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VIRGINIA INSTITUTE OF MARINE SCIENCE

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ANNUAL PROGRESS REPORT: 2022 - 2023

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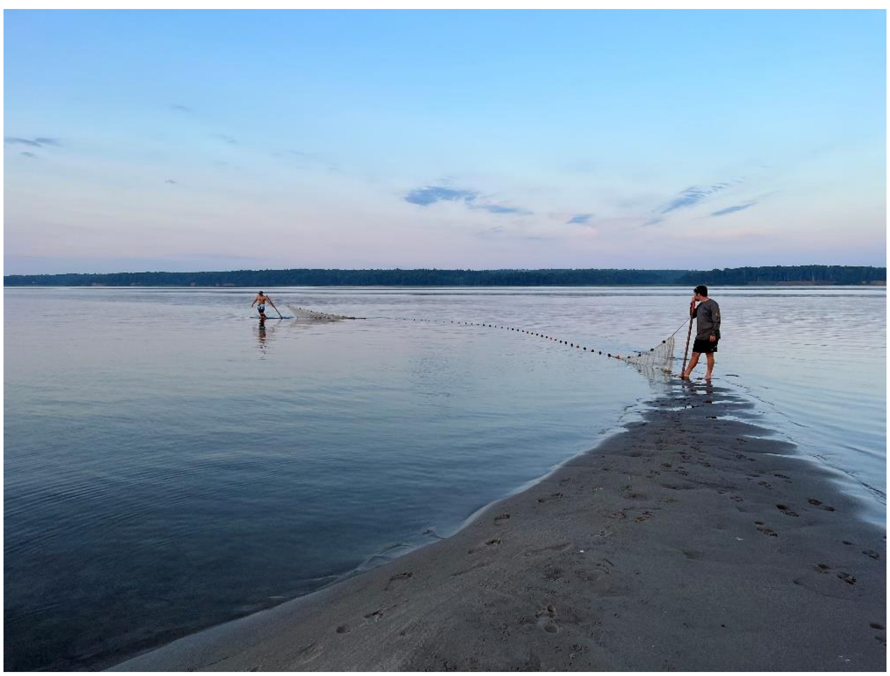

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Cover image

Field Assistants Ethan Dewald and Justin Mitchell seine for juvenile striped bass on the York River.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The 2022 juvenile Striped Bass abundance index was 7.95 and was not significantly different than the reference mean of 7.77 for the period 1980 to 2009. Abundance indices were average in the York and Rappahannock rivers and below average in the James River in 2022 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 2022.

Indices of abundance were also calculated for three additional economically and recreationally important fishes in Virginia waters. Juvenile White Perch abundance indices in 2022 were above historic averages in the York and Rappahannock river systems, but similar to the historic average in the James River. Atlantic Croaker abundance in 2022 was similar to the historic average observed in Virginia waters. In contrast, the abundance index for Spot in 2022 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. Record high indices were recorded for Banded Killifish and Inland Silverside in 2022. Juvenile abundance indices for Atlantic Silverside and Spottail Shiner were generally above their historic averages in 2022. The abundance index for American Shad was the highest recorded in the Rappahannock River, above average in the Mattaponi River, average in the Pamunkey River, and below average in the James, Chickahominy, and York rivers. The abundance index for Alewife was below average in the James River, but average in the York and Rappahannock rivers. Juvenile abundance indices for Blueback Herring were average in the James, York, and Rappahannock rivers. Together, these results suggest relatively moderate to high production of forage fish prey for piscivores in Virginia.

Exploratory sampling was conducted at two sites, JC4 on the Chickahominy River and AP1 on the Appomattox River, in 2022. Both sites were sampled once during each round for a total of five hauls at each site. Site JC4 provides increased geographic

coverage and sample size for the Chickahominy River. In five hauls at site JC4, 70 juvenile Striped Bass were collected, while only 44 juvenile striped bass were captured at index sites JC1 and JC3, where a combined total of 20 hauls were completed. Site AP1 was sampled to understand juvenile Striped Bass recruitment in the Appomattox River. In the five hauls at AP1, 36 juvenile Striped Bass were collected. We intend to continue sampling both sites next year and further evaluate the potential value of these sites to the seine survey.

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 2022 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 steady 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 2022). Results from the 2022 benchmark stock assessment indicated that the stock was no longer experiencing overfishing, but remained overfished.

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 2022 program were to:

1. estimate the relative abundance of the 2022 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 14 June to 22 August 2022. Pilot sampling was conducted in late May and early June at all index sites when the sites are checked for potential winter damage. A total of 24 hauls were conducted, which revealed that juvenile Striped Bass were of the size range encountered in early July (number of fish = 73; median = 31 mm fork length (FL); range = 22-44 mm). Sampling was initiated in mid-June, about two weeks earlier than the traditional start period (early July), as this coincided with more favorable tide conditions that would allow researchers to properly sample sites throughout the survey's duration.

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 grounds in years of high juvenile abundance. In 2022, extensive growth of underwater vegetation (mostly *Hydrilla*) at sites J46 and P56 (in rounds 3-5) and JC1 and JC3 (in rounds 4-5) resulted in hauls being moved to the nearest area of vegetation-free water.

In addition to the 18 index stations and 21 auxiliary stations, exploratory sampling was conducted at two locations. In an effort to increase the number of sites sampled in the Chickahominy River, a suitable site for sampling was identified approximately 0.5 miles upriver of site JC3. To better understand juvenile Striped Bass recruitment in the Appomattox River, a site approximately two miles from the river mouth was sampled. Both sites were sampled once per round. Due to the exploratory nature of the data from these sites, they were not included in the 2022 juvenile abundance index calculation, however, catch information is provided in Appendices I and II.

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. 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, 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, and dissolved oxygen concentration were measured after the first haul was completed using a YSI water-quality sampler, and turbidity was 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

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

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 2022 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 2022 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 2022 were compared graphically with long-term average conditions to assess changes in habitat condition for juvenile Striped Bass. For temperature and salinity, the long-term average was calculated using observations from 1989 to 2021; 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 has been measured since 1992, so the long-term average was calculated using observations from 1992 to 2021. In all cases, conditions in 2022 were compared with those in the period 1989 to 2021 (temperature, salinity) or 1992 to 2021 (dissolved oxygen).

RESULTS AND DISCUSSION

Juvenile Striped Bass Index of Abundance for Virginia

We collected 2,236 young-of-the-year Striped Bass in 2022 from 180 seine hauls at index stations and 423 individuals from 105 hauls at auxiliary stations (Table 1). Using index-station catches from both hauls, the estimated Striped Bass recruitment index in 2022 was 7.95 (lower confidence interval [LCI] = 6.05, upper confidence interval [UCI] =

10.29; Table 2), which was not significantly different 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 2022, 1,485 young-of-the-year Striped Bass were collected, resulting in an index of 10.42 (LCI = 7.09, UCI = 14.92, Table 3), which was not significantly different than the first-haul reference period index of 9.57 (LCI = 7.43, UCI = 12.17). The first-haul index was also not significantly different from 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 2021 (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 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 remains 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 2021, 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 2022 varied relative to their individual means from the 1980-2009 reference period (Table 4; Figure 3). The 2022 JAI for the James River drainage was 5.00 (LCI = 3.09, UCI = 7.60), which was significantly lower than the reference period index of 10.41 (LCI = 7.83, UCI = 13.64; Table 4). The 2022 JAI for the York River drainage was 7.05 (LCI = 4.80, UCI = 10.03), which was not significantly different from the reference period index of 5.85 (LCI = 4.50, UCI = 7.48; Table 4). The 2022 JAI for the Rappahannock River drainage was 15.24 (LCI = 8.50, UCI = 26.17), which was not significantly different 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 six mid-river stations: four in the James River (J36, J42, J46, J51) and two in the Chickahominy River (C1, C3). Historically, these six stations tend to have relatively high and stable abundance. In 2022, 40% 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 (52%) or downriver sites (8%; 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 2022 JAI for the James River main stem (excluding the Chickahominy River) was 7.08 (LCI = 4.07, UCI = 11.51), which was not significantly different from the reference period index of 9.72 (LCI = 7.06, UCI = 13.12; Table 4). In contrast, the 2022 JAI for the Chickahominy River was 2.13 (LCI = 0.64, UCI = 4.37), which was significantly lower than the reference period index of 11.95 (LCI = 8.70, UCI = 16.15; Table 4). In

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 the two index sites (JC1 and JC3) in the Chickahominy River. 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 2022, 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 2022 Pamunkey River JAI of 4.09 (LCI = 2.37, UCI = 6.45) was not significantly different than the reference period index of 6.90 (LCI = 4.90, UCI = 9.44; Table 4), and the 2022 Mattaponi River index of 10.15 (LCI = 6.03, UCI = 16.32) 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 2022, as the majority of Striped Bass were captured within the core nursery area in the Pamunkey (57%) and Mattaponi (95%) rivers. Overall, approximately 17% of Striped Bass in the York River drainage were collected from the Pamunkey River and 77% from the Mattaponi River in 2022; the remainder (6%) were from the York River auxiliary stations (Table 1).

The 2022 JAI for the Rappahannock River drainage was 15.24 (LCI = 8.50, UCI = 26.17), which was not significantly different 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 2022, 89% of the total Rappahannock River catch was taken within the core nursery area (Table 1). The remaining Striped Bass were captured at upriver (9%) or downriver sites (2%; Table 1).

Striped Bass Collections from Auxiliary Stations

Figures 4-6 illustrate the spatial distribution of the 2022 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 2022, which suggests that fish mostly remained within the core nursery area.

During 2022, juvenile Striped Bass were captured at all auxiliary sites in the James River. Catches of juvenile Striped Bass in the James River were relatively low at the lower-most sites (Tables 1 and 5; Figure 4). Striped Bass were collected from all auxiliary sites in the Pamunkey and Mattaponi rivers in 2022 (Tables 1 and 5; Figure 5). In the York River main stem, relatively high numbers of 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. 2021). In 2022, we detected few juvenile Striped Bass at the uppermost auxiliary site in the Pamunkey (P56; 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 site P56 may have been affected by the altered state of the nearshore area. For example, the presence of dense *Hydrilla* stands at site P56 may be forcing Striped Bass into deeper waters; 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 River (site J46) and Chickahominy rivers (sites JC1 and JC3) indicating expansion of *Hydrilla* beds in Virginia's waters and the potential for further sampling issues in the future.

Relatively high numbers of juvenile Striped Bass were collected at upriver Rappahannock sites (R60, R65, R69, R76) in 2022, equating to JAIs that exceeded historical values for those sites (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 2022 with no individuals collected at site R12 and two at site R21 (Table 1; Figure 6).

Juvenile Striped Bass Indices by Sampling Round

Indices of juvenile abundance calculated by sampling round in 2022 were not significantly different from the averages calculated during the 1980-2009 reference period (Table 6). The largest number of young-of-the-year Striped Bass were collected during rounds 1 and 3 in 2022, 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 2022, 33% of all juvenile Striped Bass were captured in round 1; this was followed by a modest decline (-38%) in the number of Striped Bass captured in round 2, a pattern that was greater than average declines observed between rounds 1 and 2 during the reference period (-22%). A slight increase (8.5%) 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 (-25.6%). There were also modest declines in 2022 catches during the fourth (-32%) and fifth (-45%) rounds, which were greater than reference period averages of -11.9% in the fourth and -30.8% 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 in 2022: mean water temperatures were generally below historic averages during rounds 1 and 2 and ranged between 25 and 29°C (Figure 7). During round 3, mean water temperatures generally increased to historic averages. Mean water temperatures were generally above historic averages in round 4. In round 5, mean water temperatures returned to near historic averages (Figure 7). These high temperatures were largely consistent with statewide average air temperatures from June to August of 2022, which were “above average” in Virginia (NCDC 2022). Relatively high water temperatures in Striped Bass nursery areas have now occurred during ten consecutive years, with a similarly high range of temperatures observed since 2013 (Buchanan et al. 2022). This temperature pattern did not seem to affect catches in previous years, however. Similarly, catch rates in 2022 followed the historic pattern with respect to water temperature: 100% of juvenile Striped Bass caught at 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 that was typically observed prior to 2022 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 2022, average salinities were generally similar to historical averages on all rivers, except for the Chickahominy River, where salinity was 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 2022 were obtained at salinities less than 5 ppt on average (Table 5). In 2022, salinities at downriver stations were similar to their historic averages. No index stations exhibited mean salinities exceeding 10.0 ppt in 2022, although mean salinities as high as 17.5 ppt were observed at one auxiliary station in the York River (Y15) (Table 5).

Historically, mean dissolved oxygen (DO) concentrations decrease from rounds 1 to 2, stabilize during rounds 3 and 4, then increase slightly in round 5 (Figure 9). Mean DO concentrations in 2022 generally were greater than long-term averages during rounds 1 and 2 (Figure 9). During rounds 3, 4, and 5, DO concentrations generally overlapped, or were less than, historical averages, the exception being the James River in round 3 and the Pamunkey in round 5 where DO concentrations were greater than the historic average. Relationships between DO 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. Thus, instantaneous measures of DO concentrations do not appear to affect seine-based abundance estimates of juvenile Striped Bass.

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 2022 (December 2021-May

2022) was “near average” in Virginia relative to historical conditions since 1895 (NCDC 2022). Although these regional precipitation conditions were “near average,” salinities were generally below 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 10, USGS 2022). In 2022 and in most Virginia rivers, freshwater flow was generally below average from January to September, with peaks in March and May (Figure 10). 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 2022, more than 62,000 individuals comprising 74 species were collected (Table 8). The five most common species encountered in 2022 were Atlantic Menhaden (*Brevoortia tyrannus*), Atlantic Silverside (*Menidia menidia*), Spottail Shiner (*Notropis hudsonius*), White Perch (*Morone americana*), and Banded Killifish (*Fundulus diaphanus*). This was different from 2021, when Bay Anchovy (*Anchoa mitchilli*) and Mummichog (*Fundulus heteroclitus*) were among the top five species captured, and Atlantic Menhaden and Atlantic Silverside were not among the top five. In 2022, a Smallmouth Flounder (*Etropus microstomus*) was captured at site J62 on the James River; this was the first time in the history of the seine survey that this species was observed. Indices of abundance were estimated for 10 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 1967-2010.

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 2022 sampling period, 4,447 young-of-the-year White Perch were collected from 132 seine hauls at 34 sites (10 sites in the James, 13 in the York and 10 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, river-specific JAIs for White Perch suggest above-average recruitment in the York and Rappahannock rivers, but average in the James river in 2022 (Figures 12-14). 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 Fish Trawl Survey (Tuckey and Fabrizio 2022); 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 2022 were spawned during fall 2021. 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 (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 (Table 10; Figure 15). Based on 2022 catches from 16 stations during rounds 1 to 3, we encountered 229 young-of-the-year Atlantic Croaker in 32 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 2022). In 2022, an 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 11; Figure 16). Based on catches from 22 stations during 5 rounds in 2022, 732 young-of-the-year Spot were collected in 60 seine hauls. Using the delta-lognormal approach, we observed below-average relative abundance for Spot in 2022, similar to estimates from the previous seven years (Table 11; Figure 16).

Indices of relative abundance for common forage species within the tidal nearshore zone were computed for Spottail Shiner (28 stations; Table 12), Atlantic Silverside (17 stations; Table 13), Inland Silverside (*Menidia beryllina*; 32 stations; Table 14), and Banded Killifish (*Fundulus diaphanus*; 26 stations; Table 15). Catches from all 5 rounds were used to estimate abundance indices for these species. The 2022 Spottail Shiner delta-lognormal mean of 41.0 was greater than the historic average of 28.5 (Table 12). The 2022 Atlantic Silverside delta-lognormal mean of 80.5 was greater than the historic average of 48.5 (Table 13). The 2022 Inland Silverside delta-lognormal mean of 21.2 was the highest index observed since 1989 and higher than the historic average of 5.5 (Table 14). The 2022 Banded Killifish delta-lognormal mean of 17.8 was the highest index observed since 1989 and higher than the historic average of 5.7 (Table 15). Together, these results suggest modest production of forage fish prey was available for piscivores in Virginia waters in 2022. In addition, we note that abundance indices for the four freshwater forage species (Spottail Shiner, Atlantic Silverside, Inland Silverside and Banded Killifish) have been increasing since 1989.

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 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 2022 geometric mean abundance index for American Shad was the highest recorded in the Rappahannock River, however, below-average indices were recorded in the James and York rivers (Figure 17). For Alewife, the 2022 geometric mean abundance index was below average in the James and average in the York and

Rappahannock rivers (Figure 18). The 2022 geometric mean abundance indices for Blueback Herring were average in the three river systems (Figure 19).

CONCLUSION

The 2022 juvenile abundance index (JAI) for Striped Bass (7.95) was not significantly different than the average for 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 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 or deteriorating conditions in nursery areas. The Juvenile White Perch abundance index in 2022 was higher than the historic average. The Atlantic Croaker abundance index was similar to the historic average, while the Spot abundance index was below the historic average in 2022. Abundance indices for three Alosine species were generally average or below-average in the James and York rivers and average or above-average in the Rappahannock River in 2022, 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 2022. Two hauls were completed at each index station (bold). Sampling was completed in June (rounds 1 and 2), July (rounds 3 and 4), and August (round 5).

Drainage																Round Total
JAMES		Station	J12	J26	**J29**	**J36**	J42	**C1**	**C3**	**J46**	J51	**J56**	J62	J68	J77	
	Round	1	1	0	0/0	2/2	1	0/0	1/0	2/0	13	1/1	11	0	0	35
		2	0	0	1/2	3/0	18	5/13	0/0	0/0	6	21/2	2	0	0	73
		3	0	1	2/6	0/3	2	13/6	0/0	5/23	17	62/18	9	8	9	184
		4	1	1	3/5	19/7	6	3/0	0/0	0/7	3	40/18	11	1	4	129
		5	0	0	15/4	1/0	14	0/1	1/1	0/0	9	17/19	3	10	0	95
														James Total		**516**
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56						
	Round	1	0	3	6	11	0/2	26/3	24/4	6						85
		2	0	6	5	10	4/2	2/0	3/0	0						32
		3	1	8	8	5	4/1	2/0	3/0	0						32
		4	0	7	3	1	2/3	1/0	1/0	0						18
		5	0	0	4	0	7/0	3/2	1/2	0						19
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52					
	Round	1				80/5	11	39/4	3/2	1/1	3					149
		2				57/15	3	1/1	14/14	1/0	0					106
		3				211/0	7	15/0	15/10	3/0	0					261
		4				13/2	13	3/1	9/5	1/6	2					55
		5				13/3	2	2/4	2/0	1/10	0					37
														York Total		**794**
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76		
	Round	1	0	2	1/0	0/2	10	194/111	43/22	127/45	7	27	2	9		602
		2	0	0	0/0	1/0	0	58/79	62/31	34/35	6	33	3	0		342
		3	0	0	0/0	1/0	1	2/5	28/8	17/37	5	11	3	2		120
		4	0	0	1/0	0/0	0	11/6	27/28	55/62	11	1	0	0		202
		5	0	0	0/0	1/0	1	2/7	14/6	22/27	3	0	0	0		83
														Rappahannock Total		**1,349**
														2022 Catch		**2,659**

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
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.

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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	0.97	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
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 2022 summarized by drainage and river.

	2022				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	355	5.00	3.09-7.60	60	17,650	10.41	7.83-13.64	30
James	311	7.08	4.07-11.51	40	10,727	9.72	7.06-13.12	30
Chickahominy	44	2.13	0.64-4.37	20	6,923	11.95	8.70-16.15	30
YORK	669	7.05	4.80-10.03	70	12,470	5.85	4.50-7.48	30
Pamunkey	102	4.09	2.37-6.45	30	6,442	6.90	4.90-9.44	30
Mattaponi	567	10.15	6.03-16.32	40	6,028	5.16	4.06-6.45	30
RAPPAHANNOCK	1,212	15.24	8.50-26.17	50	13,407	7.90	5.63-10.82	30
Overall	2,236	7.95	6.05-10.29	180	43,527	7.77	6.01-9.89	30

Table 5. Striped Bass indices and average site salinity during 2022 compared to average index values during the auxiliary monitoring period (1989-2021), 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**	**J46**	J51	**J56**	J62	J68	J77
	1989-2021	Avg. Sal.	14.4	4.9	4.7	2.3	1.2	1.3	1.1	0.5	0.2	0.2	0.2	0.1	0.1
		Index	1.4	16.0	11.0	16.0	9.9	21.8	12.1	24.5	17.7	11.0	11.2	6.0	3.0
	2022	Avg. Sal.	15.7	7.1	4.6	1.6	0.8	0.8	0.7	0.2	0.1	0.1	0.1	0.1	0.1
		Index	0.7	0.7	5.2	5.6	12.6	5.0	0.7	1.8	19.0	39.4	13.8	4.3	2.7
YORK		Station	Y15	Y21	Y28	P36	**P42**	**P45**	**P50**	P56					
	1989-2021	Avg. Sal.	16.4	13.6	10.5	4.0	1.7	0.6	0.4	0.1					
		Index	1.3	2.7	6.8	10.8	5.2	12.8	18.7	1.0					
	2022	Avg. Sal.	17.5	14.3	10.8	3.3	1.5	0.4	0.1	0.1					
		Index	0.3	8.2	11.3	7.7	5.9	8.1	7.7	1.1					
		Station				**M33**	M37	**M41**	**M44**	**M47**	M52				
	1989-2021	Avg. Sal.				4.4	2.2	1.0	0.4	0.2	0.1				
		Index				9.3	10.8	7.3	9.2	5.9	1.4				
	2022	Avg. Sal.				4.6	1.7	0.3	0.1	0.1	0.0				
		Index				101.5	13.6	13.4	15.5	3.0	1.5				
RAPPAHANNOCK		Station	R12	R21	**R28**	**R37**	R41	**R44**	**R50**	**R55**	R60	R65	R69	R76	
	1989-2021	Avg. Sal.	14.1	12.7	9.9	5.1	2.8	1.7	0.7	0.4	0.2	0.1	0.1	0.1	
		Index	0.6	0.7	4.3	3.0	5.5	12.5	23.2	49.3	6.3	4.8	2.6	0.3	
	2022	Avg. Sal.	14.6	12.8	9.7	4.5	1.3	0.4	0.1	0.1	0.0	0.0	0.1	0.1	
		Index	0.0	0.6	0.7	1.2	2.6	35.5	70.8	89.2	13.6	14.7	2.7	2.2	

Table 6. Catch of young-of-the-year Striped Bass at index stations in 2022 summarized by sampling round.

	2022					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	748	9.37	4.48-17.79		30	13,467	11.97	9.15-15.48	
(2nd)	36	461	8.29	4.15-15.11	-38.4%	30	10,535	9.11	6.84-11.95	-21.8%
July (3rd)	36	500	8.59	4.51-15.11	8.5%	30	7,838	7.26	5.44-9.50	-25.6%
(4th)	36	339	8.17	4.53-13.73	-32.2%	26	6,907	6.88	5.12-9.04	-11.9%
Aug. (5th)	36	188	5.75	3.35-9.17	-44.5%	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 2022 summarized by water temperature.

	2022				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	-	-	-	-	2,430	4.13	3.61-4.70	568
25.0-29.9	1,847	7.24	5.35-9.61	154	33,808	9.11	8.66-9.57	3,588
> 30.0	389	13.38	6.99-24.20	26	6,871	9.66	8.60-10.82	679

Table 8. Fish species collected during the 2022 seine survey (index and auxiliary stations).

Scientific Name	Common Name	Total Caught
Brevoortia tyrannus	Atlantic Menhaden	12,494
Menidia menidia	Atlantic Silverside	7,803
Notropis hudsonius	Spottail Shiner	7,401
Morone americana	White Perch	7,100
Fundulus diaphanus	Banded Killifish	4,779
Menidia beryllina	Inland Silverside	4,080
Anchoa mitchilli	Bay Anchovy	3,205
Fundulus heteroclitus	Mummichog	3,004
Morone saxatilis	Striped Bass	2,659
Alosa sapidissima	American Shad	1,729
Trinectes maculatus	Hogchoker	1,175
Dorosoma cepedianum	Gizzard Shad	959
Leiostomus xanthurus	Spot	918
Notropis analostanus	Satinfin Shiner	665
Dorosoma petenense	Threadfin Shad	588
Alosa aestivalis	Blueback Herring	438
Etheostoma olmstedi	Tessellated Darter	393
Micropogonias undulatus	Atlantic Croaker	344
Fundulus majalis	Striped Killifish	284
Hybognathus regius	Eastern Silvery Minnow	265
Micropterus salmoides	Largemouth Bass	258
Lepomis macrochirus	Bluegill	180
Anchoa hepsetus	Striped Anchovy	162
Enneacanthus gloriosus	Bluespotted Sunfish	140
Lepomis gibbosus	Pumpkinseed	125
Lepomis auritus	Redbreast Sunfish	70
Mugil cephalus	Striped Mullet	69
Ictalurus furcatus	Blue Catfish	63
Notropis bifrenatus	Bridle Shiner	61
Notemigonus crysoleucas	Golden Shiner	60
Membras martinica	Rough Silverside	57
Perca flavescens	Yellow Perch	51
Menticirrhus americanus	Southern Kingfish	50
Strongylura marina	Atlantic Needlefish	47
Anguilla rostrata	American Eel	40
Gambusia affinis	Mosquitofish	28
Bairdiella chrysoura	Silver Perch	28
Cynoscion regalis	Weakfish	27
Ictalurus catus	White Catfish	27
Mugil curema	White Mullet	25
Morone saxatilis age 1+	Striped Bass Age 1+	25

Table 8. (continued)

Scientific Name	Common Name	Total Caught
Ictalurus punctatus	Channel Catfish	21
Pomatomus saltatrix	Bluefish	18
Pomoxis nigromaculatus	Black Crappie	15
Synodus foetens	Inshore Lizardfish	15
Scomberomorus maculatus	Spanish Mackerel	14
Symphurus plagiusa	Blackcheek Tonguefish	14
Hemiramphus brasiliensis	Ballyhoo	14
Nocomis raneyi	Bull Chub	13
Alosa pseudoharengus	Alewife	12
Moxostoma macrolepidotum	Shorthead Redhorse	11
Paralichthys dentatus	Summer Flounder	10
Lagodon rhomboides	Pinfish	10
Lepisosteus osseus	Longnose Gar	9
Ictalurus nebulosus	Brown Bullhead	7
Gobiesox strumosus	Skilletfish	7
Alosa mediocris	Hickory Shad	6
Sciaenops ocellatus	Red Drum	5
Cynoscion nebulosus	Spotted Seatrout	5
Cyprinus carpio	Common Carp	4
Trachinotus falcatus	Permit	4
Syngnathus fuscus	Northern Pipefish	3
Elops saurus	Ladyfish	3
Hippocampus erectus	Lined Seahorse	2
Lepomis microlophus	Redear Sunfish	2
Chaetodipterus faber	Atlantic Spadefish	1
Noturus gyrinus	Tadpole Madtom	1
Gobiosoma bosci	Naked Goby	1
Rhinoptera bonasus	Cownose Ray	1
Astroscopus guttatus	Northern Stargazer	1
Etropus microstomus	Smallmouth Flounder	1
Amia calva	Bowfin	1
Syngnathus louisianae	Chain Pipefish	1
Paralichthys lethostigma	Southern Flounder	1
	Total	62,109

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	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	1,702	47.7	1,085	28.8	1,660	45.8	132

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	1.8	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
Overall (1980-2021)	14,904	9.4	42 (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	49.0	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
Overall (1967-2021)	38,375	14.0	49 (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	18.0	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	5,672	41.0	113
Overall (1989-2021)	116,612	28.5	33 (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	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
Overall (1989-2021)	115,794	48.5	33 (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	3.0	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	3,445	21.2	126
Overall (1989-2021)	30,493	5.5	33 (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	1.5	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	2,989	17.8	104
Overall (1989-2021)	26,514	5.7	33 (years)

FIGURES

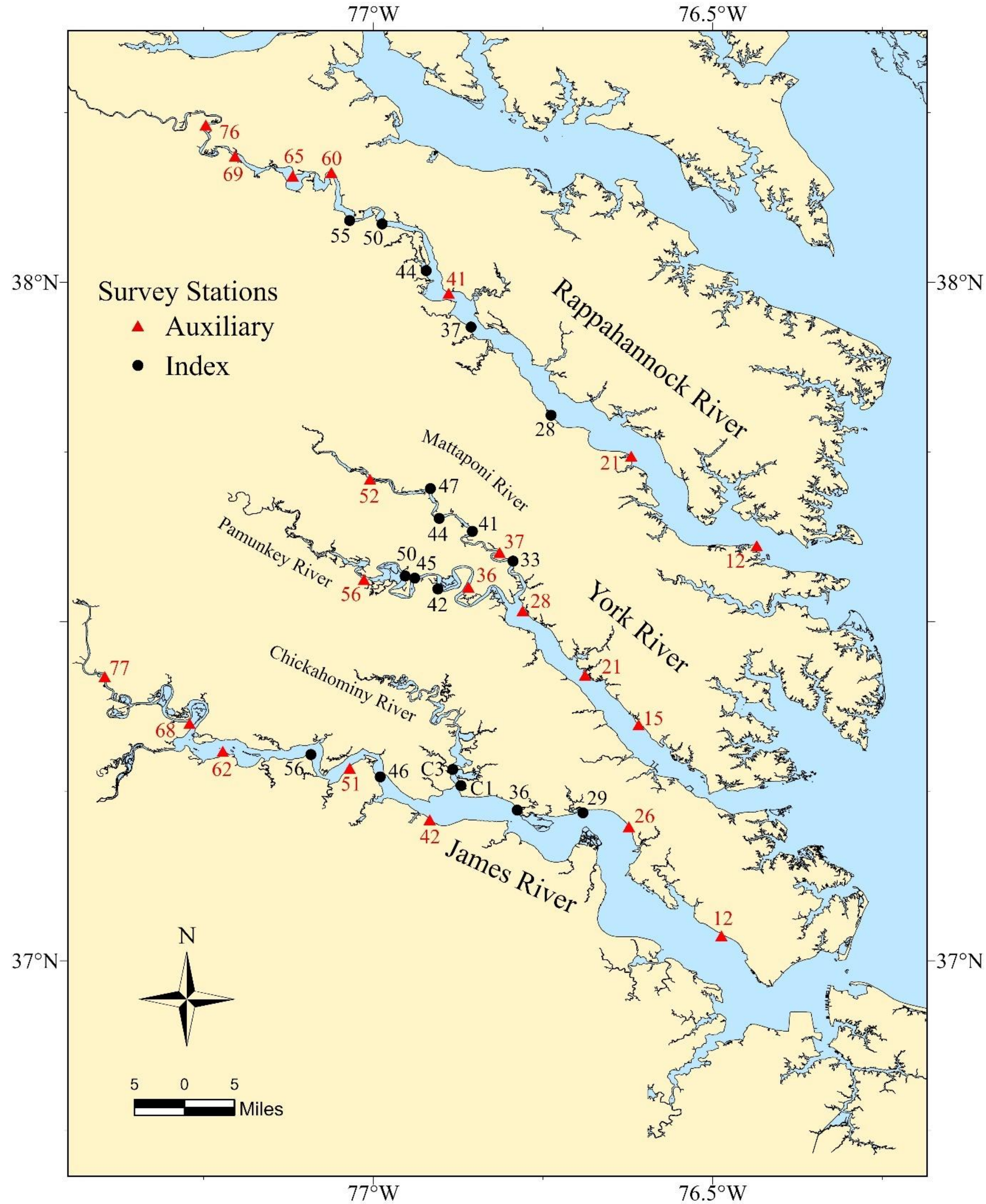


Figure 1. Juvenile Striped Bass seine survey stations. Station numbers denote the approximate river mile from the mouth.

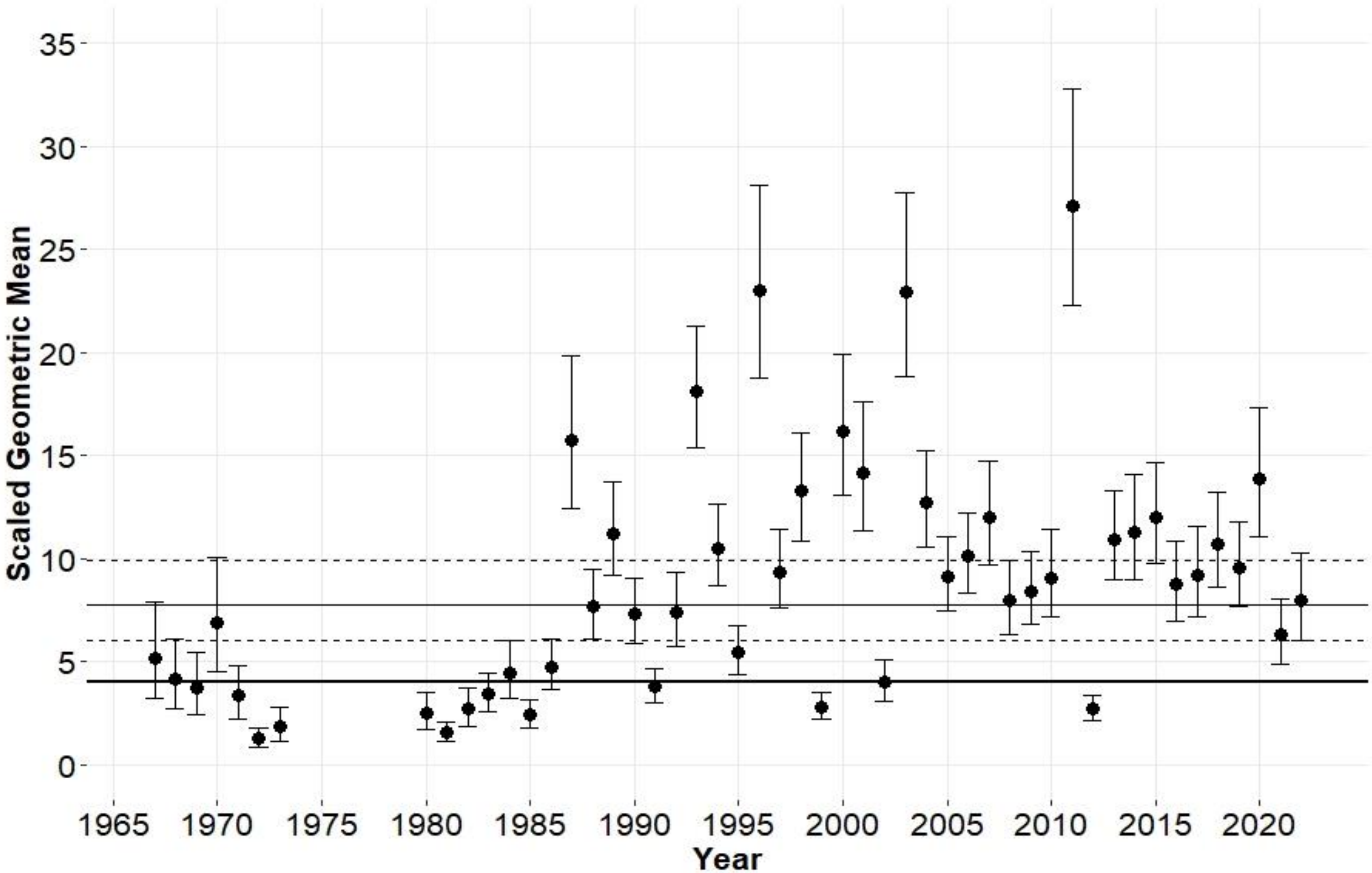


Figure 2. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by year. Vertical bars are 95% confidence intervals as estimated by ± 2 standard errors of the mean. Horizontal lines indicate the arithmetic mean (thin solid), confidence intervals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

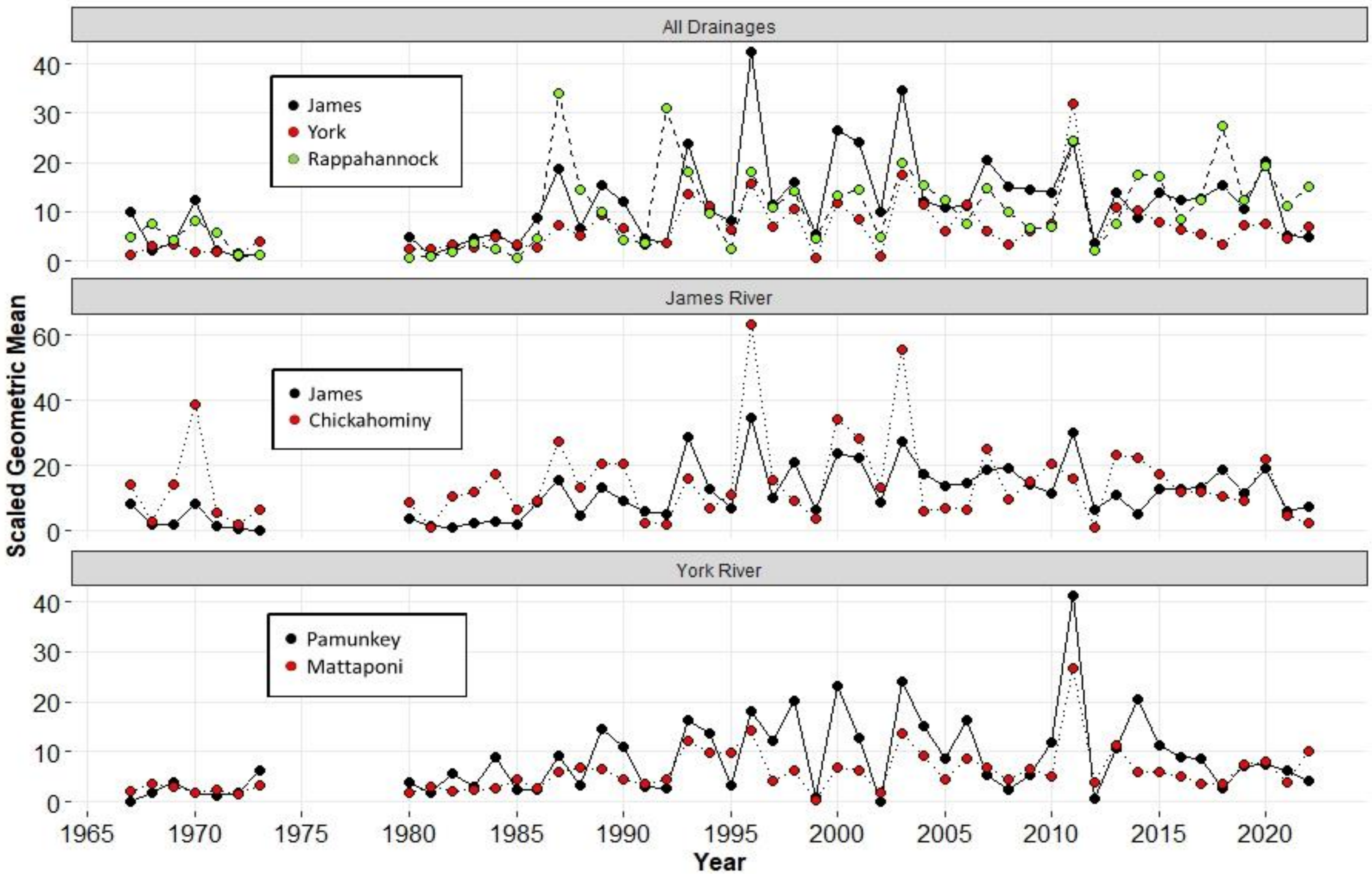


Figure 3. Scaled geometric mean of young-of-the-year Striped Bass in the primary nursery areas of Virginia (index stations) by drainage and river.

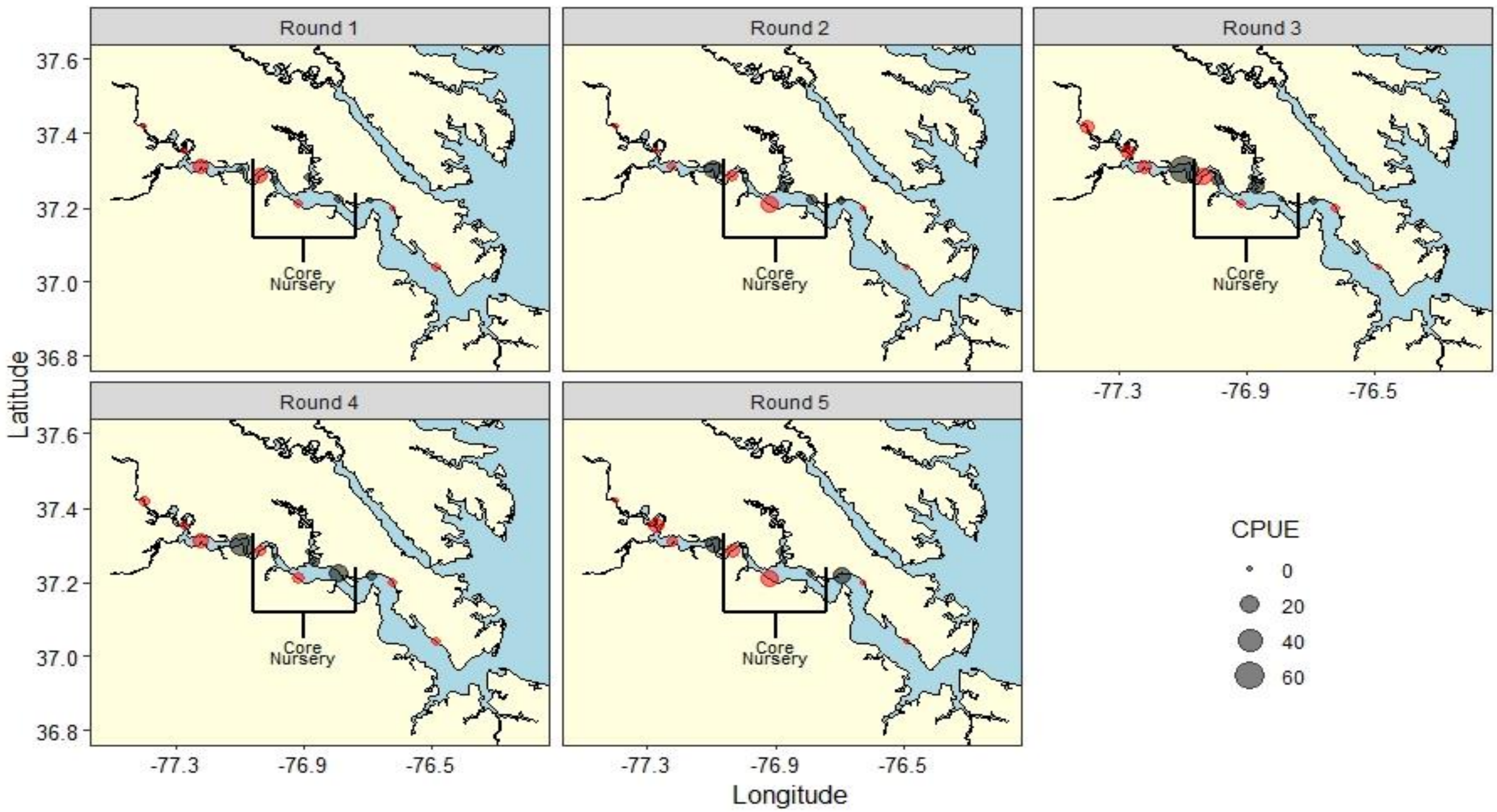


Figure 4. Catch per unit effort of juvenile Striped Bass by station in the James River drainage during each round in 2022. Data are shown for index (black) and auxiliary (red) stations, using the first haul only. The core nursery area is delineated by thick black lines. Hauls were not completed at all index and auxiliary stations during all rounds in 2022 (see Methods).

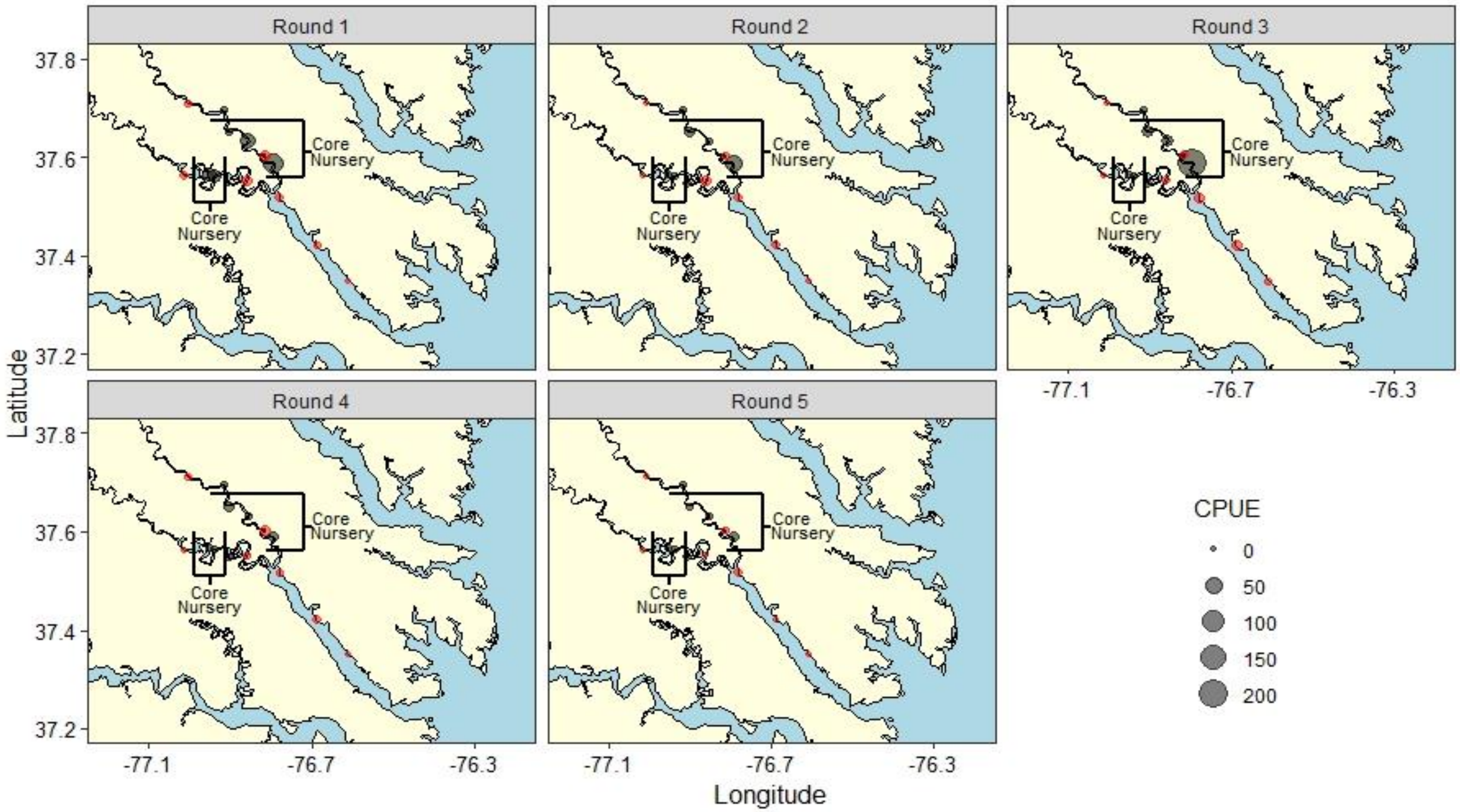


Figure 5. Catch per unit effort of juvenile Striped Bass by station in the York River drainage during each round in 2022. Data are shown for index (black) and auxiliary (red) stations, using the first haul only. Core nursery areas in the Pamunkey and Mattaponi rivers are delineated by thick black lines. Hauls were not completed at all index and auxiliary stations during all rounds in 2022 (see Methods).

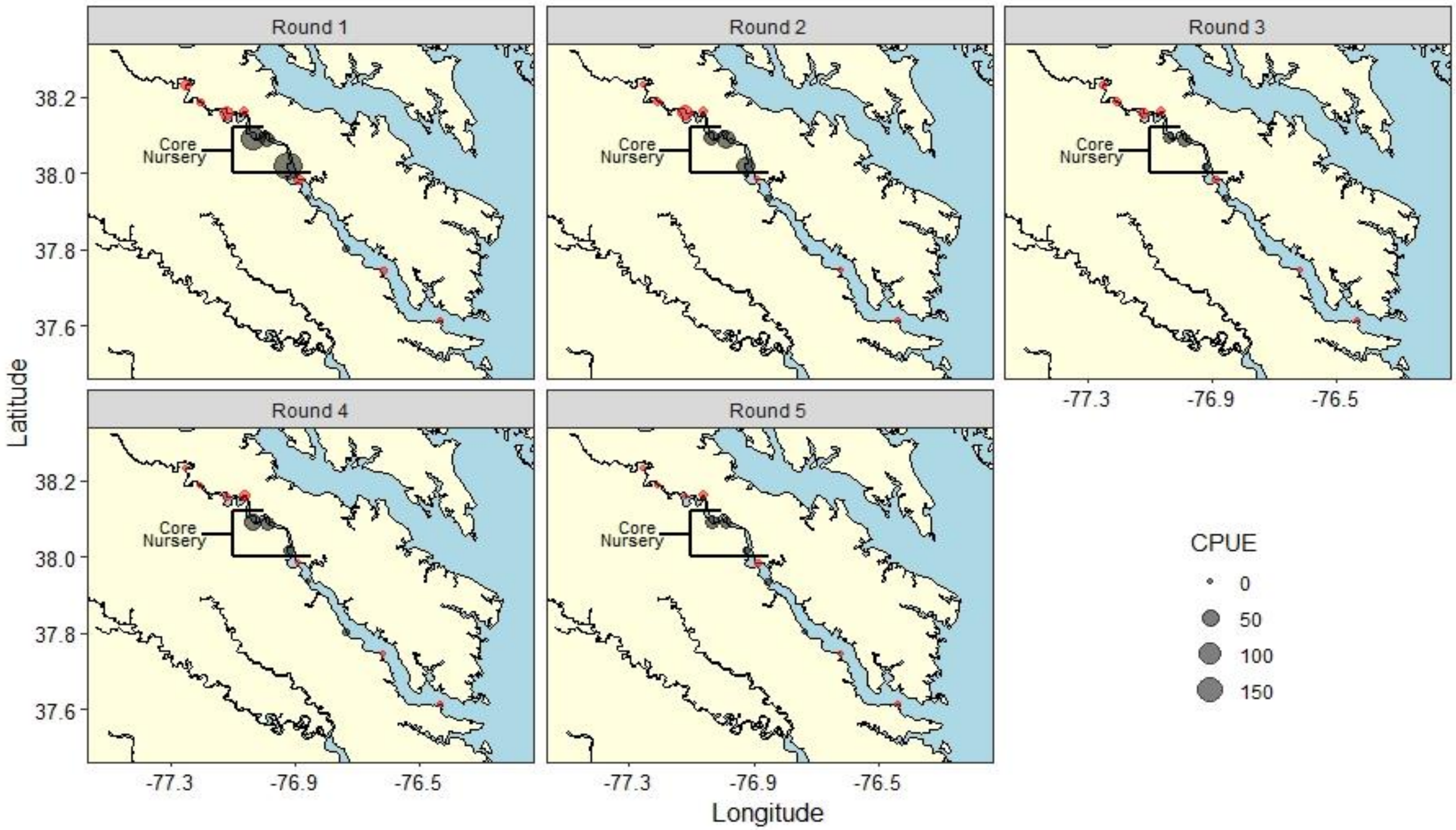


Figure 6. Catch per unit effort of juvenile Striped Bass by station in the Rappahannock River drainage during each round in 2022. Data are shown index (black) and auxiliary (red) stations, using the first haul only. The core nursery area is delineated by thick black lines. Hauls were not completed at all index and auxiliary stations during all rounds in 2022 (see Methods).

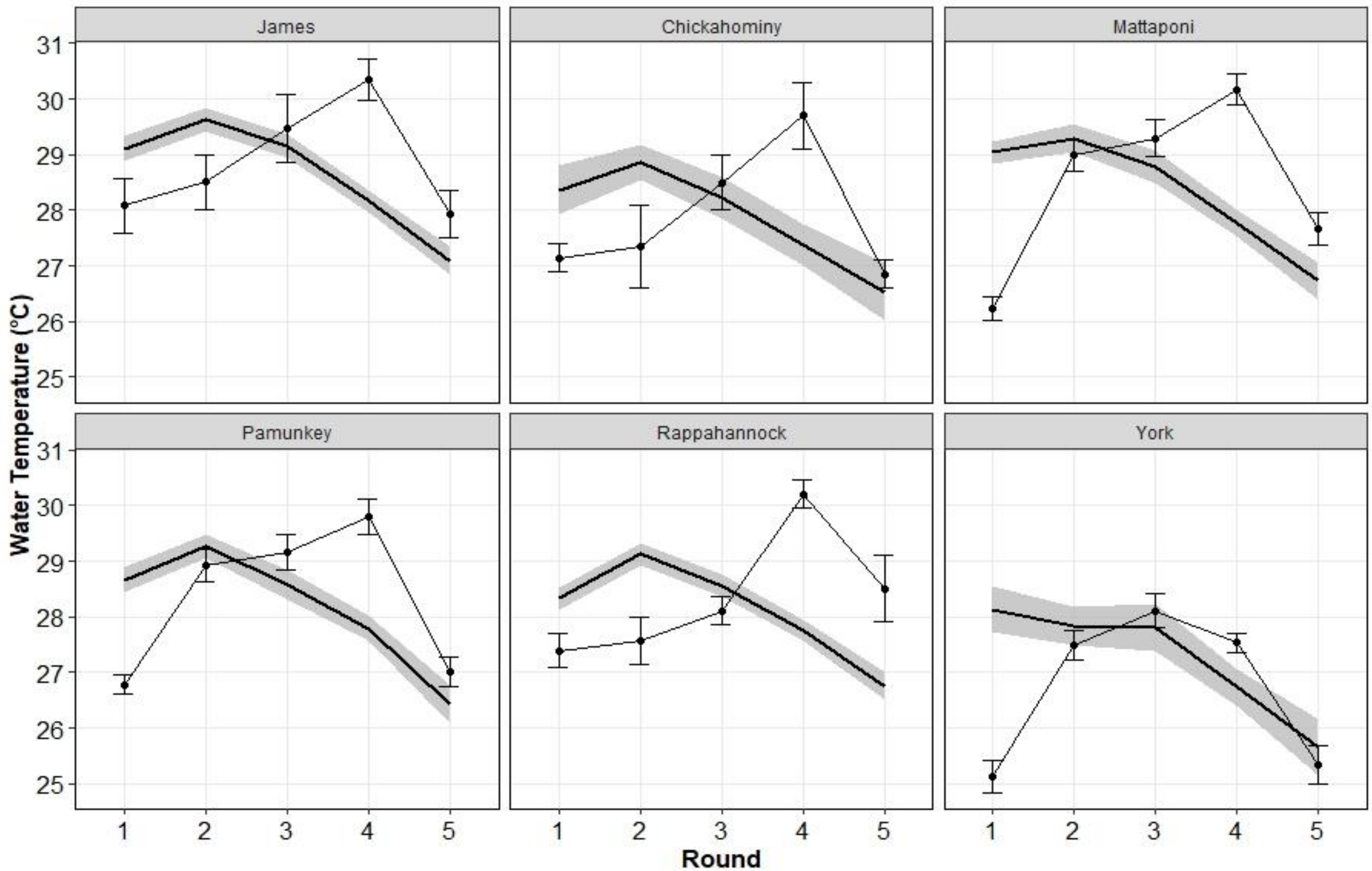


Figure 7. Mean water temperature and 95% confidence intervals during each round (x-axis) in each river during 2022 (thin line and error bars) and the auxiliary monitoring period from 1989-2021 (thick line and shaded region).

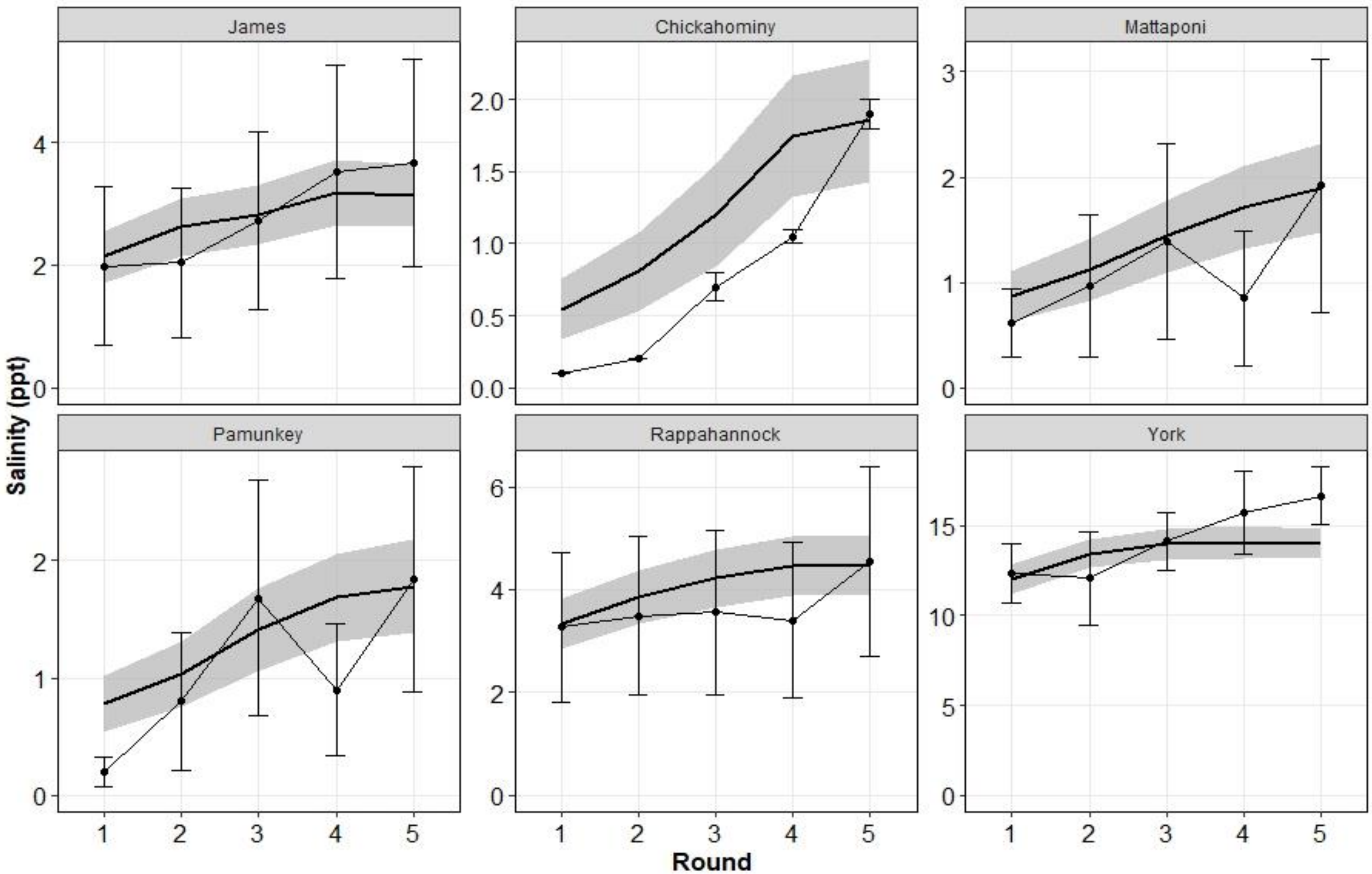


Figure 8. Mean salinity and 95% confidence intervals during each round (x-axis) in each river during 2022 (thin line and error bars) and the auxiliary monitoring period from 1989-2021 (thick line and shaded region). Note that the scale of the y-axis varies by river.

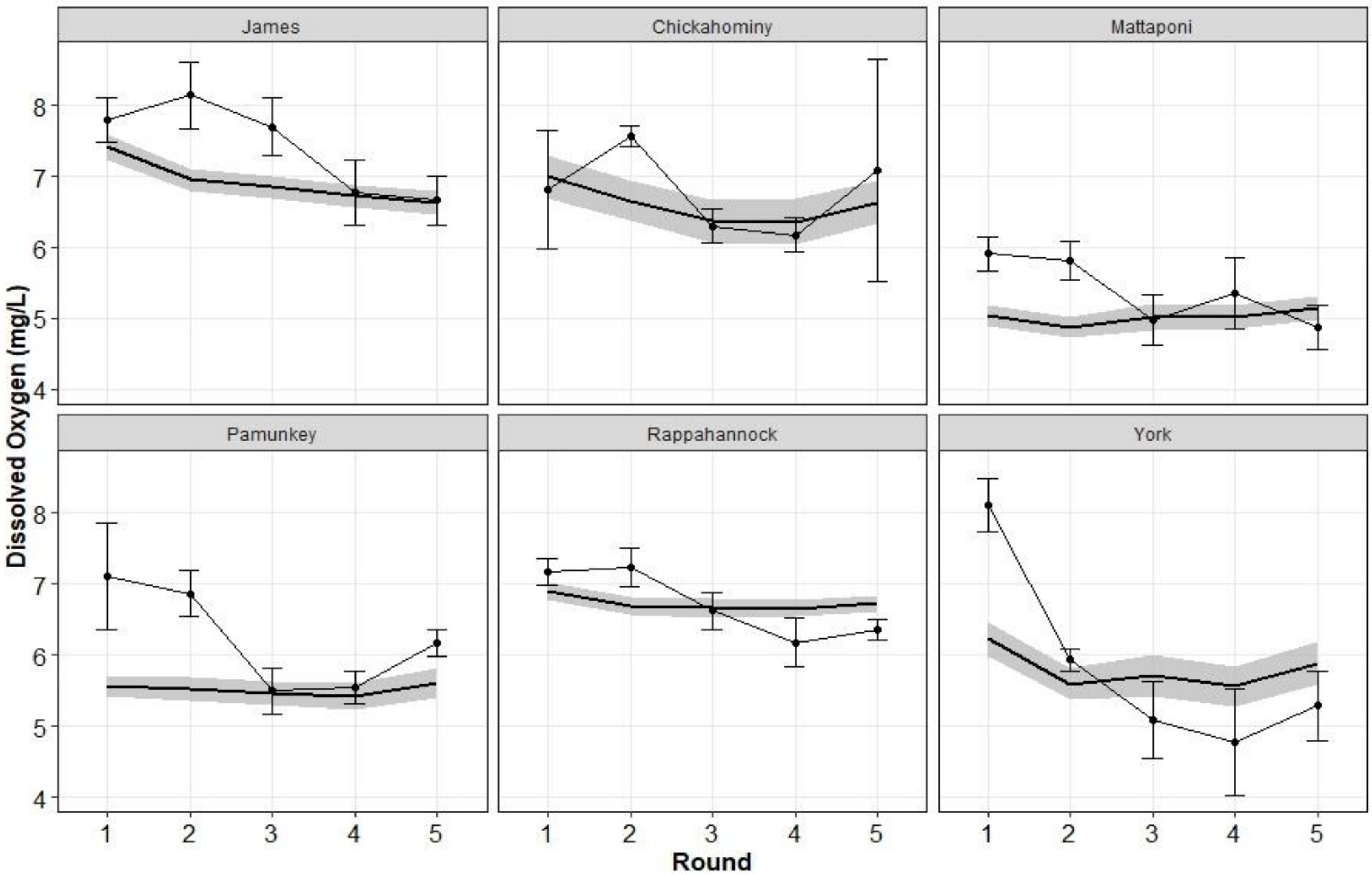


Figure 9. Mean dissolved oxygen and 95% confidence intervals during each round (x-axis) in each river during 2022 (thin line and error bars) and the monitoring period from 1992-2021 (thick line and shaded region). Note that dissolved oxygen was not measured on the seine survey before 1992.

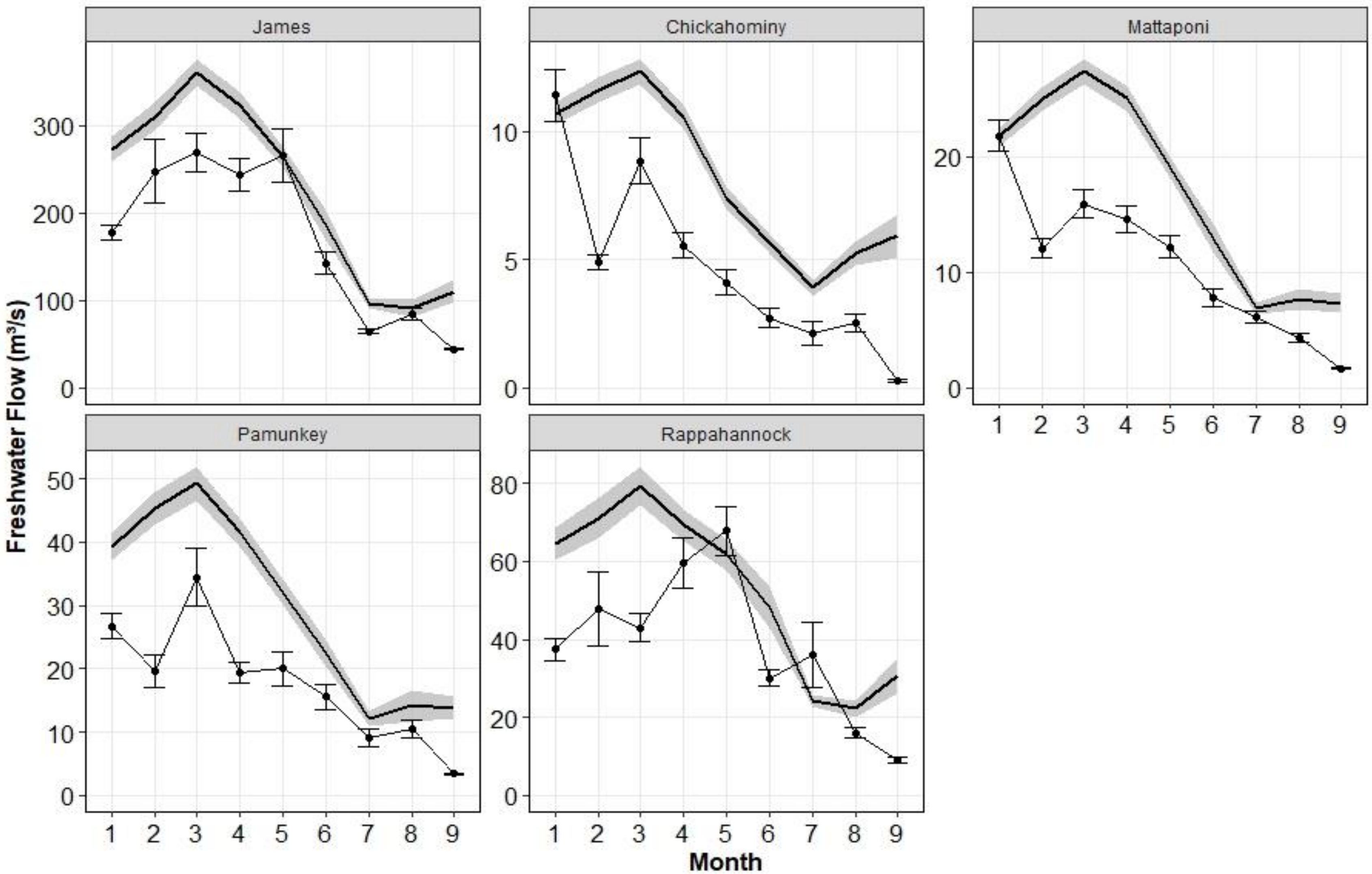


Figure 10. Mean freshwater flow and 95% confidence intervals during each month from January to September (x-axis) in each river during 2022 (thin line and error bars) and the historical monitoring period from 1967-2021 (thick line and shaded region). Data are from USGS (2022).

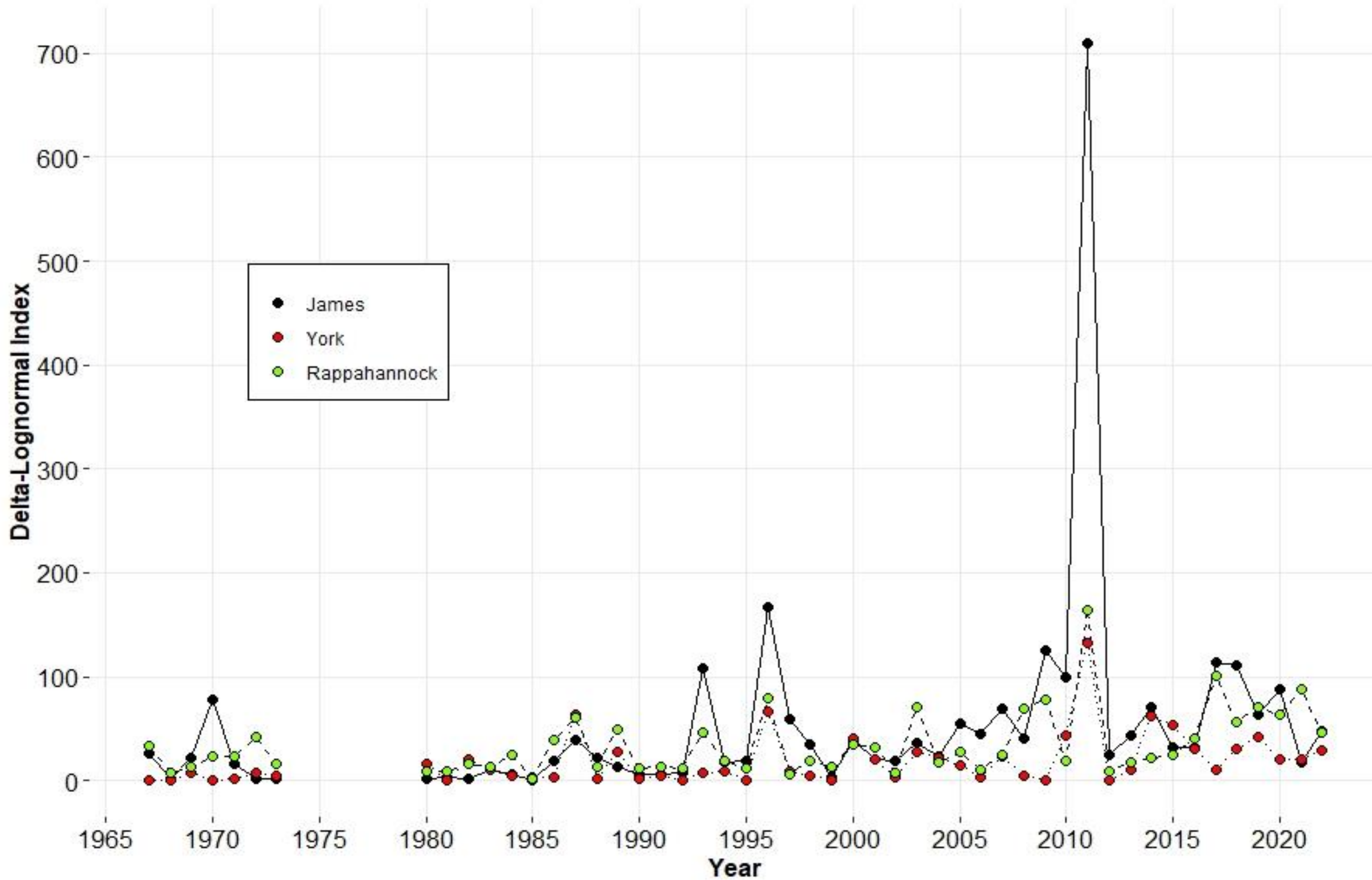


Figure 11. Delta-lognormal mean of young-of-the-year White Perch from select seine survey stations by drainage and year.

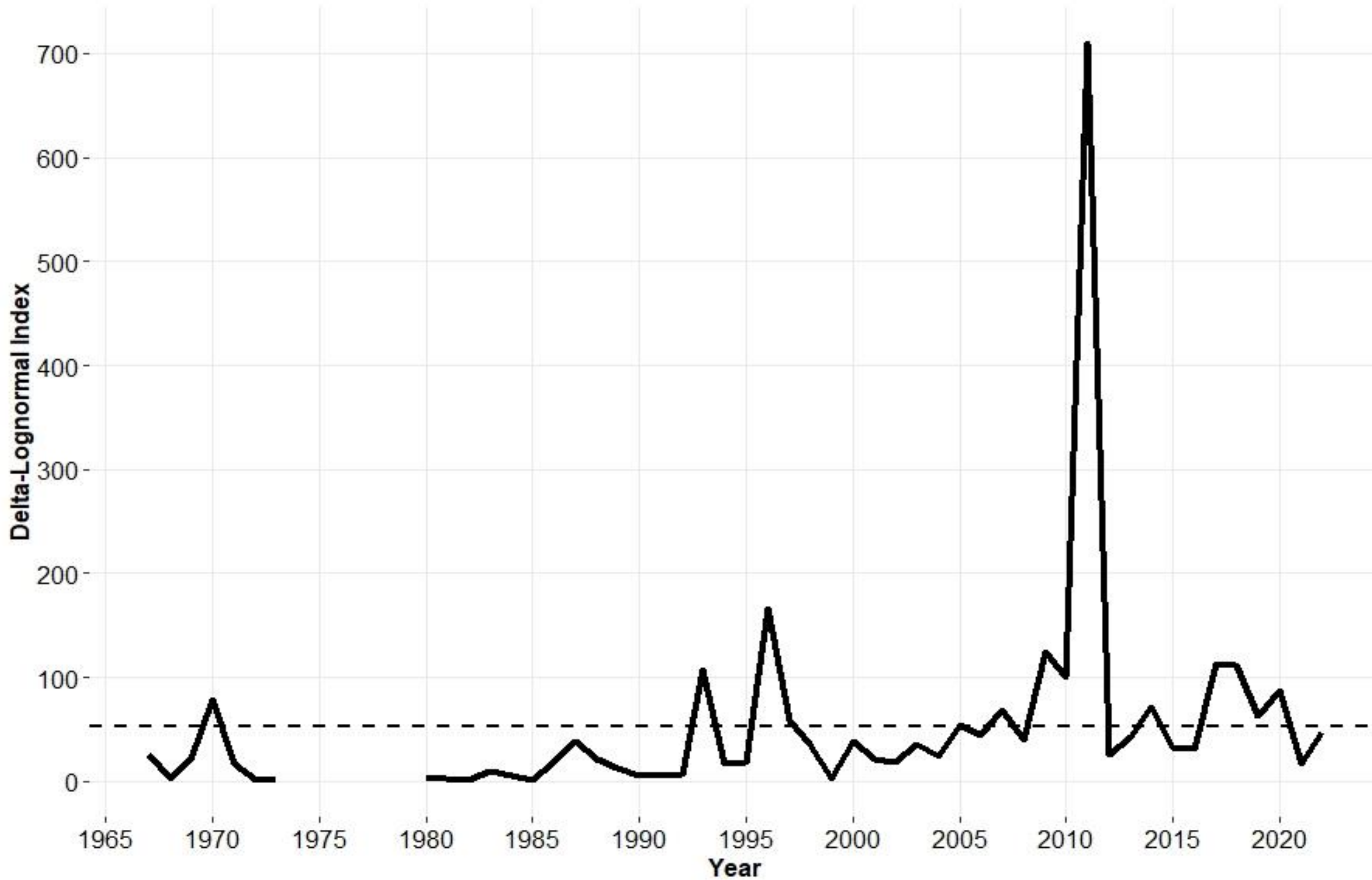


Figure 12. Delta-lognormal mean of young-of-the-year White Perch from the James River nursery area from 1967-2022. The time series average is shown by the horizontal line.

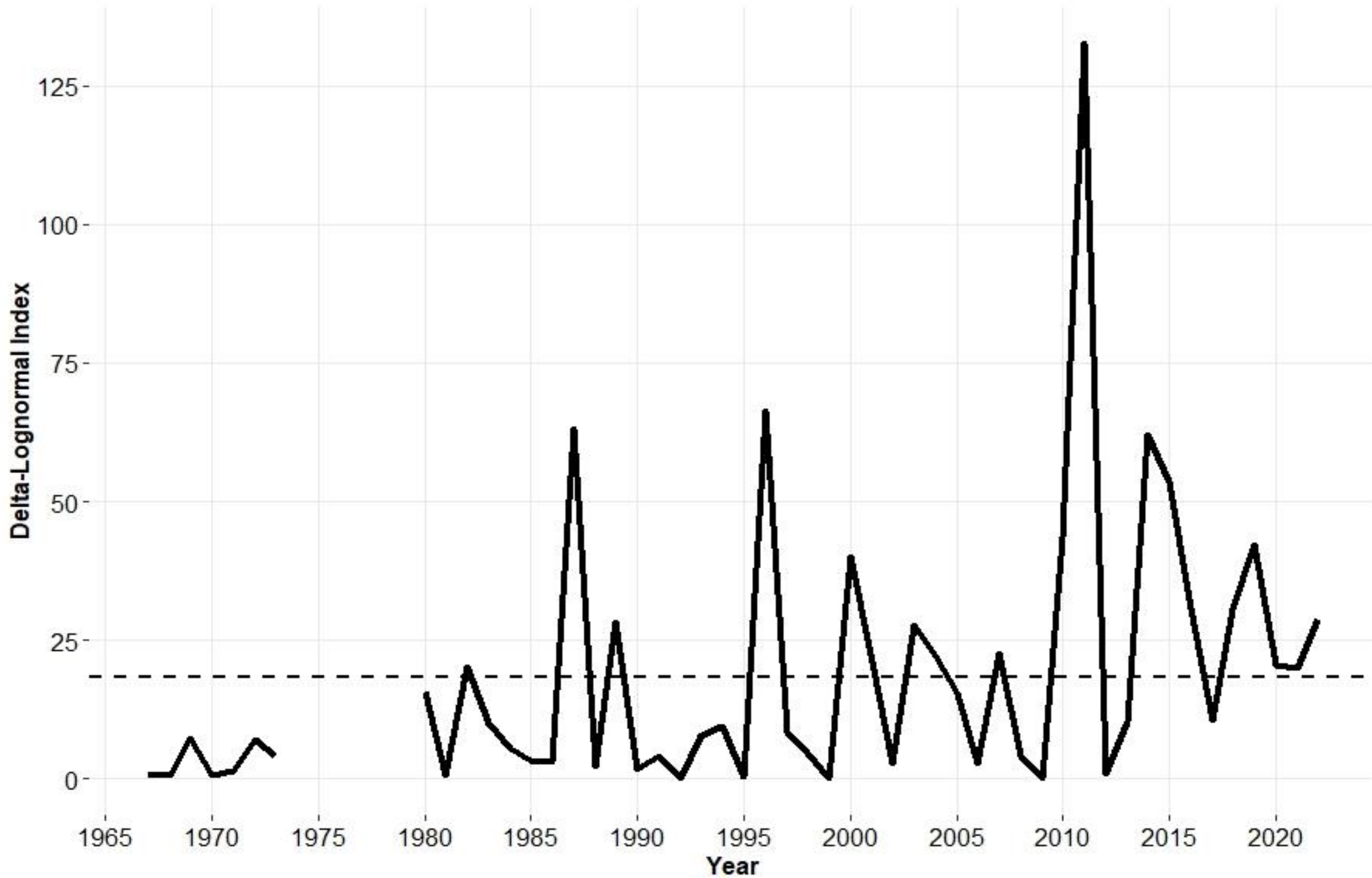


Figure 13. Delta-lognormal mean of young-of-the-year White Perch from the York River nursery area from 1967-2022. The time series average is shown by the horizontal line.

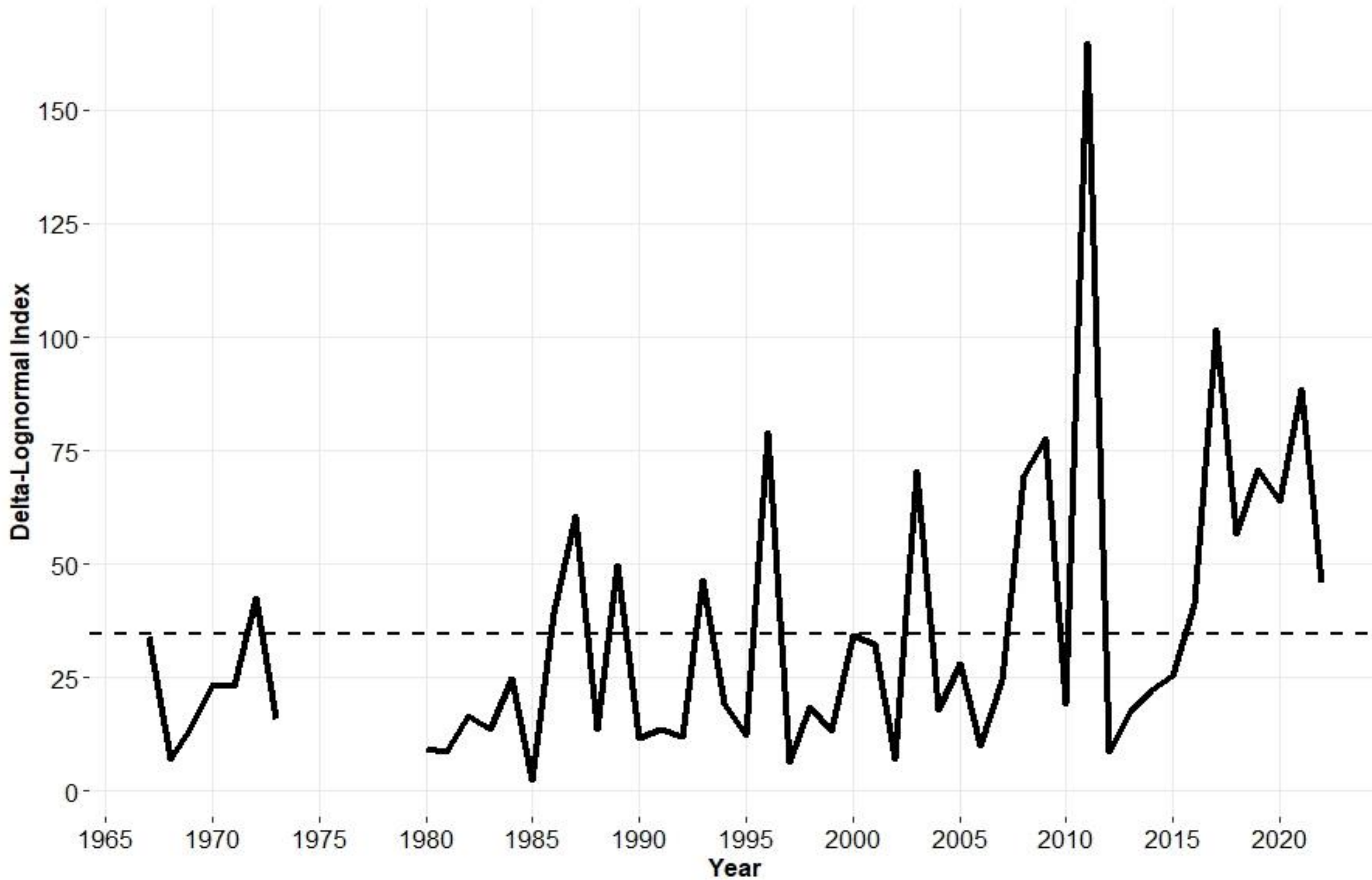


Figure 14. Delta-lognormal mean of young-of-the-year White Perch from the Rappahannock River nursery area from 1967-2022. The time series average is shown by the horizontal line.

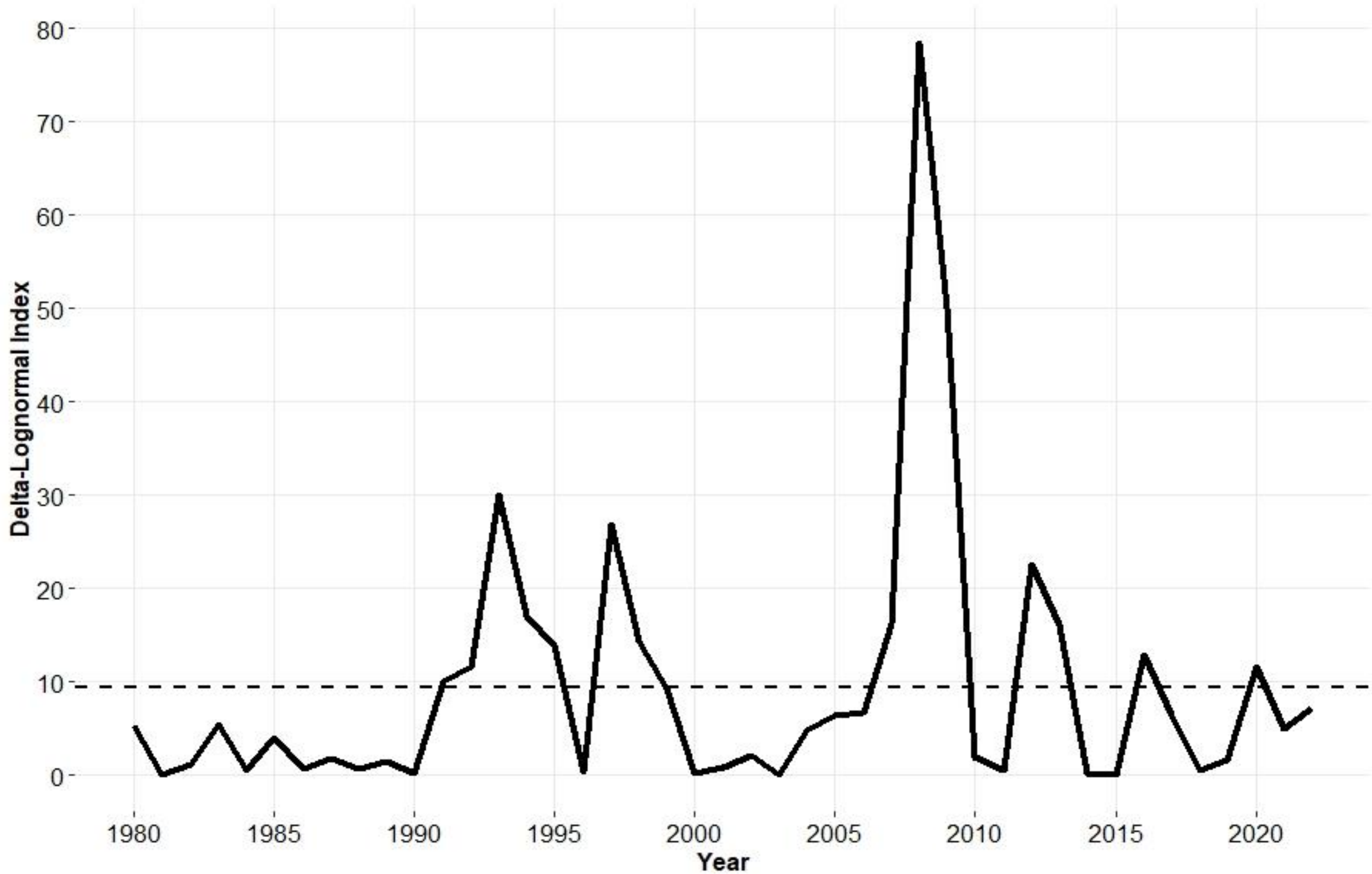


Figure 15. Delta-lognormal mean of young-of-the-year Atlantic Croaker from select seine survey stations in Virginia tributaries of Chesapeake Bay from 1980-2022. The time series average is shown by the horizontal line.

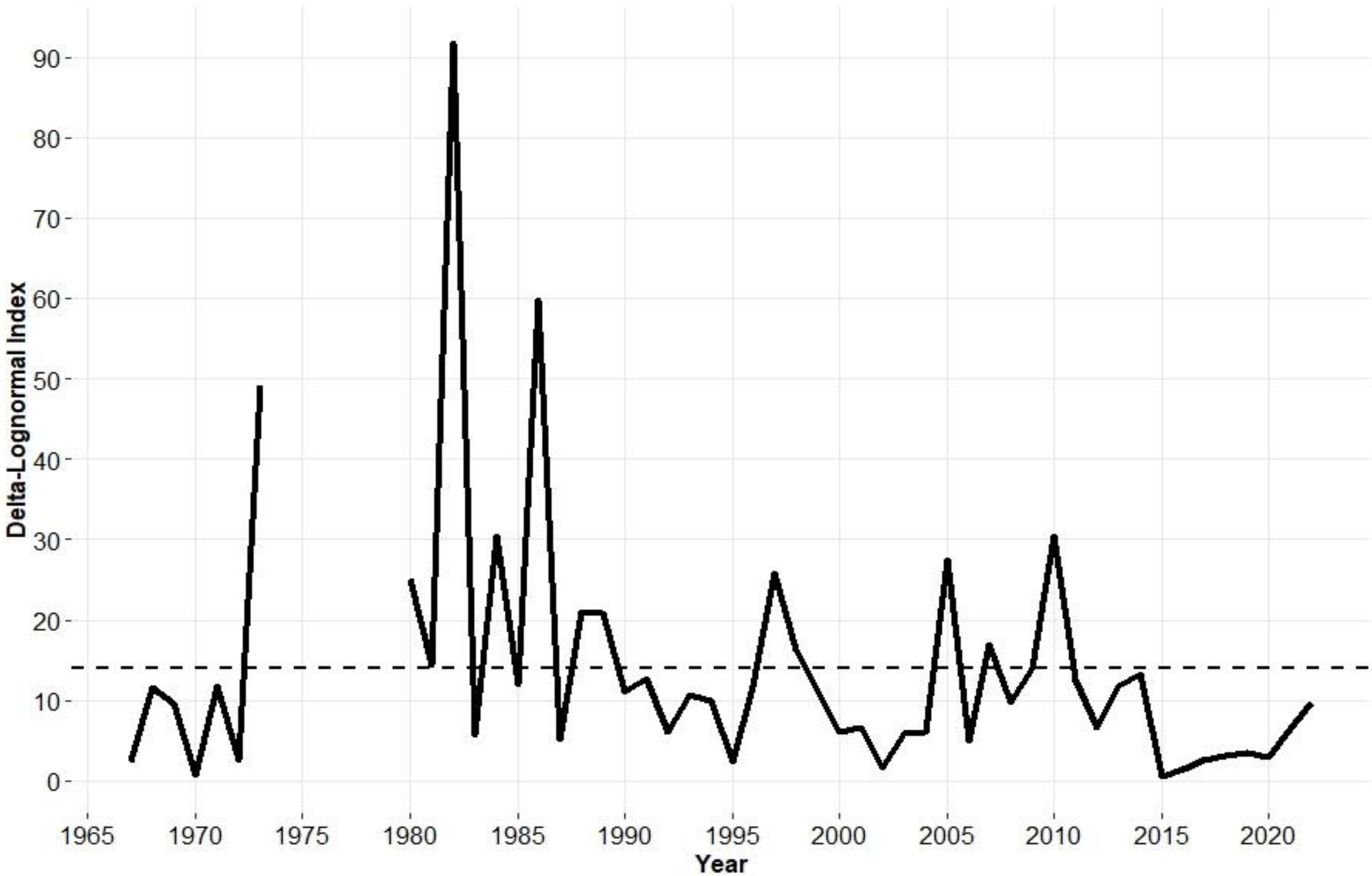


Figure 16. Delta-lognormal mean of young-of-the-year Spot from select seine survey stations in Virginia tributaries of Chesapeake Bay from 1967-2022. The time series average is shown by the horizontal line.

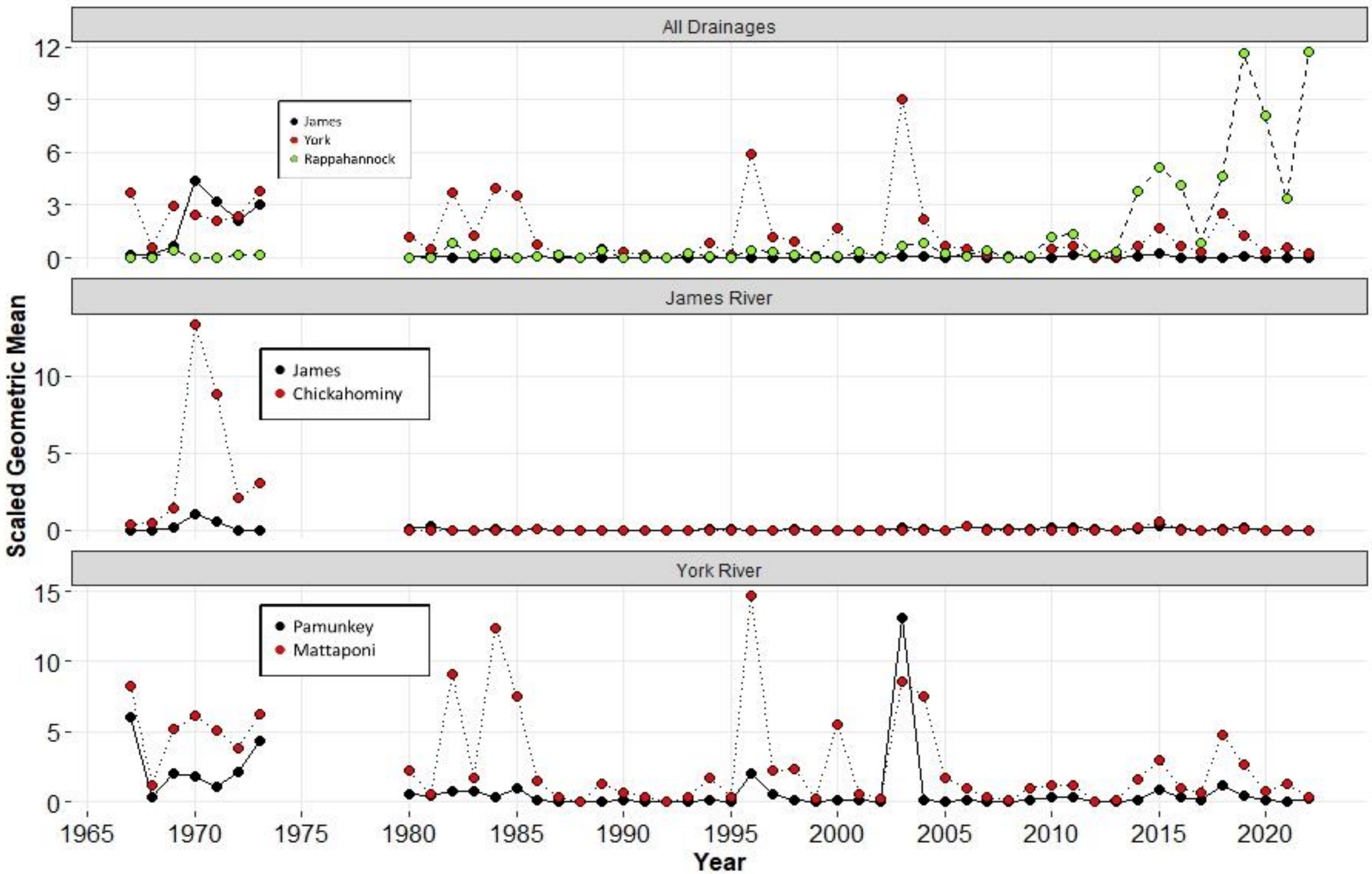


Figure 17. Scaled geometric mean of American Shad in the primary nursery areas of Virginia by drainage and river, using the first haul only.

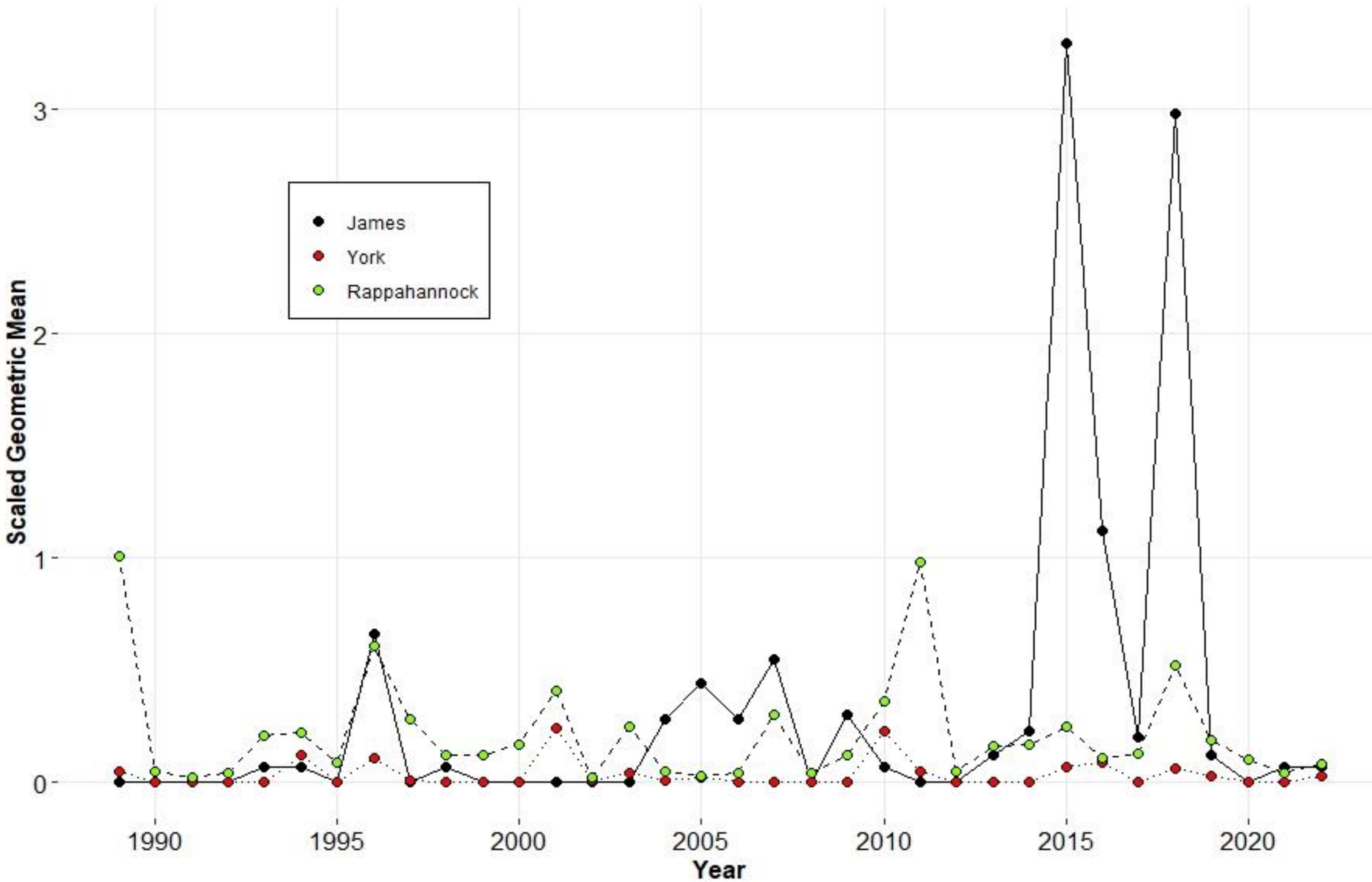


Figure 18. Scaled geometric mean of Alewife in the primary nursery areas of Virginia by drainage, using the first haul only.

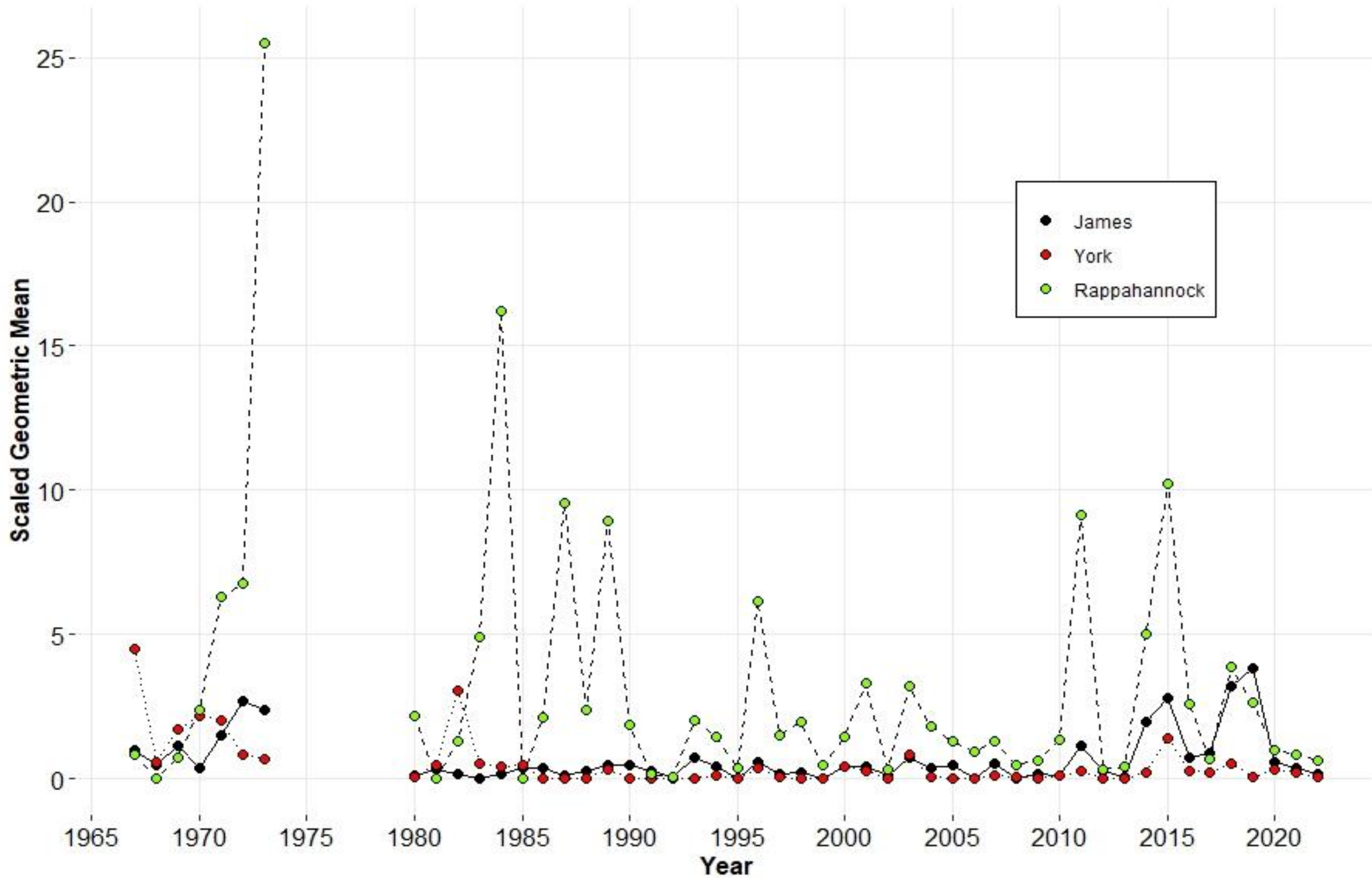
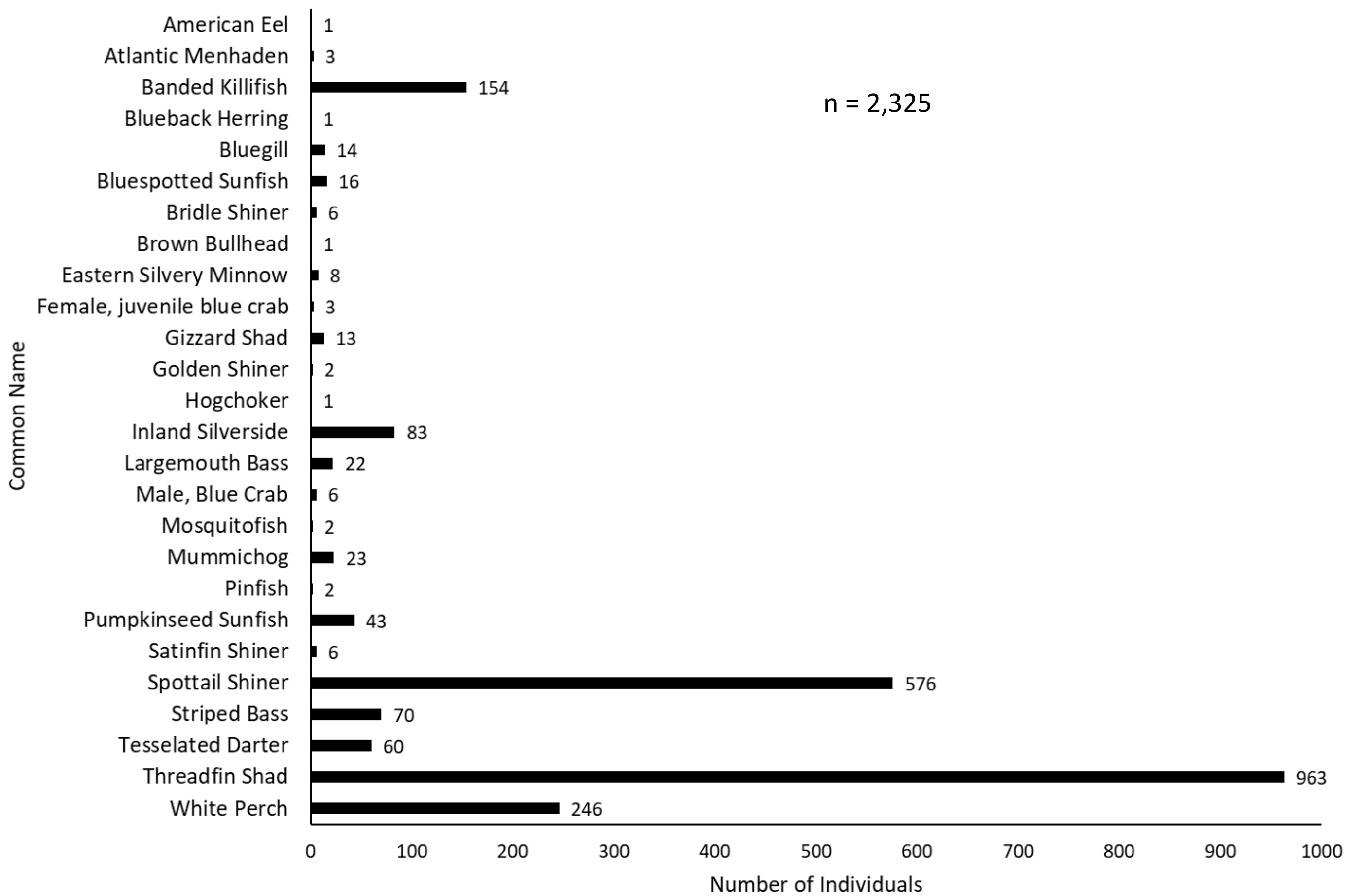


Figure 19. Scaled geometric mean of Blueback Herring in the primary nursery areas of Virginia by drainage, using the first haul only.

APPENDICES

Appendix Figure 1. Species collected during five exploratory hauls conducted approximately one mile upriver of site JC3 on the Chickahominy River in 2022. This site, JC4, provides increased geographic coverage and sample size on the Chickahominy River. A total of 2,316 fishes, comprising 24 species, were collected at JC4. Nine blue crabs (three juvenile female and six male) were also collected. It is worth noting that 70 juvenile striped bass were caught in the five hauls at JC4, while only 44 juvenile striped bass were collected in the 20 hauls at JC1 and JC3.



Appendix Figure 2. Species collected during five exploratory hauls conducted approximately 3.5 miles upriver of the mouth of the Appomattox River in 2022. This site, AP1, is just upstream of two recently approved water intake projects. A total of 880 fishes, comprising 18 species, were collected at AP1. Two male blue crabs were also collected. Additionally, 36 striped bass were caught. Continued sampling at site AP1 may provide valuable insight into juvenile Striped Bass recruitment in the Appomattox River.