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

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EXECUTIVE SUMMARY

The 2017 Striped Bass juvenile abundance index was 9.17 and was not significantly different from the reference mean of 7.77 from 1980-2009. Abundance indices in the James, York and Rappahannock rivers in 2017 were average compared with their individual reference means (1980-2009). Relatively low catches of young-of-the-year Striped Bass at upriver and downriver auxiliary sites suggested Striped Bass largely remained within core nursery areas in 2017. Juvenile White Perch abundance indices in 2017 were above-average in the James and Rappahannock rivers, but near the historic average in the York River. Additional paired hauls with old and new seine nets were conducted in 2017 to supplement calibration sampling in 2015, and the inclusion of these data resulted in calibration factors that were not significantly different than 1 for Striped Bass or White Perch (i.e., no difference in the relative catch efficiency between nets). Thus, the preliminary calibration factors that were used to adjust catches of these species in the 2016 report have been discontinued and no future adjustments are necessary. In addition, the 2016 indices have been recalculated using this new information.

The abundance index for Atlantic Croaker was near the historic average, whereas another below-average year class for Spot appears to have occurred in 2017. Abundance indices for American Shad, Alewife, and Blueback Herring were below historic averages in Virginia waters in 2017. Above-average indices for Spottail Shiner, Atlantic Silverside, and Inland Silverside suggested adequate production of these forage fishes for populations of commercially and recreationally important piscivores in Virginia waters.

PREFACE

The primary objective of the Virginia Institute of Marine Science juvenile Striped Bass seine 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 2017 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 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 6 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; 1.2 m x 30.5 m x 6.4 mm mesh) showed virtually no statistical differences in catch, and Virginia adopted the "Maryland seine" after 1987 (Colvocoresses 1987). The gear comparison study aimed to standardize methods 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 2017 program were to:

1. estimate the relative abundance of the 2017 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 22 June to 31 August 2017. Pilot sampling in the James River during mid-June revealed that Striped Bass were of the size typically encountered in early-July (mean = 47 mm; range = 31-63 mm). Therefore, sampling was initiated approximately two weeks earlier in 2017 (late-June) than the traditional start period (early-July), as done in 2012 (Machut and Fabrizio 2013) and 2016 (Gallagher et al. 2017). Early initiation of sampling may become increasingly common in the future, because Striped Bass will likely spawn earlier in the spring as average temperatures continue to rise in Chesapeake Bay (Peer and Miller 2014). 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 Striped Bass 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 completed at each auxiliary station, and duplicate hauls, with an interlude of at least 30 minutes, were completed at each index station. Every fish collected during a haul was removed from the net and placed into a water-filled bucket. 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 (DO) concentrations were measured after the first haul using a handheld 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. To test if the mesh material influenced the relative catch efficiency of the net, paired hauls of old and new nets were conducted during the 2015 sampling season, and these data were used to estimate species-specific calibration factors for juvenile Striped Bass and White Perch (Fabrizio et al. 2017). The estimated calibration factor was 0.52 for Striped Bass and 0.65 for White Perch, implying that the new net captured more Striped Bass and White Perch than the old net (i.e., catches in the new net were adjusted by multiplying by the calibration factor; Fabrizio et al. 2017). However, due to low sample sizes (number of paired hauls < 30), these calibration factors were viewed as preliminary (Gallagher et al. 2017) and additional paired hauls were conducted during the 2017 sampling season. The addition of observations from 2017 markedly increased sample sizes (number of paired hauls > 70), and resulted in new calibration factors that were not significantly different from 1 for either species

(Appendix Table 1). Therefore, catches of Striped Bass and White Perch obtained with the new net in 2016 and 2017 were not adjusted prior to estimation of abundance indices.

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 (× 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 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 regulations targeting the development of a sustainable fishery.

The 2017 annual index calculated from both hauls was compared with the average index from 1980-2009 (hereafter referred to as the reference period) to reflect the time period used in the definition of recruitment failure in Virginia, as stipulated by Addendum II to Amendment 6 of the Striped Bass fishery management plan (ASMFC 2010). In addition, an average index value for 1990-2016 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 2017 annual index.

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 2,060 young-of-the-year Striped Bass in 2017 from 180 seine hauls at index stations and 338 individuals from 105 hauls at auxiliary stations (Table 1). Using index-station catches from both hauls, the estimated Striped Bass recruitment index in 2017 was 9.17 (LCI = 7.18, UCI = 11.57; Table 2), which was not significantly different from the average of 7.77 during the reference period (LCI = 6.01, UCI = 9.89; Figure 2). Using index station catches from only the first haul in 2017, 1,200 young-of-the-year Striped Bass were collected, resulting in an index of 10.09 (LCI = 7.13, UCI = 13.96, Table

3), which was not significantly different from the first-haul reference period index of 9.57 (LCI = 7.43, UCI = 12.17), and not significantly different from the mean index estimated for the post-recovery period (post-recovery index = 11.94; LCI = 9.63, UCI = 14.69).

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 late-August or mid-September because after this time, sampling efficiency decreases due to increased avoidance of the sampling gear and movement of juveniles into deeper waters. Indices calculated from catches after this period are therefore biased low. Starting in 2011, recruitment calculations were made using catch data from the currently established sampling season (July through mid-September, or late-June through August) 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 more recently from 2013 to 2017 (Figure 2). Below-average year classes were observed in 1991, 1999, 2002, and 2012 (Figure 2). In the past decade, recruitment has been average or above 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 in producing states (i.e., the index value is below the first quartile in the time series; Figure 1). Such periods of persistently low recruitment have occurred in Virginia from 1971-1973 and 1980-1983 (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 Striped Bass recruitment was reported to be above-average in Maryland and average in Virginia); such differences may arise due to annual changes in the relative 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 2017 were average compared with their means from the reference period (1980-2009; Table 4; Figure 3). The 2017 JAI for the James River drainage was 12.69 (LCI = 9.19, UCI = 17.26), compared with the reference period index of 10.41 (LCI = 7.83, UCI = 13.64; Table 4). The 2017 JAI value for the York River drainage was 5.34 (LCI = 3.70, UCI = 7.42), compared with the reference period index of 5.85 (LCI = 4.50, UCI = 7.48; Table 4). The 2017 JAI value for the Rappahannock River drainage was 12.40 (LCI = 6.83, UCI = 21.38), compared with the reference period index of 7.90 (LCI = 5.63, UCI = 10.82; 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 and Rappahannock river systems. In 2017, 48% of all young-of-the-year Striped Bass occurred in the core nursery zone of the James River (C1, C3, and J46; Table 1). The remaining Striped Bass were captured at upriver (26%) and downriver sites (26%; Table 1). Similarly, 90% of the total catch in the Rappahannock River was taken from the three uppermost index sites in 2017 (R44, R50, R55; Table 1). These three sites have consistently dominated the catches in this drainage for more than two decades.

No index sites are located along the main stem of the York River, thus, the watershed JAI is compiled from catches at sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. The 2017 Pamunkey River JAI of 8.72 (LCI = 4.91, UCI = 14.53) was not significantly different from the reference period index of 6.90 (LCI = 4.90, UCI = 9.44; Table 4), and the 2017 Mattaponi River index of 3.51 (LCI = 2.23, UCI = 5.15) was also not significantly different from the reference period average of 5.16 (LCI = 4.06, UCI = 6.45; Table 4). Approximately 63% of Striped Bass in the York River were collected from the Pamunkey River and 29% from the Mattaponi River; the remainder (8%) were from the York River auxiliary stations (Table 1).

Striped Bass Collections from Auxiliary Stations

Figures 4-6 illustrate the spatial distribution of the 2017 year class throughout nursery areas sampled by this survey. Note that the scaling of CPUE 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 nursery areas that may 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 low catches of young-of-the-year Striped Bass at upriver and downriver auxiliary sites in 2017, which suggests that fish mostly remained within the core nursery area.

Juvenile Striped Bass were captured at all auxiliary stations in the James River during 2017, although catches were low at the upper- and lower-most stations (Tables 1 and 5; Figure 4). Striped Bass were collected from all auxiliary sites in the Pamunkey and Mattaponi rivers in 2017, although only one individual was captured at the uppermost site (P55) in the Pamunkey river (Tables 1 and 5; Figure 5). Relatively few Striped Bass were collected from the three auxiliary stations in the York River (Table 1).

We previously suggested that the lack of Striped Bass at auxiliary stations in the upper reaches of 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 2017, we detected few juvenile Striped Bass at the upper-most auxiliary sites in the Pamunkey (P55) and Mattaponi (M52) rivers (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. Catches in recent years at these two sites, especially P55, may have been affected by the altered state of the nearshore area of these sites. Striped Bass may have been forced into deeper waters by the dense *Hydrilla* beds; alternatively, Striped Bass may 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 nearshore areas where *Hydrilla* is present.

Relatively low numbers of Striped Bass were collected at upriver Rappahannock River auxiliary stations during 2017. 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 at R21 in 2017 (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 2017 (Table 1; Figure 6), long-term average JAI values at auxiliary stations upstream of Tappahannock (near R37) appear comparable to JAIs at index stations R28 and R37 (Table 5).

Comparison among Sampling Rounds

Indices of abundance calculated by sampling round in 2017 were not significantly different from averages observed during the reference period from 1980 to 2009 (Table 6). The largest number of young-of-the-year Striped Bass were collected during rounds 1 and 2 in 2017, with fewer recorded in subsequent rounds (Table 6). This follows patterns observed during the reference period, where 55% of the Striped Bass captured within the primary nursery areas of Virginia occurred in the first two rounds of sampling. In 2017, we observed 40% of Striped Bass in round 1, which was followed by a modest decline (-30%) in the number captured in round 2 that was similar to declines during the reference period (-22%). There was a relatively steep decline in catches during round 3 (-57%), followed by a modest increase in round 4 (+17%). Finally, round 5 exhibited a steeper decline in catches (-61%) compared to that typically observed during the reference period (Table 6).

Environmental Conditions and Potential Relationships to Striped Bass Abundance

The juvenile Striped Bass seine survey routinely records temperature, salinity and DO at each station during each round of sampling. Environmental conditions during each round in 2017 were compared to long-term average conditions (Figures 7-9). For temperature and salinity, the long-term average was calculated using data from 1989-2016 to include all years when auxiliary stations were sampled, thereby maximizing and standardizing the spatial extent of sampling (Figure 1). Dissolved oxygen has been measured only since 1992, so the long-term average for DO was calculated using data from 1992-2016.

Water temperatures tend to exhibit a well-defined pattern of high temperatures in rounds 1 and 2, followed by declining temperatures as the sampling season progresses (rounds 3-5; Figure 7). However, a different pattern was observed in 2017: mean water temperatures were mostly above historic averages during rounds 2 and 3, ranging from 27-31°C throughout this period (Figure 7). In addition, water temperatures were above average in round 5 with the exception of the Mattaponi and York rivers (Figure 7), which were likely influenced by a storm event 1 to 2 days before sampling. These high water temperatures were consistent with statewide average air temperatures from July-September of 2017, which were “above average” in Virginia (NCDC 2017). Relatively high water temperatures in Striped Bass nursery areas have now occurred in five consecutive years, especially during later rounds (Davis et al. 2016, Gallagher et al. 2017). This temperature pattern did not seem to affect catches in previous years, however. Catch rates in 2017 followed the historic pattern with respect to water temperature: 100% of juvenile Striped Bass 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 Striped Bass catches and decreasing temperature is considered to be largely the result of a coincident downward decline in catch rates (due to gear avoidance by larger Striped Bass) and water temperatures as the season progresses rather than any direct effects of water temperature on juvenile fish distribution.

Across years, salinity tends to steadily increase from round 1 to 3, and level off during rounds 4 and 5 (Figure 8). In 2017, average salinities during rounds 3-5 were generally higher than long-term averages, especially in the Chickahominy, Mattaponi, Pamunkey and York rivers (Figure 8). Mean salinities were above-average in the James River and average in the Rappahannock River in 2017, although it is important to note that sampling across a more extensive salinity gradient (historical range = 0.1-14.0 ppt; Table 5) typically results in wider confidence intervals in these rivers (Figure 8). As observed in the past, greater catches of young-of-the-year Striped Bass in 2017 were obtained at sites exhibiting low salinities within the primary nursery area (Table 5). Only one index station (R28) exhibited salinities exceeding 10.0 ppt on average, although mean salinities as high as 19.3 ppt were observed at one auxiliary site in the York River (Table 5). Whereas juvenile Striped Bass were captured at downstream sites with average salinities ranging from 10.0 to 19.0 ppt in 2017, JAIs were distinctly lower at such sites compared with catches in lower salinity areas (Table 5).

Mean DO concentrations in 2017 were higher than long-term averages during most rounds within most rivers (Figure 9). 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 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 in the Patuxent River is 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 varies seasonally, with monthly averages since 1967 showing relatively high flow during the winter, peaking in early-spring (March-April), and declining steadily through the late-spring and summer (Figure 10). In most rivers during 2017, freshwater flow was near-average in January, below-average from February to April, above-average during May, then below-average from June to September (Figure 10). Notable exceptions to this pattern were the Pamunkey and Mattaponi rivers, which were characterized by below-average flow in all months in 2017. In contrast, statewide precipitation during the winter and spring of 2017 (December 2016-May 2017) was "above average" in Virginia relative to historical conditions since 1895 (NCDC 2017). However, the coastal region of Virginia had "near average" precipitation over this period, which was lower than western regions of the state (NCDC 2017). Despite the relatively low precipitation and freshwater flow during several months in 2017, 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 fish species are encountered by the juvenile Striped Bass seine survey annually because the sampling domain spans from euryhaline to freshwater zones. The five most common species encountered in 2017 were White Perch (*Morone americana*), Spottail Shiner (*Notropis hudsonius*), Atlantic Silverside (*Menidia menidia*), Bay Anchovy (*Anchoa mitchilli*), and Hogchoker (*Trinectes maculatus*). In 2017, more than 43,000 individuals comprising 66 species were collected (Table 8). Indices of abundance were estimated for ten of these species (in addition to Striped Bass) based on catches from the first haul only. A different subset of index and auxiliary stations was used for each species, based on the range of sites where the species was commonly encountered within each tributary from 1967 to 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 2017). The general overlap in spawning time and use of nursery grounds by White Perch and Striped Bass suggests 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 the seine survey 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 late-June through August 2017, 6,840 young-of-the-year White Perch were collected from 126 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, 2017 river-specific JAIs for White Perch suggest above-average recruitment in the Rappahannock and James rivers (Figures 12 and 14), whereas abundance in the York River was near the historic average (Figure 13). Although we feel confident in the estimation of annual mean relative abundance of White Perch, 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 2017) regularly collected by the seine survey. Young-of-the-year Atlantic Croaker are collected at predominately mesohaline sampling sites during rounds 1-3, 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 2017 were spawned during the fall of 2016. 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 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.

Atlantic Croaker are coastal shelf spawners with larval migration into Chesapeake Bay. Therefore, we report a Virginia-wide estimate of juvenile abundance (Table 10; Figure 15). Based on catches from 21 stations in late-June through August of 2017, we encountered a total of 230 young-of-the-year Atlantic Croaker and these fish were captured in 24 seine hauls (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 2017.

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 2017, 221 young-of-the-year Spot were collected in 42 seine hauls. Using the delta-lognormal approach, we observed a below-average year class for Spot in 2017, similar to estimates from the previous two years (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 2017 Spottail Shiner delta-lognormal mean of 43.6 was greater than the historic average of 27.0 (Table 12). The 2017 Atlantic Silverside delta-lognormal mean of 79.9 was greater than the historic average of 46.0 (Table 13). The 2017 Inland Silverside abundance index of 9.2 was greater than the historic average of 5.0 (Table 14). The 2017 Banded Killifish delta-lognormal mean of 4.5 was similar to the historic average of 4.9 (Table 15). Average to above-average indices for all four of these species in 2017 suggest that a robust population of forage fishes was available for commercially and recreationally important piscivores in Virginia waters. In addition, it is worth noting that abundance indices for the three freshwater forage species (Spottail Shiner, Inland Silverside and Banded Killifish) have been increasing on average since 1989, with each species displaying a statistically significant temporal trend.

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 (*Alosa sapidissima*; Watkins et al.

2011), Alewife (*Alosa pseudoharengus*), Blueback Herring (*Alosa aestivalis*), and Atlantic Menhaden (*Brevoortia tyrannus*; 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 annually 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 2017 geometric mean abundance indices for American Shad were relatively low in the James, York, and Rappahannock rivers, which halted an increasing trend observed during the previous three years (Figure 17). The 2017 geometric mean abundance indices for Alewife were average or below average in the three rivers (Figure 18). The 2017 geometric mean abundance indices for Blueback Herring were relatively low in the James, York, and Rappahannock rivers (Figure 19).

CONCLUSION

The 2017 juvenile abundance index (JAI) for Striped Bass (9.17) was not significantly different from the average during the reference period (7.77) for Virginia waters. Compared with reference period averages, we observed average recruitment in the James, York and Rappahannock rivers. Continued monitoring 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 stock biomass. Juvenile White Perch abundance indices in 2017 were similar to or greater than the historic averages for the species. Forage fish abundance index values were average or above average in 2017. Abundance indices were below average for three alosine species in Virginia waters in 2017, relative to index values observed in previous years.

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TABLES

Table 1. Catch of young-of-the-year Striped Bass per seine haul in 2017. 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	J15	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	Total
	Round	1	2	18	6/3	3/7	2	18/1	18/23	17/11	7	8/3	18	1	0	166
		2	0	13	3/19	11/9	1	3/4	49/31	11/17	17	2/2	14	0	9	215
		3	0	2	3/0	2/0	4	7/1	9/2	12/20	5	1/2	9	3	1	83
		4	0	6	21/13	8/9	3	1/0	10/40	14/10	10	5/65	0	3	5	223
		5	0	0	8/5	0/8	5	3/0	1/2	13/9	0	2/1	0	2	0	59
														James Total		**746**
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55						
	Round	1	0	3	3	6	4/6	8/21	18/15	1						85
		2	1	5	8	3	3/0	15/17	44/19	0						115
		3	3	0	1	1	0/3	7/4	18/5	0						42
		4	0	4	2	1	0/1	1/0	10/4	0						23
		5	0	1	1	1	0/0	1/2	5/0	0						11
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				7/5	7	1/5	7/2	3/3	0					40
		2				4/0	2	2/0	2/2	2/4	1					19
		3				0/0	0	1/0	6/4	4/3	1					19
		4				0/0	3	1/0	3/0	0/7	2					16
		5				2/1	1	0/0	0/0	6/8	0					18
														York Total		**388**
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75		
	Round	1	6	0	0/0	1/4	13	53/21	196/153	131/42	15	4	0	0		639
		2	8	0	0/0	0/0	18	80/21	133/38	17/14	5	9	8	2		353
		3	1	0	1/2	0/0	3	14/7	56/30	11/15	2	1	0	1		144
		4	0	0	3/1	0/0	3	0/0	27/13	11/15	2	4	1	0		80
		5	0	0	1/0	0/0	1	0/3	9/9	2/14	3	5	1	0		48
														Rappahannock Total		**1,264**
														2016 Catch		**2,398**

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) × 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	181
2015	1,879	1.84	1.13	12.00	9.78-14.64	179
2016	1,557	1.58	1.17	8.74	6.98-10.84	180
2017	2,060	1.61	1.28	9.17	7.18-11.57	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, Index = (exp(ln(x + 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)
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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	91
2016	783	1.60	1.16	9.06	6.60-12.21	90
2017	1,200	1.69	1.29	10.09	7.13-13.96	90
1980-2009	26,735	1.65	0.54	9.57	7.43-12.17	30 (years)
1990-2016	29,157	1.83	0.46	11.94	9.63-14.69	27 (years)

Table 4. Catch of young-of-the-year Striped Bass per seine haul at index stations in 2017 summarized by drainage and river.

	2017				Reference Period (1980-2009)			
Drainage River	Total Fish	Index	C.I. (± 2 SE)	N (hauls)	Total Fish	Index	C.I. (± 2 SE)	N (years)
JAMES	586	12.69	9.19-17.26	60	17,650	10.41	7.83-13.64	30
James	363	13.20	9.26-18.50	40	10,727	9.72	7.06-13.12	30
Chickahominy	223	11.71	5.79-22.00	20	6,923	11.95	8.70-16.15	30
YORK	326	5.34	3.70-7.42	70	12,470	5.85	4.50-7.48	30
Pamunkey	231	8.72	4.91-14.53	30	6,442	6.90	4.90-9.44	30
Mattaponi	95	3.51	2.23-5.15	40	6,028	5.16	4.06-6.45	30
RAPPAHANNOCK	1,148	12.40	6.83-21.38	50	13,407	7.90	5.63-10.82	30
Overall	2,060	9.17	7.18-11.57	180	43,527	7.77	6.01-9.89	30

Table 5. Striped Bass indices and average site salinity during 2017 compared with average index values during the monitoring period from 1989 to 2016, with corresponding average salinities (Avg. Sal., ppt). The York drainage includes Pamunkey and Mattaponi rivers. Index stations are indicated by bold font. Indices are calculated using only the 1st haul (Rago et al. 1995).

Drainage														
JAMES		Station	J15	J22	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77
	1989-2016	Avg. Sal.	14.4	7.8	4.9	2.5	1.4	1.4	1.2	0.5	0.3	0.2	0.2	0.1	0.1
		Index	1.7	13.1	10.9	17.7	11.5	23.9	12.1	26.0	17.1	9.8	11.3	6.7	3.1
	2017	Avg. Sal.	16.6	9.8	5.6	2.9	1.4	1.6	1.4	0.5	0.2	0.1	0.2	0.2	0.2
		Index	0.6	10.5	14.6	7.3	6.2	10.2	24.1	30.2	12.0	6.8	8.9	3.4	3.7
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P55					
	1989-2016	Avg. Sal.	16.6	13.8	10.8	4.2	1.8	0.7	0.4	0.2					
		Index	1.4	2.1	7.1	12.6	5.7	14.1	19.0	4.4					
	2017	Avg. Sal.	19.3	16.4	13.5	6.3	3.0	1.2	0.9	0.3					
		Index	1.2	4.5	5.4	4.5	1.9	10.0	34.4	0.3					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1989-2016	Avg. Sal.				4.6	2.3	1.2	0.4	0.2	0.1				
		Index				10.0	10.5	8.6	9.3	5.7	1.3				
	2017	Avg. Sal.				6.4	2.9	0.8	0.3	0.2	0.0				
		Index				3.7	4.3	2.0	6.1	5.4	1.5				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R75	
	1989-2016	Avg. Sal.	14.2	12.9	10.2	5.4	3.0	1.8	0.8	0.5	0.2	0.2	0.1	0.1	
		Index	0.5	0.7	4.3	3.2	5.9	11.7	20.4	48.2	5.9	4.0	2.8	3.6	
	2017	Avg. Sal.	15.6	13.9	10.6	3.9	2.4	0.9	0.4	0.2	0.1	0.1	0.1	0.1	
		Index	3.7	0.0	1.7	0.3	11.7	18.7	118.7	34.0	9.4	9.0	2.4	1.0	

Table 6. Catch of young-of-the-year Striped Bass at index stations in 2017 summarized by sampling round. Note that the survey was started 2 weeks early (late-June) in 2017 compared with most years (early-July).

	2017					Reference Period (1980-2009)				
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	824	19.19	11.72-30.65		30	13,467	11.97	9.15-15.48	
July (2nd)	36	578	13.76	7.81-23.2	-29.9%	30	10,535	9.11	6.84-11.95	-21.8%
(3rd)	36	250	7.50	4.48-11.88	-56.7%	30	7,838	7.26	5.44-9.50	-25.6%
Aug. (4th)	36	293	7.12	3.82-12.19	17.2%	26	6,907	6.88	5.12-9.04	-11.9%
(5th)	36	115	3.94	2.26-6.23	-60.8%	23	4,780	6.04	4.73-7.61	-30.8%

Table 7. Catch of young-of-the-year Striped Bass per seine haul in the primary nursery areas of Virginia in 2017 summarized by water temperature. N/A is not applicable (i.e., no sampling occurred in waters of these temperatures).

	2017				Reference Period (1980-2009)			
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	47	1.98	0.46-4.34	19
20.0-24.9	N/A			0	2,430	4.13	3.61-4.7	568
25.0-29.9	1,499	7.63	5.68-10.06	138	33,808	9.11	8.66-9.57	3,588
> 30.0	561	16.11	10.71-23.75	42	6,871	9.66	8.6-10.82	679

Table 8. Fish species captured during the 2017 seine survey (index and auxiliary stations).

Scientific Name	Common Name	Total Captured
Morone americana	White Perch	10,332
Notropis hudsonius	Spottail Shiner	6,707
Menidia menidia	Atlantic Silverside	6,204
Anchoa mitchilli	Bay Anchovy	4,095
Trinectes maculatus	Hogchoker	2,696
Morone saxatilis	Striped Bass	2,407
Menidia beryllina	Inland Silverside	2,341
Fundulus heteroclitus	Mummichog	1,813
Fundulus diaphanus	Banded Killifish	1,108
Alosa aestivalis	Blueback Herring	860
Brevoortia tyrannus	Atlantic Menhaden	739
Notropis analostanus	Satinfin Shiner	591
Fundulus majalis	Striped Killifish	472
Alosa sapidissima	American Shad	384
Micropogonias undulatus	Atlantic Croaker	379
Dorosoma cepedianum	Gizzard Shad	350
Etheostoma olmstedi	Tessellated Darter	299
Leiostomus xanthurus	Spot	269
Menticirrhus americanus	Southern Kingfish	220
Ictalurus furcatus	Blue Catfish	185
Membras martinica	Rough Silverside	129
Dorosoma petenense	Threadfin Shad	112
Lepomis gibbosus	Pumpkinseed	100
Mugil curema	White Mullet	86
Lepomis macrochirus	Bluegill	78
Alosa pseudoharengus	Alewife	74
Hyporhamphus unifasciatus	Halfbeak	72
Perca flavescens	Yellow Perch	62
Hybognathus regius	Eastern Silvery Minnow	60
Micropterus salmoides	Largemouth Bass	53
Gambusia affinis	Mosquitofish	41
Bairdiella chrysoura	Silver Perch	35
Lepomis auritus	Redbreast Sunfish	34
Syngnathus fuscus	Northern Pipefish	33
Enneacanthus gloriosus	Bluespotted Sunfish	32
Anguilla rostrata	American Eel	30
Anchoa hepsetus	Striped Anchovy	24
Notemigonus crysoleucas	Golden Shiner	18
Mugil cephalus	Striped Mullet	18
Ictalurus punctatus	Channel Catfish	17

Table 8. (continued)

Scientific Name	Common Name	Total Captured
Gobiosoma bosci	Naked Goby	16
Cynoscion nebulosus	Spotted Seatrout	14
Pogonius cromis	Black Drum	13
Alosa mediocris	Hickory Shad	11
Ictalurus nebulosus	Brown Bullhead	11
Strongylura marina	Atlantic Needlefish	10
Cynoscion regalis	Weakfish	9
Moxostoma macrolepidotum	Shorthead Redhorse	9
Synodus foetens	Inshore Lizardfish	8
Micropterus punctulatus	Spotted Bass	8
Ictalurus catus	White Catfish	7
Lepisosteus osseus	Longnose Gar	6
Hippocampus erectus	Lined Seahorse	6
Paralichthys dentatus	Summer Flounder	5
Menticirrhus saxatilis	Northern Kingfish	4
Chaetodipterus faber	Atlantic Spadefish	4
Symphurus plagiusa	Blackcheek Tonguefish	3
Cyprinus carpio	Common Carp	2
Gobiesox strumosus	Skilletfish	2
Pomatomus saltatrix	Bluefish	1
Sciaenops ocellatus	Red Drum	1
Scomberomorus maculatus	Spanish Mackerel	1
Sphoeroides maculatus	Northern Puffer	1
Cyprinodon variegatus	Sheepshead Minnow	1
Chasmodes bosquianus	Striped Blenny	1
Eucinostomus argenteus	Spotfin Mojarra	1
	Total	43,714

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	1,582	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	1,177	60.5	63
1988	457	22.1	69	2.2	287	13.7	61
1989	424	13.0	807	28.2	1,349	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	3,812	107.8	344	7.6	1,177	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	4,784	166.9	1,654	66.5	2,294	78.9	126
1997	1,703	59.0	305	8.3	248	6.3	102
1998	1,432	35.5	195	4.7	457	18.5	108
1999	159	3.4	1	0.0	486	13.2	67
2000	1,540	38.5	1,363	40.0	1,184	34.2	121
2001	948	20.8	799	21.1	1,126	32.3	123
2002	790	19.1	129	2.7	275	7.0	83
2003	1,364	35.7	1,132	27.8	1,849	70.4	120
2004	1,030	23.8	799	22.0	670	17.9	130
2005	1,871	54.9	579	15.3	834	28.1	122
2006	2,064	44.9	95	2.8	388	10.0	99
2007	2,896	69.2	417	22.7	830	24.5	113
2008	1,627	40.5	184	4.1	1,512	69.6	107
2009	3,825	125.2	10	0.2	1,813	77.7	90
2010	3,085	100.1	1,632	43.6	728	19.1	130
2011	15,805	709.0	4,112	132.6	4,169	164.6	140
2012	1,233	25.1	47	1.0	338	8.8	99
2013	1,591	43.3	433	10.4	623	17.5	119
2014	2,198	71.4	2,373	62.0	841	22.0	120
2015	1,544	32.6	1,621	53.5	1,017	25.3	140
2016	1,474	31.6	980	30.5	1,286	41.2	121
2017	3,804	113.9	460	10.6	2,576	101.6	126

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	1,115	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	1,306	78.4	52
2009	1,724	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	483	12.9	23
2017	230	6.4	24
Overall (1980-2016)	13,579	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	2,306	49	72
1980	2,174	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	1,338	59.8	33
1987	161	5.1	15
1988	943	21	37
1989	1,319	20.9	52
1990	1,050	11.1	62
1991	1,069	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	1,900	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	2,711	27.6	87
2006	471	5	66
2007	977	16.9	77
2008	906	9.7	84
2009	1,208	14.1	73
2010	2,801	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
2017	221	2.6	42
Overall (1967-2016)	36,715	13.6	44 (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	2,843	22.3	115
1990	2,019	15.3	104
1991	1,394	10.8	94
1992	2,313	17.5	99
1993	1,708	12.8	99
1994	2,286	18.6	110
1995	2,212	18	105
1996	2,182	18.4	109
1997	3,568	25.9	105
1998	2,100	16.3	101
1999	1,149	8.3	81
2000	4,857	40.2	113
2001	2,721	21.7	113
2002	1,381	9.9	71
2003	3,070	23.4	126
2004	5,133	42	127
2005	3,597	30.6	112
2006	3,464	29.2	107
2007	3,837	33.7	111
2008	2,147	17.9	95
2009	3,035	24.1	101
2010	3,989	27	105
2011	6,284	58.5	122
2012	4,022	30.8	103
2013	4,325	33.7	109
2014	3,401	24.8	125
2015	4,463	33.8	131
2016	3,397	25.1	122
2017	5,436	43.6	112
Overall (1989-2016)	86,897	27.0	28 (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	1,089	10.8	27
1990	2,917	51.0	51
1991	2,855	39.9	68
1992	6,087	125.8	58
1993	2,364	31.8	59
1994	2,305	34.1	52
1995	3,079	41.4	59
1996	4,871	85.3	52
1997	1,160	13.2	55
1998	2,434	26.0	66
1999	6,822	68.2	88
2000	3,778	44.0	65
2001	4,015	54.7	73
2002	5,387	67.0	96
2003	3,351	53.9	35
2004	1,503	20.9	39
2005	1,979	22.1	69
2006	2,847	31.1	67
2007	2,067	29.2	68
2008	3,454	36.5	58
2009	2,916	37.6	72
2010	1,723	18.6	86
2011	3,585	47.5	75
2012	1,381	14.2	68
2013	6,814	92.4	59
2014	4,891	69.6	67
2015	7,542	103.1	74
2016	2,397	27.0	56
2017	5,259	79.9	73
Overall (1989-2016)	95,613	46.0	28 (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	1,125	6.6	84
2005	419	2.5	78
2006	1,184	7.5	88
2007	861	5.4	78
2008	704	3.9	92
2009	1,751	9.8	113
2010	1,507	8.8	78
2011	1,476	7.6	89
2012	962	5.2	111
2013	1,658	10.3	109
2014	1,849	10.7	107
2015	1,618	9.9	108
2016	2,160	10.9	119
2017	1,627	9.2	117
Overall (1989-2016)	23,639	5.0	28 (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	1,383	9.6	89
2005	715	5.6	68
2006	498	4	48
2007	692	5	75
2008	1,025	6.8	87
2009	1,208	9	85
2010	1,965	14.8	97
2011	1,958	13.9	88
2012	1,865	13.3	97
2013	638	4.5	70
2014	715	4.6	87
2015	885	5.5	94
2016	1,834	13.2	108
2017	697	4.5	105
Overall (1989-2016)	20,425	4.9	28 (years)

FIGURES

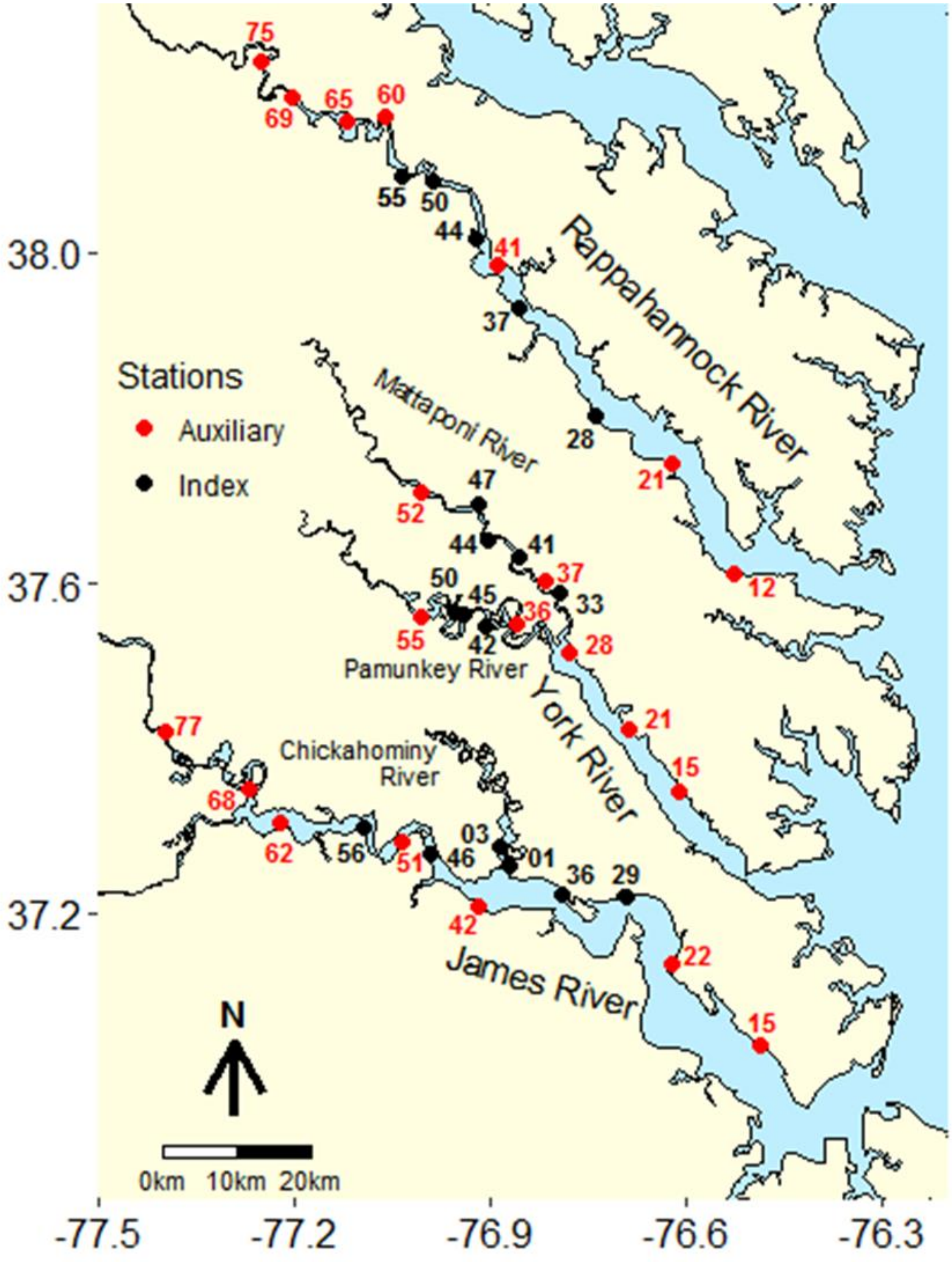

Figure 1. Juvenile Striped Bass seine survey stations. Station numbers denote the approximate river mile from the mouth.

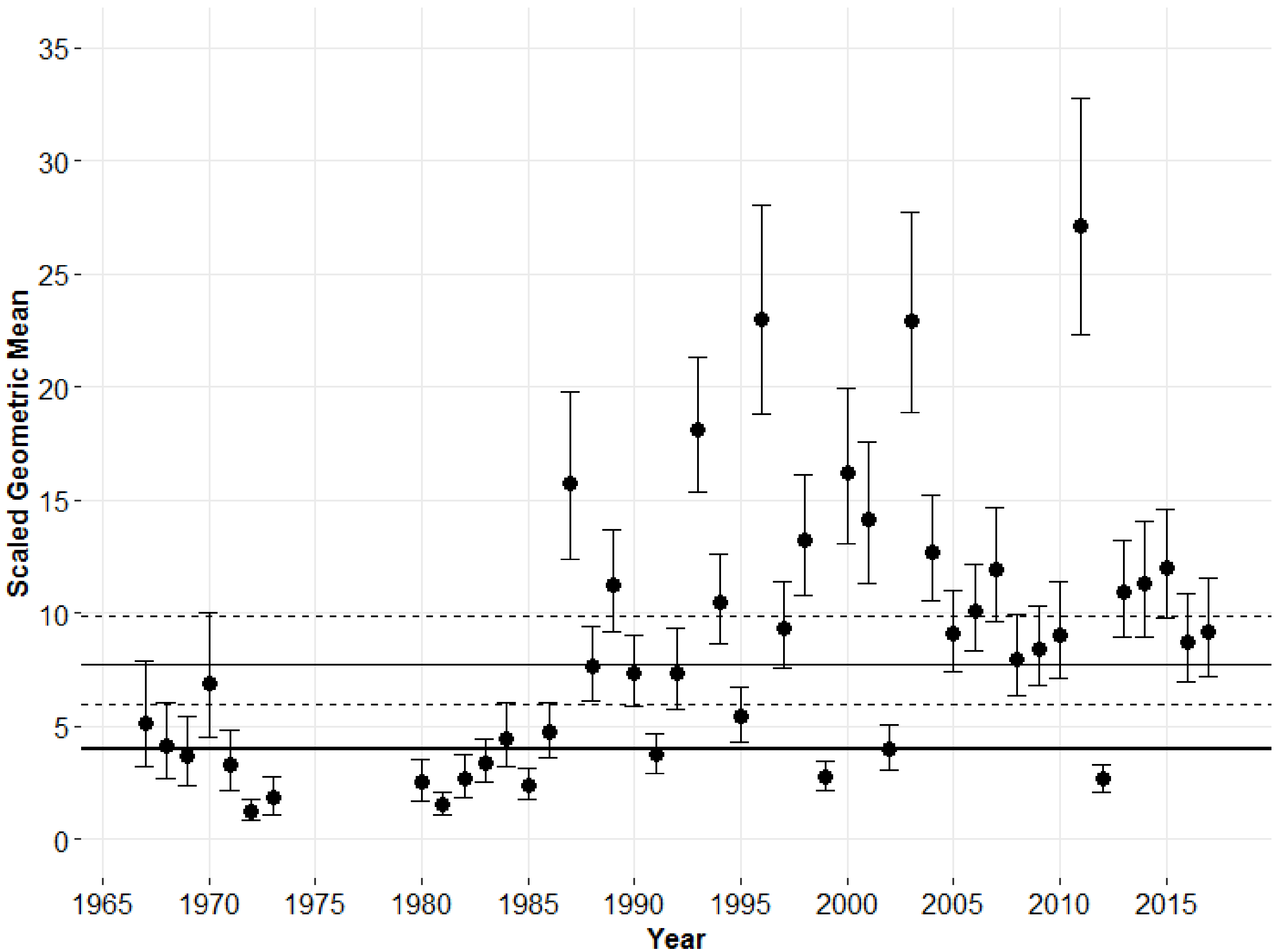

Figure 2. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate the geometric mean (thin solid), confidence intervals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

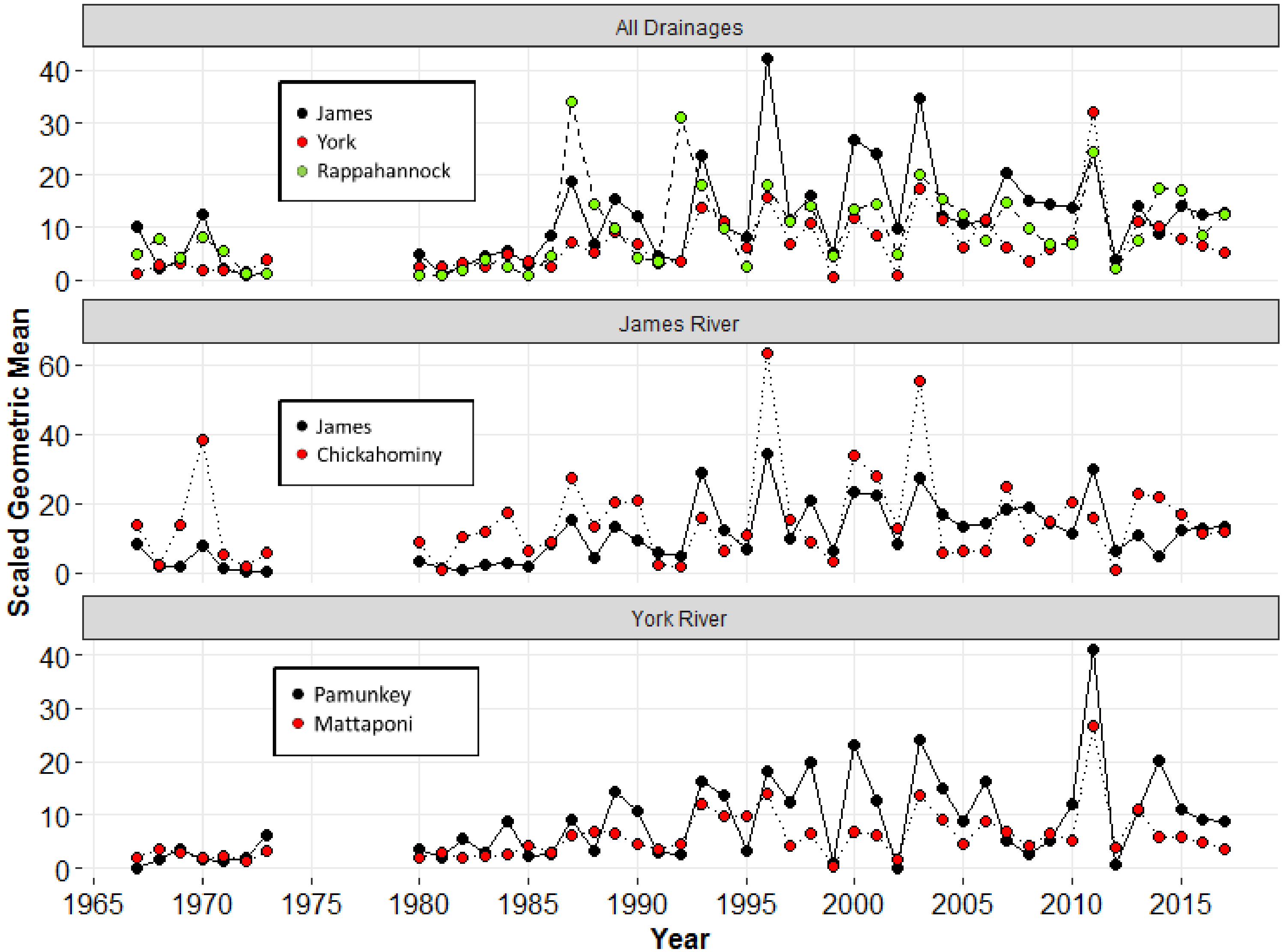

Figure 3. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by drainage and river.

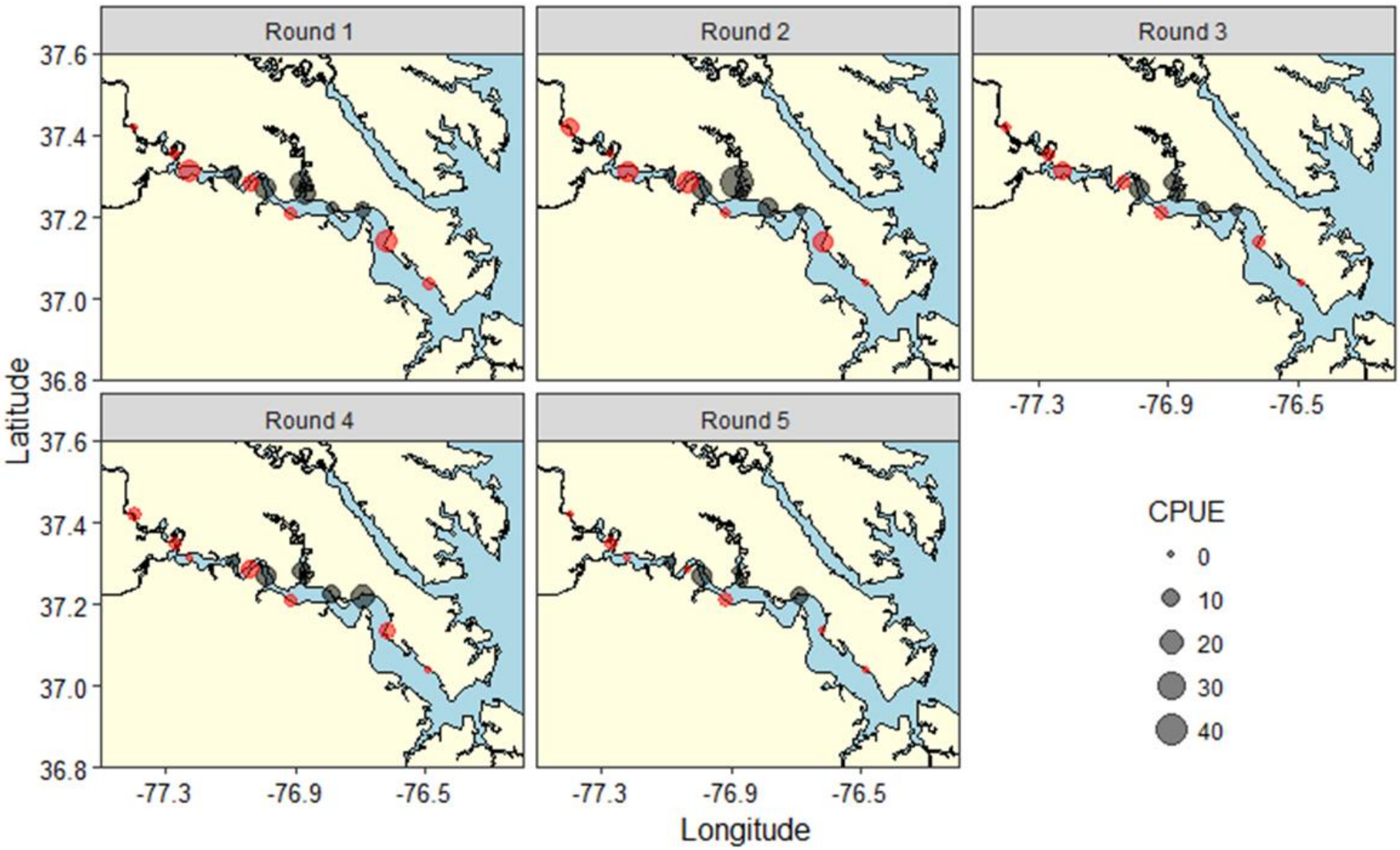

Figure 4. Catch per unit effort (CPUE) of juvenile Striped Bass by station in the James River drainage during each round in 2017. Data are shown for index (black) and auxiliary (red) stations, using the first haul only. Hauls were completed at all stations during all rounds in 2017.

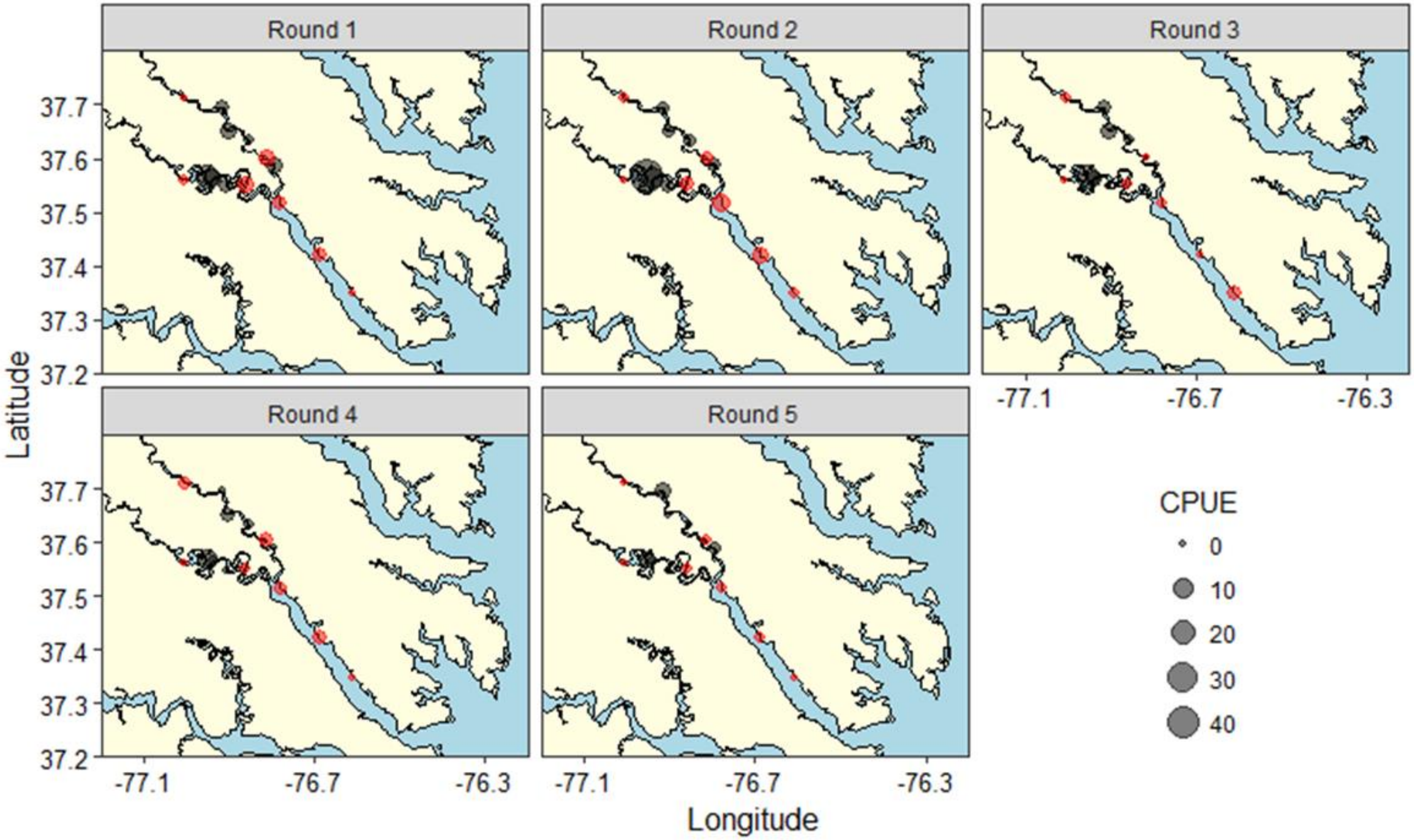

Figure 5. Catch per unit effort (CPUE) of juvenile Striped Bass by station in the York River drainage during each round in 2017. Data are shown for index (black) and auxiliary (red) stations, using the first haul only. Hauls were completed at all stations during all rounds in 2017.

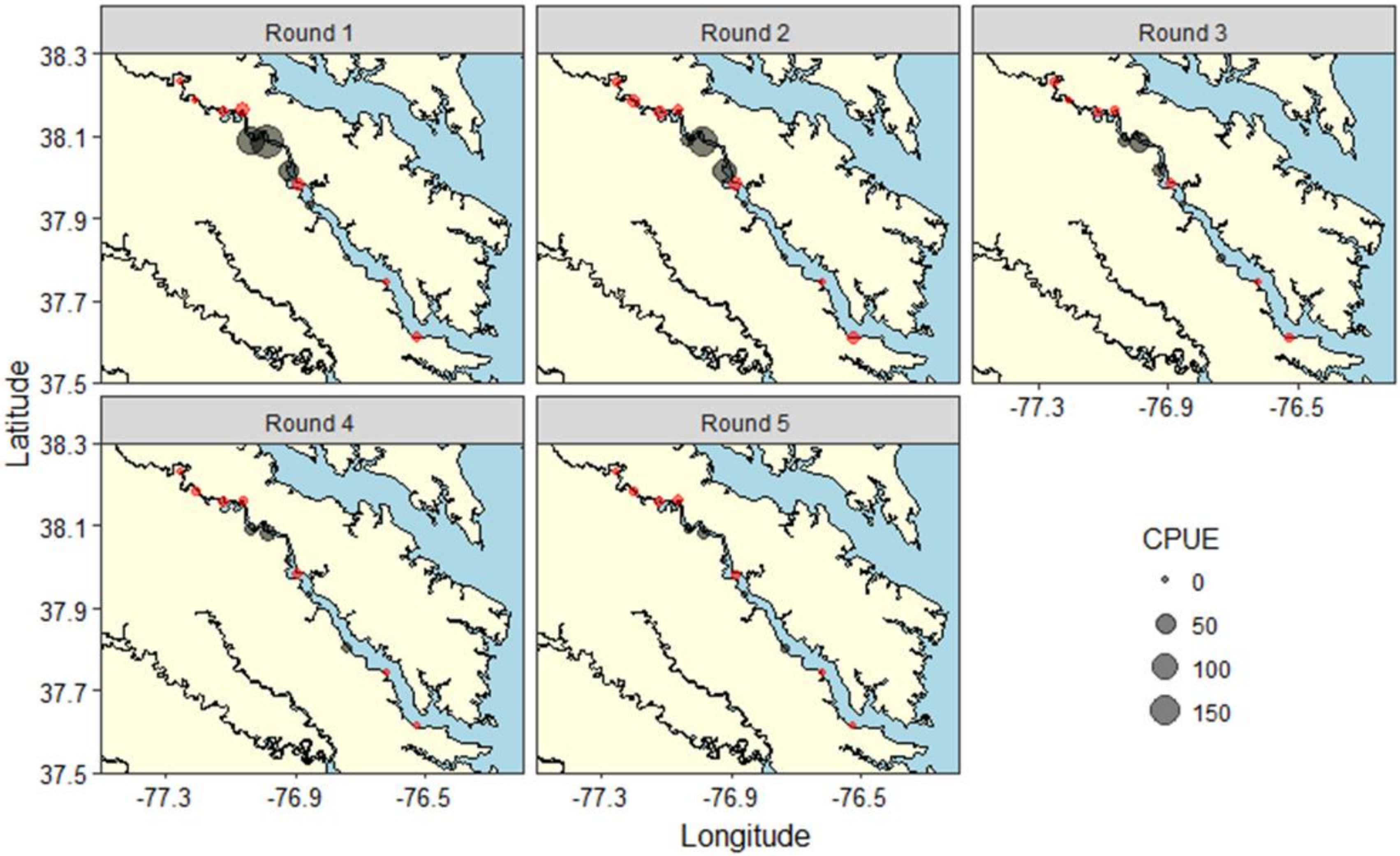

Figure 6. Catch per unit effort (CPUE) of juvenile Striped Bass by station in the Rappahannock River drainage during each round in 2017. Data are shown index (black) and auxiliary (red) stations, using the first haul only. Hauls were completed at all stations during all rounds in 2017.

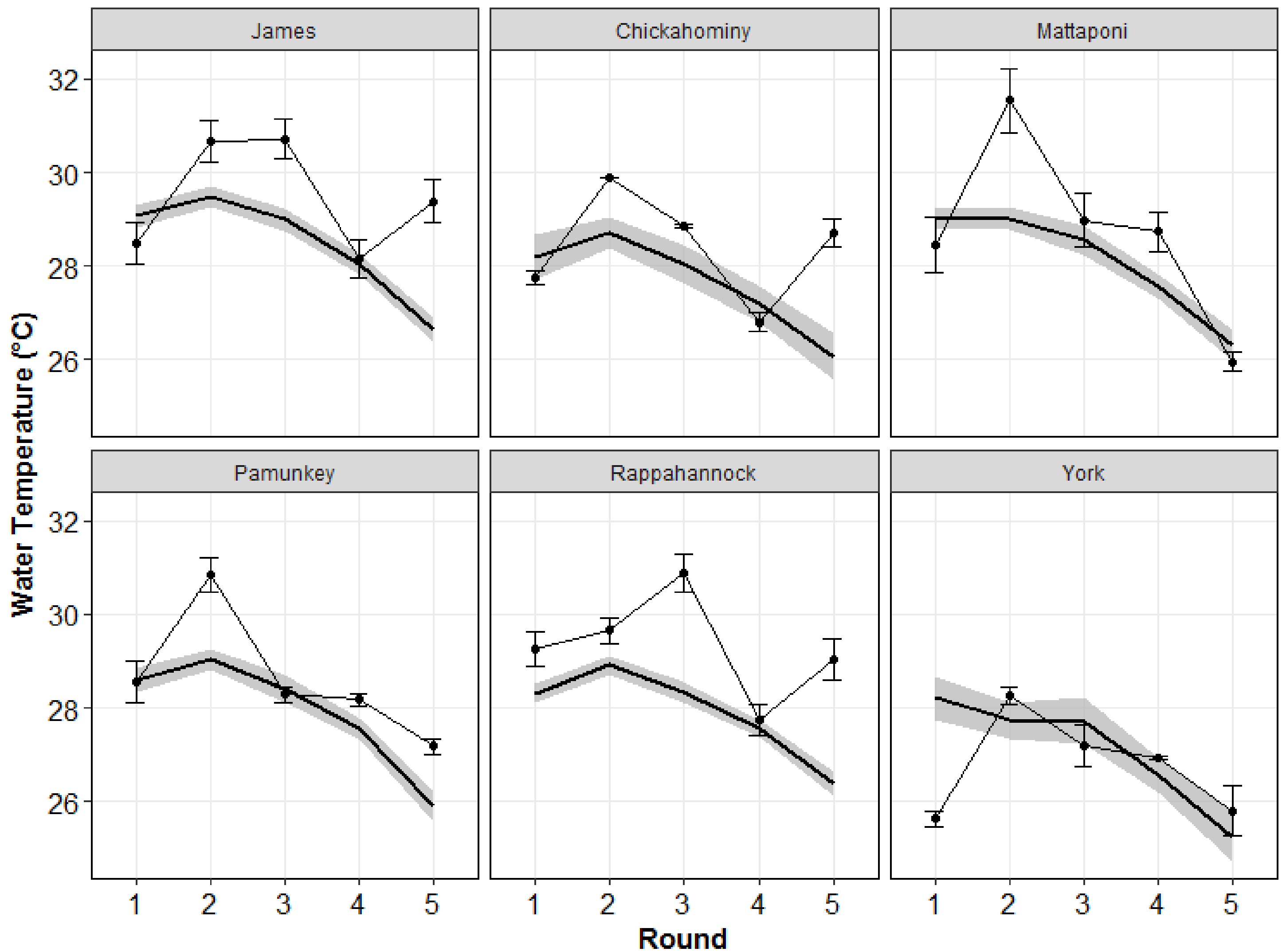

Figure 7. Mean water temperature and 95% confidence intervals during each round (x-axis) in each river during 2017 (thin line and error bars) and the monitoring period from 1989 to 2016 (thick line and shaded region).

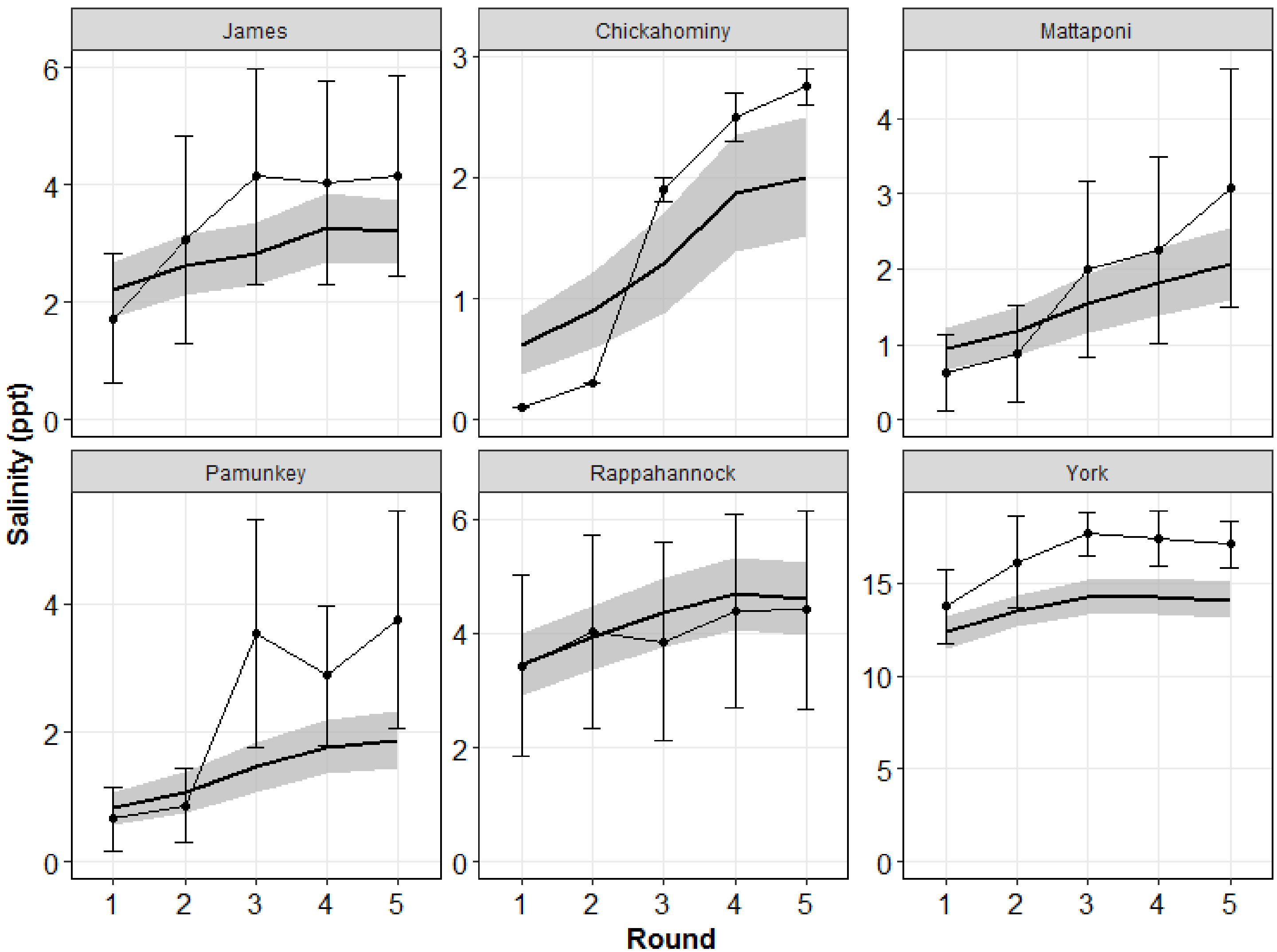

Figure 8. Mean salinity and 95% confidence intervals during each round (x-axis) in each river during 2017 (thin line and error bars) and the monitoring period from 1989 to 2016 (thick line and shaded region). Note that the scale of the y-axis varies by river.

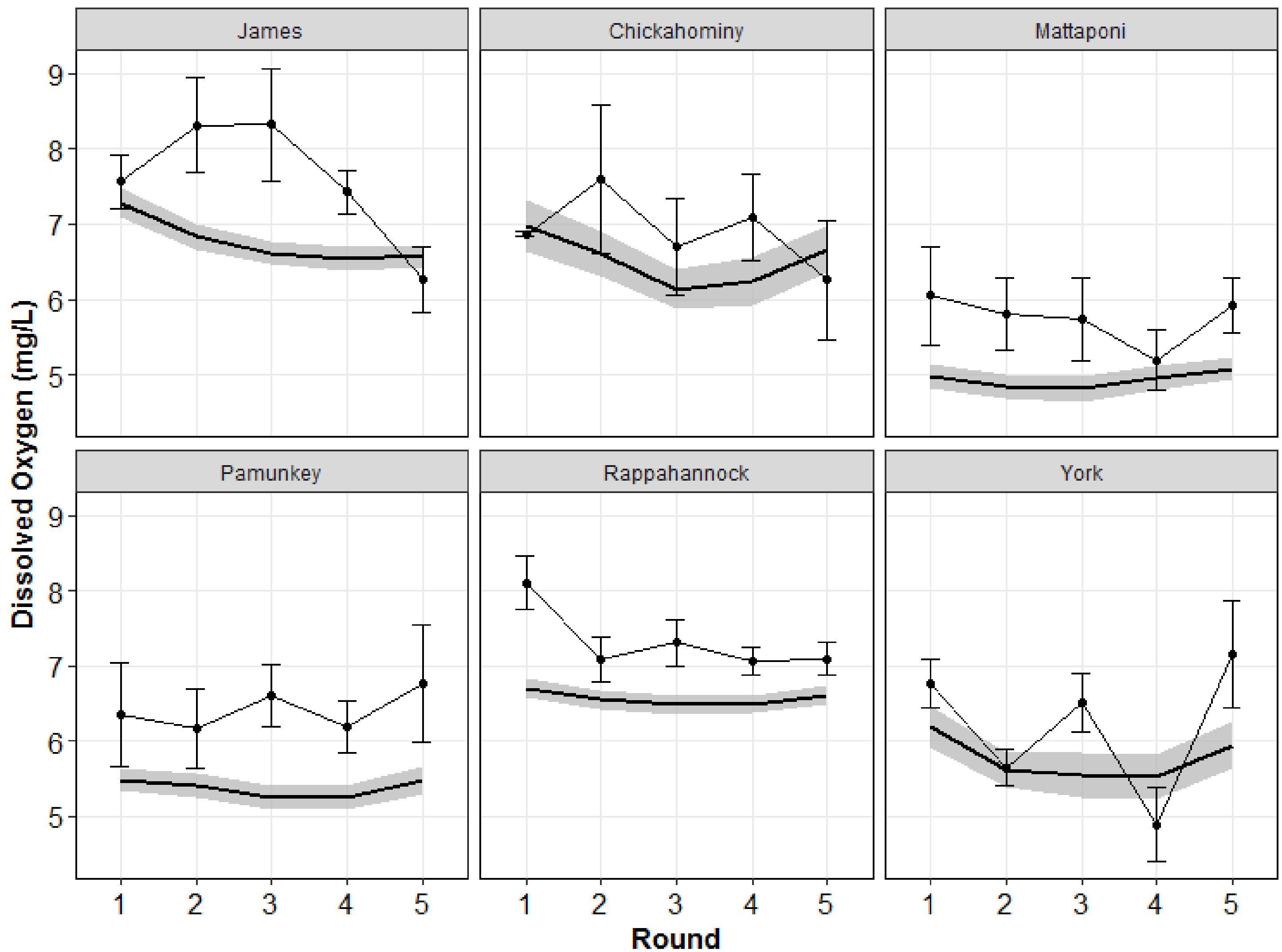

Figure 9. Mean dissolved oxygen and 95% confidence intervals during each round (x-axis) in each river during 2017 (thin line and error bars) and the monitoring period from 1992 to 2016 (thick line and shaded region). Note that dissolved oxygen was not measured before 1992.

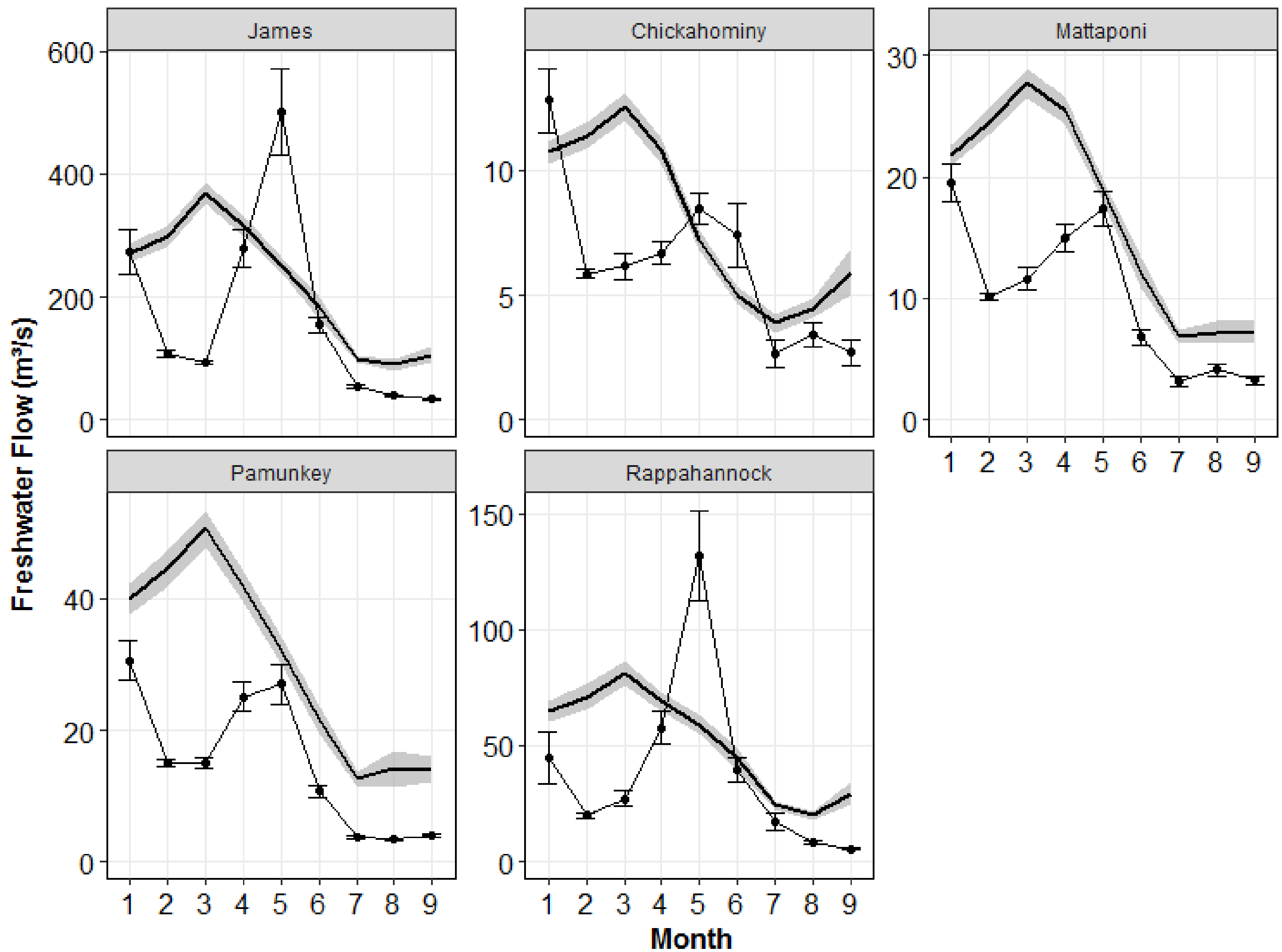

Figure 10. Mean freshwater flow and 95% confidence intervals during each month from January to September (x-axis) in each river during 2017 (thin line and error bars) and the historical monitoring period from 1967 to 2016 (thick line and shaded region). Note that the scale of the y-axis varies by river. Data are from USGS (2017).

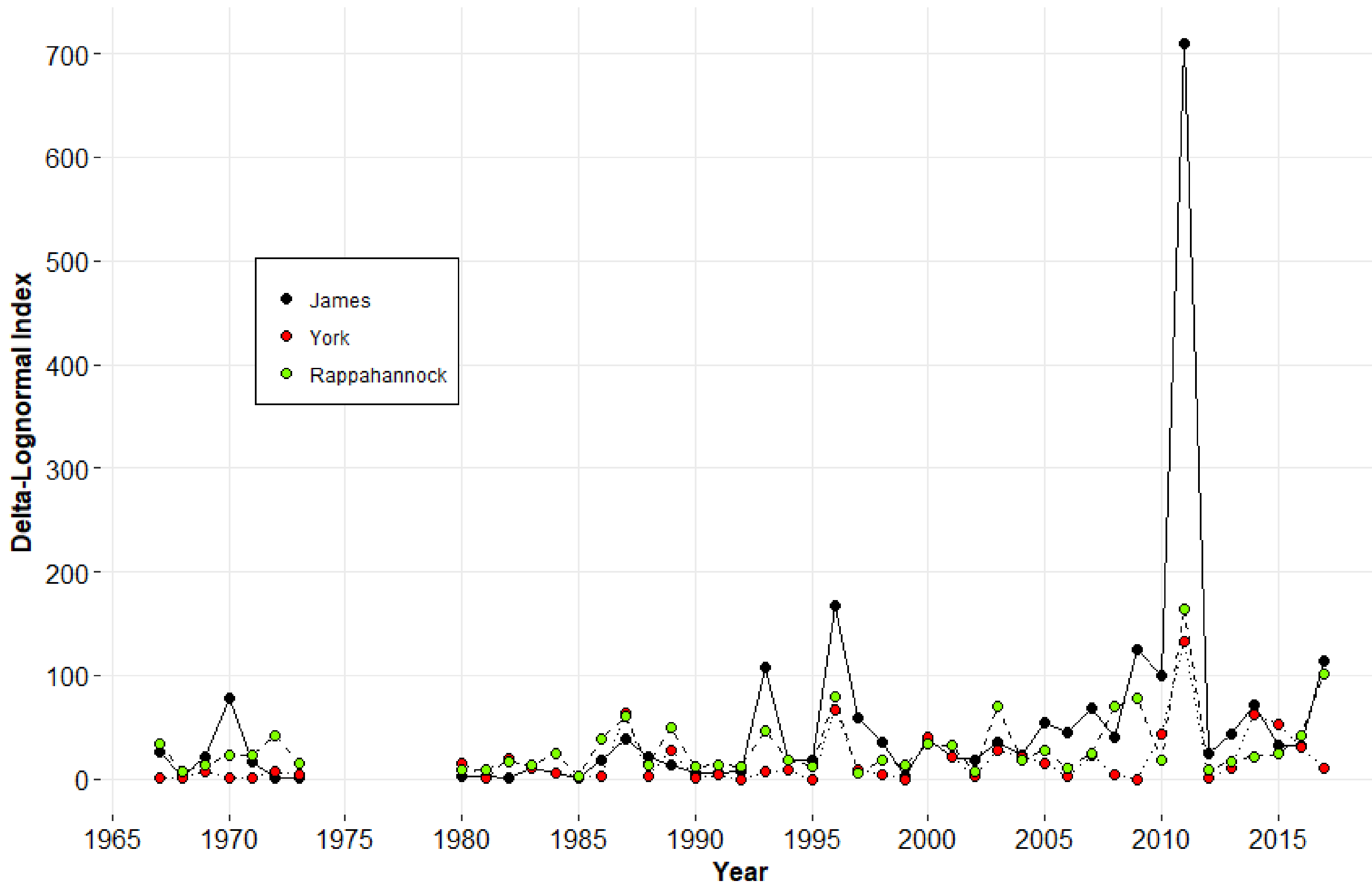

Figure 11. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by drainage and year.

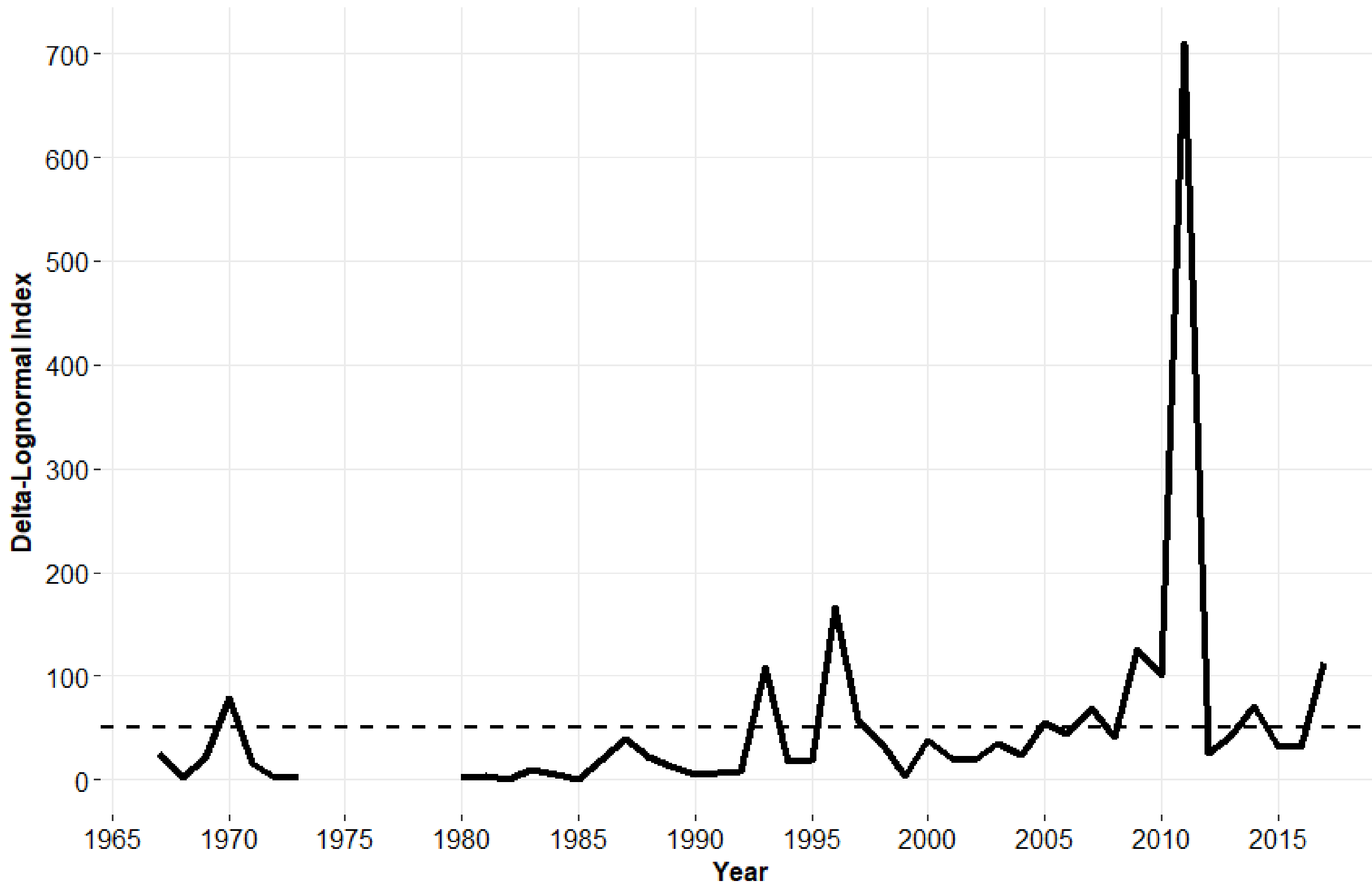

Figure 12. Delta-lognormal mean of young-of-the-year White Perch from the James River nursery area from 1967-2017. The time series average is shown by the dashed horizontal line.

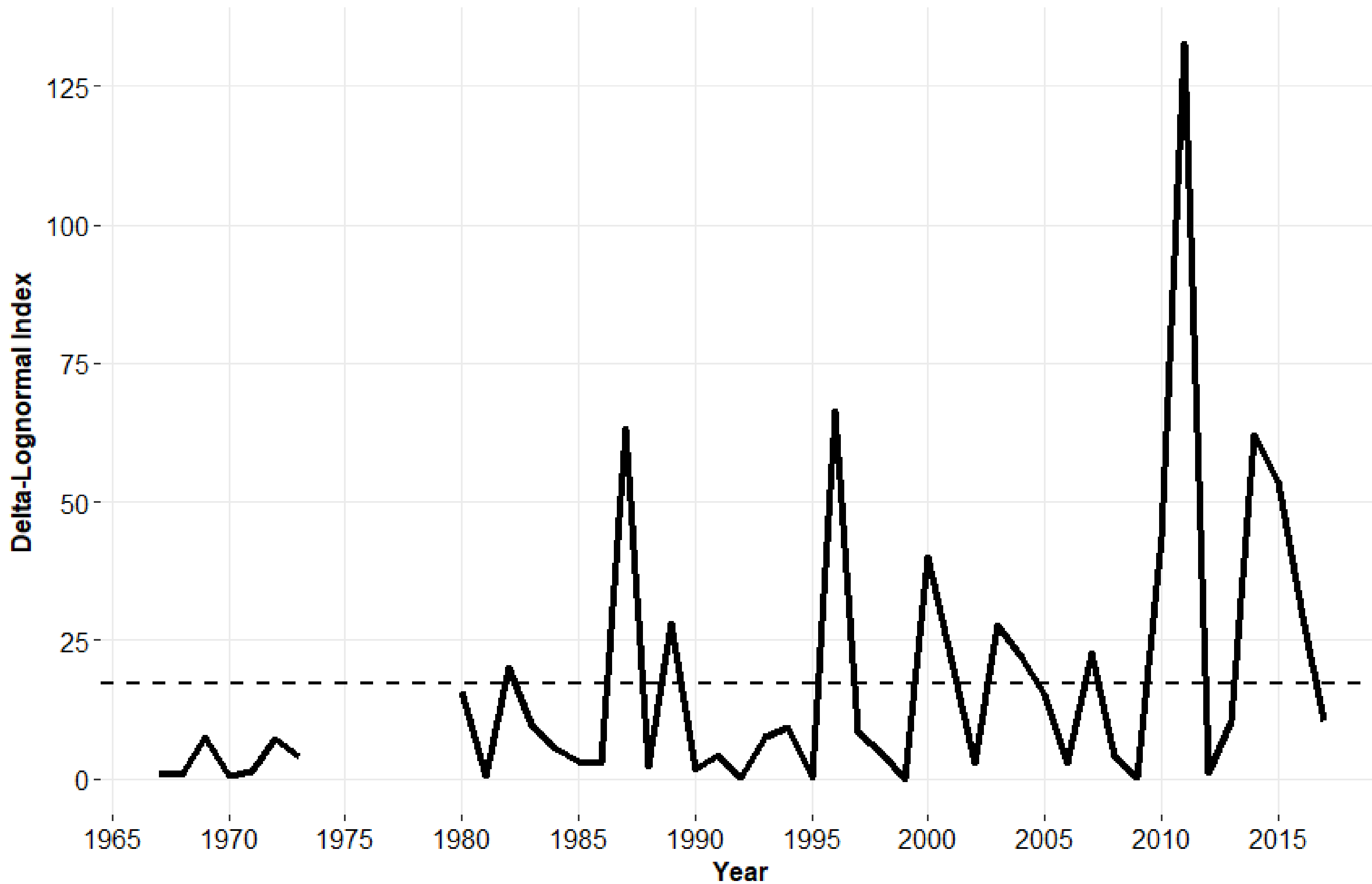

Figure 13. Delta-lognormal mean of young-of-the-year White Perch from the York River nursery area from 1967-2017. The time series average is shown by the dashed horizontal line.

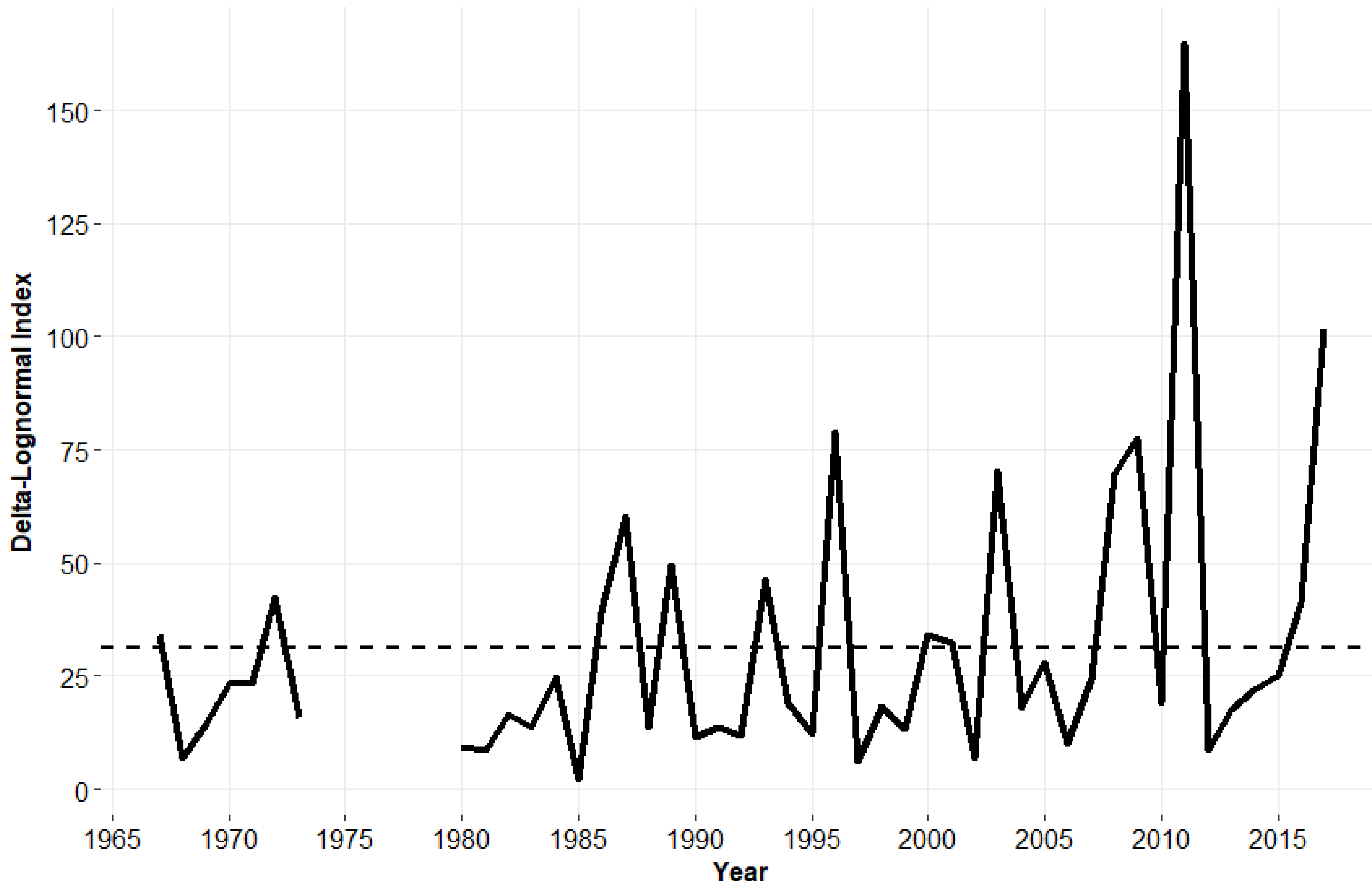

Figure 14. Delta-lognormal mean of young-of-the-year White Perch from the Rappahannock River nursery area from 1967-2017. The time series average is shown by the dashed horizontal line.

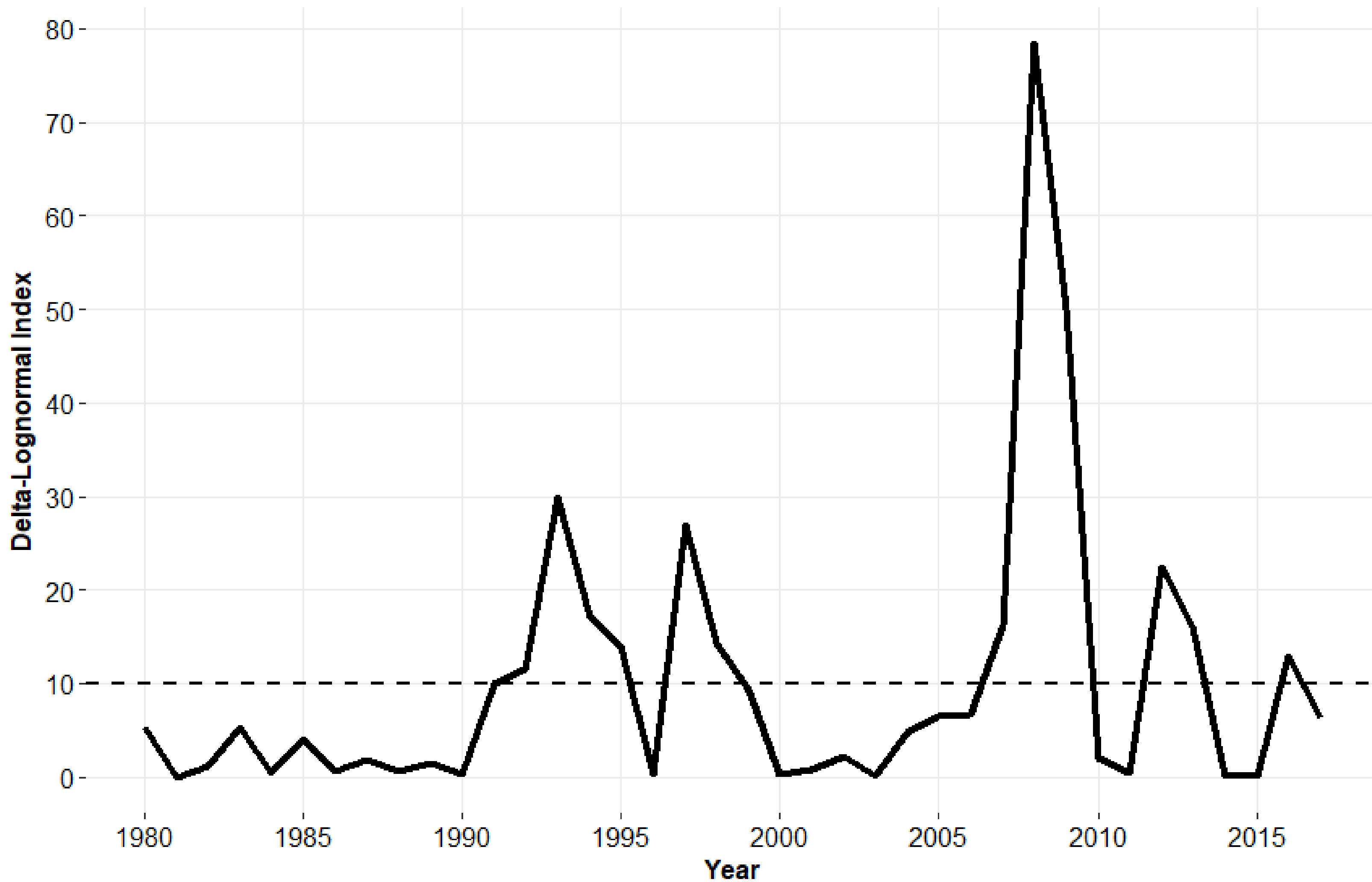

Figure 15. Delta-lognormal mean of young-of-the-year Atlantic Croaker from select seine survey stations in Virginia tributaries of Chesapeake Bay from 1980 to 2017. The time series average is shown by the dashed horizontal line.

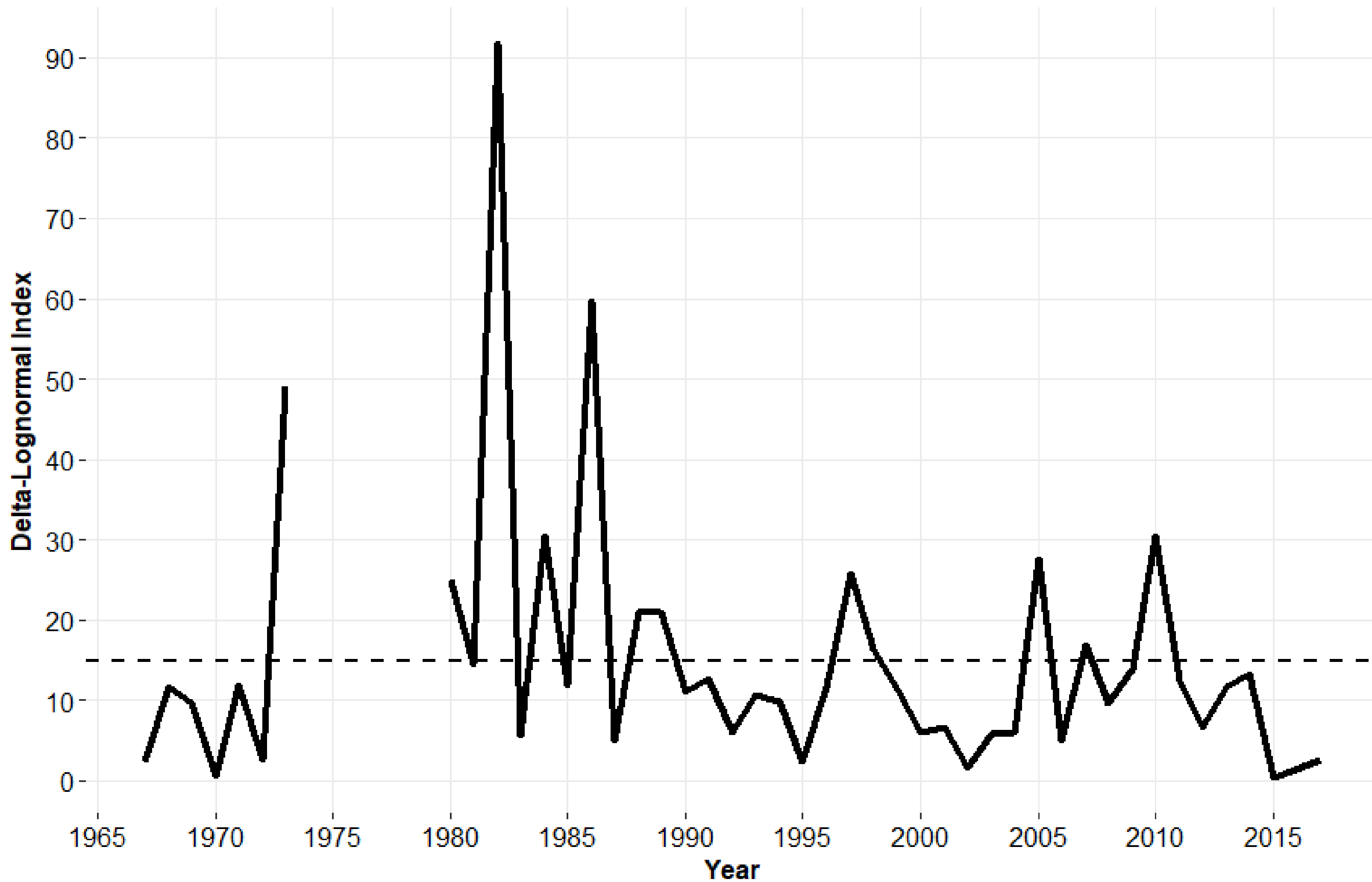

Figure 16. Delta-lognormal mean of young-of-the-year Spot from select seine survey stations in Virginia tributaries of Chesapeake Bay from 1967 to 2017. The time series average is shown by the dashed horizontal line.

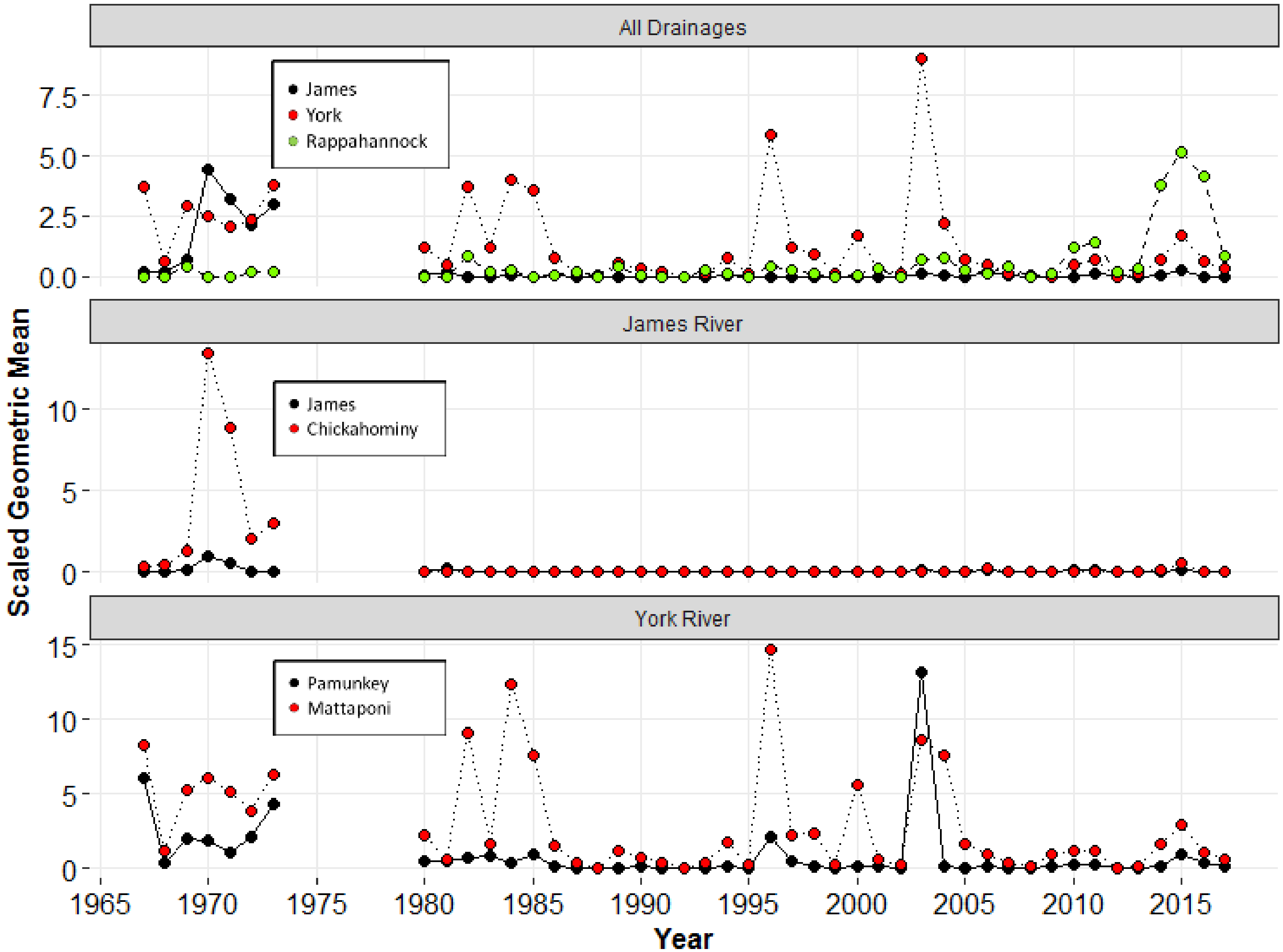

Figure 17. Scaled geometric mean of American Shad in the primary nursery areas of Virginia by drainage and river, using the first haul only.

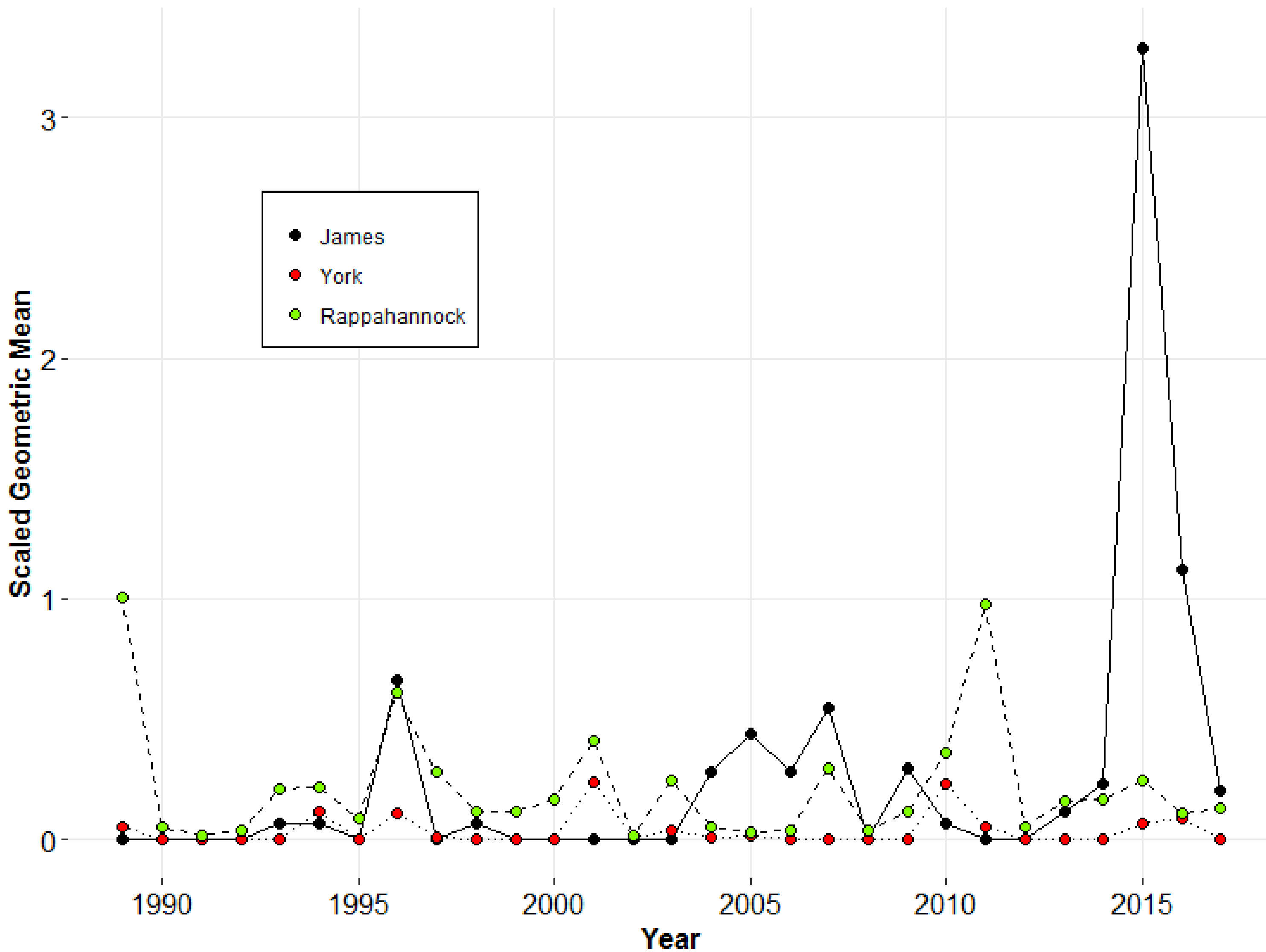

Figure 18. Scaled geometric mean of Alewife in the primary nursery areas of Virginia by drainage, using the first haul only.

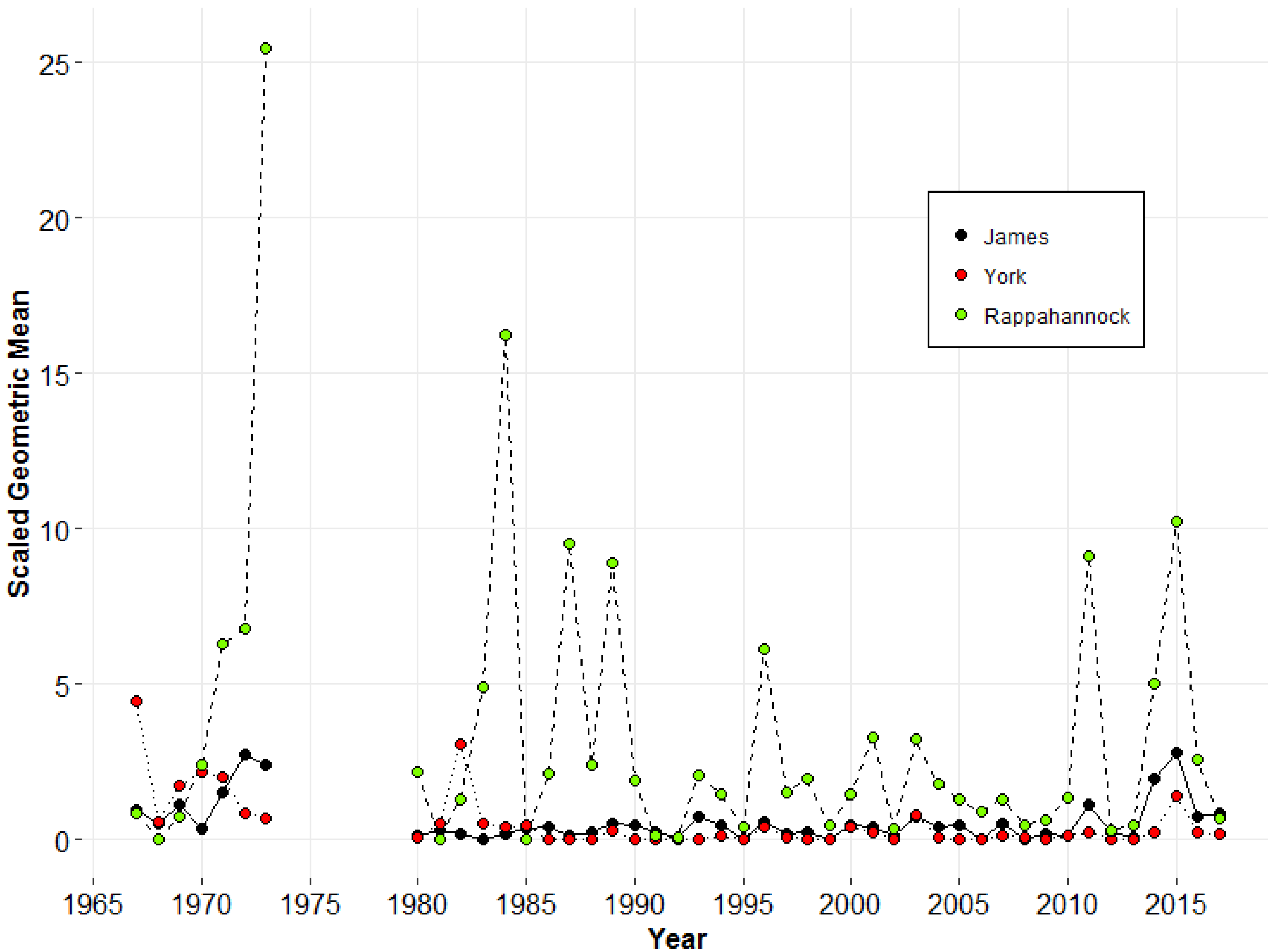

Figure 19. Scaled geometric mean of Blueback Herring in the primary nursery areas of Virginia by drainage, using the first haul only.

APPENDIX

Appendix Table 1. Calibration factors, 95% confidence intervals and sample sizes (N = number of paired hauls) for Striped Bass and White Perch based on paired hauls of the old and new seine nets in 2015 and 2017. Calibration factors are used to adjust catches from the new net and result in old net equivalent catches (see Fabrizio et al. 2017 for details). In the table below, calibration factors were estimated with (2015 and 2017) and without (2015) the addition of observations from 2017. Note that the 95% confidence intervals for these species overlap with 1 when data from 2017 are included.

Species	Year	N	Calibration Factor	95% CI
Striped Bass	2015	21	0.52	0.40-0.83
	2015 and 2017	76	1.11	0.92-1.38
White Perch	2015	27	0.65	0.46-0.86
	2015 and 2017	75	0.85	0.69-1.04