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2021 Annual Report Estimating Relative Juvenile Abundance of Ecologically Important Finfish in the Virginia Portion of Chesapeake Bay (1 July 2020 – 30 June 2021)

Troy D. Tuckey
Virginia Institute of Marine Science

Mary C. Fabrizio
Virginia Institute of Marine Science

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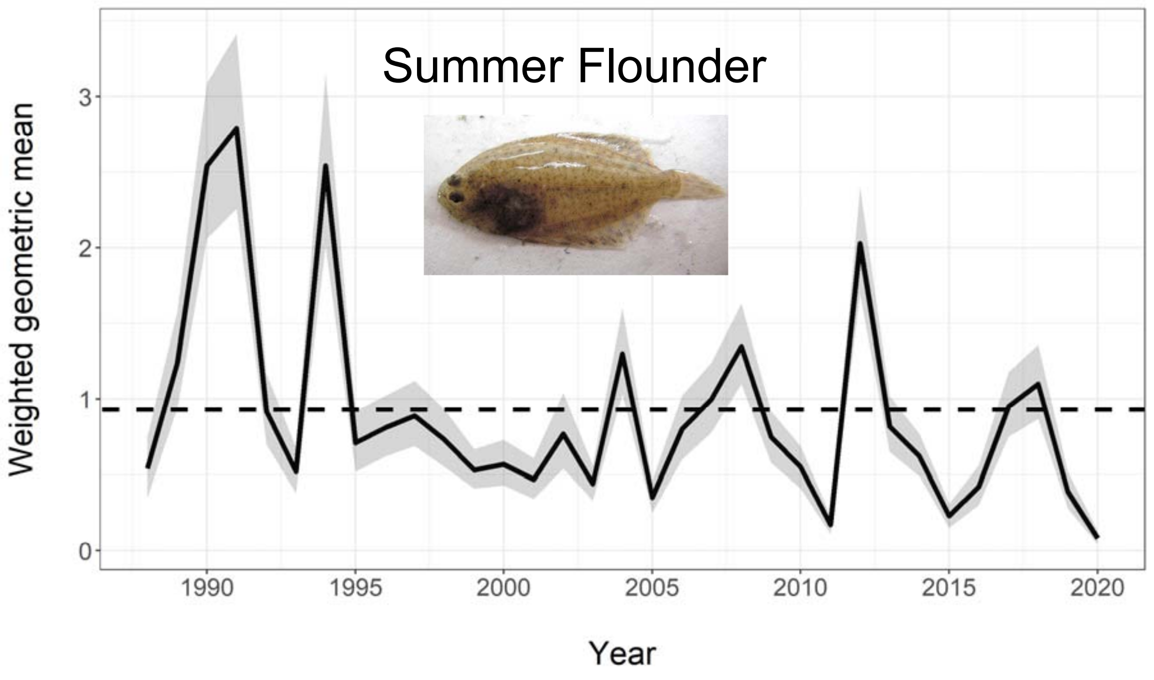

Prepared by:
Troy D. Tuckey
Mary C. Fabrizio

VIRGINIA INSTITUTE OF MARINE SCIENCE

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2021 ANNUAL REPORT

Estimating Relative Juvenile Abundance of Ecologically Important Finfish in the Virginia Portion of Chesapeake Bay
(1 July 2020 – 30 June 2021)

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SALTWATER RECREATIONAL FISHING DEVELOPMENT FUND

Prepared by:

Troy D. Tuckey and Mary C. Fabrizio

Virginia Institute of Marine Science
William & Mary, Gloucester Point, Virginia 23062

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Cover image

The 2020 Summer Flounder index was the lowest value observed since 1988.

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EXECUTIVE SUMMARY

1 July 2020 – 30 June 2021

The Trawl Survey provides crucial data to state, regional, and national fisheries management agencies, including the Virginia Marine Resources Commission (VMRC), the Atlantic States Marine Fisheries Commission (ASMFC), the Mid-Atlantic Fisheries Management Council (MAFMC), and the National Marine Fisheries Service (NMFS). The MAFMC recognizes the juvenile trawl survey as one of the key predictors of Summer Flounder recruitment. Annual indices of juvenile abundance have been generated from trawl survey data for species of key recreational and ecological importance in the Virginia portion of Chesapeake Bay. These include Spot, Atlantic Croaker, Weakfish, Summer Flounder, Black Sea Bass, Scup, Striped Bass, White Perch, White Catfish, Channel Catfish, Blue Catfish, Silver Perch, American Eel, and Bay Anchovy.

We completed most targeted tows this past year and only missed the upper-river stations in the James and Rappahannock rivers and a few shallow Bay stations during July and August 2020 due to COVID-19 safety restrictions. As a result, we could not calculate an index for American Eel in the James and Rappahannock rivers. We are also unable to calculate an index for the 2019 year-class of Black Sea Bass due to the stay-at-home order that included May 2020, which was an important index month for this species. A summary of other species affected by COVID-19 restrictions is shown in the table below.

We completed 902 tows from July 2020 to June 2021 and collected 544,355 fishes. Bay Anchovy continue to be the most abundant species observed in the survey, accounting for 66% of all fishes collected. Of the target species for which we provide indices of relative abundance, 21 species categories (considering YOY and age 1+ as distinct categories) exhibited below-average abundance in 2020 – 2021 (American Eel [York River], Atlantic Croaker, Blue Catfish YOY [Rappahannock River], Channel Catfish juveniles and age 1+ [all three rivers], Scup, Silver Perch YOY, Striped Bass YOY, Summer Flounder YOY, Weakfish YOY, White Catfish juveniles and age 1+ [York and Rappahannock rivers], White Perch YOY (York and Rappahannock rivers), and age 1+ White Perch in the York River. Seven species categories exhibited average abundances including Bay Anchovy, Spot, White Catfish juveniles and age 1+ (James River), White Perch YOY (James River), and White Perch age 1+ (James and Rappahannock rivers). Only YOY Blue Catfish (York and James rivers) and age 1+ Blue Catfish (all three rivers) exhibited above-average abundances in 2020-2021.

Summary of species affected by COVID-19 restrictions with the target number of sites during normal years and the actual number visited during COVID-19. Numbers in parentheses are the percent of target samples collected. Indices of abundance were not calculated for species highlighted in gray.

Species	N_{target}	N_{covid}
Bay anchovy	624	586 (94%)
Black sea bass	153	90 (59%)
Spot	420	382 (91%)
Striped bass	120	102 (85%)
Weakfish	325	297 (91%)

	N_{target}	N_{covid}		
Species	Each river	Rapp	York	James
American eel	132	48 (36%)	88 (67%)	46 (35%)
White perch yoy	30	22 (73%)	30 (100%)	20 (67%)
White perch 1+	30	22 (73%)	30 (100%)	20 (67%)

INTRODUCTION

Relative abundance estimates of early juvenile (age-0) fishes and invertebrates generated from fishery-independent survey programs provide a reliable and early indicator of year-class strength (Goodyear, 1985), and may be used to evaluate the efficacy of management actions. The Chesapeake Bay Stock Assessment Committee (CBSAC) reviewed available indices of juvenile abundance for important fishery resources in Chesapeake Bay (hereafter referred to as the “Bay”) and recommended that "a unified, consistent trawl program should be one of the primary monitoring tools for finfish and crab stock assessment" (Chesapeake Bay Program Stock Assessment Plan, Chesapeake Executive Council, 1988). Subsequently, pilot studies directed at developing a comprehensive trawl survey for the Chesapeake Bay began at the Virginia Institute of Marine Science (VIMS) with monthly trawl sampling in the main stem of the lower Bay. This effort complemented and expanded the monthly trawl sampling conducted in major Virginia tributaries (James, York, and Rappahannock rivers) by VIMS.

The present sampling program, which includes the Bay and its tributaries, ensures that data are of sufficient geographic coverage to generate relative abundance indices for recreationally and ecologically important finfishes. The National Marine Fisheries Service Marine Recreational Information Program shows that recent recreational catches in Virginia are dominated by Atlantic Croaker (*Micropogonias undulatus*), Summer Flounder (*Paralichthys dentatus*), Spot (*Leiostomus xanthurus*), Striped Bass (*Morone saxatilis*), Black Sea Bass (*Centropristis striata*), Bluefish (*Pomatomus saltatrix*), Pigfish (*Orthopristis chrysoptera*), Weakfish (*Cynoscion regalis*), and Kingfishes (*Menticirrhus* spp.). These species depend on the lower Bay and its tributaries as nursery areas and, with the exception of Bluefish, are highly vulnerable to bottom trawls. Additional species of recreational interest, such as Scup (*Stenotomus chrysops*), White Perch (*Morone americana*), Silver Perch *(Bairdiella chrysoura)*, White Catfish (*Ameiurus catus)*, Channel Catfish (*Ictalurus punctatus)* and Blue Catfish (*I. furcatus*), are also taken with sufficient regularity during trawling operations to provide information suitable for the generation of juvenile abundance indices or document recent declines in their relative abundance. Many species of interest are captured in significant numbers across several year classes. As a result, both juvenile and age 1+ (i.e., all fish older than age-0) indices are reported for White Perch, White Catfish, Channel Catfish, and Blue Catfish.

Although annual juvenile indices are the primary focus of this project, data from the survey can be used to address other aspects of finfish population biology, such as habitat utilization, early growth and survival, environmental effects on recruitment, or disease prevalence. For example, episodic climatic events, such as hurricanes, were shown to affect recruitment of shelf-spawning species such as Atlantic Croaker (Montane and Austin, 2005). Tuckey and Fabrizio (2013) used trawl survey data to examine the influence of survey design on fish assemblages comparing fishes captured from fixed sites with those captured at random sites. For some species, the fixed survey design provided adequate sampling for determination of temporal trends, thus extending the utility of historical (pre-1988) survey catches. Additionally, Tuckey and Fabrizio (2016) examined the indirect effects of hypoxia on fish tissue proximate composition in Bay tributaries. Severe hypoxia, such as that observed in the lower Rappahannock River, reduced the ability of Atlantic Croaker to accumulate lipids in their ovaries, likely affecting their reproductive output (Tuckey and Fabrizio, 2016). Stock assessment models that ignore the effects of hypoxia may yield overly optimistic production estimates for hypoxia-exposed populations, particularly if environmentally invariant fecundity and growth are assumed (Tuckey and Fabrizio, 2016). Using models to describe multi-decadal changes in size of juvenile Summer Flounder, Nys et al. (2015) concluded that variable conditions in nursery habitats may influence production of Summer Flounder year classes through effects on maturation and survival. Additionally, Schloesser and Fabrizio (2015) compared methods to estimate energy density of juvenile Summer Flounder, Striped Bass, and Atlantic Croaker, and demonstrated that the lipid-to-energy conversion factors commonly used in bioenergetics models overestimate energy density of juvenile fishes. Such information can be used to better inform models for ecosystem-based fisheries management because such models rely on inputs from bioenergetics models and because juvenile fishes are an important component of the forage base in the Bay. Schloesser and Fabrizio (2016) described the temporal dynamics of juvenile fish condition using multiple condition metrics; they found that juveniles that remain in the estuary during winter used the liver to store energy and that this energy-storage strategy was common among the species examined. In addition, Striped Bass and Summer Flounder juveniles exhibited density-dependent effects on mean condition (Schloesser and Fabrizio 2016), suggesting the need to consider relative local abundance when examining condition indices for juvenile fishes. This study provided a more complete understanding of energy-storage strategies for juvenile fishes and highlighted the need to consider temporal dynamics of individual fish condition. In a follow-up study, Schloesser and Fabrizio (2017) described appropriate condition metrics for juvenile fishes based on energy-storage strategies and life history. Together, these studies provide insight on the application of juvenile fish condition metrics as measures of nursery habitat health; additional research on this topic is currently underway, as is a study of the suitability of Chesapeake Bay habitats for forage fishes. Recently, Nepal and Fabrizio (2020) and Nepal et al. (2020) used trawl survey data to assess population dynamics of invasive blue catfish by examining density-dependent growth of juvenile Blue Catfish and phenotypic plasticity of Blue Catfish populations in Virginia. Trawl survey observations were also used to characterize the salinity of tidal habitats used by Blue Catfish and to determine that larger fish are more likely to use high salinity (> 10 psu) habitats than smaller fish (Nepal and Fabrizio 2019). Reproductive characteristics of Blue Catfish were found to differ in the James and York rivers, further supporting the notion of unique stocks in each tributary (Nepal et al.

2021). Fabrizio et al. (2021) summarized the management objectives for Blue Catfish in Chesapeake Bay and synthesized existing information on this invasive species. Finally, Tuckey et al. (2021) document the growth of penaeid shrimp populations in Chesapeake Bay and examined the incidence of black gill disease syndrome. The utility and value of VIMS trawl survey data grow each year, in step with the questions being asked of the data.

The development of juvenile indices requires a continuous time series of data to determine the most appropriate area-time sequences for index calculations. Provisional annual juvenile abundance indices were developed for Spot, Weakfish, Atlantic Croaker, Summer Flounder, and Black Sea Bass (Colvocoresses and Geer, 1991), followed by Scup (Colvocoresses et al., 1992), White Perch and Striped Bass (Geer et al., 1994), and White Catfish, Channel Catfish, and Silver Perch (Geer and Austin, 1994). More recently, Blue Catfish, American Eel (*Anguilla rostrata*), and Bay Anchovy (*Anchoa mitchilli*) indices were developed. Through the use of gear conversion factors and post stratification, a time series of index values can be produced back to 1955 for many species (Geer and Austin, 1997).

This report summarizes the activity of the VIMS Juvenile Finfish Trawl Survey from July 2020 through June 2021. We provide abundance indices from 1988 to the present, along with the mean value estimated across the time series; indices for years prior to 1988 are available in previous reports, though sampling design and survey gear differed, and results are not necessarily directly comparable. This year’s indices have been corrected for the change in vessel/gear that occurred in 2015 and values are reported as catches comparable to the R/V *Fish Hawk* for continuity of the time series.

METHODS

Field Sampling

A trawl net with a 5.8-m head line, 40 mm stretch-mesh body, and a 6.4-mm liner was towed along the bottom for 5 minutes during daylight hours. Sampling in the Bay occurred monthly except January and March, when few target species are available. Sampling in the tributaries occurred monthly, at both the random stratified and historical fixed (mid-channel) stations. The stratification system is based on depth and latitudinal regions in the Bay, or depth and longitudinal regions in the rivers. Each Bay region spanned 15 latitudinal minutes and consisted of six strata: western and eastern shore shallow (4-12 ft), western and eastern shoal (12-30 ft), central plain (30-42 ft), and deep channel (≥ 42 ft). Each tributary was partitioned into four regions of approximately ten longitudinal minutes, with four depth strata in each (4-12 ft, 12-30 ft, 30-42 ft, and ≥ 42 ft; Figure 1). Strata were collapsed in areas where certain depths are limited. Fixed stations were assigned to a stratum according to their location and depth. Additional details of the field sampling protocol are described in Lowery and Geer (2000).

With the exception of the fixed stations in the rivers, trawling sites within strata were selected randomly from the National Ocean Service's Chesapeake Bay bathymetric grid, a database of depth records measured or calculated at 15-cartographic-second intervals. Between two and four trawling sites were randomly selected for each Bay stratum each month, and the number varied seasonally. Exceptions included the shallow-water strata where only a single station was sampled each month. For most river strata, one to two random stations were selected per month. Sampling in the York River was altered slightly as of 1991 to make the deeper depth strata (≥30 ft) more similar to those in the James and Rappahannock rivers and main stem Bay. The stratification scheme for the tributaries was modified in January 1996 to further partition the deep strata into two strata of 30-42 ft and ≥ 42 ft (Geer and Austin, 1996). Because tributary sampling occurred at these depths prior to 1996, samples collected previously were reassigned to the strata established in 1996.

Fixed stations were sampled monthly (nearly continuously) since 1980 with sites in each tributary spaced at approximately 5-mile intervals from the river mouth up to the freshwater interface. From the mid-1950s (York River) and early-1960s (James and Rappahannock rivers) to 1972, fixed stations were sampled monthly using an unlined 30' trawl (gear code 010). During 1973-79, semi-annual random stratified sampling was performed by the VIMS Ichthyology Department, while the VIMS Crustaceology Department continued monitoring the fixed tributary stations on a limited monthly basis (May-November). Area-based weightings for the tributaries were previously assigned by dividing each river into two approximately equal length 'strata' by assuming that the stations in each stratum were representative of the channel areas in those reaches (see Lowery and Geer, 2000). As of 1996, all three tributaries were sampled with a random stratified design; the fixed stations were assigned to a stratum based on location and depth. The current design (combined fixed and random stations) provides greater spatial coverage and a long-term historical reference (Tuckey and Fabrizio, 2013).

At the completion of each tow, all fishes were identified to species, counted, and measured to the nearest millimeter fork length (FL), total length (TL), or total length centerline (TLC, Black Sea Bass only). Species that have varying size ranges were measured and counted by size class and large catches of a particular species were randomly subsampled, measured, and the remaining unmeasured catch was counted. In instances of extremely large catches (e.g., Bay Anchovy), subsampling was performed volumetrically.

Juvenile Index Computations

Many of the target species of this study are migratory and abundance estimation presents special difficulties, particularly if the timing and duration of migration varies annually. Juvenile fishes that use estuarine nursery areas are especially vulnerable to the vagaries of the environment, as many rely on wind-driven and tidal circulation patterns for transport into the estuaries as larvae and early juveniles (Norcross, 1983; Bodolus, 1994; Wood, 2000). In addition, the outward migration of some species from the nursery area may follow annually variable environmental cues (e.g., temperature). Ideally, juvenile abundance should be measured when young fish are fully recruited to the nursery area under study. In practice, however, this can only be accomplished if the time of maximal abundance and size at recruitment to the gear can be predicted (and surveys timed accordingly), or if surveys can be conducted with high frequency over the season of potential maximal abundance. Neither of these two approaches are practical. The period of maximal abundance and the spatial extent of the area occupied by juvenile fish have proven to be variable among years and among species. This observation, coupled with multispecies monitoring objectives, precludes temporally intense surveys. Consequently, the survey is operated with a regular periodicity (monthly) and sample-site selection was performed using a standard sampling design for multispecies resource surveys.

A monthly size threshold value was applied to the length-frequency information collected for each target species to partition the catch data into young-of-year and older components for index calculation (Table 1). Threshold values varied among months for each species and were based on modal analyses of historical, composite length-frequency data and on reviews of ageing studies (Colvocoresses and Geer, 1991). For earlier months of the biological year, threshold values were somewhat arbitrary and fell between completely discrete modal size ranges. In the later part of the biological year, when the size of early spawned, rapidly growing individuals of the most recent year class may approach that of later spawned, slower growing individuals of the previous year class, threshold values were selected to preserve the numeric proportionality between year classes despite the potential misclassification of some individuals (Table 1). The extent of overlapping lengths and the proportion within that range attributable to each year class were estimated based on the shapes of the modal curve during the months prior to the occurrence of overlap. A length value was then selected, which preserves the proportional separation of year classes. Although this process involved considerable subjectivity and ignored possible interannual variability in average growth rates, the likelihood of significant error is small, because only a small fraction of the total number of young-of-year individuals fell within the zone of overlap, and furthermore, with a few exceptions, most of the data used to construct juvenile indices were drawn from months when no overlap was present.

After removing non-target individuals from consideration, monthly stratum-specific abundances and occurrence rates were calculated for each target species. Numbers of individuals captured were natural-log transformed (ln(n+1)) prior to abundance calculations following Chittenden (1991). Average catch rates (and the approximate 95% confidence intervals as estimated by ± 2 standard errors of the mean) were then back-transformed to geometric means.

The stratum-specific coefficient of variation was expressed as the standard deviation divided by the log-transformed mean catch: STD/ $E[Y_{st}]$ (Cochran, 1977). The catch data were examined for area-time combinations that provided the best basis for juvenile index calculations. Criteria applied during the selection process included identification of maximal abundance levels, uniformity of distribution, minimization of overall variance, and avoidance of periods during which distribution patterns indicated migratory behavior. Although identification of areas most suitable for index calculations (primary nursery zones) was generally clear, selection of appropriate time windows was more complex. Surveys that are timed on regular monthly intervals may or may not coincide with periods of maximal recruitment to the nursery areas. The use of a single (maximal) month's survey result was therefore inappropriate and would decrease sample size, increase confidence intervals, and increase the risk of sampling artifacts. Conversely, the temporal series of data incorporated into index calculations should not be longer than that necessary to capture the period of maximal juvenile use of the nursery area. With this approach, three- or four-month periods (but six months for Bay Anchovy and American Eel) that provided reasonable abundance data for each species were identified (Table 1).

Using catch data from area-time combinations, an annual juvenile index was calculated as the weighted geometric mean catch per tow (Random Stratified Index, RSI_{GM}) for all species except American Eel, Atlantic Croaker, and Blue Catfish. The RSI_{GM} was obtained by calculating stratum-specific means and variances and combining the stratum-specific estimates using weights based on stratum area (Cochran, 1977). Because stratum areas are not uniform, a weighted mean provides an index that more closely approximates actual population abundance. For American Eel, Atlantic Croaker, and Blue Catfish, whose catches follow a lognormal distribution, an index is calculated assuming a delta lognormal approach (RSI_{Delta}). The delta lognormal index method calculates stratum-specific means on log-transformed positive values only and adjusts the stratum means by the proportion of positive tows within each stratum. The stratified mean is then calculated in the usual manner. We are currently developing confidence interval estimates for the annual relative abundance index, but these are not available for this report.

Indices (Random Stratified Index – RSI_{GM} or RSI_{Delta}) were produced for each species from 1988 to the present using all spatially appropriate data. Data collected prior to 1988 were excluded from this report because results from the longer time series are considered provisional (i.e., indices prior to 1988 require both gear and vessel conversion factors, and concerns about conversion factors for this period have not yet been addressed).

Data collected after 2015 were adjusted by a species-specific calibration factor to express catches from the R/V *Tidewater* in units comparable to the R/V *Fish Hawk* and thus maintain the continuity of the time series (Appendix Table 2). To accomplish the estimation of calibration factors, we performed side-by-side comparison tows in 2014 and 2015 (40 side-by-side tows were completed in 2016 to target Scup, which were undersampled in 2014-2015 due to low abundances). We compared the catch of the old research vessel and net (R/V *Fish Hawk*) with those of the new research vessel and net (R/V *Tidewater*) based upon completion of 1,141 paired tows. The calibration factor is the ratio of R/V *Fish Hawk* catches to R/V *Tidewater* catches and represents the relative catch efficiency of the *Fish Hawk* to the *Tidewater*. These factors are required for each species-age group because availability, selectivity, and efficiency of the net varies by species and relative size of the individuals captured. Calibration factors (or relative catch efficiency) can be estimated using a number of models, but one of the fundamental characteristics of catch data is that they follow a binomial distribution – either the species is captured by the paired tow or not. The binomial distribution does not account for the additional variation (overdispersion) that is typically observed (McCullagh and Nelder, 1989), so in addition to the binomial model, we considered models that specifically address overdispersion. We considered four models to account for the overdispersed catch data: the beta-binomial model, a random-clumped binomial distribution model, and a generalized linear overdispersion model based on the beta-binomial distribution. The best model was selected using information-theoretic approaches, namely Akaike's Information Criterion corrected for small sample sizes (AIC_c). The model selected to calculate the calibration factor varied by species, and is discussed under the description for each species. The calibration factor was applied at the individual tow-level and equated catches of fish from the R/V *Tidewater* with those from the R/V *Fish Hawk* (historic data). We included tow direction, current speed, Secchi depth, and an offset for the ratio of the distance towed by each vessel as explanatory factors in the probability of success (i.e., the probability of catching the target group). We used salinity as an explanatory factor for the variation in the overdispersion parameter in models that included an overdispersion parameter.

RESULTS

A summary of tows completed from 1988 through June 2021 (Table 2) provides a synopsis of the sampling completed for this report. For the 2020-2021 project year (1 July 2020 through 30 June 2021), 902 sites were sampled resulting in 544,355 fishes identified and enumerated, representing 94 species (Table 3). Bay Anchovy, Hogchoker, and Spot accounted for 81% of the catch by numbers. Ignoring Bay Anchovy and Hogchoker, five species – Spot, Atlantic Croaker, Weakfish, Blue Catfish, and White Perch – represented 76% of the catch numerically (Table 3).

Water temperature, salinity, and dissolved oxygen were measured at the end of each trawl tow and are presented here as weighted means (with 95% confidence intervals; Figures 2 - 4). Mean annual bottom-water temperature from 1988 to 2010 was about 16^oC in the James, Rappahannock, and York River subestuaries, mean temperatures increased in recent years to about 18 – 20 ^oC, and returned to the long-term average in 2020 (Figure 2). Mean annual bottom-water temperature exhibited an upward trend in the Virginia portion of the Bay from around 15^{o}C in 1988 to 18^{o}C in recent years. Mean annual salinity in the region exhibited similar interannual patterns with highest salinity found in the Bay, lowest salinity found in the James River subestuary and intermediate salinities found in the Rappahannock River and York River subestuaries (Figure 3). Mean salinity increased slightly in all regions this past year returning to previous levels observed in the time series (Figure 3). Annual bottom dissolved oxygen averaged between 6 and 9 mg/L in all regions sampled, with greater variability in the Rappahannock River subestuary compared with the other regions (Figure 4).

Relative abundance indices are described below for the following species: American Eel – York River, Atlantic Croaker, Bay Anchovy, Blue Catfish**,** Channel Catfish, Scup, Silver Perch, Striped Bass, Spot, Summer Flounder, Weakfish, White Catfish, and White Perch. In addition, the distribution of each species, number captured, mean length and size range of fish during index months and from index strata are also reported. Furthermore, mean bottom-water temperature, salinity, and dissolved oxygen at sites where positive catches of each species occurred (during the index period) were compared with water quality observations from all sites and strata sampled during the index period. Length-frequency distributions for each species are shown in Appendix Figure 1 with index-sized fish indicated in black. Relative abundance indices were calculated on a subset of the data as described below and time-series averages included all years except the most recent.

American Eel (*Anguilla rostrata*) – American Eel are present along the Atlantic and Gulf coasts of North America and inland in the St. Lawrence Seaway and Great Lakes (Murdy et al*.,* 1997). This catadromous species is panmictic and is supported throughout its range by a single spawning population (Haro et al., 2000). Spawning takes place during winter to early spring in the Sargasso Sea. The eggs hatch into leaf-shaped, ribbon-like larvae called leptocephali, which are transported by ocean currents (over 9-12 months) in a generally northwesterly direction. Within a year, metamorphosis into the next life stage (glass eel) occurs in the Western Atlantic near the east coast of North America. Coastal currents and active migration transport the glass eels into rivers and estuaries from February to June in Virginia and Maryland. As growth continues, eels become pigmented (elver stage) and within 12 –14 months they acquire a dark color with underlying yellow (yellow eel stage). Many eels migrate upriver into freshwater rivers, streams, lakes, and ponds, while others remain in estuaries. Most of the eel’s life is spent in these habitats as a yellow eel. Age at maturity varies greatly with location and latitude, and in the Bay may range from 8 to 24 years; most eels in the Bay area are immature and less than 7 years old (Owens and Geer, 2003). Eels from the Bay mature and migrate at an earlier age than eels from northern areas (Hedgepeth, 1983). Metamorphosis into the silver eel stage occurs during the seaward migration that occurs from late summer through autumn, as mature eels migrate back to the Sargasso Sea to spawn and die (Haro et al., 2000).

The current American Eel index includes all eels > 152 mm TL collected in each of the major tributaries (Figure 6) during April through September (Fenske et al., 2011). The best model supported by the data (n=27 paired tows) to estimate the calibration factor was the binomial model resulting in a calibration factor equal to 0.8731.

American Eel indices exhibited above-average abundance in the Rappahannock River (mean RSI_{Delta} = 1.93) and the James River (mean RSI_{Delta} = 1.72) in the late 1980's and 1990's and below-average abundance thereafter (Table 4; Figure 5). In the York River, below-average abundance (mean RSI_{Delta} = 0.53) has been observed since 1997. We are unable to calculate an index for the Rappahannock and James rivers in 2020 due to missing core stations resulting from the COVID-19 pandemic. Due to logistics with keeping field crews safe, we could not sample the upper James and upper Rappahannock rivers, which is the area where most eels are captured. However, we were able to sample most of the upper York River stations (we sampled 67% of the targeted stations) and the York River 2020 index remained below the historic average. During the index period and historically, American Eel are more abundant in the Rappahannock River compared with the James and York rivers (Figure 6). Positive catches of American Eel are associated with average water temperature (Figure 7), average to below-average salinity (Figure 8), and average to above-average dissolved oxygen content compared with conditions at all sites sampled from index months and strata (Figure 9).

Atlantic Croaker (*Micropogonias undulatus*) – Atlantic Croaker are typically captured in high abundance and are widely distributed throughout the survey area (Figure 10, bottom). Spawning takes place over a protracted period, such that small juveniles (<30 mm TL) can be present in catches year-round (Norcross, 1983; Colvocoresses and Geer, 1991; Colvocoresses et al., 1992; Geer et al., 1994). For some year classes, peak abundance occurs in the fall at lengths less than 100 mm TL, but for other year classes, the peak occurs the following spring. Previously, we provided two estimates of the index: a juvenile fall index (October-December) based on catches in the tributaries, and a spring recruit index (May-August) based on catches in the Bay and tributaries combined. Because the fall index does not reflect over-winter mortality, only the modified spring index, after Woodward (2009), is presented. The spring index is calculated using a delta-lognormal model with juvenile Atlantic Croaker collected from all regions of the Bay and tributaries from April to June. The beta-binomial model was the best model (n=283) and resulted in a calibration factor of 1.4770.

The 2020 year class of Atlantic Croaker exhibited average recruitment with the confidence interval spanning the long-term average (Figure 10). We are unable to estimate an index for the 2019 year class of Atlantic Croaker due to reduced sampling resulting from a stay-at-home order from the Governor of Virginia amidst the COVID-19 pandemic.

Bay Anchovy (*Anchoa mitchilli*) – Bay Anchovy are the most abundant finfish in the Bay and its tributaries, and are found in salinities ranging from 1-33 psu (Murdy et al*.,* 1997). Bay Anchovy feed mostly on zooplankton and are an important prey of other Bay fishes (Murdy et al*.,* 1997). In years of average freshwater inflow (e.g., 1997-2000), Atlantic Menhaden, Bay Anchovy, and Atlantic Croaker often dominate fish biomass in the Bay (Jung, 2002). Only two models converged for estimating the calibration factor for Bay Anchovy and the beta-binomial model was best supported by the data (n=504 paired tows) with a calibration factor of 0.8014.

Bay Anchovy abundance increased in recent years from a period of low recruitment observed during 2001 - 2003 (Table 6; Figure 15). However, from 2014 to 2016, Bay Anchovy exhibited below-average recruitment. We completed sampling at 94% of the targeted stations for Bay Anchovy in 2020 and the resulting index was average (RSI_{GM} = 19.12). As expected, Bay Anchovy were ubiquitous in trawl survey catches with many stations having thousands of individuals in a single tow (Figure 16). Positive catches of Bay Anchovy occurred in cooler waters (Figure 17), with average salinity (Figure 18), and in areas with average to higher dissolved oxygen (Figure 19) compared with all sites sampled from index months and strata.

Black Sea Bass (*Centropristis striata*) – Black Sea Bass are seldom taken in large numbers but regularly occur in survey catches. Young-of-year Black Sea Bass occur throughout the Bay and appear occasionally in the lower portions of the tributaries. Index calculations are based on all Bay strata and the lower James stratum from May through July only (Figure 18, bottom). Although some early juveniles appear in the Bay during their first summer and fall, more young-of-year enter the estuary during the following spring. Black Sea Bass spawn in the summer in the Mid-Atlantic Bight (Musick and Mercer, 1977). Thus, the index is calculated for the year class spawned the previous calendar year (i.e., the index for the 2019 year class is based on catches from May to July 2020). The best model for estimating the calibration factor for Black Sea Bass (n=25 paired tows) was the binomial model resulting in a calibration factor equal to 0.6336.

We are unable to calculate an index for Black Sea Bass in 2020 (2019 year class) due to our inability to complete sampling (we sampled 59% of targeted stations). The Black Sea Bass index was generally above average or average (mean RSI_{GM} = 0.62) prior to 2002, but fell below average in 10 of the last 16 years (Table 7; Figure 20). Historically, positive catches of Black Sea Bass were variable with respect to water temperature (Figure 22), but were associated with higher salinity (Figure 23) and normoxic conditions (Figure 24) compared with all sites sampled during index months and strata.

Blue Catfish (*Ictalurus furcatus*) – The Blue Catfish, one of Virginia's largest freshwater fishes (Jenkins and Burkhead, 1993), was introduced to the Bay area as a sportfish in the James, Rappahannock, and Mattaponi rivers between 1974 and 1989 (Virginia Department of Game and Inland Fisheries, 1989 as reported by Connelly, 2001). The Blue Catfish is an omnivorous bottom feeder that inhabits the main channels and backwaters of rivers (Murdy et al., 1997). Blue Catfish are distributed from the mesohaline portions of the major tributaries upstream into freshwater habitats, beyond the sampling limits of the trawl survey (Figures 23 and 28; Schloesser et al., 2011). Because Blue Catfish are restricted in their distribution, an index of abundance is calculated for each tributary incorporating strata from portions of the lower river and all upper river strata. For estimating calibration factors for juvenile and age 1+ Blue Catfish, the beta-binomial model was best supported by the data ($n_{juvenile}$=78 paired tows; $n_{age\text{-}1+}$ =123 paired tows) and resulted in a calibration factor equal to 1.0023 for juvenile Blue Catfish and 1.4289 for age 1+ Blue Catfish. In 2018, the recruitment window for juvenile and age 1+ Blue Catfish was changed from the period December to March to the new period between September and November (Tuckey and Fabrizio 2018). To maintain consistency, all of the annual indices for Blue Catfish were recalculated based on the new recruitment window.

The James River typically has the highest juvenile Blue Catfish index with above-average recruitment (mean RSI_{Delta} = 1.62) in 1996, 2003, 2004, 2011, 2013, 2016, and the highest recruitment ever in 2018 (Table 8; Figure 25). The 2020 juvenile index for Blue Catfish in the James River was above average (RSI_{Delta} = 8.11). Recruitment of Blue Catfish juveniles in the Rappahannock River was highest in 2003 (RSI_{Delta} = 10.40) followed by 2011 and 2018. The 2020 index for the Rappahannock River showed below-average recruitment (RSI_{Delta} = 0.02). In the York River, Blue Catfish juveniles in 2004 (RSI_{Delta} = 18.56) were 6 times more abundant than the previous record (RSI_{Delta} = 2.97 in 2003; Figure 25), and twice the value observed in 2018 (RSI_{Delta} = 9.89). The 2020 index (RSI_{Delta} = 12.72) for the York River population was the second highest index observed in this system (mean RSI_{Delta} = 1.55). Juvenile Blue Catfish were most abundant in the upper James River (Figure 26). Positive catches of juvenile Blue Catfish occurred in average water temperatures (Figure 27) with lower salinity (Figure 28) and similar dissolved oxygen (Figure 29) compared with conditions at all sites sampled during index months and strata.

Age 1+ Blue Catfish resided in mesohaline portions of the Rappahannock, York and James rivers (as well as freshwater habitats not sampled by the survey; Figure 31). The 2020 abundance index for age 1+ Blue Catfish in the Rappahannock River (RSI_{Delta} = 48.11) was above average (mean long-term RSI_{Delta} = 24.54; Table 9; Figure 30). In the York River, abundance indices for age 1+ Blue Catfish have been average or above average since 2014 (mean long-term RSI_{Delta} = 1.53; Table 9; Figure 30). Recent age 1+ Blue Catfish abundance estimates from the York River have been among the highest observed in this system; the 2020 abundance index was 3.80. In the James River, above-average abundance estimates for age 1+ Blue Catfish have been observed for the past six years (mean long-term RSI_{Delta} = 32.94; Table 9; Figure 30). The 2020 index was 47.74. Positive catches of Age 1+ Blue Catfish occurred in average water temperature (Figure 32), with lower salinity (Figure 33), and in a wide range of dissolved oxygen conditions (Figure 34) compared with conditions at all sites sampled during index months and strata. We note that positive catches of age 1+ Blue Catfish have been occurring in higher salinity waters in recent years compared with the early portion of the times series (Figure 33), suggesting possible adaptation to more saline environments.

Blue Catfish indices have been increasing since the mid-1990's and the ecosystem effects of this invasive species are unknown (Schloesser et al., 2011); the objectives and results of several studies currently underway or recently completed were summarized in a 2014 report submitted to the Sustainable Fisheries Goal Implementation Team. Diets of small Blue Catfish are dominated by invertebrates (mostly amphipods, isopods and mud crabs), whereas larger Blue Catfish consume invertebrates, Atlantic Menhaden (*Brevoortia tyrannus*), and Gizzard Shad (*Dorosoma cepedianum*; Parthree et al., 2008; Schmitt et al., 2017). Other catfishes (White and Channel) have similar diets and may compete with Blue Catfish for the same prey resources (Schloesser et al., 2011). We are currently investigating the trophic interactions of Blue Catfish in the lower James River, where salinities are generally higher than those sampled in previously published studies.

Channel Catfish *(Ictalurus punctatus)* and **White Catfish** *(Ameiurus catus)* – Channel Catfish and White Catfish are usually found in the upper portions of the tributaries (Figures 36, 41, 76, and 81). Although each river system is unique, spawning typically occurs from late May to early July in Virginia (Menzel, 1945); consequently, June was selected as the start of the biological year. The survey typically catches both species up to 600 mm FL with young-of-the-year fish (≤ 50 mm FL) first recruiting to the gear in June. In most years, juvenile recruitment occurs from September to November for both species in the upriver strata only. Because of the low number of paired tows that contained juvenile and age 1+ Channel Catfish and juvenile White Catfish, we used the model-based calibration factor for Blue Catfish for these species. The beta-binomial model was the best model for Blue Catfish and resulted in a calibration factor equal to 1.0023 for YOY catfishes and 1.4289 for age 1+ catfishes. In 2018, the recruitment window for juvenile and age 1+ Channel Catfish and White Catfish was changed from January to April to the new period that occurs from September to November. Annual indices were recalculated to reflect the new recruitment period.

The Channel Catfish was introduced to Virginia in the late 1800s (Jenkins and Burkhead, 1993). Juvenile Channel Catfish exhibited low or failed recruitment in most years with a few notable peaks. In the past 13 years, only nine juvenile Channel Catfish were captured by the trawl survey and none were captured in 2020 (Table 10, Figure 35). Positive catches of juvenile Channel Catfish were associated with average water temperature (Figure 37), below-average salinity (Figure 38), and average dissolved oxygen (Figure 39) compared with all sites sampled during index months and strata.

The age 1+ Channel Catfish RSI_{GM} exhibited below-average values since the early 1990's in the Rappahannock River with only three fish captured since 2018 and none in 2020. In the York River, no age 1+ Channel Catfish have been captured since 2004. In the James River, no age 1+

Channel Catfish have been captured since 2014, and none were captured in 2020 (Table 11; Figure 40). Age 1+ Channel Catfish were found in below-average water temperature (Figure 42), below-average salinity (Figure 43), and average dissolved oxygen conditions (Figure 44) compared with all sites sampled during index months and strata.

Juvenile White Catfish reappeared in the York River in 2018 after a succession of years (2003-2017) when no recruitment was observed (Table 18; Figure 75). Only two juvenile White Catfish were observed in the York River in 2020. Juvenile White Catfish were most abundant in the James River, however abundance was below-average (RSI_{Delta} = 0.09; Figure 75). Positive catches of juvenile White Catfish occurred in average water temperature (Figure 77), below-average salinity (Figure 78), and average dissolved oxygen conditions (Figure 79) compared with all sites sampled during index months and strata.

We had a sufficient number of comparison tows (n=32 paired tows) to estimate a calibration factor for age 1+ White Catfish and the best model was the binomial model resulting in a calibration factor equal to 0.6918. Abundance indices for age 1+ White Catfish were below-average since 2010 in the James River (average = 0.36), below-average since 2004 in the York River (average = 0.11), and below-average since 1997 in the Rappahannock River (average = 0.16; Table 19; Figure 80). Age 1+ White Catfish were most abundant in the James River (Figure 81). Positive catches of age 1+ White Catfish tended to occur in cooler water in the Rappahannock and York rivers, compared with all sites sampled in these two systems, whereas age 1+ White Catfish were captured in average to above-average water temperatures in the James River (Figure 82). Low salinity waters (Figure 83) with average dissolved oxygen conditions (Figure 84) were preferred by age 1+ White Catfish compared with all sites sampled from index months and strata.

Scup (*Stenotomus chrysops*) – Scup are primarily a marine, summer spawning species that use the Bay in a manner similar to Black Sea Bass. The estuary is rarely used as a nursery area by early juveniles (25-40 mm FL), which occasionally appear in survey catches in June. Older juveniles can be found in the Bay during their second summer and first appear in catches in May; by June, they range from 45 to 215 mm FL. Using the original length threshold for Scup that was based on ageing studies (Morse, 1978), trawl survey catches were found to typically include three age groups (age 0, age 1, and age 2+). Because catches of age 1 and age 2+ Scup are highly variable and low, index calculations using trawl survey catches are based on age-0 individuals only. Age-0 fish are present in the Bay and available to the gear for the entire summer and early fall (June to September).

During index months, Scup are predominantly collected in the lower Bay (Figure 46). Catch rates for Scup usually peak in July, and the index was calculated from catches taken in June to September. The generalized linear overdispersion model based on the beta-binomial distribution was the model most supported by the data (n=27 paired tows) resulting in a calibration factor equal to 1.3471.

Scup indices were above average in several recent years (2006, 2008, and 2009), and below average most other years since 1993 (mean long-term RSI_{GM} = 1.23; Table 12; Figure 45). Scup abundance in 2020 (2019 year-class) was below-average and the third lowest index in the time series (RSI_{GM} = 0.18; Table 12). Positive catches of Scup occurred in a variety of water temperatures from below-average to above-average conditions (Figure 47), typically with higher salinity, though that has changed the past three years (Figure 48), and average dissolved oxygen conditions (Figure 49) compared with all sites sampled from index months and strata.

Silver Perch *(Bairdiella chrysoura)* – Silver Perch are found in all sampling strata (Figure 46, bottom). Spawning occurs in the deep waters of the Bay and offshore from May to July, and juveniles (≤ 100 mm TL) enter the Bay by July (Chao and Musick, 1977; Rhodes, 1971). The beta-binomial model was best supported by the data (n=118 paired tows) resulting in a calibration factor for juvenile Silver Perch equal to 0.7524.

Abundance indices for Silver Perch were consistent and stable through 2003 and increased to higher levels thereafter (Table 13; Figure 50). The time series average RSI_{GM} index for Silver Perch was 0.74 and the 2020 index (RSI_{GM} = 0.58) was below-average. Silver Perch were found in all regions sampled, but were most abundant in the York and Rappahannock River systems (Figure 51). Positive catches of juvenile Silver Perch were associated with a wide range of water temperatures (Figure 52), salinities (Figure 53), and dissolved oxygen conditions (Figure 54) that varied relative to all sites sampled from index months and strata.

Spot (*Leiostomus xanthurus*) – Spot were widely distributed throughout the Bay and tributaries (Figure 50, bottom); abundance indices for this species were calculated using all strata from July to October. Spot is often one of the most abundant recreational species captured by the survey. Two models were equally supported by the data (n=187 paired tows) and we chose the simpler model (Beta-binomial model) resulting in a calibration factor equal to 1.1654.

We were able to sample 91% of the target sites for Spot in 2020. Below-average abundance was observed between 1992 and 2007, with average or above average abundance observed during 2008, 2010, 2012, 2013, and 2018 (Table 14; Figure 55). The RSI_{GM} index (10.53) in 2020 was average (mean long-term RSI_{GM} = 12.99). Spot were found throughout the Bay and river systems (Figure 56). Positive catches of Spot were associated with average water temperature (Figure 57), salinity (Figure 58), and dissolved oxygen conditions (Figure 59) compared with all sites sampled from the same index months and strata.

Striped Bass (*Morone saxatilis*) – Striped Bass use the upper tributaries of the Bay as spawning and nursery grounds; spawning occurs from early to mid-April through the end of May, in tidal freshwater areas just above the salt wedge. Juvenile Striped Bass often appear in catches from

May to July in size classes less than 50 mm and up to 100 mm FL during years of high abundance, and we used August to November as the index period. Index calculations were from those juvenile Striped Bass captured in the major tributaries only (Figure 54, bottom), although Striped Bass were encountered in other areas throughout the year. The beta-binomial model was best supported by the data (n=90 paired tows) resulting in a calibration factor equal to 1.2009. In 2018, the recruitment window for juvenile Striped Bass was changed from the period December to February to the new period between August and November. Annual indices were recalculated to reflect the new recruitment period.

Juvenile Striped Bass showed periods of stronger recruitment after the 1995 year class (Table 15; Figure 60). We sampled 85% of the target sites for Striped Bass in 2020. The index value for the 2020 year class (RSI_{GM} = 0.10) was below-average for the time-series (mean RSI_{GM} = 0.40). Juvenile Striped Bass were more abundant in the James River (Figure 61) than in the York or Rappahannock rivers. Positive catches of juvenile Striped Bass varied with respect to water temperatures (Figure 62), but tended to occur in lower salinity (Figure 63) and higher dissolved oxygen conditions (Figure 64) compared with all sites sampled from index months and strata.

Summer Flounder (*Paralichthys dentatus*) – Summer Flounder spawn on the continental shelf from September through January with a peak occurring in October and November (Murdy et al., 1997). Summer Flounder larvae enter the Bay and other Virginia estuaries from October through May with juveniles using shallow fine-substrate areas adjacent to seagrass beds (Murdy et al., 1997; Wyanski, 1990). Whereas low water temperatures can have significant effects on growth and survival of individuals that enter the estuary in the winter (Able and Fahay, 1998), high water temperatures during summer can also have negative effects on the size of individual juvenile Summer Flounder (Nys et al., 2015). Juvenile Summer Flounder first appear in catches in late March, which was used as the beginning of the biological year. Juvenile Summer Flounder abundance increases steadily throughout the summer and early fall to a late fall peak, and then trawl catches decline, presumably reflecting emigration of young fish during December. For our trawl survey, September, October, and November usually encompass the months of greatest abundance of juvenile Summer Flounder. Juvenile Summer Flounder are broadly distributed throughout the Bay and lower rivers. Consequently, index calculations are based on catches from the Bay and lower river strata during September, October, and November (Figure 66). The beta-binomial model was the best model (n=146 paired tows) resulting in a calibration factor equal to 1.0308

Juvenile Summer Flounder indices were greater during the early 1990s compared with recent years with notable peaks in 2004, 2008, and 2012 (Table 16; Figure 65). The 2020 Summer Flounder index (RSI_{GM} = 0.08) was the lowest index value ever observed (mean RSI_{GM} = 0.93). During index months, juvenile Summer Flounder were captured throughout the Bay and lower portions of the rivers (Figure 59), though juvenile Summer Flounder often occur in upriver habitats. Positive catches of juvenile Summer Flounder occurred in average to warmer water temperature (Figure 67) with above average salinity (Figure 68) and variable dissolved oxygen conditions (Figure 69) compared with all sites sampled from index months and strata.

Weakfish (*Cynoscion regalis*) – Weakfish are one of the dominant species in trawl survey catches, and juveniles are found throughout the Bay and tributaries (Figure 62, bottom). Juvenile catches occur in late May and June, with June considered the beginning of the biological year. The best model for estimating the calibration factor was the beta-binomial model (n=220 paired tows) resulting in a calibration factor equal to 1.1924.

We sampled 91% of the target sites for Weakfish in 2020. Overall, the Weakfish index was consistent through time indicating steady recruitment between 1988 and 2013 (mean RSI_{GM} = 5.86; Table 17; Figure 70). However, we observed below-average recruitment since 2014, with the 2020 index (RSI_{GM} = 2.36) slightly above last years' record low. Juvenile Weakfish are found throughout the Bay and rivers with most being found in the York and Rappahannock rivers (Figure 71). Positive catches of juvenile Weakfish occurred in a wide range of water temperatures (Figure 72) with average salinity (Figure 73) and normoxic dissolved oxygen conditions (Figure 74) compared with all sites sampled from index months and strata.

White Perch (*Morone americana*) – Spawning of White Perch occurs in the upper tributaries (Figure 86) from March to July with a peak occurring from late April to early May. Index months include August to October for juveniles and age 1+. Index stations are from the upper river strata and a separate index is calculated for each river. The beta-binomial model was best supported by the data for each size group ($n_{juvenile}$=161 paired tows; $n_{age\text{-}1+}$=210 paired tows) resulting in a calibration factor equal to 1.0679 for YOY White Perch and 1.1676 for age-1+ White Perch. In 2018, the recruitment window for juvenile White Perch was changed from the period December to February to the new period between August and October. Similarly, the recruitment window for White Perch age 1+ was changed from November to February to the new period between August and October. Annual indices were recalculated to reflect the new recruitment period.

Juvenile White Perch recruitment has been stable in each of the rivers, with high and low periods of recruitment (Table 20; Figure 85). The three rivers exhibited different time-series averages with greater numbers of juvenile White Perch occurring in the James River (mean RSI_{GM} = 1.20) followed by the Rappahannock River (mean RSI_{GM} = 0.13) and the York River (mean RSI_{GM} = 0.02). We sampled 73% of the target sites in the Rappahannock River, 100% of the sites in the York River and 67% of the target sites in the James River in 2020. Recruitment was average in the James River, and below-average in the York and Rappahannock rivers in 2020 (Figure 85). Positive catches of juvenile White Perch were associated with average water temperature (Figure 87), average to below-average salinity (Figure 88), and average dissolved oxygen (Figure 89) compared with all sites sampled from index months and strata.

Abundance of age-1+ White Perch was average in the Rappahannock River (mean RSI_{GM} = 0.70) for most of the time series (Table 21; Figure 90). In the York River, abundance of age-1+ White Perch was average or above-average (mean RSI_{GM} = 0.05) prior to 1997 and average to below-average values have been observed since 1998, except 2003 and 2004 (Table 21; Figure 90). Abundance of age-1+ White Perch has been average in the James River (mean RSI_{GM} = 1.33) with above-average abundance between 1995 and 2004 (Table 21; Figure 90). Age-1+ White Perch were collected throughout the upper rivers and more than 380 fish have been observed in a single tow (Figure 91). Positive catches of age-1+ White Perch occurred in average water temperature (Figure 92), average salinity (Figure 93), and normoxic conditions (Figure 94) compared with all sites sampled from index months and strata.

DISCUSSION

Juvenile indices contribute to the assessment and management of important recreational species in Chesapeake Bay and the mid-Atlantic Bight. For example, the VIMS Trawl Survey was recognized by the Mid-Atlantic Fisheries Management Council (MAFMC) as an important source of the Summer Flounder recruitment index; the VIMS index was instrumental in shaping protective harvest regulations in Virginia for this species. Other indices utilized by management agencies include those for American Eel, Atlantic Croaker, Atlantic Menhaden, Black Sea Bass, Bluefish, Red Drum, Spot, and Weakfish. Although a bottom trawl is not the preferred gear with which to sample American Eel, Eel indices from the Trawl Survey played an important role in the 2006 ASMFC American Eel FMP (ASMFC, 2006). In addition to management needs, the VIMS Trawl Survey also fulfills data and specimen requests from a variety of agencies, institutes, and individuals for research and educational purposes (e.g., Woodland et al., 2012; Sobocinski et al., 2013; Nys et al., 2015; Nepal and Fabrizio, 2020). Between July 2020 and June 2021, we responded to 40 requests for information and specimens (Appendix Table 1).

Efforts to improve recruitment indices continue and include evaluation of the size ranges and months (the index period) used in index calculations. For example, the distributional assumptions of the catch of YOY Weakfish and Atlantic Croaker were addressed in a VIMS Master's thesis (Woodward, 2009); the results showed that the nonzero catch data for Weakfish are best described by a gamma distribution and those for Atlantic Croaker appear to follow a lognormal distribution. Such findings indicate that indices of abundance calculated for these species could benefit from further refinements. In addition, the use of different index months for Weakfish and Atlantic Croaker may improve YOY indices by ensuring fewer age-1+ fish are included in YOY index calculations. Additional work may address potential effects of depth on the distribution and catch of these species (Woodward, 2009; Tuckey and Fabrizio, 2013).

The Trawl Survey provides more than relative abundance indices used to tune stock assessments and aid in management activities. The data can also be used to investigate factors that influence species abundance that operate on time periods beyond annual recruitment cycles. For example, using fishery-independent survey data from 1968 to 2004 for estuarine-dependent species, Wood and Austin (2009) found that recruitment of anadromous species was negatively correlated with recruitment of species that spawn on the continental shelf. Furthermore, recruitment patterns favored one group over the other for periods greater than one decade and shifts between recruitment regimes occurred within a short period of time (2-3 years; Wood and Austin, 2009). Understanding that long-term recruitment cycles may dominate for decades is an important development that could inform management options.

Information from the Trawl Survey also provides a basis for monitoring species interactions. For example, annual catch rates of Channel Catfish and White Catfish have declined since 1991, while abundance of the introduced Blue Catfish has increased dramatically (Schloesser et al., 2011; Fabrizio et al. 2018). Because diets and distributions of these species overlap, the observed trends may be due to competition and thus, species interactions warrant further study. Furthermore, the shift in diet of older Blue Catfish to include other fishes may affect ecosystem function (Schloesser et al., 2011; Schmitt et al. 2017). An effort is underway in the Bay to understand the biology and ecology of Blue Catfish and coordinate management throughout the Bay through the Sustainable Fisheries Goal Implementation Team (coordinated by NOAA, Chesapeake Bay Office, and the EPA Chesapeake Bay Program).

Changes in catches of important recreational species may be associated with degradation of estuarine nursery habitats, overfishing, poor recruitment, or a combination of these factors (Murdy et al., 1997). Although it is not possible to determine the cause of recruitment variability from trawl survey data alone, some general observations are possible. Spot recruitment indices for the Bay region have declined greatly over the past 50 years, but year-class strength of this oceanic spawner appears to be controlled by environmental factors occurring outside the Bay (Homer and Mihursky, 1991; Bodolus, 1994). Three of the highest Spot recruitment indices from the past 20 years were observed within the past ten years, indicating favorable conditions for this species in recent years. Atlantic Croaker recruitment indices show significant interannual variability with fluctuations possibly related to environmental conditions that vary annually. Norcross (1983) found that cold winters increased mortality in overwintering juvenile Atlantic Croaker and during some years may “push” the spawning population further south, thereby impeding access of early-stage juveniles to nursery areas in the Bay. The warm winter of 2011-2012 may have contributed to greater winter survival and the high index of abundance for this species observed in 2012, whereas the cold winter of 2014 - 2015 may have contributed to the low index observed in 2015 for Atlantic Croaker. Weakfish recruitment indices remained stable from 1988 to 2013. However, the index for Weakfish for the past seven years has been below average with five of the lowest index values ever observed occurring during this time period. There has also been a decline in adult abundance which may be attributed to an increase in total mortality (ASMFC, 2012). Striped Bass display great recruitment variability and one or two strong year classes may dominate the population at any one time (Richards and Rago, 1999). Finally, recruitment of Summer Flounder to the Bay nurseries in 2020 was the lowest ever observed. Observed declines in the abundance of the adult stock of Summer Flounder may have been due to overfishing or year-class failure (Terceiro, 2006); spawning stock biomass has been steadily decreasing in recent years and is approaching the management threshold. The spawner-recruit relationship in Summer Flounder is highly uncertain, suggesting that environmental conditions during the pre-recruit stage play a role in structuring year-class strength. A meta-analysis of the stock-recruitment relationship for 225 marine stocks suggests that for most stocks, environmental effects may exert a stronger influence on recruitment than spawning stock biomass (Szuwalski et al., 2014). Furthermore, environmental conditions in Bay nurseries may affect juvenile abundance through indirect effects on growth. For example, Nys et al. (2015) found that high water temperature during the summer and a high density of juvenile Summer Flounder negatively affected the observed size of juvenile Summer Flounder in Chesapeake Bay nurseries. Smaller juvenile Summer Flounder may experience higher mortality rates due to size-based predation.

The VIMS Trawl Survey program supplies critical data for management of fishery resources that use the Bay as a spawning or nursery ground. Because the Bay serves as a nursery area for many coastal migratory fish, annual recruitment data are critical for multi-state management efforts along the Atlantic Coast. Furthermore, the Trawl Survey serves as a foundation to conduct research on basic biological characteristics of Bay and tributary fishes, as well as a platform from which emerging issues may be addressed.

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TABLES

Table 1. Spatial, temporal, and length (mm) criteria used to calculate recruitment indices. Highlighted boxes indicate strata, months and sizes used to calculate indices. Cross-hatched boxes indicate that only a portion of those strata are used in index calculations.

	VIMS Trawl Survey - Area / Time / Size Values by Species																				
Species - Age	VIMS	Strata Used									Month											
	SP. CODE	Bay			James		York		Rapp		Size Cut-off Values (mm) - Darkened Areas Represent Index Months											
		BOTTOM	LOWER	UPPER	LOWER	UPPER	LOWER	UPPER	LOWER	UPPER	January	February	March	April	May	June	July	August	September	October	November	December
American Eel 1+	0060				■	■	■	■	■	■	---	---	---	**>152**	**>152**	**>152**	**>152**	**>152**	**>152**	---	---	---
Atlantic Croaker (spring)	0005	■	■	■	■	■	■	■	■	■	0-100	0-100	0-100	**0-110**	**0-135**	**0-160**	0-180	0-220	0-50	0-80	0-100	0-100
Bay Anchovy Y-O-Y	0103	■	■	■	■	■	■	■	■	■	0-77	0-80	0-80	0-80	0-80	0-80	**0-44**	**0-51**	**0-56**	**0-61**	**0-65**	**0-70**
Black Seabass Y-O-Y	0002	■	■	■	■						0-110	0-110	0-110	0-110	**0-110**	**0-150**	**0-175**	0-70	0-85	0-100	0-105	0-110
Blue Catfish Y-O-Y	0314				▨	■	▨	■	▨	■	0-165	0-165	0-165	0-50	0-50	0-75	0-100	0-115	**0-130**	**0-130**	**0-130**	0-165
Blue Catfish 1+	0314				▨	■	▨	■	▨	■	>165	>165	>165	>175	>225	>250	>250	>115	**>130**	**>130**	**>130**	>165
Channel Catfish Y-O-Y	0040					■		■		■	0-130	0-130	0-130	0-140	0-150	0-50	0-80	0-105	**0-120**	**0-130**	**0-130**	0-130
Channel Catfish 1+	0040					■		■		■	>130	>130	>130	>140	>150	>50	>80	>105	**>120**	**>130**	**>130**	>130
Scup	0001	■	■								90-170	90-170	90-170	90-170	35-90	**40-100**	**50-125**	**60-145**	**75-160**	85-170	90-170	90-170
Silver Perch Y-O-Y	0213	■	■	■	■	■	■	■	■	■	0-160	0-160	0-160	0-160	0-165	0-170	0-100	0-130	**0-150**	**0-160**	**0-160**	0-160
Spot Y-O-Y	0033	■	■	■	■	■	■	■	■	■	0-200	0-200	0-50	0-75	0-100	0-135	**0-160**	**0-180**	**0-200**	**0-200**	0-200	0-200
Striped Bass Y-O-Y	0031					■		■		■	0-200	0-200	0-200	0-200	0-50	0-80	0-100	**0-120**	**0-135**	**0-150**	**0-175**	0-190
Summer Flounder Y-O-Y	0003	■	■	■	■		■		■		0-290	0-290	0-60	0-100	0-140	0-170	0-200	0-225	**0-250**	**0-275**	**0-290**	0-290
Weakfish Y-O-Y	0007	■	■	■	■	■	■	■	■	■	0-200	0-200	0-200	0-225	0-240	0-90	0-120	**0-150**	**0-180**	**0-200**	0-200	0-200
White Catfish Y-O-Y	0039					■		■		■	0-110	0-110	0-110	0-110	0-120	0-50	0-65	0-80	**0-90**	**0-100**	**0-110**	0-110
White Catfish 1+	0039					■		■		■	>110	>110	>110	>110	>120	>50	>65	>80	**>90**	**>100**	**>110**	>110
White Perch Y-O-Y	0032					■		■		■	0-85	0-85	0-85	0-95	0-35	0-65	0-73	**0-80**	**0-85**	**0-85**	0-85	0-85
White Perch 1+	0032					■		■		■	>86	>86	>86	>96	>36	>66	>74	**>81**	**>86**	**>85**	>86	>86

Table 2. Sample collection history of the VIMS Trawl Survey, 1988 – June 2021. Each entry in the table represents the number of completed tows for the regular survey (not including Mobjack Bay); YR is year, TOT is total, STAT. TYPE is station type. Other codes are below and are based on Wojcik and Van Engel (1988), Appendices A – C.

YR	TOT	MONTH												WATER SYSTEM						Vessel			Gear		STAT. TYPE		TOW DURATION/DISTANCE		
		J	F	M	A	M	J	J	A	S	O	N	D	CL	JA	PO	RA	YK	ZZ	FH	TW	OT	070	108	F	R	5	OT	DIS
1988	889	69	69	62	48	82	82	82	82	82	82	80	69	576	97	0	105	111	0	0	0	889	889	0	313	576	885	0	4
1989	840	61	61	61	66	76	76	76	76	76	76	76	59	479	108	0	124	129	0	0	0	840	840	0	361	479	840	0	0
1990	827	61	61	61	61	76	76	77	75	76	69	76	58	473	108	0	119	127	0	279	0	548	827	0	354	473	826	0	1
1991	930	61	25	61	61	73	94	95	95	97	97	97	74	411	108	0	120	291	0	930	0	0	0	930	357	573	928	1	1
1992	982	79	47	79	79	97	88	88	88	89	88	88	72	404	110	0	124	344	0	982	0	0	0	982	361	621	975	7	0
1993	915	40	73	40	71	88	89	88	88	88	88	87	75	370	110	0	126	309	0	915	0	0	0	915	365	550	914	1	0
1994	911	40	73	40	73	88	88	88	88	88	88	88	69	368	110	0	124	309	0	911	0	0	0	911	363	548	906	5	0
1995	993	40	73	40	73	92	88	88	88	105	105	99	102	411	96	0	201	285	0	993	0	0	0	993	314	679	984	9	0
1996	1176	52	91	71	106	106	107	108	108	107	108	107	105	435	228	0	258	255	0	1176	0	0	0	1176	279	897	1168	6	2
1997	1220	68	105	66	98	110	111	111	112	111	112	111	105	425	265	0	264	266	0	1220	0	0	0	1220	302	918	1217	3	0
1998	1262	66	105	66	105	111	111	128	59	138	124	130	119	388	265	0	256	264	89	1262	0	0	0	1262	322	940	1261	1	0
1999	1382	79	122	80	122	120	118	119	118	122	124	131	127	402	264	0	264	265	187	1382	0	0	0	1382	363	1019	1380	2	0
2000	1367	52	129	85	101	158	111	128	125	121	141	111	105	433	250	17	266	265	136	1367	0	0	0	1367	363	1004	1367	0	0
2001	1122	30	30	30	75	112	144	111	112	135	136	111	96	384	230	35	230	230	13	1017	0	105	0	1122	277	845	1119	1	2
2002	1090	66	90	66	90	96	106	96	97	95	96	96	96	288	264	0	264	264	10	1090	0	0	0	1090	300	790	1089	1	0
2003	1191	66	96	66	96	96	111	111	111	111	111	111	105	399	264	0	264	264	0	1191	0	0	0	1191	300	891	1191	0	0
2004	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	1224	0	0	0	1224	300	924	1224	0	0
2005	1211	66	105	66	105	111	111	111	111	113	111	111	90	419	264	0	264	264	0	1211	0	0	0	1211	300	911	1211	0	0
2006	1193	66	105	66	105	111	111	111	111	113	111	78	105	423	242	0	264	264	0	1193	0	0	0	1193	292	901	1193	0	0
2007	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	1224	0	0	0	1224	300	924	1224	0	0
2008	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	1224	0	0	0	1224	300	924	1224	0	0
2009	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	1224	0	0	0	1224	300	924	1224	0	0
2010	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	170	1224	0	0	0	1224	300	924	1224	0	0
2011	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	204	1224	0	0	0	1224	300	924	1224	0	0
2012	1205	66	105	66	105	111	111	111	111	111	111	92	105	432	264	0	264	264	148	1205	0	0	0	1205	300	905	1205	0	0
2013	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	1224	0	0	0	1224	300	924	1224	0	0
2014	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	1224	0	0	0	1224	300	924	1224	0	0
2015	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	453	771	0	0	1224	300	924	1224	0	0
2016	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	0	1224	0	0	1224	300	924	1224	0	0
2017	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	0	1224	0	0	1224	300	924	1224	0	0
2018	1053	0	0	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	0	1053	0	0	1053	250	803	1053	0	0
2019	1224	66	105	66	105	111	111	111	111	111	111	111	105	432	264	0	264	264	0	0	1224	0	0	1224	300	924	1224	0	0
2020	918	66	105	66	0	0	61	91	91	111	111	111	105	298	200	0	200	220	0	0	918	0	0	918	234	684	918	0	0
2021	564	66	105	66	105	111	111							168	132	0	132	132	0	0	564	0	0	564	102	462	564	0	0
TOT	37,929	2,052	3,035	2,162	3,110	3,468	3,548	3,461	3,389	3,532	3,532	3,434	3,206	14,002	7,411	52	7,665	8,554	957	28,569	6,978	2,382	2,556	35,373	10,372	27,557	37,882	37	10

System: CL - Lower Chesapeake Bay (Virginia Portion), JA - James River, PO - Potomac River, RA - Rappahannock River, YK - York River, ZZ - includes: Atlantic Ocean (AT) - 1971, 78-79, 2002; Piankatank R. (PK) - 1970-71, 98-00; Mobjack Bay (MB) - 1970-73, 98-01, 10-12; Pocomoke Sound (CP) -1973-81, 98-01; Great Wicomico R. (GW) - 1998-00. **Vessel:** FH - Fish Hawk, TW - Tidewater, OT – Other **Gear Code:** 30' Gear 070 - Lined, tickler chain, 60' bridle, 54"x24" doors, 108 - Lined, tickler chain, 60' bridle, metal china-v doors. **Station Type:** F – Fixed, R – Random. **Tow type**: OT is tow duration in minutes for those not listed. DIS is distance.

Table 3. VIMS Trawl Survey pooled catch for July 2020 to June 2021 from 902 tows.

Adjusted Percent of Catch Excludes Bay Anchovy and Hogchoker

Species	Number of Fish (All)	Frequency	Percent of Catch	Catch Per Trawl	Adjusted Percent of Catch	Number of Fish YOY	Average Length (mm)	Standard Error (length)	Minimum Length (mm)	Maximum Length (mm)
Bay Anchovy	358,444	954	65.85	301.21	.	315,106	52	0.05	18	102
Hogchoker	52,017	544	9.56	43.71	.	13,198	80	0.19	23	184
Spot	27,991	624	5.14	23.52	20.91	23,304	123	0.19	11	212
Atlantic Croaker	25,520	615	4.69	21.45	19.06	20,762	90	0.44	11	263
Weakfish	21,757	440	4	18.28	16.25	20,981	92	0.46	18	328
Blue Catfish	15,685	257	2.88	13.18	11.71	6,216	202	0.97	32	855
White Perch	11,312	304	2.08	9.51	8.45	1,378	143	0.42	27	280
Striped Anchovy	8,104	149	1.49	6.81	6.05	7,935	72	0.48	17	128
Atlantic Menhaden	5,913	139	1.09	4.97	4.42	315	111	1.44	21	289
Silver Perch	3,940	301	0.72	3.31	2.94	3,837	111	0.44	26	197
Spotted Hake	2,650	194	0.49	2.23	1.98	2,648	106	0.79	41	272
Blackcheek Tonguefish	2,562	313	0.47	2.15	1.91	586	121	0.56	45	194
Southern Kingfish	1,547	188	0.28	1.3	1.16	1,455	106	1.31	31	305
Atlantic Thread Herring	719	83	0.13	0.6	0.54	.	79	1.23	34	173
White Catfish	646	132	0.12	0.54	0.48	229	163	2.78	29	466
Butterfish	576	103	0.11	0.48	0.43	482	98	1.01	30	202
Threadfin Shad	569	60	0.1	0.48	0.42	.	87	0.68	57	156
Gizzard Shad	527	88	0.1	0.44	0.39	335	178	2.75	91	402
Atlantic Cutlassfish	472	94	0.09	0.4	0.35	.	279	6.95	71	932
Star Drum	405	29	0.07	0.34	0.3	.	65	1.76	27	157
Black Sea Bass	372	136	0.07	0.31	0.28	301	99	1.66	33	209
Striped Bass	331	115	0.06	0.28	0.25	190	196	5.56	25	494
American Shad	255	87	0.05	0.21	0.19	254	89	0.99	65	147
Blueback Herring	213	54	0.04	0.18	0.16	211	72	0.74	51	161
Northern Searobin	163	43	0.03	0.14	0.12	163	101	2.38	21	139
Summer Flounder	149	110	0.03	0.13	0.11	111	204	6.52	16	488
Banded Drum	132	21	0.02	0.11	0.1	.	149	2.04	65	222
Harvestfish	115	55	0.02	0.1	0.09	107	70	3.17	19	181
Spotfin Mojarra	113	38	0.02	0.09	0.08	93	105	1.82	45	171
Inshore Lizardfish	111	69	0.02	0.09	0.08	85	165	5.21	40	297
Atlantic Moonfish	100	37	0.02	0.08	0.07	.	76	1.65	41	106
Atlantic Spadefish	90	39	0.02	0.08	0.07	.	73	2.93	26	136
Alewife	86	35	0.02	0.07	0.06	84	97	2.11	46	161
Oyster Toadfish	77	47	0.01	0.06	0.06	.	146	8.4	33	334
Striped Searobin	52	35	0.01	0.04	0.04	.	60	3.26	19	160
Atlantic Silverside	44	18	0.01	0.04	0.03	44	79	1.59	60	102
American Eel	38	28	0.01	0.03	0.03	.	302	17.58	64	550
Black Drum	38	16	0.01	0.03	0.03	.	184	5.66	123	271
Northern Pipefish	36	28	0.01	0.03	0.03	.	154	8.47	37	250
Longnose Gar	36	17	0.01	0.03	0.03	.	771	31.22	287	1148
Smallmouth Flounder	34	26	0.01	0.03	0.03	30	74	3.72	33	116
Pigfish	30	15	0.01	0.03	0.02	.	128	6.54	34	169
Spanish Mackerel	28	14	0.01	0.02	0.02	.	120	8.73	40	220
Striped Cusk-eel	28	8	0.01	0.02	0.02	.	148	3.61	104	180
Naked Goby	25	17	0	0.02	0.02	.	43	1.76	25	57
Northern Puffer	24	22	0	0.02	0.02	20	86	9.53	17	195
Bluefish	23	19	0	0.02	0.02	.	216	5.38	147	273
Lined Seahorse	19	13	0	0.02	0.01	.	77	6.72	32	138
Silver Seatrout	17	10	0	0.01	0.01	.	155	7.54	102	206
Spiny Dogfish	16	6	0	0.01	0.01	.	642	30.07	506	901
Feather Blenny	14	13	0	0.01	0.01	.	77	5.14	42	107
Skilletfish	14	8	0	0.01	0.01	.	35	3.93	22	68

Table 3. (continued)

Species	Number of Fish (All)	Frequency	Percent of Catch	Catch Per Trawl	Adjusted Percent of Catch	Number of Fish YOY	Average Length (mm)	Standard Error (length)	Minimum Length (mm)	Maximum Length (mm)
Spotted Seatrout	12	11	0	0.01	0.01	.	183	15.9	109	284
Seaboard Goby	12	8	0	0.01	0.01	.	37	1.63	28	48
Atlantic Stingray	10	8	0	0.01	0.01	.	283	21.55	220	391
Blue Runner	10	8	0	0.01	0.01	.	131	6.69	112	181
Clearnose Skate	8	8	0	0.01	0.01	.	499	34.33	428	665
Atlantic Sturgeon	7	7	0	0.01	0.01	.	516	61.41	197	690
Darter Goby	7	7	0	0.01	0.01	.	67	3.07	55	78
Chain Pipefish	7	6	0	0.01	0.01	.	277	12.54	243	338
Atlantic Herring	7	4	0	0.01	0.01	.	241	12.78	200	292
Fringed Flounder	6	6	0	0.01	0	.	102	6.14	78	121
Red Drum	6	5	0	0.01	0	.	333	25.65	237	396
Bluntnose Stingray	6	5	0	0.01	0	.	429	75.35	215	715
Cownose Ray	6	2	0	0.01	0	.	500	22.1	392	532
Windowpane	5	5	0	0	0	4	119	16.44	71	174
Striped Burrfish	5	5	0	0	0	.	173	29.53	58	221
Guaguanche	5	5	0	0	0	.	92	15.24	57	145
Spottail Shiner	5	4	0	0	0	.	87	6.07	69	105
Spiny Butterfly Ray	4	3	0	0	0	.	551	4.23	540	558
Kingfish spp	4	2	0	0	0	4	27	6.08	16	44
Hickory Shad	3	3	0	0	0	.	122	20.7	81	145
Florida Pompano	3	3	0	0	0	.	150	3.28	144	155
Brown Bullhead	3	3	0	0	0	.	175	63.55	63	283
Lookdown	3	3	0	0	0	.	81	6.89	73	95
Northern Stargazer	3	3	0	0	0	.	29	4.16	23	37
Striped Mullet	3	2	0	0	0	.	176	26.36	148	229
Spotfin Mojarra	3	2	0	0	0	.	100	3.84	93	106
Sheepshead	2	2	0	0	0	.	296	204	92	500
Tessellated Darter	2	2	0	0	0	.	56	12.5	43	68
Sea Lamprey	2	2	0	0	0	.	150	3	147	153
Bullnose Ray	2	2	0	0	0	.	397	109.5	287	506
Bigeye Scad	2	2	0	0	0	.	112	12.5	99	124
Cobia	2	1	0	0	0	.	744	13.5	730	757
Channel Catfish	2	1	0	0	0	1	151	77	74	228
Tautog	1	1	0	0	0	.	126	.	126	126
Northern Kingfish	1	1	0	0	0	1	110	.	110	110
Round Herring	1	1	0	0	0	.	252	.	252	252
Green Goby	1	1	0	0	0	.	41	.	41	41
Striped Blenny	1	1	0	0	0	.	76	.	76	76
Sandbar Shark	1	1	0	0	0	.	578	.	578	578
Conger Eel	1	1	0	0	0	.	459	.	459	459
Silver Jenny	1	1	0	0	0	.	67	.	67	67
Speckled Worm Eel	1	1	0	0	0	.	318	.	318	318
All Species Combined	544,355									

Table 4. American Eel indices (RSI$_{\text{Delta;}}$ 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019; ** Indicates we were unable to calculate an index for 2020 in the Rappahannock and James rivers because of a pause in sampling due to COVID-19. Average values calculated from 1987 to 2019.

	Rappahannock			York			James		
Year	Index	Prop. pos.	N	Index	Prop. pos.	N	Index	Prop. pos.	N
1988	2.31	0.20	35	1.27	0.33	40	2.32	0.30	30
1989	11.82	0.37	43	3.50	0.27	49	6.08	0.37	38
1990	13.34	0.40	43	4.90	0.30	50	9.69	0.42	38
1991	4.89	0.38	42	0.64	0.18	49	1.82	0.26	38
1992	1.95	0.28	43	0.83	0.19	47	8.99	0.42	38
1993	1.87	0.30	43	0.33	0.16	49	5.74	0.42	38
1994	3.45	0.40	43	0.33	0.16	49	2.21	0.37	38
1995	2.83	0.37	43	0.33	0.18	49	1.74	0.37	46
1996	2.54	0.36	128	0.58	0.25	126	3.90	0.41	126
1997	2.71	0.45	132	0.47	0.19	132	1.77	0.36	132
1998	2.02	0.31	124	0.48	0.19	132	1.91	0.35	132
1999	0.71	0.23	132	0.23	0.14	133	1.16	0.31	132
2000	1.38	0.32	133	0.24	0.16	133	0.87	0.28	132
2001	0.58	0.18	133	0.16	0.14	133	0.58	0.23	134
2002	0.28	0.16	132	0.24	0.15	132	0.73	0.23	132
2003	0.61	0.20	132	0.14	0.11	132	0.57	0.23	132
2004	0.44	0.25	132	0.14	0.11	132	0.46	0.16	132
2005	0.14	0.11	132	0.09	0.05	132	0.26	0.17	132
2006	0.08	0.05	132	0.04	0.04	132	0.14	0.11	132
2007	0.20	0.11	132	0.08	0.06	132	0.11	0.10	132
2008	0.47	0.22	132	0.21	0.17	132	0.17	0.13	132
2009	0.48	0.17	132	0.14	0.12	132	0.33	0.16	132
2010	0.51	0.21	132	0.16	0.14	132	0.19	0.11	132
2011	0.85	0.30	132	0.10	0.10	132	0.34	0.17	132
2012	0.85	0.27	132	0.12	0.11	132	0.18	0.09	132
2013	0.96	0.25	132	0.16	0.12	132	0.43	0.14	132
2014	0.55	0.20	132	0.18	0.16	132	0.22	0.14	132
2015*	0.32	0.17	132	0.08	0.08	132	0.11	0.10	132
2016*	0.30	0.18	132	0.07	0.07	132	0.09	0.10	132
2017*	0.18	0.14	132	0.05	0.04	132	0.15	0.11	132
2018*	0.23	0.10	132	0.06	0.06	132	0.07	0.08	132
2019*	0.25	0.13	132	0.04	0.04	132	0.08	0.06	132
2020**	-	-	-	0.02	0.02	88	-	-	-
Average	1.88			0.51			1.67		

Table 5. Spring Atlantic Croaker indices ($\text{RSI}_{\text{Delta}}$; 1987–2020). ^ indicates the 2008 Index if a single large catch of Atlantic Croaker in the Bay is included; *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015; ** Indicates we were unable to calculate an index for the 2019 year-class because of a pause in sampling due to COVID-19. Average values calculated from 1987 to 2018.

Year Class	Year	Mean all	LCI all	UCI all
1987	1988	0.95	0.27	2.30
1988	1989	14.14	1.43	36.26
1989	1990	6.40	0.60	12.01
1990	1991	28.39	4.93	113.38
1991	1992	2.80	2.17	3.51
1992	1993	7.22	3.27	13.37
1993	1994	0.52	0.26	0.83
1994	1995	2.06	1.25	3.05
1995	1996	0.03	0.01	0.05
1996	1997	65.51	8.67	218.30
1997	1998	12.68	8.42	23.21
1998	1999	4.98	2.46	10.37
1999	2000	1.17	0.70	1.70
2000	2001	1.55	0.21	6.37
2001	2002	7.64	4.61	10.79
2002	2003	0.90	0.07	2.39
2003	2004	4.36	2.90	5.95
2004	2005	2.72	1.59	4.84
2005	2006	9.46	5.79	16.17
2006	2007	6.36	4.18	9.66
2007	2008	28.06	22.21	36.08
2008	2009	10.21	6.58	15.75
^		114.71	7.32	555.36
2009	2010	29.07	6.63	73.25
2010	2011	4.43	1.36	8.36
2011	2012	56.20	39.68	84.44
2012	2013	23.23	12.01	51.44
2013	2014	56.56	2.95	522.71
2014	2015	4.74	0.76	20.11
2015*	2016	27.41	3.58	79.57
2016*	2017	15.19	6.83	34.43
2017*	2018	0.61	0.27	1.33
2018*	2019	15.64	7.29	38.18
2019**	2020	-	-	-
2020*	2021	6.87	3.45	11.60
Average		14.10		

Table 6. Bay Anchovy indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019.

	Random Stratified Index (RSI)			
Year	Geo. Mean	95% C.I.'s	C.V.	N
1988	18.25	12.17 - 27.15	6.42	346
1989	52.47	36.27 - 75.71	4.54	374
1990	6.79	4.41 - 10.22	8.89	369
1991	22.51	15.05 - 33.43	6.04	491
1992	40.14	27.17 - 59.09	5.10	448
1993	43.31	28.80 - 64.89	5.23	449
1994	14.67	9.93 - 21.46	6.54	444
1995	18.36	12.84 - 26.07	5.66	540
1996	15.31	11.20 - 20.82	5.21	607
1997	18.96	13.63 - 26.23	5.19	625
1998	30.26	20.75 - 43.93	5.27	579
1999	15.47	11.20 - 21.22	5.35	606
2000	36.58	26.69 - 49.99	4.21	619
2001	9.55	6.93 - 13.04	6.06	627
2002	5.51	3.58 - 8.24	9.36	540
2003	18.03	13.17 - 24.56	5.01	624
2004	23.06	16.71 - 31.70	4.82	624
2005	22.27	16.01 - 30.85	4.98	613
2006	19.31	14.00 - 26.50	5.03	592
2007	23.76	17.33 - 32.44	4.69	624
2008	50.29	36.21 - 69.68	4.07	624
2009	30.12	22.30 - 40.55	4.21	624
2010	84.92	61.27 - 117.54	3.61	624
2011	26.56	19.20 - 36.59	4.68	624
2012	51.53	36.84 - 71.92	4.14	611
2013	23.76	16.92 - 33.19	5.03	624
2014	5.18	3.69 - 7.14	7.57	624
2015*	8.73	6.34 - 11.90	6.20	624
2016*	11.72	8.82 - 15.48	5.09	624
2017*	27.56	20.40 - 37.12	4.30	624
2018*	17.79	13.00 - 24.20	5.01	624
2019*	10.16	7.75 - 13.73	5.76	624
2020*	19.12	14.05 - 25.91	4.84	586
Average	25.09			

Table 7. Black Sea Bass indices (RSI_{GM}; Year Class 1988–2019). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015; ** Indicates we were unable to calculate an index for 2020 because of a pause in sampling due to COVID-19. Average values calculated from year class 1988 to 2018.

		Random Stratified Index (RSI)			
Year	Year class	Geo. Mean	95% C.I.'s	C.V.	N
1989	1988	0.84	0.59 - 1.13	11.89	138
1990	1989	2.36	1.70 - 3.17	8.93	138
1991	1990	1.12	0.78 - 1.53	11.63	128
1992	1991	1.28	0.91 - 1.72	10.76	129
1993	1992	0.22	0.13 - 0.32	18.86	129
1994	1993	1.05	0.74 - 1.42	11.46	129
1995	1994	1.06	0.74 - 1.45	11.85	129
1996	1995	0.50	0.33 - 0.69	14.47	151
1997	1996	0.36	0.22 - 0.52	17.99	152
1998	1997	0.46	0.31 - 0.63	14.63	153
1999	1998	0.57	0.35 - 0.82	16.40	135
2000	1999	0.58	0.41 - 0.77	12.22	146
2001	2000	0.74	0.50 - 1.02	13.39	153
2002	2001	1.29	0.85 - 1.84	12.89	108
2003	2002	0.64	0.41 - 0.90	15.16	138
2004	2003	0.12	0.06 - 0.18	25.11	153
2005	2004	0.06	0.02 - 0.10	34.69	153
2006	2005	0.19	0.12 - 0.26	17.66	153
2007	2006	0.44	0.30 - 0.60	14.14	153
2008	2007	0.83	0.53 - 1.18	14.68	153
2009	2008	0.41	0.27 - 0.57	14.90	153
2010	2009	0.32	0.19 - 0.47	19.23	153
2011	2010	1.11	0.83 - 1.43	9.41	153
2012	2011	0.65	0.47 - 0.85	11.61	153
2013	2012	0.19	0.11 - 0.28	19.21	153
2014	2013	0.30	0.20 - 0.42	16.21	153
2015*	2014	0.15	0.09 - 0.21	19.18	153
2016*	2015	0.21	0.14 - 0.29	16.07	153
2017*	2016	0.54	0.38 - 0.71	12.28	153
2018*	2017	0.08	0.04 - 0.12	26.02	153
2019*	2018	0.60	0.43 - 0.79	11.82	153
2020**	2019	-	-	-	-
	Average	0.62			

Table 8. Blue Catfish juvenile indices (RSI_{Delta}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

Young-of-the-year blue catfish relative abundance indices (delta lognormal) and the time series average by

	Rappahannock			York			James		
Year Class	Index	Prop. pos.	N	Index	Prop. pos.	N	Index	Prop. pos.	N
1988	0.00	0.00	34	0.00	0.00	36	0.00	0.00	24
1989	0.00	0.00	32	0.00	0.00	36	0.00	0.00	20
1990	0.00	0.00	30	0.00	0.00	32	0.00	0.00	22
1991	0.00	0.00	34	0.00	0.00	34	0.00	0.00	24
1992	0.00	0.00	34	0.00	0.00	32	0.00	0.00	24
1993	0.00	0.00	32	0.00	0.00	36	0.00	0.00	22
1994	0.00	0.00	32	0.00	0.00	36	0.00	0.00	24
1995	0.00	0.00	36	0.00	0.00	36	0.14	0.07	28
1996	0.17	0.02	92	0.00	0.00	82	6.41	0.41	78
1997	0.00	0.00	48	0.00	0.00	45	0.00	0.00	44
1998	0.00	0.00	48	0.00	0.00	45	0.16	0.04	46
1999	0.00	0.00	48	0.00	0.00	45	0.49	0.14	43
2000	0.00	0.00	49	0.00	0.00	45	0.07	0.04	45
2001	0.00	0.00	49	0.00	0.00	46	0.04	0.02	46
2002	0.00	0.00	48	0.00	0.00	45	0.16	0.02	45
2003	10.40	0.08	48	2.97	0.18	45	18.89	0.42	45
2004	0.25	0.06	48	18.56	0.22	45	7.93	0.53	45
2005	0.00	0.00	48	0.04	0.02	45	1.56	0.20	45
2006	0.02	0.02	48	0.56	0.07	45	1.51	0.37	30
2007	0.00	0.00	48	0.00	0.00	45	0.16	0.04	45
2008	0.00	0.00	48	1.69	0.04	45	0.00	0.00	45
2009	0.00	0.00	48	0.00	0.00	45	0.27	0.09	45
2010	0.00	0.00	48	0.04	0.04	45	0.00	0.00	45
2011	6.74	0.17	48	1.05	0.13	45	2.61	0.27	45
2012	0.00	0.00	48	6.12	0.09	45	0.00	0.00	45
2013	0.11	0.08	48	1.80	0.09	45	4.98	0.22	45
2014	0.40	0.04	48	1.14	0.09	45	0.12	0.04	45
2015*	0.08	0.04	48	1.81	0.13	45	0.20	0.02	45
2016*	0.00	0.00	48	3.11	0.09	45	2.94	0.13	45
2017*	0.00	0.00	48	0.07	0.02	45	0.04	0.04	45
2018*	7.75	0.33	48	9.89	0.33	45	44.30	0.58	45
2019*	0.40	0.08	48	0.86	0.13	45	0.19	0.04	45
2020*	0.02	0.02	48	12.72	0.11	45	8.11	0.27	45
Average	0.82			1.55			2.91		

Table 9. Blue Catfish age 1+ indices ($\text{RSI}_{\text{Delta}}$; 1988 –2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

Age1+ blue catfish relative abundance indices (delta lognormal) and the time series average by river from 1989 to

	Rappahannock			York			James		
Year	Index	Prop. pos.	N	Index	Prop. pos.	N	Index	Prop. pos.	N
1988	0.00	0.00	34	0.00	0.00	36	0.00	0.00	24
1989	0.00	0.00	32	0.00	0.00	36	0.30	0.10	20
1990	0.00	0.00	30	0.00	0.00	32	0.00	0.00	22
1991	0.00	0.00	34	0.00	0.00	34	0.00	0.00	24
1992	0.00	0.00	34	0.00	0.00	32	0.00	0.00	24
1993	0.00	0.00	32	0.00	0.00	36	0.00	0.00	22
1994	1.70	0.25	32	0.00	0.00	36	0.00	0.00	24
1995	0.31	0.11	36	0.00	0.00	36	8.97	0.29	28
1996	36.31	0.33	92	0.00	0.00	82	4.30	0.51	78
1997	137.30	0.23	48	0.02	0.02	45	33.76	0.32	44
1998	56.81	0.25	48	0.00	0.00	45	27.01	0.35	46
1999	7.91	0.17	48	0.04	0.04	45	29.11	0.63	43
2000	19.18	0.29	49	0.00	0.00	45	17.44	0.53	45
2001	6.30	0.20	49	0.04	0.04	46	4.56	0.28	46
2002	1.08	0.08	48	0.02	0.02	45	2.91	0.22	45
2003	34.66	0.63	48	0.76	0.22	45	7.26	0.69	45
2004	17.97	0.48	48	1.73	0.29	45	47.27	0.78	45
2005	37.61	0.25	48	3.44	0.18	45	47.07	0.51	45
2006	48.95	0.33	48	1.13	0.16	45	39.19	0.73	30
2007	1.95	0.15	48	0.80	0.11	45	22.66	0.47	45
2008	3.03	0.19	48	1.05	0.11	45	11.39	0.51	45
2009	13.61	0.42	48	0.49	0.11	45	38.20	0.56	45
2010	8.40	0.29	48	1.35	0.13	45	16.45	0.53	45
2011	17.18	0.73	48	1.59	0.40	45	30.45	0.71	45
2012	17.37	0.27	48	2.07	0.16	45	28.86	0.47	45
2013	69.93	0.42	48	1.19	0.18	45	24.69	0.67	45
2014	32.72	0.44	48	2.30	0.20	45	15.86	0.58	45
2015*	124.35	0.35	48	2.98	0.33	45	58.84	0.64	45
2016*	27.51	0.27	48	5.95	0.18	45	109.37	0.60	45
2017*	12.83	0.31	48	3.63	0.18	45	54.18	0.47	45
2018*	15.29	0.71	48	11.92	0.56	45	56.37	0.87	45
2019*	35.07	0.35	48	6.56	0.20	45	317.77	0.42	45
2020*	48.11	0.50	48	3.80	0.40	45	47.74	0.78	45
Average	24.54			1.53			32.94		

Table 10. Channel Catfish juvenile indices (RSI$_{GM}$; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Rappahannock				York				James			
Year	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.
1988	0.07	9	35.33	0.02 - 0.13	0.00	12		0	1.03	8	11.03	0.74 - 1.38
1989	0.31	9	25.18	0.14 - 0.50	0.00	12		0	0.11	6	100.00	0.00 - 0.35
1990	0.18	7	16.88	0.12 - 0.25	0.00	10		0	0.25	6	40.98	0.04 - 0.50
1991	0.05	9	100.00	0.00 - 0.15	0.00	11		0	0.00	6		0
1992	0.07	9	66.96	0.00 - 0.17	0.00	10		0	0.05	6	100.00	0.00 - 0.16
1993	0.03	9	65.63	0.00 - 0.07	0.03	12	68.31	0.00 - 0.08	0.02	6	100.00	0.00 - 0.07
1994	0.10	9	47.85	0.00 - 0.21	0.01	12	100.00	0.00 - 0.03	0.04	6	100.00	0.00 - 0.13
1995	0.01	9	100.00	0.00 - 0.03	0.00	12		0	1.09	10	12.96	0.72 - 1.52
1996	0.19	27	18.12	0.12 - 0.26	0.02	26	83.63	0.00 - 0.05	0.46	27	16.28	0.29 - 0.65
1997	0.07	30	52.70	0.00 - 0.16	0.01	30	68.29	0.00 - 0.01	0.37	30	30.09	0.13 - 0.65
1998	0.05	30	47.56	0.00 - 0.09	0.00	30		0	0.21	30	40.41	0.04 - 0.42
1999	0.03	30	71.98	0.00 - 0.08	0.00	30	66.14	0.00 - 0.01	0.36	30	31.85	0.12 - 0.66
2000	0.02	31	43.32	0.00 - 0.04	0.00	29	100.00	0.00 - 0.01	0.10	30	52.35	0.00 - 0.21
2001	0.05	31	85.40	0.00 - 0.14	0.00	30		0	0.06	30	67.50	0.00 - 0.15
2002	0.06	30	93.64	0.00 - 0.12	0.00	30	100.00	0.00 - 0.01	0.03	30	80.93	0.00 - 0.09
2003	0.04	30	82.71	0.00 - 0.12	0.00	30		0	0.13	30	55.85	0.00 - 0.29
2004	0.01	30	77.15	0.00 - 0.03	0.00	30		0	0.12	30	37.83	0.03 - 0.21
2005	0.00	30		0	0.00	30		0	0.03	30	54.57	0.00 - 0.07
2006	0.02	30	88.27	0.00 - 0.07	0.00	30		0	0.02	20	89.12	0.00 - 0.06
2007	0.00	30	71.24	0.00 - 0.01	0.00	30		0	0.05	30	76.69	0.03 - 0.14
2008	0.00	30		0	0.00	30		0	0.01	30	79.68	0.00 - .02
2009	0.00	30		0	0.00	30		0	0.00	30	100.00	0.00 - 0.01
2010	0.00	30		0	0.00	30		0	0.00	30		0
2011	0.00	30		0	0.00	30		0	0.04	30	93.85	0.00 - 0.13
2012	0.00	30		0	0.00	30		0	0.00	30		0
2013	0.02	30	100.00	0.00 - 0.06	0.00	30		0	0.00	30		0
2014	0.00	30		0	0.00	30		0	0.00	30		0
2015*	0.00	30		0	0.00	30		0	0.00	30		0
2016*	0.00	30		0	0.00	30		0	0.00	30		0
2017*	0.00	30		0	0.00	30		0	0.00	30		0
2018*	0.00	30		0	0.00	30		0	0.01	30	78.80	0.00 - 0.03
2019*	0.00	30		0	0.00	30		0	0.00	30		0
2020*	0.00	30		0	0.00	30		0	0.00	30		0
Average	0.04				0.00				0.14			

Table 11. Channel Catfish age 1+ indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Rappahannock				York				James			
Year	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.
1988	0.00	9		0	0.00	12		0	0.00	8		0
1989	0.01	9	100.00	0.00 - 0.04	0.00	12		0	0.05	6	100.00	0.00 - 0.16
1990	0.00	7		0	0.00	10		0	0.00	6		0
1991	0.00	9		0	0.00	11		0	0.00	6		0
1992	0.05	9	100.00	0.00 - 0.17	0.00	10		0	0.00	6		0
1993	0.00	9		0	0.00	12		0	0.00	6		0
1994	0.00	9		0	0.01	12	100.00	0.00 - 0.03	0.00	6		0
1995	0.00	9		0	0.00	12		0	0.51	10	0.00	0.51 - 0.51
1996	0.00	27		0	0.00	26		0	0.10	27	67.76	0.00 - 0.26
1997	0.00	30		0	0.00	30		0	0.00	30		0
1998	0.00	30		0	0.01	30	70.71	0.00 - 0.02	0.00	30		0
1999	0.00	30		0	0.00	30		0	0.00	30		0
2000	0.00	31	100.00	0.00 - 0.01	0.00	29		0	0.00	30	100.00	0.00 - 0.01
2001	0.00	31		0	0.00	30		0	0.00	30	100.00	0.00 - 0.01
2002	0.00	30		0	0.00	30		0	0.00	30		0
2003	0.00	30	100.00	0.00 - 0.01	0.02	30	58.88	0.00 - 0.04	0.17	30	37.27	0.04 - 0.32
2004	0.00	30	100.00	0.00 - 0.01	0.00	30	66.14	0.00 - 0.01	0.01	30	100.00	0.00 - 0.02
2005	0.00	30		0	0.00	30		0	0.00	30		0
2006	0.00	30		0	0.00	30		0	0.00	20		0
2007	0.00	30		0	0.00	30		0	0.00	30		0
2008	0.00	30		0	0.00	30		0	0.00	30		0
2009	0.00	30		0	0.00	30		0	0.00	30		0
2010	0.00	30		0	0.00	30		0	0.00	30		0
2011	0.00	30		0	0.00	30		0	0.00	30		0
2012	0.00	30		0	0.00	30		0	0.00	30		0
2013	0.00	30		0	0.00	30		0	0.04	30	100.00	0.00 - 0.12
2014	0.00	30		0	0.00	30		0	0.00	30	100.00	0
2015*	0.00	30		0	0.00	30		0	0.00	30		0
2016*	0.00	30		0	0.00	30		0	0.00	30		0
2017*	0.00	30		0	0.00	30		0	0.00	30		0
2018*	0.00	30	100.00	0.00 - 0.01	0.00	30		0	0.00	30		0
2019*	0.00	30		0	0.00	30		0	0.00	30		0
2020*	0.00	30		0	0.00	30		0	0.00	30		0
Average	0.00				0.00				0.03			

Table 12. Scup indices (RSI_{GM}; 1988–2019). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2018.

	Random Stratified Index (RSI)			
Year Class	Geo. Mean	95% C.I.'s	C.V.	N
1988	3.06	2.05 - 4.41	10.20	112
1989	4.92	3.14 - 7.45	10.03	112
1990	1.90	1.11 - 2.99	14.99	103
1991	0.65	0.41 - 0.93	15.67	104
1992	3.36	2.16 - 5.01	10.90	104
1993	0.90	0.53 - 1.35	16.67	104
1994	0.39	0.21 - 0.59	21.36	104
1995	0.54	0.29 - 0.83	20.37	104
1996	0.21	0.09 - 0.35	28.00	104
1997	0.50	0.27 - 0.75	19.83	79
1998	0.27	0.06 - 0.52	37.91	88
1999	0.13	0.02 - 0.25	41.14	105
2000	1.34	0.88 - 1.90	12.80	111
2001	0.24	0.11 - 0.37	24.52	64
2002	0.96	0.58 - 1.42	15.89	104
2003	0.46	0.28 - 0.67	17.38	104
2004	1.11	0.71 - 1.59	13.89	104
2005	1.58	0.99 - 2.36	13.77	104
2006	2.99	2.07 - 4.19	9.47	104
2007	0.20	0.09 - 0.31	25.12	104
2008	2.97	2.07 - 4.13	9.28	104
2009	4.11	2.79 - 5.89	9.14	104
2010	0.82	0.51 - 1.20	15.70	104
2011	0.22	0.07 - 0.39	33.06	104
2012	0.74	0.46 - 1.06	15.48	104
2013	0.16	0.08 - 0.25	25.35	104
2014*	1.15	0.68 - 1.76	16.14	104
2015*	0.32	0.09 - 0.60	34.75	104
2016*	0.25	0.12 - 0.39	24.99	104
2017*	0.78	0.44 - 1.20	18.35	104
2018*	0.81	0.47 - 1.22	17.55	104
2019*	0.18	0.06 - 0.31	31.36	104
Average	1.23			

Table 13. Silver Perch indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019.

	Random Stratified Index (RSI)			
Year	Geo. Mean	95% C.I.'s	C.V.	N
1988	0.61	0.35 - 0.92	18.30	172
1989	0.53	0.33 - 0.76	16.32	189
1990	0.69	0.49 - 0.92	11.94	185
1991	0.35	0.21 - 0.51	17.33	179
1992	0.81	0.49 - 1.18	15.80	178
1993	0.45	0.29 - 0.63	16.01	180
1994	0.25	0.11 - 0.40	25.42	180
1995	0.58	0.34 - 0.87	15.65	180
1996	0.59	0.38 - 0.84	15.63	304
1997	0.71	0.50 - 0.94	12.07	316
1998	0.24	0.15 - 0.33	16.77	316
1999	0.70	0.49 - 0.94	12.42	309
2000	0.68	0.46 - 0.93	13.56	317
2001	0.70	0.47 - 0.97	13.77	327
2002	0.44	0.24 - 0.67	20.16	269
2003	0.63	0.40 - 0.90	15.49	315
2004	0.34	0.22 - 0.48	16.50	315
2005	0.76	0.52 - 1.03	12.64	315
2006	1.21	0.84 - 1.64	11.31	283
2007	0.75	0.50 - 1.03	13.53	315
2008	0.49	0.34 - 0.66	13.31	315
2009	1.00	0.72 - 1.32	10.83	315
2010	1.27	0.95 - 1.65	9.29	315
2011	0.77	0.53 - 1.04	12.41	315
2012	0.80	0.55 - 1.08	12.38	302
2013	0.59	0.41 - 0.79	13.16	315
2014	1.14	0.76 - 1.60	12.82	315
2015*	0.58	0.44 - 0.74	10.36	315
2016*	1.78	1.30 - 2.35	9.19	315
2017*	1.40	0.98 - 1.91	11.06	315
2018*	1.44	1.07 - 1.87	9.13	315
2019*	0.37	0.26 - 0.48	12.76	315
2020*	0.58	0.44 - 0.73	10.19	315
Average	0.74			

Table 14. Spot indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019.

	Random Stratified Index (RSI)			
Year	Geo. Mean	95% C.I.'s	C.V.	N
1988	67.01	46.36 - 96.67	4.29	231
1989	31.41	24.51 - 40.18	3.44	252
1990	44.78	32.34 - 61.85	4.14	248
1991	16.83	12.28 - 21.60	4.66	238
1992	1.92	1.45 - 2.49	8.20	238
1993	9.78	7.23 - 13.13	5.68	240
1994	9.23	6.88 - 12.27	5.61	240
1995	1.56	1.15 - 2.05	9.25	248
1996	5.26	4.15 - 6.60	5.30	407
1997	11.50	9.11 - 14.45	4.20	421
1998	2.51	1.92 - 3.23	7.36	374
1999	4.72	3.63 - 6.07	6.07	402
2000	3.32	2.57 - 4.23	6.51	421
2001	3.09	2.45 - 3.85	6.06	432
2002	2.89	2.10 - 3.88	8.38	360
2003	2.85	2.25 - 3.56	6.32	420
2004	3.96	3.14 - 4.95	5.68	420
2005	12.12	9.80 - 14.94	3.78	420
2006	3.37	2.71 - 4.16	5.61	420
2007	9.17	7.38 - 11.35	4.18	420
2008	19.89	15.16 - 26.01	4.22	420
2009	6.08	4.96 - 7.40	4.39	420
2010	74.97	59.30 - 94.70	2.67	420
2011	5.29	4.22 - 6.57	5.05	420
2012	17.18	13.49 - 21.82	3.92	420
2013	12.38	10.14 - 15.08	3.54	420
2014	3.26	2.60 - 4.04	5.84	420
2015*	0.83	0.61 - 1.07	10.50	420
2016*	2.39	1.90 - 2.96	6.36	420
2017*	4.46	3.57 - 5.54	5.27	420
2018*	14.70	11.76 - 18.33	3.77	420
2019*	7.11	5.55 - 9.05	5.12	420
2020*	10.53	8.43 - 13.08	4.10	382
Average	12.99			

Table 15. Striped Bass indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Random Stratified Index (RSI)			
Year class	Geo. Mean	95% C.I.'s	C.V.	N
1988	0.18	0.17 - 0.20	3.72	38
1989	0.02	0.00 - 0.05	100.00	36
1990	0.02	0.00 - 0.06	100.00	32
1991	0.16	0.00 - 0.48	78.57	34
1992	0.00	0		34
1993	0.21	0.07 - 0.36	30.97	36
1994	0.10	0.00 - 0.32	100.00	36
1995	0.00	0		42
1996	0.68	0.10 - 1.58	40.79	107
1997	0.26	0.04 - 0.52	41.26	120
1998	0.30	0.13 - 0.49	26.33	112
1999	0.16	0.00 - 0.43	72.11	120
2000	0.72	0.36 - 1.18	21.88	120
2001	1.04	0.54 - 1.68	19.44	121
2002	0.54	0.34 - 0.77	15.92	120
2003	0.49	0.16 - 0.90	31.15	120
2004	0.79	0.35 - 1.36	24.13	120
2005	0.47	0.18 - 0.83	28.91	120
2006	0.38	0.07 - 0.78	40.11	110
2007	0.21	0.00 - 0.48	51.04	120
2008	0.68	0.14 - 1.47	37.01	120
2009	0.47	0.06 - 1.04	42.96	120
2010	0.30	0.04 - 0.62	42.08	120
2011	1.15	0.60 - 1.88	19.15	120
2012	0.09	0.00 - 0.22	62.94	120
2013	0.47	0.14 - 0.90	33.16	120
2014	0.45	0.19 - 0.77	26.42	120
2015*	0.74	0.34 - 1.27	23.83	120
2016*	0.17	0.00 - 0.55	91.33	120
2017*	0.35	0.08 - 0.68	36.54	120
2018*	0.99	0.60 - 1.48	16.00	120
2019*	0.34	0.00 - 0.82	52.28	120
2020*	0.10	0.00 - 0.25	67.67	102
Average	0.40			

Table 16. Summer Flounder indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019.

	Random Stratified Index (RSI)			
Year	Geo. Mean	95% C.I.'s	C.V.	N
1988	0.54	0.35 - 0.75	14.99	143
1989	1.24	0.94 - 1.58	8.77	162
1990	2.54	2.06 - 3.09	5.73	162
1991	2.79	2.26 - 3.41	5.66	153
1992	0.92	0.70 - 1.17	9.25	153
1993	0.52	0.38 - 0.68	11.87	153
1994	2.54	2.01 - 3.15	6.39	153
1995	0.71	0.52 - 0.92	10.89	149
1996	0.81	0.62 - 1.02	9.32	224
1997	0.89	0.69 - 1.12	8.77	226
1998	0.73	0.55 - 0.93	9.92	226
1999	0.53	0.41 - 0.67	9.94	219
2000	0.57	0.43 - 0.73	10.81	227
2001	0.47	0.34 - 0.61	11.84	236
2002	0.77	0.54 - 1.04	12.21	179
2003	0.44	0.33 - 0.56	10.95	225
2004	1.30	1.03 - 1.60	7.50	225
2005	0.35	0.25 - 0.46	13.18	225
2006	0.80	0.60 - 1.02	10.03	203
2007	1.00	0.78 - 1.24	8.22	225
2008	1.35	1.10 - 1.63	6.68	225
2009	0.75	0.58 - 0.92	8.76	225
2010	0.55	0.41 - 0.69	10.61	225
2011	0.17	0.11 - 0.23	17.54	225
2012	2.03	1.69 - 2.40	5.29	212
2013	0.82	0.65 - 1.02	8.42	225
2014	0.62	0.49 - 0.77	8.94	225
2015*	0.23	0.15 - 0.31	16.09	225
2016*	0.42	0.30 - 0.56	13.09	225
2017*	0.95	0.75 - 1.18	8.03	225
2018*	1.10	0.87 - 1.36	7.84	225
2019*	0.39	0.28 - 0.52	13.24	225
2020*	0.08	0.04 - 0.13	24.58	225
Average	0.93			

Table 17. Weakfish indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from 1988 to 2019.

	Random Stratified Index (RSI)			
Year	Geo. Mean	95% C.I.'s	C.V.	N
1988	8.13	5.37 - 12.07	8.12	173
1989	11.74	8.18 - 16.88	6.44	189
1990	4.46	3.10 - 6.26	8.44	184
1991	3.16	2.32 - 4.21	7.92	179
1992	6.78	4.74 - 9.53	7.39	178
1993	5.81	4.06 - 8.17	7.76	180
1994	2.51	1.76 - 3.47	9.59	180
1995	5.95	4.26 - 8.18	7.20	186
1996	7.26	5.33 - 9.78	6.31	305
1997	6.81	5.26 - 8.74	5.38	316
1998	7.60	5.46 - 10.45	6.65	269
1999	6.78	5.01 - 9.06	6.28	303
2000	8.35	6.34 - 10.92	5.42	316
2001	5.09	3.74 - 6.82	6.93	327
2002	6.93	4.27 - 10.94	9.89	270
2003	9.23	6.72 - 12.54	6.04	315
2004	6.66	4.94 - 8.88	6.24	315
2005	5.69	4.26 - 7.50	6.31	315
2006	6.34	4.83 - 8.25	5.80	315
2007	5.35	3.99 - 7.08	6.51	315
2008	5.77	4.33 - 7.60	6.26	315
2009	6.18	4.75 - 7.96	5.63	315
2010	14.11	11.16 - 17.78	4.00	315
2011	5.23	3.86 - 6.99	6.78	315
2012	3.02	2.30 - 3.90	7.14	315
2013	9.41	7.30 - 12.07	4.85	315
2014	3.77	2.91 - 4.82	6.39	315
2015*	1.59	1.17 - 2.09	9.36	315
2016*	1.44	1.06 - 1.88	9.42	315
2017*	2.41	1.76 - 3.22	8.70	315
2018*	2.80	2.09 - 3.68	7.80	315
2019*	1.02	0.76 - 1.32	9.68	315
2020*	2.36	1.76 - 3.08	8.08	297
Average	5.86			

Table 18. White Catfish juvenile indices (RSI$_{GM}$; 1988–2020). Juvenile White Catfish indices were not adjusted as too few were captured. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Rappahannock				York				James			
Year class	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.
1988	0.00	9		0	0.03	12	100.00	0.06 - 0.10	0.08	8	100.00	0.00 - 0.27
1989	0.01	9	100.00	0.00 - 0.04	0.13	12	48.32	0.00 - 0.26	0.58	6	61.32	0.00 - 1.78
1990	0.00	7		0	0.02	10	100.00	0.00 - 0.05	0.00	6		0
1991	0.00	9		0	0.00	11		0	0.00	6		0
1992	0.00	9		0	0.00	10		0	0.00	6		0
1993	0.00	9		0	0.08	12	52.52	0.00 - 0.16	0.00	6		0
1994	0.00	9		0	0.03	12	65.63	0.00 - 0.07	0.00	6		0
1995	0.00	9		0	0.01	12	100.00	0.00 - 0.02	0.38	10	0.00	0.38 - 0.39
1996	0.02	27	100.00	0.00 - 0.06	0.03	26	34.00	0.01 - 0.05	0.18	27	46.25	0.01 - 0.37
1997	0.00	30		0	0.01	30	72.57	0.00 - 0.02	0.06	30	52.32	0.00 - 0.14
1998	0.00	30		0	0.01	30	64.14	0.00 - 0.03	0.01	30	100.00	0.00 - 0.03
1999	0.00	30		0	0.00	30		0	0.00	30		0
2000	0.00	31		0	0.01	29	65.47	0.00 - 0.01	0.00	30		0
2001	0.00	31		0	0.00	30		0	0.00	30		0
2002	0.00	30		0	0.00	30		0	0.00	30		0
2003	0.00	30	69.46	0.00 - 0.01	0.05	30	22.40	0.03 - 0.07	0.01	30	72.05	0.00 - 0.03
2004	0.00	30		0	0.00	30		0	0.10	30	37.89	0.02 - 0.18
2005	0.00	30		0	0.00	30		0	0.00	30		0
2006	0.00	30		0	0.00	30		0	0.00	20		0
2007	0.00	30		0	0.00	30		0	0.00	30		0
2008	0.00	30		0	0.00	30		0	0.00	30		0
2009	0.00	30		0	0.00	30		0	0.09	30	74.02	0.00 - 0.24
2010	0.00	30		0	0.00	30		0	0.00	30		0
2011	0.00	30		0	0.00	30		0	0.00	30		0
2012	0.00	30		0	0.00	30		0	0.00	30		0
2013	0.00	30		0	0.00	30		0	0.00	30		0
2014	0.00	30		0	0.00	30		0	0.04	30	100.00	0.00 - 0.12
2015	0.00	30		0	0.00	30		0	0.07	30	89.85	0.00 - 0.22
2016	0.00	30		0	0.00	30		0	0.01	30	78.33	0.00 - 0.03
2017	0.00	30		0	0.00	30		0	0.00	30		0
2018	0.00	30		0	0.01	30	72.16	0.00 - 0.01	0.14	30	25.53	0.07 - 0.21
2019	0.00	30		0	0.00	30			0.01	30	100.00	0.00 - 0.04
2020	0.00	30		0	0.00	30	100.00	0.00 - 0.01	0.09	30	30.68	0.03 - 0.15
Average	0.00				0.01				0.06			

Table 19. White Catfish age 1+ indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Rappahannock				York				James			
Year	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.
1988	0.18	9	20.26	0.10 - 0.26	0.18	12	28.57	0.07 - 0.30	0.20	8	100.00	0.00 - 0.75
1989	0.87	9	30.00	0.28 - 1.72	0.56	12	20.74	0.30 - 0.88	0.99	6	27.08	0.37 - 1.89
1990	0.32	7	44.20	0.03 - 0.70	0.46	10	22.67	0.23 - 0.74	1.83	6	14.17	1.11 - 2.81
1991	0.22	9	26.85	0.10 - 0.36	0.15	11	42.79	0.02 - 0.29	0.53	6	29.45	0.19 - 0.97
1992	0.52	9	20.32	0.28 - 0.80	0.37	10	21.08	0.20 - 0.57	0.63	6	48.39	0.02 - 1.67
1993	0.14	9	32.97	0.05 - 0.24	0.28	12	19.89	0.16 - 0.41	0.66	6	92.83	0.00 - 3.26
1994	1.06	9	22.36	0.49 - 1.84	0.28	12	22.53	0.15 - 0.43	0.06	6	50.00	0.00 - 0.13
1995	0.19	9	22.49	0.10 - 0.28	0.12	12	28.23	0.05 - 0.20	1.31	10	12.99	0.86 - 1.87
1996	0.43	27	18.32	0.25 - 0.62	0.21	26	15.74	0.14 - 0.29	0.79	27	12.82	0.54 - 1.08
1997	0.24	30	29.41	0.09 - 0.41	0.08	30	23.61	0.04 - 0.12	0.37	30	25.96	0.16 - 0.61
1998	0.13	30	24.05	0.07 - 0.20	0.05	30	23.28	0.03 - 0.07	0.22	30	34.26	0.06 - 0.40
1999	0.09	30	22.66	0.05 - 0.14	0.12	30	19.85	0.07 - 0.18	0.48	30	26.71	0.20 - 0.82
2000	0.10	31	39.54	0.02 - 0.19	0.06	29	30.44	0.02 - 0.11	0.05	30	34.98	0.02 - 0.09
2001	0.03	31	42.82	0.00 - 0.06	0.03	30	27.95	0.01 - 0.05	0.14	30	29.65	0.06 - 0.23
2002	0.02	30	52.04	0.00 - 0.04	0.03	30	23.05	0.02 - 0.05	0.16	30	30.14	0.06 - 0.27
2003	0.14	30	57.67	0.00 - 0.31	0.08	30	23.47	0.04 - 0.11	0.12	30	30.75	0.05 - 0.21
2004	0.11	30	48.09	0.00 - 0.23	0.12	30	17.33	0.08 - 0.16	0.24	30	31.44	0.08 - 0.43
2005	0.03	30	72.33	0.00 - 0.07	0.05	30	34.59	0.01 - 0.08	0.15	30	36.31	0.04 - 0.28
2006	0.02	30	58.93	0.00 - 0.04	0.04	30	32.04	0.02 - 0.07	0.10	20	48.38	0.00 - 0.21
2007	0.01	30	54.81	0.00 - 0.03	0.03	30	29.47	0.01 - 0.05	0.11	30	41.79	0.02 - 0.21
2008	0.03	30	74.14	0.00 - 0.07	0.03	30	30.29	0.01 - 0.05	0.05	30	43.00	0.01 - 0.09
2009	0.02	30	43.73	0.00 - 0.05	0.02	30	35.53	0.01 - 0.04	0.18	30	26.92	0.08 - 0.29
2010	0.02	30	49.58	0.00 - 0.04	0.02	30	45.48	0.00 - 0.04	0.41	30	33.55	0.12 - 0.78
2011	0.06	30	63.45	0.00 - 0.13	0.04	30	30.66	0.02 - 0.06	0.24	30	27.36	0.10 - 0.39
2012	0.00	30		0	0.03	30	31.31	0.01 - 0.05	0.18	30	31.16	0.06 - 0.30
2013	0.01	30	56.41	0.00 - 0.02	0.03	30	25.57	0.01 - 0.04	0.19	30	26.69	0.09 - 0.31
2014	0.01	30	77.60	0.00 - 0.02	0.03	30	28.06	0.01 - 0.05	0.34	30	36.83	0.08 - 0.66
2015*	0.01	30	47.92	0.00 - 0.01	0.02	30	40.80	0.00 - 0.03	0.20	30	27.07	0.09 - 0.32
2016*	0.00	30		0	0.01	30	57.20	0.00 - 0.01	0.13	30	28.22	0.05 - 0.21
2017*	0.00	30		0	0.00	30		0	0.16	30	30.82	0.06 - 0.27
2018*	0.04	30	74.17	0.00 - 0.04	0.02	30	26.98	0.01 - 0.04	0.17	30	19.92	0.10 - 0.25
2019*	0.00	30	100.00	0.00 - 0.01	0.02	30	36.25	0.00 - 0.03	0.23	30	39.07	0.05 - 0.44
2020*	0.03	30	95.04	0.00 - 0.08	0.01	30	43.40	0.00 - 0.03	0.32	30	19.71	0.18 - 0.47
Average	0.16				0.11				0.36			

Table 20. White Perch juvenile indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Rappahannock				York				James			
Year	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.
1988	0.00	9		0	0.01	12	100.00	0.00 - 0.03	0.00	6		0
1989	0.03	9	100.00	0.00 - 0.09	0.12	12	25.98	0.06 - 0.19	0.00	6		0
1990	0.00	7		0	0.00	10		0	0.00	6		0
1991	0.00	8		0	0.00	12		0	0.00	6		0
1992	0.01	9	100.00	0.00 - 0.04	0.00	10		0	0.00	6		0
1993	0.00	9		0	0.00	12		0	0.00	6		0
1994	0.00	9		0	0.00	12		0	0.00	6		0
1995	0.00	9		0	0.00	12		0	0.31	12	22.94	0.16 - 0.48
1996	0.12	27	81.05	0.00 - 0.33	0.05	27	28.81	0.02 - 0.08	5.00	27	5.59	3.91 - 6.33
1997	0.00	30		0	0.00	30		0	1.14	30	32.02	0.31 - 2.47
1998	0.00	22		0	0.02	30	80.74	0.00 - 0.05	1.98	30	16.21	1.09 - 3.24
1999	0.00	30		0	0.00	30		0	0.21	30	52.77	0.00 - 0.48
2000	0.00	31		0	0.03	29	60.08	0.00 - 0.07	1.52	30	8.45	1.15 - 1.94
2001	0.02	31	100.00	0.00 - 0.06	0.01	30	100.00	0.00 - 0.03	1.94	30	15.60	1.10 - 3.11
2002	0.00	30		0	0.00	30		0	0.08	30	50.00	0.00 - 0.17
2003	1.53	30	15.04	0.92 - 2.35	0.05	30	26.57	0.02 - 0.08	3.59	30	9.67	2.42 - 5.16
2004	0.12	30	66.00	0.00 - 0.31	0.03	30	34.37	0.01 - 0.05	2.90	30	9.05	2.05 - 4.00
2005	0.07	30	59.16	0.00 - 0.16	0.01	30	100.00	0.00 - 0.04	2.08	30	10.97	1.41 - 2.95
2006	0.00	30		0	0.00	30		0	1.62	30	11.27	1.11 - 2.26
2007	0.00	30		0	0.00	30		0	0.48	30	45.36	0.04 - 1.11
2008	0.00	30	100.00	0.00 - 0.01	0.00	30		0	0.20	30	86.54	0.00 - 0.63
2009	0.02	30	100.00	0.00 - 0.06	0.00	30		0	0.73	30	49.39	0.01 - 1.97
2010	0.00	30		0	0.01	30	100.00	0.00 - 0.02	0.48	30	17.00	0.30 - 0.70
2011	0.56	30	20.33	0.30 - 0.86	0.04	30	32.87	0.01 - 0.07	2.13	30	9.73	1.50 - 2.90
2012	0.00	30		0	0.00	30		0	0.23	30	69.54	0.00 - 0.63
2013	0.00	30		0	0.02	30	47.48	0.00 - 0.04	1.54	30	19.15	0.78 - 2.63
2014	0.03	30	81.99	0.00 - 0.07	0.07	30	36.80	0.02 - 0.13	0.93	30	20.83	0.47 - 1.54
2015*	0.05	30	96.24	0.00 - 0.16	0.08	30	28.86	0.03 - 0.12	0.95	30	25.39	0.39 - 1.74
2016*	0.00	30		0	0.01	30	50.00	0.00 - 0.01	1.22	30	13.30	0.80 - 1.75
2017*	0.00	30		0	0.00	30		0	1.29	30	21.59	0.60 - 2.27
2018*	1.55	30	26.39	0.55 - 3.16	0.08	30	39.85	0.01 - 0.14	4.99	30	13.71	2.66 - 8.78
2019*	0.14	30	55.17	0.00 - 0.31	0.04	30	22.28	0.02 - 0.06	0.84	30	12.93	0.57 - 1.16
2020*	0.00	22		0	0.00	30		0	1.00	20	34.51	0.24 - 2.23
Average	0.13				0.02				1.20			

Table 21. White Perch age 1+ indices (RSI_{GM}; 1988–2020). Note: *Indices were adjusted with a calibration factor to account for gear and vessel changes that occurred in 2015. Average values calculated from year class 1988 to 2019. All indices have been recalculated to reflect the new recruitment window.

	Rappahannock				York				James			
Year	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.	RSI	N	CV	95% C.I.
1988	0.40	9	13.74	0.27 - 0.53	0.06	12	70.44	0.00 - 0.15	0.00	6		0
1989	0.83	9	40.27	0.12 - 1.97	0.19	12	12.55	0.14 - 0.24	1.44	6	28.92	0.46 - 3.09
1990	0.29	7	59.98	0.00 - 0.74	0.30	10	22.99	0.15 - 0.46	0.52	6	43.09	0.06 - 1.17
1991	0.17	8	23.80	0.09 - 0.26	0.05	12	47.83	0.00 - 0.11	0.09	6	77.06	0.00 - 0.25
1992	0.35	9	34.23	0.10 - 0.66	0.05	10	60.62	0.00 - 0.10	0.33	6	73.84	0.00 - 1.04
1993	0.10	9	44.89	0.01 - 0.20	0.06	12	33.97	0.02 - 0.10	0.00	6		0
1994	0.24	9	29.15	0.09 - 0.40	0.05	12	63.25	0.00 - 0.12	0.00	6		0
1995	0.20	9	10.98	0.15 - 0.25	0.01	12	100.00	0.00 - 0.02	2.28	12	8.73	1.66 - 3.03
1996	1.26	27	13.57	0.81 - 1.81	0.10	27	23.58	0.05 - 0.16	1.73	27	12.84	1.11 - 2.53
1997	0.39	30	32.33	0.12 - 0.71	0.02	30	47.03	0.00 - 0.04	2.20	30	14.16	1.30 - 3.44
1998	0.88	22	63.40	0.00 - 3.21	0.03	30	36.03	0.01 - 0.04	1.53	30	14.86	0.92 - 2.34
1999	1.24	30	20.88	0.60 - 2.14	0.03	30	56.64	0.00 - 0.06	3.05	30	15.05	1.66 - 5.16
2000	0.81	31	21.07	0.41 - 1.32	0.06	29	38.31	0.01 - 0.10	1.85	30	25.95	0.65 - 3.9
2001	0.26	31	36.81	0.06 - 0.49	0.02	30	36.48	0.01 - 0.04	1.99	30	17.27	1.05 - 3.37
2002	0.10	30	48.47	0.00 - 0.21	0.05	30	41.05	0.01 - 0.09	1.03	30	13.43	0.68 - 1.45
2003	2.42	30	8.46	1.77 - 3.21	0.14	30	20.71	0.08 - 0.20	3.06	30	6.89	2.35 - 3.93
2004	1.02	30	19.96	0.53 - 1.68	0.10	30	21.50	0.06 - 0.15	2.36	30	18.62	1.14 - 4.27
2005	0.55	30	14.48	0.36 - 0.76	0.03	30	48.33	0.00 - 0.07	0.96	30	29.87	0.31 - 1.94
2006	0.88	30	18.30	0.49 - 1.36	0.02	30	42.19	0.00 - 0.04	1.15	30	14.95	0.71 - 1.70
2007	0.49	30	55.70	0.00 - 1.33	0.01	30	70.71	0.00 - 0.02	0.28	30	39.34	0.05 - 0.55
2008	0.73	30	32.46	0.21 - 1.47	0.01	30	46.70	0.00 - 0.03	0.50	30	52.19	0.00 - 1.30
2009	0.83	30	32.70	0.23 - 1.71	0.01	30	41.23	0.00 - 0.02	1.08	30	38.08	0.19 - 2.64
2010	0.59	30	36.02	0.14 - 1.22	0.00	30		0	0.65	30	13.51	0.44 - 0.89
2011	0.99	30	16.98	0.58 - 1.52	0.01	30	53.94	0.00 - 0.02	1.66	30	18.44	0.86 - 2.82
2012	0.84	30	23.81	0.38 - 1.47	0.03	30	42.86	0.00 - 0.05	0.89	30	22.33	0.42 - 1.51
2013	0.95	30	29.07	0.32 - 1.88	0.02	30	51.81	0.00 - 0.05	1.34	30	15.07	0.81 - 2.02
2014	0.62	30	31.96	0.19 - 1.21	0.05	30	27.91	0.02 - 0.08	1.25	30	18.07	0.68 - 2.02
2015*	0.62	30	50.57	0.00 - 1.65	0.06	30	28.75	0.03 - 0.10	2.03	30	9.96	1.43 - 2.78
2016*	0.45	30	45.94	0.03 - 1.04	0.03	30	54.04	0.00 - 0.07	2.11	30	12.33	1.35 - 3.11
2017*	0.91	30	26.21	0.36 - 1.69	0.01	30	51.81	0.00 - 0.02	1.57	30	26.88	0.55 - 3.27
2018*	1.47	30	29.14	0.46 - 3.17	0.06	30	43.91	0.01 - 0.11	2.66	30	15.49	1.45 - 4.47
2019*	0.62	30	24.86	0.28 - 1.06	0.07	30	29.63	0.03 - 0.12	0.97	30	16.52	0.58 - 1.47
2020*	0.42	22	35.57	0.11 - 0.82	0.02	30	38.39	0.01 - 0.04	1.60	20	33.58	0.37 - 3.93
Average	0.70				0.05				1.33			

FIGURES

Figure 1. The VIMS Trawl Survey random stratified design in the Chesapeake Bay. Transect lines indicate geographic regions as designated below.

Chesapeake Bay	B1	Bottom Bay
	B2	Lower Bay
	B3	Upper Bay
James River	J1	Bottom James
	J2	Lower James
	J3	Upper James
	J4	Top James
York River	Y1	Bottom York
	Y2	Lower York
	Y3	Upper York
	Y4	Top York (lower Pamunkey River)
Rappahannock River	R1	Bottom Rappahannock
	R2	Lower Rappahannock
	R3	Upper Rappahannock
	R4	Top Rappahannock
Mobjack Bay	MB	Routine monitoring established March 2010 and ending December 2012

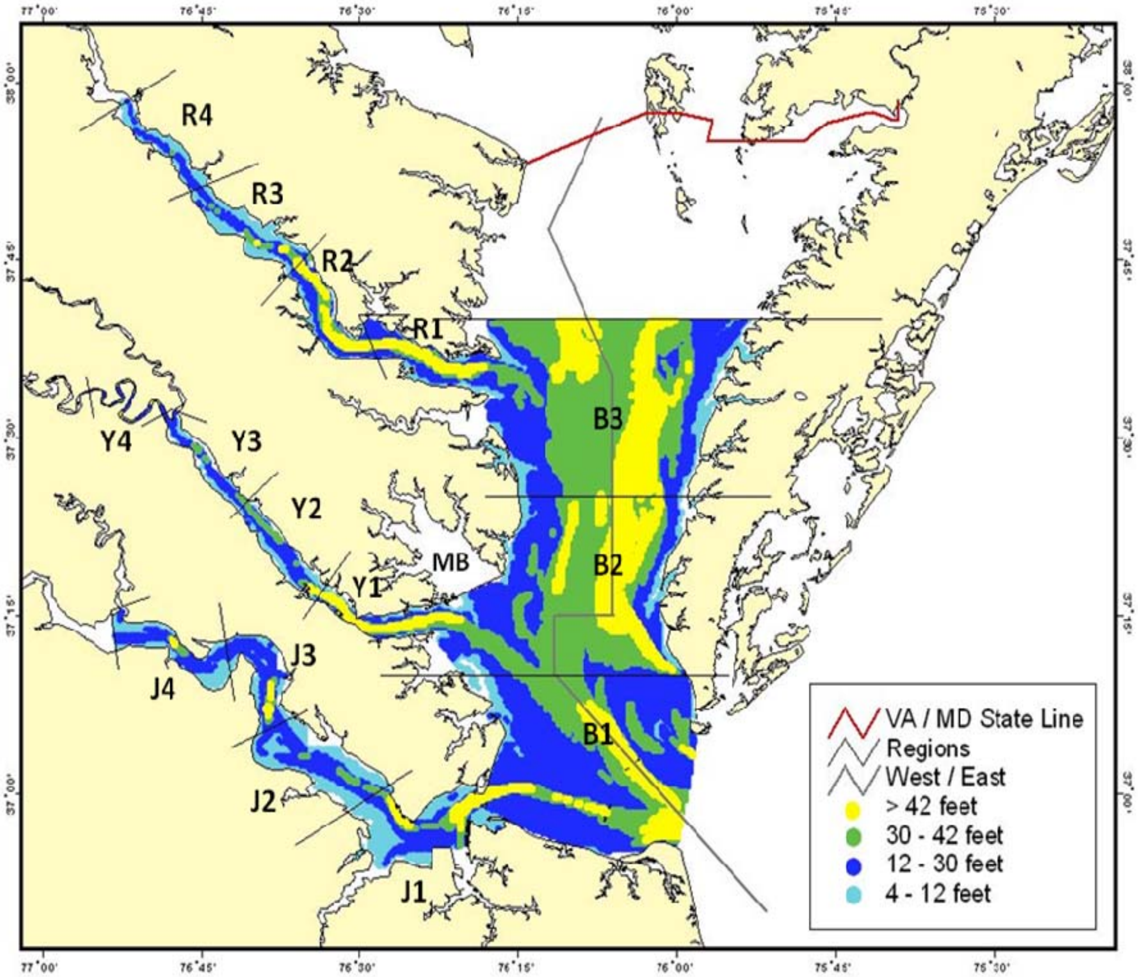


Figure 1 (continued)

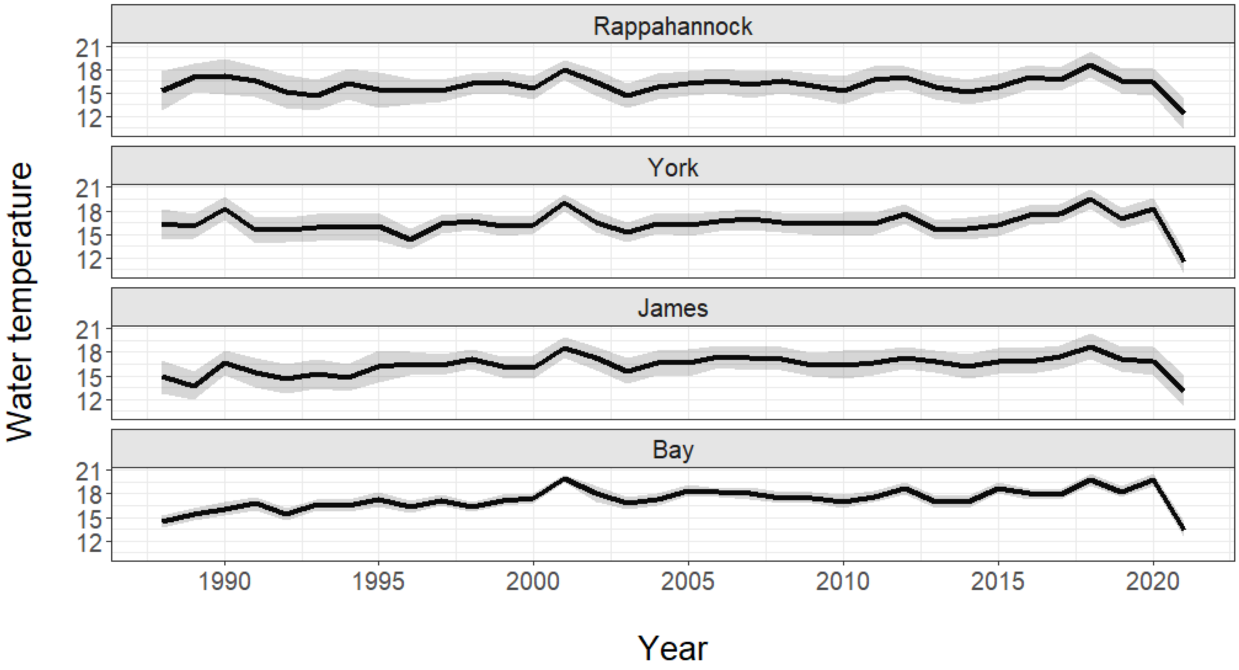


Figure 2. Weighted mean bottom water temperature (°C) and 95% confidence interval (shaded region) measured at all sites in the Rappahannock, York, and James rivers, and the Virginia portion of Chesapeake Bay from 1988 to June 2021.

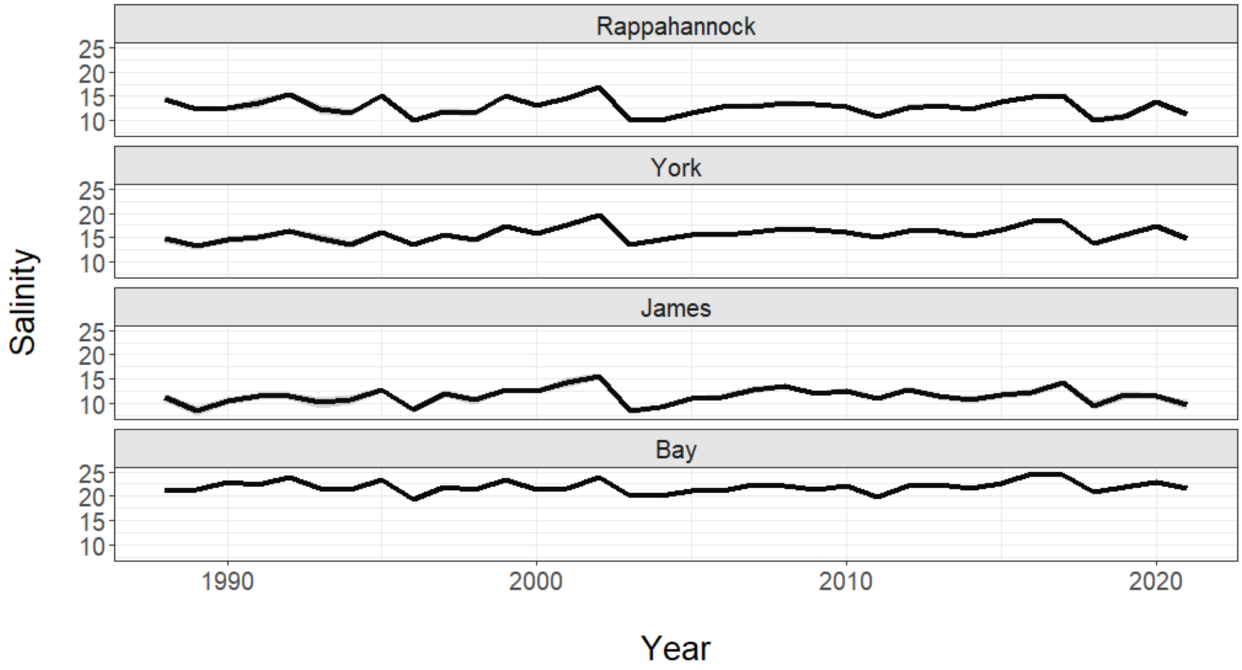


Figure 3. Weighted mean bottom salinity (psu) and 95% confidence interval (shaded region) measured at all sites in the Rappahannock, York, and James rivers, and the Virginia portion of Chesapeake Bay from 1988 to June 2021.

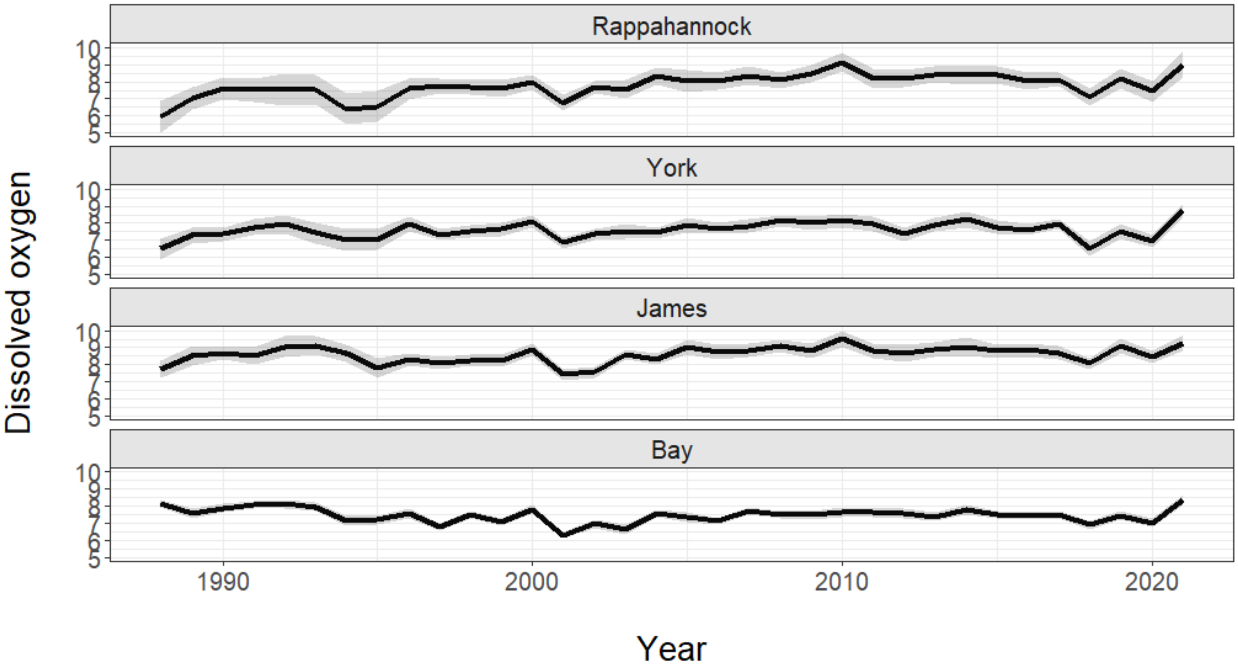


Figure 4. Weighted mean bottom dissolved oxygen (mg/L) and 95% confidence interval (shaded region) measured at all sites in the Rappahannock, York, and James rivers, and the Virginia portion of Chesapeake Bay from 1988 to June 2021.

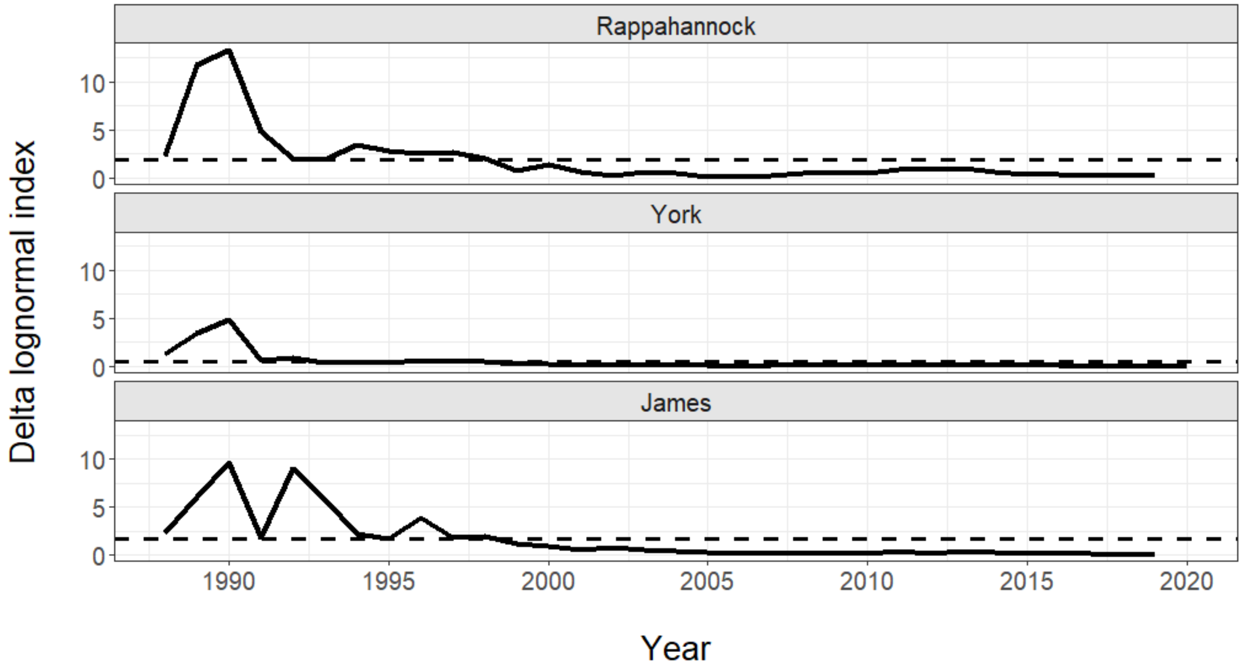


Figure 5. American Eel random stratified index (RSI_{Delta}) and time series averages (dotted line) based on the RSI_{Delta}'s from the Rappahannock, York, and James rivers from 1988 to 2019. NOTE: Index values could not be calculated for the Rappahannock and James rivers in 2020 due to missing stations as described in the species account.

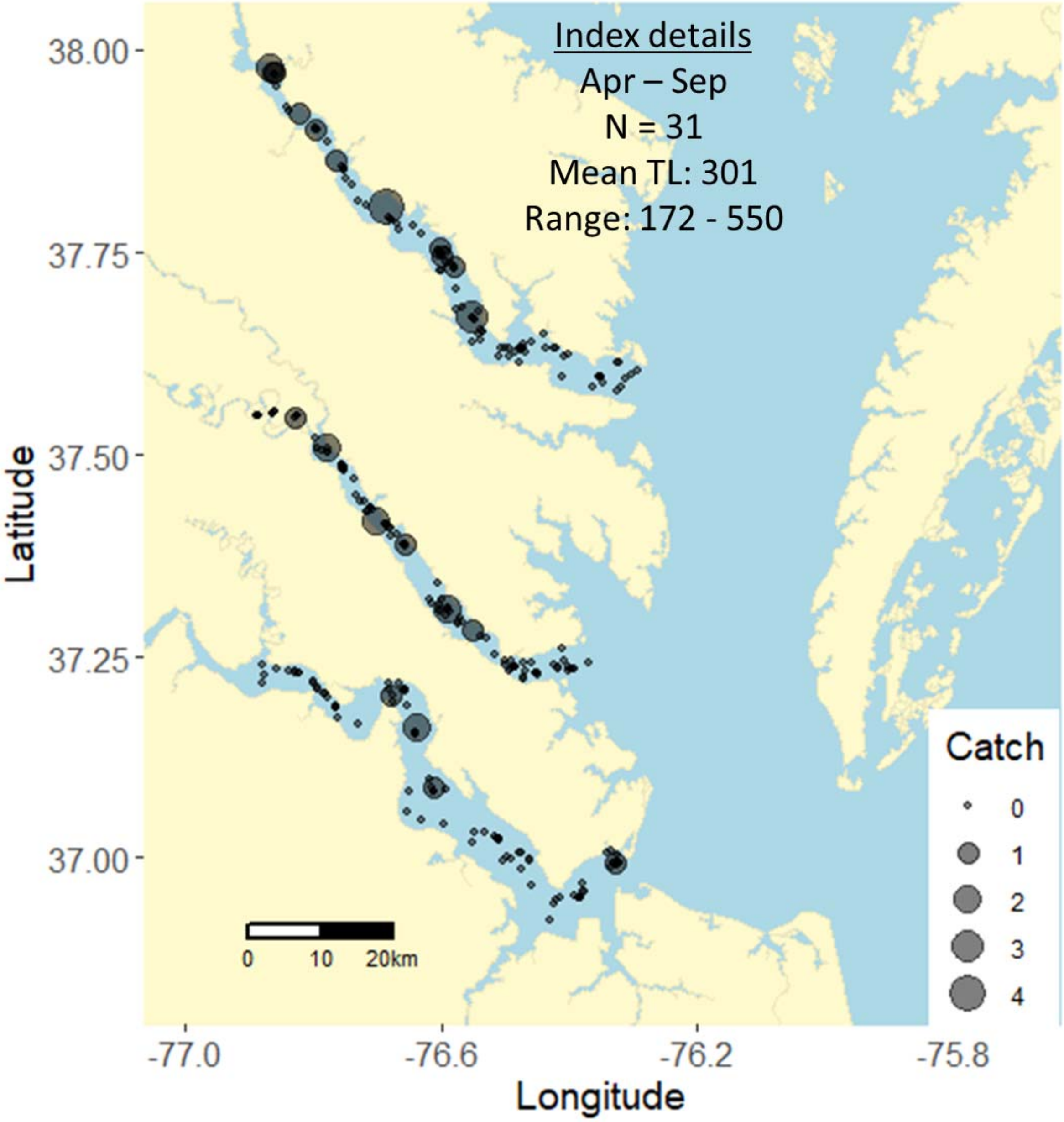


Figure 6. Distribution of index-sized American Eel in 2021, number captured, mean length and range from index strata and months. NOTE: Index values could not be calculated for the Rappahannock or James rivers in 2020 due to missing stations as described in the species account.

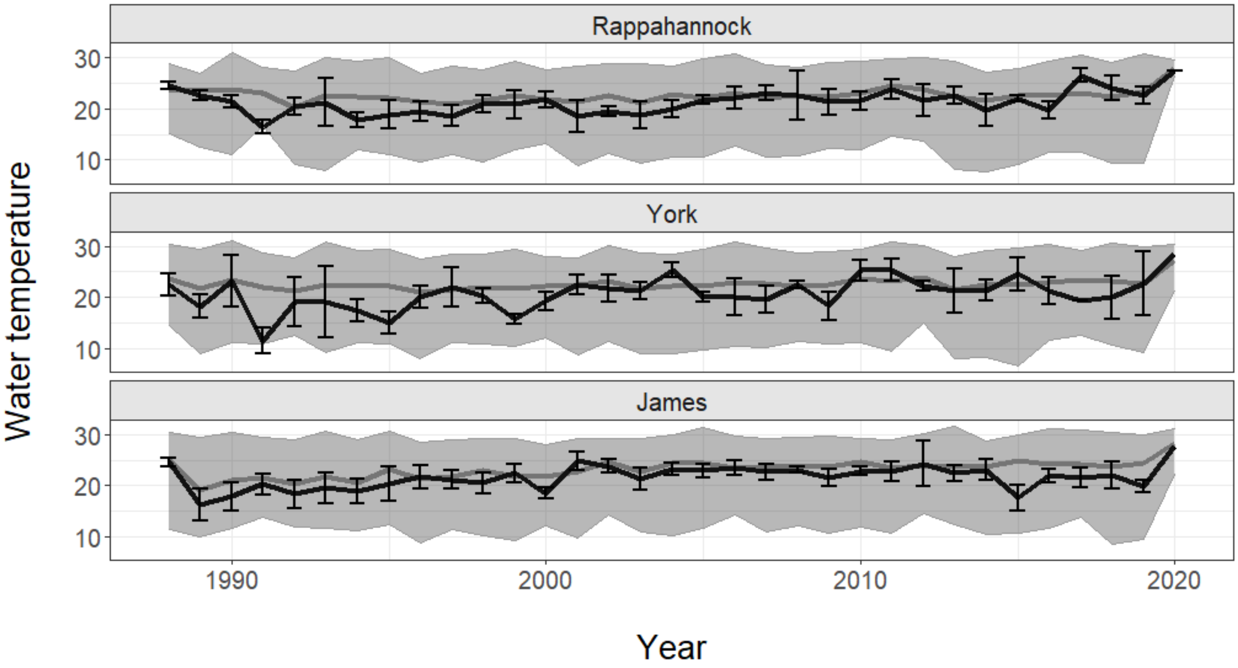


Figure 7. American Eel - Mean bottom water temperature and 95% C.I. (°C; black line) at sites with positive catches of American Eel during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2019. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed water temperatures represent years with low numbers of positive catches of American Eel. NOTE: mean bottom water temperature could not be calculated for 2020 due to missing stations as described in the species account.

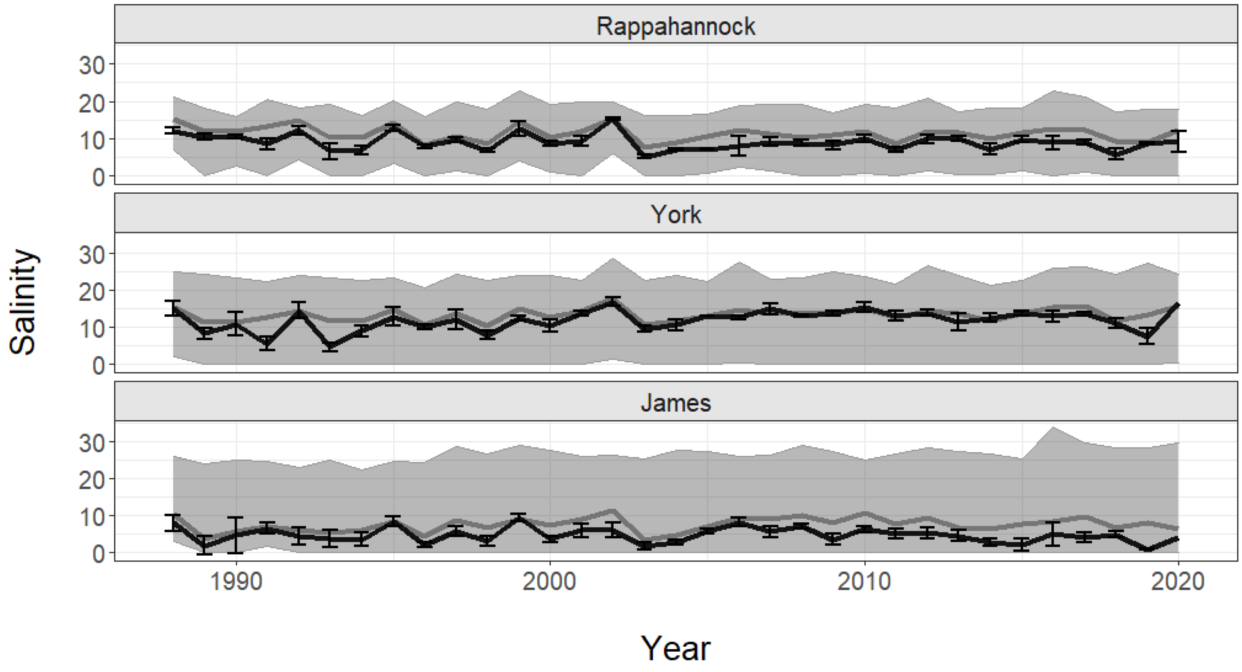


Figure 8. American Eel - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of American Eel during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2019. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata. NOTE: mean salinity could not be calculated for 2020 due to missing stations as described in the species account.

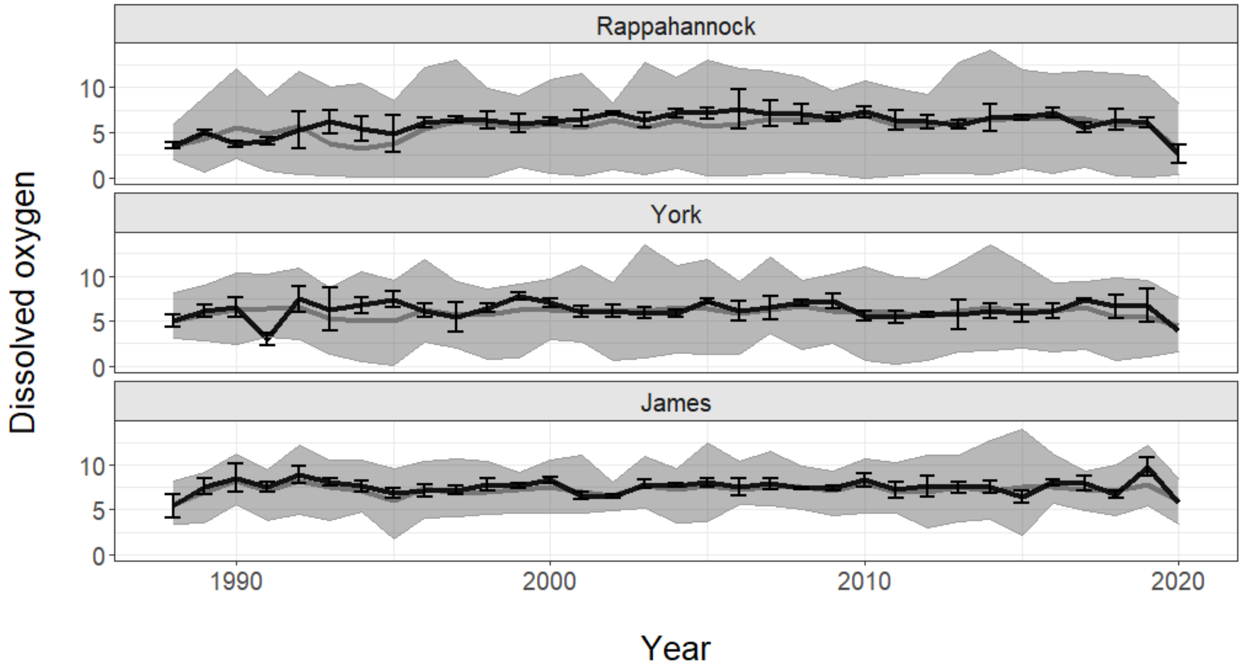


Figure 9. American Eel - Mean dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of American Eel during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2019. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata. NOTE: mean dissolved oxygen could not be calculated for 2020 due to missing stations as described in the species account.

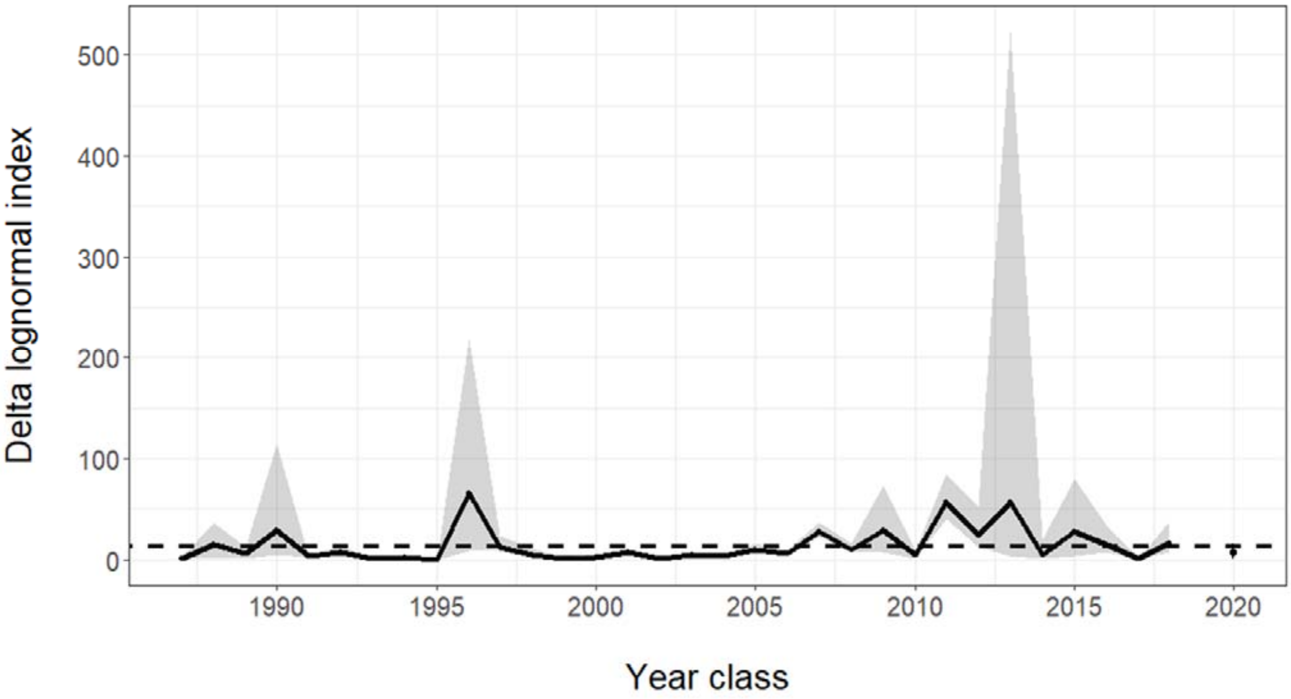


Figure 10. Spring juvenile Atlantic Croaker random stratified index (shaded 95% C.I.) and the time series average (dotted line) from 1988 to 2018. No index is available for the 2019 year class due to temporary cessation of sampling due to COVID-19.

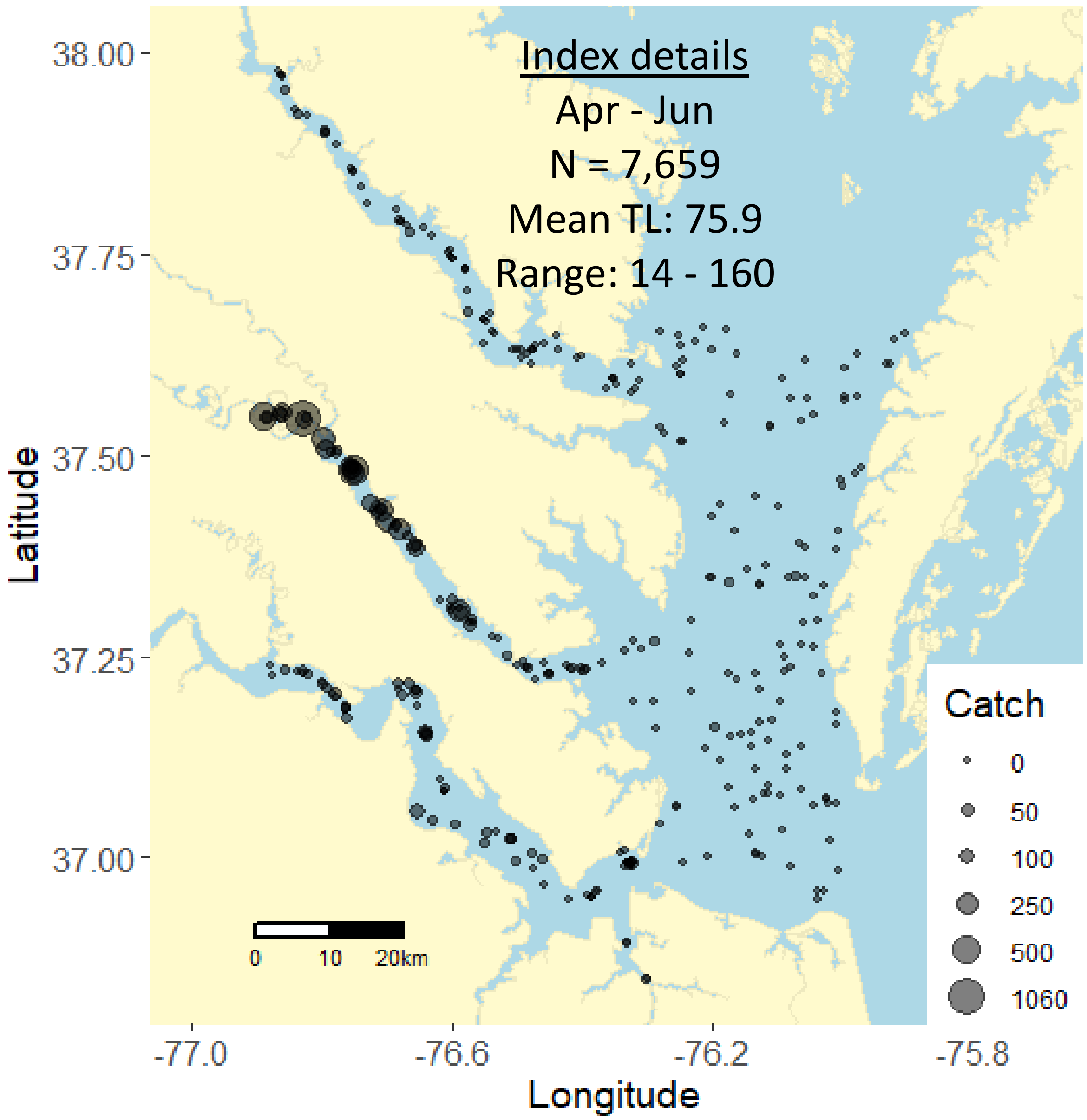


Figure 11. Distribution of index-sized juvenile Atlantic Croaker, number captured, and mean length and range from index strata and months.

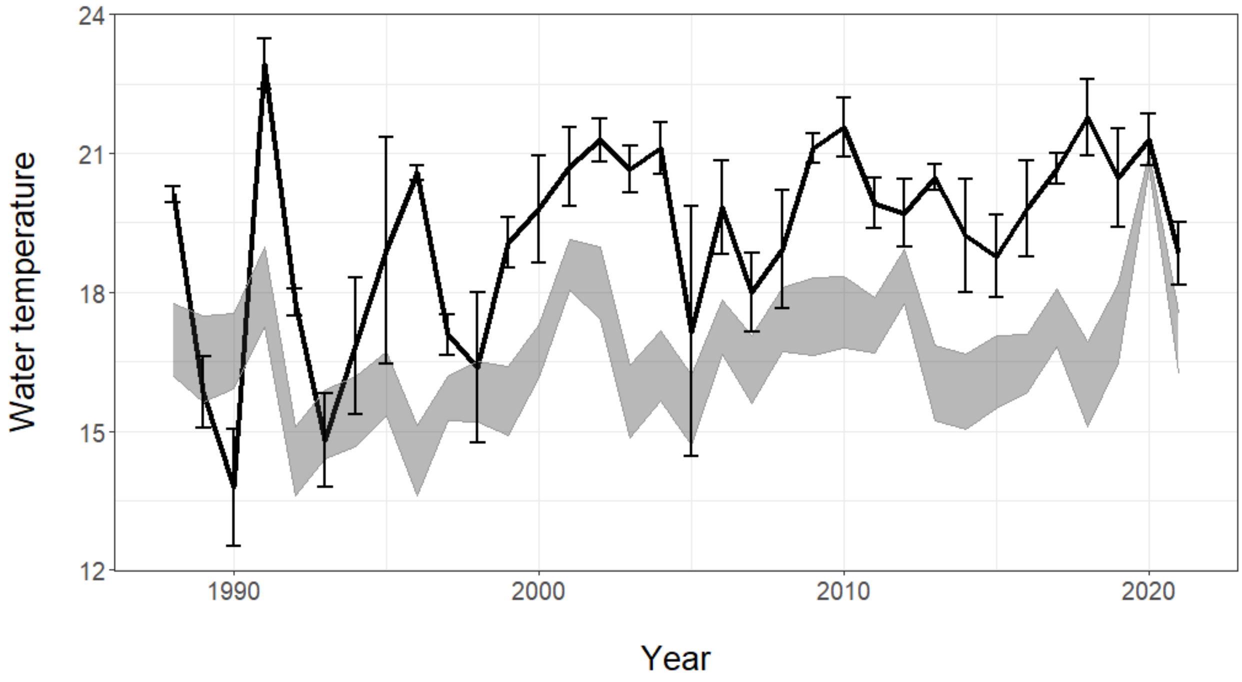


Figure 12. Atlantic Croaker - Mean bottom water temperature (^{o}C; black line) and 95% C.I. at sites with positive catches of Atlantic Croaker during index months and strata from 1988 to 2021. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

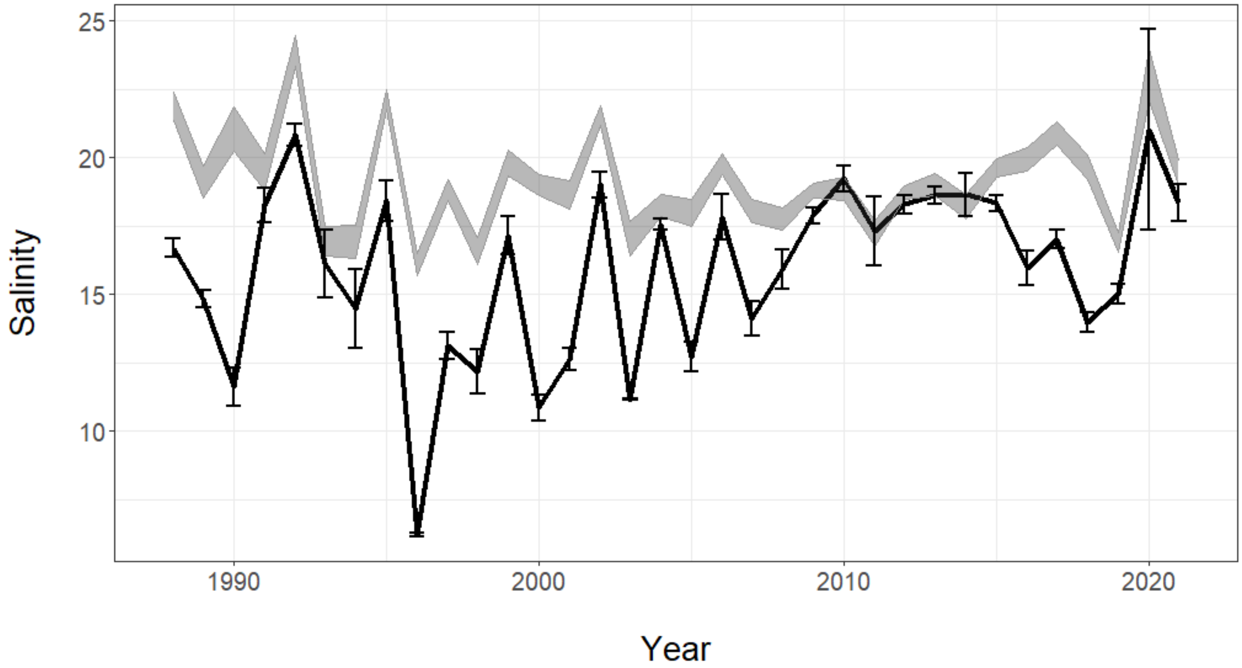


Figure 13. Atlantic Croaker - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of Atlantic Croaker during index months and strata from 1988 to 2021. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

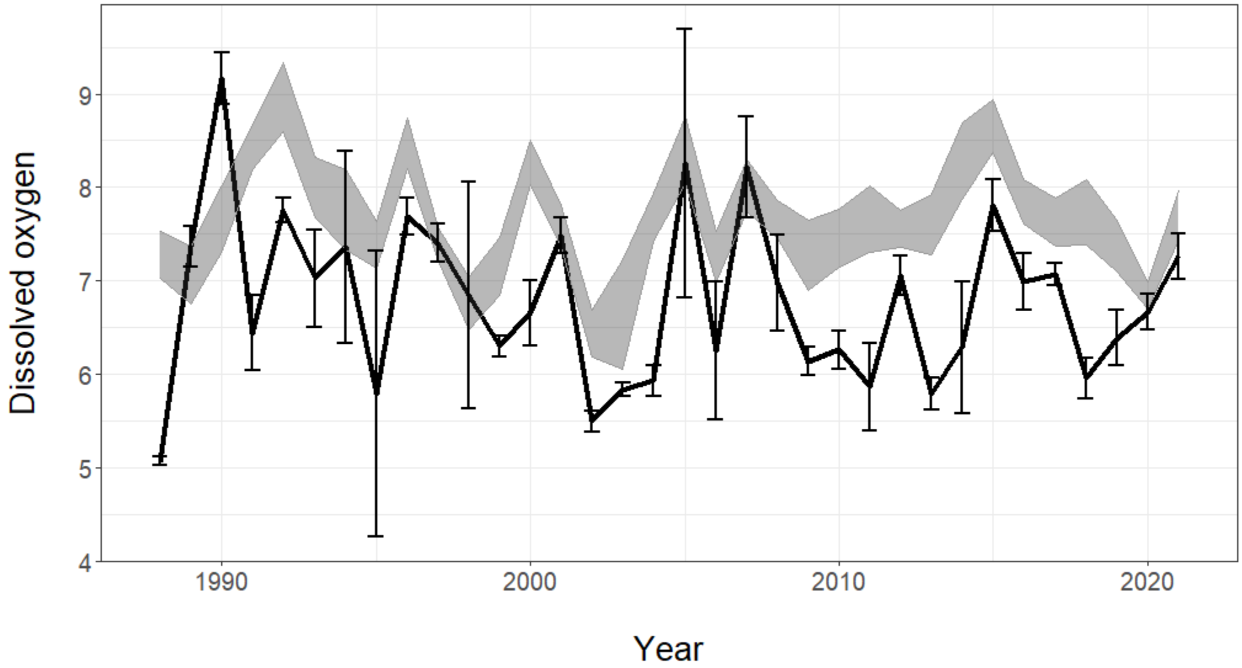


Figure 14. Atlantic Croaker - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of Atlantic Croaker during index months and strata from 1988 to 2021. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

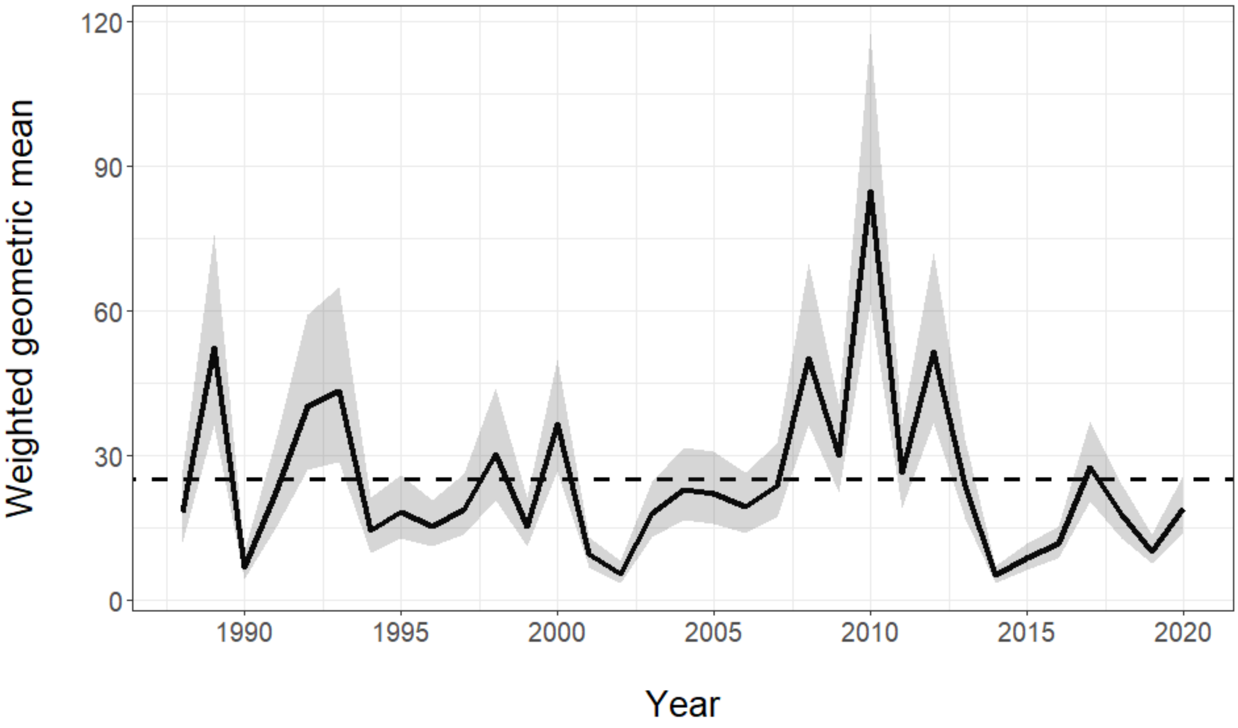


Figure 15. Juvenile Bay Anchovy random stratified index (RSI_{GM}, 95% C.I.) and the time series average based on the RSI_{GM} (dotted line) from 1988 to 2019.

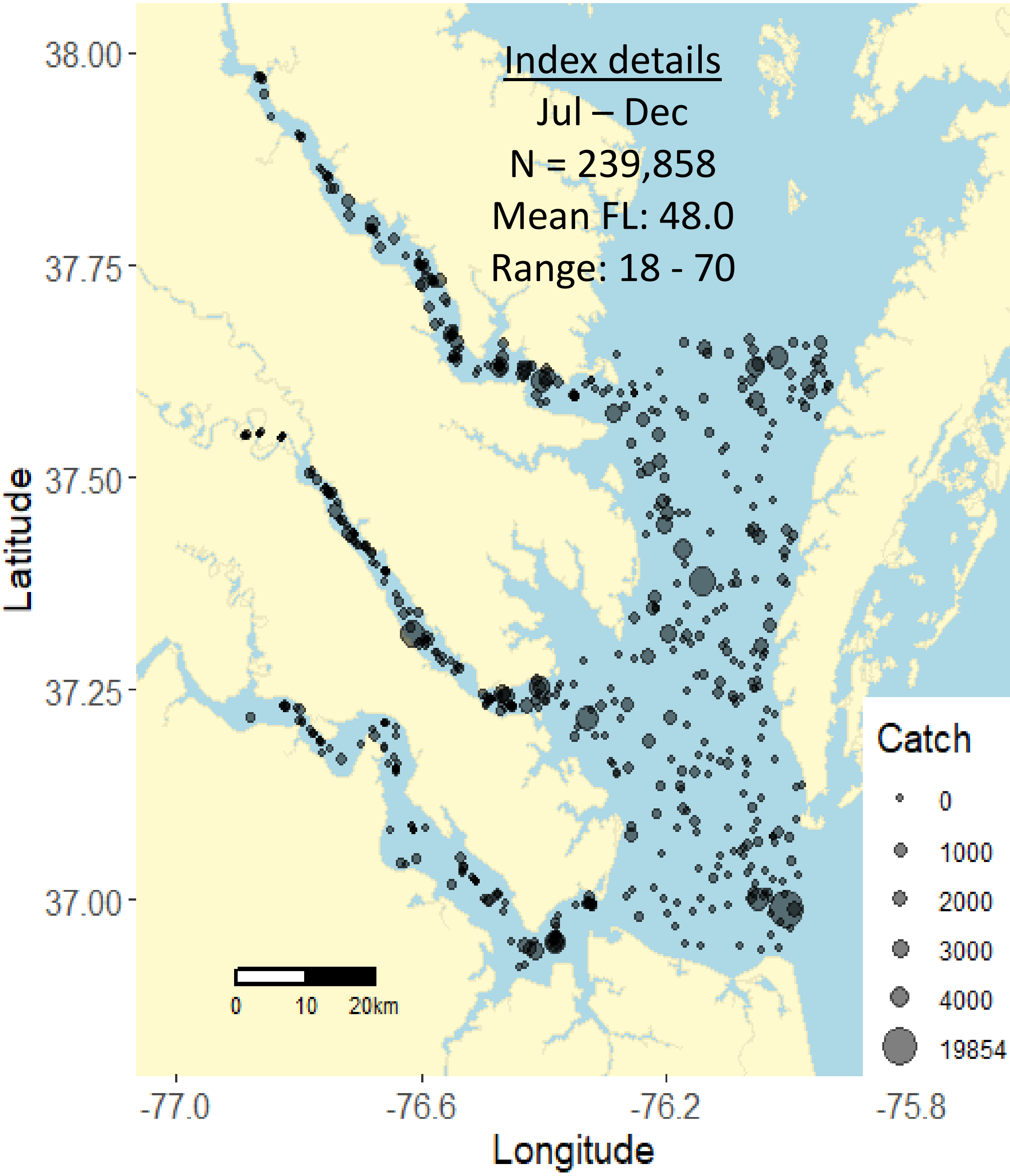


Figure 16. Distribution of juvenile Bay Anchovy, number captured, and mean length and range from index strata and months.

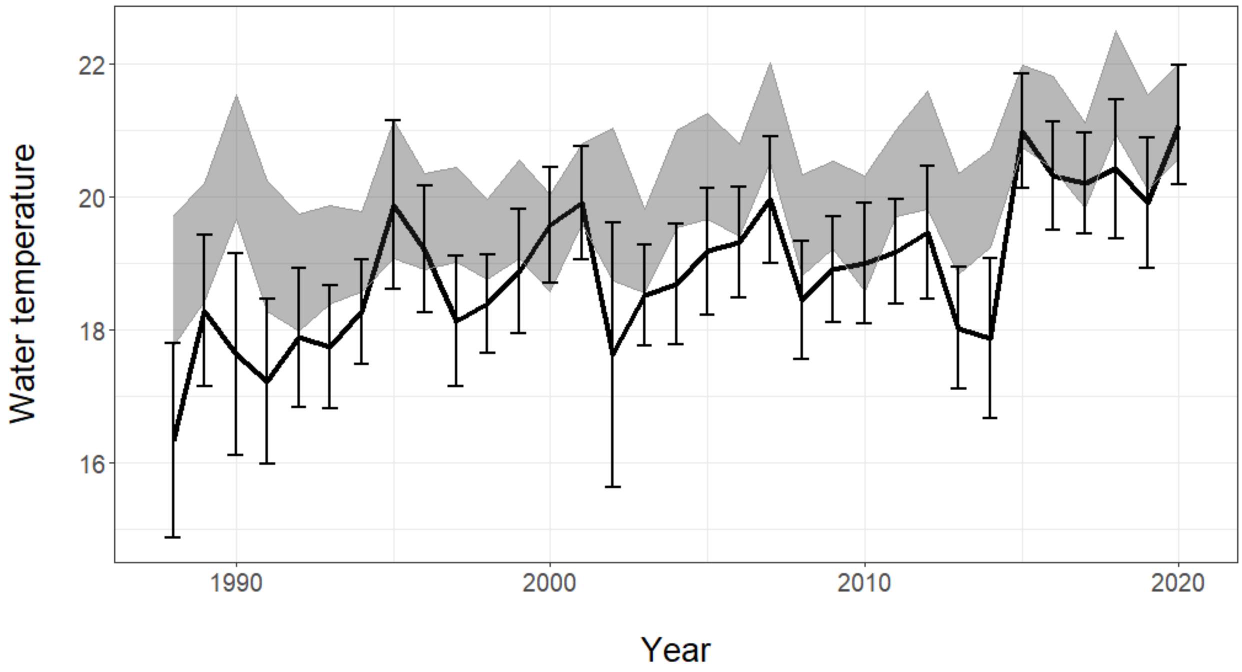


Figure 17. Bay Anchovy - Mean bottom water temperature (^{o}C; black line) and 95% C.I. at sites with positive catches of Bay Anchovy during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

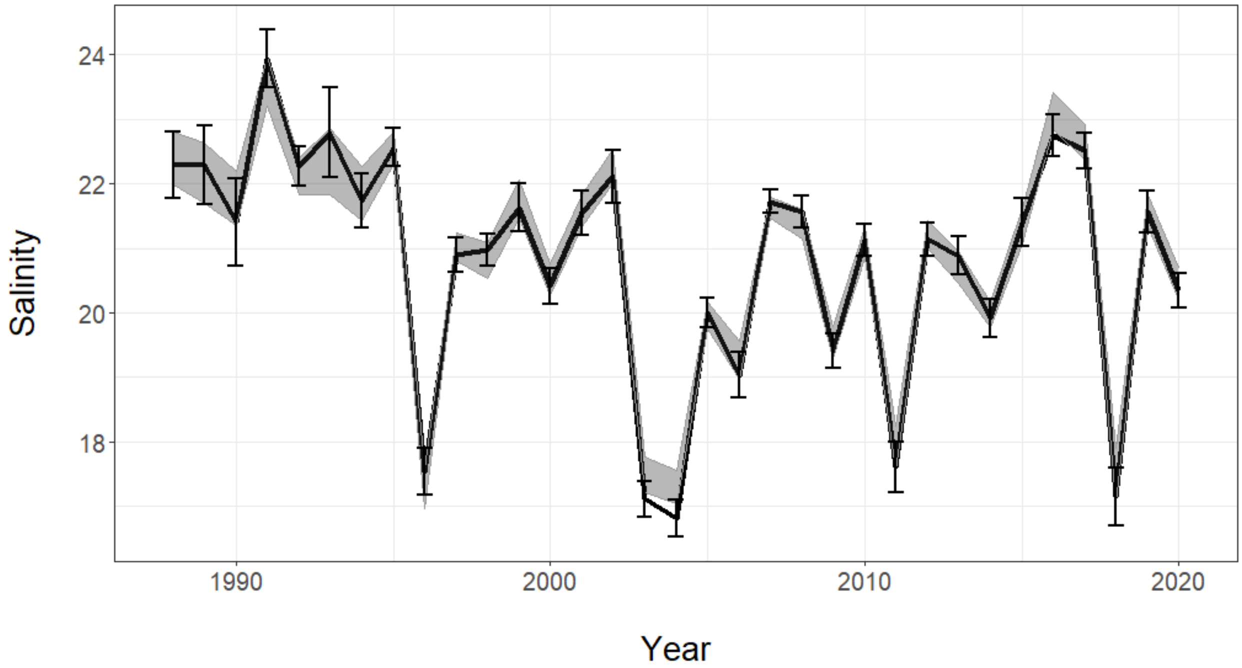


Figure 18. Bay Anchovy - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of Bay Anchovy during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

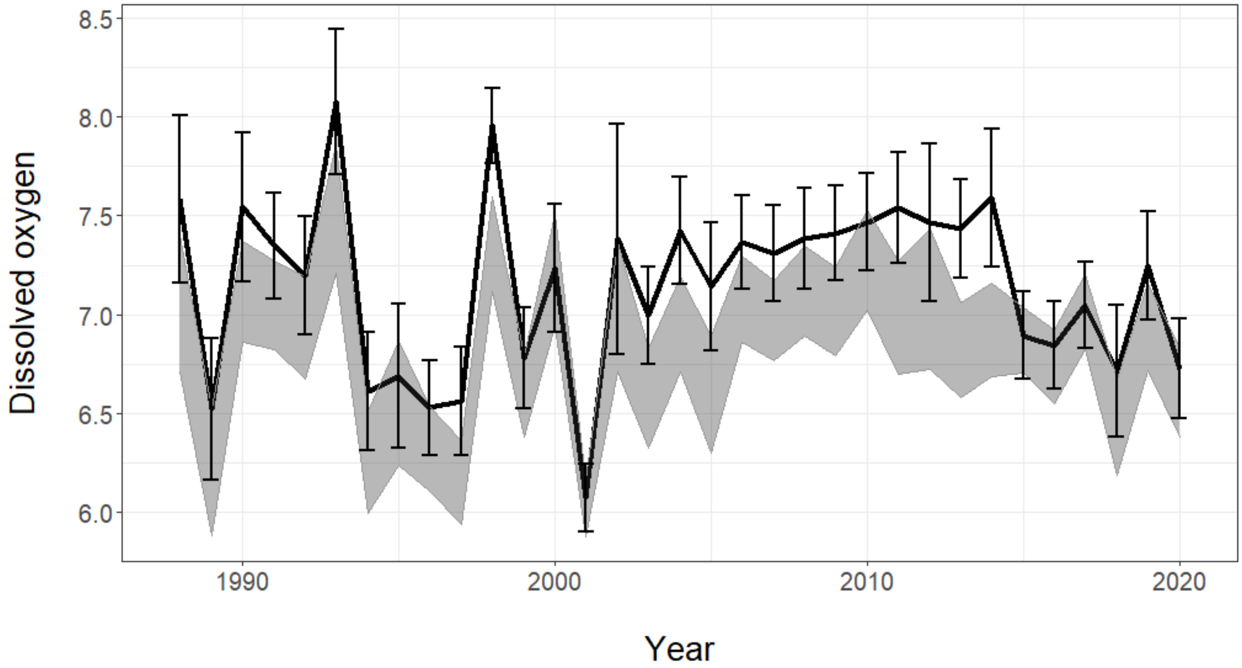


Figure 19. Bay Anchovy - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of Bay Anchovy during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

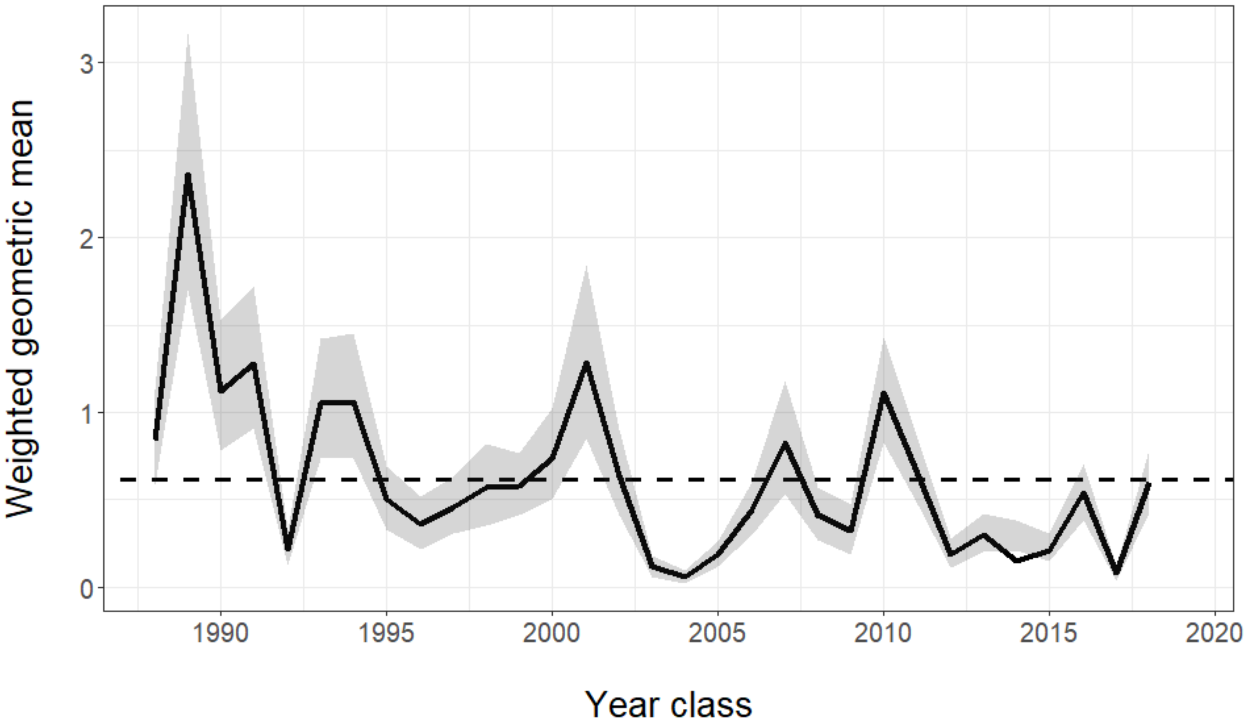


Figure 20. Black Sea Bass random stratified index (RSI$_{GM}$, 95% C.I.) and the time series average (dotted line) from 1988 to 2018. NOTE: an index for the 2019 year class could not be calculated due to missing stations resulting from COVID-19.

Figure 21. No map is available because an index could not be calculated for juvenile Black Sea Bass 2019 year class due to missing stations resulting from COVID-19.

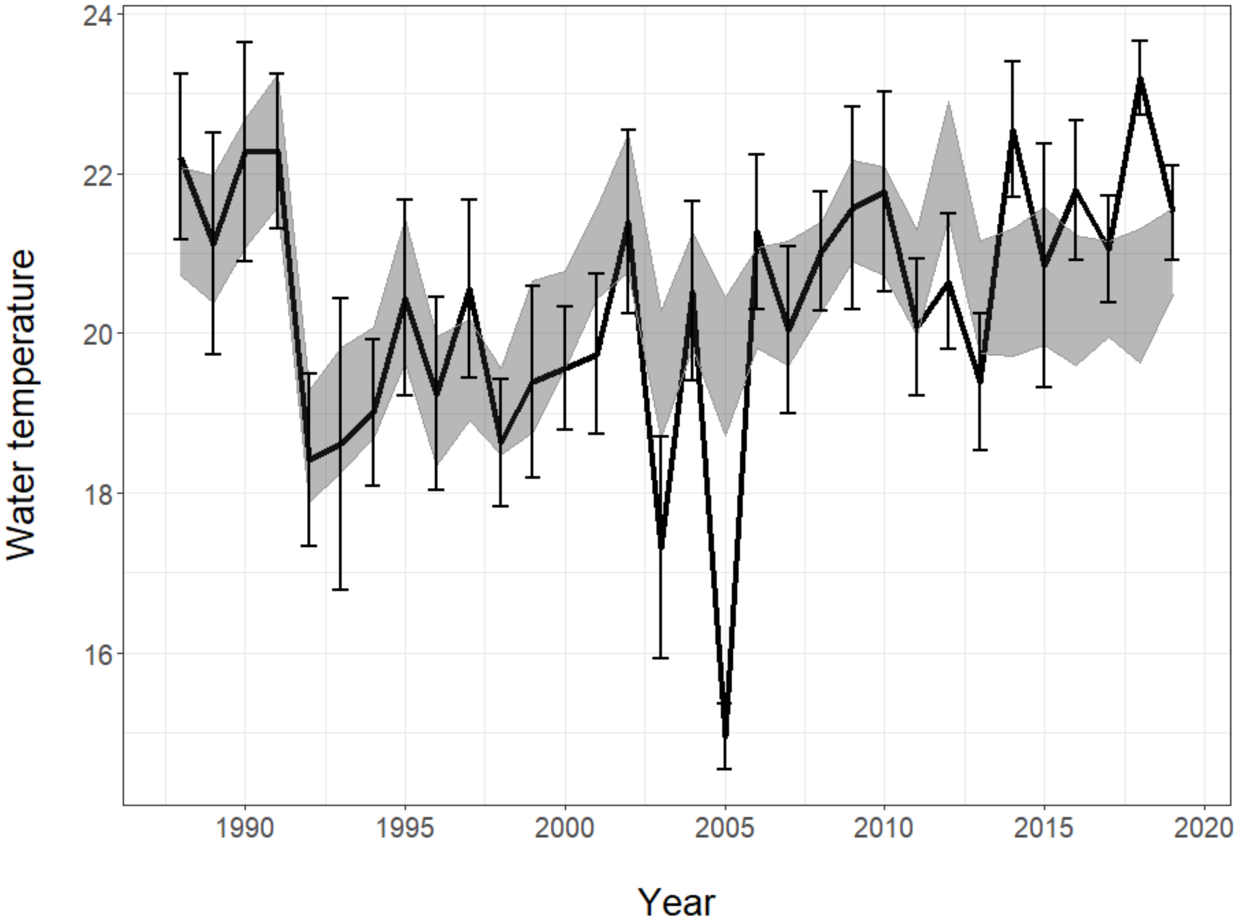


Figure 22. Black Sea Bass - Mean bottom water temperature (^{o}C; black line) and 95% C.I. at sites with positive catches of Black Sea Bass during index months and strata from 1988 to 2019. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata. This figure has not been updated for 2020 due to missing stations.

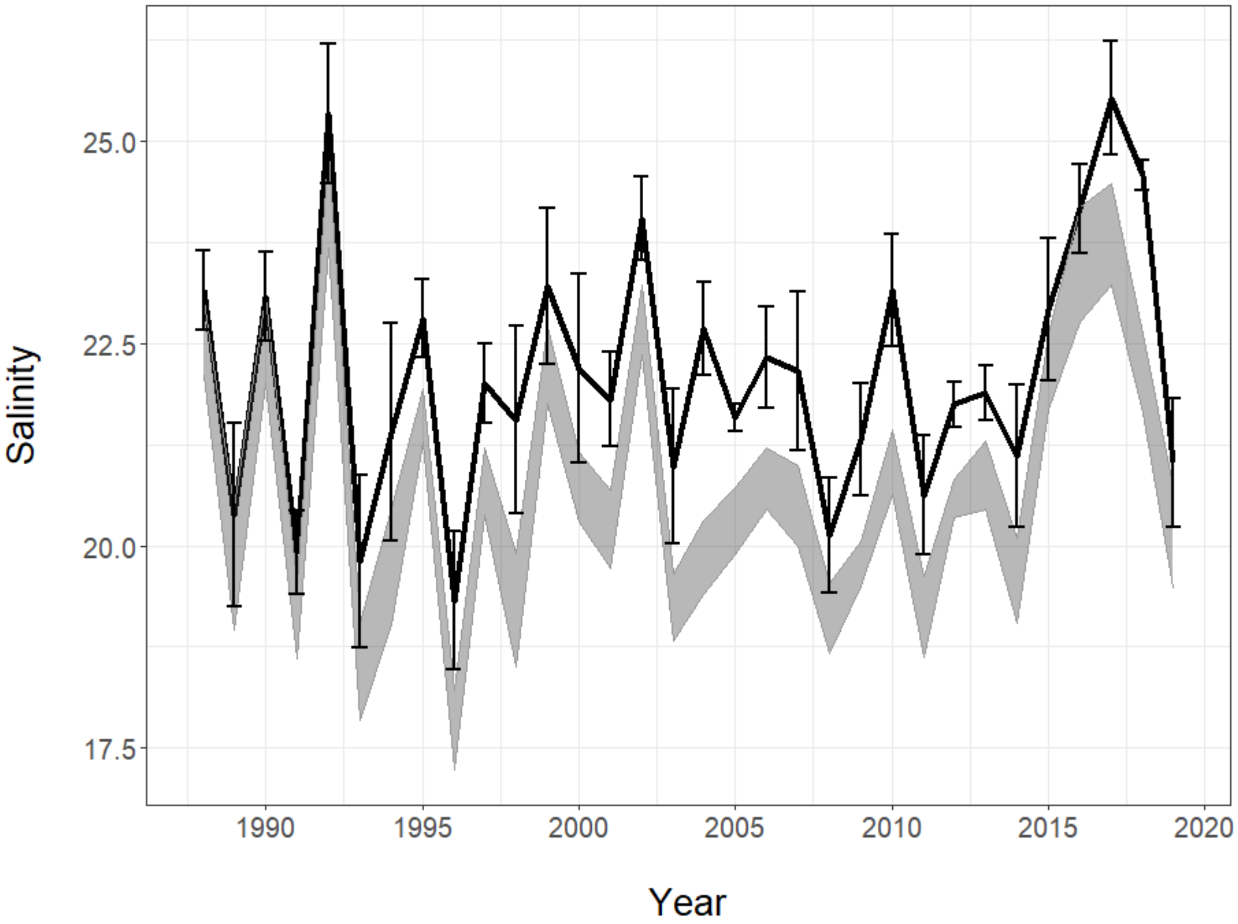


Figure 23. Black Sea Bass - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of Black Sea Bass during index months and strata from 1988 to 2019. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata. This figure has not been updated for 2020 due to missing stations.

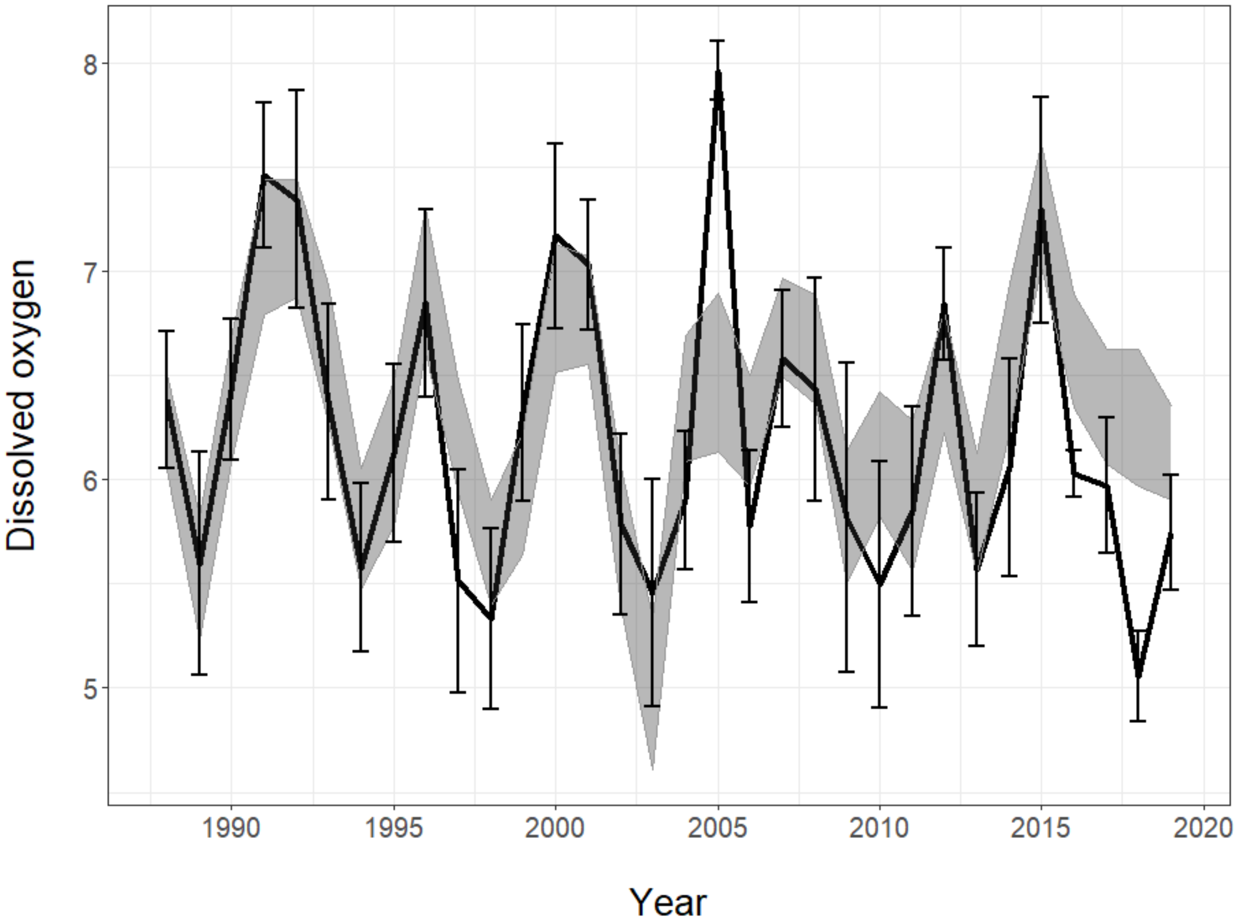


Figure 24. Black Sea Bass - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of Black Sea Bass during index months and strata from 1988 to 2019. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata. This figure has not been updated for 2020 due to missing stations.

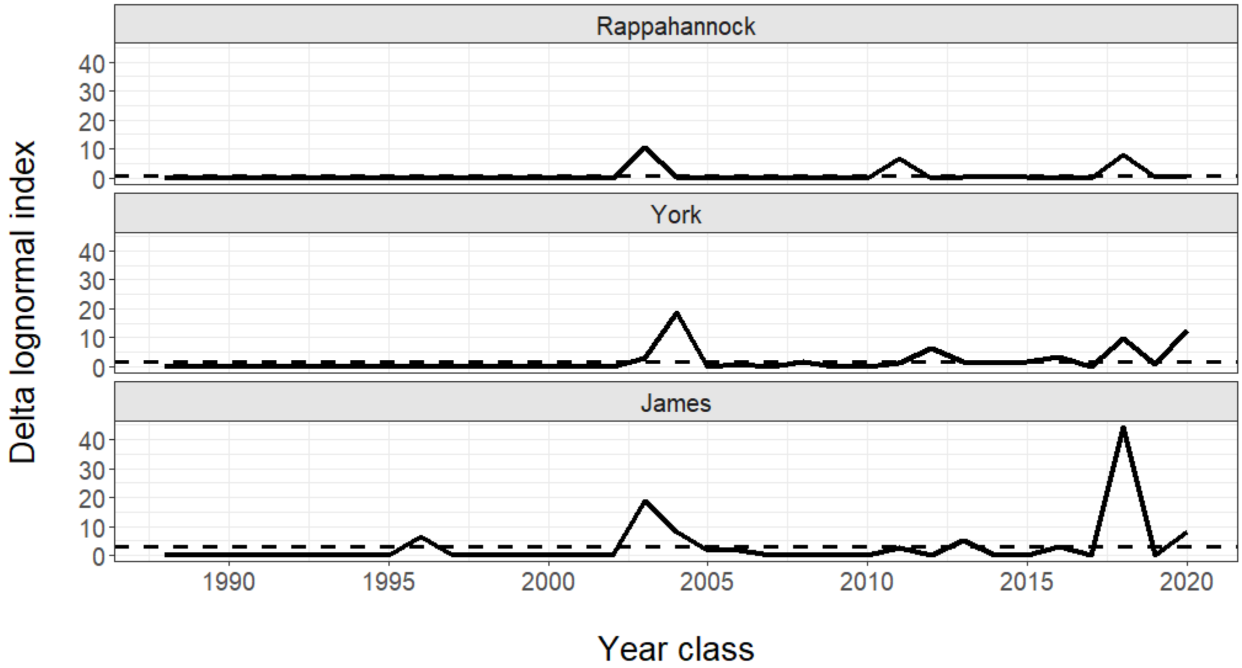


Figure 25. Juvenile Blue Catfish random stratified index (RSI_{Delta}) and time series averages (dotted lines) based on the RSI_{Delta}'s from the Rappahannock, York, and James rivers from 1988 to 2020.

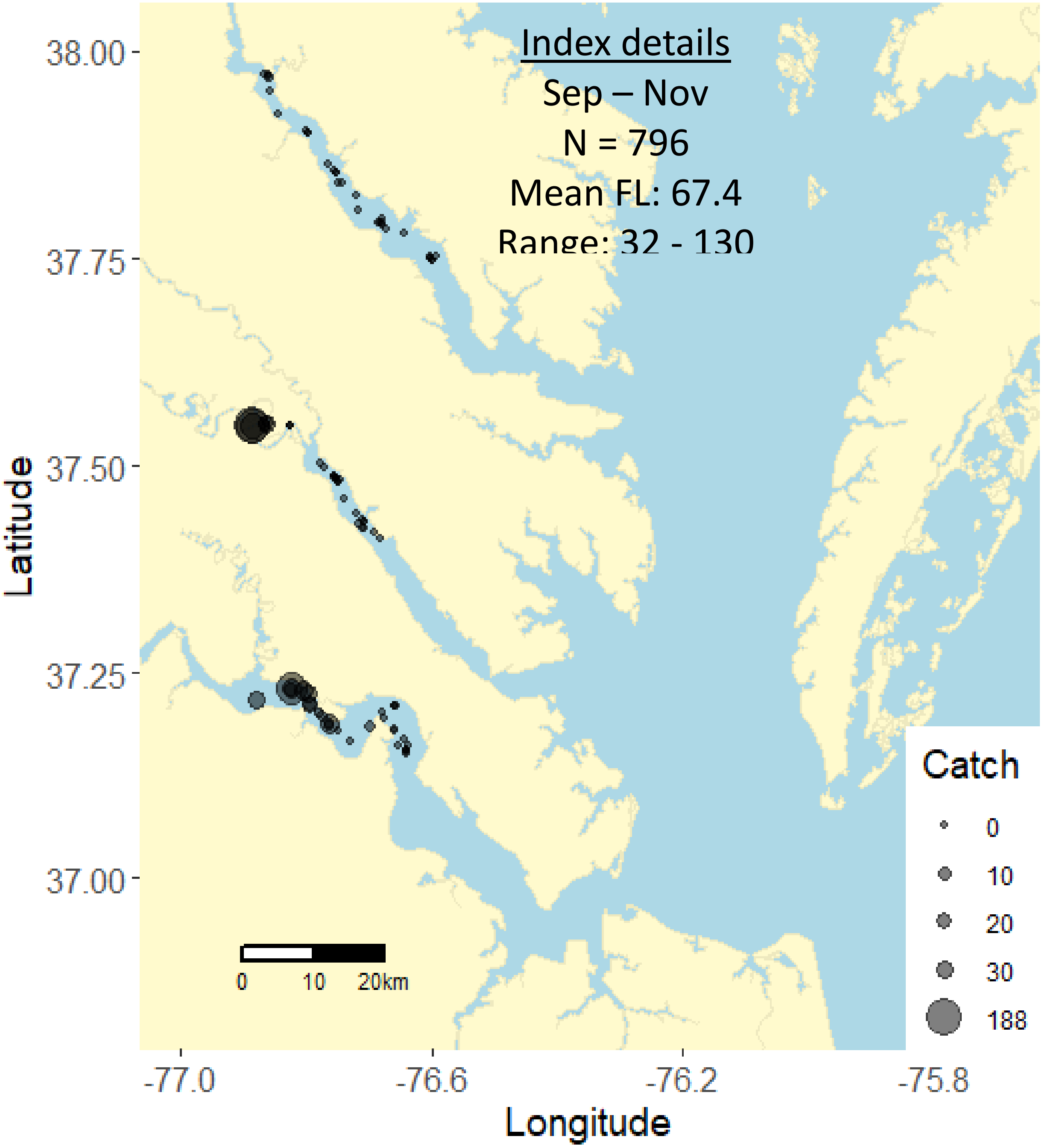


Figure 26. Distribution of index-sized juvenile Blue Catfish, the number captured, and mean length and range from index strata and months.

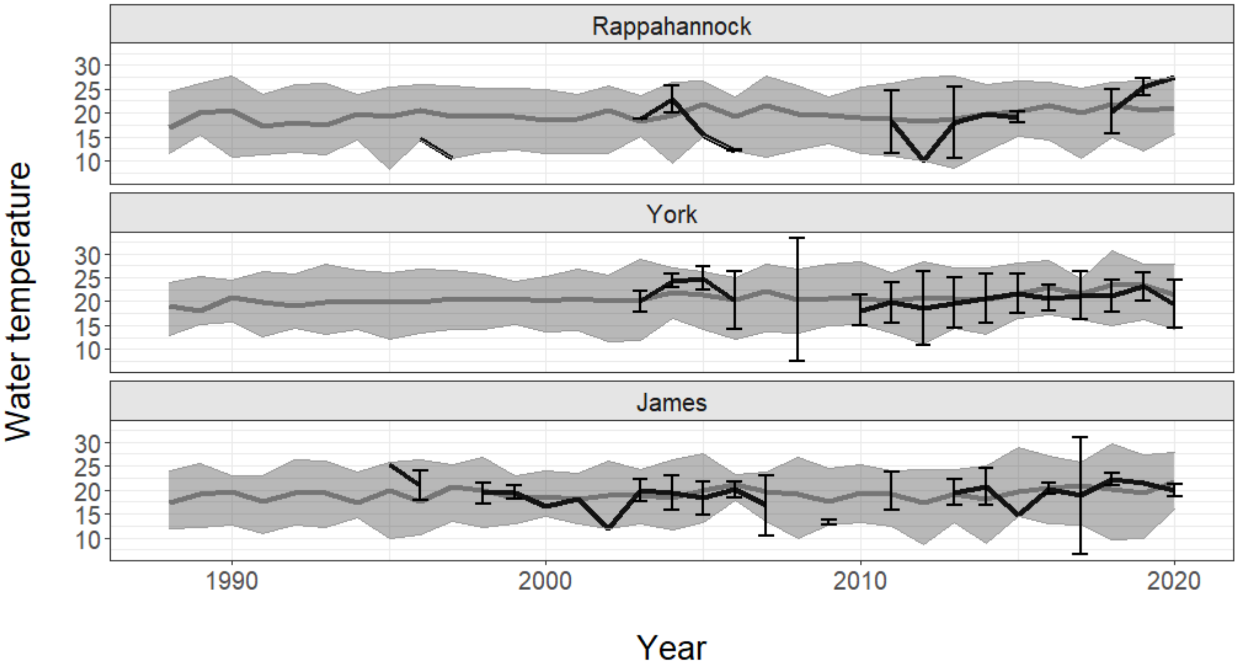


Figure 27. Juvenile Blue Catfish - Mean bottom water temperature and 95% C.I. (°C; black line) at sites with positive catches of juvenile Blue Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed water temperatures represent years with low numbers of positive catches of juvenile Blue Catfish.

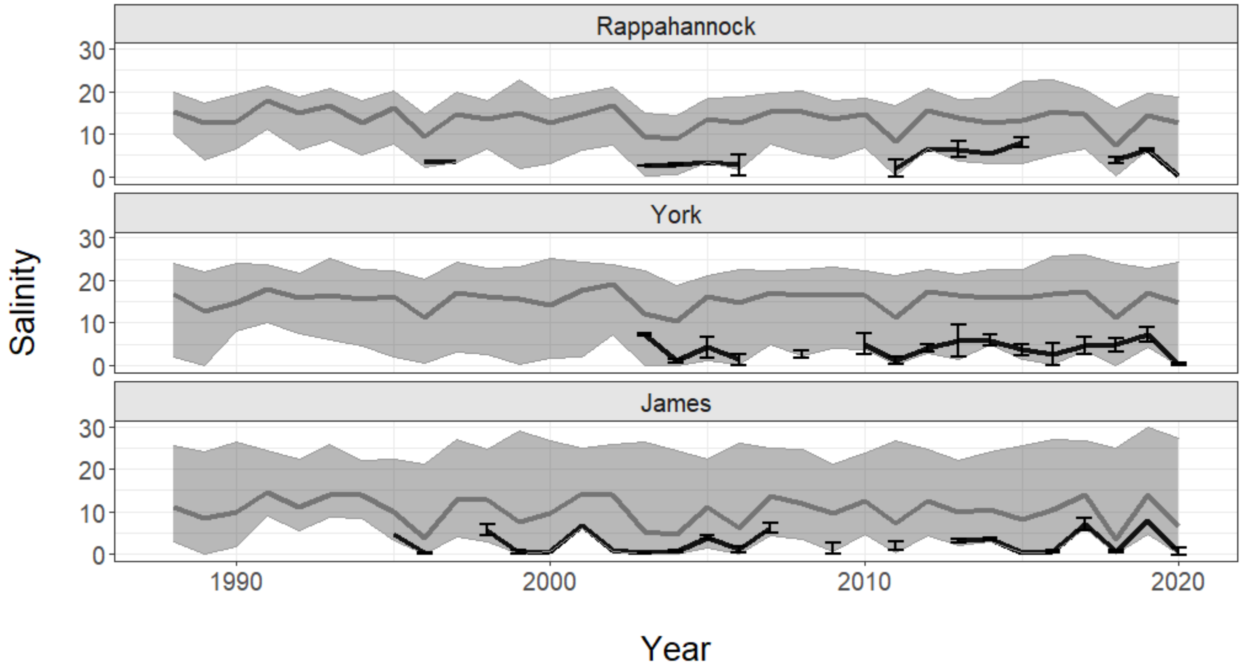


Figure 28. Juvenile Blue Catfish - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of juvenile Blue Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata.

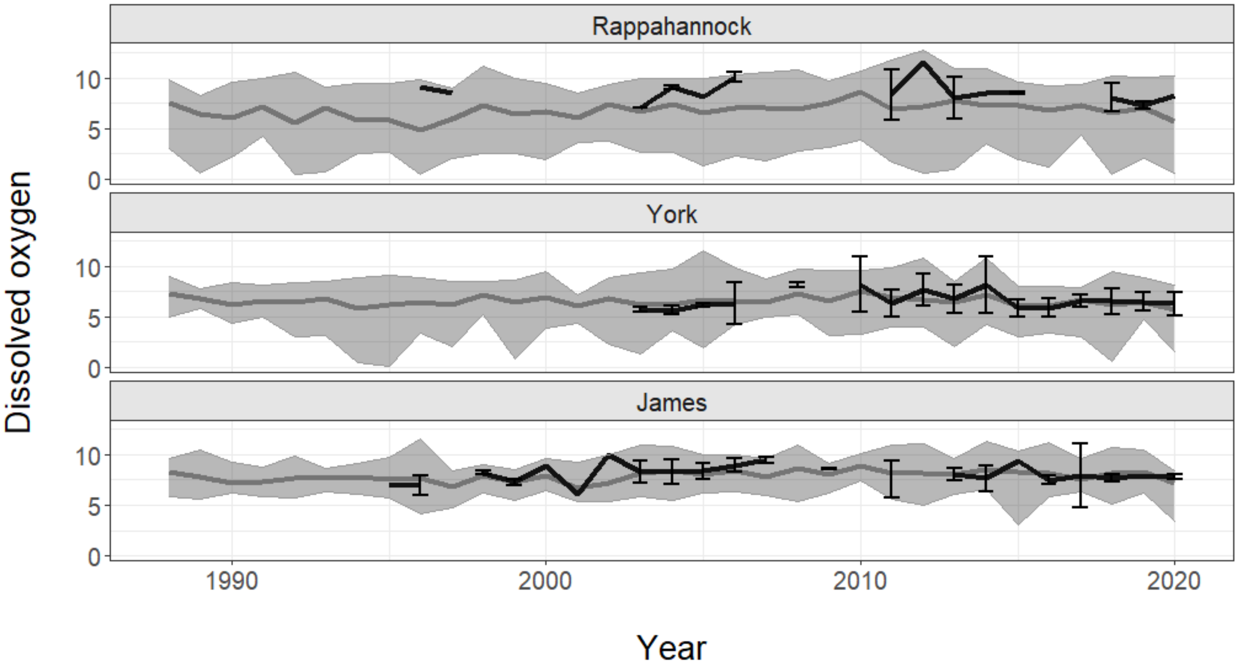


Figure 29. Juvenile Blue Catfish - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of juvenile Blue Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata.

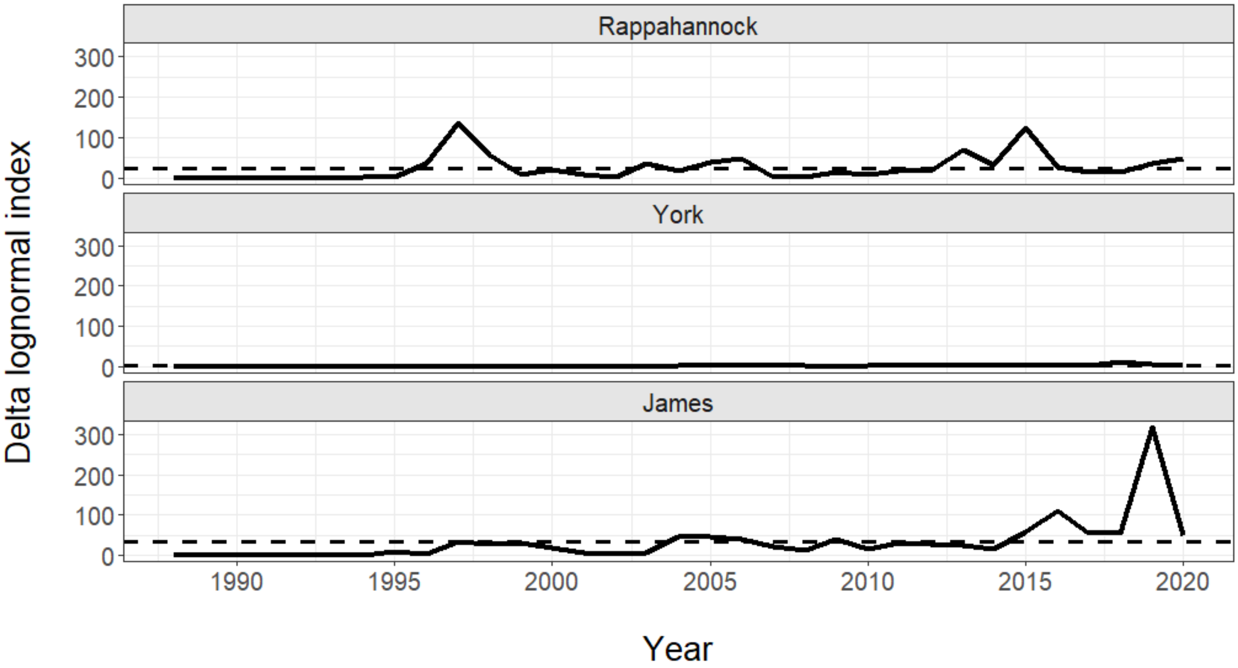


Figure 30. Age 1+ Blue Catfish random stratified index (RSI_{Delta}) and time series averages (dotted lines) based on the RSI_{Delta}'s from the Rappahannock, York, and James rivers from 1988 to 2020.

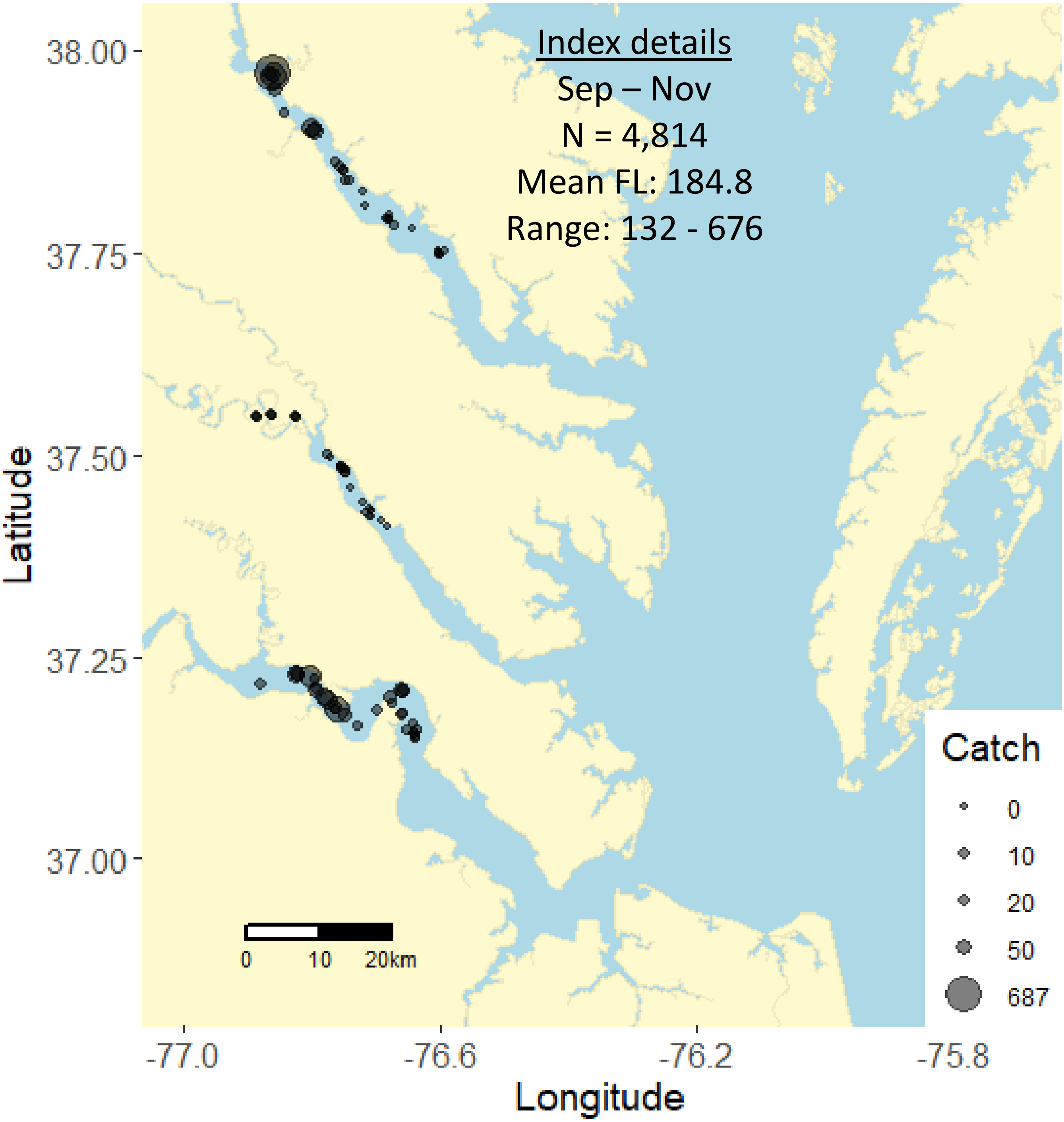


Figure 31. Distribution of Age 1+ Blue Catfish, the number captured, and mean length and range from index strata and months.

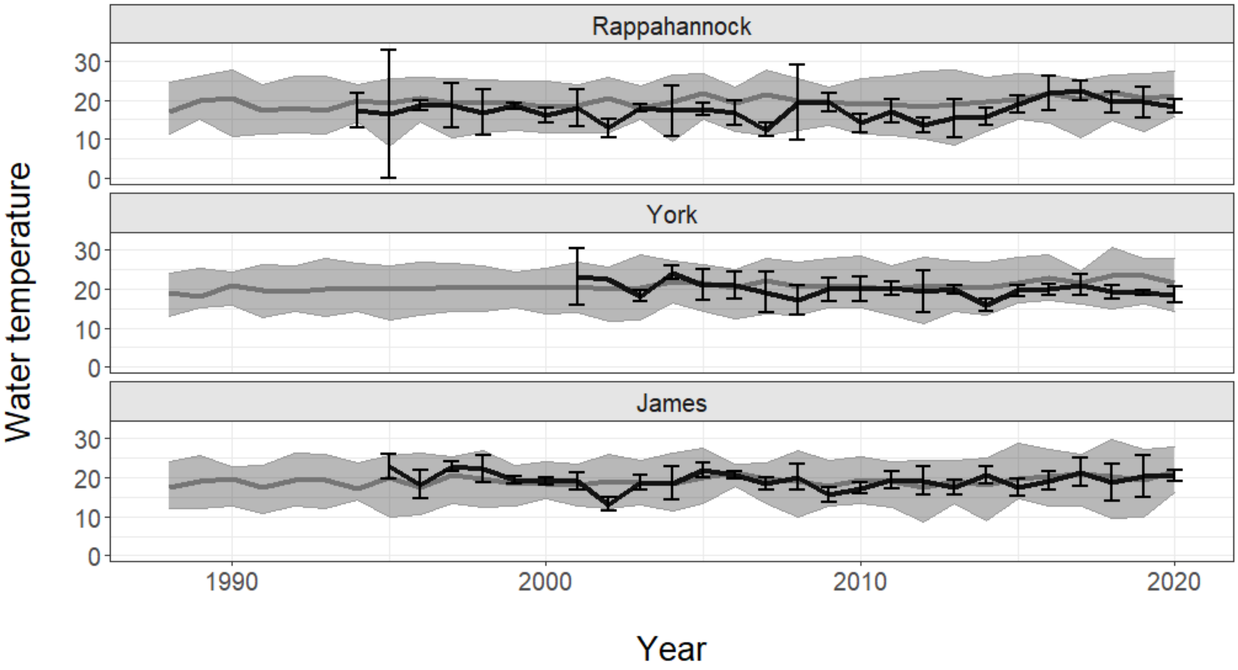


Figure 32. Age 1+ Blue Catfish - Mean bottom water temperature and 95% C.I. (^{o}C; black line) at sites with positive catches of Age 1+ Blue Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata.

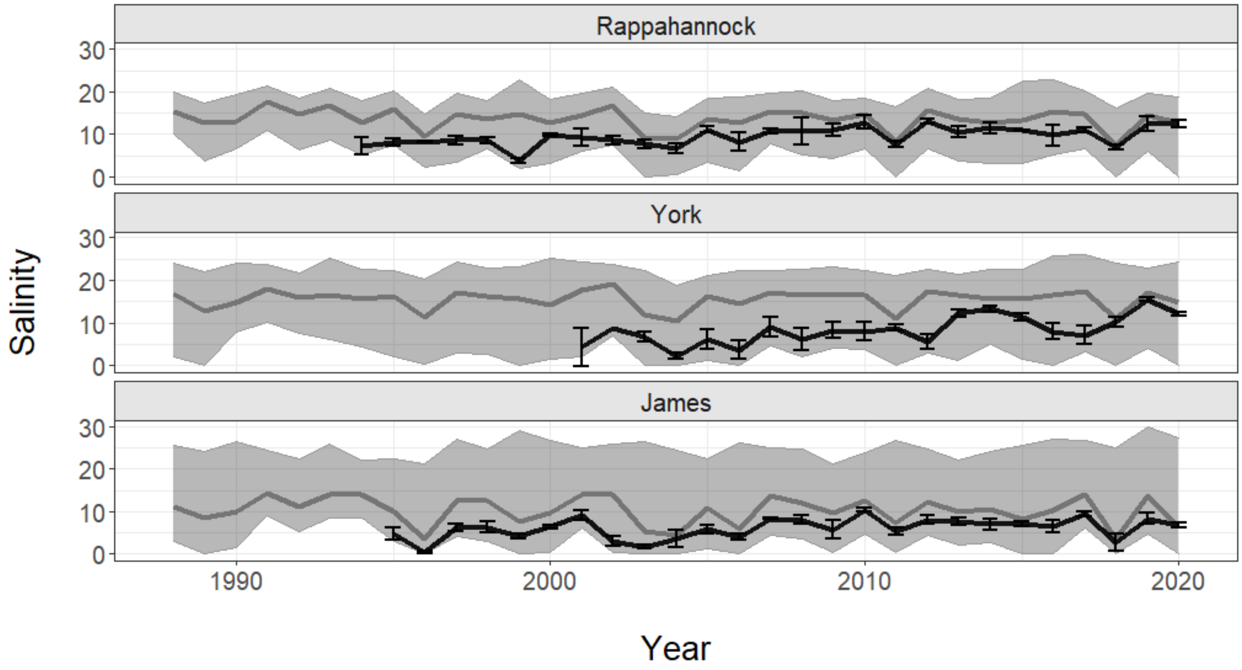


Figure 33. Age 1+ Blue Catfish - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of Age 1+ Blue Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata.

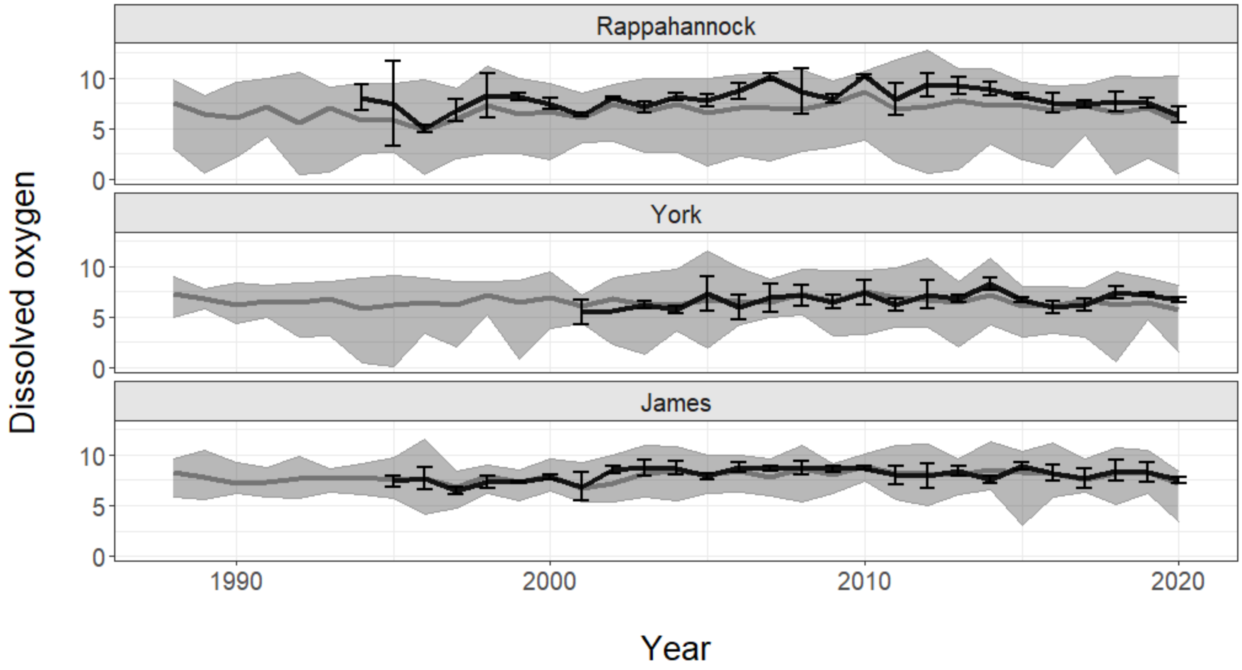


Figure 34. Age 1+ Blue Catfish - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of Age 1+ Blue Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata.

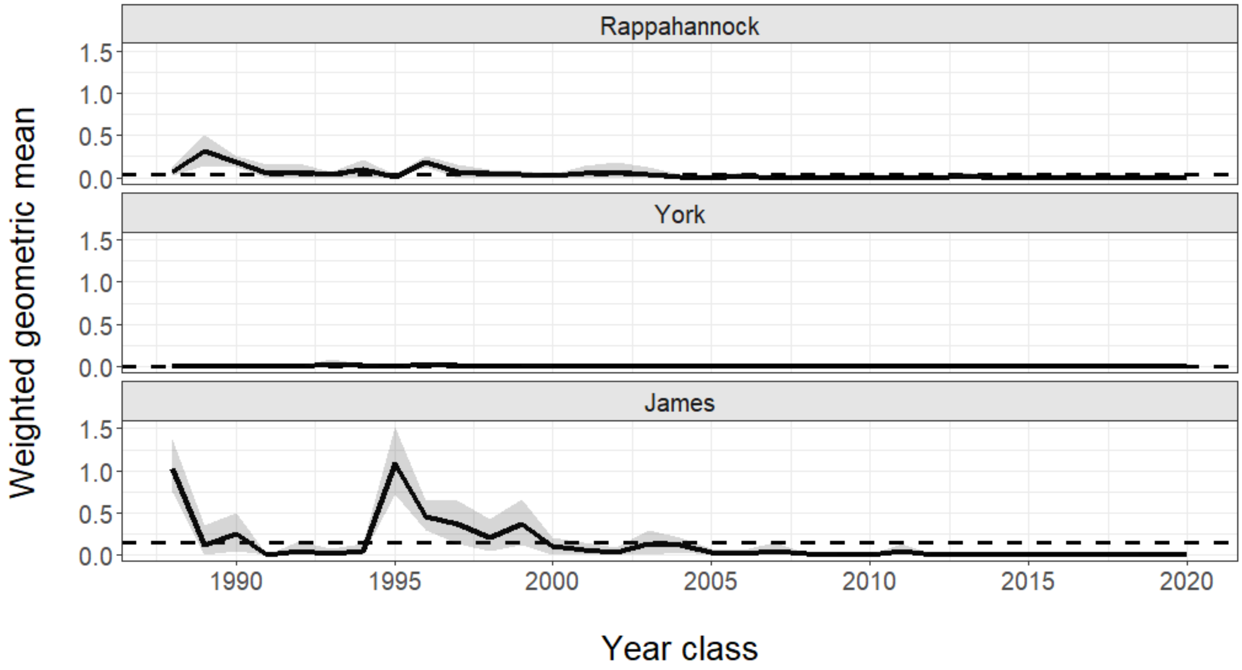


Figure 35. Juvenile Channel Catfish random stratified indices (RSI_{GM}, 95% C.I.) and time series averages (dotted lines) based on the RSI_{GM}'s from the Rappahannock, York, and James rivers.

Figure 36. No juvenile Channel Catfish were captured from index strata and months.

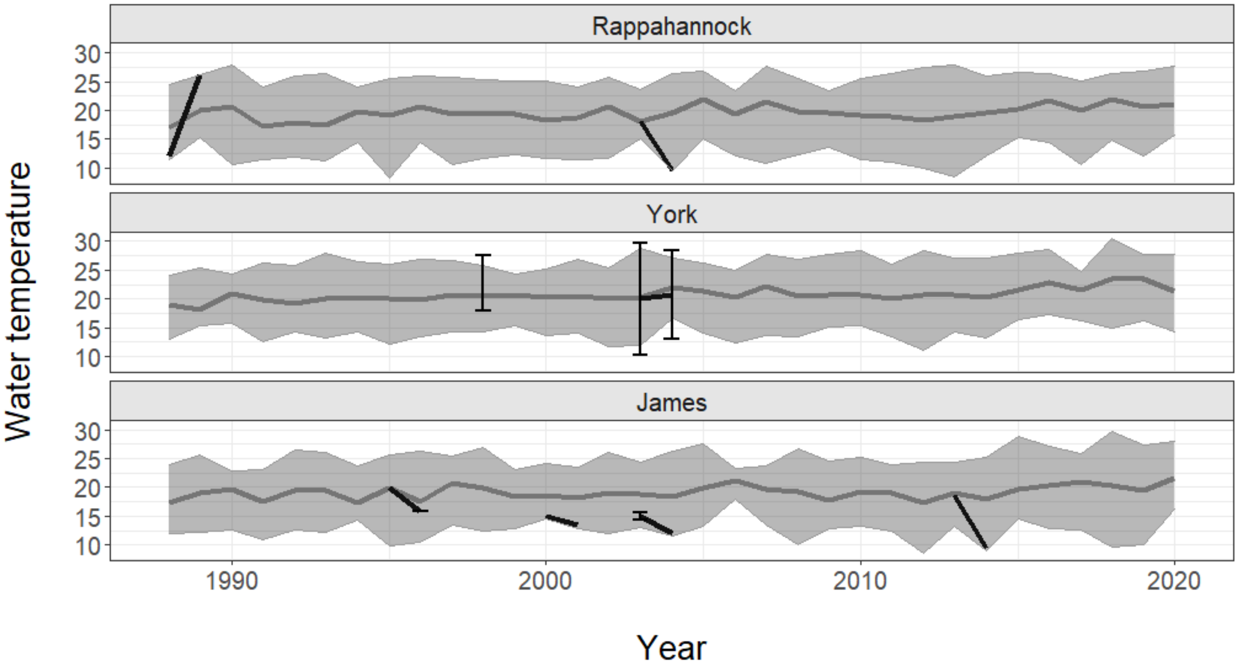


Figure 37. Juvenile Channel Catfish - Mean bottom water temperature and 95% C.I. (^{o}C; black line) at sites with positive catches of juvenile Channel Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed water temperatures represent years with low numbers of positive catches of juvenile Channel Catfish.

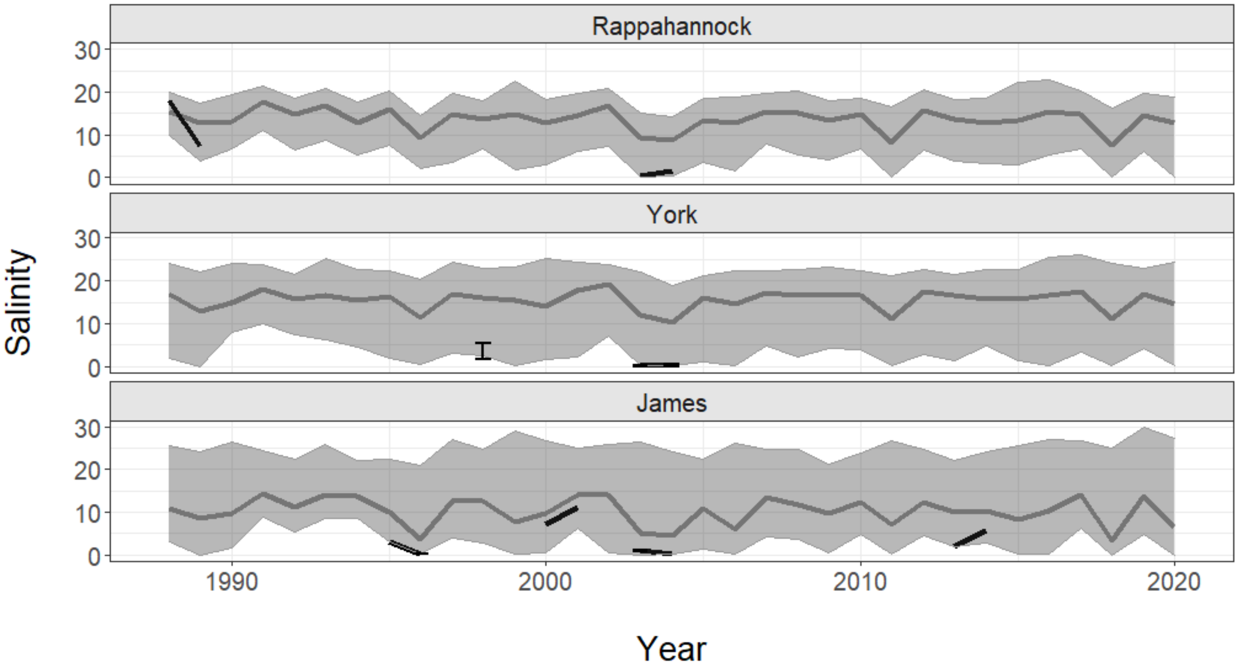


Figure 38. Juvenile Channel Catfish - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of juvenile Channel Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed salinity represent years with low numbers of positive catches of juvenile Channel Catfish.

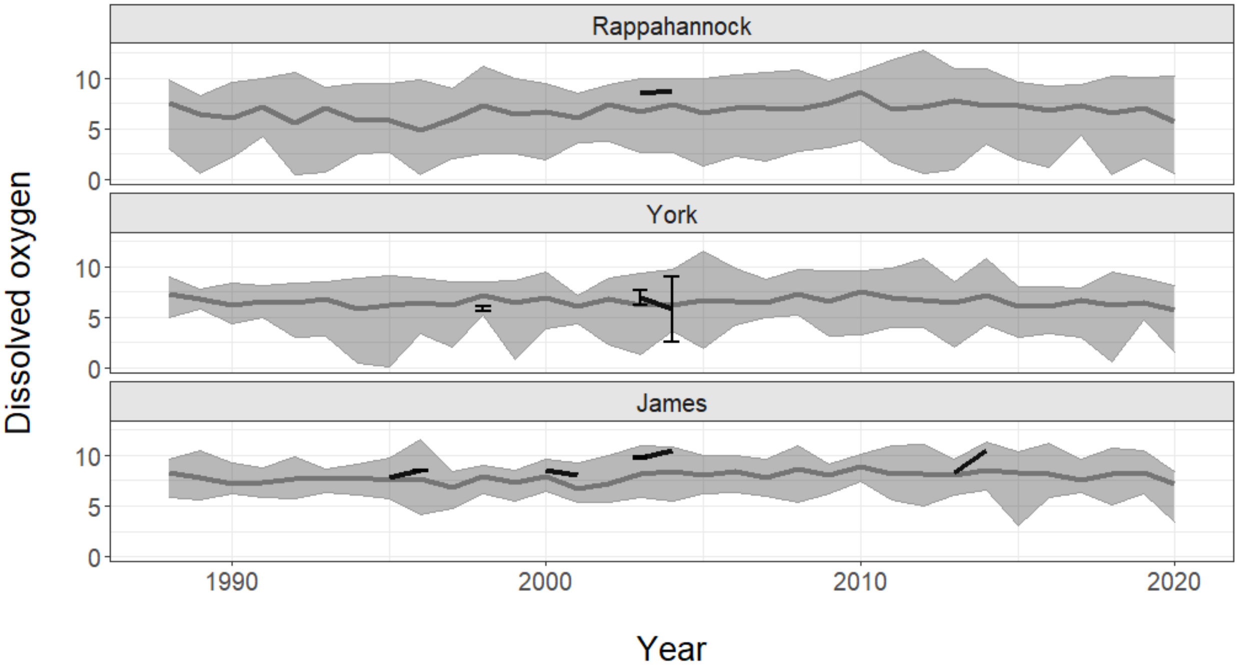


Figure 39. Juvenile Channel Catfish - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of juvenile Channel Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata.

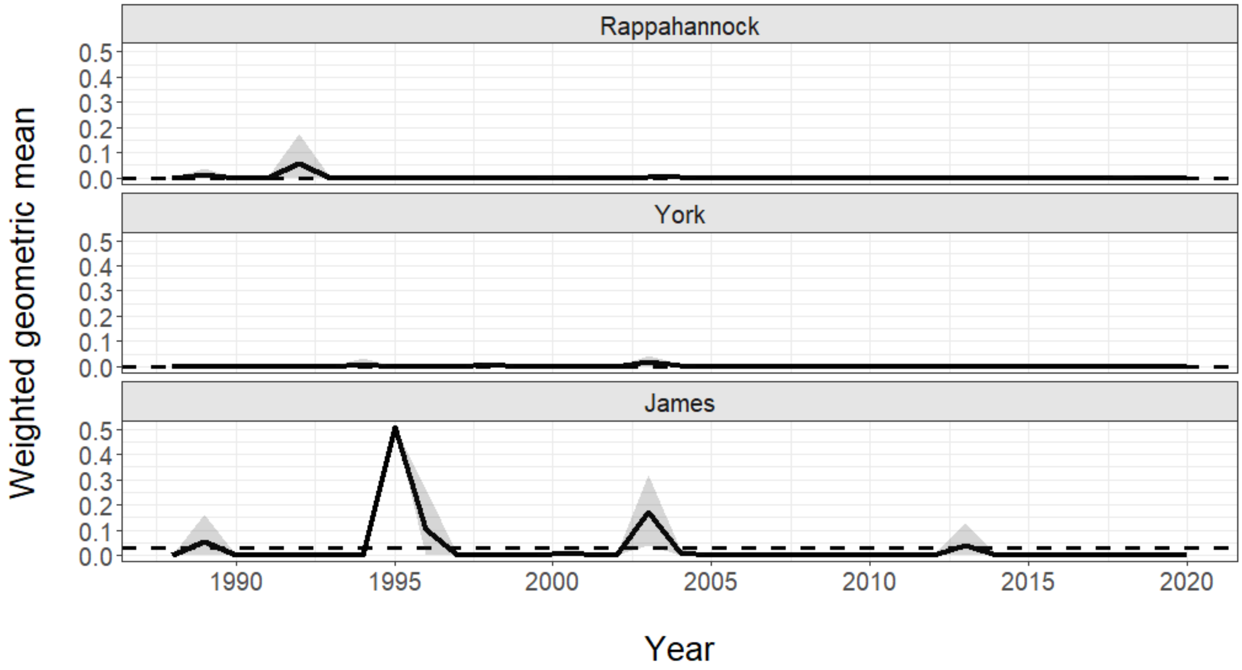


Figure 40. Age 1+ Channel Catfish random stratified indices (RSI$_{GM}$, 95% C.I.) and time series averages (dotted lines) based on the RSI$_{GM}$'s from the Rappahannock, York, and James rivers.

Figure 41. No Age 1+ Channel Catfish were captured from index strata and months.

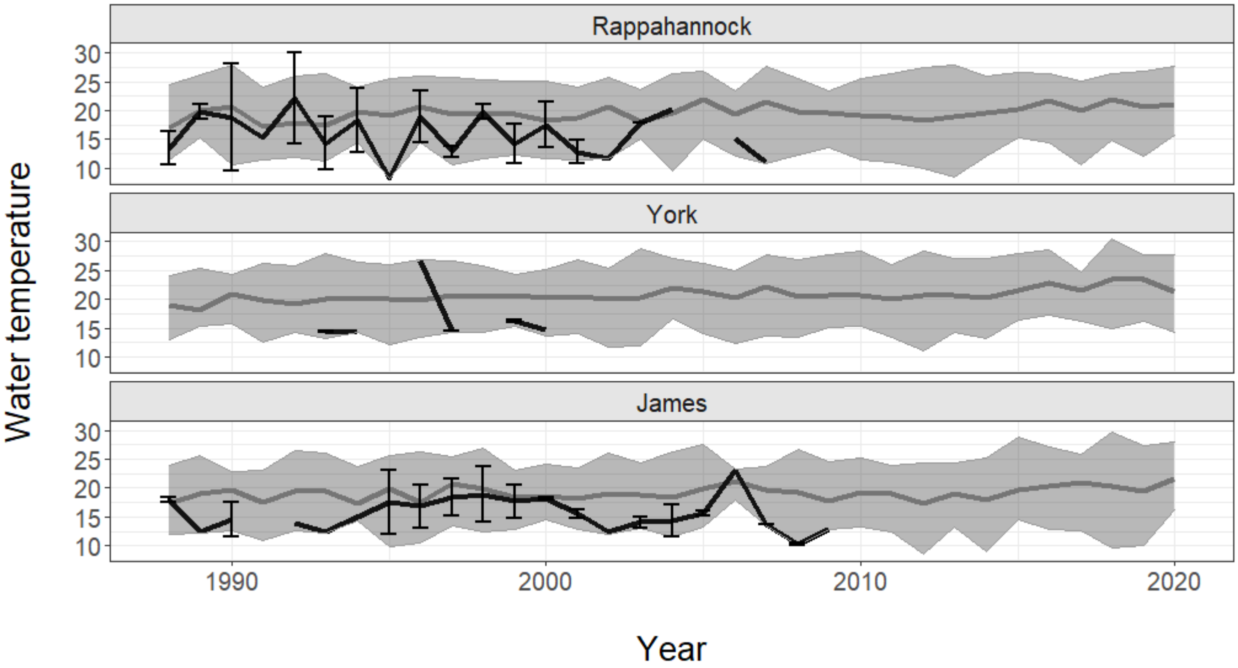


Figure 42. Age 1+ Channel Catfish - Mean bottom water temperature and 95% C.I. (^{o}C; black line) at sites with positive catches of Age 1+ Channel Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata.

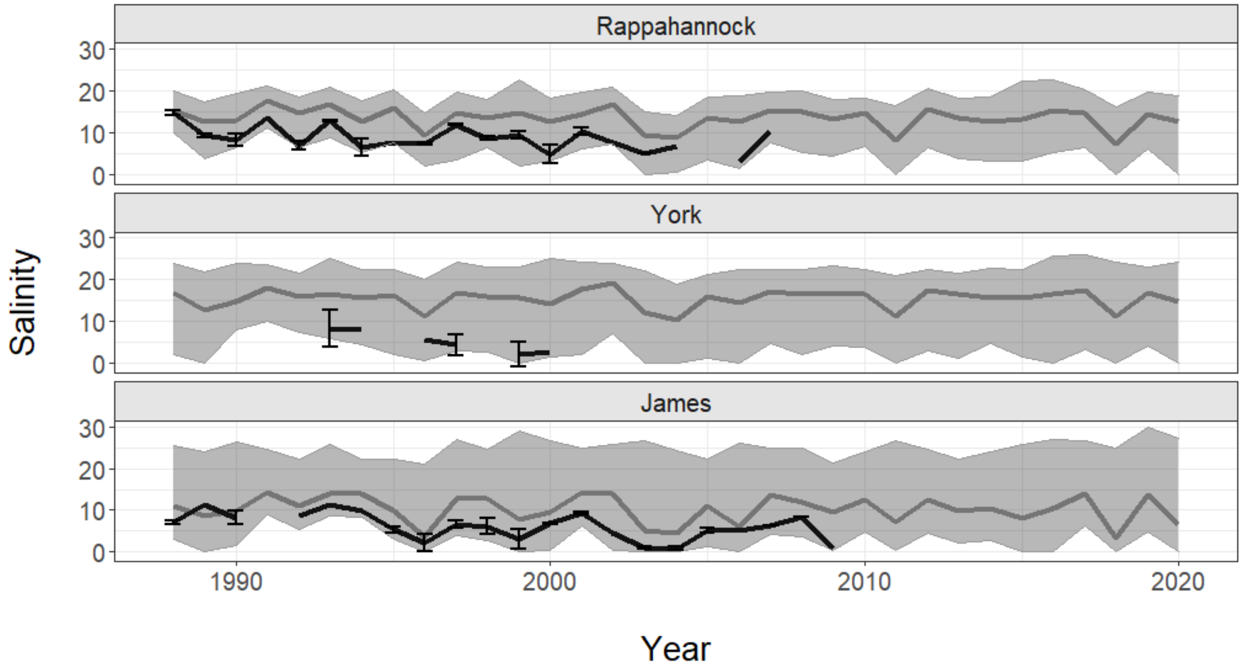


Figure 43. Age 1+ Channel Catfish - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of Age 1+ Channel Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata.

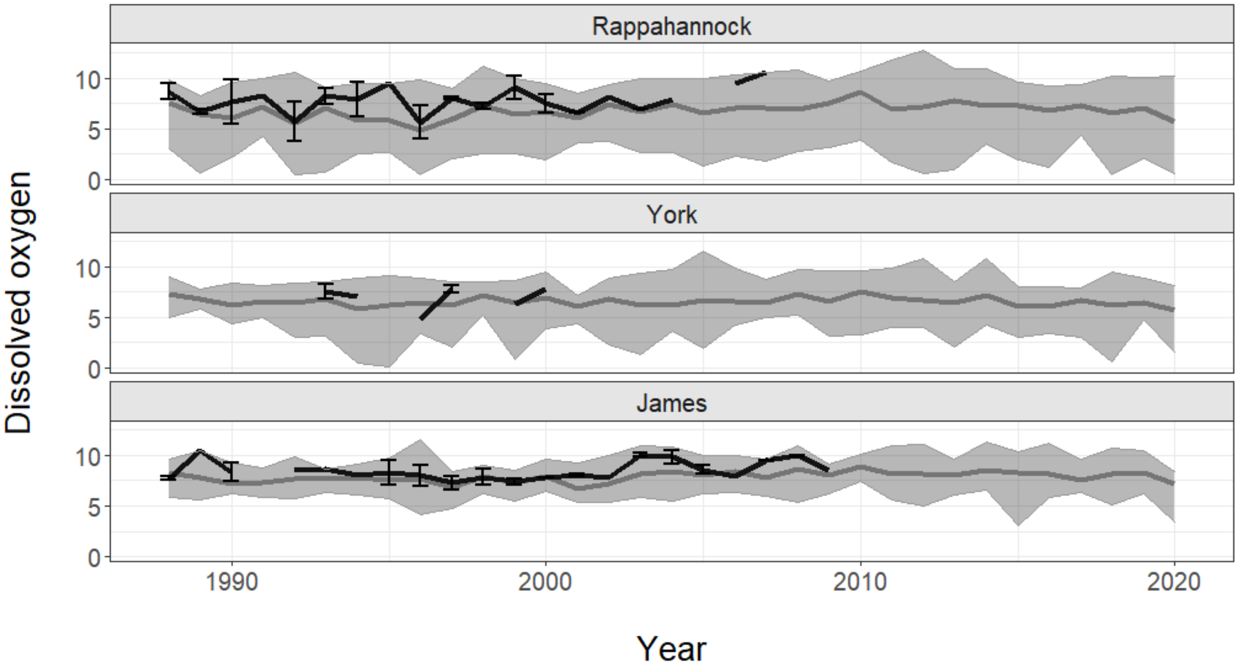


Figure 44. Age 1+ Channel Catfish - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of Age 1+ Channel Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata.

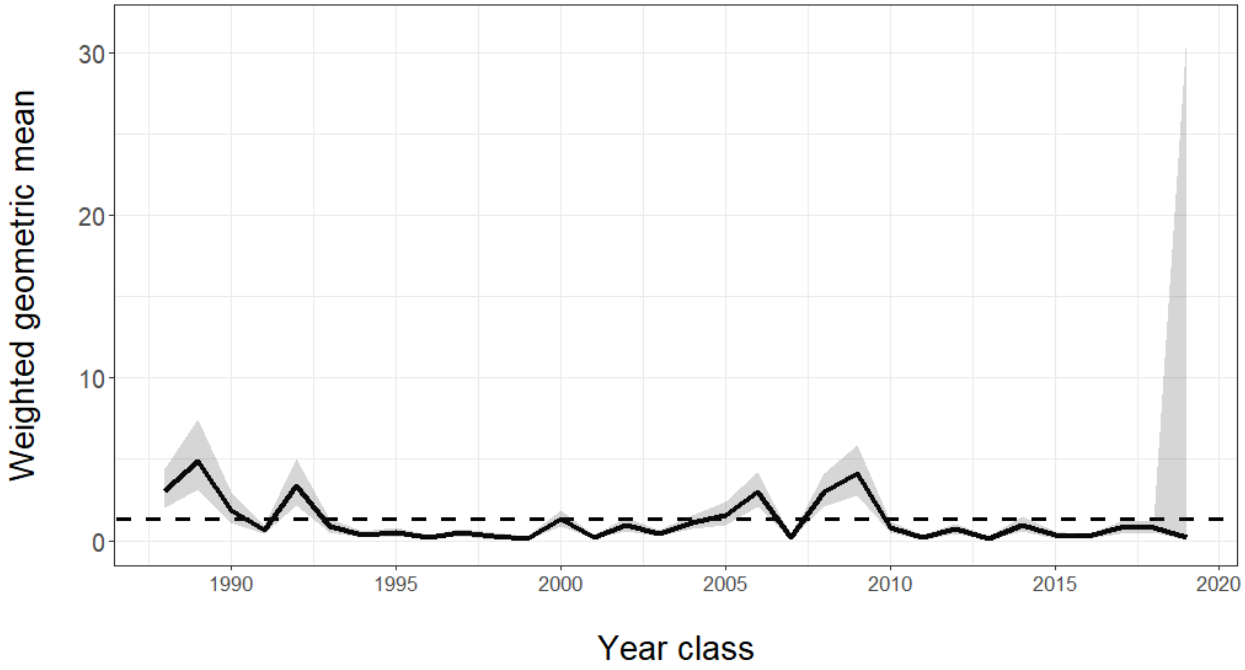


Figure 45. Juvenile Scup random stratified index (RSI_{GM}, 95% C.I.) and the time series average (dotted line) from 1988 to 2018.

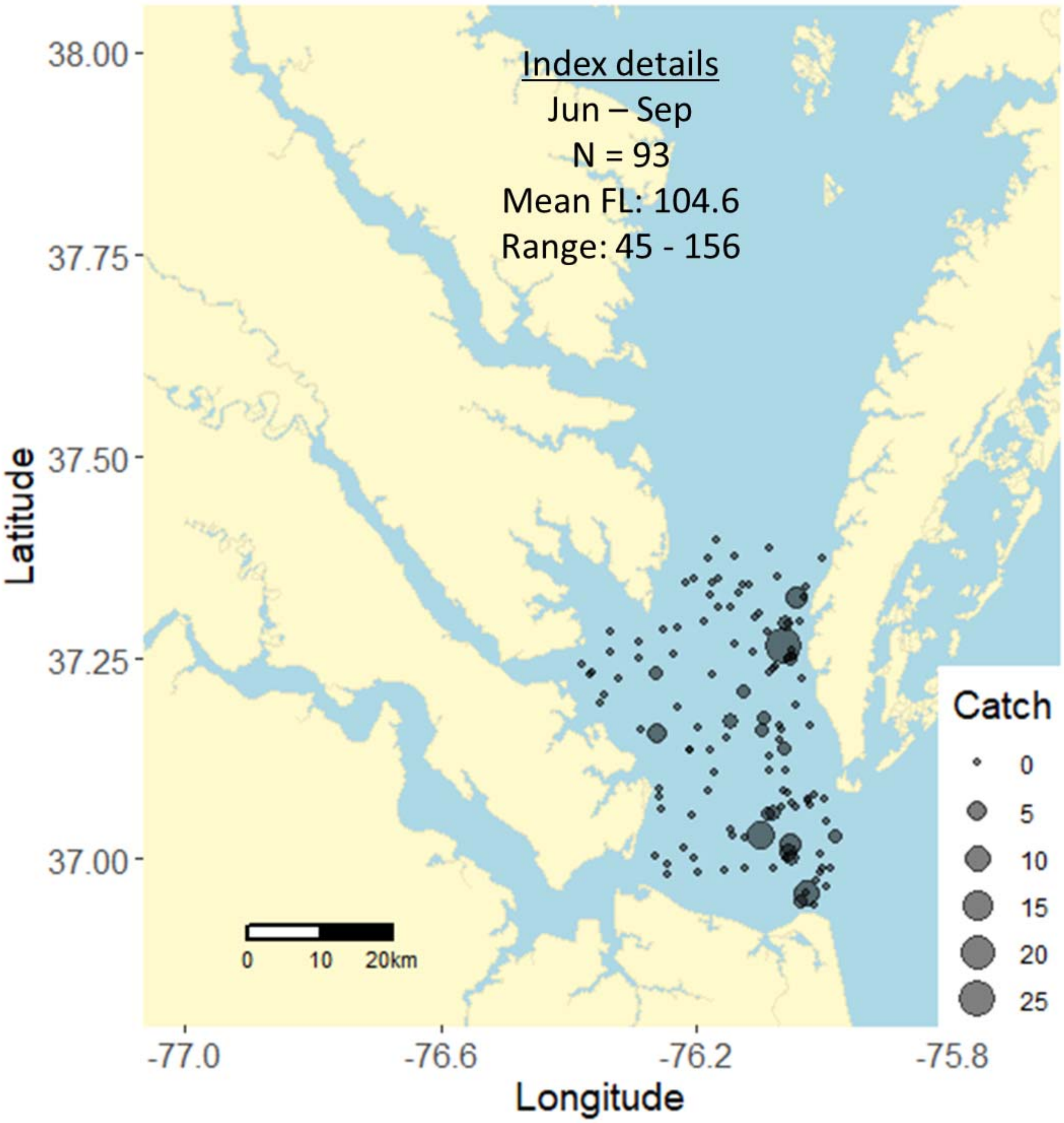


Figure 46. Distribution of juvenile Scup, the number captured, and mean length and range from index strata and months.

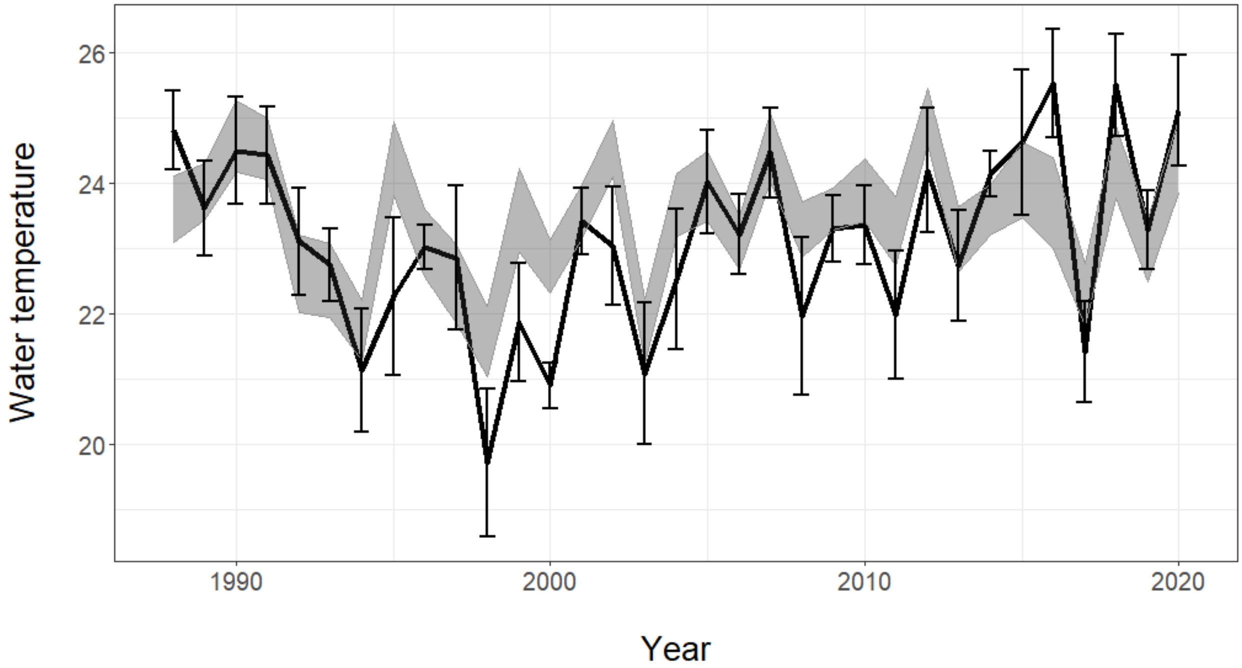


Figure 47. Scup - Mean bottom water temperature (°C; black line) and 95% C.I. at sites with positive catches of Scup during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

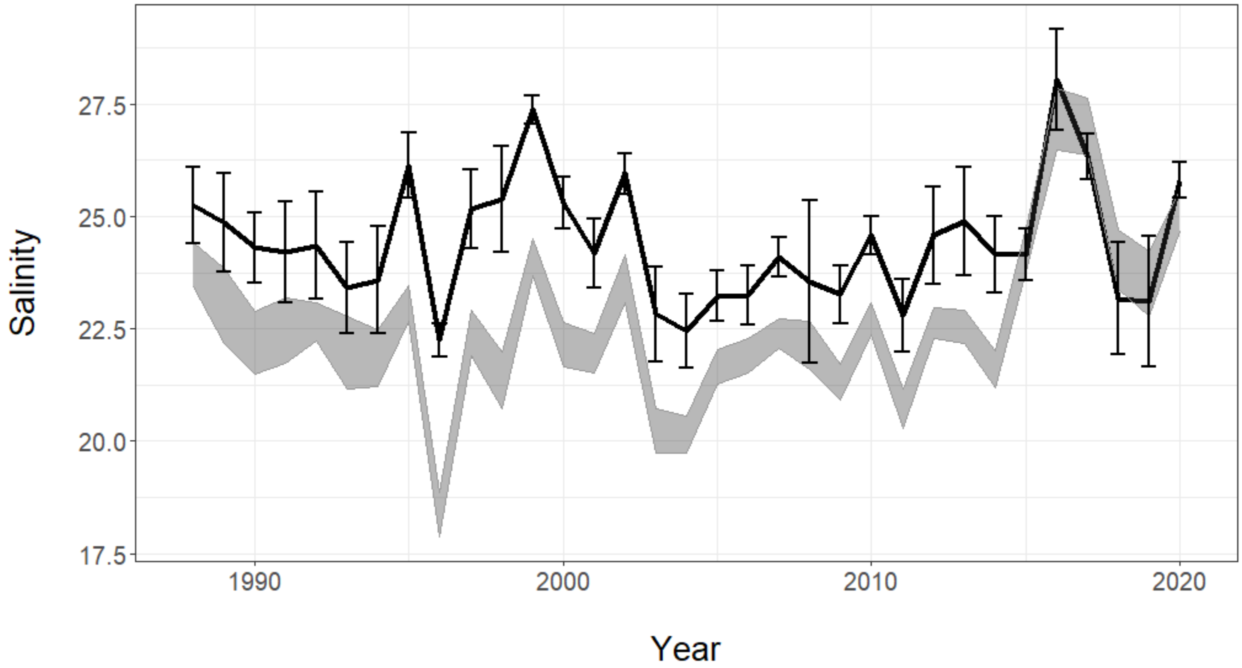


Figure 48. Scup - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of Scup during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

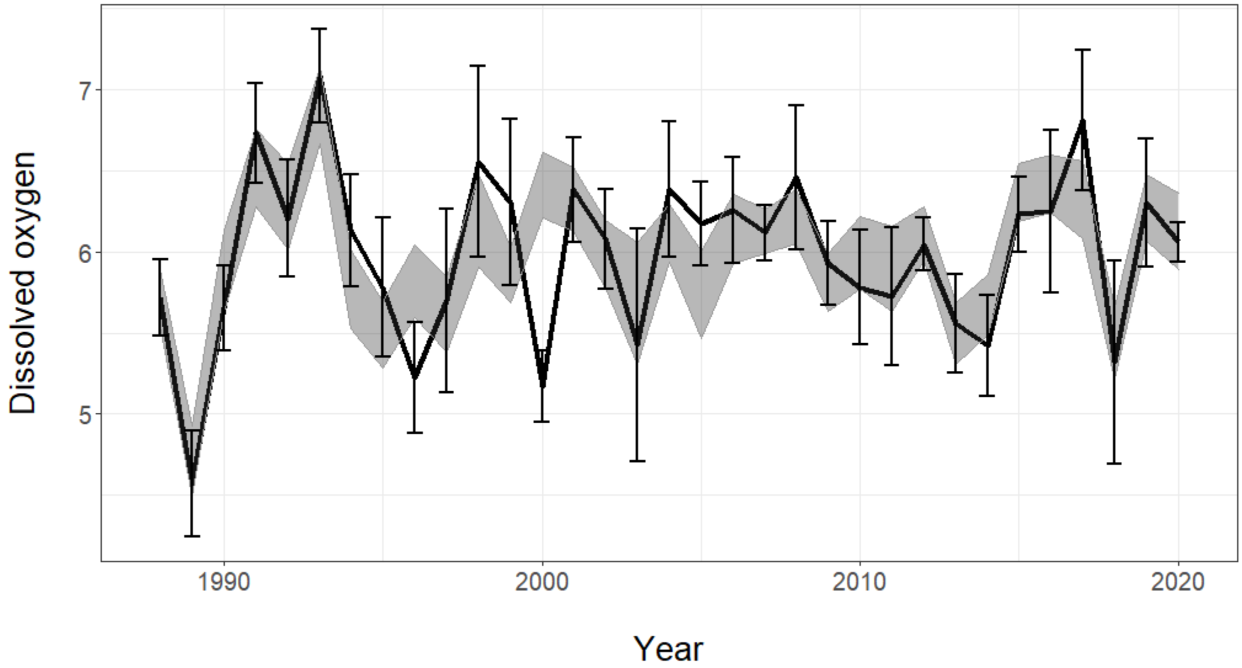


Figure 49. Scup - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of Scup during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

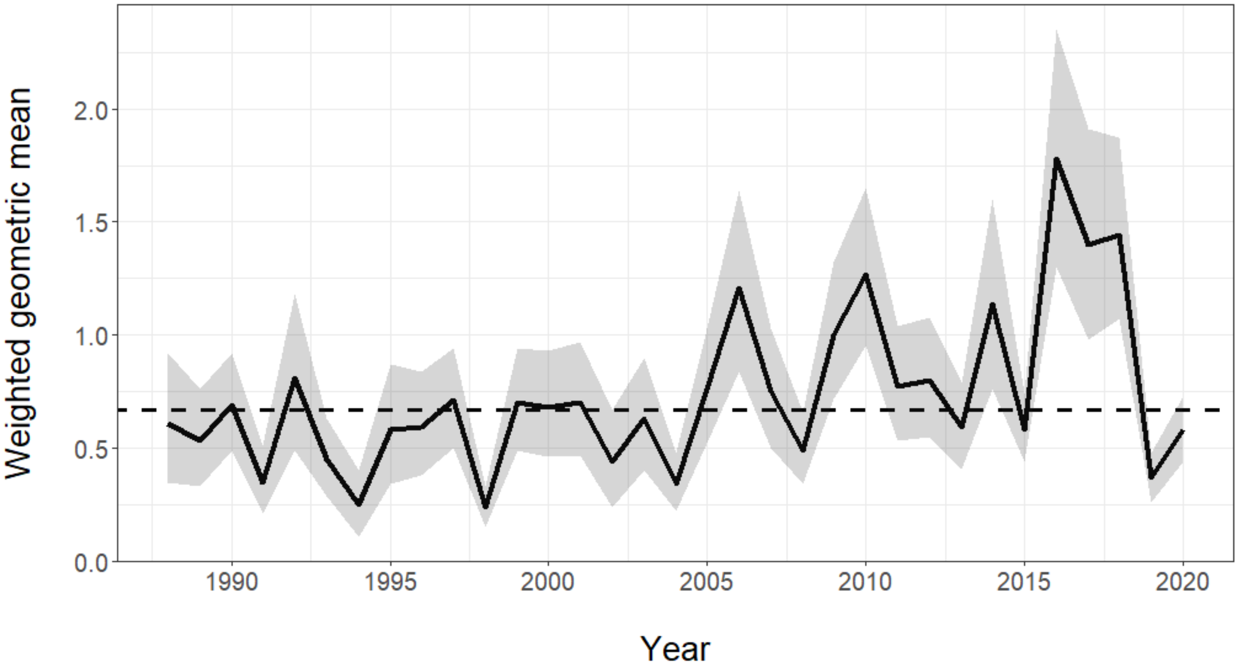


Figure 50. Juvenile Silver Perch random stratified index (RSI_{GM}, 95% C.I.) and the time series average (dotted line) from 1988 to 2019.

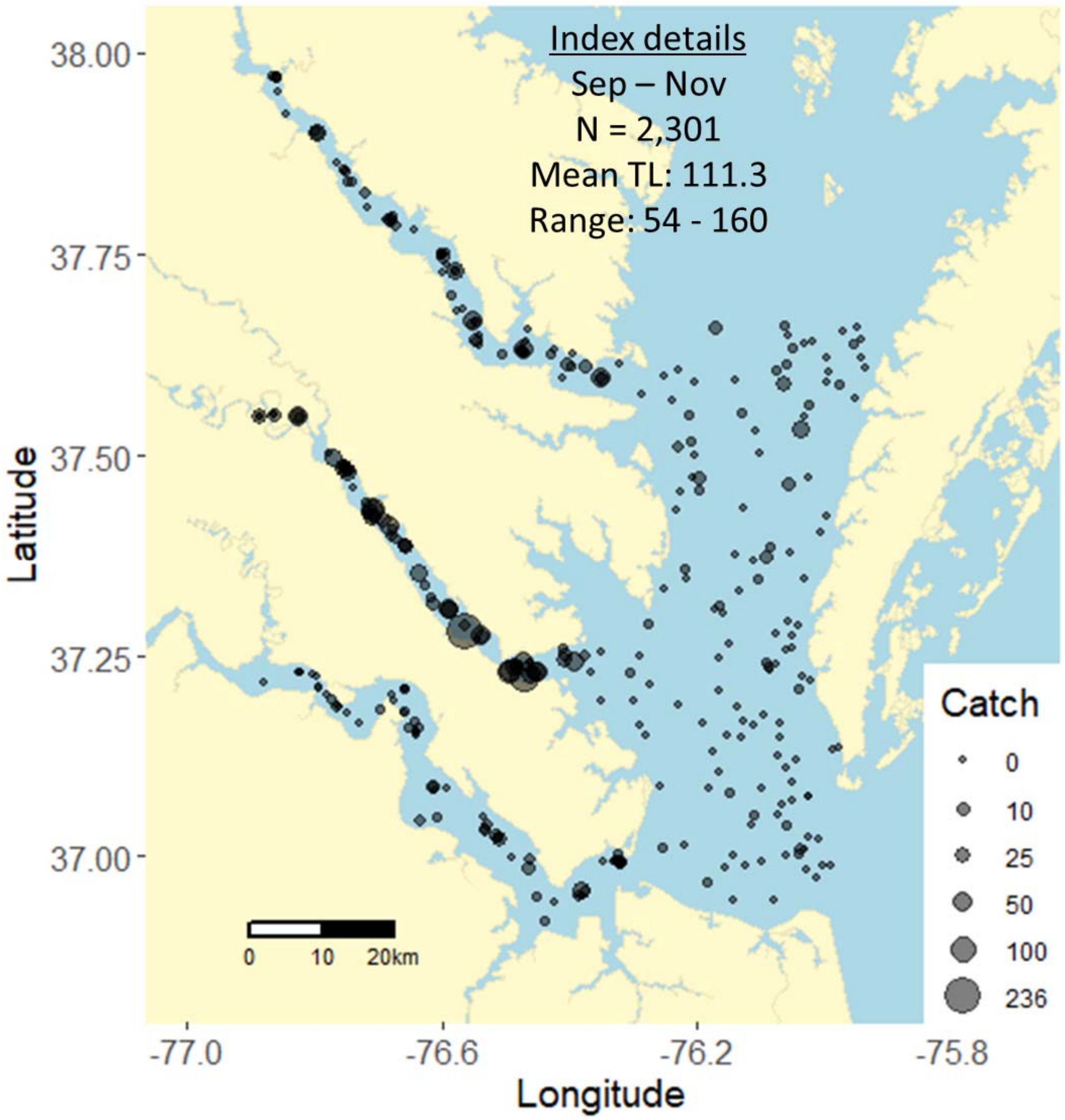


Figure 51. Distribution of juvenile Silver Perch, the number captured, mean length and range from index strata and months.

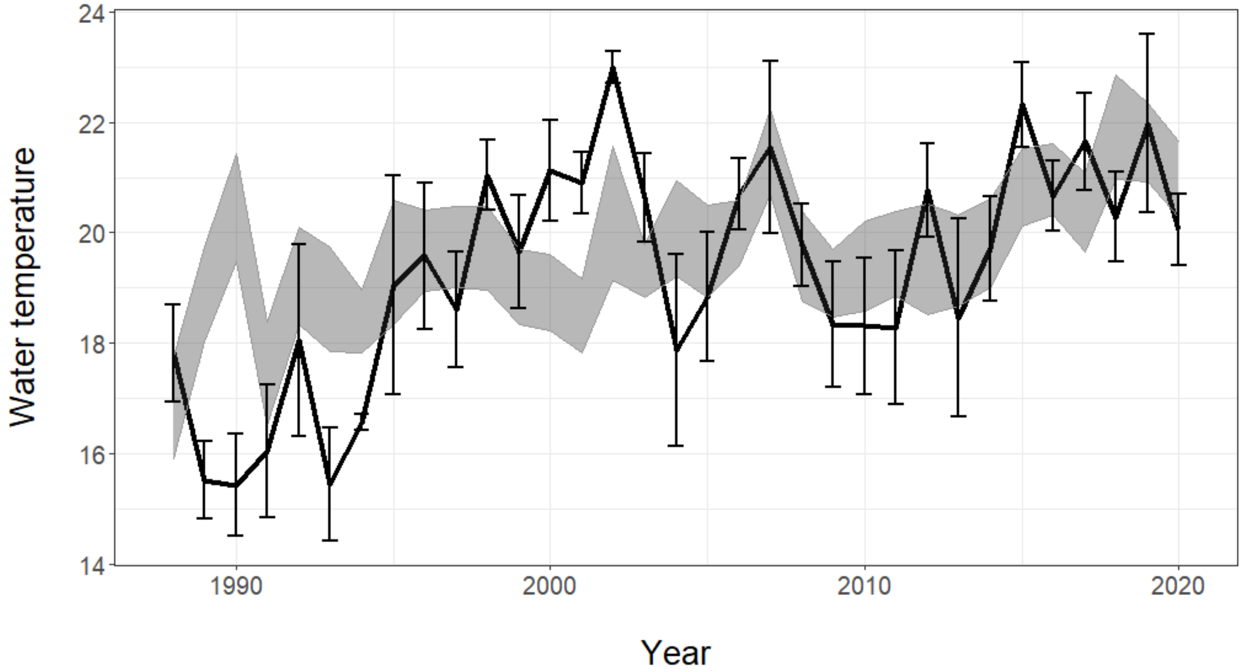


Figure 52. Juvenile Silver Perch - Mean bottom water temperature (°C; black line) and 95% C.I. at sites with positive catches of juvenile Silver Perch during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

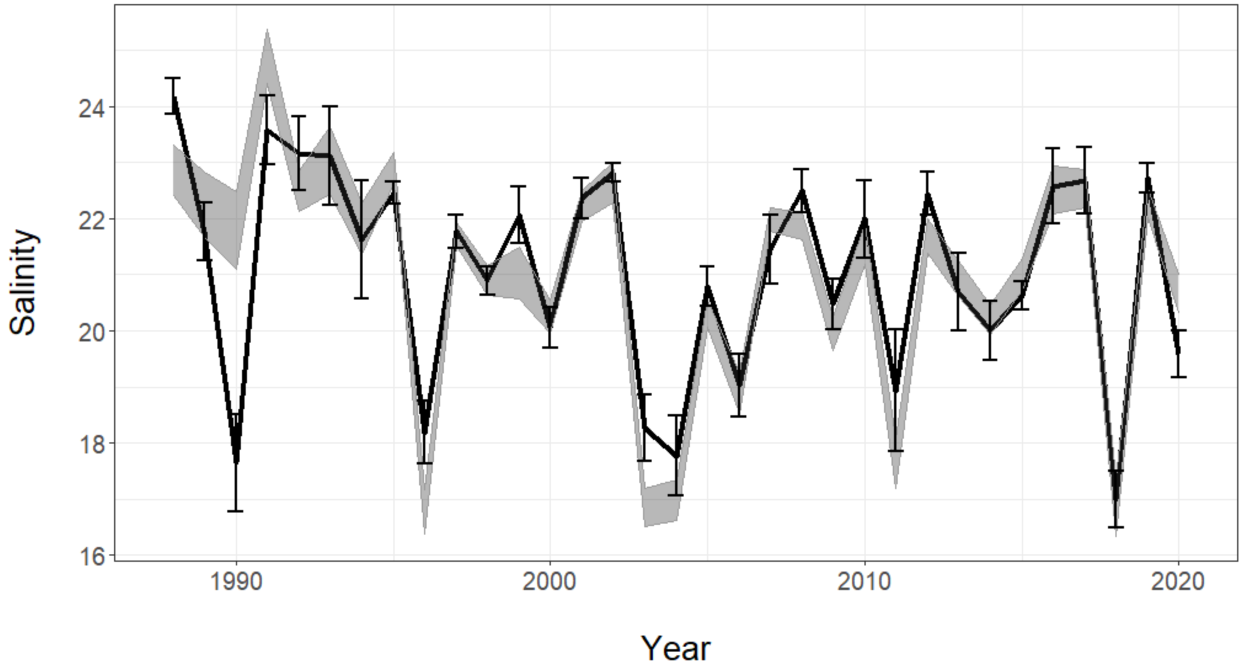


Figure 53. Juvenile Silver Perch - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of juvenile Silver Perch during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

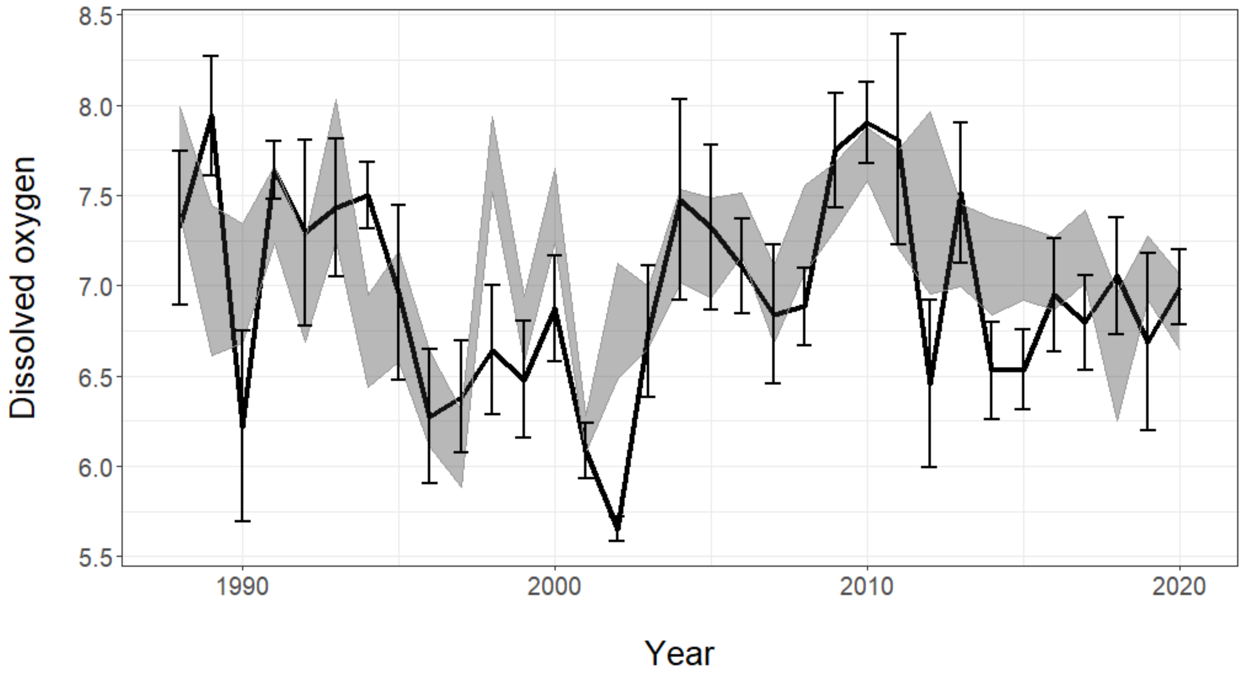


Figure 54. Juvenile Silver Perch - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of juvenile Silver Perch during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

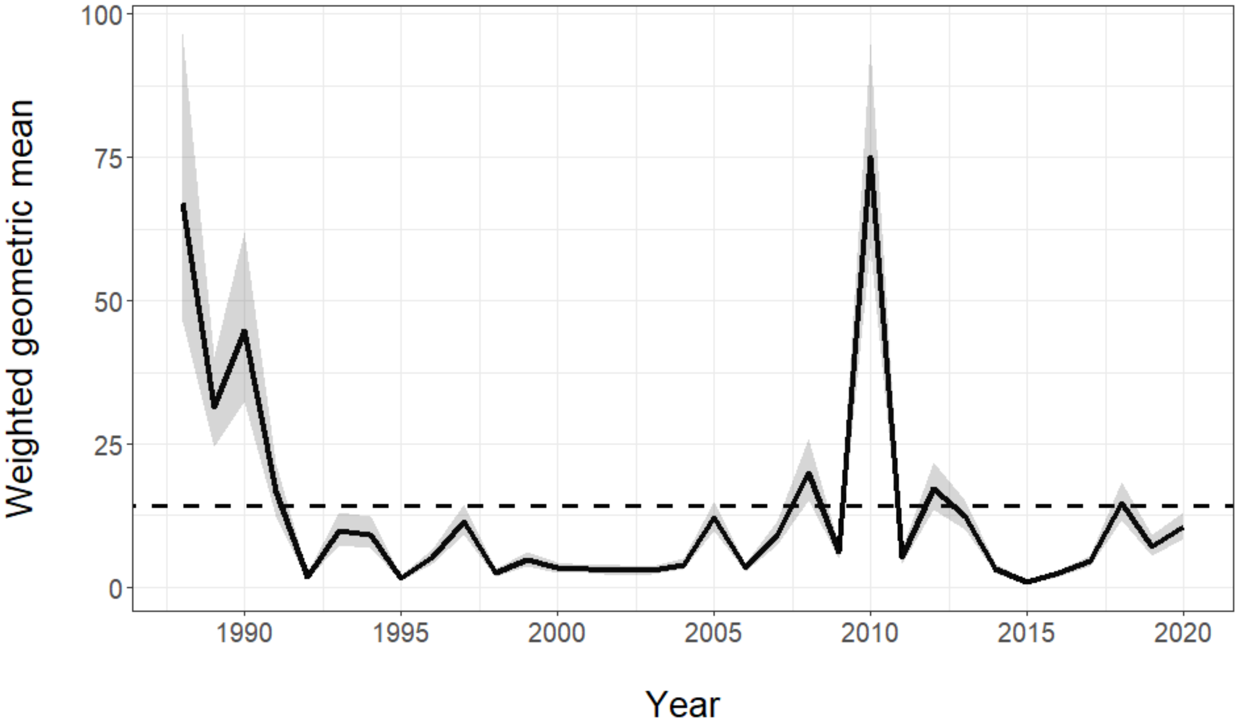


Figure 55. Juvenile Spot random stratified index (RSI_{GM}, 95% C.I.), the time series average (dotted line) from 1988 to 2019.

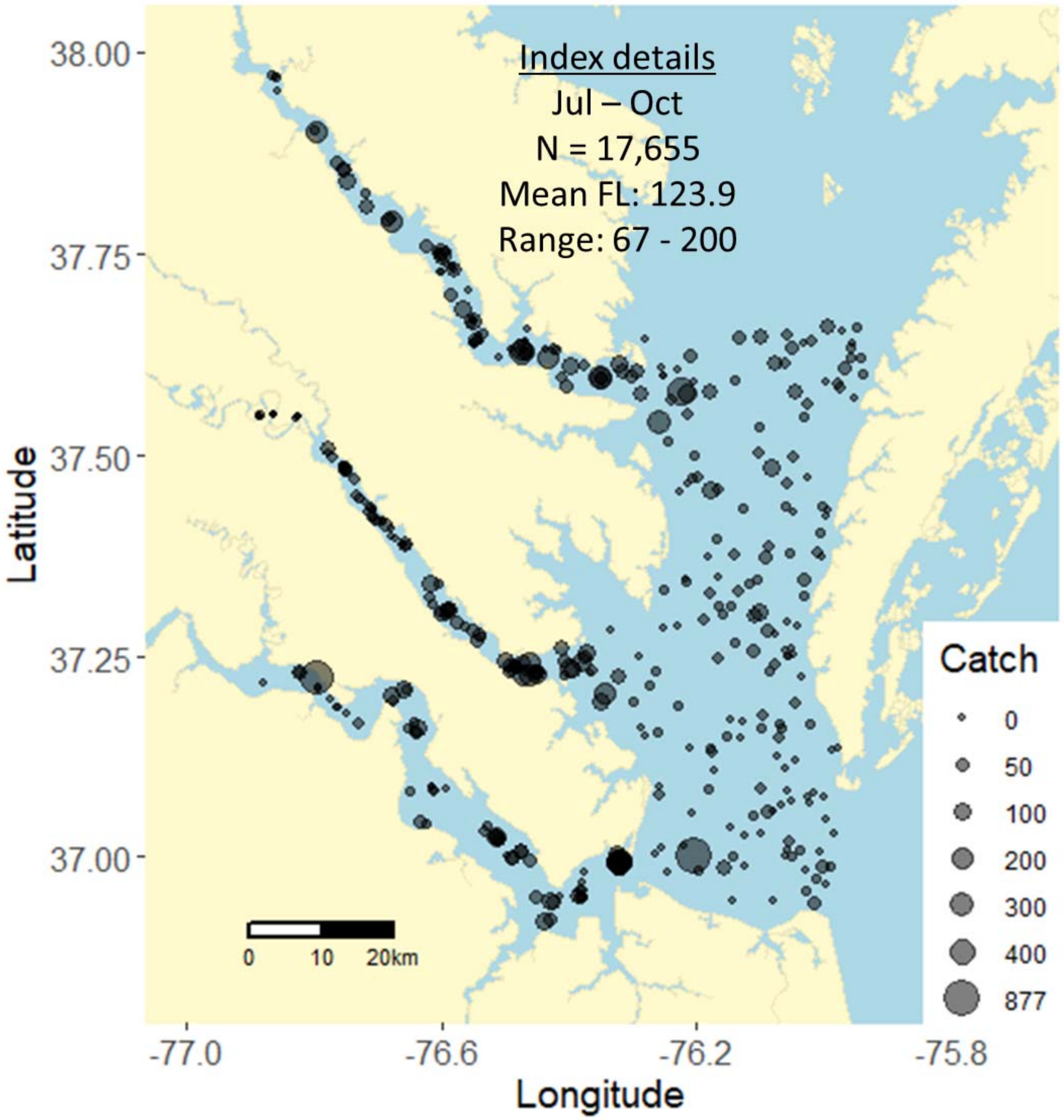


Figure 56. Distribution of juvenile Spot, the number captured, mean length and range from index strata and months.

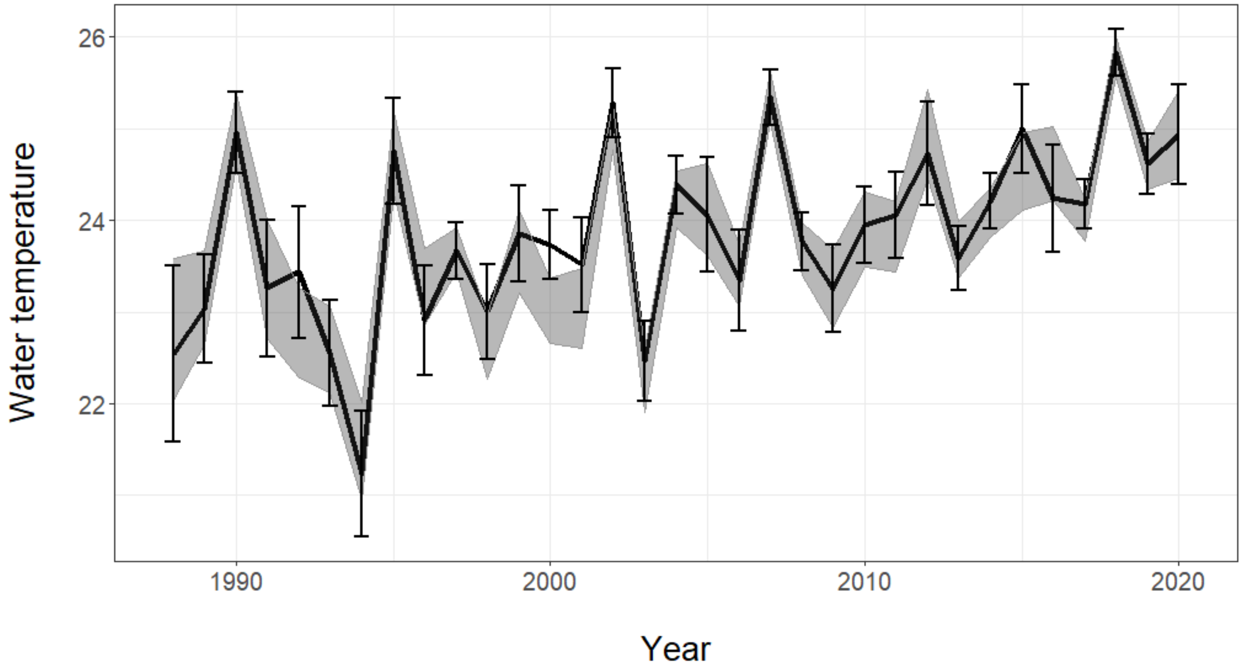


Figure 57. Juvenile Spot - Mean bottom water temperature (°C; black line) and 95% C.I. at sites with positive catches of juvenile Spot during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

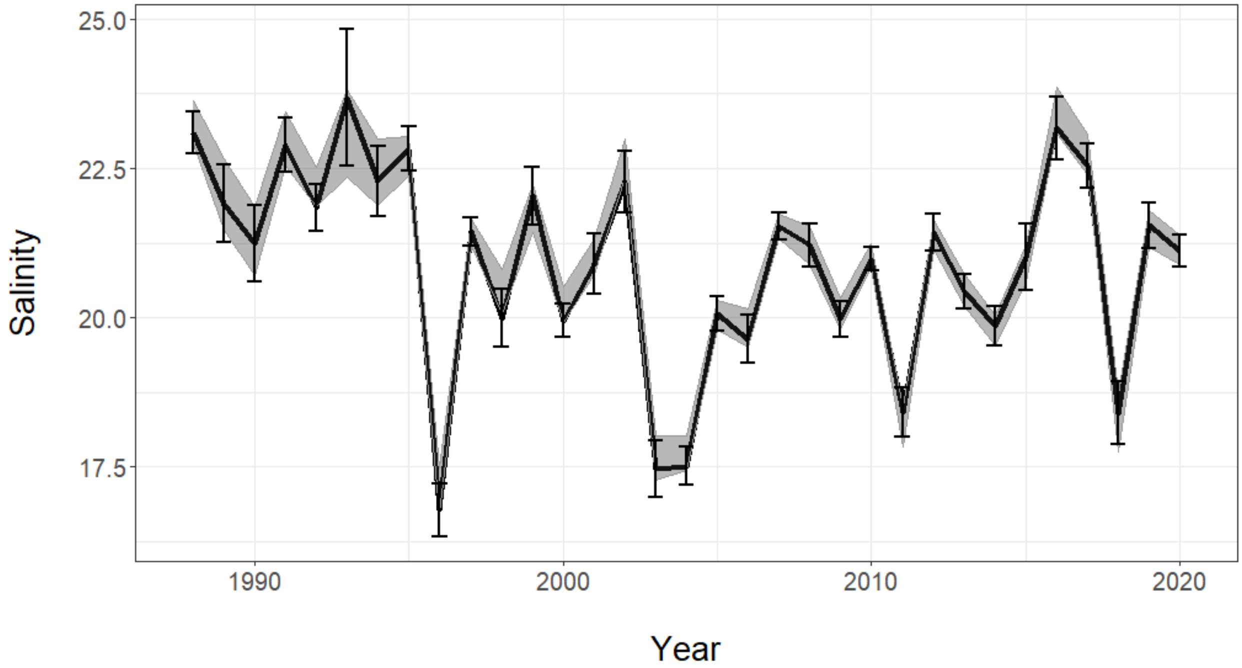


Figure 58. Juvenile Spot - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of juvenile Spot during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

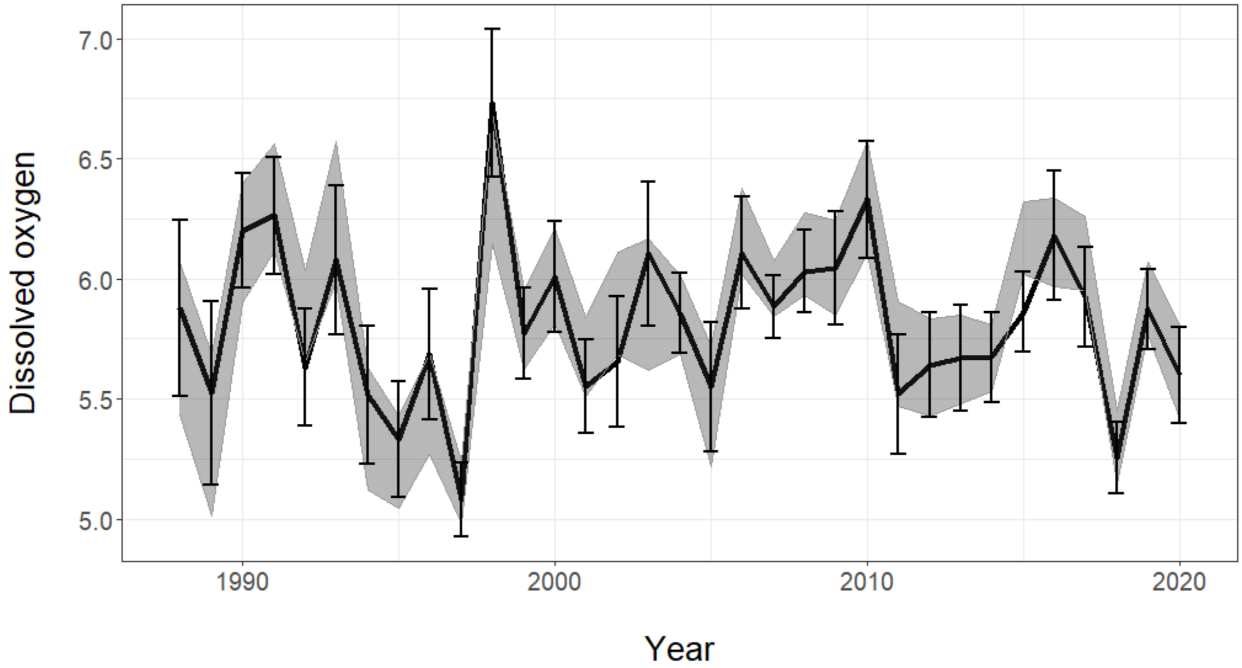


Figure 59. Juvenile Spot - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of juvenile Spot during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

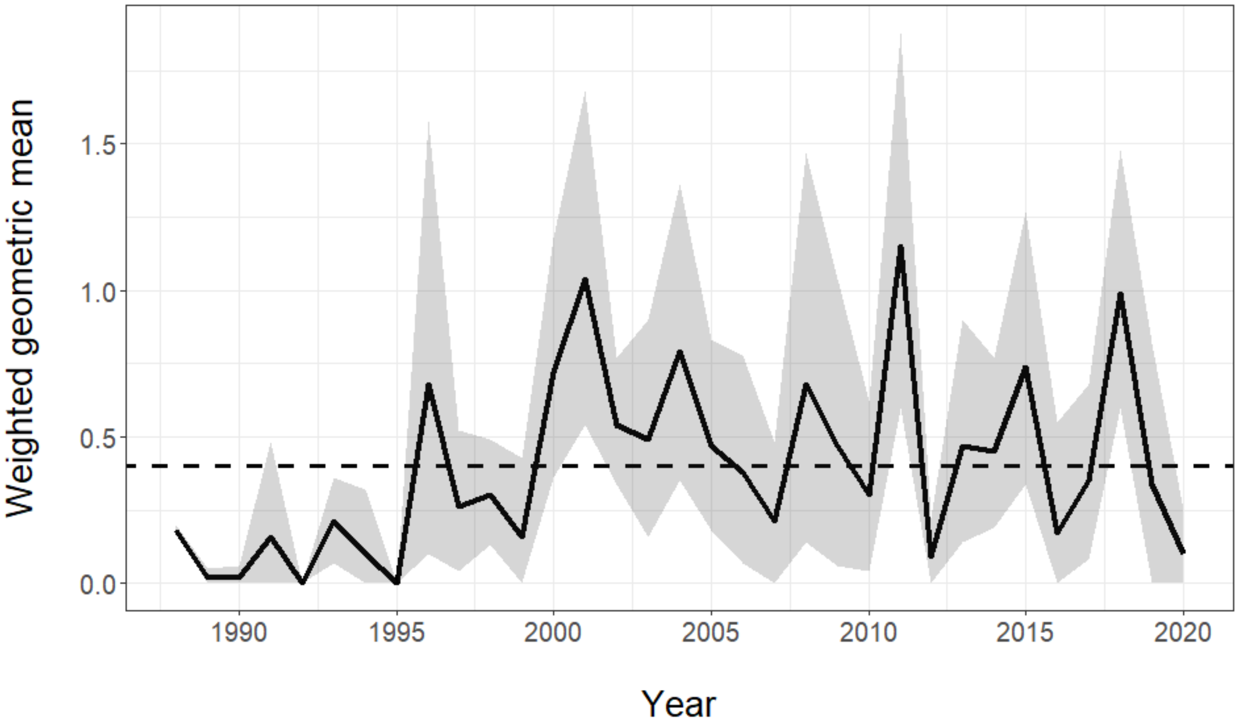


Figure 60. Juvenile Striped Bass random stratified index (RSI_{GM}, 95% C.I.), the time series average (dotted line) from 1988 to 2019.

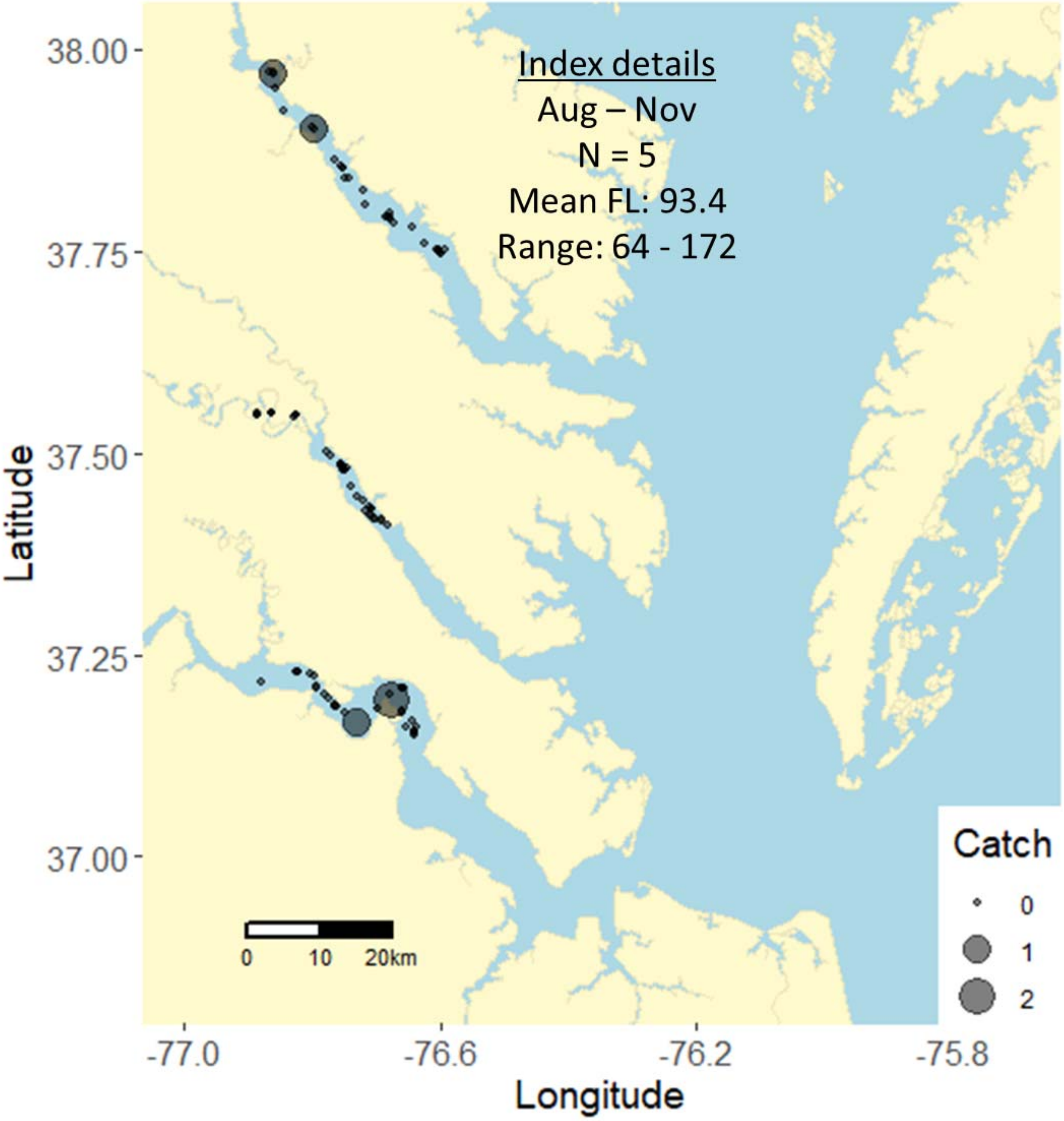


Figure 61. Distribution of juvenile Striped Bass, the number captured, mean length and range from index strata and months.

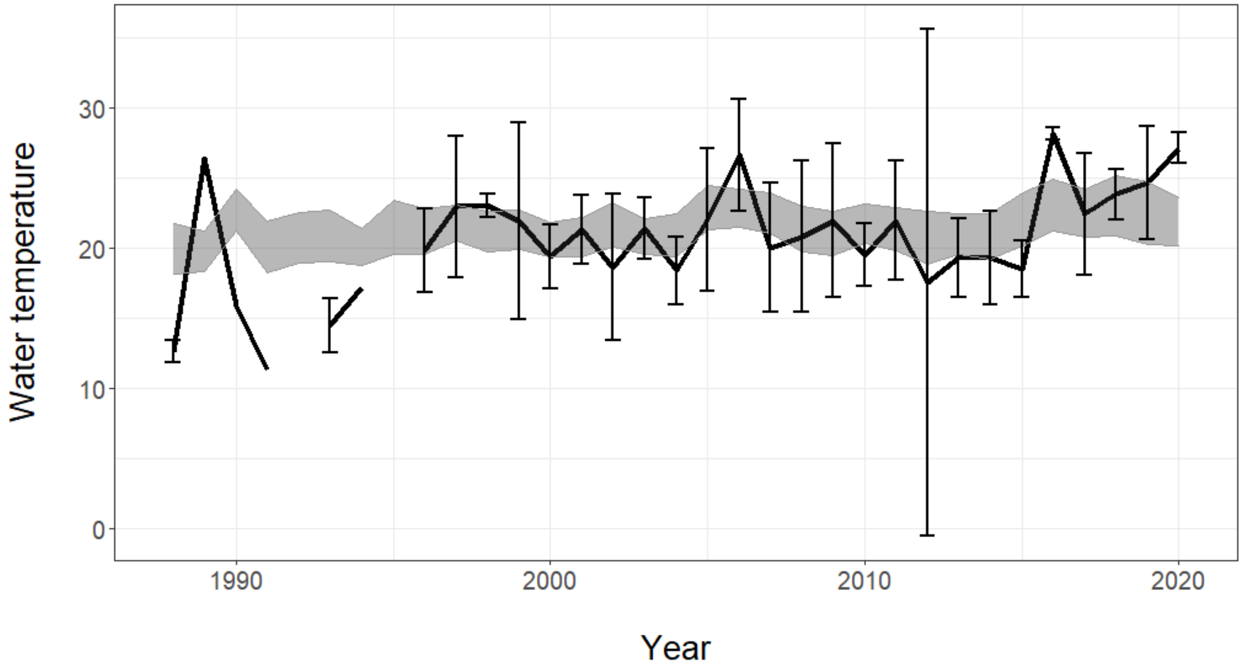


Figure 62. Juvenile Striped Bass - Mean bottom water temperature (°C; black line) and 95% C.I. at sites with positive catches of juvenile Striped Bass during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

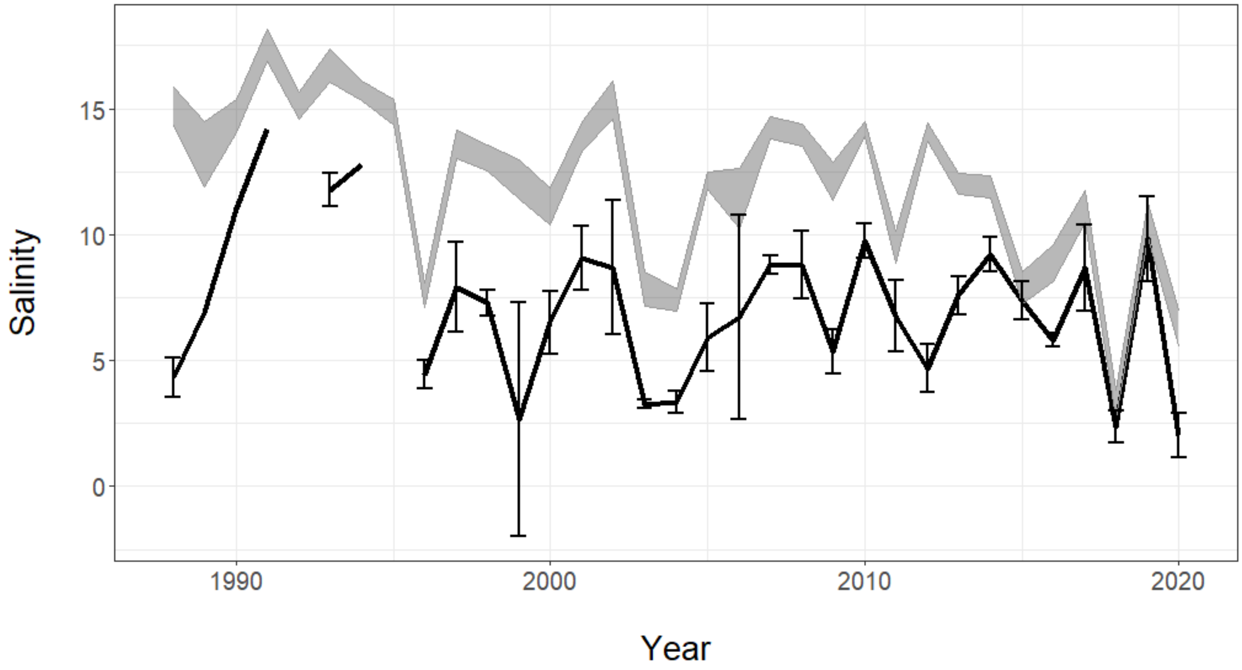


Figure 63. Juvenile Striped Bass - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of juvenile Striped Bass during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

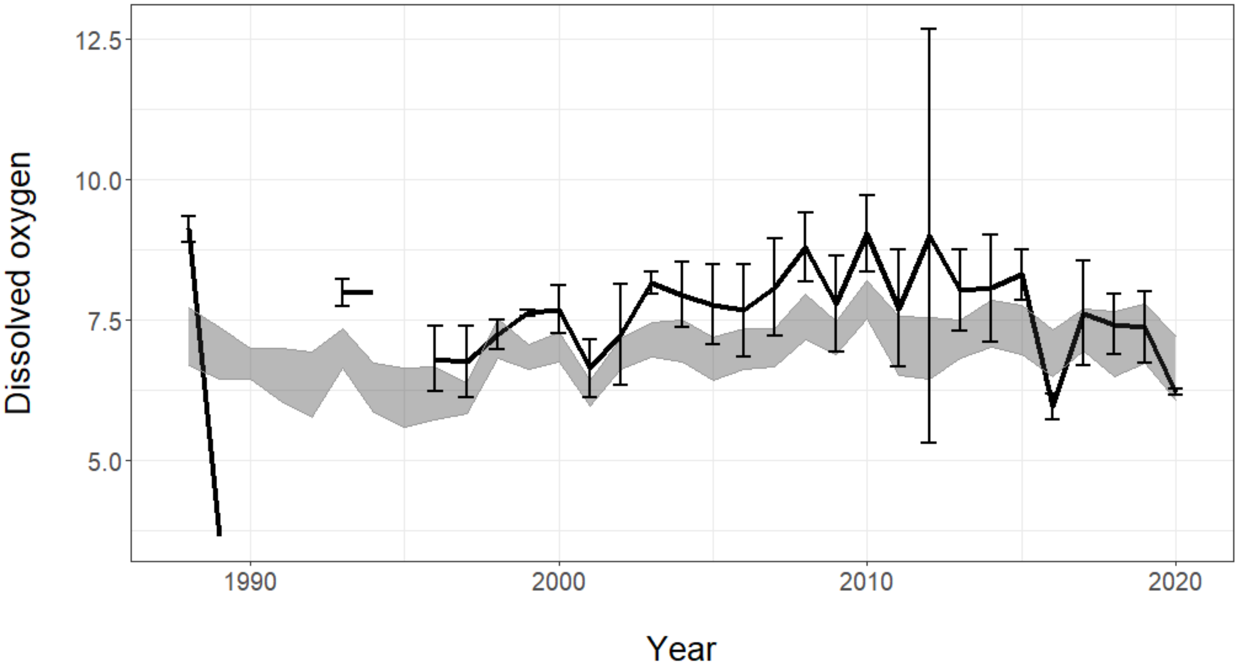


Figure 64. Juvenile Striped Bass - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of juvenile Striped Bass during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

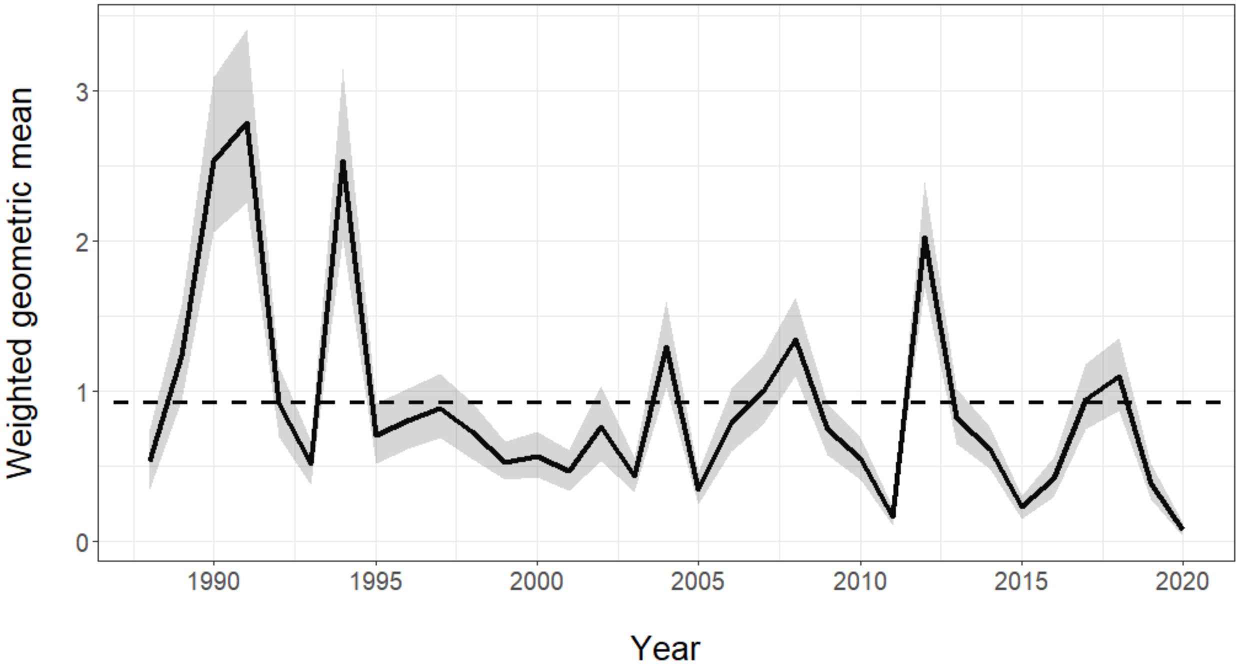


Figure 65. Juvenile Summer Flounder random stratified index (RSI$_{GM}$, 95% C.I.) and the time series average (dotted line) from 1988 to 2019.

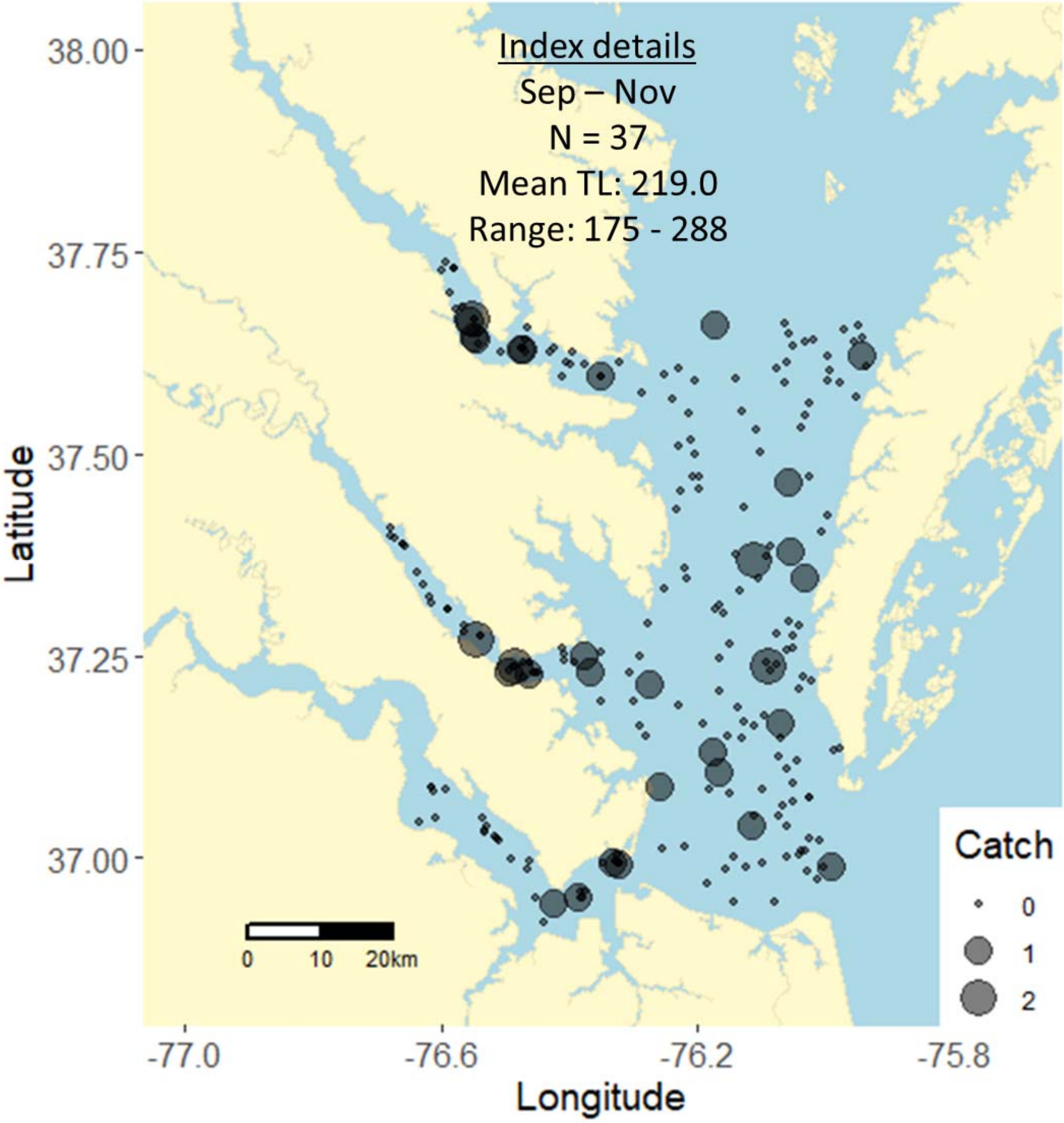


Figure 66. Distribution of juvenile Summer Flounder, the number captured, mean length and range from index strata and months.

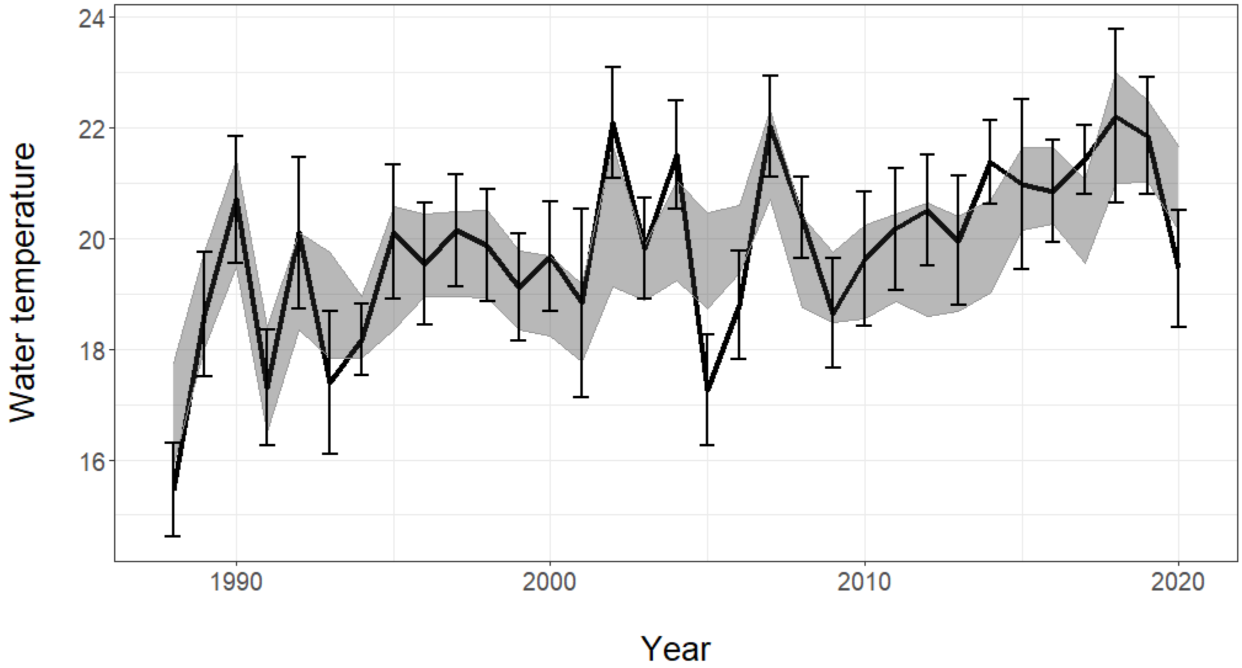


Figure 67. Juvenile Summer Flounder - Mean bottom water temperature (^{o}C; black line) and 95% C.I. at sites with positive catches of juvenile Summer Flounder during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

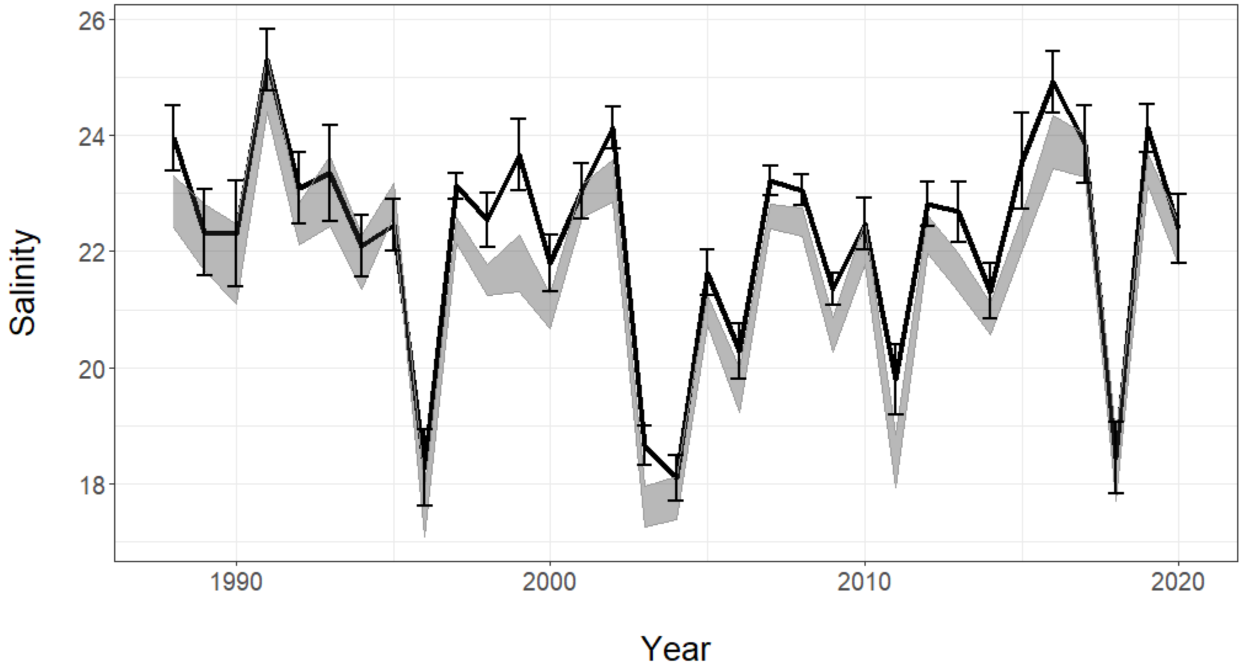


Figure 68. Juvenile Summer Flounder - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of juvenile Summer Flounder during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

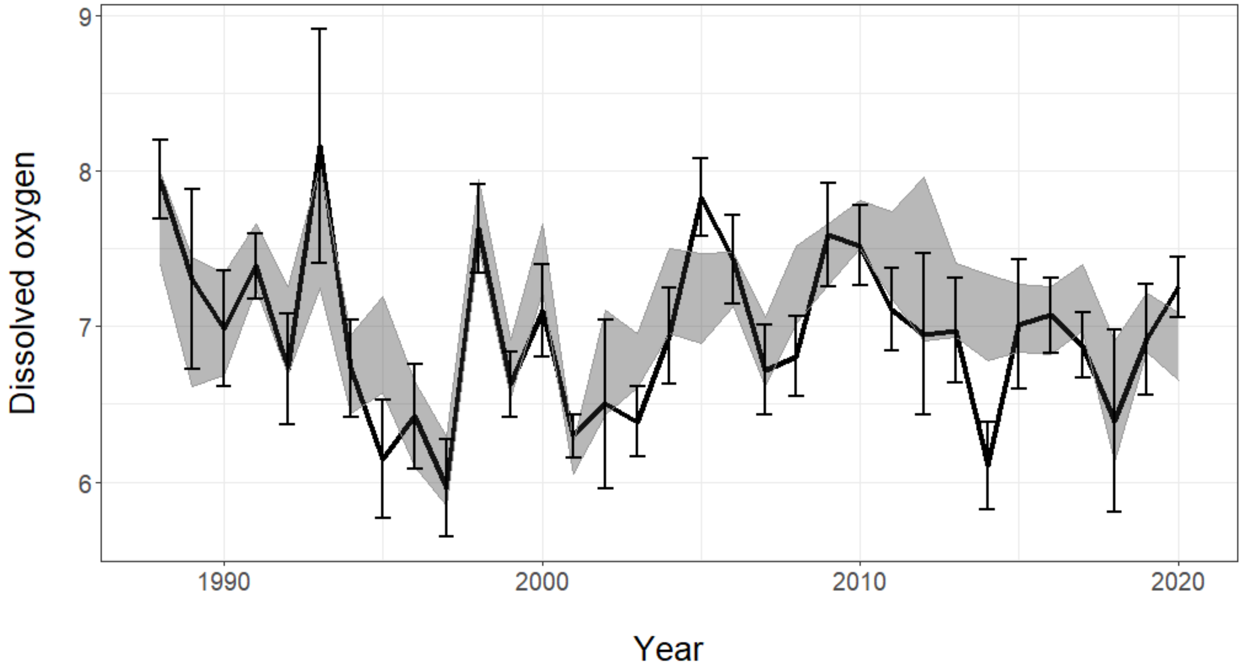


Figure 69. Juvenile Summer Flounder - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of juvenile Summer Flounder during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

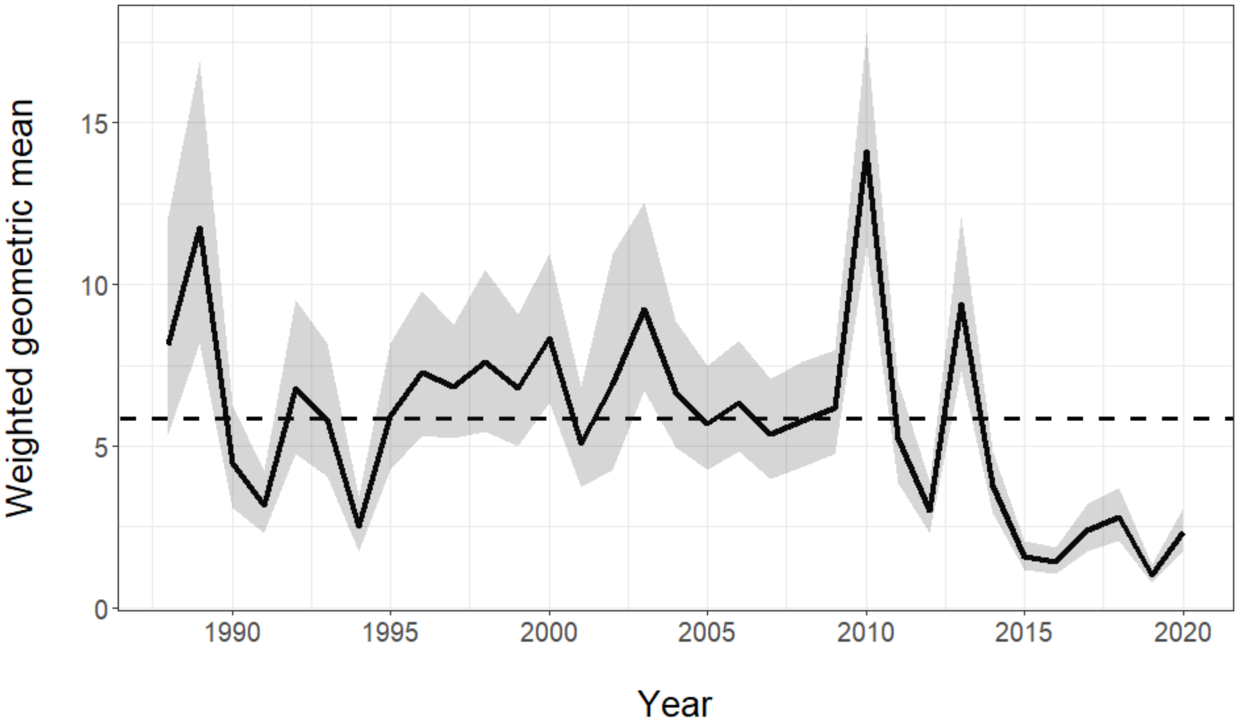


Figure 70. Juvenile Weakfish random stratified index (RSI_{GM}, 95% C.I.) and the time series average (dotted line) from 1988 to 2019.

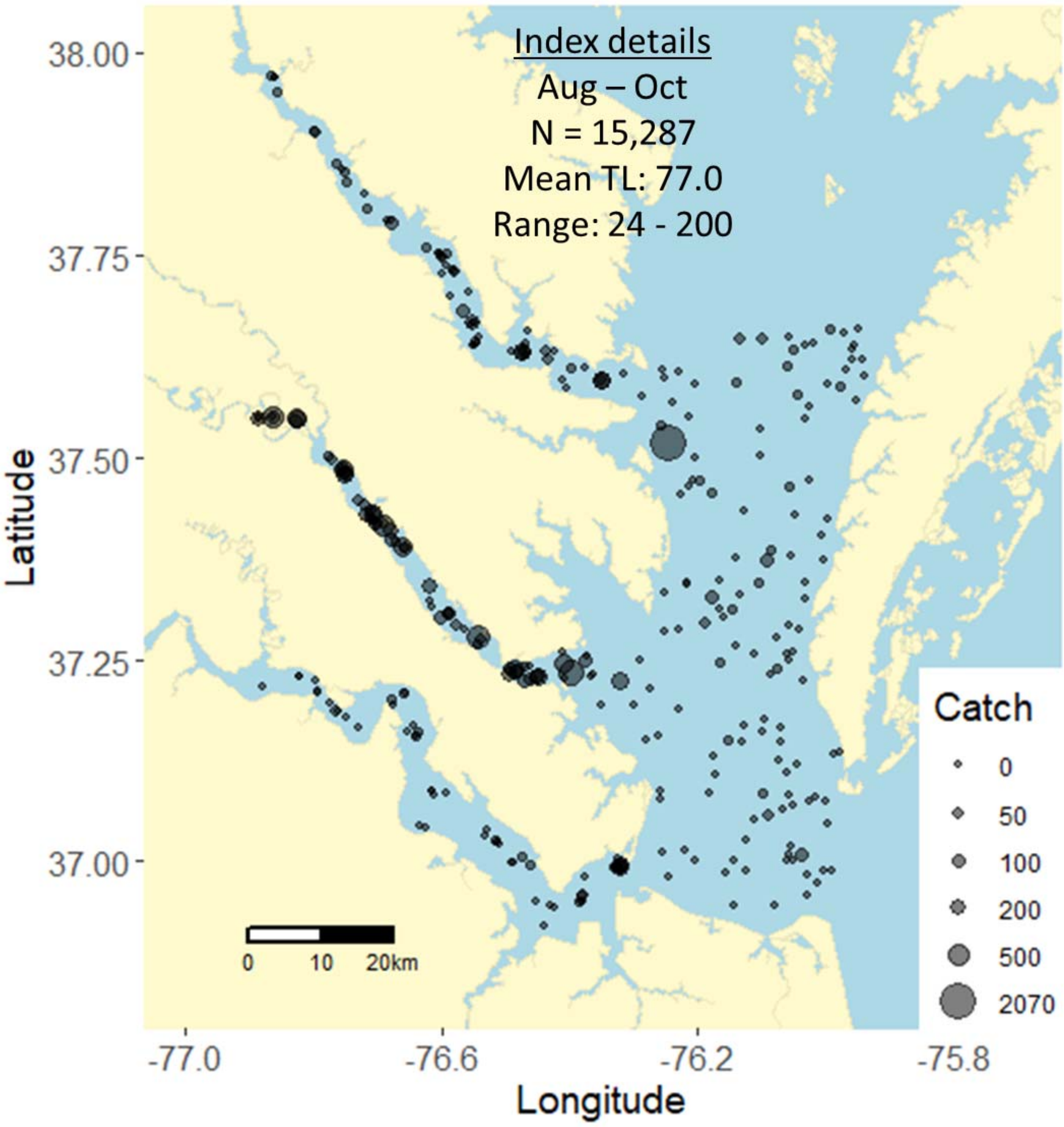


Figure 71. Distribution of juvenile Weakfish, the number captured, and mean length and range from index strata and months.

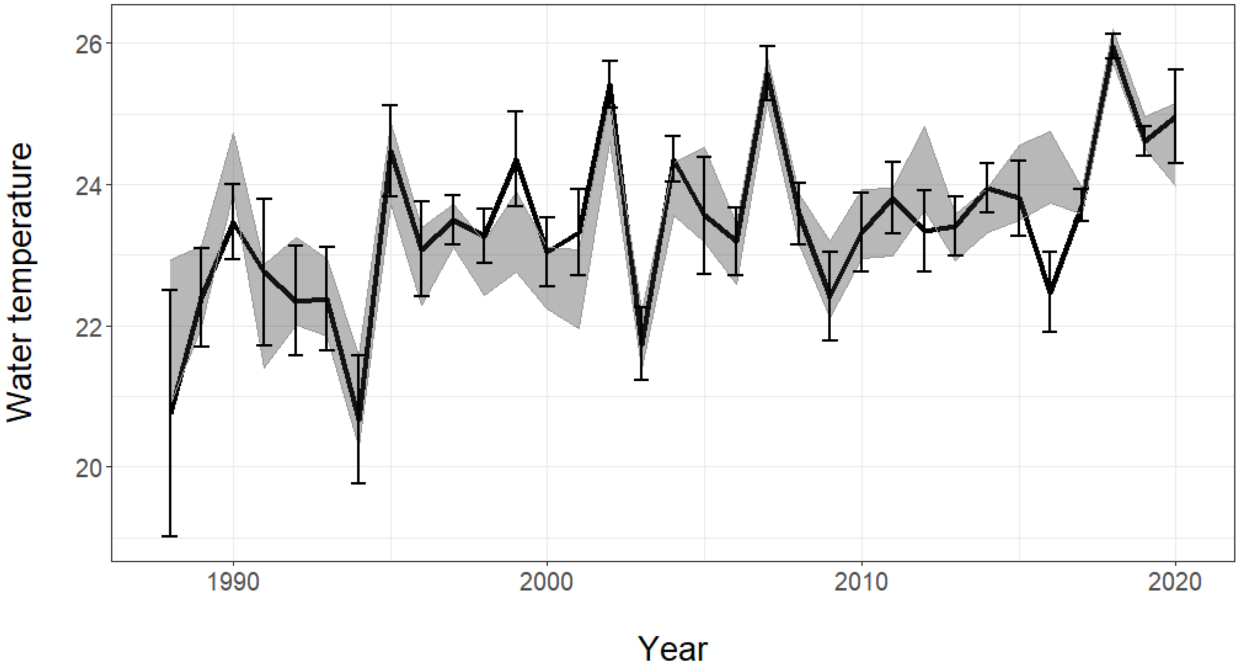


Figure 72. Juvenile Weakfish - Mean bottom water temperature (°C; black line) and 95% C.I. at sites with positive catches of juvenile Weakfish during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean water temperature measured at all sites sampled from the same index months and strata.

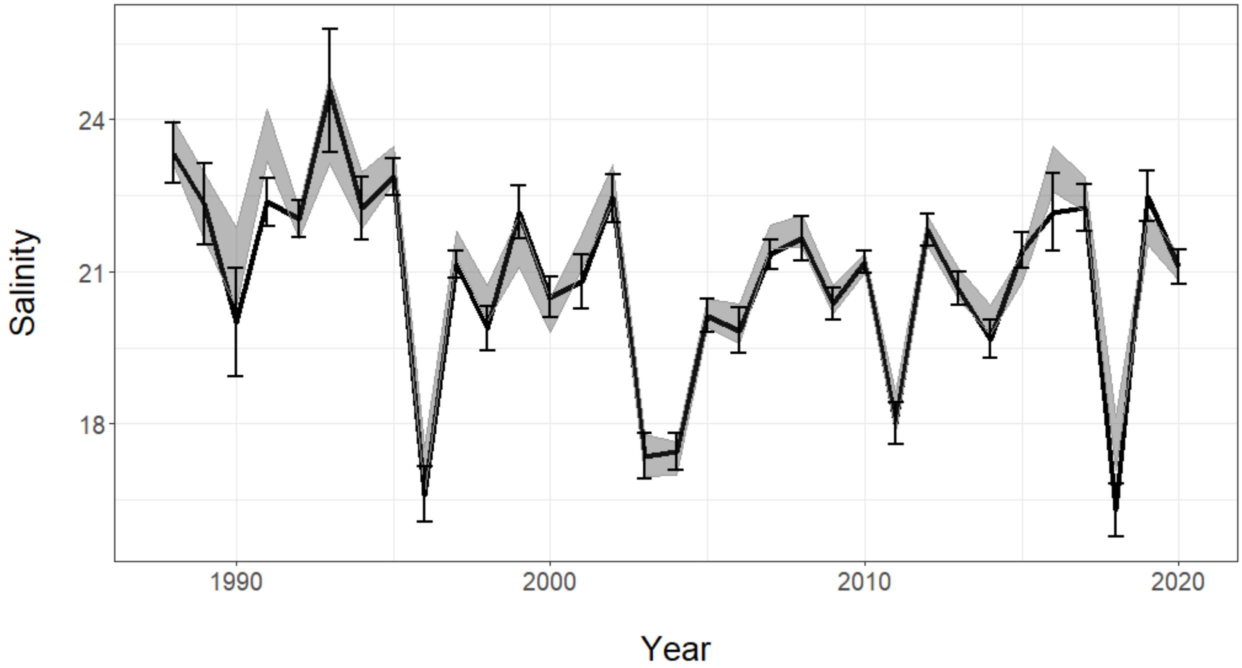


Figure 73. Juvenile Weakfish - Mean bottom salinity (psu; black line) and 95% C.I. at sites with positive catches of juvenile Weakfish during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean salinity measured at all sites sampled from the same index months and strata.

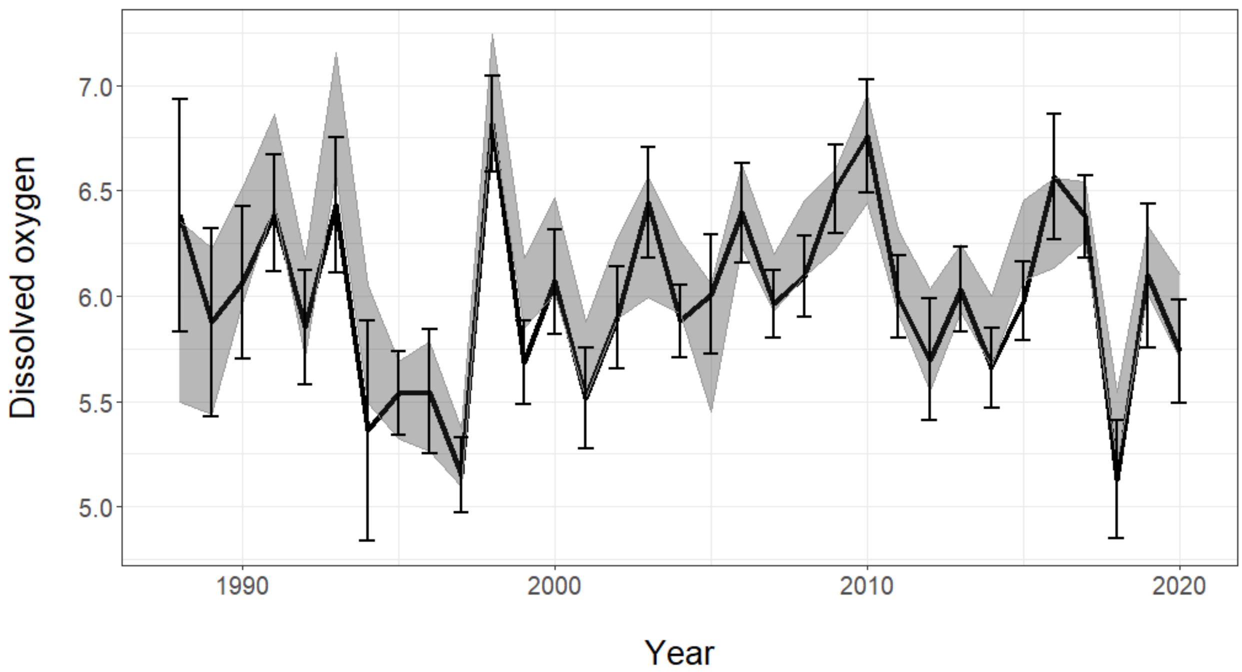


Figure 74. Juvenile Weakfish - Mean bottom dissolved oxygen (mg/L; black line) and 95% C.I. at sites with positive catches of juvenile Weakfish during index months and strata from 1988 to 2020. Shaded region represents the 95% C.I. for mean dissolved oxygen measured at all sites sampled from the same index months and strata.

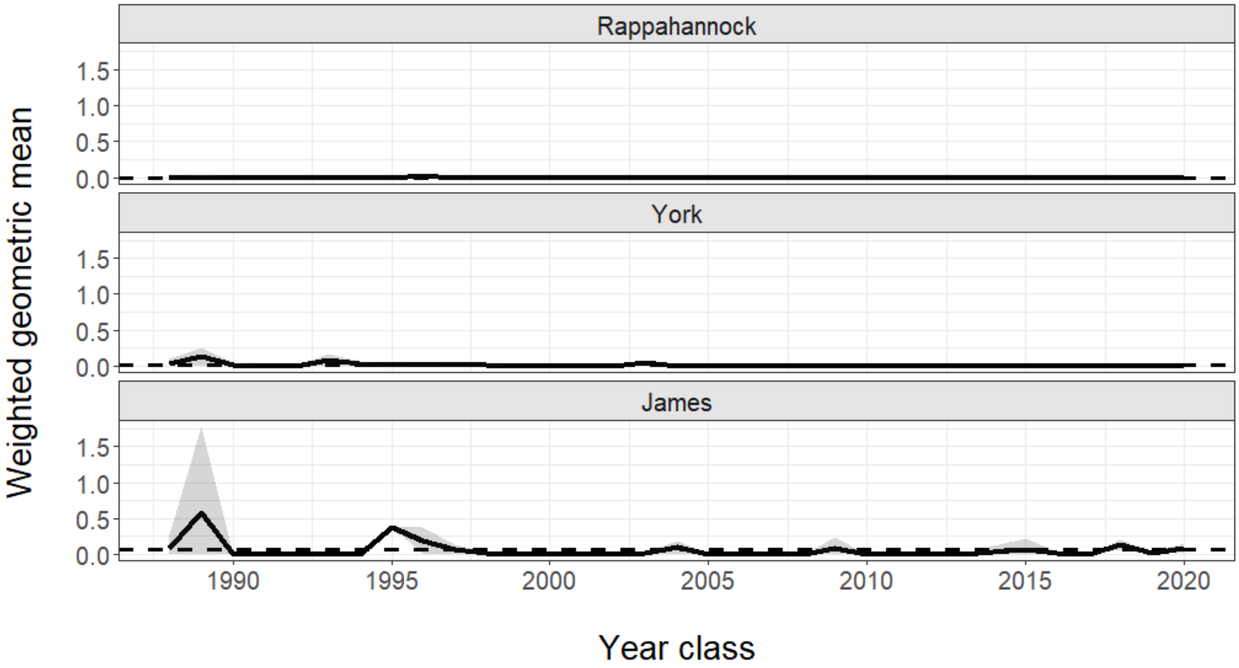


Figure 75. Juvenile White Catfish random stratified indices (RSI_{GM}, 95% C.I.) and times series averages (dotted line) based on RSI_{GM}'s from the Rappahannock, York, and James rivers.

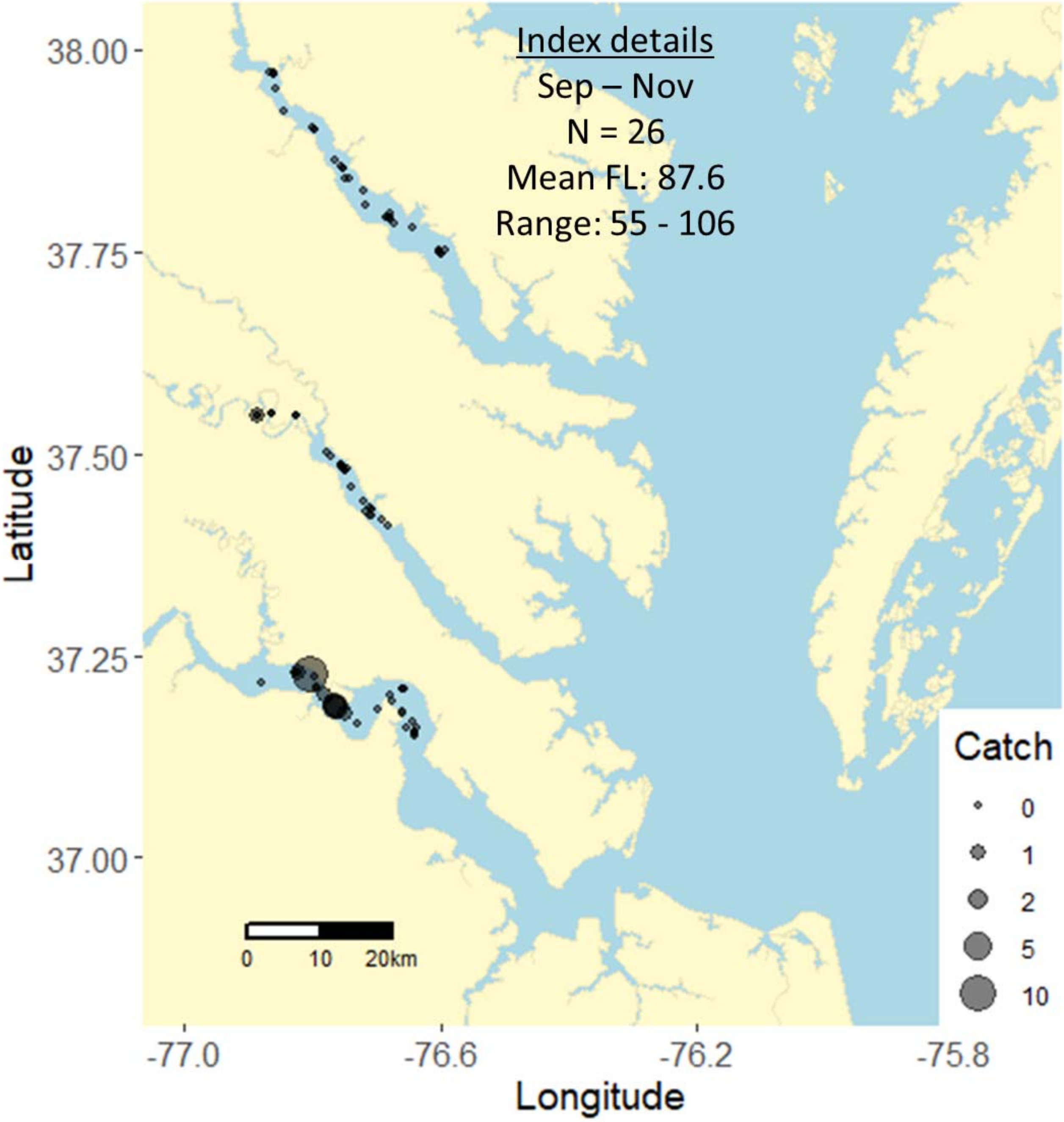


Figure 76. Distribution of juvenile White Catfish, the number captured, mean length and range from index strata and months.

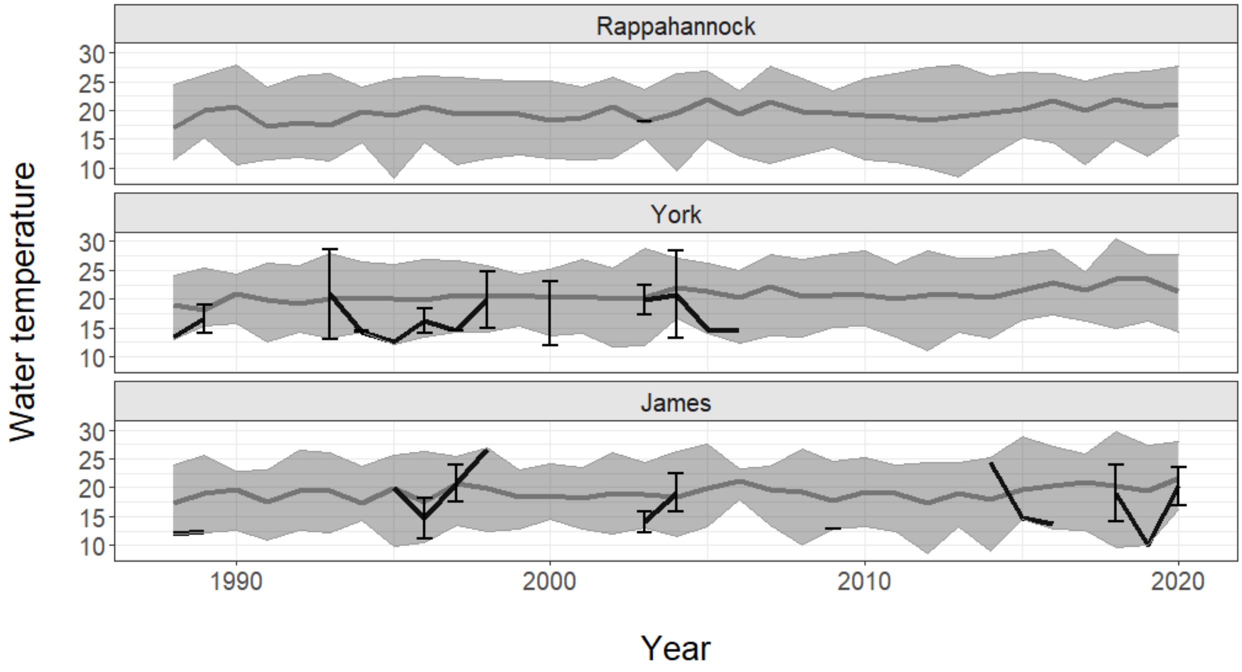


Figure 77. Juvenile White Catfish - Mean bottom water temperature and 95% C.I. (^{o}C; black line) at sites with positive catches of juvenile White Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed water temperatures represent years with low numbers of positive catches of juvenile White Catfish.

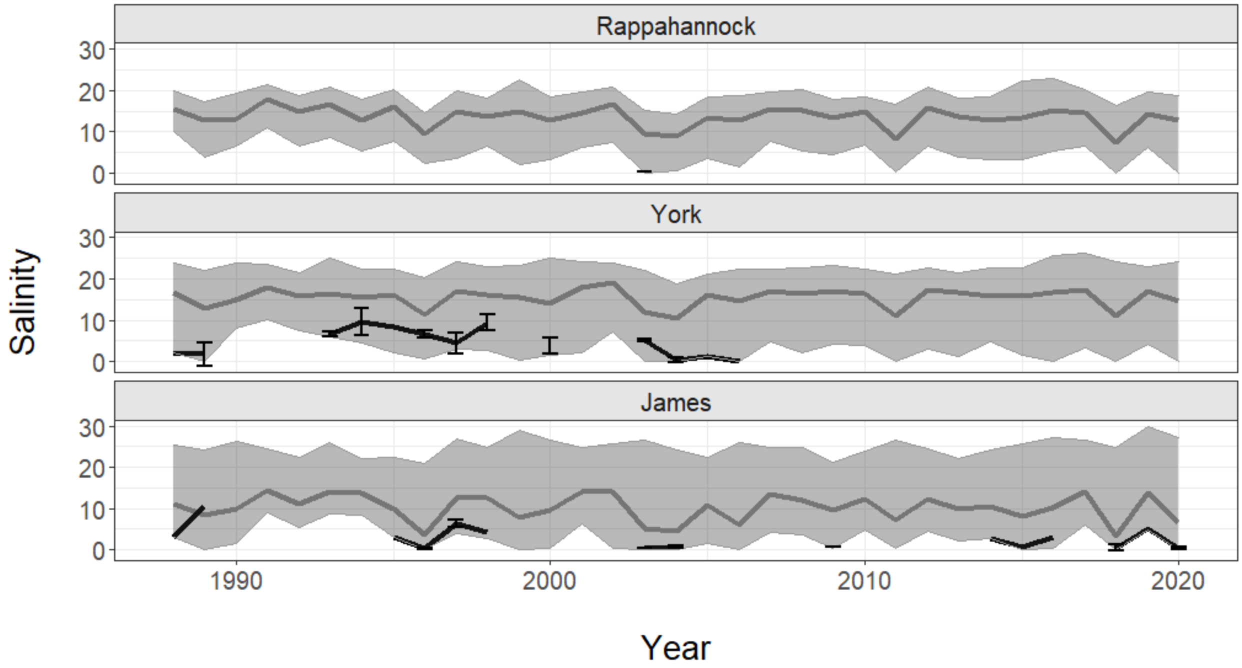


Figure 78. Juvenile White Catfish - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of juvenile White Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata.

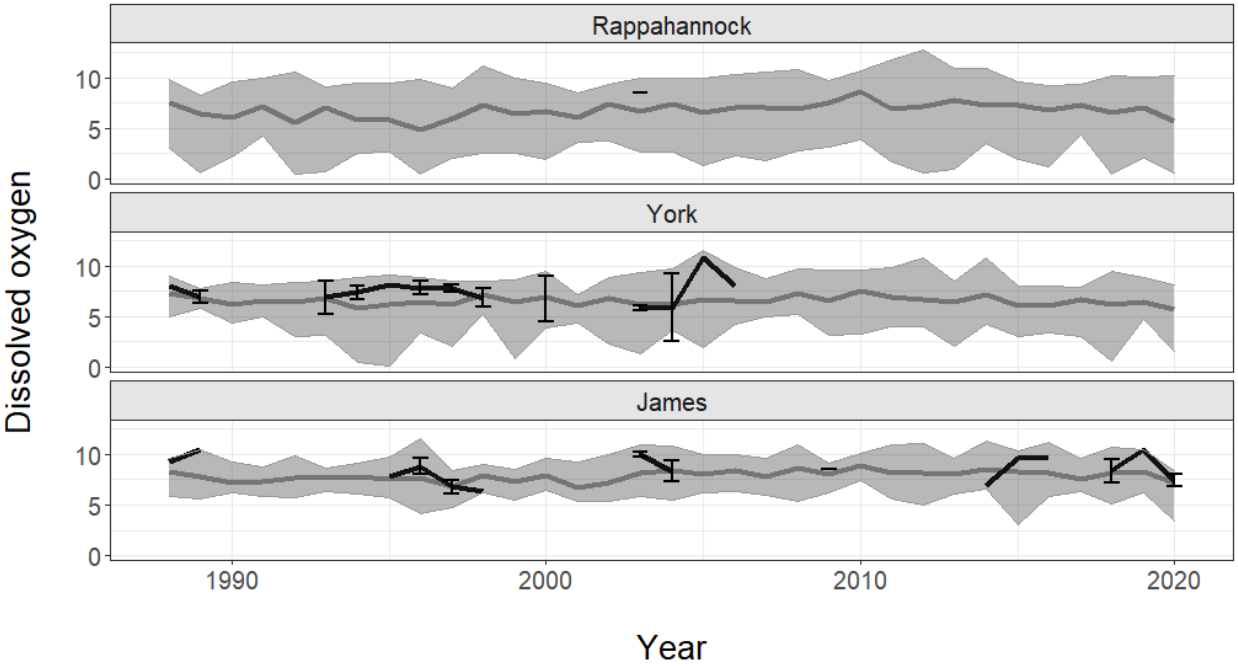


Figure 79. Juvenile White Catfish - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of juvenile White Catfish during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed dissolved oxygen represent years with low numbers of positive catches of juvenile White Catfish.

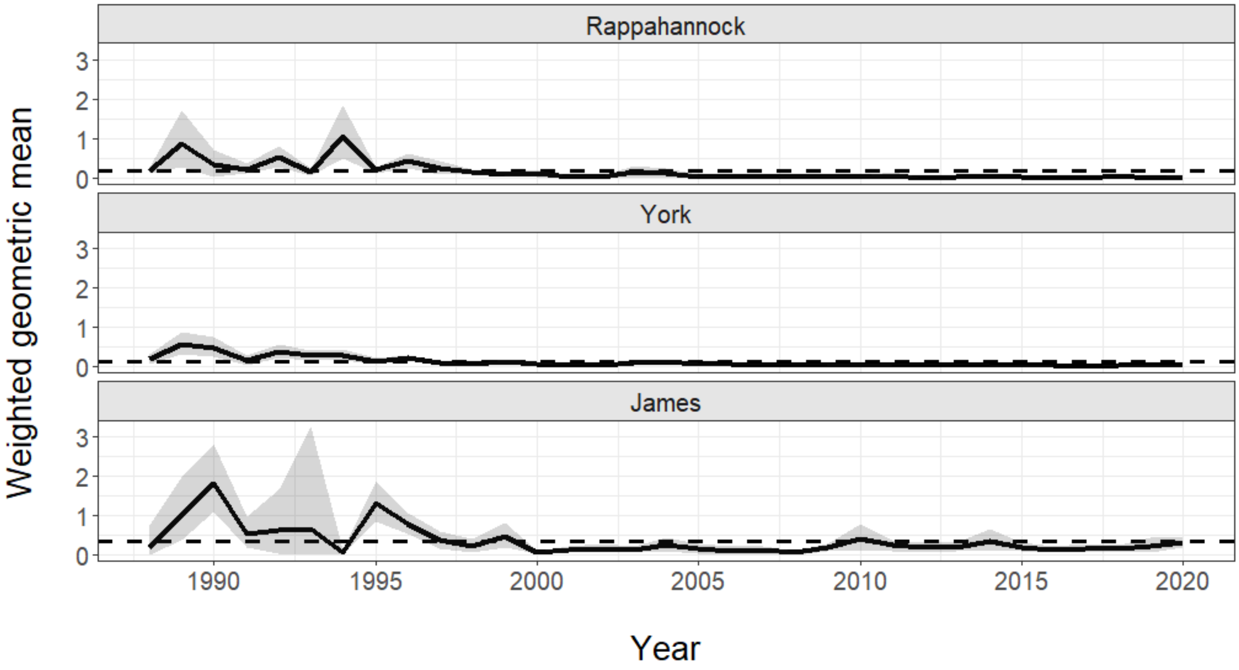


Figure 80. Age 1+ White Catfish random stratified indices (RSI_{GM}, 95% C.I.) and time series averages (dotted line) based on RSI_{GM}'s from the Rappahannock, York, and James rivers.

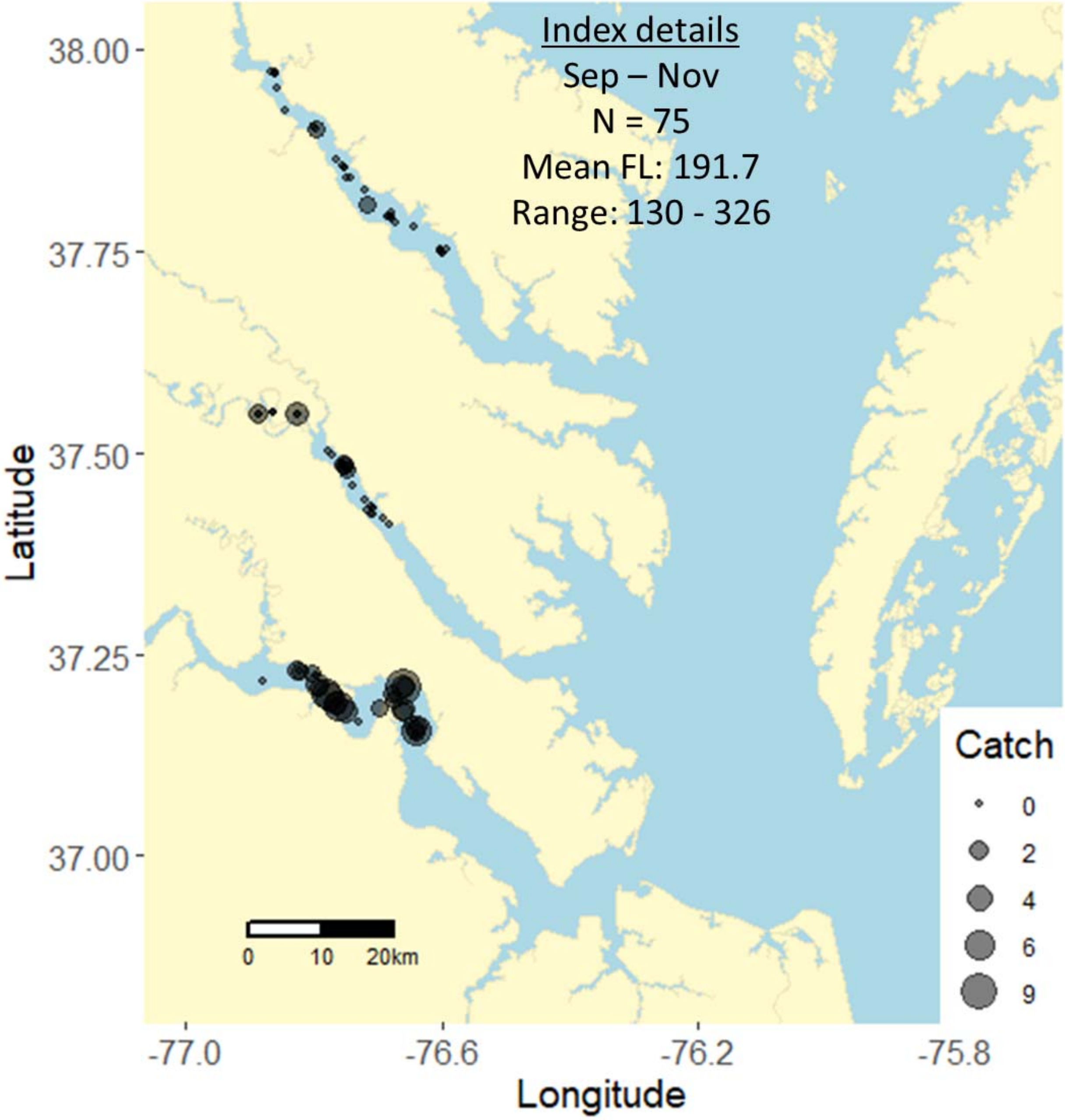


Figure 81. Distribution of White Catfish age 1+, the number captured, and mean length and range from index strata and months.

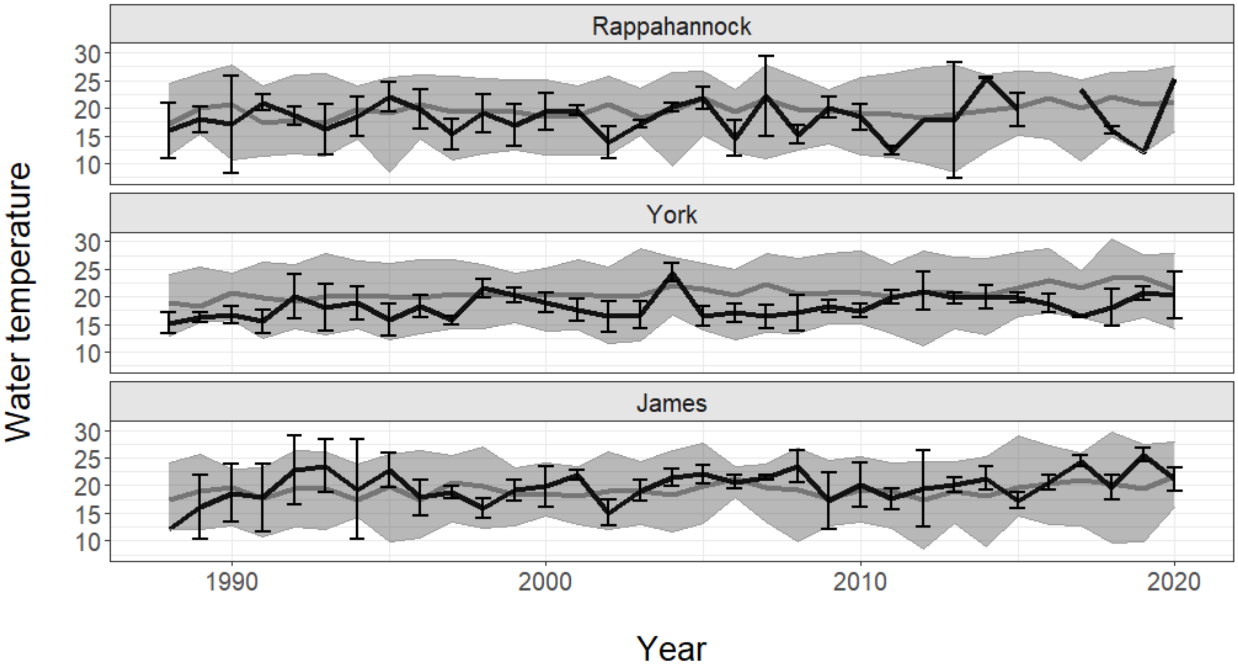


Figure 82. Age 1+ White Catfish age - Mean bottom water temperature and 95% C.I. (°C; black line) at sites with positive catches of White Catfish age 1+ during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata. Note: 95% C.I. that are outside the range of observed water temperatures represent years with low numbers of positive catches of White Catfish age 1+.

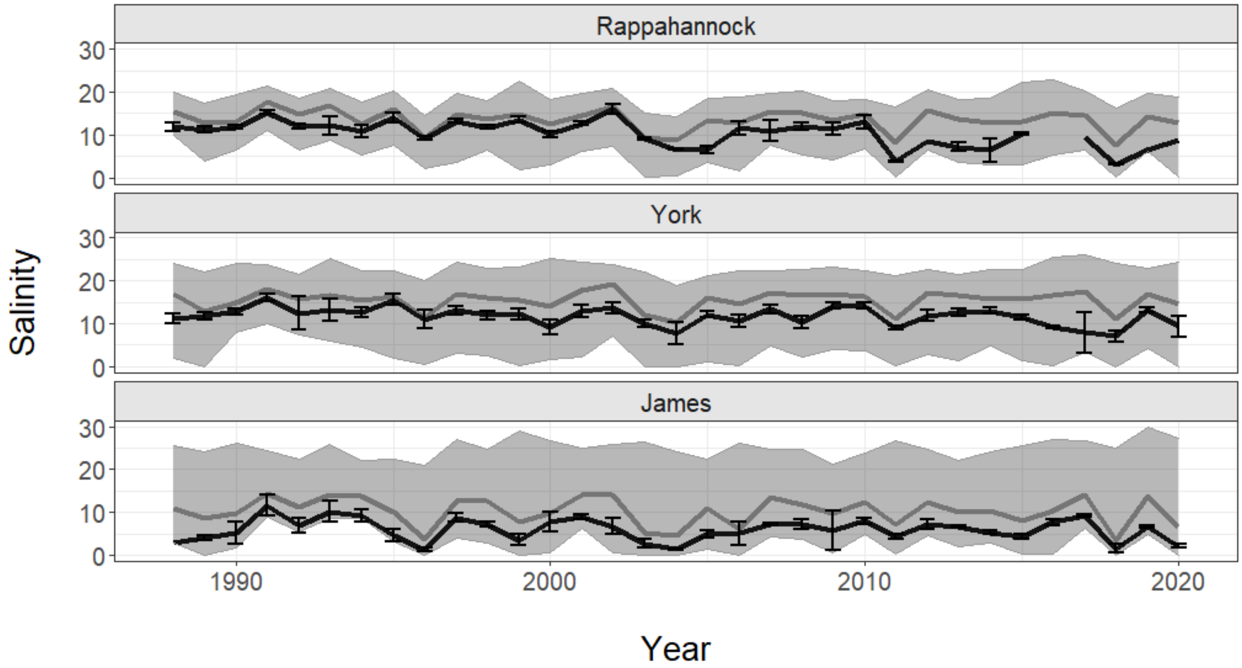


Figure 83. Age 1+ White Catfish age - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of White Catfish age 1+ during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata.

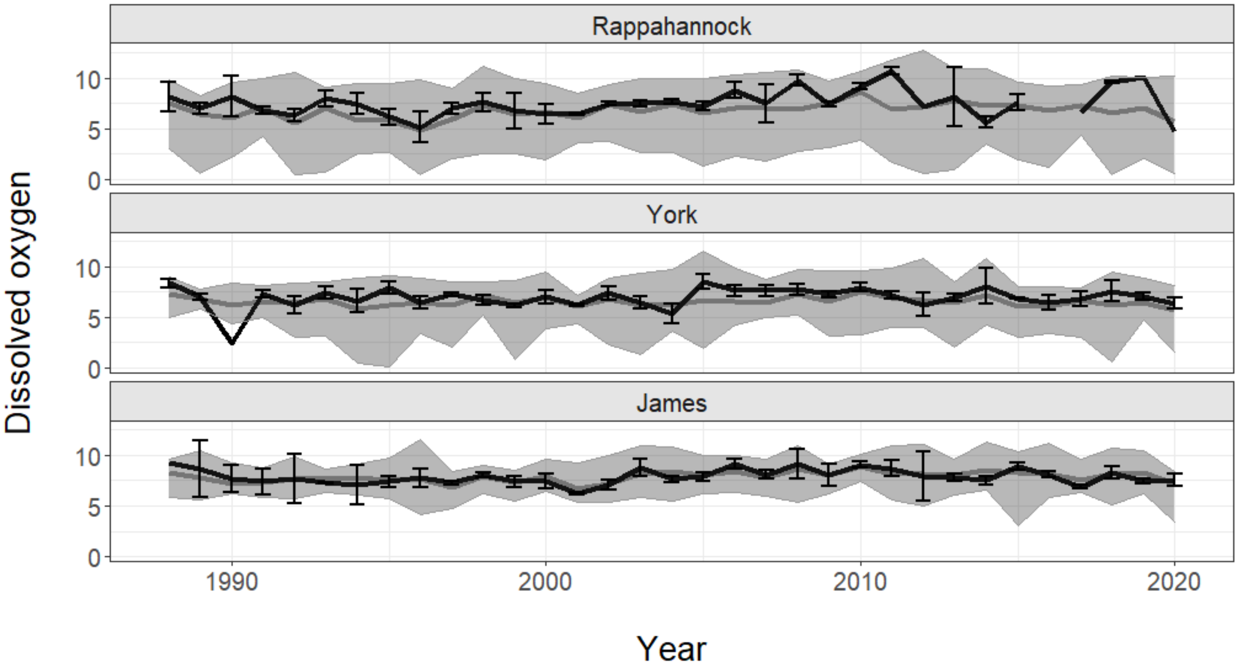


Figure 84. Age 1+ White Catfish age - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of White Catfish age 1+ during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata.

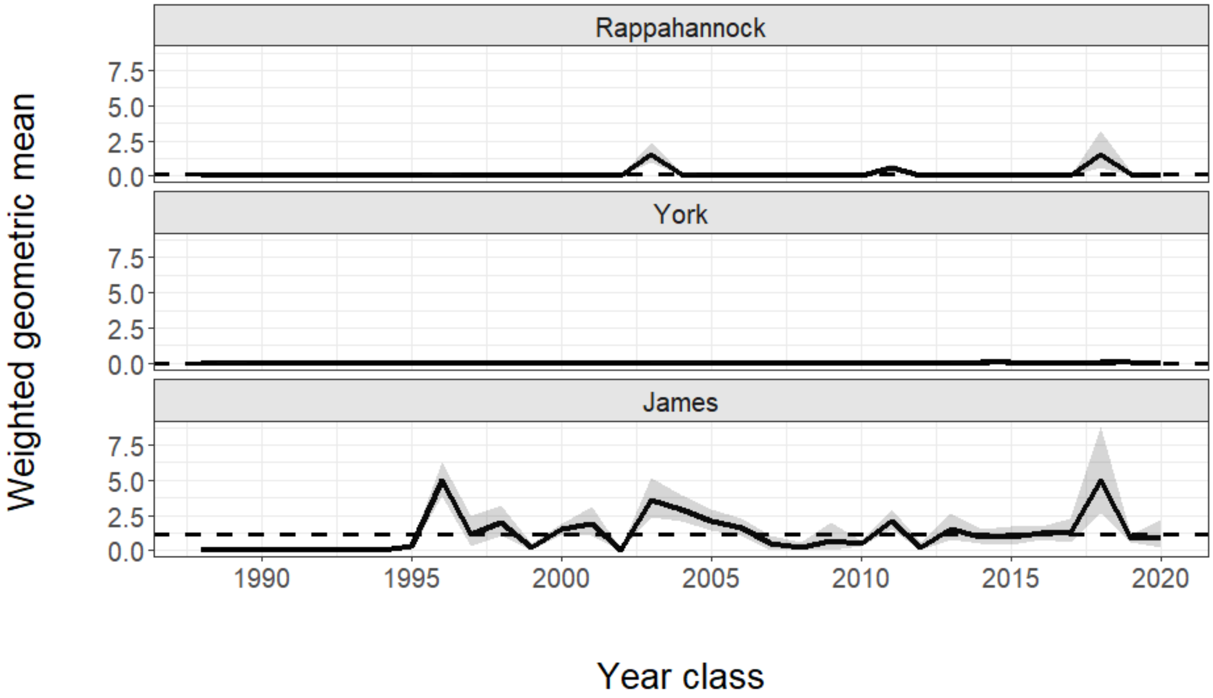


Figure 85. Juvenile White Perch random stratified indices (RSI_{GM}, 95% C.I.) and time series averages (dotted line) based on RSI_{GM}'s from the Rappahannock, York, and James rivers.

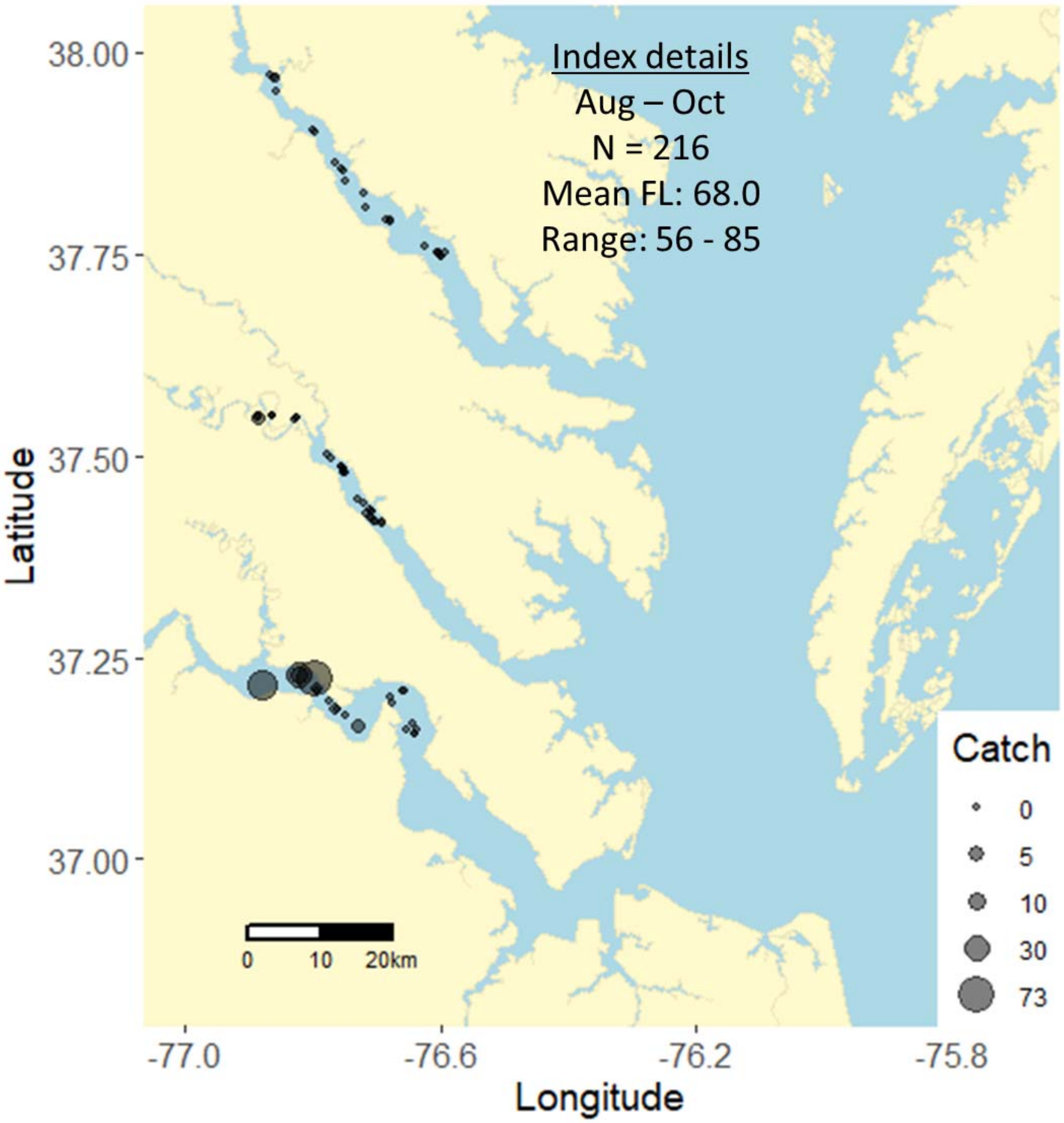


Figure 86. Distribution of juvenile White Perch, the number captured, and mean length and range from index strata and months.

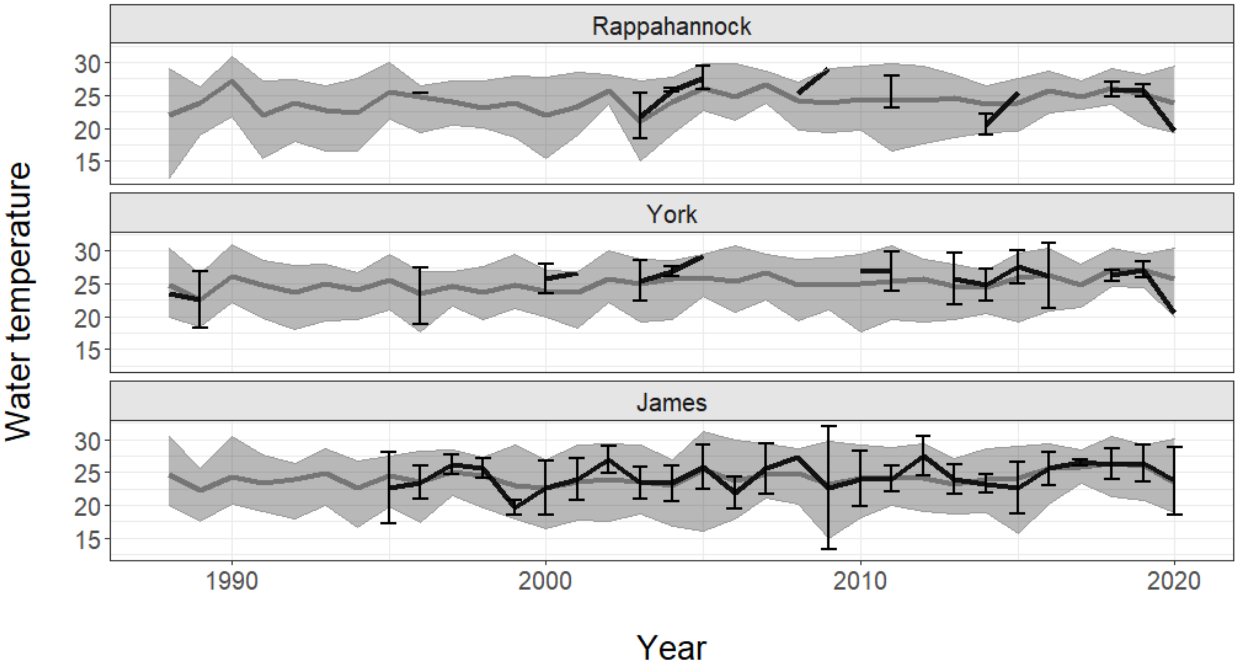


Figure 87. Juvenile White Perch - Mean bottom water temperature and 95% C.I. (°C; black line) at sites with positive catches of juvenile White Perch during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata.

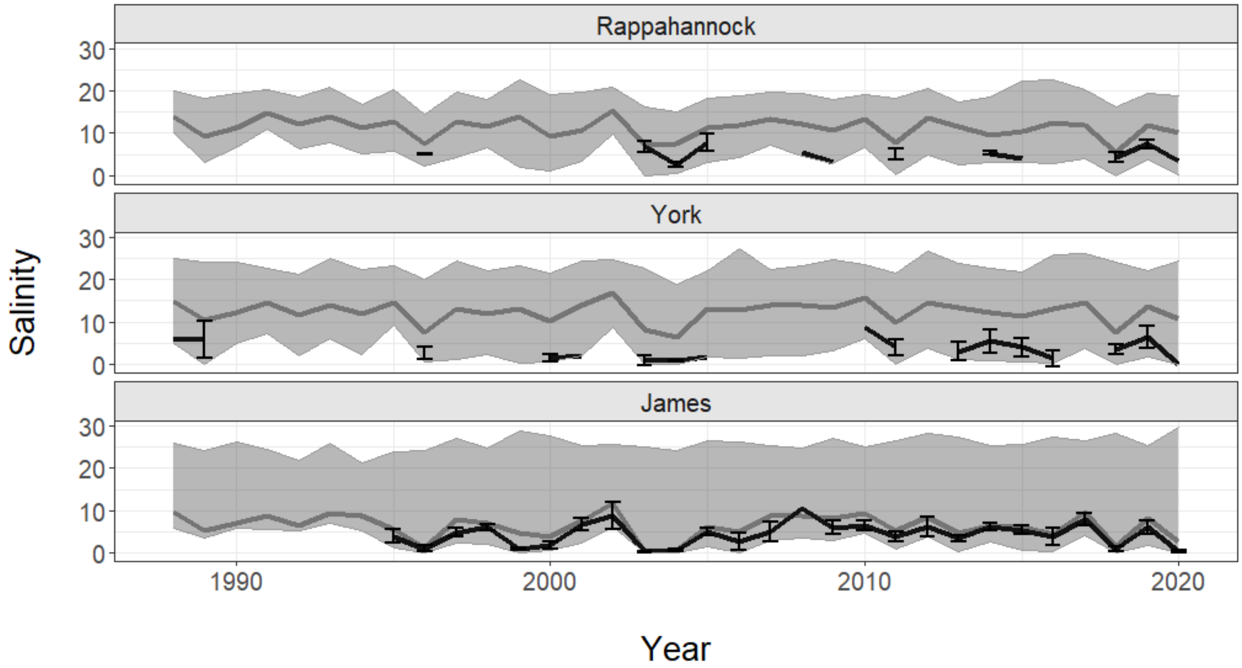


Figure 88. Juvenile White Perch - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of juvenile White Perch during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled from the same index months and strata.

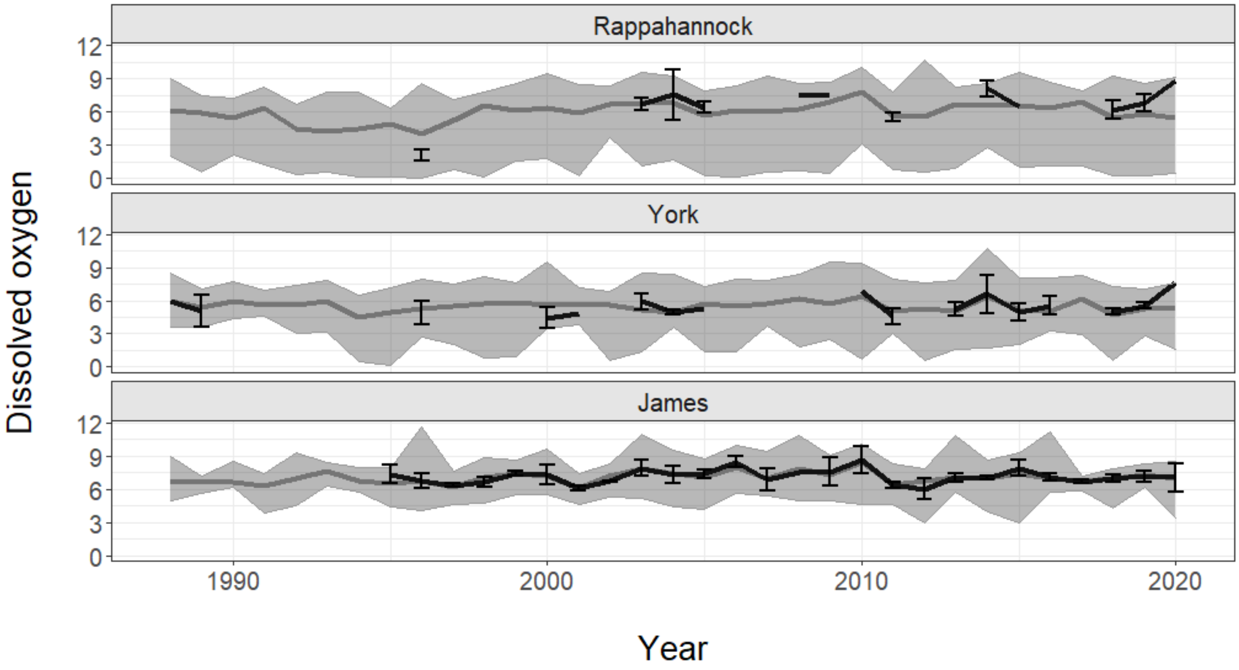


Figure 89. Juvenile White Perch - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of juvenile White Perch during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled from the same index months and strata.

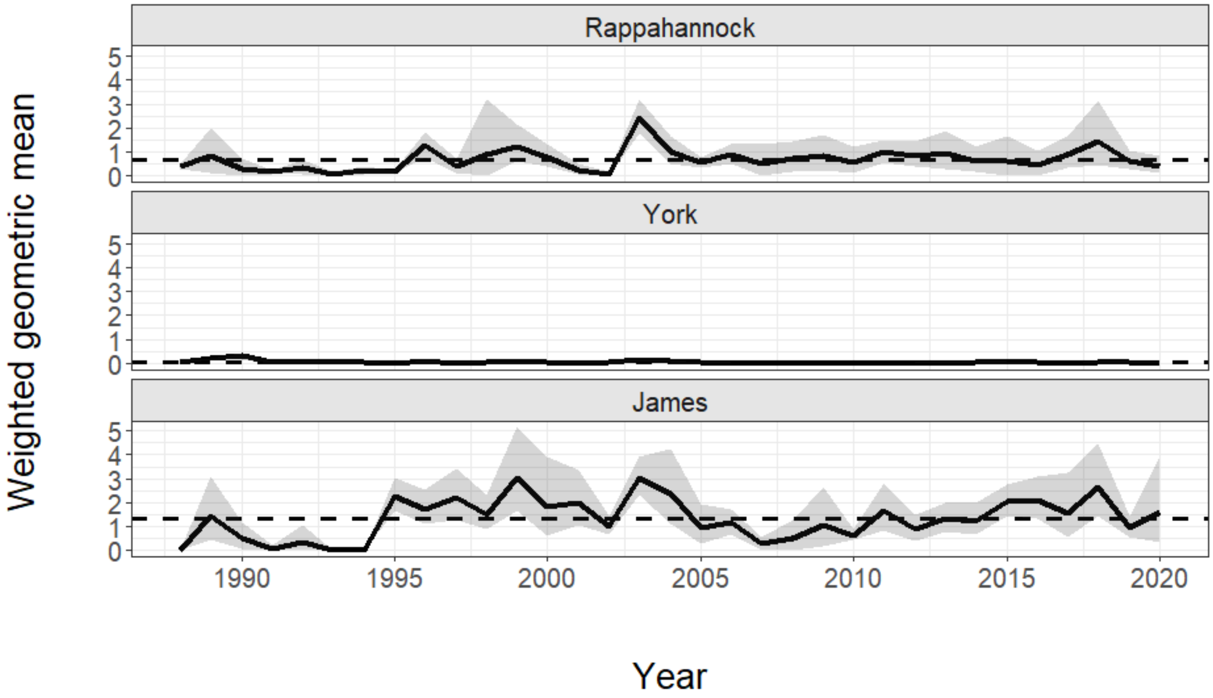


Figure 90. Age 1+ White Perch random stratified indices (RSI_{GM}, 95% C.I.) and time series averages (dotted line) based on RSI_{GM}'s from the Rappahannock, York, and James rivers.

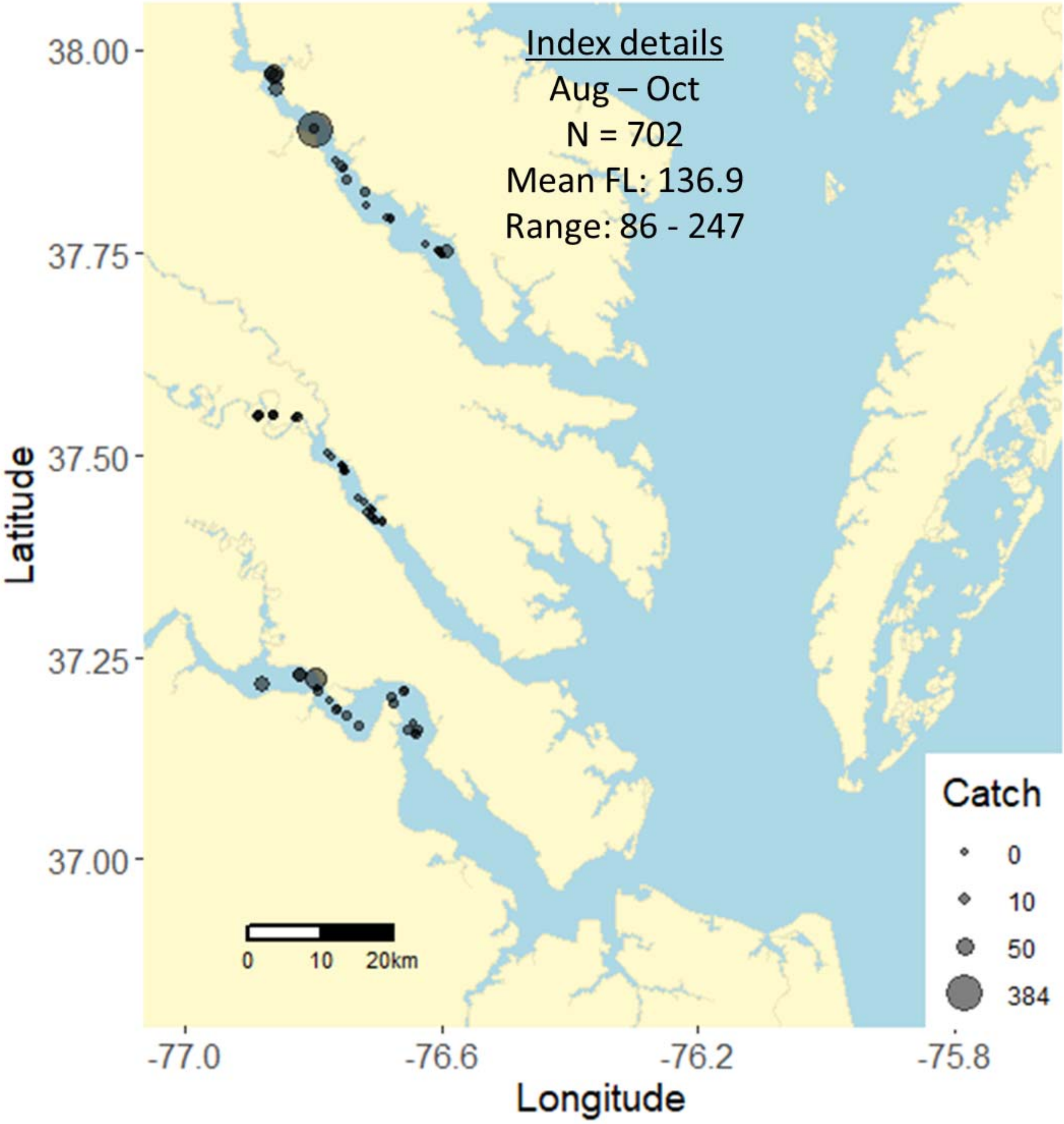


Figure 91. Distribution of White Perch age 1+, the number captured, and mean length and range from index strata and months.

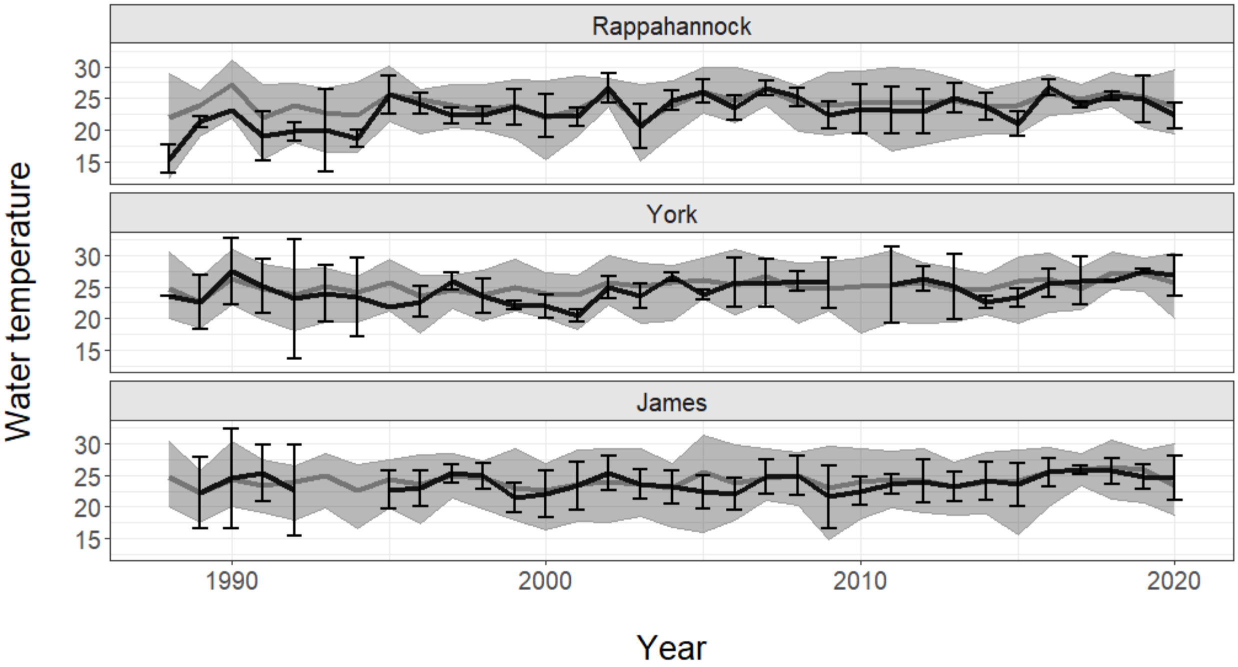


Figure 92. Age 1+ White Perch - Mean bottom water temperature and 95% C.I. (°C; black line) at sites with positive catches of White Perch age 1+ during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean water temperature (gray line) measured at all sites sampled from the same index months and strata.

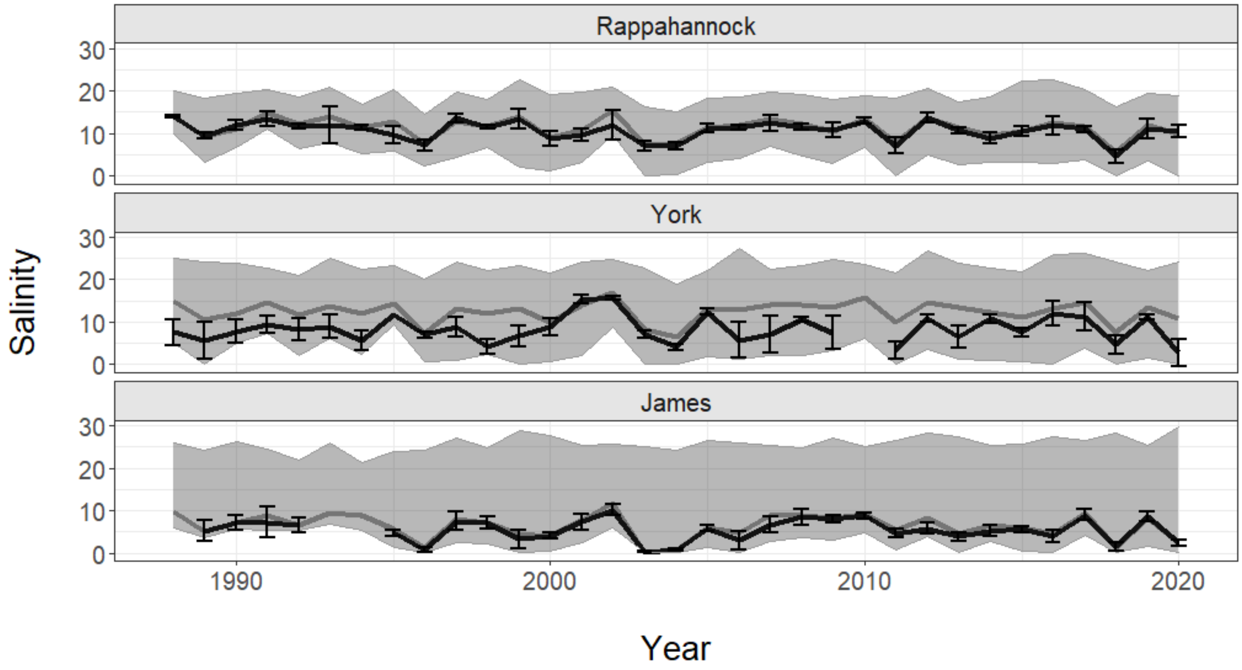


Figure 93. Age 1+ White Perch - Mean bottom salinity and 95% C.I. (psu; black line) at sites with positive catches of White Perch age 1+ during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean salinity (gray line) measured at all sites sampled during the same index months and strata.

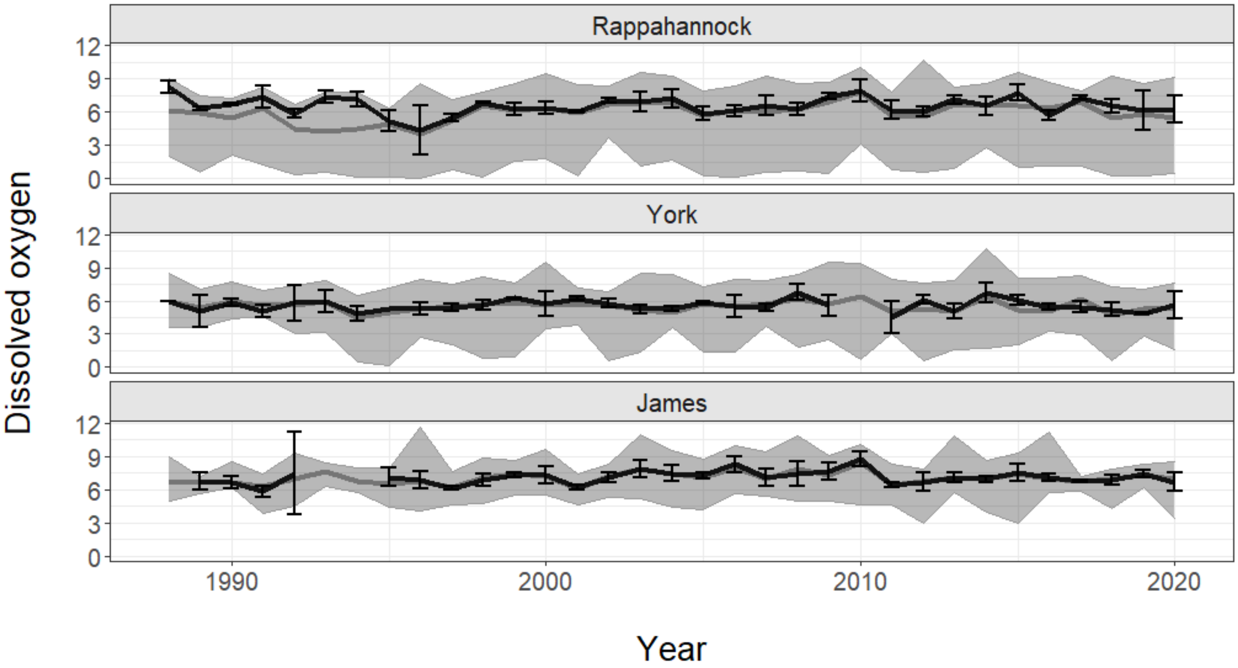


Figure 94. Age 1+ White Perch - Mean bottom dissolved oxygen and 95% C.I. (mg/L; black line) at sites with positive catches of White Perch age 1+ during index months and strata in the Rappahannock, York, and James rivers from 1988 to 2020. Shaded region represents the minimum, maximum, and mean dissolved oxygen (gray line) measured at all sites sampled during the same index months and strata.

Appendix Table 1. Trawl Survey advisory requests, data requests, and specimen requests from July 2020 to June 2021.

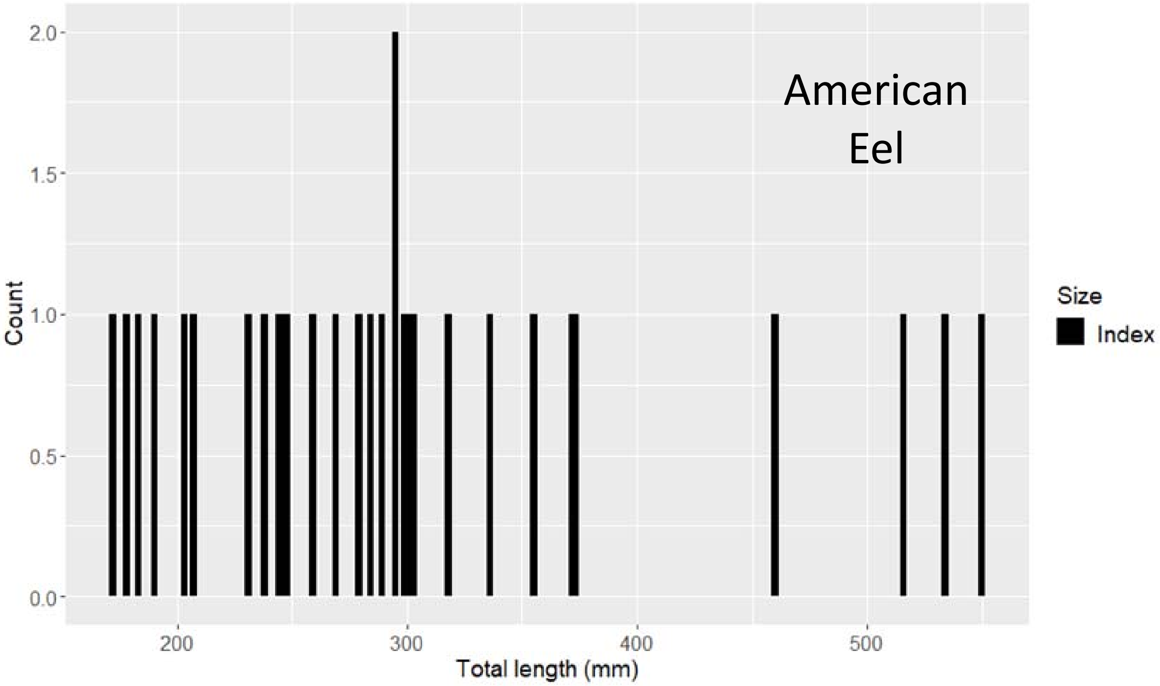
Juvenile trawl survey specimen or data requests from 2020 - 2021 by month.

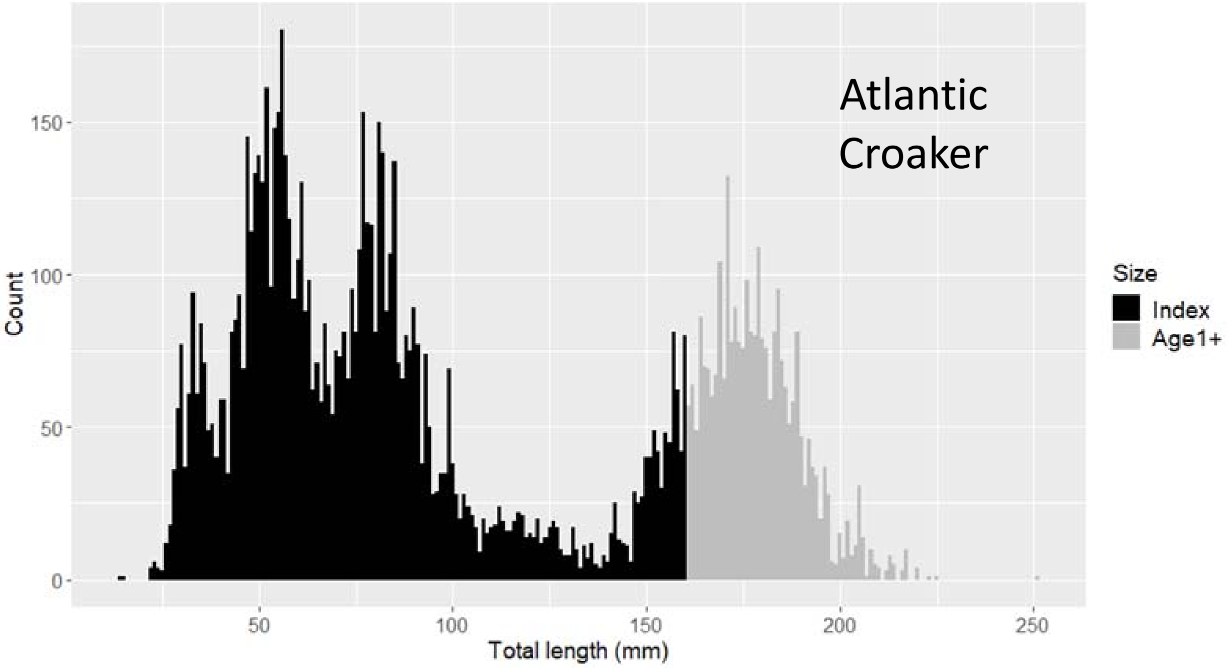
			2020						2021					
Name	Agency	Nature of request	J	A	S	O	N	D	J	F	M	A	M	J
Troy Tuckey	VIMS - Fisheries	White Perch juveniles	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Troy Tuckey	VIMS - Fisheries	American Eels	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
Ethan Simpson	VMRC	Red Drum data			▨									
Ryan Carnegie	VIMS - AHS	Oyster samples							▨					
Chris Davis	VMRC	Shrimp indices							▨					
Pat Geer	VMRC	Weakfish data									▨			
Pat Geer	VMRC	Scup data									▨			
Eric Hilton	VIMS	Alosine data										▨		
Pat Geer	VMRC	Croaker data											▨	
Pat Geer	VMRC	American eel data											▨	
Chris McDonough	ASMFC	Spot and Croaker data											▨	
Protected species	NOAA	Atlantic sturgeon interactions			▨	▨	▨				▨	▨		▨
Friends of the Rappahannock	FOR	American eel index												▨

Appendix Table 2. Trawl Survey comparison study summary showing the best model, number of paired comparison tows used to estimate the calibration factor (N), and the calibration factor used to multiply each tow from the R/V *Tidewater* to convert it to R/V *Fish Hawk* equivalents by species. Due to low or no catches of White and Channel Catfish in the comparison study, we applied the best model from Blue Catfish to adjust index values for these species.

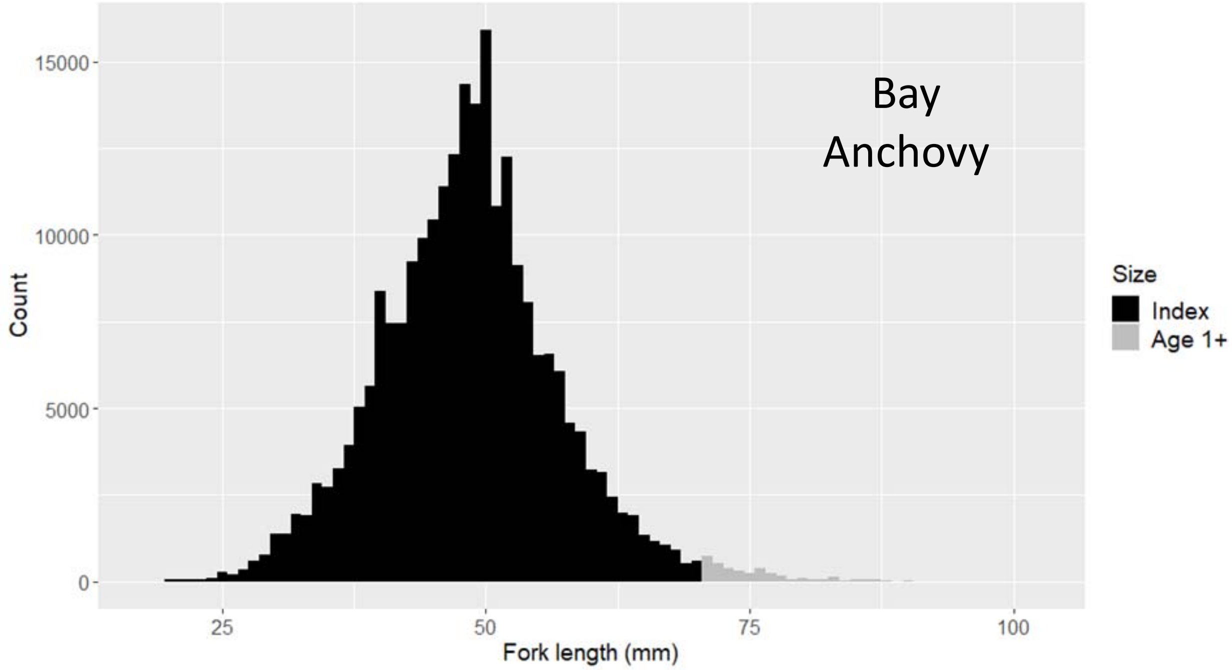
Species	N	Model	Calibration Factor
American Eel age 1+	27	Binomial	0.8731
Atlantic Croaker YOY	283	Beta-binomial	1.4770
Bay Anchovy YOY	504	Beta-binomial	0.8014
Black Sea Bass YOY	25	Binomial	0.6336
Blue Catfish YOY	78	Beta-binomial	1.0023
Blue Catfish age 1+	123	Beta-binomial	1.4289
Channel Catfish YOY	0	Blue Catfish YOY	1.0023
Channel Catfish age 1+	0	Blue Catfish age 1+	1.4289
Scup	27	Beta-binomial with random paired-tow effect	1.3471
Silver Perch YOY	118	Beta-binomial	0.7524
Spot YOY	187	Beta-binomial	1.1654
Striped Bass YOY	90	Beta-binomial	1.2009
Summer Flounder YOY	146	Beta-binomial	1.0308
Weakfish YOY	220	Beta-binomial	1.1924
White Catfish YOY	10	Blue Catfish YOY	1.0023
White Catfish age 1+	32	Binomial	0.6918
White Perch YOY	161	Beta-binomial	1.0679
White Perch age 1+	210	Beta-binomial	1.1676

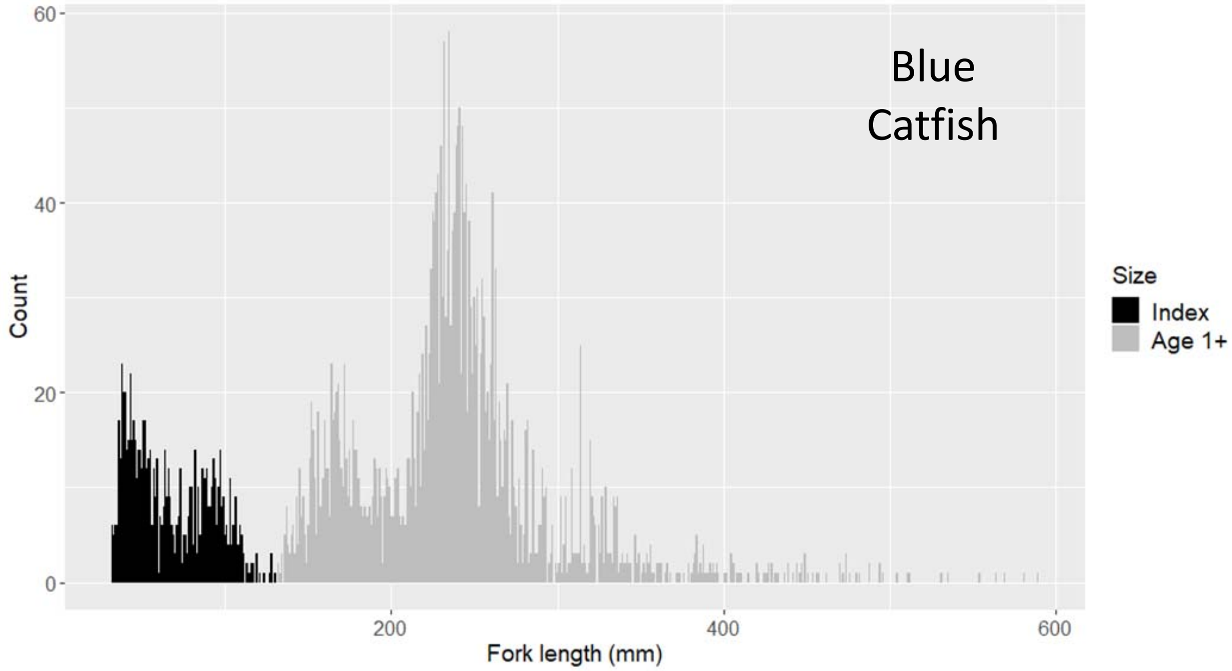
Appendix Figure 1. Length frequency distributions by species from July 2019 through June 2021. (Note that actual indices are calculated using a subset of months and strata. Therefore, not all index-sized fish are included in index calculations.)



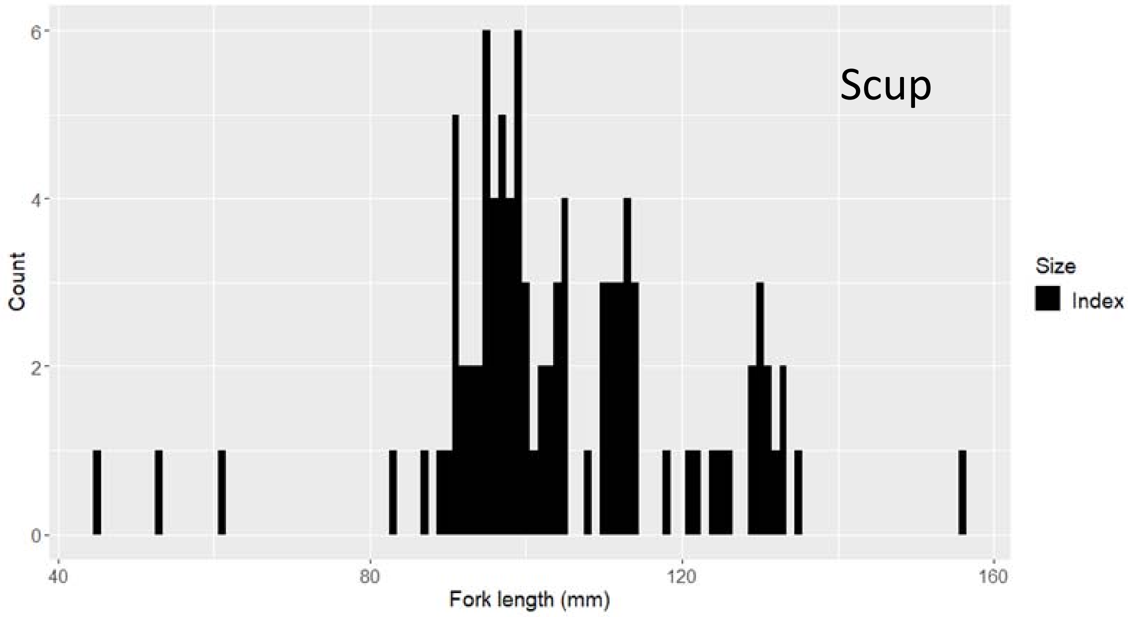


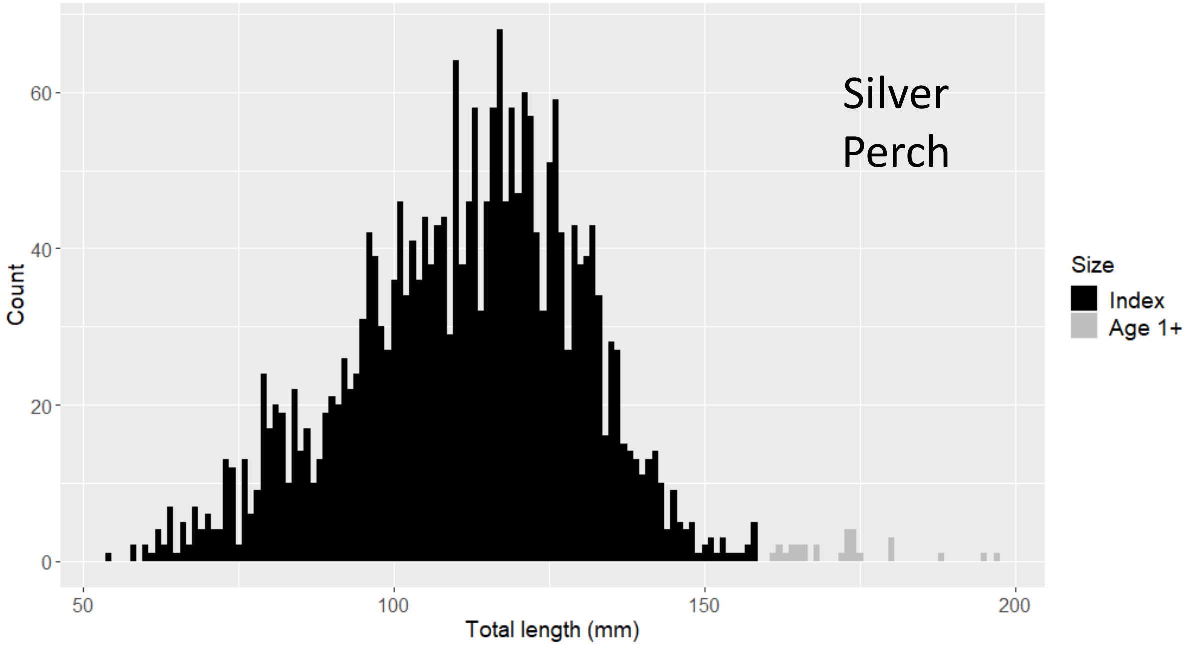
Appendix Figure 1. (continued)



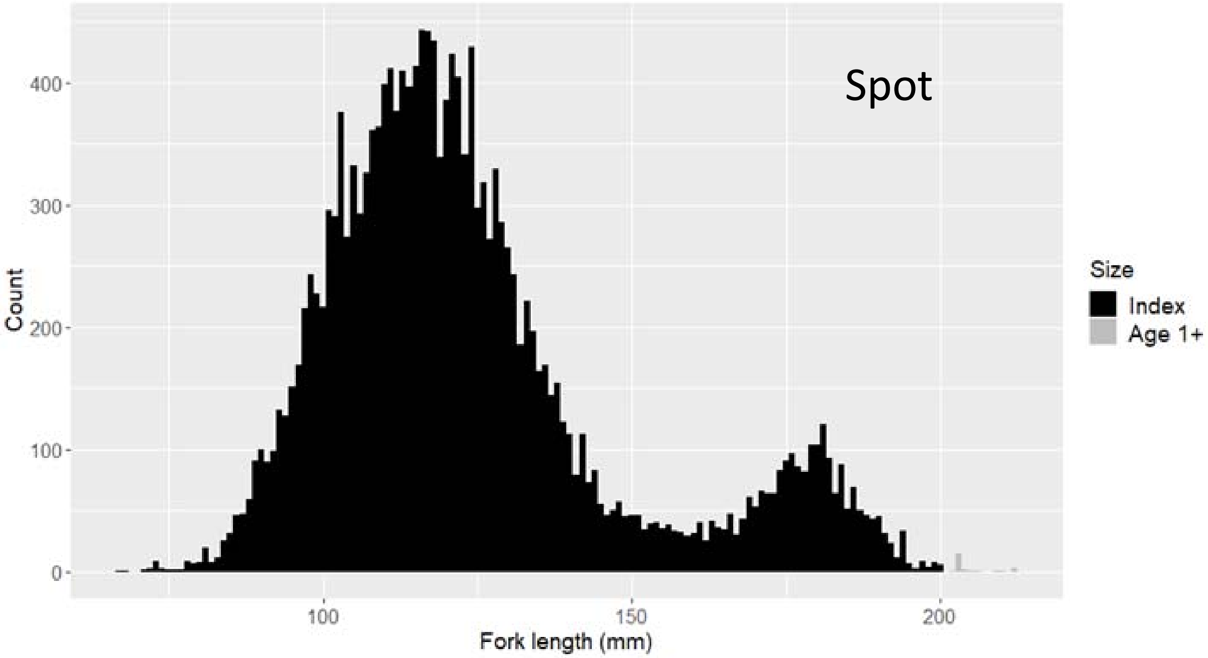


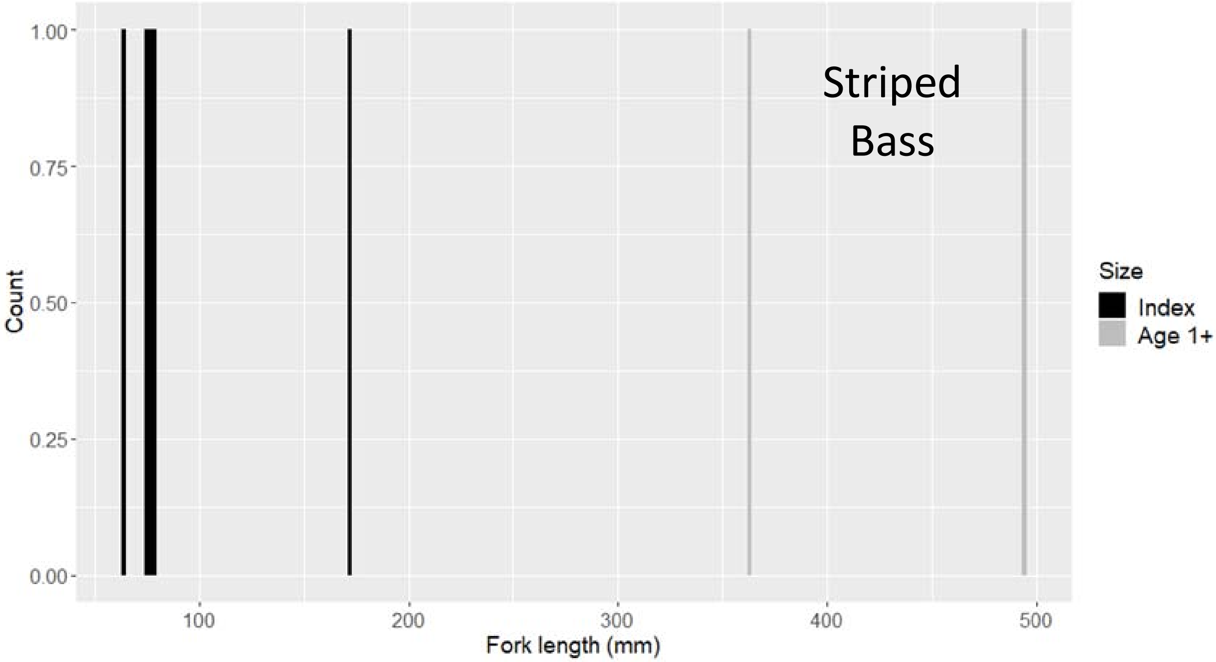
Appendix Figure 1. (continued)



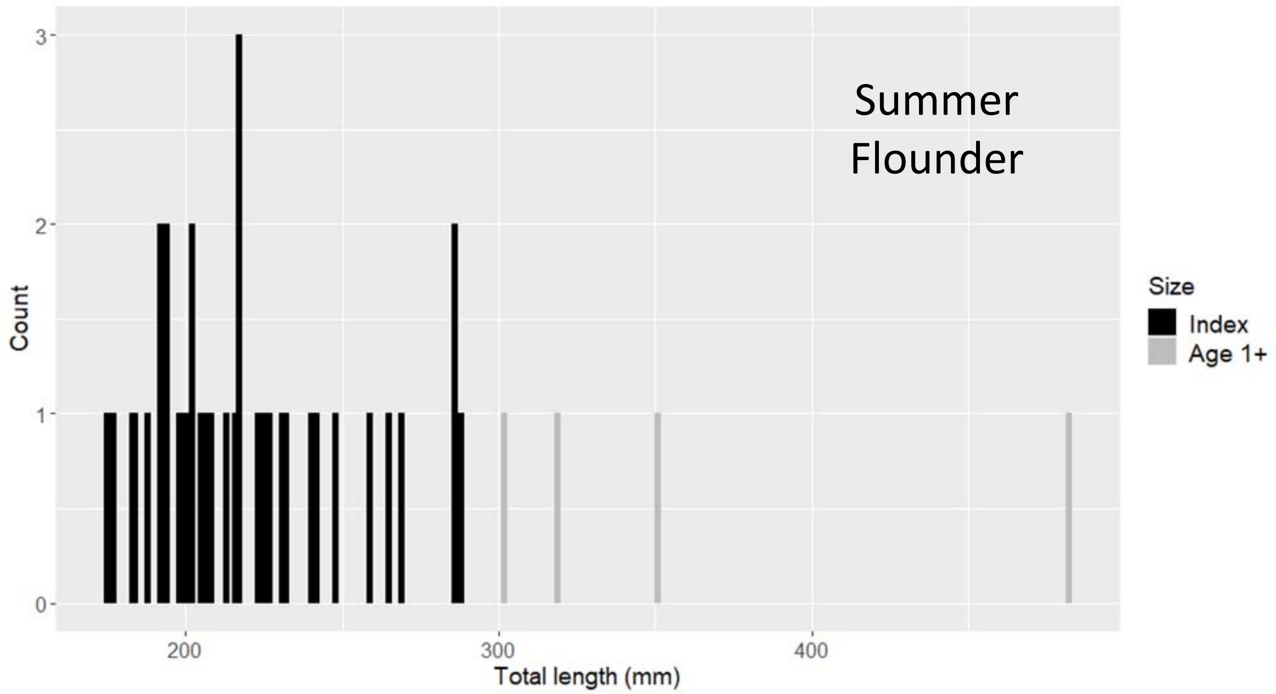


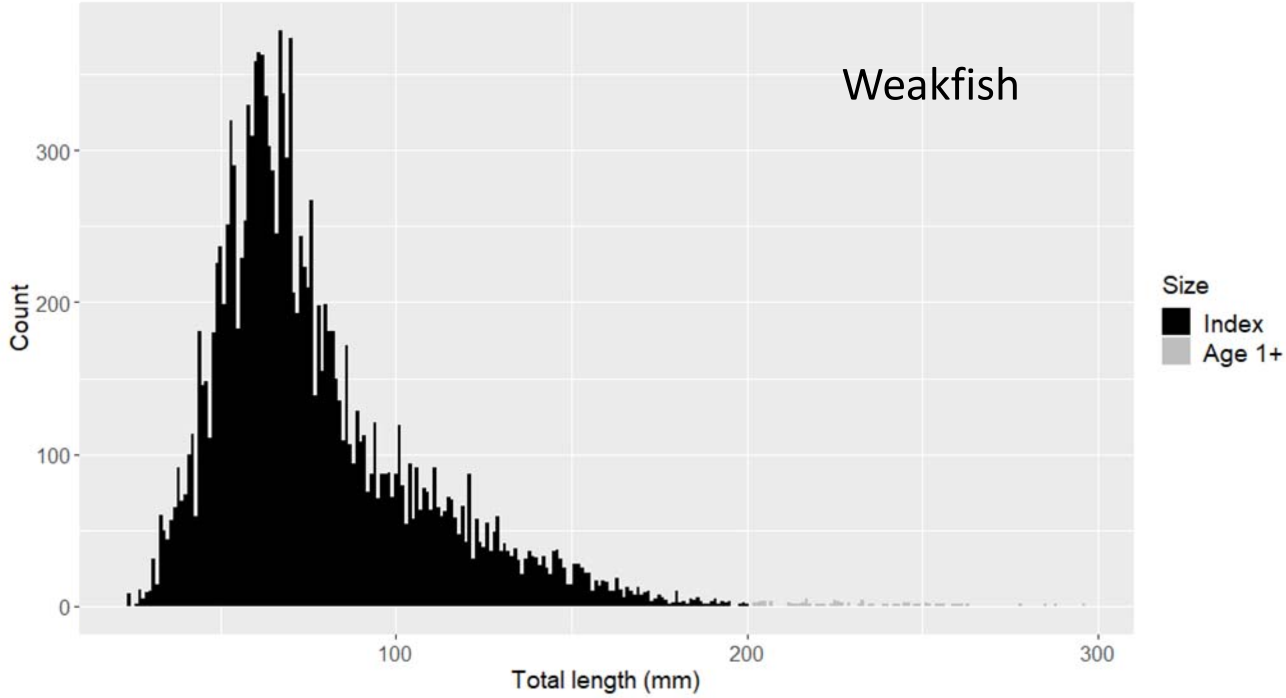
Appendix Figure 1 (continued).





Appendix Figure 1. (continued)





Appendix Figure 1. (continued)