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

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Brian K. Gallagher
Mary C. Fabrizio
Troy D. Tuckey

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

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EXECUTIVE SUMMARY

The 2016 Striped Bass juvenile abundance index was 5.15 and was not significantly different from the reference mean of 7.77 observed from 1980-2009. Abundance indices in the James, York and Rappahannock rivers in 2016 were not significantly different than their historic averages (1967-2015). Juvenile White Perch abundance indices in 2016 were near historic averages in the York and Rappahannock rivers, but below the historic average in the James River. Because a new seine net was used during the 2016 survey, catches of Striped Bass and White Perch were adjusted using preliminary calibration factors derived from paired hauls of the old and new nets, thus ensuring that 2016 indices were directly comparable to previous years.

The abundance index for Atlantic Croaker was near the historic average, whereas another below-average year class was observed for Spot in 2016. In contrast, American Shad and Alewife abundance indices were above average in Virginia waters in 2016. Blueback Herring abundance was near the historic average. Average to above-average indices for most forage fishes suggested adequate production of key prey resources for populations of commercial and recreational piscivores in Virginia waters.

PREFACE

The primary objective of the Virginia Institute of Marine Science juvenile Striped Bass seine survey is to assess the 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 2016 sampling period and compares these results to those observed in 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 in this region 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 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 used to estimate mean abundance (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. More recently, 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 surveys (Woodward 2009).

Objectives for the 2016 program were to:

1. estimate the relative abundance of the 2016 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 20 June to 25 August 2016. Pilot sampling in early June revealed that Striped Bass were of the size typically encountered in early July. Therefore, sampling was initiated approximately two weeks earlier in 2016 than the traditional start date. 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 juvenile abundance.

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, Secchi depth 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.

From 1999-2015, the VIMS seine survey used a net comprised of 0.25 inch knotless oval mesh. However, this netting was no longer available from the manufacturer in 2015, so a new net was constructed from 0.25 inch knotless rhomboid mesh material that is significantly thinner and lighter in color than the material used in previous years. The relative catch efficiency of the new net was estimated using catches from paired hauls of the old and new nets; these calibration hauls were completed in 2015 (Fabrizio et al. 2017). Data from paired hauls were used to estimate calibration factors for juvenile Striped Bass and White Perch; calibration factors represent the relative catch in the old net conditional on the total catch across both nets (Fabrizio et al. 2017). The estimated calibration factor was 0.5175 for Striped Bass and 0.6537 for White Perch, implying that the new net captured more Striped Bass and White Perch than the old net (i.e., new net catches were adjusted by multiplying the number of Striped Bass or White Perch captured by their respective calibration factors for each haul; Fabrizio et al. 2017). However, due to low sample sizes ($n < 30$), these calibration factors should be viewed as preliminary. Additional paired hauls of the old and new nets are planned for 2017 to increase sample sizes considered in the calibration model; these additional paired hauls may result in changes to the estimated calibration factors used here.

In this report, comparisons of Striped Bass recruitment indices with prior years are made for the “primary nursery” area only, 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

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

where *totnum* is the total number of Striped Bass per seine haul, and *calfac* is the calibration factor; 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 × calfac)+1)]) was applied to the data prior to analysis (Sokal and Rohlf 1981). Mean values are back-transformed and scaled arithmetically (× 2.28) to allow comparisons with Maryland indices. Thus, a "scaled" index refers to an index that is directly comparable with the Maryland index. Inclusion of the calibration factor enabled the 2016 index to be comparable to previous years when Striped Bass were sampled using the old net (Fabrizio et al. 2017).

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 computed 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 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 during which regulations targeted the development of a sustainable fishery.

The 2016 annual index calculated from both hauls was compared to the average index from 1980-2009 (hereafter referred to as the reference period) to reflect the time period recommended for consideration when determining recruitment failure, as stipulated by Addendum II to Amendment 6 of the Striped Bass fishery management plan (ASMFC 2010, Table 1). In addition, an average index value for 1990-2015 was calculated using 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 2016 annual index. The historic average (1967-2015) 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 1,559 young-of-the-year Striped Bass in 2016 from 180 seine hauls at index stations, and 310 individuals from 105 hauls at auxiliary stations (Table 1). Using index-station catches from both hauls, the estimated Striped Bass recruitment index in 2016 was 5.15 (LCI = 4.14, UCI = 6.30; Table 2), which was not significantly different from the average of 7.77 observed for the reference period (LCI = 6.01, UCI = 9.89; Figure 2). Using index station catches from only the first haul in 2016, 823 young-of-the-year Striped Bass were collected, resulting in an index of 5.44 (LCI = 4.02, UCI = 7.18, Table 3), which was significantly less than the first-haul reference period index of 9.57 (LCI = 7.43, UCI = 12.17), and significantly less than the mean index estimated for the post-recovery period (post-recovery index = 12.06; LCI = 9.66, UCI = 14.94). It is important to note that application of the calibration factor to Striped Bass catches (0.5175) resulted in indices that were lower than those that would be calculated from the raw, unadjusted catches. If the analysis of additional paired hauls (as planned for 2017) changes the estimated calibration factor, Striped Bass indices of abundance for 2016 and subsequent years may change accordingly.

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 (typically 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, 1996, 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 low recruitment (i.e., the index value is below the first quartile) in producing states. Such periods of persistently low recruitment have previously occurred in Virginia from 1971-1973 and 1980-1984 (Figure 2).

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 and Virginia reported average recruitment); 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 2016 were average compared with their respective historic means (1967-2015; Table 4; Figure 3). The 2016 JAI for the James River drainage was 7.23 (LCI = 5.00, UCI = 10.15), compared with the historic James River index of 9.05 (LCI = 6.97, UCI = 11.59; Table 4). The 2016 JAI value for the York River drainage was 3.65 (LCI = 2.75, UCI = 4.71), compared with the historic York River index of 5.52 (LCI = 4.32, UCI = 6.94; Table 4). The 2016 JAI value for the Rappahannock River was 5.28 (LCI = 3.17, UCI = 8.21), compared with the historic Rappahannock River index of 7.46 (LCI = 5.66, UCI = 9.68; Table 4). In all cases, point estimates were less than the respective historic means, but due to the uncertainty in these estimates, the 2016 JAIs for individual watersheds were considered average.

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, 60% of the observed young-of-the-year Striped Bass in 2016 occurred in the core nursery zone (C1, C3, and J46; Table 1). The remaining Striped Bass were captured at upriver (30%) and downriver (10%; Table 1) sites.

Because no index sites are located along the main stem of the York River, the watershed JAI was compiled from sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. The 2016 Pamunkey River JAI of 4.95 (LCI = 3.38, UCI = 6.96) was not significantly different than the historic index of 6.32 (LCI = 4.59, UCI = 8.49), and the 2016 Mattaponi River index of 2.82 (LCI = 1.85, UCI = 4.03) was also not significantly different from the historic average of 4.97 (LCI = 4.00, UCI = 6.09). About 49% of Striped Bass in the York River were collected from the Pamunkey River and 47% from the Mattaponi River; the remainder (4%) were from York River auxiliary stations (Table 1).

The Rappahannock River yielded an index of 5.28 (LCI = 3.17, UCI = 8.21) in 2016, which was not significantly different from the historic average of 7.46 (LCI = 5.66, UCI = 9.68; Table 4). In 2016, 93% 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 4-6 illustrate the spatial distribution of the 2016 year class throughout the nursery areas sampled by this survey. Note that the scaling of CPUE, representing the number of Striped Bass captured per seine haul, 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 in response 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 low catches of young-of-the-year Striped Bass at upriver and downriver auxiliary sites in 2016, which suggests that most fish remained within the core nursery area.

Juvenile Striped Bass were captured at all auxiliary stations in the James River during 2016, although catches were relatively low 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 2016, although only one individual was captured at the uppermost site (M52) in the Mattaponi river (Tables 1 and 5; Figure 5). Relatively few Striped Bass were collected from the three auxiliary stations within the York River watershed, with no individuals collected from the lowermost site (Y15; Table 1).

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 many of these sites (Machut and Fabrizio 2010). In 2016, we detected juvenile Striped Bass at two out of three York River auxiliary sites (Table 1), but not all fish may have been detected in the area 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 presence of vegetation in the nearshore zone at these sites. For example, Striped Bass may have avoided the dense *Hydrilla* beds in the nearshore zone and used deeper waters at these sites; alternatively, Striped Bass may have preferentially used *Hydrilla* habitats but were not detected by 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 nearshore areas where *Hydrilla* is present.

Relatively low numbers of Striped Bass were collected at all upriver Rappahannock River auxiliary stations during 2016, with no individuals collected from one site (R69). 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. No juvenile Striped Bass were collected from these sites in 2016 (Table 1; Figure 6). 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. Although few juvenile Striped Bass were captured at these sites in 2016 (Table 1; Figure 6), 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 2016, 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. In 2016, we observed 27% of Striped Bass during round 1 and 29% during round 2. This resulted in some notable differences in the percent change between rounds compared to historic patterns, with increased catches during round 2, and a steeper decline in catches in round 5 (Table 6).

Environmental Conditions and Potential Relationships to 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 (Figure 7). This pattern was significantly altered in 2016: mean water temperatures were consistently above historic averages during late July and August (rounds 3-5), and ranged from 28-32°C throughout this period (Figure 7). These high water temperatures were consistent with statewide average air temperatures from July-September of 2016, which were “much above average” in Virginia (NCDC 2016). The altered pattern in water temperatures in Striped Bass nursery areas has now occurred in four consecutive years, with similar water temperatures observed in 2013, 2014, and 2015 (Davis et al. 2016). This temperature pattern did not seem to affect catches in previous years, however. Catch rates in 2016 followed the historic pattern with respect to water temperature: most fish (99%) were captured at temperatures above 25.0°C (Table 7). 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 2016, average salinities during all rounds were generally lower than those observed historically, especially in the James, Chickahominy, Mattaponi, and Pamunkey Rivers (Figure 8). As observed in the past, greater catches of young-of-the-year Striped Bass in 2016 were obtained at sites exhibiting relatively low salinities within the primary nursery area (Table 5). Only one index station (R28) had salinities exceeding 10.0 ppt on average, although mean salinities as high as 17.0 ppt were observed at one auxiliary site in the York River (Table 5). Although juvenile Striped Bass were captured at downstream sites with average salinities up to 14 ppt, catches were distinctly lower at such sites compared with catches in lower salinity areas.

Mean dissolved oxygen (DO) concentrations in 2016 overlapped with historic averages during most rounds within most rivers (Figure 9). A notable exception to this pattern was in the Mattaponi River, where DO concentrations were below average (~4 mg/L) during the last two rounds of sampling in August. Relationships between DO and juvenile Striped Bass catches are difficult to ascertain, as lower-than-average values occur inconsistently through time and across sampling sites. In previous years, high seasonal catches at index stations occurred during periods when DO was more than one standard error (SE) below the historic average, as well as when DO concentrations 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 in the Patuxent River has been positively associated with high freshwater flow during the preceding winter (Wingate and Secor 2008). One of the strongest Striped Bass year classes in Virginia was produced in 2011, which was characterized by relatively high freshwater flow in winter and spring (Machut and

Fabrizio 2012). Freshwater flow in Virginia tidal tributaries (USGS 2016) varies seasonally, with relatively high flow during the winter, peaks in early spring (March-April), followed by steady declines in late spring and summer (Figure 10). In all rivers during 2016, freshwater flow was above average in February, below average in March and April, above average during May, then approximately average from June-September (Figure 10). Precipitation during winter and spring of 2016 (December 2015 - May 2016) was "above average" in Virginia (NCDC 2016). Despite the above average precipitation in winter and spring of 2016, Striped Bass indices of abundance were average in all rivers. 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 2016 were Atlantic Menhaden (*Brevoortia tyrannus*), Mummichog (*Fundulus heteroclitus*), White Perch (*Morone americana*), Spottail Shiner (*Notropis hudsonius*), and Atlantic Silverside (*Menidia menidia*). In 2016, more than 72,000 individuals comprising 62 species were collected (Table 8). Indices of abundance were estimated for ten of these species (in addition to Striped Bass) based on catches at a subset of index and auxiliary stations, using catches from only the first haul. A different subset of stations was used for each species, based on the range of sites where the species was commonly encountered within each tributary from 1967-2010.

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 June through August 2016, 3,791 young-of-the-year White Perch were collected in 123 seine hauls at 30 stations (11 in the James, 10 in the York and 9 in the Rappahannock). 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 system separately (Table 9; Figures 11 - 14). Generally, 2016 river-specific JAIs for White Perch suggest average recruitment for this species throughout Virginia (Figures 12-14). Similar to Striped Bass, we used the estimated calibration factor (0.6537) to adjust White Perch catches observed with the new net. (As before, we note that additional paired hauls planned for 2017 may result in a change in the estimated calibration factor used in subsequent reports.) The White Perch JAI developed by the seine survey complements 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 predominantly 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 2016 were spawned during the fall of 2015. Similar to White Perch, Atlantic Croaker raw catches exhibit high annual variability in the proportion of nonzero hauls. To address this variation and accommodate data with a high proportion of zero hauls, we calculated 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.

Based on catches from 21 stations in July and early August 2016, we encountered at total of 485 young-of-the-year Atlantic Croaker and these fish were captured in 25 seine hauls (Table 10; Figure 15). Because Atlantic Croaker are coastal shelf spawners with larval migration into Chesapeake Bay, we report a Virginia-wide estimate of juvenile abundance (Table 10; Figure 15). 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 average year class for Atlantic Croaker appears to have occurred during 2016.

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 11; Figure 16). Based on catches from 21 stations during all five rounds in 2016, 113 young-of-the-year Spot were collected in 27 seine hauls. Using the delta-lognormal approach, we observed a below-average year class for Spot in 2016 (Table 11; Figure 16).

Indices of abundance for common forage species within the tidal nearshore zone were computed for: Spottail Shiner (*Notropis hudsonius*; 32 stations; Table 12), Atlantic Silverside (*Menidia menidia*; 24 stations; Table 13), Inland Silverside (*Menidia beryllina*; 36 stations; Table 14), and Banded Killifish (*Fundulus diaphanus*; 32 stations; Table 15). Catches from all five sampling rounds were used to estimate indices for these species. The 2016 Spottail Shiner delta-lognormal mean of 25.1 was similar to the historic average of 24.6 (Table 12). The 2016 Atlantic Silverside delta-lognormal mean of 22.4 was lower than the historic average of 46.8 (Table 13). The 2016 Inland Silverside abundance index of 10.9 was higher than the historic average of 4.7 (Table 14). The 2016 Banded Killifish delta-lognormal mean of 12.9 was higher than the historic average of 4.6 (Table 15). Average to above-average indices for most of these species in 2016 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 fish communities 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 2016 geometric mean abundances for American Shad from 26 stations in the James, York, and Rappahannock rivers exhibited an increase during the past three years after nearly a decade of low recruitment (Figure 17). Indices of abundance for American Shad have greatly increased in the Rappahannock River, but also showed modest increases in the Pamunkey and Mattaponi rivers (Figure 17). Based on catches at 21 stations, the 2016 geometric mean abundance indices for Alewife were average or above average in the three rivers (Figure 18). Most notably, another strong year class appears to have occurred in the James River, following the record high abundance observed in 2015 (Figure 18). The 2016 geometric mean abundance indices for Blueback Herring across 20 stations were average in the James, York, and

Rappahannock rivers (Figure 19). Overall, the recent but modest increase in abundance of these three alosine species is encouraging.

CONCLUSION

The 2016 juvenile abundance index (JAI) for Striped Bass (5.15) was not significantly different from the average during the reference period (7.77) for Virginia waters. Compared with historic averages, we observed average recruitment in the James, York and Rappahannock rivers. Continued evaluation of juvenile Striped Bass abundance is important in forecasting 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 juvenile abundance which, if persistent, serves as an early warning of potential declines in Striped Bass stock biomass. Juvenile White Perch abundance indices in 2016 were similar to the historic averages for this species. Forage fish abundance index values were average or above average in 2016. Abundance indices were average or above average for three alosine species in Virginia waters in 2016 relative to index values observed in previous years.

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LITERATURE CITED

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

ASMFC (Atlantic States Marine Fisheries Commission). 2010. Addendum II to Amendment #6 to the Interstate Fishery Management Plan: definition of recruitment failure. Atlantic States Marine Fisheries Commission, Washington, D.C. 18 p.

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

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

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

Colvocoresses, J. A. 1988. Comparisons among York River White Perch stock abundance measures. NOAA Tech. Rept. TRS-SAC-91-021, 18 p.

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

Davis, C.D., M.C. Fabrizio, and T.D. Tuckey. 2016. Estimation of juvenile Striped Bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2015. Virginia Institute of Marine Science, Gloucester Point, VA. 68 p.

Fabrizio, M.C., T.D. Tuckey, O.M. Phillips and B.K. Gallagher. 2017. Tracking decadal changes in striped bass recruitment: A calibration study of seine surveys in Chesapeake Bay. Virginia Institute of Marine Science, Gloucester Point, VA. 71 p.

Fletcher, D. 2008. Confidence intervals for the mean of the delta-lognormal distribution. Environmental and Ecological Statistics 15: 175 - 189.

Goodyear, C. P. 1985. Relationship between reported commercial landings and abundance of young Striped Bass in Chesapeake Bay, Maryland. Transactions of the American Fisheries Society 114: 92 – 96.

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

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

Machut, L. S., and M.C. Fabrizio. 2010. Estimation of juvenile Striped Bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2009. Virginia Institute of Marine Science, Gloucester Point, VA. 45 p.

Machut, L. S., and M.C. Fabrizio. 2011. Estimation of juvenile Striped Bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2010. Virginia Institute of Marine Science, Gloucester Point, VA. 47 p.

Machut, L. S., and M.C. Fabrizio. 2012. Estimation of juvenile Striped Bass relative abundance in the Virginia portion of Chesapeake Bay. Annual Report 2011. Virginia Institute of Marine Science, Gloucester Point, VA. 55 p.

Mulligan, T. J., and R. W. Chapman. 1989. Mitochondrial DNA analysis of Chesapeake Bay White Perch, *Morone americana*. Copiea 3: 679 – 688.

Murdy, E. O., R. S. Birdsong, and J.A. Musick. 1997. Fishes of Chesapeake Bay. Smithsonian Institution Press, Washington, D. C. 324 p.

NCDC (National Climate Data Center). 2016. National temperature and precipitation maps. Site accessed December 2016. https://www.ncdc.noaa.gov/temp-and-precip/us-maps/.

NMFS (National Marine Fisheries Service). 2012. Annual commercial landing statistics. Site accessed March 2012. https://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html.

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

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

Tuckey, T.D., and M.C. Fabrizio. 2012. Estimating relative juvenile abundance of ecologically important finfish in the Virginia portion of Chesapeake Bay. Final Report to the Virginia Marine Resources Commission.

United States Geological Survey (USGS). 2016. Current conditions for Virginia: streamflow (USGS Water Data for the Nation). Site accessed October 2016. https://waterdata.usgs.gov/va/nwis/current/?type=flow.

Watkins, B.J. Olney, and R. O'Reilly. 2011. A summary of Virginia's American Shad fisheries in 2010 and results of monitoring and restoration programs: annual compliance report to the Atlantic States Marine Fisheries Commission American Shad Technical Committee, Virginia Institute of Marine Sciences, Gloucester Point, VA. 43 pp.

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

Williams, B. D. and M. C. Fabrizio. 2011. Detectability of estuarine fishes in a beach seine survey of tidal tributaries of lower Chesapeake Bay. Transactions of the American Fisheries Society 140: 1340-1350.

Wingate, R. L., and D. H. Secor. 2008. Effects of winter temperature and flow on a summer-fall nursery fish assemblage in the Chesapeake Bay, Maryland. Transactions of the American Fisheries Society 137: 1147 - 1156.

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

Woodward, J.R. 2009. Investigating the relationships between recruitment indices and estimates of adult abundance for Striped Bass, Weakfish, and Atlantic Croaker. Master's thesis. College of William and Mary, Williamsburg, VA.

VMRC (Virginia Marine Resources Commission). 2010. Atlantic Menhaden compliance report for Virginia: Report to the Atlantic States Marine Fisheries Commission. Fisheries Management Division, Newport News, VA. 16 pp.

TABLES

Table 1. Catch of young-of-the-year Striped Bass per seine haul in 2016. Two hauls were completed at each index station (bold). Sampling was completed in June (round 1), July (rounds 2 and 3), and August (rounds 4 and 5).

Drainage																Round
JAMES		Station	J12	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Total
	Round	1	0	1	3/0	6/3	3	19/21	6/13	47/5	32	4/8	4	3	0	178
		2	1	1	0/0	3/1	12	73/59	3/0	14/39	16	5/14	23	0	1	265
		3	0	2	2/0	10/3	9	67/0	2/1	44/53	18	14/11	20	5	0	261
		4	0	1	1/0	1/5	0	9/3	1/1	15/15	3	25/21	8	1	1	111
		5	0	7	8/8	1/3	0	0/2	0/1	5/24	3	7/9	0	12	1	91
														James Total		**906**
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	0	0	2	4	2/4	3/19	11/2	5						52
		2	0	0	1	1	2/2	13/10	11/10	10						60
		3	0	5	2	6	3/3	13/2	4/1	0						39
		4	0	0	4	5	1/3	11/2	18/8	1						53
		5	0	0	3	0	0/3	4/1	5/0	0						16
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				10/5	6	12/9	3/2	11/3	0					61
		2				2/2	1	1/2	3/5	1/2	1					20
		3				2/0	4	1/1	4/1	1/4	0					18
		4				0/0	13	1/1	41/1	9/4	0					70
		5				3/1	16	0/0	0/3	3/0	0					26
														York Total		**415**
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75		
	Round	1	0	0	0/0	1/2	1	19/33	25/53	44/52	9	6	0	2		247
		2	0	0	1/0	0/0	0	29/10	32/44	31/34	1	0	0	0		182
		3	0	0	1/0	1/1	2	1/1	11/22	6/26	2	5	0	0		79
		4	0	0	0/0	0/0	5	1/4	0/0	0/0	0	0	0	0		10
		5	0	0	0/0	0/0	1	0/2	14/5	2/6	0	0	0	0		30
													Rappahannock Total			**548**
														2016 Catch		**1,869**

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 and calfac=calibration factor (applied in 2016 only), Index =(exp(ln(x*calfac + 1)) - 1) × 2.28, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean ln(x+1)	SD	Index	CI (± 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	2,191	2.07	1.23	15.74	12.40-19.83	144
1988	1,348	1.47	1.13	7.64	6.10-9.45	180
1989	1,978	1.78	1.12	11.23	9.15-13.68	180
1990	1,249	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	1,769	1.44	1.24	7.35	5.72-9.31	180
1993	2,323	2.19	0.98	18.11	15.35-21.30	180
1994	1,510	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	3,759	2.41	1.23	23.00	18.77-28.07	180
1997	1,484	1.63	1.10	9.35	7.59-11.41	180
1998	2,084	1.92	1.14	13.25	10.82-16.12	180
1999	442	0.80	0.86	2.80	2.19-3.50	180
2000	2,741	2.09	1.24	16.18	13.06-19.92	180
2001	2,624	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	3,406	2.40	1.18	22.89	18.84-27.71	180
2004	1,928	1.88	1.04	12.70	10.54-15.22	180
2005	1,352	1.61	1.05	9.09	7.45-11.02	180
2006	1,408	1.69	1.04	10.10	8.31-12.18	180
2007	1,999	1.83	1.18	11.96	9.66-14.70	180
2008	1,518	1.50	1.17	7.97	6.33-9.93	180
2009	1,408	1.55	1.10	8.42	6.80-10.32	180
2010	1,721	1.61	1.25	9.07	7.14-11.40	180
2011	4,189	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	1,620	1.76	1.08	10.94	8.97-13.25	180
2014	2,293	1.78	1.26	11.30	8.98-14.09	180
2015	1,879	1.84	1.13	12.00	9.79-14.62	180
2016	1,557	1.18	0.97	5.15	4.14-6.30	180
Reference (1980-2009)	43,527	1.48	0.53	7.77	6.01-9.89	30 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), where x = total fish, calfac=calibration factor (applied in 2016 only), Index =(exp(ln(x*calfac + 1)) - 1) × 2.28, SD = Standard Deviation, and SE = Standard Error.

Year	Total Fish (x)	Mean ln(x+1)	SD	Index	CI (± 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	2.40-4.97	71
1986	449	1.35	1.07	6.53	4.56-9.06	72
1987	1,314	2.27	1.22	19.77	14.25-27.13	72
1988	820	1.57	1.21	8.66	6.20-11.85	90
1989	1,427	2.06	1.18	15.68	11.71-20.77	90
1990	720	1.58	1.12	8.76	6.44-11.70	90
1991	462	1.17	1.05	5.04	3.59-6.85	90
1992	1,143	1.65	1.31	9.63	6.76-13.41	90
1993	1,241	2.34	0.89	21.36	17.31-26.25	90
1994	969	1.93	1.09	13.37	10.17-17.40	90
1995	559	1.37	1.07	6.71	4.89-8.99	90
1996	2,326	2.60	1.27	28.29	21.11-37.69	90
1997	931	1.83	1.14	11.92	8.90-15.76	90
1998	1,365	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	1,528	2.22	1.23	18.70	13.91-24.90	90
2001	1,671	2.16	1.32	17.52	12.70-23.89	90
2002	486	1.17	1.13	5.03	3.48-7.01	90
2003	2,042	2.50	1.26	25.61	19.09-34.13	90
2004	1,129	2.07	1.04	15.75	12.19-20.19	90
2005	835	1.79	1.07	11.42	8.64-14.90	90
2006	767	1.76	1.06	11.02	8.34-14.36	90
2007	1,271	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	2,397	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	1,401	2.01	1.24	14.81	10.87-19.93	90
2015	993	1.93	1.09	13.35	10.16-17.37	90
2016	823	1.22	0.97	5.44	4.02-7.18	90
1980-2009	26,735	1.65	0.54	9.57	7.43-12.17	30 years
1990-2015	28,374	1.84	0.47	12.06	9.66-14.94	26 years

Table 4. Catch of young-of-the-year Striped Bass per seine haul in the primary nursery area in 2016 summarized by drainage and river.

	2016				All Years Combined (1967-2015)			
Drainage / River	Total Fish	Index	C.I. (± 2 SE)	N (hauls)	Total Fish	Index	C.I. (± 2 SE)	N (years)
JAMES	718	7.23	5.00-10.15	60	22,200	9.05	6.97-11.59	43
James	437	7.39	4.86-10.81	40	13,392	8.17	6.09-10.77	43
Chickahominy	281	6.93	3.09-13.52	20	8,808	11.45	8.71-14.88	43
YORK	325	3.65	2.75-4.71	70	16,582	5.52	4.32-6.94	43
Pamunkey	171	4.95	3.38-6.96	30	8,338	6.32	4.59-8.49	43
Mattaponi	154	2.82	1.85-4.03	40	8,244	4.97	4.00-6.09	43
RAPPAHANNOCK	514	5.28	3.17-8.21	50	18,150	7.46	5.66-9.68	43
Overall	1,557	5.15	4.14-6.30	180	56,932	7.21	5.75-8.94	43

Table 5. Site-specific Striped Bass indices and average site salinity during 2016 compared with historic (1967 - 2015) 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
	1967-2015	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	0.1
		Index	1.8	13.6	7.4	12.4	12.1	17.3	7.6	18.9	16.9	6.5	11.2	6.3	2.3
	2016	Avg. Sal.	14.1	6.8	2.7	0.9	0.4	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1
		Index	0.2	2.3	1.6	3.6	3.5	16.6	2.2	23.9	12.4	12.3	8.5	3.5	0.7
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1967-2015	Avg. Sal.	16.5	13.7	10.6	4.1	1.7	0.7	0.4	0.3					
		Index	1.4	2.2	6.8	11.9	4.6	9.1	12.7	4.2					
	2016	Avg. Sal.	17.0	13.8	9.8	1.8	0.3	0.1	0.1	0.1					
		Index	0.0	0.7	2.7	3.0	2.5	7.1	6.2	2.3					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1967-2015	Avg. Sal.				4.5	2.3	1.1	0.4	0.3	0.1				
		Index				6.2	8.9	6.7	5.6	4.6	1.4				
	2016	Avg. Sal.				2.7	0.3	0.1	0.0	0.0	0.0				
		Index				2.1	7.4	2.1	3.8	3.5	0.2				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	1967-2015	Avg. Sal.	14.1	12.8	9.9	5.3	3.1	2.0	0.9	0.5	0.2	0.2	0.1	0.0	
		Index	0.5	0.7	2.8	3.4	6.1	8.4	14.0	38.5	6.0	4.1	2.9	2.5	
	2016	Avg. Sal.	16.1	14.1	11.1	5.9	1.7	0.7	0.1	0.1	0.1	0.1	0.0	0.0	
		Index	0.0	0.0	0.2	0.5	1.7	6.1	20.5	16.7	2.3	2.0	0.0	0.4	

Table 6. Catch of young-of-the-year Striped Bass in the primary nursery areas of Virginia in 2016 summarized by sampling round and month.

	2016					All Years Combined (1967-2015)				
Month (Round)	N (hauls)	Total Fish	Index	C.I. (± 2 SE)	Change From Previous Round	N (years)	Total Fish	Index	C.I. (± 2 SE)	Change From Previous Round
June (1st)	36	415	8.36	5.57-12.14		43	17,906	11.72	9.18-14.83	
July (2nd)	36	458	6.78	3.93-10.93	10.4%	43	14,249	8.63	6.71-10.96	-20.4%
(3rd)	36	317	5.10	3.05-7.95	-30.8%	43	10,274	6.70	5.24-8.43	-27.9%
Aug. (4th)	36	247	4.46	2.67-6.88	-22.1%	39	8,507	6.16	4.78-7.81	-17.2%
(5th)	36	120	2.43	1.43-3.69	-51.4%	36	5,996	4.93	3.86-6.19	-29.5%

Table 7. Catch of young-of-the-year Striped Bass per seine haul in the primary nursery areas of Virginia in 2016 summarized by water temperature.

	2016				All Years Combined (1967-2015)			
Temp (°C)	Total Fish	Index	C.I. (± 2 SE)	N (sites)	Total Fish	Index	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	9	5.10	2.31-9.59	2	2,668	3.96	3.49-4.47	653
25.0-29.9	1,007	5.39	4.07-6.98	110	44,099	8.84	8.46-9.24	4,717
> 30.0	541	4.77	3.31-6.62	68	9,736	9.44	8.55-10.41	955
Overall	1,557	5.15	4.14-6.30	180	56,932	8.20	7.89-8.52	6,410

Table 8. Fish species collected during the 2016 seine survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Brevoortia tyrannus	Atlantic Menhaden	21,581
Fundulus heteroclitus	Mummichog	15,507
Morone americana	White Perch	7,529
Notropis hudsonius	Spottail Shiner	4,648
Menidia menidia	Atlantic Silverside	2,949
Fundulus diaphanus	Banded Killifish	2,822
Menidia beryllina	Inland Silverside	2,700
Trinectes maculatus	Hogchoker	2,454
Morone saxatilis	Striped Bass	1,876
Anchoa mitchilli	Bay Anchovy	1,775
Alosa aestivalis	Blueback Herring	1,444
Fundulus majalis	Striped Killifish	1,244
Alosa sapidissima	American Shad	962
Micropogonias undulatus	Atlantic Croaker	613
Dorosoma cepedianum	Gizzard Shad	492
Dorosoma petenense	Threadfin Shad	469
Menticirrhus americanus	Southern Kingfish	335
Notropis spilopterus	Spotfin Shiner	318
Hybognathus regius	Eastern Silvery Minnow	317
Bairdiella chrysoura	Silver Perch	229
Etheostoma olmstedi	Tessellated Darter	221
Ictalurus furcatus	Blue Catfish	167
Leiostomus xanthurus	Spot	149
Membras martinica	Rough Silverside	149
Alosa pseudoharengus	Alewife	130
Perca flavescens	Yellow Perch	129
Anchoa hepsetus	Striped Anchovy	90
Lepomis gibbosus	Pumpkinseed	90
Notropis analostanus	Satinfin Shiner	87
Notemigonus crysoleucas	Golden Shiner	80
Mugil curema	White Mullet	64
Lepomis macrochirus	Bluegill	62
Lepomis auritus	Redbreast Sunfish	58
Gambusia affinis	Mosquitofish	56
Micropterus salmoides	Largemouth Bass	55
Menticirrhus saxatilis	Northern Kingfish	39
Strongylura marina	Atlantic Needlefish	35
Enneacanthus gloriosus	Bluespotted Sunfish	35
Ictalurus punctatus	Channel Catfish	30
Anguilla rostrata	American Eel	24

Table 8. (cont'd.)

Scientific Name	Common Name	Total Caught
Micropterus punctulatus	Spotted Bass	23
Lepisosteus osseus	Longnose Gar	22
Mugil cephalus	Striped Mullet	20
Cynoscion regalis	Weakfish	13
Moxostoma macrolepidotum	Shorthead Redhorse	10
Hemiramphus brasiliensis	Ballyhoo	10
Pomatomus saltatrix	Bluefish	8
Cyprinodon variegatus	Sheepshead Minnow	7
Ictalurus catus	White Catfish	6
Cynoscion nebulosus	Spotted Seatrout	6
Peprilus alepidotus	Harvestfish	4
Micropterus dolomieui	Smallmouth Bass	4
Peprilus triacanthus	Butterfish	2
Pomoxis annularis	White Crappie	2
Paralichthys dentatus	Summer Flounder	1
Scomberomorus maculatus	Spanish Mackerel	1
Catostomus commersoni	White Sucker	1
Ictalurus nebulosus	Brown Bullhead	1
Syngnathus fuscus	Northern Pipefish	1
Gobiesox strumosus	Skilletfish	1
Hyporhamphus unifasciatus	Halfbeak	1
	Total	72,181

Table 9. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by river system and year.

Year	James River		York River		Rappahannock River		N
	# of Fish	Delta Mean	# of Fish	Delta Mean	# of Fish	Delta Mean	(hauls)
1967	341	26.3	6	0.7	256	34.0	26
1968	48	2.4	10	0.7	125	6.9	19
1969	446	21.6	106	7.4	242	14.0	39
1970	1582	78.2	7	0.5	267	23.5	48
1971	334	16.6	17	1.5	311	23.2	44
1972	38	1.4	247	7.1	392	42.5	57
1973	34	1.4	71	4.1	296	15.9	53
1980	62	2.3	211	15.6	145	9.3	34
1981	98	3.2	22	0.6	133	8.8	45
1982	18	1.3	292	20.2	126	16.5	28
1983	151	10.5	175	9.9	128	13.7	39
1984	94	5.6	100	5.4	156	24.7	44
1985	23	1.0	88	3.2	31	2.3	25
1986	421	18.8	79	2.9	336	39.1	49
1987	712	39.3	880	63.2	1177	60.5	63
1988	457	22.1	69	2.2	287	13.7	61
1989	424	13.0	807	28.2	1349	49.6	104
1990	235	5.9	70	1.7	487	11.7	84
1991	296	6.4	169	4.2	387	13.5	91
1992	338	7.7	4	0.1	395	11.9	67
1993	3812	107.8	344	7.6	1177	46.5	113
1994	608	17.8	420	9.4	655	19.1	125
1995	741	18.8	17	0.3	418	12.2	93
1996	4784	166.9	1654	66.5	2294	78.9	126
1997	1703	59.0	305	8.3	248	6.3	102
1998	1432	35.5	195	4.7	457	18.5	108
1999	159	3.4	1	0.0	486	13.2	67
2000	1540	38.5	1363	40.0	1184	34.2	121
2001	948	20.8	799	21.1	1126	32.3	123
2002	790	19.1	129	2.7	275	7.0	83
2003	1364	35.7	1132	27.8	1849	70.4	120
2004	1030	23.8	799	22.0	670	17.9	130
2005	1871	54.9	579	15.3	834	28.1	122
2006	2064	44.9	95	2.8	388	10.0	99
2007	2896	69.2	417	22.7	830	24.5	113
2008	1627	40.5	184	4.1	1512	69.6	107
2009	3825	125.2	10	0.2	1813	77.7	90
2010	3085	100.1	1632	43.6	728	19.1	130
2011	15805	709.0	4112	132.6	4169	164.6	140
2012	1233	25.1	47	1.0	338	8.8	99
2013	1591	43.3	433	10.4	623	17.5	119
2014	2198	71.4	2373	62.0	841	22.0	120
2015	1544	32.6	1621	53.5	1017	25.3	140
2016	1525	20.1	980	17.8	1286	25.9	123

Table 10. 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
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	48
1992	717	11.6	41
1993	1115	30.0	47
1994	862	16.8	39
1995	598	14	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	78.4	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
2016	485	8.6	25
Overall (1980-2015)	13,096	10.8	37 (years)

Table 11. 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	72
1980	2174	25	72
1981	829	14.5	43
1982	631	91.7	18
1983	129	5.6	16
1984	899	30.5	19
1985	406	12	26
1986	1338	59.8	33
1987	161	5.1	15
1988	943	21	37
1989	1319	20.9	52
1990	1050	11.1	62
1991	1069	12.8	74
1992	525	6	65
1993	961	11.1	74
1994	990	10	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	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
2016	113	1.1	27
Overall (1967-2015)	36,602	13.9	43 (years)

Table 12. Delta-lognormal mean of young-of-the-year 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	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	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	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
2016	3397	25.1	122
Overall (1989-2015)	86,897	24.6	27 (years)

Table 13. Delta-lognormal mean of young-of-the-year Atlantic Silverside from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Delta Mean	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	4891	69.6	67
2015	7542	104.0	74
2016	2397	22.4	56
Overall (1989-2015)	95,613	46.8	27 (years)

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

Year	Total Fish	Delta Mean	N (Hauls)
1989	495	3	86
1990	591	3.8	76
1991	286	1.8	66
1992	339	1.8	60
1993	385	2.3	59
1994	171	1	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	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
2016	2181	10.9	121
Overall (1989-2015)	23,660	4.7	27 (years)

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

Year	Total Fish	Delta Mean	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	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	48
2007	692	5	75
2008	1025	6.8	87
2009	1208	9	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
2016	1843	12.9	109
Overall (1989-2015)	20,434	4.6	27 (years)

FIGURES

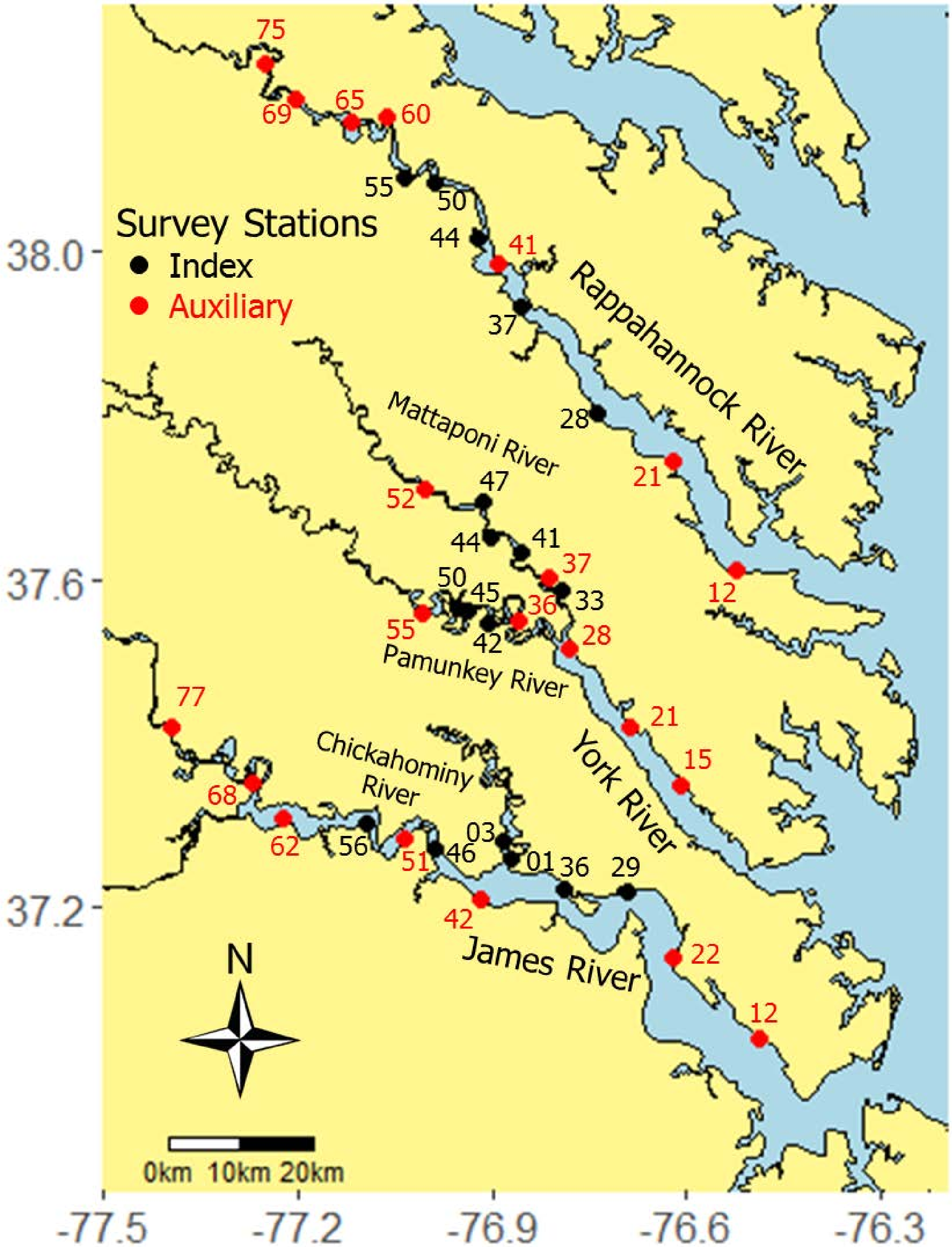

Figure 1. Juvenile Striped Bass seine survey stations. Numeric portion of station designation indicates approximate mile from the mouth of river.

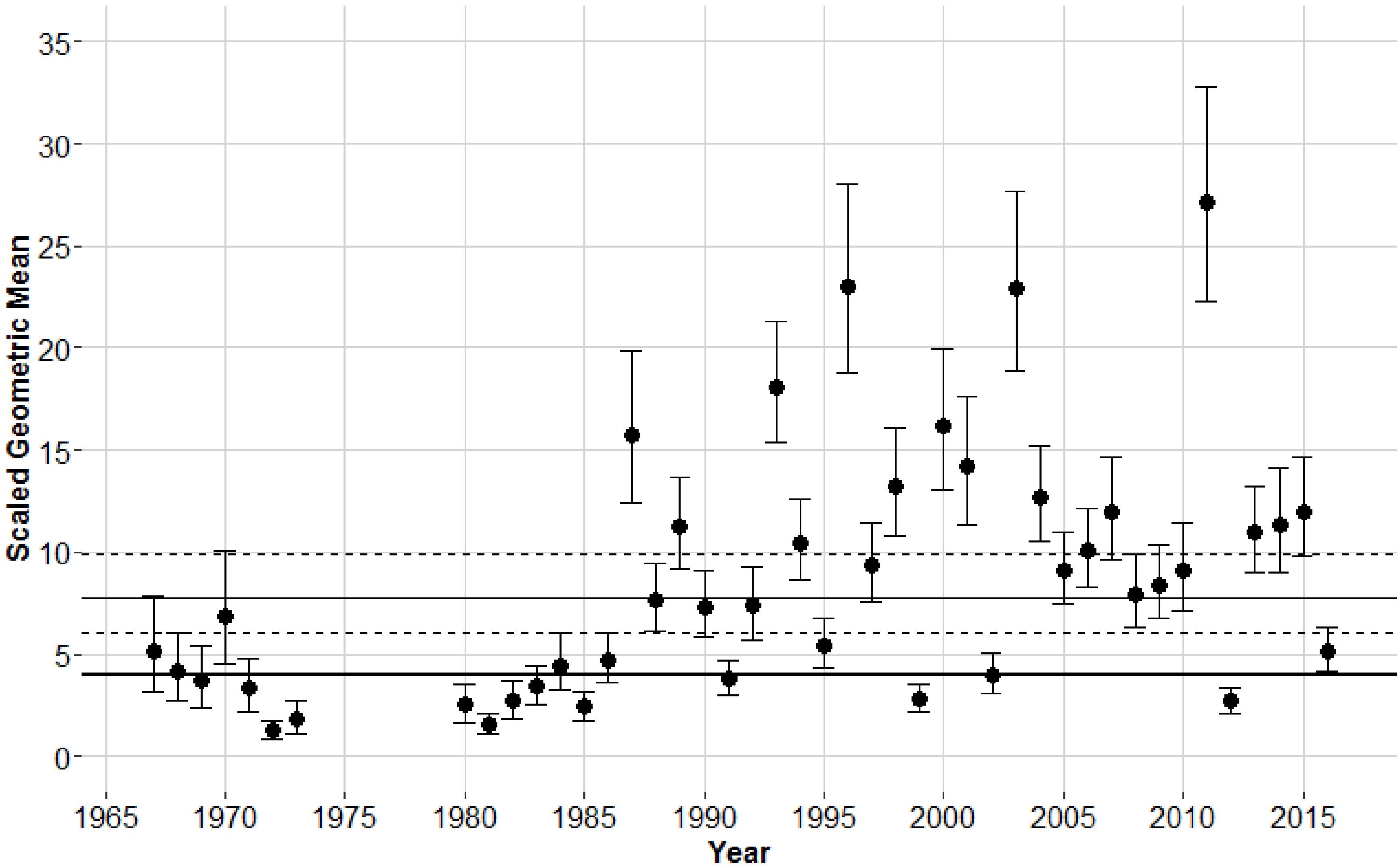

Figure 2. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by + 2 standard errors of the mean. Horizontal lines indicate the arithmetic mean (thin solid), confidence intervals on the mean (dashed), and 1st quartile (thick solid) during the reference period from 1980-2009 (ASMFC 2010).

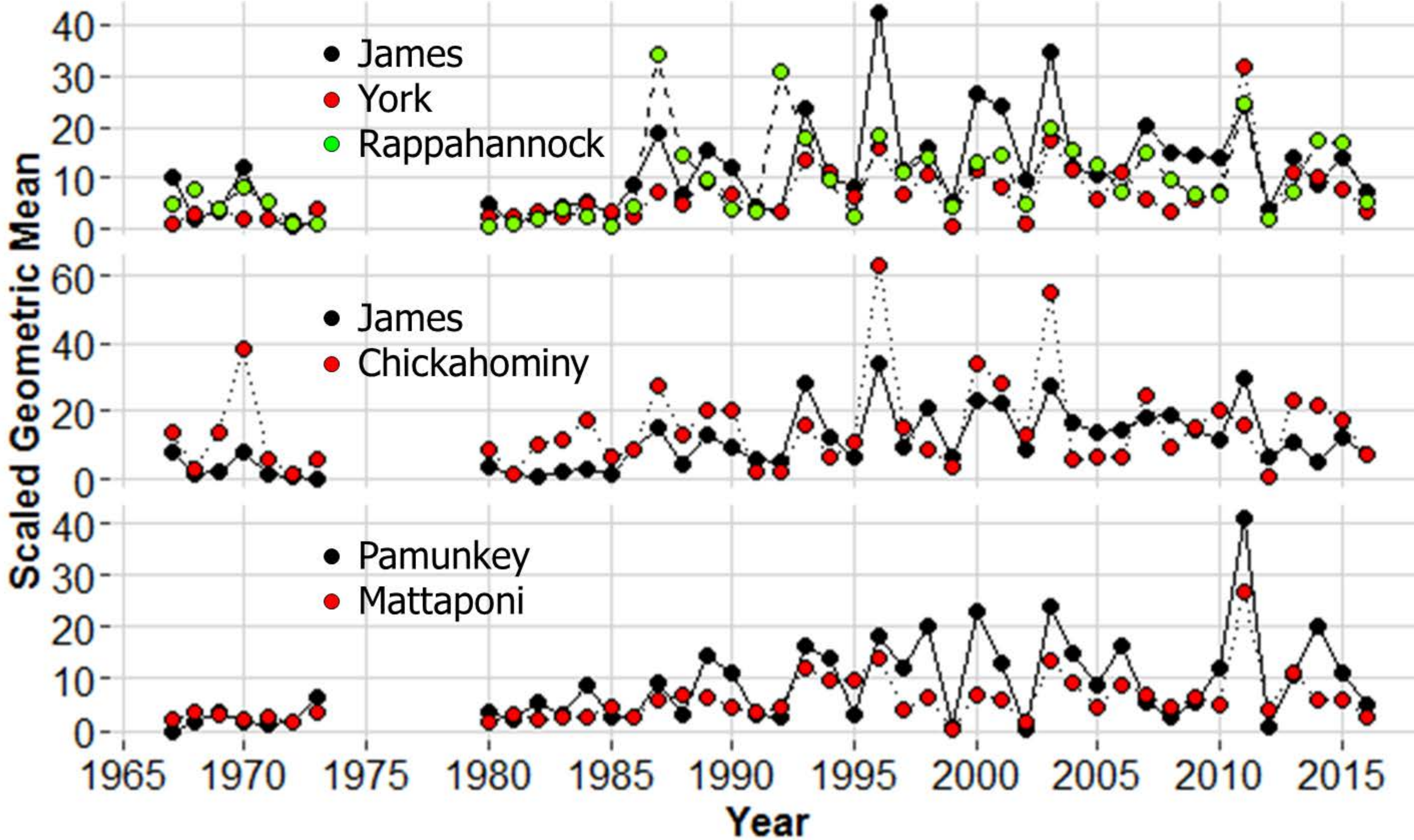

Figure 3. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by drainage and river.

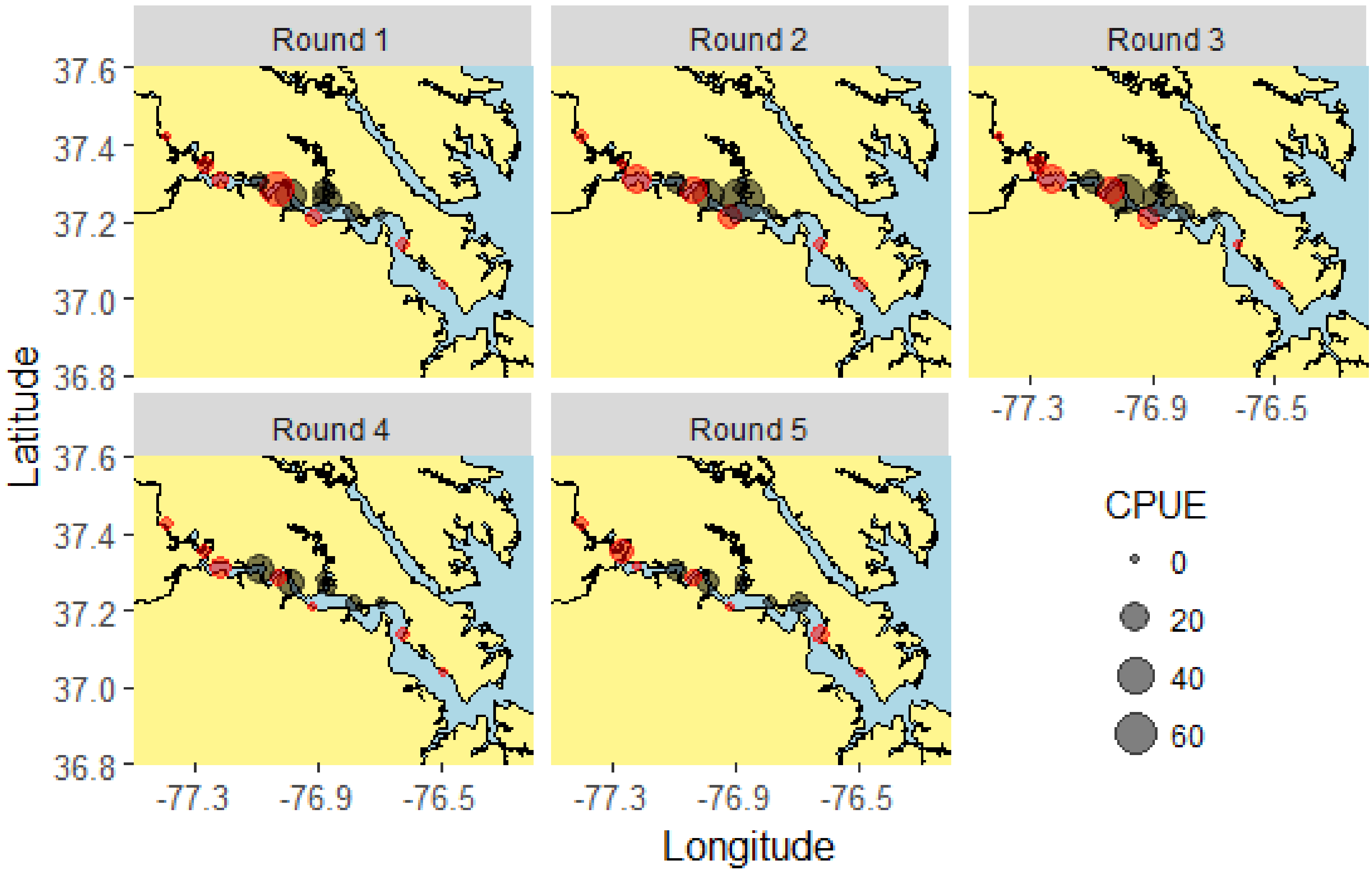

Figure 4. Catch of young-of-the-year Striped Bass by station in the James River drainage in 2016. Index station (black) catch represents an average of two hauls; auxiliary station (red) catch represents one haul. Hauls were completed at all stations during all rounds in 2016.

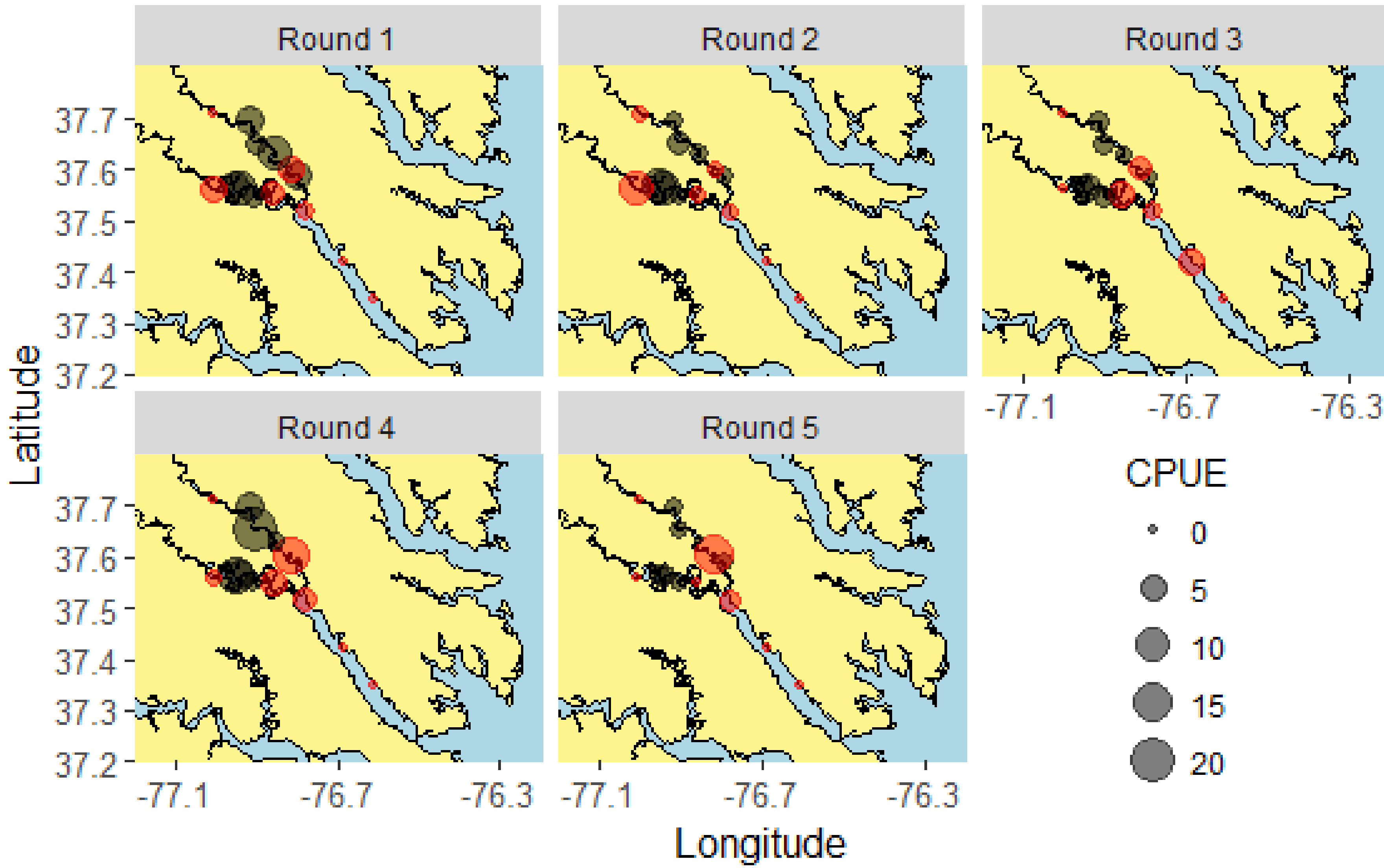

Figure 5. Catch of young-of-the-year Striped Bass by station in the York River drainage in 2016. Index station (black) catch represents an average of two hauls; auxiliary station (red) catch represents one haul. Hauls were completed at all stations during all rounds in 2016.

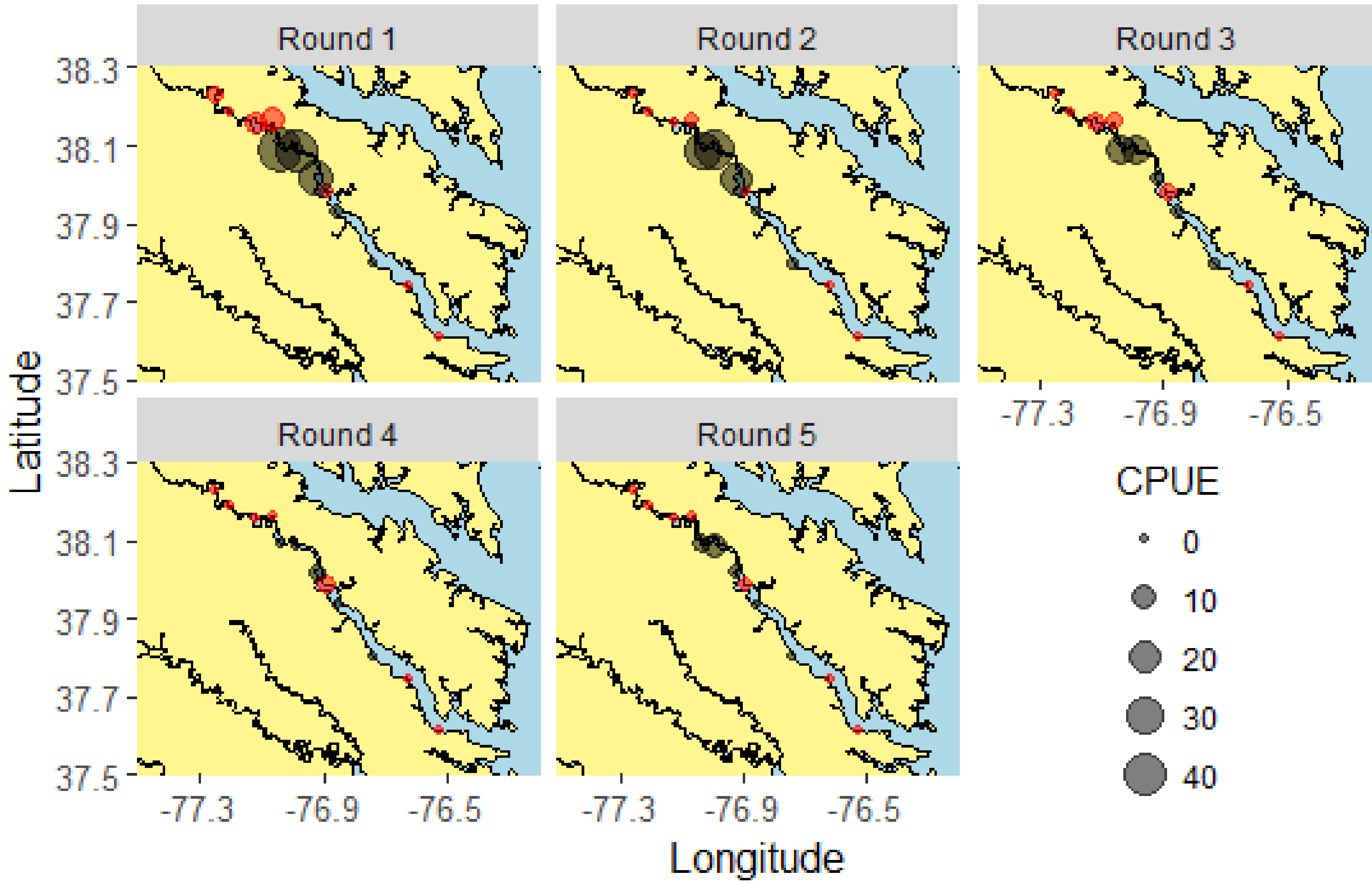

Figure 6. Catch of young-of-the-year Striped Bass by station in the Rappahannock River drainage in 2016. Index station (black) catch represents an average of two hauls; auxiliary station (red) catch represents one haul. Hauls were completed at all stations during all rounds in 2016.

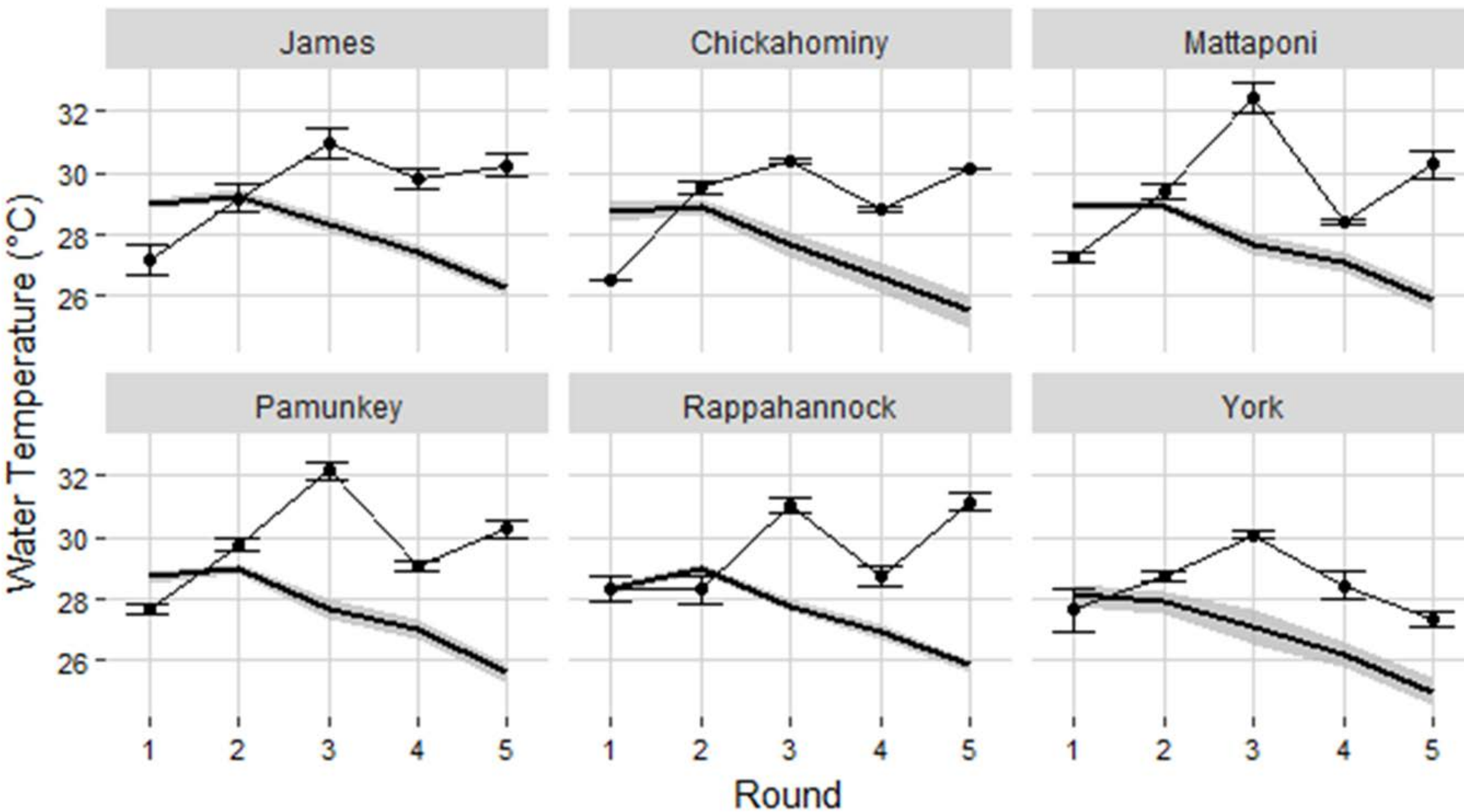

Figure 7. Mean water temperature and 95% confidence intervals during each round (x-axis) in each river during 2016 (thin line and error bars) and the historical period from 1967-2015 (thick line and shaded region).

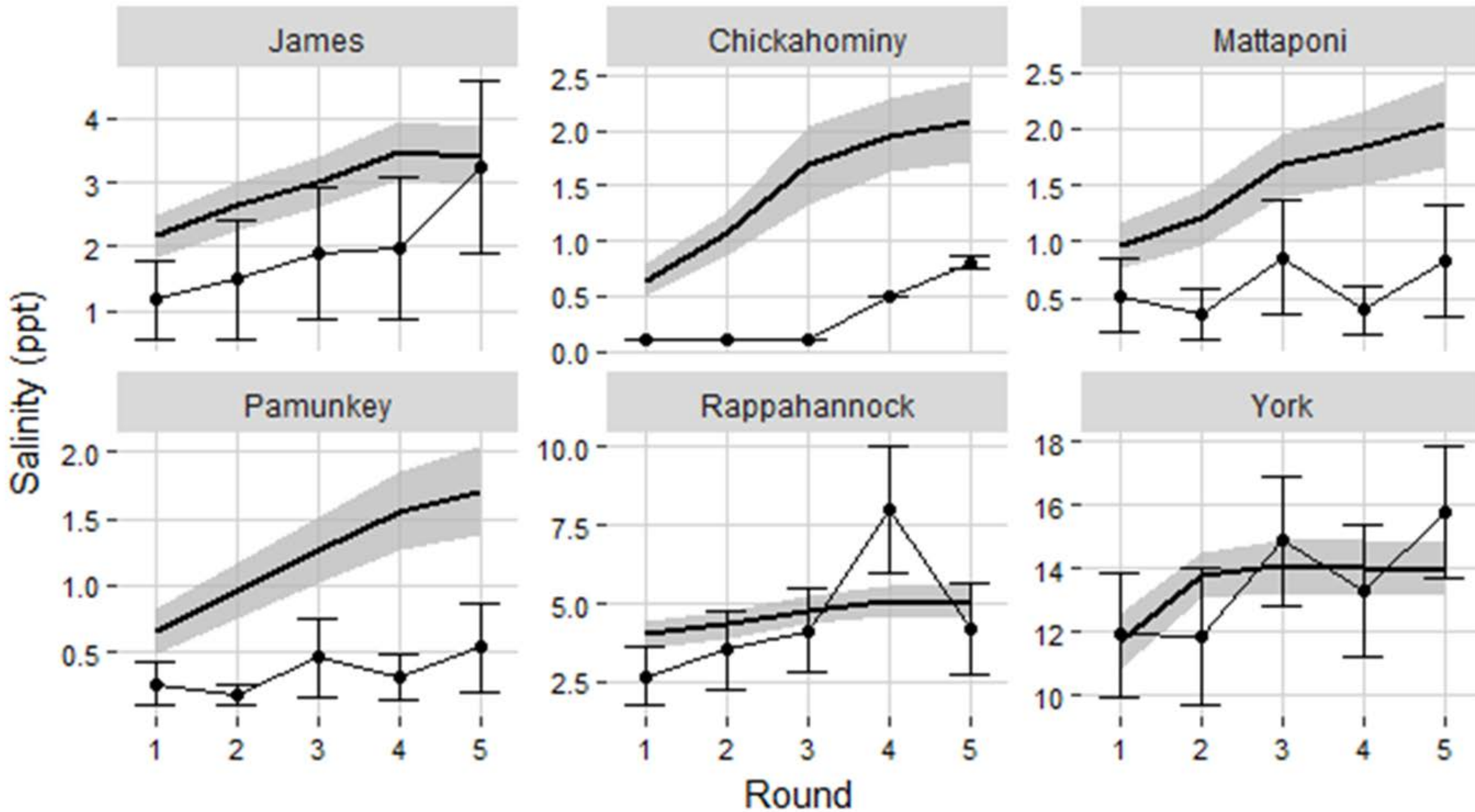

Figure 8. Mean salinity and 95% confidence intervals during each round (x-axis) in each river during 2016 (thin line and error bars) and the historical period from 1967-2015 (thick line and shaded region). Note that the scale of the y-axis varies by river.

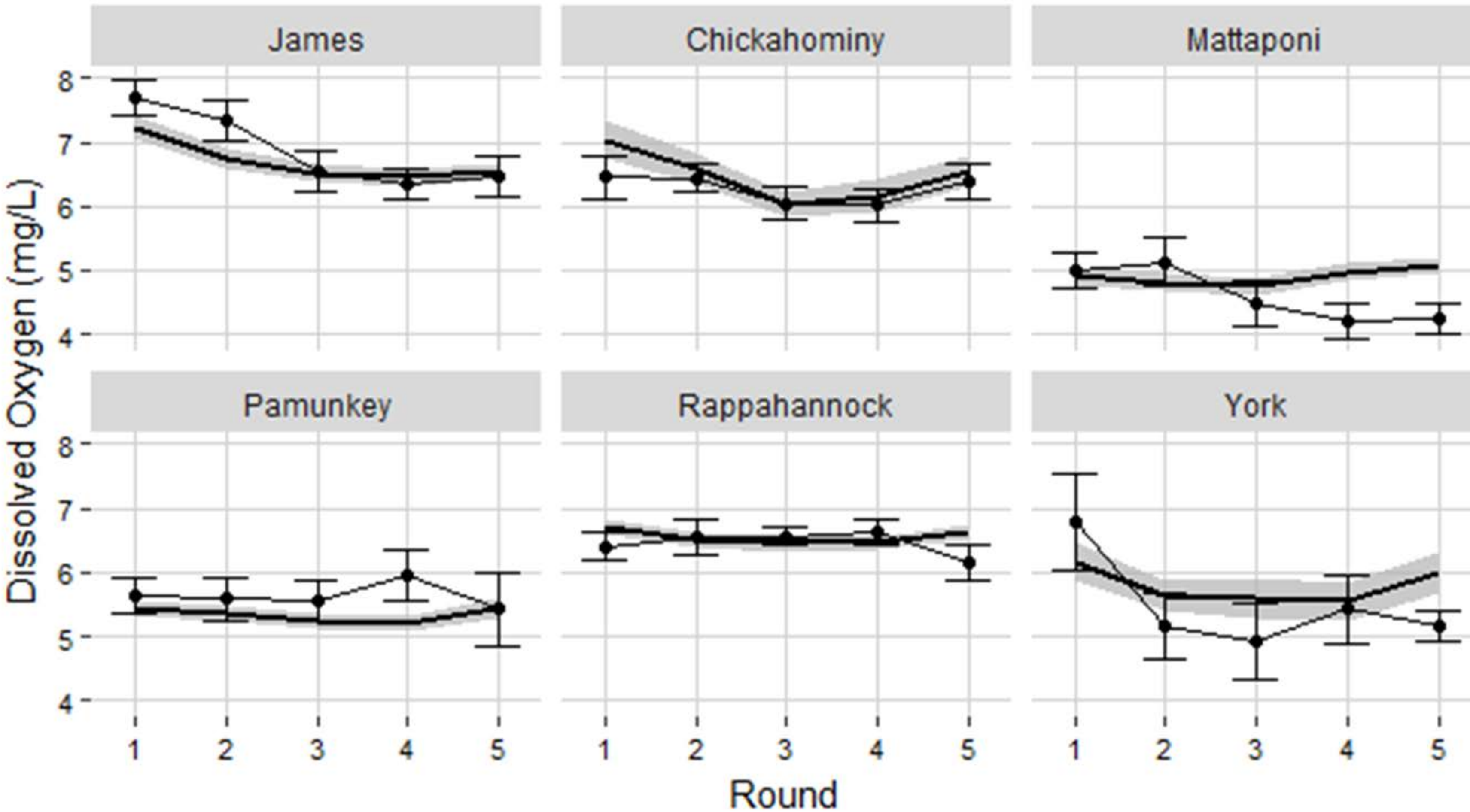

Figure 9. Mean dissolved oxygen and 95% confidence intervals during each round (x-axis) in each river during 2016 (thin line and error bars) and the historical period from 1992-2015 (thick line and shaded region). Note that dissolved oxygen was not measured on the seine survey before 1992.

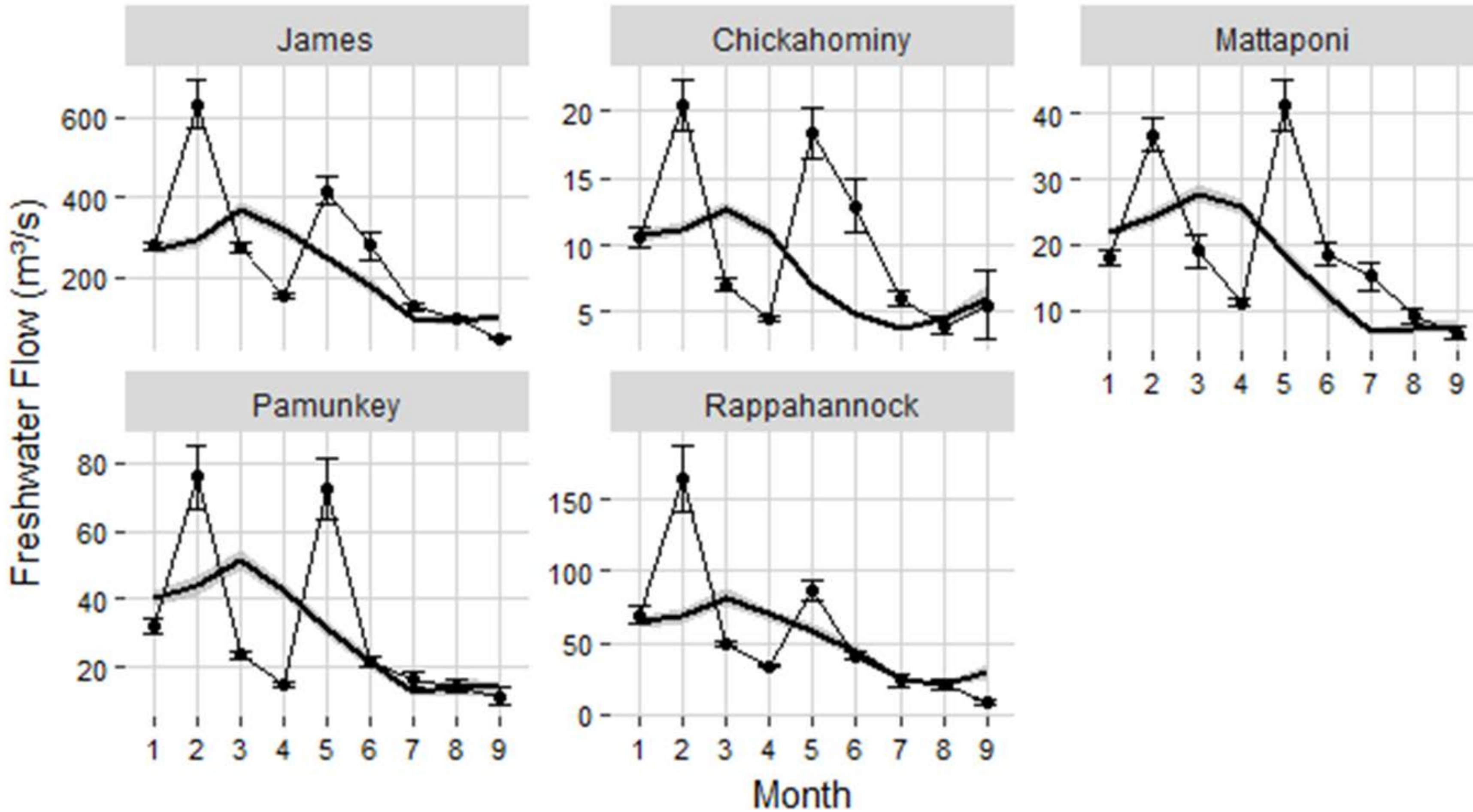

Figure 10. Mean freshwater flow and 95% confidence intervals during each month from January to September (x-axis) in each river during 2016 (thin line and error bars) and the historical period from 1967-2015 (thick line and shaded region). Data are from USGS (2016). Note that the scale of the y-axis varies by river, and only five rivers are shown because USGS does not have a gauge in the mainstem of the York River.

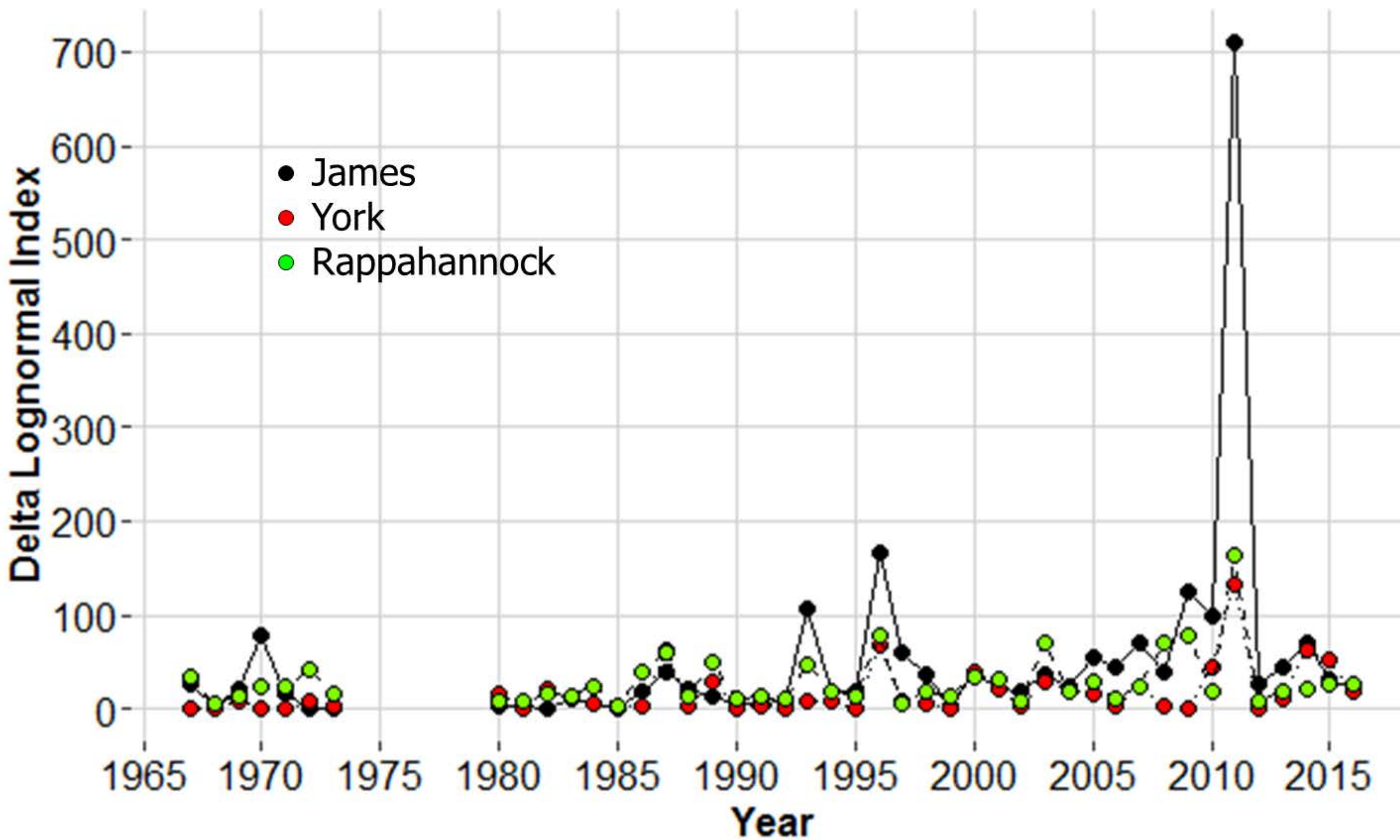

Figure 11. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by river system and year.

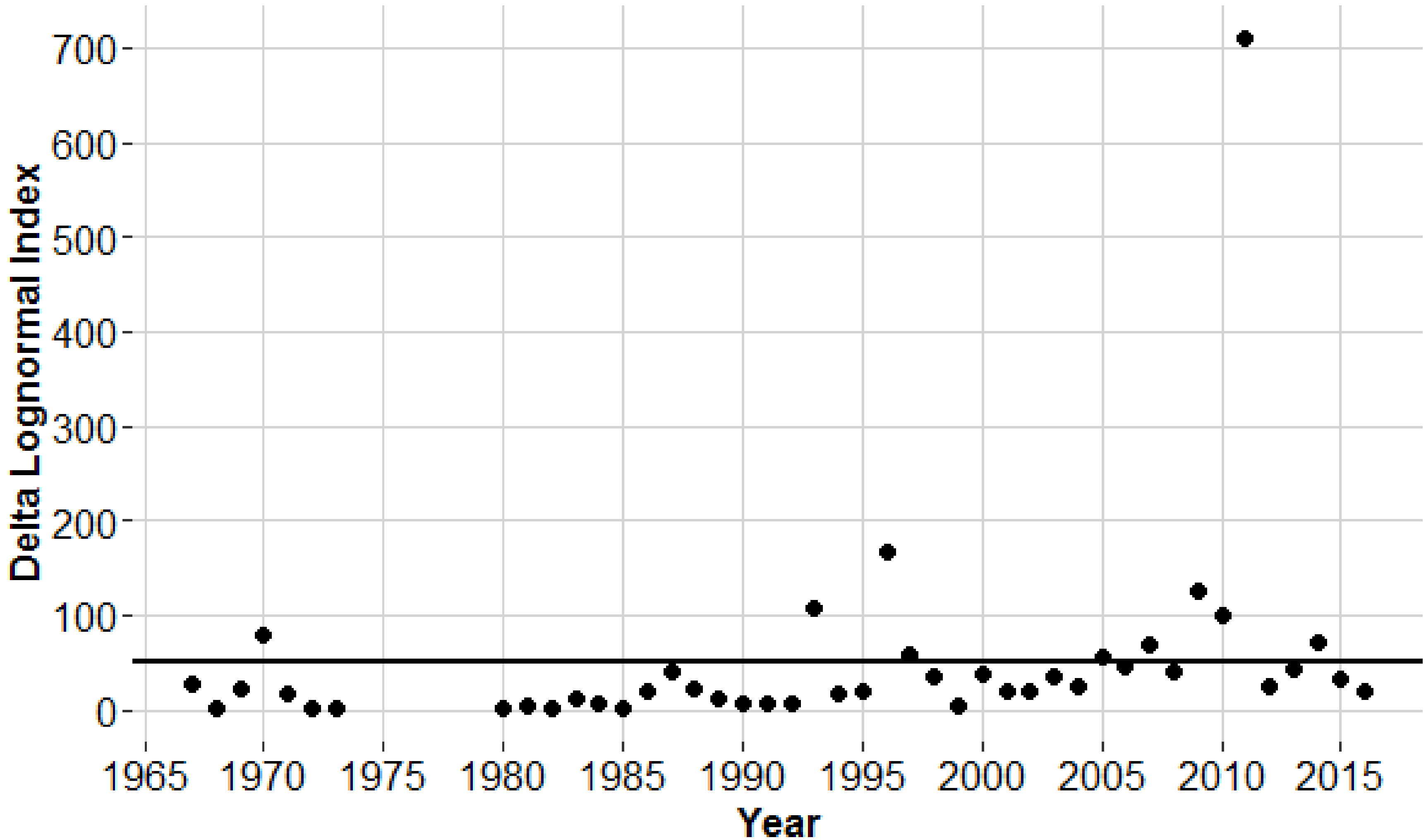

Figure 12. Delta-lognormal mean of young-of-the-year White Perch from the James River nursery area by year. The horizontal line indicates the historical mean for 1967-2015.

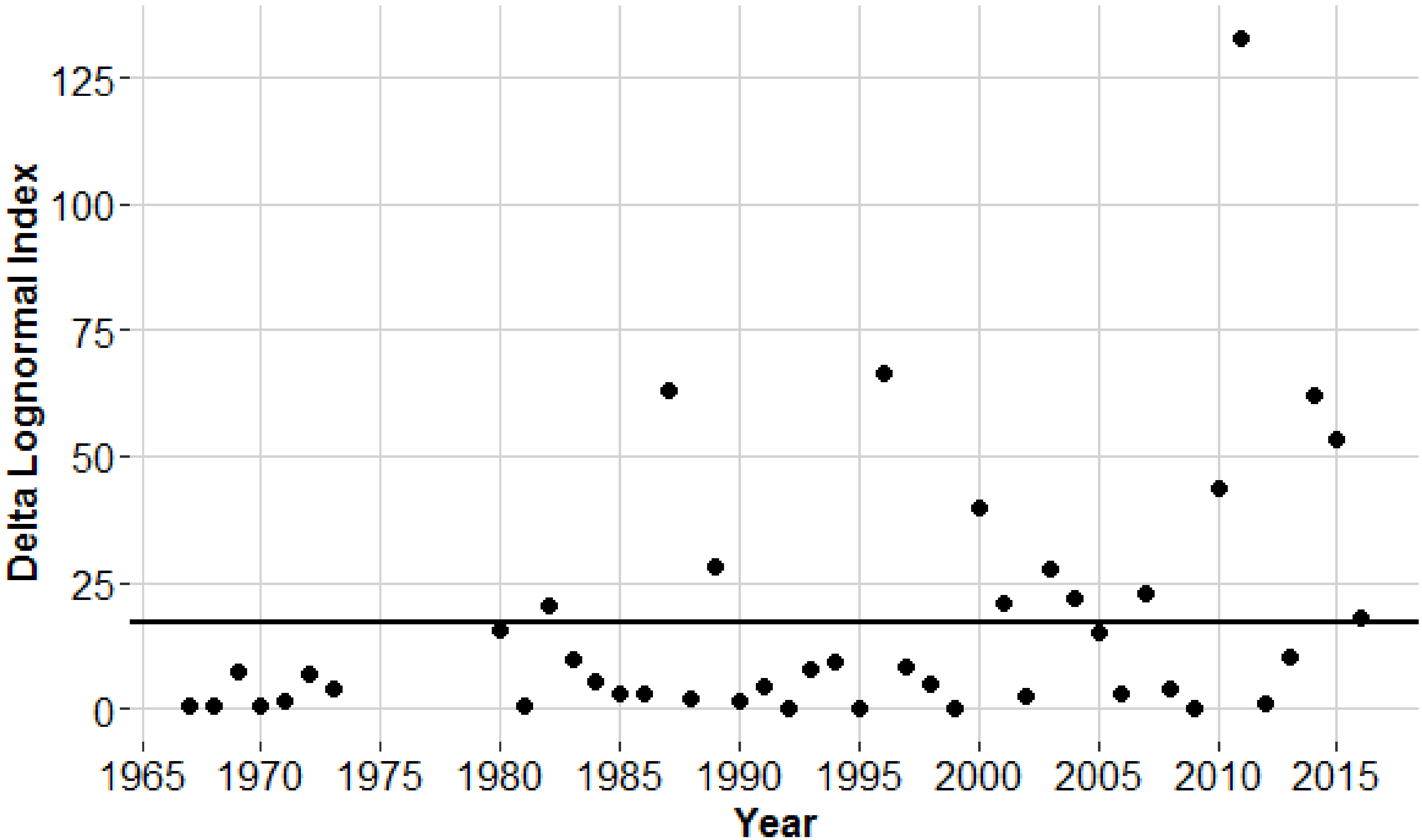

Figure 13. Delta-lognormal mean of young-of-the-year White Perch from the York River nursery area by year. The horizontal line indicates the historical mean for 1967-2015.

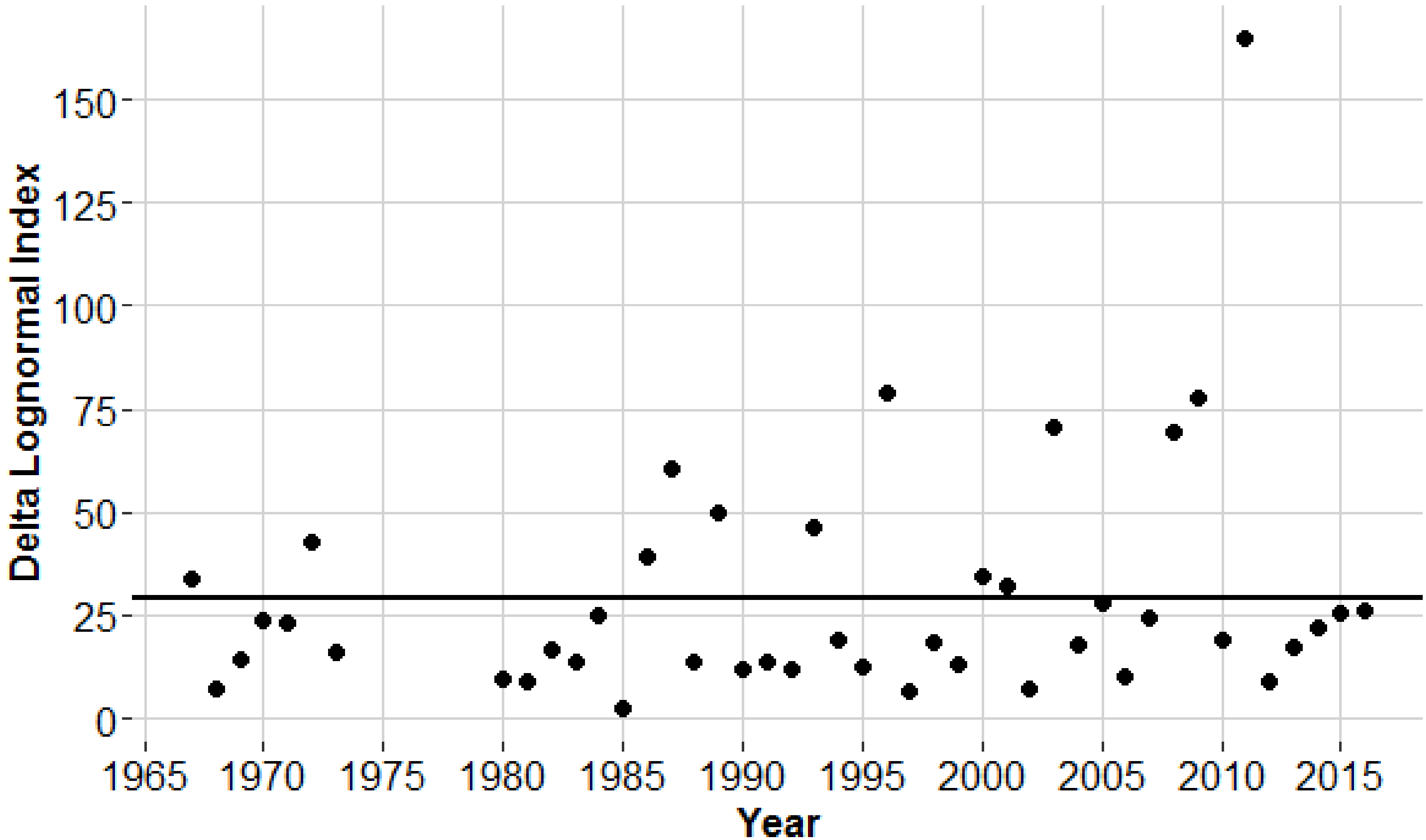

Figure 14. Delta-lognormal mean of young-of-the-year White Perch from the Rappahannock River nursery area by year. The horizontal line indicates the historical mean for 1967-2015.

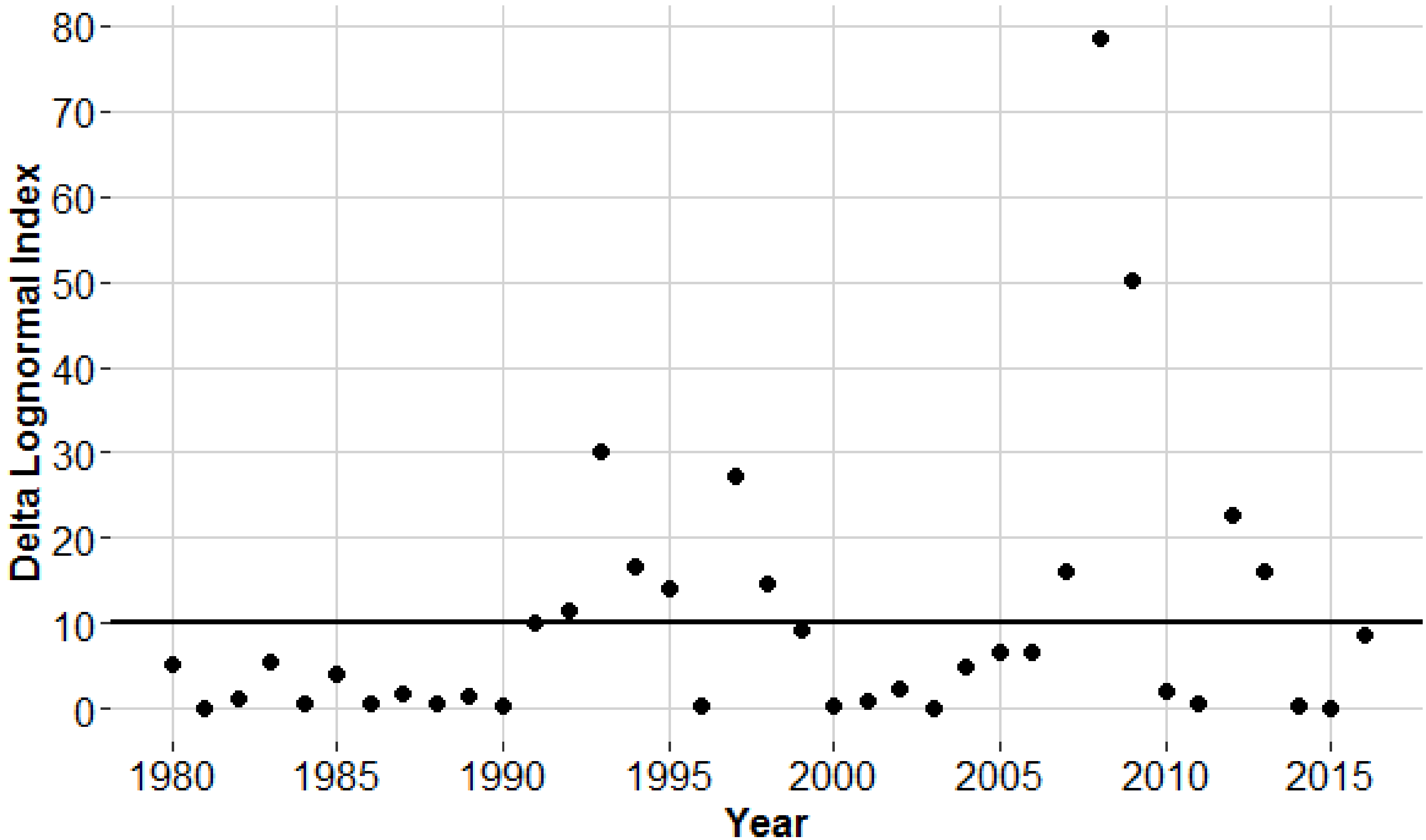

Figure 15. Delta-lognormal mean of young-of-the-year Atlantic Croaker from select seine survey stations in Virginia tributaries of Chesapeake Bay by year. The horizontal line indicates the historical mean for 1980-2015.

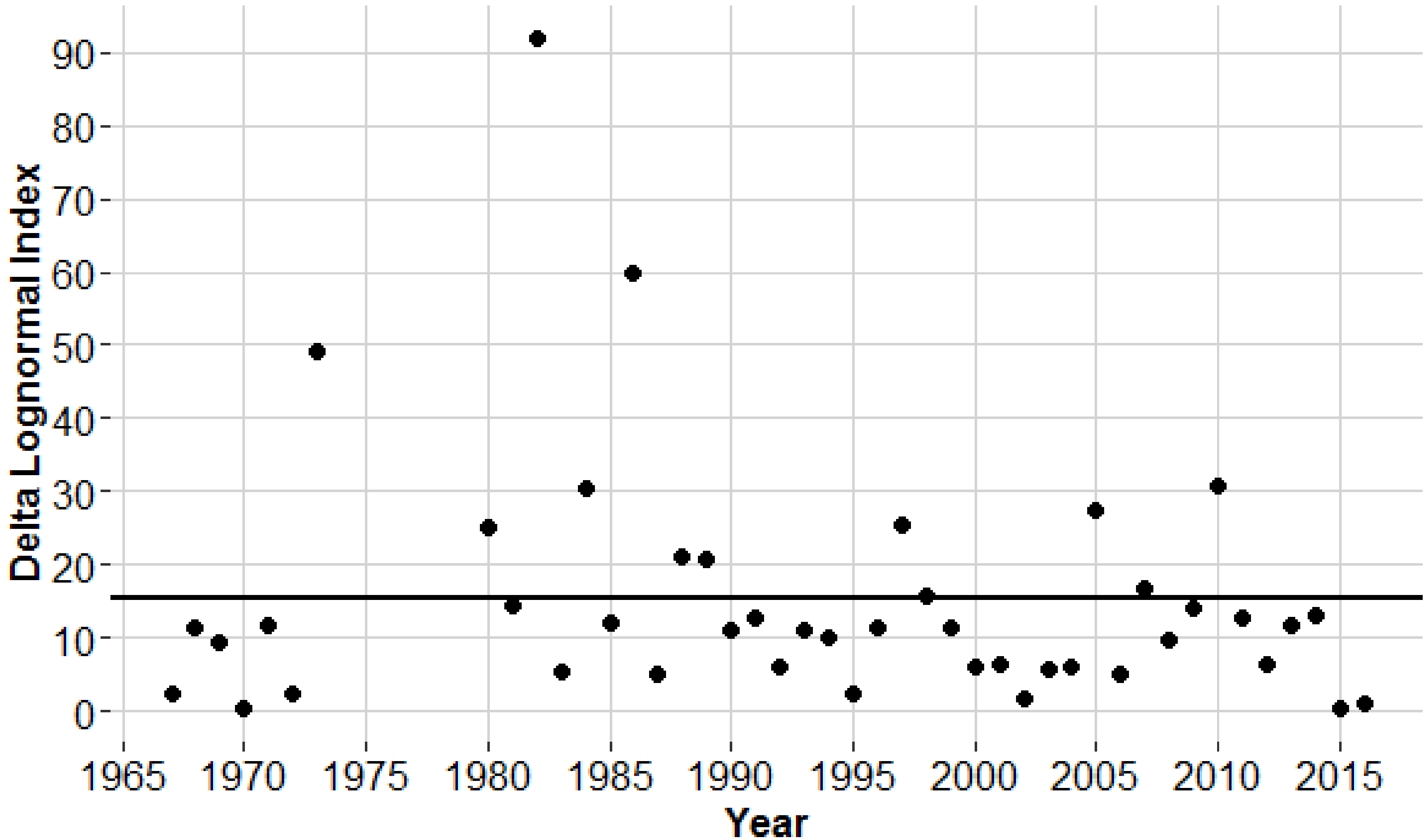

Figure 16. Delta-lognormal mean of young-of-the-year Spot from select seine survey stations in Virginia tributaries of Chesapeake Bay by year. The horizontal line indicates the historical mean for 1967-2015.

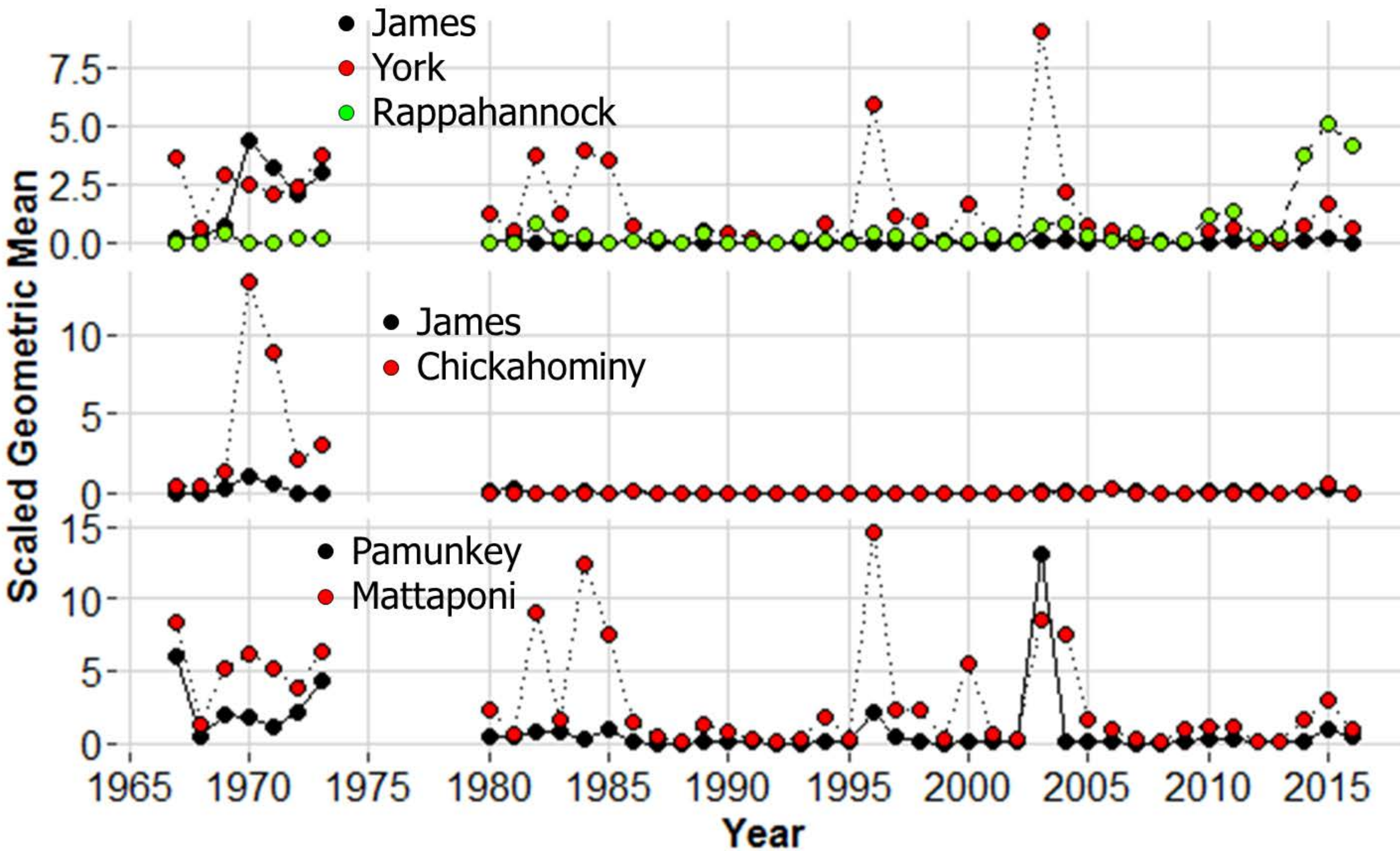

Figure 17. Scaled geometric mean of American Shad in the primary nursery areas of Virginia (index stations) by drainage and river using only the 1st haul.

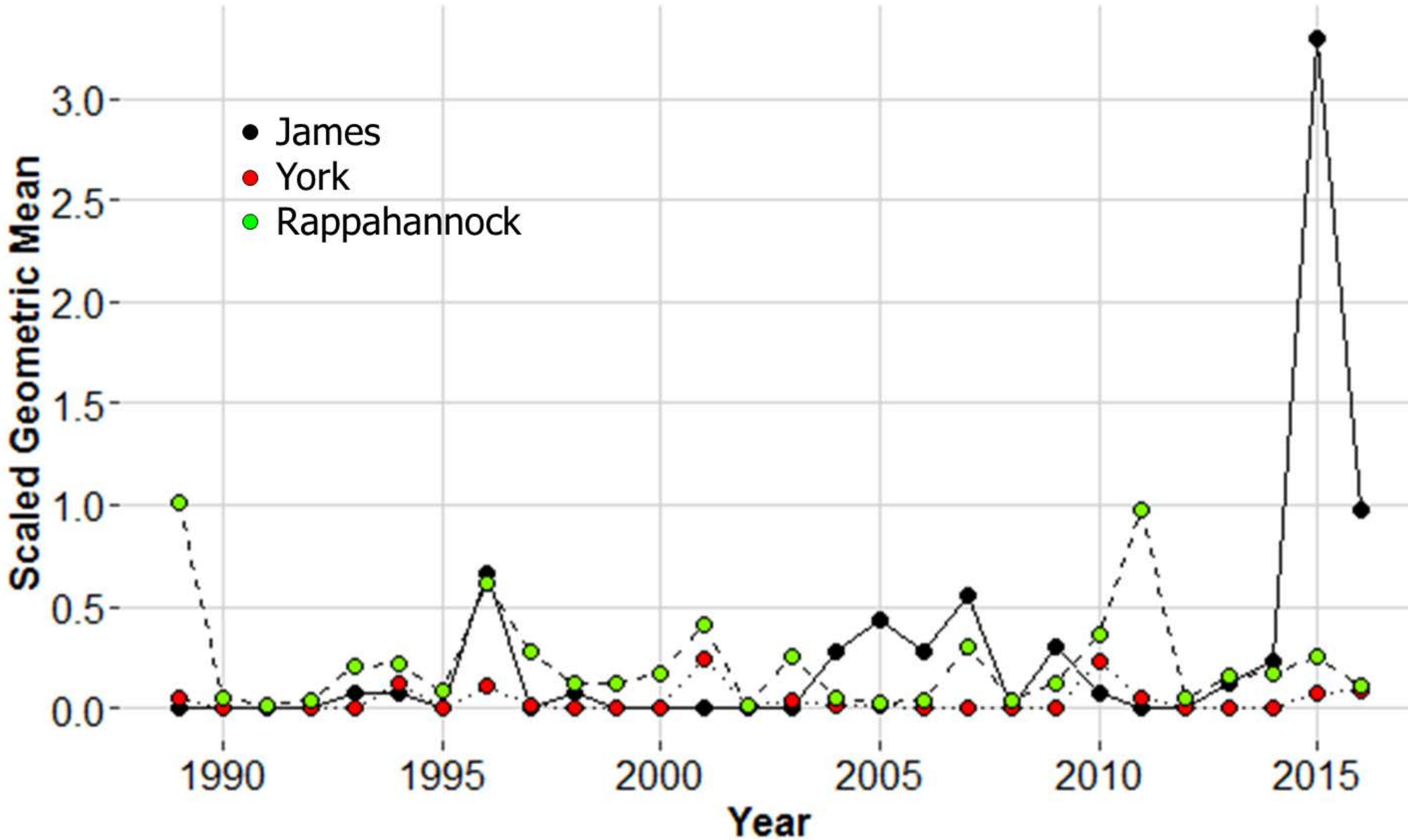

Figure 18. Scaled geometric mean of Alewife in the primary nursery areas of Virginia (index stations) by drainage, using only the 1st haul.

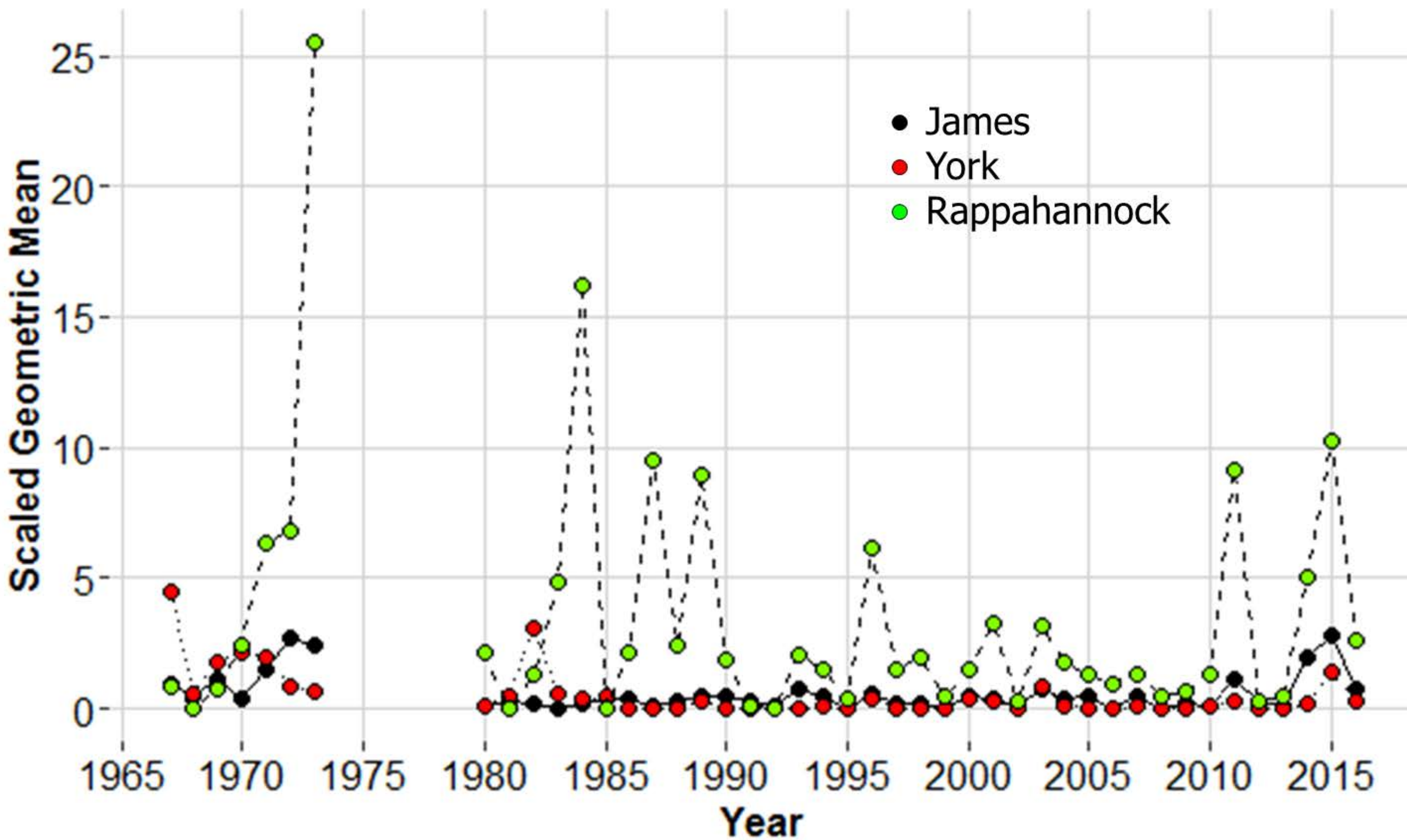

Figure 19. Scaled geometric mean of Blueback Herring in the primary nursery areas of Virginia (index stations) by drainage, using only the 1st haul.