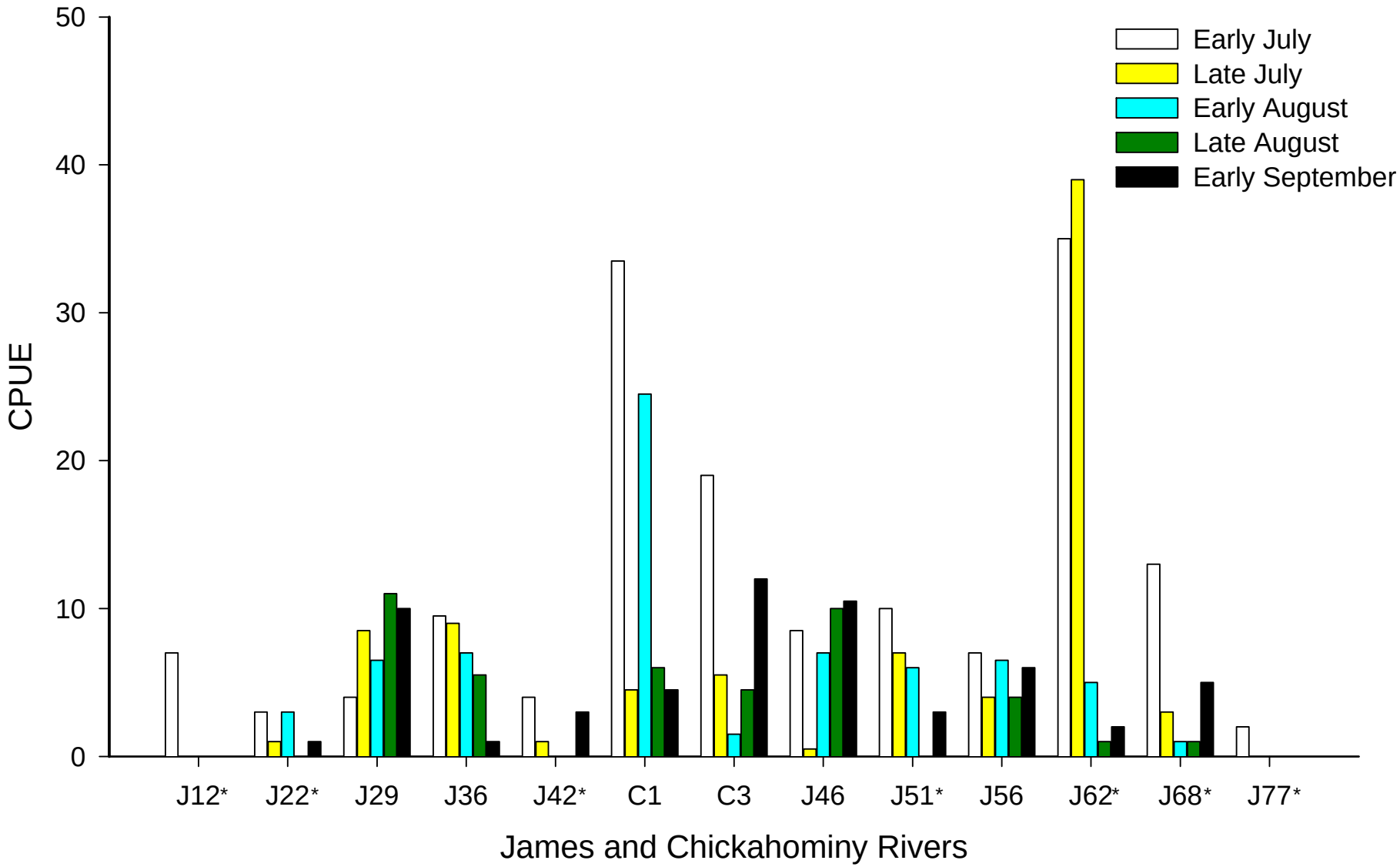

Figure 4. Catch of young-of-the-year Striped Bass by station in the James River drainage in 2015. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. Hauls were completed at all stations during all rounds in 2015.

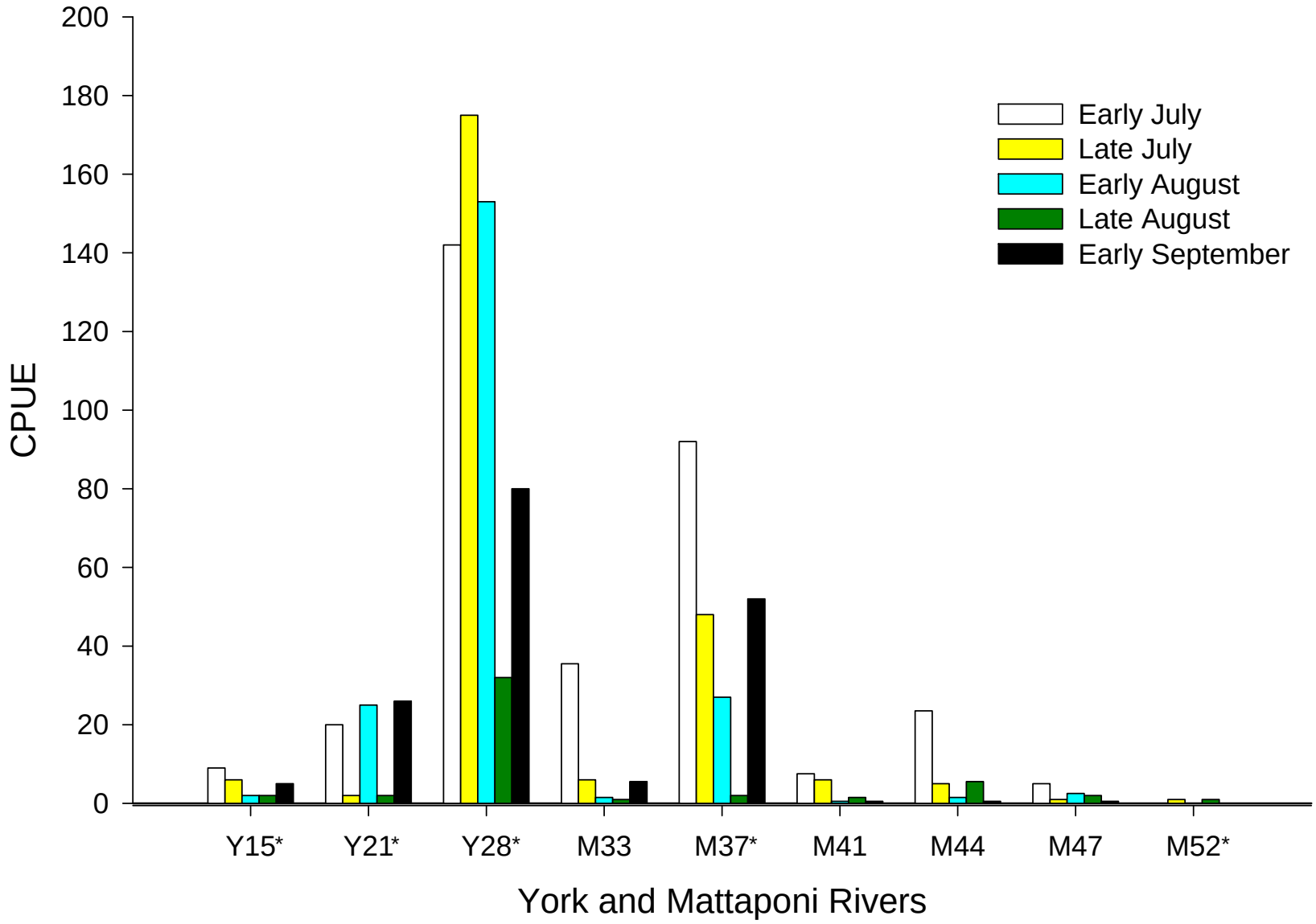

Figure 5. Catch of young-of-the-year Striped Bass by station in the York and Mattaponi rivers in 2015. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. Hauls were completed at all stations during all rounds in 2015.

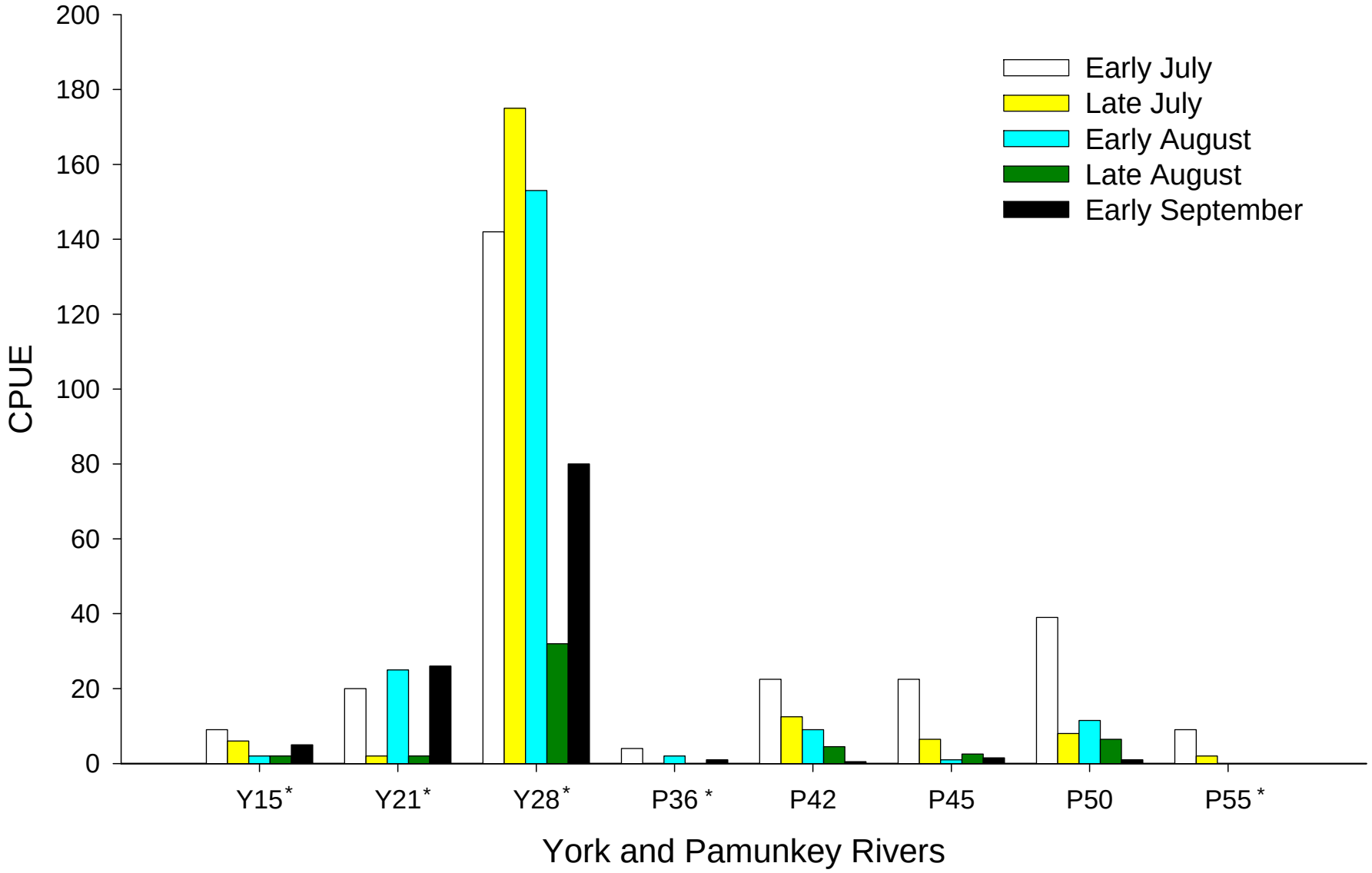

Figure 6. Catch of young-of-the-year Striped Bass by station in the York and Pamunkey rivers in 2015. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. Hauls were completed at all stations during all rounds in 2015.

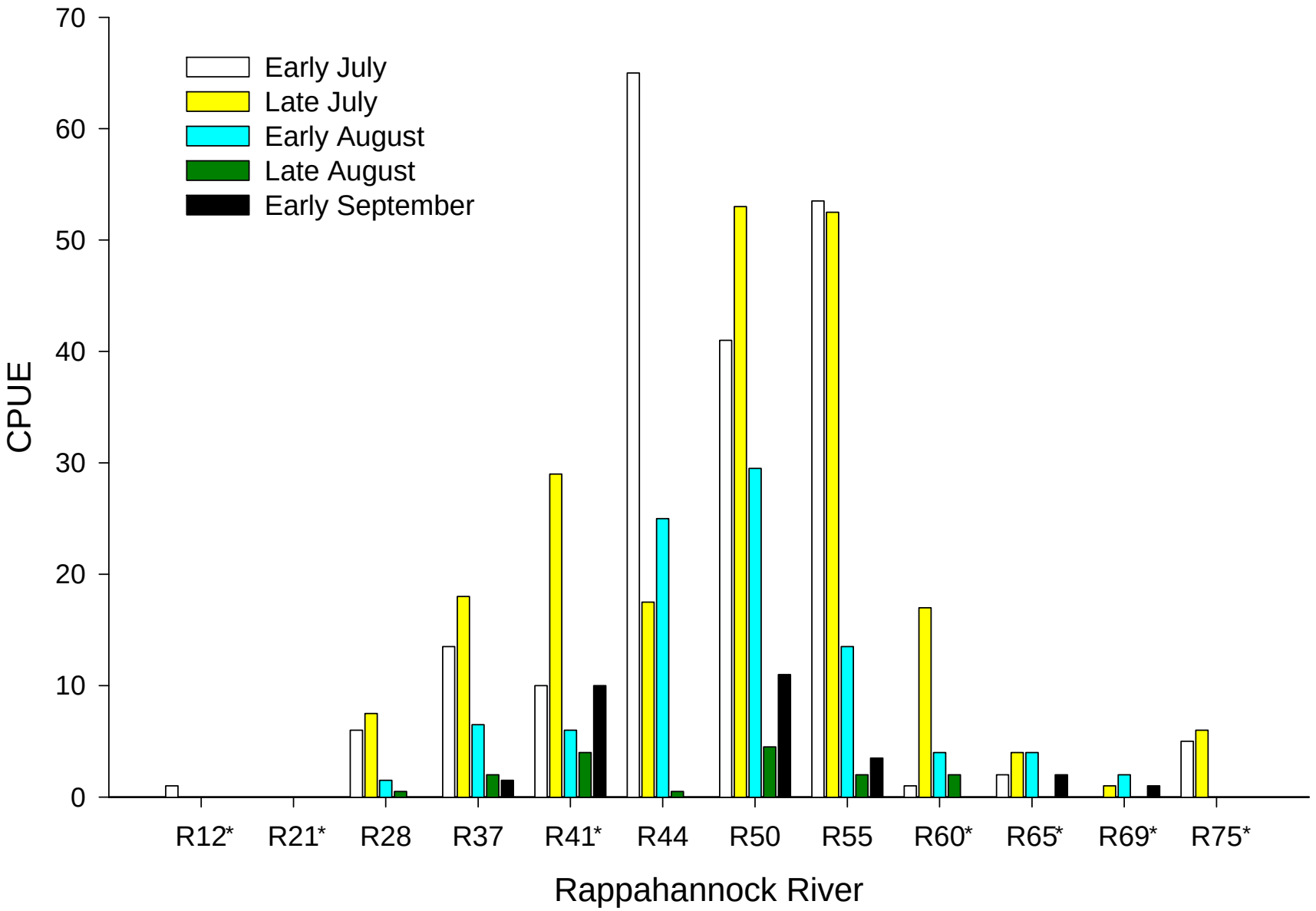

Figure 7. Catch of young-of-the-year Striped Bass by station in the Rappahannock River in 2015. Index station catch represents an average of two hauls; auxiliary station (starred) catch represents one haul. Hauls were completed at all stations during all rounds in 2015.

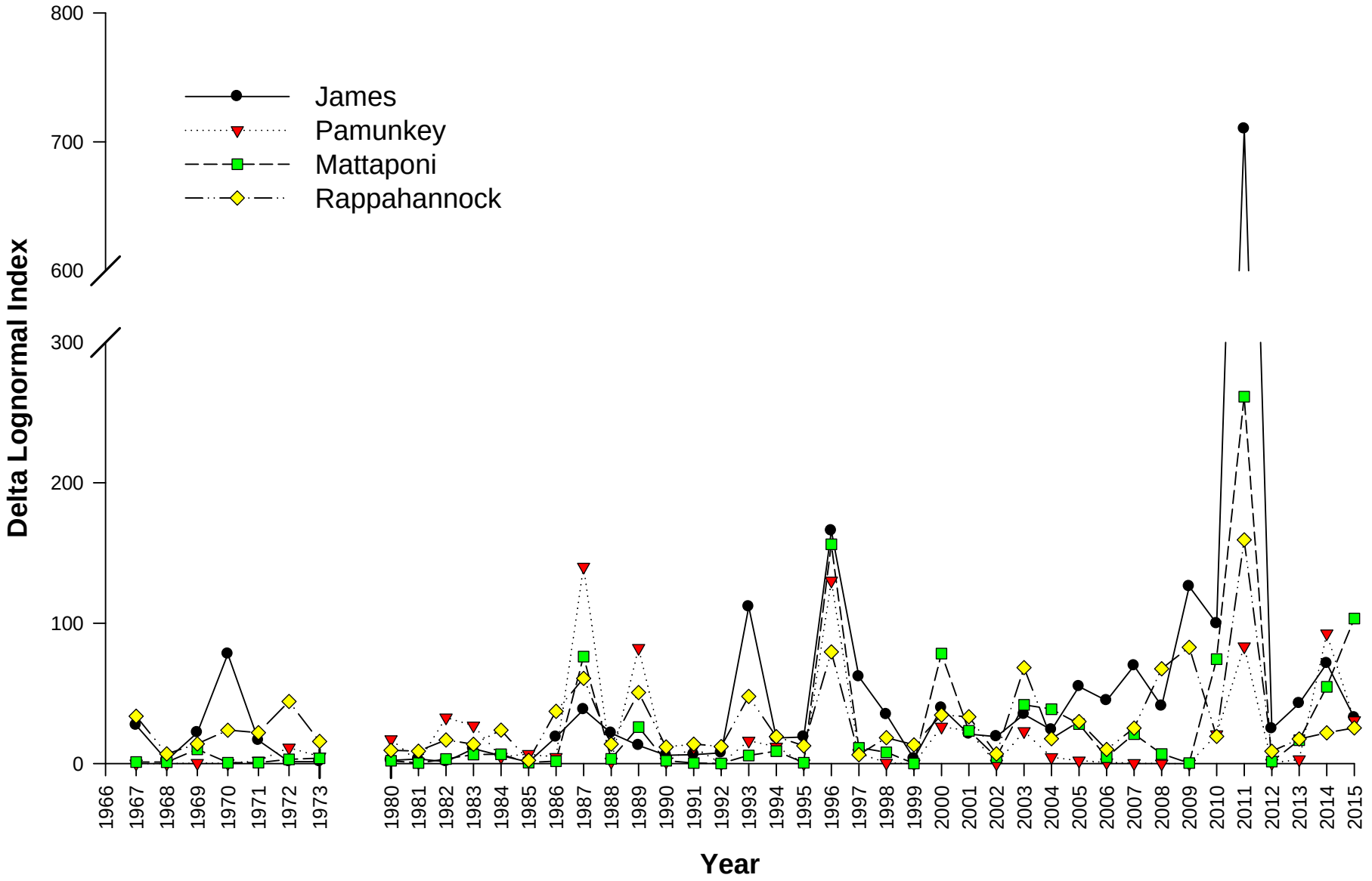

Figure 8. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by river and year.

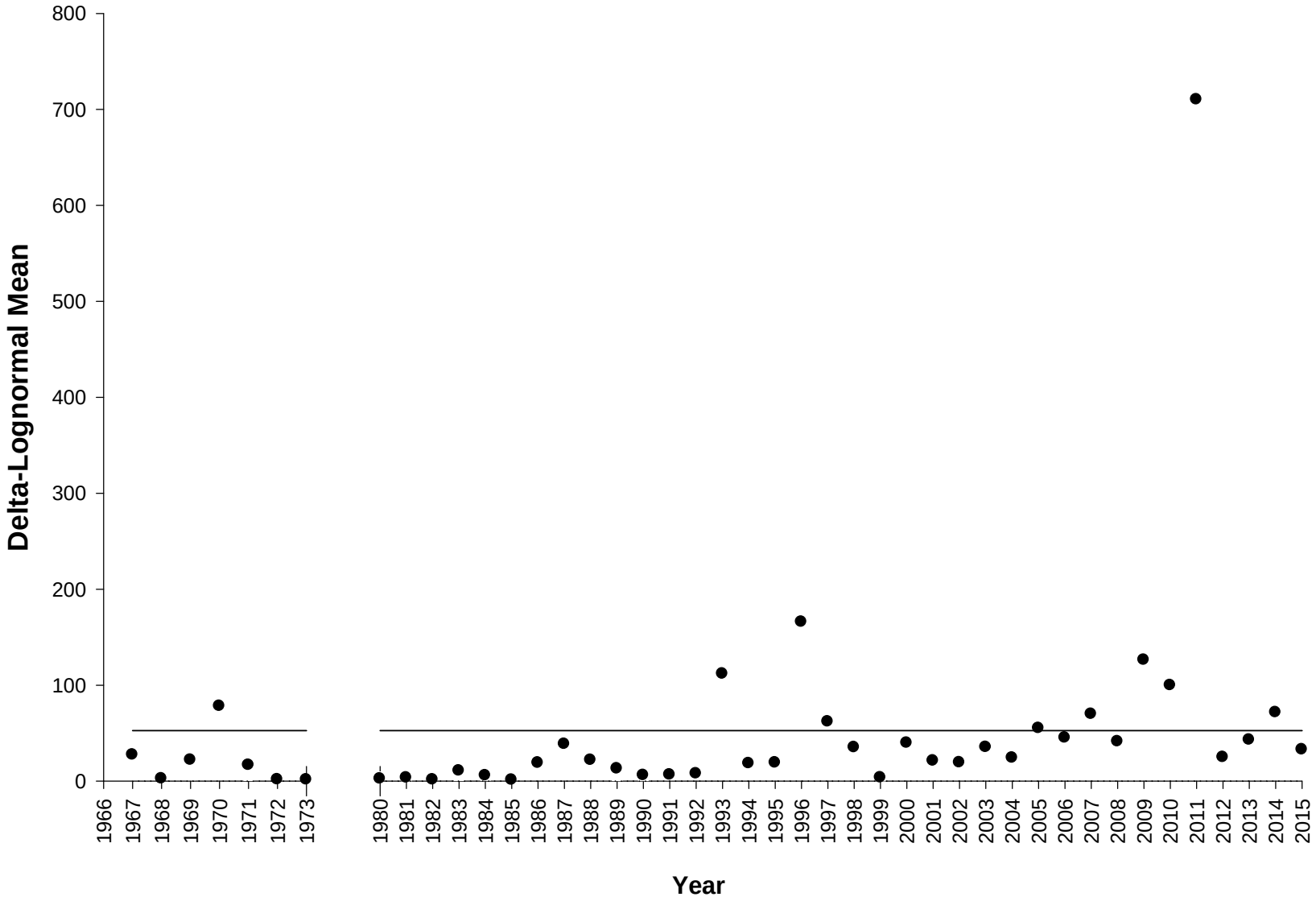

Figure 9. Delta-lognormal mean of young-of-the-year White Perch from the James River nursery area by year. The horizontal line indicates the historical mean for 1967-2014.

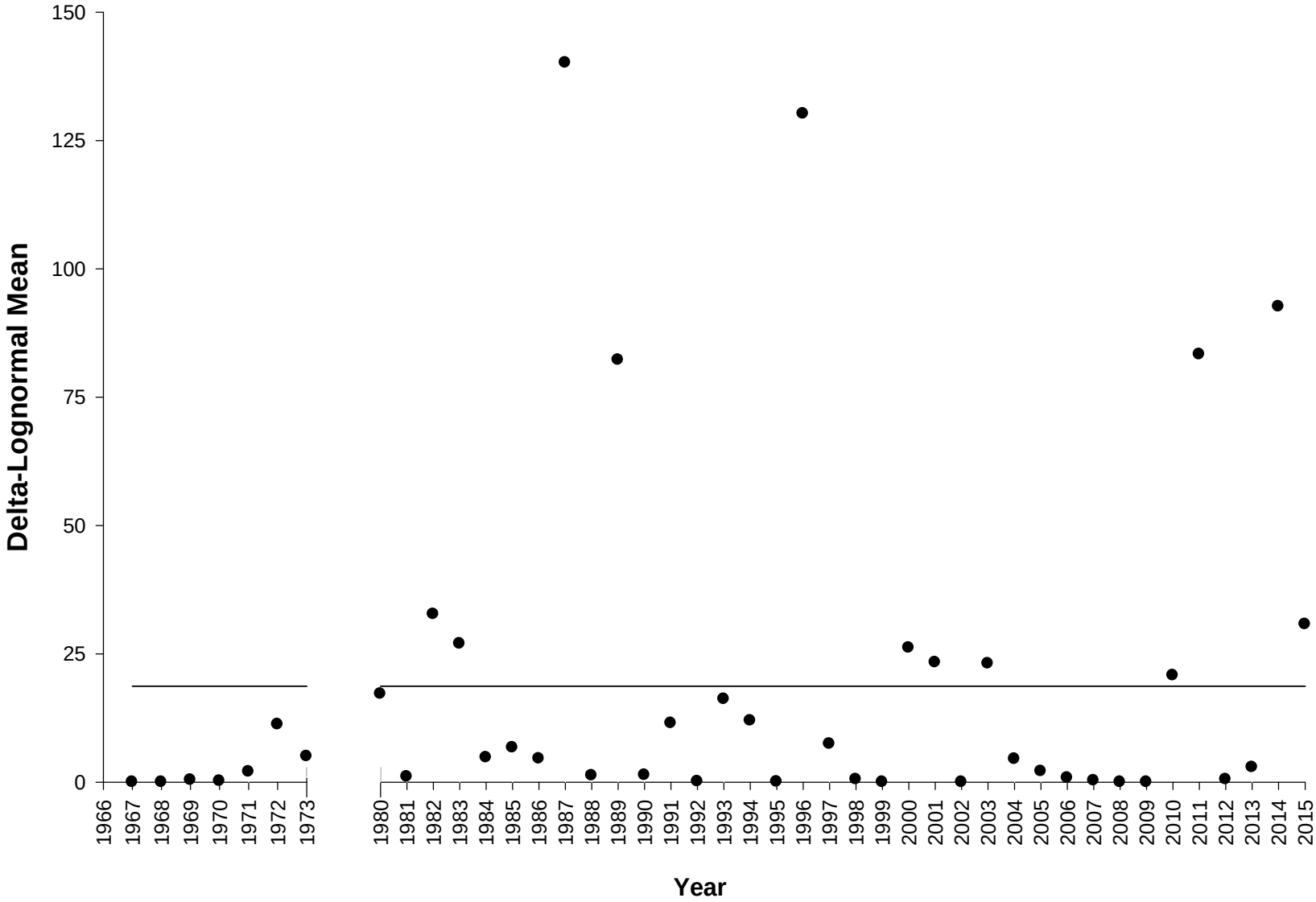

Figure 10. Delta-lognormal mean of young-of-the-year White Perch from the Pamunkey River nursery area by year. The horizontal line indicates the historical mean for 1967-2014.

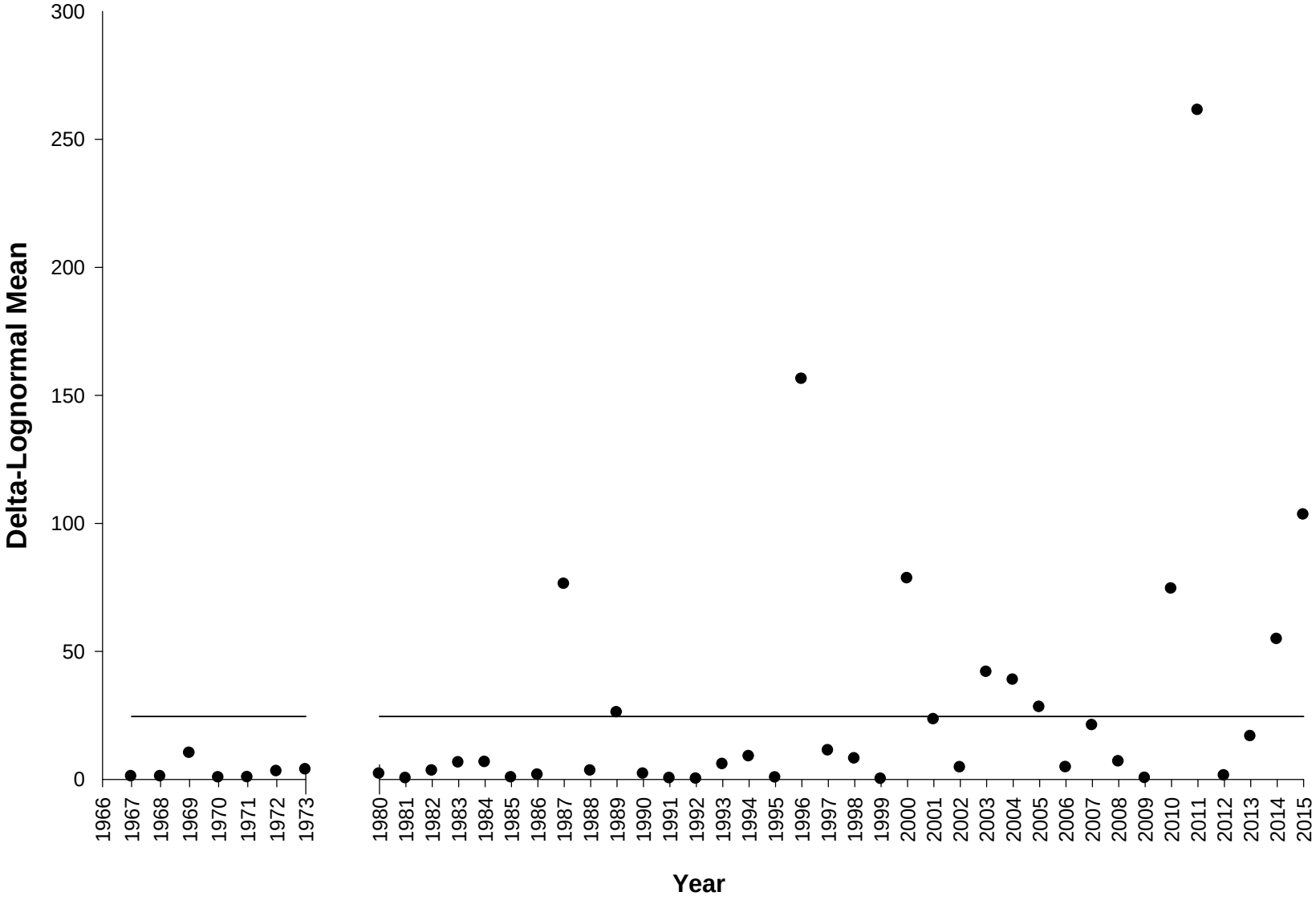

Figure 11. Delta-lognormal mean of young-of-the-year White Perch from the Mattaponi River nursery area by year. The horizontal line indicates the historical mean for 1967-2014

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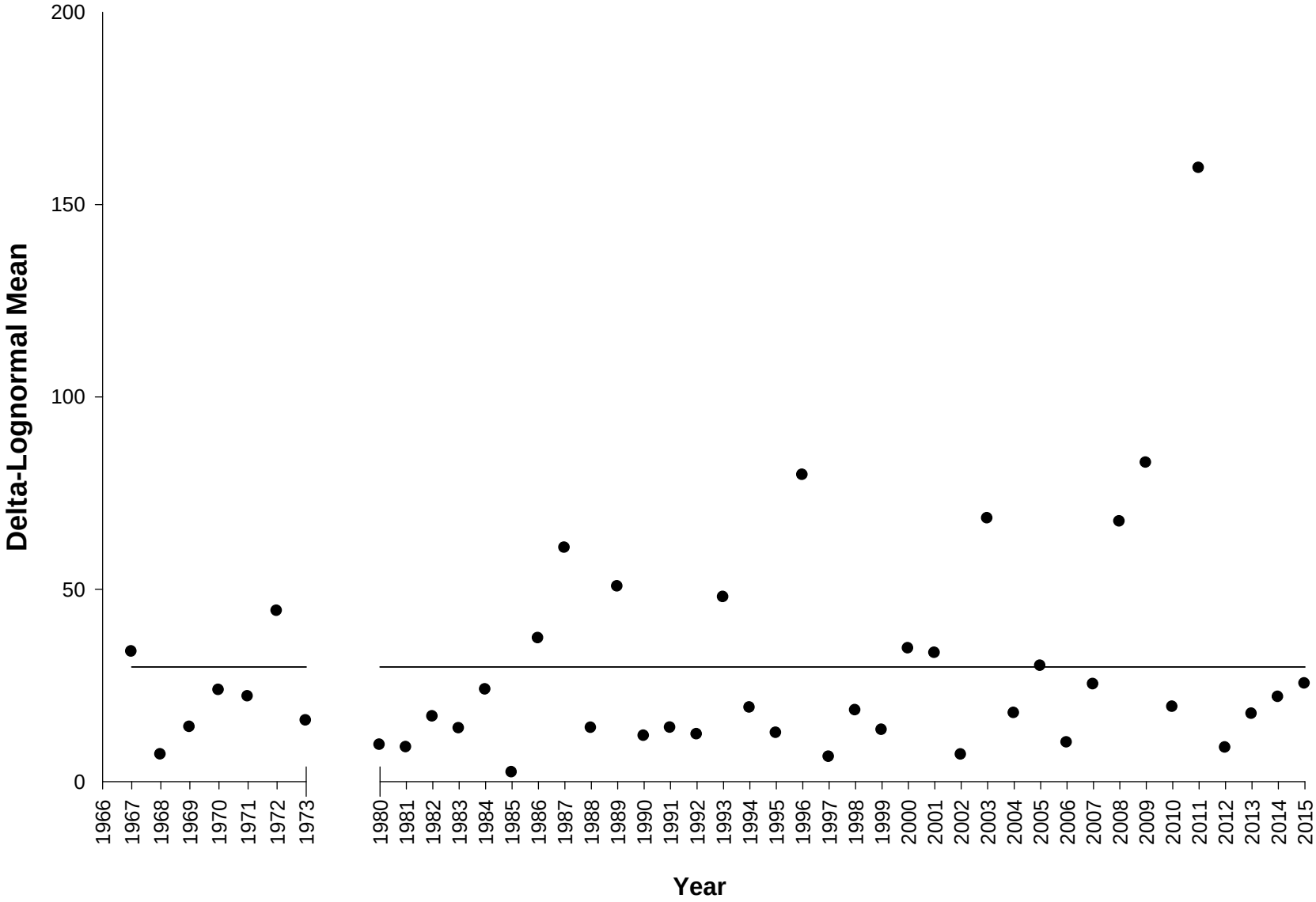

Figure 12. Delta-lognormal mean of young-of-the-year White Perch from the Rappahannock River nursery area by year. The horizontal line indicates the historical mean for 1967-2014.

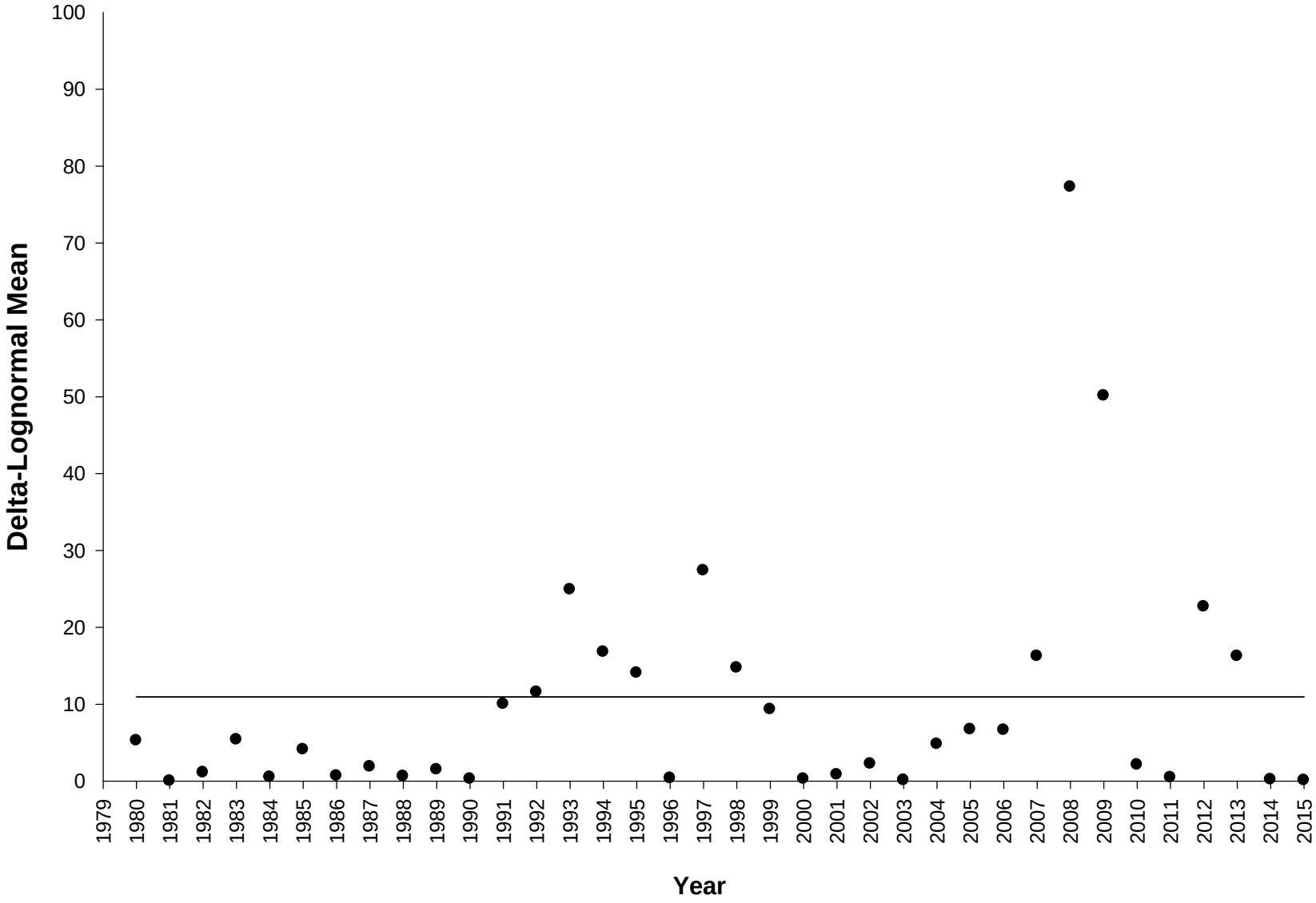

Figure 13. Delta-lognormal mean of young-of-the-year Atlantic Croaker from select seine survey stations in Virginia tributaries of Chesapeake Bay by year. The horizontal line indicates the historical mean for 1980-2014.

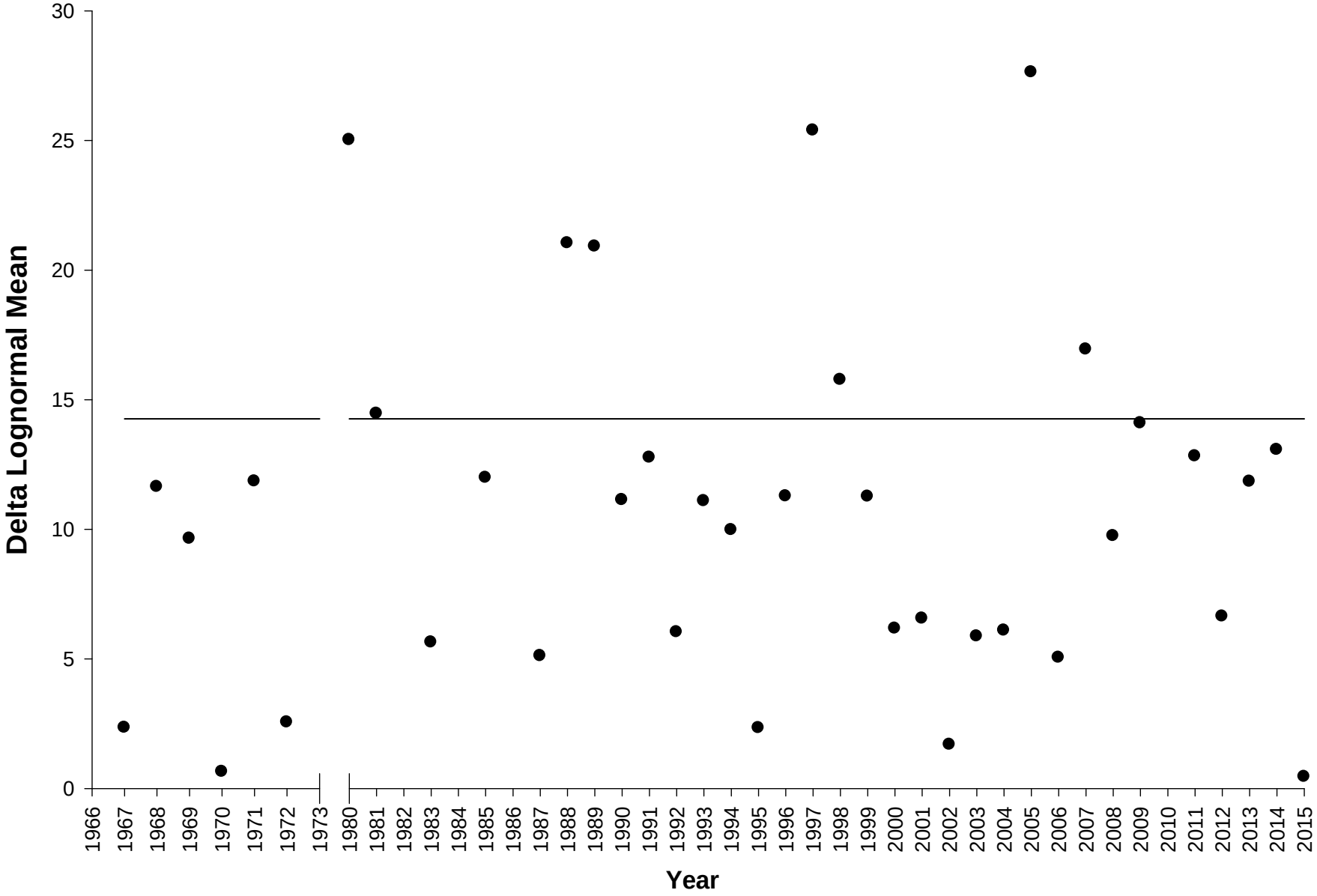

Figure 14. Delta-lognormal mean of young-of-the-year Spot from select seine survey stations in Virginia tributaries of Chesapeake Bay by year. The horizontal line indicates the historical mean for 1967-2014.

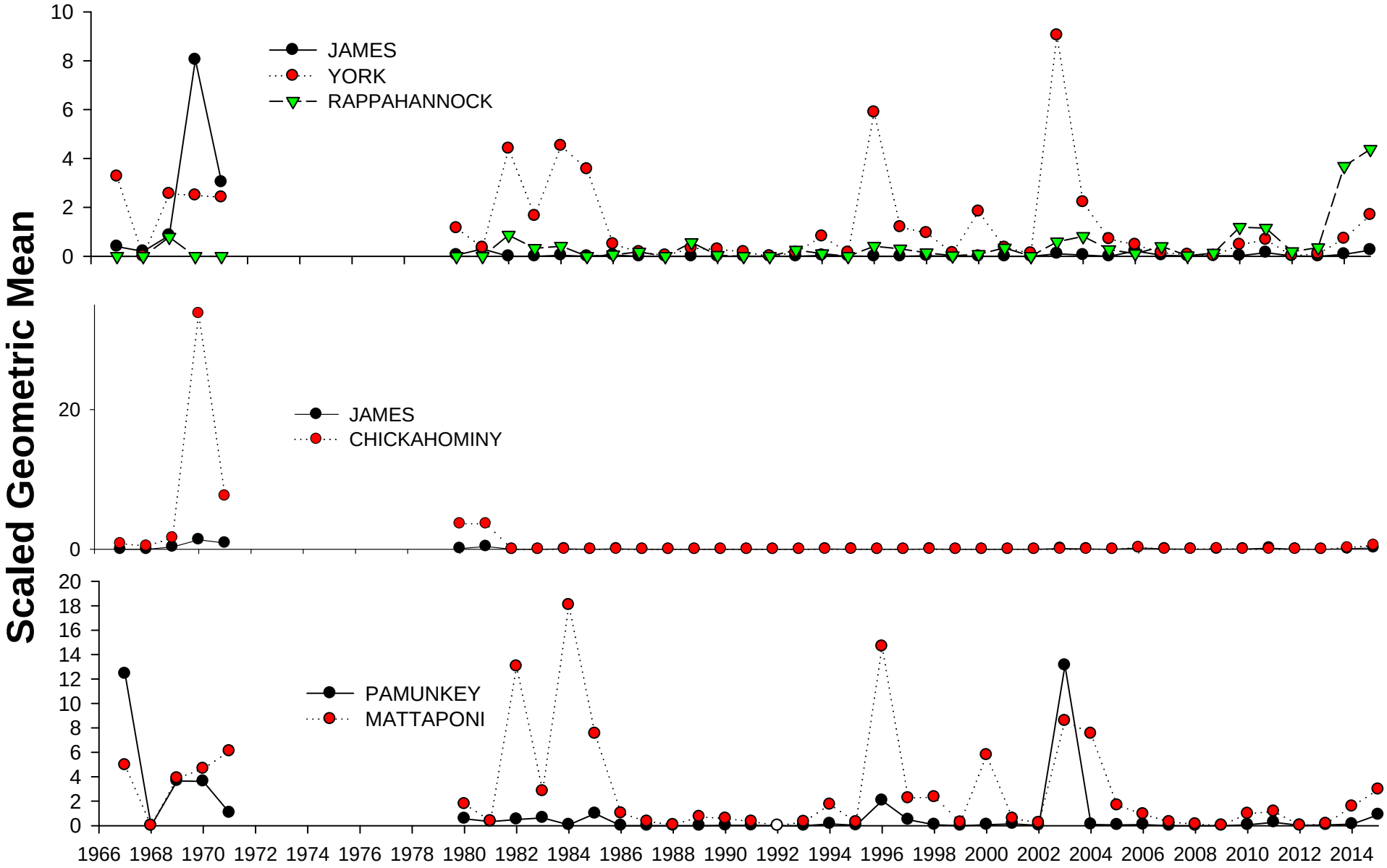

Figure 15. Scaled geometric mean of American Shad in the primary nursery areas of Virginia (index stations) by drainage and river using only the 1st haul.

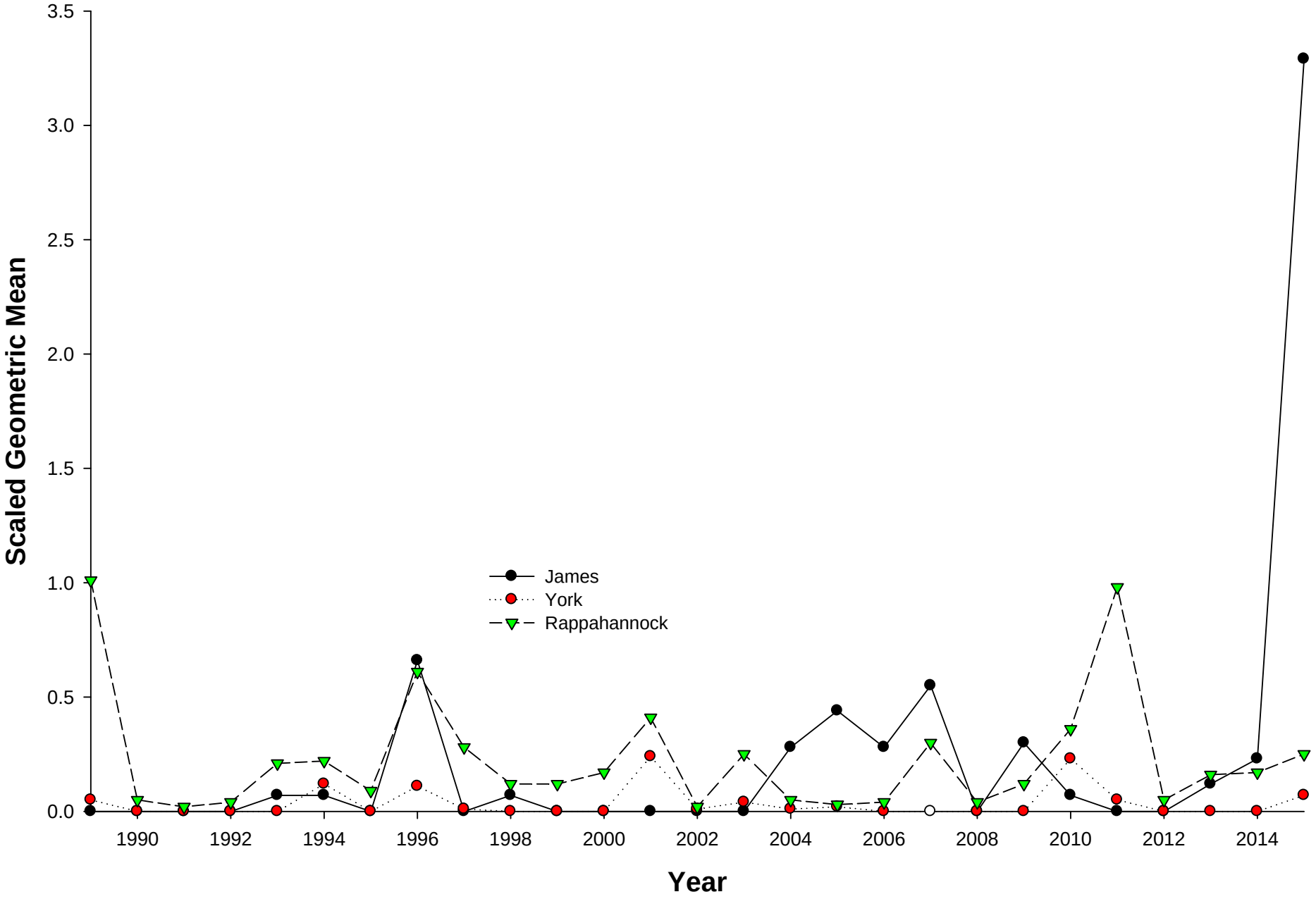

Figure 16. Scaled geometric mean of Alewife in the primary nursery areas of Virginia (index stations) by river using only the 1st haul.

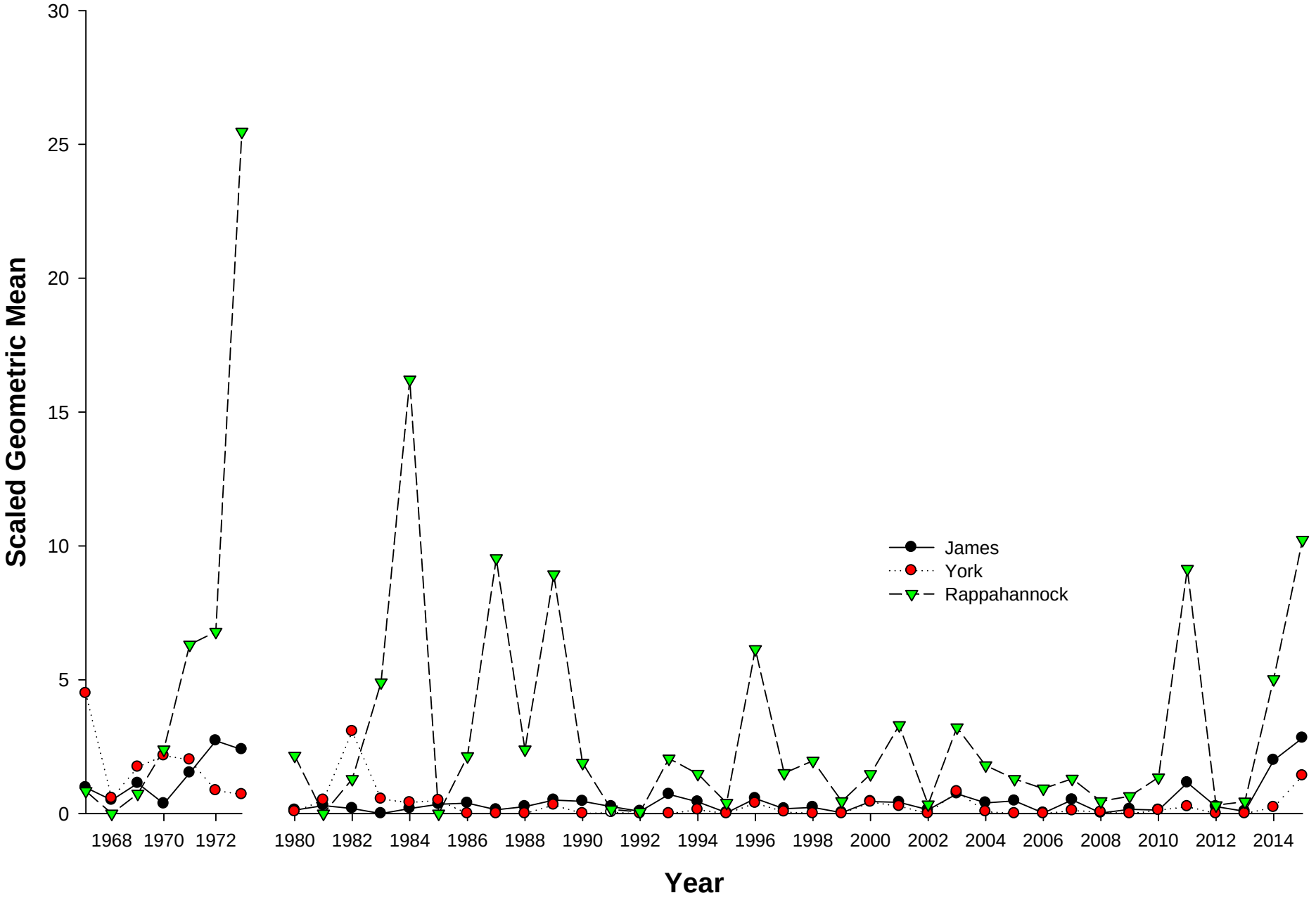

Figure 17. Scaled geometric mean of Blueback Herring in the primary nursery areas of Virginia (index stations) by river using only the 1st haul.