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Estimation of Juvenile Striped Bass Relative Abundance in the Virginia Portion of Chesapeake Bay Annual Progress Report: 2023 - 2024

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ANNUAL PROGRESS REPORT: 2023 - 2024

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Cover image

Field Assistants Joseph Phillips and Anna DeMotte seine for juvenile striped bass on the York River.

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EXECUTIVE SUMMARY

The 2023 juvenile Striped Bass abundance index was 4.26 and was significantly lower than the reference mean of 7.77 for the period 1980 to 2009. Abundance indices were below average in the James and Rappahannock rivers and average in the York River in 2023 compared with the river-specific reference means (1980-2009). Relatively low catches of young-of-the-year Striped Bass from sites upriver and downriver of core nursery areas suggest juvenile Striped Bass largely remained within core nursery areas in 2023.

Indices of abundance were calculated for three additional economically and recreationally important fishes in Virginia waters. Juvenile White Perch abundance indices in 2023 were below historic averages in the James, York, and Rappahannock river systems. Atlantic Croaker abundance in 2023 was greater than the historic average observed in Virginia waters. In contrast, the abundance index for Spot in 2023 was generally below the historic average in Virginia waters.

Indices of abundance were calculated for seven common forage species within the tidal nearshore zone of Virginia waters. In 2023, the abundance index was also calculated for another common forage species in Virginia waters, Mummichog (*Fundulus heteroclitus*). Abundance indices for Atlantic Silverside and Mummichog were generally below their historic averages in 2023. The abundance indices for Banded Killifish, Inland Silverside, and Spottail Shiner were generally similar to their historic averages in 2023. For the second consecutive year, a record high abundance index was recorded for American Shad in the Rappahannock River. The abundance index for American Shad was average in the Mattaponi and Pamunkey rivers, and below average in the James, Chickahominy, and York rivers. The abundance indices for Alewife were below average in the James and York rivers, but average in the Rappahannock River. Abundance indices for Blueback Herring were average in the James and York rivers, but below average in the Rappahannock River. Together, these results suggest modest production of forage fish prey for piscivores in Virginia.

PREFACE

The primary objective of the Virginia Institute of Marine Science 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 2023 sampling period and compares these results with previous years.

INTRODUCTION

Striped Bass (*Morone saxatilis*) is one of the most recreationally sought-after fish species on the east coast of the United States. Decreases in the harvest of Striped Bass in the 1970s paralleled the decline in abundance of Striped Bass along the east coast; Chesapeake Bay stock abundances were particularly depressed. Declines in coastwide harvests mirrored declines in juvenile recruitment in Chesapeake Bay (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 seven 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. In 2019, Addendum VI to Amendment 6 called for an 18% reduction in removals relative to 2017 removals to reduce fishing mortality rates on the stock, because the 2018 benchmark assessment found that the Striped Bass stock was experiencing overfishing. The estimated spawning stock biomass (SSB) has been below the SSB threshold since 2013 and hence, the stock has been overfished according to the 2018 benchmark stock assessment. This finding required ending overfishing within one year and rebuilding the stock by 2029. In 2022, Amendment 7 was approved to the FMP, which established new requirements for management triggers, conservation equivalency, recreational release mortality

measures, and a stock rebuilding plan (ASMFC 2022a). Results from the 2022 benchmark stock assessment indicated that the stock was no longer experiencing overfishing, but remained overfished (ASMFC 2022b). Since 2022, multiple measures, including slot and bag limits, gear restrictions, and commercial quota reductions, have been instituted to reduce fishing mortality and support Striped Bass stock rebuilding by 2029. The next Striped Bass stock assessment will be conducted in 2024.

Initially, juvenile Striped Bass abundance was assessed in Virginia with 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 the 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 method used to estimate the index (MD: arithmetic mean; VA: geometric mean). 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. In 2009, 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), suggesting that a bay-wide geometric mean would be reasonable.

Primary objectives for the 2023 study were to:

1. estimate the relative abundance of the 2023 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 30 June to 8 September 2023. Pilot sampling at 11 sites spanning the Appomattox, James,

Chickahominy, Mattaponi, Pamunkey, and Rappahannock rivers in early to mid-June revealed that juvenile Striped Bass were relatively small and unlikely to be fully recruited to the gear (number of hauls = 13; number of fish = 77; median = 35 mm fork length (FL); range = 23-51 mm), which suggested that sampling did not need to be initiated in mid-June, as was done in 2017, 2019, and 2021 (Buchanan et al. 2022).

During each round, seine hauls were conducted at 18 index stations and 23 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 grounds in years of high juvenile abundance. In 2023, extensive growth of underwater vegetation (mostly *Hydrilla*) at sites JC3, J46, P56, R65, R69, and R76 (in rounds 2-5) resulted in hauls being moved to the nearest area of vegetation-free water. In cases where vegetation-free water was unavailable, hauls were modified to reduce the impact of vegetation on the capture efficiency of the seine. Additionally, due to an obstruction encountered during round 3 in 2023, the location of auxiliary site R12 was shifted downstream 100 ft.

As in previous years, collections were made by deploying a 100-ft. (30.5 m) long, 4-ft. (1.2 m) deep, and 0.25-inch (6.4 mm) mesh minnow seine perpendicular to the shoreline until either the net was fully extended or a depth of 4 ft. (1.2 m) was encountered, and then pulling the offshore end down-current and back to shore. During each round, a single haul was conducted at each auxiliary station, whereas duplicate hauls with an interlude of at least 30 minutes were completed at each index station. Fish were removed from the net and placed into a water-filled bucket. All Striped Bass were measured to the nearest mm FL, and for all other species, a subsample 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 so as to eliminate the possibility of duplicate counting. All captured fish were returned to the capture site at the conclusion

of sampling. Sampling time, tidal stage, and weather conditions were recorded at each sampling location. Salinity, water temperature, dissolved oxygen concentration, pH, and turbidity (Formazin Nephelometric Unit or FNU) were measured after the first haul was completed using a YSI water-quality sampler. To ensure continuity with previous years, turbidity was also measured using a Secchi disk.

From 1999 to 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 determine if the change in 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 0.5175 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., catches in the new net were adjusted by multiplying by the calibration factor; Fabrizio et al. 2017). Due to low sample sizes ($n < 30$), these calibration factors were considered preliminary (Gallagher et al. 2017) and additional paired hauls were conducted during the 2017 sampling season. The addition of the 2017 data markedly increased sample sizes ($n > 70$), and resulted in calibration factors that were not significantly different from 1 for either species. Therefore, Striped Bass and White Perch catch data were not adjusted to estimate indices of abundance from the new net.

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). Thus, 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 (which is based on the arithmetic mean).

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 was also recomputed using only the first haul at each index station.

Prior to 2011, annual recruitment indices were calculated from all collections made during a sampling year including fish captured 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 data that included catches after mid-September are therefore biased low. Starting in 2011, recruitment calculations were made using catch data from the currently established sampling season (July through mid-September, or late-June through August) to permit uniform comparisons of annual recruitment (Tables 2-4).

The 2023 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 fixed-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, the 2023 annual index was calculated using only the first haul at each index site and compared with the average index value for 1990-2012 (using the first haul only) to provide a benchmark for interpreting recruitment strength during the period when the stock was recovering and was not overfished.

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.

Environmental conditions during each round in 2023 were compared graphically with long-term average conditions to assess changes in habitat condition for juvenile Striped Bass in Virginia's nursery areas. For temperature and salinity, the long-term average was calculated using observations from 1989 to 2022; this allowed us to include all years when auxiliary stations were sampled, thereby maximizing and standardizing the spatial extent of sampling (Figure 1). Dissolved oxygen and Secchi depth were measured since 1992, so long-term averages were calculated using observations from 1992 to 2022. pH was measured from 1992 to 2006 and was reinstated in 2023, so the long-term average was calculated using observations from 1992 to 2006. In all cases, conditions in 2023 were compared with those in the period 1989 to 2022 (water temperature, salinity), 1992 to 2022 (dissolved oxygen and Secchi), or 1992 to 2006 (pH).

RESULTS AND DISCUSSION

Juvenile Striped Bass Index of Abundance for Virginia

We collected 707 young-of-the-year Striped Bass in 2023 from 180 seine hauls at index stations and 318 individuals from 115 hauls at auxiliary stations (Table 1). Using index-station catches from both hauls, the estimated Striped Bass recruitment index in 2023 was 4.26 (lower confidence interval [LCI] = 3.36, upper confidence interval [UCI] =

5.31; Table 2), which was significantly less than 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 2023, 435 young-of-the-year Striped Bass were collected, resulting in an index of 4.83 (LCI = 3.37, UCI = 6.67, Table 3), which was significantly less than the first-haul reference period index of 9.57 (LCI = 7.43, UCI = 12.17). The first-haul index was also significantly less than the mean index estimated for the post-recovery period from 1990-2012 during which the population was not overfished (post-recovery index = 11.91; LCI = 9.25, UCI = 15.17).

Striped Bass recruitment success in the Virginia portion of Chesapeake Bay was 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 2022 (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 every year, 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 2). Such periods of persistently low recruitment have previously 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, particularly now that the spawning stock biomass is below the threshold. 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 indices from

Virginia and Maryland provide divergent estimates of year-class strength (such as 2022, when Virginia reported average recruitment and Maryland reported below-average recruitment for Striped Bass); such differences may arise due to annual changes in the relative contribution of nursery areas throughout Chesapeake Bay.

Juvenile Striped Bass Index of Abundance for Individual Watersheds

Using index-station catches from both hauls, the estimated Striped Bass recruitment indices in the three Virginia watersheds during 2023 varied relative to their individual means from the 1980-2009 reference period (Table 4; Figure 3). The 2023 JAI for the James River drainage was 4.71 (LCI = 2.93, UCI = 7.10), which was significantly lower than the reference period index of 10.41 (LCI = 7.83, UCI = 13.64; Table 4). The 2023 JAI for the York River drainage was 4.55 (LCI = 3.28, UCI = 6.11), which was not significantly different from the reference period index of 5.85 (LCI = 4.50, UCI = 7.48; Table 4). The 2023 JAI for the Rappahannock River drainage was 3.41 (LCI = 2.01, UCI = 5.29), which was significantly lower than the reference period index of 7.90 (LCI = 5.63, UCI = 10.82, Table 4).

The core nursery area within the James River drainage consists of seven mid-river stations: four in the James River (J36, J42, J46, J51) and three in the Chickahominy River (C1, C3, C4). Historically, these seven stations tend to exhibit relatively high and stable abundance. In 2023, 42% of all young-of-the-year Striped Bass collected from the James River drainage were captured from this core nursery area (Table 1). The remaining Striped Bass were captured at upriver (50%) or downriver sites (9%; Table 1). The James River drainage includes the James River proper and the Chickahominy River. Differences were observed between indices from the James River main stem and the Chickahominy River. The 2023 JAI for the James River main stem (excluding the Chickahominy River) was 5.89 (LCI = 3.23, UCI = 9.81), which was not significantly different from the reference period index of 9.72 (LCI = 7.06, UCI = 13.12; Table 4). In contrast, the 2023 JAI for the Chickahominy River was 2.84 (LCI = 1.23, UCI = 5.19), which was significantly lower than the reference period index of 11.95 (LCI = 8.70, UCI =

16.15; Table 4). In fall 2020, shoreline modifications, including tree removal and shoreline stabilization through the installation of sills with bank grading and marsh creation, were made to a campground between two index sites in the Chickahominy River (JC1 and JC3). Historically, these sites exhibit a pattern of three to five years of average to above-average recruitment, followed by one to two years of below-average recruitment. In 2023, low recruitment was observed at sites JC1 and JC3 (Table 5). We will continue to monitor catches at these sites to determine if the recent shoreline modifications have influenced relative abundance in the Chickahominy River.

No index sites are located along the main stem of the York River; thus, the watershed JAI is estimated from catches at sites located within the two principle York River tributaries, the Mattaponi and Pamunkey rivers. The 2023 Pamunkey River JAI of 5.00 (LCI = 3.14, UCI = 7.51) was not significantly different than the reference period index of 6.90 (LCI = 4.90, UCI = 9.44; Table 4), and the 2023 Mattaponi River index of 4.23 (LCI = 2.62, UCI = 6.37) was also not significantly different from the reference period average of 5.16 (LCI = 4.06, UCI = 6.45; Table 4). Distinct core nursery areas are found within the Pamunkey (P45, P50) and Mattaponi rivers (M33, M37, M41, M44), and these areas generally exhibit high and stable catches compared with other sites in these rivers. This pattern held true in 2023, as the majority of Striped Bass were captured within the core nursery area in the Pamunkey (79%) and Mattaponi (72%) rivers. Overall, approximately 39% of Striped Bass in the York River drainage were collected from the Pamunkey River and 59% from the Mattaponi River in 2023; the remainder (2%) were from the York River auxiliary stations (Table 1).

The 2023 JAI for the Rappahannock River drainage was 3.41 (LCI = 2.01, UCI = 5.31), which was significantly lower than the reference period index of 7.90 (LCI = 5.63, UCI = 10.82, Table 4). The core nursery area within the Rappahannock River consists of the three uppermost index sites (R44, R50, R55) that have consistently dominated the catches in this drainage for more than two decades. In 2023, 79% of the total Rappahannock River catch was taken within the core nursery area (Table 1). The remaining Striped Bass were captured at upriver (14%) or downriver sites (7%; Table 1).

Striped Bass Collections from Auxiliary Stations

Figures 4-6 illustrate the spatial distribution of the 2023 year class of Striped Bass throughout the areas sampled by this survey. Note that the scaling of CPUE is not constant across these 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 help reveal spatial changes in the nursery areas that may occur due to annual changes in river flow and other factors. 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 2023, which suggests that fish occurred primarily within the core nursery area.

During 2023, juvenile Striped Bass were captured at all auxiliary sites in the James River except site J12 (Table 1). Catches of juvenile Striped Bass in the James River were relatively low at the lower-most sites (Tables 1 and 5; Figure 4). In the Appomattox River, where exploratory sampling began in 2022, 20 Striped Bass were collected in 2023 at auxiliary site A1 (Table 1; Figure 4), compared with 36 Striped Bass collected at site A1 in 2022. Striped Bass were collected from all downstream and upstream auxiliary sites, with the exception of P56, in the Pamunkey and Mattaponi rivers in 2023 (Tables 1 and 5; Figure 5). In the York River main stem, relatively few Striped Bass were collected from the three auxiliary stations (Table 5).

We previously suggested that the lack of juvenile 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; Buchanan et al. 2023). In 2023, no juvenile Striped Bass were detected at the uppermost auxiliary site in the Pamunkey (P56; Table 1), but fish may not 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 site P56 may have been affected by the altered state of the nearshore area. For example, Striped Bass may be using habitats in deeper waters at site P56 due to the presence of dense *Hydrilla* stands along the shoreline; alternatively, Striped Bass may utilize *Hydrilla* habitats but remain unavailable to the sampling gear. The continued sampling difficulties at this station 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. In addition to site P56 on the Pamunkey River, dense stands of *Hydrilla* were encountered this year on the James (site J46), Chickahominy (site JC3), and Rappahannock rivers (sites R65, R69, and R76) indicating expansion of *Hydrilla* beds in Virginia's waters and the potential for changes in catchability at these sites in 2023 and in future surveys.

Relatively low numbers of juvenile Striped Bass were collected at upriver Rappahannock sites (R60, R65, R69, R76) in 2023 (Tables 1 and 5; Figure 6). In recent years, few fish have been collected at downriver auxiliary sites in the Rappahannock River (R12, R21) even though these sites have favorable substrate and no obstructions to compromise seining. A similar pattern was observed in 2023 with no individuals collected at site R12 and only a single individual collected at site R21 (Table 1; Figure 6).

Juvenile Striped Bass Indices by Sampling Round

Indices of juvenile abundance calculated by sampling round in 2023 were not significantly different from the averages calculated during the 1980-2009 reference period, except for Round 1, during which the juvenile Striped Bass index was 5.65 (LCI = 3.31, UCI = 8.98), which was significantly lower than the reference period index of 11.97 (LCI = 9.15, UCI = 15.48; Table 6) in Round 1. The largest number of young-of-the-year Striped Bass were collected during rounds 1 and 3 in 2023, with fewer observed in other rounds (Table 6). This pattern differs from the pattern observed during the reference period, in which the largest number of Striped Bass were collected during rounds 1 and 2, with fewer observed in subsequent rounds. In 2023, 25% of all juvenile Striped Bass were captured in round 1; this was followed by a modest decline (-19%) in the number

of Striped Bass captured in round 2, a pattern that was similar to average declines observed between rounds 1 and 2 during the reference period (-22%). A slight increase (9%) in the number of Striped Bass captured was observed from rounds 2 and 3, which differs from the average decline observed between rounds 2 and 3 during the reference period (-26%). There were modest declines in 2023 catches during the fourth (-15%) and fifth (-26%) rounds, which were similar to reference period averages of -12% in the fourth and -31% in the fifth (Table 6).

Environmental Conditions and Potential Relationships to Striped Bass Abundance

Historically, water temperatures tended to follow a well-defined pattern of high temperatures in rounds 1 and 2, followed by declining temperatures as the sampling season progressed (rounds 3, 4, and 5; Figure 7). This pattern was altered slightly in 2023: mean water temperatures were generally similar to or above historic averages during rounds 1, 2, 4, and 5 ranging between 25 and 33°C (Figure 7). During round 3, mean water temperatures generally declined to averages similar to or below historic averages. The high temperatures observed in rounds 1, 2, 3, and 5 were largely consistent with statewide average air temperatures from July to September of 2023, which were "above average" in Virginia (NCDC 2023). Relatively high water temperatures in Striped Bass nursery areas have now occurred during 11 consecutive years, with a similarly high range of temperatures observed since 2013 (Buchanan et al. 2023). This temperature pattern did not seem to affect catches in previous years, however. Similarly, catch rates in 2023 followed the historic pattern with respect to water temperature: 99% of juvenile Striped Bass from index sites were captured at temperatures exceeding 25°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 typically observed prior to 2023 between declining

Striped Bass catches and decreasing temperatures during rounds 3, 4, and 5 is considered to be largely the result of a coincident downward decline in catch rates and water temperatures as the season progresses (after early-August) rather than any direct effects of water temperature on juvenile fish distribution.

Across years, mean salinity tended to increase steadily from rounds 1 to 3, then stabilize during rounds 4 and 5 (Figure 8). In 2023, average salinities were generally above historical averages for all rivers, except the Chickahominy River, where salinity was similar to or lower than the historical means in rounds 1-4 (Figure 8). As observed in the past, greater catches of young-of-the-year Striped Bass in 2023 were obtained at salinities less than 5 ppt on average (Table 5). In 2023, salinities at downriver stations were higher than historic averages. Only one index site in the Rappahannock River (R28) exhibited mean salinities exceeding 10.0 ppt in 2023, although mean salinities as high as 21.2 ppt were observed at one auxiliary station in the York River (Y15; Table 5). While juvenile Striped Bass were captured at downstream sites with average salinities up to 18.4 ppt, catches were distinctly lower at such sites compared with catches in lower salinity areas.

Historically, mean dissolved oxygen (DO) concentrations tended to decrease from rounds 1 to 4, then increase slightly in round 5 (Figure 9). Mean DO concentrations in 2023 were generally greater than long-term averages during all rounds, with the exception of the York River, where DO concentrations were below historic averages in rounds 2, 4, and 5 (Table 8; Figure 9). Relationships between instantaneous measures of DO concentrations and juvenile Striped Bass catches are difficult to ascertain, as lower-than-average DO conditions occur inconsistently through time and across sampling sites. In previous years, high seasonal catches at index stations occurred during periods when DO concentrations were more than one standard error (SE) below the historic average, as well as when DO concentrations were within one SE of the historic average. However, DO concentrations are typically greater than 4 mg/L and not likely limiting Striped Bass habitats. Thus, instantaneous measures of DO concentrations do not appear to affect juvenile Striped Bass abundance estimates in this survey. Dixon et al.

(2022), however, concluded that DO is an important environmental factor for delineating suitable habitat for juvenile Striped Bass in Chesapeake Bay.

Historically, mean pH tended to increase slightly from rounds 1 to 2, decrease from rounds 2 to 3, increase during rounds 3 and 4, then decrease in round 5 (Figure 10). Mean pH in 2023 was generally similar to or greater than long-term averages during all rounds (Table 9; Figure 10). In 2023, a relationship between site-based mean pH and juvenile Striped Bass abundance is not evident as high and low abundances were recorded in both acidic and basic (alkaline) conditions (Table 9).

Turbidity was measured using a Secchi disk and a YSI water quality sampler. Historically, mean Secchi depth tended to generally increase from rounds 1 to 4, then decrease slightly in round 5 for all rivers, except for the Rappahannock River where mean Secchi values decreased from rounds 1 to 3, then increased in rounds 4 and 5 (Figure 11). In 2023, mean Secchi was generally similar to or less than the historical mean, except for the upriver sites on the Rappahannock River (Table 10; Figure 11). Mean turbidity (FNU) was sampled for the first time in 2023, thus, comparisons to a historical mean are not possible. In 2023, mean turbidity (FNU) was generally higher at midriver sites than down-river or upriver sites (Table 11).

Regional climate patterns during winter and spring may partially explain Striped Bass recruitment variability in Chesapeake Bay (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, a year characterized by relatively high freshwater flow in winter and spring (Machut and Fabrizio 2012). Statewide precipitation during the winter and spring of 2023 (December 2022-May 2023) was “near average” in Virginia relative to historical conditions since 1895 (NCDC 2023). Although these regional precipitation conditions were “near average,” salinities were generally above historic averages at most Virginia sample sites (Table 5). Freshwater flow in Virginia tidal tributaries varies seasonally, with monthly averages since 1967 showing relatively high flow during the winter, peaks in early-spring (March-

April), followed by steady declines through the late-spring and summer (Figure 12; USGS 2023). In 2023 and in most Virginia rivers, freshwater flow was generally below average from January to September, with a peak in February (Figure 12). The effect of such seasonal changes in precipitation and flow on annual variations in recruitment of juvenile Striped Bass remain unclear.

Abundance Indices for Other Fishes

A variety of fish species are encountered annually by the juvenile Striped Bass seine survey due to a sampling regime that spans the euryhaline to freshwater zone. In 2023, more than 36,000 individuals comprising 77 species of fishes were collected (Table 12). The five most common species encountered in 2023 were Spottail Shiner (*Notropis hudsonius*), Atlantic Silverside (*Menidia menidia*), White Perch (*Morone americana*), Bay Anchovy (*Anchoa mitchilli*), and Atlantic Menhaden (*Brevoortia tyrannus*) (Table 12). This was different from 2022, when Banded Killifish (*Fundulus diaphanus*) was among the top five species captured, and Bay Anchovy was not among the top five. Indices of abundance were estimated for 11 commonly occurring species (in addition to juvenile Striped Bass) based on catches from only the first haul at a subset of index and auxiliary stations. 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 to 2010.

One of the most common species captured annually by the seine survey, White Perch, supports important recreational 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 suggest that the seine survey may adequately sample juvenile White Perch and the 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 collections 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 up to 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.

During the 2023 sampling period, 2,202 young-of-the-year White Perch were collected from 117 seine hauls at 31 sites (12 sites in the James, 10 in the York and 9 in the Rappahannock rivers). 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 13; Figures 13-16). River-specific JAIs for White Perch suggest below-average recruitment in the James, York, and Rappahannock rivers in 2023 (Figures 14-16). 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 complements the juvenile White Perch index currently reported by the VIMS Juvenile Finfish Trawl Survey (Tuckey and Fabrizio 2023); 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 economically 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 predominantly mesohaline regions during rounds 1 to 3, before fish are able to avoid capture by the net (Williams and Fabrizio 2011). Murdy et al. (1997) report peak spawning of Atlantic Croaker from August to October; thus, young-of-the-year fish collected during 2023 were spawned during fall 2022. Similar to White Perch, Atlantic Croaker 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 (as described above). Atlantic Croaker are coastal shelf spawners, and their larvae migrate into Chesapeake Bay and enter nursery areas in the tributaries (Murdy et al. 1997). Therefore, we report a Virginia-wide estimate of juvenile abundance. Based on 2023 catches from 21 stations during rounds 1 to 3, we encountered 1,357 young-of-the-year Atlantic Croaker in 46 seine hauls (Table 14; Figure 17). Periods of strong recruitment from 1992-1995, 1997-1998, and 2007-2009 correspond with patterns observed by the VIMS Juvenile Finfish Trawl Survey (Tuckey and Fabrizio 2023). In 2023, an above-average year class for Atlantic Croaker appears to have occurred.

Spot (*Leiostomus xanthurus*), like Atlantic Croaker, is another economically and recreationally important species that is collected by the seine survey and reported as a Virginia-wide estimate of juvenile abundance (Table 15; Figure 18). Based on catches from 21 stations during 5 rounds in 2023, 770 young-of-the-year Spot were collected in 65 seine hauls. Using the delta-lognormal approach, we observed below-average relative abundance for Spot in 2023, similar to estimates for the previous eight years (Table 15; Figure 18).

Indices of relative abundance for common forage species within the tidal nearshore zone were computed for Spottail Shiner (33 stations; Table 16), Atlantic Silverside (25 stations; Table 17), Inland Silverside (*Menidia beryllina*; 37 stations; Table 18), Banded Killifish (*F. diaphanus*; 33 stations; Table 19), and Mummichog (*F. heteroclitus*; 25 stations; Table 20). Catches from all 5 rounds were used to estimate abundance indices for these species. The 2023 Spottail Shiner delta-lognormal mean of 24.8 was similar to the historic average of 29.0 (Table 16). The 2023 Atlantic Silverside delta-lognormal mean of 27.1 was less than the historic average of 49.3 (Table 17). The 2023 Inland Silverside delta-lognormal mean of 7.5 was greater than the historic average of 5.9 (Table 18). The 2023 Banded Killifish delta-lognormal mean of 7.7 was similar to the historic average of 6.1 (Table 19). The 2023 Mummichog delta-lognormal mean of 6.0 was less than the historic average of 26.4 (Table 20). Together, these results suggest modest production of forage fish prey was available for piscivores in

Virginia waters in 2023. In addition, we note that abundance indices for the five freshwater forage species (Atlantic Silverside, Banded Killifish, Inland Silverside, Mummichog, and Spottail Shiner) have been increasing since 1989.

Indices of abundance derived from seine survey collections are reported for species of management concern to fulfill Commonwealth compliance requirements to the ASMFC; these species include American Shad (Watkins et al. 2011), Alewife, Blueback Herring, and Atlantic Menhaden (VMRC 2010). Abundance estimates for juvenile American Shad from the seine survey were highly correlated with those from push-net sampling (Wilhite et al. 2003), providing support for the seine survey-based index. These indices are provided to VMRC when requested and are also reported here. Alosines greatly contribute to the dynamics of freshwater, estuarine, and marine habitats serving as prey for many large, predatory fishes and consuming large amounts of plankton. Many stocks of alosine species are currently at record lows or of unknown status because of a lack of data to assess populations accurately, especially within riverine environments. Data collected on American Shad, Alewife, and Blueback Herring from the seine survey are critical for assessing populations in the James, York, and Rappahannock rivers. The 2023 geometric mean abundance index for American Shad was the highest recorded in the Rappahannock River, however, average indices were recorded in the Mattaponi and Pamunkey rivers and below-average indices were recorded in the James, Chickahominy, and York rivers (Figure 19). For Alewife, the 2023 geometric mean abundance index was average in the Rappahannock River, but below average in the James and York rivers (Figure 20). The 2023 geometric mean abundance indices for Blueback Herring were average in the James and York rivers, but below average in the Rappahannock River (Figure 21).

CONCLUSION

The 2023 juvenile abundance index (JAI) for Striped Bass (4.26) was significantly lower than the average for the reference period (7.77) for Virginia waters. Compared with reference period averages, we observed below-average recruitment in the James

and Rappahannock rivers and average recruitment in the York River. Continued monitoring of juvenile Striped Bass abundance is important in predicting recruitment to the 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 spawning stock biomass, deteriorating conditions in nursery areas, or both. The juvenile White Perch abundance index in 2023 was lower than the historic average. The Atlantic Croaker abundance index was greater than the historic average, while the Spot abundance index was below the historic average in 2023. The abundance indices for Banded Killifish, Inland Silverside, and Spottail Shiner were generally similar to their historic averages in 2023. Conversely, for Atlantic Silverside and Mummichog, abundance indices were generally below average in Virginia waters in 2023, relative to historic averages. Abundance indices for three alosine species were generally average or below average in the James and York rivers and average in the Rappahannock River in 2023, relative to index values in previous years.

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TABLES

Table 1. Catch of young-of-the-year Striped Bass per seine haul in 2023. Two hauls were completed at each index station (bold). Sampling was completed in June (round 1), July (rounds 2 and 3), August (rounds 4 and 5).

Drainage																	Round
JAMES		Station	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	C4	**J46**	J51	**J56**	J62	A1	J68	J77	Total
	Round	1	0	5	0/2	3/0	2	0/0	0/2	5	1/0	43	24/21	12	2	1	0	123
		2	0	2	3/1	12/0	14	0/1	1/7	2	0/0	19	18/6	8	3	0	2	98
		3	0	3	6/1	0/3	12	1/7	2/3	7	0/1	14	36/14	6	9	0	3	121
		4	0	7	6/6	0/0	1	9/6	0/0	4	0/0	6	32/14	4	5	1	5	106
		5	0	0	1/5	3/0	17	6/1	1/10	8	1/2	10	28/18	4	1	1	0	111
																James Total		**559**
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56								
	Round	1	0	0	2	2	3/2	2/3	22/6	0								42
		2	0	1	1	1	1/3	2/5	9/2	0								25
		3	0	0	1	0	6/2	6/1	7/8	0								31
		4	0	0	0	1	0/0	1/3	0/0	0								5
		5	0	0	0	0	0/1	0/1	4/3	0								9
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52							
	Round	1				8/3	2	0/1	5/6	6/0	1							32
		2				3/1	13	1/1	4/3	8/5	3							42
		3				4/0	8	0/1	18/9	7/6	0							53
		4				7/0	3	0/0	7/2	3/6	0							28
		5				1/0	3	0/1	0/0	0/0	0							5
																York Total		**272**
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76				
	Round	1	0	1	0/0	0/1	0	6/6	8/11	16/8	1	7	3	1				69
		2	0	0	0/0	0/0	0	1/2	4/2	25/13	1	0	0	0				48
		3	0	0	0/0	0/1	0	0/0	0/0	12/1	2	7	0	0				23
		4	0	0	0/0	4/1	0	0/0	3/1	14/8	2	0	0	0				33
		5	0	0	0/0	4/2	0	0/1	3/0	2/6	3	0	0	0				21
																Rappahannock Total		**194**
																2023 Catch		**1,025**

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
2018	1,875	1.74	1.19	10.72	8.61-13.24	180
2019	1,624	1.65	1.14	9.54	7.69-11.74	180
2020	1,836	1.96	1.15	13.89	11.08-17.29	145
2021	1,512	1.33	1.22	6.30	4.88-8.01	180
2022	2,236	1.50	1.38	7.95	6.05-10.29	180
2023	707	1.05	1.00	4.26	3.36-5.31	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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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	0.97	0.94	3.74	2.36-5.54	52
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	900	1.83	1.11	11.99	9-15.76	90
2014	1,401	2.01	1.24	14.81	10.87-19.93	90
2015	978	1.92	1.09	13.21	10.02-17.22	90
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
2018	1,072	1.80	1.24	11.54	8.37-15.66	90
2019	880	1.70	1.18	10.24	7.49-13.77	90
2020	1,256	2.04	1.17	15.29	11.43-20.24	89
2021	954	1.46	1.30	7.54	5.18-10.64	90
2022	1,485	1.72	1.44	10.42	7.09-14.92	90
2023	435	1.14	1.09	4.83	3.37-6.67	90
1980-2009	26,735	1.65	0.54	9.57	7.43-12.17	30 (years)
1990-2012	25,103	1.83	0.50	11.91	9.25-15.17	23 (years)

Table 4. Catch of young-of-the-year Striped Bass per seine haul at index stations in 2023 summarized by drainage and river.

	2023				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	311	4.71	2.93-7.10	60	17,650	10.41	7.83-13.64	30
James	266	5.89	3.23-9.81	40	10,727	9.72	7.06-13.12	30
Chickahominy	45	2.84	1.23-5.19	20	6,923	11.95	8.70-16.15	30
YORK	230	4.55	3.28-6.11	70	12,470	5.85	4.50-7.48	30
Pamunkey	103	5.00	3.14-7.51	30	6,442	6.90	4.90-9.44	30
Mattaponi	127	4.23	2.62-6.37	40	6,028	5.16	4.06-6.45	30
RAPPAHANNOCK	166	3.41	2.01-5.29	50	13,407	7.90	5.63-10.82	30
Overall	707	4.26	3.36-5.31	180	43,527	7.77	6.01-9.89	30

Table 5. Striped Bass indices and average site salinity during 2023 compared to average index values during the auxiliary monitoring period (1989-2022), 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	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	C4	**J46**	J51	**J56**	J62	J68	J77
1989-2022	Avg. Sal.	14.4	5.6	4.7	2.3	1.2	1.3	1.1	0.6	0.4	0.2	0.2	0.2	0.1	0.1
	Index	1.4	7.8	10.7	15.4	10.0	20.9	11.4	15.9	23.1	17.8	11.5	11.3	6.0	3.0
2023	Avg. Sal.	18.0	7.7	5.2	2.2	0.8	1.1	1.0	0.8	0.2	0.1	0.1	2.5	0.1	0.1
	Index	0.0	5.9	5.3	4.4	14.4	3.7	0.3	10.9	0.7	34.0	61.3	14.3	1.2	3.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56						
1989-2022	Avg. Sal.	16.5	13.7	10.5	4.0	1.7	0.6	0.4	0.1						
	Index	1.3	2.8	6.9	10.7	5.2	12.7	18.3	1.0						
2023	Avg. Sal.	21.2	18.4	12.7	7.3	3.6	1.3	0.5	0.3						
	Index	0.0	0.3	1.5	1.5	2.8	3.7	11.9	0.0						
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
1989-2022	Avg. Sal.				4.4	2.1	1.0	0.4	0.2	0.1					
	Index				10.1	10.9	7.5	9.4	5.8	1.4					
2023	Avg. Sal.				8.9	5.0	1.7	0.6	0.4	0.1					
	Index				8.9	10.7	0.3	10.0	8.2	1.2					
RAPPAHANNOCK		R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
1989-2022	Avg. Sal.	14.1	12.7	9.9	5.0	2.7	1.6	0.7	0.4	0.2	0.1	0.1	0.1		
	Index	0.6	0.7	4.1	3.0	5.4	12.9	24.0	50.2	6.5	5.0	2.6	0.9		
2023	Avg. Sal.	16.9	16.1	14.2	8.9	5.0	3.2	1.4	0.8	0.2	0.1	0.1	0.1		
	Index	0.0	0.3	0.0	2.1	0.0	1.6	6.2	25.3	3.9	3.0	0.7	0.3		

Table 6. Catch of young-of-the-year Striped Bass at index stations in 2023 summarized by sampling round.

	2023					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	176	5.65	3.31-8.98		30	13,467	11.97	9.15-15.48	
(2nd)	36	143	4.95	3.01-7.59	-18.8%	30	10,535	9.11	6.84-11.95	-21.8%
July (3rd)	36	156	4.59	2.57-7.44	9.1%	30	7,838	7.26	5.44-9.50	-25.6%
(4th)	36	133	3.63	1.88-6.13	-14.7%	26	6,907	6.88	5.12-9.04	-11.9%
Aug. (5th)	36	99	2.87	1.55-4.65	-25.6%	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 2023 summarized by water temperature.

	2023				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	-	-	-	-	47	1.98	0.46-4.34	19
20.0-24.9	6	6.55	3.02-12.44	2	2,430	4.13	3.61-4.70	568
25.0-29.9	530	4.04	3.02-5.25	134	33,808	9.11	8.66-9.57	3,588
> 30.0	171	4.91	3.11-7.33	44	6,871	9.66	8.60-10.82	679

Table 8. Striped Bass indices and average site dissolved oxygen during 2023 compared to average index values during the auxiliary monitoring period (1992-2022), with corresponding average dissolved oxygen (Avg. DO, mg/L). 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	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	C4	**J46**	J51	**J56**	J62	J68	J77
1992-2022	Avg. DO	6.9	6.6	7.1	6.2	7.7	7.1	6.1	7.4	6.8	6.1	6.8	8.8	6.5	6.3
	Index	1.3	7.8	10.4	16.3	10.0	20.6	11.6	15.9	23.2	19.3	12.1	12.9	6.6	2.9
2023	Avg. DO	8.3	8.6	8.3	6.1	8.9	7.1	7.2	8.0	9.4	7.5	7.1	10.2	7.8	7.4
	Index	0.0	5.9	5.3	4.4	14.4	3.7	0.3	10.9	0.7	34.0	61.3	14.3	1.2	3.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56						
1992-2022	Avg. DO	6.1	5.8	5.5	5.0	5.6	5.7	5.3	6.4						
	Index	1.4	3.2	7.4	10.4	5.2	11.9	19.2	1.0						
2023	Avg. DO	5.5	5.6	5.6	5.0	6.1	6.7	6.5	8.2						
	Index	0.0	0.3	1.5	1.5	2.8	3.7	11.9	0.0						
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
1992-2022	Avg. DO				4.4	4.5	4.8	5.0	5.9	5.6					
	Index				9.9	11.4	7.4	10.2	6.2	1.5					
2023	Avg. DO				4.5	4.5	5.4	6.2	7.0	6.7					
	Index				8.9	10.7	0.3	10.0	8.2	1.2					
RAPPAHANNOCK		R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
1992-2022	Avg. DO	7.0	6.7	6.5	6.5	6.8	7.5	6.5	6.8	6.3	7.3	6.4	6.2		
	Index	0.7	0.8	4.6	3.2	5.6	13.1	26.8	50.1	6.3	5.4	2.8	0.9		
2023	Avg. DO	8.1	8.2	7.9	6.1	7.4	8.1	7.4	7.4	7.1	7.7	7.5	7.0		
	Index	0.0	0.3	0.0	2.1	0.0	1.6	6.2	25.3	3.9	3.0	0.7	0.3		

Table 9. Striped Bass indices and average site pH during 2023 compared to average index values during the auxiliary monitoring period (1992-2006), with corresponding average pH (Avg. pH). 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). A hyphen (-) indicates a site that was not sampled during the 1992-2006 auxiliary monitoring period.

Drainage															
JAMES	Station	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	C4	**J46**	J51	**J56**	J62	J68	J77
1992-2006	Avg. pH	7.6	-	7.7	7.5	8.2	7.8	7.4	-	7.7	7.5	7.9	8.1	7.4	7.7
	Index	2.6	-	13.5	24.0	7.0	24.6	11.5	-	26.9	16.1	8.5	9.6	6.8	3.6
2023	Avg. pH	7.9	7.8	7.9	7.6	8.3	7.7	7.6	7.6	8.3	7.8	7.7	8.3	7.6	7.7
	Index	0.0	5.9	5.3	4.4	14.4	3.7	0.3	10.9	0.7	34.0	61.3	14.3	1.2	3.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56						
1992-2006	Avg. pH	7.5	7.4	7.1	7.0	7.0	7.1	7.1	-						
	Index	1.4	2.3	5.7	11.9	5.3	15.0	23.1	-						
2023	Avg. pH	7.6	7.5	7.3	7.1	7.1	7.3	7.2	7.4						
	Index	0.0	0.3	1.5	1.5	2.8	3.7	11.9	0.0						
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
1992-2006	Avg. pH				6.8	6.8	6.7	6.8	6.8	6.7					
	Index				11.0	11.4	9.4	7.6	5.2	1.6					
2023	Avg. pH				7.1	6.9	6.9	6.9	7.0	6.8					
	Index				8.9	10.7	0.3	10.0	8.2	1.2					
RAPPAHANNOCK		R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
1992-2006	Avg. pH	7.7	7.6	7.5	7.5	7.2	7.7	7.3	7.4	7.4	7.8	7.3	-		
	Index	0.7	1.2	4.9	4.4	4.9	14.7	21.3	49.6	7.2	5.1	3.6	-		
2023	Avg. pH	7.9	7.9	7.8	7.3	7.4	7.6	7.3	7.3	7.3	7.5	7.0	7.0		
	Index	0.0	0.3	0.0	2.1	0.0	1.6	6.2	25.3	3.9	3.0	0.7	0.3		

Table 10. Striped Bass indices and average site Secchi during 2023 compared to average index values during the auxiliary monitoring period (1992-2022), with corresponding average Secchi (Avg. Secchi, depth in meters). 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	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	C4	**J46**	J51	**J56**	J62	J68	J77
1992-2022	Avg. Secchi	0.5	0.7	0.5	0.5	0.5	0.4	0.5	0.7	0.5	0.5	0.5	0.4	0.6	0.7
	Index	1.3	7.8	10.4	16.3	10.0	20.6	11.6	15.9	23.2	19.3	12.1	12.9	6.6	2.9
2023	Avg. Secchi	0.5	0.4	0.6	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.6	0.3	0.4	0.5
	Index	0.0	5.9	5.3	4.4	14.4	3.7	0.3	10.9	0.7	34.0	61.3	14.3	1.2	3.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56						
1992-2022	Avg. Secchi	0.6	0.4	0.3	0.3	0.4	0.5	0.5	0.5						
	Index	1.4	3.2	7.4	10.4	5.2	11.9	19.2	1.0						
2023	Avg. Secchi	0.6	0.5	0.2	0.2	0.3	0.4	0.6	0.3						
	Index	0.0	0.3	1.5	1.5	2.8	3.7	11.9	0.0						
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
1992-2022	Avg. Secchi				0.4	0.4	0.6	0.6	0.6	0.8					
	Index				9.9	11.4	7.4	10.2	6.2	1.5					
2023	Avg. Secchi				0.3	0.4	0.4	0.2	0.3	0.3					
	Index				8.9	10.7	0.3	10.0	8.2	1.2					
RAPPAHANNOCK		R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
1992-2022	Avg. Secchi	0.8	0.6	0.5	0.3	0.4	0.4	0.5	0.5	0.4	0.4	0.5	0.5		
	Index	0.7	0.8	4.6	3.2	5.6	13.1	26.8	50.1	6.3	5.4	2.8	0.9		
2023	Avg. Secchi	0.7	0.7	0.4	0.3	0.4	0.3	0.4	0.4	0.6	0.8	0.8	0.8		
	Index	0.0	0.3	0.0	2.1	0.0	1.6	6.2	25.3	3.9	3.0	0.7	0.3		

Table 11. Striped Bass indices and average site turbidity (Avg. Turbidity, FNU) during 2023. 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	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	C4	**J46**	J51	**J56**	J62	J68	J77
	Avg. Turbidity	12.0	19.1	12.2	15.6	19.8	15.3	11.9	24.6	47.4	17.9	10.2	42.0	27.7	29.3
	Index	0.0	5.9	5.3	4.4	14.4	3.7	0.3	10.9	0.7	34.0	61.3	14.3	1.2	3.1
YORK	Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56						
	Avg. Turbidity	9.5	14.0	87.9	72.1	60.2	25.9	11.7	19.3						
	Index	0.0	0.3	1.5	1.5	2.8	3.7	11.9	0.0						
	Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Avg. Turbidity				19.9	16.7	15.7	30.9	29.8	16.9					
	Index				8.9	10.7	0.3	10.0	8.2	1.2					
RAPPAHANNOCK		R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Avg. Turbidity	10.1	7.3	15.9	30.1	23.2	35.2	54.5	23.9	9.8	6.2	6.7	6.1		
	Index	0.0	0.3	0.0	2.1	0.0	1.6	6.2	25.3	3.9	3.0	0.7	0.3		

Table 12. Fish species collected during the 2023 seine survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Notropis hudsonius	Spottail Shiner	3632
Menidia menidia	Atlantic Silverside	3484
Morone americana	White Perch	3368
Anchoa mitchilli	Bay Anchovy	3014
Brevoortia tyrannus	Atlantic Menhaden	2763
Trinectes maculatus	Hogchoker	2686
Dorosoma petenense	Threadfin Shad	1963
Micropogonias undulatus	Atlantic Croaker	1892
Menidia beryllina	Inland Silverside	1788
Fundulus diaphanus	Banded Killifish	1538
Alosa sapidissima	American Shad	1457
Fundulus heteroclitus	Mummichog	1087
Leiostomus xanthurus	Spot	1026
Morone saxatilis	Striped Bass	1025
Alosa aestivalis	Blueback Herring	745
Enneacanthus gloriosus	Bluespotted Sunfish	682
Notropis analostanus	Satinfin Shiner	495
Etheostoma olmstedi	Tessellated Darter	486
Dorosoma cepedianum	Gizzard Shad	442
Ictalurus furcatus	Blue Catfish	211
Mugil cephalus	Striped Mullet	202
Fundulus majalis	Striped Killifish	201
Notropis bifrenatus	Bridle Shiner	190
Menticirrhus americanus	Southern Kingfish	162
Anchoa hepsetus	Striped Anchovy	155
Lepomis macrochirus	Bluegill	148
Notemigonus crysoleucas	Golden Shiner	148
Micropterus punctulatus	Spotted Bass	141
Bairdiella chrysoura	Silver Perch	115
Membras martinica	Rough Silverside	97
Hybognathus regius	Eastern Silvery Minnow	94
Peprilus alepidotus	Harvestfish	92
Lepomis spp.	Sunfish Spp.	79
Lepomis auritus	Redbreast Sunfish	72
Gambusia spp.	Mosquitofish	52
Anguilla rostrata	American Eel	40
Symphurus plagiusa	Blackcheek Tonguefish	38
Lepomis gibbosus	Pumpkinseed	35
Ictalurus punctatus	Channel Catfish	34
Micropterus salmoides	Largemouth Bass	32
Strongylura marina	Atlantic Needlefish	23
Cynoscion regalis	Weakfish	20

Table 12. (continued)

Scientific Name	Common Name	Total Caught
Nocomis raneyi	Bull Chub	16
Perca flavescens	Yellow Perch	16
Alosa mediocris	Hickory Shad	14
Lepomis microlophus	Redear Sunfish	13
Ameiurus catus	White Catfish	13
Sciaenops ocellatus	Red Drum	12
Morone saxatilis age 1+	Striped Bass Age 1+	12
Paralichthys dentatus	Summer Flounder	11
Alosa pseudoharengus	Alewife	9
Enneacanthus obesus	Banded Sunfish	9
Synodus foetens	Inshore Lizardfish	9
Moxostoma macrolepidotum	Shorthead Redhorse	8
Hemiramphus brasiliensis	Ballyhoo	5
Pogonius cromis	Black Drum	5
Ameiurus nebulosus	Brown Bullhead	5
Cyprinus carpio	Common Carp	5
Cynoscion nebulosus	Spotted Seatrout	5
Chaetodipterus faber	Atlantic Spadefish	4
Pomatomus saltatrix	Bluefish	4
Lepisosteus osseus	Longnose Gar	4
Cyprinodon variegatus	Sheepshead Minnow	4
Sphoeroides maculatus	Northern Puffer	3
Micropterus dolomieui	Smallmouth Bass	3
Noturus gyrinus	Tadpole Madtom	3
Mugil curema	White Mullet	2
Syngnathus louisianae	Chain Pipefish	1
Rhinoptera bonasus	Cownose Ray	1
Caranx hippos	Crevalle Jack	1
Lepomis cyanellus	Green Sunfish	1
Gobiosoma bosc	Naked Goby	1
Menticirrhus saxatilis	Northern Kingfish	1
Syngnathus fuscus	Northern Pipefish	1
Astroscopus guttatus	Northern Stargazer	1
Nocomis micropogon	River Chub	1
Gobiesox strumosus	Skilletfish	1
Etropus microstomus	Smallmouth Flounder	1
Scomberomorus maculatus	Spanish Mackerel	1
	Total	36,160

Table 13. 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	97	3.2	18	0.6	133	8.8	41
1982	18	1.3	292	20.2	126	16.5	28
1983	162	10.5	175	9.9	128	13.7	40
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	1,640	43.3	433	10.4	623	17.5	119
2014	2,198	71.4	2,373	62.0	841	22.0	120
2015	1,518	32.6	1,621	53.5	1,017	25.3	139
2016	1,474	32.0	980	30.8	1,286	41.2	121
2017	3,804	113.9	460	10.6	2,576	101.6	126
2018	4,757	111.1	1,025	30.7	1,976	56.6	136
2019	2,961	63.7	1,746	42.2	2,529	70.6	141
2020	3,658	87.4	867	20.6	1,780	64.0	133
2021	762	17.1	867	20.0	2,205	88.4	131
2022	1,947	48.0	1,085	28.8	1,660	45.8	137
2023	1,196	23.0	166	3.6	840	20.9	117

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

Year	Total Fish	Delta Mean	N (hauls)
1980	167	5.3	20
1981	0	0	0
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	1.8	9
1988	10	0.6	4
1989	112	1.4	16
1990	20	0.3	2
1991	636	10.0	48
1992	717	11.6	41
1993	1,115	30.1	47
1994	862	16.9	39
1995	598	13.8	36
1996	18	0.4	3
1997	955	27.1	48
1998	840	14.6	43
1999	519	9.4	38
2000	21	0.3	10
2001	35	0.9	11
2002	146	2.2	29
2003	8	0.1	4
2004	185	4.7	20
2005	177	6.5	24
2006	399	6.7	37
2007	329	16.3	21
2008	1,306	71.4	52
2009	1,724	50.1	46
2010	76	2.0	13
2011	36	0.5	10
2012	953	22.8	49
2013	771	16.4	36
2014	9	0.2	2
2015	7	0.1	2
2016	483	12.8	23
2017	230	6.4	24
2018	65	0.6	13
2019	68	1.7	13
2020	749	11.6	40
2021	191	4.9	18
2022	229	7.3	32
2023	1,357	28.0	46
Overall (1980-2022)	15,133	9.3	43 (years)

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

Year	Total Fish	Delta Mean	N (hauls)
1967	73	2.3	14
1968	655	11.6	38
1969	528	9.6	50
1970	57	0.6	25
1971	704	11.8	58
1972	443	2.6	54
1973	2,306	49.0	72
1980	2,174	25.0	72
1981	829	14.5	43
1982	631	91.7	18
1983	130	5.6	17
1984	899	30.6	19
1985	406	12.2	26
1986	1,338	60.1	33
1987	161	5.1	15
1988	943	20.9	37
1989	1,319	21.1	52
1990	1,050	11.1	62
1991	1,069	12.7	74
1992	525	5.9	65
1993	961	10.9	74
1994	990	9.9	60
1995	237	2.3	40
1996	728	11.6	44
1997	1,900	25.3	78
1998	881	15.6	55
1999	888	11.0	78
2000	465	6.1	46
2001	484	6.5	53
2002	185	1.7	44
2003	470	5.9	27
2004	581	6.1	51
2005	2,711	27.6	87
2006	471	5.1	66
2007	977	17.0	77
2008	906	9.7	84
2009	1,208	13.9	73
2010	2,801	30.4	87
2011	669	12.4	60
2012	581	6.6	66
2013	635	12.1	58
2014	566	13.0	45
2015	44	0.5	11
2016	113	1.3	27
2017	221	2.6	42
2018	294	3.1	34
2019	316	3.4	43
2020	305	3.0	50
2021	547	6.4	59
2022	732	9.7	60
2023	770	8.0	65
Overall (1967-2022)	39,107	13.9	50 (years)

Table 16. 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	18.0	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	42.0	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	27.0	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
2018	6,528	60.3	125
2019	8,169	70.8	124
2020	3,436	26.3	121
2021	6,146	48.9	120
2022	6,248	45.0	118
2023	2,924	24.8	101
Overall (1989-2022)	122,860	29.0	34 (years)

Table 17. 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	41
1990	2,917	46.6	51
1991	2,855	42.2	68
1992	6,087	122.8	58
1993	2,364	32.0	59
1994	2,305	32.4	52
1995	3,079	41.3	59
1996	4,871	93.4	52
1997	1,160	13.3	55
1998	2,434	26.4	66
1999	6,822	68.6	88
2000	3,778	43.9	65
2001	4,015	53.4	73
2002	5,387	67.0	96
2003	3,351	55.4	35
2004	1,503	21.8	39
2005	1,979	22.1	69
2006	2,847	31.7	67
2007	2,067	29.5	68
2008	3,454	34.7	58
2009	2,916	37.4	72
2010	1,723	18.4	86
2011	3,585	47.2	75
2012	1,381	13.9	68
2013	6,814	95.1	59
2014	4,891	69.6	67
2015	7,542	103.1	74
2016	2,397	27.1	56
2017	5,259	80.5	73
2018	8,071	136.9	46
2019	2,561	32.5	54
2020	2,500	30.4	53
2021	1,790	19.4	61
2022	7,330	80.5	61
2023	2,621	27.1	79
Overall (1989-2022)	125,745	49.3	34 (years)

Table 18. 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	3.0	86
1990	591	3.8	76
1991	286	1.8	66
1992	339	1.8	60
1993	385	2.3	59
1994	171	1.0	49
1995	109	0.7	48
1996	807	5.4	60
1997	201	1.2	57
1998	213	1.4	61
1999	307	1.9	58
2000	729	5.1	77
2001	660	4.1	66
2002	498	3.0	67
2003	574	3.4	98
2004	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
2018	1,095	6.3	105
2019	1,277	8.1	105
2020	1,686	10.2	105
2021	1,169	7.3	103
2022	3,528	21.1	131
2023	1,344	7.5	103
Overall (1989-2022)	34,021	5.9	34 (years)

Table 19. 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	1.5	47
1990	238	1.6	50
1991	263	2.0	42
1992	153	1.1	35
1993	264	2.0	41
1994	203	1.4	43
1995	287	2.1	38
1996	654	5.0	64
1997	365	2.6	60
1998	311	2.2	61
1999	297	2.1	49
2000	252	1.7	54
2001	355	2.3	70
2002	364	2.6	49
2003	802	5.7	68
2004	1,383	9.7	89
2005	715	5.6	68
2006	498	4.0	48
2007	692	5.1	75
2008	1,025	6.7	87
2009	1,208	9.0	85
2010	1,965	14.8	97
2011	1,958	14.1	88
2012	1,865	13.6	97
2013	638	4.5	70
2014	715	4.6	87
2015	879	5.4	93
2016	1,834	13.2	108
2017	697	4.5	105
2018	849	5.7	94
2019	1,714	11.4	108
2020	1,232	9.1	91
2021	1,603	11.6	102
2022	3,143	18.2	105
2023	1,134	7.7	89
Overall (1989-2022)	29,657	6.1	34 (years)

Table 20. Delta-lognormal mean of young-of-the-year Mummichog from select seine survey stations in Virginia tributaries of Chesapeake Bay by year.

Year	Total Fish	Delta Mean	N (Hauls)
1989	230	2.3	29
1990	354	3.6	30
1991	759	8.3	55
1992	797	7.9	56
1993	997	9.8	66
1994	741	8.7	45
1995	673	7.8	45
1996	1,241	13.6	60
1997	1,182	12.4	49
1998	2,039	26.3	58
1999	893	8.7	40
2000	620	5.7	51
2001	875	7.6	68
2002	5,692	104.5	56
2003	1,016	10.4	57
2004	1,539	17.9	63
2005	1,601	15.7	77
2006	1,800	20.9	55
2007	999	10.8	53
2008	1,366	11.8	64
2009	860	8.5	61
2010	2,466	25.3	75
2011	3,883	34.5	81
2012	23,115	173.3	80
2013	798	8.2	54
2014	2,034	21.0	50
2015	1,146	11.2	62
2016	14,902	188.4	73
2017	1,594	17.7	63
2018	1,142	12.3	48
2019	1,449	13.5	68
2020	1,398	17.1	55
2021	2,665	29.4	72
2022	2,630	23.2	76
2023	730	6.0	55
Overall (1989-2022)	85,496	26.4	34 (years)

FIGURES

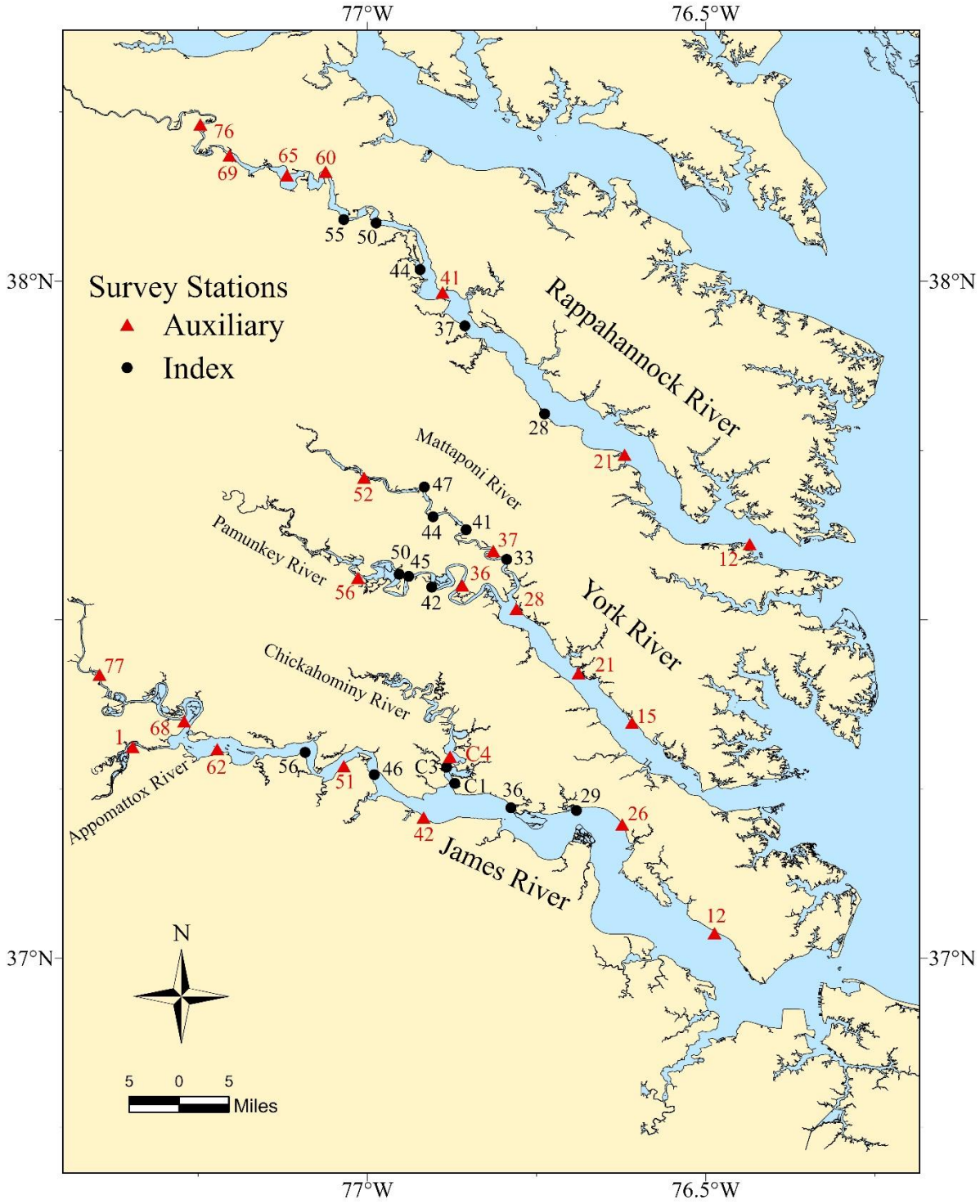

Figure 1. Juvenile Striped Bass seine survey stations. Station numbers denote the approximate river mile from the mouth.

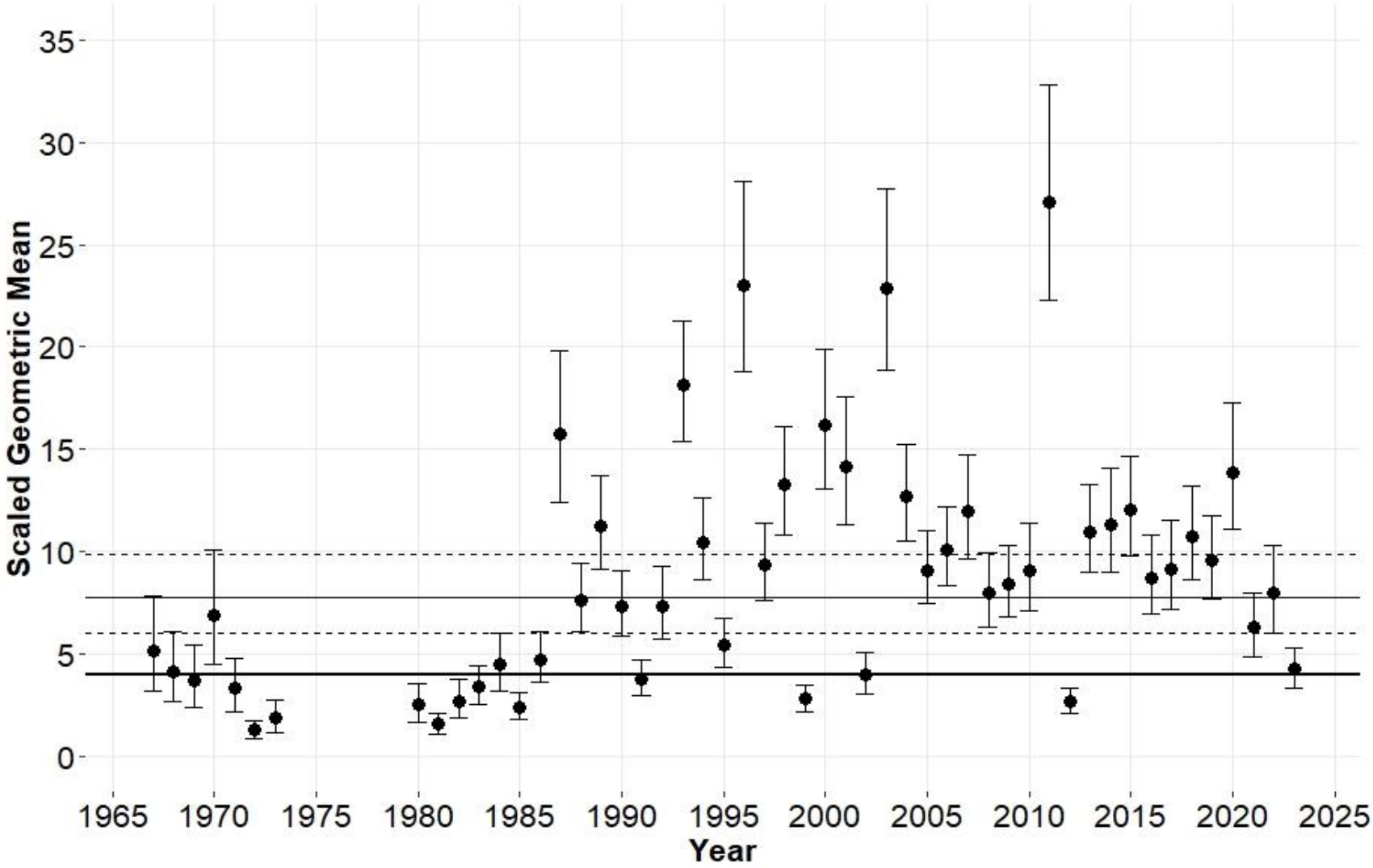

Figure 2. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate the arithmetic mean (thin solid), confidence intervals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

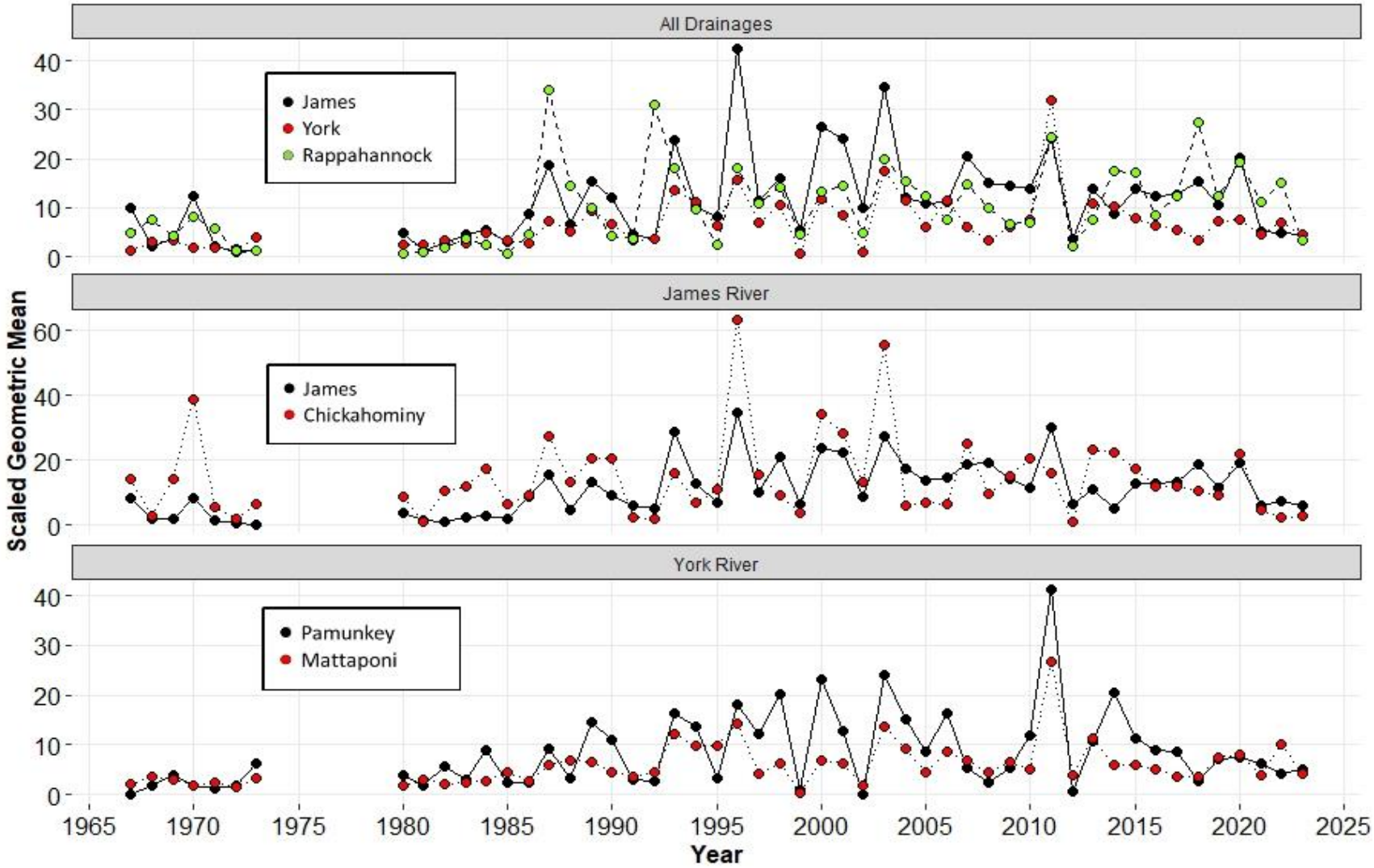

Figure 3. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by drainage and river.

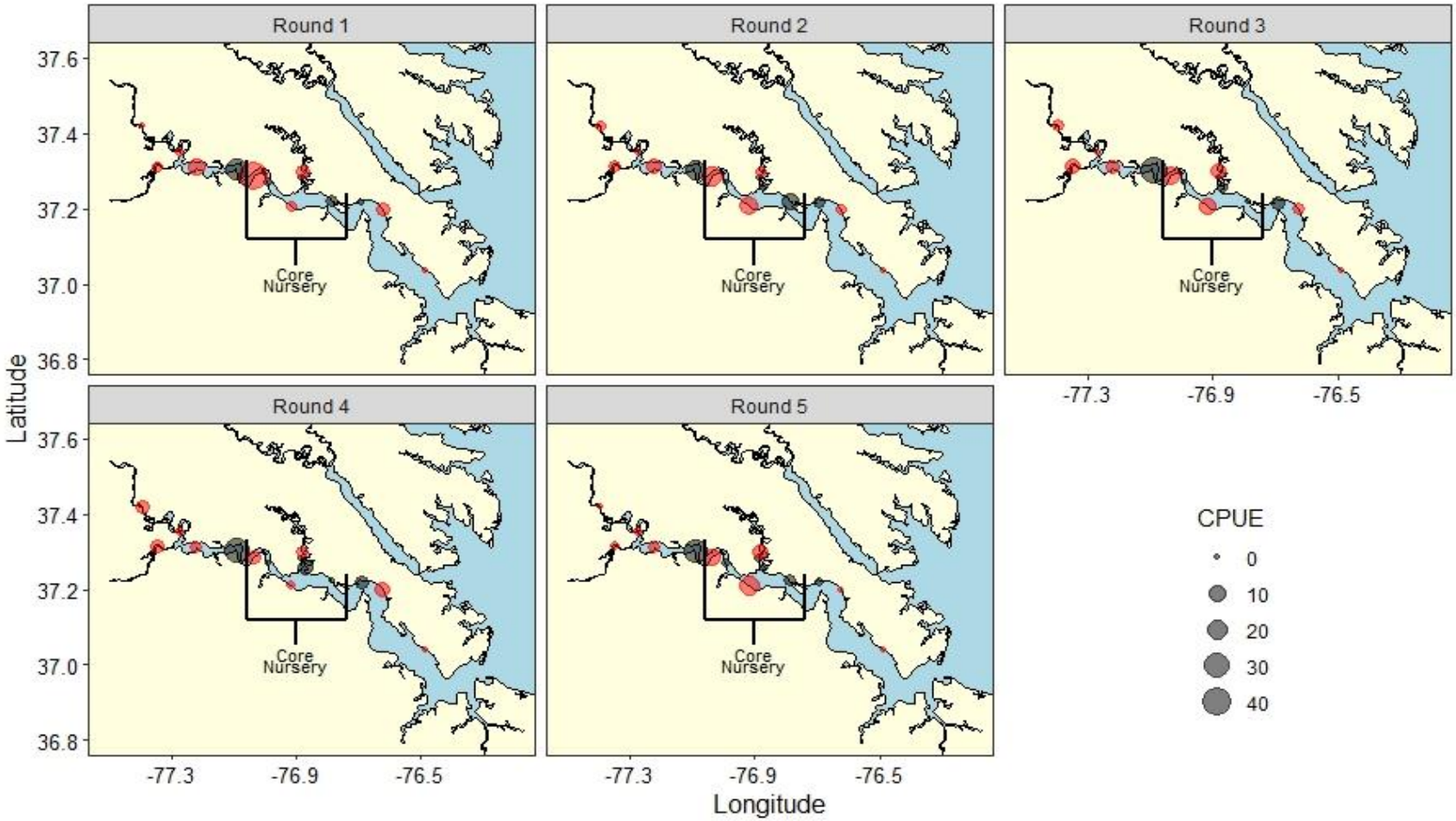

Figure 4. Catch per unit effort of juvenile Striped Bass by station in the James River drainage during each round in 2023. Data are shown for index (black) and auxiliary (red) stations, using the first haul only. The core nursery area is delineated by thick black lines.

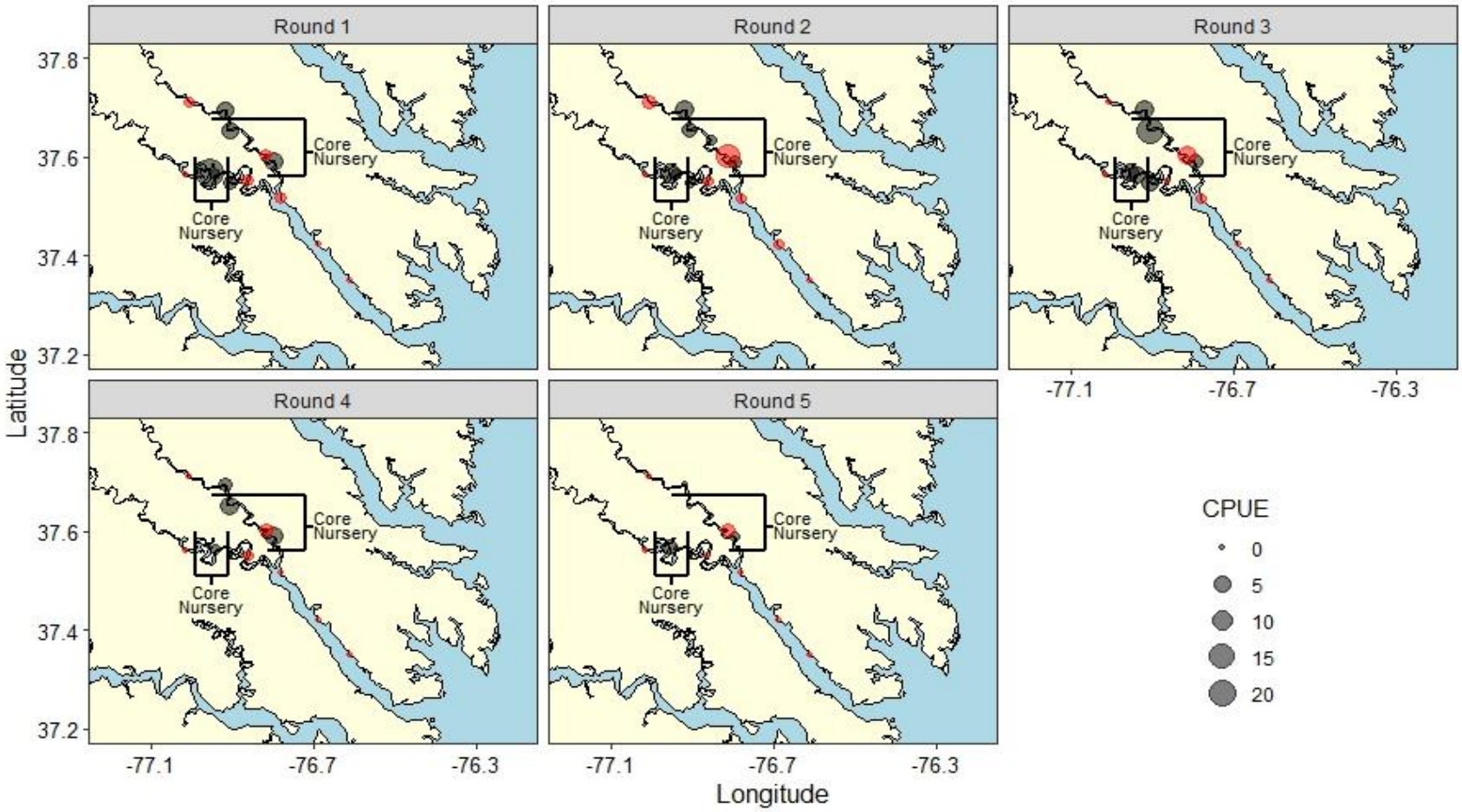

Figure 5. Catch per unit effort of juvenile Striped Bass by station in the York River drainage during each round in 2023. Data are shown for index (black) and auxiliary (red) stations, using the first haul only. Core nursery areas in the Pamunkey and Mattaponi rivers are delineated by thick black lines.

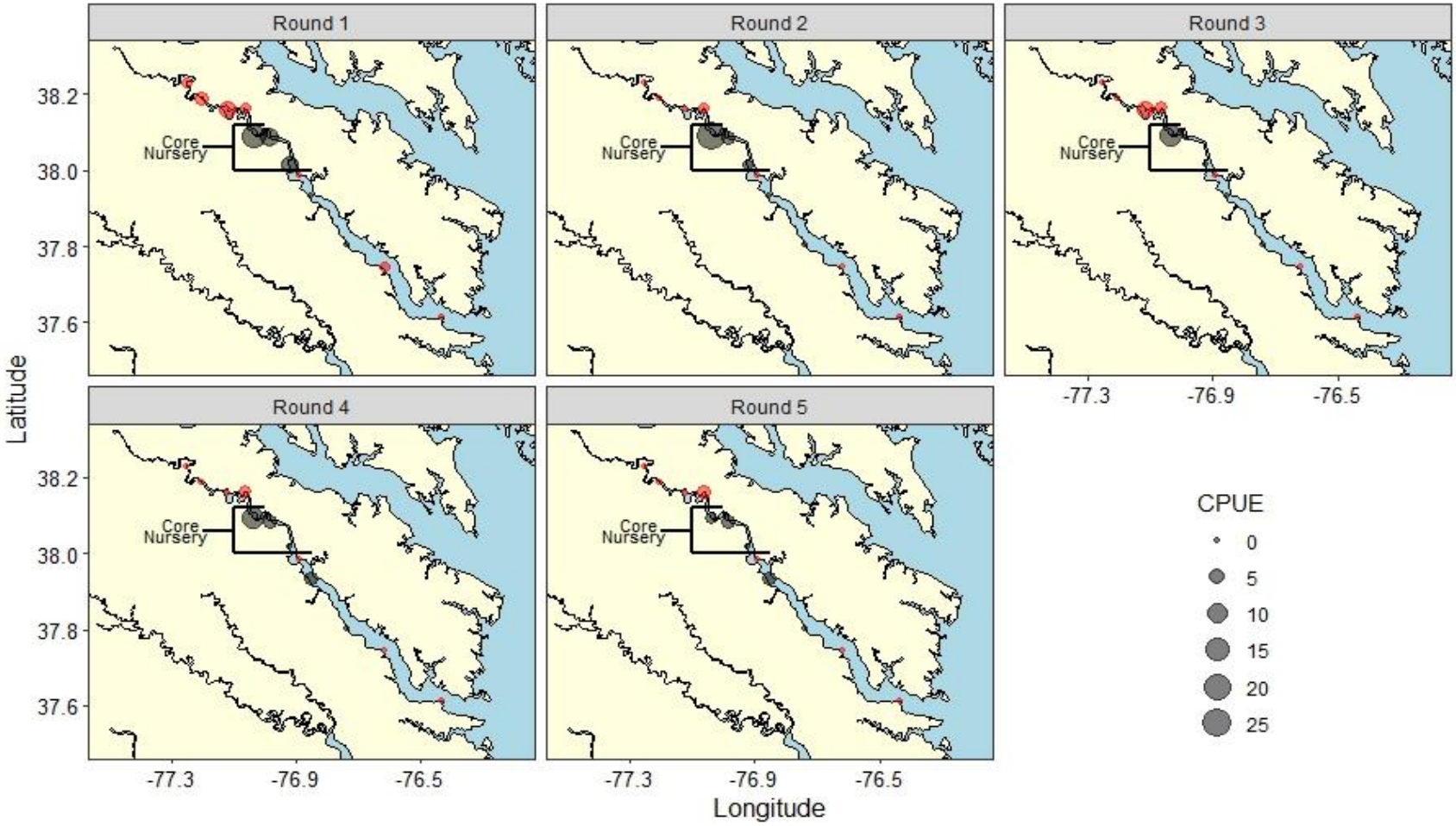

Figure 6. Catch per unit effort of juvenile Striped Bass by station in the Rappahannock River drainage during each round in 2023. Data are shown index (black) and auxiliary (red) stations, using the first haul only. The core nursery area is delineated by thick black lines.

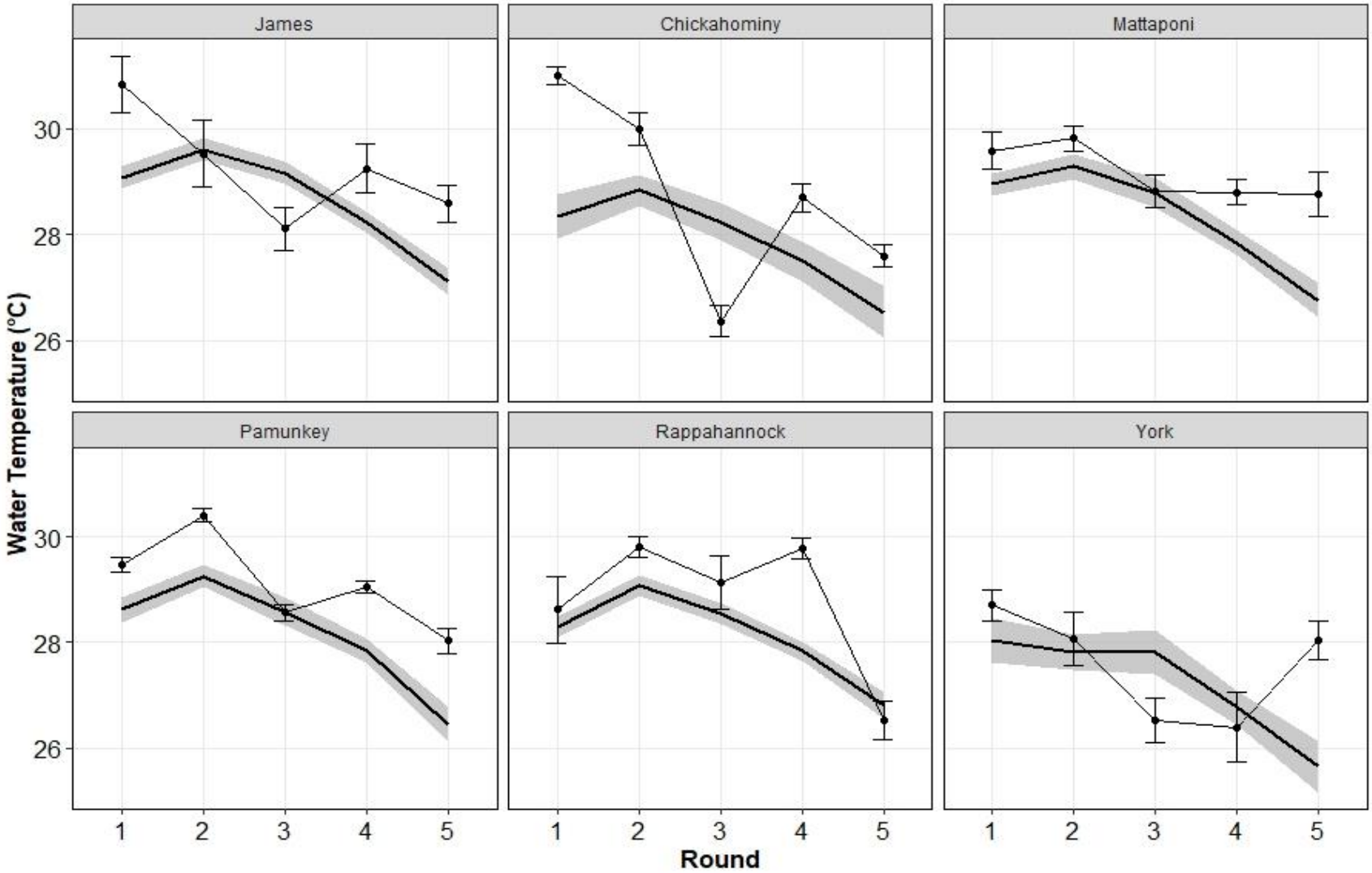

Figure 7. Mean water temperature and 95% confidence intervals during each round (x-axis) in each river during 2023 (thin line and error bars) and the auxiliary monitoring period from 1989-2022 (thick line and shaded region).

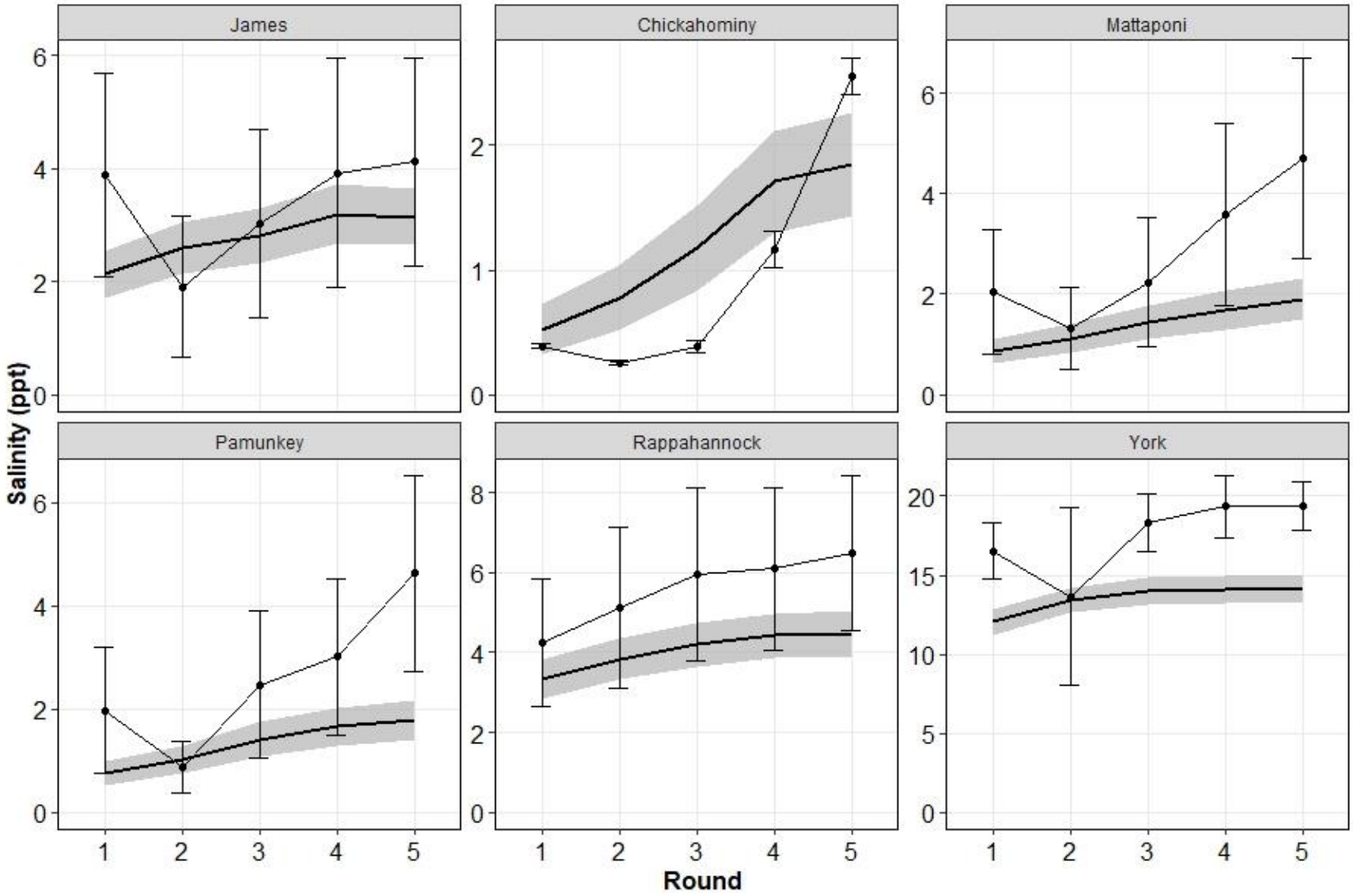

Figure 8. Mean salinity and 95% confidence intervals during each round (x-axis) in each river during 2023 (thin line and error bars) and the auxiliary monitoring period from 1989-2022 (thick line and shaded region). Note that the scale of the y-axis varies by river.

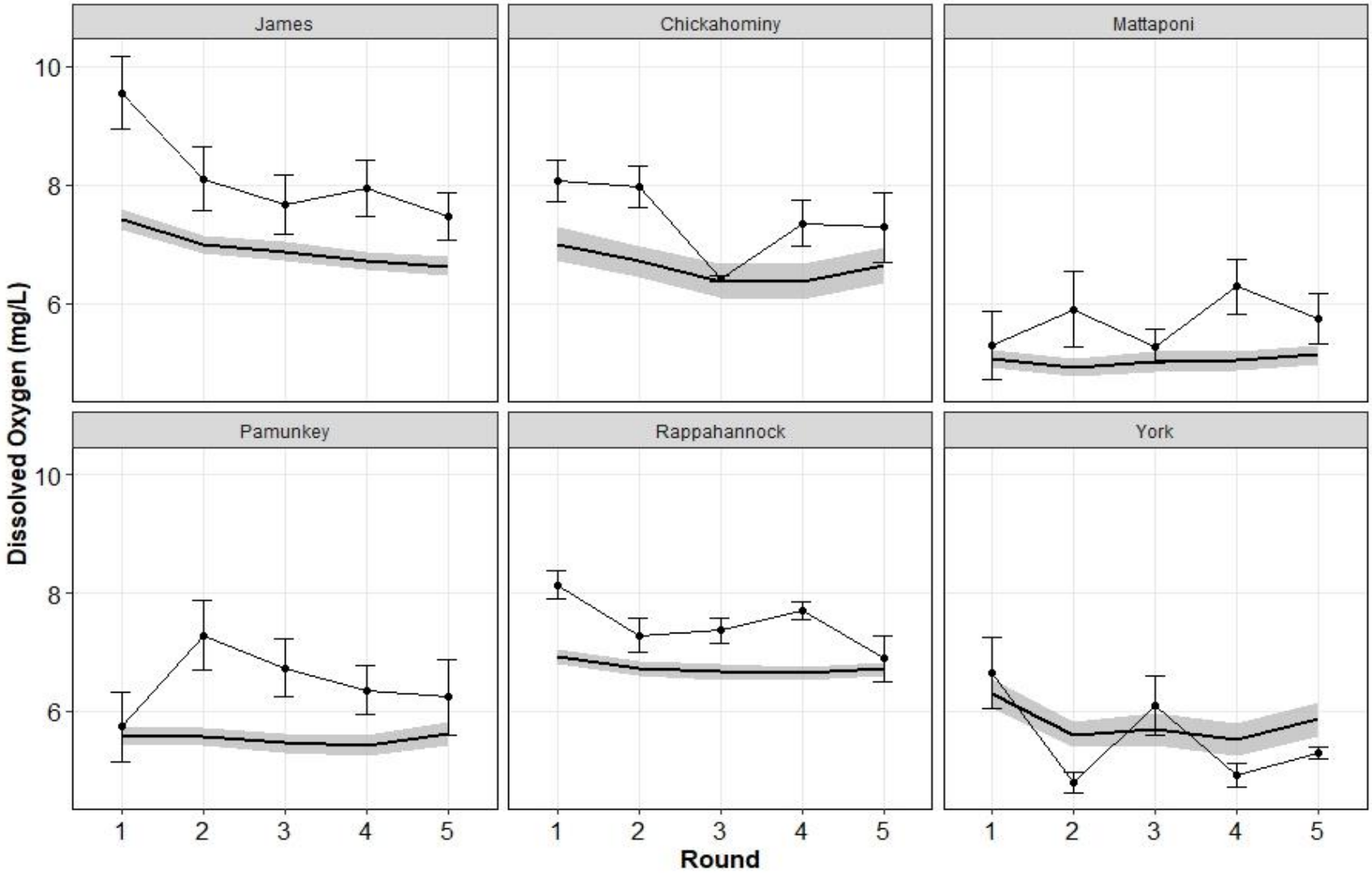

Figure 9. Mean dissolved oxygen and 95% confidence intervals during each round (x-axis) in each river during 2023 (thin line and error bars) and the monitoring period from 1992-2022 (thick line and shaded region). Note that dissolved oxygen was not measured on the seine survey before 1992.

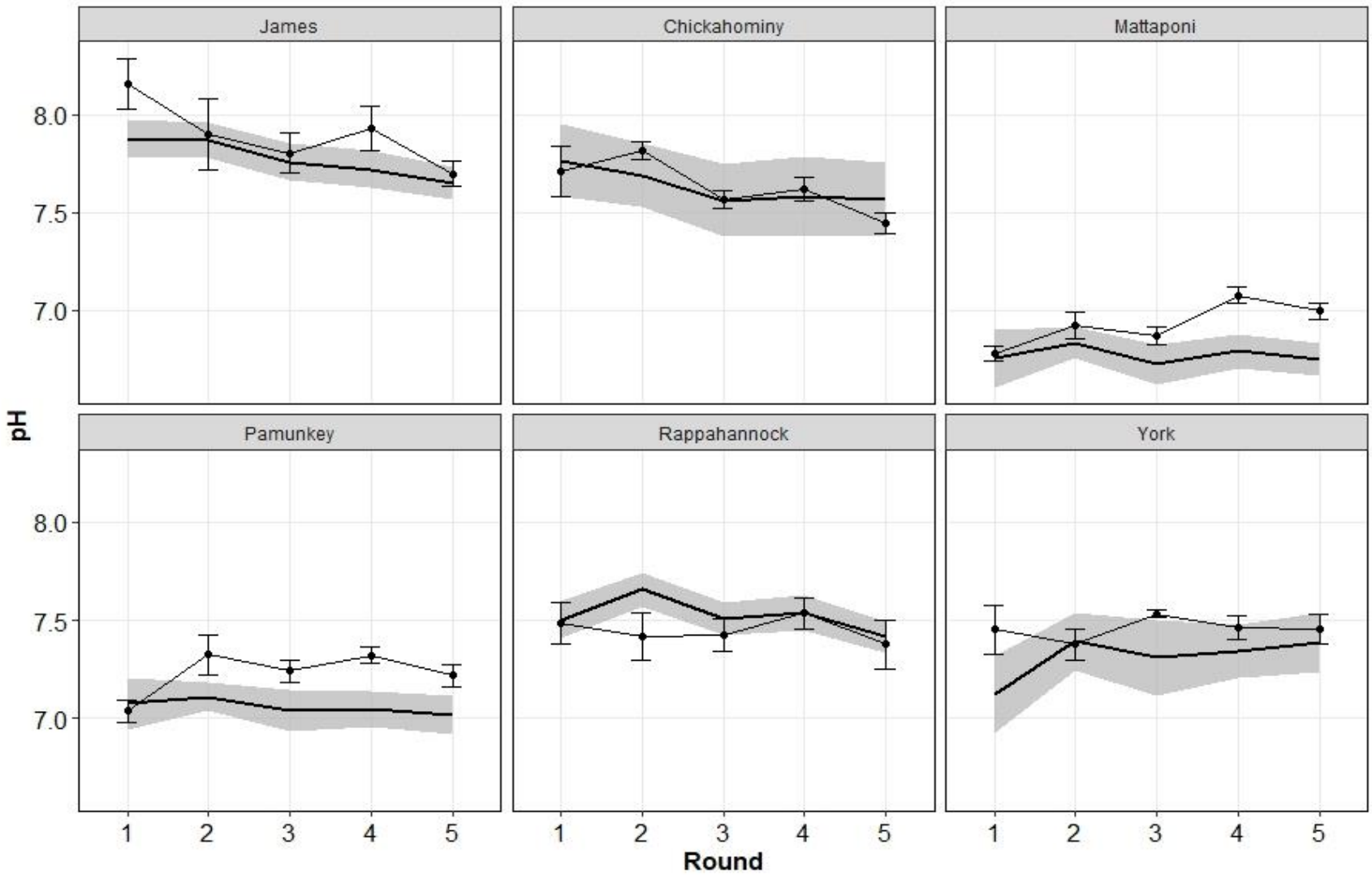

Figure 10. Mean pH and 95% confidence intervals during each round (x-axis) in each river during 2023 (thin line and error bars) and the monitoring period from 1992-2006 (thick line and shaded region). Note that pH was not measured on the seine survey before 1992 and was stopped during 2006.

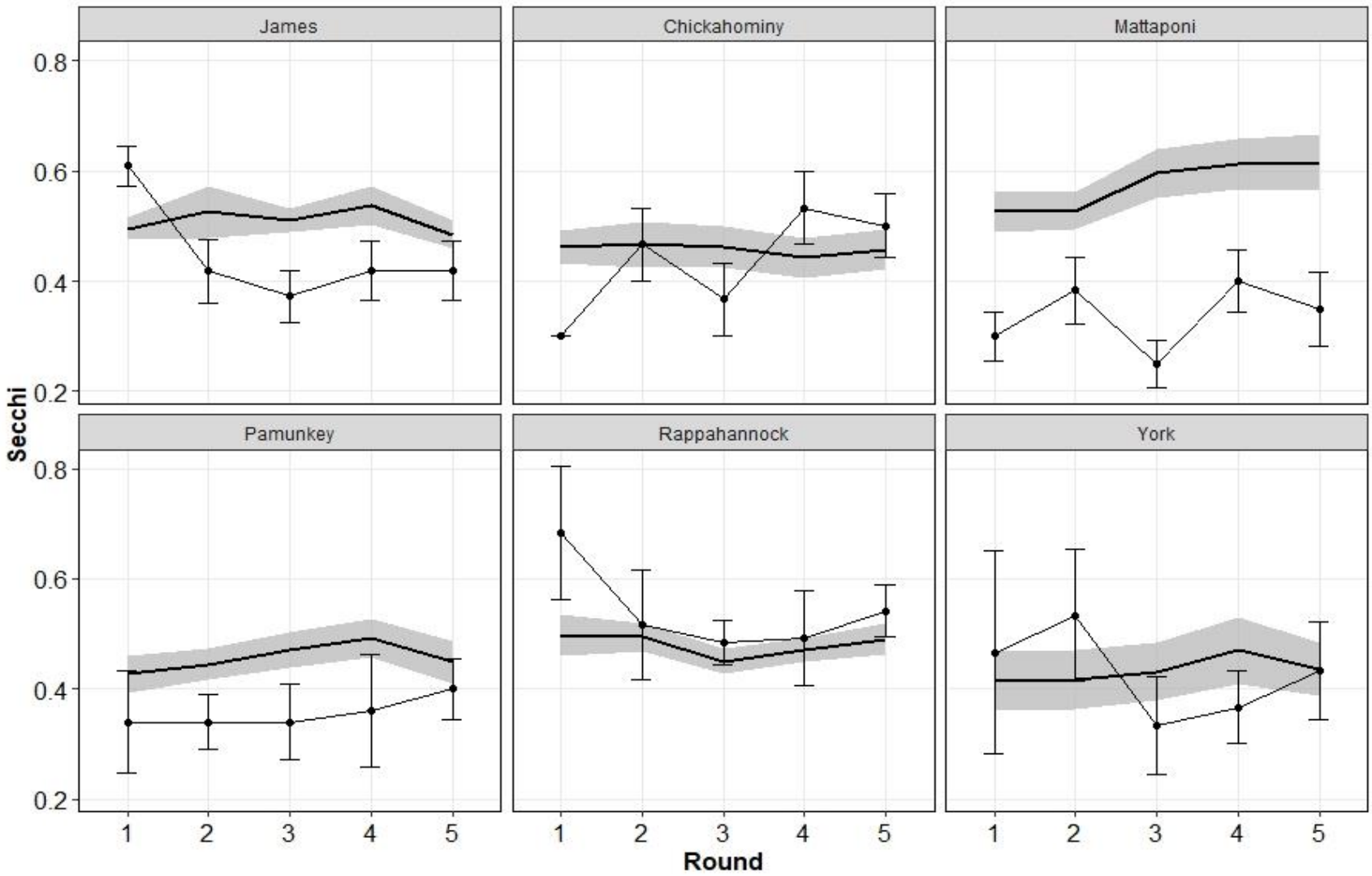

Figure 11. Mean Secchi and 95% confidence intervals during each round (x-axis) in each river during 2023 (thin line and error bars) and the monitoring period from 1992-2022 (thick line and shaded region). Note that Secchi was not measured on the seine survey before 1992.

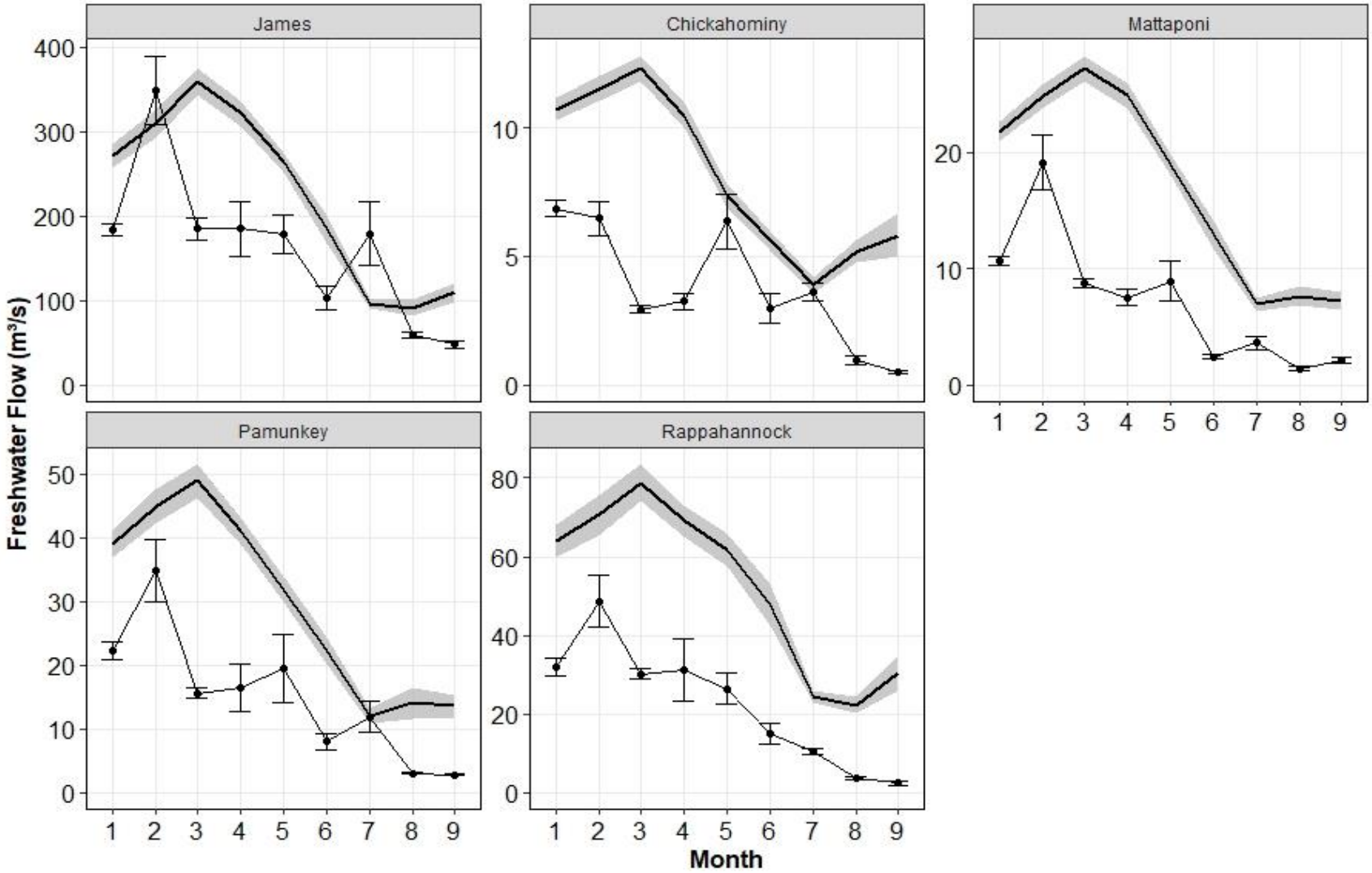

Figure 12. Mean freshwater flow and 95% confidence intervals during each month from January to September (x-axis) in each river during 2023 (thin line and error bars) and the historical monitoring period from 1967-2022 (thick line and shaded region). Note that the scale varies by river. Data are from USGS (2023).

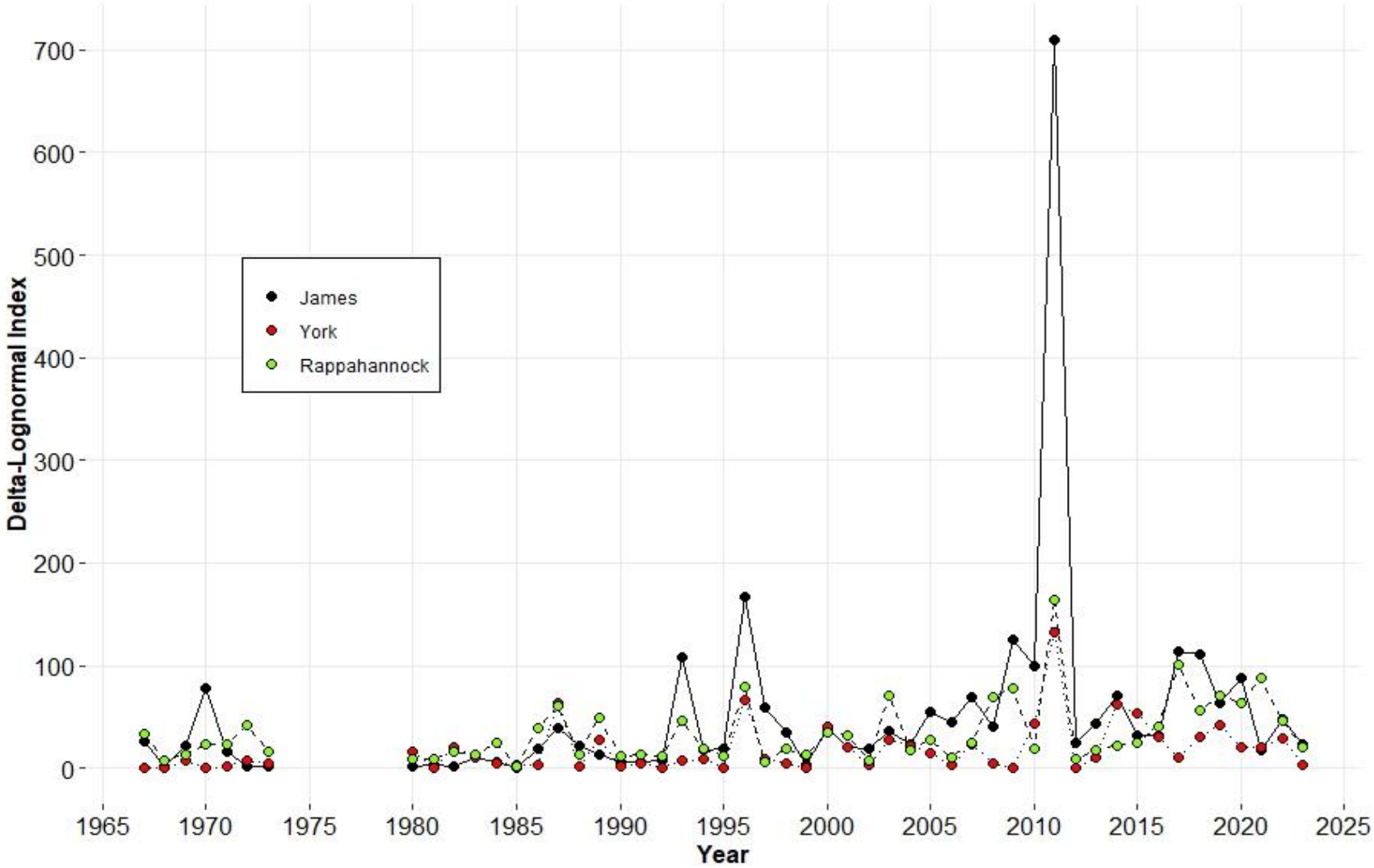

Figure 13. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by drainage and year.

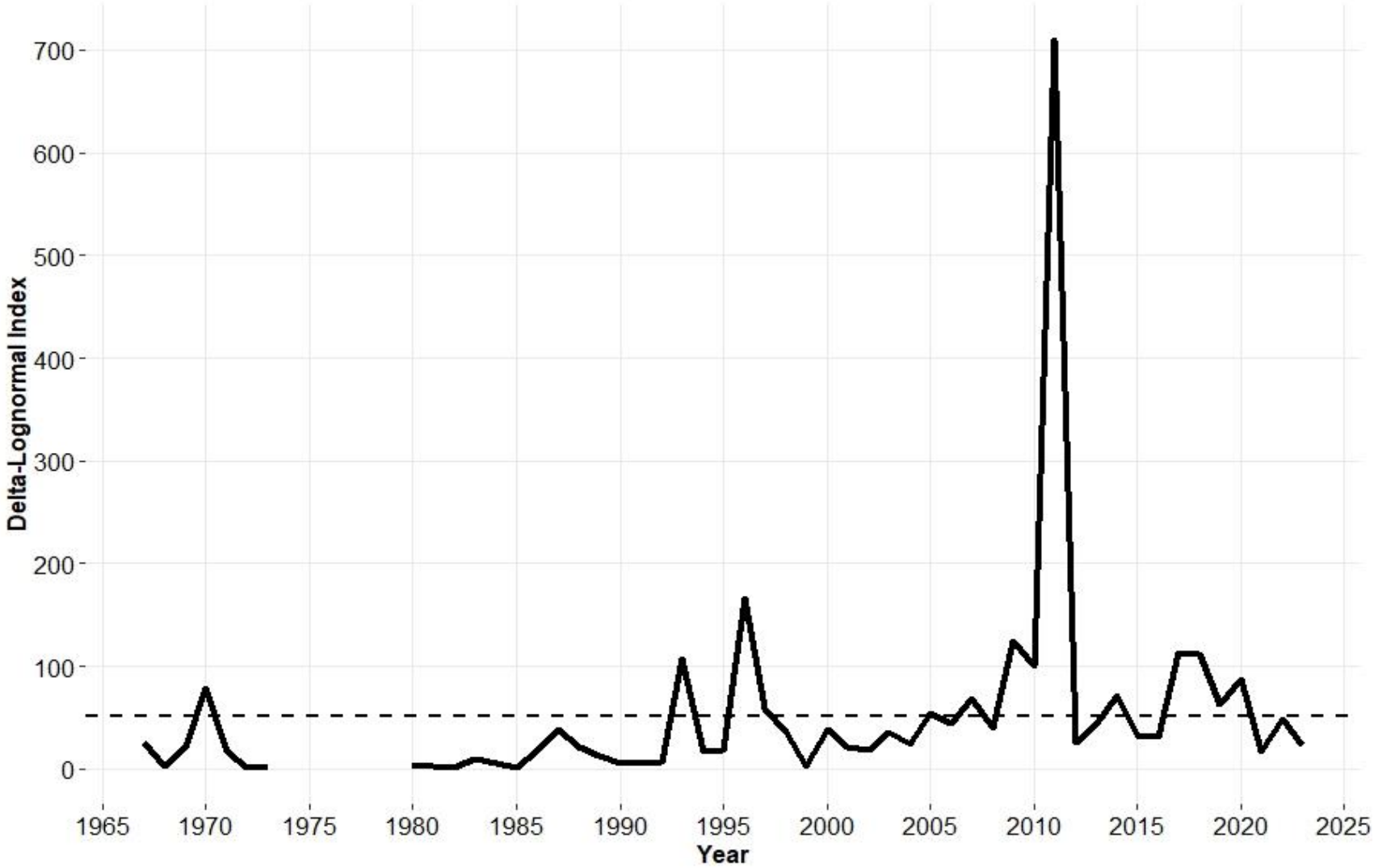

Figure 14. Delta-lognormal mean of young-of-the-year White Perch from the James River nursery area from 1967-2023. The time series average is shown by the horizontal line.

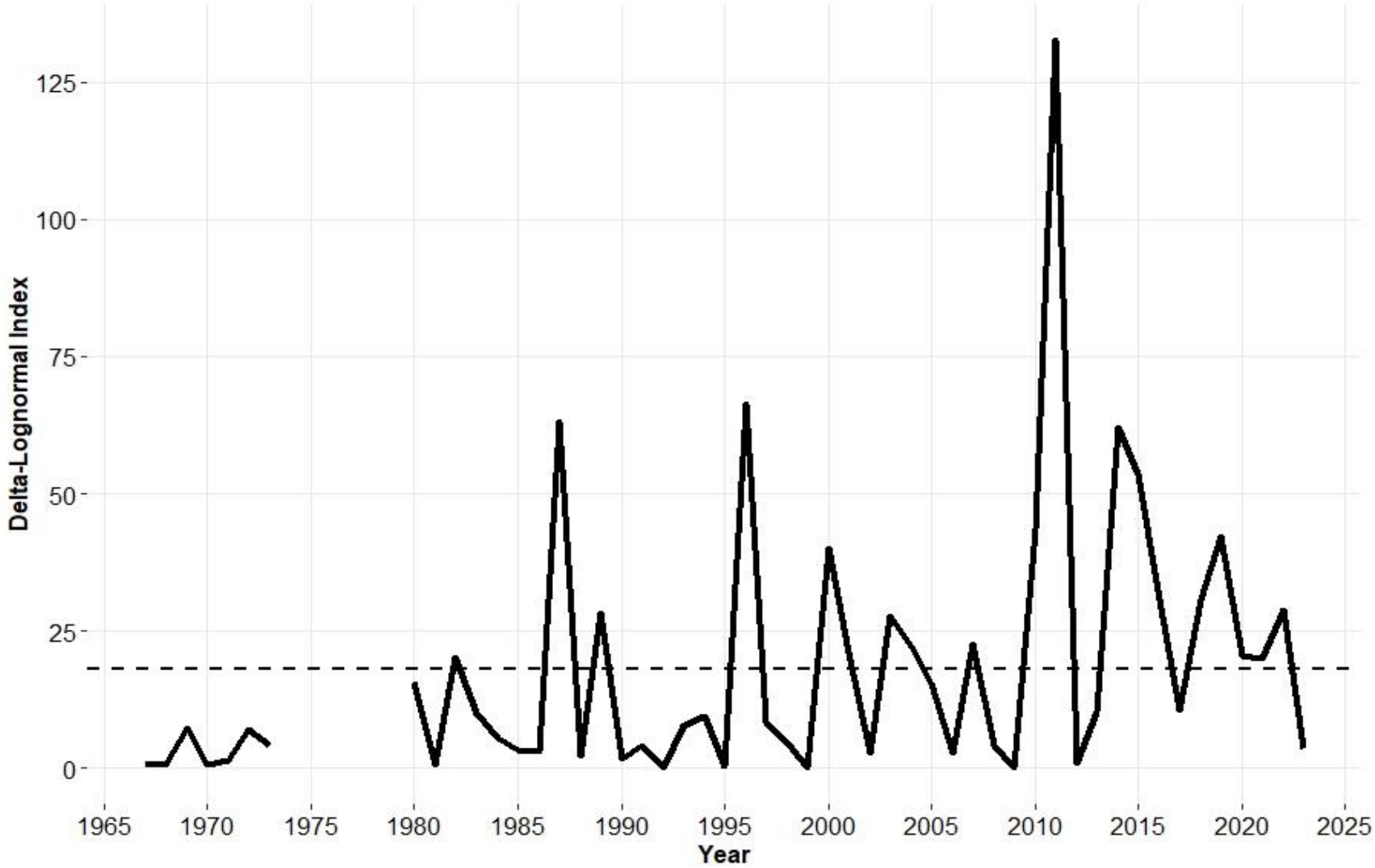

Figure 15. Delta-lognormal mean of young-of-the-year White Perch from the York River nursery area from 1967-2023. The time series average is shown by the horizontal line.

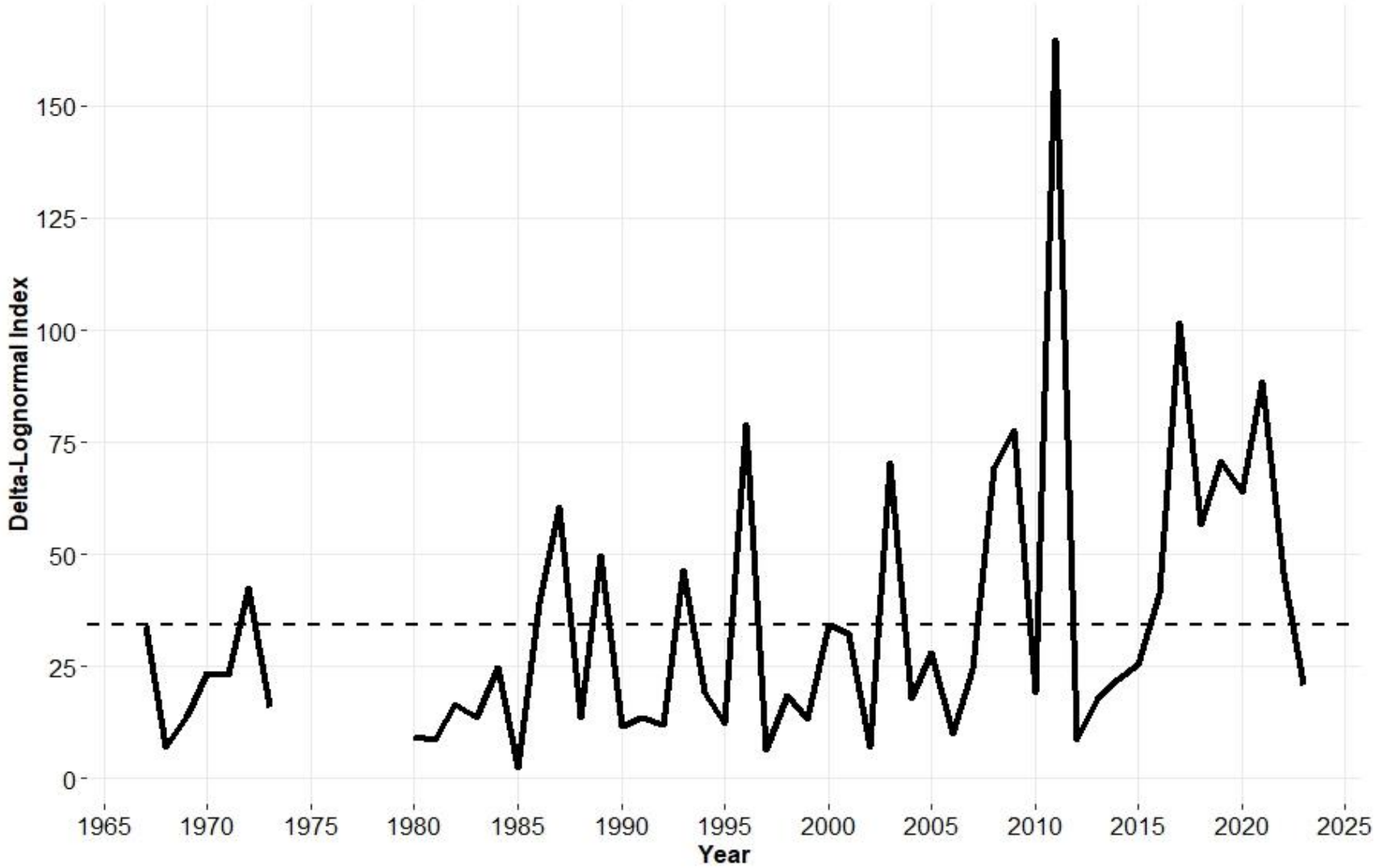

Figure 16. Delta-lognormal mean of young-of-the-year White Perch from the Rappahannock River nursery area from 1967-2023. The time series average is shown by the horizontal line.

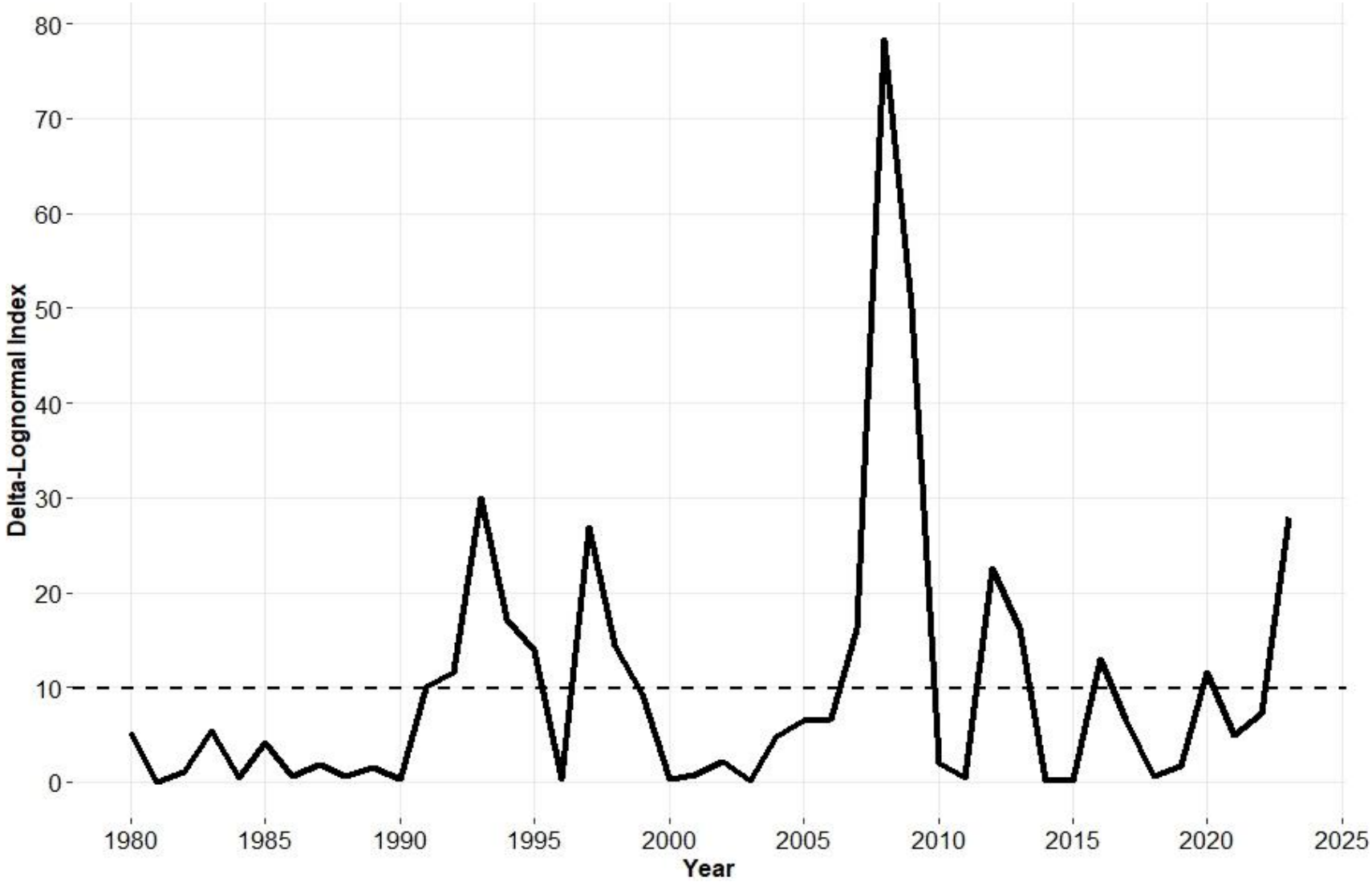

Figure 17. Delta-lognormal mean of young-of-the-year Atlantic Croaker from select seine survey stations in Virginia tributaries of Chesapeake Bay from 1980-2023. The time series average is shown by the horizontal line.

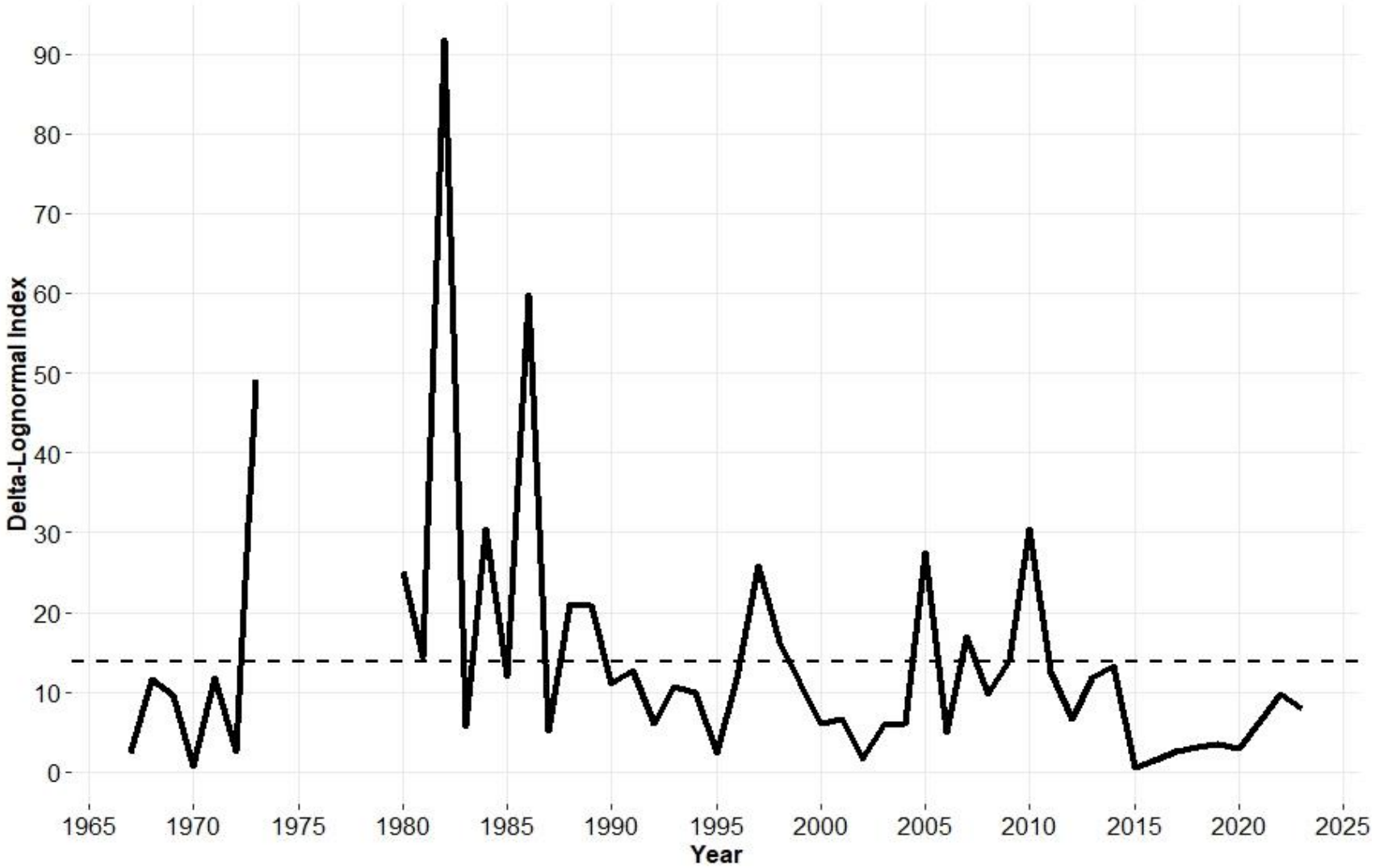

Figure 18. Delta-lognormal mean of young-of-the-year Spot from select seine survey stations in Virginia tributaries of Chesapeake Bay from 1967-2023. The time series average is shown by the horizontal line.

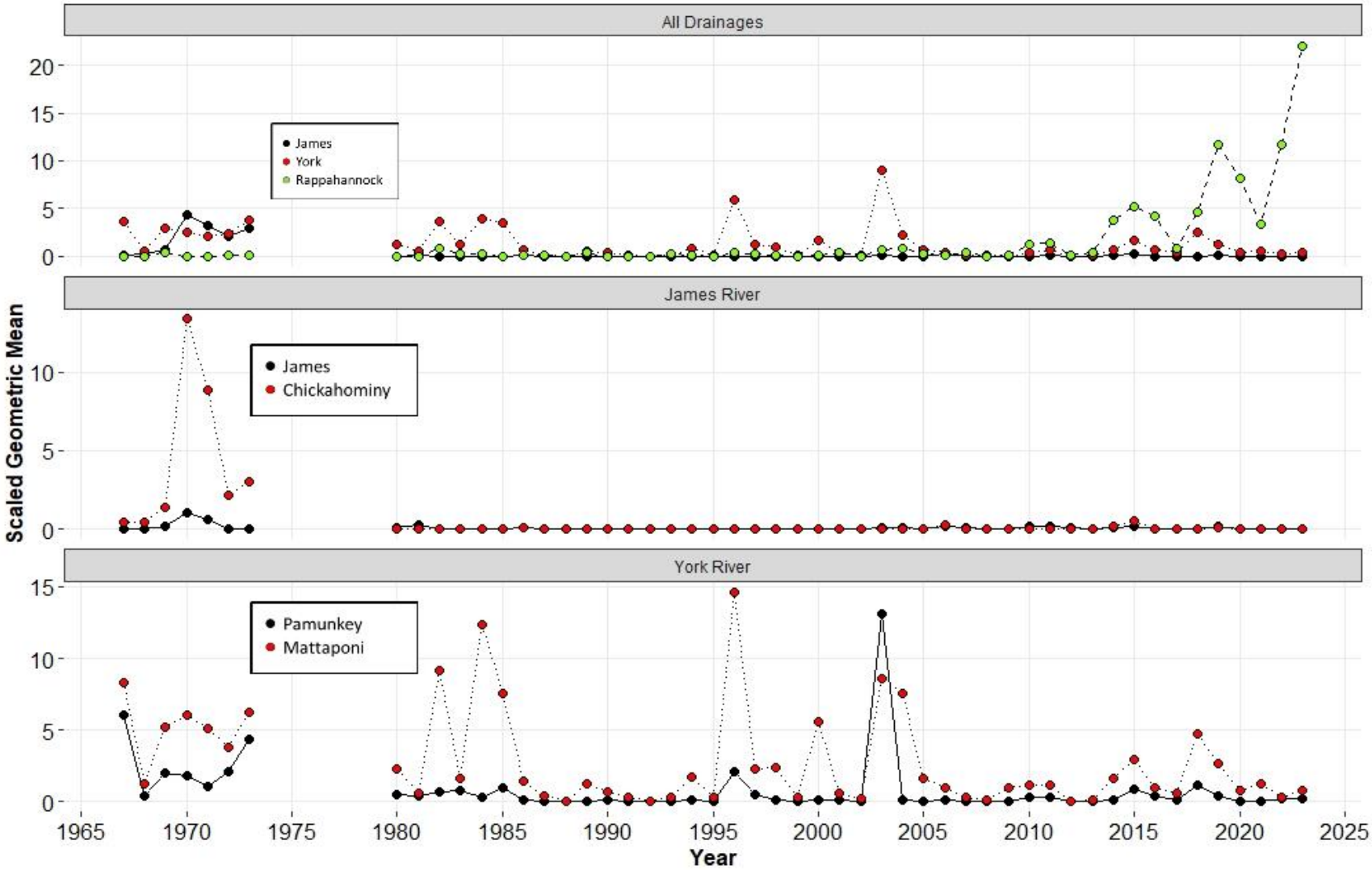

Figure 19. Scaled geometric mean of American Shad in the primary nursery areas of Virginia by drainage and river, using the first haul only.

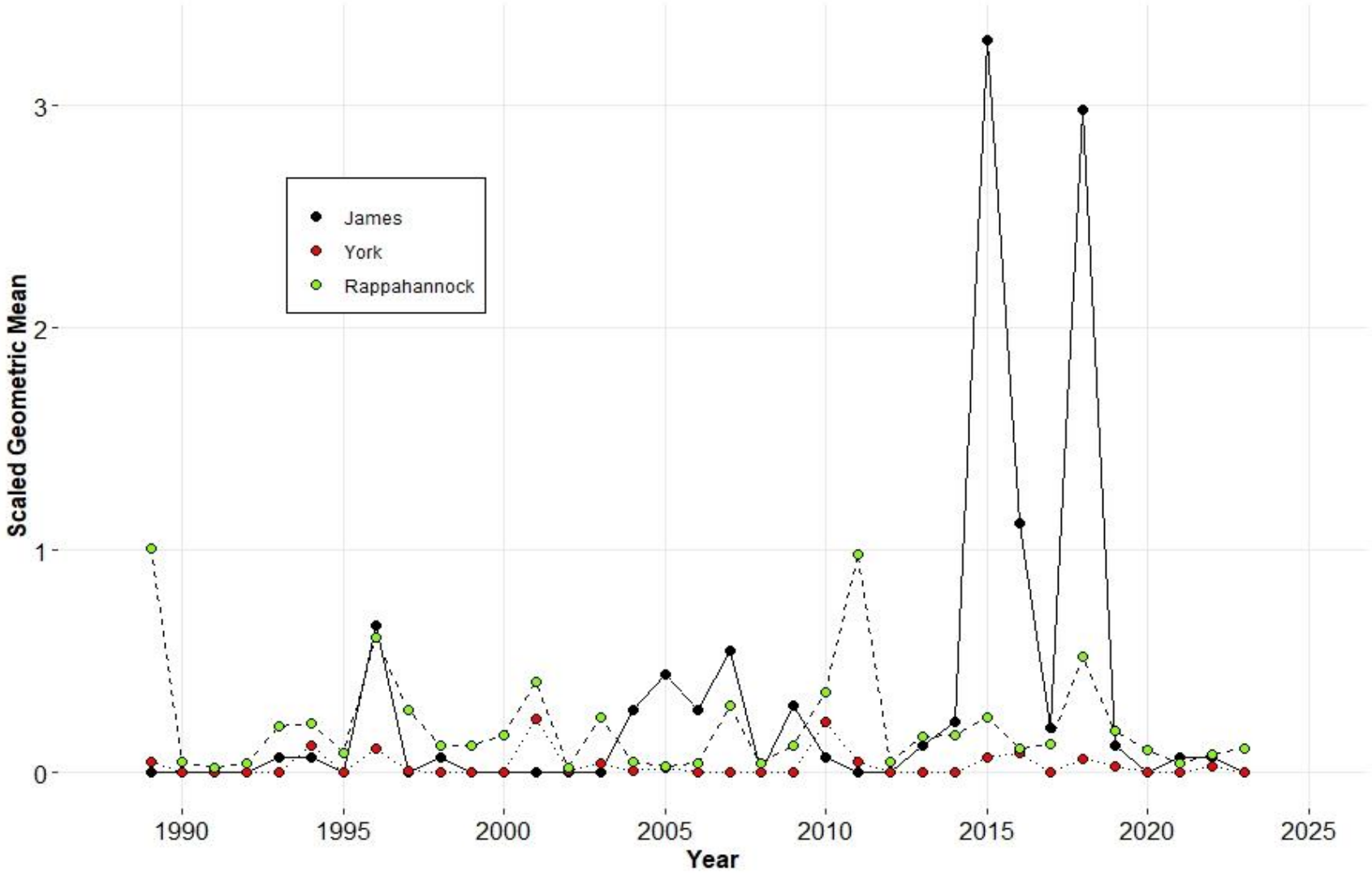

Figure 20. Scaled geometric mean of Alewife in the primary nursery areas of Virginia by drainage, using the first haul only.

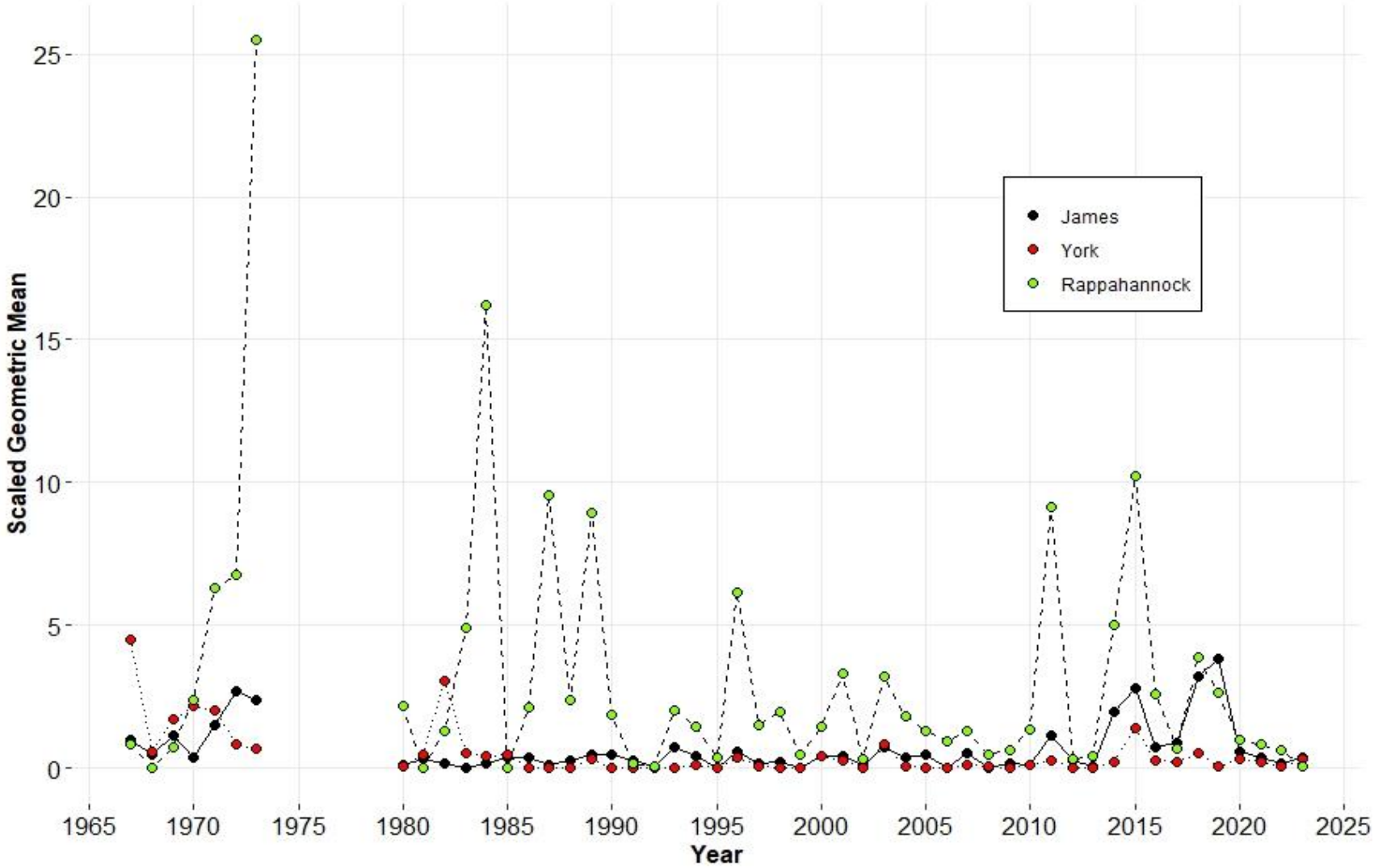

Figure 21. Scaled geometric mean of Blueback Herring in the primary nursery areas of Virginia by drainage, using the first haul only.