6-2022

ANNUAL REPORT 2022 - Data collection and analysis in support of single and multispecies stock assessments in Chesapeake Bay: The Chesapeake Bay Multispecies Monitoring and Assessment Program

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Recommended Citation

Ralph, G. M., Bonzek, C. F., Gartland, J., Gauthier, D. J., Gregg, J., & Latour, R. J. (2022) ANNUAL REPORT 2022 - Data collection and analysis in support of single and multispecies stock assessments in Chesapeake Bay: The Chesapeake Bay Multispecies Monitoring and Assessment Program. Virginia Institute of Marine Science, William & Mary. doi.org/10.25773/pnw1-0717

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ANNUAL REPORT

Data collection and analysis in support of single and multispecies stock assessments in Chesapeake Bay:

The Chesapeake Bay Multispecies Monitoring and Assessment Program

Prepared for:

Virginia Marine Resources Commission

and

U.S. Fish & Wildlife Service

For Sampling During:

Calendar Year 2022 and Previous Years

Project Number:

F-130-R-18

Submitted:

June 2023

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Abstract

The threats affecting living marine resources are diverse, including overfishing, climate change, and pollution. In response to long-term challenges in fisheries management, a more holistic evaluation of the natural and anthropogenic drivers of populations sizes is needed. Ecosystem management (EM), a suite of strategies that incorporate ecosystem considerations into fisheries and ecosystem management, can be difficult to implement in practice. In the Mid-Atlantic, efforts to implement EM are ongoing; one output has been the annual 'State of the Ecosystem Report' for the region, synthesizes available data on a variety of environmental, ecological, and socioeconomic factors. Historically, the data needed for EM in Chesapeake Bay were either incomplete or nonexistent. In 2002, the Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) was developed to assist in filling these data gaps, and ultimately to support Bay-specific species and ecosystem assessment modeling. ChesMMAP is a fishery-independent monitoring survey that uses a bottom trawl designed to sample late juvenile-to-adult fishes in the mainstem of Chesapeake Bay. Since 2002, this program has provided data on relative abundance, length, weight, sex ratio, maturity, age, and trophic interactions for several important fish species that inhabit the Bay seasonally. In this annual progress report, we synthesize available biological data on 12 bony fishes that support local recreational fisheries, including abundance (biomass and number), length- and age-structure, sex ratio, maturity stage, and diet composition. However, in 2019, the survey underwent a major redesign: VIMS took possession of a new research vessel, the *R/V Virginia*, and the survey bottom trawl gear was replaced with a net consistent with the gear used by other regional bottom trawl surveys (i.e., the Northeast Area Monitoring and Assessment Program and Northeast Fisheries Science Center trawl surveys). At this time, the survey stratification was revised and changes were made to the cruise schedule. During 15 calibration cruises (2019-2022), 516 paired-tows were completed, which was deemed sufficient for robust statistical analysis. Species-specific intercalibrations have been conducted by applying log-Gaussian Cox processes to the paired-tow data and modeling the size distribution of the population at each sampling site and the size-structured clustering of fish at small temporal and spatial scales. The manuscript describing the application to the ChesMMAP calibration data is currently in review. The ChesMMAP data inform Bay- and coast-wide fisheries management decisions and the broader use of these data in theses, dissertations, and the peer-reviewed literature contributes to a better understanding of the Bay ecosystem.

Introduction

Living marine resources provide important economic, cultural and social benefits that are threatened by myriad anthropogenic pressures, including overfishing, climate change, and pollution (Steneck and Pauly, 2019). Despite this diversity of threats, managers typically have direct control over few of the factors affecting populations of exploited species. As a result, fisheries management efforts have focused on single-species approaches, where each species is assessed and managed in isolation. However, over the past several decades, a more holistic evaluation of the natural and anthropogenic drivers of population sizes has been identified as necessary to improve the status and sustainability of fisheries (Link et al., 2020).

A suite of strategies, collectively termed ecosystem management (EM), have been developed to incorporate biotic and abiotic drivers of populations into fisheries management (see Dolan et al., 2016). The terms used to refer to these various strategies exist along a continuum reflecting the scale at which ecosystem-level considerations are included in the management framework (Dolan et al., 2016). Similar to single-species approaches to fisheries management, the ecosystem approach to fisheries management (EAFM) typically produces biological reference points for a single species or stock; the primary difference between the two approaches is the inclusion of environmental, ecological, and/or socioeconomic factors in EAFM (Link, 2002). Ecosystem-based fisheries management (EBFM) extends beyond this focus on an individual species to consider trade-offs across the ecosystem, such that multiple, or even all, fisheries are evaluated together to optimize yields (Link, 2010; Link and Marshak, 2022). At this scale, species-specific biological reference points must be supplemented by additional criteria or indicators. For example, aggregate biological reference points, such as multispecies maximum sustainable yield (Gaichas et al., 2012), and systemic reference points, such as ecosystem overfishing (Link, 2021) can be developed and applied to specific ecosystems and fisheries. Finally, ecosystem-based management (EBM) considers the ecosystem holistically, with three focal concerns: sustainability, ecological health, and inclusion of humans in the ecosystem (Arkema et al., 2006).

Despite calls for further implementation of EM, in practice, environmental drivers and trophic interactions are rarely integrated into short-term fisheries management decisions (i.e., on total allowable catch: Skern-Mauritzen et al., 2016). While many of the perceived obstacles to more holistic approaches to fisheries management have been addressed (Patrick and Link, 2015), region-specific challenges remain in implementation (e.g., Cowan et al., 2012; Link and Marshak, 2019). In the Mid-Atlantic, efforts to implement EM are ongoing (Gaichas et al., 2018), resulting in the development of the first 'State of the Ecosystem' Report for the region in 2017. Updated annually, these reports synthesize available data on a variety of environmental, ecological, and socioeconomic factors (NOAA National Marine Fisheries Service, 2023).

Historically, the data needed for EM in Chesapeake Bay were either incomplete or nonexistent. The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) was developed to assist in filling these data gaps, and ultimately to support Bay-specific species and ecosystem assessment modeling. ChesMMAP is a fishery-independent monitoring survey that uses a bottom trawl designed to sample late juvenile-to-adult fishes in the mainstem of Chesapeake Bay. While no single gear or monitoring program can collect all of the data necessary for all species and assessment approaches, ChesMMAP was designed to maximize the biological and ecological information collected for several recreationally, commercially, and ecologically important species in the Bay. Since 2002, this program has provided data on relative abundance, length, weight, sex ratio, maturity, age, and trophic interactions for several important fish species that inhabit the Bay seasonally.

The overarching goal of ChesMMAP is to collect and provide the data necessary to support species and ecosystem assessment modeling and ultimately support the development of fisheries ecosystem plans and regional ocean plans for Chesapeake Bay.

- Task 1: Conduct research cruises
- Task 2: Synthesize data for single species analyses
- Task 3: Quantify trophic interactions for multispecies analyses
- Task 4: Estimate abundance
- Task 5: Evaluation of alternative sampling gear

Objectives

1. To conduct ChesMMAP research cruises between June 2022 and March 2023. Two full-Bay cruises, with up to 80 sites distributed throughout the main stem of Chesapeake Bay, will be conducted, one each in June and September. In addition, two half-Bay cruises will take place, with up to 45 sites in the lower Bay (Virginia) in November and up to 35 sites in the upper Bay (Maryland) in March. This objective is associated with Task 1.

2. To estimate the population-level parameters necessary to conduct single and multispecies stock assessments. Those include (when appropriate), abundance (biomass and number), length- and age-structure, sex ratio, maturity stage, and diet composition. This objective is associated with Tasks 2-4. The focal species include:

   - Atlantic croaker, *Micropogonias undulatus*
   - Black sea bass, *Centropristis striata*
   - Bluefish, *Pomatomus saltatrix*
   - Butterfish, *Peprilus triacanthus*
   - Kingfishes, *Menticirrhus* spp.
   - Northern puffer, *Sphoeroides maculatus*
   - Scup, *Stenotomus chrysops*
   - Spot, *Leiostomus xanthurus*
   - Striped bass, *Morone saxatilis*
   - Summer flounder, *Paralichthys dentatus*
   - Weakfish, *Cynoscion regalis*
   - White perch, *Morone americana*

3. To estimate calibration coefficients for the updated vessel/gear combination. This objective is associated with Task 5.

4. To serve as a sampling platform for other Bay-related studies focused on, for example, fish disease, water quality, habitat mapping, etc. This is an additional objective associated with Task 1.

Methods

Task 1

Field methods

In 2022, we conducted four ChesMMAP cruises:

- A half-Bay cruise (35 sites) in March in the upper Bay (Maryland), focusing on anadromous species (mainly striped bass and white perch) during spawning,
- Two full-Bay cruises (80 sites each) in June and September, when the Bay is fully populated with both resident and summer-migrant species, and
- A second half-Bay cruise (45 sites) in November in the lower Bay (Virginia), focusing on species during their migration out of the Bay.

Sampling locations were selected using a stratified random design prior to each cruise and the order in which sites were sampled depended on weather, tides, and other logistical considerations. Stratification was simplified in 2019 to four latitudinal regions (two in Maryland, two in Virginia) and two depth strata within each region (≤ 12.2 m, > 12.2 m), and this stratification scheme was followed for all cruises conducted in 2022.

We used the *R/V Virginia*, a 28.3 m steel hull vessel with twin diesels tied to a single controllable-pitch propeller and a dynamic positioning system for station-holding, equipped with a “200 x 12 cm” bottom trawl rigged with a 3.8 cm cookie sweep and using Thyboron Type IV 44” trawl doors for all cruises in 2022 (see Appendix I for further details). At each sampling site, a full profile of the water column, including water temperature, salinity, and dissolved oxygen data were recorded electronically at approximately 1 m intervals using the Hach Hydrolab MS5 Sonde and Hydras recording software. The net was deployed with a depth-dependent tow-wire scope ratio of 3:1 to 6:1 and towed along the bottom for 20 minutes with the tidal current at approximately 3.0 knots. If obstructions or other logistical issues forced a tow to be shortened, the tow still provided a representative sample for the site as long as it was at least 10 minutes in duration.

After retrieval of the net, the catch was sorted by species (and modal size-class, where appropriate) and a subsample was taken from each species and size-class for full processing. The data collected from the subsampled specimens included length and weight, as well as sex and maturity stage (determined macroscopically). Stomachs were removed and those containing prey items were preserved on-board for post-cruise examination (see Task 3). Sagittal otoliths and/or scales were collected from select managed species at all sites in the mainstem of the Chesapeake Bay; these structures were removed, labeled and stored for later age determination. Aggregate weights were recorded by species/size-class for all specimens not selected for full processing, and either all or a representative subsample were enumerated and measured for length. Standardized quality control procedures were implemented during and at the conclusion of each research cruise to ensure that the data collected in the field were complete and consistent with properly functioning gear, equipment, and protocols.

Diet

Diets, typically inferred by stomach content analysis, provide essential information on the trophic structure of ecosystems, which can be incorporated into fisheries management frameworks through multispecies models. To date, the inclusion of multispecies models into formal stock assessment processes has been relatively limited; most efforts have supplemented single-species assessment models rather than forming the basis of management advice (see Karp et al., 2023). In this context, forage fishes are of particular interest, and the transition from a single-species approach to an ecosystem approach for Atlantic menhaden (*Brevoortia tyrannus*) represents a major step forward in quantitative, ecosystem approaches to tactical fisheries management (Anstead et al., 2021).

Stomach samples collected and preserved in the field were brought back to VIMS and processed following standard diet analysis procedures (Hyslop, 1980). In general, these protocols involved identifying each prey item to the lowest possible taxonomic level and recording counts and wet weights of the various items. Several diet indices can be calculated to identify the main prey types for each species, including percent by weight, percent by number, and percent frequency-of-occurrence.

Ageing

Information on the age distribution of fishes can provide essential information for fisheries management, and accurate ageing is imperative for understanding population dynamics and informing stock assessments (Campana, 2001). Calcified structures, such as whole otoliths, transverse sectioned otoliths, and scales, typically display seasonal growth patterns that are interpreted as annuli. Transverse sectioned otolith methodology has been validated on several different species within the Chesapeake Bay (Barbieri et al., 1994; Lowerre-Barbieri et al., 1994; Sipe and Chittenden, 2001, 2002; Ihde and Chittenden Jr, 2002) and is recommended by the Atlantic States Marine Fisheries Commission (ASMFC). Thus, this approach is preferred for the assignment of accurate ages for ChesMMAP samples.

Sagittal otoliths and scales collected in the field were brought back to VIMS to determine age assignments under a standard set of criteria. As only a subsample of individuals can be aged, ChesMMAP-specific age-length keys (ALKs) were developed (Coggins Jr et al., 2013). This was required due to the multiple annual sampling events (i.e. bi-monthly cruises) and inter-cruise growth. The updated ALKs use year-specific data but in-year cruise data are pooled over two seasons, spring (typically, March - June) and summer (typically, July - November). Once the ALKs were established for each season, all non-aged measured specimens were assigned to length bins, the total number of specimens captured within each length bin at each site was summed (specimens which had been aged remained in the assigned age class), and the season-specific age-at-length proportions was applied to those sums to determine the total number of age-specific fish caught at each site.

<u>Task 2</u>

For the focal species presented here, the vast majority of ageing structures (i.e., otoliths, scales) have been analyzed. Currently, most of the ageing structures that remain to be processed represent species that are: 1) of relatively minor management interest (e.g., oyster toadfish otoliths); 2) involve significantly different preparation and analysis techniques (e.g., elasmobranch vertebrae); or currently have no accepted processing protocols (e.g., butterfish sampled from inshore waters).

Species-specific data were synthesized to characterize age- and length-frequency distributions across various spatial and temporal scales (e.g., by year, season, or region of the Bay) for each species. When available, sex ratio and maturity data were used to develop sex-specific analyses.

Task 3

As with the ageing structures, the vast majority of stomach samples have been analyzed. The diet indices were calculated using a cluster sampling estimator, as each tow yields a cluster of fish at each sampling location (Buckel et al., 1999). Although a variety of diet indices can be calculated using ChesMMAP data, we focused on the contribution by weight, as trophic models typically use biomass as the metric of interest (e.g., Pauly et al., 2000; Buchheister and Latour, 2016; Anstead et al., 2021). Specifically, the contribution of each prey type to the diet by weight (%Q_k) is given by:

$$Q_k = \frac{\sum_{i=1}^{n} M_i \, q_{ik}}{\sum_{i=1}^{n} M_i},$$

where

$$q_{ik} = \frac{w_{ik}}{w_i} * 100,$$

and where n is the number of clusters (species/size-class combinations) of the predator of interest sampled, M_i is the number of individuals of this predator species represented in cluster i, w_i is the total weight of all prey items encountered in the stomachs of that predator sampled from cluster i, and w_{ik} is the total weight of prey type k in those stomachs.

For this report, standardized categories of prey types (fishes, crustaceans, molluscs, worms, misc.) have been developed for all ChesMMAP species. Only those specific prey types greater than or equal to 1.0% of the overall diet are shown (unless the entire category is less than 1.0%). All other specific prey are lumped into a category called ‘x - other’ (x = fishes, molluscs, etc.), which is distinct from unidentified prey types within the category. For the reader’s convenience, the color scheme used for all focal species is the same.

These indices can be coupled with the information generated from Task 2 such that age-, length-, and sex-specific diet characterizations can be developed for each species. Characterizing spatial and temporal variability in these diets is also possible using ChesMMAP data.

Task 4

For each species sampled by the ChesMMAP Survey, a variety of relative abundance trends can be generated according to year, season, and location within Chesapeake Bay.

Absolute abundance estimates (i.e., minimum trawlable abundance) can be generated for each species by combining catch with the area swept by the trawl and gear efficiency. While minimum total or absolute abundance estimates are important for certain bioenergetics and ecosystem level analyses, these estimates can be highly dependent on the underlying assumptions. Thus, fishery assessments typically depend upon relative abundance indices as indicators of abundance. Previous ChesMMAP annual reports have presented an evolving series of relative and absolute abundance estimates, and, from 2011 to 2022, age-specific indices of abundance were presented for species for which identifiable age cohorts are identifiable (Berg et al., 2014).

For this report, we present arithmetic mean abundance indices; this approach was chosen for its consistency with design-based analytical methodology and to complement existing abundance indices throughout the region. Delta-lognormal indices, model-based indices, and other methods of calculating relative abundance are being explored and may replace these indices in future reports, on a species-by-species basis (e.g., Lo et al., 1992).

Task 5

As indicated in Task 1 and detailed further in Appendix I, the ChesMMAP survey began using a new vessel/gear combination in June 2019. Since then, calibration cruises have been undertaken outside of regular survey operations to ensure that no side-by-side vessel effects would bias the survey data. These trips were made soon after regularly scheduled ChesMMAP cruises were completed. Side-by-side tows were completed as simultaneously as possible with the two vessels within approximately one quarter mile of one another. All deployment and retrieval procedures were identical to those employed during regular surveys, including randomly selecting sites for each calibration cruise. Catches were sorted by species and size-class (where appropriate). Aggregate weight and individual length were recorded for each species.

In 2022, we conducted four calibration trips, during which 149 paired tows were completed. This brings our total number of paired tows (2019-2022) to 516, taken during 15 calibration cruises. This was deemed sufficient for robust statistical analysis and thus no further calibration cruises are required.

After considering several statistical analyses, we determined that intercalibration of the two vessel-trawl combinations would be best approached by applying log-Gaussian Cox processes to the paired-tow data (following Thygesen et al., 2019). This method models the size distribution of the population at each sampling site and the size-structured clustering of fish at small temporal and spatial scales to estimate selectivity ratios across the domain of observed size classes. By utilizing a Poisson probability distribution for the catch numbers conditional on latent log-Gaussian variables, the method allows for overdispersion and correlation between catch counts in neighboring size classes. The manuscript describing the application to the ChesMMAP calibration data is currently in review (Latour et al., in review); following its acceptance and publication, we anticipate updating indices for all focal species in the 2024 annual report.

Results

Task 1

The four cruises conducted in 2022, with 240 sites sampled, required a total of 25 work days to complete. As indicated in previous reports, the change in survey design in 2019 (from five 80-station, full-Bay trips prior to 2019 to two 80-station, full-Bay trips and two half-Bay trips from 2019 to present) resulted in a decrease in the total number of work days each year from approximately 40 with the *R/V Bay Eagle* to 25-28 days with the *R/V Virginia*. However, the slower cruising speed of the *R/V Virginia* (~8 kt) compared to the *R/V Bay Eagle* (11-12 kt) and the much higher catch rates and therefore station processing times with the new gear configuration resulted in a lower average number of stations completed per day since 2019.

As anticipated, catch rates for most species increased substantially coinciding with use of the new gear configuration. For some species, much of the increase is due to catching a broader size range, especially on the smaller end, but the increase is very large for almost every species.

Tasks 2-4

For the 12 focal species, we present data summaries in the form of species profiles that address each task element (i.e., single-species stock parameter summarizations, trophic interaction summaries, and estimates of abundance). The profiles are organized first by species, then by type of analysis (task); however, note that the analyses are not labeled with a task number.

For each of the focal species (where sufficient high-quality data are available), the following data are included:

1. A summary table with numbers and biomass captured and measured during each survey year, as well as the numbers of ageing structure and stomach samples preserved and processed.
2. A series of maps showing total biomass at each sampling site, for each cruise during 2022. Note that biomass at each site was standardized by the area swept (i.e., tow distance * net width) and scaled to 10,000 m^2, such that the resulting biomass is presented as kg 10,000 m^{-2}.
3. Figures of overall area-swept-corrected abundance indices by number and biomass, calculated using arithmetic means.
4. Length-frequency data by year, for sexes combined and separately.
5. Age-frequency distributions by year (for those species where appreciable numbers have been captured and otoliths have been processed) in both histogram and bubble plot format, as described above.
6. Diet analyses by weight, using all data collected and analyzed 2002-2022.

Throughout these profiles, when relevant, years during which the survey was conducted aboard the *R/V Bay Eagle* and using the old trawl configuration are indicated by light gray, whereas years during which the survey was conducted aboard the *R/V Virginia* and using the new trawl configuration are indicated by light yellow.

These analyses represent a subset of the biological and ecological analyses which could be completed using ChesMMAP data. Stock assessments regularly include data from ChesMMAP and these data form the basis of many peer-reviewed manuscripts focusing on Chesapeake Bay fishes.

Task 5

Preliminary results of the intercalibration analyses indicate that the *R/V Virginia* captured more total individuals across wider size ranges, and captured animals more frequently as evidenced by consistently higher proportion of tows where at least one animal is collected (Figure 1). Model application was generally successful, suggesting that this is a reasonable approach to intercalibration of the survey data.

Across the size domains of the four species, most of the estimated calibration coefficients exceeded 1.0 indicating that *R/V Bay Eagle* catch data should be scaled upwards to appropriately reflect expected *R/V Virginia* survey catches (i.e., converting *R/V Bay Eagle* survey data into *R/V Virginia* units). For Atlantic croaker and summer flounder, the magnitude of the calibration estimates was quite large over the size range most effectively sampled (Figure 2).

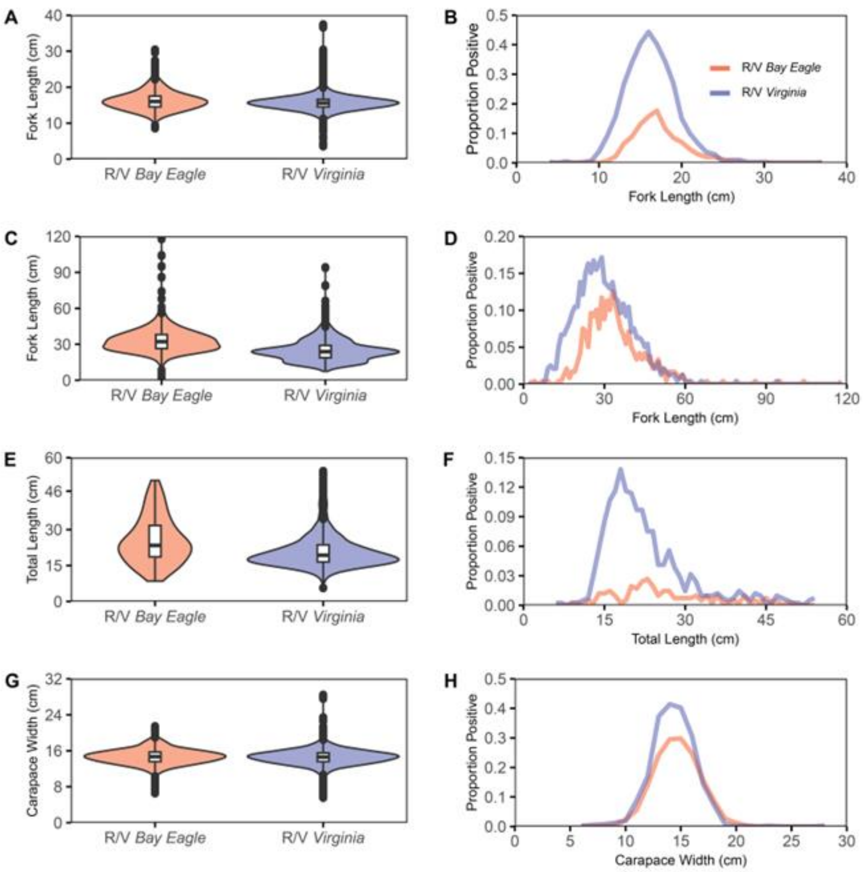

Figure 1: Vessel-specific size composition (first column) and proportion of positive tows in relation to size (second column) data summaries from the paired-tow calibration experiment for (A, B) Atlantic croaker, (C, D) striped bass, (E, F) summer flounder, and (G, H) adult female blue crab.

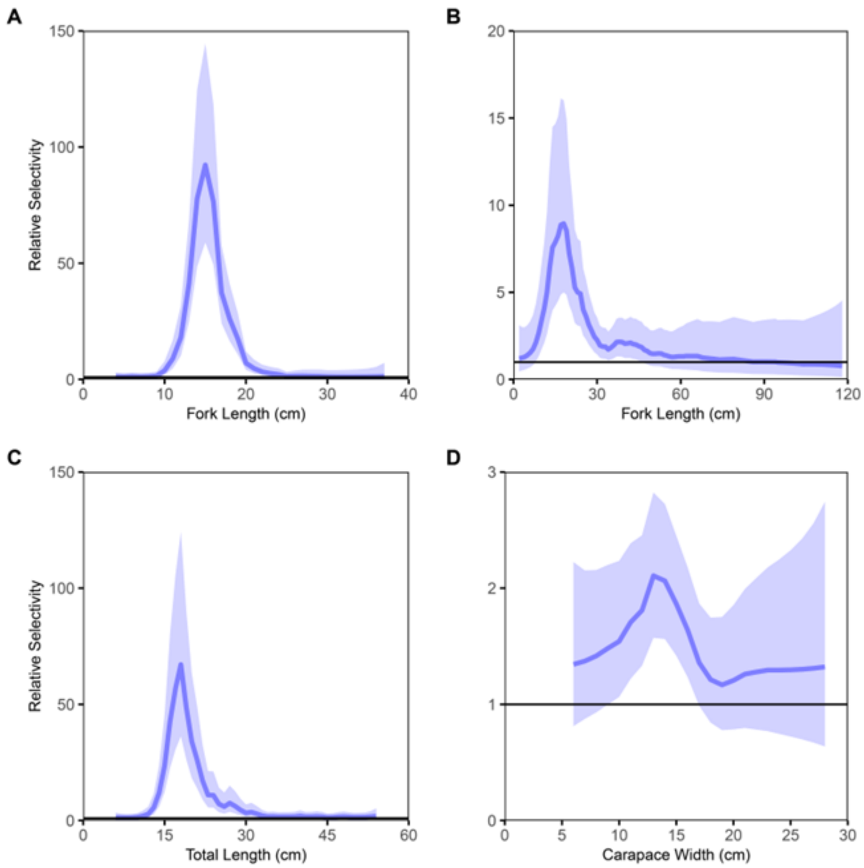

Figure 2: Relative selectivity (blue lines) of the trawl gear on the R/V Virginia (new fishing system) with that on the R/V Bay Eagle (original fishing system) for (A) Atlantic croaker, (B) striped bass, (C) summer flounder, and (D) adult female blue crab. For the new fishing system, values above the horizonal lines indicate higher selectivity, values below indicate lower selectivity, and values at the horizonal lines denote no selectivity differences. Shaded areas are 95% confidence intervals.

Species profiles

Atlantic croaker, *Micropogonias undulatus*

Abundance: Atlantic croaker are frequently collected in high abundance in ChesMMAP catches (Table 1), with over 195,000 individuals captured since 2002. Atlantic croaker declined from relatively high catches in the mid-2000s to a low in 2018. Since 2019, large numbers of small individuals with relatively low total biomass have dominated the catches, suggesting that the new gear is substantially more efficient at capturing these size classes. In 2022, total catch of Atlantic croaker was the third highest in the time series by number.

As a seasonal resident in Chesapeake Bay, Atlantic croaker are typically rare in spring, most abundant in summer cruises and in the southern regions, and decrease in fall during their migration out of the Bay. A similar pattern occurred in 2022, with the majority of Atlantic croaker taken in September in regions C and D (Figure 3).

Through 2018, relative abundance indices were calculated using data collected during May, July, and September, in regions 4 and 5 from only the mid-depth and deep strata. With the 2019 restratification, data from both depth strata of regions C and D in June and September were used. Both relative abundance indices were variable in the early part of the time series, until about 2008, after which both indices experienced a steady decline (Figure 4). Although this decline may be related to large-scale, cyclic patterns in abundance of Atlantic croaker, it has also been linked to a decrease in the utilization of Chesapeake Bay relative to the coastal ocean that has not been documented in the more northern Delaware Bay (Schonfeld et al., 2022). Since 2019, abundances have been higher and more variable, but this is at least partially explained by the change in vessel and sampling gear.

Length and age: In the survey, specimens of Atlantic croaker ranged from about 1.4 to 49.9 cm total length. The size distribution of this species exhibited high interannual variation (Figure 5). Since 2010, the presence of larger (> 30 cm) fish has steadily declined and no individuals > 38 cm total length have been captured. The *R/V Virginia* more efficiently collects small specimens of Atlantic croaker, as evidenced by the larger catches since 2019, but the trend towards a more restricted length-frequency distribution has continued through 2022. Males and females exhibited similar patterns in annual length-frequency distributions (Figure 6). The sex ratio in the catches was variable, usually close to 1:1; however, in some years, such as 2004 and 2018, high catches of females resulted in sex ratios of 1.5-3.5:1.

Ages of Atlantic croaker taken by the survey range from 0 to 17 years (Figure 7). However, as reported in previously, the ChesMMAP survey collects some very small specimens that are designated as age -1; these are fish that were spawned in late summer and fall of a given year, prior to the birth date (1 January) set during an Atlantic croaker ageing workshop sponsored by the Atlantic States Marine Fisheries Commission (see Bonzek et al., 2022). While older specimens (> 8 years) were not uncommon prior to about 2010, a truncation of the age structure, similar to that observed in the length distribution, has occurred. Catches in 2022 continue to display this reduction in older fishes, with only 5 individuals greater than age-2 captured since 2020.

Diet: In the Bay, Atlantic croakers consumed a variety of benthic polychaetes, which represent nearly 40% of their diet by weight (Figure 8). Other invertebrates, including crustaceans, molluscs, and to a lesser degree echinoderms and sea squirts, accounted for another 20% of the diet, and only a small amount of the diet consisted of other fishes. Nearly 30% of the total diet was made up of unidentified material (animal or otherwise), highlighting the benthic and opportunistic nature of this species' feeding habits.

Table 1: Atlantic croaker sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	12,689	2,834.0	68.6	7,082	1,126	1,126	1,104	95
2003	12,217	2,850.3	83.1	5,721	548	548	542	62
2004	20,394	5,330.5	93.5	8,850	717	717	702	254
2005	13,281	3,184.8	89.6	7,757	716	716	704	261
2006	14,878	3,486.6	86.5	8,904	854	854	834	749
2007	12,678	1,963.6	88.5	5,974	526	526	523	503
2008	6,260	1,031.3	65.8	3,070	480	480	460	454
2009	3,797	523.0	82.7	3,250	369	369	361	358
2010	3,243	454.3	67.9	2,355	322	322	317	309
2011	5,187	605.5	67.9	2,776	322	322	291	287
2012	2,448	152.9	50.0	1,998	312	312	280	269
2013	8,971	655.1	53.8	3,684	282	282	237	229
2014	1,449	143.3	34.6	620	111	111	73	71
2015	1,723	167.4	43.6	1,402	160	160	110	107
2016	919	90.6	33.3	551	113	113	69	69
2017	1,318	92.9	35.9	1,037	247	247	190	187
2018	1,164	51.6	26.9	455	88	88	56	56
2019	11,685	919.7	84.4	5,792	354	354	233	227
2020	34,291	1,816.6	84.4	6,970	303	303	194	190
2021	8,832	552.9	81.1	3,849	316	316	205	203
2022	18,038	989.3	71.1	3,788	270	270	136	131

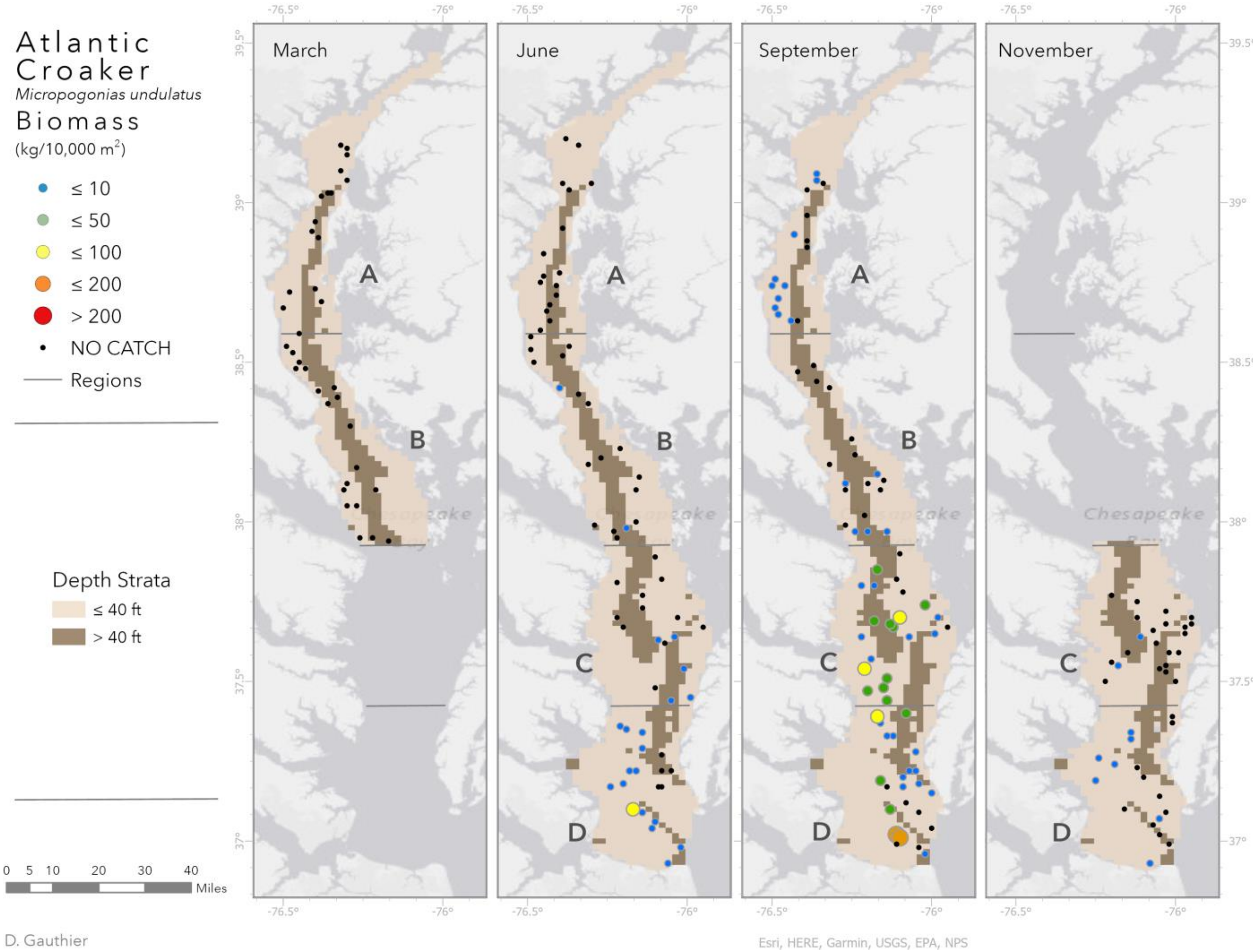

Figure 3: Site-level estimates of biomass (kg 10,000 m^{-2}) of Atlantic croaker in 2022.

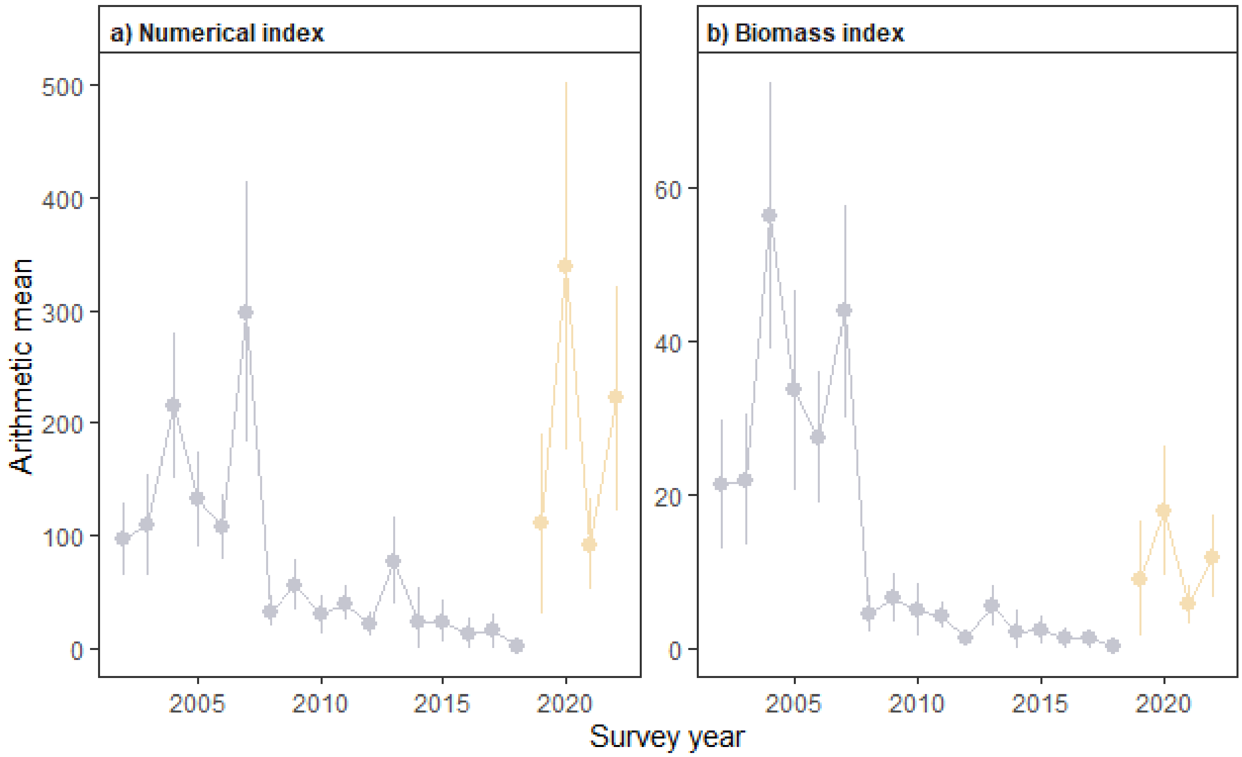

Figure 4: Indices of abundance for Atlantic croaker, by number and biomass, for all ages combined.

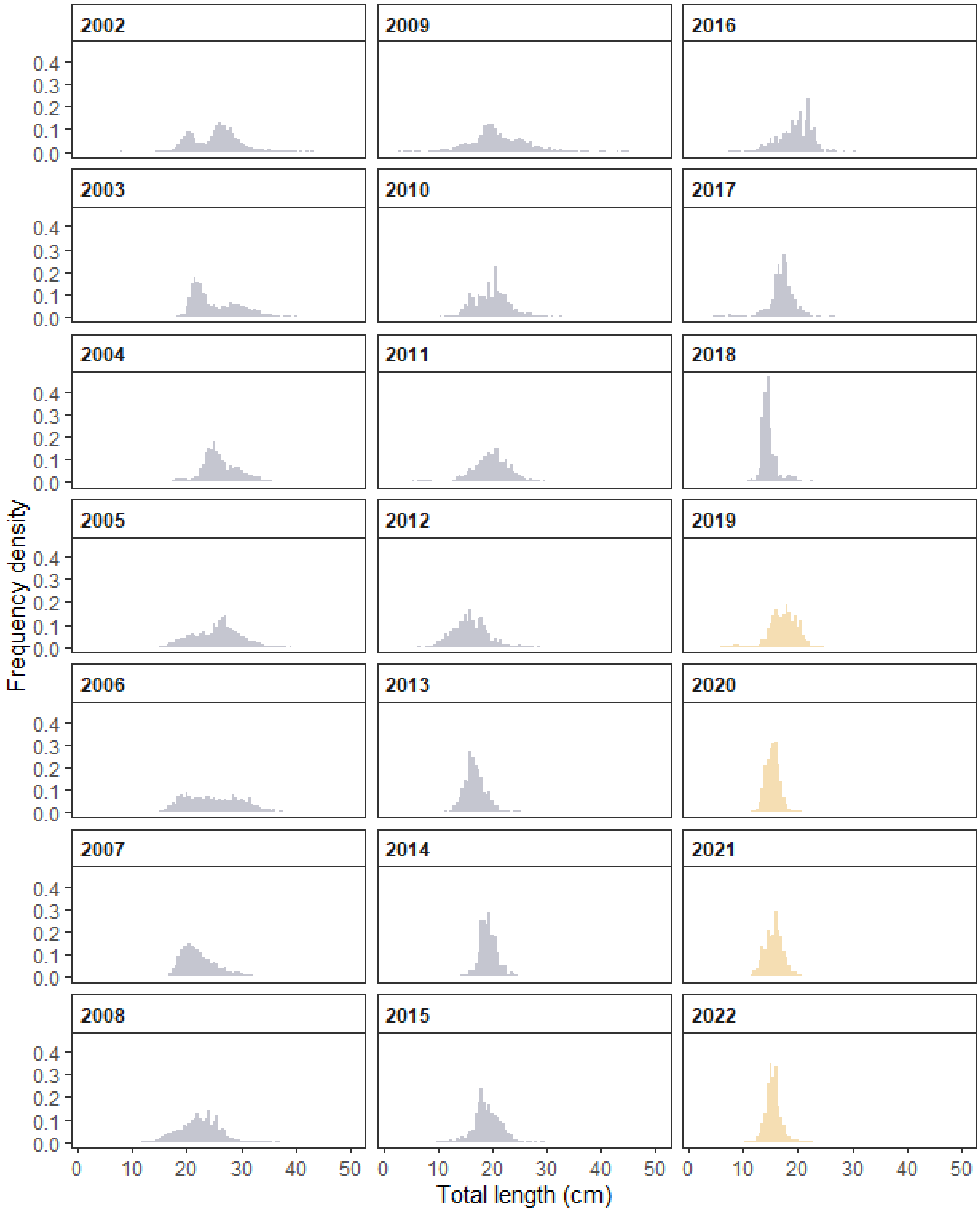

Figure 5: Length-frequency of Atlantic croaker from 2002-2022.

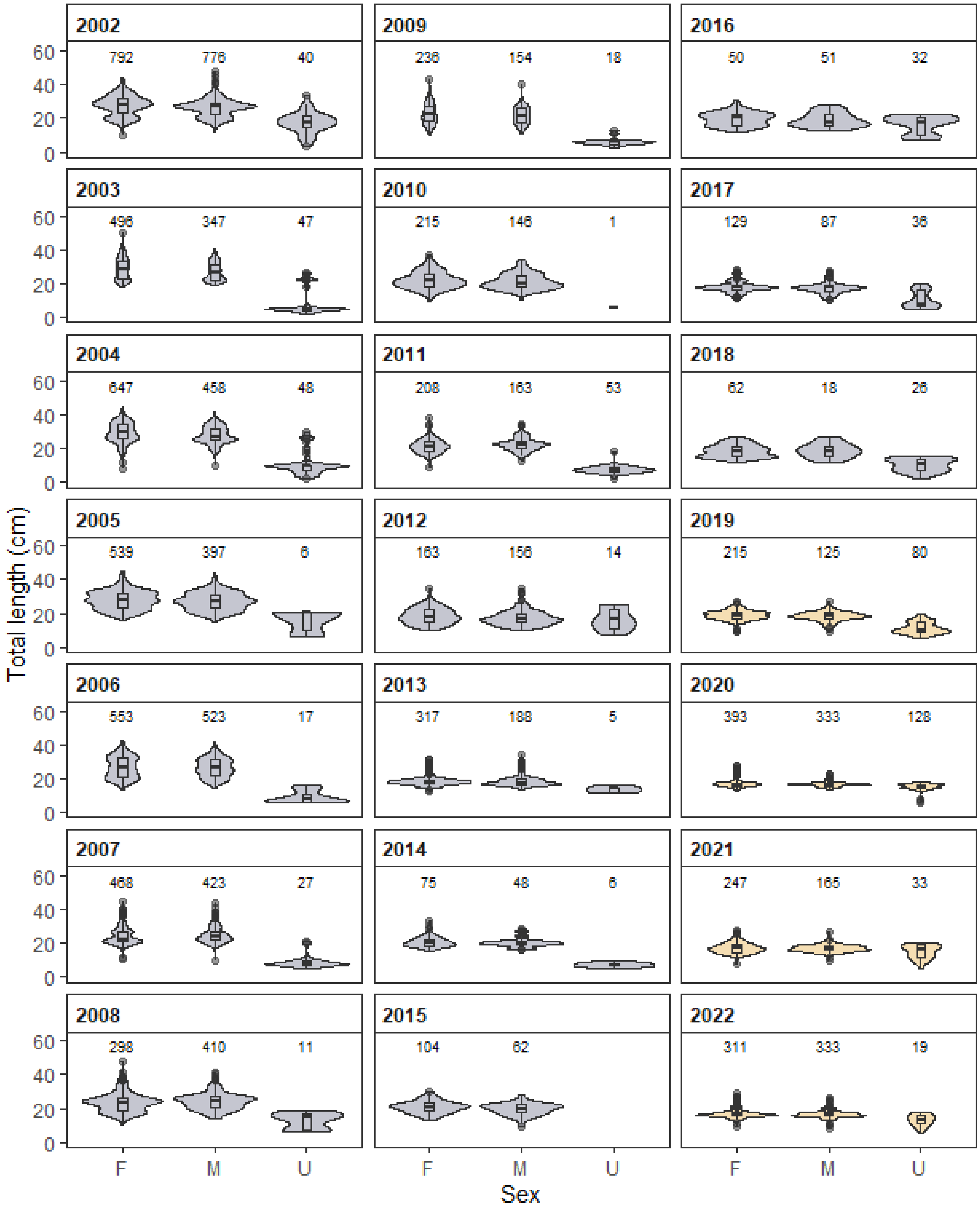

Figure 6: Length-frequency of Atlantic croaker from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

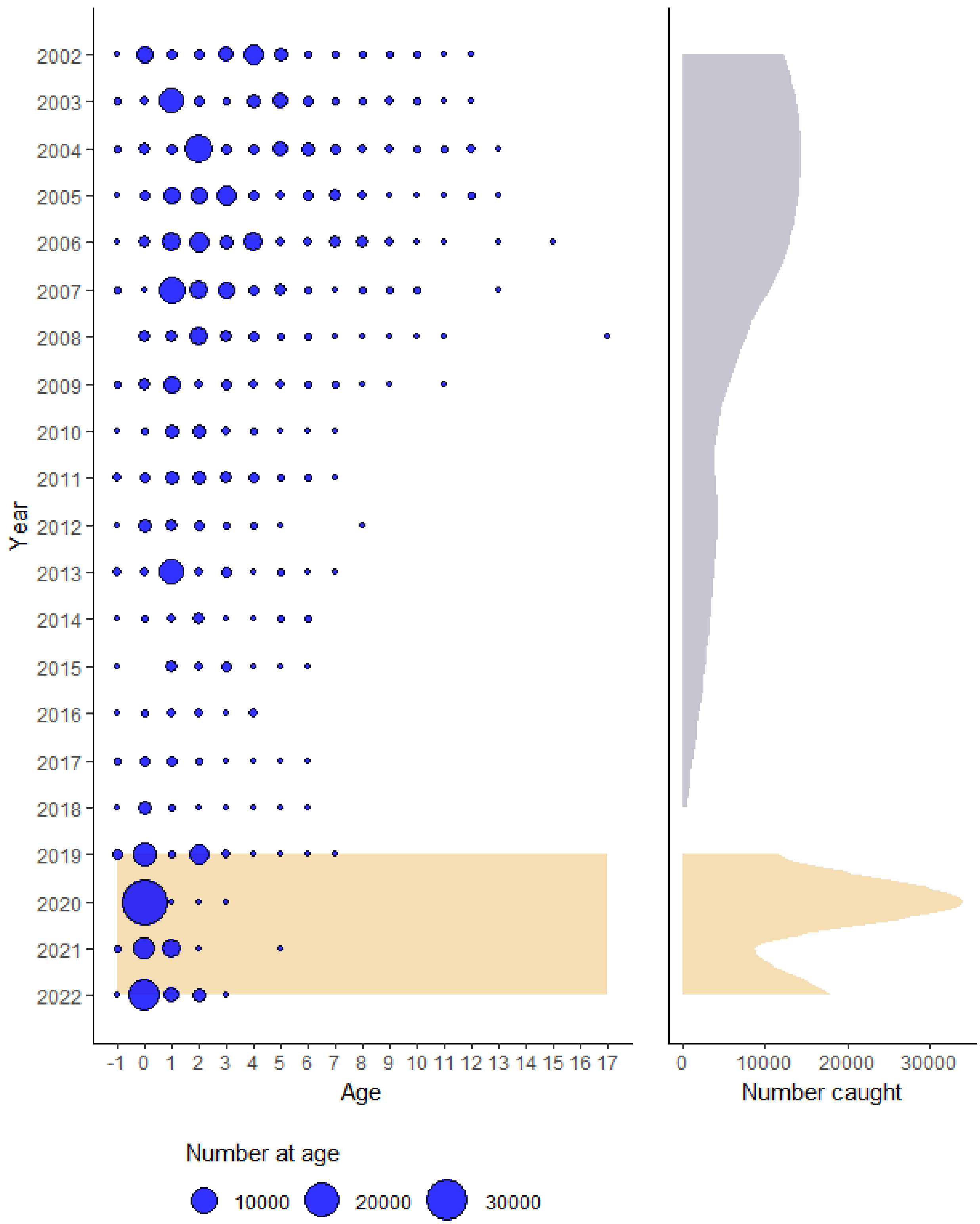

Figure 7: Atlantic croaker age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

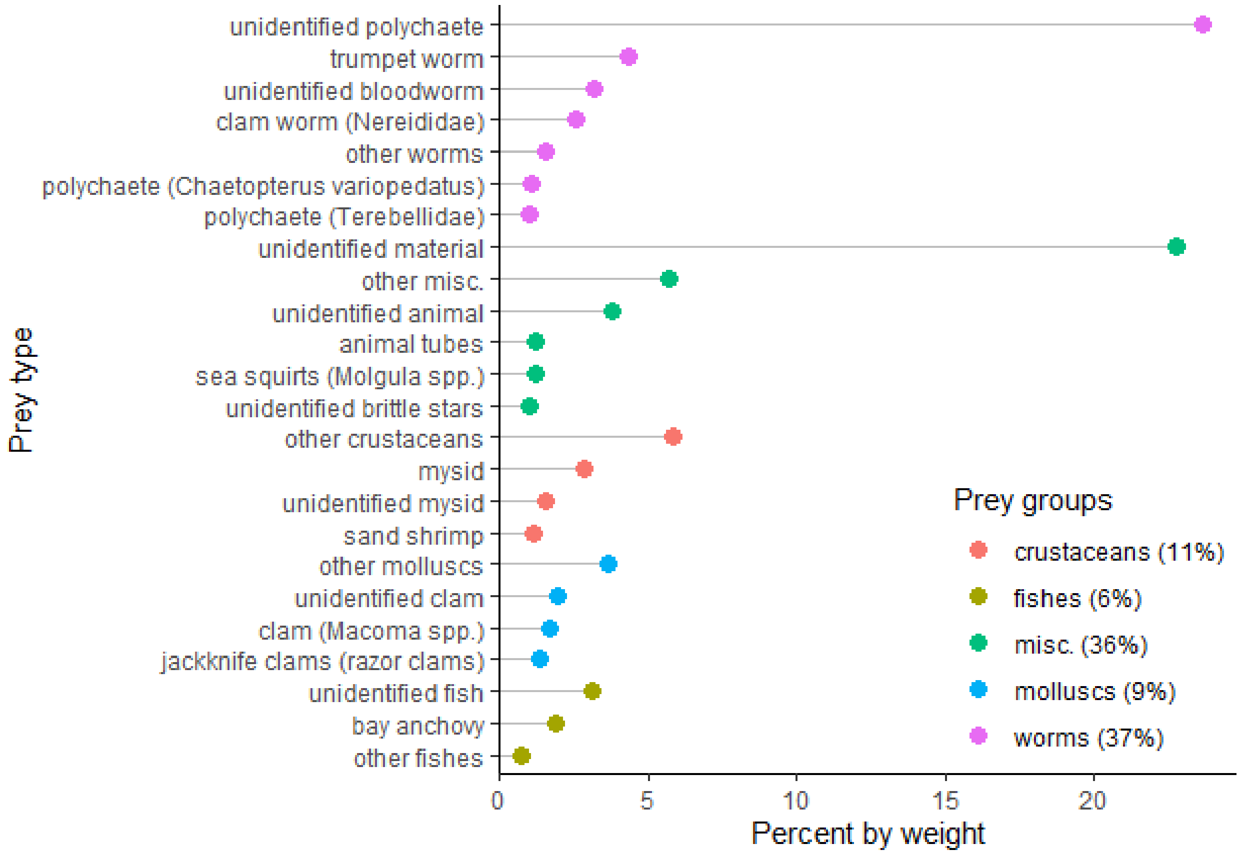

Figure 8: Diet composition of Atlantic croaker, expressed as percent by weight, based on 5084 fish and 2281 clusters.

Black sea bass, *Centropristis striata*

Abundance: Trawling is generally not considered an effective method of sampling structure-oriented species such as black sea bass, and the original ChesMMAP gear caught only 2-50 individuals annually (Table 2). Since 2019, with the new gear configuration, catches have been substantially higher (about 200 to over 500 individuals annually). Total catches were relatively variable, with periods of higher and lower catches. Although only four years of data are available using the new gear, the variability seems to have continued.

Black sea bass were found primarily in the southern regions (C and D), with occasional catches in region B. The highest catches were typically concentrated along the edges of channels (Figure 9).

Through 2018, relative abundance indices were calculated using data collected during July, September, and November, in regions 4 and 5 from all depth strata. With the 2019 restratification, data from both depth strata of regions C and D in June, September, and November were used. Both relative abundance indices were low and variable in the early part of the time series (Figure 10). Since 2019, the indices increased substantially, likely due to the change in vessel and sampling gear; however, the 2022 indices were the lowest since 2019.

Length and age: Specimens of black sea bass captured in this survey ranged from about 4 to 27 cm total length. During the early part of the time series, the size distribution exhibited high interannual variation (Figure 11), due in part to the relatively limited number of specimens captured each year. As more specimens have been captured annually since 2019, a more complete picture of the length-frequency distribution of black sea bass in the Bay has been documented. That being said, specimens captured in this survey are generally small relative to the maximum size of this species (61 cm: Murdy et al., 1997). Due to the small sizes of most individuals captured by ChesMMAP, the majority of specimens observed of this protogynous hermaphroditic species have been females (Figure 12). Black sea bass taken by the survey were young, ranging from 0 to 2 years; individuals aged 1 or even 0 dominate the catches in most years (13).

Diet: In the Bay, black sea bass primarily consume small-bodied crustaceans (e.g.,mysids, amphipods, isopods, mud crabs), which represent over 60% of their diet by weight (Figure 14). Other invertebrates, including polychaetes, brittle stars, and razor clams, account for another 20% of the diet. Only a small amount of the diet consists of other fishes, particularly bay anchovy. Less than 10% of the total diet is made up of unidentified material (animal or otherwise).

Table 2: Black seabass sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	50	4.4	9.8	50	48	48	46	46
2003	42	5.0	15.3	42	32	32	31	31
2004	14	2.2	7.8	14	14	14	14	14
2005	13	1.7	5.3	13	13	13	13	12
2006	22	1.7	6.7	22	17	17	16	16
2007	30	1.8	13.6	30	30	30	29	28
2008	34	2.2	5.9	34	28	28	26	25
2009	35	2.0	14.1	35	35	35	35	34
2010	23	0.6	8.9	23	23	23	22	22
2011	23	1.4	9.7	23	23	23	21	21
2012	9	0.4	2.3	9	9	9	8	7
2013	2	0.1	1.5	2	2	2	1	1
2014	11	0.6	3.7	11	11	11	8	8
2015	11	0.5	5.9	11	11	11	9	9
2016	42	2.0	16.3	42	42	42	30	29
2017	35	1.3	7.4	35	34	34	22	22
2018	8	0.4	1.5	8	8	8	4	4
2019	445	11.1	51.1	445	209	209	148	147
2020	507	16.7	60.7	507	256	256	192	189
2021	514	19.7	57.8	514	263	263	179	177
2022	220	7.5	40.7	220	155	155	99	99

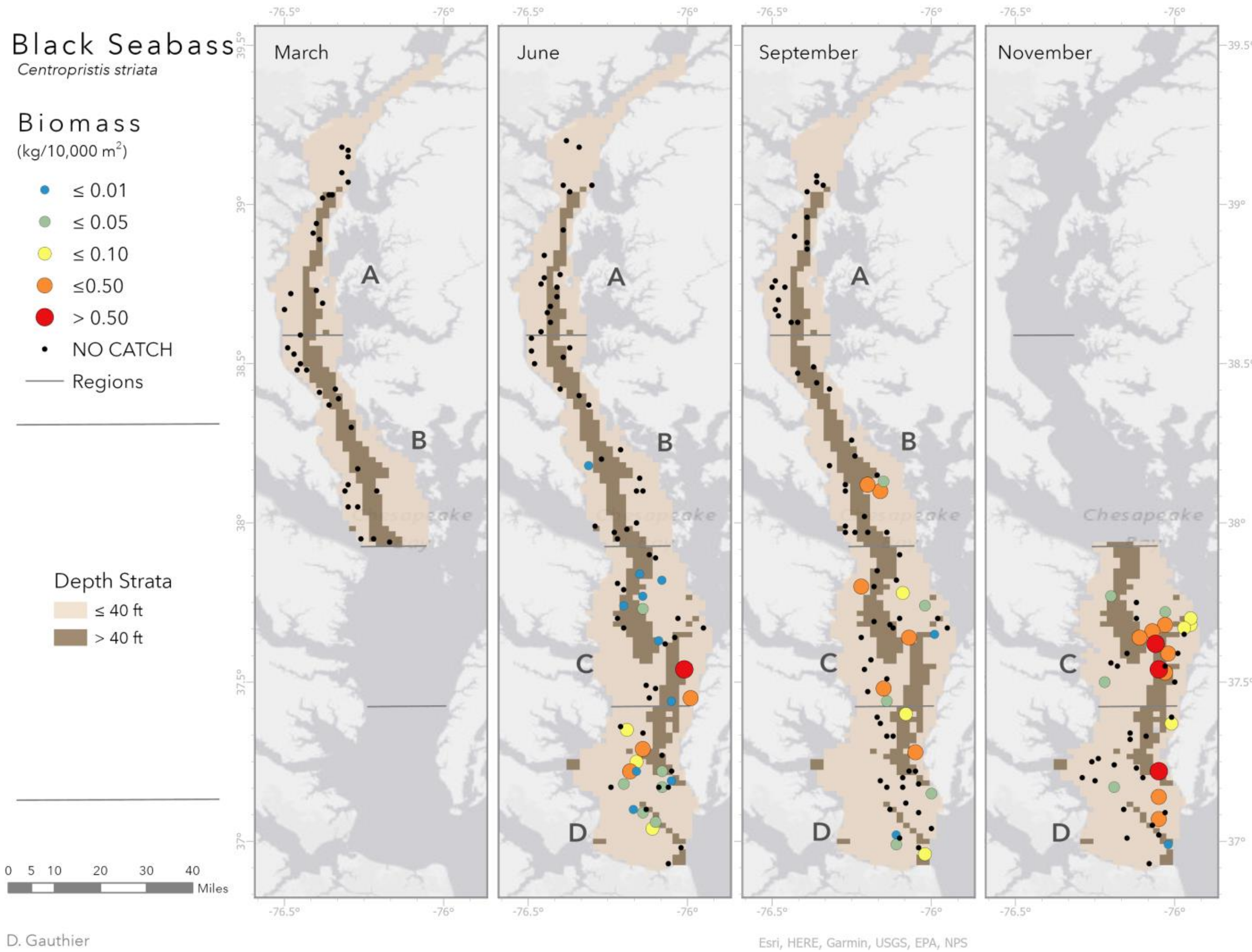

Figure 9: Site-level estimates of biomass (kg 10,000 m^{-2}) of black seabass in 2022.

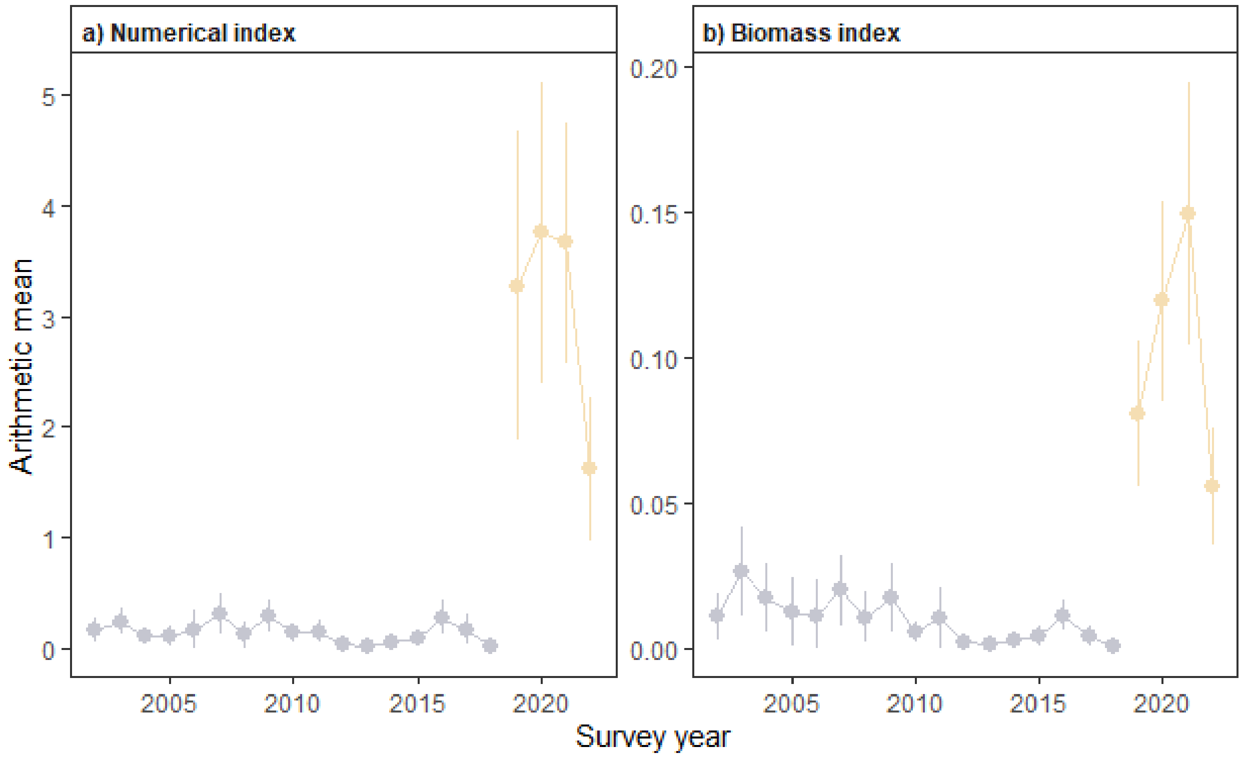

Figure 10: Indices of abundance for black seabass, by number and biomass, for all ages combined.

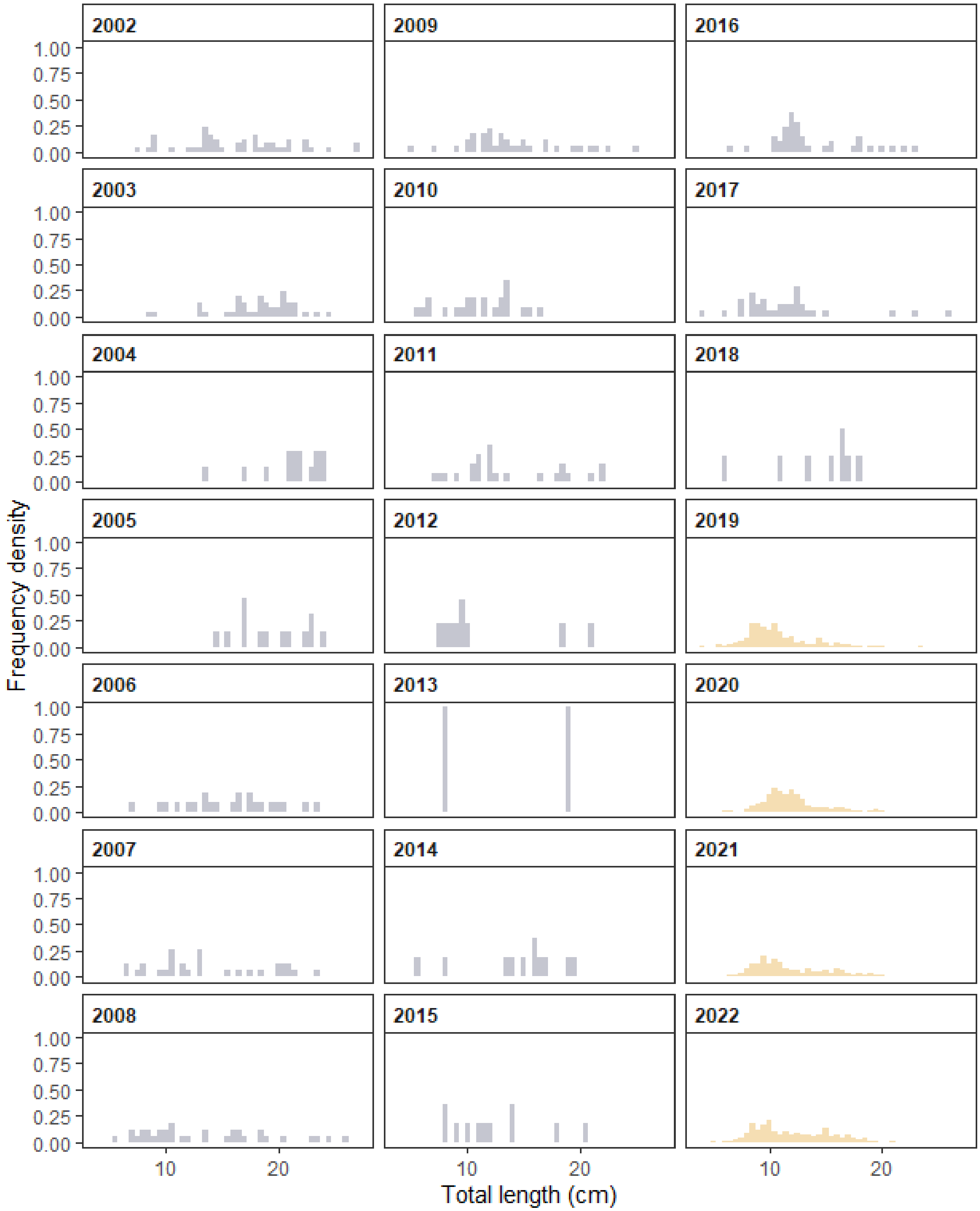

Figure 11: Length-frequency of black seabass from 2002-2022.

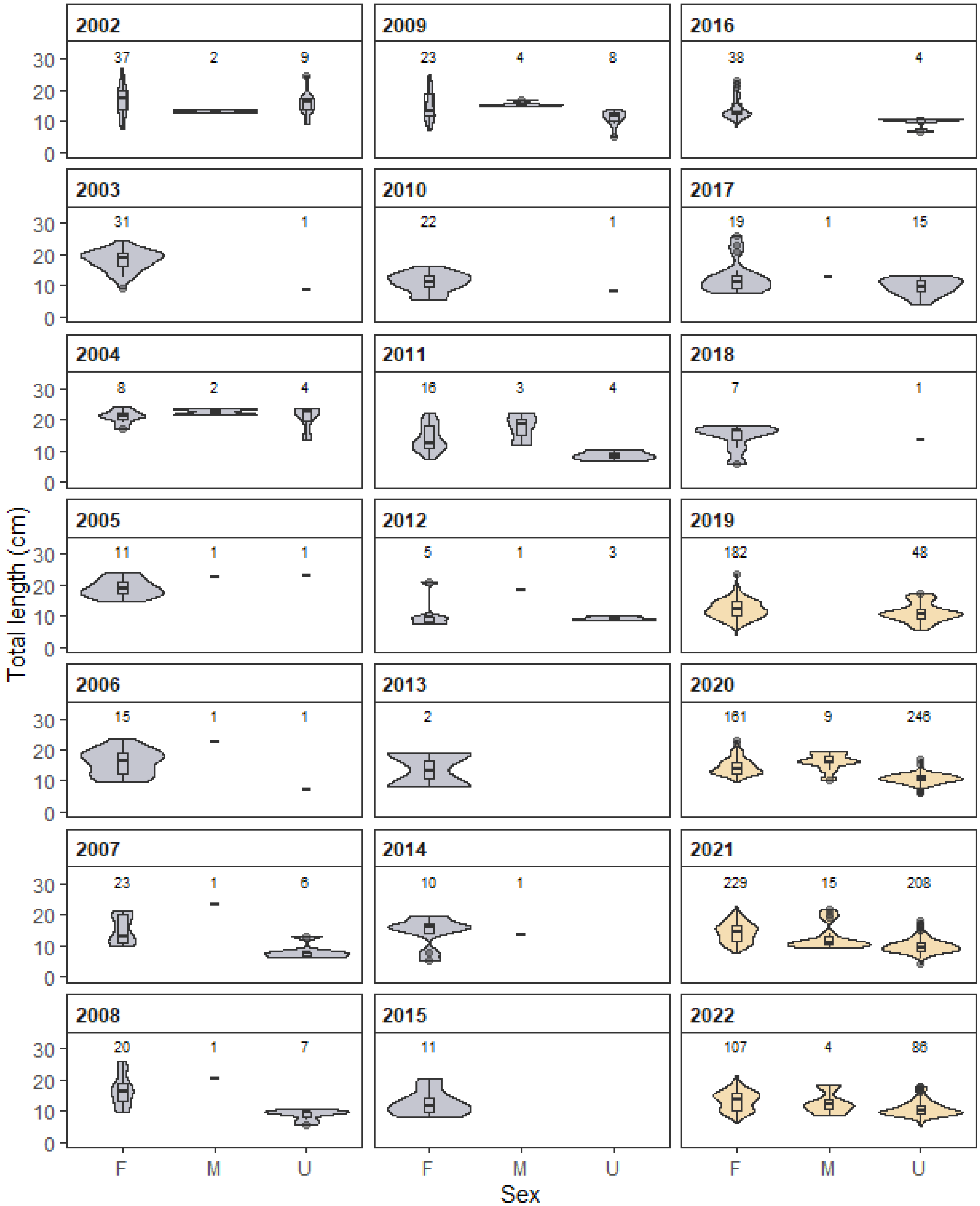

Figure 12: Length-frequency of black seabass from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

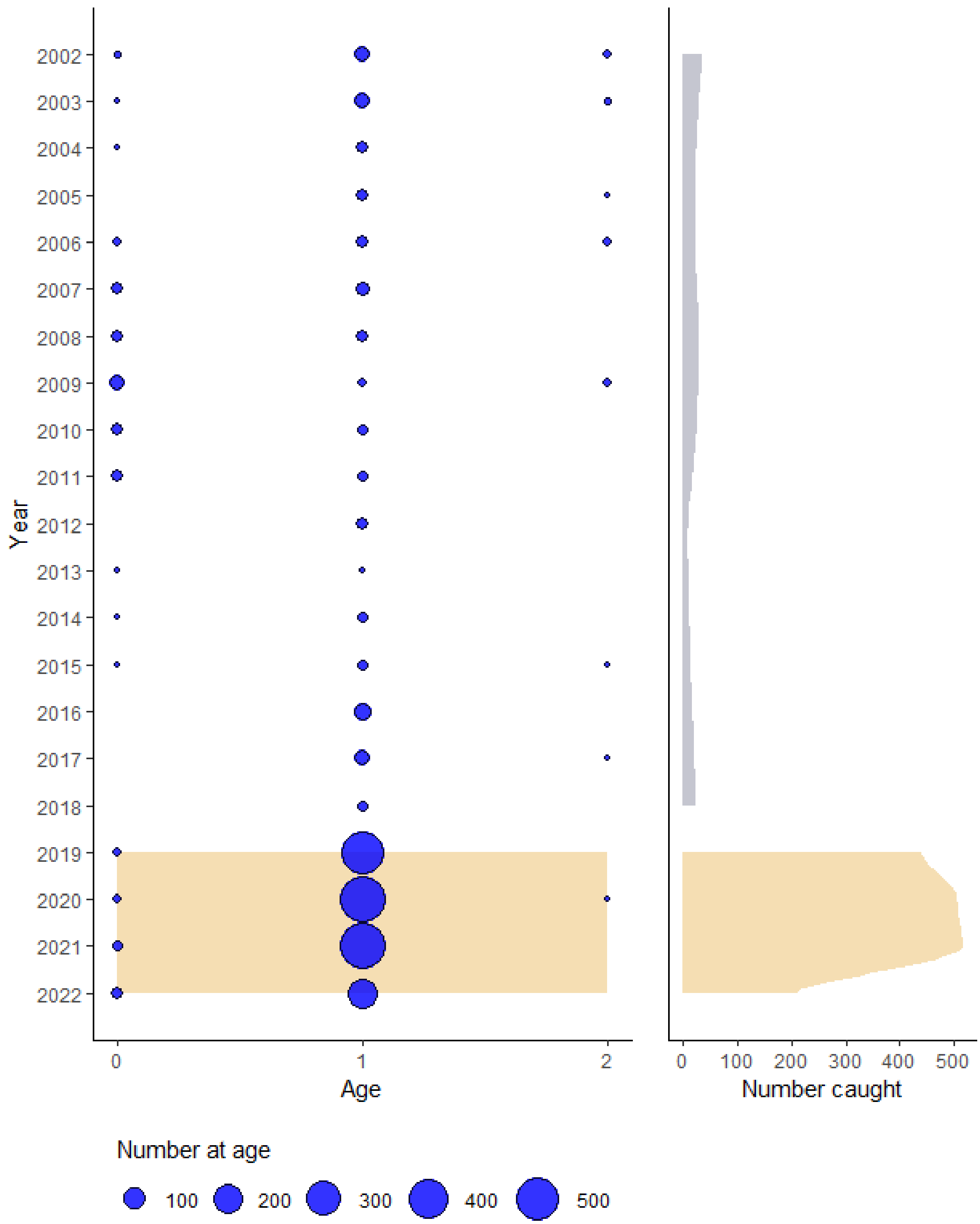

Figure 13: Black seabass age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

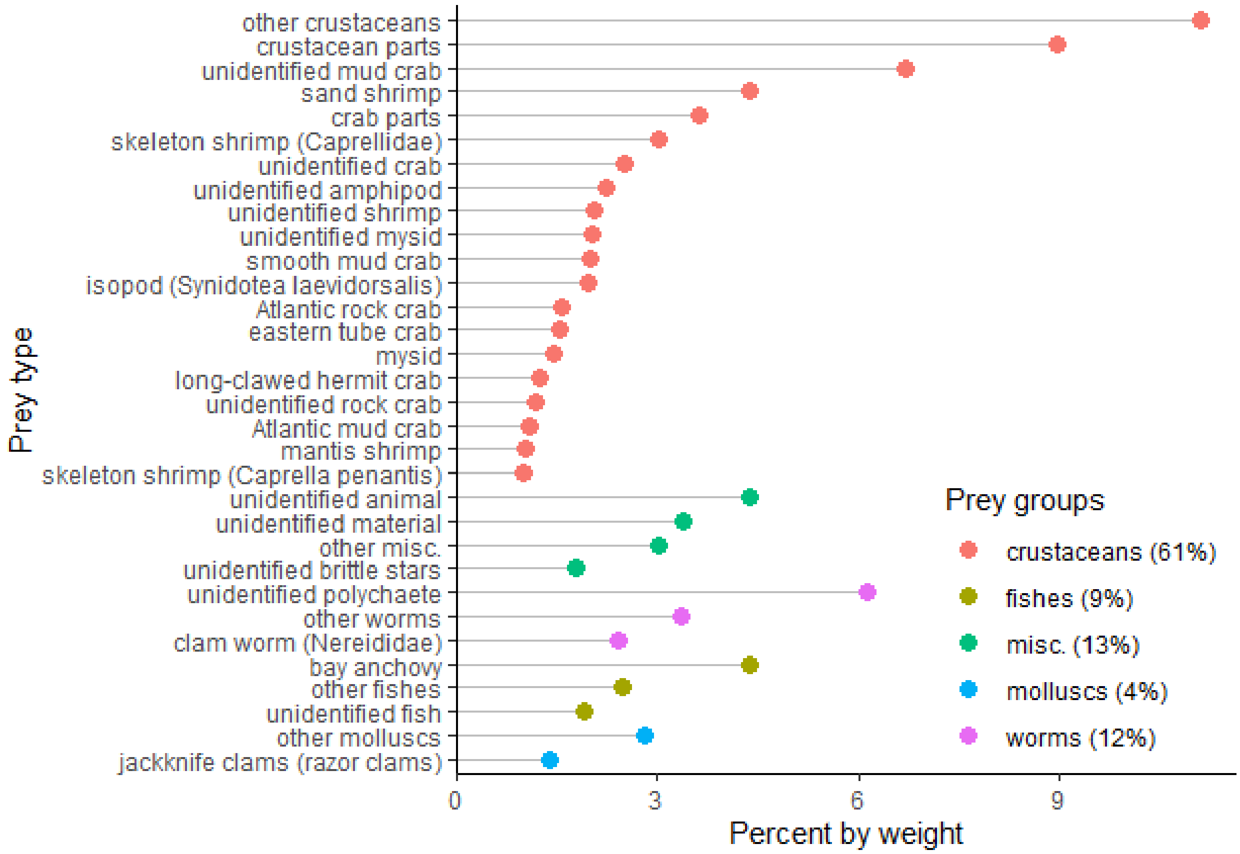

Figure 14: Diet composition of black seabass, expressed as percent by weight, based on 941 fish and 477 clusters.

Bluefish, *Pomatomus saltatrix*

Abundance: Due to the fast-swimming and pelagic nature of bluefish, this species is not considered to be well sampled by ChesMMAP, though some useful information can be generated from these survey data. The original ChesMMAP gear caught 8-126 individuals annually (Table 3). Since 2019, with the new gear configuration, catches have been more variable, with time-series high catches occurring in 2020 and 2021 (208 and 247 individuals, respectively), followed by only 60 individuals in 2022. Whether the high catches were primarily due to increased abundance or increased efficiency of the sampling gear is currently unknown.

Bluefish were caught sporadically throughout the Bay, though abundance is generally highest in southern regions (C and D) and shallow depths (Figure 15). Catches were typically highest late in the year, presumably as the young-of-the year fish are moving into deeper waters in preparation for migration out of the Bay.

Through 2018, relative abundance indices were calculated using data collected during September and November cruises, in regions 4 and 5 (note that some previous reports used all five regions) from all depth strata. With the 2019 restratification, data from both depth strata of regions C and D in September and November were used. Both relative abundance indices were variable prior to 2011, with alternating years of high and low abundance (Figure 16). From 2012 to 2018, indices remained consistently fairly low, though with an increasing trend. Since 2019, with the change in vessel and gear, indices became increasingly volatile at both intra- and inter-annual scales.

Length and age: Most individuals sampled in the survey are less than 35 cm fork length and, due to the small number of specimens captured and to the protracted spawning season of this species, it is difficult to differentiate cohorts in length frequencies (Figure 17). No pattern of sexual differentiation by size has been observed and sex ratios are relatively variable (Figure 18). Nearly all bluefish captured in the survey are age-0 or age-1 individuals, and in most years, the majority are age-0 fish (Figure 19).

Diet: Bluefish collected in the survey are highly piscivorous, with almost 90% of the diet constituting small-bodied fishes such as bay anchovy, spot, and Altantic menhaden (Figure 20). Crustaceans, mainly mysids and sand shrimp, represent most of the remainder of the diet.

Table 3: Bluefish sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	34	10.7	1.3	34	34	34	24	23
2003	114	31.7	29.4	114	74	74	63	62
2004	28	10.0	12.9	28	27	27	22	22
2005	108	22.2	22.1	108	71	71	60	60
2006	23	5.5	12.7	23	23	23	17	17
2007	58	18.2	31.8	58	50	50	44	44
2008	52	15.8	6.7	52	27	27	14	13
2009	11	2.3	6.7	11	11	11	9	9
2010	126	20.2	3.3	82	30	30	13	12
2011	8	2.3	5.6	8	8	8	7	6
2012	17	4.0	8.3	17	17	17	12	12
2013	32	5.4	7.9	32	32	32	26	26
2014	44	5.9	16.7	44	39	39	26	25
2015	125	18.5	17.8	125	49	49	28	28
2016	36	9.8	6.7	36	36	36	19	19
2017	40	6.6	7.8	40	31	31	20	20
2018	85	8.4	14.4	85	41	41	24	24
2019	35	6.4	6.7	35	33	33	14	14
2020	208	23.2	27.8	208	97	97	54	53
2021	247	23.9	28.9	247	122	122	81	79
2022	60	12.2	18.9	60	52	52	27	26

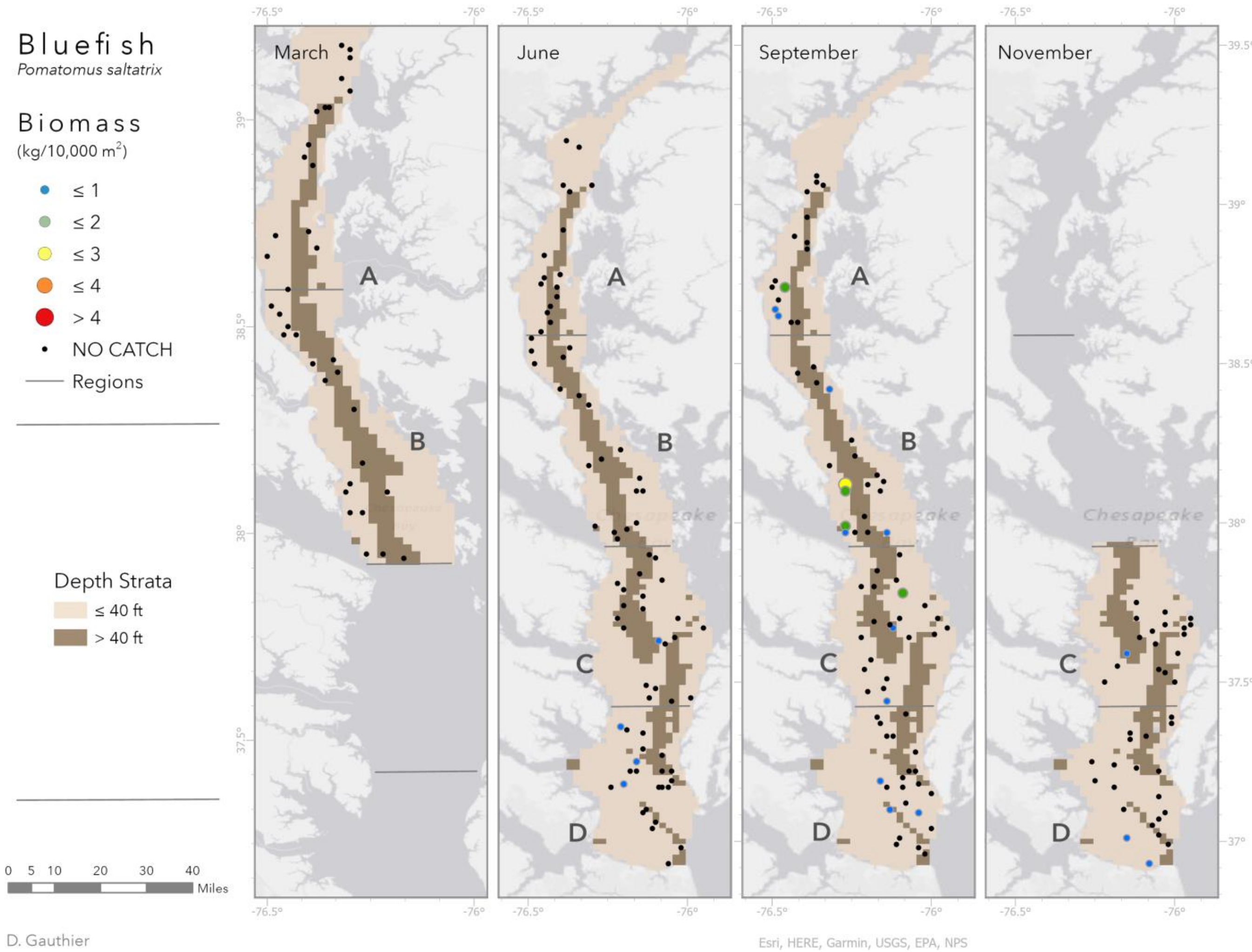

Figure 15: Site-level estimates of biomass (kg 10,000 m^{-2}) of bluefish in 2022.

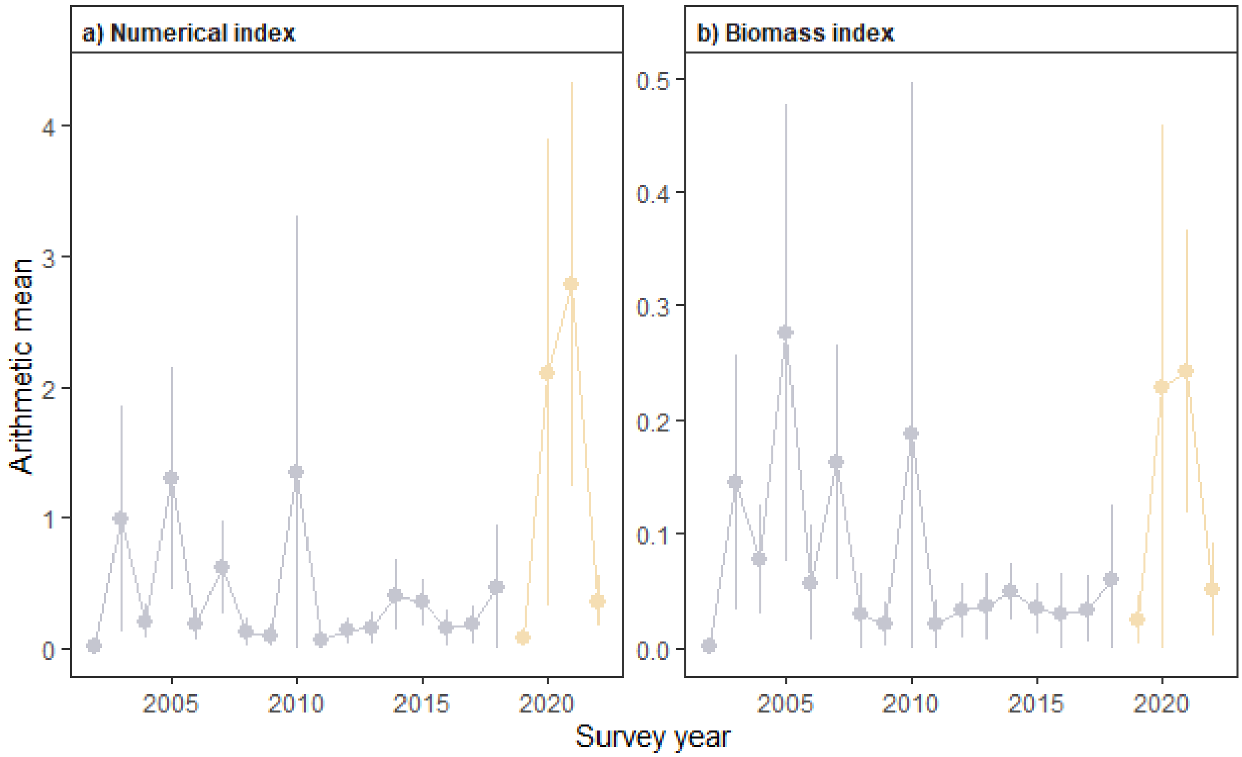

Figure 16: Indices of abundance for bluefish, by number and biomass, for all ages combined.

Figure 17: Length-frequency of bluefish from 2002-2022.

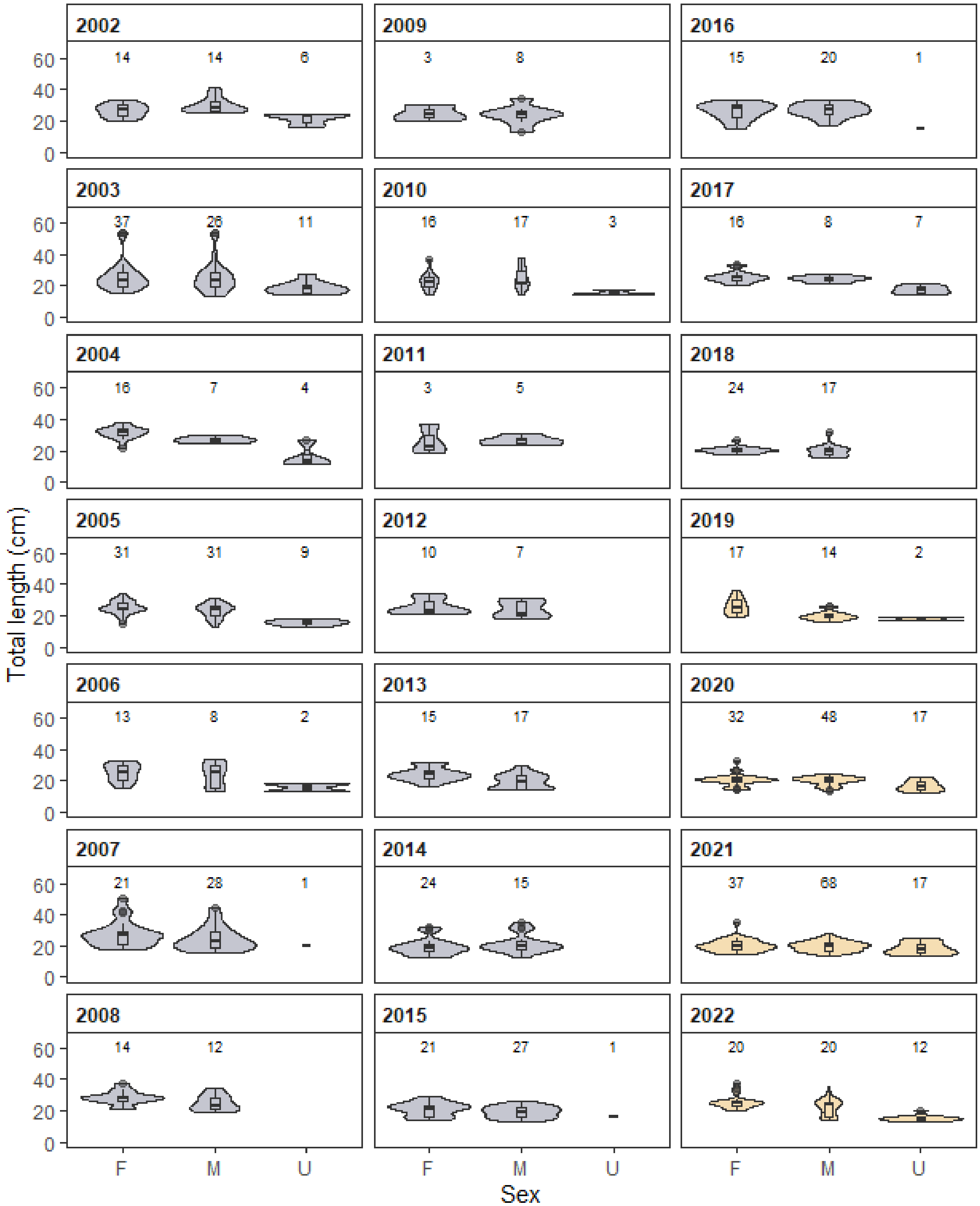

Figure 18: Length-frequency of bluefish from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

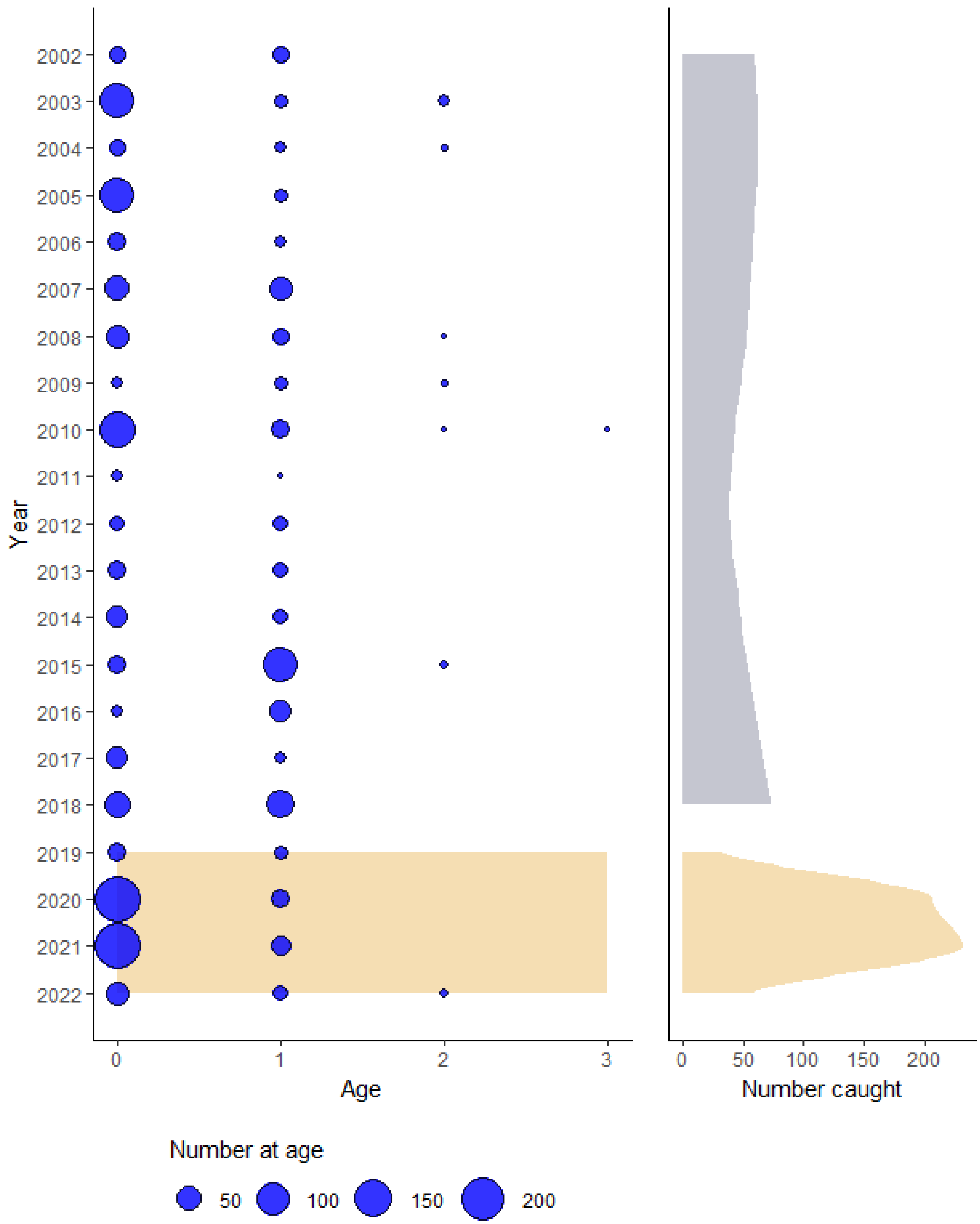

Figure 19: Bluefish age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

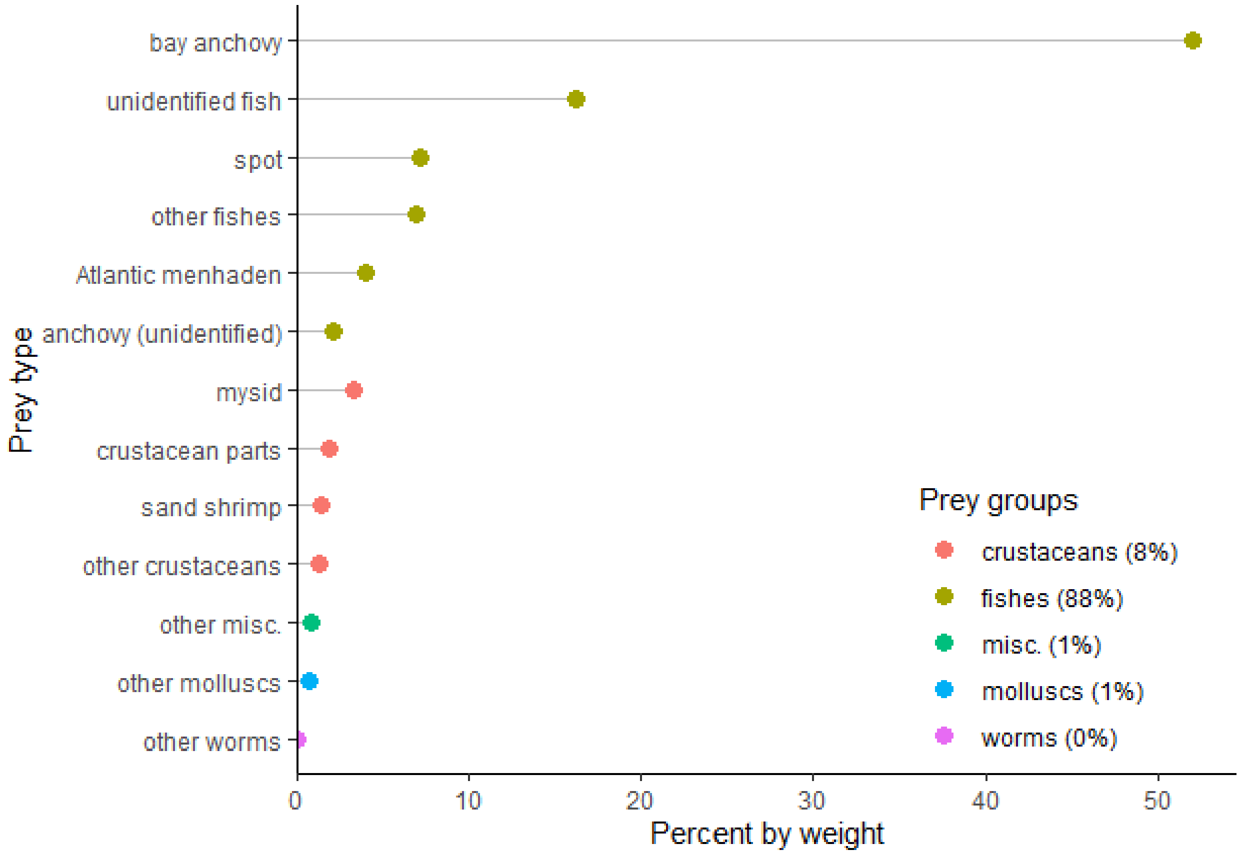

Figure 20: Diet composition of bluefish, expressed as percent by weight, based on 594 fish and 340 clusters.

Butterfish, *Peprilus triacanthus*

Abundance: Butterfish are moderately abundant in the survey, with several hundred to over 2,600 specimens typically captured during any survey year (Table 4). Since 2019, with the new gear configuration, catches have been high, with the three largest catches occurring in 2020, 2021, and 2022. These high catches are likely due to increased efficiency of the new sampling gear, though this requires verification.

Butterfish were caught almost exclusively in the southern regions (C and D) and shallow depths (Figure 21). Butterfish abundance follows a generally predictable annual pattern, building from near-zero during March, increasing in abundance through the spring and summer (albeit still low), and reaching a maximum during the September and November cruises; however, in 2022, catches were lower in November relative to the June and September cruises.

Through 2018, relative abundance indices were calculated using data collected during September and November cruises, in regions 4 and 5 from all depth strata (note that some previous reports used only the mid-depth strata). With the 2019 restratification, data from both depth strata of regions C and D in September and November were used. Prior to 2019, the numerical abundance index was variable but with a slight decline after 2006 while the biomass index indicated a more significant decline in the mid-2000s to 2018 (Figure 22). Since 2019, both indices have increased, likely due to increased gear efficiency.

Length and age: Yearly length-frequency distributions appear to reveal at least two year-classes of varying strength present in the Chesapeake Bay fish during any given year (Figure 23), however this will require further analysis. This program (and others) has found butterfish collected from estuarine areas extremely difficult to age. We are still investigating methods to obtain accurate age determinations from otolith samples.

Diet: Analyses of butterfish stomachs early in the program revealed a high percentage of generally unidentifiable gelatinous zooplankton and other unidentifiable items. It was determined that further analyses of butterfish diets were not an efficient use of resources and the decision was made to discontinue preservation and analysis of butterfish stomachs.

Table 4: Butterfish sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	310	18.3	18.7	310	170	0	168	158
2003	1,000	57.4	62.7	1,000	334	0	334	17
2004	1,133	113.4	55.9	1,071	316	0	316	1
2005	693	48.0	57.0	693	294	0	293	0
2006	634	43.7	62.0	634	3	0	1	0
2007	204	18.8	47.7	204	0	0	0	0
2008	318	22.0	37.8	318	2	0	0	0
2009	415	18.7	55.6	415	0	0	0	0
2010	429	21.8	36.7	429	0	0	0	0
2011	366	22.5	44.9	366	0	0	0	0
2012	991	65.3	35.7	991	0	0	0	0
2013	220	9.6	29.2	220	1	0	0	0
2014	409	20.2	36.7	409	0	0	0	0
2015	402	25.6	21.1	402	0	0	0	0
2016	300	23.3	28.9	300	0	0	0	0
2017	408	21.8	36.7	408	0	0	0	0
2018	124	6.7	20.0	124	0	0	0	0
2019	828	39.9	35.6	828	0	0	0	0
2020	2,616	75.6	61.1	1,876	0	0	0	0
2021	1,569	73.9	57.8	1,569	0	0	0	0
2022	1,359	62.0	70.0	1,359	0	0	0	0

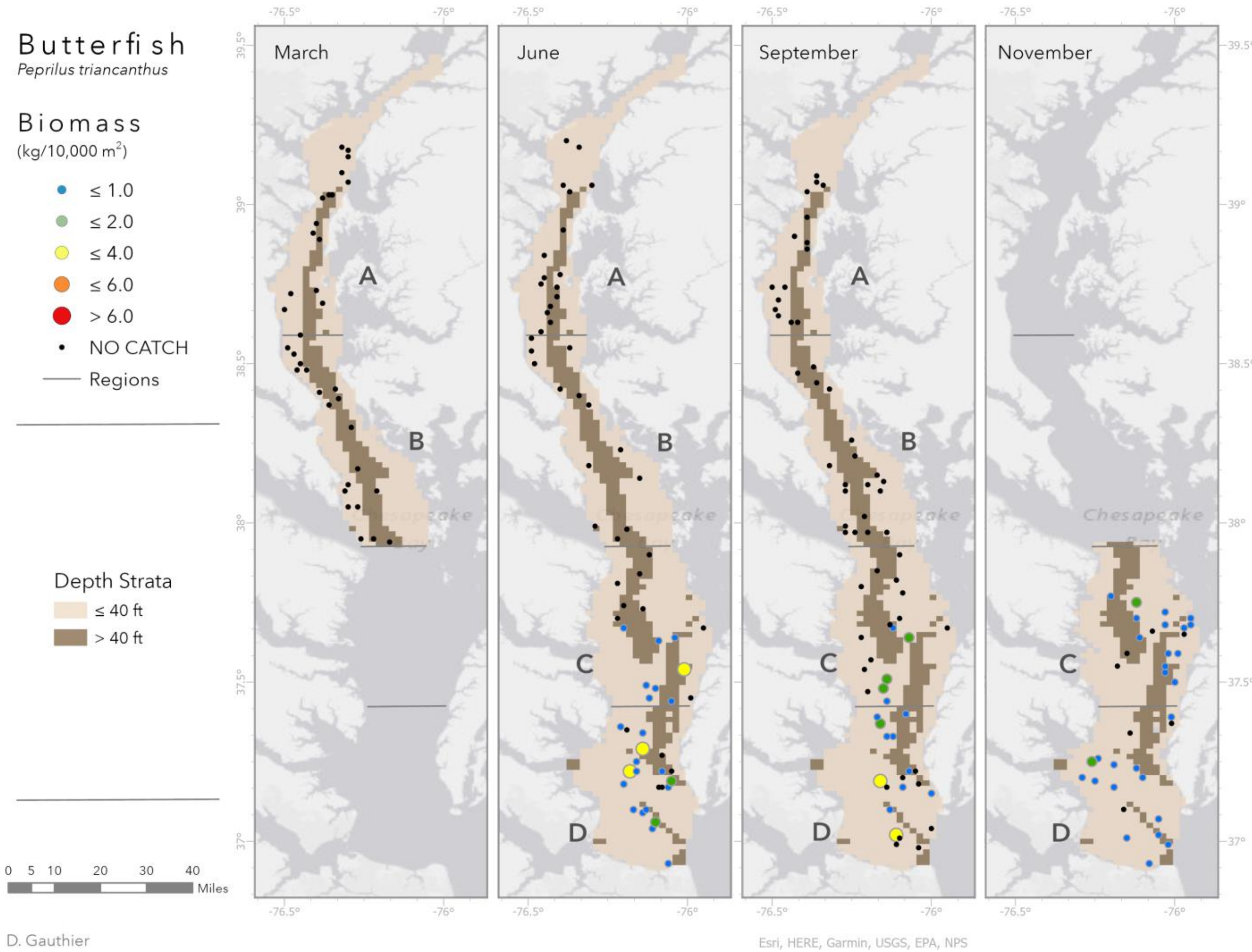

Figure 21: Site-level estimates of biomass (kg 10,000 m^{-2}) of butterfish in 2022.

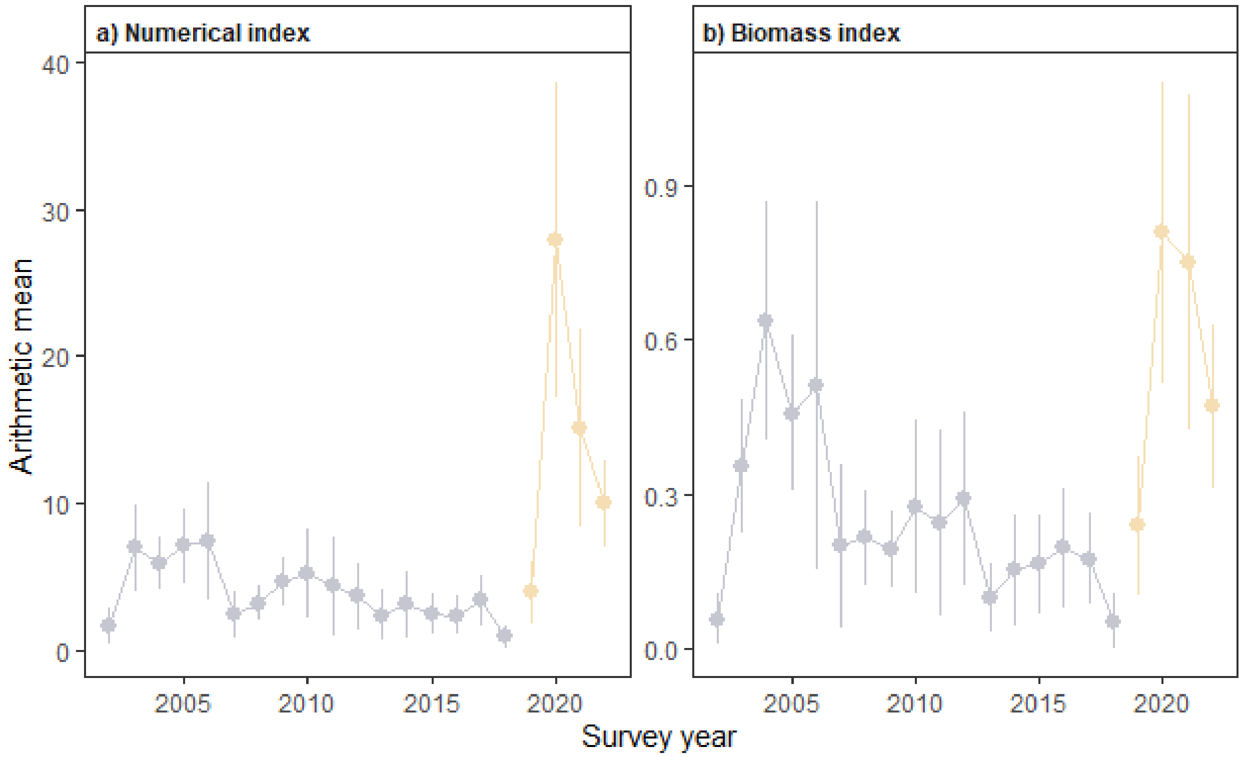

Figure 22: Indices of abundance for butterfish, by number and biomass, for all ages combined.

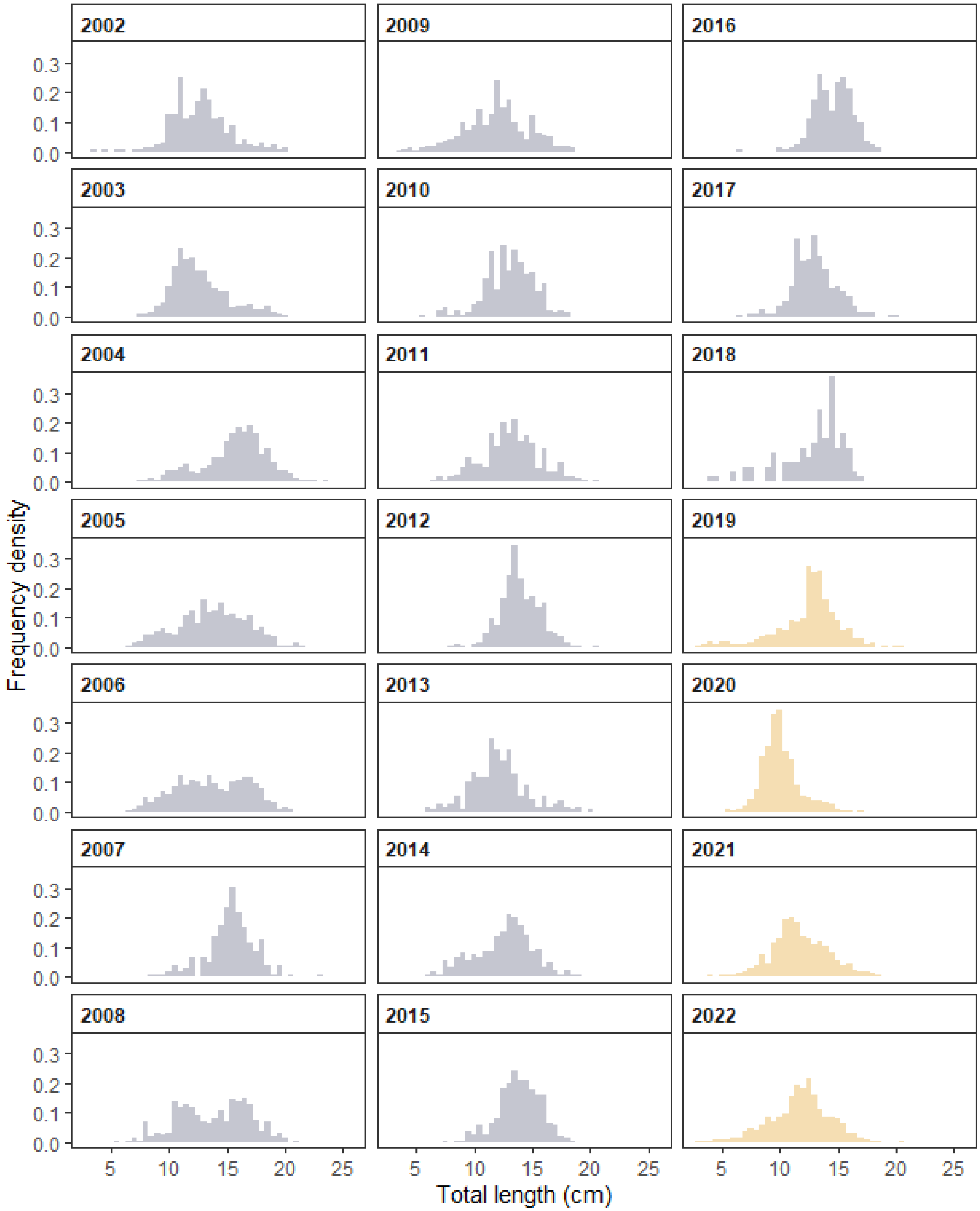

Figure 23: Length-frequency of butterfish from 2002-2022.

Kingfishes, *Menticirrhus* spp.

The ranges of three closely related species, northern kingfish (*Menticirrhus saxatilis*), southern kingfish (*Menticirrhus americanus*), and Gulf kingfish (*Menticirrhus littoralis*) overlap in Chesapeake Bay. While some specimens are easily separable in the field, many are not. We have therefore adopted the practice of combining all of these specimens into a single category of kingfishes (*Menticirrhus* spp.). This practice is consistent with the manner in which these species are landed and reported in the fishery.

Abundance: Kingfishes were moderately abundant in the survey, with the original ChesMMAP gear catching approximately 100-600 individuals annually (Table 5). Since 2019, with the new gear configuration, catches have been much higher, about 1,500-6,000 per year. Whether the high catches were primarily due to increased abundance or increased efficiency of the sampling gear is currently unknown.

Catches of kingfishes occurred almost exclusively in the southern regions (C and D) and shallow depths (Figure 24). Catches were highest in the warmer months and remained high into November.

Through 2018, relative abundance indices were calculated using data collected during May, July, September, and November cruises, in regions 4 and 5 from all depth strata. With the 2019 restratification, data from both depth strata of regions C and D in June, September, and November were used. Both relative abundance indices were increasing through about 2010, followed by a decline from 2011-2015 that brought the indices back to levels observed at the beginning of the time series (Figure 25). Indices declined again from a high in 2016 until the change in vessel and gear in 2019; since then, indices have been very high and variable at both intra- and inter-annual scales.

Length and age: Due to the relatively small number of specimens captured during early survey years and the overlapping sizes-at-age, it is difficult to interpret length-frequency distributions, though at least two cohorts are apparent in many years (Figure 26). No differential growth patterns between male and female kingfishes have been observed (Figure 27).

Specimens between ages 0 and 7 have been captured in the survey, with most individuals being aged 4 or younger (Figure 28). Year-classes of high (e.g. 2002) and low (e.g. 2004) abundance do seem to track through the stock from year to year, which indicates consistent survey sampling and otolith analysis. This species did not fully recruit to the original ChesMMAP sampling gear until at least age-1 and perhaps even age-2, but the new gear appears to more efficiently capture younger, smaller individuals. As this species is not subjected to regular stock assessments, specimen processing is assigned a lower level of priority and there is currently a backlog of unprocessed otoliths dating to 2012; ages were assigned using the age-length key that was developed based on specimens captured and processed to date.

Diet: Kingfishes collected in the survey have a varied diet (Figure 29). About 40% of the diet was composed of small-bodied crustaceans, such as amphipods and shrimp. Other invertebrates, including worms and molluscs, made up another 45% of the diet; the remainder of the diet included lancelets, unidentified material, and a small amount of fishes.

Table 5: Kingfishes sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	143	18.5	16.4	143	91	91	87	79
2003	68	19.2	12.9	68	55	55	55	50
2004	67	16.0	14.0	67	55	55	50	48
2005	86	15.3	19.3	86	72	72	69	68
2006	120	24.1	26.1	120	94	94	84	83
2007	122	17.7	25.6	122	88	88	78	76
2008	333	62.6	21.7	300	113	113	97	97
2009	195	24.8	36.3	195	152	152	135	134
2010	447	82.5	35.8	447	231	231	206	199
2011	336	55.7	32.4	336	176	175	155	155
2012	148	24.6	25.9	148	114	0	96	92
2013	165	32.1	24.0	165	106	0	77	77
2014	76	14.2	12.8	76	57	0	39	36
2015	156	24.1	19.4	156	112	0	61	60
2016	613	80.1	42.8	613	265	0	166	163
2017	361	55.2	30.6	361	198	0	138	136
2018	239	39.0	37.2	239	167	0	104	104
2019	3,871	435.9	71.9	2,904	331	0	217	213
2020	5,767	579.1	88.1	3,163	282	0	192	191
2021	1,409	188.9	75.6	1,409	264	0	181	179
2022	2,970	351.1	78.5	2,057	358	0	231	229

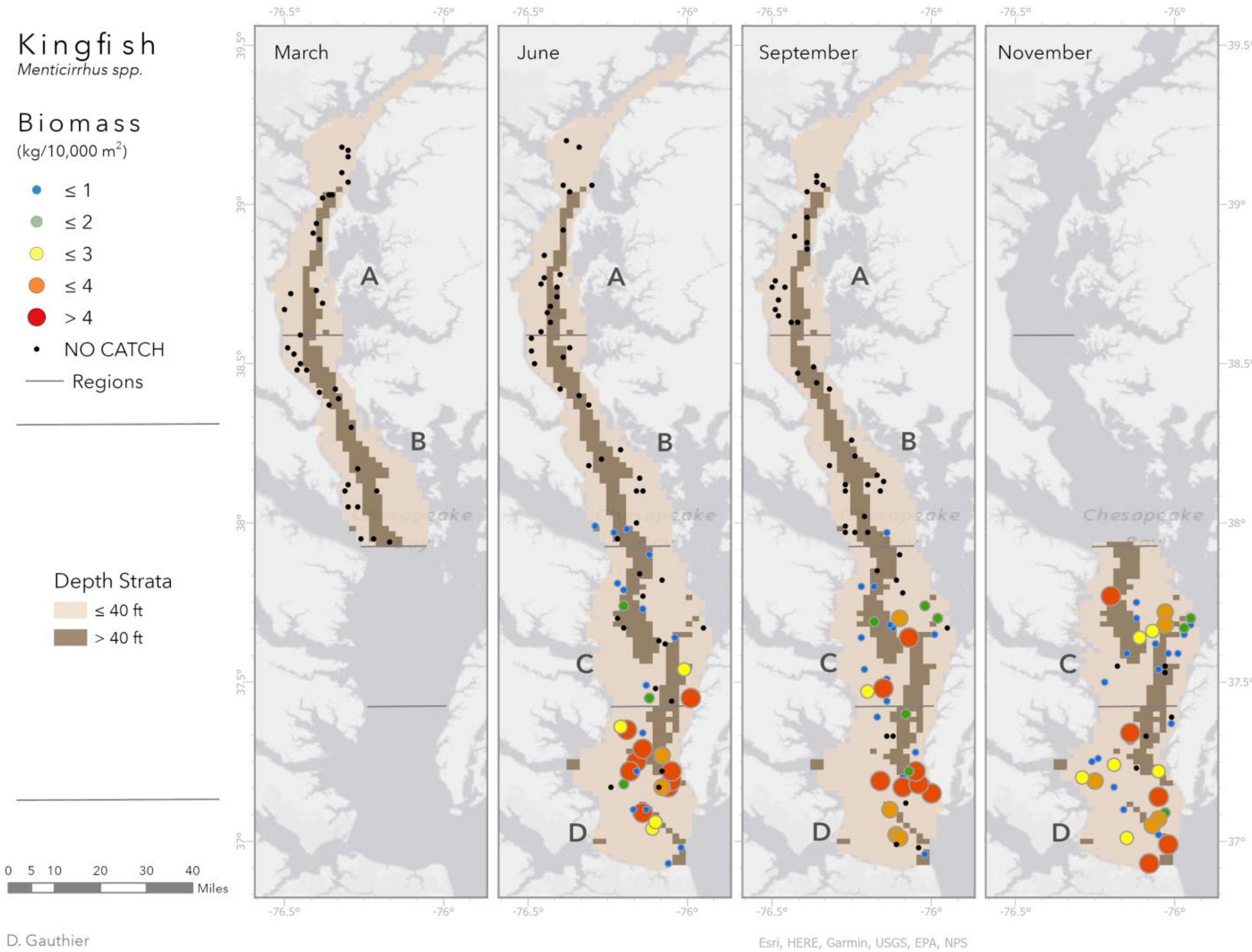

Figure 24: Site-level estimates of biomass (kg 10,000 m^{-2}) of kingfishes in 2022.

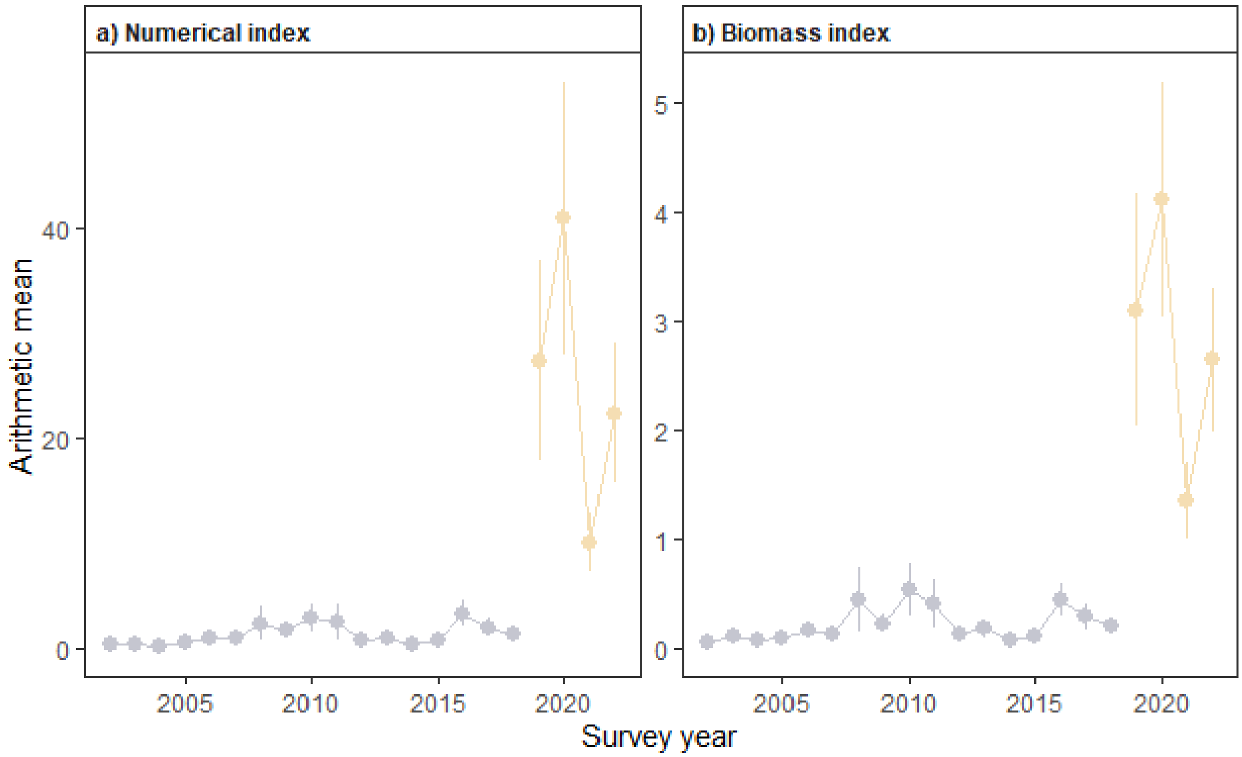

Figure 25: Indices of abundance for kingfishes, by number and biomass, for all ages combined.

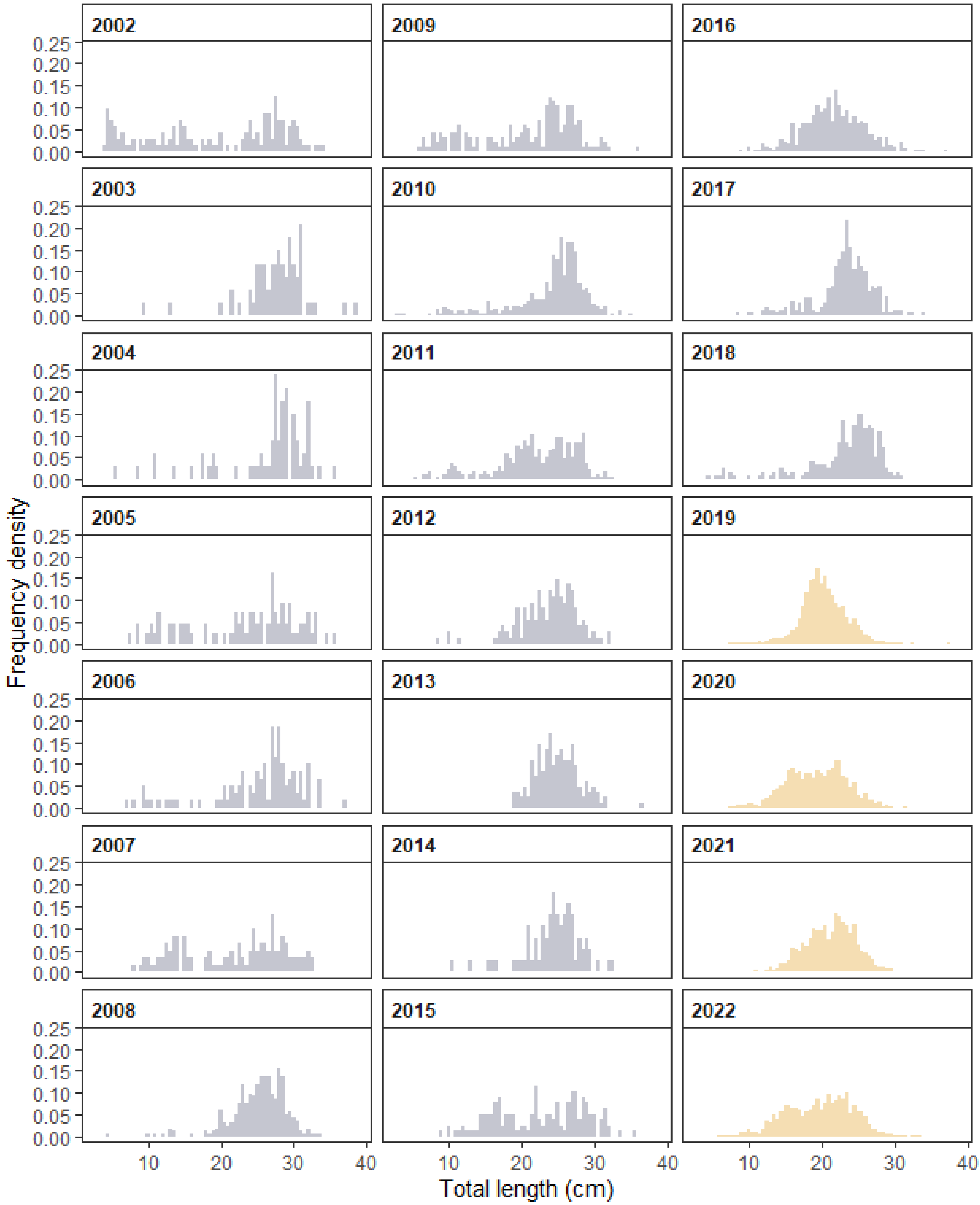

Figure 26: Length-frequency of kingfishes from 2002-2022.

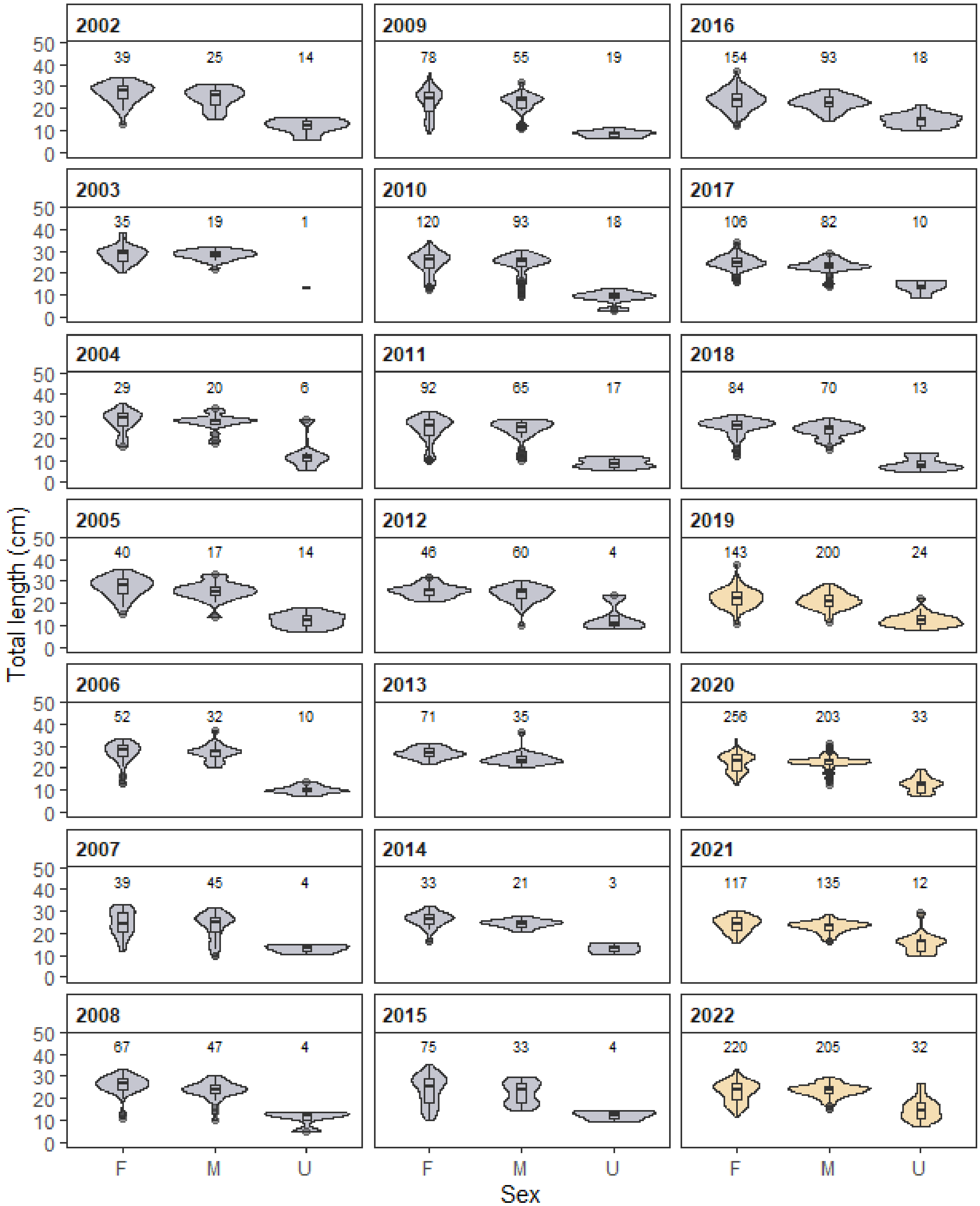

Figure 27: Length-frequency of kingfishes from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

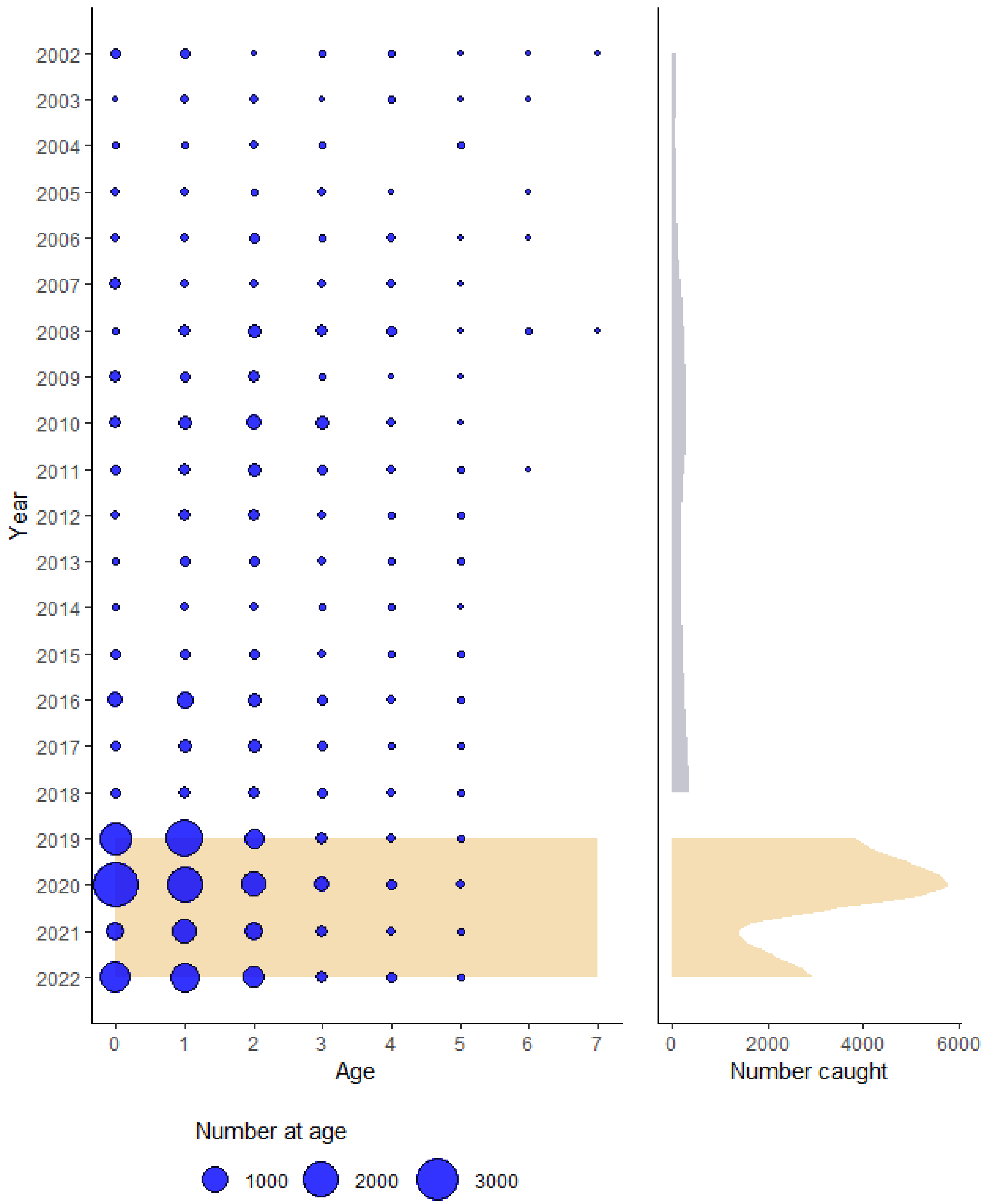

Figure 28: Kingfishes age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches. Note that the ages of specimens collected from 2012-present were estimated based on season age-length keys developed from aged specimens collected prior to 2012.

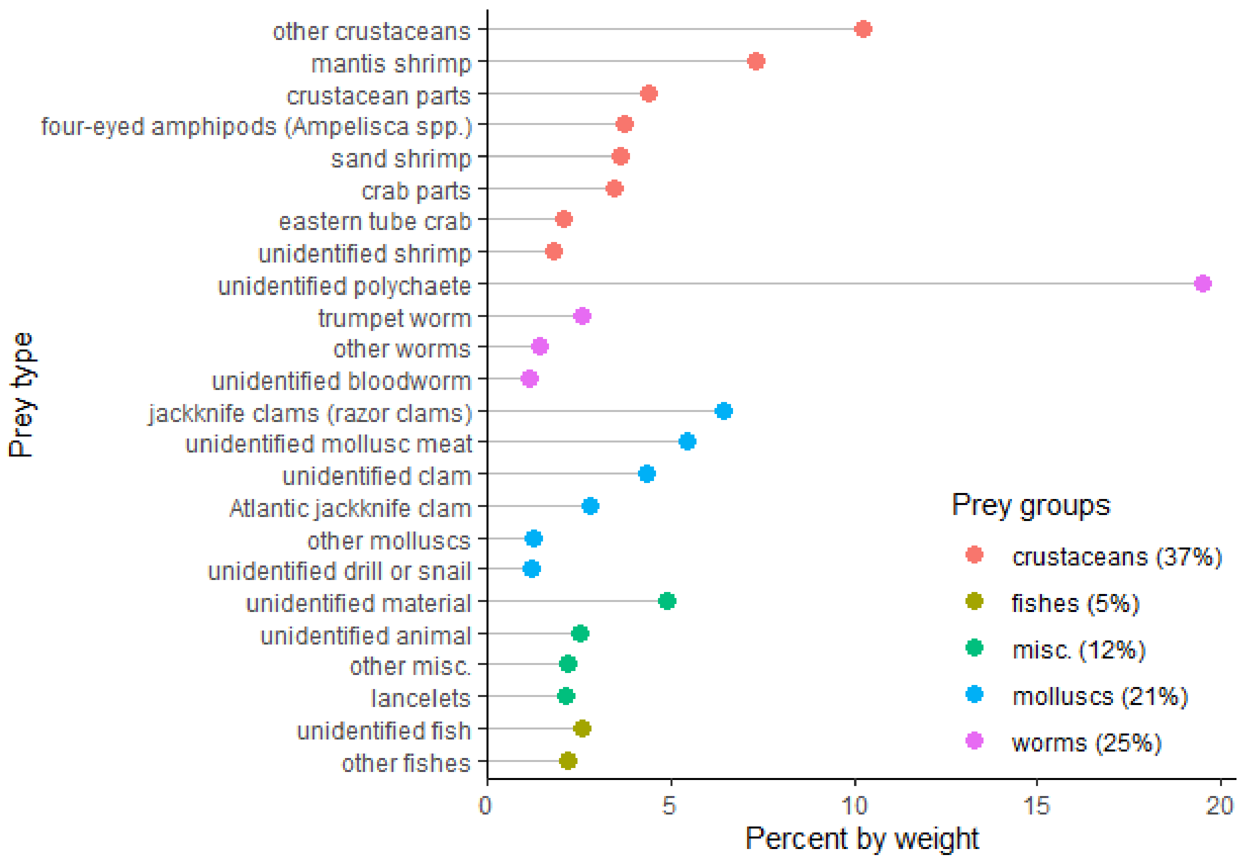

Figure 29: Diet composition of kingfishes expressed as percent by weight, based on 2469 fish and 1122 clusters.

Northern puffer, *Sphoeroides maculatus*

Abundance: Catches of northern puffer varied by an order of magnitude among years, from as few as 41 in 2005 to over 600 in 2011 (Table 6). Catch rates with the new sampling gear were comparable to those in previous years.

Typical patterns of abundance for this species in the survey are minimal numbers in spring and early summer, followed by a peak in abundance during the September and/or November cruises, perhaps as the summer residents are migrating toward offshore wintering grounds. This pattern was also observed in 2022 (Figure 30). Catches were consistently greatest in the southern regions (C and D), though the species can occur in the lower part of region B.

Through 2018, relative abundance indices were calculated using data collected during September and November cruises, in regions 4 and 5 from all depth strata. With the 2019 restratification, data from both depth strata of regions C and D in September and November were used. As catches in the survey are patchy, estimates of abundance for this species are of unknown reliability. Both relative abundance indices exhibited high intra- and inter-annual variability through 2018 (Figure 31). Indices have been lower and less variable since the change in vessel and gear in 2019.

Length and age: Specimens measuring 2.5 to 30.5 cm total length have been captured by the survey, though most individuals measured have been between 10 and 25 cm (Figure 32). The length composition varied year to year, likely as a result of varying year-classes entering and leaving the Bay stock. The new trawl gear may capture some number of smaller specimens than were previously observed in the survey. The largest individuals captured have generally been females but there appears to be no overall pattern of differential growth between sexes (Figure 33).

Northern puffer is not a high-priority species for stock assessments and standard ageing protocols have not been established. Thus, ageing of vertebrae has not yet been attempted, though the preserved vertebrae remain in storage.

Diet: The diet of northern puffer is diverse and fairly even; in ChesMMAP specimens, miscellaneous prey items including unidentified material, molluscs, and crustaceans made up approximately equal parts of the diet (Figure 34). Worms contributed nearly all of the remainder of the diet with fish tissue contributing only minimally to the diet.

Table 6: Northern puffer sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	231	23.9	20.0	231	177	0	171	156
2003	225	32.5	36.3	225	100	0	92	91
2004	41	6.9	9.7	41	31	0	27	26
2005	131	13.7	25.6	131	84	0	84	83
2006	52	5.5	17.7	52	51	0	48	47
2007	155	19.8	75.0	155	127	0	124	124
2008	90	6.9	21.1	90	78	0	77	77
2009	76	7.2	24.4	76	69	0	68	67
2010	326	54.7	44.4	326	176	0	157	156
2011	614	55.0	50.6	614	247	0	238	236
2012	50	5.3	11.9	50	50	0	41	40
2013	63	4.2	15.7	63	61	0	55	52
2014	49	3.6	12.2	49	39	0	16	16
2015	290	44.1	36.7	290	157	0	54	54
2016	519	65.6	40.0	519	231	0	99	97
2017	231	22.4	25.6	231	148	0	116	116
2018	246	24.5	28.9	246	128	0	87	87
2019	143	13.6	22.2	143	99	0	77	74
2020	80	7.0	35.6	80	54	0	23	23
2021	43	5.0	18.9	43	34	0	23	23
2022	57	3.6	21.1	57	42	0	13	13

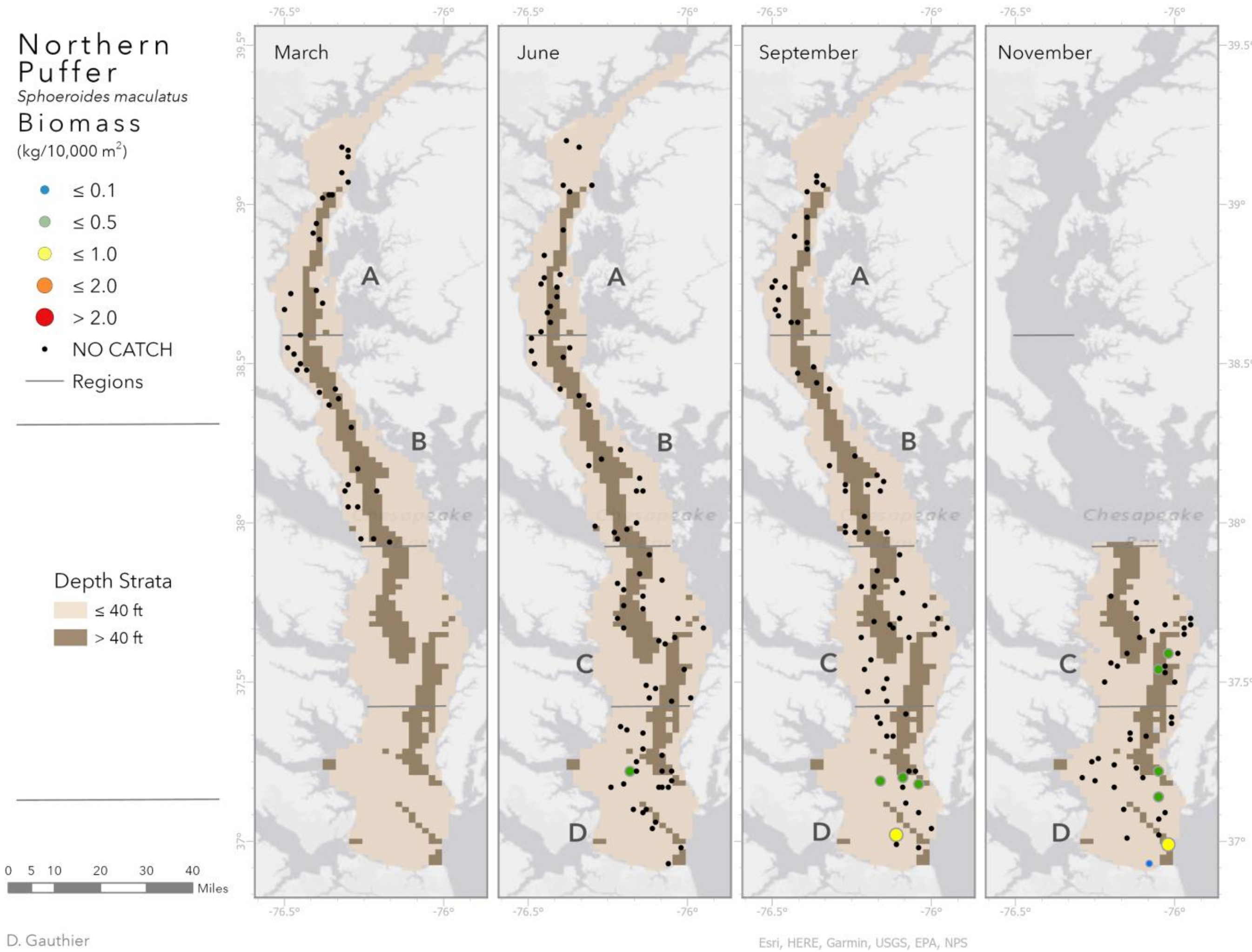

Figure 30: Site-level estimates of biomass (kg 10,000 m^{-2}) of northern puffer in 2022.

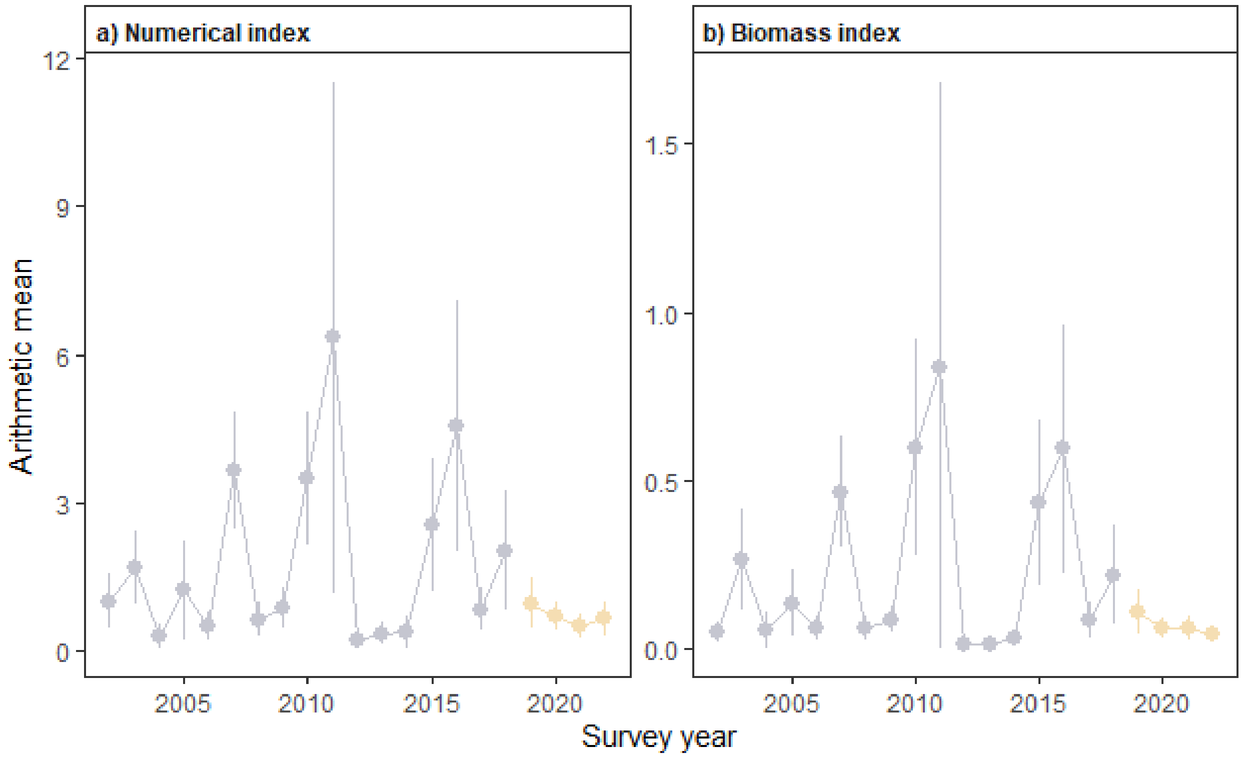

Figure 31: Indices of abundance for northern puffer, by number and biomass, for all ages combined.

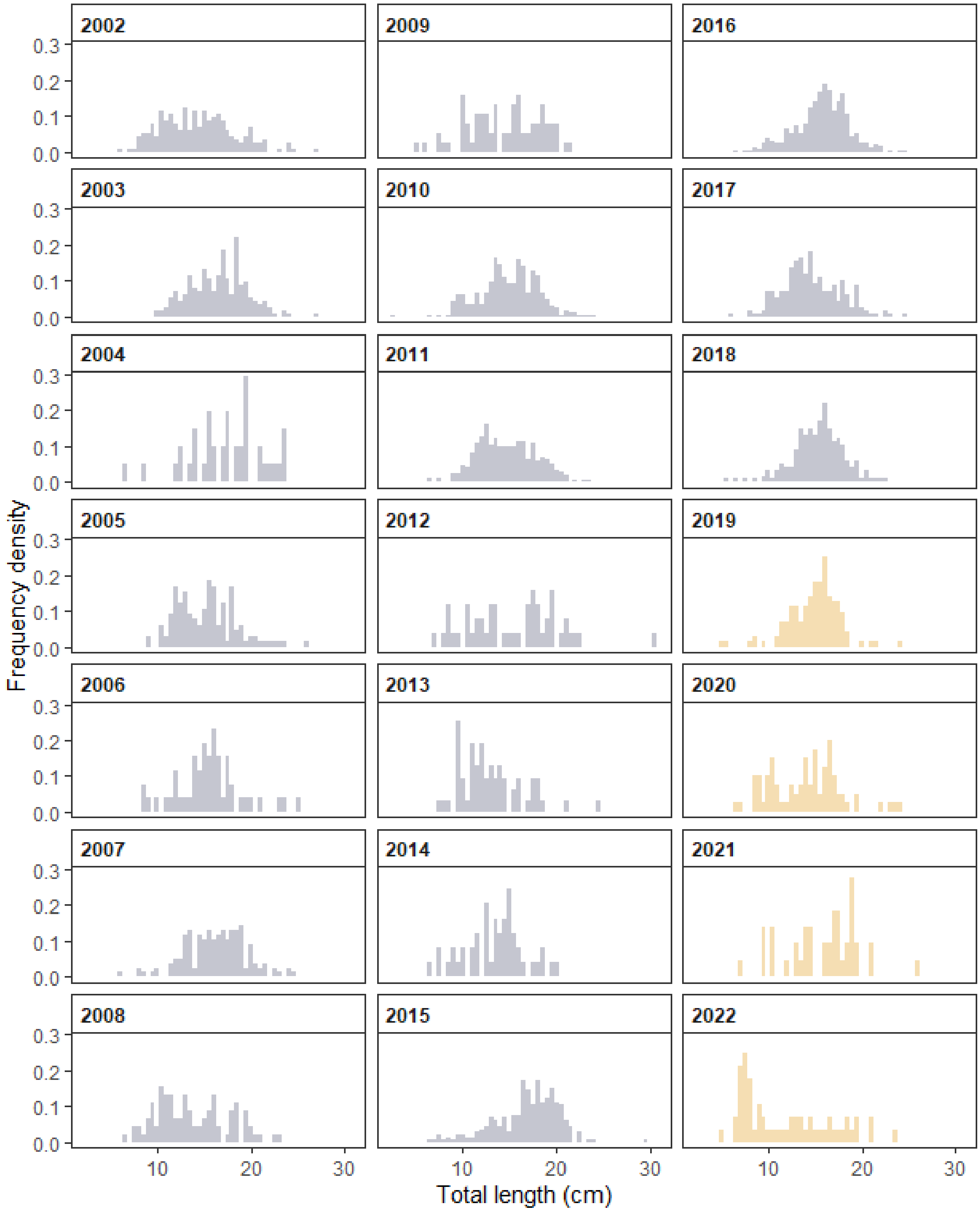

Figure 32: Length-frequency of northern puffer from 2002-2022.

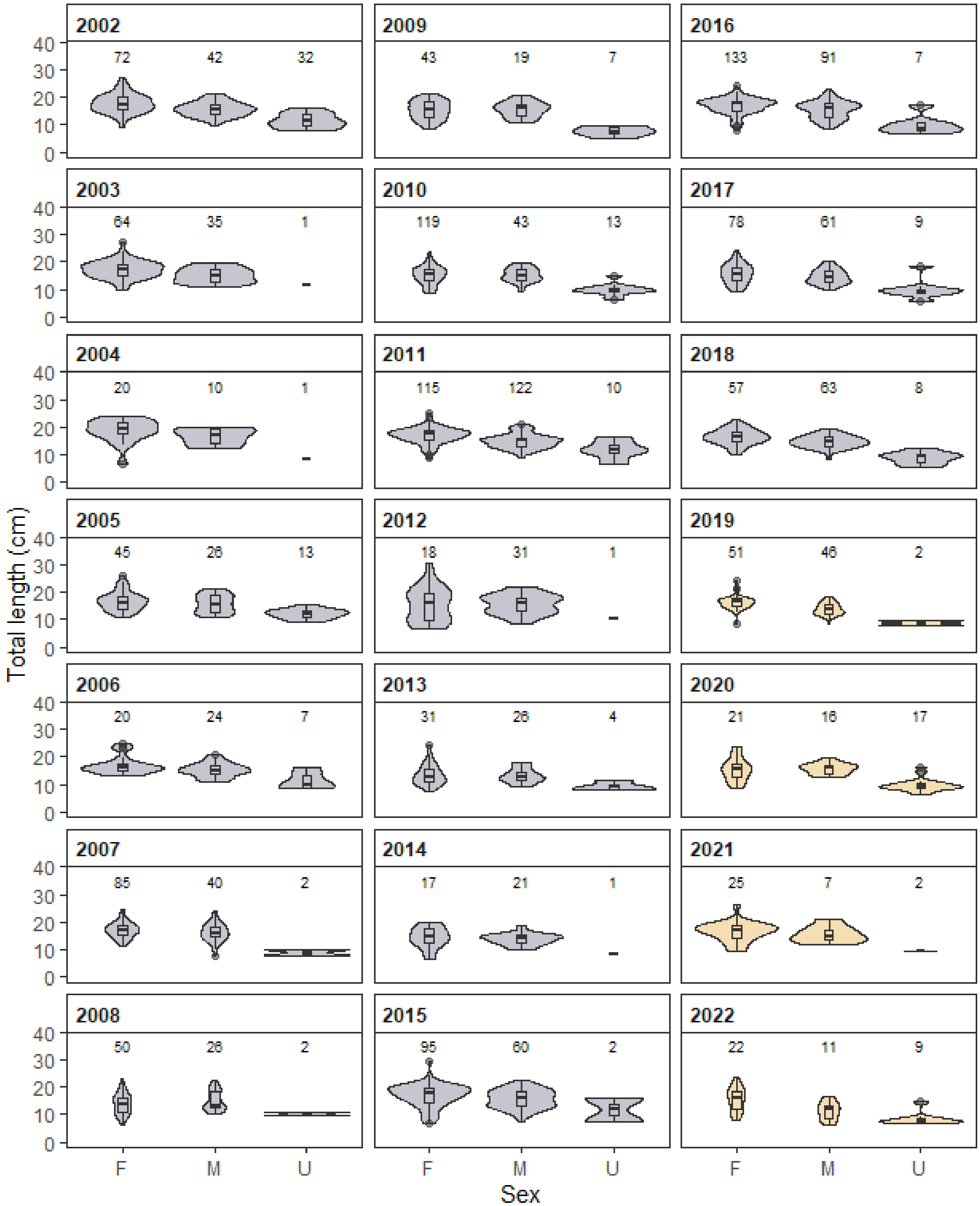

Figure 33: Length-frequency of northern puffer from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

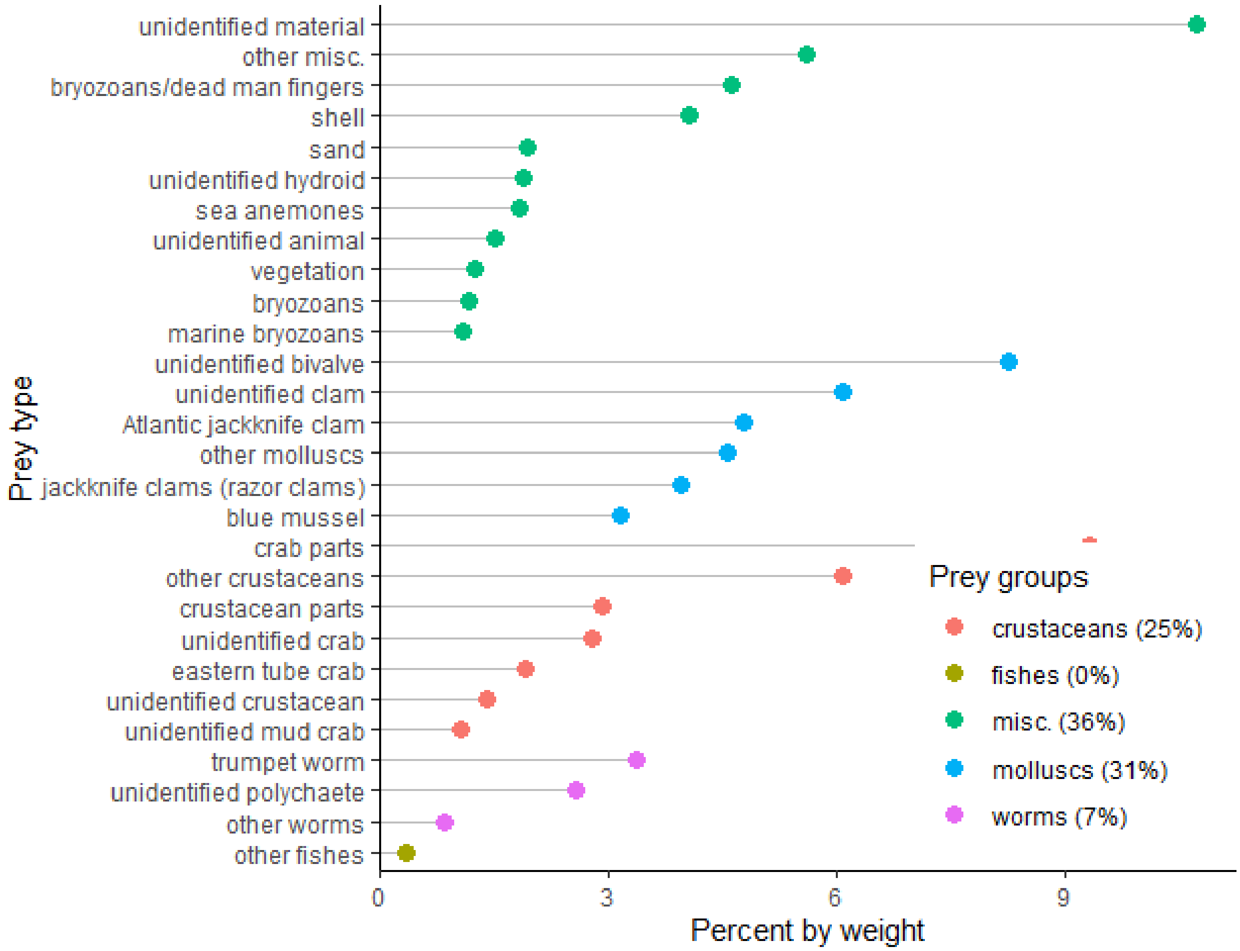

Figure 34: Diet composition of northern puffer, expressed as percent by weight, based on 1658 fish and 728 clusters.

Scup, *Stenotomus chrysops*

Abundance: Total yearly captures of scup are highly variable, probably as a result of both actual coast-wide abundance and availability to the survey gear (Table 7). Since 2019, with the new gear configuration, catches have been generally higher than in the early years.

Survey catches of scup are typically rare during spring through early summer and nearly always reach a peak in September before declining again in November as fish leave the Bay; in 2022, all but three of the sites where scup were caught occurred in September (Figure 35).

Through 2018, relative abundance indices were calculated using data collected during July, September, and November cruises, in regions 4 and 5 from shallow and mid-depth strata. With the 2019 restratification, data from shallow depth strata of regions C and D in June, September, and November were used. Note that 2007 data are limited due to the cancellation of the September cruise. Both relative abundance indices were highly variable at intra- and inter-annual time scales (Figure 36). The apparent large increase since 2019 is likely to be largely due to the change in survey gear, but requires verification.

Length and age: Most specimens captured in the survey are less than 20 cm fork length and at least two size classes are apparent in length data (Figure 37). Due to the small size and sexual immaturity of the majority of scup sampled, sex cannot be determined in the field for large numbers of specimens. Sex-specific length frequencies do not display any discernible pattern of differences in sex ratios at size (Figure 38).

Nearly all specimens captured are either age-0 or age-1, so it is difficult to discern whether year-class abundance can be followed through time in age frequency figures (Figure 39). Both the length-frequency and age-frequency distributions were similar before and after the gear change.

Diet: The diets of scup collected in the survey were composed primarily of worms and miscellaneous items (including unidentified material), representing over 70% by weight, combined (Figure 40). Crustaceans, including mysids and hermit crabs, and primarily unidentified mollusc meat consitute most of the remainder of the diet, with fish tissue contributing only minimally.

Table 7: Scup sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	107	7.8	10.7	84	40	40	39	34
2003	192	11.1	20.2	192	100	100	99	90
2004	475	26.0	41.5	475	155	155	150	144
2005	674	30.6	21.6	674	86	86	85	82
2006	317	12.7	29.6	317	115	115	112	111
2007	211	6.5	36.7	211	128	128	121	119
2008	56	4.1	12.9	56	42	0	42	42
2009	201	6.6	17.2	201	97	0	92	91
2010	853	29.2	25.0	653	126	0	125	123
2011	72	2.7	23.9	72	56	0	51	51
2012	12	0.4	3.4	12	12	0	12	12
2013	49	1.8	7.6	49	28	28	25	23
2014	63	2.6	6.5	63	26	26	19	19
2015	988	45.6	38.7	988	186	186	88	87
2016	65	2.0	9.7	65	40	40	20	20
2017	25	0.4	4.3	25	20	20	12	12
2018	386	12.2	29.0	386	94	94	58	58
2019	1,126	35.1	40.0	883	196	196	135	135
2020	626	18.7	25.7	626	34	34	23	23
2021	1,135	45.7	28.6	1,135	112	112	59	59
2022	419	19.2	28.6	295	90	90	34	30

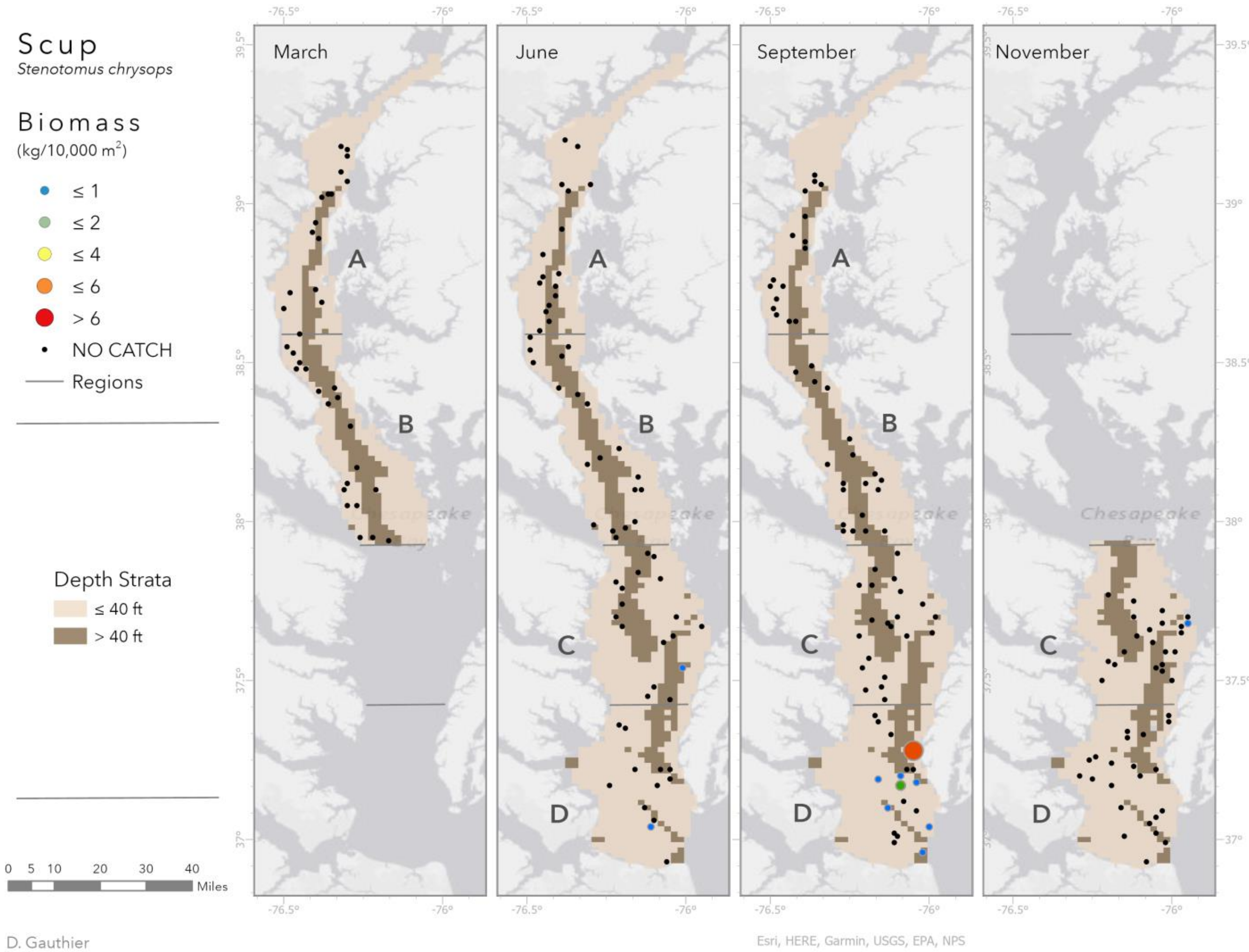

Figure 35: Site-level estimates of biomass (kg 10,000 m^{-2}) of scup in 2022.

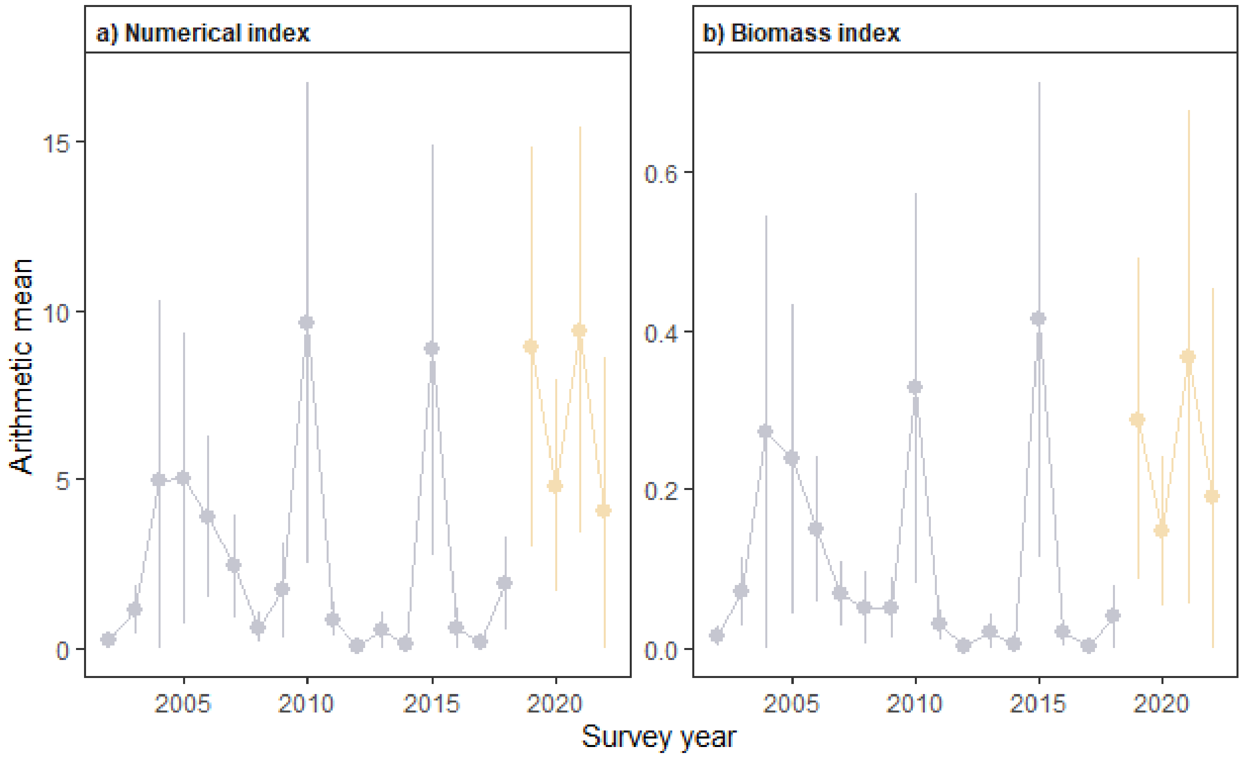

Figure 36: Indices of abundance for scup, by number and biomass, for all ages combined.

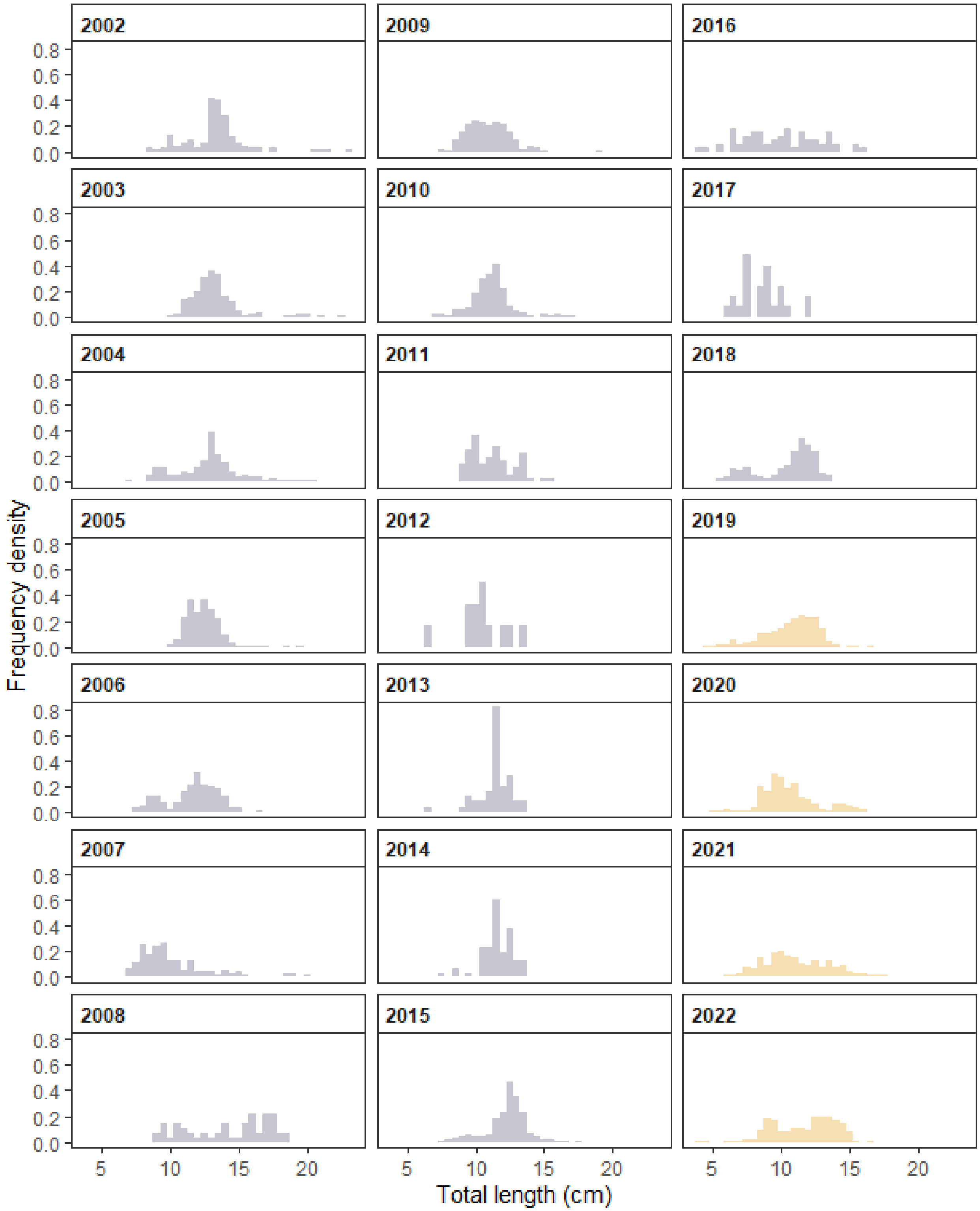

Figure 37: Length-frequency of scup from 2002-2022.

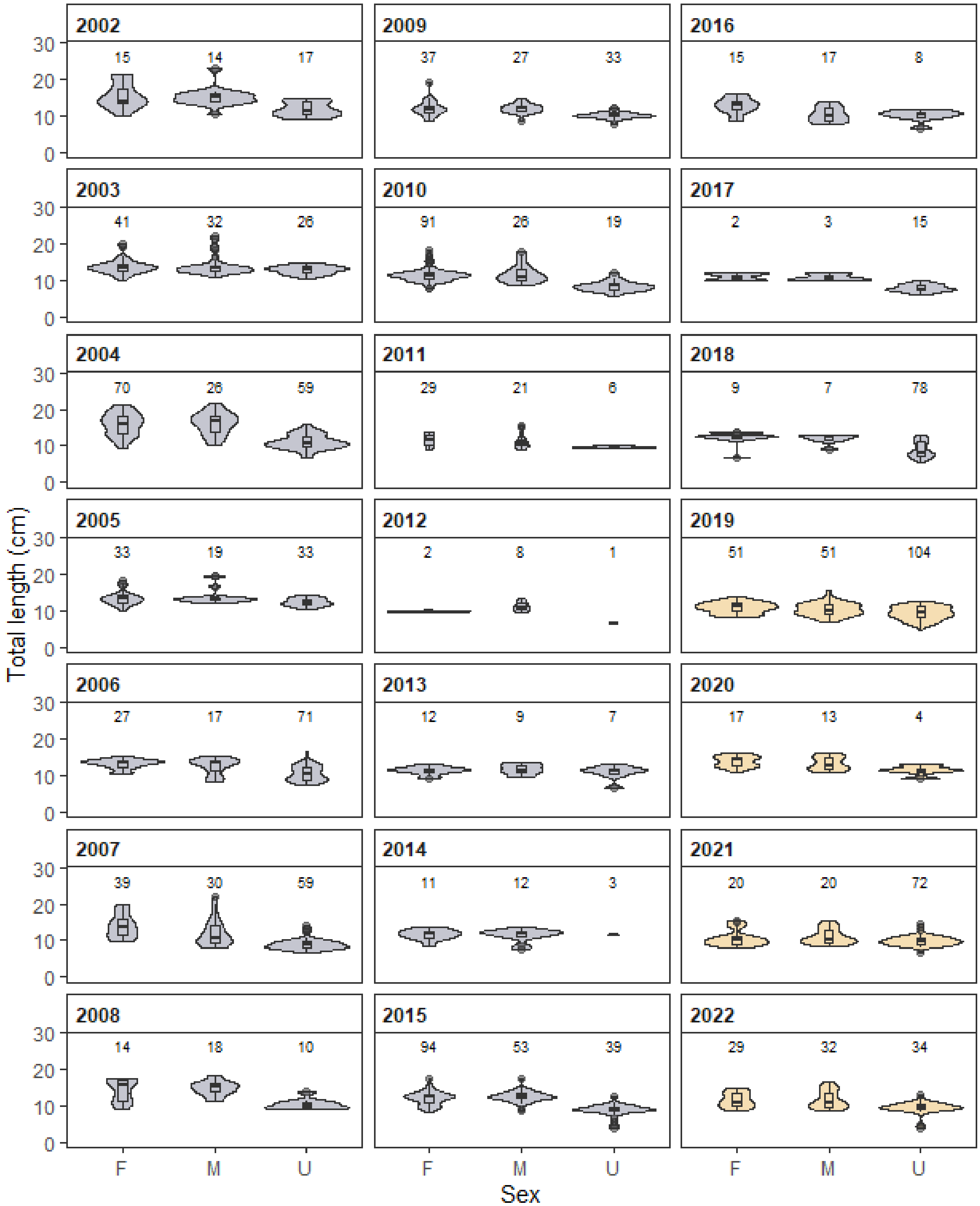

Figure 38: Length-frequency of scup from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

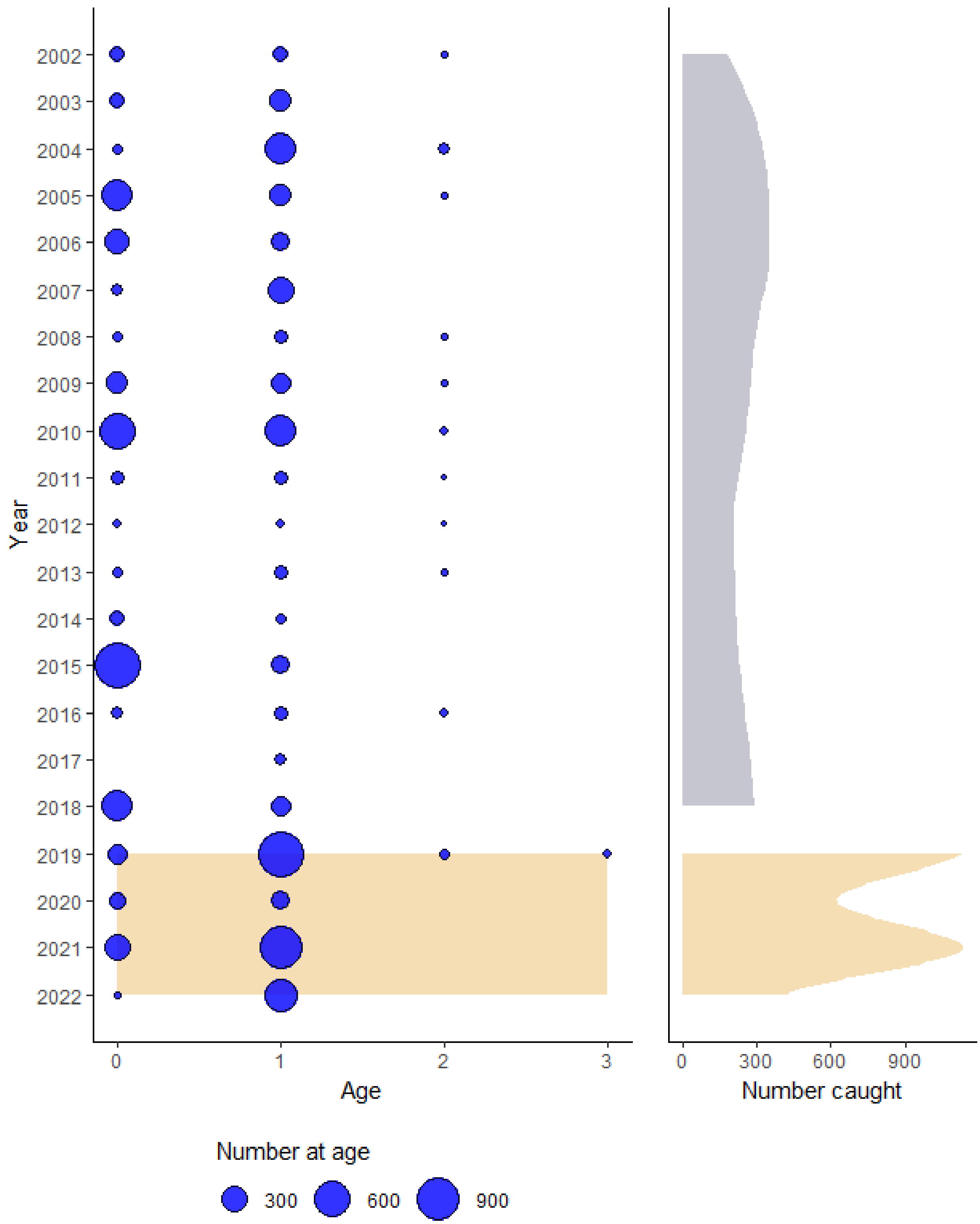

Figure 39: Scup age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches. Note that the ages of specimens collected from 2008-2012 were estimated based on season age-length keys developed from aged specimens collected from 2002-2019.

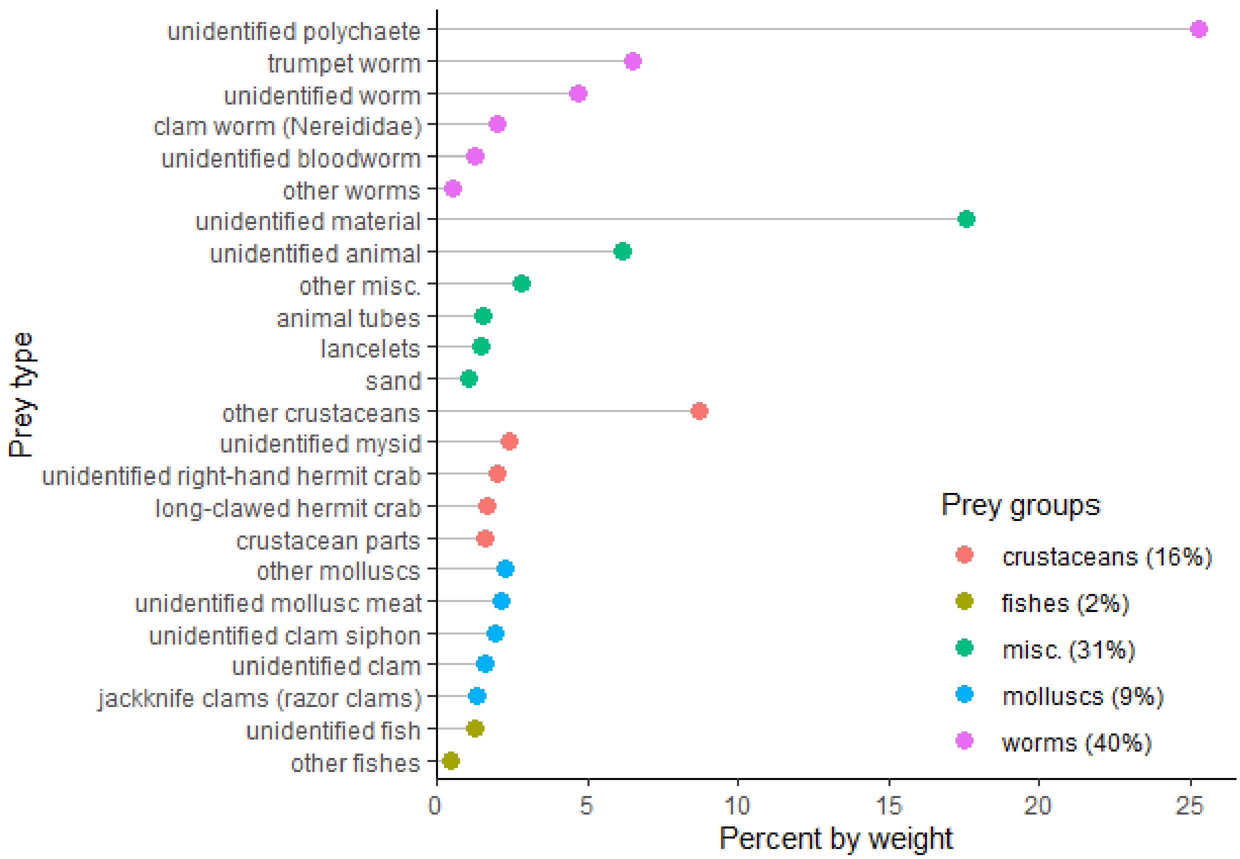

Figure 40: Diet composition of scup, expressed as percent by weight, based on 1365 fish and 565 clusters.

Spot, *Leiostomus xanthurus*

Abundance: Spot are typically among the most abundant species in the survey. Prior to 2014, 2,000-11,500 spot were captured annually; however, total annual catches declined afterwards to a time-series minimum of only 400 fish in 2015, followed by a moderate increase to around 1,500 individuals annually from 2016-2018. Deployment of the new gear in 2019 resulted in increased annual catches of 16-33 times the average catches using the old gear (Table 8).

This species is typically common throughout all cruises, except for March, and this pattern was observed in 2022 (Figure 41). It occurred throughout the Bay, though catches were highest in the southern regions (C and D).

Relative abundance indices were calculated using data collected from all region and depth strata. Prior to 2019, data from the July, September, and November cruises were used; after the 2019 restratification, data from the June, September, and November cruises were used. Both relative abundance indices displayed a general increase in the early years, through about 2009, followed by a steady decline through 2018 (Figure 42). The considerable increase in abundance indices since 2019 are likely due to the increase capture rate of small, young fish.

Length and age: Most specimens captured in the survey were 10-25 cm fork length and at least two size classes were apparent in some years (Figure 43). Sex-specific length frequencies do not display any discernible differences between males and females (Figure 44).

Nearly all fish in the survey are either age-0 or age-1, with the oldest fish (5 total specimens) captured at age-4 (Figure 45). As discussed above, even though the age distribution of this species in Chesapeake Bay is not wide, the relative numbers of smaller vs. larger specimens can vary significantly year to year. This likely represents both changes in relative year-class strength and the numbers and sizes of specimens moving into the Bay each year. Much of the very large increase in catch of this species with the new gear appears to come in smaller, age-0, specimens.

Diet: The majority of the diet of this bottom-feeding species comprised unidentified material (animal or otherwise) and unidentified polychaetes (Figure 46).

Table 8: Spot sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	3,122	443.2	37.0	3,034	672	672	647	19
2003	4,081	568.8	51.7	3,102	414	395	396	4
2004	4,131	419.6	64.4	4,089	619	619	578	19
2005	11,561	1,011.2	73.2	10,690	1,030	1,030	979	3
2006	7,080	700.4	71.0	6,439	680	656	632	7
2007	5,729	462.8	72.3	5,396	626	626	602	4
2008	6,256	417.5	63.3	5,197	785	785	742	734
2009	5,191	682.6	47.1	3,481	465	449	447	442
2010	6,744	255.3	67.2	6,336	687	687	652	623
2011	2,867	278.0	39.0	2,867	352	352	320	316
2012	2,161	114.5	35.9	1,758	345	345	259	253
2013	4,087	316.0	44.4	3,430	428	428	289	278
2014	939	117.3	23.3	939	188	188	89	88
2015	401	54.0	15.4	401	102	102	11	11
2016	1,059	67.2	27.1	835	167	167	43	40
2017	1,586	116.4	26.8	1,586	213	213	105	102
2018	1,635	77.0	32.7	1,635	204	204	101	98
2019	67,938	3,529.2	78.4	22,694	556	556	229	225
2020	132,547	6,173.8	89.3	34,056	370	370	134	131
2021	73,427	3,428.0	84.9	21,513	686	686	283	275
2022	107,849	5,005.6	87.3	24,987	699	699	236	233

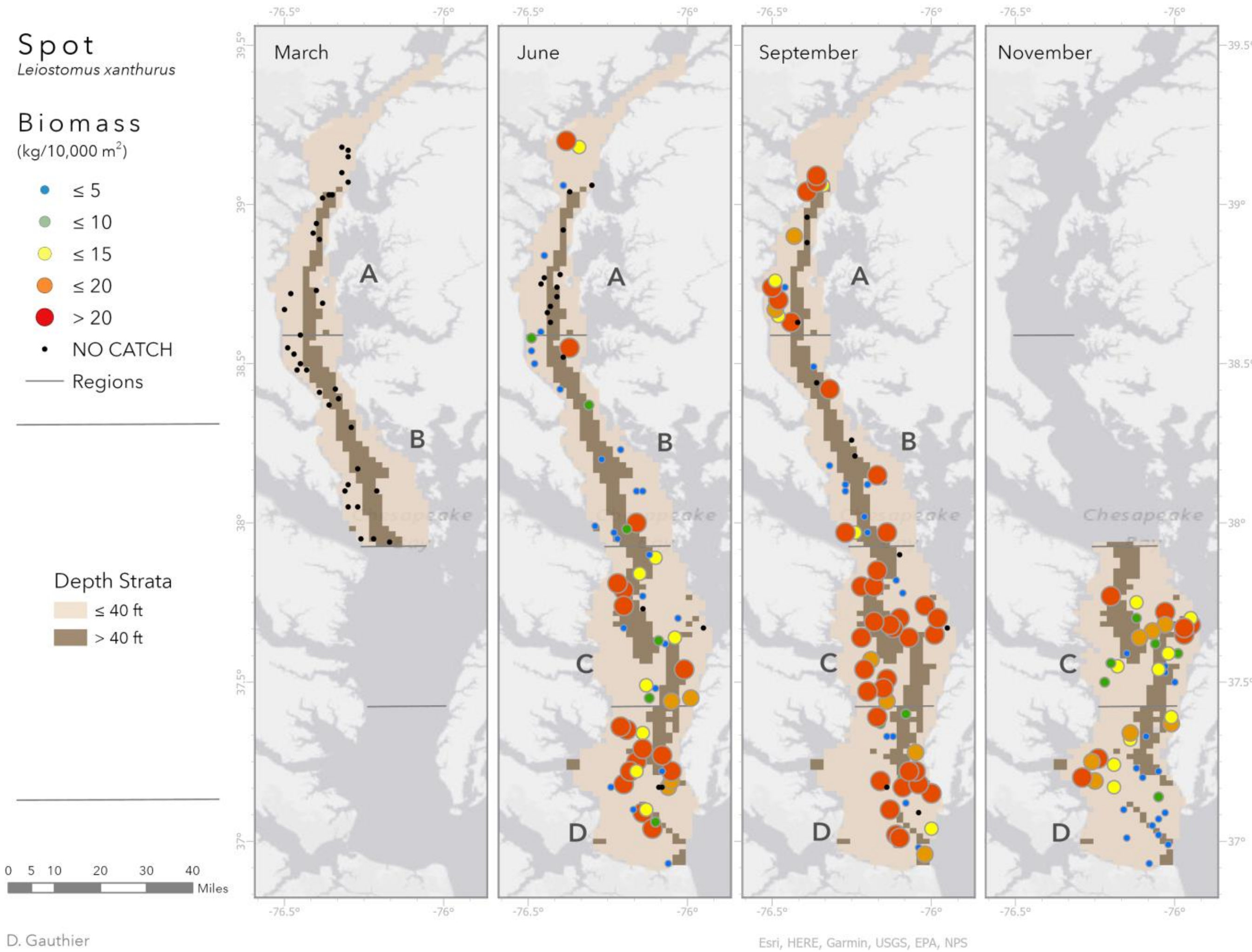

Figure 41: Site-level estimates of biomass (kg 10,000 m^{-2}) of spot in 2022.

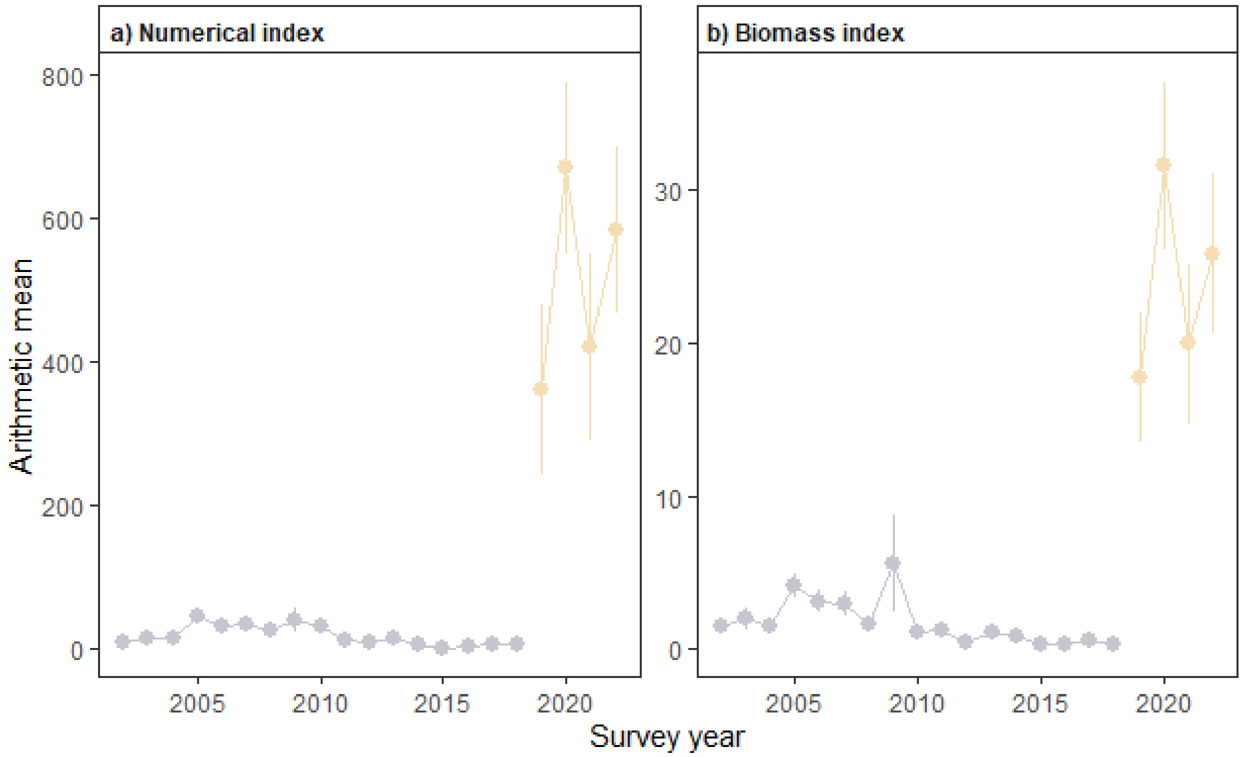

Figure 42: Indices of abundance for spot, by number and biomass, for all ages combined.

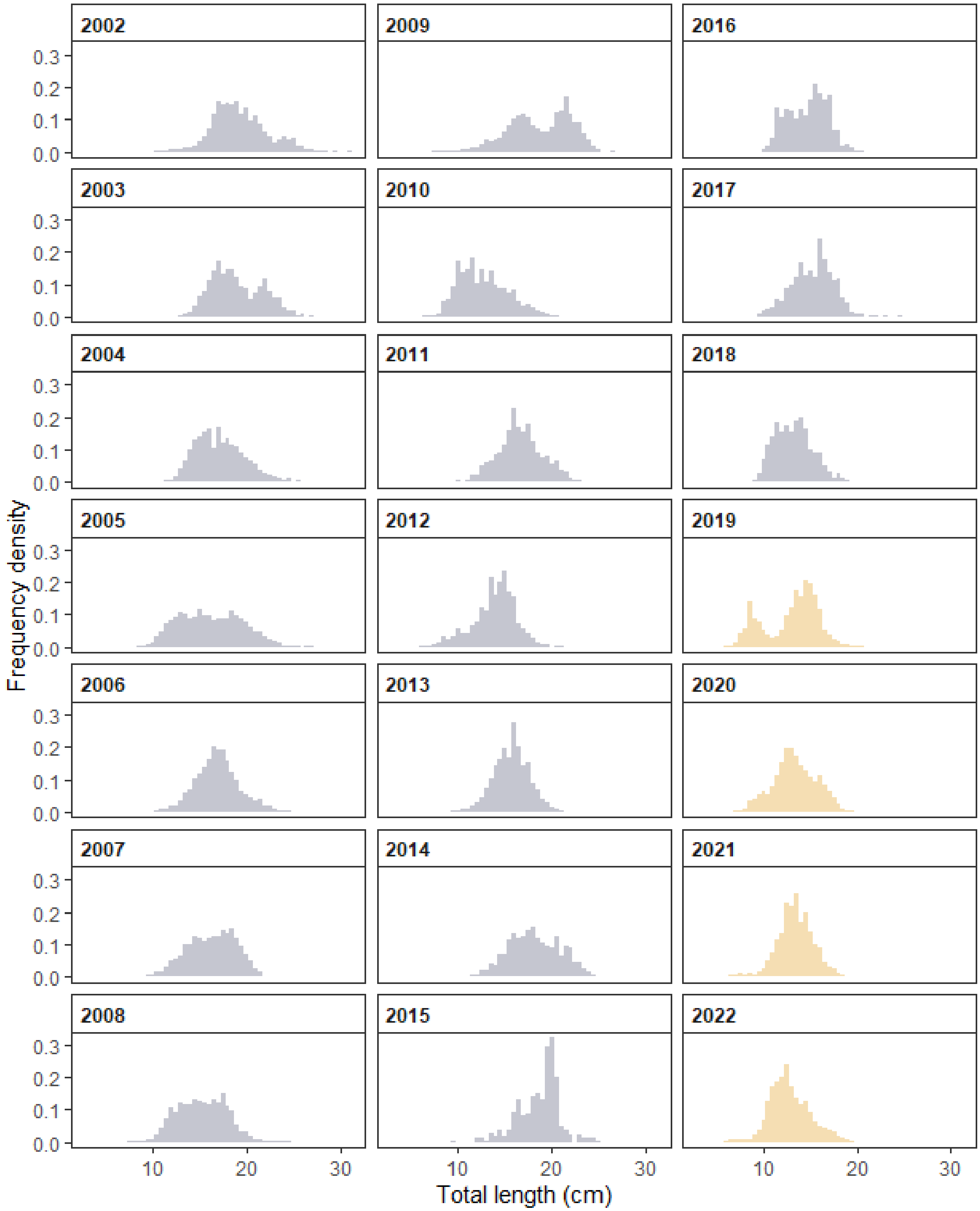

Figure 43: Length-frequency of spot from 2002-2022.

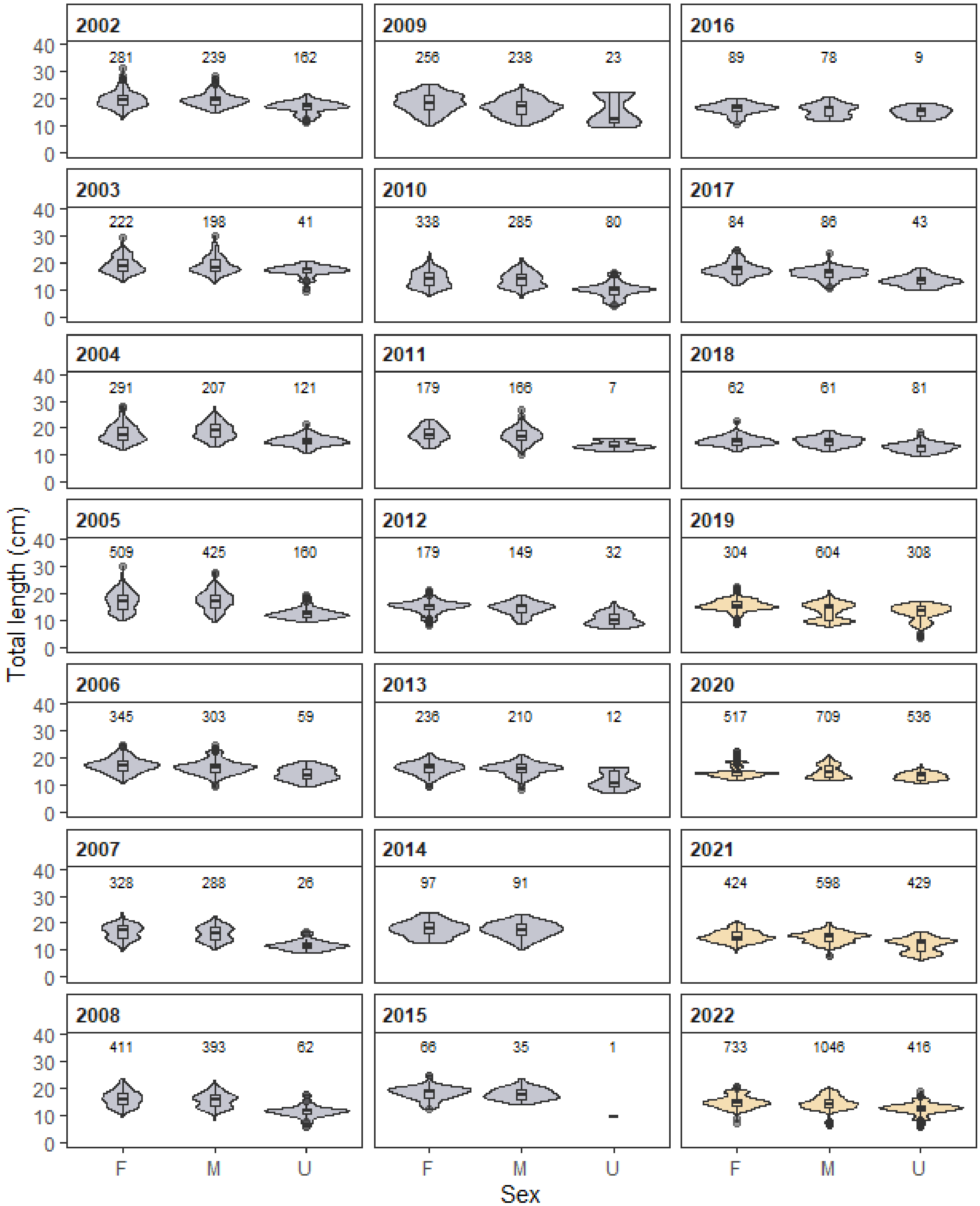

Figure 44: Length-frequency of spot from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

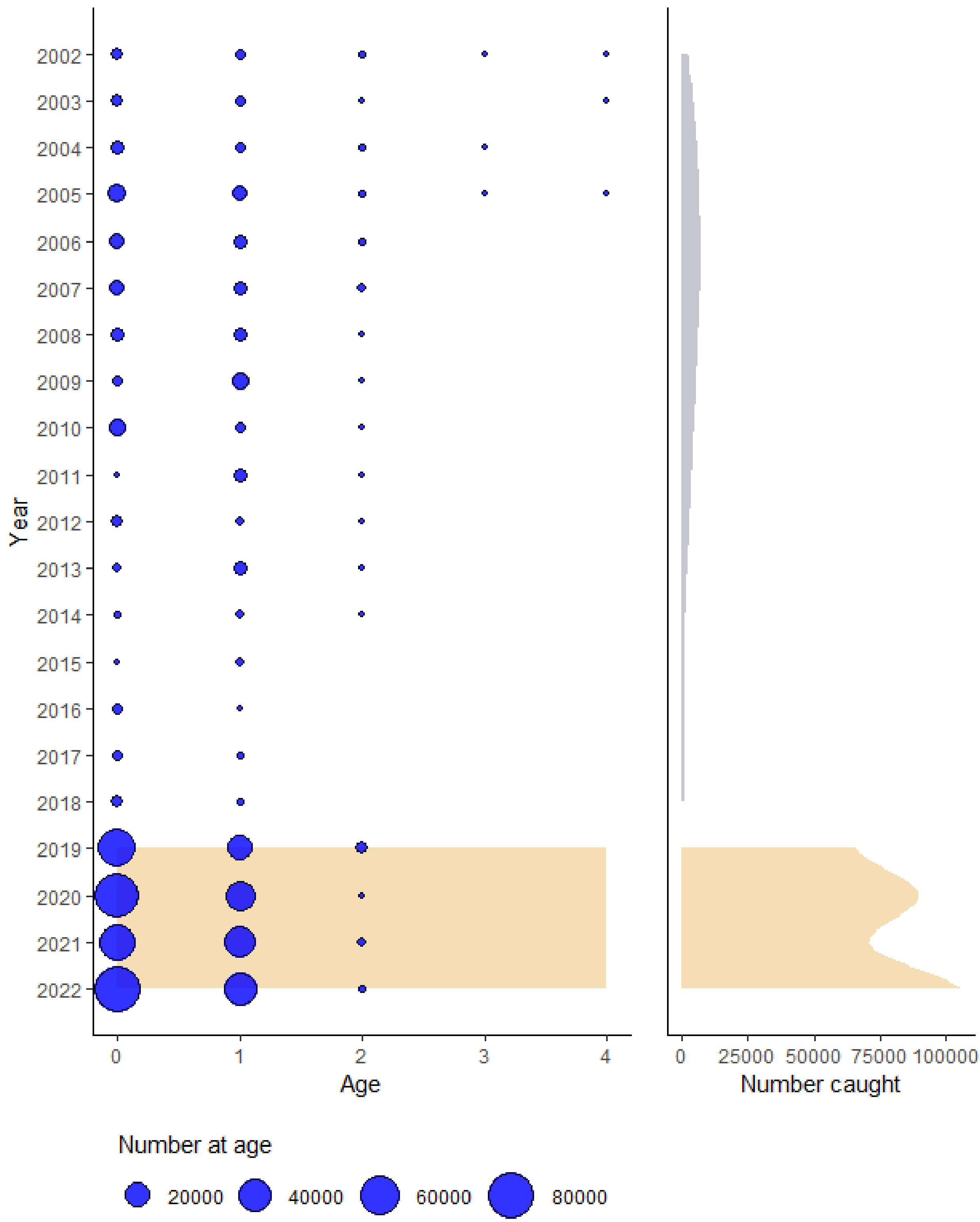

Figure 45: Spot age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

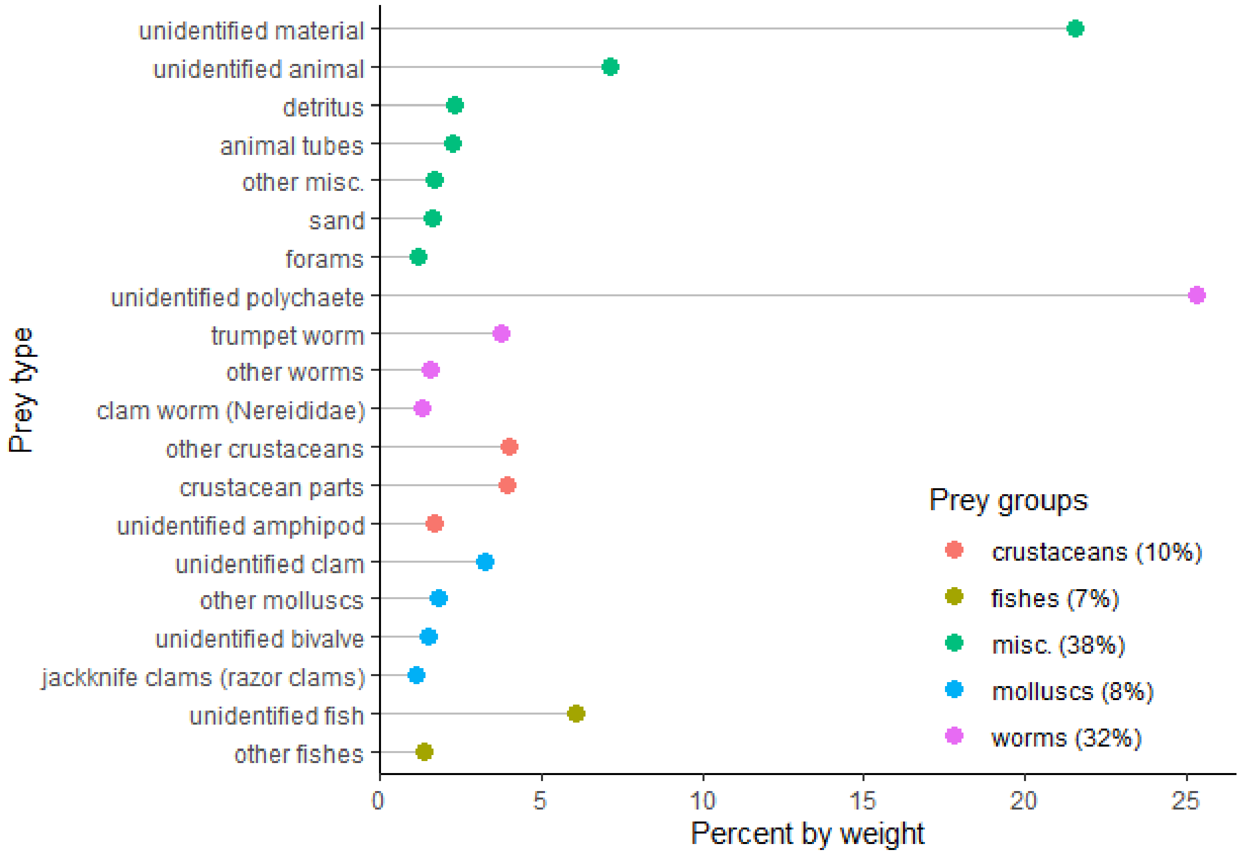

Figure 46: Diet composition of spot, expressed as percent by weight, based on 3905 fish and 1833 clusters.

Striped bass, *Morone saxatilis*

Abundance: Striped bass are typically captured in relatively high abundance each year, with almost 1,000 specimens collected on average over the entire time series (Table 9)

This species exhibits consistency in its intra-annual abundance pattern, with large numbers of spawning migrants captured during the March cruise, followed by lower numbers in summer as the spawners leave the Bay. Fewer captures occur in July and September, and higher numbers are encountered again in November as fish school before leaving the Bay for offshore wintering grounds. This pattern was not as clearly observed in 2022; the vast majority of captures were in northern regions (A and B) during March, with only limited captures in June and September, and virtually none were caught in November (Figure 47).

Two sets of abundance indices have been calculated for this species:

1. The spring spawning stock was evaluated using data from the March cruises, including all depth strata of the northern regions (1-3 prior to 2019, and A and B from 2019 to present).
2. The summer residents were evaluated using data from November, including all depth strata in all regions (prior to 2019) and in the southern regions (C and D, from 2019 to present). Note that the fall index may need to be reexamined as regions A and B are no longer sampled in November.

The spring relative abundance index based on numbers caught displayed a general increase in the early years, through about 2005, followed by a steady decline through 2017 (Figure 48). The spring relative abundance index based on biomass followed a similar pattern, though a few years of high biomass (i.e., 2008 and 2012) interrupted the otherwise steady decline in biomass from about 2005 to 2017. A March cruise was not conduced in 2018 due to a funding shortfall. Note that the spring 2019 cruise was conducted using the original sampling gear and the *R/V Bay Eagle*, so the large increases in spring abundances due to the new sampling system was not observed until 2020.

The two fall indices exhibited a peak in 2005, declined until about 2011, and then experienced a period of relatively higher values until 2019 (Figure 48). The 2019 indices were extremely high, but were followed by several years of low values, at or near time-series lows. However, as mentioned earlier, the fall striped bass index has been affected by the change in the annual sampling schedule, as no samples were or will be collected in regions A and B (Maryland) in November. Further work is needed to evaluate how these changes impact the reliability of the fall index.

Length and age: Most specimens captured in the survey were less than 60 cm fork length (Figure 49). Due to the relatively long-lived nature of this species, the varying life history scenarios for different portions of the stock and associated variable growth rates, along with variable young-of-year recruitment, it is difficult to differentiate year-classes within length-frequency distributions. The largest individuals, typically mature females captured during spring spawning, approached 100 cm, while resident male fish were captured up to about 50 cm (Figure 50).

Striped bass captured in the survey were typically less than about age-10, with specimens up to age-20, captured relatively infrequently. Age-frequency diagrams revealed trends in year-class strength, where high or low abundances recorded during one year tend to follow into succeeding years (Figure 51). These patterns were generally supported by strong and weak year-classes as measured by the

Maryland and Virginia young-of-year beach seine surveys (Durell and Weedon, 2022; Buchanan et al., 2023). The most recent years appeared to be exhibiting a contraction of the age distribution, with only 6 older than age-10.

Diet: Fishes comprised the largest taxonomic group in the diet of striped bass captured in this survey, with bay anchovy making up over 30% of the diet, and all fishes together representing nearly two-thirds of the diet. Crustaceans, primarily small-bodied taxa such as amphipods, mysids, and mantis shrimp, and a variety of worms, make up another 25% of the diet. Miscellaneous items, primarily unidentified material, and molluscs represent only minimal contributions to the diet.

Results of diet analyses from this study differ appreciably from some previous studies using specimens from Chesapeake Bay (e.g., Walter and Austin, 2003). These differences are likely the result of both sampling methodological differences (the broad temporal and geographic scale of ChesMMAP as well as the gear used compared to many studies which were limited in temporal or geographical scale or which used capture methodologies which yield a narrower size range) and analytical differences in calculating percentages in the diet, as results similar to those presented here were obtained by Overton et al. (2009), using a broad geographic scope, large size range of individuals, and similar cluster-sampling methodology.

Table 9: Striped bass sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	495	313.9	7.8	495	337	337	248	230
2003	765	710.1	55.6	765	501	501	367	355
2004	918	668.9	66.7	918	590	590	476	458
2005	2,245	982.4	63.5	1,919	724	724	528	513
2006	911	839.1	60.6	911	535	535	412	407
2007	579	423.4	47.3	579	389	389	246	241
2008	472	476.9	52.2	472	380	380	317	309
2009	315	243.1	37.2	315	198	198	152	149
2010	288	285.4	29.2	288	205	205	147	144
2011	284	224.9	46.9	284	237	237	178	178
2012	935	330.5	52.8	935	257	257	197	196
2013	695	482.3	50.9	695	373	373	259	123
2014	578	355.8	39.1	578	255	255	186	183
2015	718	398.5	38.3	718	319	319	133	132
2016	1,266	530.2	70.4	1,266	534	534	280	278
2017	1,466	829.0	43.0	1,313	426	426	270	267
2018	313	157.2	35.0	313	173	173	100	100
2019	2,559	679.0	55.6	1,134	265	265	200	200
2020	2,201	412.1	50.0	1,432	300	300	137	134
2021	1,881	528.8	33.8	1,400	195	195	104	102
2022	548	277.4	33.8	548	155	155	67	64

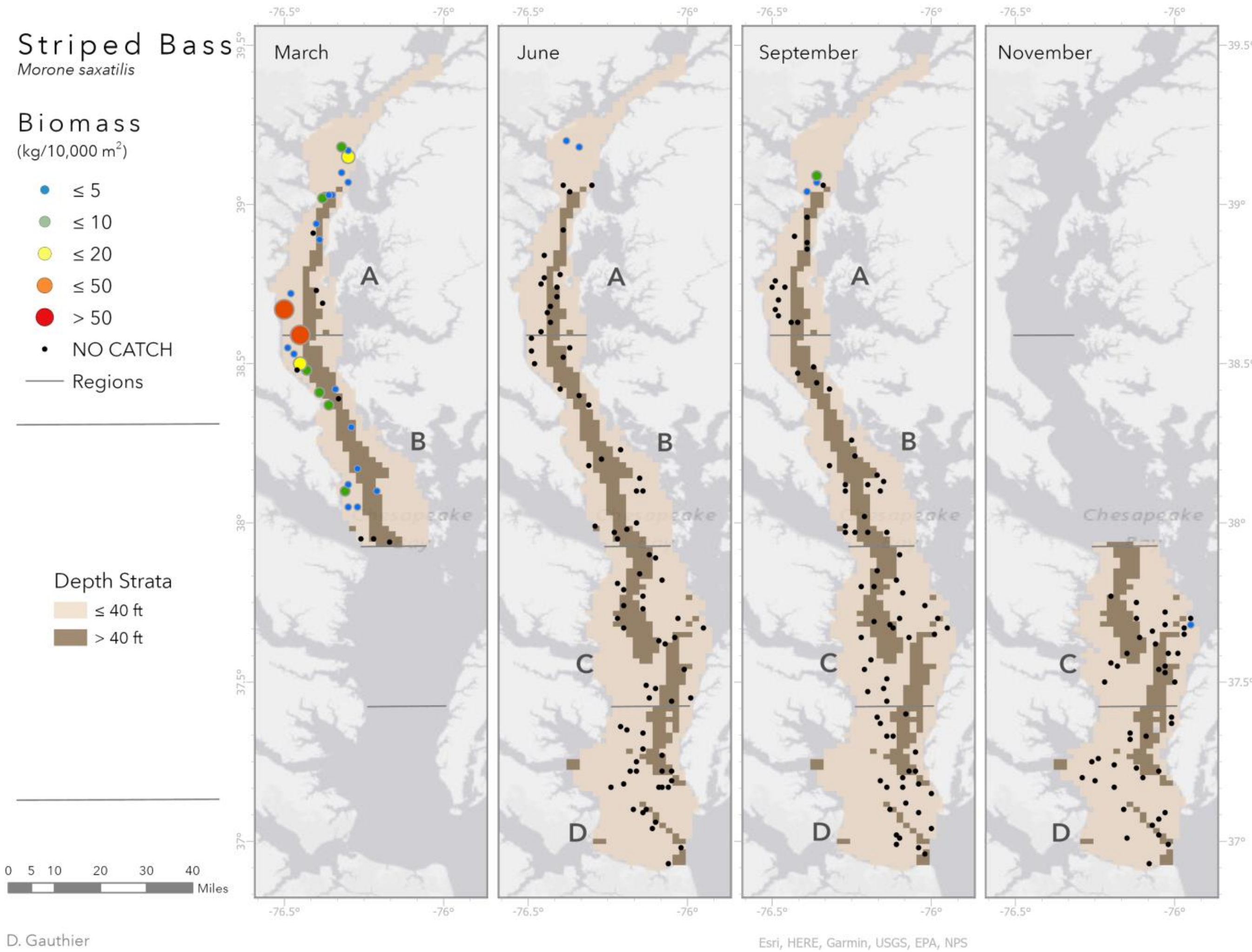

Figure 47: Site-level estimates of biomass (kg 10,000 m^{-2}) of striped bass in 2022.

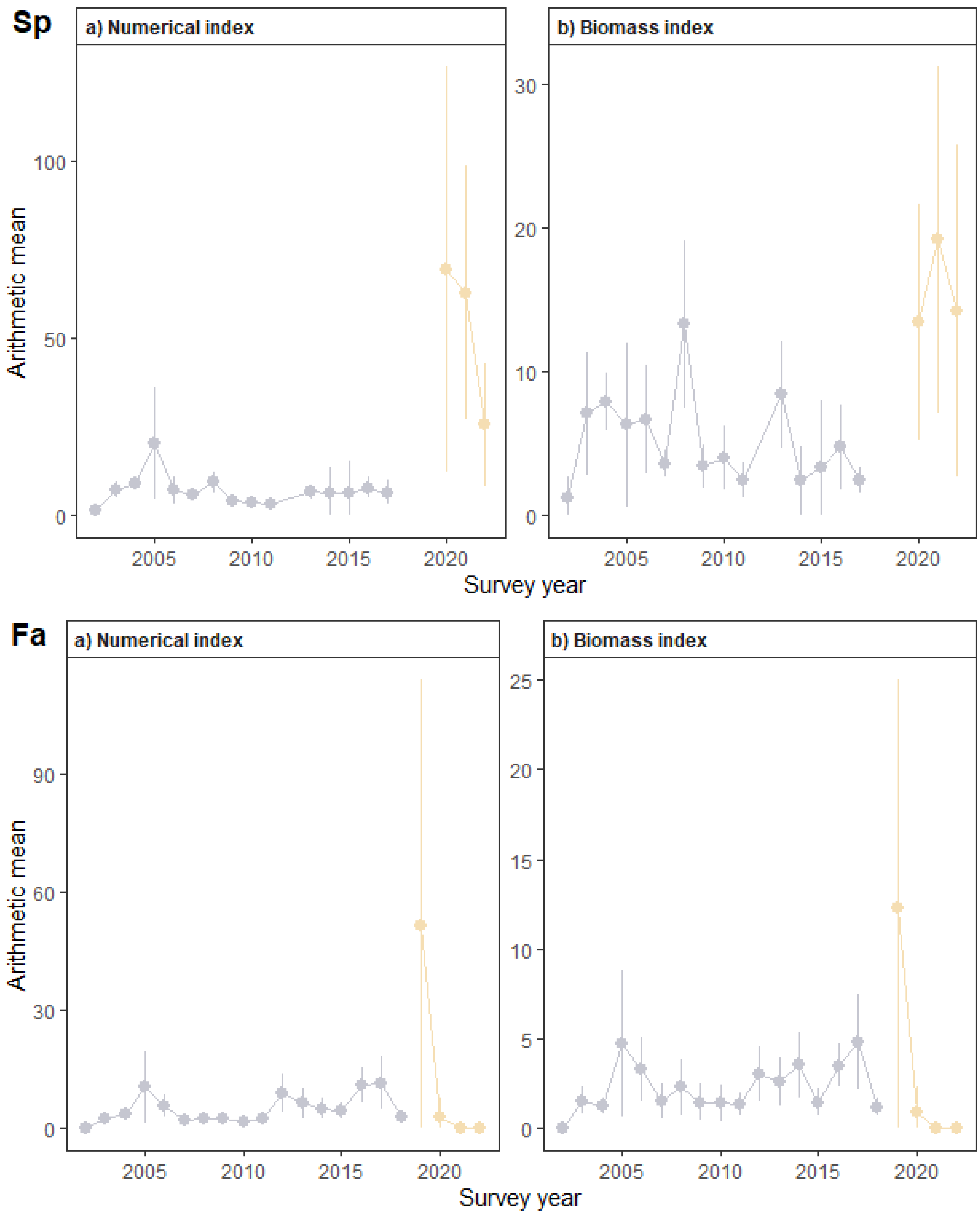

Figure 48: Indices of abundance for striped bass, by number and biomass, for all ages combined; Sp = spring (March) only and Fa = fall (November) only.

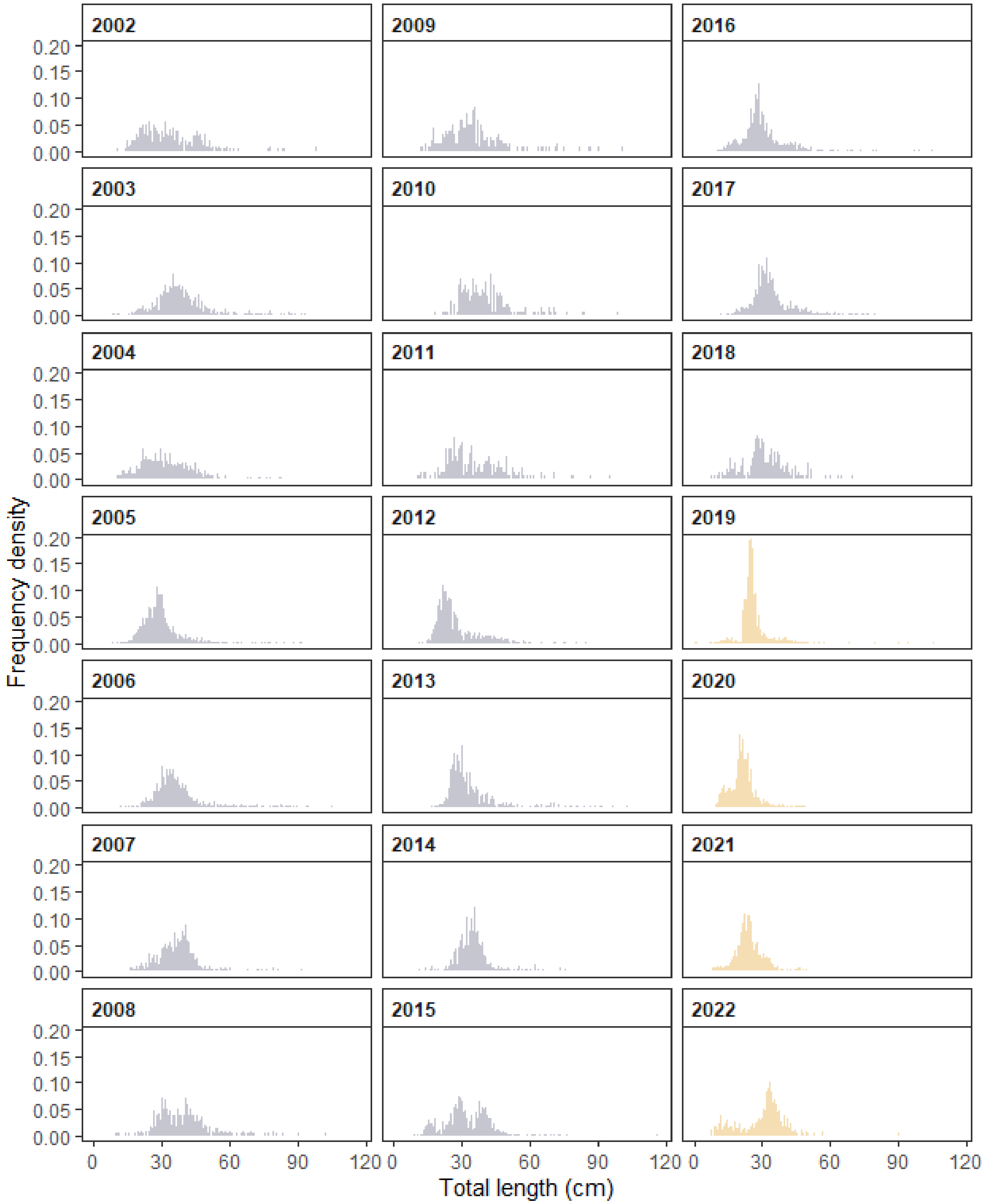

Figure 49: Length-frequency of striped bass from 2002-2022.

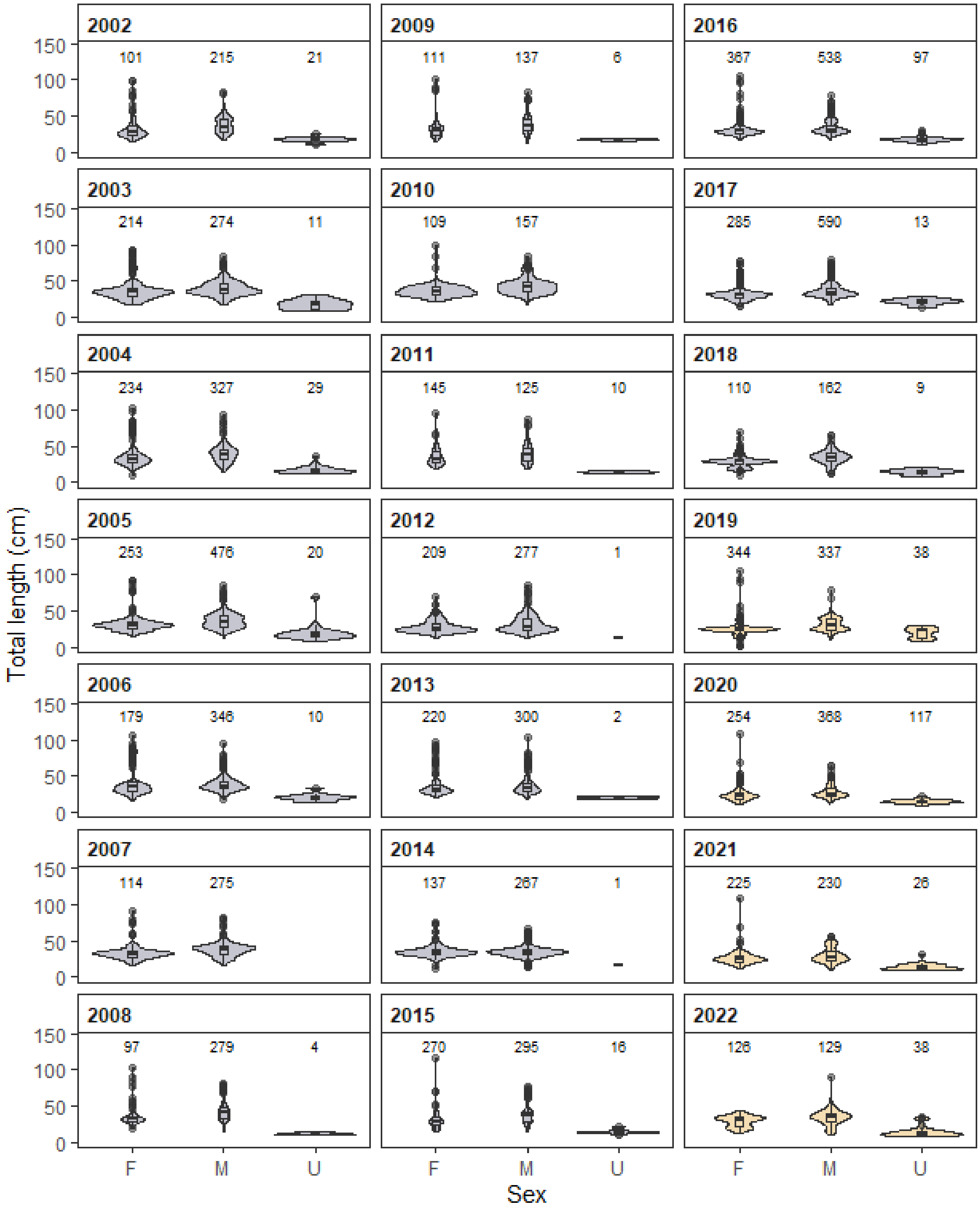

Figure 50: Length-frequency of striped bass from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

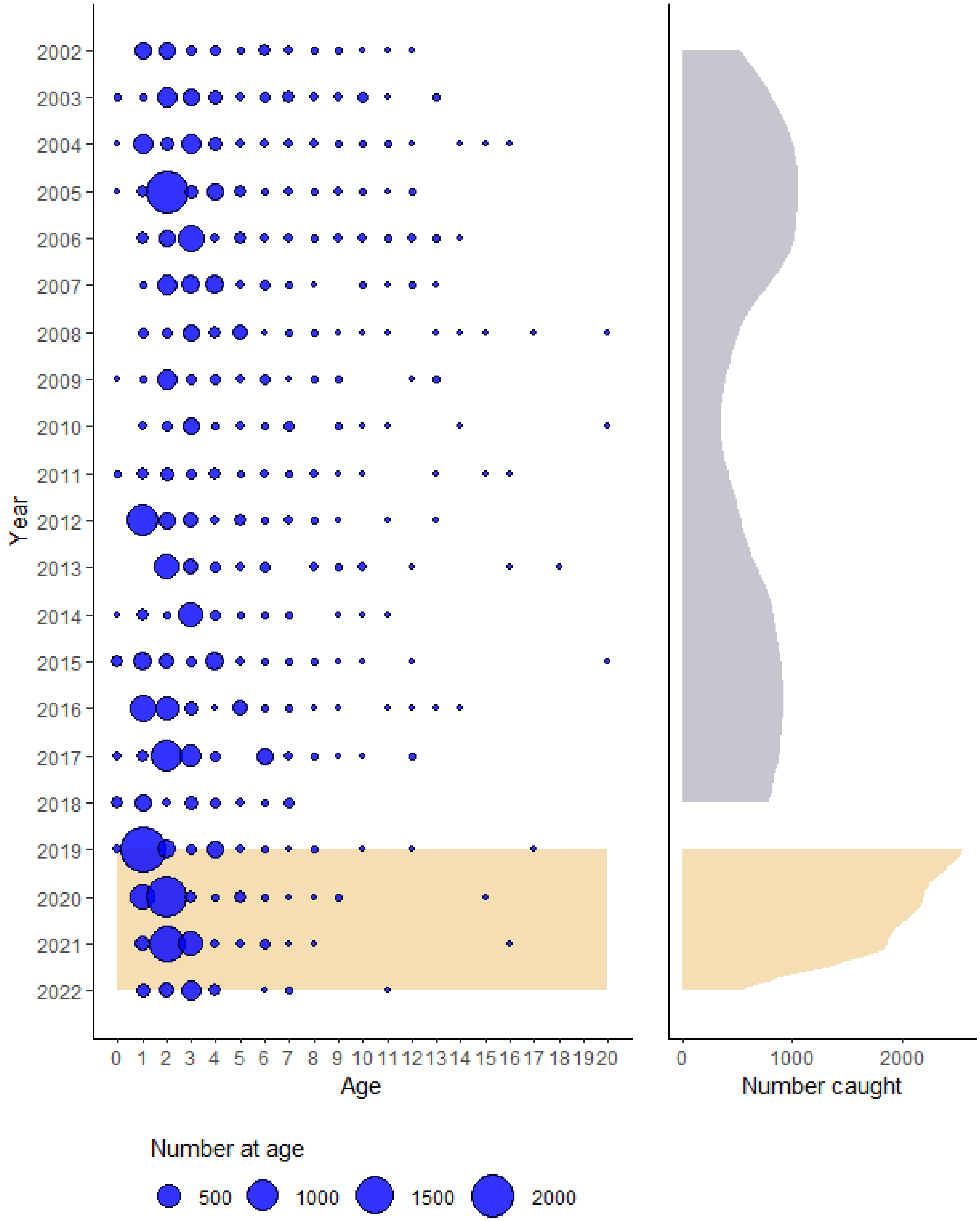

Figure 51: Striped bass age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

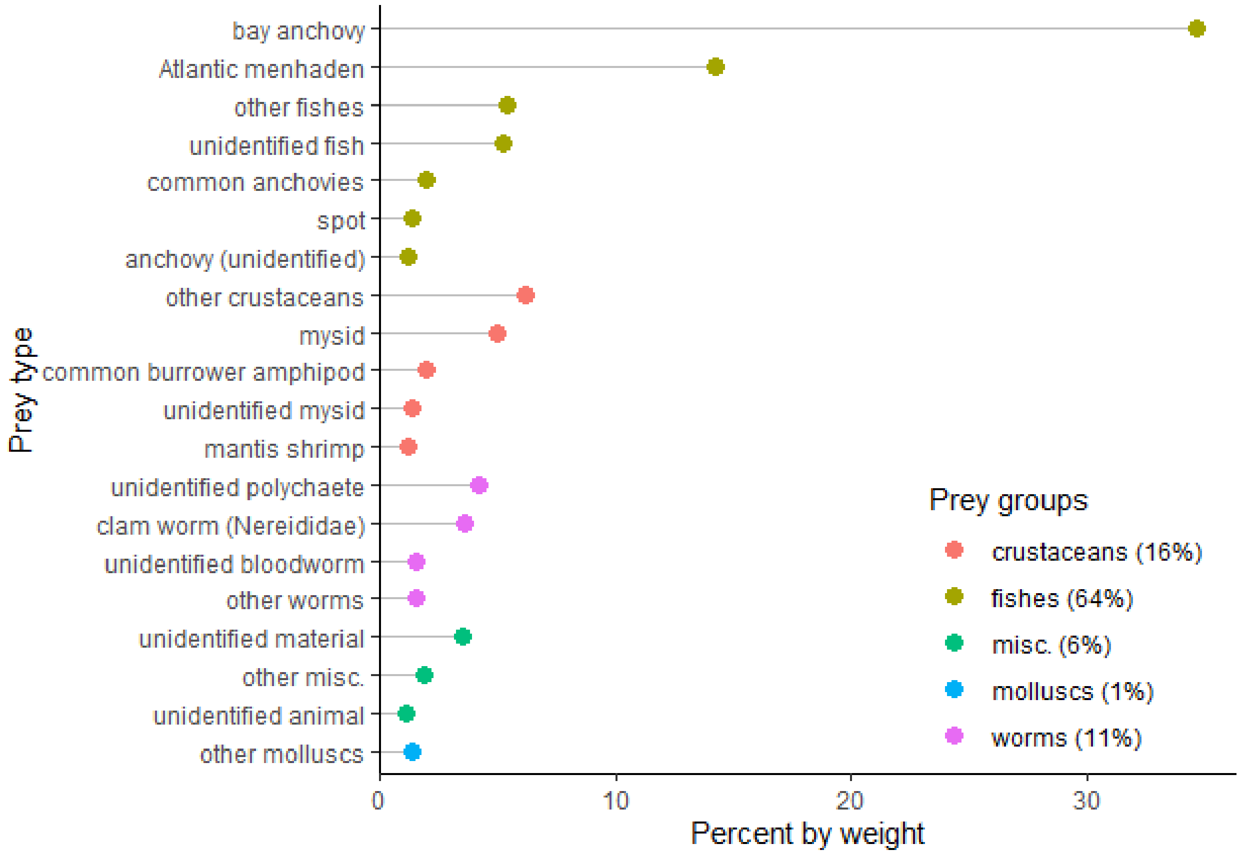

Figure 52: Diet composition of striped bass, expressed as percent by weight, based on 4765 fish and 1799 clusters.

Summer flounder, *Paralichthys dentatus*

Abundance: Summer flounder are a primary target species for the survey, with several hundred individuals caught in most years (Table 10). While total numbers caught with the new sampling gear (2019-2022) were significantly higher than those from the later years with the *R/V Bay Eagle*, they were within the range captured in the earliest survey years (i.e, 2002-2008).

This species is typically increasingly abundant from spring into late fall, with highest catches in September and/or November, and this pattern was observed in 2022 (Figure 53). It was most abundant in the southern regions (C and D), though catches were not uncommon in the northern regions in September.

Relative abundance indices were calculated based on data collected during the September and November cruises. Prior to 2019, all depth strata in regions 4 and 5 were used; after the 2019 restratification, data from both depth strata in regions C and D were used. Both relative abundance indices were highly variable in the earlier part of the time-series and exhibited a substantial decline from a peak in 2006 to low, consistent values from 2012 to 2018 (Figure 54). Changes in the abundance of summer flounder in Chesapeake Bay have been linked to a decrease in the utilization of the Bay relative to the coastal ocean that has not been documented in the more northern Delaware Bay (Schonfeld et al., 2022). Since 2019, with the new gear, the indices rose substantially, though within the historical range, declined in 2020 and 2021, and increased again in 2022. The new gear appears to be more efficient at capturing smaller specimens when compared to the original ChesMMAP gear.

Length and age: Summer flounder measuring 20-50 cm total length are most common in the survey catches, but specimens as large as 75 cm have been captured (Figure 55). In several years, a large number of fish under 30 cm were present in the Bay. This species exhibits sexually dimorphic growth patterns (Dery, 1981); the vast majority of ChesMMAP specimens larger than 35 cm and nearly all individuals larger than 40 cm are females (Figure 56).

Most fish in the survey are age-5 and under, and the oldest fish yet captured are three specimens at age-12. It is more difficult, compared to other species, to follow abundance trends of particular year-classes in successive years after age-2 (Figure 57). This could be the result of differential migration patterns among different sized fish or of fishery preferences and/or regulations. As well as the declining abundance estimates described above, the summer flounder occurring in the Bay appear to have a restricted age distribution in recent years (since about 2007). In 2021, no individuals older than age-1 were captured, but a broader age composition was observed in 2022, with individuals up to age-6.

Diet: The diet of summer flounder comprised fishes, particularly bay anchovy and weakfish, and crustaceans, primarily small-bodied mysids and shrimps (Figure 58), together representing more than 90% by weight. No other prey group constituted more than 2% of the diet.

Table 10: Summer flounder sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	770	430.5	42.7	770	649	649	425	410
2003	563	341.5	67.6	562	441	441	325	316
2004	728	309.7	72.0	728	565	565	377	372
2005	759	386.7	89.5	759	669	669	420	410
2006	932	453.1	88.6	932	755	755	444	430
2007	567	259.1	81.8	563	489	489	317	313
2008	638	280.9	77.8	638	543	543	354	348
2009	393	187.1	66.7	393	369	369	243	239
2010	385	180.0	67.8	385	354	354	215	209
2011	211	125.3	62.9	211	208	208	111	107
2012	92	33.4	31.0	92	91	91	57	52
2013	110	35.7	33.7	110	107	107	51	45
2014	63	16.7	30.0	63	63	63	40	40
2015	129	41.9	35.6	129	127	127	72	72
2016	77	21.8	30.0	77	77	77	40	39
2017	135	35.0	28.9	135	128	128	85	84
2018	105	26.5	15.6	105	96	96	44	44
2019	623	78.7	90.0	623	385	385	220	216
2020	286	42.0	64.4	286	215	215	105	105
2021	267	23.6	67.8	267	185	185	82	80
2022	688	74.2	76.7	688	426	426	201	197

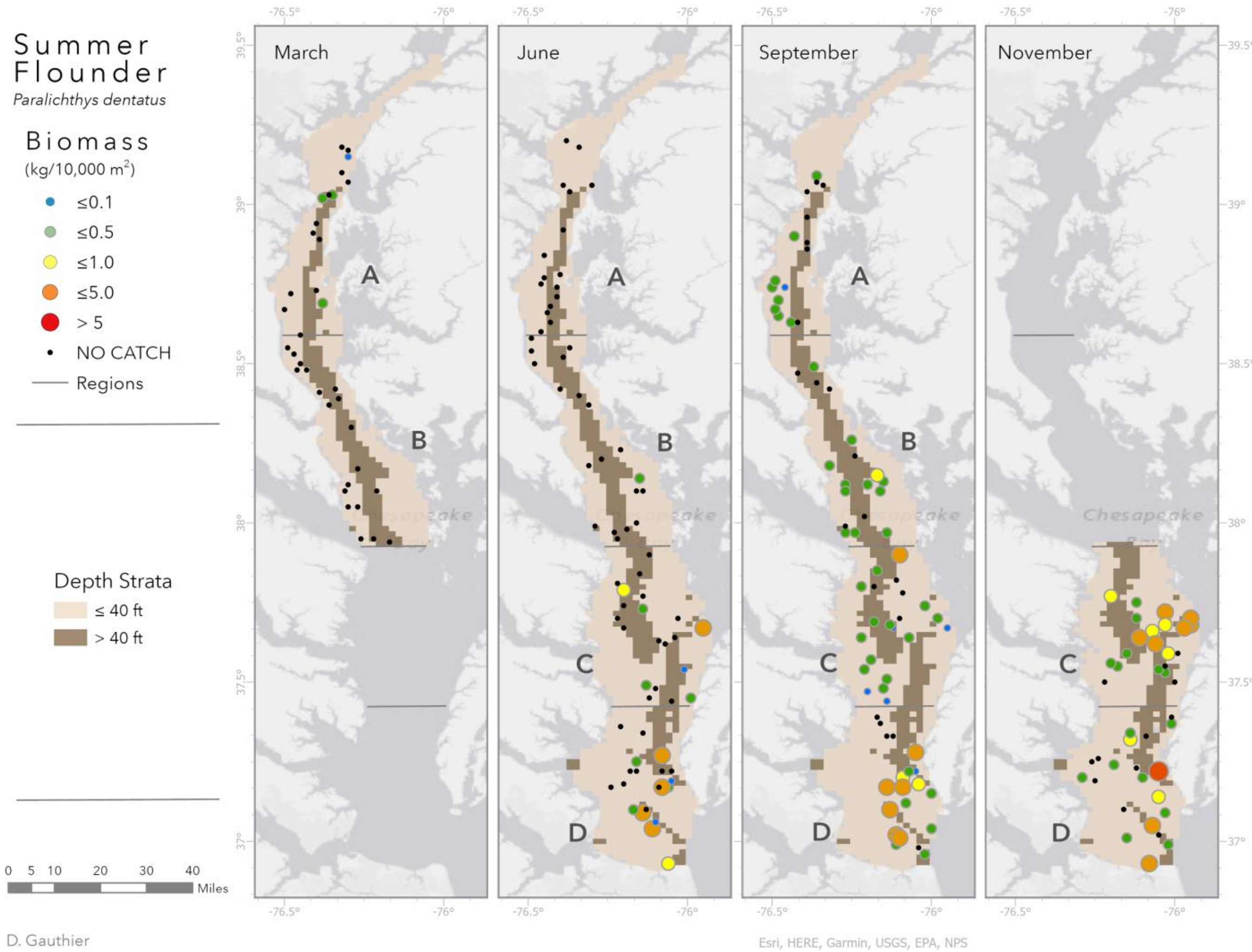

Figure 53: Site-level estimates of biomass (kg 10,000 m^{-2}) of summer flounder in 2022.

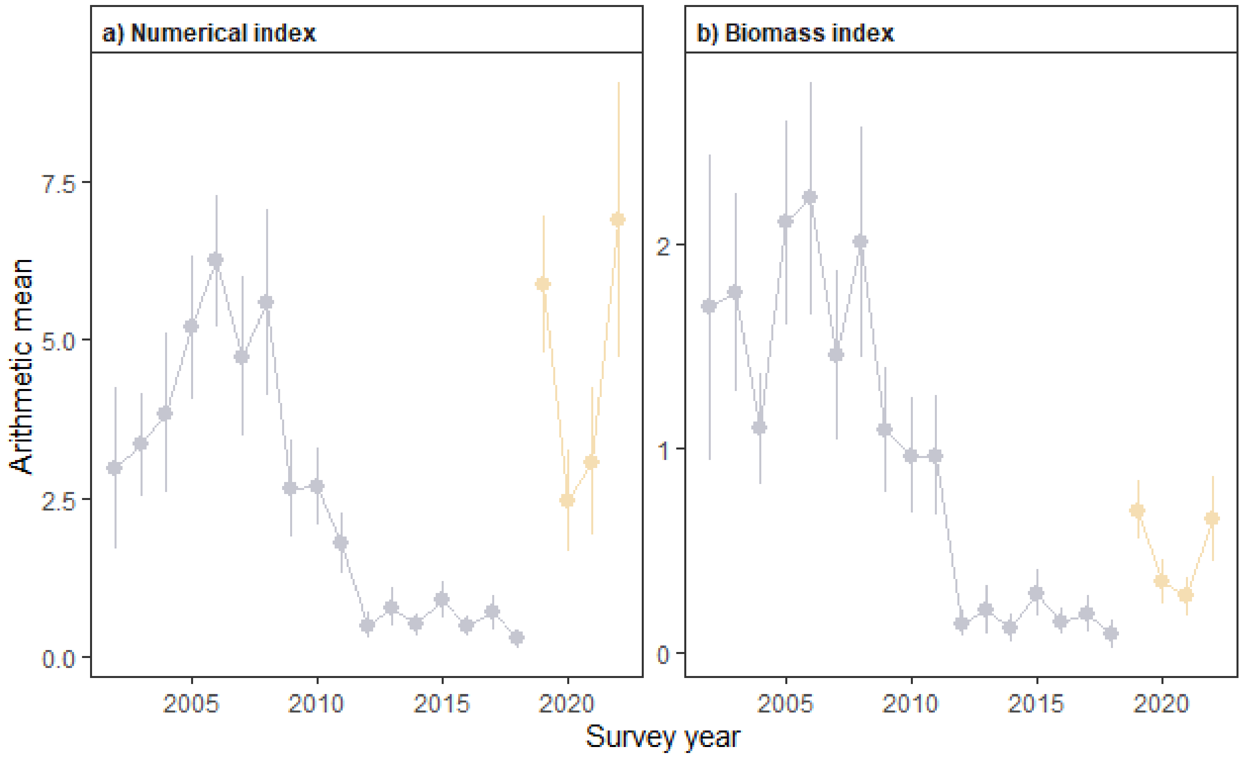

Figure 54: Indices of abundance for summer flounder by number and biomass, for all ages combined.

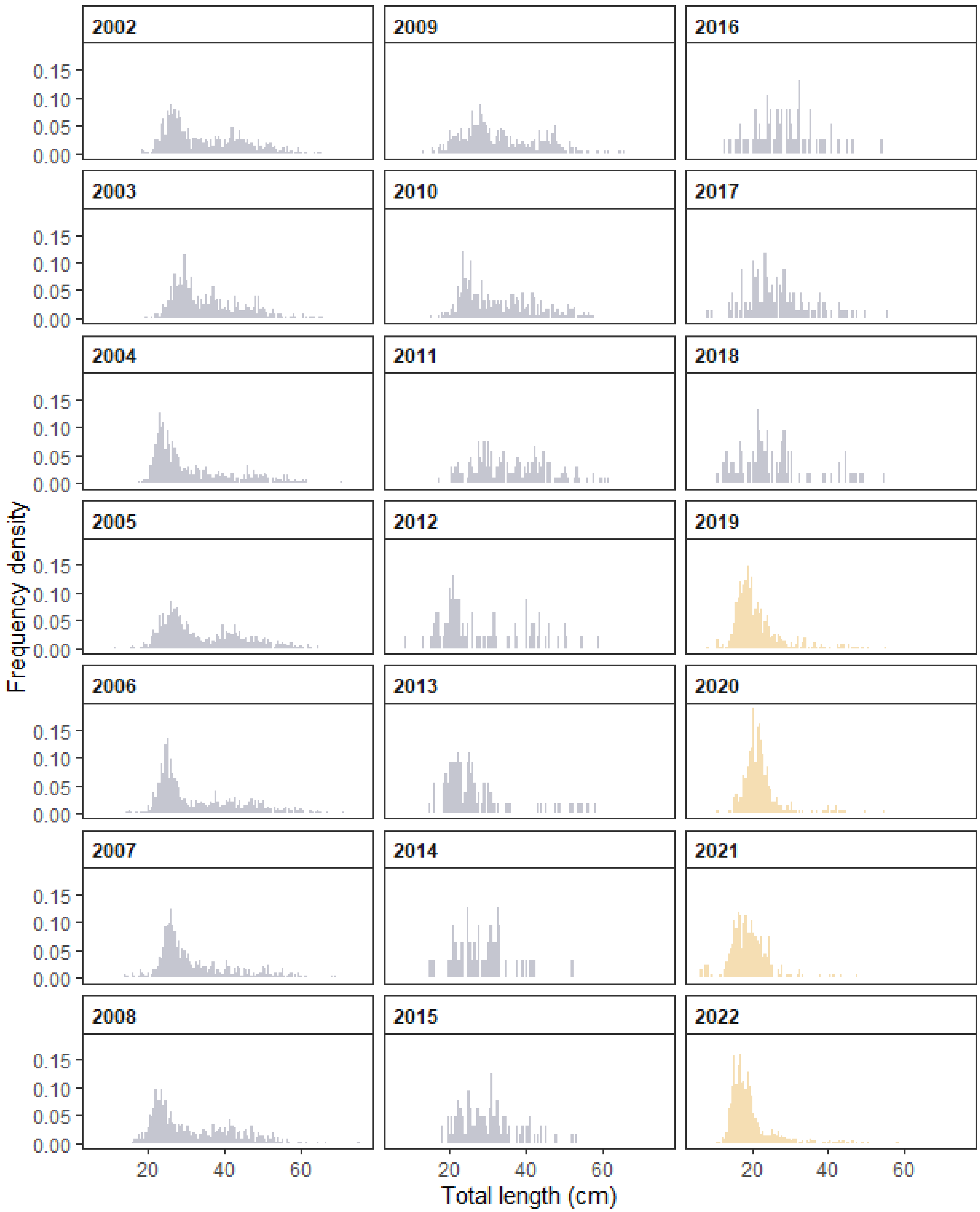

Figure 55: Length-frequency of summer flounder from 2002-2022.

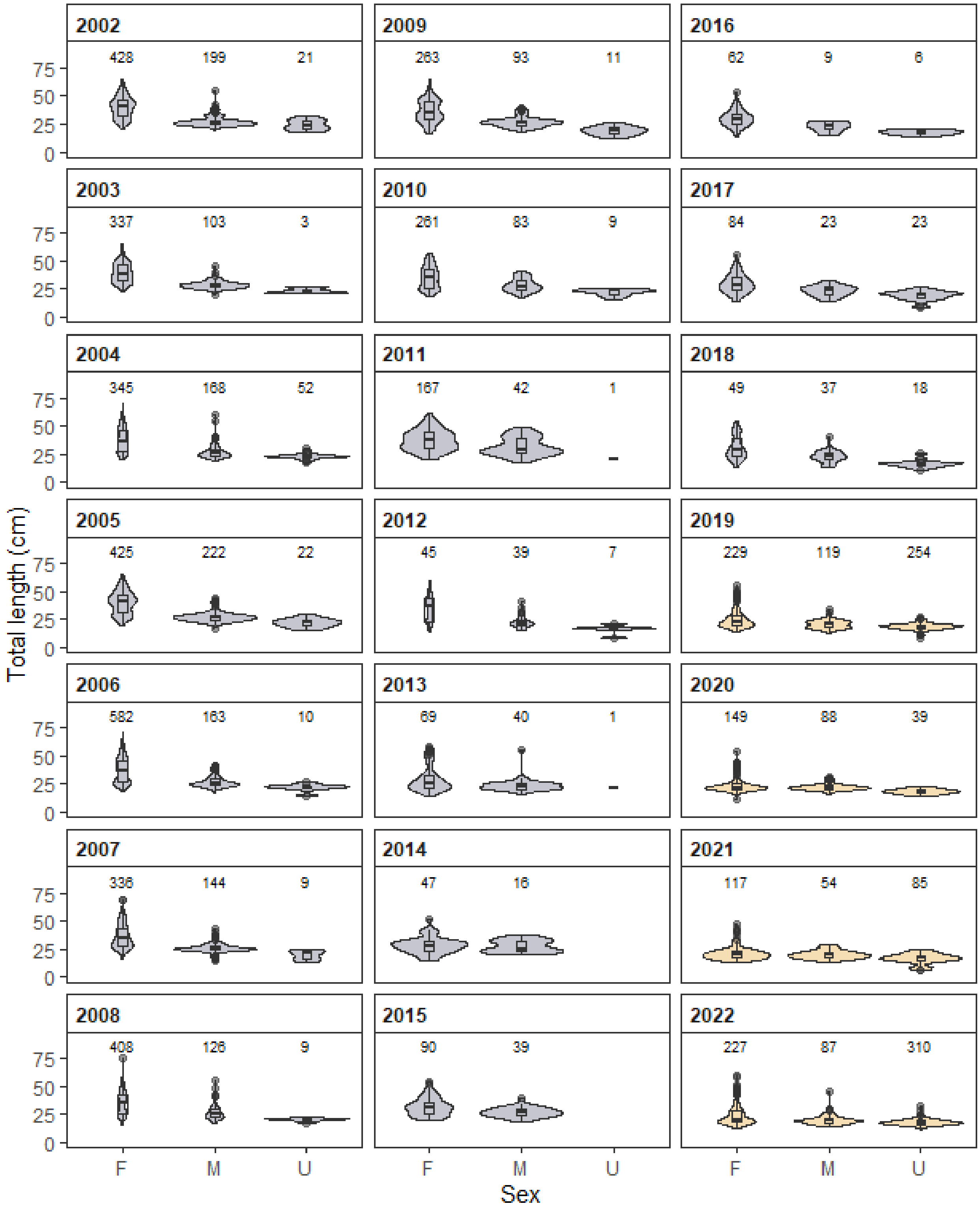

Figure 56: Length-frequency of summer flounder from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

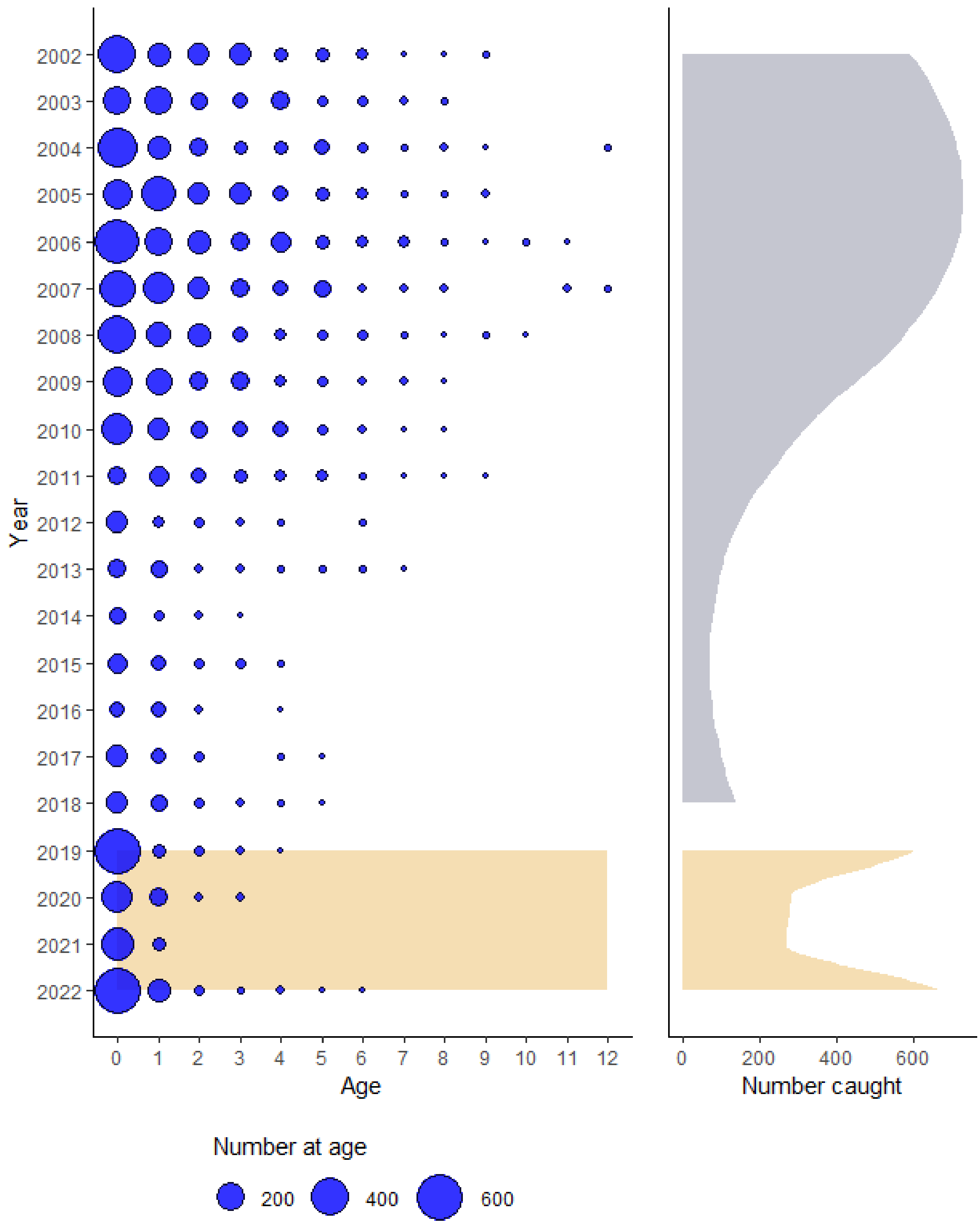

Figure 57: Summer flounder age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

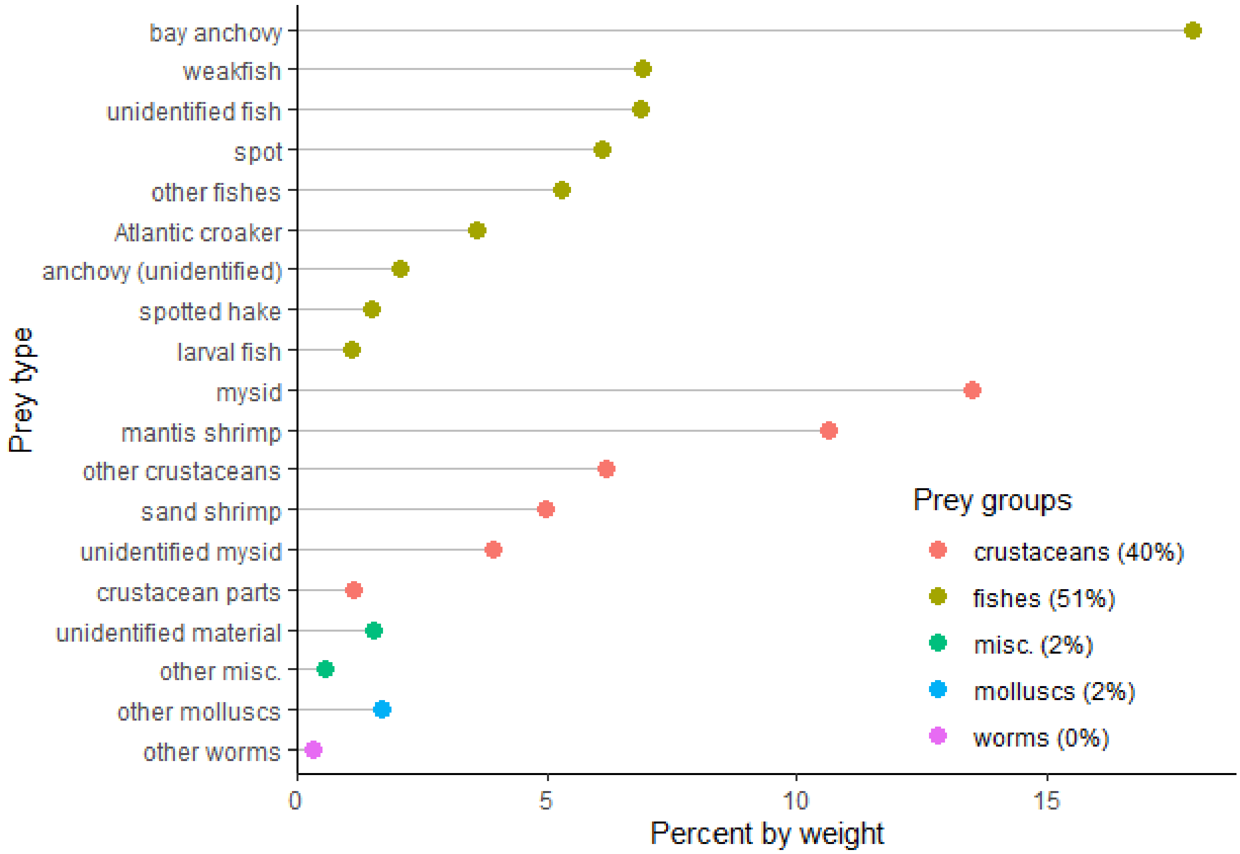

Figure 58: Diet composition of summer flounder, expressed as percent by weight, based on 4129 fish and 1968 clusters.

Weakfish, *Cynoscion regalis*

Abundance: Weakfish are among the most abundant species in the survey, with 1,000-3,500 individuals caught through 2010 (Table 11). Overall, total catches were lower from 2011 to 2018, though over 1,000 individuals were captured in a few years. In 2019, with the new gear, catches increased 5- to 10-fold, ranging from about 15,000 to 24,000 annual captures.

This seasonal resident typically migrates into the Bay in late spring, early summer, such that March catches are low, but the remainder of the year is characterized by generally high abundance. Peak catches are usually in September and decline somewhat in November as fish begin their late fall migration out of the Bay. In 2022, weakfish were abundant primarily in southern regions in the June, September, and November cruises (Figure 59). It was most abundant in the southern regions (C and D), especially at moderate depths.

Prior to 2019, relative abundance indices were calculated using all depth strata in regions 4 and 5 from the July, September, and November cruises; after the 2019 restratification, data from both depth strata in regions C and D were used from the June, September, and November cruises. Both relative abundance indices exhibited a decline from a peak in 2004-2005 to low, consistent values through 2018 (Figure 60). The most recent stock assessment found that the coast-wide stock was depleted (Commission, 2019), and changes in the abundance of weakfish in Chesapeake Bay have been linked to a decrease in the utilization of the Bay relative to the coastal ocean that has not been documented in the more northern Delaware Bay (Schonfeld et al., 2022). Since 2019, the indices increased substantially, likely due to the change in gear.

Length and age: Most weakfish captured by the survey measured 20-35 cm total length, but specimens as large as 61.6 cm have been captured (Figure 61). The length-frequency distribution based on samples collected with the new gear (2019-2022) are similar to those in other survey years, though at much higher numbers. Sex-specific length frequencies do not display any discernible differences between males and females (Figure 62).

With only a few exceptions, most fish captured over 40 cm were sampled during the first two years of the survey (2002 and 2003). Likewise, the age structure of Chesapeake Bay weakfish has compressed over the past several years, with few individuals older than age-2 captured in recent years and almost none older than age-3 (Figure 63). In this survey, each sampling year seems to result in (what appear to be) reasonable numbers of young fish but very few of these specimens are captured in successive years as older fish.

Diet: Fishes constituted a majority of prey in the weakfish diet, representing over two-thirds by weight, with bay anchovy the predominant prey item (Figure 64). Crustaceans made up much of the remainder of the diet, with other taxa contributing minimally. Notably, weakfish account for more than 1% of prey in the diet of weakfish. The relatively low percent of Atlantic menhaden observed in the survey stomach samples, when compared to earlier studies, may be due to a combination of the truncation of the size range of weakfish in Chesapeake Bay, the broad geographic and temporal scale of this survey, and the cluster-sampling analytical methodology applied here.

Table 11: Weakfish sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	1,734	304.7	30.3	1,692	803	803	607	583
2003	2,315	400.0	58.0	2,198	707	707	654	640
2004	3,851	561.9	69.5	3,551	1,108	1,108	901	889
2005	2,715	378.5	65.6	2,711	1,119	1,119	918	908
2006	1,476	159.5	60.8	1,462	728	728	561	554
2007	1,214	128.0	55.7	1,210	554	554	439	435
2008	812	83.8	42.2	812	368	368	330	322
2009	873	46.2	60.0	873	478	478	387	384
2010	1,207	76.8	60.7	1,207	607	607	542	530
2011	918	57.5	55.2	918	454	454	323	322
2012	886	72.2	35.7	886	328	328	260	256
2013	301	42.0	28.4	301	187	187	130	128
2014	172	8.6	23.0	172	126	126	72	72
2015	688	51.9	26.7	688	285	285	141	140
2016	1,115	91.2	38.5	1,115	281	281	143	141
2017	943	68.3	36.3	943	335	335	194	191
2018	1,621	61.5	43.7	1,621	273	273	173	172
2019	18,987	1,327.2	80.7	11,355	661	661	387	381
2020	23,685	1,305.0	90.4	10,855	372	372	171	168
2021	16,901	1,044.4	85.9	9,794	467	467	277	273
2022	15,304	740.0	81.5	6,625	466	466	207	205

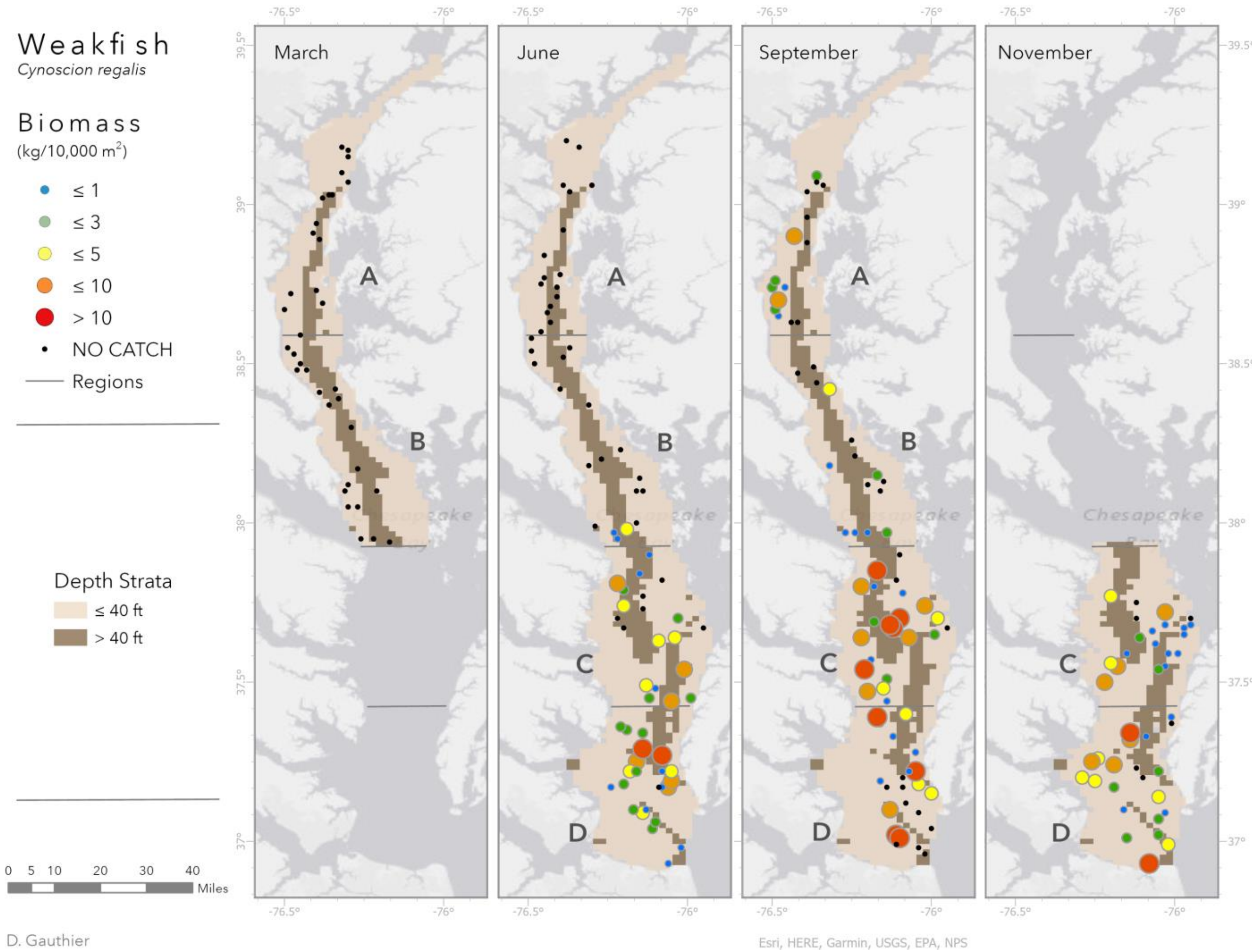

Figure 59: Site-level estimates of biomass (kg 10,000 m^{-2}) of weakfish in 2022.

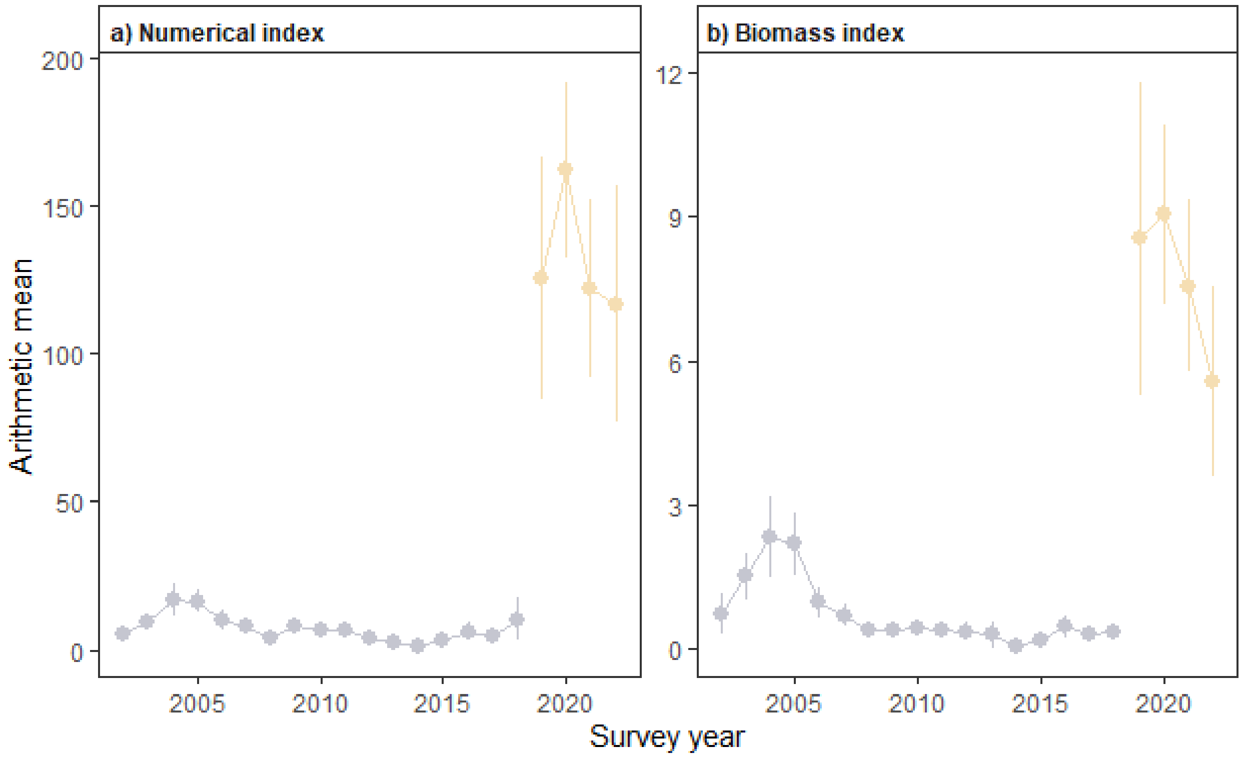

Figure 60: Indices of abundance for weakfish, by number and biomass, for all ages combined.

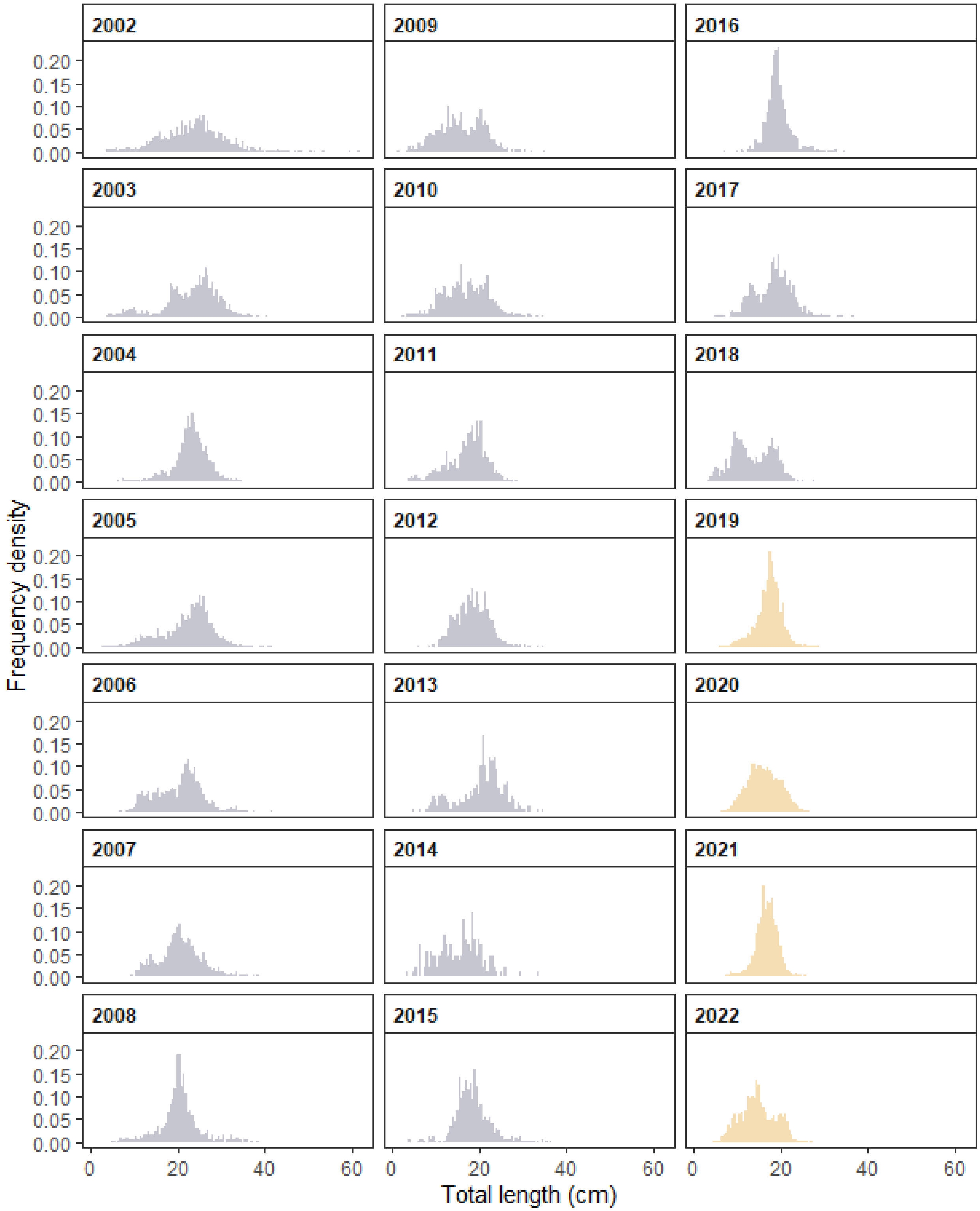

Figure 61: Length-frequency of weakfish from 2002-2022.

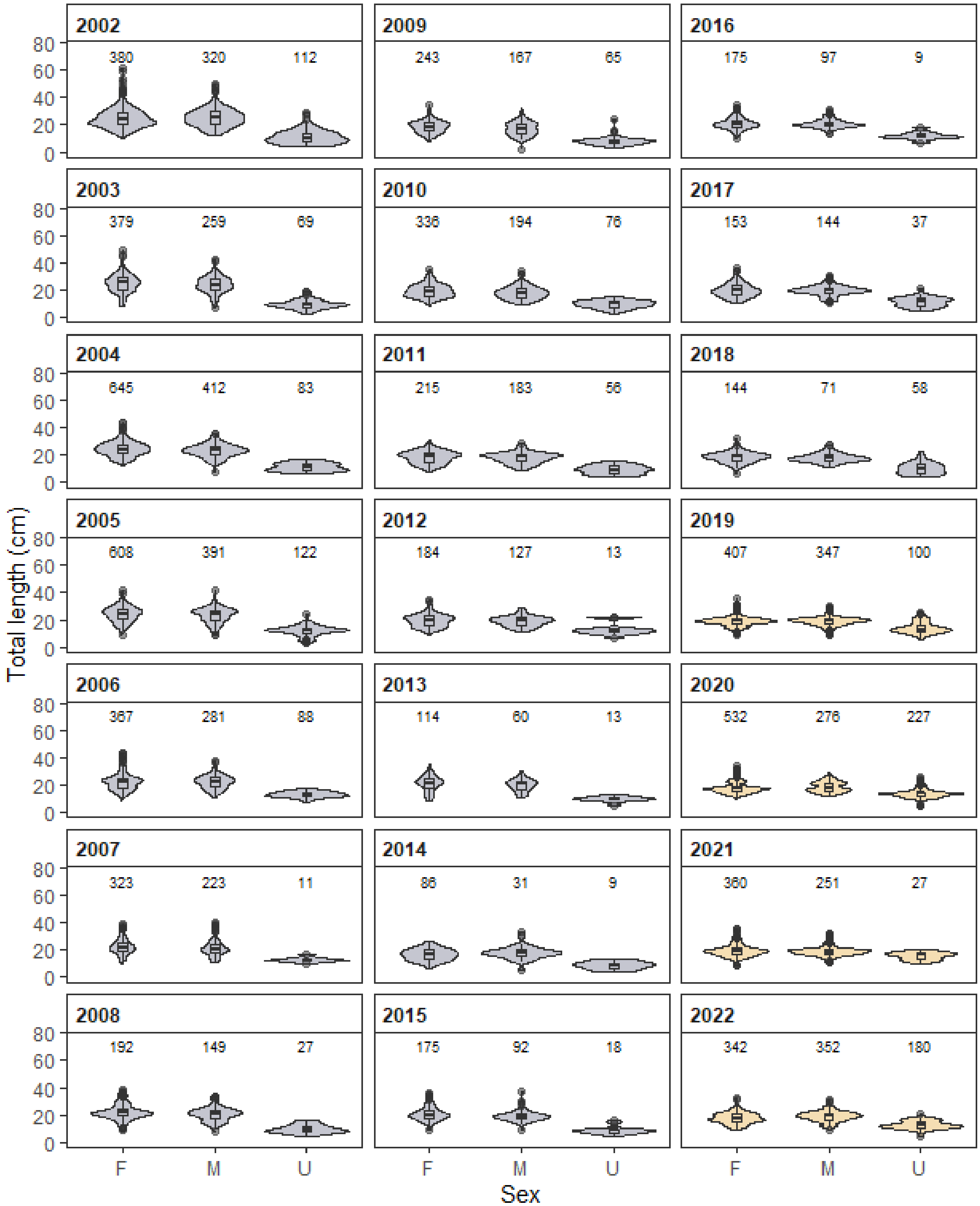

Figure 62: Length-frequency of weakfish from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

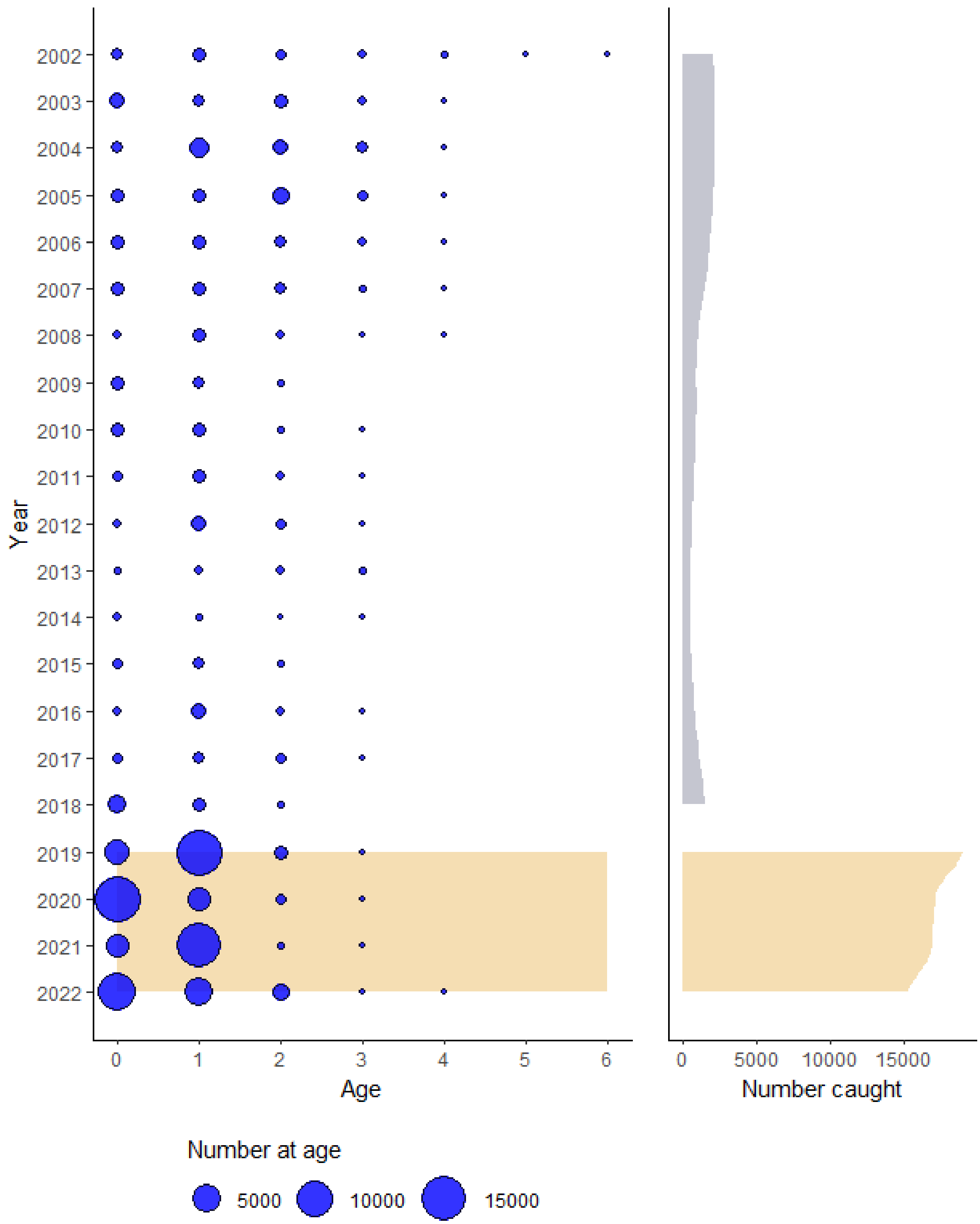

Figure 63: Weakfish age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

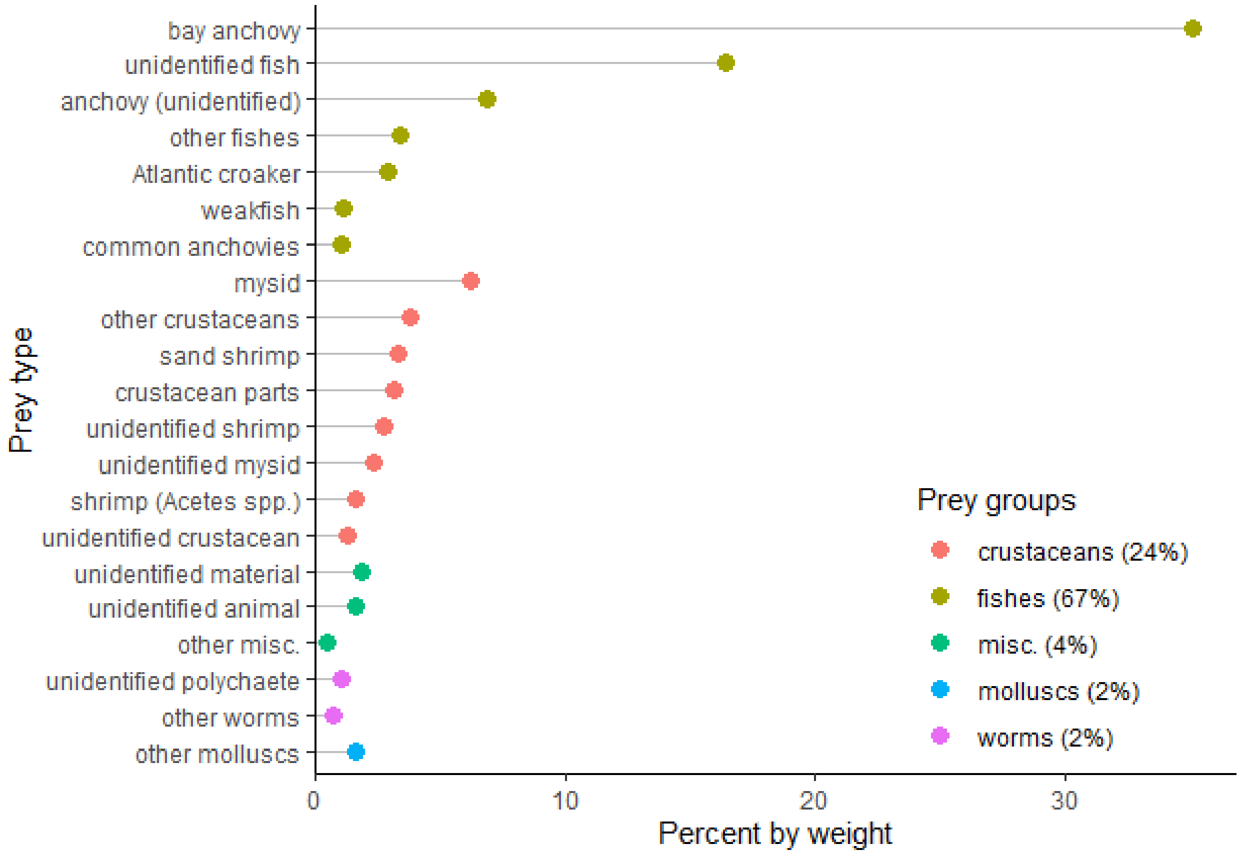

Figure 64: Diet composition of weakfish, expressed as percent by weight, based on 7694 fish and 2581 clusters.

White perch, *Morone americana*

Abundance: White perch can be extremely abundant in the survey samples in the northern regions of the Bay; over the entire time series, 3,000 to almost 16,000 specimens were collected annually (Table 12).

This species is typically most abundant in shallow strata in the northern regions and is rarely captured at the deepest stations. In 2022, the majority of captures of this species occurred in region A in March (Figure 65); only 567 specimens were caught during the remainder of the year, all of which were taken in region A.

Two sets of abundance indices have been calculated for this species:

1. The spring spawning stock was evaluated using data the from March cruises, including the northern regions (1-3) and the shallow and mid-depth strata (prior to 2019); since 2019, only the shallow depth strata of the northern regions (A and B) were included.
2. The summer residents were evaluated using data from September and November, including the shallow and mid-depth strata in regions 1 and 2 (prior to 2019) and regions A and B (from 2019 to present). Note that the fall index may need to be reexamined as regions A and B are no longer sampled in November.

Interestingly, the two sets of abundance indices displayed varying trends in abundance (Figure 66). The spring relative abundance indices increased in the early part of the time series, through about 2006-2007, were generally lower until 2015, then increased through 2018. The fall indices were much more variable year-to-year, and often the fall indices were high when spring indices were low (e.g., in 2009 and 2015). A March cruise was not conduced in 2018 due to a funding shortfall. Note that the spring 2019 cruise was conducted using the original sampling gear and the *R/V Bay Eagle*, so the large increases in spring abundances due to the new sampling system was not observed until 2020.

Note that these results should be interpreted with caution. The ChesMMAP survey covers only a portion of the range of the species and catches can be significantly influenced by salinity. Furthermore, due to the cessation of November sampling in the northern regions (A and B), the fall white perch indices should be re-evaluated.

Length and age: White perch of sizes greater than approximately 15 cm fork length are well sampled in the survey (Figure 67). Due to the relatively small maximum size, long life, and slow growth rates it is difficult to separate year-classes of this species using length-frequency. Length-frequency distributions based on samples collected with the new gear were similar to those from earlier years, though smaller individuals appeared to be somewhat more efficiently sampled using the near gear. Overall, the survey collected more females than males and females reach a slightly larger maximum size as compared to males (Figure 68).

This species is not well sampled by the survey until approximately age-4; however, past that age, the survey appears to adequately represent all age classes. A small number of age-19 specimens have been captured, but most specimens were younger than age-11. The age distribution appeared to be regulated by the relative success of each year-class. Year-class specific peaks in abundance can be easily followed during successive years in survey samples (e.g., 1993, 1996, 2000, 2003, 2011 year-classes).

Diet: Crustaceans constituted about one-third of the diet of white perch captured in this survey, primarily small-bodied taxa such as amphipods, isopods, copepods, and mud crabs (Figure 70). Worms and unidentified material (animal or otherwise) made up about half of the diet. A variety of molluscs (*Macoma* spp. and unidentified tissue) and a small amount of fishes (mostly bay anchovy) contributed the remainder of the diet.

Table 12: White perch sampling rates and preserved specimen analysis status by year. Note shaded rows represent the change in vessel and trawl gear beginning in June 2019.

Year	Number Caught	Biomass Caught (kg)	Presence at Index Stations (%)	Number Measured	Age Specimens	Ages Read	Stomach Specimens	Stomachs Analyzed
2002	6,625	996.6	25.0	4,020	552	552	471	402
2003	3,782	511.5	53.8	1,882	177	168	147	127
2004	11,021	1,727.4	66.7	6,677	356	356	270	267
2005	7,243	843.6	60.0	5,884	429	429	287	280
2006	11,980	1,611.0	60.7	5,899	385	385	263	254
2007	4,915	517.9	62.8	3,194	318	318	277	277
2008	2,924	340.1	52.5	2,360	260	257	227	224
2009	5,130	686.2	47.5	1,749	158	151	126	126
2010	2,996	453.6	50.8	1,627	207	207	158	157
2011	4,619	675.1	45.8	2,392	231	231	177	173
2012	3,737	459.9	58.1	2,423	151	151	111	109
2013	3,249	421.1	59.0	2,469	199	199	109	55
2014	3,208	341.6	55.7	1,844	153	153	94	92
2015	13,708	2,157.4	44.3	4,098	188	188	80	81
2016	7,165	979.5	55.7	2,935	208	208	104	103
2017	7,957	1,113.9	51.7	4,517	159	159	84	80
2018	3,777	522.7	75.0	2,131	102	102	47	46
2019	9,870	888.5	20.8	3,367	129	129	80	80
2020	15,945	1,580.0	40.0	3,128	93	93	43	42
2021	11,614	986.5	42.0	4,298	129	129	69	69
2022	4,909	486.9	52.0	2,114	118	118	63	63

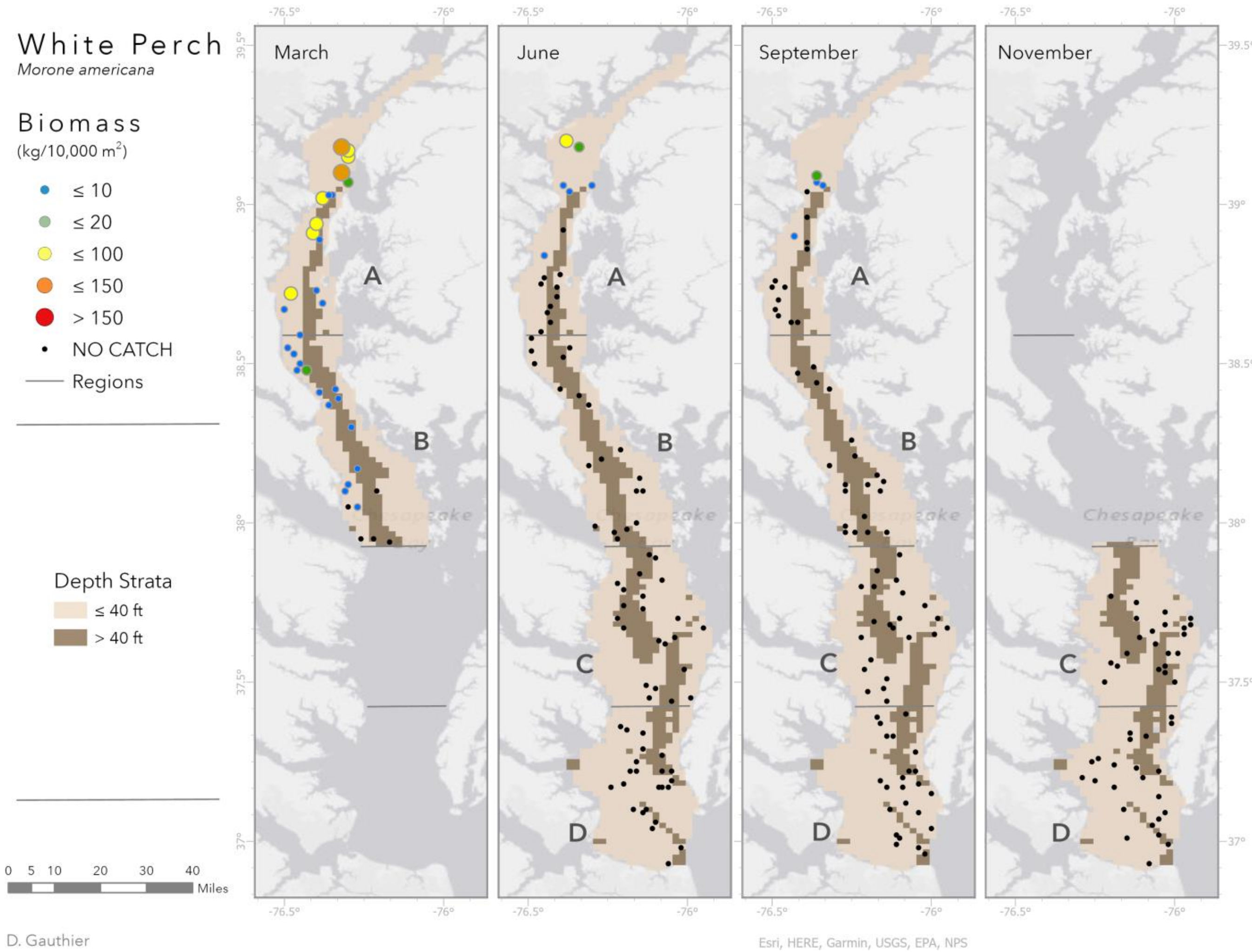

Figure 65: Site-level estimates of biomass (kg 10,000 m^{-2}) of white perch in 2022.

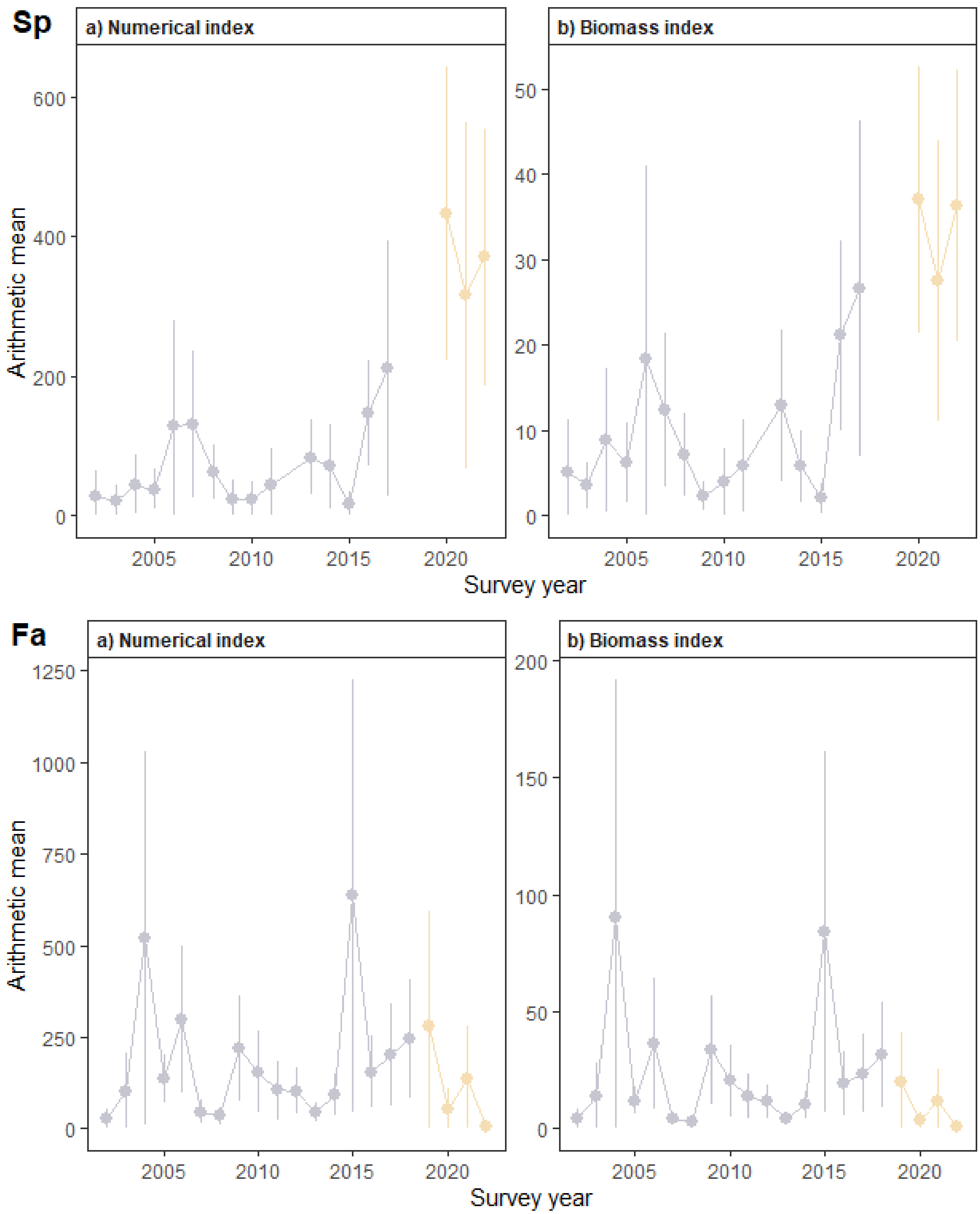

Figure 66: Indices of abundance for white perch, by number and biomass, for all ages combined; Sp = spring (March) only and Fa = fall (September and November).

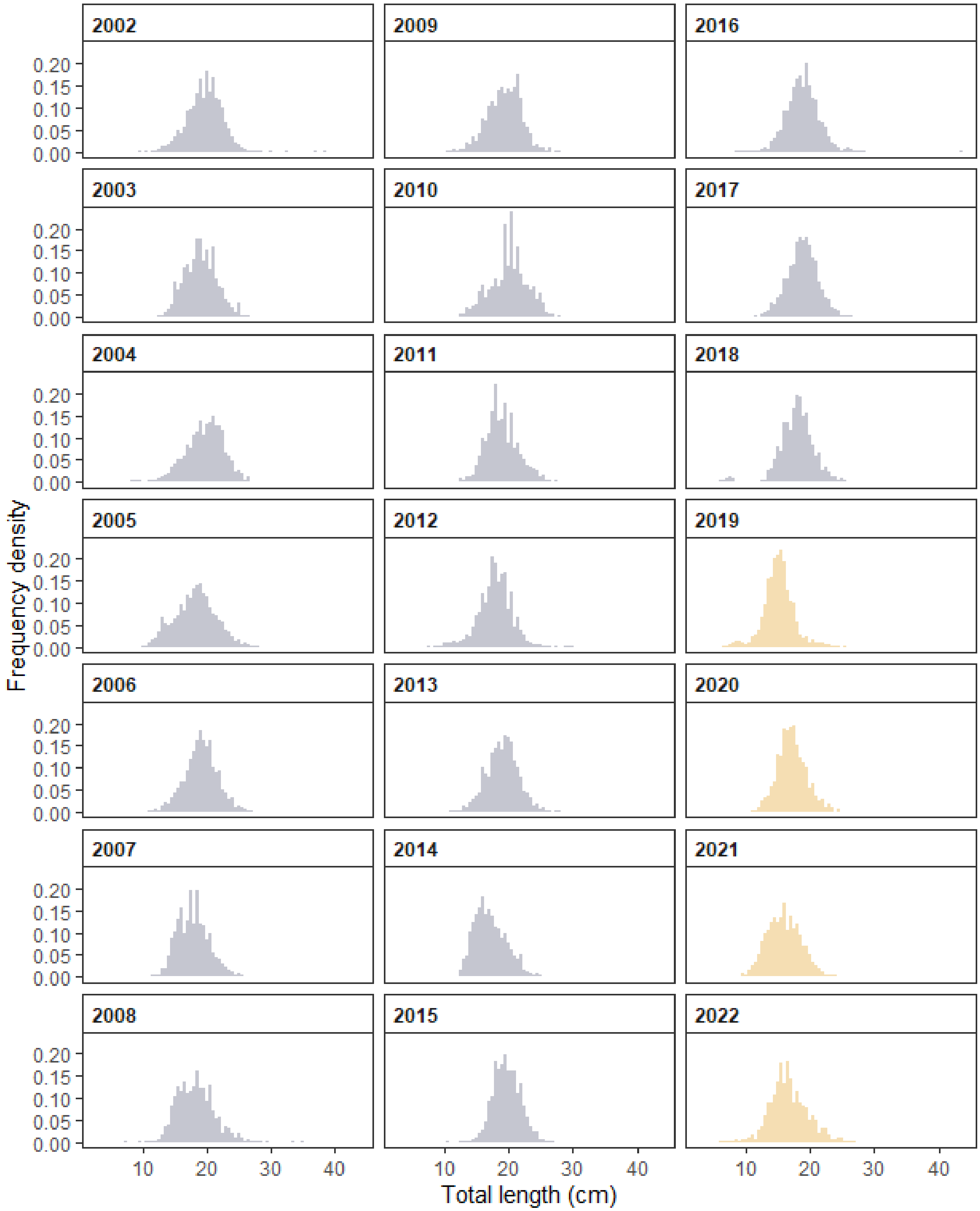

Figure 67: Length-frequency of white perch from 2002-2022.

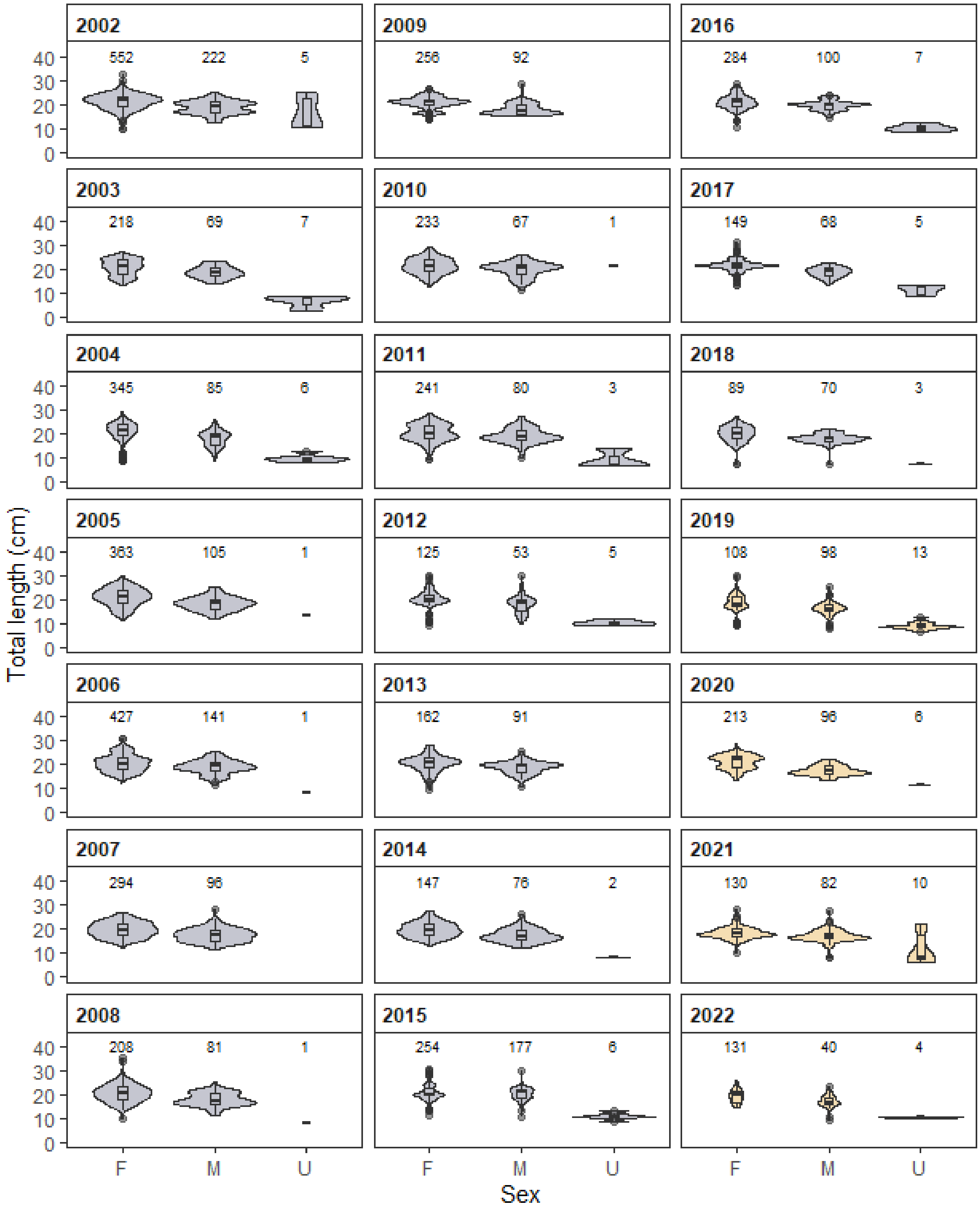

Figure 68: Length-frequency of white perch from 2002-2022, by sex (F = female, M = male, U = unknown). The numbers above each plot represent sample sizes.

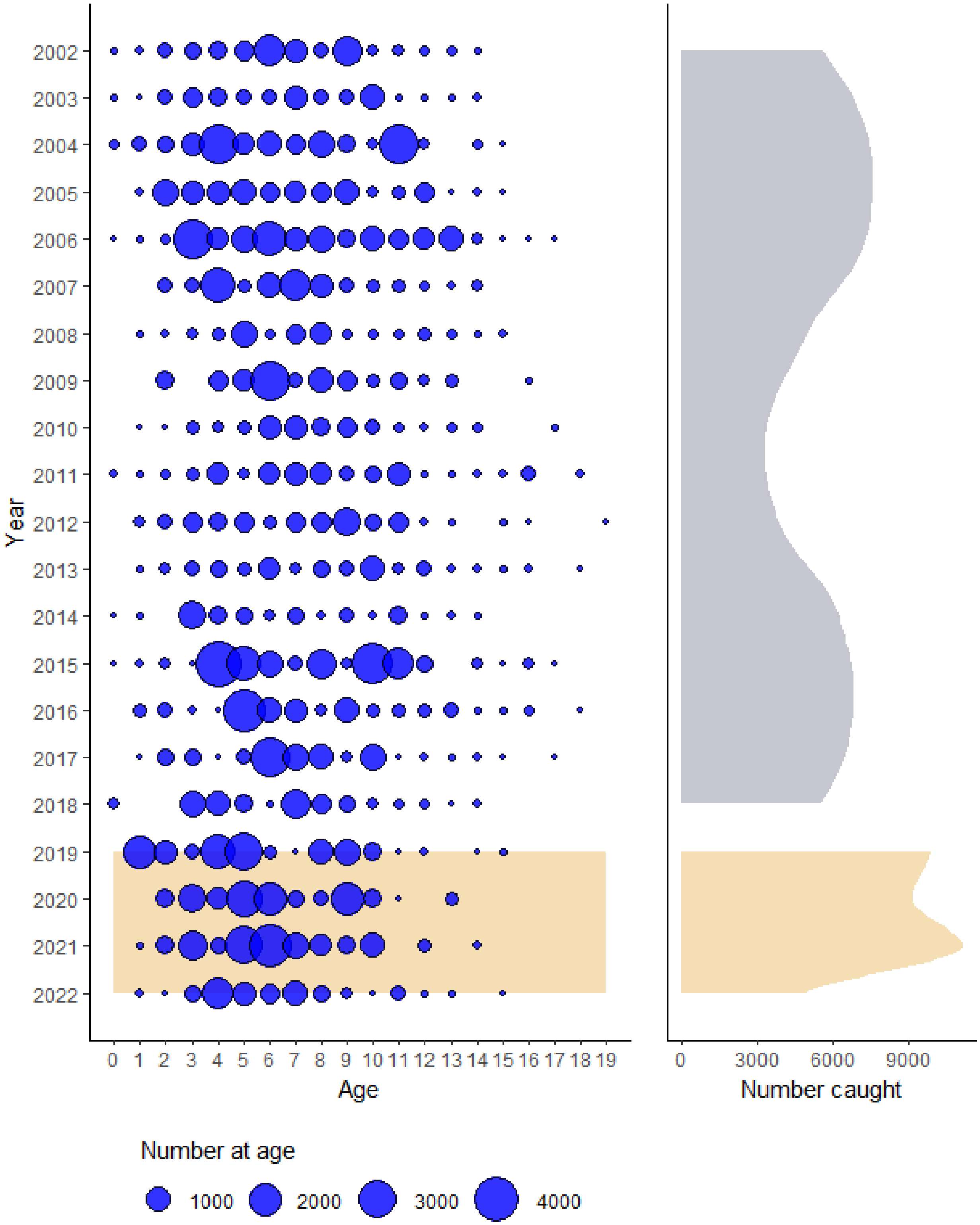

Figure 69: White perch age frequency through time, standardized by annual trawl minutes (8,000 prior to 2018, and 4,800 from 2019-2022), and smoothed annual total catches.

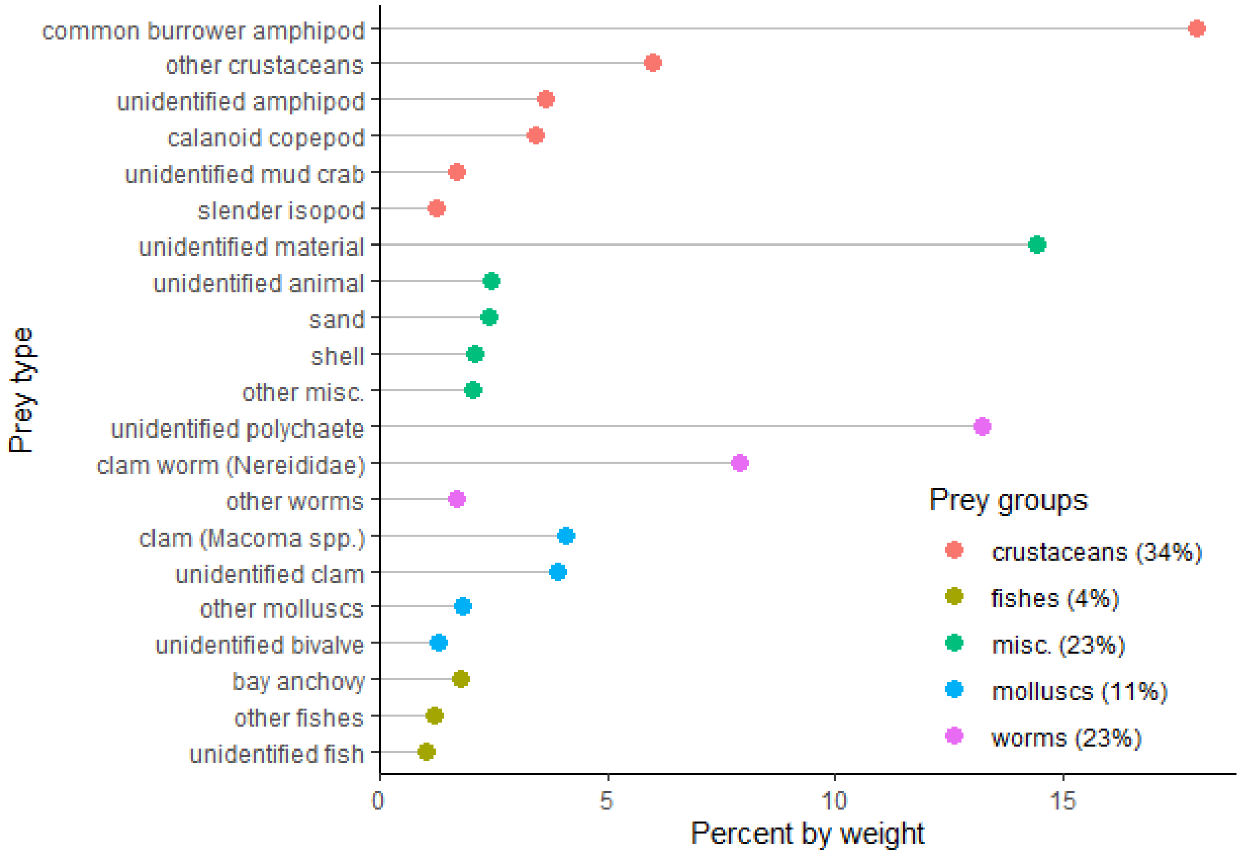

Figure 70: Diet composition of white perch, expressed as percent by weight, based on 3107 fish and 1257 clusters.

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Appendix I - Water quality

Water temperature

Interpolations

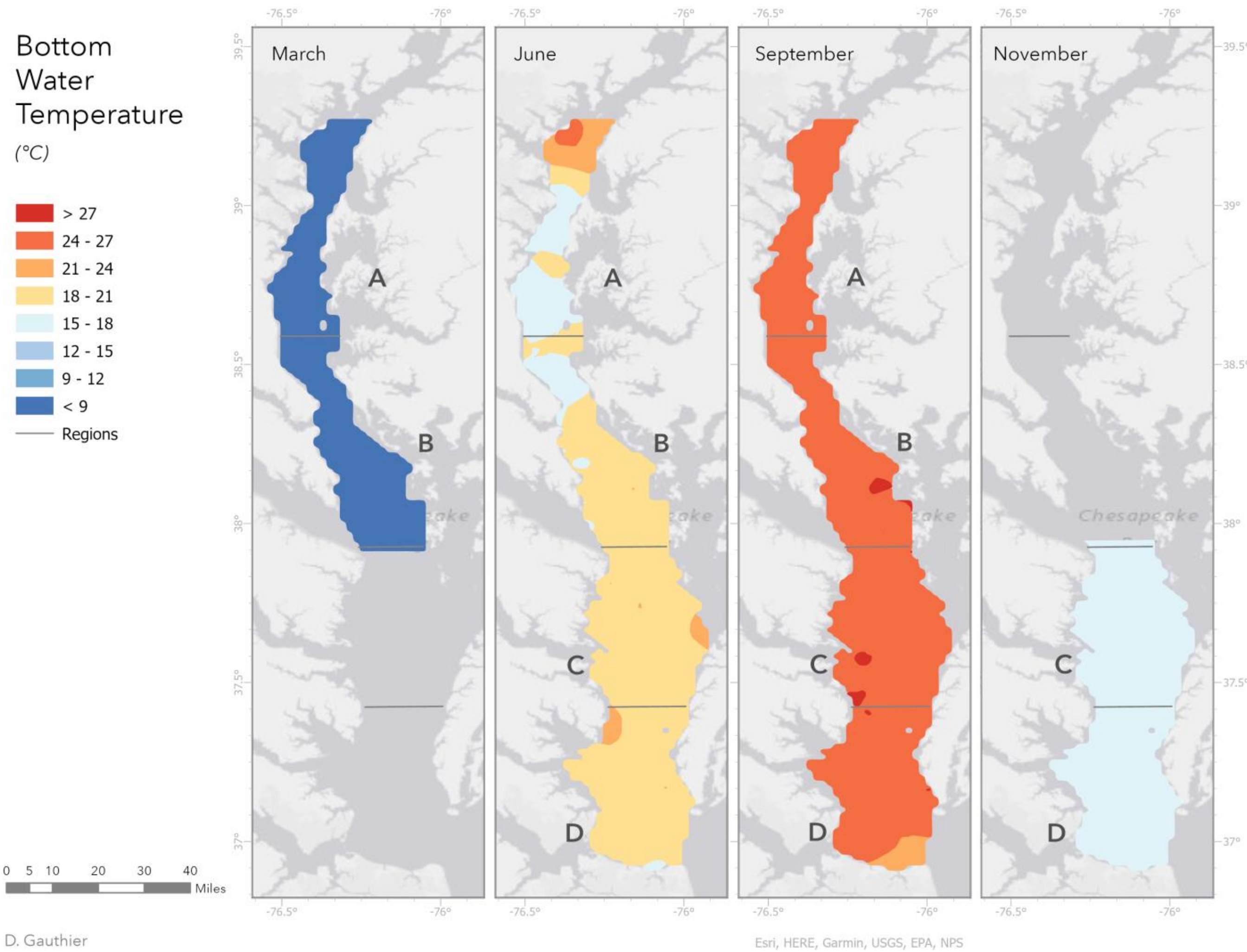

Figure 71: Interpolated bottom water temperature for 2022, by cruise.

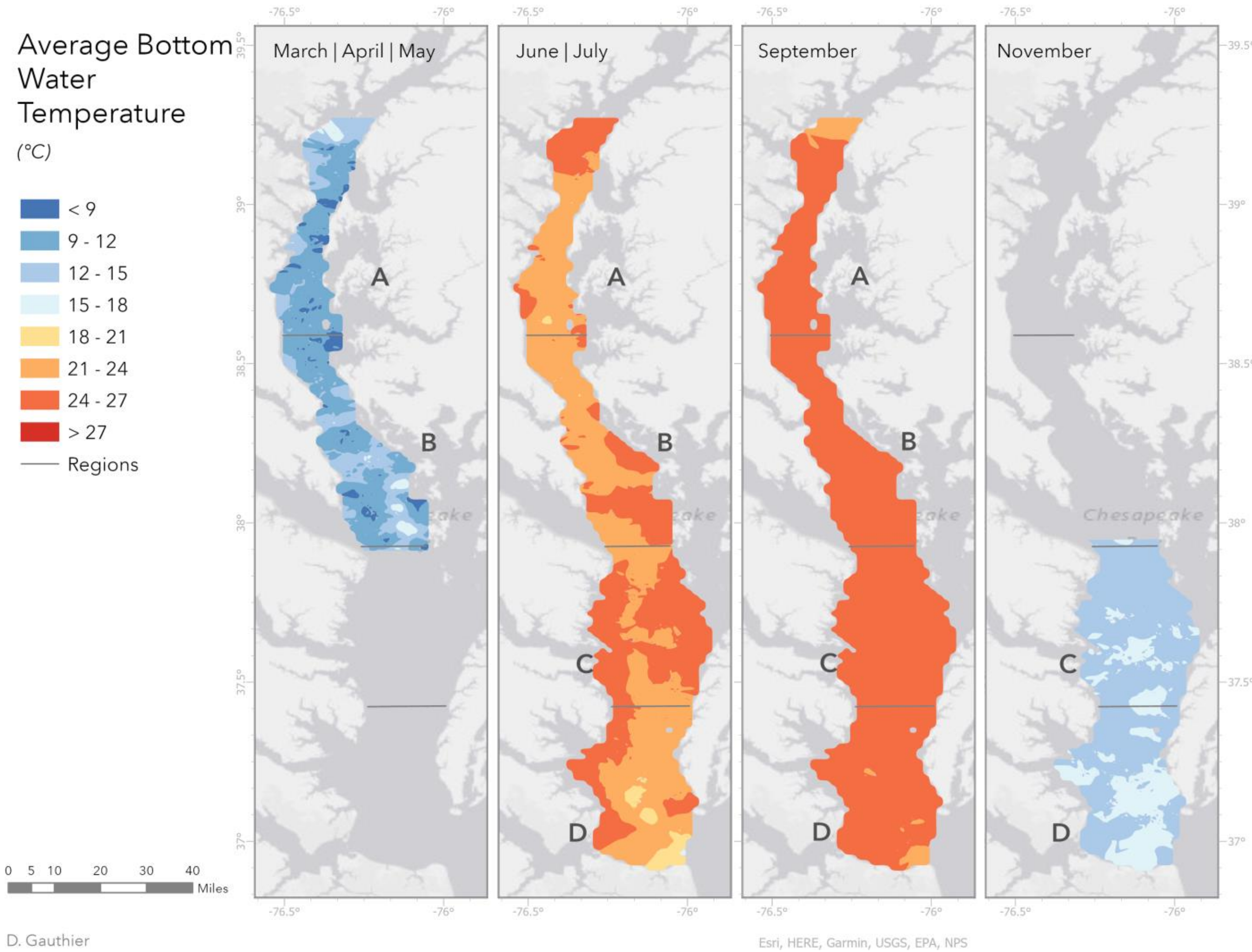

Figure 72: Interpolated bottom water temperature averaged over 2002 through 2022, by cruise.

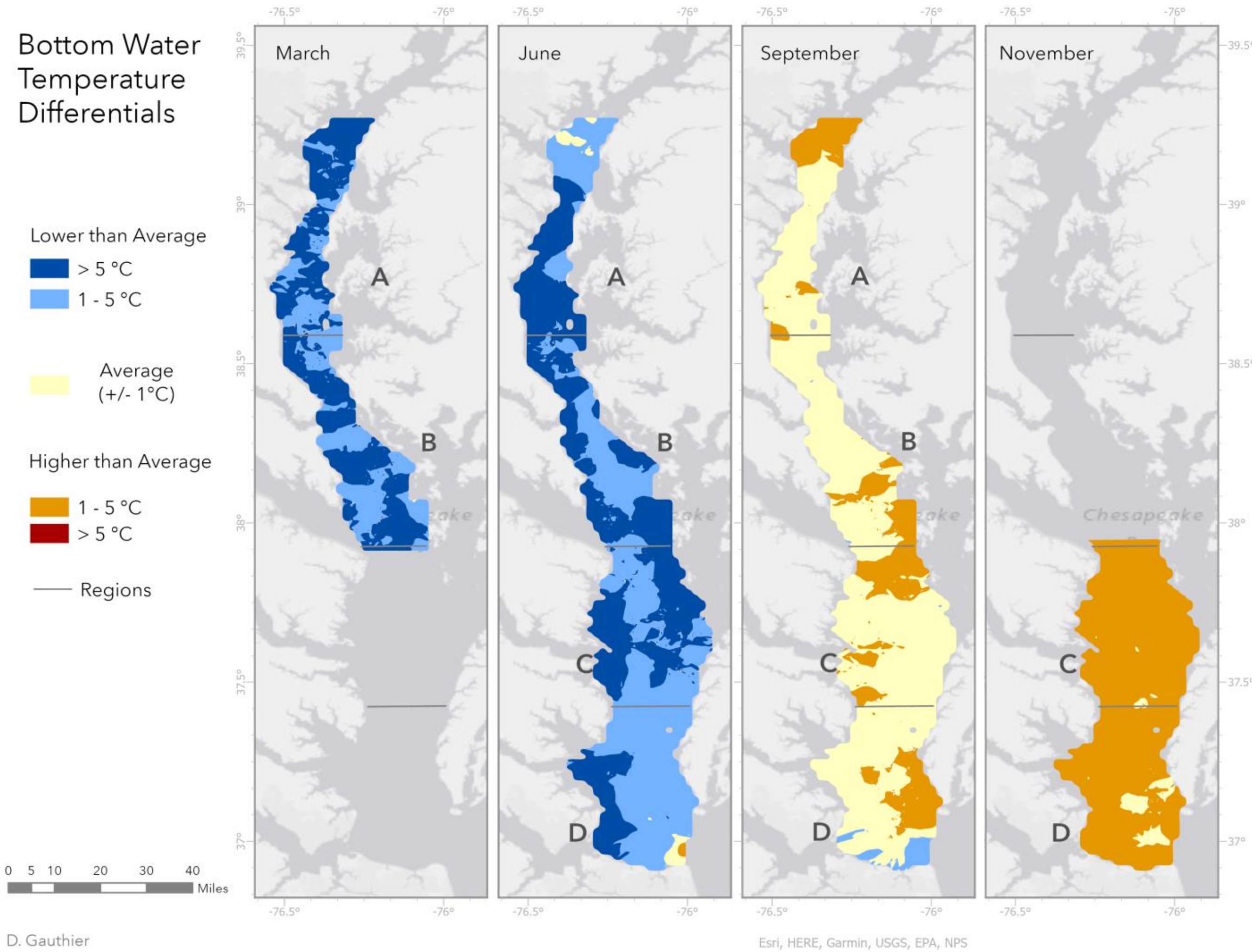

Figure 73: Interpolated 2022 bottom water temperature deviations from average, by cruise.

Profiles

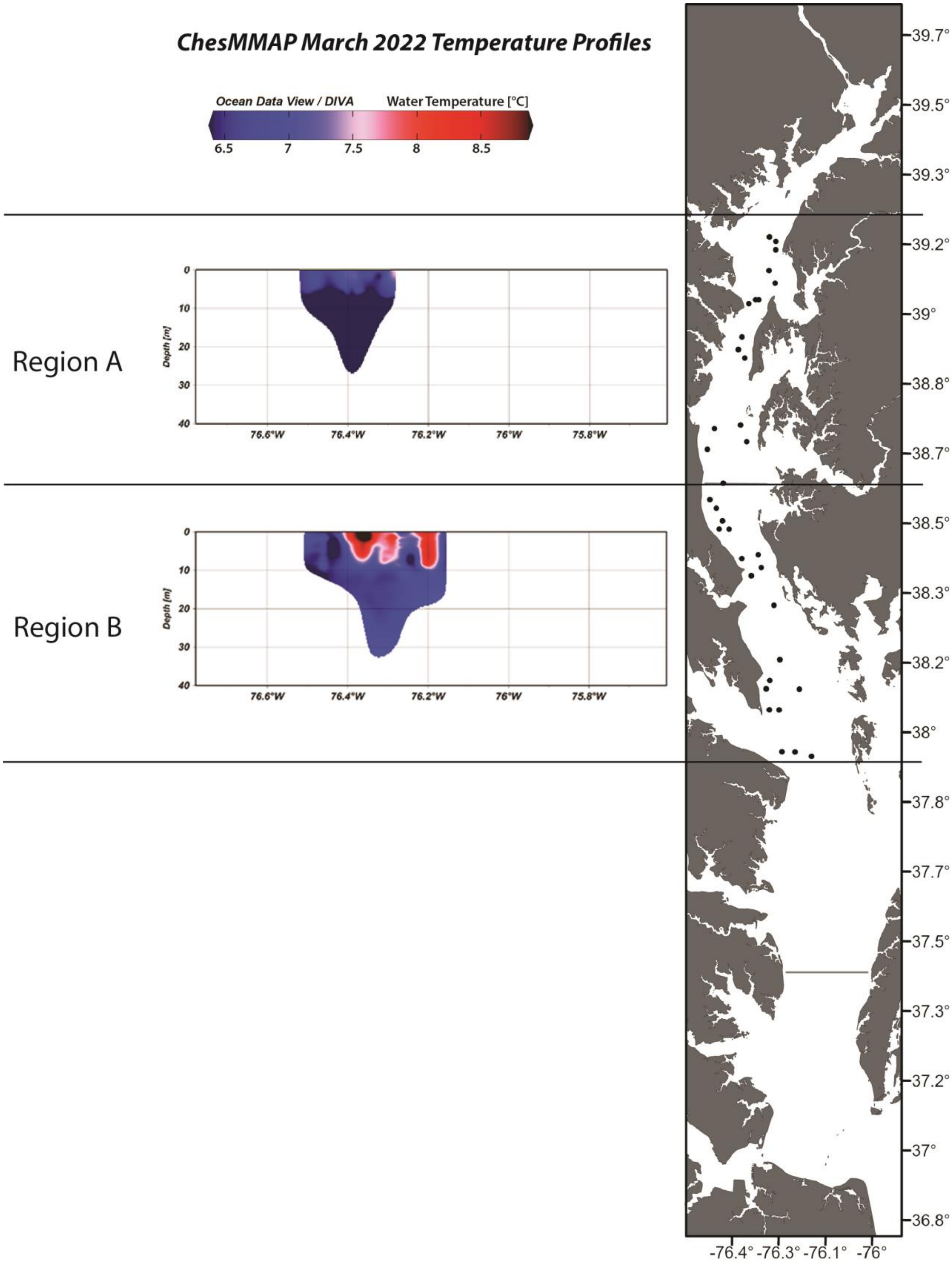

Figure 74: Interpolated bottom water temperature profile for March 2022.

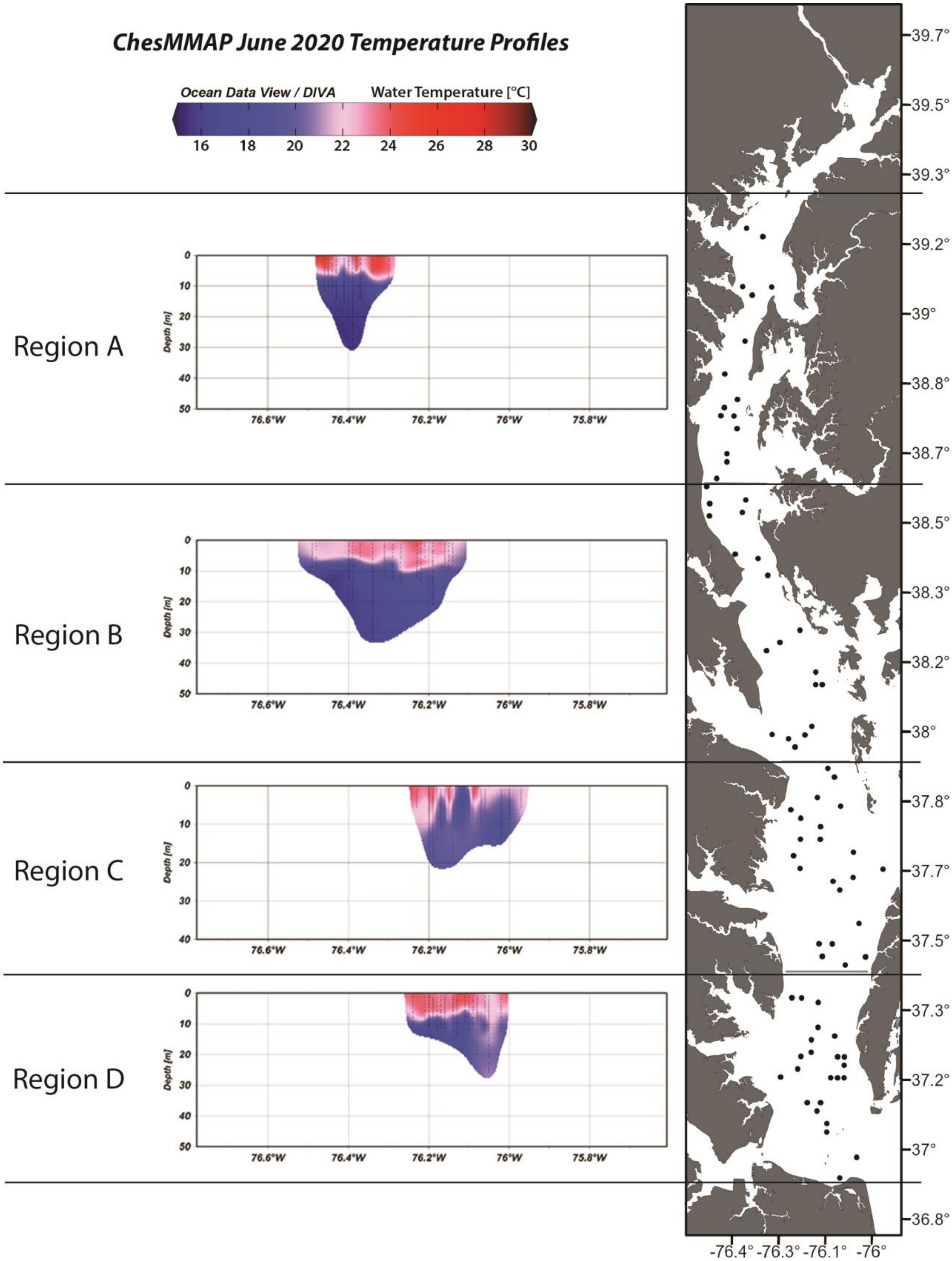

Figure 75: Interpolated bottom water temperature profile for June 2022.

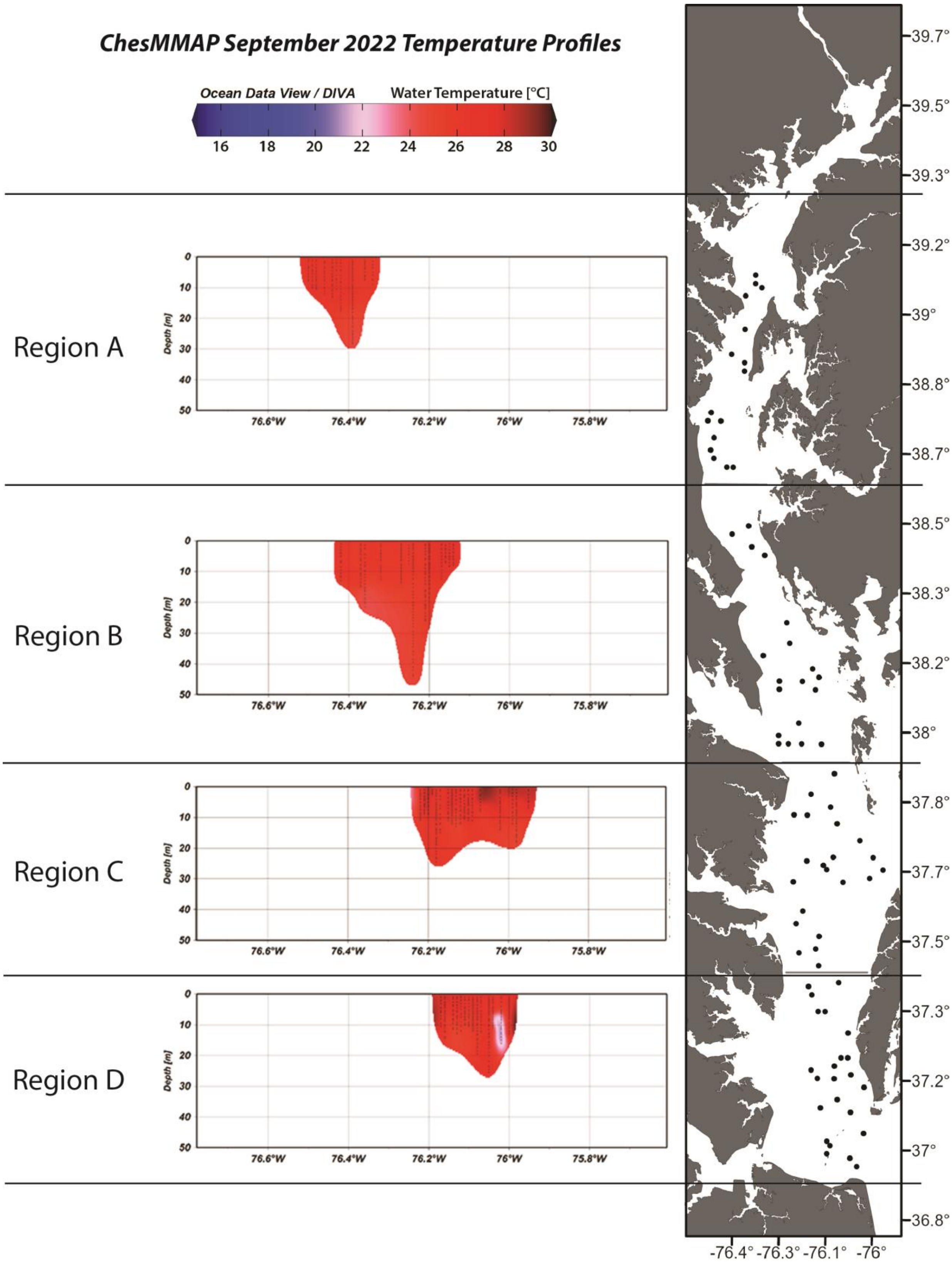

Figure 76: Interpolated bottom water temperature profile for September 2022.

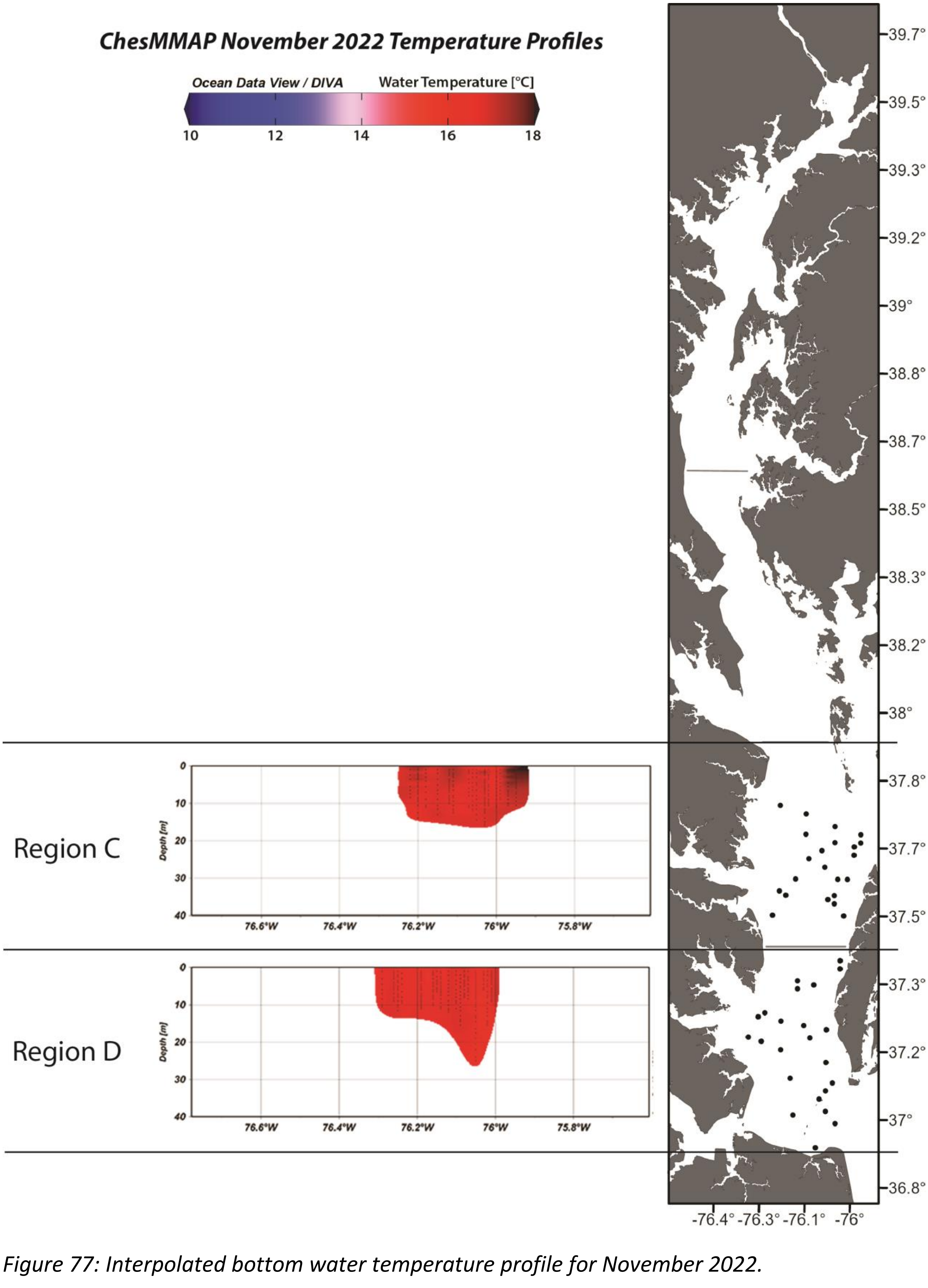

Figure 77: Interpolated bottom water temperature profile for November 2022.

Salinity

Interpolations

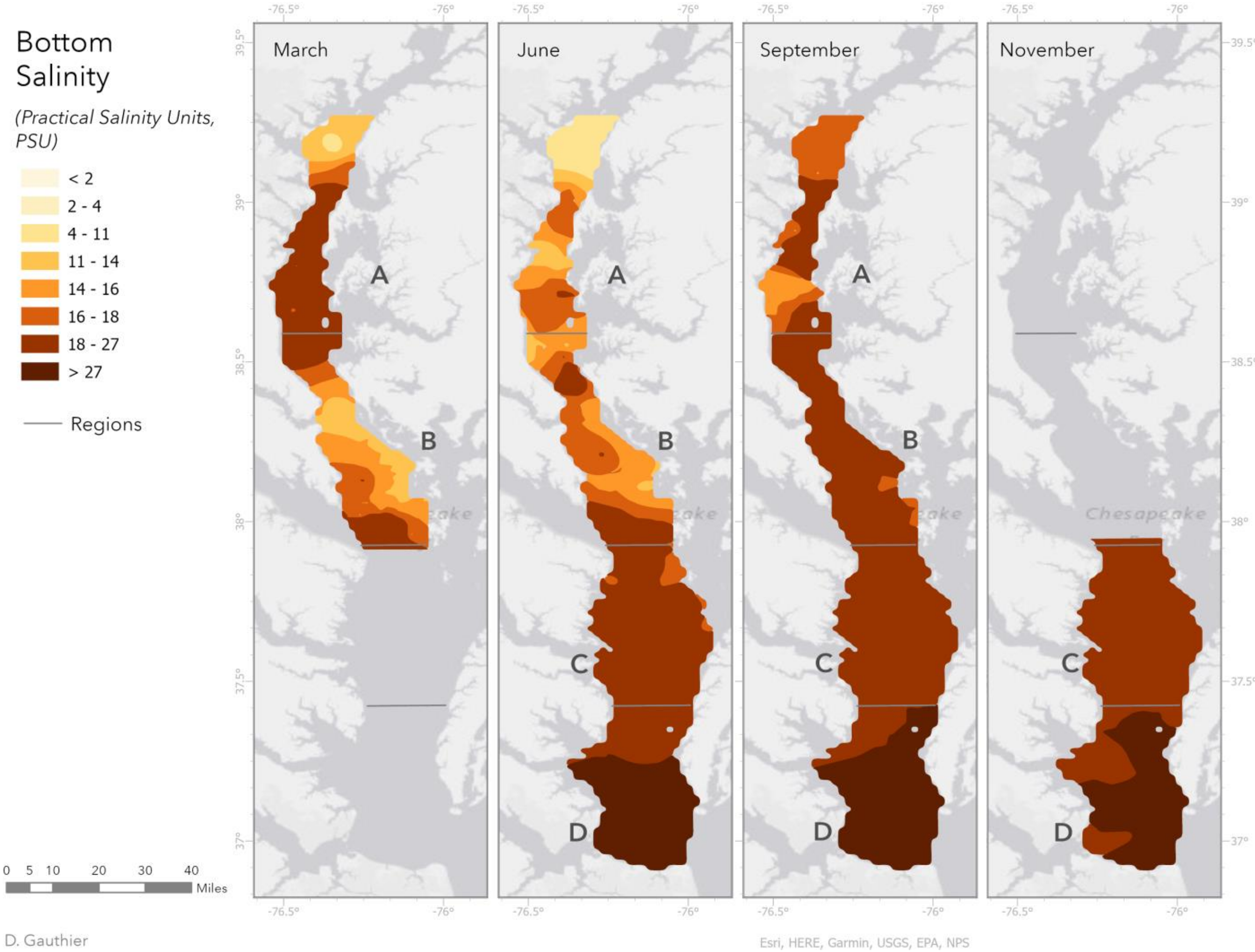

Figure 78: Interpolated bottom salinity for 2022, by cruise.

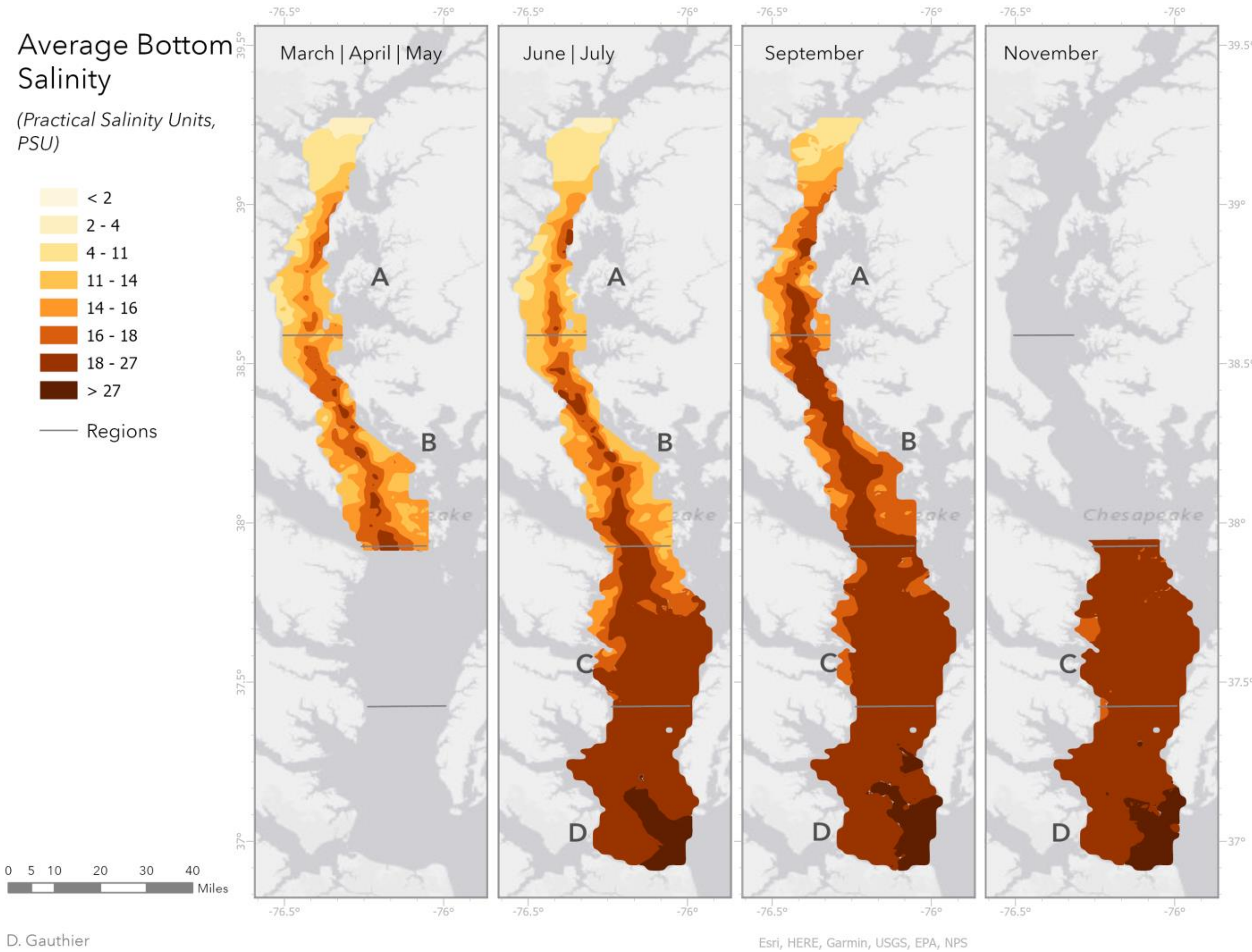

Figure 79: Interpolated bottom salinity averaged over 2002 through 2022, by cruise.

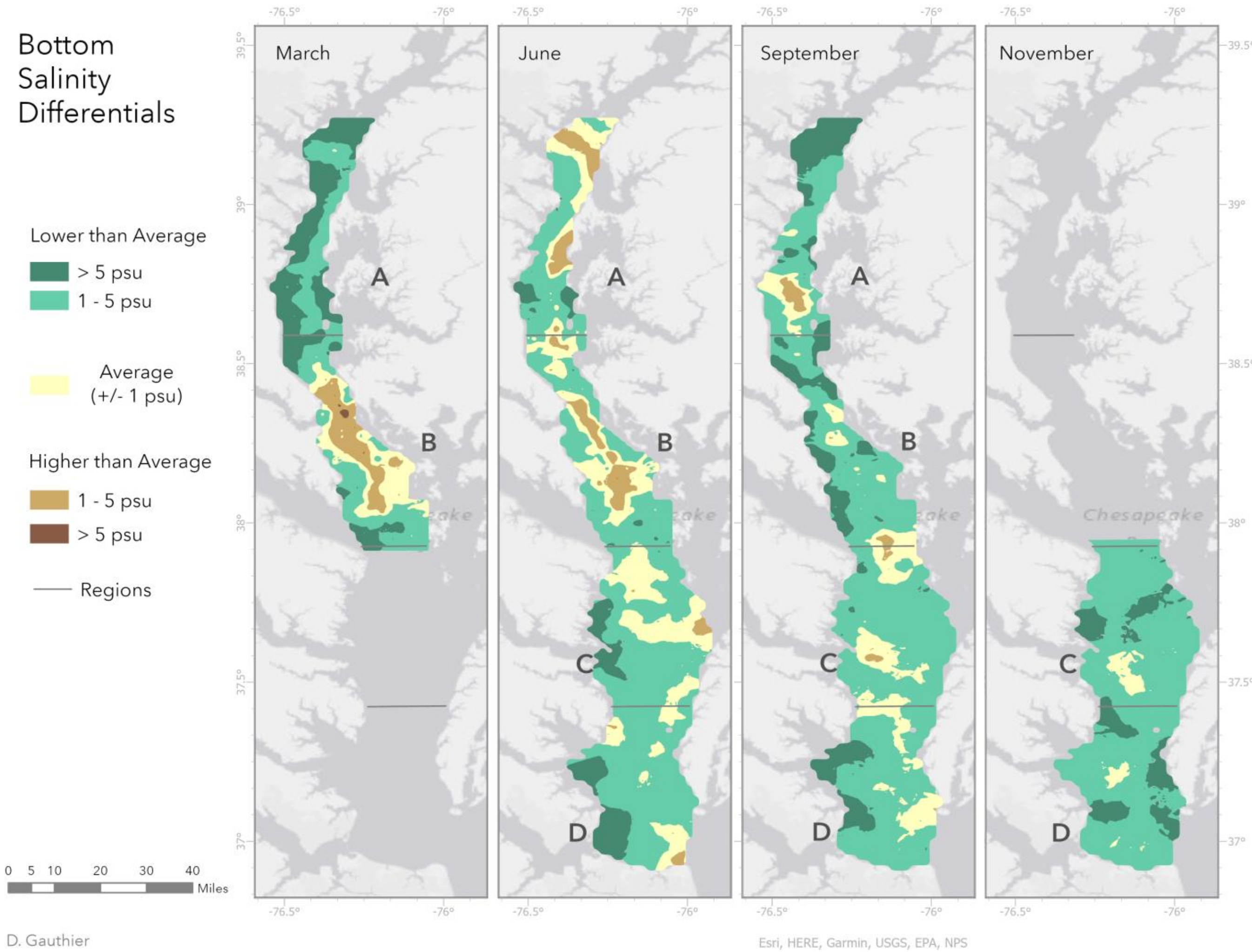

Figure 80: Interpolated 2022 bottom salinity deviations from average, by cruise.

Profiles

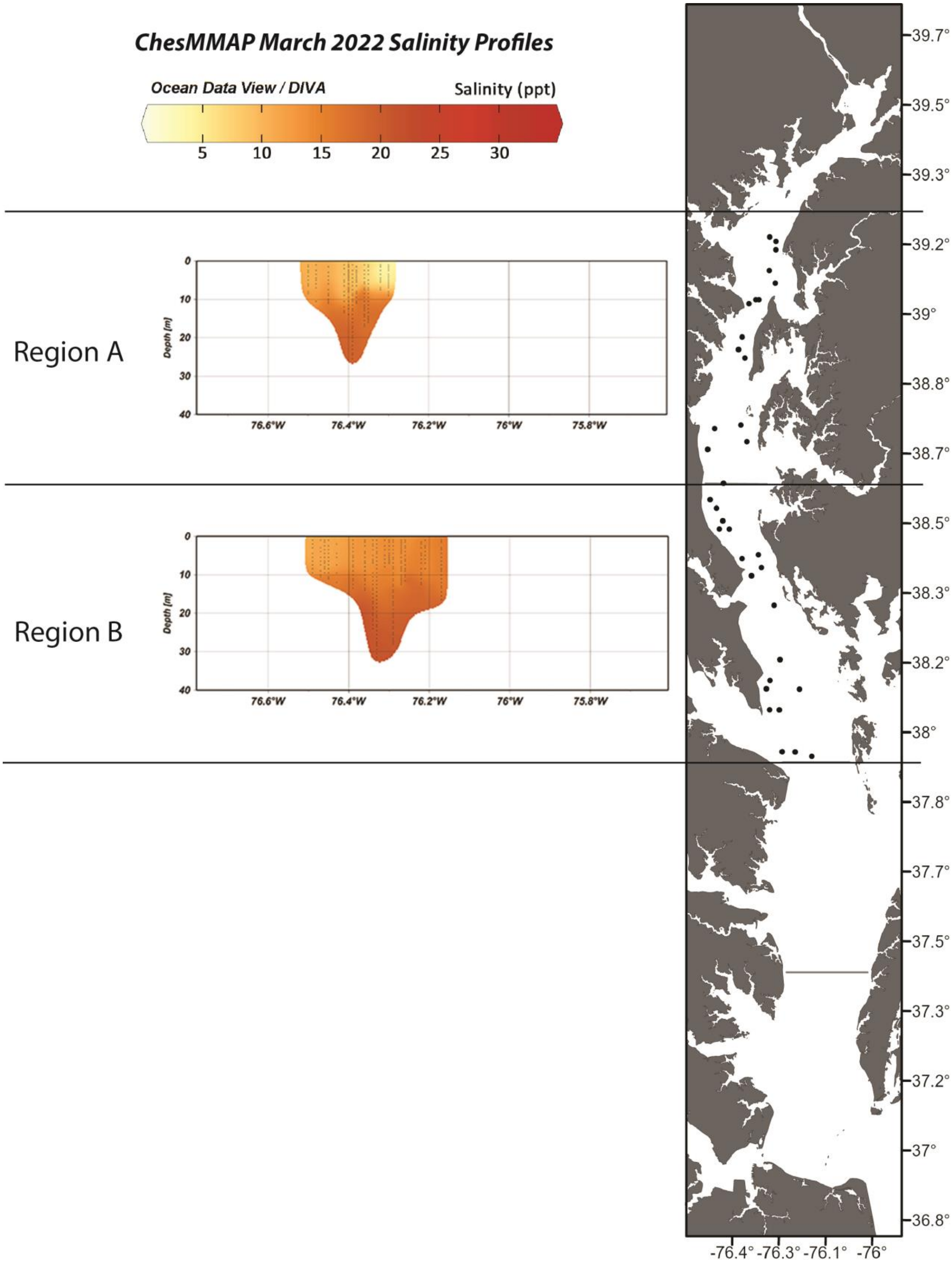

Figure 81: Interpolated bottom salinity profile for March 2022.

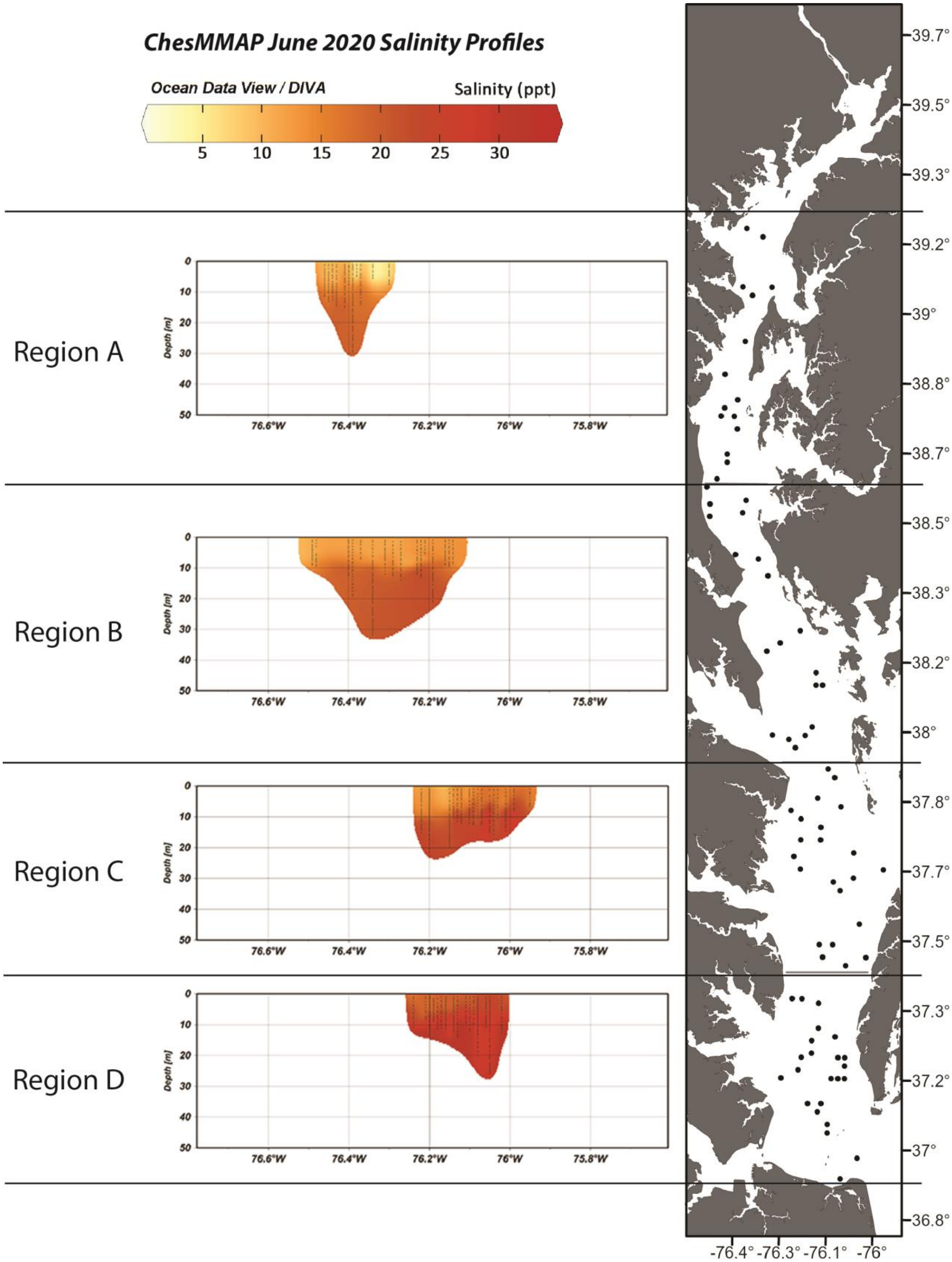

Figure 82: Interpolated bottom salinity profile for June 2022.

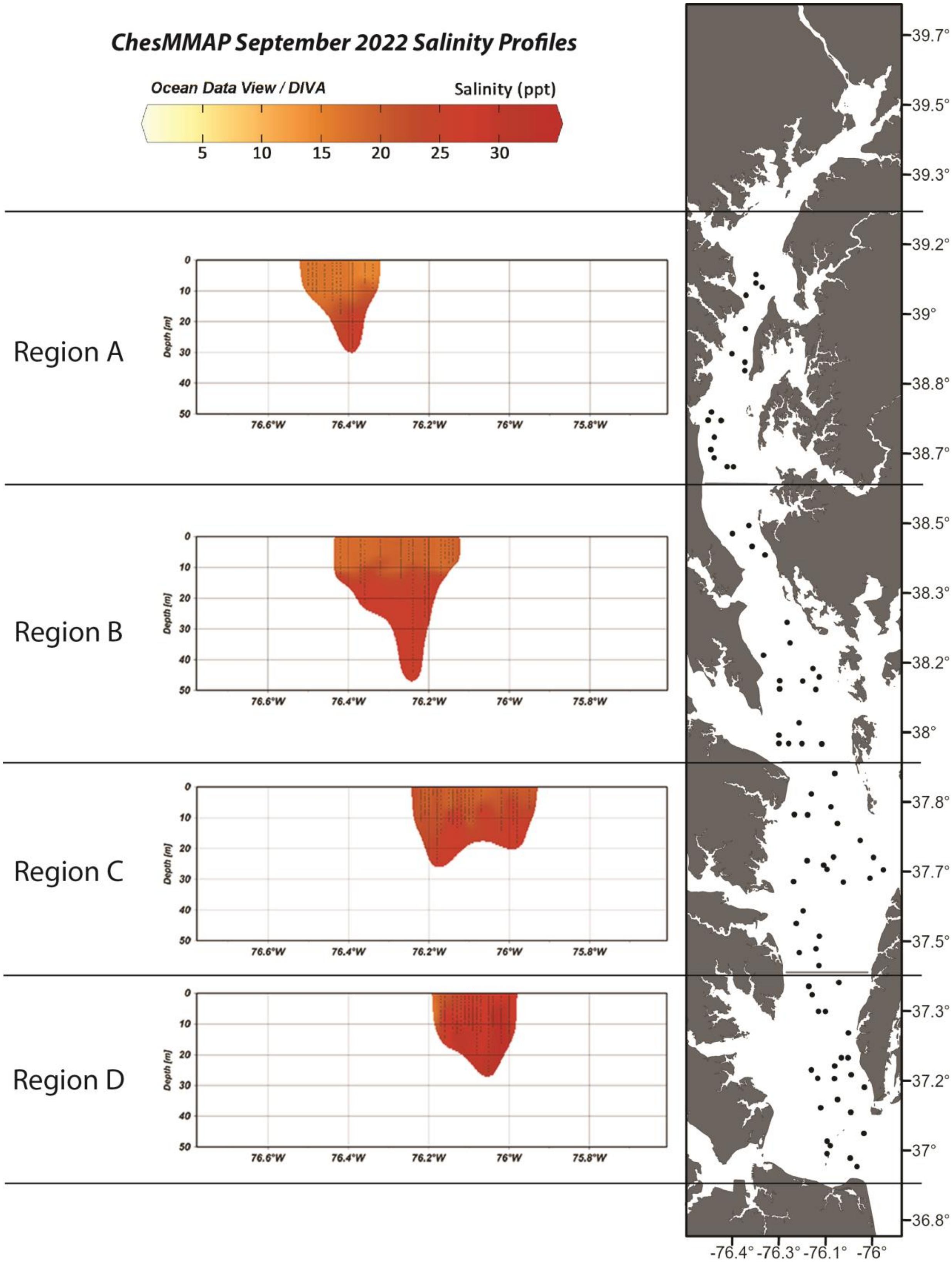

Figure 83: Interpolated bottom salinity profile for September 2022.

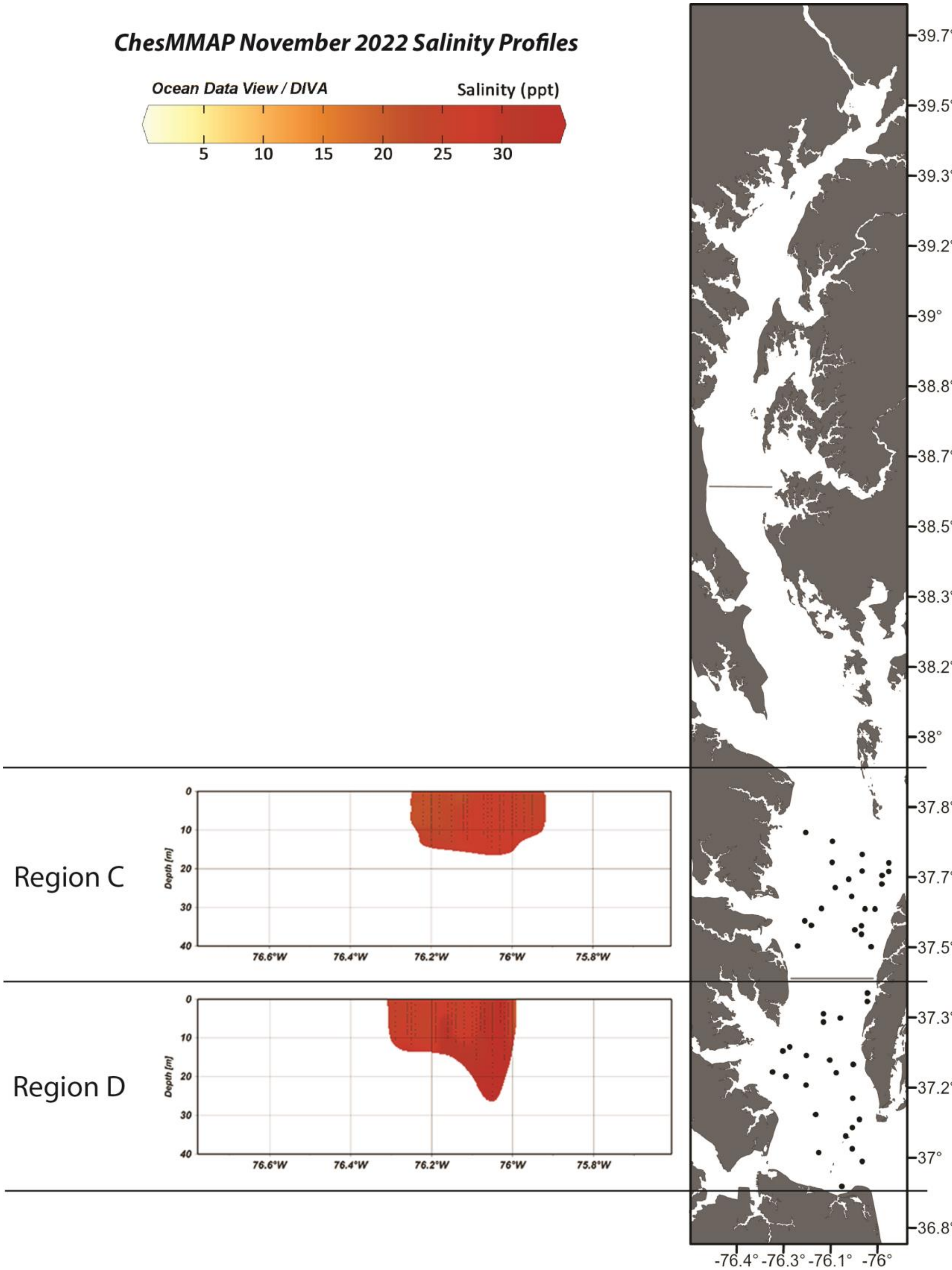

Figure 84: Interpolated bottom salinity profile for November 2022.

Dissolved oxygen

Interpolations

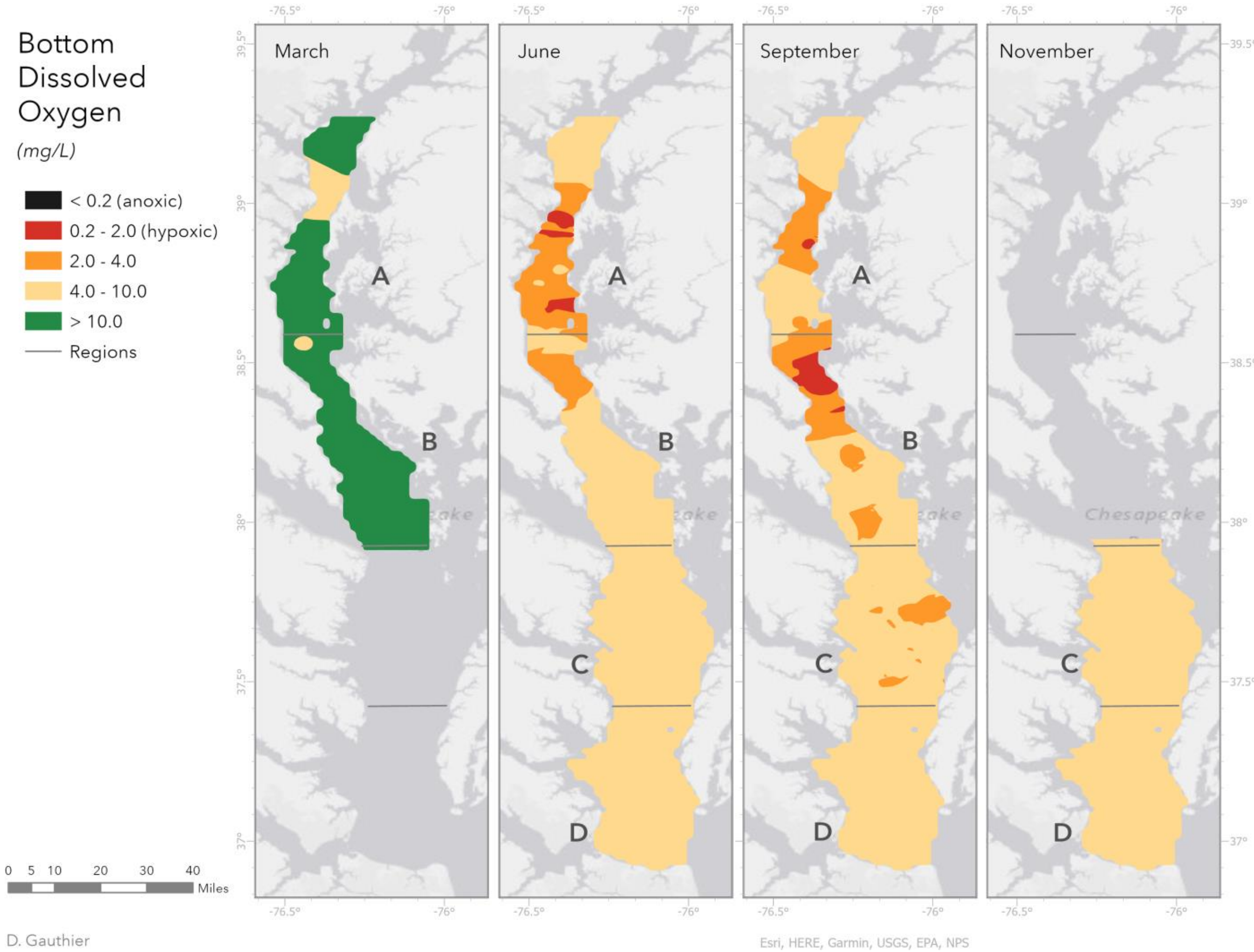

Figure 85: Interpolated bottom dissolved oxygen for 2022, by cruise.

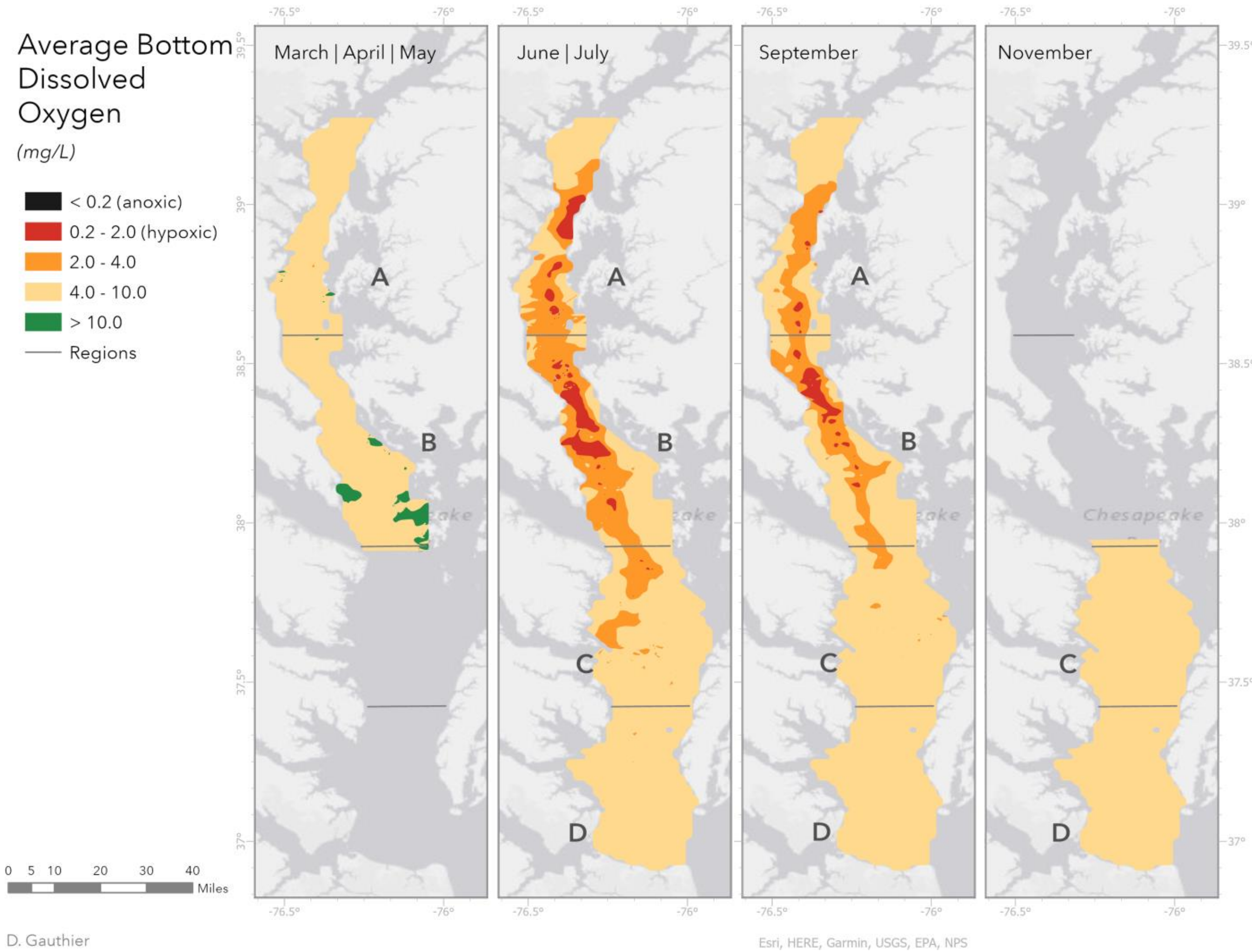

Figure 86: Interpolated bottom dissolved oxygen averaged over 2002 through 2022, by cruise.

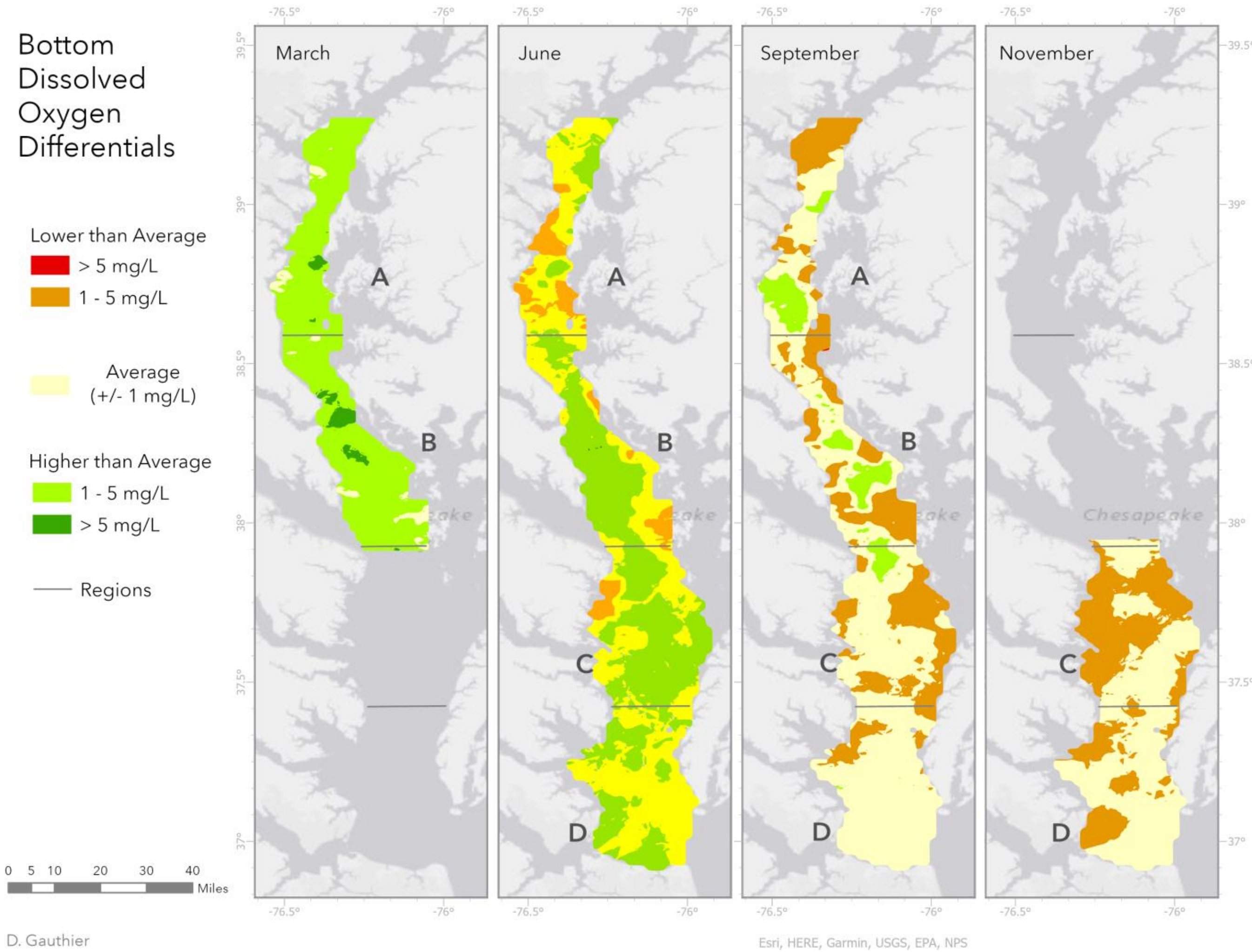

Figure 87: Interpolated 2022 bottom dissolved oxygen deviations from average, by cruise.

Profiles

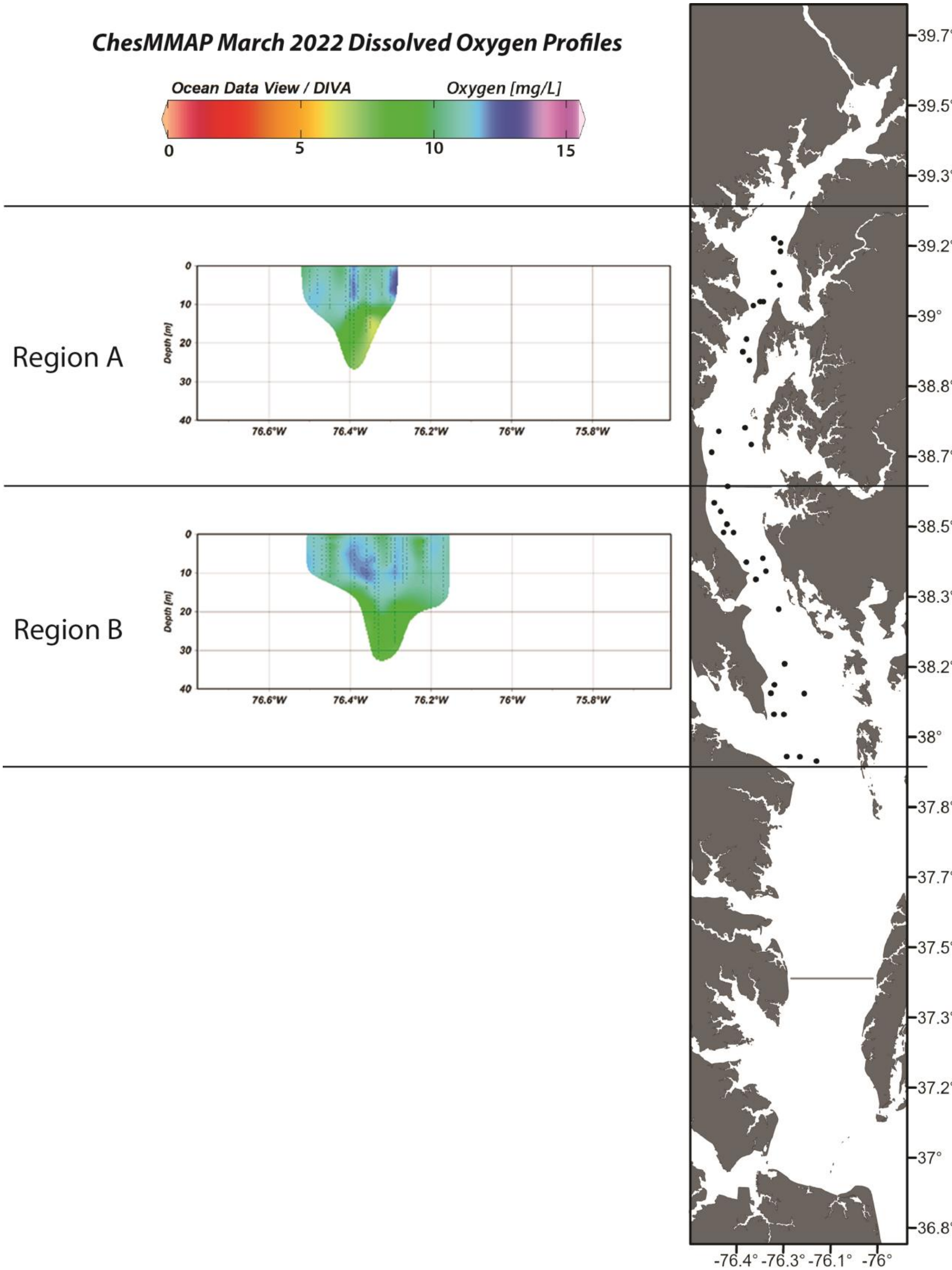

Figure 88: Interpolated bottom dissolved oxygen profile for March 2022.

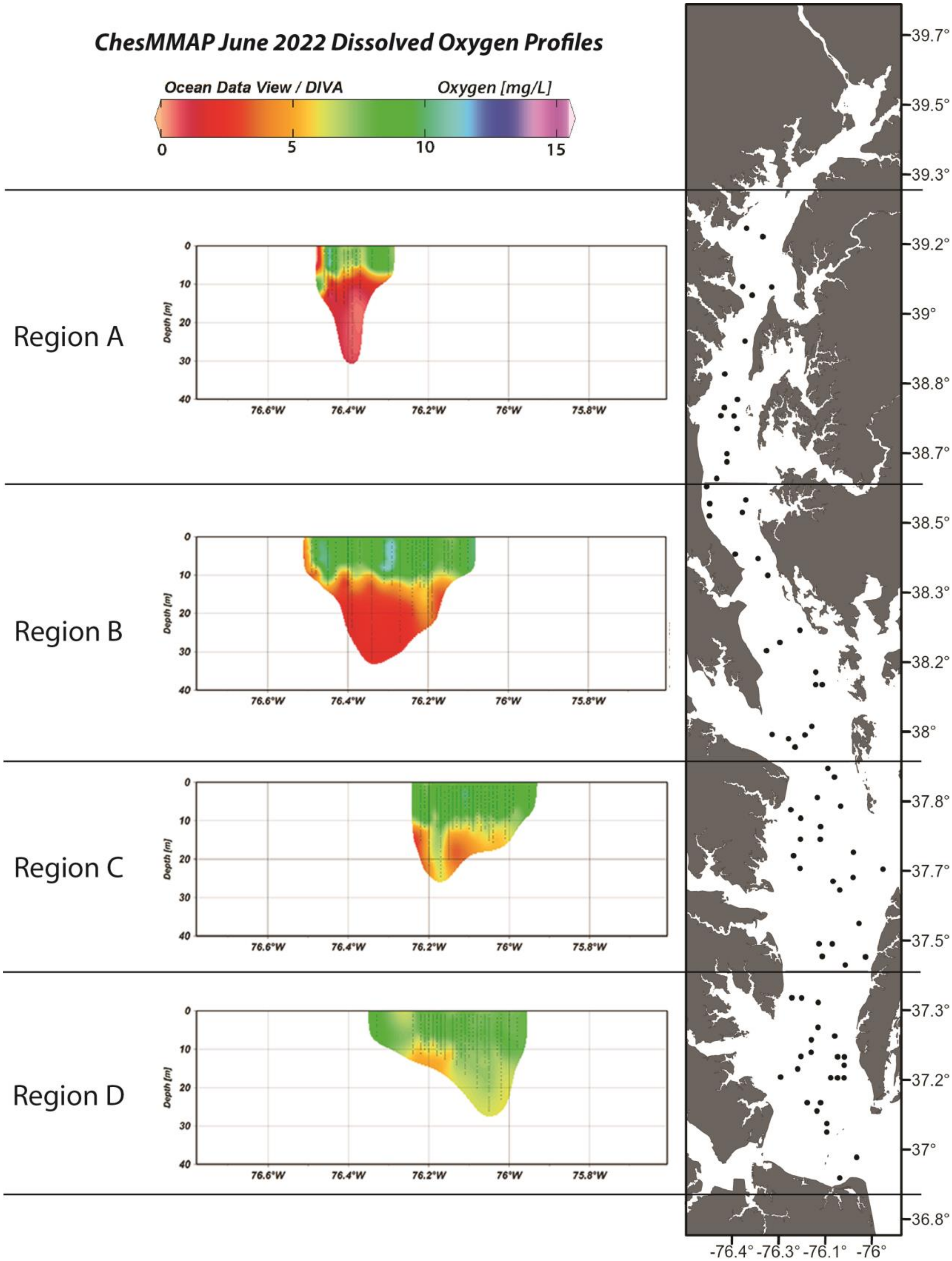

Figure 89: Interpolated bottom dissolved oxygen profile for June 2022.

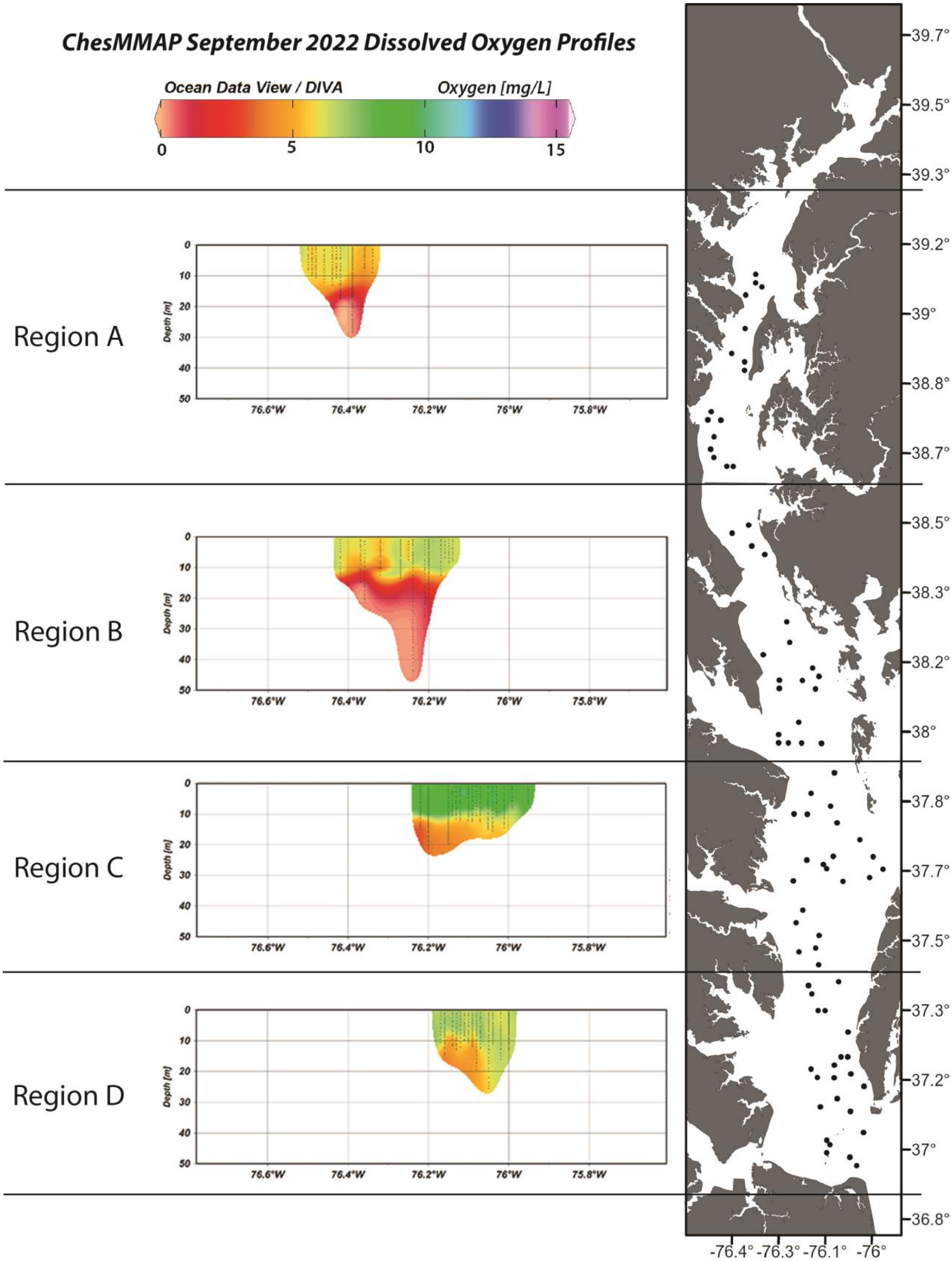

Figure 90: Interpolated bottom v profile for September 2022.

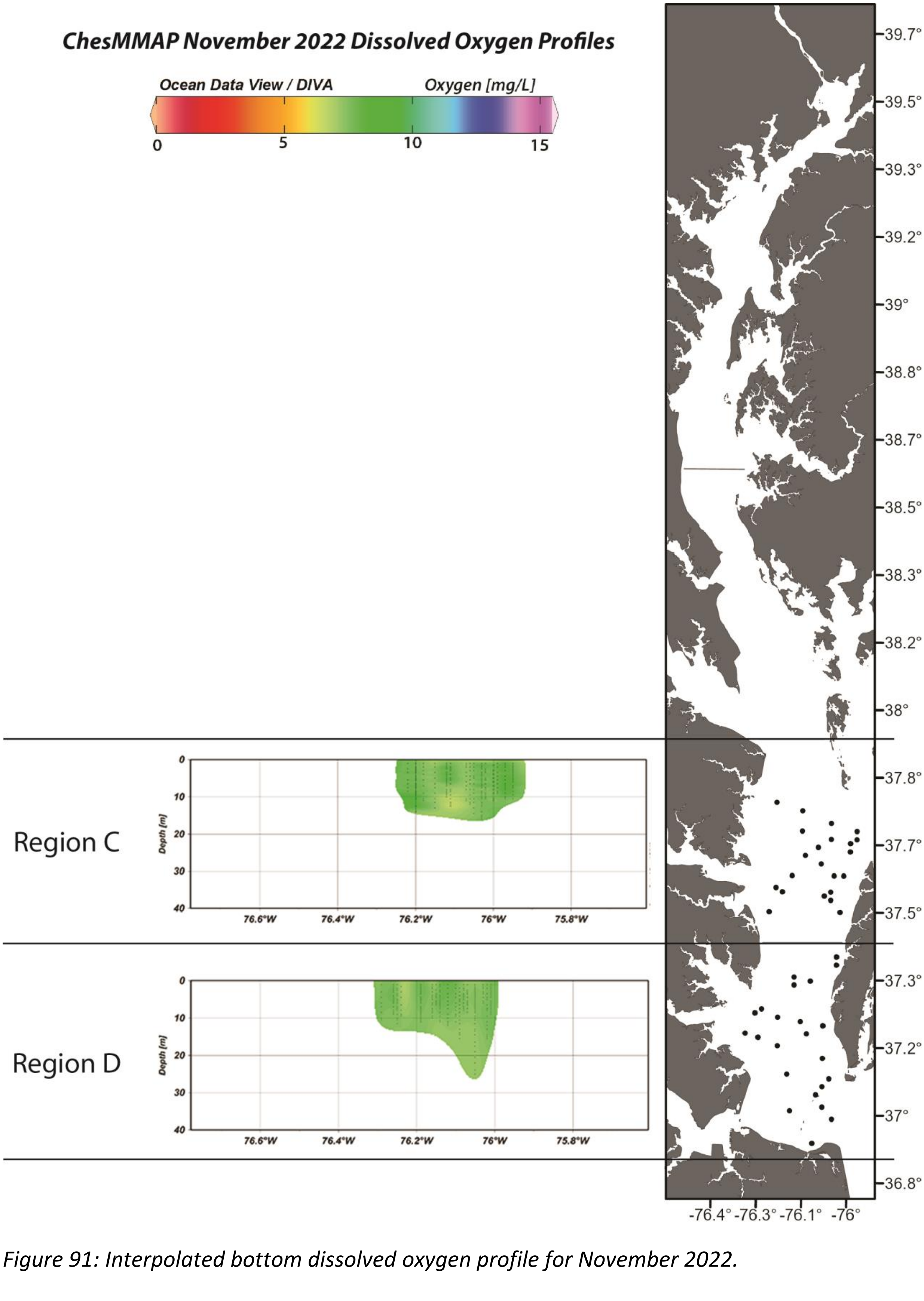

Figure 91: Interpolated bottom dissolved oxygen profile for November 2022.

Appendix II - History of ChesMMAP sampling design

Historically, the ChesMMAP sampling protocol included five 80-site surveys per year, one each in March, May, July, September and November. This general schedule was occasionally interrupted by funding shortfalls and/or logistical hurdles (e.g., vessel breakdowns). The *R/V Bay Eagle*, a 19.8 m aluminum hull, twin diesel vessel owned and operated by VIMS, served as the sampling platform for all cruises during this time period. Fishes (and select invertebrates) were collected using a 13.7 m (headrope length), two-bridle, four-seam bottom trawl manufactured by Reidar's Manufacturing Inc. of New Bedford, MA. The top belly, bottom belly, and side panels of the net are constructed of 15.2 cm stretch mesh (2.6 mm diameter twine), and the cod-end is constructed of 7.6 cm stretch mesh (1.6 mm diameter twine). The bridles (legs) of the net are 6.1 m and connected directly to 1.3 m x 0.8 m steel-V trawl doors weighing 71.8 kg each. The trawl net was deployed with a single-warp system using 9.5 mm diameter stainless steel main cable and a 37.6 m bridle constructed of 7.9 mm stainless steel wire rope.

The goal of each cruise was to sample 80 sites throughout the mainstem of Chesapeake Bay. Sampling sites were selected using a stratified random design. The Bay was stratified by dividing the mainstem into five regions of 30 latitudinal minutes each (the upper and lower regions being slightly smaller and larger than 30 minutes, respectively). Regions were numbered 1 through 5 from north to south. Regions 1-3 coincide with the Maryland portion of the Bay and regions 4-5 correspond with Virginia waters (note that due to the irregular state boundary it is possible that sites in the very southernmost portion of Region 3 may actually be in Virginia and likewise sites in the northernmost reaches of Region 4 may be north of the state border). Within each region, three depth strata ranging from 3.0 m-9.1 m, 9.1 m-15.2 m, and >15.2 m were defined. A grid of 1.9 km^2 cells was superimposed over the mainstem, where each cell represented a potential sampling location. The number of sites sampled in each region and in each stratum was proportional to the surface area of water represented. Sites were sampled without replacement and those north of Pooles Island (39° 17' N) have not been sampled since July 2002 due to repeated loss of trawl gear.

Tows were normally conducted in the same general direction as the tidal current, as pilot work conducted in November 2001 indicated that the survey gear performed most consistently when towed with the current rather than against the current. The net was generally deployed at a 4:1 scope, which refers to the cable length: water depth ratio. For shallow sites, however, the bridle wires were always fully deployed, implying that the scope ratio could be quite high in these situations. The target tow speed was 3.0 knots, but this occasionally varied depending on wind and tidal conditions. Based on data collected from the net monitoring gear, tow speed and scope were adjusted to ensure that the net maintained expected geometry. Tows were 20 minutes in duration, unless obstructions or other logistical issues forced a tow to be shortened; if the duration of a tow was at least 10 minutes, it was considered valid. Computer software was used to record data from the net monitoring gear (i.e., wingspread and headrope height) as well as a continuous GPS stream during each tow. On occasions when the monitoring gear failed or was not deployed, the trawl geometry was assumed to follow cruise averages and beginning and ending tow coordinates were recorded by hand from the vessel's GPS system.

In October 2018, VIMS took possession of its new research vessel, the *R/V Virginia*, a 28.3 m steel hull vessel with twin diesels tied to a single controllable-pitch propeller and a dynamic positioning system for station-holding. This vessel replaced the *R/V Bay Eagle* as the sampling platform for the ChesMMAP survey, and all future ChesMMAP sampling will occur on this new ship. In addition to the change in vessel, adjustments to the sampling gear were required. The new sampling gear is a "200 x 12 cm" (200, 12 cm meshes at the front of the net, i.e. the "fishing circle") bottom trawl rigged with a 3.8 cm cookie sweep and using Thyboron Type IV 44" trawl doors. The cod end is lined with a 2.5 cm knotless liner with an effective mesh size of approximately 1.6 cm. This sampling system is a one-half scale version of the net used by the North East Area Monitoring and Assessment Program (NEAMAP) and Northeast Fisheries Science Center (NEFSC) surveys and is approximately a twice-sized version of the net now being used by the VIMS Juvenile Fishes and Blue Crab Trawl Survey.

The sampling schedule changed in 2019 due to a combination of increased costs associated with the *R/V Virginia* and a decreasing budget, such that 3 sampling cruises could be conducted. However, in considering the annual pattern of fish abundances and in examining the subsets of the data used for the various species' abundance indices, an alternative approach was implemented. In the early season (March) cruise none of the data from sampling in Virginia are used for any abundance indices. Likewise, in late season sampling (November), data for only one species in Maryland strata are used. Rather than settling for 3 full cruises we now sample in March, June, September and November, with the March and November trips sampling only in the upper (Maryland) and lower (Virginia) regions, respectively. While not ideal, we can still sample during the entire spring/summer/fall annual cycle.

Knowing that significant changes would be coming to the survey with the change in research vessel and sampling gear, survey stratification was evaluated. Analyses revealed that the prior design was over-stratified, with small numbers of samples coming from small strata but being over-represented in the design due to the criterion of sampling at least three sites from every stratum. Both the number of regions and the number of depth strata were reduced. The prior three regions corresponding to the Maryland portion of the Bay were condensed to two and similarly the number of depth strata in each region was reduced from three (3.0 m-9.1 m, 9.1 m-15.2 m, and > 15.2 m) to two (≤ 12.2 m, > 12.2 m). Thus, the total number of strata sampled during any cruise was reduced from 14 (there was no deep stratum in Region 1) to 8. Regions are now described as regions A (upper Maryland), B (lower Maryland), C (upper Virginia) and D (lower Virginia) and depth strata are similarly named A (shallow) and B (deep). While it may be somewhat confusing to use a similar labeling system for both the regions and depth strata, these conventions provide a clear distinction from the previous classifications.

Appendix III - Additional species profiles

Blue crab

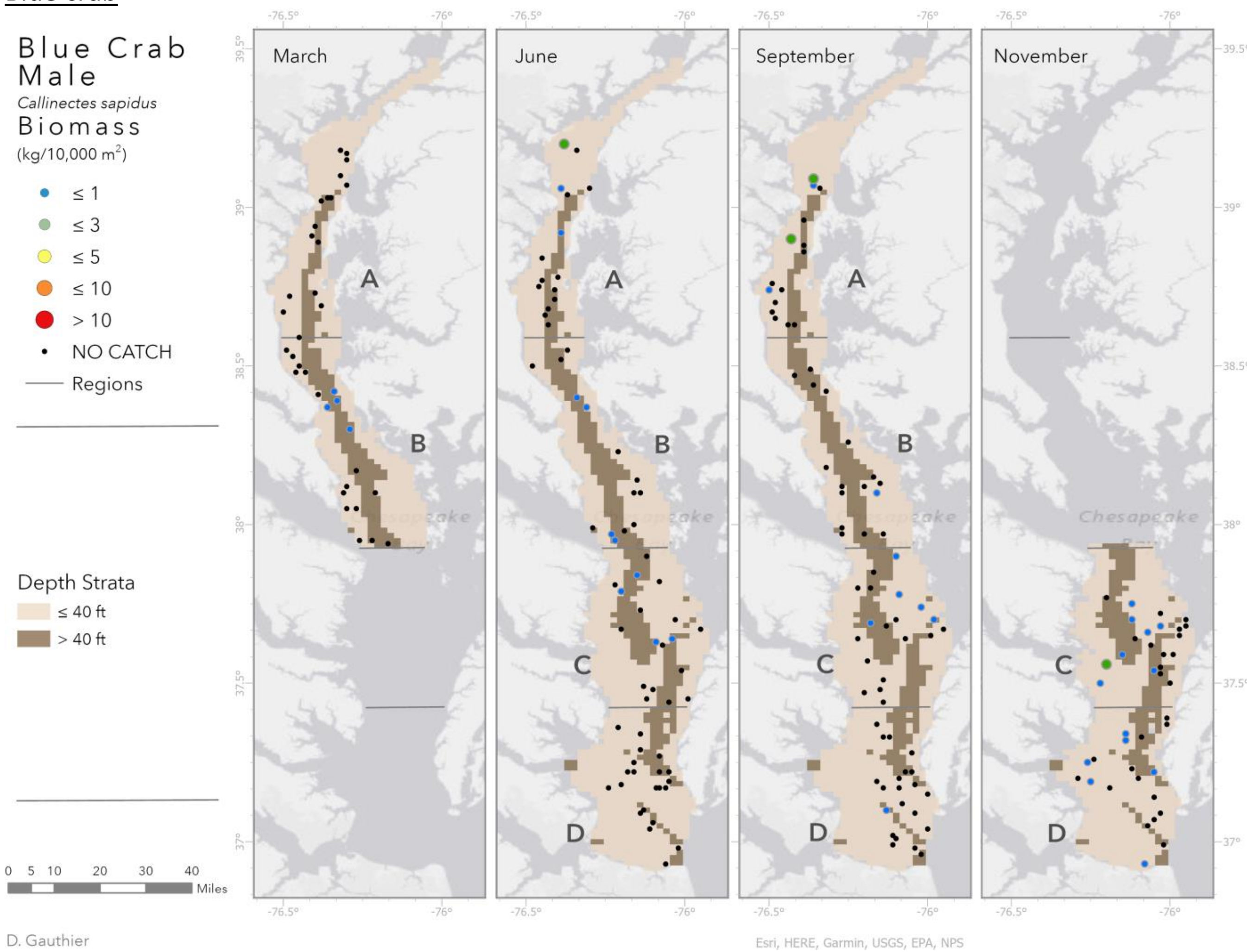

Figure 92: Site-level estimates of biomass (kg 10,000 m^{-2}) of male blue crabs in 2022.

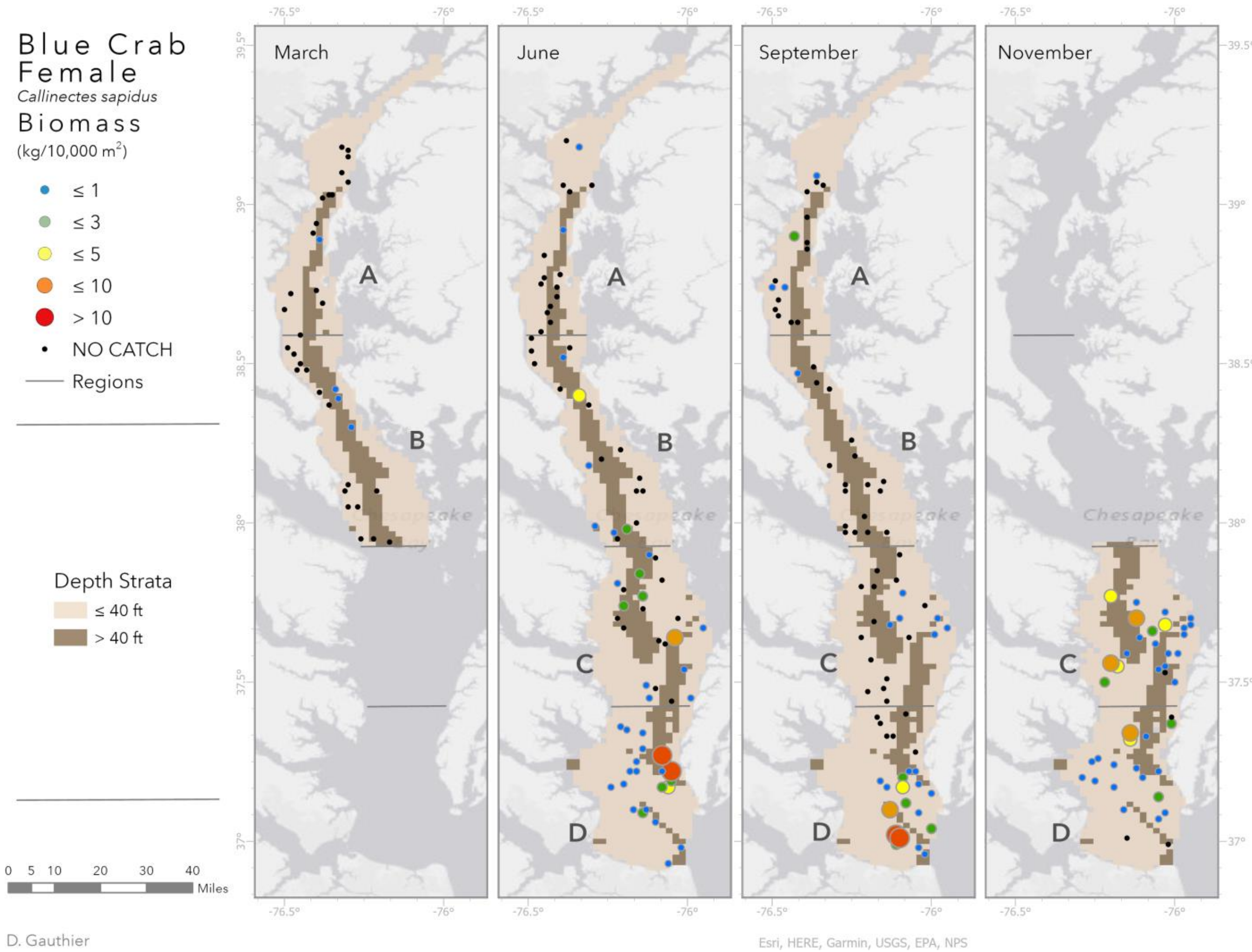

Figure 93: Site-level estimates of biomass (kg 10,000 m^{-2}) of female blue crabs in 2022.

Clearnose skate

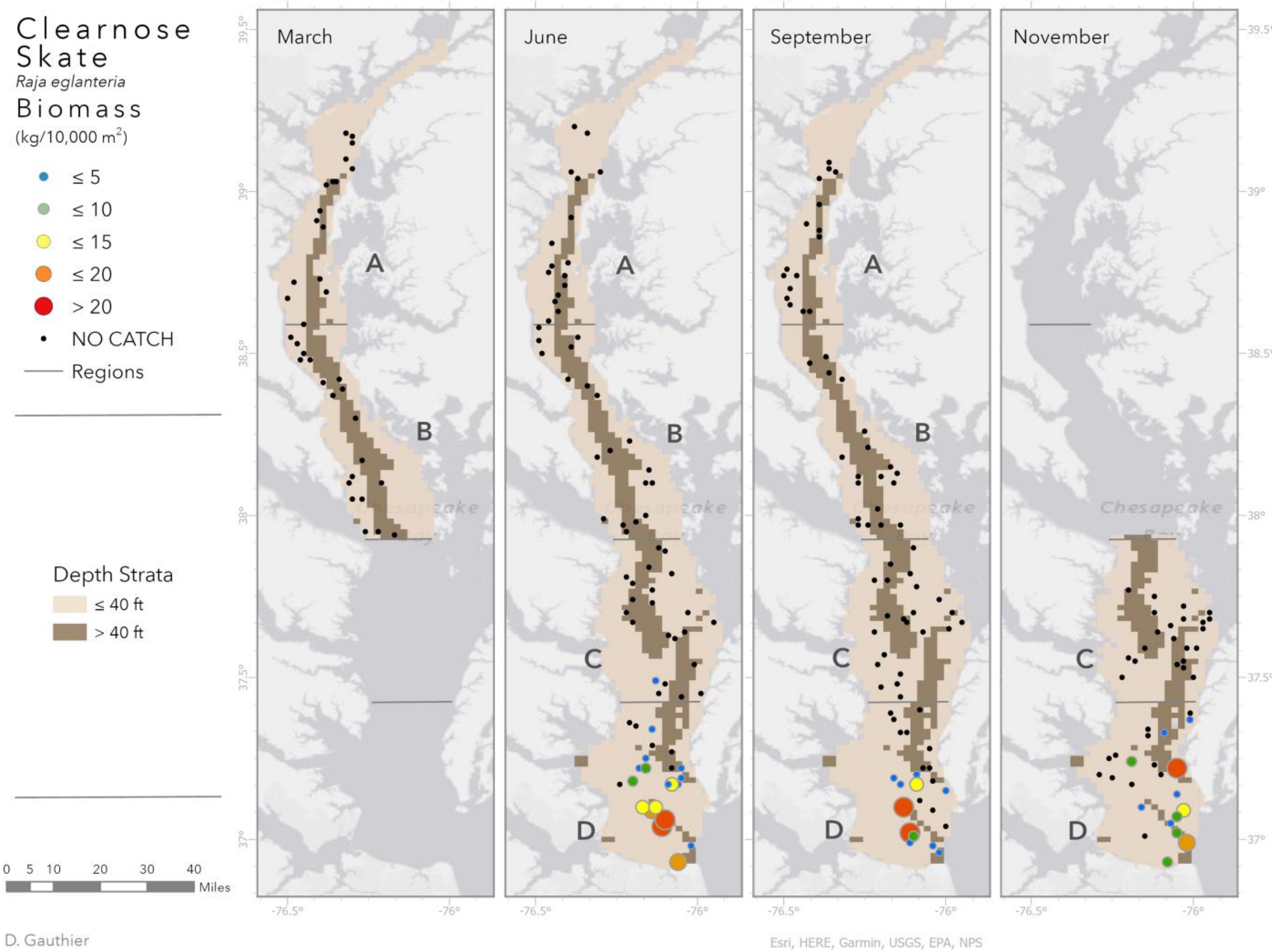

Figure 94: Site-level estimates of biomass (kg 10,000 m^{-2}) of clearnose skate in 2022.

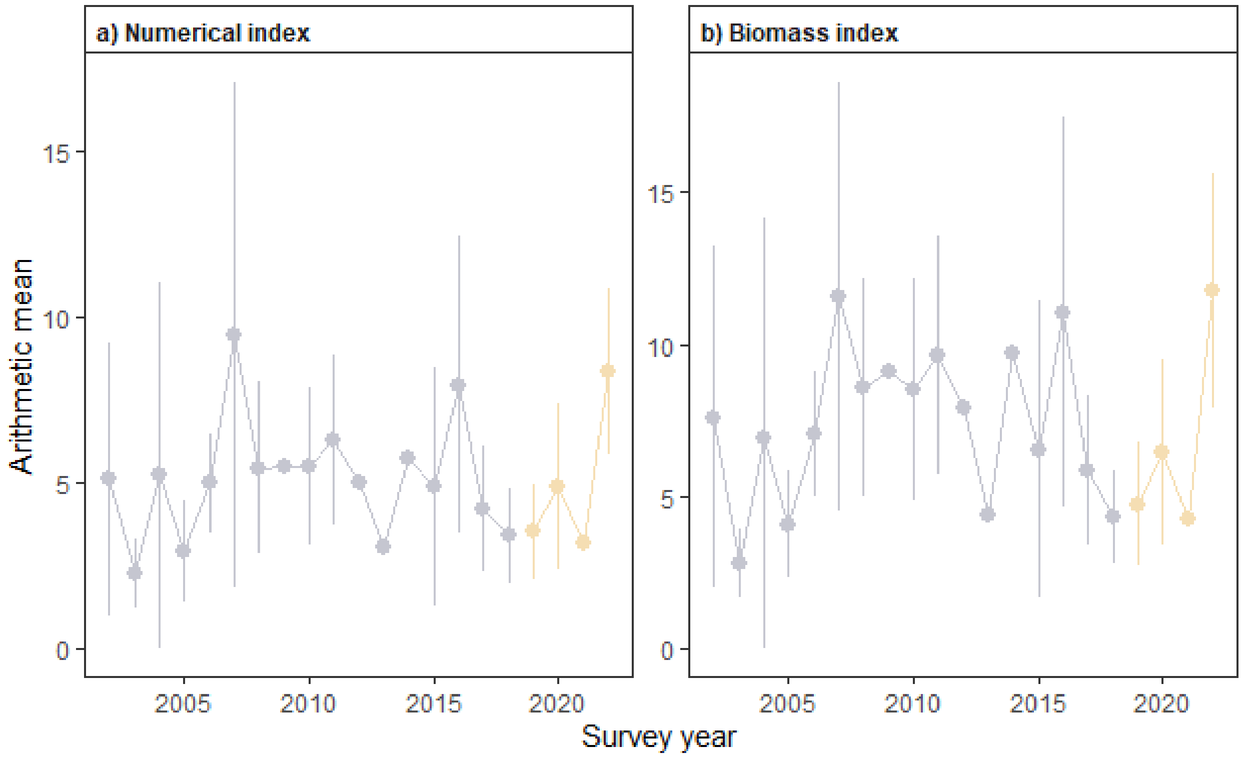

Figure 95: Indices of abundance for clearnose skate by number and biomass, for all ages combined.