The Chesapeake Bay Multispecies Monitoring & Assessment Program

ChesMMAP

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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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Introduction

Historically, fisheries management has been based on the results of single-species stock assessment models that focus on the interplay between exploitation level and sustainability. There currently exists a suite of standard and accepted analytical frameworks (e.g., virtual population analysis (VPA), biomass dynamic production modeling, delay difference models, etc.) for assessing the stocks, projecting future stock size, evaluating recovery schedules and rebuilding strategies for overfished stocks, setting allowable catches, and estimating fishing mortality or exploitation rates. A variety of methods also exist to integrate the biological system and the fisheries resource system, thereby enabling the evaluation of alternative management strategies on stock status and fishery performance. These well-established approaches have specific data requirements involving biological (life history), fisheries-dependent, and fisheries-independent data (Table 1). From these, there are two classes of stock assessment or modeling approaches used in fisheries: partial assessment based solely on understanding the biology of a species, and full analytical assessment including both biological and fisheries data.

Table 1. Summary of biological, fisheries-dependent and fisheries-independent data requirements for single-species analytical stock assessment models.

Data Category	Assessment Type	Data Description
Biological / Life History	Partial	Growth (length / weight)
		Maturity schedule
		Fecundity
		Partial recruitment schedules
		Longevity
		Life history strategies (reproductive and behavioral)
Fishery-Dependent Data	Analytical	Catch, landings, and effort
		Biological characterization of the harvest (size, sex, age)
		Gear selectivity
		Discards/bycatch
Fishery-Independent Data	Analytical	Biological characterization of the population (size, sex, age)
		Mortality rates
		Estimates of annual juvenile recruitment

Although single-species assessment models are valuable and informative, a primary shortcoming is that they generally fail to consider the ecology of the species under management (e.g., habitat requirements, response to environmental change), ecological interactions (e.g., predation, competition), and technical interactions (e.g., discards, bycatch) (NMFS 1999, Link 2002a,b). Inclusion of ecological processes into fisheries management plans is now strongly recommended (NMFS 1999) and in some cases even mandated (NOAA 1996). Multispecies assessment models have been developed to move towards an ecosystem-based approach to fisheries management (Hollowed et al. 2000, Whipple et al. 2000, Link 2002a,b). Although such models are still designed to yield information about sustainability, they are structured to do so by incorporating the effects of ecological processes among interacting populations.

Over the past decade, the number and type of multispecies models designed to provide insight about fisheries questions has grown significantly (Hollowed et al. 2000, Whipple et al. 2000). While this growth has been fueled primarily by the need to better inform fisheries policy makers and managers, recent concerns about effects of fishing on the structure of ecosystems have also prompted research activities on multispecies modeling and the predator-prey relationships that are implied. From a theoretical perspective, basing fisheries stock assessments on multispecies rather than single-species models certainly appears to be more appropriate, since multispecies approaches allow a greater number of the processes that govern population abundance to be modeled. However, this increase in realism leads to an increased number of model parameters, which in turn, creates the need for additional types of data.

In the Chesapeake Bay region, there has been a growing interest in ecosystem-based fisheries management, as evidenced by the recent development of fisheries steering groups (e.g., ASMFC multispecies committee), the convening of technical workshops (Miller et al. 1996, Houde et al. 1998), and the goals for ecosystem-based fisheries management set by the Chesapeake Bay 2000 (C2K) Agreement. In many respects, it can be argued that the ecosystem-based fisheries mandates inherent to the C2K Agreement constitute the driving force behind this growing awareness. The exact language of the C2K agreement, as it pertains to multispecies fisheries management, reads as follows:

1. By 2004, assess the effects of different population levels of filter feeders such as menhaden, oysters and clams on bay water quality and habitat.

2. By 2005, develop ecosystem-based multispecies management plans for targeted species.

3. By 2007, revise and implement existing fisheries management plans to incorporate ecological, social and economic considerations, multispecies fisheries management and ecosystem approaches.

If either single-species or ecosystem-based management plans are to be developed, they must be based on sound stock assessments. In the Chesapeake Bay region, however, the data needed to perform single and multispecies assessments has been either partially available 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 stock assessment modeling activities at both single and multispecies scales. While no single gear or monitoring program can collect all of the data necessary for both types of assessments, ChesMMAP was designed to maximize the biological and ecological information collected for several recreationally, commercially, and ecologically important species in the bay.

In general, ChesMMAP is fishery-independent monitoring survey that uses a large-mesh bottom trawl to sample late juvenile-to-adult fishes in the mainstem of Chesapeake Bay. This program currently provides data on relative abundance, length, weight, sex ratio, maturity, age, and trophic interactions for several important fish species that inhabit the bay seasonally. This report summarizes the data generated from the field and laboratory components of this project.

Among the research agencies in the Chesapeake Bay region, only VIMS has a program focused on multispecies issues involving the late juvenile and adult (i.e., harvested) components of the exploited fish species that seasonally inhabit the bay. The research group is also responsible for executing the nearshore trawl survey for the Northeast Area Monitoring and Assessment Program (NEAMAP), and recently become responsible for the future conduct of the VIMS elasmobranch longline survey. In this report, we summarize the ChesMMAP field, laboratory, and data analysis activities through the 2010 sampling year.

A new ChesMMAP task included during this segment was initial evaluation of a potential new sampling gear system. This system includes a one-half size (200 x 12cm fishing circle) version of the same trawl net in use for the NEFSC and NEAMAP surveys (400 x 12cm fishing circle). Scale model flume tank testing occurred during the previous segment and initial field testing took place during 2010.

The following Tasks are addressed in this report:

- 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 – Begin evaluation of alternative sampling gear.

Methods

Task 1 – *Conduct research cruises*

In 2010, five research cruises were conducted bimonthly from March to November in the mainstem of Chesapeake Bay. The July cruise included sampling only in regions 4 and 5, i.e. Virginia (see below), to conserve resources so that extra sampling could be accomplished with a potential new trawling gear (few ChesMMAP abundance indices use data from regions 1-3 in July and catches then are typically very low due to extensive areas of low dissolved oxygen in Maryland during July). The timing of the cruises was chosen so as to coincide with the seasonal abundances of fishes in the bay. 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 this survey. 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 codend is constructed of 7.6cm 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 is deployed with a single-warp system using 9.5 mm (dia.) steel main cable and a 37.6 m bridle constructed of 7.9 mm stainless steel wire rope.

For each cruise (except July, see above), the goal 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). For easy reference, regions are 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. 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 stations sampled in each region and in each stratum was proportional to the surface area of water represented. Stations were sampled without replacement and those north of Pooles Island (latitude 39^o 17') have not been sampled since July 2002 due to repeated loss of gear. In the future, we plan to use sidescan sonar to identify potential sampling locations in this area.

Tows were normally conducted in the same general direction as the tidal current (pilot work conducted using the net monitoring gear 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 stations, however, bridle wires were always fully deployed, implying that the scope ratio could be quite high in these particular situations. The target tow speed was 3.0 kts but occasionally varied depending on wind and tidal conditions. Based on data collected from the net monitoring gear, tow speed and scope were adjusted occasionally 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.

Task 2 – *Synthesize data for single species analyses*

Once onboard, the catch from each tow was sorted and measured by species and size-class if distinct classes within a particular species were evident. A subsample of each species/size-class was further processed for individual weight determination, stomach contents, ageing, and determination of sex and maturity stage. In addition to these biological data, water temperature, salinity, and dissolved oxygen readings were recorded at each sampling location. During 2010, acquisition of a new water quality instrument which takes near instantaneous readings of all parameters allowed measurement of these parameters throughout the water column rather than only at the surface and near bottom as had previously been practiced. At each location, water quality parameters were electronically recorded approximately at 1m, 2m, and at 2m intervals until the instrument reaches the bottom (data from these additional water column readings are not presented in this report but will be in future publications).

Single-species assessment models typically require information on (among others) age-, length-, and weight-structure, sex ratio, and maturity stage. Data were synthesized to characterize annual length- and age-frequency distributions. Analytical computer programs to characterize each of the assessment-related data elements (length, weight, age, sex, maturity) were developed to allow for the summarization of these characteristics across a variety of spatial and temporal scales (e.g., by year, season, or region of the bay) for each species.

Task 3 – *Quantify trophic interactions for multispecies analyses*

In addition to the population-level information described under Task 2, multispecies assessment models require information on predator-prey interactions across broad seasonal and spatial scales. In general, these procedures involve examining the stomach contents of predators and identifying each prey item to the lowest possible taxonomic level. As such, stomach samples were collected and preserved in the field and were processed at VIMS following standard diet analysis procedures (Hyslop 1980). Several diet indices were calculated to identify the main prey types for each species sampled by the ChesMMAP Survey: percent weight, percent number, and percent frequency-of-occurrence

In previous annual reports only percent weight analyses have been presented. Both percent weight and percent number are offered in this report. In the food habits figures presented for each species, prey types are ordered first in decreasing percentage (by weight) order by major taxa (e.g. fish, crustaceans, molluscs, etc.) and within each taxon by decreasing percentage for each species or subgroup. To make comparisons between percent by weight vs. by number readily accomplished, the same order of major taxa is maintained in the succeeding percent by number figure though the species or subgroup order is allowed to vary (by decreasing percentage) within each major taxon.

These indices were coupled with the information generated from Task 2 and age-, length-, and sex-specific diet characterizations were developed for each species. Efforts also focused on characterizing spatial and temporal variability in these diets.

As noted above, several diet index values were calculated to identify the main prey in the diet of predators in the mainstem Chesapeake Bay. Since trawl collections essentially yield a cluster of fish at each sampling location, these indices were calculated using a cluster sampling estimator (Buckel et al. 1999).

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.

Task 4 – *Estimate abundance*

Time-series of abundance information are standard products developed from the basic catch data of a fishery independent monitoring survey. 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 can be generated for each species by combining abundance data with area swept by the trawl and gear efficiency. Area swept was calculated for each tow by multiplying tow distance (provided by GPS) by average wingspread (provided by net monitoring gear). Gear efficiency estimates, gained through hydroacoustic data collection as described in previous project reports, have been estimated for two species common in ChesMMAP catches (Atlantic croaker and white perch) and results were recently published (Hoffman et al. 2009). Though calculated for previous annual reports these absolute abundance estimates are not presented for this current segment.

While minimum total or absolute abundance estimates are important for certain bioenergetics and ecosystem level analyses, fishery assessments typically depend upon relative abundance indices from surveys as important indicators of abundance. Previous ChesMMAP project progress reports have presented an evolving series of relative and absolute abundance estimates. A new step in the evolution of those indices is introduced in this report. Specifically, the primary calculation method used to report relative abundance is based on the delta lognormal distribution (Shimizu, 1988). This method attempts to account both for a high number of zero catches for many species and for a skewed distribution which are both typical of fish survey data. For comparative purposes, indices are also presented based on the previous 'geometric mean' calculation method (though the units are slightly different than in previous reports and a small number of corrections have been made both to the ChesMMAP data base and to the program used to calculate these indices). Arithmetic means are also shown, primarily for purposes of showing the relative y-axis scales of the other methods (i.e., to give the reader an idea of how many were 'really' caught regardless of the statistical treatment of the data). Age-specific indices presented in the previous two annual reports are not shown in the current report because the delta lognormal calculation algorithms have only recently been applied to the ChesMMAP data and there has not been adequate time to develop these for the age-specific data. Such indices will appear again in future reports.

Abundance index calculations presented here are calculated according to:

1. Raw catch data used for each species index are restricted by month, region, and depth strata such that only those strata with maximum catch-per-unit-effort for that species are used. The methods used to determine these species-specific restrictions were briefly described in a previous progress report (Bonzek et al. 2009). For a small number of species these limiting parameters have been updated as a further refinement.

2. Delta Lognormal Mean: This data treatment (Shimizu, 1988) is becoming more common for calculation of abundance estimates from fishery surveys as a means of dealing with the odd statistical properties of catch data from such surveys.

   Examination of the raw catch-per-tow data for each species within specific strata indicated presence of a high proportion of zero catches, or alternatively, a low proportion of tows where at least one individual of the species of interest was captured. Zero catches can arise for many reasons, and it was reasoned that the use of an active sampling gear combined with the schooling nature of most fishes was the likely cause. Although a variety of strategies can be used to deal with zero catches, we elected to apply the delta-lognormal distribution where the mean catch-per-unit-effort for the ith stratum (CPUEi) was modeled as the product of probability of obtaining a zero catch (pi) with the lognormal mean CPUEi derived from the non-zero tows (Aitchison 1955). Therefore, the estimator for the mean abundance within each stratum (, expressed either as number or biomass) was calculated as:

$$\overline{Y}_i = \hat{p}\cdot e^{\left(\log_e\left(\frac{1}{t_i}\sum_{i=1}^{t_i} CPUE_i\right)+0.5\cdot \mathrm{var}(\log_e(CPUE_i))\right)}.$$

The overall mean relative abundance for species s was then calculated as:

$$\overline{Y}_s = \sum_{i=1}^{n} w_i \overline{Y}_i,$$

where wi represents the weighting term (expressed as a proportion) associated with the ith stratum. All calculations were completed using the software package R, version 2.11.0 (R Development Core Team, 2010).

3. Geometric Mean: Using the restricted data, annual geometric mean catch per area swept indices for each species for all ages combined, were calculated according to the formula:

$$\mathbf{I} = \mathbf{exp}\left\{\sum_{i=1}^{n}\left(\log\left(\frac{C}{a}+\mathbf{1}\right)\right)\times w\right\} - \mathbf{1}$$

where: *I = Index*
C = number or biomass caught at a station
a = area swept at a station
i = ith stratum
n = number of strata
w = stratum weight

4. Arithmetic Mean: This methodology, while likely not appropriate for data from the ChesMMAP survey due to lack of statistical normality in survey catches, is presented for comparative and scaling purposes. Calculations are identical to those listed under the geometric mean above except that the data are not log-transformed prior to analysis, and thus not back-transformed after analysis.

Task 5 – *Begin evaluation of alternative sampling gear*

As discussed in previous project reports, personnel associated with the ChesMMAP Trawl Survey worked in conjunction with *Reidar's Manufacturing, Inc.* to design a survey trawl that could serve as a replacement for the sampling net currently used by this program. Specifically, a three-bridle, four-seam, 200 x 12cm (fishing circle) bottom trawl had been developed (Figure 66). This net is identical in design to that used to sample the near shore coastal ocean by the NEAMAP Trawl Survey, and is nearly-identical to that used by the Northeast Fisheries Science

Center's (NEFSC) Bottom Trawl Survey. Because the survey vessel used by ChesMMAP is appreciably smaller than those used by NEAMAP and by the NEFSC, however, the three-bridle, four-seam net developed for this program is half of the size of those used by the latter two (i.e., 200 x 12cm fishing circle net for ChesMMAP vs. 400 x 12 cm fishing circle net for NEAMAP and NEFSC). Again, flume trials conducted on model trawls in December 2009 indicated that the 200 x 12cm net may be a more appropriate sampling gear than the current two-bridle four-seam, semi-balloon bottom trawl used by ChesMMAP, as the optimal configuration and performance consistency of the alternate net appeared to be superior to that of the current gear.

In an effort to begin to document and evaluate the performance of the 200 x 12cm trawl in the field, ChesMMAP purchased a single net, along with all associated rigging hardware, from *Reidar's* during the summer of 2010. With respect to matching a set of trawl doors to this net, several options were available. Senior project personnel worked closely with trawl door specialists at *Trawlworks Inc.* in Narragansett, Rhode Island to identify those that were most likely capable of consistently providing the optimal wingspread for the 200 x 12cm net (i.e., 6.5m, as defined by the flume trials). It was determined that the doors currently used by ChesMMAP, a set of $1m^2$ steel-vee doors, could not generate the necessary spreading power. Three alternative options were therefore identified; namely, #2 Bison doors ($0.86m^2$ surface area), 44" Thyboron Type IV doors ($0.88m^2$), and 0.6 Patriot doors ($0.67m^2$).

Calculations showed that the Patriot doors would be able to provide sufficient spreading power. These doors, while they are the smallest, are the heaviest of the three and would therefore likely be the most difficult to handle onboard the vessel. As such, these doors were eliminated from consideration. The Thyboron doors also had more than sufficient spreading power to achieve optimal wingspread for the 200 x 12cm trawl, and these doors weigh approximately half that of the Patriots. The Bison doors were by far the lightest, although it was determined that nearly the full spreading power of these doors would be needed to achieve the optimal configuration of the trawl. In the end, project personnel decided to begin field testing of this alternate net using the #2 Bison doors as they theoretically should provide sufficient spreading power, were the lightest and therefore easiest to handle, and were already on hand (VIMS owned a set of #2 Bison doors from a previous experiment, representing a potential time and cost savings to the project) (Figure 67). All hardware replacement and rigging necessary to match the #2 Bison doors with the 200 x 12cm trawl took place in the summer of 2010.

Following the plan outlined in the 2010 project proposal, all field testing of this alternate survey gear package took place in the late summer and fall. This period was chosen as both the abundance and diversity of fishes typically reaches a maximum in Chesapeake Bay during this time, meaning that conducting trials during this season would most likely provide the best indication of the ability of this trawl to sample fishes. Further, normally very few days are lost to the weather during these months, so delays due to poor conditions were likely to be minimized by completing the sea trials during this time. As such, field experimentation with this 200 x 12cm trawl/#2 Bison door combination began on September 5, 2010, and tows were conducted approximately 2nm west of Kiptopeake, VA. Unfortunately, the gear was hung on the bottom partway through the second tow and suffered extensive damage in the port wing and first bottom belly. Survey personnel were able to repair the trawl and the field trials of this gear configuration resumed on November 16 & 18, 2010 in the York River and around York Spit; all tows were completed without incident.

Again, as presented in the 2010 project proposal, these gear trials began with a series of rigging and towing (e.g., vessel speed, warp length, tow direction relative to the current, etc.) adjustments in an attempt to identify protocols that would consistently yield the theoretical optimal configuration of this net. These experiments were followed by a series of 're-tows', where sampling sites occupied earlier during regular survey operations (using the two-bridle, four-seam, semi-balloon bottom trawl) were towed again with the new net/door combination using standard sampling protocols in an effort to compare catch rates and compositions. A full detailing of the rigging and towing adjustments made and their associated outcomes, along with a description of catches under standard sampling conditions, is given in the results section below.

Results

Task 1 – *Conduct Research Cruises*

Cruise dates and the numbers of stations completed during each survey since 2002 are shown in Table 2. For years 2002-2004 the target number of stations per cruise was 90 and since 2005 that target number has been 80 (extensive analyses of data collected through 2004 revealed that the target number could be decreased by 10 stations per cruise with little effect on survey precision, but that decreases below 80 do have a significant negative effect on precision). Examination of the data presented in Table 2 reveals that as experience has been gained and survey procedures improved, the number of calendar days per cruise has decreased from an average of 11-13 days down to 9-11 (or even fewer days if we are fortunate to have a good weather window). Likewise, the number of actual work days has decreased from a range of 8-10 down to 7-8. As the survey only pays vessel costs on days actually worked, this increased efficiency has resulted in significant cost savings (note however that some of these efficiencies have likely resulted from an overall decrease in the number of fish caught, described below).

In mid-2008 we gained the ability to plot previous successful tow tracks onto electronically displayed overlays of selected sampling cells for each cruise. In difficult trawling areas, which are very common in Chesapeake Bay, by approximately retracing a successful tow track it becomes much less likely that the trawl gear will ‘hang up’ and/or be significantly damaged. This has resulted both in a further increase in efficiency (much less time is spent retrieving ‘hung’ gear so more time is spent sampling) and a decrease in the number of nets requiring major repair or replacement. Both of these elements offer further cost savings.

As previously explained, as a cost redistribution strategy, which allowed for field testing of the new survey gear, only regions 4 and 5 were sampled during July. According to the project proposal for this segment, additional half-only cruises were planned for May 2010 (regions 4 and 5 only) and for March 2011 (regions 1-3 only) but due to acquisition of supplemental VIMS funds, complete cruises were conducted during the latter two sampling periods.

Table 2. Cruise dates and number of stations completed during ChesMMAP research cruises since 2002.

Year	Cruise	Begin Date	End Date	Stations Completed	Calendar Days	Work Days
2002	March	3/29/2002	4/16/2002	50	19	8
	May	5/20/2002	5/28/2002	80	9	8
	July	7/8/2002	7/16/2002	77	9	8
	September	9/13/2002	9/22/2002	76	10	10
	November	10/28/2002	11/10/2002	74	14	9
2003	March	3/24/2003	4/4/2003	69	12	8
	May	5/20/2003	5/23/2003	29	4	4
	July	6/30/2003	7/10/2003	87	11	8
	September	9/30/2003	10/8/2003	73	9	8
	November	10/28/2003	11/5/2003	76	9	9
2004	March	3/20/2004	3/31/2004	90	12	8
	May	5/17/2004	5/26/2004	90	10	10
	July	7/1/2004	7/10/2004	59	10	7
	September	9/2/2004	9/15/2004	80	14	8
	November	10/28/2004	11/10/2004	86	14	10
2005	March	3/16/2005	3/25/2005	80	10	8
	May	5/2/2005	5/10/2005	80	9	8
	July	7/1/2005	7/12/2005	80	12	8
	September	9/8/2005	9/18/2005	76	11	8
	November	10/31/2005	11/9/2005	80	10	9
2006	March	3/23/2006	3/31/2006	80	9	8
	May	5/15/2006	5/25/2006	80	11	8
	July	6/28/2006	7/13/2006	73	16	7
	September	8/30/2006	9/13/2006	70	15	8
	November	10/30/2006	11/7/2006	74	9	8
2007	March	3/13/2007	3/23/2007	77	11	8
	May	5/9/2007	5/23/2007	77	15	9
	July	7/2/2007	7/10/2007	78	9	9
	September			0	0	0
	November	10/30/2007	11/12/2007	77	14	8
2008	March	3/17/2008	3/26/2008	80	10	8
	May	5/20/2008	5/27/2008	78	8	8
	July	6/28/2008	7/7/2008	80	10	7
	September	9/2/2008	9/11/2008	80	10	7
	November	10/30/2008	11/11/2008	80	13	8
2009	March	3/16/2009	3/26/2009	80	11	7
	May			0	0	0
	July	7/14/2009	7/20/2009	80	7	7
	September	9/2/2009	9/12/2009	80	11	8
	November	11/3/2009	11/10/2009	78	8	7
2010	March	3/22/2009	3/31/2009	79	10	7
	May	5/22/2010	5/28/2010	79	7	7
	July	7/6/2010	7/9/2010	45	4	4
	September	8/31/2010	9/11/2010	80	12	8
	November	11/2/2010	11/15/2010	79	14	8

After reaching a maximum during the third survey year (2004), the total number of specimens sampled annually has steadily declined (Table 3). While total samples collected and processed was higher in 2010 than in 2009, the 26,337 specimens collected in 2010 represents a 45% decrease in total catch compared to 2004, with comparable levels of total sampling effort.

Table 3. Number of specimens collected, measured and processed for age determination and diet composition information from ChesMMAP, 2002 – 2010.

Year	Fish collected	Fish measured	Otoliths collected	Otoliths processed	Stomachs collected	Stomachs processed
2002	32,019	23,605	5,487	4,494	4,560	3,021
2003	30,924	20,828	3,913	3,055	3,250	2,417
2004	47,622	31,245	5,169	4,290	4,272	3,330
2005	45,204	36,909	6,065	5,006	5,067	3,432
2006	43,957	31,243	5,413	4,229	4,402	3,503
2007	30,893	22,124	4,282	3,253	3,671	2,869
2008	26,299	19,596	4,206	3,048	3,677	3,429
2009	22,050	15,694	3,227	2,205	2,729	2,640
2010	26,337	20,566	4,003	in process	3,424	3,236

Concerns as to whether this decrease in catch is due to actual changes in species abundance or is an artifact of unknown sampling effects were examined in the previous segment report (Bonzek et al., 2010). That analysis revealed that much of the decrease in total catch can be attributed to declines in measured abundance of a single species, Atlantic croaker. Catch rates of other commonly abundance species, (e.g. spot, weakfish, March white perch) have also declined when compared to the mid-2000s. There is still some uncertainty in the investigators' minds as to whether these declines represent real biological abundance in Chesapeake Bay or are a sampling artifact. Future sampling with the new three-bridle, four-seam, 200x12 net may aid in this determination.

The vast majority of ageing structure (i.e. otoliths, opercles, etc.) and stomach samples preserved have been analyzed (Table 3). Currently, most of the otolith and stomach samples that remain to be processed represent species which are either of relatively minor management interest (e.g. oyster toadfish otoliths), which involve significantly different preparation and analysis techniques (e.g. elasmobranch vertebrae), which are particularly difficult to analyze (e.g. Atlantic menhaden stomachs), or which currently have no accepted processing protocols (e.g., butterfish sampled from inshore waters). Most of the ageing structures from 2010 have been processed in the laboratory and read by at least two readers, but for most species, especially those of management interest, only the final steps of reconciling differences among readers and including assigned ages into the data base remain.

Tasks 2-4 – *Data Summaries*

The data summaries in this report represent a subset of the biological and ecological analyses which could be calculated from the ChesMMAP data set. For those species which are well-sampled by the survey, overall abundance estimates are presented. Estimates of ‘minimum trawlable abundance’ as presented in previous segment reports are not included here and likely will not be in future reports. These estimates are useful in certain bioenergetics analyses and represented a first step in development of ChesMMAP abundance indices but are not typically useful in a management context. For most species, relative abundances are given using three analytical methods (as previously described), the delta lognormal, the geometric mean, and the arithmetic mean. For certain species (typically those in which a small number of extremely large catches have been experienced) the delta lognormal calculation becomes unstable and an improved geometric mean calculation has been substituted.

Relative abundance index calculations were based on limiting the data used for each species to the months, regions, and depth strata of maximum abundance over all years (Table 4). Those limiting parameters have been updated for some species based on subsequent analyses conducted during the past year (but not presented here).

Table 4. Selected months, regions, and depth strata data used for abundance indices for each species (modified in comparison to previous segment reports).

Species	**Sp. Code**	**Month**					**Region**					**Depth**		
		03	05	07	09	11	01	02	03	04	05	01	02	03
Atlantic croaker	0005	⬜	🟦	🟦	🟦	⬜	⬜	⬜	⬜	🟨	🟨	⬜	🟩	🟩
black seabass	0002	⬜	⬜	🟦	🟦	🟦	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩
bluefish	0009	⬜	⬜	⬜	🟦	🟦	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩
butterfish	0004	⬜	⬜	⬜	🟦	🟦	⬜	⬜	⬜	🟨	🟨	⬜	🟩	⬜
kingfish sp.	0013	⬜	🟦	🟦	🟦	🟦	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩
northern puffer	0050	⬜	⬜	⬜	🟦	🟦	⬜	⬜	⬜	⬜	🟨	🟩	🟩	⬜
scup	0001	⬜	⬜	🟦	🟦	🟦	⬜	⬜	⬜	⬜	🟨	🟩	🟩	⬜
spot	0033	⬜	⬜	🟦	🟦	⬜	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩
striped bass (March)	0031	🟦	⬜	⬜	⬜	⬜	🟨	🟨	⬜	⬜	⬜	🟩	🟩	⬜
striped bass (November)	0031	⬜	⬜	⬜	⬜	🟦	🟨	🟨	⬜	⬜	⬜	🟩	🟩	⬜
summer flounder	0003	⬜	⬜	⬜	🟦	🟦	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩
weakfish	0007	⬜	⬜	⬜	🟦	🟦	⬜	⬜	⬜	🟨	🟨	⬜	🟩	🟩
white perch (March)	0032	🟦	⬜	⬜	⬜	⬜	🟨	🟨	⬜	⬜	⬜	🟩	🟩	⬜
white perch (November)	0032	⬜	⬜	⬜	⬜	🟦	🟨	🟨	⬜	⬜	⬜	🟩	🟩	⬜
Additional species														
blue crab - ad. female	6143	⬜	⬜	⬜	⬜	🟦	⬜	⬜	⬜	🟨	🟨	🟩	🟩	🟩
blue crab - male	6141	⬜	⬜	⬜	🟦	🟦	🟨	🟨	⬜	⬜	⬜	🟩	🟩	🟩
clearnose skate	0170	⬜	🟦	🟦	🟦	🟦	⬜	⬜	⬜	⬜	🟨	🟩	🟩	🟩

Length-frequency, age-frequency (for those species for which ageing has been completed) and overall diet summaries are also presented. Some analyses (e.g. sex ratios, length-weight relationships, growth equations) presented in previous project reports are not included. It is assumed that, when needed, assessment scientists and managers will request specific analyses of these data types which could not be fully anticipated in this report. Therefore, only those general data summaries of the most universal possible use are included. The profiles that follow are organized first by species and then by type of analysis ('Task'). Each Task element (single-species stock parameter summarizations, trophic interaction summaries, and estimates of abundance) is included but is not labeled with a Task number and is not necessarily shown in Task number order (note also that not all analysis types are available for all species).

For each species, the following data summaries are presented (note that some data/analyses may not be available for all species):

1) Figures presenting overall area-swept abundance indices by number and biomass, calculated using delta lognormal, geometric, and arithmetic means. Included on each figure is a table with index values and coefficients of variation (CV).
2) Length-frequency data by year.
3) Age-frequency distributions by year (for those species where appreciable numbers have been captured and otoliths have been processed).
4) A series of GIS figures showing total abundance at each sampling site overlaid on the survey depth strata, for each cruise during the year (Note that in earlier project reports figures for all survey years have been presented. To compare results in 2010 to prior years refer to the previous project reports – e.g. Bonzek et al. 2009).
5) Diet analyses by weight and number, using all data collected and analyzed 2002-2010.

Species Data Summaries

Atlantic Croaker (*Micropogonias undulatus*)

Abundance: Atlantic croaker is typically among the most abundant species in ChesMMAP survey catches, especially during the mid-year. The majority of fish are captured in regions 4 and 5 (Virginia) but are regularly captured in all survey regions. Catches decline in September and November as this summer resident species leaves bay waters (Figure 4).

Relative abundance indices for all ages combined calculated as delta lognormal, geometric and arithmetic means follow similar trends, both in numbers and biomass (Figure 1). Low values in 2002 and 2003 were followed by high abundance throughout 2004-2007 but indices reflect time-series low abundance though the period 2008 to 2010. Whether the low abundance for this species in 2008-2010 ChesMMAP samples is a result of migratory irregularities or represents a more coastwide phenomenon can be determined by examination of data from outside Chesapeake Bay.

Length and Age: Specimens between 14mm and 499mm in total length (Figure 2) and between age 0 and 15 (Figure 3) appear in survey data; most individuals range between 150mm and 350mm and ages 1-5. Croakers to age 8 are not uncommon for this survey. During 2008, program personnel attended an Atlantic croaker ageing workshop sponsored by the Atlantic States Marine Fisheries Commission. The consensus report from that workshop set a birth date of 1 January each year, as that date is the approximate mid-point of spawning in the southern portion (i.e., south of Cape Hatteras) of the species' range. Spawning north of Hatteras, including Virginia's waters, occurs several months earlier, and is often complete by early December. As a result, all croaker ages in the ChesMMAP data base were adjusted down one year and it is now possible to capture age-negative 1 fish in the survey. This occurs when fish spawned in late summer and autumn of a given year are collected during the September or November cruises of that year. Those fish are not considered age-0 (or young-of-the year) until that upcoming January, so to place them in the correct year-class, they are assigned an age-negative 1.

The length distribution of this species changes considerably year-to-year as year- classes of either extremely high or extremely low abundance move through the stock. For example, a highly abundant 2002 year class was seen as a peak in the length-frequency histograms between 2003 and 2007 and as a distinctly abundant year class in the age-frequency figures even into 2008. There appears to be evidence of mildly to highly successful year class in 2006 which was still abundant in 2007 and 2008 but was not found in appreciable numbers in 2009. Conversely, the 2007 year class appears to have been nearly absent in Chesapeake Bay and similarly was not abundant in 2008. In 2009 these two-year-old fish were the most abundant age class but number captured was very low compared with other years.

Diet: Miscellaneous polychaetes (19.4% by weight (W) and 18.8% by number(N)) represent the largest single prey type in the diet of Atlantic croaker and all worms combined (42.4% W, 33.2%

N) represent the largest taxonomic group. Unidentifiable material (13.5% W, 8.8% N - likely constituted largely of worms and soft-bodied molluscs) is the second largest single prey type by weight while mysids (9.6% W, 17.8% N) are the second largest prey category by number. Molluscs (12.8% W, 10.3% N - mostly bivalves) and crustaceans (17.1% W, 31.2% N – primarily mysids and amphipods) nearly equal in importance. It is notable that, in the habitats sampled by the survey, blue crabs did not constitute an appreciable amount of the diet (defined here as 1% of the diet). Other categories of prey constituted relatively minor portions of the diet (Figure 5).

Figure 1. Overall abundance indices (number and biomass) for Atlantic croaker based on delta lognormal mean (A), geometric (B) and arithmetic (C) means.

Figure 2. Atlantic croaker length-frequency in Chesapeake Bay, 2002-2010.

Figure 3. Atlantic croaker age-structure in Chesapeake Bay, 2002-2009.

Figure 4. Abundance (kg per hectare swept) of Atlantic croaker in Chesapeake Bay, 2010.

Figure 5. Diet composition, expressed as percent by weight (A) and percent by number (B) of Atlantic croaker collected during ChesMMAP cruises in 2002-2010 combined.

Black Sea Bass **(*Centropristis striata*)**

Abundance: The ChesMMAP survey gear and sampling methodology are not considered particularly effective for this structure-oriented species (locations of known complex bottom structures and other 'hangs' are purposely avoided). However, enough individuals are captured for a certain amount of information to be extracted from survey samples. Catches are typically highest during the July, September and November cruises and are concentrated in regions 4 and 5 but are not uncommon in region 3 (Figure 9). Significant differences in catch rates among depth strata were not observed (Bonzek et al., 2009).

Overall relative abundance indices expressed either in numbers or biomass and calculated as delta lognormal, geometric, and arithmetic means exhibit relatively consistent inter-annual patterns. Concentrating on the delta lognormal index, 2006 abundance was estimated as the lowest value in the time series, followed by higher index values in the succeeding three years then a decline again in 2010. However, it is difficult to discern a time series trend (Figure 6). As catch rates for this species are low and inconsistent and coefficients of variation (CV) on the abundance estimates are broad.

Comparisons of abundance estimates between this and other surveys has not yet been accomplished but may give insight as to the reliability of data from this and other programs.

Length and Age: Specimens captured in the survey tend to be relatively small (<250mm) and young (age-0 and age-1) though individuals up to 270mm total length have been sampled (Figure 7). Preliminary ageing of samples from earlier survey years was completed in 2008 and revealed that in most years the survey catches are dominated by age-1 specimens, though in the 2006 and 2007 survey years the number of age-0 specimens increased (Figure 8). Otoliths taken during 2009 and 2010 have not yet been analyzed as protocols used coastwide to age this species have been called into question. This will be examined by consultation with scientists inside and outside the Chesapeake region.

Diet: Though the sample size is relatively small (207 specimens, 129 clusters) and the size range of samples is limited, the diet data is probably the most valuable ChesMMAP contribution for this species. Crustaceans (70.4% W, 80.5% N), dominated by mysids (15.7% W, 35.7% N), mud crabs (14.6% W, 8.1% N), and amphipods (7.9% W, 13.0% N) contribute the highest portion of the diet, by weight of identifiable prey. Fishes constitute 9.6% of the diet by both weight and number with bay anchovy (2.9% W, 1.2% N) the largest component among identifiable species. A variety of worms (5.0% W, 3.5% N) molluscs (4.6% W, 1.7% N) and other less prominent or unidentifiable taxa comprise the remainder of the diet (Figure 10).

Figure 6. Abundance indices (number and biomass) for black sea bass based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 7. Black sea bass length-frequency in Chesapeake Bay, 2002-2010.

Figure 8. Black sea bass age-structure in Chesapeake Bay, 2002-2008.

Figure 9. Abundance (kg per hectare swept) of black sea bass in Chesapeake Bay, 2010.

Figure 10. Diet composition, expressed as percent by weight (A) and percent by number (B) of black sea bass collected during ChesMMAP cruises in 2002-2010 combined.

Bluefish **(*Pomatomus saltatrix*)**

Abundance: Due to the fast-swimming and pelagic nature of bluefish, this species also is not considered to be well sampled by ChesMMAP, though some useful assessment-related information can be generated from these survey data (Figure 14). When captured, typically between one and five specimens occur in a tow, though as many as 42 have been collected in a single sampling event. Bluefish are usually captured in either the shallow (10’-30’) or mid-depth (30’-50’) strata. Catches are typically highest late in the year, presumably as the young-of-the year fish are moving into deeper waters in preparation for outmigration from the bay. Abundance is normally highest in regions 4 and 5 but notable exceptions occur such as a single capture of 26 specimens in region 1 during the September 2008 cruise (Bonzek et al. 2009).

Abundance indices for all ages of bluefish combined have varied without trend over the survey history (Figure 11). Patterns between indices by number and weight as well as among the delta lognormal, geometric, and arithmetic calculation methods are very similar except that in 2010 the index as calculated by the geometric mean remained flat while those for the delta lognormal and the arithmetic means were either at or close to time series high values.

Length and Age: Most individuals sampled in the survey are less than 350mm fork length and, due to the number of small number of specimens captured and protracted spawning season of this species, it is difficult to differentiate cohorts in length frequencies (Figure 12). Nearly all ChesMMAP bluefish are either age-0 or age-1 and in most years the majority of specimens captured are age-0 (Figure 13).

Diet: Diet data presented here are consistent with previous studies in showing that bluefish are highly piscivorous (Figure 15). For the 239 specimens examined, which represent 137 clusters, bay anchovy constitute 39.9% of the diet by weight and 45.7% by number, while spot (18.8% W, 11.9% N) and Atlantic menhaden (9.3% W, 8.5% N) are the other major identifiable fish prey, and all fish species together represent 87.7% by weight and 84.7% by number. Crustaceans (mainly mysids) at 10.3% W and 9.6% N, represent most of the remainder. Small amounts of *Loligo* squid (1.5% W, 1.4% N) were present in the diet of observed fish.

Figure 11. Abundance indices (number and biomass) for bluefish based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 12. Bluefish length-frequency in Chesapeake Bay, 2002-2010.

Figure 13. Bluefish age-structure in Chesapeake Bay, 2002-2009.

Figure 14. Abundance (kg per hectare swept) of bluefish in Chesapeake Bay, 2010.

Figure 15. Diet composition, expressed as percent by weight (A) and percent by number (B) of bluefish collected during ChesMMAP cruises in 2002-2010 combined.

Butterfish **(*Peprilus triacanthus*)**

Abundance: Butterfish abundance follows a generally predictable annual pattern, building from near-zero during March, increasing abundance (albeit low) through the spring and summer, and reaching a maximum generally during the September and November cruises (Figure 18).

Abundance indices (delta lognormal, geometric and arithmetic, numbers and biomass) appear to have varied without trend over the time series, though 2010 represented low points in all cases (Figure 16). Abundance as measured in other surveys has been increasing so whether the low ChesMMAP value in 2010 represents natural survey variation or a change in availability within Chesapeake Bay will bear future observation.

Length and Age: This program (and others) has found butterfish extremely difficult to age. We are still investigating methods to obtain accurate age determinations from otolith samples. Yearly length frequency diagrams (Figure 17) appear to reveal at least two year classes of varying strength present in the Chesapeake Bay fish during any given year, however this will require further analysis. Ageing has been accomplished for specimens captured from NMFS surveys (Kawahara, 1978) so it may be possible to estimate ChesMMAP ages from length-age keys.

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

Figure 16. Abundance indices (number and biomass) for butterfish based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 17. Butterfish length-frequency in Chesapeake Bay, 2002-2010.

Figure 18. Abundance (kg per hectare swept) of butterfish in Chesapeake Bay, 2010.

<u>Kingfish</u> **(*Menticirrhus spp.*)**

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

ChesMMAP catches for this species are almost exclusively in regions 4 and 5 (lower bay) and occur throughout the warm weather months and are often high even in November (Figure 22).

Abundance: It appears that kingfish have been on a generally increasing abundance trend throughout the survey years. Delta lognormal, geometric and arithmetic indices (expressed either numerically or in biomass units) show the same general trend, though the delta lognormal and the arithmetic based indices are more similar to each other than either is to the geometric mean. Indices throughout 2008-2010 were at least twice the values for previous years (Figure 19).

Length and Age: Due to the relatively small number of specimens captured during any particular year, it is difficult to interpret length frequencies, though at least two cohorts are apparent in some years (e.g. 2005, 2007, 2009, 2010 - Figure 20). Specimens between ages 0 and 7 have been captured with most being age-4 or less. 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. Relatively large numbers of age-0 and age-2 specimens were captured in 2009 but the number of age-3-and-older fish was very small (Figure 21).

Diet: The largest taxa of prey items in kingfish stomachs are crustaceans (43.4% W, 49.8% N), primarily small shrimps and crabs. Molluscs and worms constitute the next largest portions (25.7% W, 21.4%N and 12.0% W, 9.2% N respectively) of the diet, with fishes and several other categories completing the diet (Figure 23).

Figure 19. Abundance indices (number and biomass) for kingfish based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 20. Kingfish length-frequency in Chesapeake Bay, 2002-2010.

Figure 21. Kingfish age-structure in Chesapeake Bay, 2002-2009.

Figure 22. Abundance (kg per hectare swept) of kingfish in Chesapeake Bay, 2010.

Figure 23. Diet composition, expressed as percent by weight (A) and percent by number (B) of kingfish collected during ChesMMAP cruises in 2002-2010 combined.

Northern Puffer **(*Sphoeroides maculatus*)**

Abundance: Typical patterns of abundance for this species in the survey are minimal numbers in spring and early summer, and a peak in abundance during the November cruise, perhaps as the summer residents are migrating toward offshore wintering grounds. Catches are consistently greatest in regions 4 and 5, though the species is common into region 3 (Figure 26). As catches in the survey are spotty, estimates of abundance for this species are of unknown reliability.

Relative abundance indices from survey data have varied without trend since 2002 but were at high values (as measured by the delta lognormal index, at time series high values) in 2010. Indices calculated using all three methods, based on both numbers and biomass, tend toward good agreement (Figure 24).

Length and Age: Specimens between approximately 50mm and 270mm total length have been captured, though most individuals measured between 100mm and 250mm. The length composition varies year to year, likely as a result of varying year-classes entering and leaving the bay stock (Figure 25). However, as this is not a high priority species, ageing has not been completed.

Diet: Crustaceans (36.7% W, 38.5% N), primarily small crab species, molluscs (17.8% W, 19.1% N), and worms (10.1% W, 14.1% N), constitute the majority of identifiable items in the stomachs of this species. Unidentifiable material constitutes an appreciable (14.1% W, 9.8% N) portion of prey items examined (Figure 27).

Figure 24. Abundance indices (number and biomass) for northern puffer based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 25. Northern puffer length-frequency in Chesapeake Bay, 2002-2010.

Figure 26. Abundance (kg per hectare swept) of northern puffer in Chesapeake Bay, 2010.

Figure 27. Diet composition, expressed as percent by weight (A) and percent by number (B) of northern puffer collected during ChesMMAP cruises in 2002-2010 combined.

Scup **(*Stenotomus chrysops*)**

Abundance: 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 bay waters (Figure 31). The species is most abundant in region 5 and is rarely captured north of region 4. It is important to note that 2007 data are limited due to cancellation of the September cruise. Scup are typically most abundant in shallow strata (10'-30') and mid-depth strata (30'-50') and are rarely captured in waters over 50'.

Discerning trends over the time series is problematic due to the difficulty in interpreting 2007 data when the September cruise was cancelled resulting from a budget shortfall. Geometric mean indices for both number and biomass indicate relatively high abundance in 2007 while the delta lognormal and arithmetic mean indices show a downward trend between a peak in 2005 and time series low values in 2008. A slight upward tick was indicated in 2009 followed by time series highs for nearly all measured indices in 2010 (Figure 28).

Length and Age: Most specimens captured in the survey are less than 200mm fork length and at least two year classes are apparent in length data (Figure 29). Nearly all specimens captured are either age-0 or age-1, so it is difficult to discern whether year-class abundance can be followed in age frequency figures (Figure30). Most research groups that generate age data for this species use scales rather than the otoliths used by ChesMMAP, so scale/otolith comparisons must be completed in coming years. The Multispecies Research Group at VIMS intends to complete scale/otolith comparisons in coming years; sample collections have already begun.

Diet: By weight, worm species constitute a majority (51.3%) of identifiable items in scup stomachs and represent 30.2% of prey by number (Figure 32). Unidentifiable prey (likely largely constituted of worms and other soft-bodied prey) also make up a large portion (21.6% W, 16.3% N). At 14.7% by weight, crustaceans (primarily mysids and amphipods) are also a major prey source, and at 38.9% represent the largest single taxon in scup diets when measured by number.

Figure 28. Abundance indices (number and biomass) for scup based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 29. Scup length-frequency in Chesapeake Bay, 2002-2010.

Figure 30. Scup age-structure in Chesapeake Bay, 2002-2007.

Figure 31. Abundance (kg per hectare swept) of scup in Chesapeake Bay, 2010.

Figure 32. Diet composition, expressed as percent by weight (A) and percent by number (B) of scup collected during ChesMMAP cruises in 2002-2010 combined.

Spot **(*Leiostomus xanthurus*)**

Abundance: Spot are typically among the most abundant species in the survey during all cruises except March. Likewise this species is well distributed throughout the bay, though concentrations are highest in regions 4 and 5. Spot appear to invade the bay earlier and remain abundant later in the fall during recent years compared to earlier survey years (Figure 36). Whether this is environmentally driven or a result of other factors is unknown.

Abundances over the time series vary considerably year to year and though no trend is apparent, abundance was at a low point in 2010 after a peak in 2009 (Figure 33). Patterns among the delta lognormal, geometric and arithmetic means are in general agreement but some differences exist that will merit future examination. For example, while the trend lines for numbers and biomass for many species run nearly parallel, that is not always the case for spot, especially for the delta lognormal index. For example, in2002, the numerical index was at a relatively low level while the biomass index was at a time series high; in 2010, both measures were at low levels but while the numerical index declined by a factor of two compared to 2009, the biomass index was lower by a factor of about 11. Examination of the length frequency figures may offer an explanation. In some years (e.g. 2002, 2003, 2009) the ChesMMAP catches are dominated by specimens greater than 150mm in length, in others (e.g. 2005, 2007) the numbers above and below 150mm are comparable or those smaller than 150mm are dominant (e.g. 2010). Interestingly, with the exception of 2009 the relative number of age-0 specimens vs. the number of age-1s is somewhat constant (though the 2010 samples have not yet been examined, judging from the length data, age frequencies will likely be dominated by age-0s).

Length and Age: Individuals between 100mm and 250mm are most common in the survey, with a smaller number of specimens up to 300mm occasionally captured (Figure 34). The largest individuals are most often captured in regions 2 or 3. Nearly all fish in the survey are either age-0 or age-1 with the oldest fish captured at age-4 (Figure 35). 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 invading the bay each year.

Diet: Not surprisingly, the largest single prey type is unidentified material (30.0% W, 24.8% N) followed by worms (32.3% W, 29.2% N) which for the most part were not identifiable to specific taxa. Molluscs (primarily unidentified clams) at 13.5% by weight and 10.8% by number, and crustaceans (8.2% W, 19.3% N), principally mysids and amphipods, were also major portions of the diet for spot (Figure 37).

Figure 33. Abundance indices (number and biomass) for spot based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 34. Spot length-frequency in Chesapeake Bay, 2002-2010.

Figure 35. Spot age-structure in Chesapeake Bay, 2002-2009.

Figure 36. Abundance (kg per hectare swept) of spot in Chesapeake Bay, 2010.

Figure 37. Diet composition, expressed as percent by weight (A) and percent by number (B) of spot collected during ChesMMAP cruises in 2002-2010 combined.

<u>Striped Bass</u> **(*Morone saxatilis*)**

Abundance: Intra-annual patterns of abundance for striped bass typically follow a consistent trend. Large numbers of spawning migrants are captured during the March cruise, followed by lower numbers in May 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. Most striped bass are captured in regions 1 – 3 (Maryland waters) but the species occurs regularly in samples from all bay locations. In March, catches are high in all depth strata, but in other survey months catch rates are greatest in waters less than 50’ (Figure 42).

Two sets of abundance indices have been calculated for this species: one using data from the March cruise which assesses abundance of the spring spawning stock, and one using data from November which characterizes the number of summer residents as they school together in the fall.

Comparisons of patterns in index trends among the three calculation methods for March (spawner) striped bass are difficult to interpret. All methods find a peak in abundance in 2008, while the delta lognormal index finds another high value in 2006 which the geometric and arithmetic indices do not exhibit. The geometric mean index reached a time series high in 2004, which was also relatively high for the arithmetic mean but was generally absent for the delta lognormal (Figure 38). For most other species, the delta lognormal and arithmetic mean indices are well in agreement. These differences will merit further examination before a final methodology is decided upon for this species. In all cases, spawner abundance in 2010 was at a low value.

With the exception of data from 2005, mean November abundance indices are in general agreement, expressed both as numbers and biomass (Figure 39). Delta lognormal and arithmetic mean indices measure peak abundance in 2005 while the geometric mean index exhibits a low value in 2005. Examination of raw catch data reveal that two tows with extraordinarily large catches are likely responsible for this discrepancy. The geometric mean would tend to dampen such catches while the other index calculation methods would not. For the delta lognormal index, the actual values calculated are so unusually high that they are not presented. Graphically, a high value was substituted simply to show a peak and in the associated data table no values are given. In all cases, low index numbers were seen in 2010.

Length and Age: Most specimens captured in the survey are about 600mm fork length or less (ages 1 – 7). The largest individuals approach 1000mm and are captured during spring spawning. 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 histograms (Figure 40). However, age distribution figures (Figure 41) readily reveal year-class strength (high peaks during one year tend to follow into succeeding years, as do low abundances) and this phenomenon is being used in an attempt to validate results of young-of-year seine surveys. The oldest specimen yet sampled by the survey, at age-20 (1988 year class), was captured in 2008.

Diet: Results of diet analyses from this study differ appreciably from previous studies using specimens from Chesapeake Bay (Figure 43). Fish comprise the largest taxonomic group in the diet by weight (42.9%), but rank second to crustaceans by number (29.1% W vs. 45.5% N) due to consumption of a large number of small bodied mysids and amphipods. Among fish species, this survey consistently finds that bay anchovy contributes the highest proportion by weight (16.9%) with Atlantic menhaden second (9.5%). Mysids and amphipods combined constitute 22.3% by weight and 37.8% by number, a sharp contrast to previous studies; and worms make up the only other major prey type (15.5% W, 11.6% N). These differences from previous diet studies are likely the result both of sampling methodological differences (the broad temporal and geographic scale of ChesMMAP as well as the trawl gear used compared to many studies which were limited in temporal or geographical scale or which use capture methodologies which yield a narrower size range) and analytical/mathematical differences in calculating percentages in the diet. In brief, this study calculates fish diets using cluster-sampling theory and analytical methods whereas previous studies are thought to have used the assumption of simple random sampling of fish. The cluster method moderates the effect of a relatively small number of large predator specimens with large prey in the stomachs (e.g. Atlantic menhaden) as compared to a large number of smaller specimens with a significantly different diet.

Figure 38. Abundance indices (number and biomass) for striped bass (March) based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 39. Abundance indices (number and biomass) for striped bass (November) based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 40. Striped bass length-frequency in Chesapeake Bay, 2002-2010.

Figure 41. Striped bass age-structure in Chesapeake Bay, 2002-2009.

Figure 42. Abundance (kg per hectare swept) of striped bass in Chesapeake Bay, 2010.

Figure 43. Diet composition, expressed as percent by weight (A) and percent by number (B) of striped bass collected during ChesMMAP cruises in 2002-2010 combined.

***Summer Flounder* (*Paralichthys dentatus*)**

Abundance: The typical intra-annual pattern of numerical abundance for summer flounder shows catches increasing monthly throughout the sample year, with highest catches in September and/or November (Figure 47). Summer flounder are most abundant in regions 4 and 5 but are common in regions 2 and 3 as well. A slightly higher catch rate is exhibited for mid-depth (30’ – 50’) and deep (>50’) stations than in shallow (10’ – 30’) waters. The highest catches of summer flounder often occur along the eastern portions of regions 4 and 5 but this is not an absolute.

Abundance indices have varied considerably over the time and are in general agreement among the three analytical methods but as with striped bass, there is a single year (2008) in which the geometric mean differs substantially from the delta lognormal and arithmetic means. The latter two indices found high abundance in 2008 while the geometric mean exhibits a lower abundance estimate which gives the appearance of a near straight-line decline in abundance with the time series high in 2006. This pattern would be at odds with abundance as estimated by recent coastwide assessments (Tercerio, 2010) which measured increasing stock abundance in recent years due to stringent management efforts. However, all methodologies quantified low Chesapeake Bay abundance in 2010. Whether that represents a real localized decline or if it will reverse direction bears watching (Figure 44).

Length and Age: Fish which measure between approximately 200mm and 500mm total length are most prevalent in survey samples though fish as large as 760mm have been captured (Figure 45). In several years a large number of fish under 300mm (likely age-0) can be differentiated in length-frequency graphs. Most fish in the survey are age-5 and under, and the oldest fish yet captured are three specimens at age-12. In age classes older than age-2 it appears to be more difficult, compared to other species, to follow abundance trends of particular year classes in successive years (Figure 46). This could be the result of differential migration patterns among different sized fish or of fishery preferences and/or regulations.

Diet: As measured by percent weight, fish comprise a slight majority (52.3%) of summer flounder diets in the survey, with the primary prey being bay anchovy (17.7%), weakfish (9.6%), and spot (8.3%) (Figure 48) with crustaceans (43.9%) only slightly lower; as measured by number, crustaceans constitute nearly two-thirds of the diet (63.7%) with the main prey types being mysids (48.2%), sand shrimp (6.9%), and mantis shrimp (4.8%). The high prevalence of fish in summer flounder stomachs, especially for larger individuals, leads to the conclusion that this species should be considered a top predator in Chesapeake Bay along with striped bass, bluefish, and weakfish (Latour et al. 2008). It is noteworthy that by percent weight as measured by this survey, in Chesapeake Bay summer flounder are more highly piscivorous than are striped bass and are nearly on par with weakfish in this characteristic.

Figure 44. Abundance indices (number and biomass) for summer flounder based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 45. Summer flounder length-frequency in Chesapeake Bay, 2002-2010.

Figure 46. Summer flounder age-structure in Chesapeake Bay, 2002-2009.

Figure 47. Abundance (kg per hectare swept) of summer flounder in Chesapeake Bay, 2010.

Figure 48. Diet composition, expressed as percent by weight (A) and percent by number (B) of summer flounder collected during ChesMMAP cruises in 2002-2010 combined.

Weakfish (Cynoscion regalis)

Abundance: Weakfish is among the most abundant species in survey samples over most seasons and locations. Catches are typically low in March but by May fish have begun to migrate into the bay and remain abundant in the survey throughout the rest of the year. Peak catches are usually in September and decline somewhat in November as fish begin their late fall migration out of the bay (Figure 52). Catches are typically higher in mid-depth (30' – 50') and deep (>50') stations than at shallow ones (10' – 30').

Consistent with recent coast wide trends (ASMFC Weakfish Technical Committee, 2009), overall abundance for this species increased between 2002 and 2005 and then steadily declined over the next several years. However, after reaching a time series low in 2008 a slight upward tick was found in the successive two years, by all calculation methods (Figure 49).

Length and Age: Most weakfish captured by the survey are between 100mm and 350mm total length. Minimum and maximum sizes found during the survey are 23mm and 616mm respectively (Figure 50). With only a few exceptions, most fish captured over 400mm 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 seven years, with few individuals older than age-2 captured in recent years and almost none older than age-3 (Figure 51).

Diet: Fish, primarily bay anchovy (35.7%), comprise a majority (57.6%) of prey types in the weakfish diet as measured by biomass ingested (Figure 53). Notably, weakfish account for 4.3% of prey in the diet of weakfish, by weight. Similar to summer flounder, as measured by number, crustaceans dominate the diet of weakfish in Chesapeake Bay (63.2%), dominated by mysids at 54.7%. Bay anchovy are 20.5% of the diet by number. The relatively low percent of Atlantic menhaden seen in the survey stomach samples (2.9% W, 1.2% N), when compared to earlier studies, may be due to the truncation of the size range of weakfish in Chesapeake Bay as well as the broad geographic and temporal scale of this survey and due to the cluster sampling analytical methodology as explained for striped bass above.

Figure 49. Abundance indices (number and biomass) for weakfish based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 50. Weakfish length-frequency in Chesapeake Bay, 2002-2010.

Figure 51. Weakfish age-structure in Chesapeake Bay, 2002-2009.

Figure 52. Abundance (kg per hectare swept) of weakfish in Chesapeake Bay, 2010.

Figure 53. Diet composition, expressed as percent by weight (A) and percent by number (B) of weakfish collected during ChesMMAP cruises in 2002-2010 combined.

White Perch (Morone americana)

Abundance: White perch are extremely abundant in survey samples throughout each year in regions 1 and 2 and are common into region 3 (Figure 58). Due to this species' concentration in the shallow waters of region 1, catches are highest in the shallowest strata (10' – 30'), followed by the mid-depth strata (30' – 50'), with this species rarely seen in samples from the deepest stations (>50'). Interpretation of abundance indices for this species must account for the fact that ChesMMAP samples only a portion of the range of the species and catches can be significantly influenced by salinity.

As with striped bass, indices of abundance are presented for both the spring (March) spawning population and for the fall (November) when fish again school together. Even given the considerations expressed above, it is difficult to interpret the patterns among the three index calculation methodologies. Internally, each one is relatively consistent between the numerical and biomass based calculations but each gives a somewhat different view of the pattern of abundance over the time series (Figures 54, 55). For the March index, the delta lognormal method found abundance high values in 2005 and 2007 and lows in 2003 and 2009. The geometric mean method found highs in 2007 and 2008 and relatively stable abundance in all other years, while the arithmetic mean exhibits time series highs in 2006 and 2007. Similarly, for the November period, all three methods find some agreement in higher index values for 2004 and 2006, low values in 2007 and 2008, but significantly diverge from one another in 2009 and 2010. These differences are likely due to how each is affected by small numbers of high catches, which can regularly occur for this species. This phenomenon will demand future examination and comparison with abundance estimates from other surveys and other methodologies.

Length and Age: All white perch of sizes greater than approximately 150mm fork length are well sampled in the survey (Figure 56). 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. The peak of abundance in 2007 and 2008 samples was at a smaller size then during previous years. This species is not well sampled by the survey until approximately age-2 or 3 (Figure 57); however past that age the survey appears to adequately represent all age classes. The species age distribution appears 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 year-classes).

Diet: While unidentified material represents the largest single prey category by weight in white perch stomachs (17.5%), crustaceans (32.0% W, 46.2% N) constitute the largest identifiable taxon with amphipods (15.4% W, 25.8% N) as the primary prey, followed by a number of other small crustacean prey. Worms (25.4% W, 17.0% N), primarily *Nereis* clam worms (13.6% W, 8.9% N) and other polychaetes (11.8% W, 8.1% N), are the second most abundant prey, followed by bivalve molluscs (15.4% W, 12.9% N). Notably, a small number of bay anchovy (3.2% W, 2.1% N) are present in white perch stomachs (Figure 59).

Figure 54. Abundance indices (number and biomass) for white perch (March) based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 55. Abundance indices (number and biomass) for white perch (November) based on delta lognormal (A), geometric (B) and arithmetic (C) means.

Figure 56. White perch length-frequency in Chesapeake Bay, 2002-2010.

Figure 57. White perch age-structure in Chesapeake Bay, 2002-2009.

Figure 58. Abundance (kg per hectare swept) of white perch in Chesapeake Bay, 2010.

Figure 59. Diet composition, expressed as percent by weight (A) and percent by number (B) of white perch collected during ChesMMAP cruises in 2002-2010 combined.

Water Quality

Figures 60-61. Interpolated bay-wide water temperature values 2010, surface and bottom.

Figures 62-63. Interpolated bay-wide salinity values 2010, surface and bottom.

Figures 64-65. Interpolated bay-wide dissolved oxygen values 2010, surface and bottom.

Task 5 – *Begin evaluation of alternative sampling gear*

As noted in the 'Methods' section above, field trials of the 200 x 12cm trawl/#2 Bison door combination began on September 5, 2010 in the lower Chesapeake Bay, approximately 2nm west of Kiptopeake, VA. With respect to the rigging of the net, the configuration and sizes of the panels of webbing were consistent with those given in the original net plans (Figure 66). The codend liner of the net was made of 2.5cm knotless nylon material, and the codend bag was fitted with a 1.25cm tripper. A splitting strap/bull rope was added to the bag for handling of larger catches such that personnel would be able to take approximately 360kg onboard at a time until all of the catch was on the vessel. Thirty, 23.3cm center-hole floats were affixed to the headline, while the footgear was comprised of a 3.8cm rubber cookie footrope, a traveler, and a 3.8cm rubber cookie sweep. The sweep adjustment chain was set to 11 links on each side, which pulled the sweep ahead of the footrope and traveler and eliminated the gap (and therefore escape area) between the footrope and sweep while fishing. A Netmind headline sensor was attached to the center of the headrope of the net, while wingspread sensors were shackled to the middle jib of each wing-end. Three leg wires (10fm) connected each wing-end to each door, and no set-back extensions were added between any of the jib/leg wire connections. This net configuration was held constant throughout the entire field trial period in 2010.

The #2 Bison doors were outfitted with a three-point backstrap chain system, with two aft chains measuring 1.5m each and the forward chain cut so that a 150^0 angle was achieved between the door and the lower aft chain (Figure 67). Each backstrap system was also fitted with a 1.8m extension wire, which facilitated connecting and disconnecting the net and doors during set-out and haul-back. Like most of the more modern door designs, the Bisons can be fitted with extra weights for stability; an additional 30kg were added to each door for these trials. Again, these settings were held constant throughout the trial period as they were intended to facilitate proper door performance and efficient fishing operations. Tow wires were consistent with those currently used by the ChesMMAP Trawl Survey; namely, a 0.95mm diameter wire rope main line was connected to a 7.9mm diameter wire rope bridle.

For the first tow, the gear was set in 10.4m of water and 33.5m of bridle wire was deployed. The tow was made in the same direction as the current, which had a speed of approximately 0.5kts. Because previous calculations showed that it would likely be necessary to maximize the spreading power of these doors to achieve the optimal configuration of the net, the settings on the Bisons were adjusted so that they would perform as aggressively as possible. The towing bracket of each door has two warp attachment points, and the bridle wires were attached to the outermost location. Further, because these doors depend on ground sheer for spreading power, it was necessary to have the shoe of the door run flat on the bottom, thus maximizing sheer. The balance of these doors, and therefore the angle with which the shoes of these doors contact the bottom, is controlled by raising and lowering the height of the towing bracket. This is accomplished by packing differing numbers of washers above and below the bracket (Figure 67). These trials began with three washers above and four below the bracket. The gear package, in the aforementioned configuration, was towed along the bottom for 5 minutes at 3.0kts. The average headline height was approximately 2.9m while the wingspread was about 6.0m, indicating that the gear was somewhat under spread relative to the theoretical optimum of 6.5m of wingspread and 2.5m of headrope height (Figure 68). As mentioned earlier, a severe hang-up occurred on the second tow, so the remainder of the 2010 testing was postponed until mid-November.

The second tow was conducted on November 16, in the same water depth as the first, but with slightly more wire deployed (36.6m), a tow speed of 3.0kts, and a slack current. The average headline height was 2.7m while the wingspread was 6.3m (Figure 69). Although these values were closer to optimal configuration, it was noticed on both this and the previous tow that the wingspread would appear to reach the 6.5m target, rapidly decline by about 0.5m to 1.0m, and then move toward optimal again. Such a phenomenon occurs when doors ‘trip-in’ during a tow. In an attempt to remedy this problem, the balance of the door was adjusted by lowering the towing bracket by a single washer. Although this adjustment resulted in the correct balance of the door (as verified by the wear pattern on the shoe following the tow – Figure 70) the net remained in the under spread condition for the third tow and continued to exhibit ‘tripping-in’, even after adjusting the vessel speed for the current speed partway through the tow (Figure 71). For the next couple of tows, vessel speed and tow direction relative to the current were allowed to vary in an attempt to achieve the optimal configuration of this gear, but the net remained somewhat under spread (Figures 72 & 73).

Because the doors had been adjusted to their most aggressive position and the net remained under spread, a series of trials were run in which the length of the towing bridle was increased, under the assumption that perhaps the bridle length was restricting the spread of the doors. Specifically, the net was towed with bridle lengths of 33.5m, 39.6m, 45.7m, and 51.8m. Of these, it appeared that the gear came closest to achieving its optimal wingspread and headline height with a 45.7m towing bridle (Figure 74). A series of trials followed using the 45.7m bridle length, the results of which showed that it is possible to achieve the optimal configuration of this gear (2.5m headline height, 6.5m wingspread) using this net/door combination (Figure 75). Attaining this geometry consistently, however, was more difficult (Figures 76-78). Further, it appeared that approximately 3.0kts is a desirable vessel speed, and that towing with the current is preferable to towing against, as the net tends to lose bottom contact at moderate speeds when towing into the current and at higher speeds even when towing in the same direction as the current (Figures 76-78 – rapid increase in headline height and minor loss of wingspread is indicative of a net leaving the bottom).

While these gear trials were successful in that they showed that this 200 x 12cm trawl could be fished in its optimal configuration (2.5m headline height and 6.5m wingspread), achieving this geometry consistently was problematic and this gear did exhibit ‘tripping-in’ on all tows conducted during the trial period. Follow-up conversations with commercial trawl captains and gear manufacturers confirmed that these latter two issues were likely the result of the Bison doors operating at the extreme upper end of their spreading power. In response, survey personnel acquired a set of Thyboron, Type IV 44” doors in the late fall of 2010 (Figure 79). Because of the weight of these doors, however, modifications are needed to the survey vessel’s hydraulic systems, trawl winch, and tow wire before they can be fished with the 200 x 12cm net. It is expected that these adjustments will be complete by the end of the summer of 2011, and that a second ‘round’ of gear testing using the Thyboron doors/200x12cm trawl will occur in the fall of 2011. Because the Thyboron doors have nearly twice the spreading power of the Bisons, it is expected that consistent, optimal net performance should be achieved quickly and easily with this gear package.

Although consistently achieving the optimal configuration of the 200 x 12cm trawl proved difficult with the Bison doors, a series of ‘standard survey tows’ were made to begin a general comparison of the catch rates and species compositions sampled by these two gears (Figure 80). These tows were made after determining that no additional adjustments to this net/door combination would consistently yield the desired spread and because the new, more powerful doors were not yet available. Stations 74, 79, and 80 were sampled using the current ChesMMAP trawl during standard survey operations on November 2 & 3, 2010. Station 77 was towed on November 13. One of these sites, Station 74, was re-towed on November 16 using the 200 x 12cm trawl, while the remainder was sampled on November 18. In all cases, standard survey protocols were used. Specifically, tows were made in the same general direction as the current for 20 minutes at approximately 3.0kts. Once onboard, catches were sorted by species and, when obvious size-classes were present, by size-class as well. Aggregate weight was then recorded for each species/size-class combination, and individual length measurements were recorded from all or an appreciable subsample. While specimens were taken for diet and age determination (see above) during regular survey operations, they were not sampled for this procedure during the 200 x 12cm tows.

Overall, catches with the 200 x 12cm trawl were larger and somewhat more diverse than those with the current survey trawl. Total catch weights ranged from 24.4kg to 381.3kg, with an average of 160.3kg, using the 200 x 12cm net (Table 5). The mean number of species collected per tow was 17, with a range of 13 to 22 species. In contrast, catches at these stations using the standard survey trawl ranged from 11.4kg to 134.7kg (mean 44.5kg), and 9 to 16 species (mean 13) were encountered. The 200 x 12cm net sampled 31 species in all, while the current net collected 28 at these four sampling sites. With respect to the species composition sampled by the 200 x 12cm trawl, spot was by far dominant, followed by weakfish, spiny dogfish, horseshoe crab, and blue crab (Figure 81). Of the remaining top species, clearnose skate, summer flounder, and striped bass are managed. When considering all species sampled by these trawls, only horseshoe crabs were collected in greater quantity by the current survey net. It is worth noting that the 200 x 12cm net seemed to not only sample a greater quantity and diversity of organisms, but the size range of specimens collected seemed to be broader as well. This is not surprising given that the net is outfitted with a 2.5cm codend liner. Additional data are needed before any specific conclusions can be drawn, however. Given the construction, geometry, and consistency of the 200 x 12cm trawl relative to the current survey gear, these above results are not surprising. Additional comparison data will be collected in 2011 following the establishment of consistent, optimal performance of the 200 x 12cm net/Thyboron door combination.

Table 5. Comparison of the catch rates (in kilograms) and number of species collected per tow for the 200 x 12cm trawl and the current ChesMMAP net.

	200 x 12cm Net		Current Net	
Station Number	Total Catch (kg)	No. of Species	Total Catch (kg)	No. of Species
74	88.7	13	15.2	13
77	381.3	19	11.4	15
78	146.5	22	134.7	16
80	24.5	14	16.8	9
Mean	160.3	17	44.5	13

Appendix 1

Abundance data summaries for a selection of common species which are not considered as recreational species for funding and management purposes are provided in the Appendix. The species are blue crab – males and mature females separately, and clearnose skate

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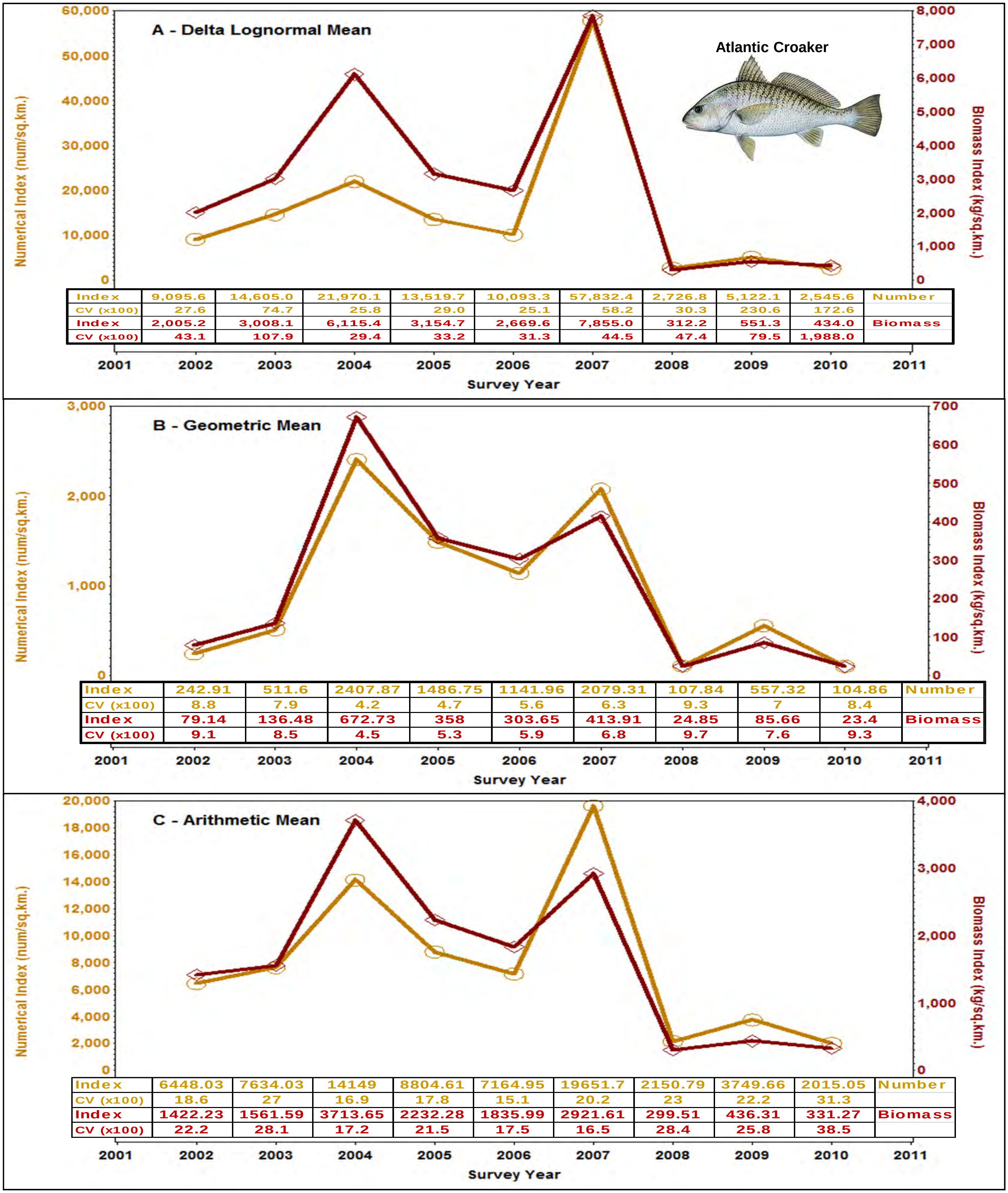
Figure 1. Overall abundance indices (number and biomass) for Atlantic croaker based on delta lognormal mean (A), geometric (B) and arithmetic (C) means.



Index	9,095.6	14,605.0	21,970.1	13,519.7	10,093.3	57,832.4	2,726.8	5,122.1	2,545.6	Number
CV (x100)	27.6	74.7	25.8	29.0	25.1	58.2	30.3	230.6	172.6	
Index	2,005.2	3,008.1	6,115.4	3,154.7	2,669.6	7,855.0	312.2	551.3	434.0	Biomass
CV (x100)	43.1	107.9	29.4	33.2	31.3	44.5	47.4	79.5	1,988.0	

Index	242.91	511.6	2407.87	1486.75	1141.96	2079.31	107.84	557.32	104.86	Number
CV (x100)	8.8	7.9	4.2	4.7	5.6	6.3	9.3	7	8.4	
Index	79.14	136.48	672.73	358	303.65	413.91	24.85	85.66	23.4	Biomass
CV (x100)	9.1	8.5	4.5	5.3	5.9	6.8	9.7	7.6	9.3	

Index	6448.03	7634.03	14149	8804.61	7164.95	19651.7	2150.79	3749.66	2015.05	Number
CV (x100)	18.6	27	16.9	17.8	15.1	20.2	23	22.2	31.3	
Index	1422.23	1561.59	3713.65	2232.28	1835.99	2921.61	299.51	436.31	331.27	Biomass
CV (x100)	22.2	28.1	17.2	21.5	17.5	16.5	28.4	25.8	38.5	

Figure 2. Atlantic croaker length-frequency in Chesapeake Bay 2002-2010.

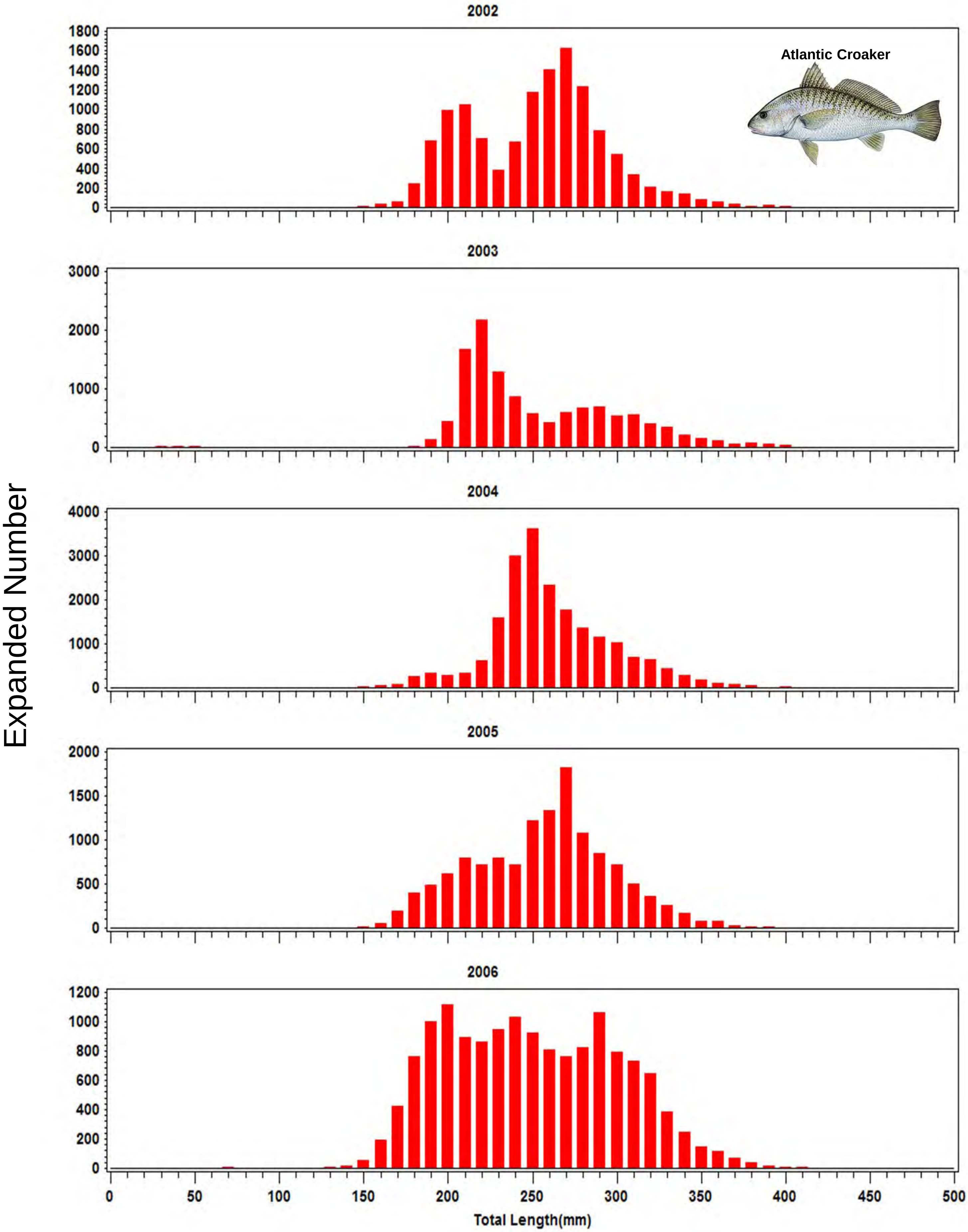


Figure 2. continued.

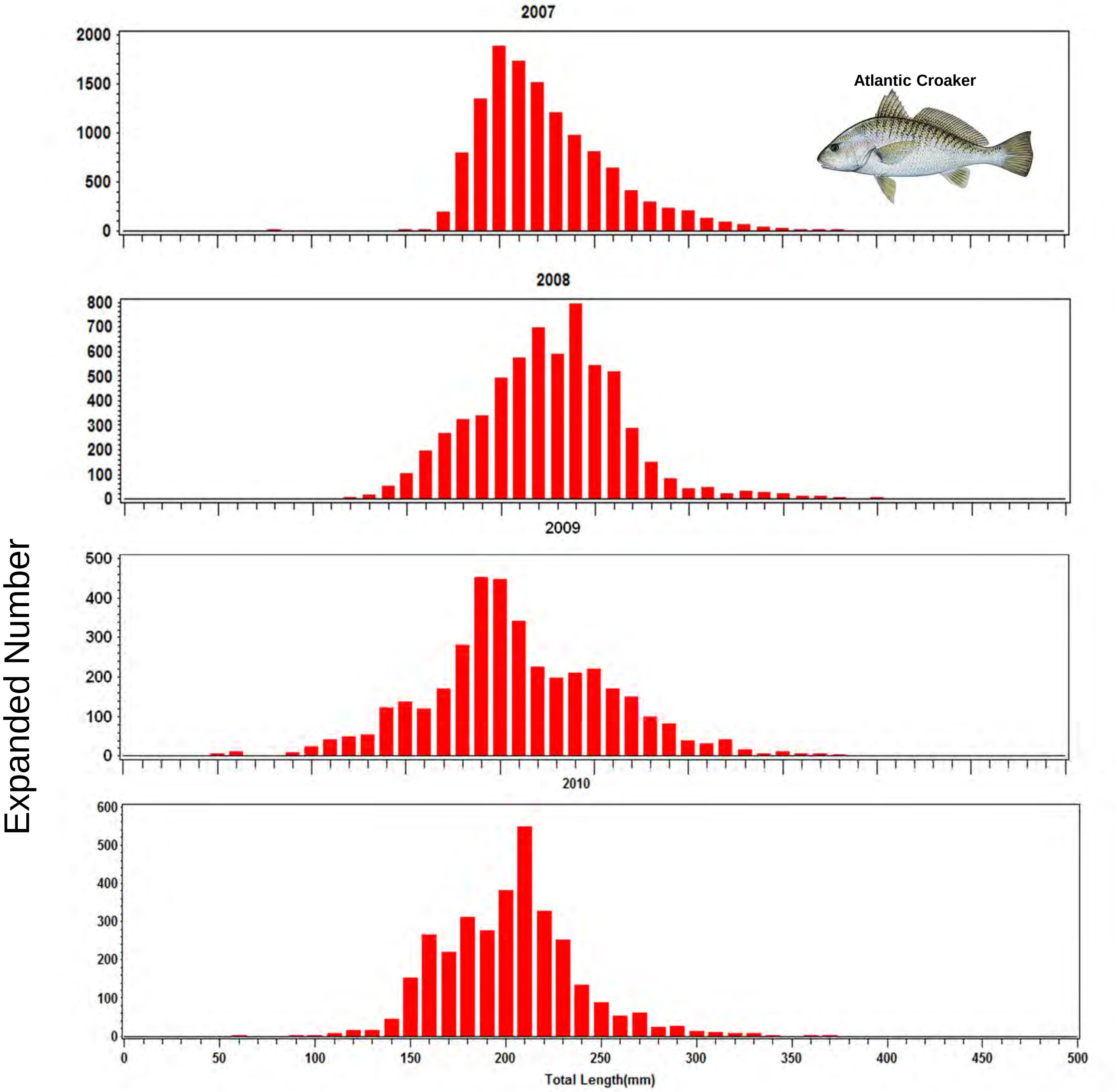


Figure 3. Atlantic croaker age-structure in Chesapeake Bay, 2002-2009.

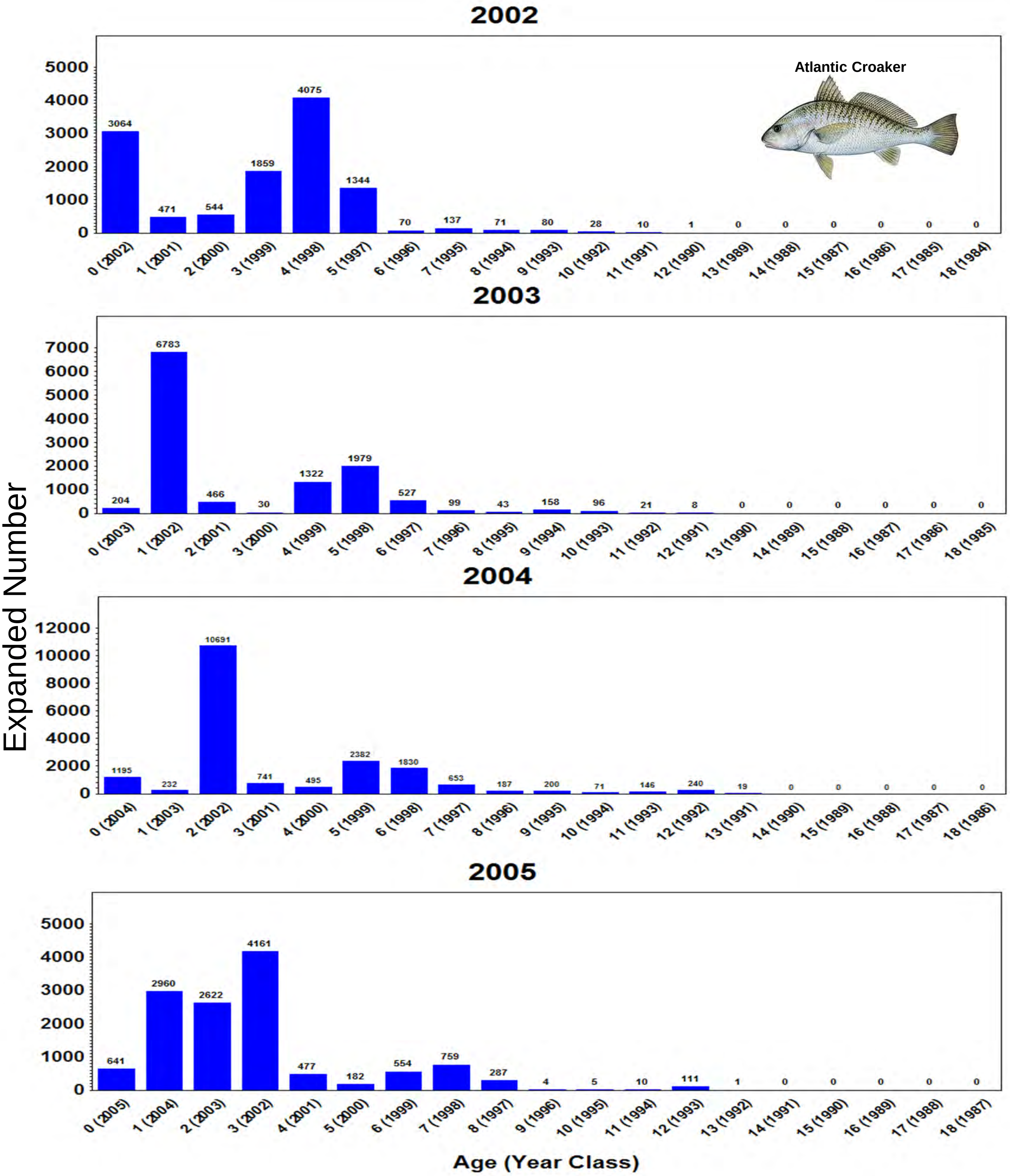


Figure 3. continued.

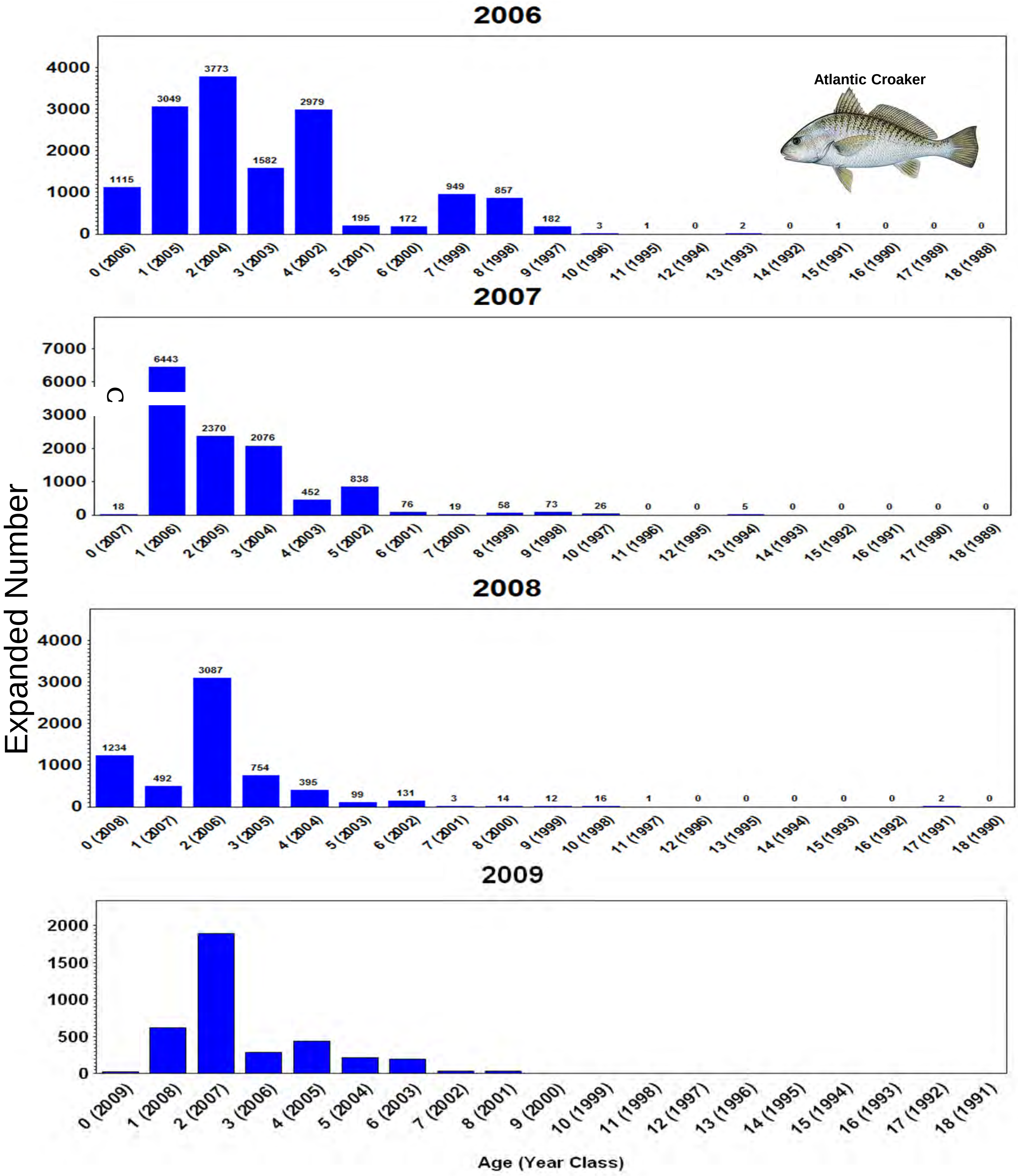


Figure 4. Abundance (kg per hectare swept) of Atlantic croaker in Chesapeake Bay, 2010.

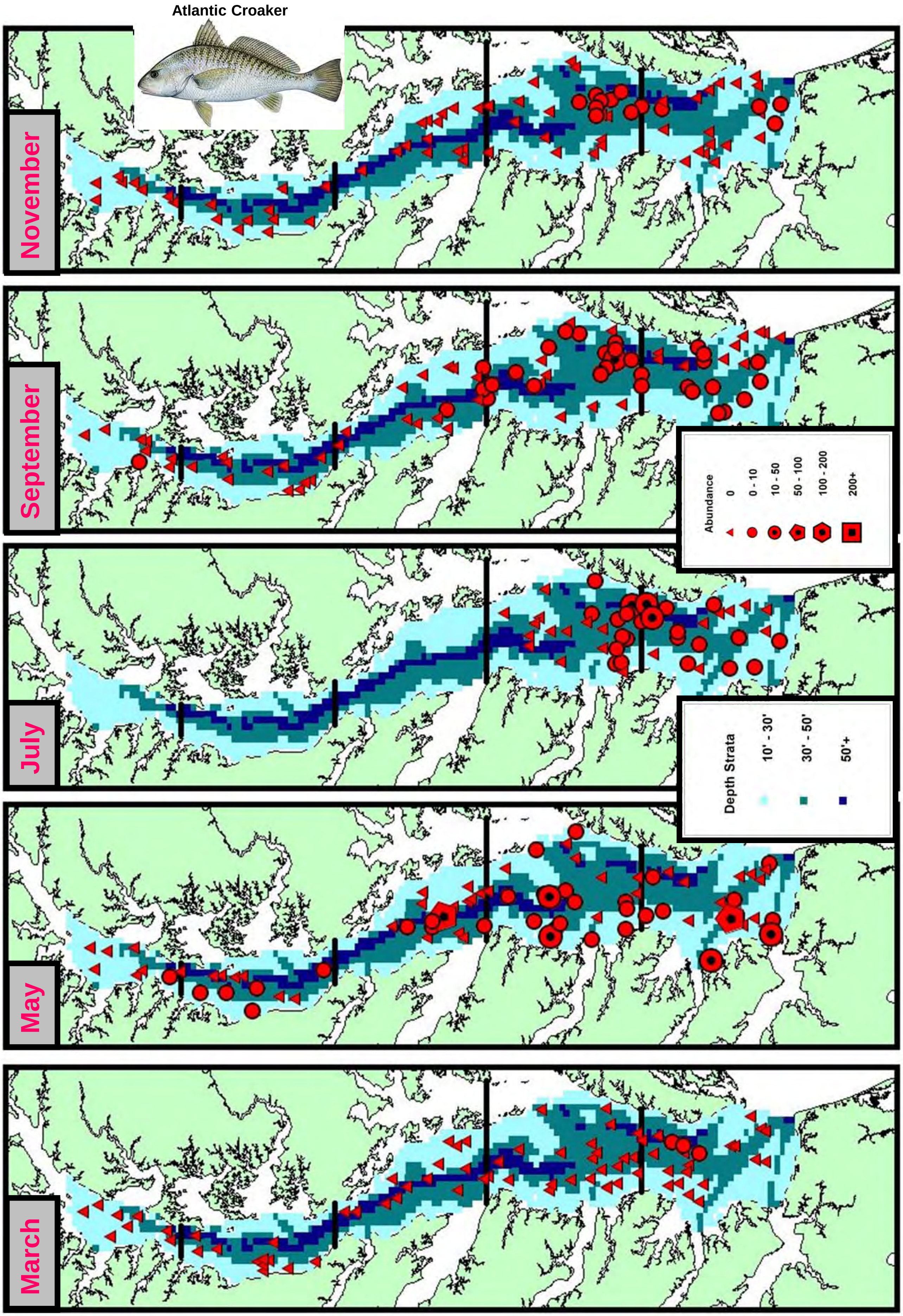


Figure 5. Diet composition, expressed as percent by weight (A) and percent by number (B) of Atlantic croaker collected during ChesMMAP cruises in 2002-2010 combined.

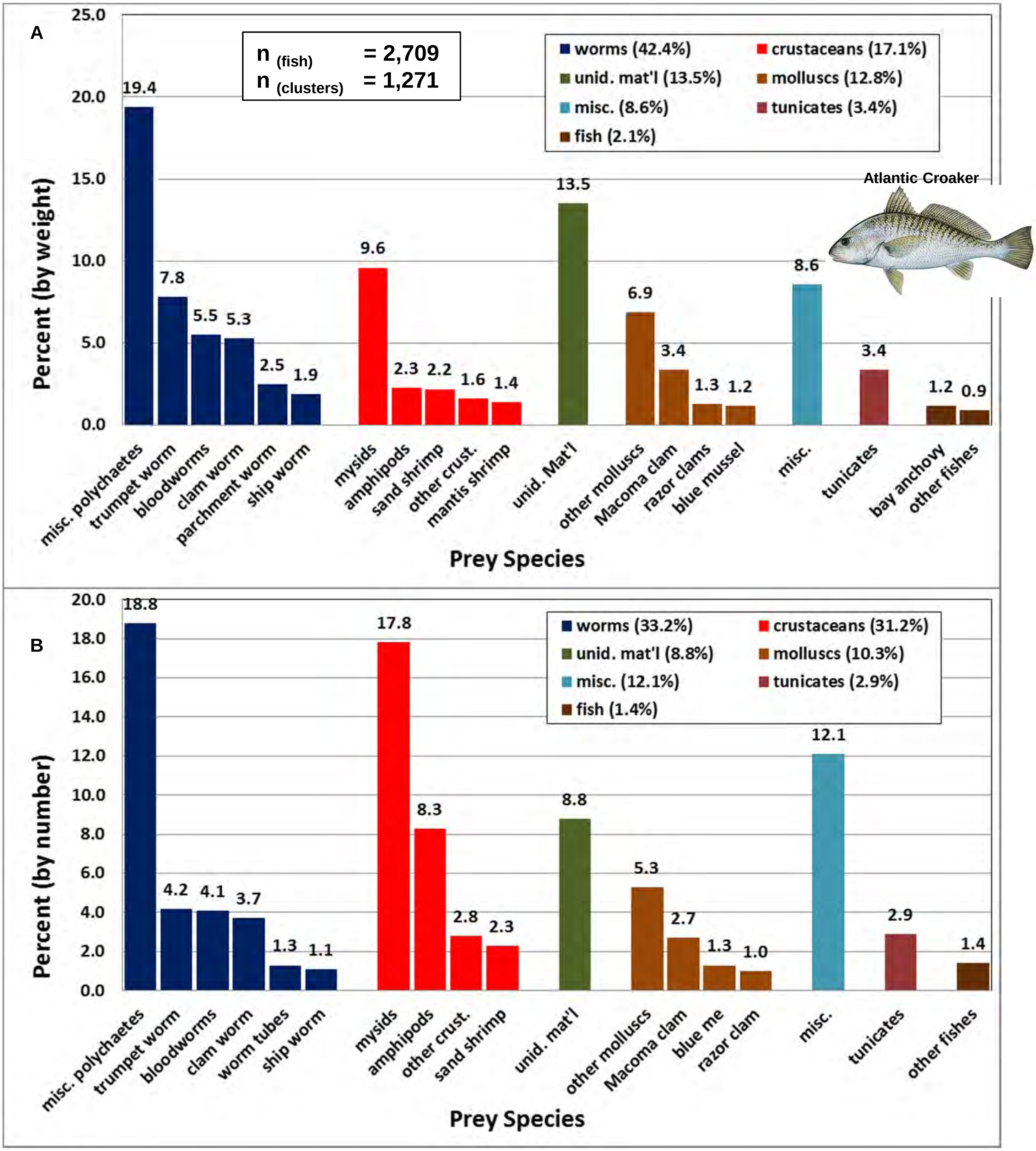
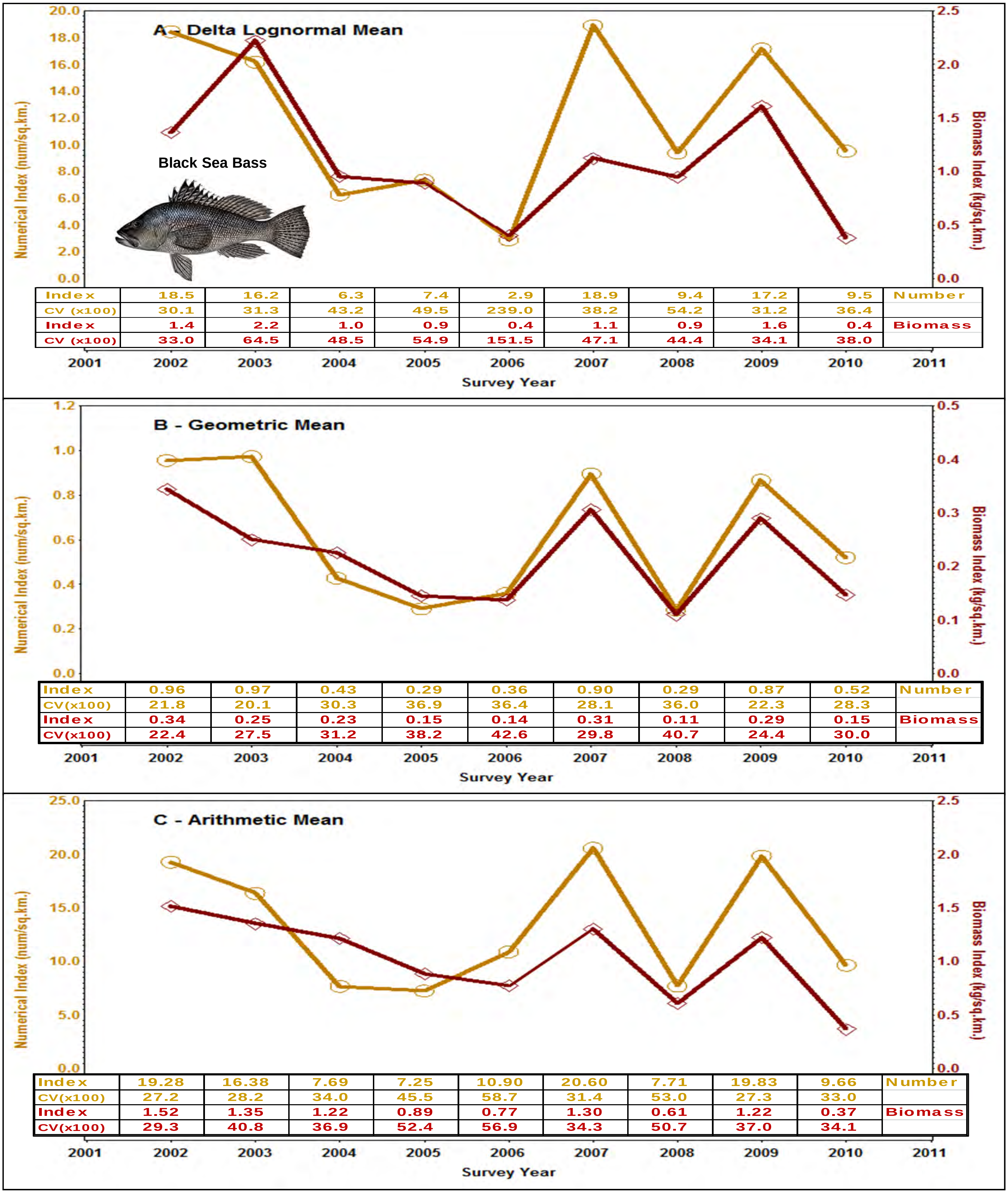


Figure 6. Abundance indices (number and biomass) for black sea bass based on delta lognormal (A), geometric (B) and arithmetic (C) means.

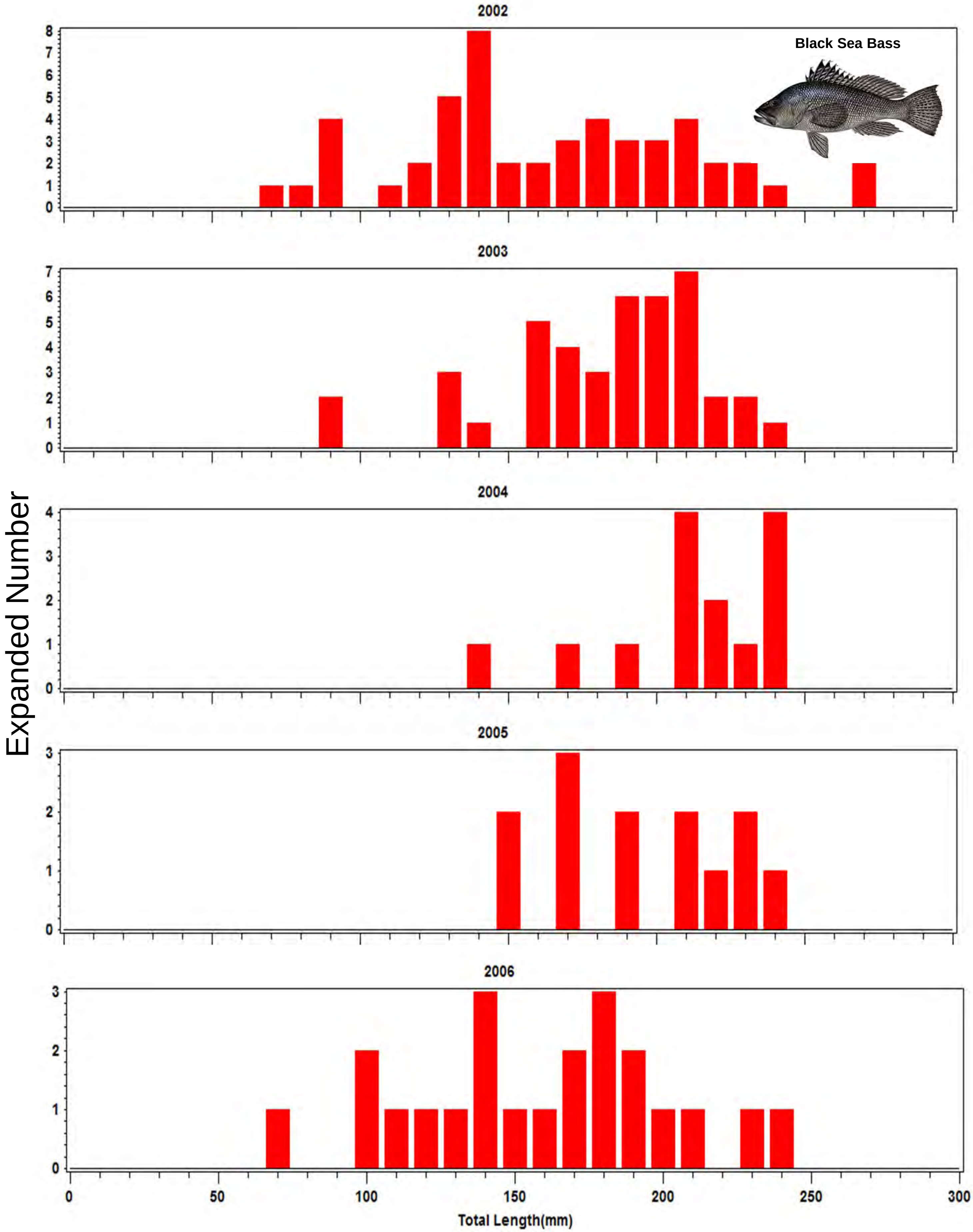


Index	18.5	16.2	6.3	7.4	2.9	18.9	9.4	17.2	9.5	Number
CV (x100)	30.1	31.3	43.2	49.5	239.0	38.2	54.2	31.2	36.4	
Index	1.4	2.2	1.0	0.9	0.4	1.1	0.9	1.6	0.4	Biomass
CV (x100)	33.0	64.5	48.5	54.9	151.5	47.1	44.4	34.1	38.0	

Index	0.96	0.97	0.43	0.29	0.36	0.90	0.29	0.87	0.52	Number
CV(x100)	21.8	20.1	30.3	36.9	36.4	28.1	36.0	22.3	28.3	
Index	0.34	0.25	0.23	0.15	0.14	0.31	0.11	0.29	0.15	Biomass
CV(x100)	22.4	27.5	31.2	38.2	42.6	29.8	40.7	24.4	30.0	

Index	19.28	16.38	7.69	7.25	10.90	20.60	7.71	19.83	9.66	Number
CV(x100)	27.2	28.2	34.0	45.5	58.7	31.4	53.0	27.3	33.0	
Index	1.52	1.35	1.22	0.89	0.77	1.30	0.61	1.22	0.37	Biomass
CV(x100)	29.3	40.8	36.9	52.4	56.9	34.3	50.7	37.0	34.1	

Figure 7. Black sea bass length-frequency in Chesapeake Bay, 2002-2010.



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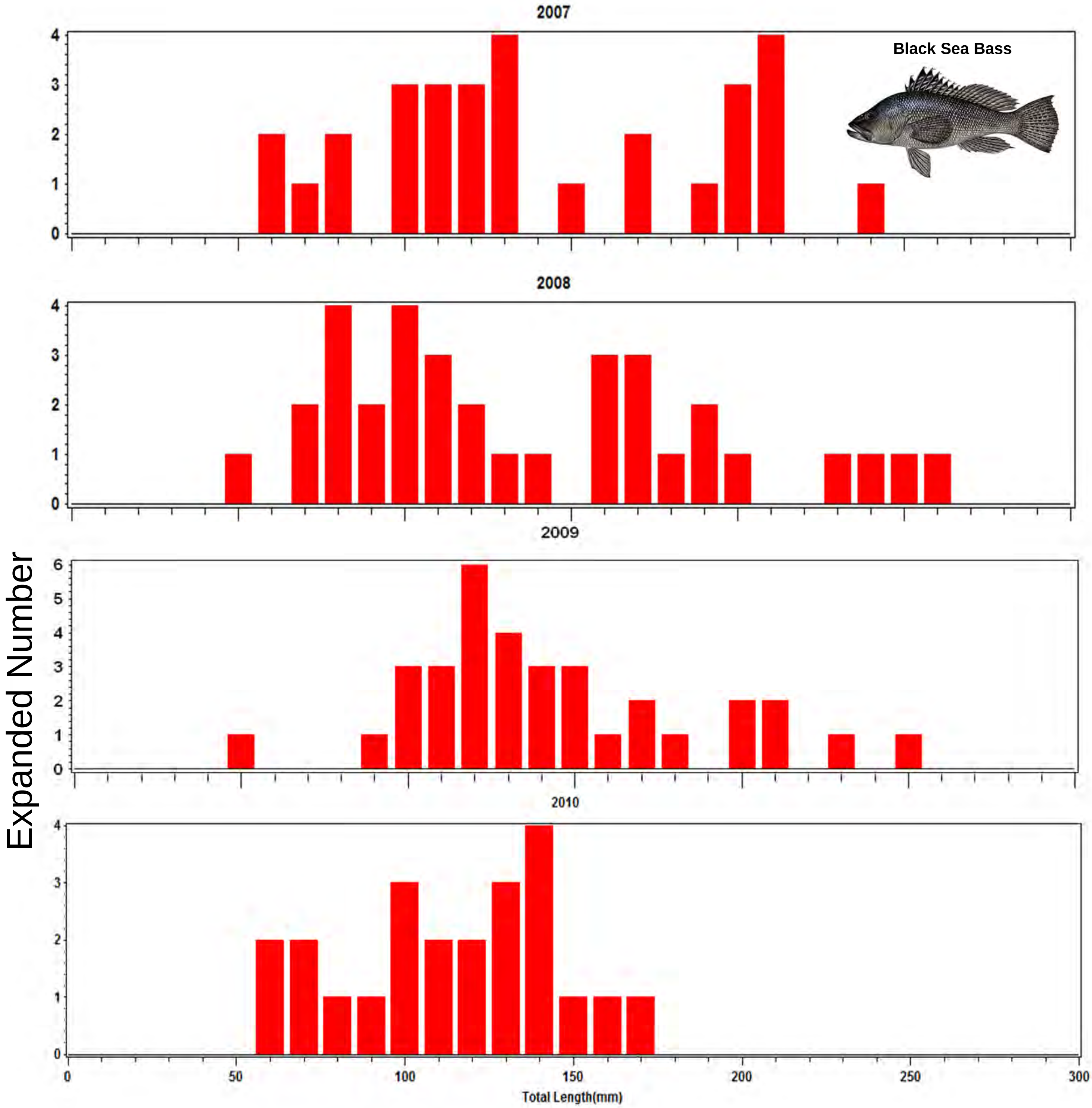
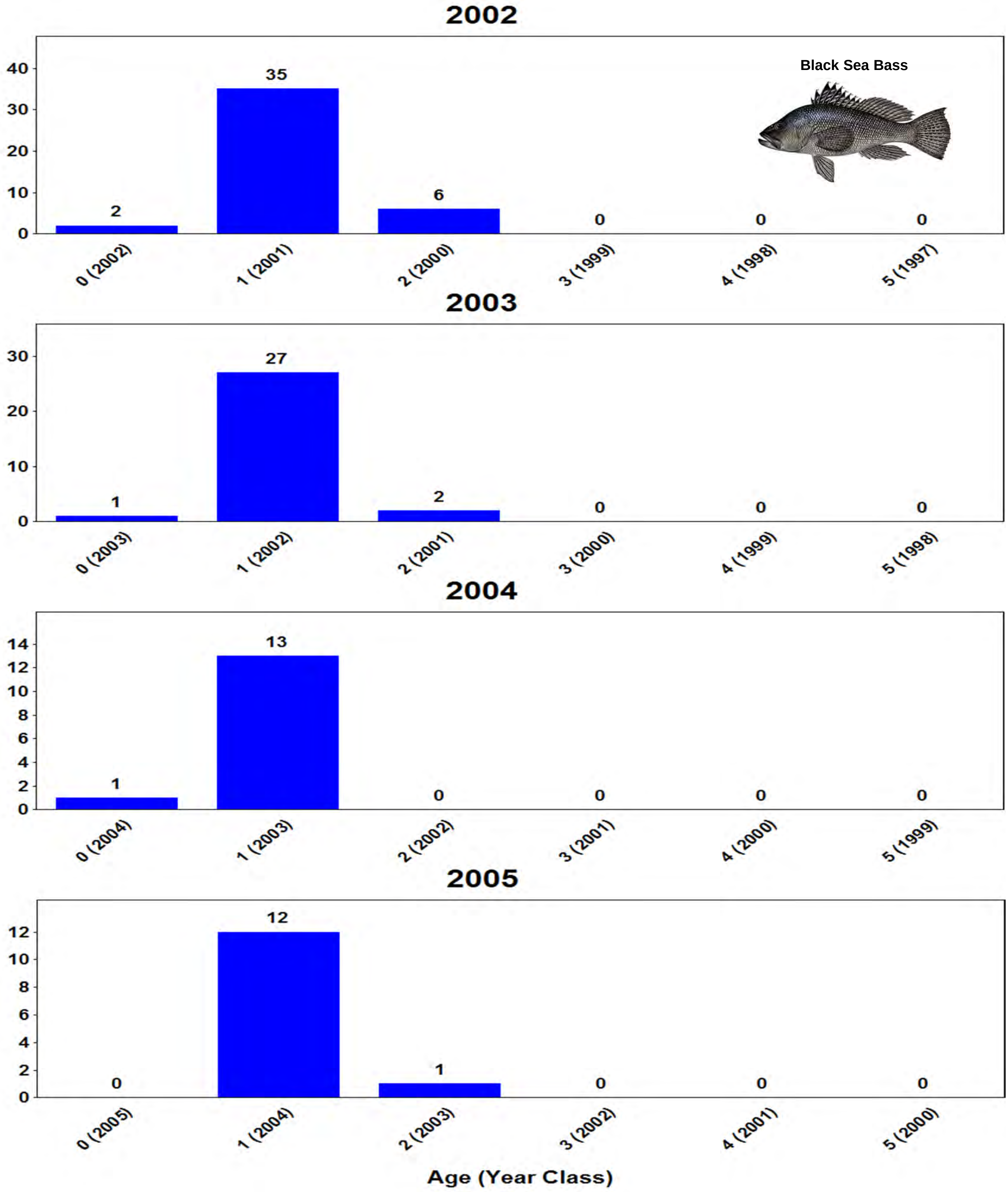


Figure 8. Black seabass age-structure in Chesapeake Bay, 2002-2008.



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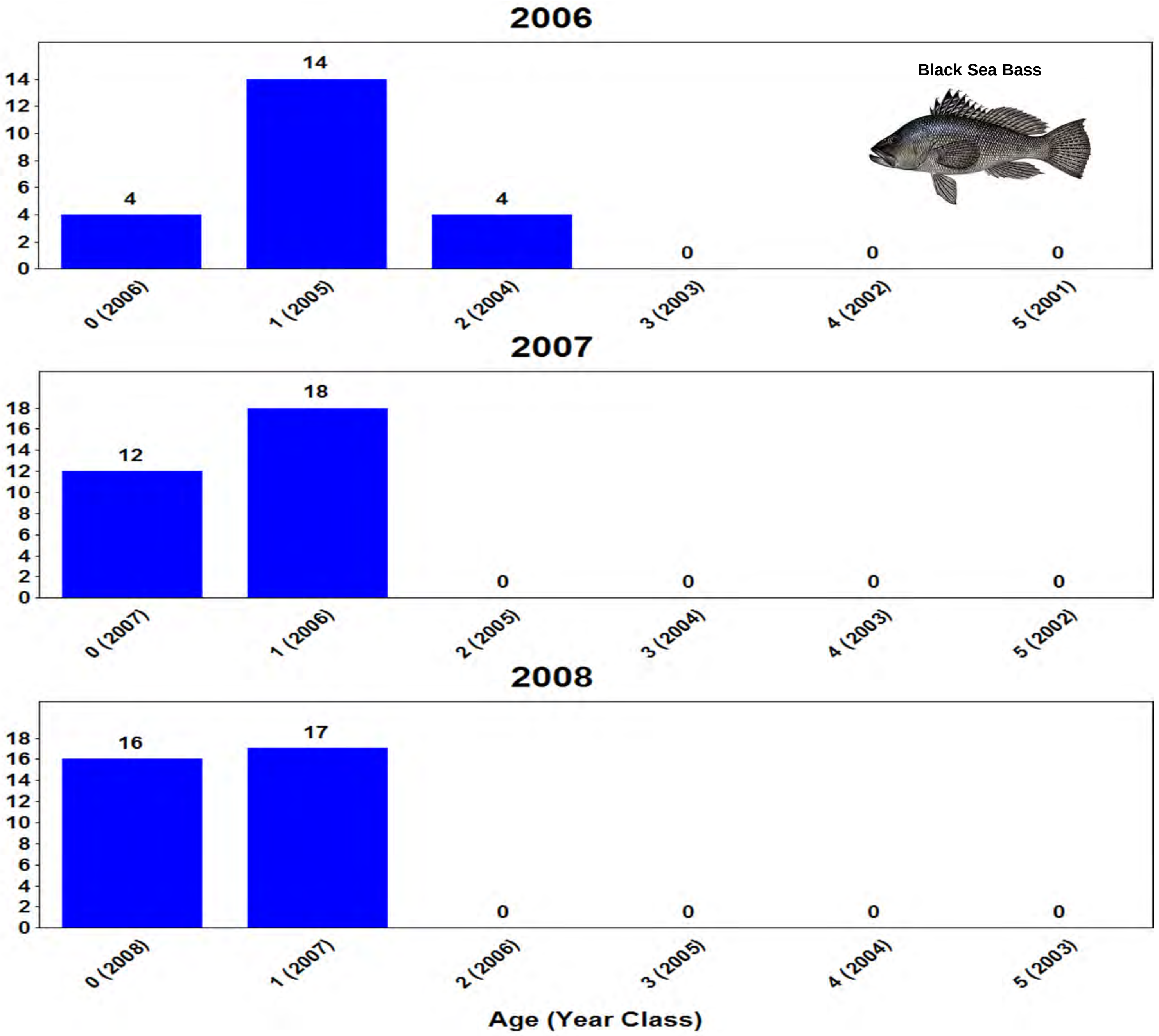


Figure 9. Abundance (kg per hectare swept) of black seabass in Chesapeake Bay, 2010.

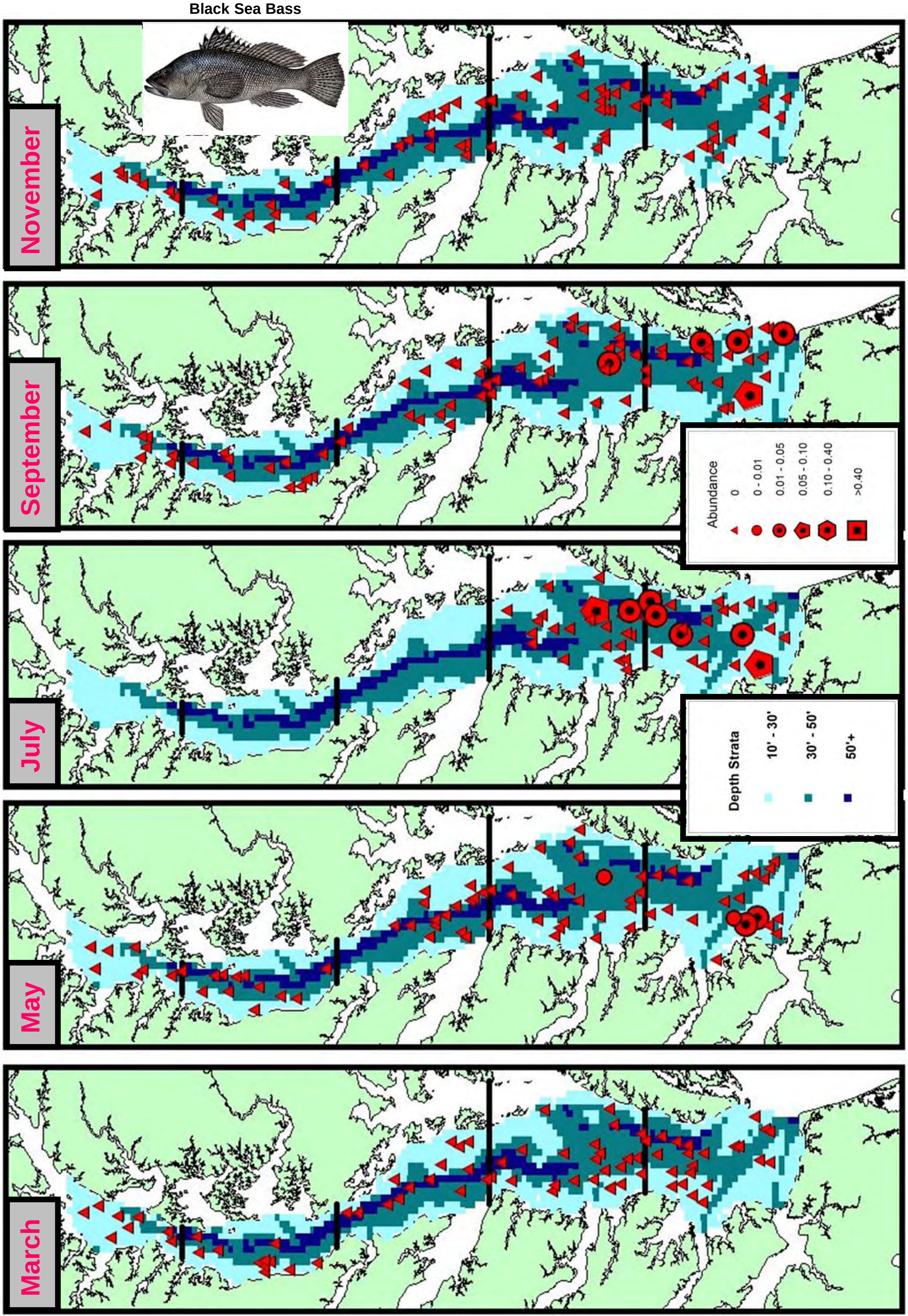


Figure 10. Diet composition, expressed as percent by weight (A) and percent by number (B) of black sea bass collected during ChesMMAP cruises in 2002-2010 combined.

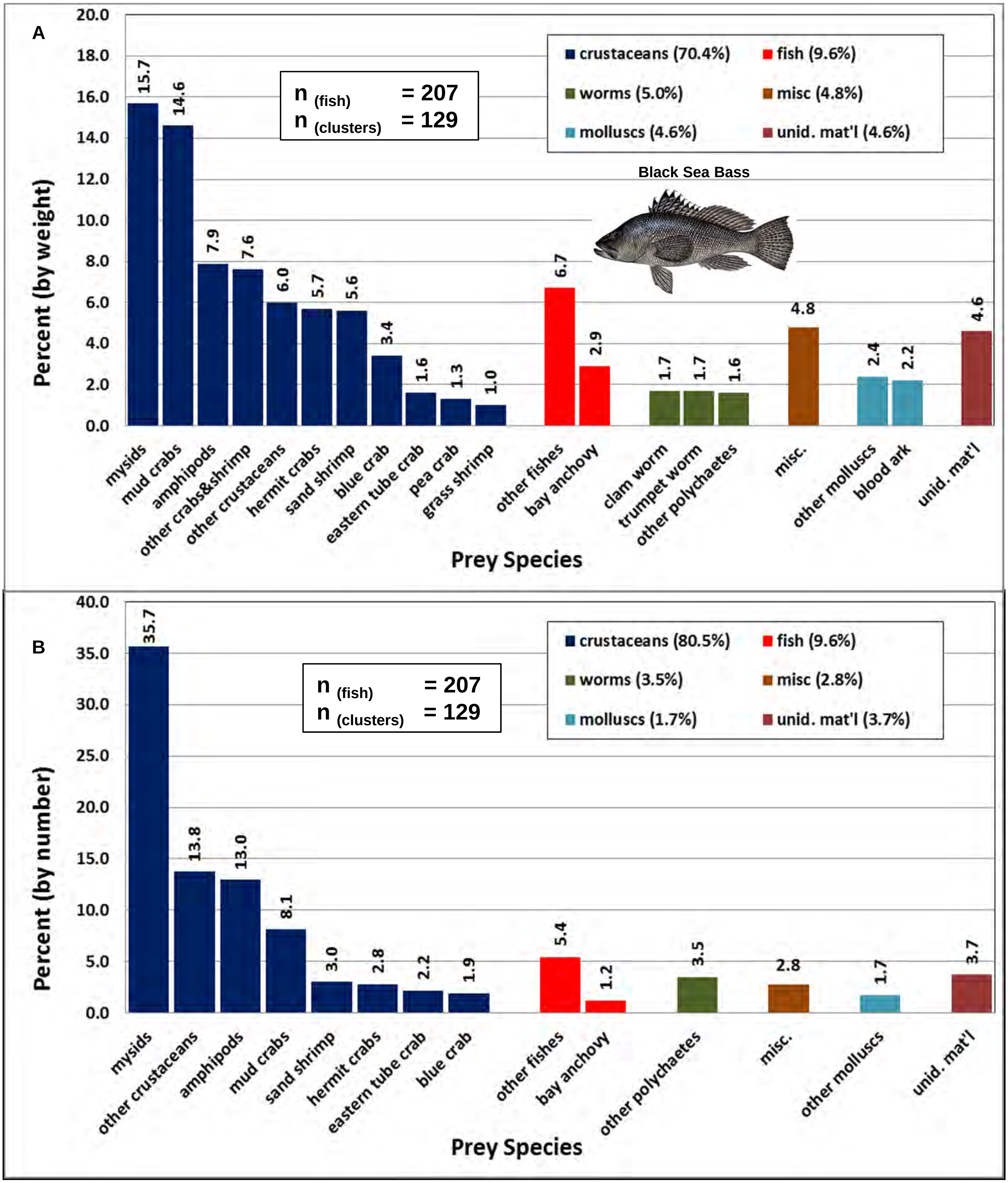
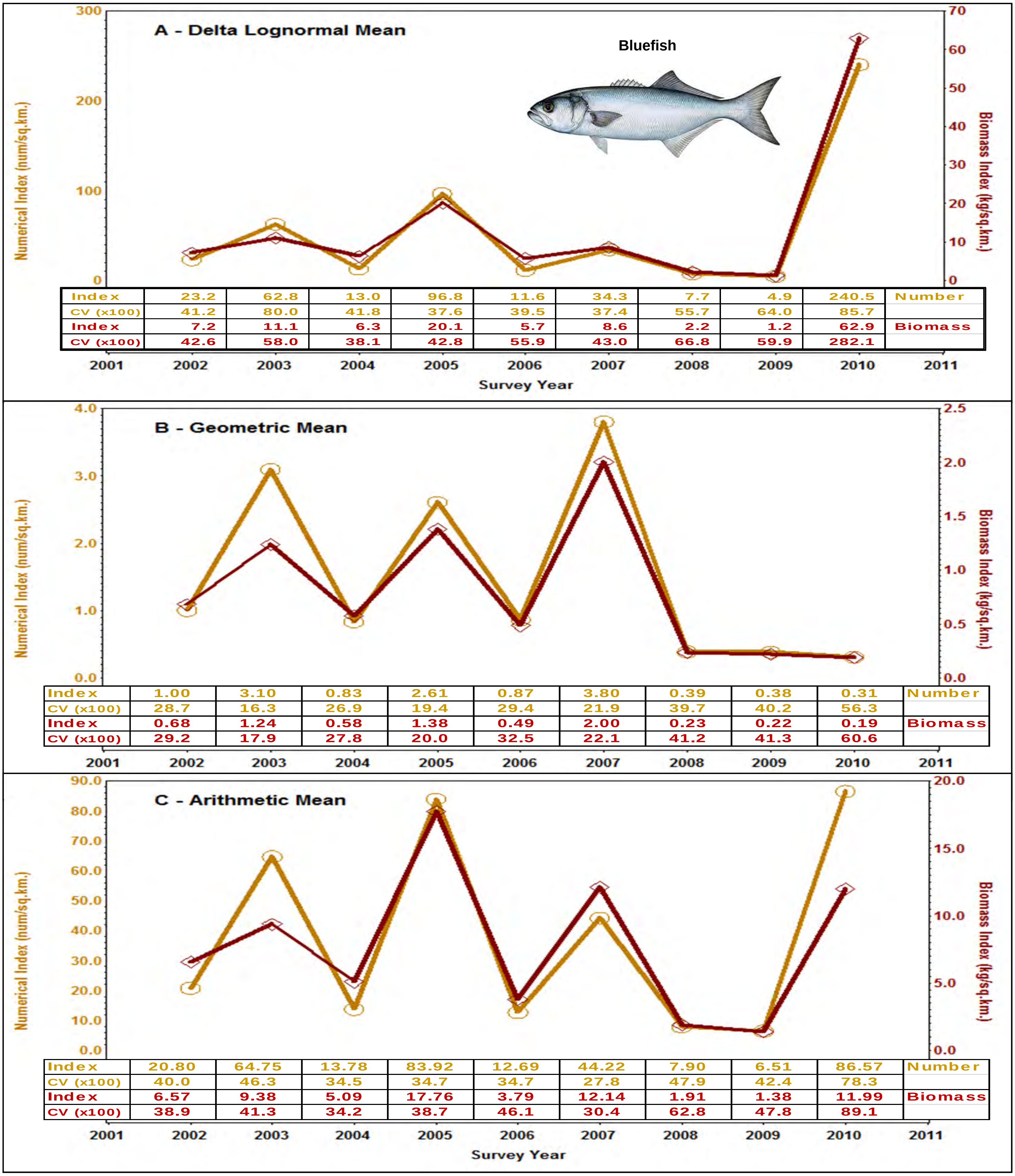


Figure 11. Abundance indices (number and biomass) for bluefish based on delta lognormal (A), geometric (B) and arithmetic (C) means.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	23.2	62.8	13.0	96.8	11.6	34.3	7.7	4.9	240.5	Number
CV (x100)	41.2	80.0	41.8	37.6	39.5	37.4	55.7	64.0	85.7	
Index	7.2	11.1	6.3	20.1	5.7	8.6	2.2	1.2	62.9	Biomass
CV (x100)	42.6	58.0	38.1	42.8	55.9	43.0	66.8	59.9	282.1	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	1.00	3.10	0.83	2.61	0.87	3.80	0.39	0.38	0.31	Number
CV (x100)	28.7	16.3	26.9	19.4	29.4	21.9	39.7	40.2	56.3	
Index	0.68	1.24	0.58	1.38	0.49	2.00	0.23	0.22	0.19	Biomass
CV (x100)	29.2	17.9	27.8	20.0	32.5	22.1	41.2	41.3	60.6	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	20.80	64.75	13.78	83.92	12.69	44.22	7.90	6.51	86.57	Number
CV (x100)	40.0	46.3	34.5	34.7	34.7	27.8	47.9	42.4	78.3	
Index	6.57	9.38	5.09	17.76	3.79	12.14	1.91	1.38	11.99	Biomass
CV (x100)	38.9	41.3	34.2	38.7	46.1	30.4	62.8	47.8	89.1	

Figure 12. Bluefish length-frequency in Chesapeake Bay, 2002-2010.

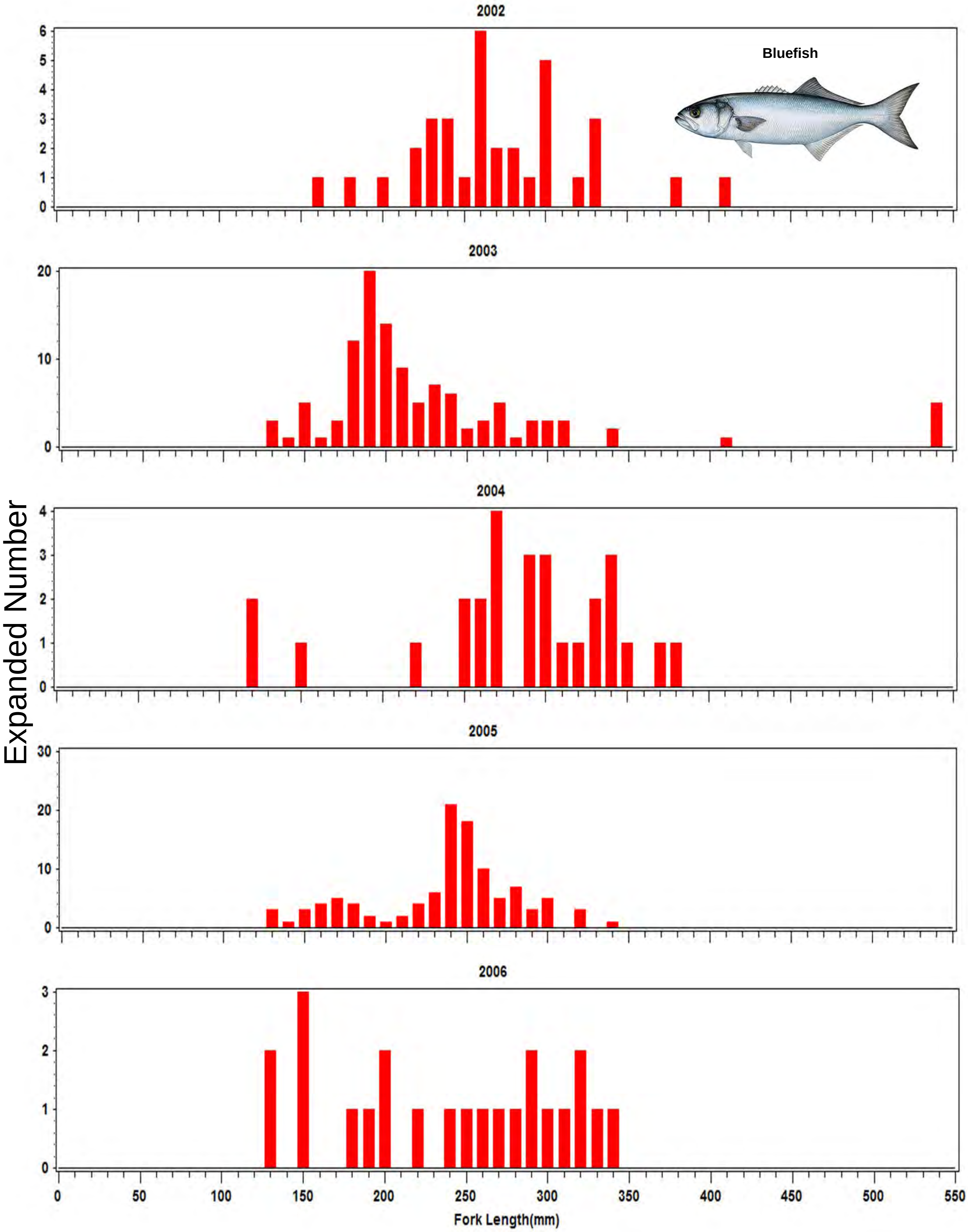


Figure 12. continued.

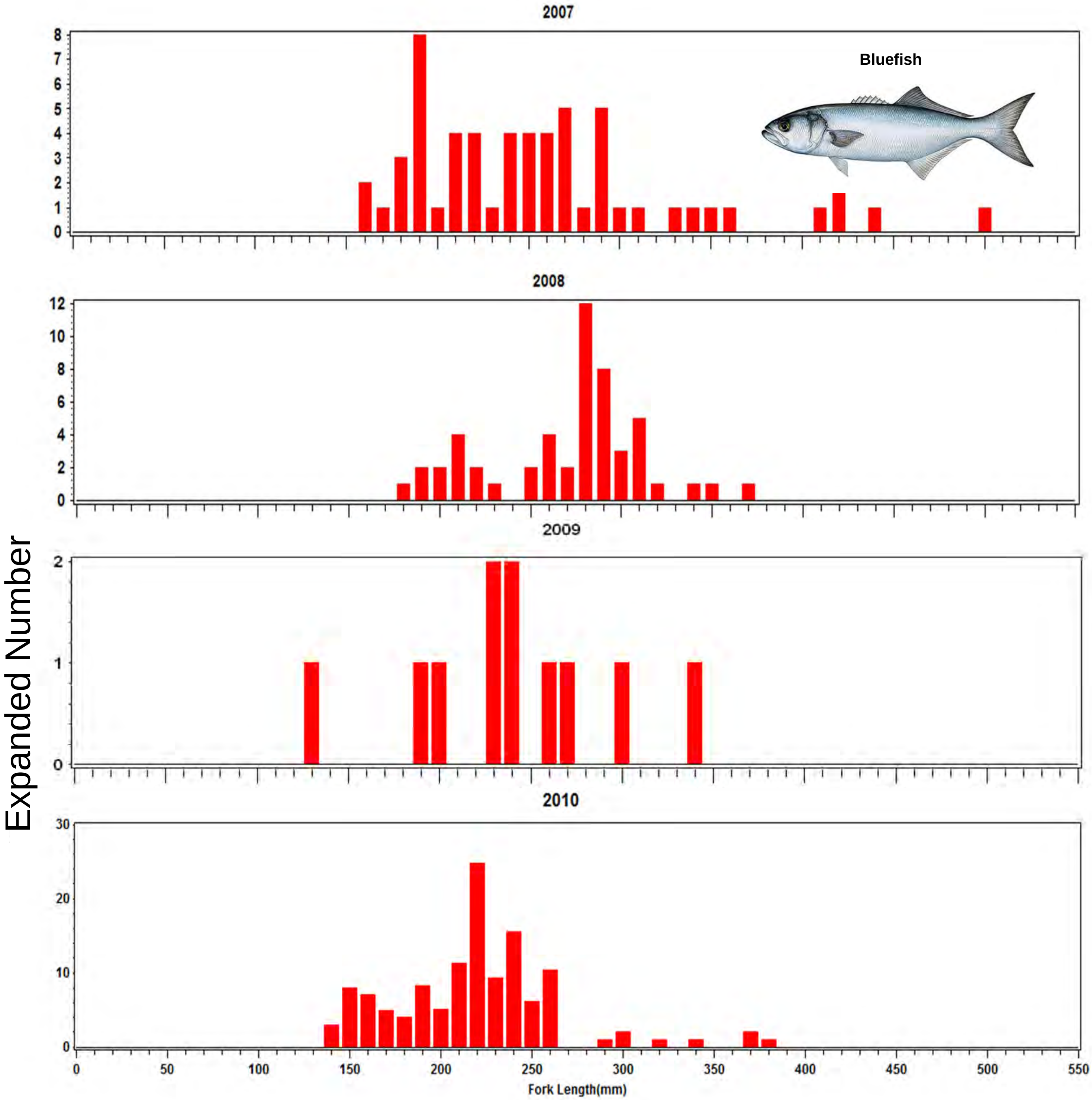


Figure 13. Bluefish age-structure in Chesapeake Bay, 2002-2009.

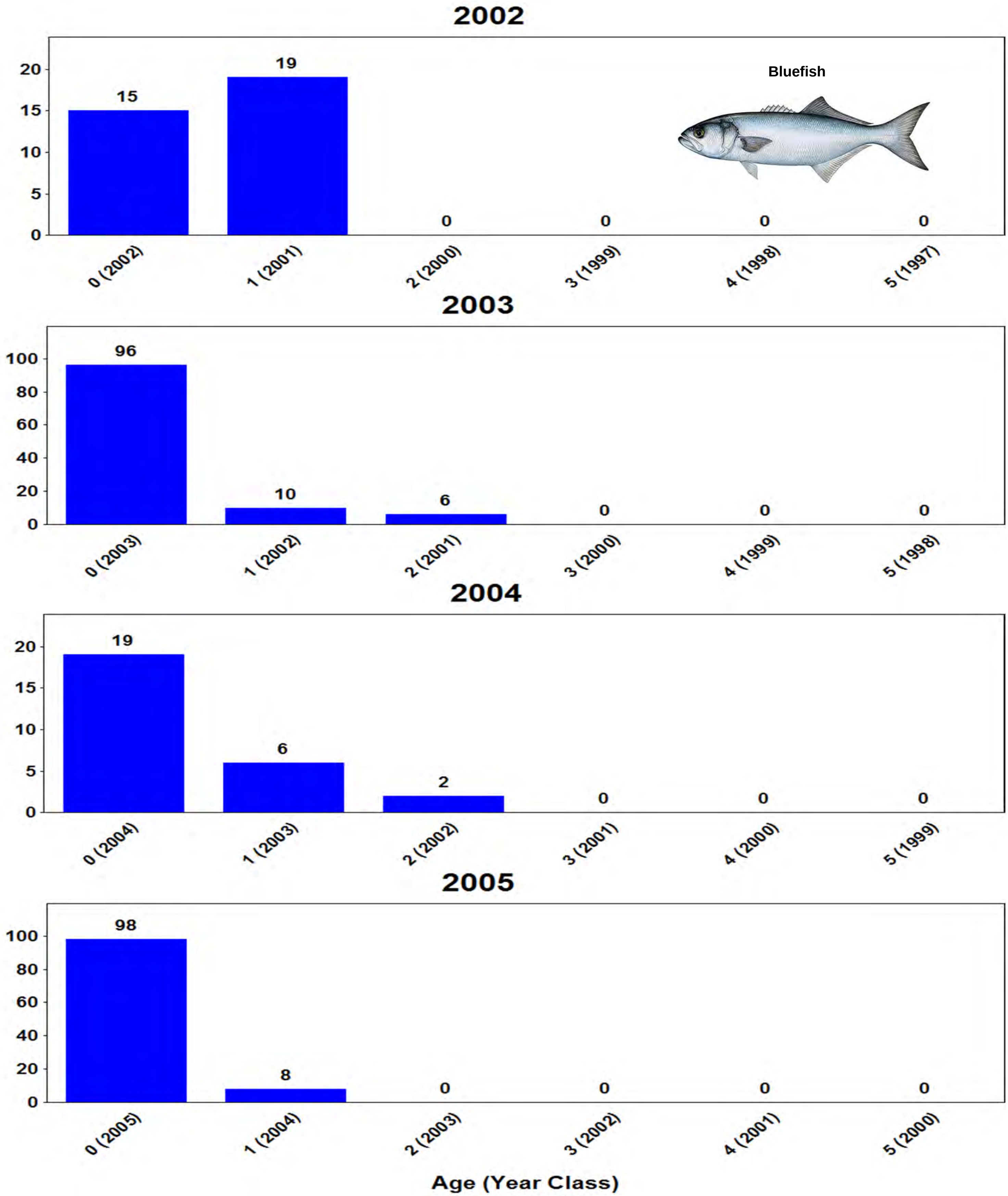


Figure 13. continued.

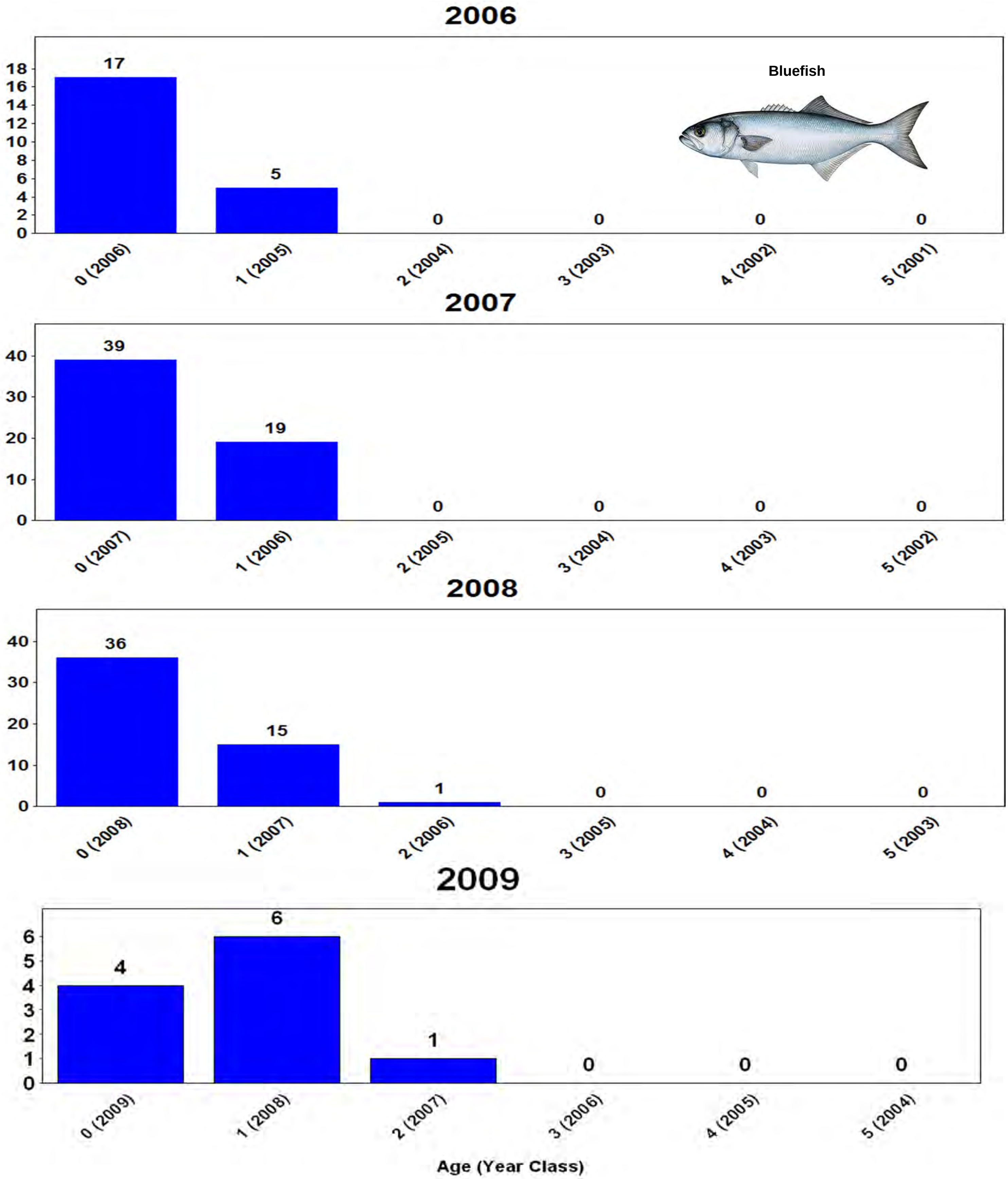


Figure 14. Abundance (kg per hectare swept) of bluefish in Chesapeake Bay, 2010.

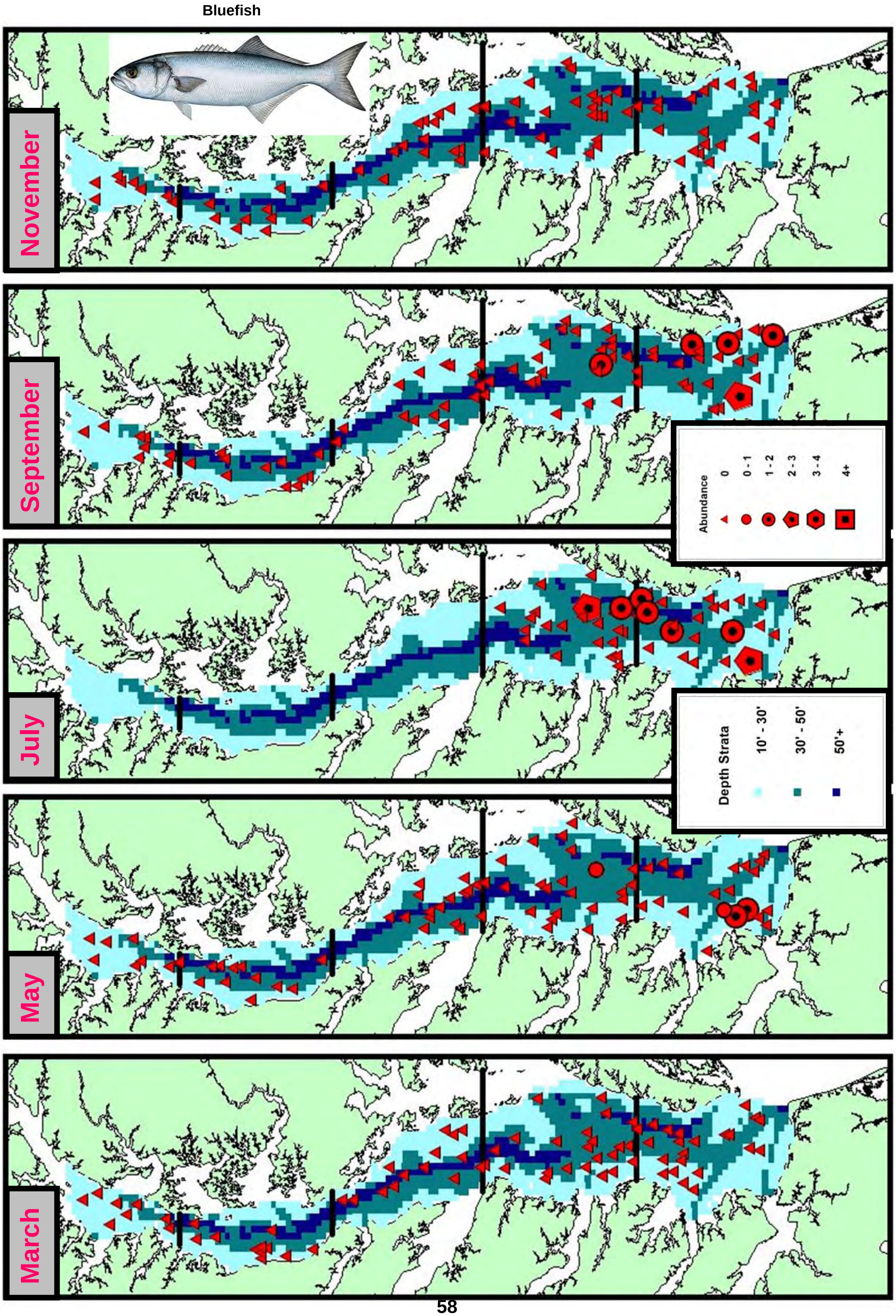


Figure 15. Diet composition, expressed as percent by weight (A) and percent by number (B) of bluefish collected during ChesMMAP cruises in 2002-2010 combined.

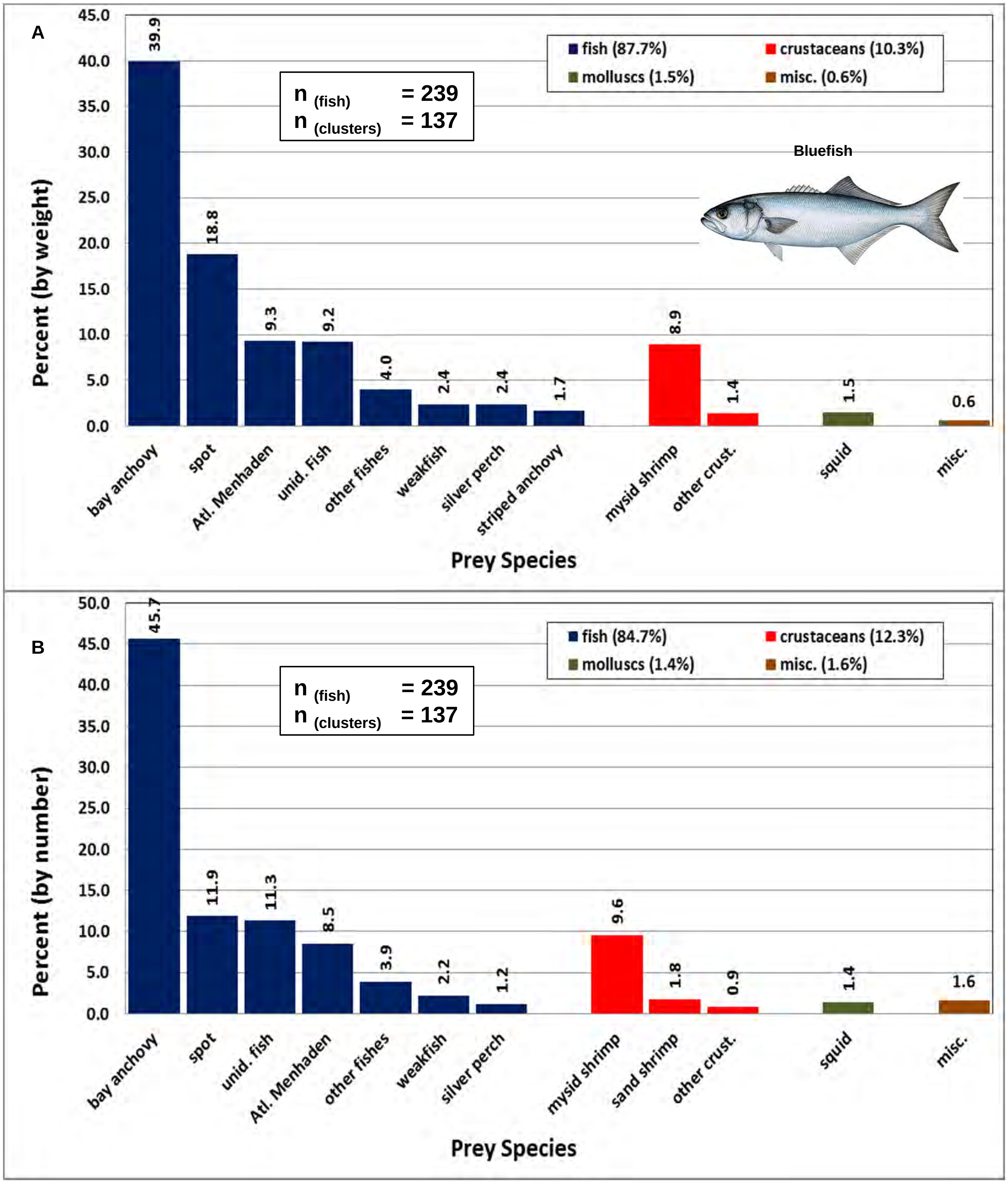
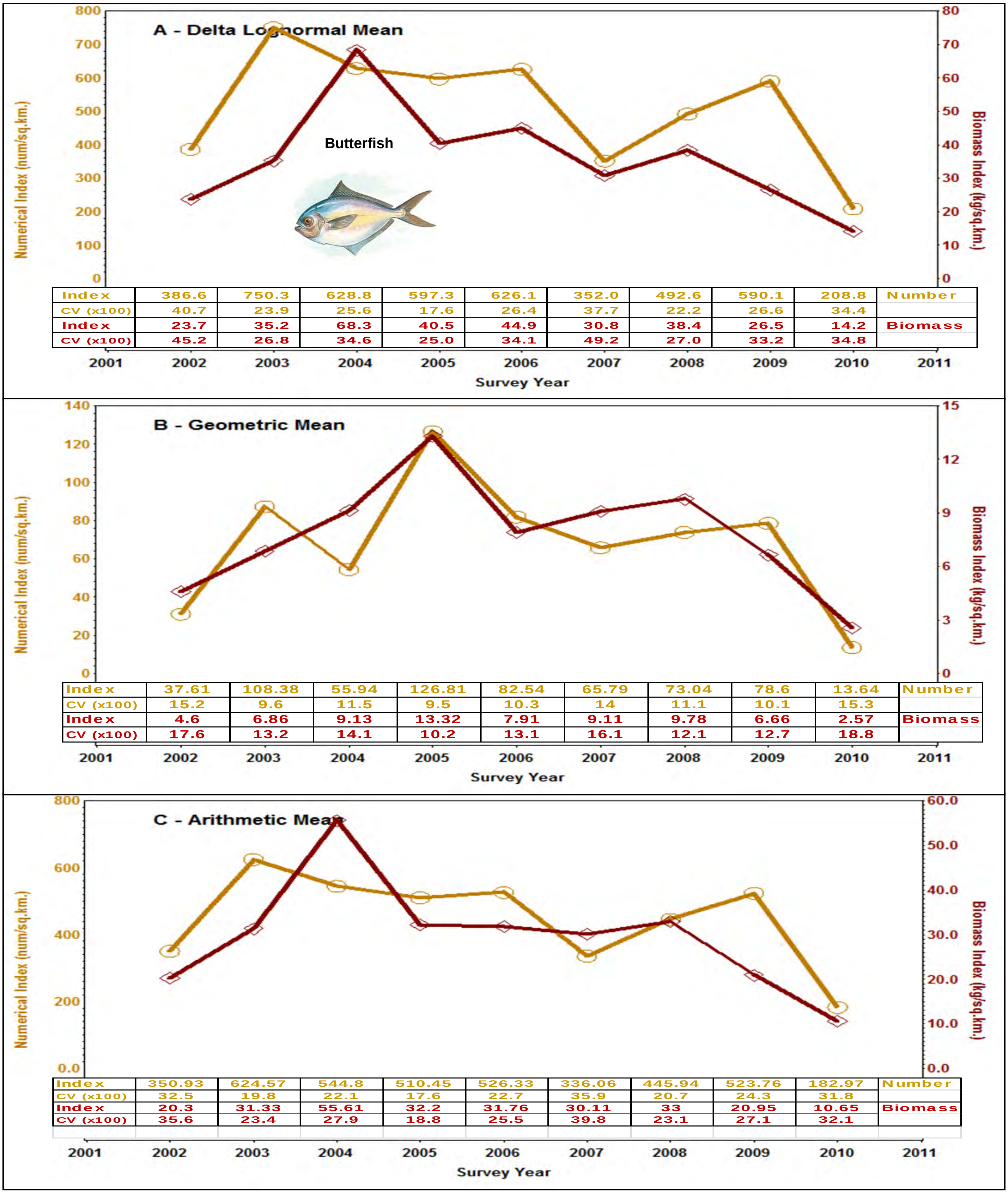


Figure 16. Abundance indices (number and biomass) for butterfish based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	386.6	750.3	628.8	597.3	626.1	352.0	492.6	590.1	208.8	Number
CV (x100)	40.7	23.9	25.6	17.6	26.4	37.7	22.2	26.6	34.4	
Index	23.7	35.2	68.3	40.5	44.9	30.8	38.4	26.5	14.2	Biomass
CV (x100)	45.2	26.8	34.6	25.0	34.1	49.2	27.0	33.2	34.8	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	37.61	108.38	55.94	126.81	82.54	65.79	73.04	78.6	13.64	Number
CV (x100)	15.2	9.6	11.5	9.5	10.3	14	11.1	10.1	15.3	
Index	4.6	6.86	9.13	13.32	7.91	9.11	9.78	6.66	2.57	Biomass
CV (x100)	17.6	13.2	14.1	10.2	13.1	16.1	12.1	12.7	18.8	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	350.93	624.57	544.8	510.45	526.33	336.06	445.94	523.76	182.97	Number
CV (x100)	32.5	19.8	22.1	17.6	22.7	35.9	20.7	24.3	31.8	
Index	20.3	31.33	55.61	32.2	31.76	30.11	33	20.95	10.65	Biomass
CV (x100)	35.6	23.4	27.9	18.8	25.5	39.8	23.1	27.1	32.1	

Figure 17. Butterfish length-frequency in Chesapeake Bay, 2002-2010.

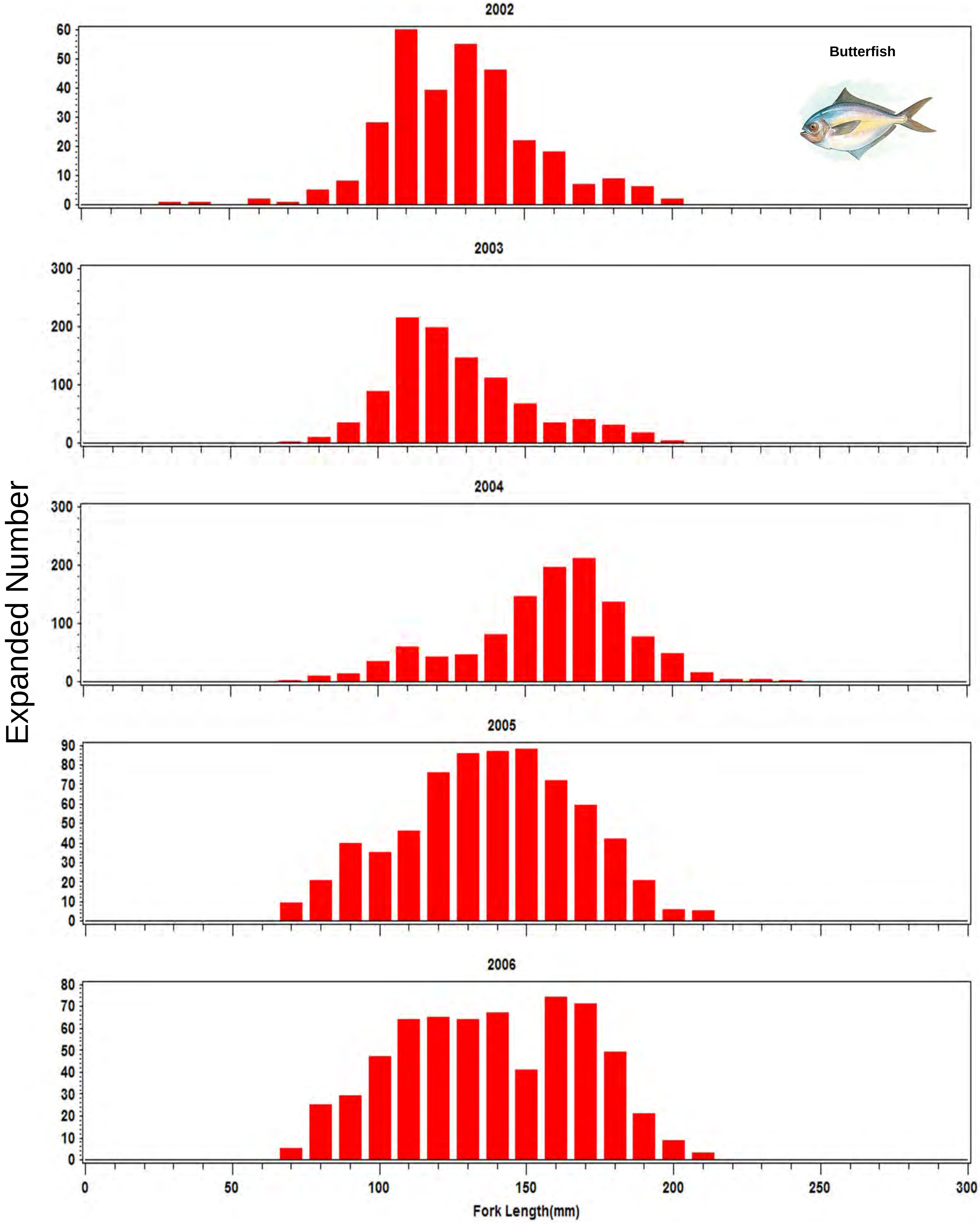


Figure 17. continued.

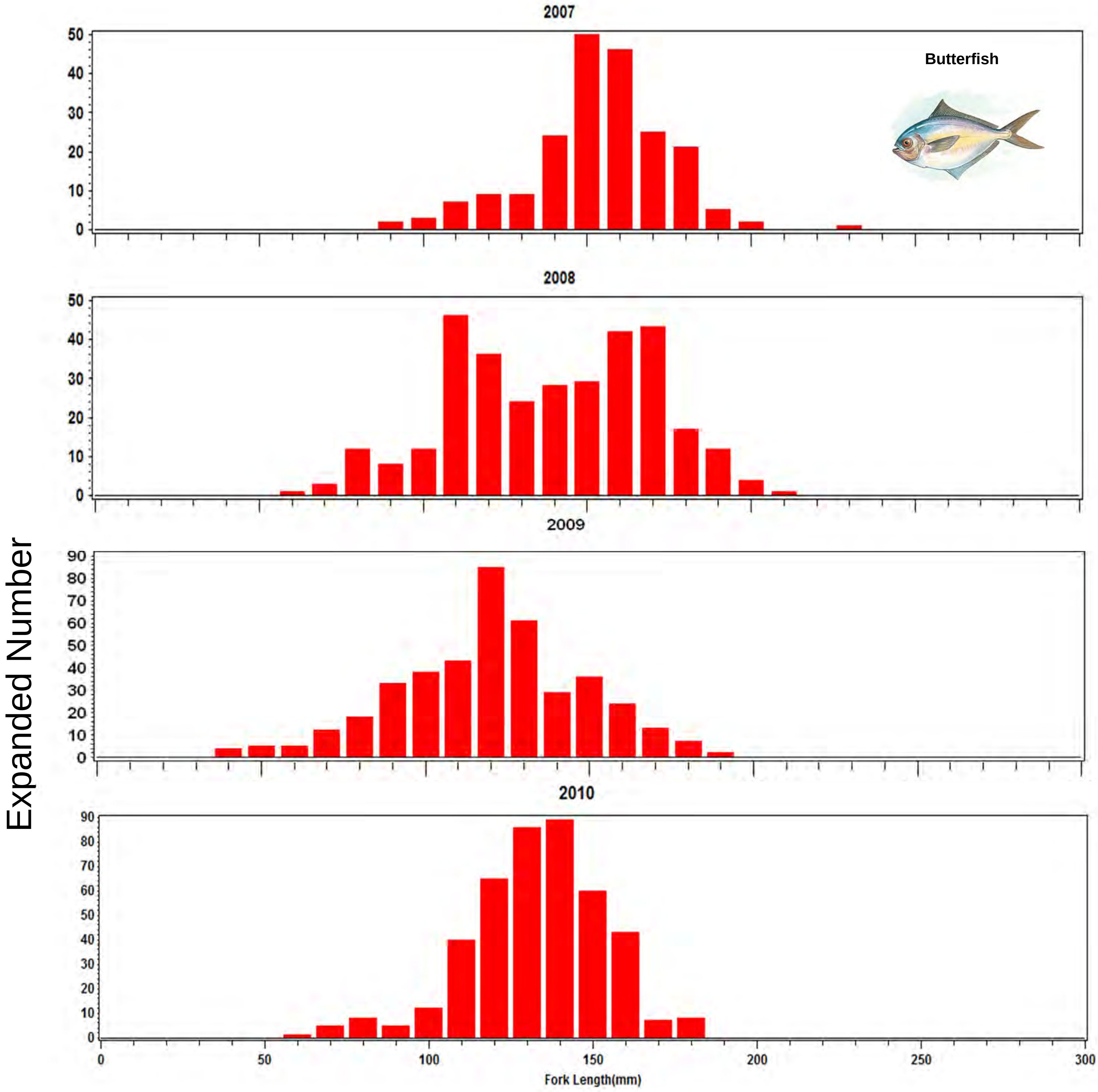


Figure 18. Abundance (kg per hectare swept) of butterfish in Chesapeake Bay, 2010.

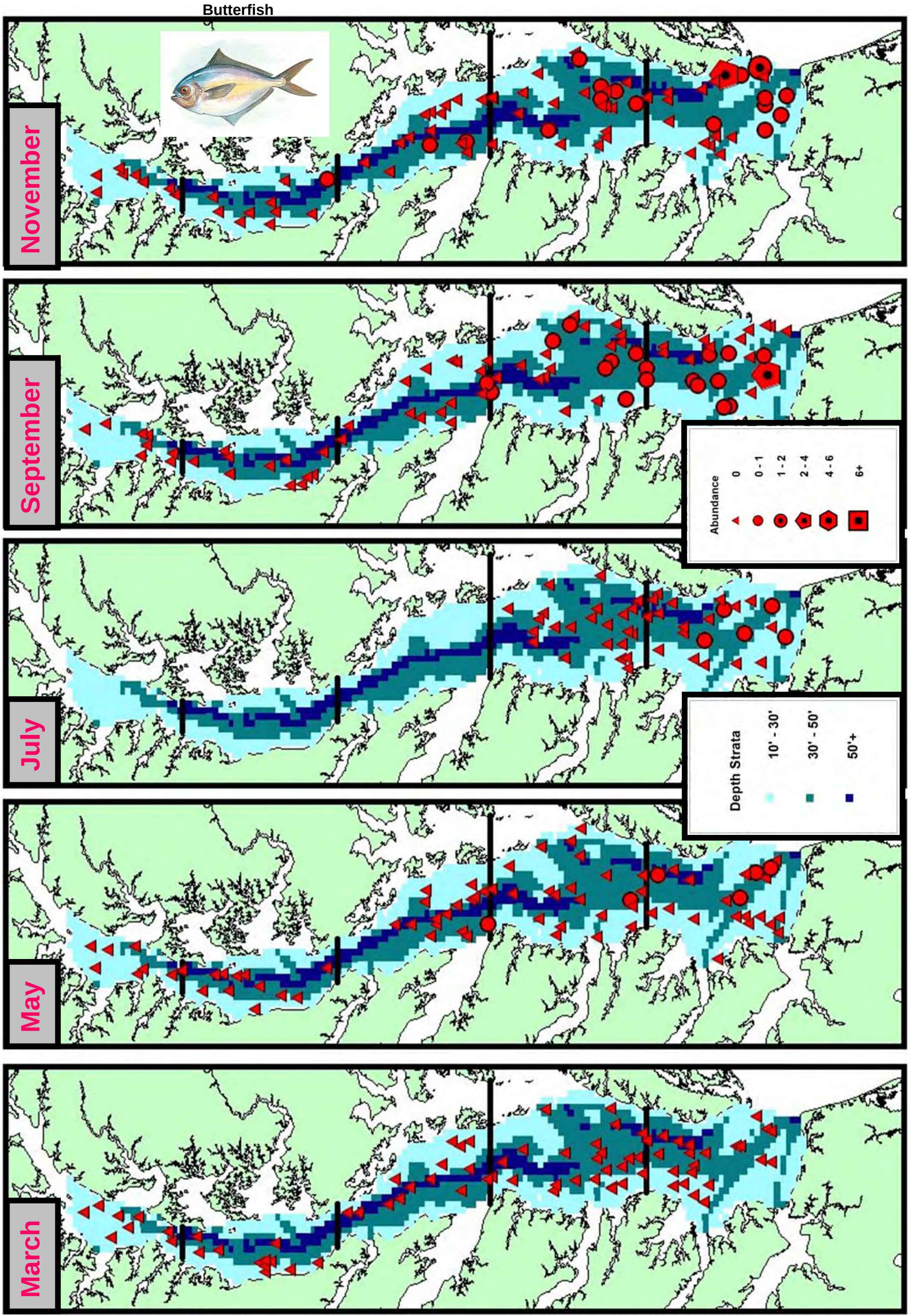
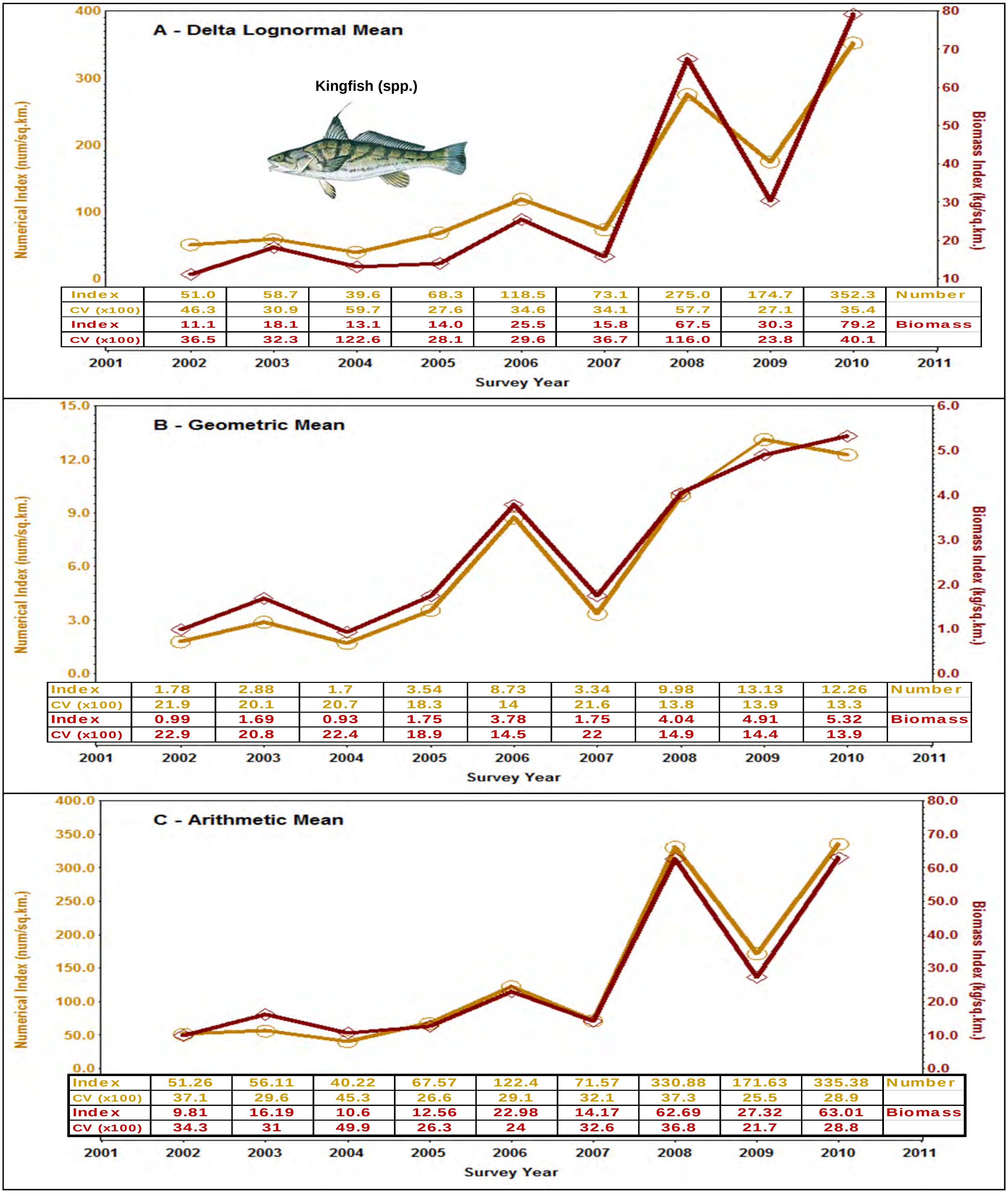


Figure 19. Abundance indices (number and biomass) for kingfish based on delta lognormal (A), geometric (B) and arithmetic (C) means.

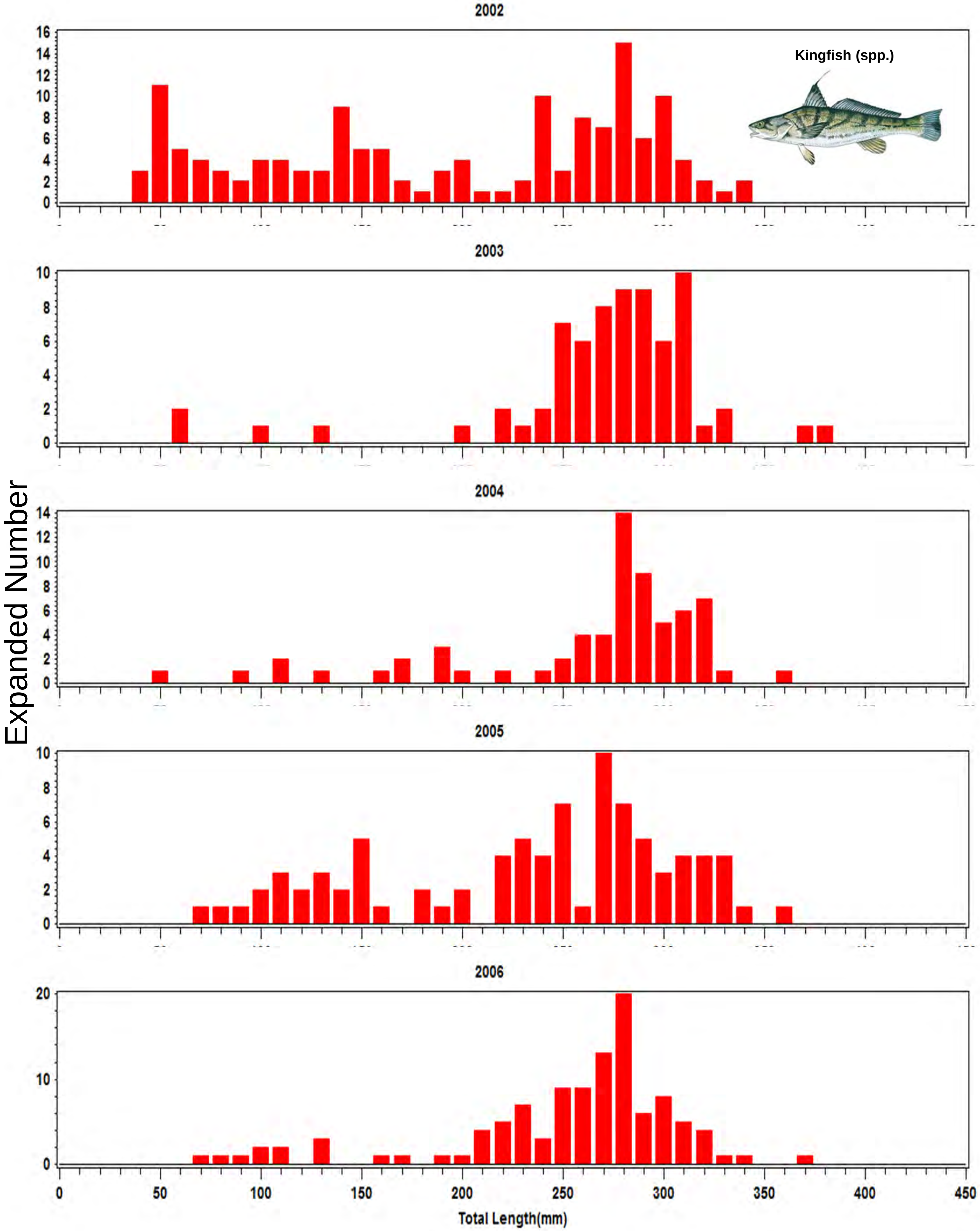


	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	51.0	58.7	39.6	68.3	118.5	73.1	275.0	174.7	352.3	Number
CV (x100)	46.3	30.9	59.7	27.6	34.6	34.1	57.7	27.1	35.4	
Index	11.1	18.1	13.1	14.0	25.5	15.8	67.5	30.3	79.2	Biomass
CV (x100)	36.5	32.3	122.6	28.1	29.6	36.7	116.0	23.8	40.1	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	1.78	2.88	1.7	3.54	8.73	3.34	9.98	13.13	12.26	Number
CV (x100)	21.9	20.1	20.7	18.3	14	21.6	13.8	13.9	13.3	
Index	0.99	1.69	0.93	1.75	3.78	1.75	4.04	4.91	5.32	Biomass
CV (x100)	22.9	20.8	22.4	18.9	14.5	22	14.9	14.4	13.9	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	51.26	56.11	40.22	67.57	122.4	71.57	330.88	171.63	335.38	Number
CV (x100)	37.1	29.6	45.3	26.6	29.1	32.1	37.3	25.5	28.9	
Index	9.81	16.19	10.6	12.56	22.98	14.17	62.69	27.32	63.01	Biomass
CV (x100)	34.3	31	49.9	26.3	24	32.6	36.8	21.7	28.8	

Figure 20. Kingfish length-frequency in Chesapeake Bay, 2002-2010.



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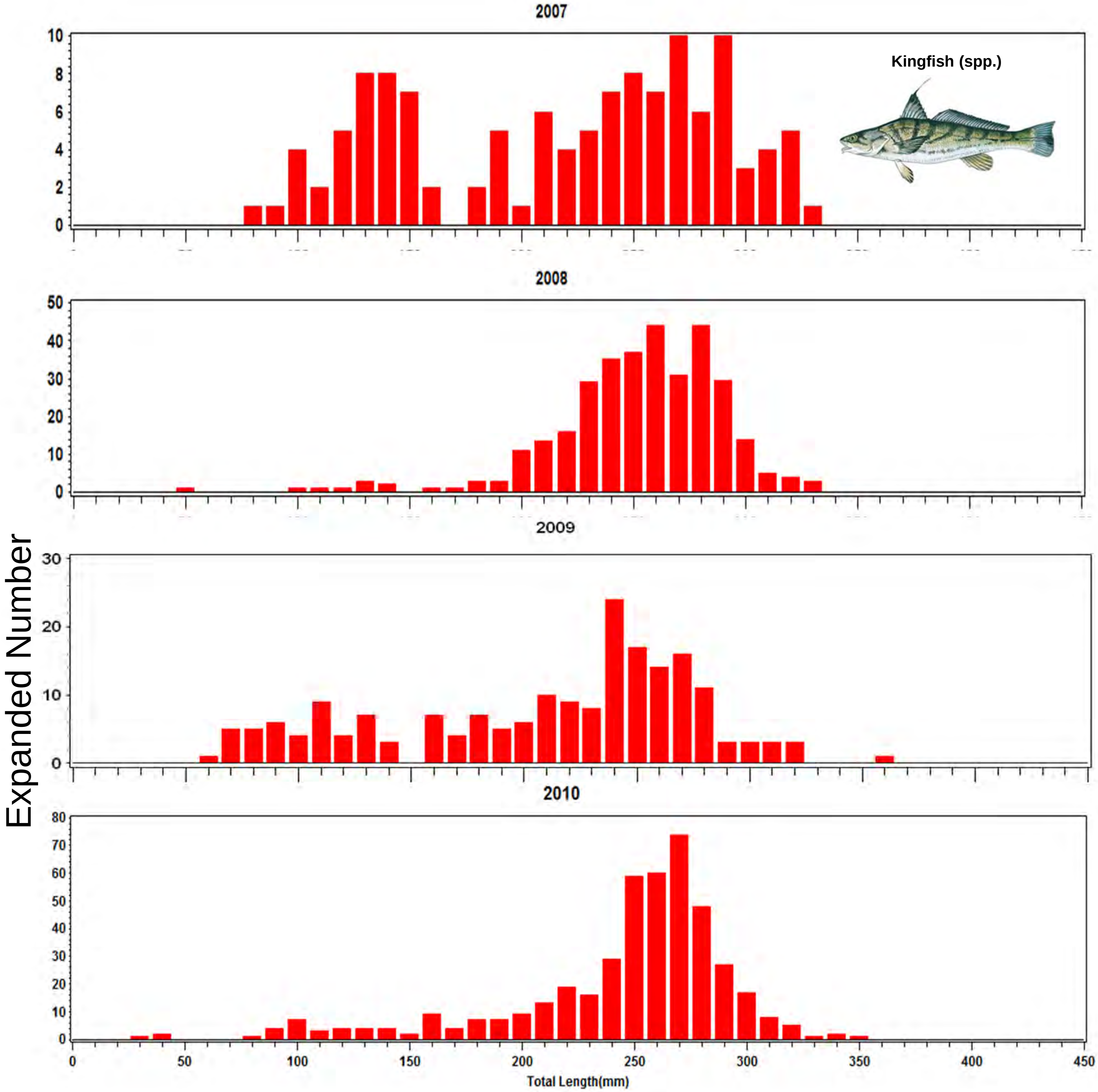


Figure 21. Kingfish age-structure in Chesapeake Bay, 2002-2009.

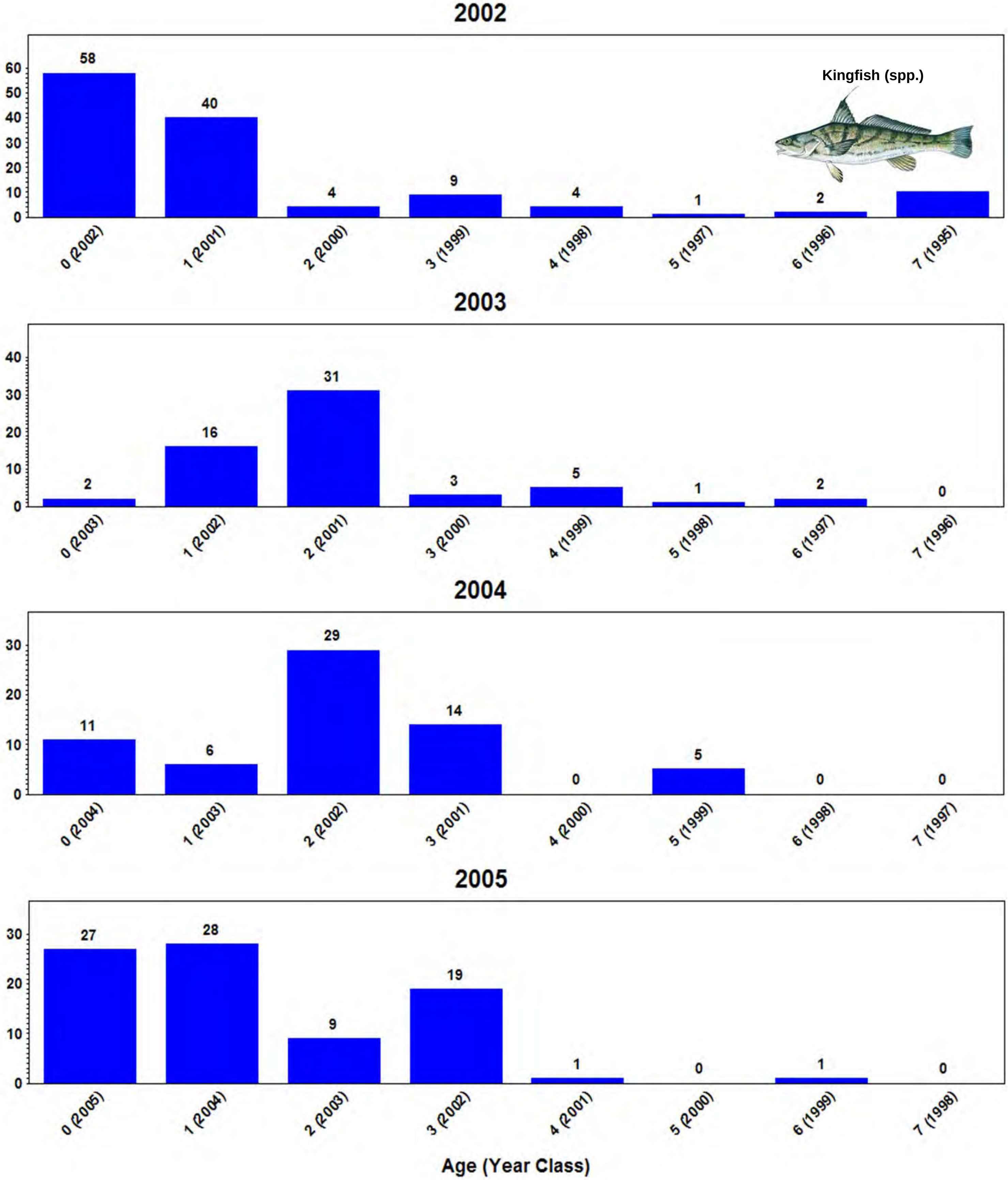


Figure 21. continued.

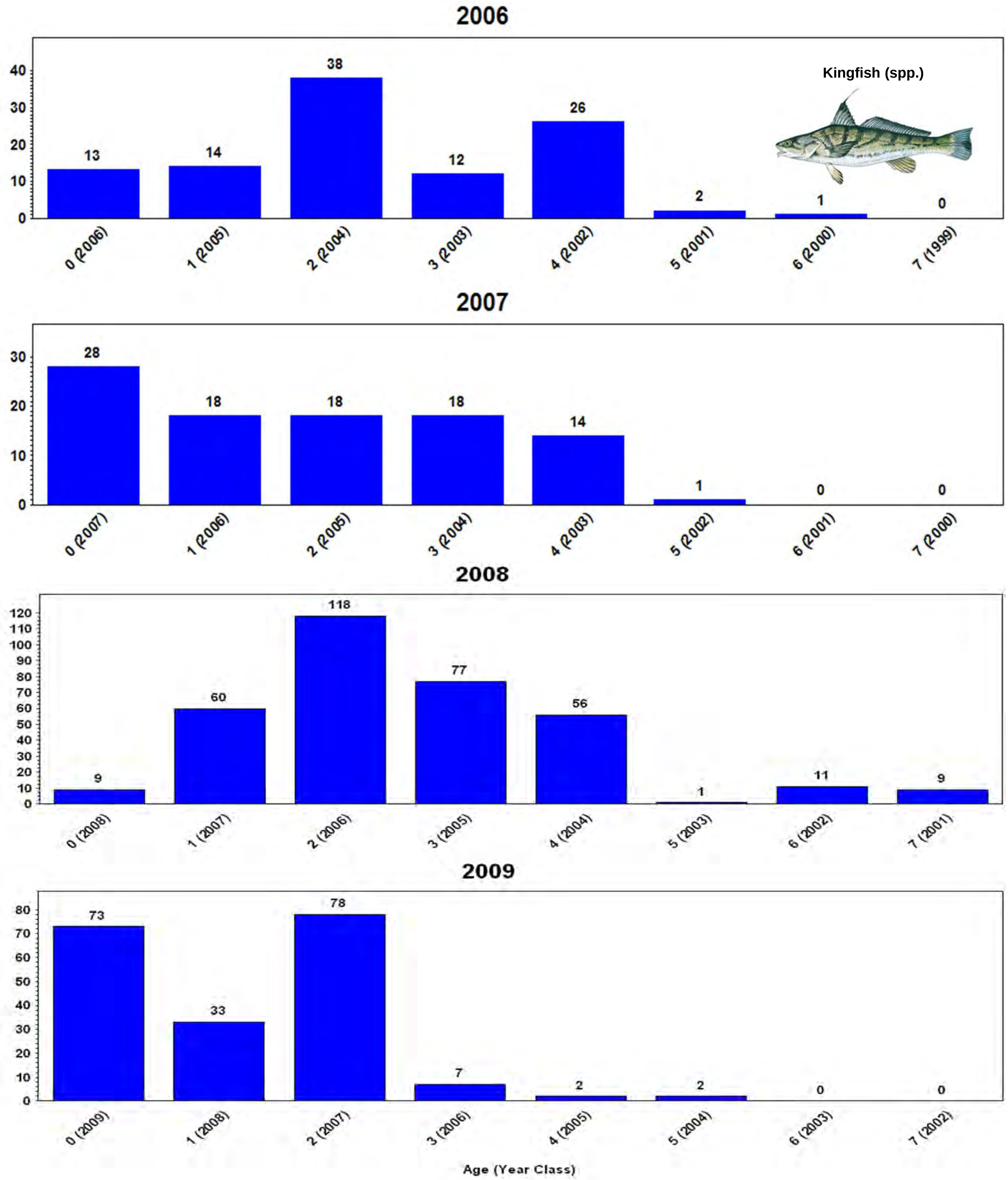


Figure 22. Abundance (kg per hectare swept) of kingfish in Chesapeake Bay, 2010.

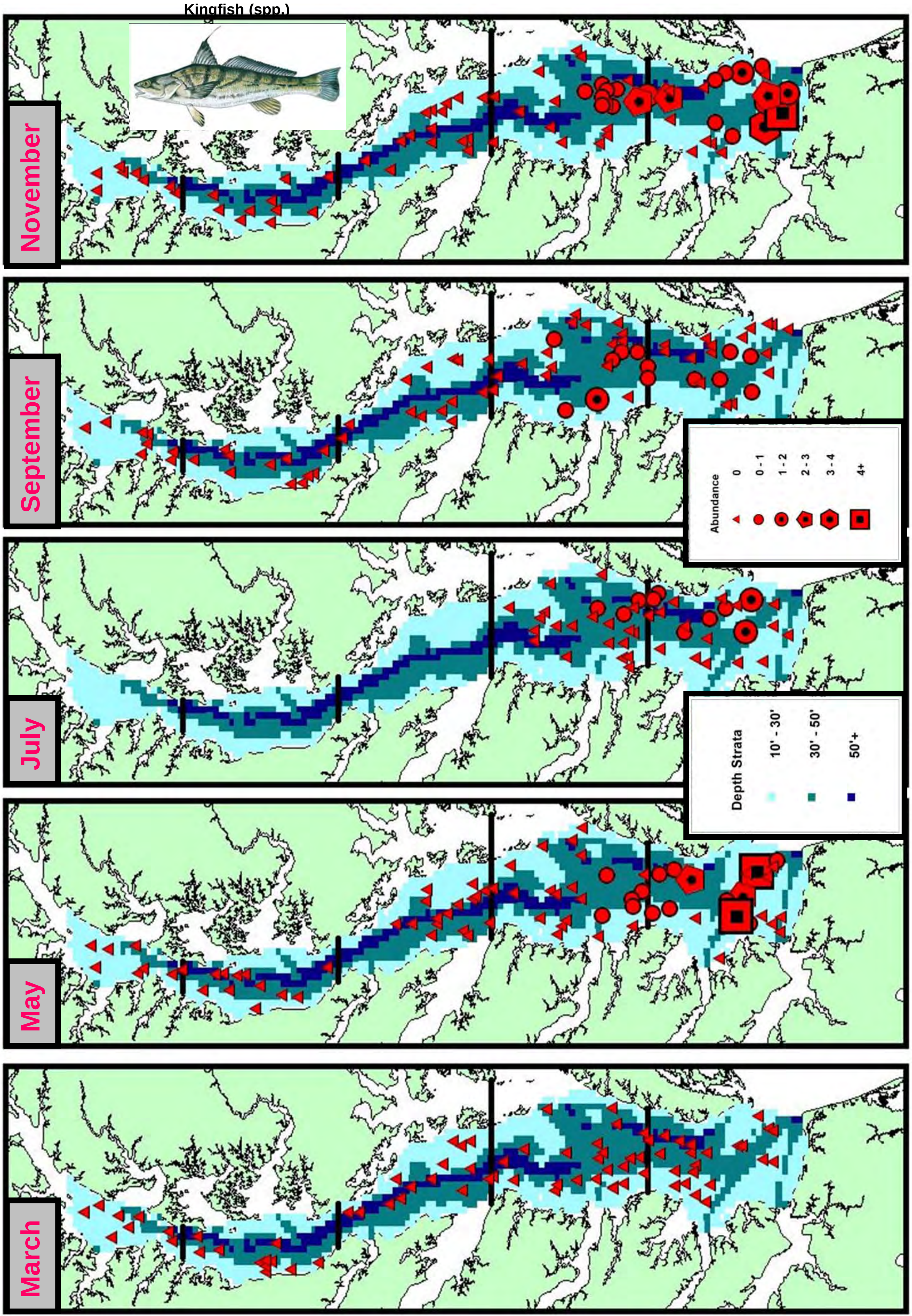


Figure 23. Diet composition, expressed as percent by weight (A) and percent by number (B) of kingfish collected during ChesMMAP cruises in 2002-2010 combined.

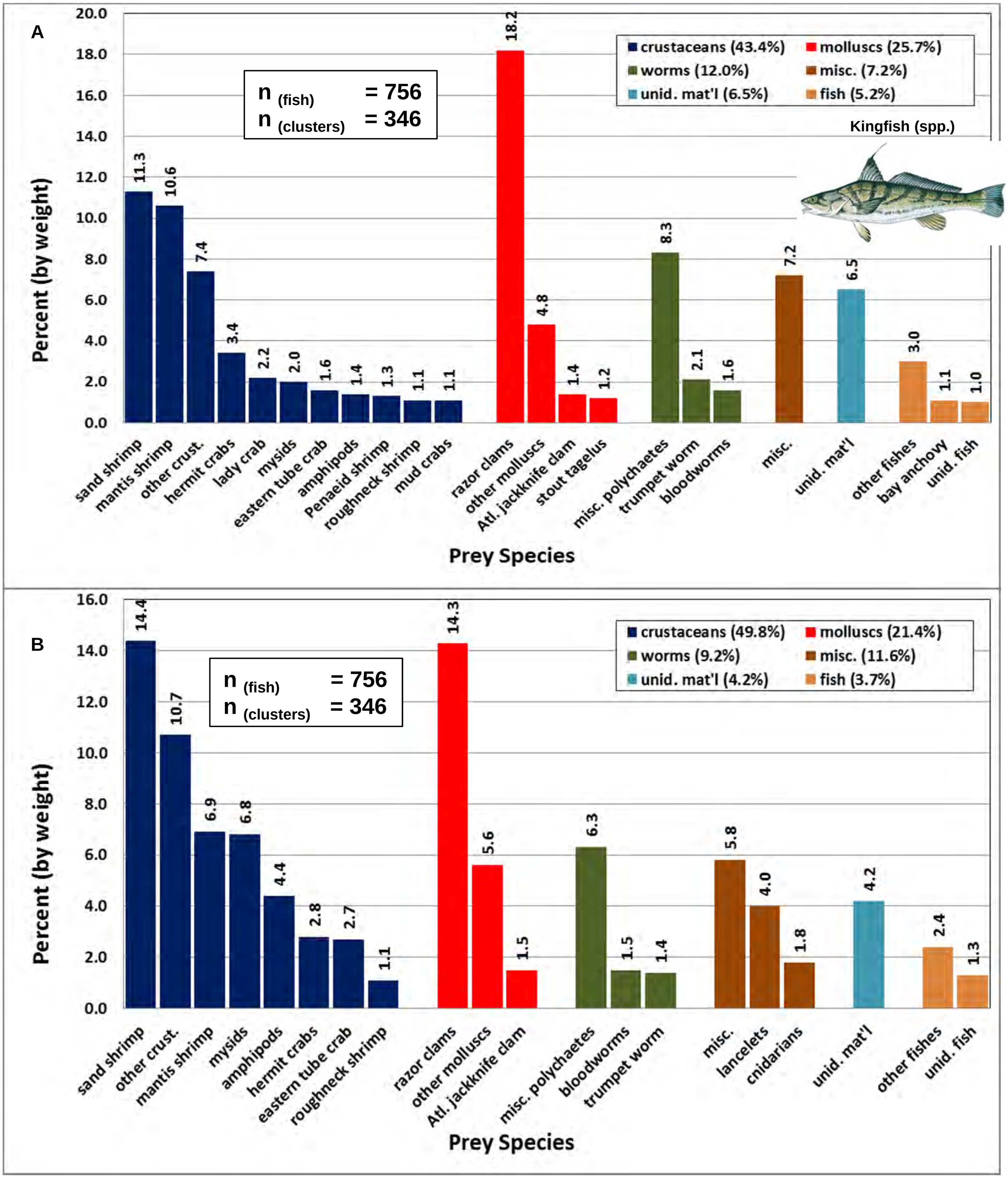
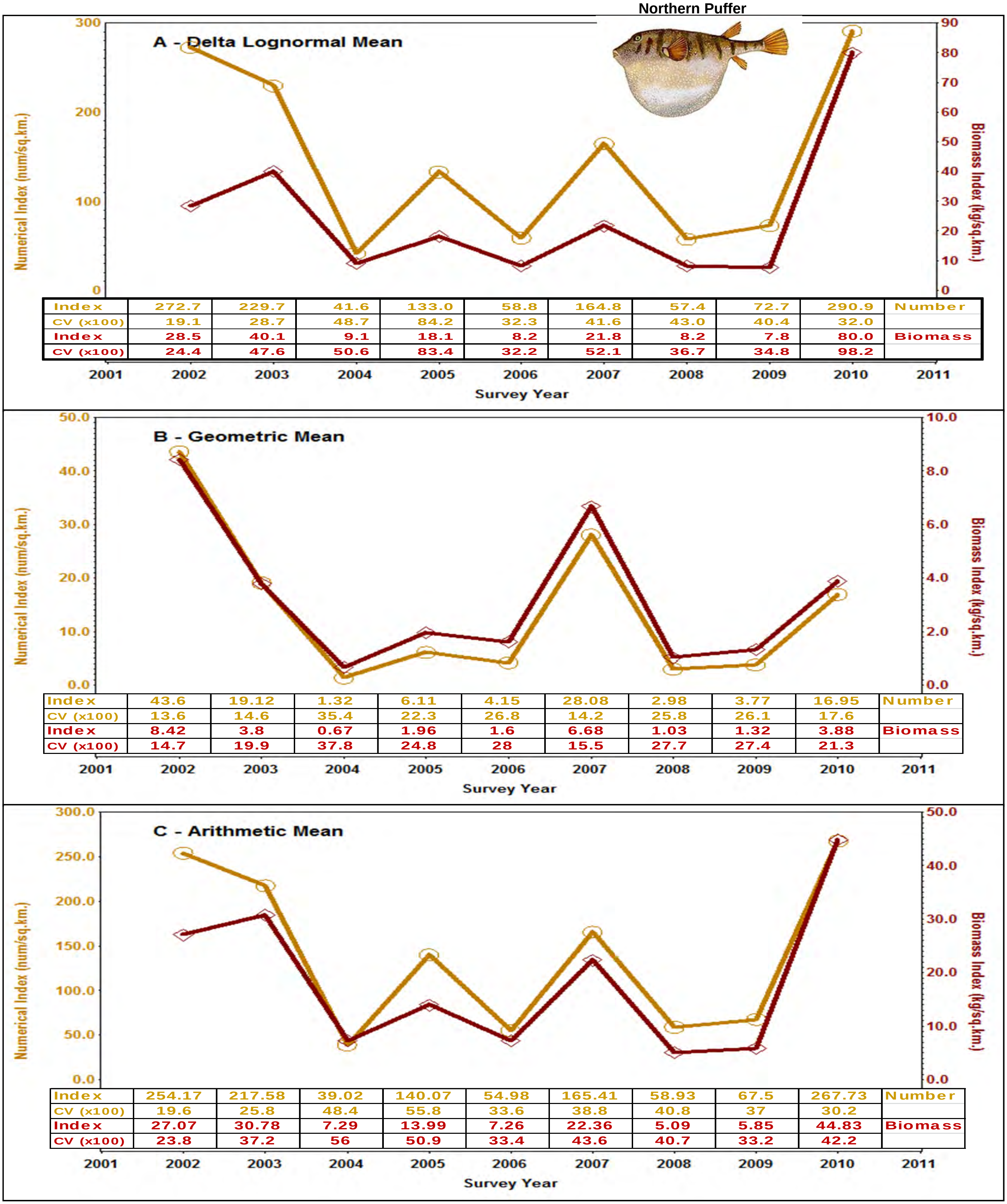


Figure 24. Abundance indices (number and biomass) for northern puffer based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	272.7	229.7	41.6	133.0	58.8	164.8	57.4	72.7	290.9	Number
CV (x100)	19.1	28.7	48.7	84.2	32.3	41.6	43.0	40.4	32.0	
Index	28.5	40.1	9.1	18.1	8.2	21.8	8.2	7.8	80.0	Biomass
CV (x100)	24.4	47.6	50.6	83.4	32.2	52.1	36.7	34.8	98.2	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	43.6	19.12	1.32	6.11	4.15	28.08	2.98	3.77	16.95	Number
CV (x100)	13.6	14.6	35.4	22.3	26.8	14.2	25.8	26.1	17.6	
Index	8.42	3.8	0.67	1.96	1.6	6.68	1.03	1.32	3.88	Biomass
CV (x100)	14.7	19.9	37.8	24.8	28	15.5	27.7	27.4	21.3	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	254.17	217.58	39.02	140.07	54.98	165.41	58.93	67.5	267.73	Number
CV (x100)	19.6	25.8	48.4	55.8	33.6	38.8	40.8	37	30.2	
Index	27.07	30.78	7.29	13.99	7.26	22.36	5.09	5.85	44.83	Biomass
CV (x100)	23.8	37.2	56	50.9	33.4	43.6	40.7	33.2	42.2	

Figure 25. Northern puffer length-frequency in Chesapeake Bay, 2002-2010.

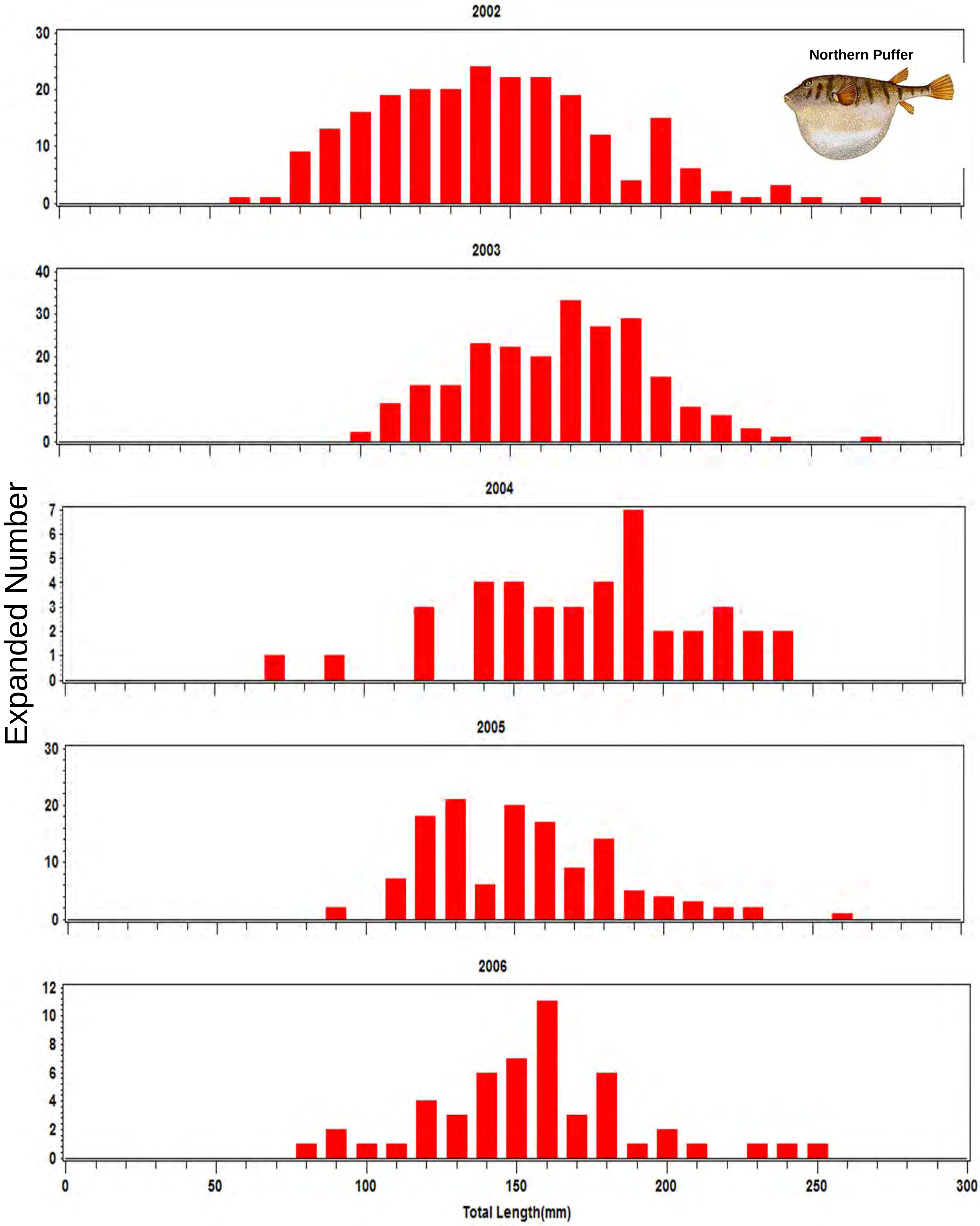


Figure 25. continued.

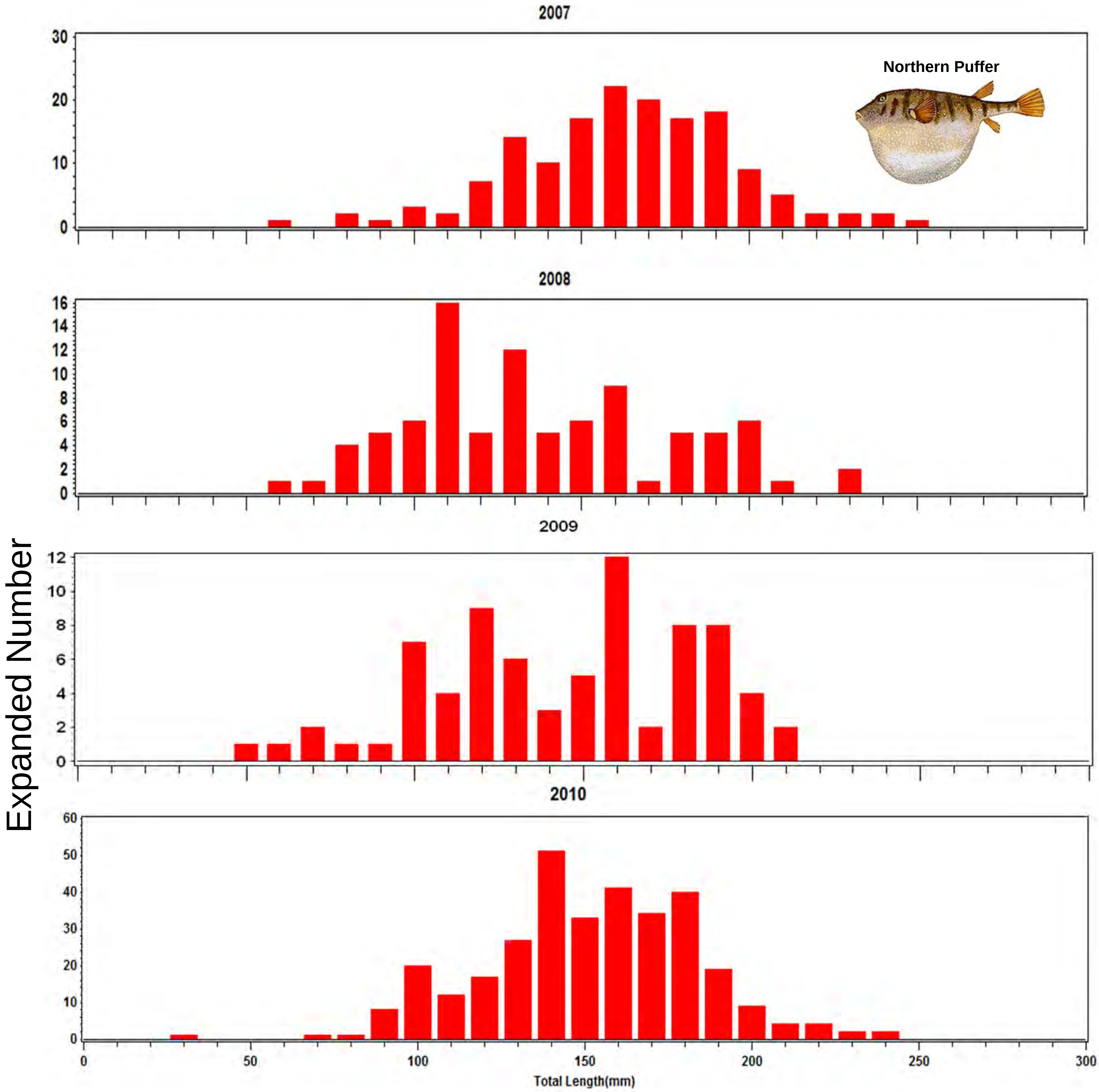


Figure 26. Abundance (kg per hectare swept) of northern puffer in Chesapeake Bay, 2010.

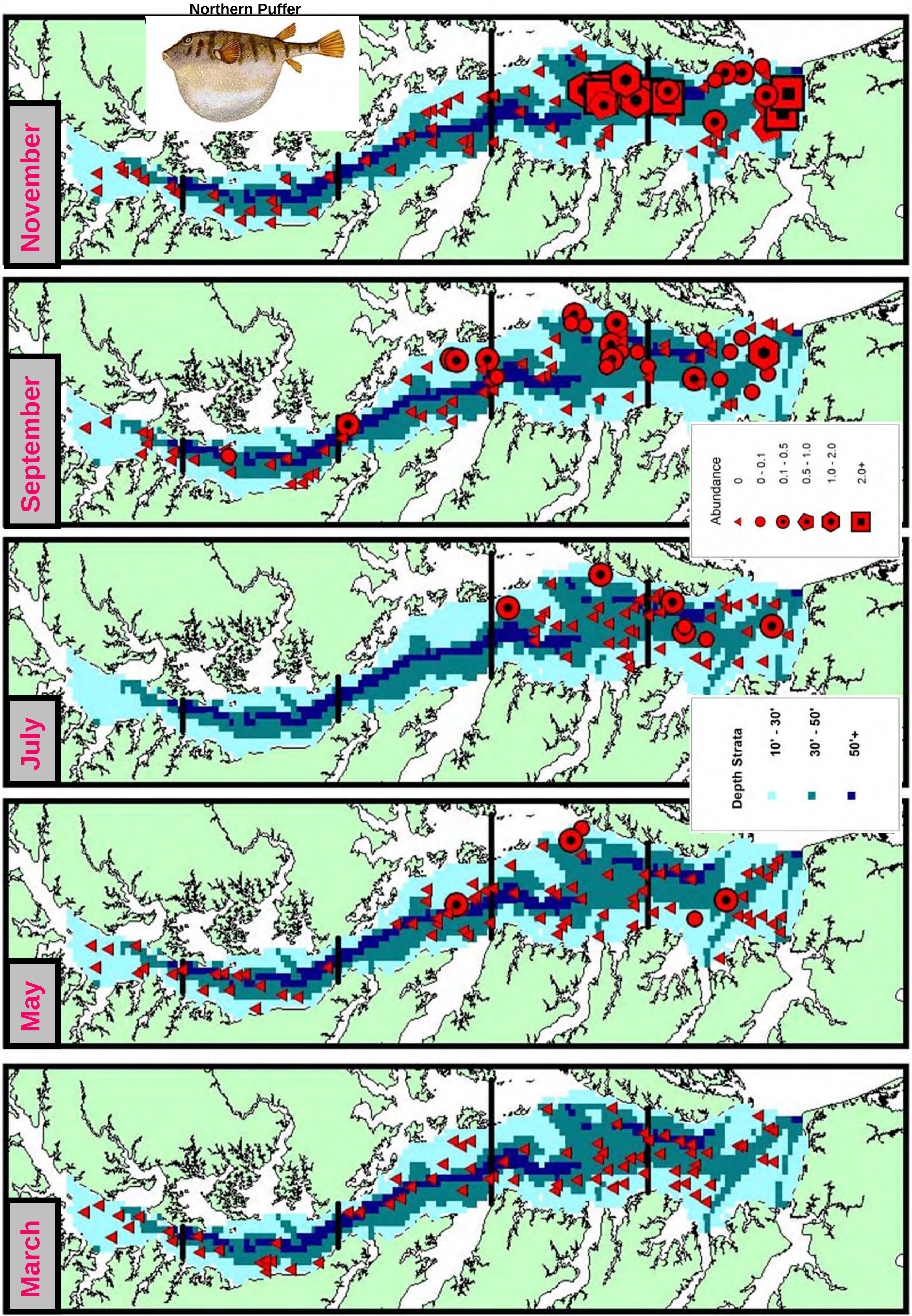


Figure 27. Diet composition, expressed as percent by weight (A) and percent by number (B) of northern puffer collected during ChesMMAP cruises in 2002-2010 combined.

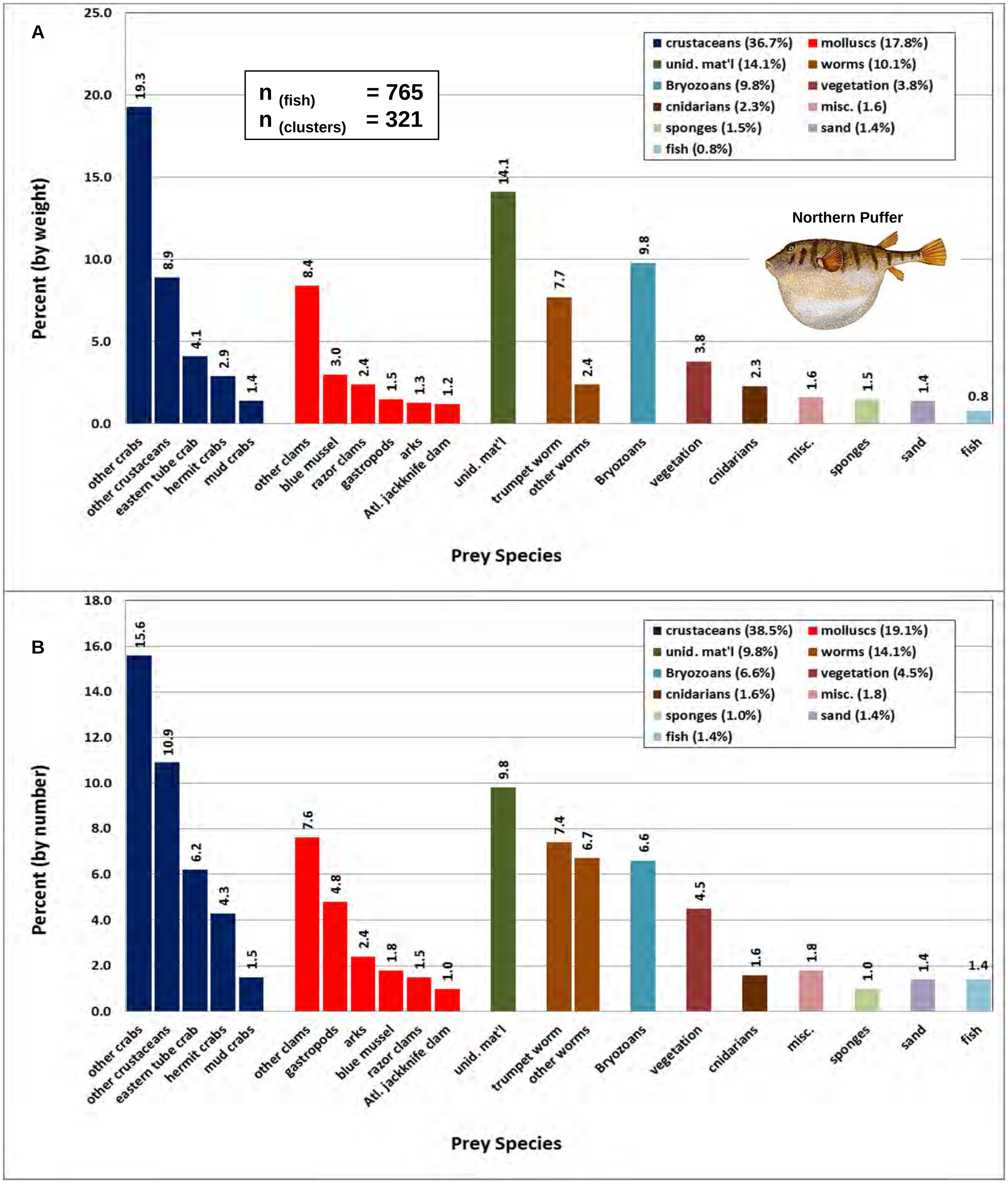
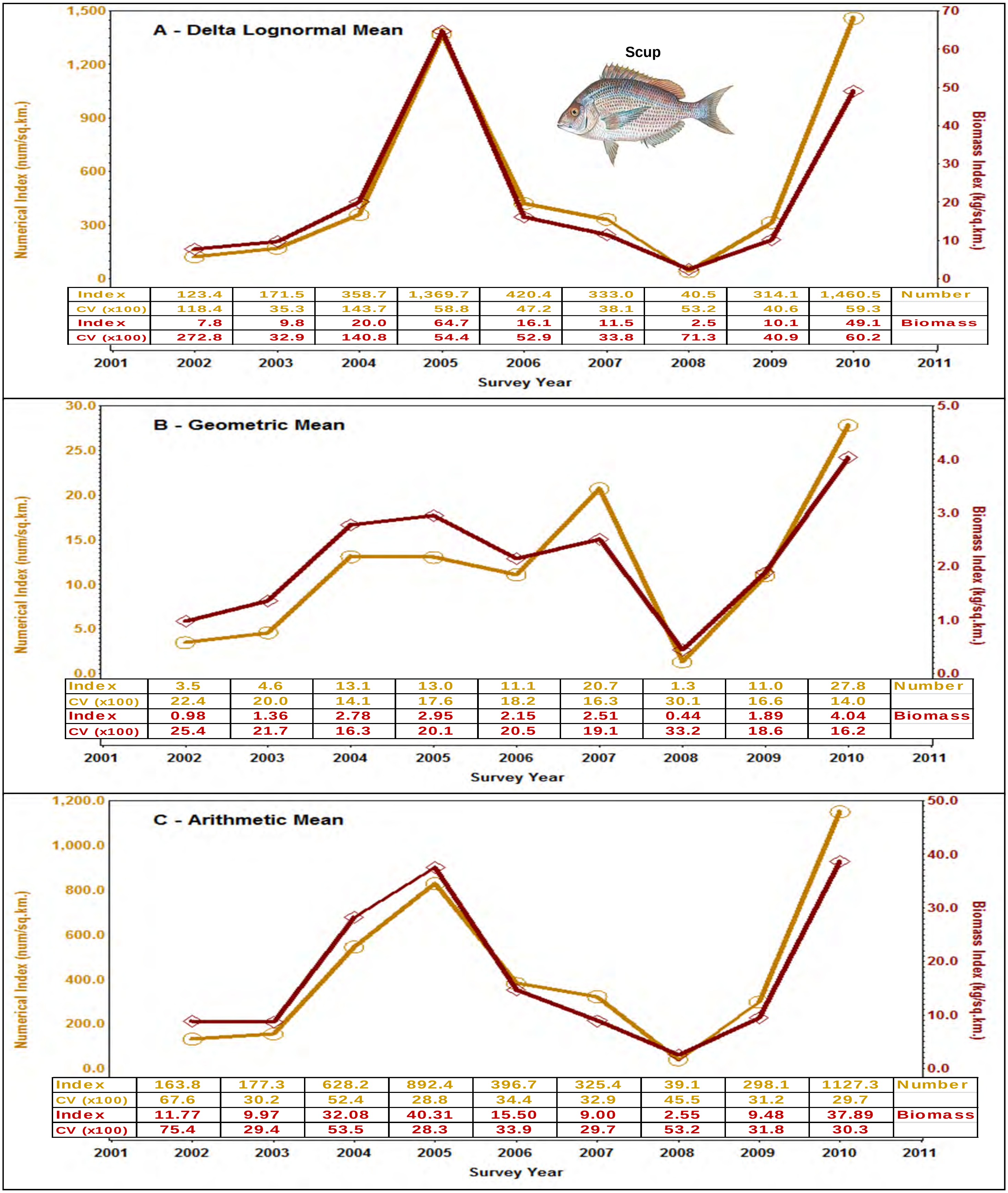


Figure 28. Abundance indices (number and biomass) for scup based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	123.4	171.5	358.7	1,369.7	420.4	333.0	40.5	314.1	1,460.5	Number
CV (x100)	118.4	35.3	143.7	58.8	47.2	38.1	53.2	40.6	59.3	
Index	7.8	9.8	20.0	64.7	16.1	11.5	2.5	10.1	49.1	Biomass
CV (x100)	272.8	32.9	140.8	54.4	52.9	33.8	71.3	40.9	60.2	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	3.5	4.6	13.1	13.0	11.1	20.7	1.3	11.0	27.8	Number
CV (x100)	22.4	20.0	14.1	17.6	18.2	16.3	30.1	16.6	14.0	
Index	0.98	1.36	2.78	2.95	2.15	2.51	0.44	1.89	4.04	Biomass
CV (x100)	25.4	21.7	16.3	20.1	20.5	19.1	33.2	18.6	16.2	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	163.8	177.3	628.2	892.4	396.7	325.4	39.1	298.1	1127.3	Number
CV (x100)	67.6	30.2	52.4	28.8	34.4	32.9	45.5	31.2	29.7	
Index	11.77	9.97	32.08	40.31	15.50	9.00	2.55	9.48	37.89	Biomass
CV (x100)	75.4	29.4	53.5	28.3	33.9	29.7	53.2	31.8	30.3	

Figure 29. Scup length-frequency in Chesapeake Bay, 2002-2010.

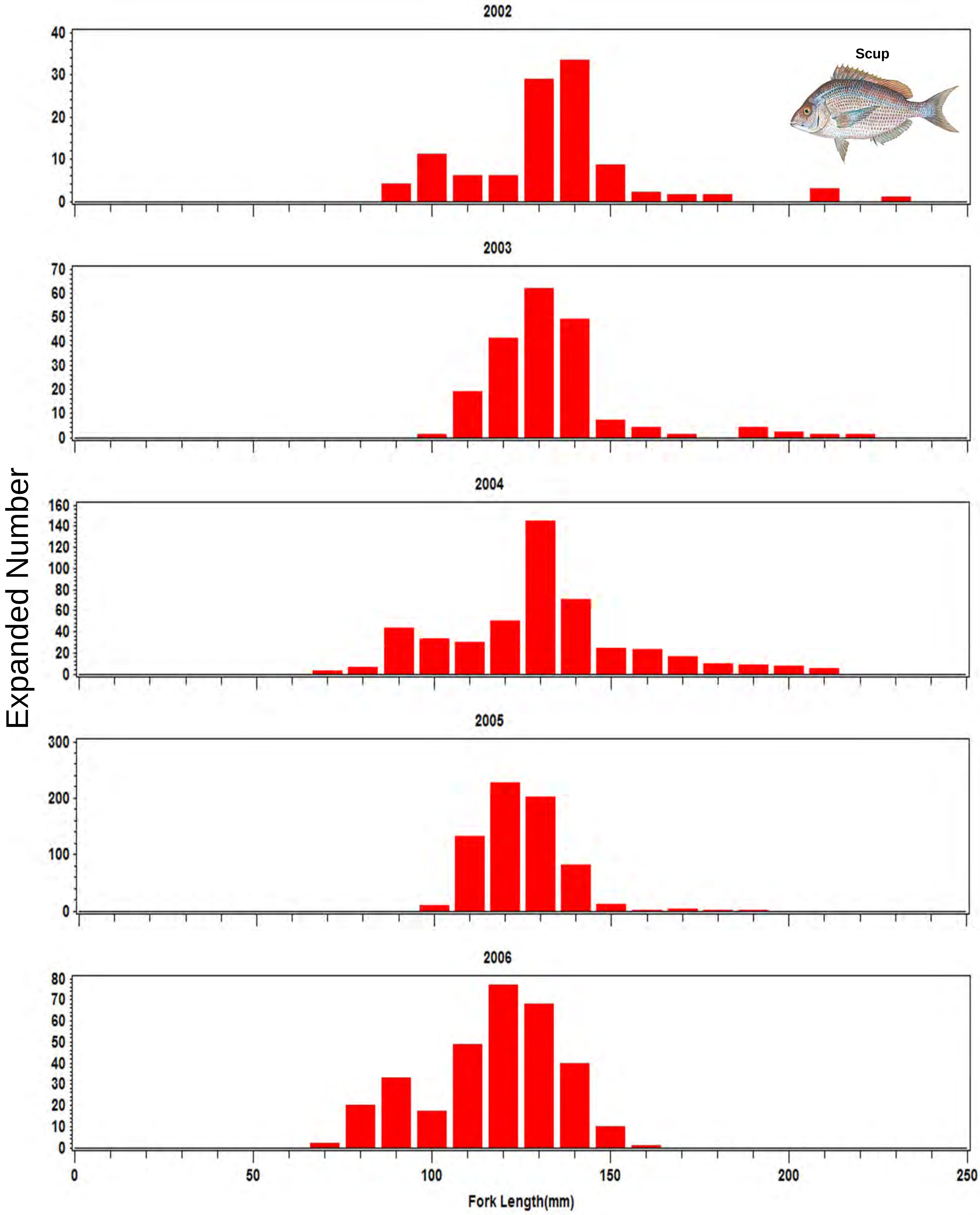


Figure 29. continued.

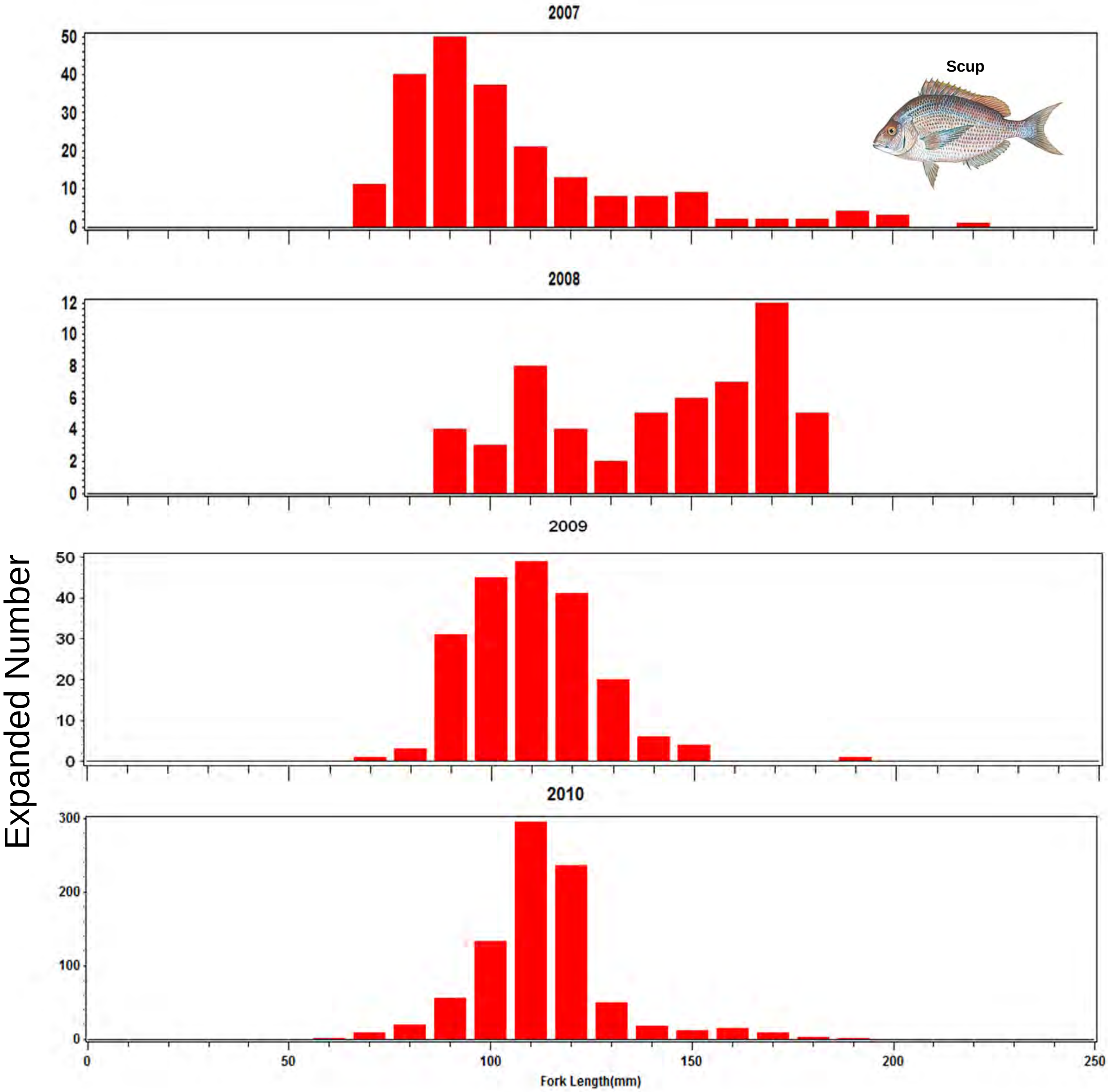


Figure 30. Scup age-structure in Chesapeake Bay, 2002-2007.

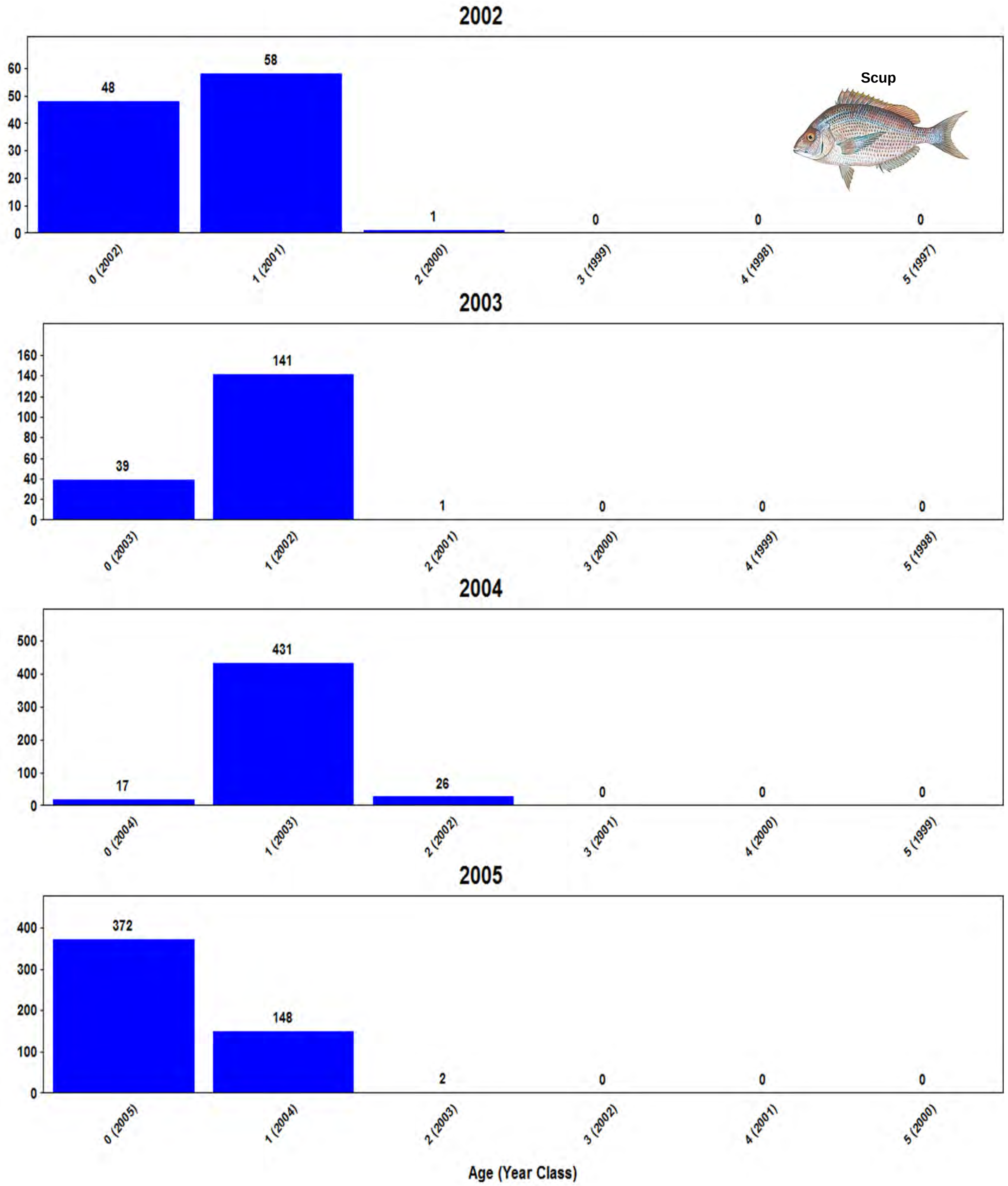


Figure 30. continued.

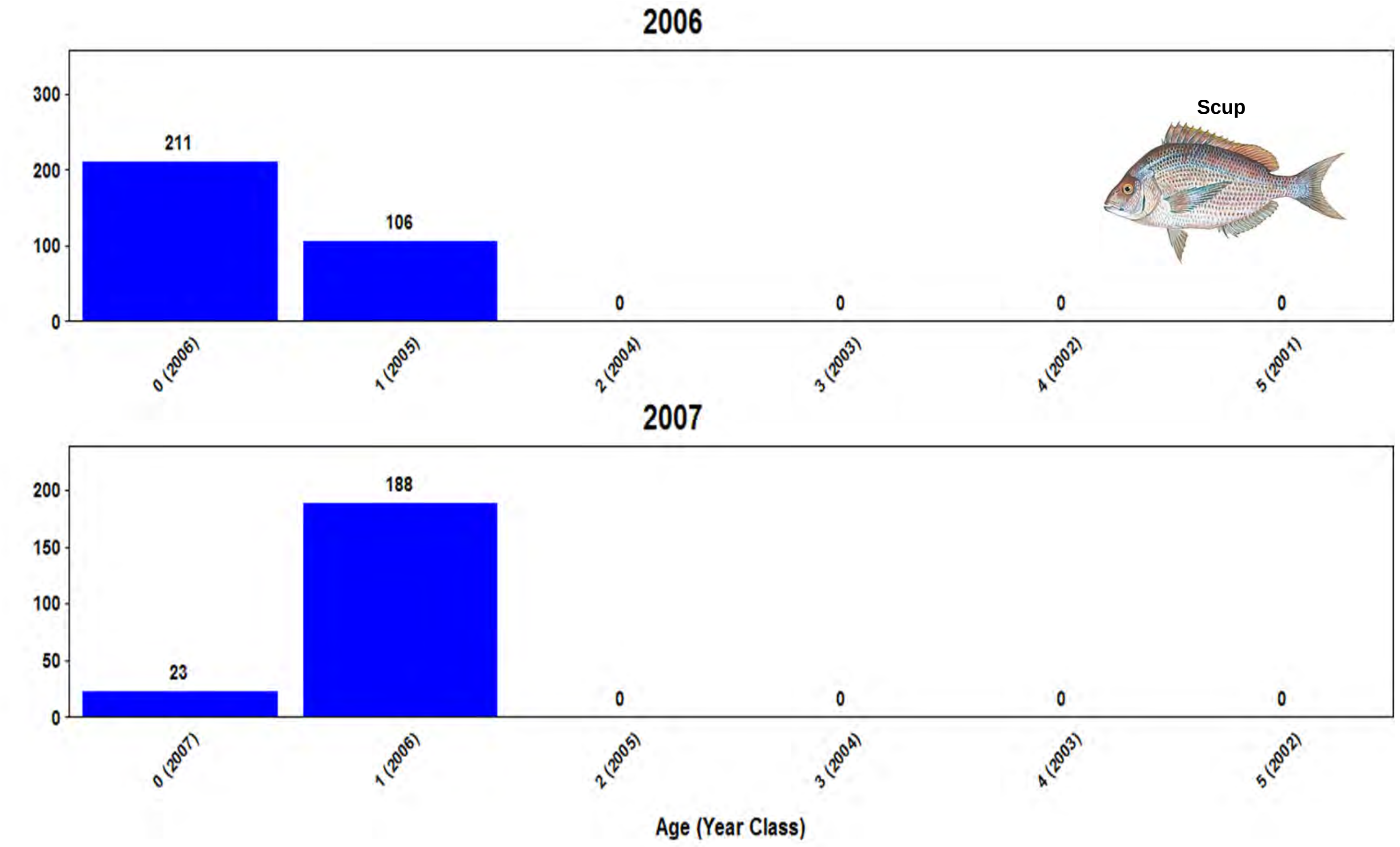


Figure 31. Abundance (kg per hectare swept) of scup in Chesapeake Bay, 2010.

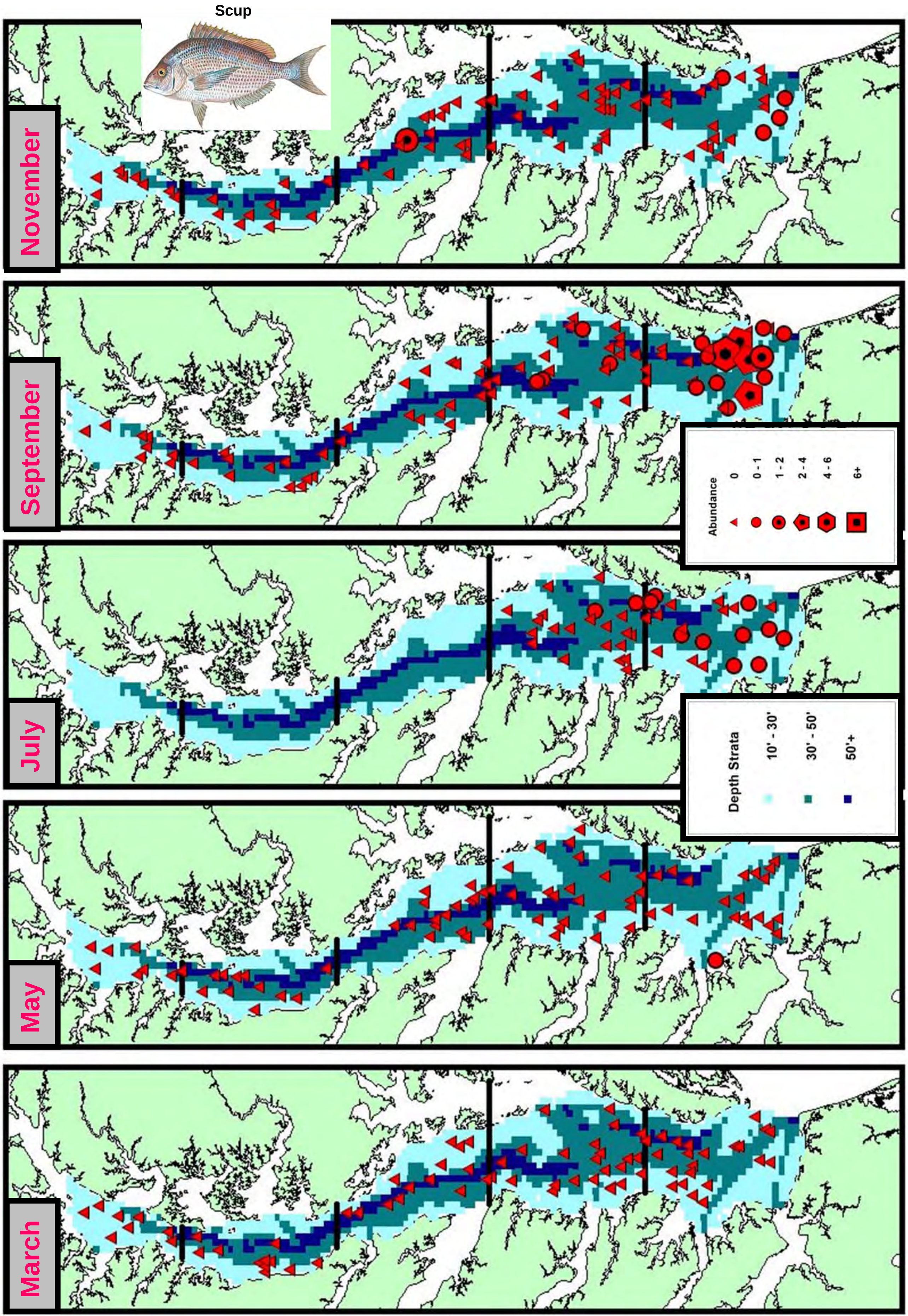


Figure 32. Diet composition, expressed as percent by weight (A) and percent by number (B) of scup collected during ChesMMAP cruises in 2002-2010 combined.

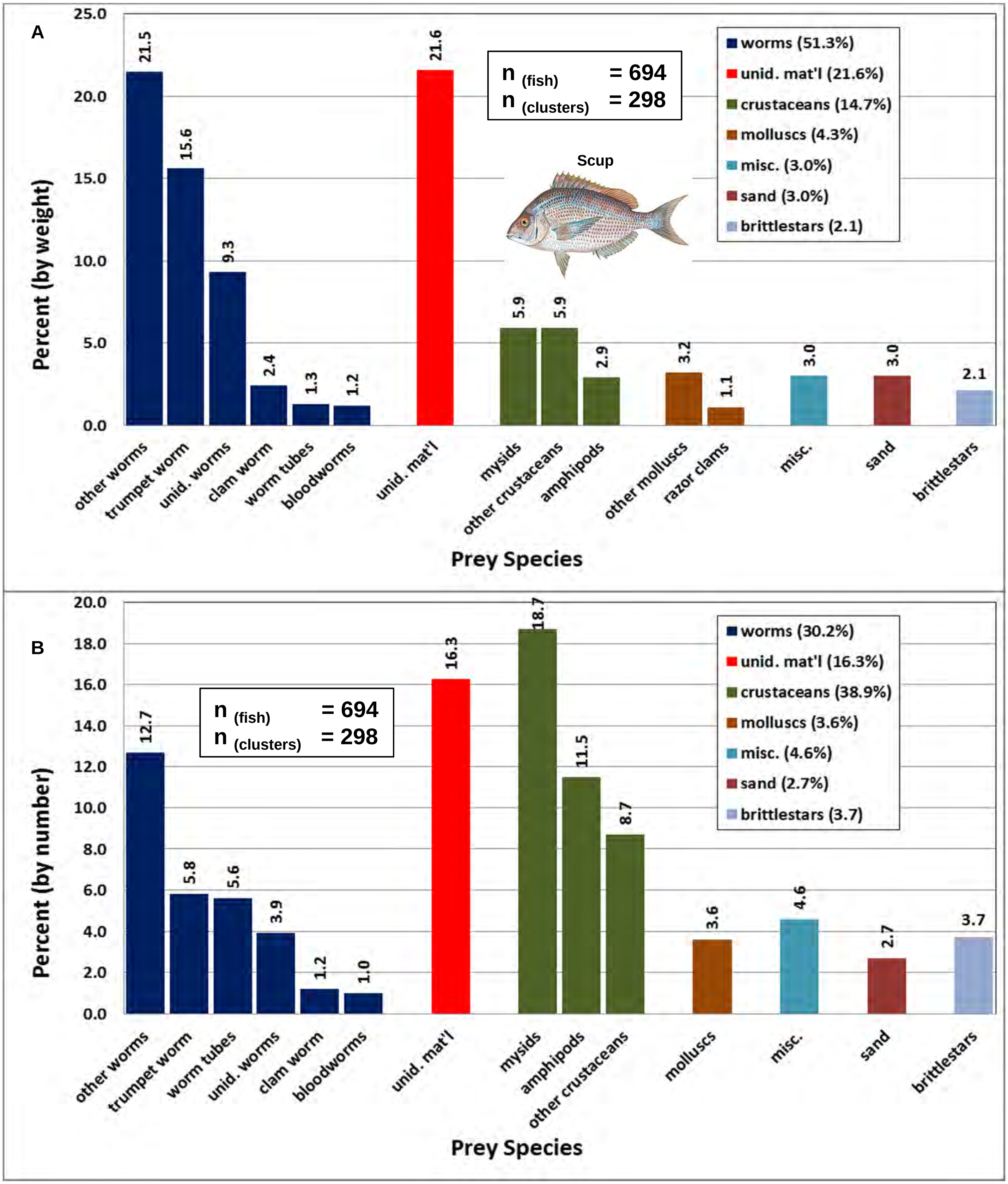
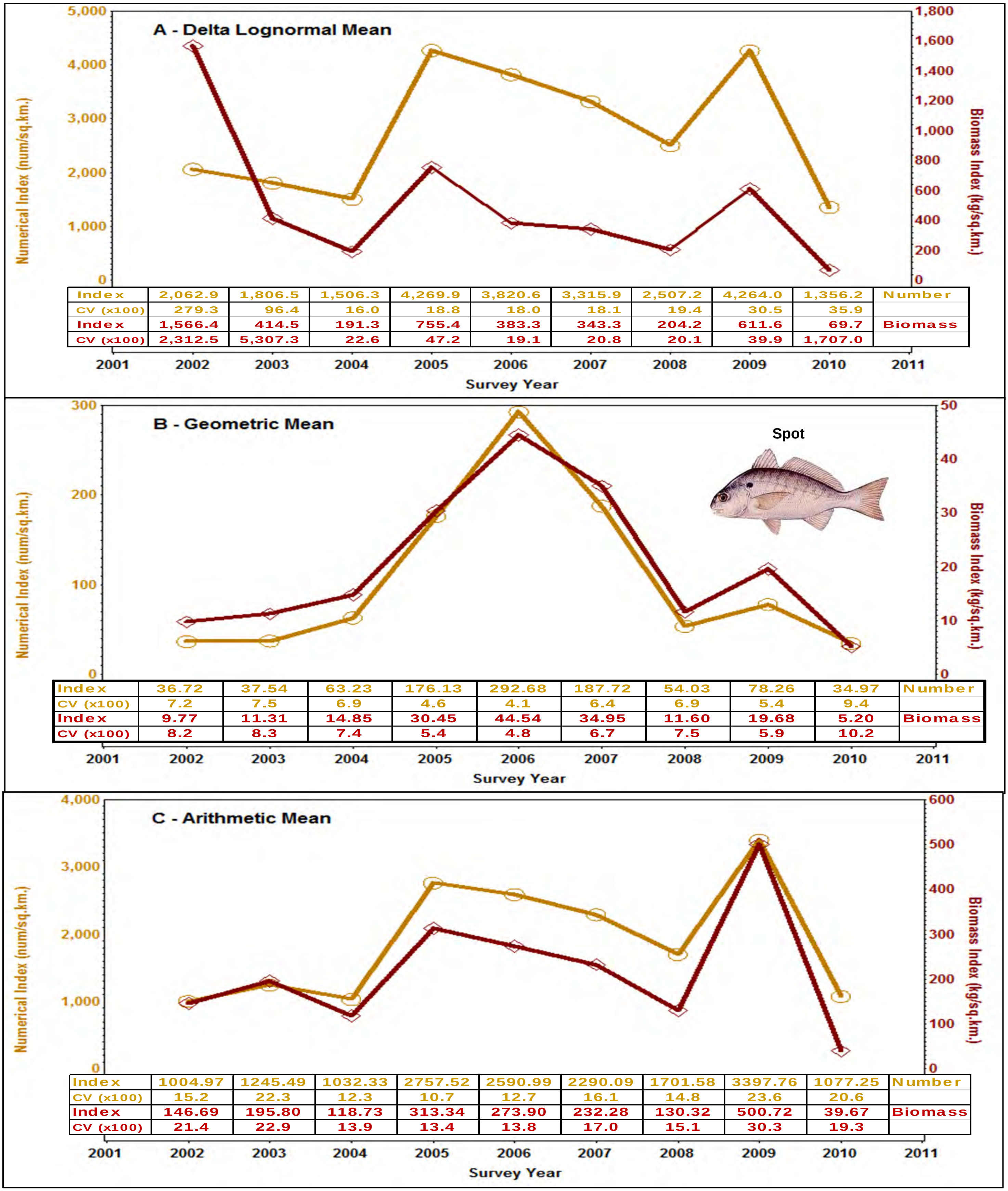


Figure 33. Abundance indices (number and biomass) for spot based on delta lognormal (A), geometric (B) and arithmetic (C) means.



Index	2,062.9	1,806.5	1,506.3	4,269.9	3,820.6	3,315.9	2,507.2	4,264.0	1,356.2	Number
CV (x100)	279.3	96.4	16.0	18.8	18.0	18.1	19.4	30.5	35.9	
Index	1,566.4	414.5	191.3	755.4	383.3	343.3	204.2	611.6	69.7	Biomass
CV (x100)	2,312.5	5,307.3	22.6	47.2	19.1	20.8	20.1	39.9	1,707.0	

Index	36.72	37.54	63.23	176.13	292.68	187.72	54.03	78.26	34.97	Number
CV (x100)	7.2	7.5	6.9	4.6	4.1	6.4	6.9	5.4	9.4	
Index	9.77	11.31	14.85	30.45	44.54	34.95	11.60	19.68	5.20	Biomass
CV (x100)	8.2	8.3	7.4	5.4	4.8	6.7	7.5	5.9	10.2	

Index	1004.97	1245.49	1032.33	2757.52	2590.99	2290.09	1701.58	3397.76	1077.25	Number
CV (x100)	15.2	22.3	12.3	10.7	12.7	16.1	14.8	23.6	20.6	
Index	146.69	195.80	118.73	313.34	273.90	232.28	130.32	500.72	39.67	Biomass
CV (x100)	21.4	22.9	13.9	13.4	13.8	17.0	15.1	30.3	19.3	

Figure 34. Spot length-frequency in Chesapeake Bay, 2002-2010.

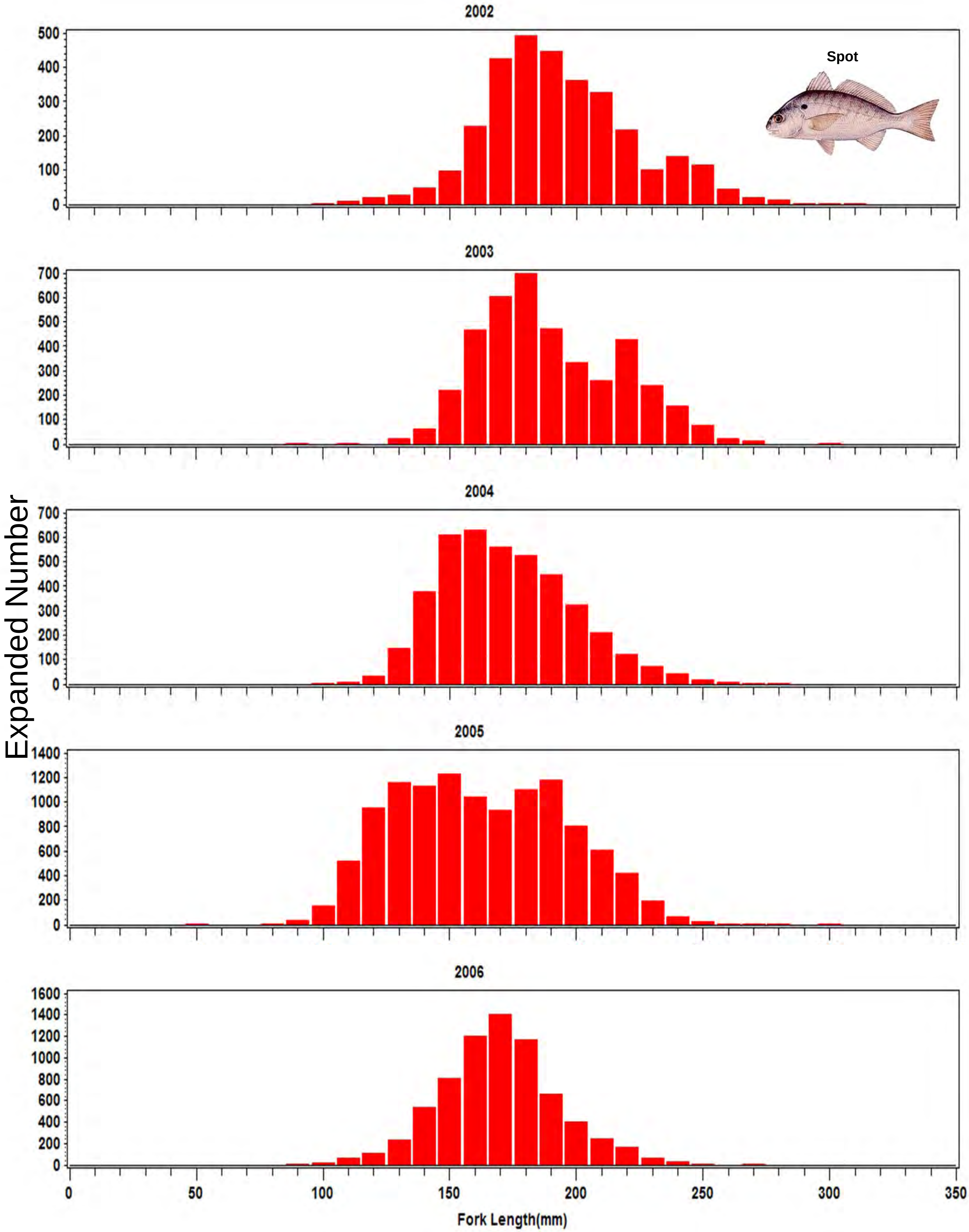


Figure 34. continued.

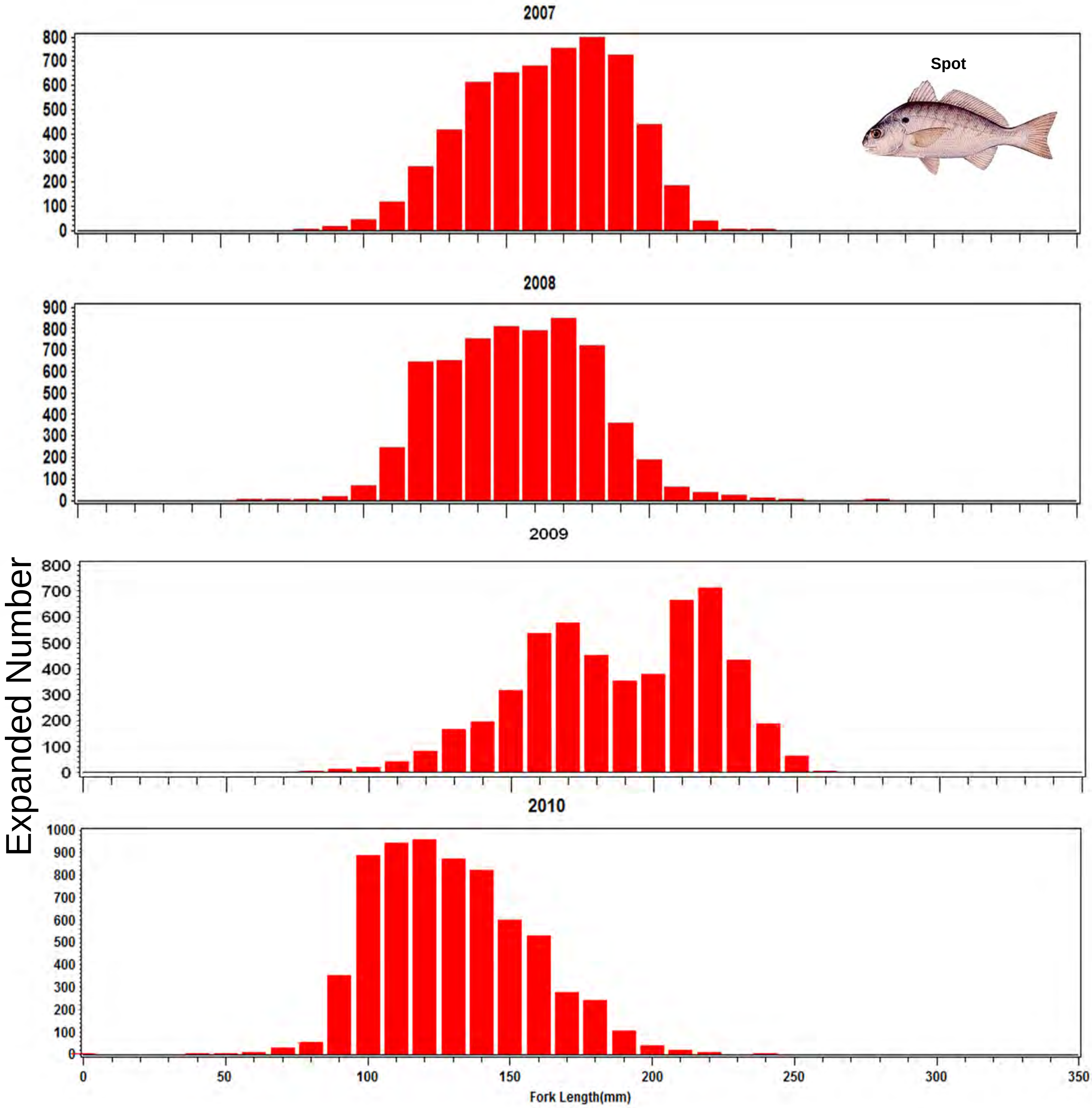


Figure 35. Spot age-structure in Chesapeake Bay, 2002-2009.

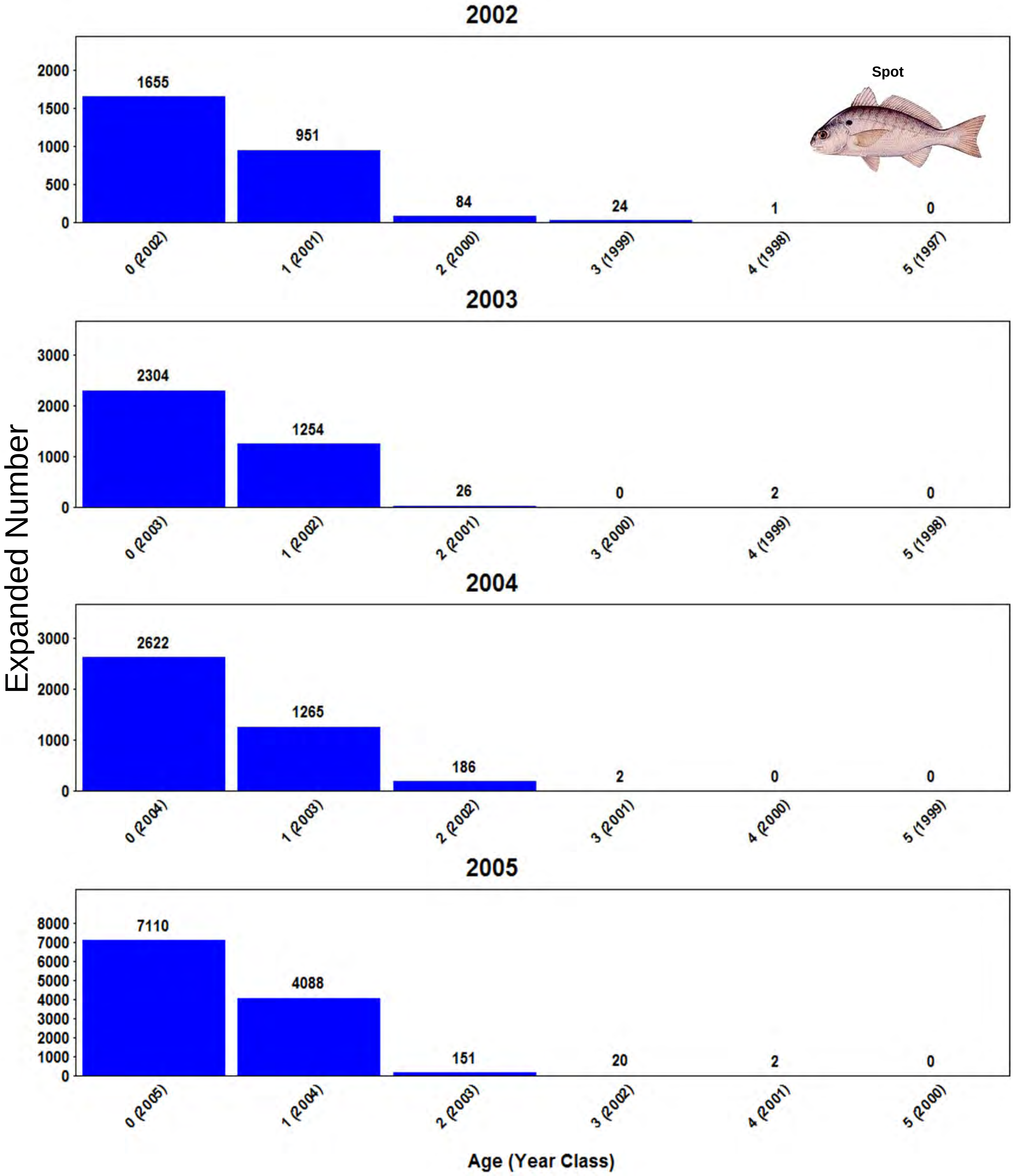


Figure 35. continued.

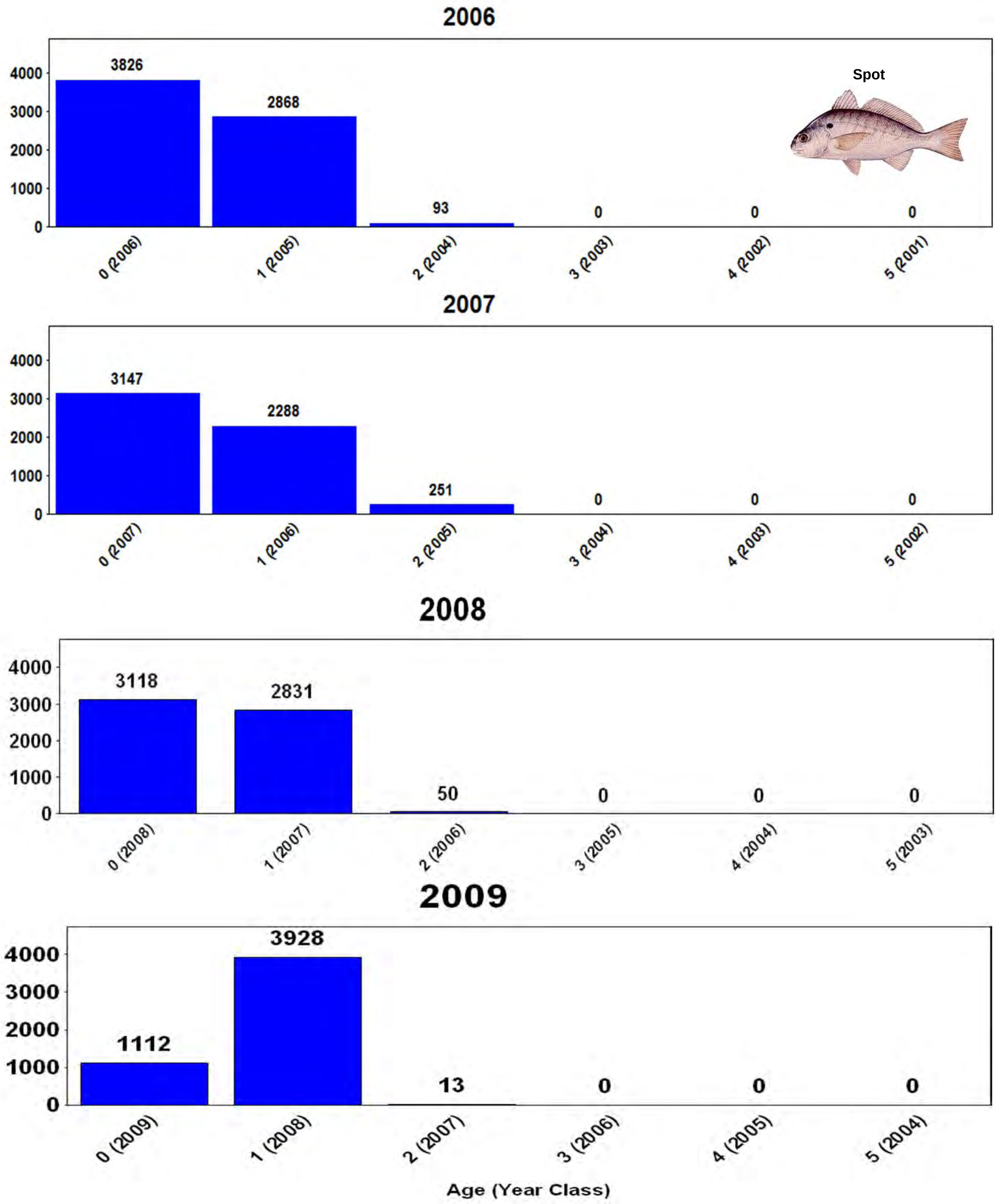


Figure 36. Abundance (kg per hectare swept) of spot in Chesapeake Bay, 2010.

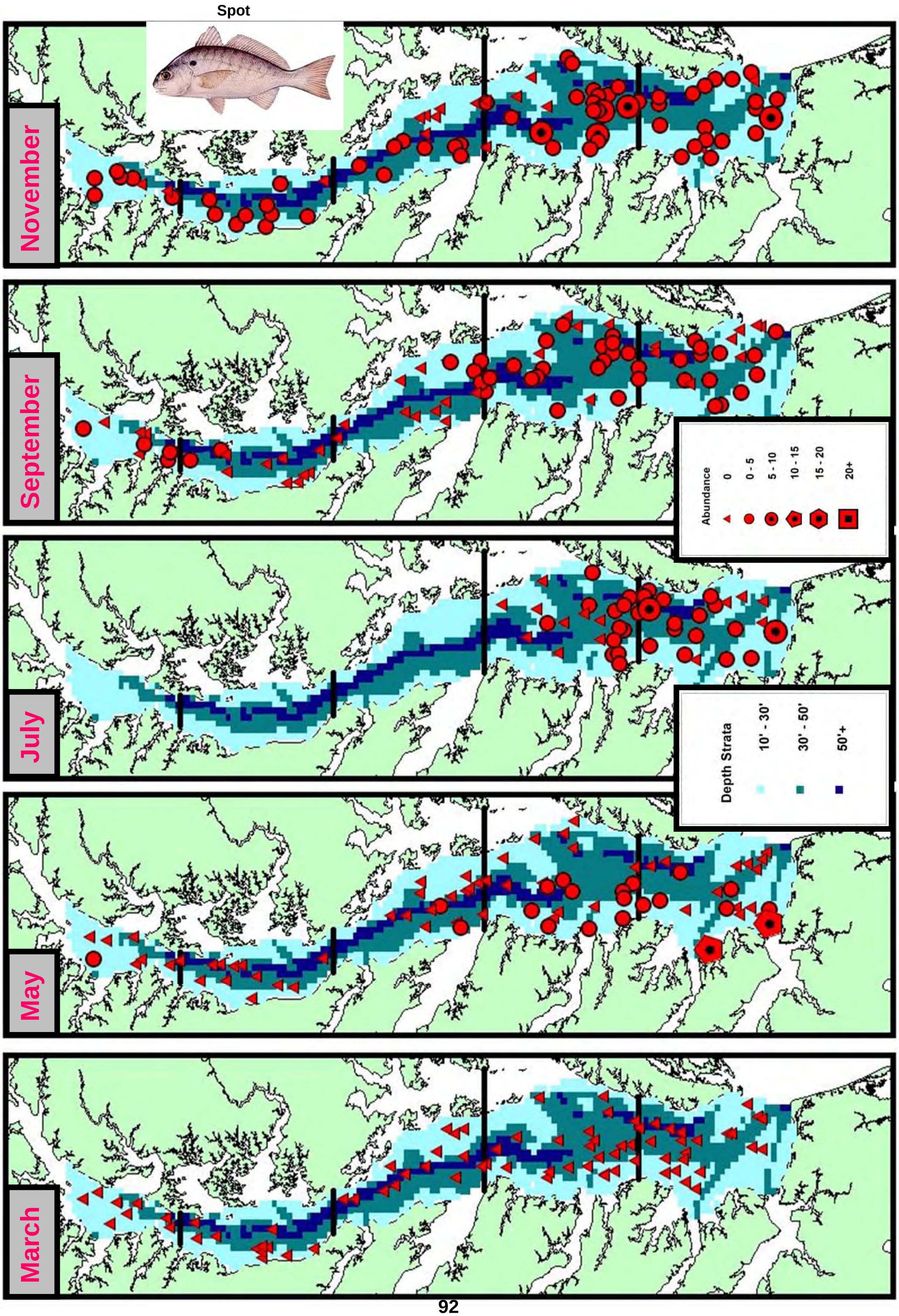


Figure 37. Diet composition, expressed as percent by weight (A) and percent by number (B) of spot collected during ChesMMAP cruises in 2002-2010 combined.

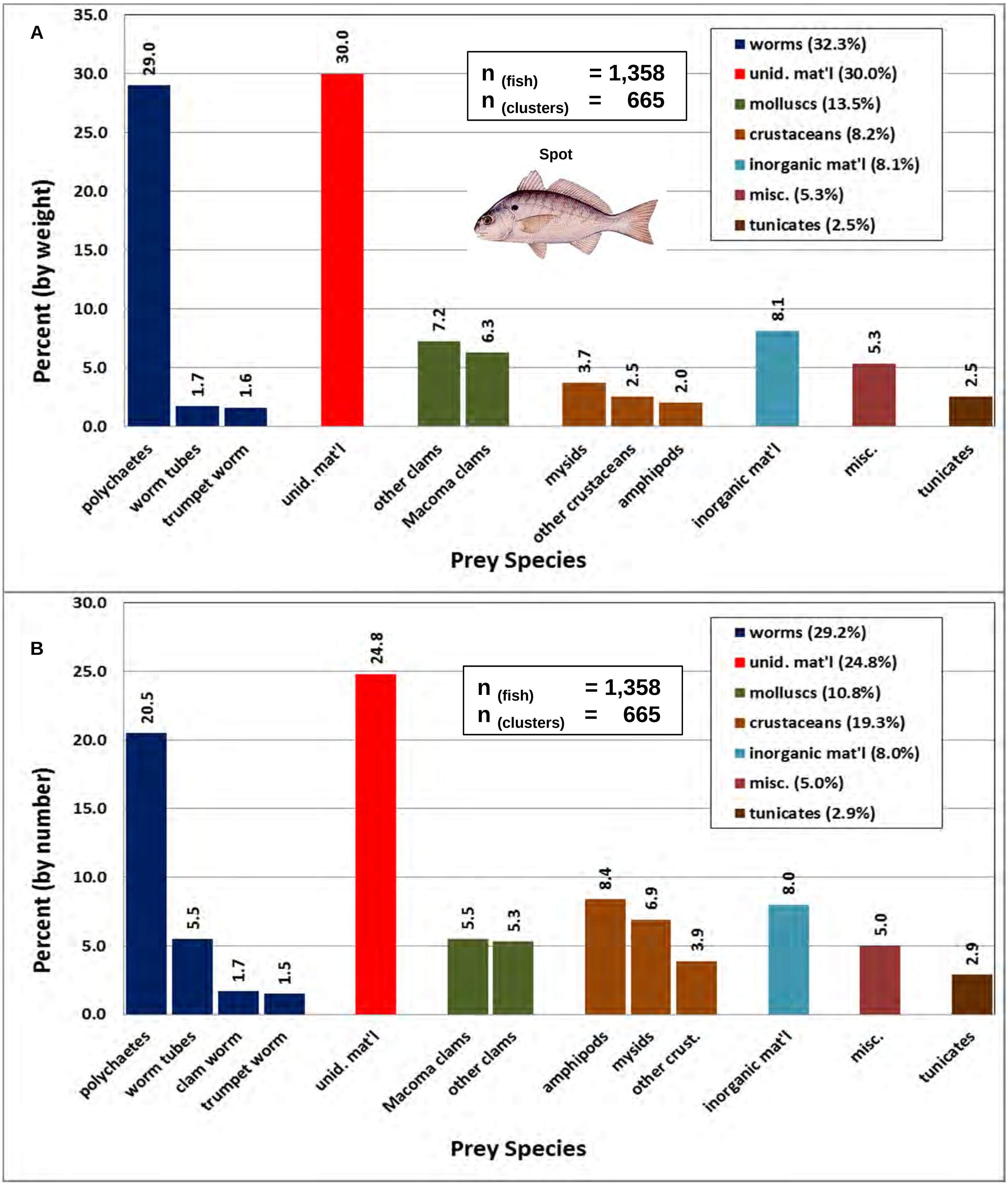
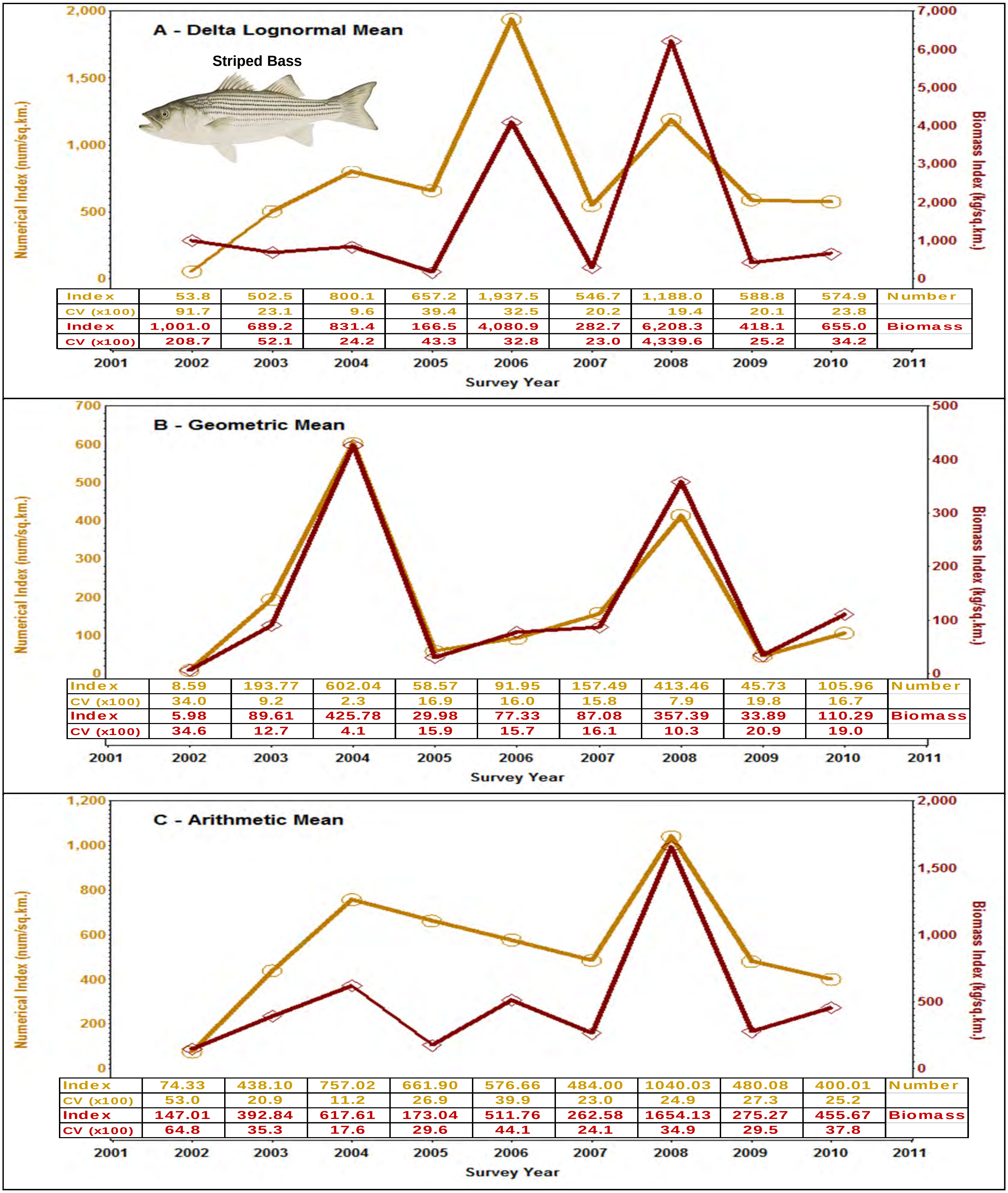


Figure 38. Abundance indices (number and biomass) for striped bass (March) based on delta lognormal (A), geometric (B) and arithmetic (C) means.

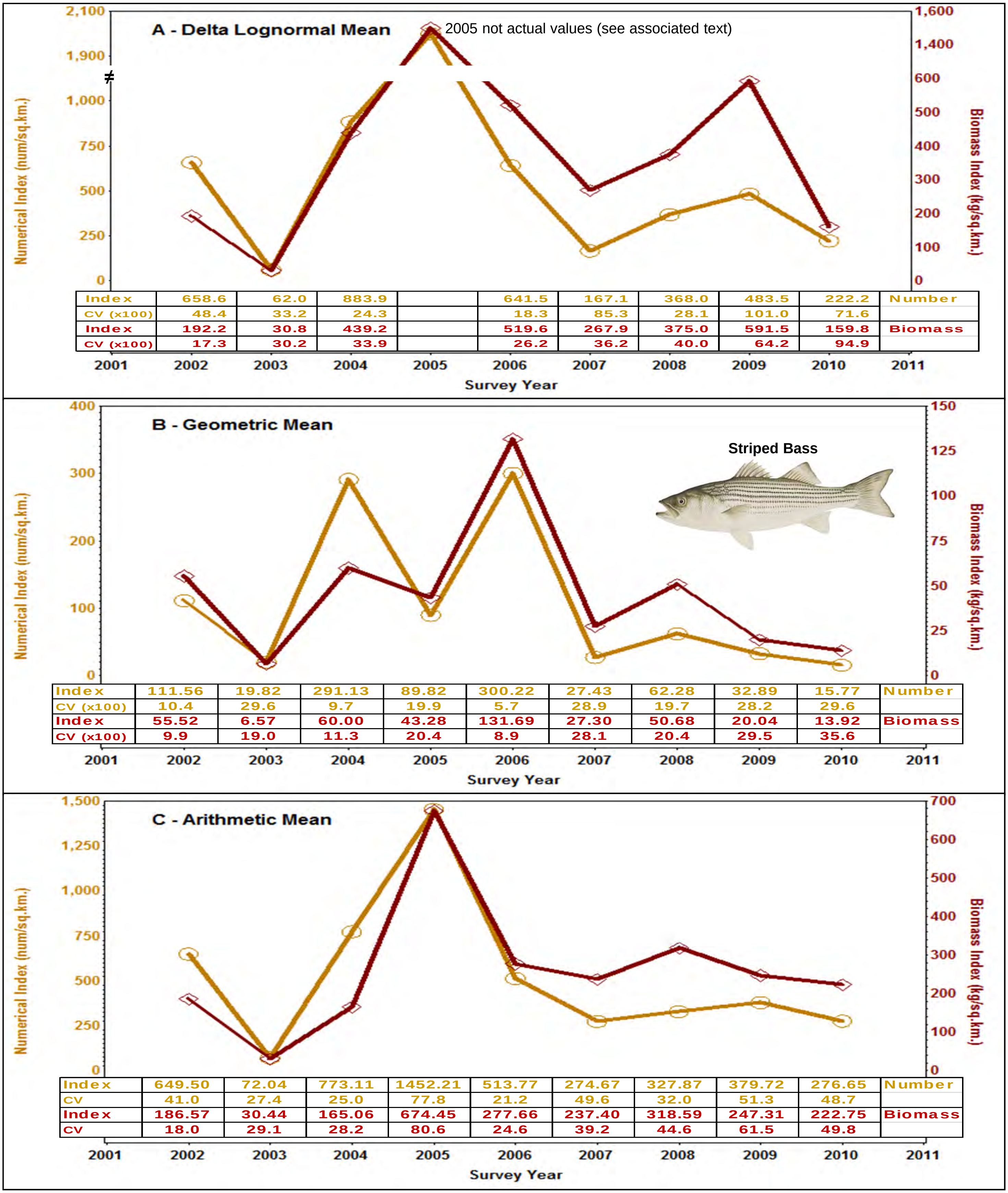


Index	53.8	502.5	800.1	657.2	1,937.5	546.7	1,188.0	588.8	574.9	Number
CV (x100)	91.7	23.1	9.6	39.4	32.5	20.2	19.4	20.1	23.8	
Index	1,001.0	689.2	831.4	166.5	4,080.9	282.7	6,208.3	418.1	655.0	Biomass
CV (x100)	208.7	52.1	24.2	43.3	32.8	23.0	4,339.6	25.2	34.2	

Index	8.59	193.77	602.04	58.57	91.95	157.49	413.46	45.73	105.96	Number
CV (x100)	34.0	9.2	2.3	16.9	16.0	15.8	7.9	19.8	16.7	
Index	5.98	89.61	425.78	29.98	77.33	87.08	357.39	33.89	110.29	Biomass
CV (x100)	34.6	12.7	4.1	15.9	15.7	16.1	10.3	20.9	19.0	

Index	74.33	438.10	757.02	661.90	576.66	484.00	1040.03	480.08	400.01	Number
CV (x100)	53.0	20.9	11.2	26.9	39.9	23.0	24.9	27.3	25.2	
Index	147.01	392.84	617.61	173.04	511.76	262.58	1654.13	275.27	455.67	Biomass
CV (x100)	64.8	35.3	17.6	29.6	44.1	24.1	34.9	29.5	37.8	

Figure 39. Abundance indices (number and biomass) for striped bass (November) based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	658.6	62.0	883.9		641.5	167.1	368.0	483.5	222.2	Number
CV (x100)	48.4	33.2	24.3		18.3	85.3	28.1	101.0	71.6	
Index	192.2	30.8	439.2		519.6	267.9	375.0	591.5	159.8	Biomass
CV (x100)	17.3	30.2	33.9		26.2	36.2	40.0	64.2	94.9	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	111.56	19.82	291.13	89.82	300.22	27.43	62.28	32.89	15.77	Number
CV (x100)	10.4	29.6	9.7	19.9	5.7	28.9	19.7	28.2	29.6	
Index	55.52	6.57	60.00	43.28	131.69	27.30	50.68	20.04	13.92	Biomass
CV (x100)	9.9	19.0	11.3	20.4	8.9	28.1	20.4	29.5	35.6	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	649.50	72.04	773.11	1452.21	513.77	274.67	327.87	379.72	276.65	Number
CV	41.0	27.4	25.0	77.8	21.2	49.6	32.0	51.3	48.7	
Index	186.57	30.44	165.06	674.45	277.66	237.40	318.59	247.31	222.75	Biomass
CV	18.0	29.1	28.2	80.6	24.6	39.2	44.6	61.5	49.8	

Figure 40. Striped bass length-frequency in Chesapeake Bay, 2002-2010.

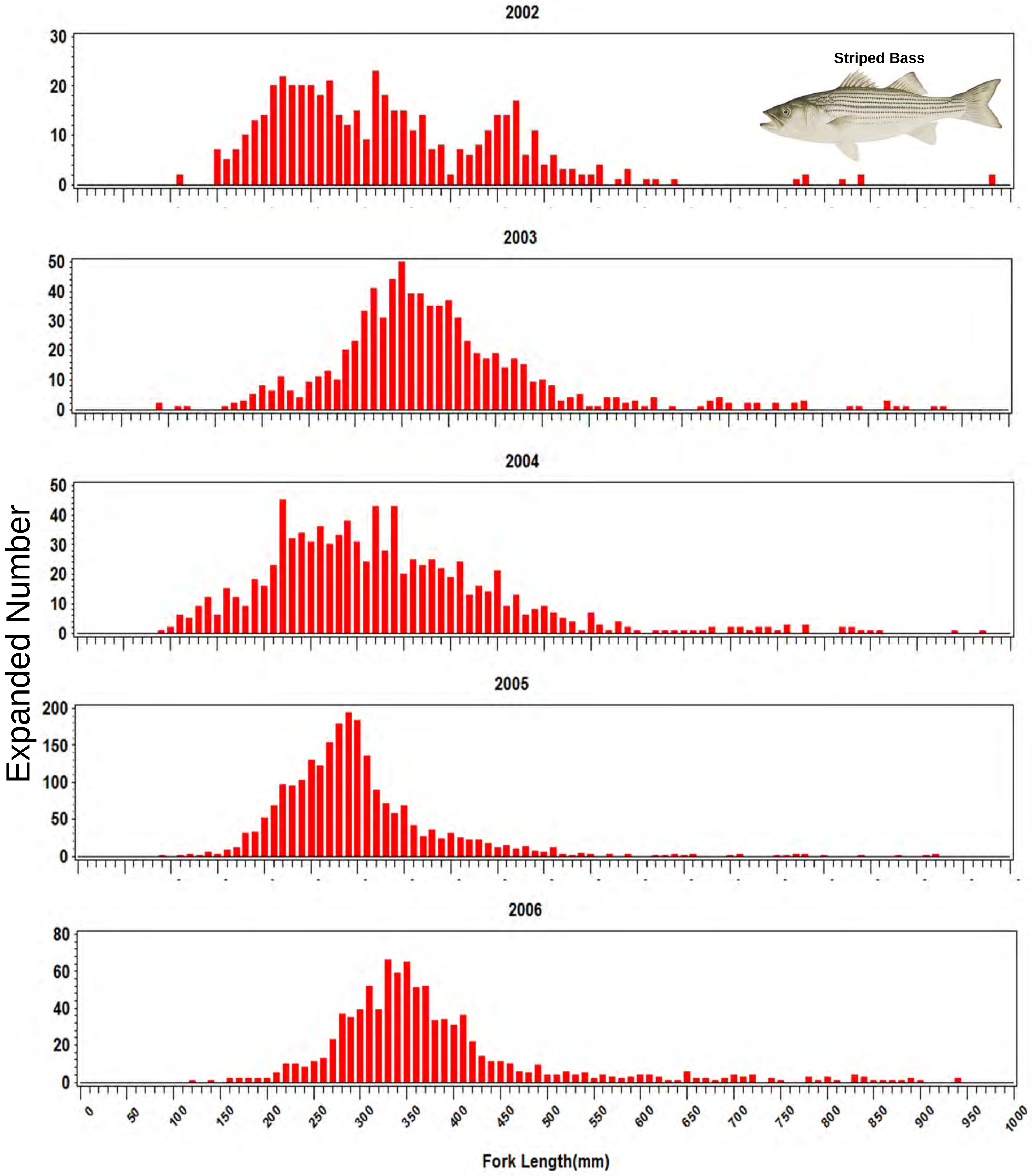


Figure 40. continued.

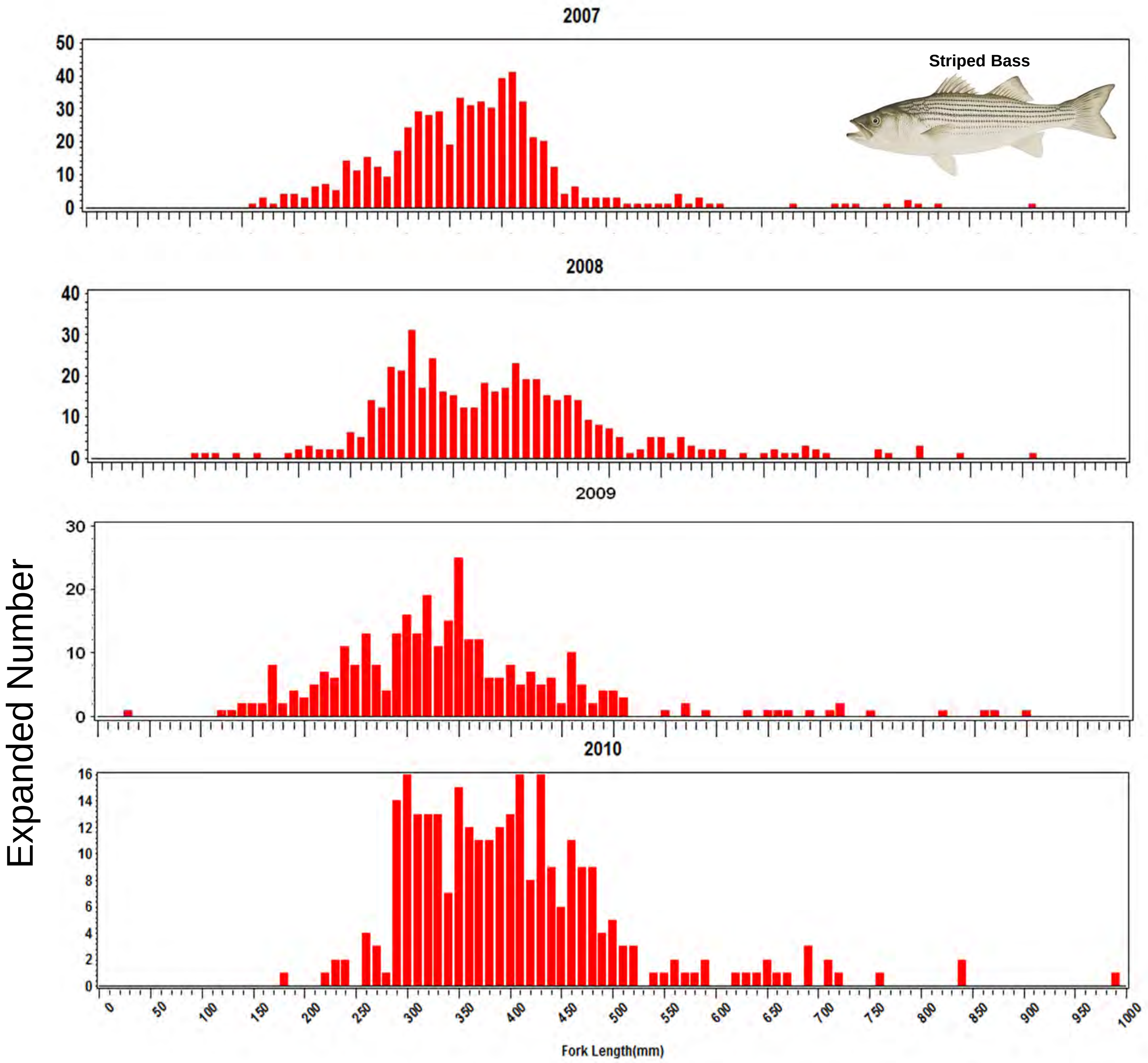


Figure 41. Striped bass age-structure in Chesapeake Bay, 2002-2009.

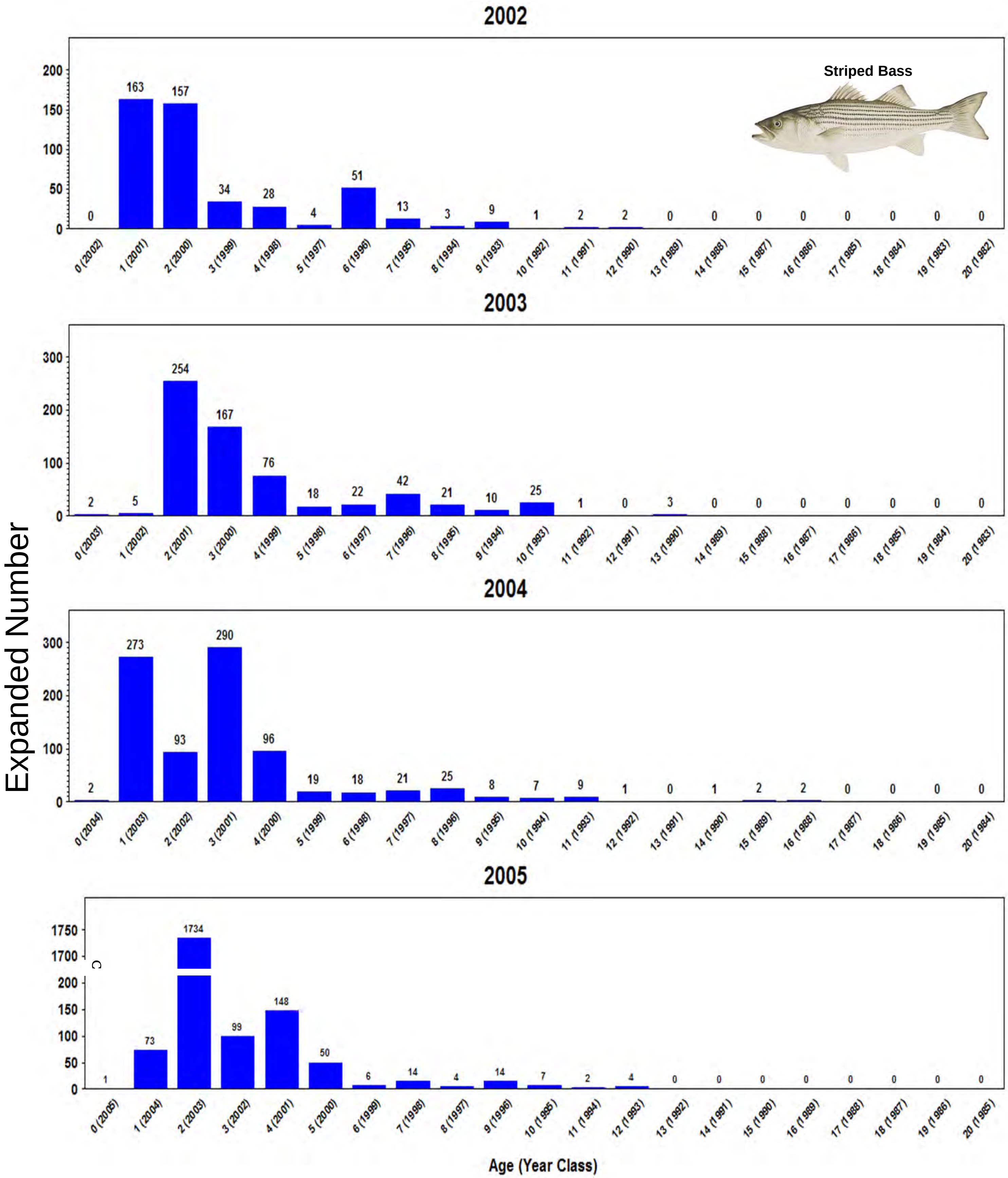


Figure 41. continued.

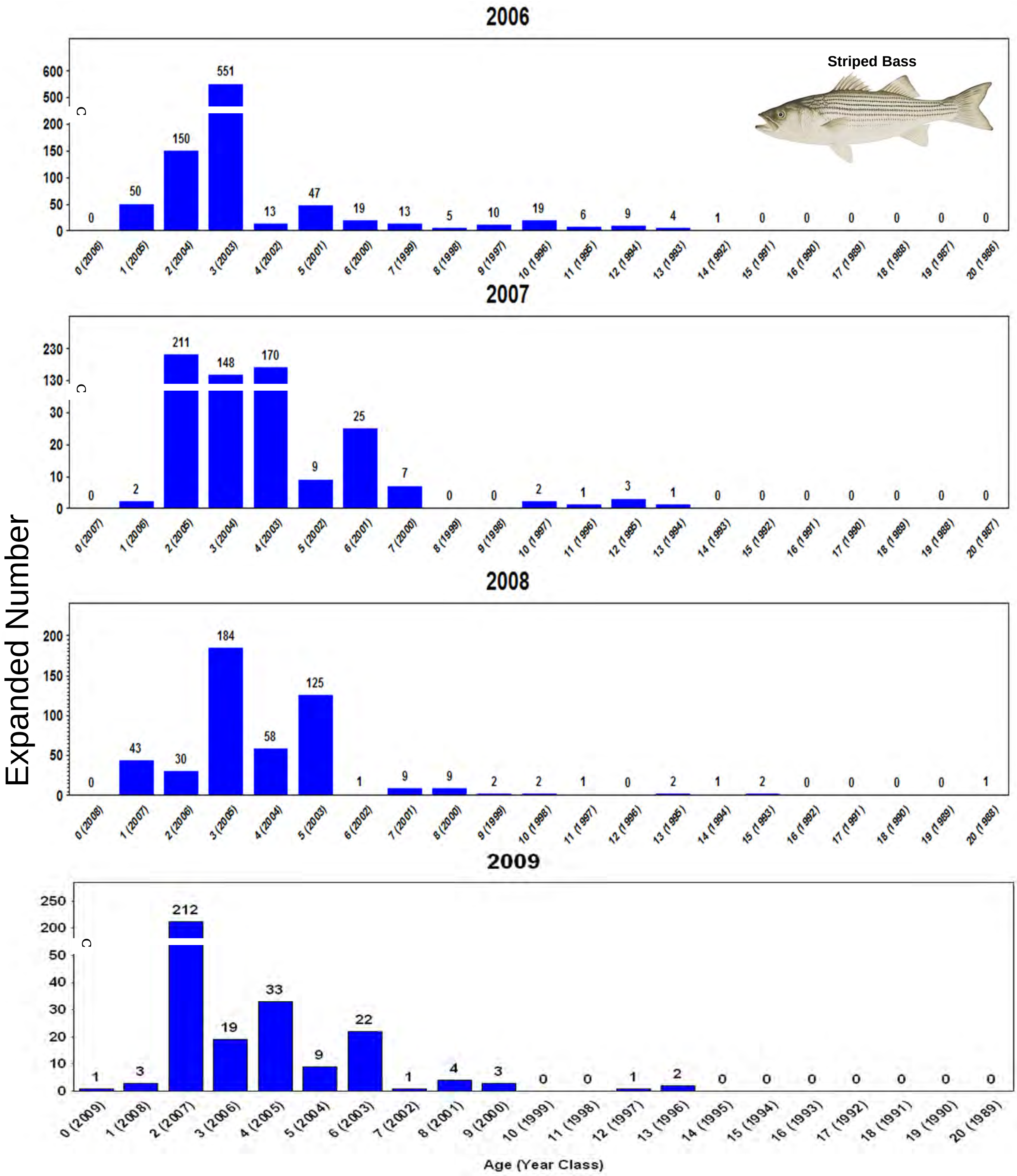


Figure 42. Abundance (kg per hectare swept) of striped bass in Chesapeake Bay, 2010.

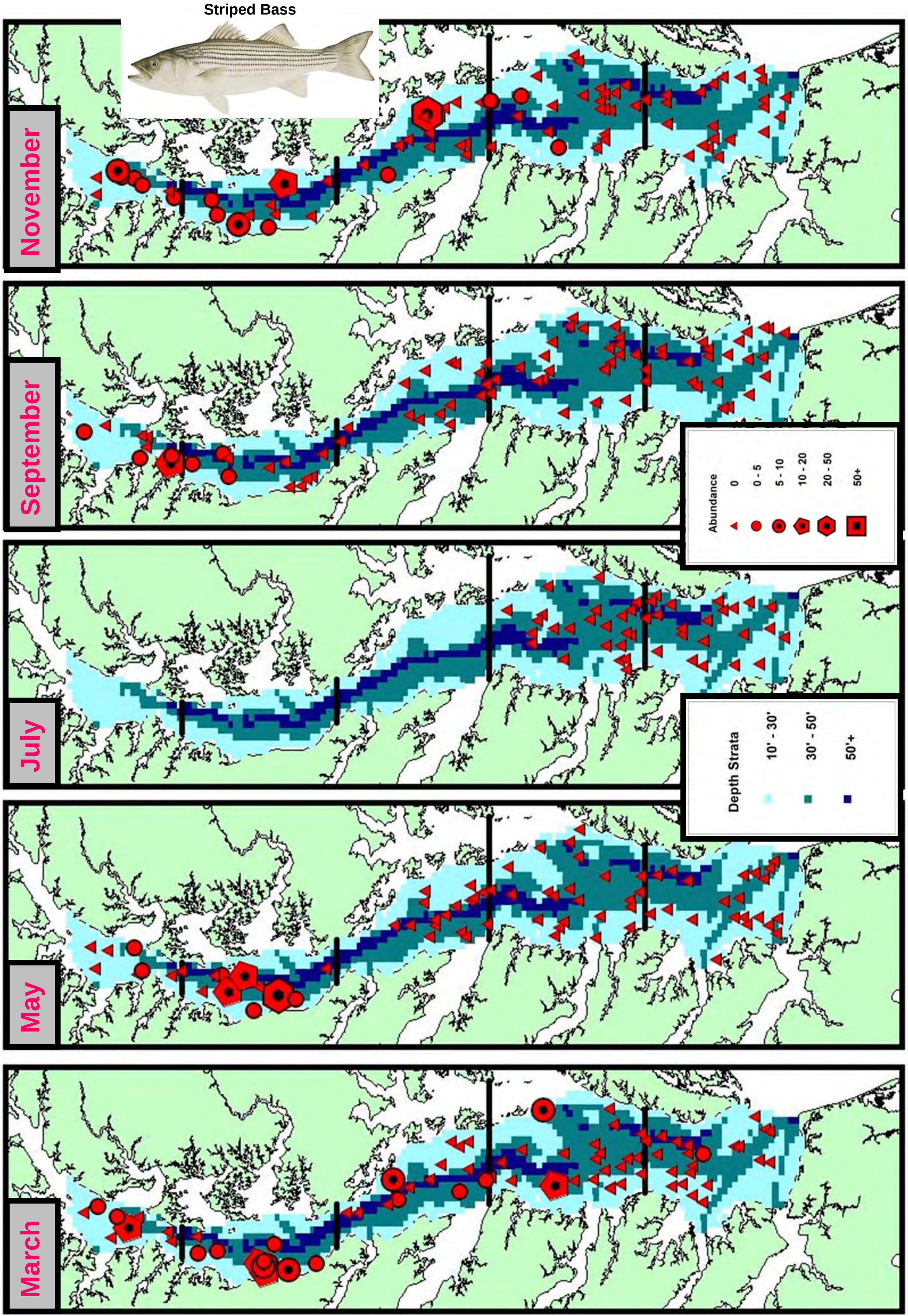


Figure 43. Diet composition, expressed as percent by weight (A) and percent by number (B) of striped bass collected during ChesMMAP cruises in 2002-2010 combined.

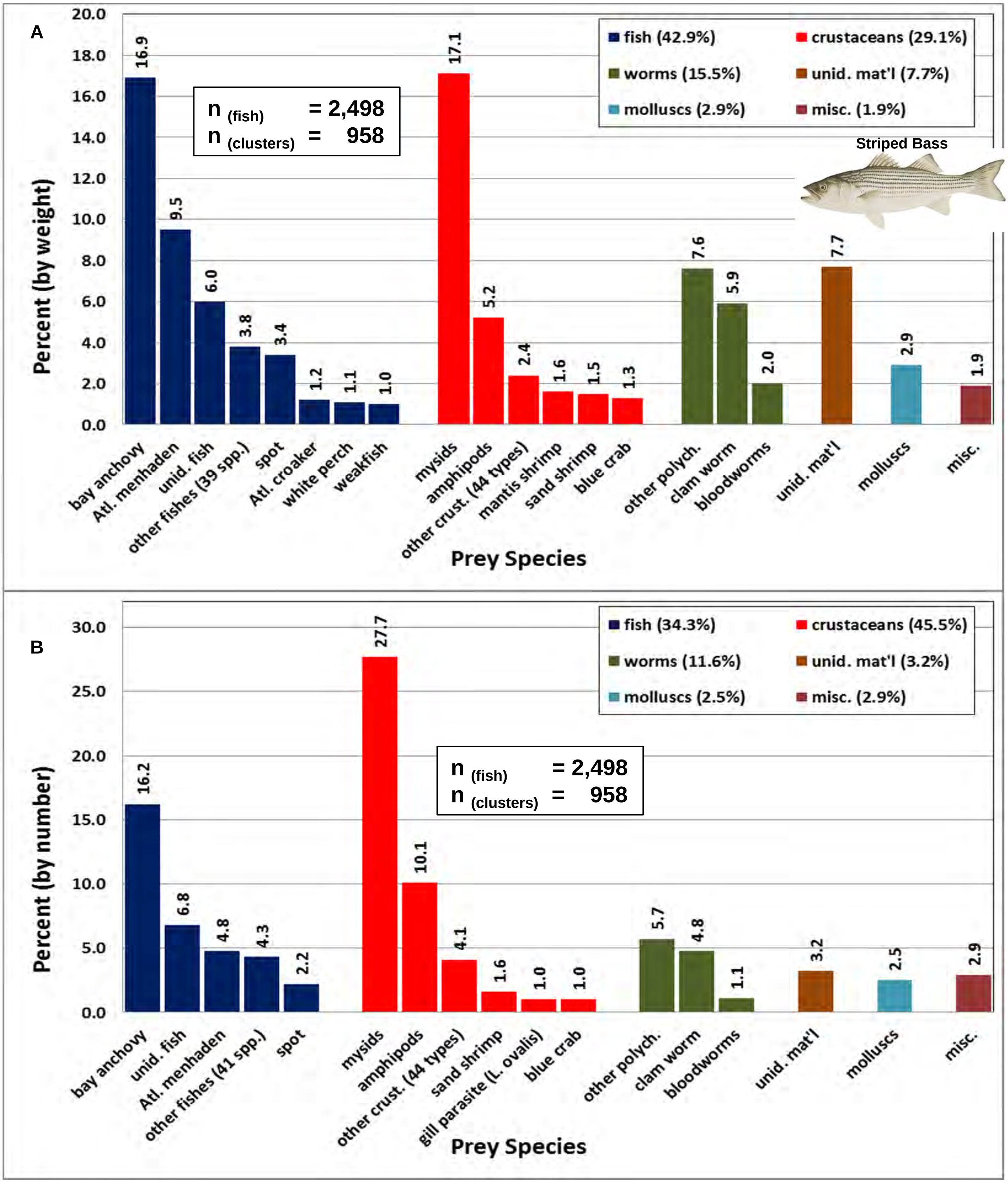
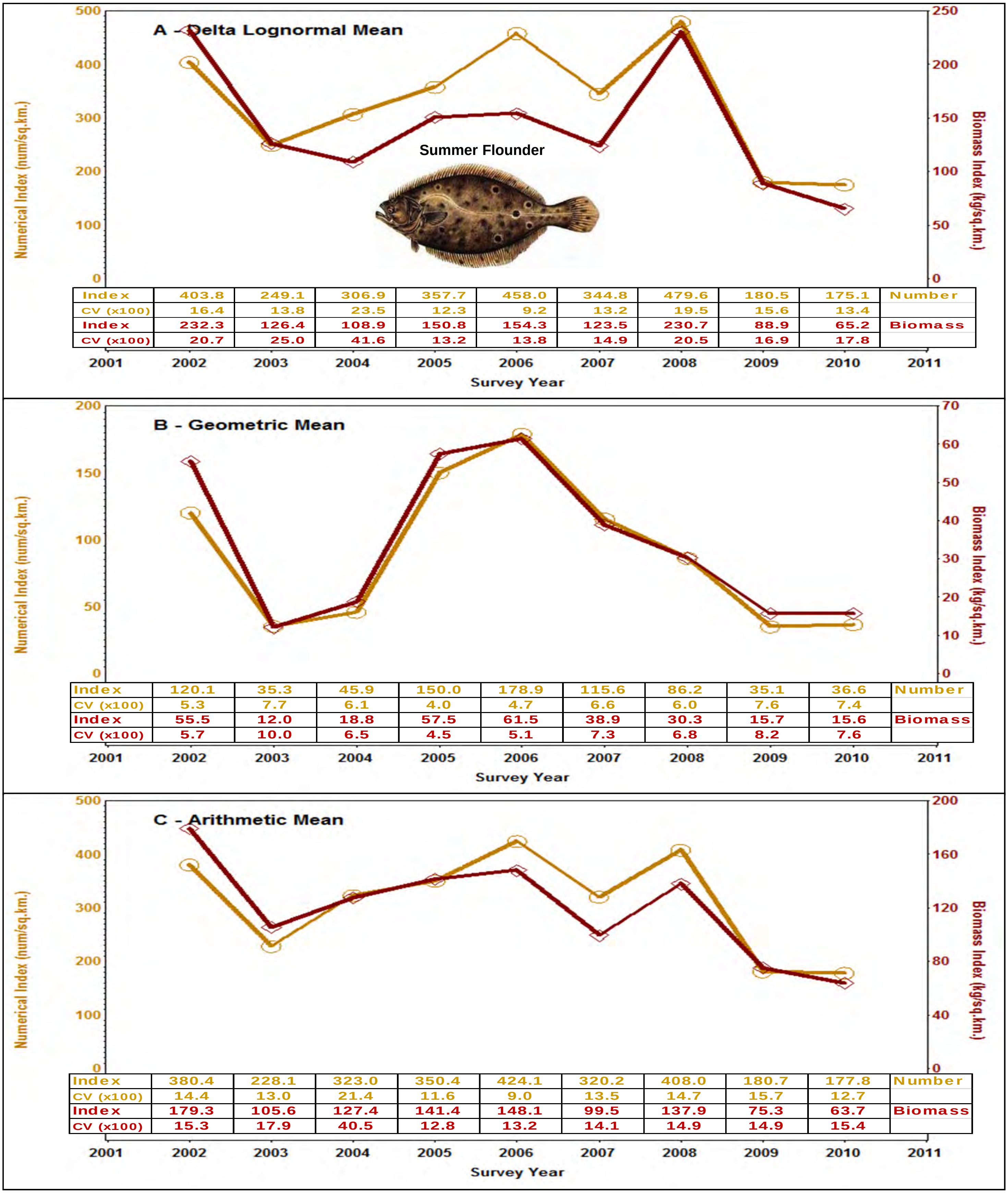


Figure 44. Abundance indices (number and biomass) for summer flounder based on delta lognormal (A), geometric (B) and arithmetic (C) means.



Index	403.8	249.1	306.9	357.7	458.0	344.8	479.6	180.5	175.1	Number
CV (x100)	16.4	13.8	23.5	12.3	9.2	13.2	19.5	15.6	13.4	
Index	232.3	126.4	108.9	150.8	154.3	123.5	230.7	88.9	65.2	Biomass
CV (x100)	20.7	25.0	41.6	13.2	13.8	14.9	20.5	16.9	17.8	

Index	120.1	35.3	45.9	150.0	178.9	115.6	86.2	35.1	36.6	Number
CV (x100)	5.3	7.7	6.1	4.0	4.7	6.6	6.0	7.6	7.4	
Index	55.5	12.0	18.8	57.5	61.5	38.9	30.3	15.7	15.6	Biomass
CV (x100)	5.7	10.0	6.5	4.5	5.1	7.3	6.8	8.2	7.6	

Index	380.4	228.1	323.0	350.4	424.1	320.2	408.0	180.7	177.8	Number
CV (x100)	14.4	13.0	21.4	11.6	9.0	13.5	14.7	15.7	12.7	
Index	179.3	105.6	127.4	141.4	148.1	99.5	137.9	75.3	63.7	Biomass
CV (x100)	15.3	17.9	40.5	12.8	13.2	14.1	14.9	14.9	15.4	

Figure 45. Summer flounder length-frequency in Chesapeake Bay, 2002-2010.

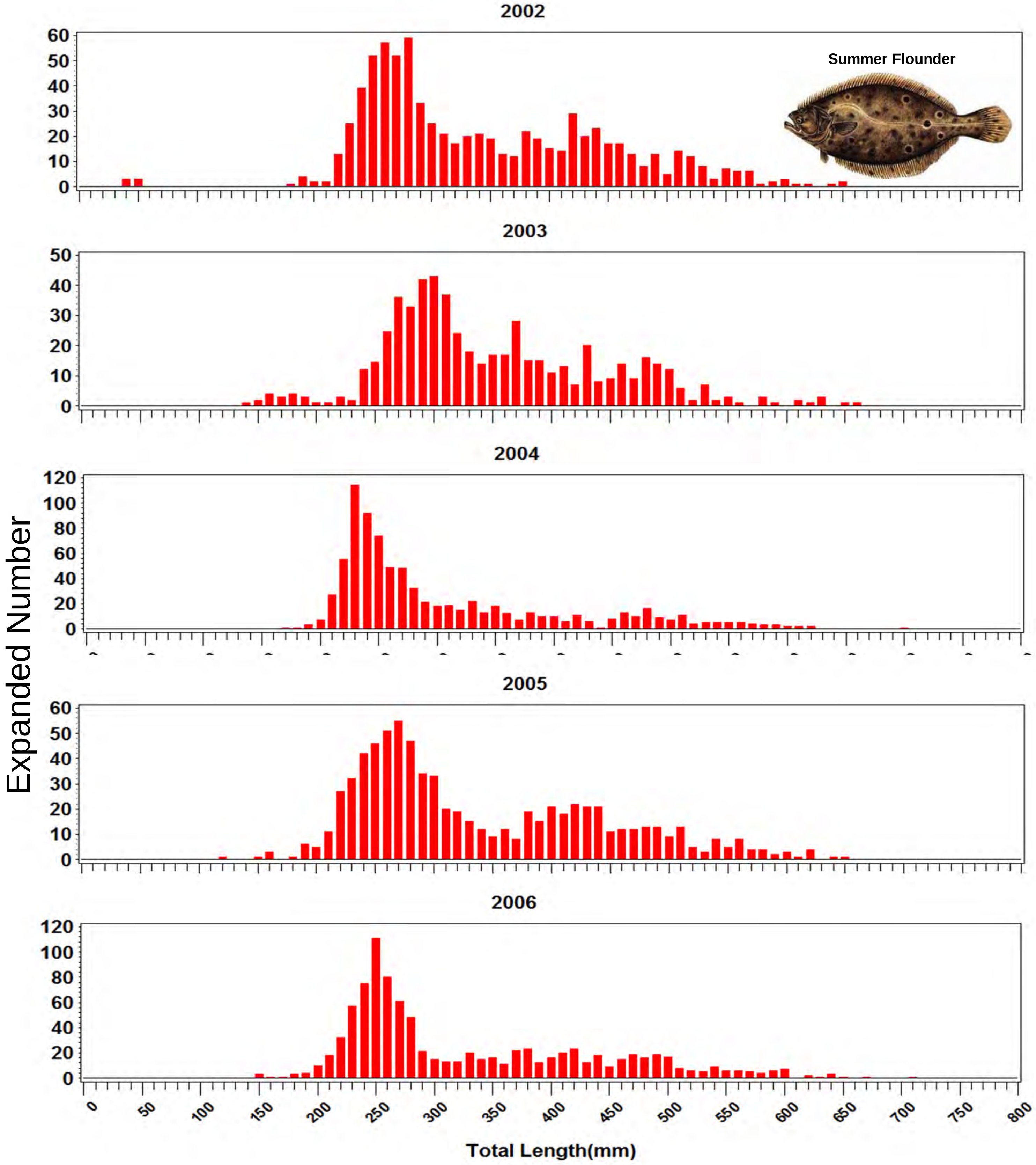


Figure 45. continued.

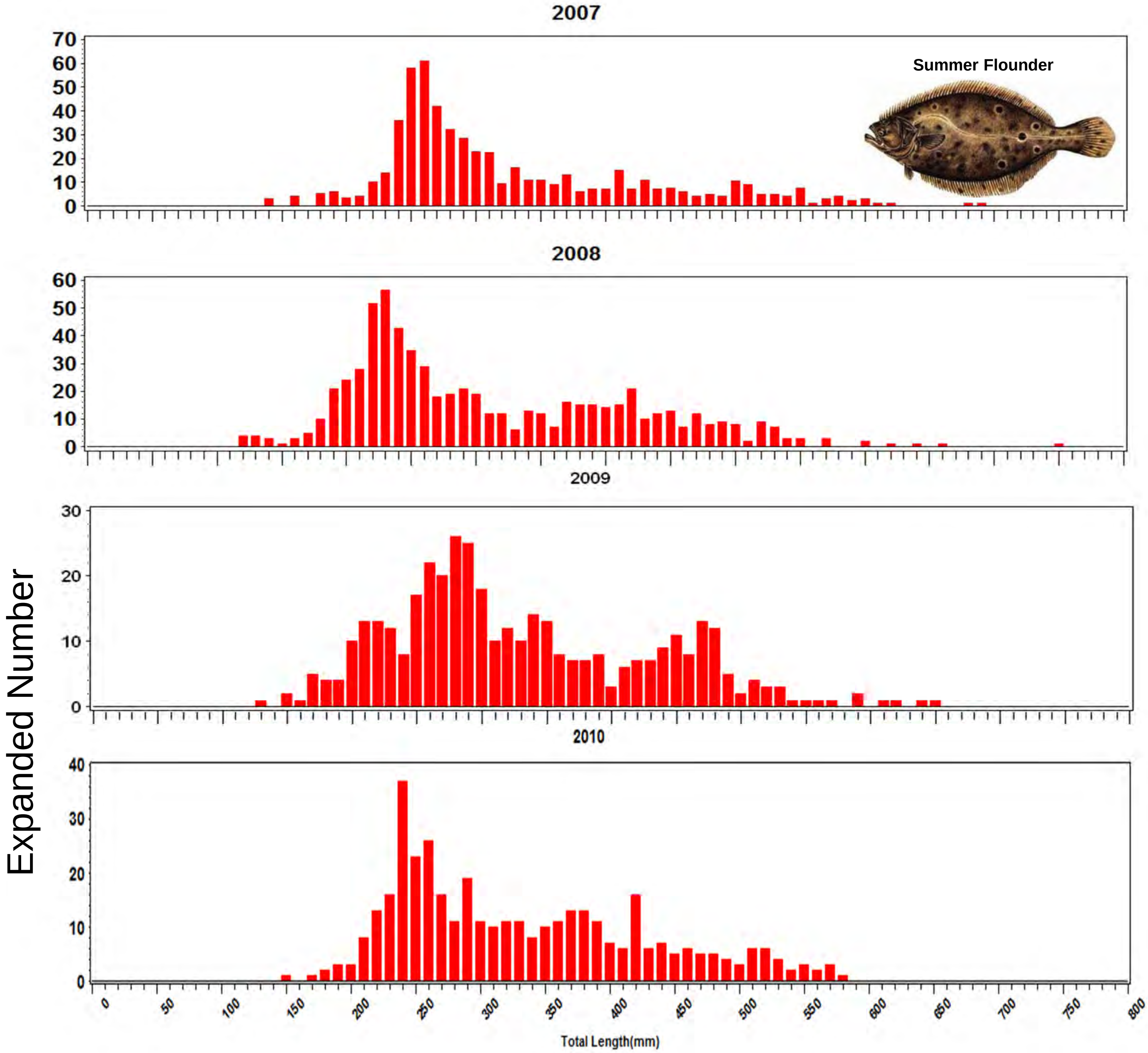


Figure 46. Summer flounder age-structure in Chesapeake Bay, 2002-2009.

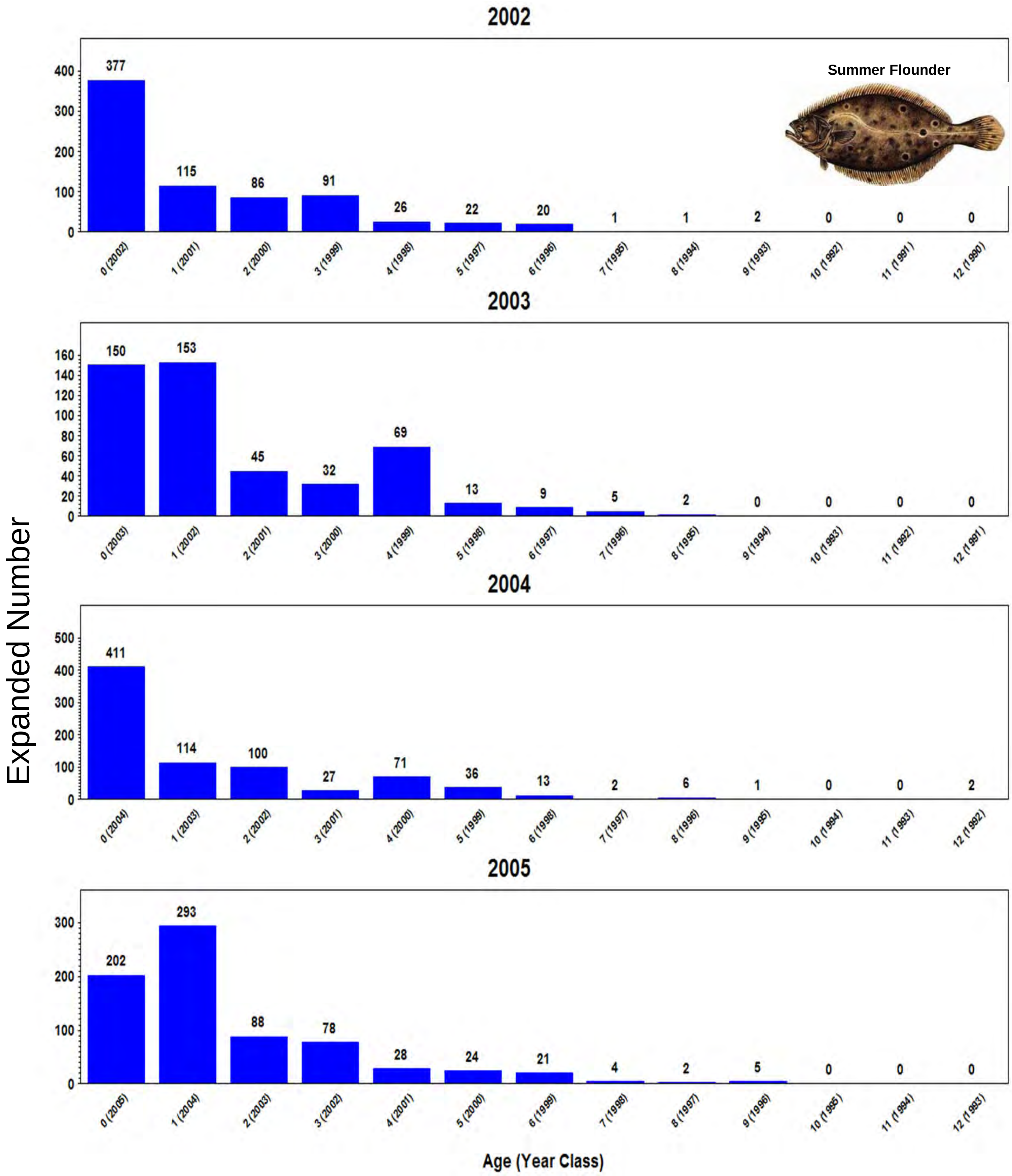


Figure 46. continued.

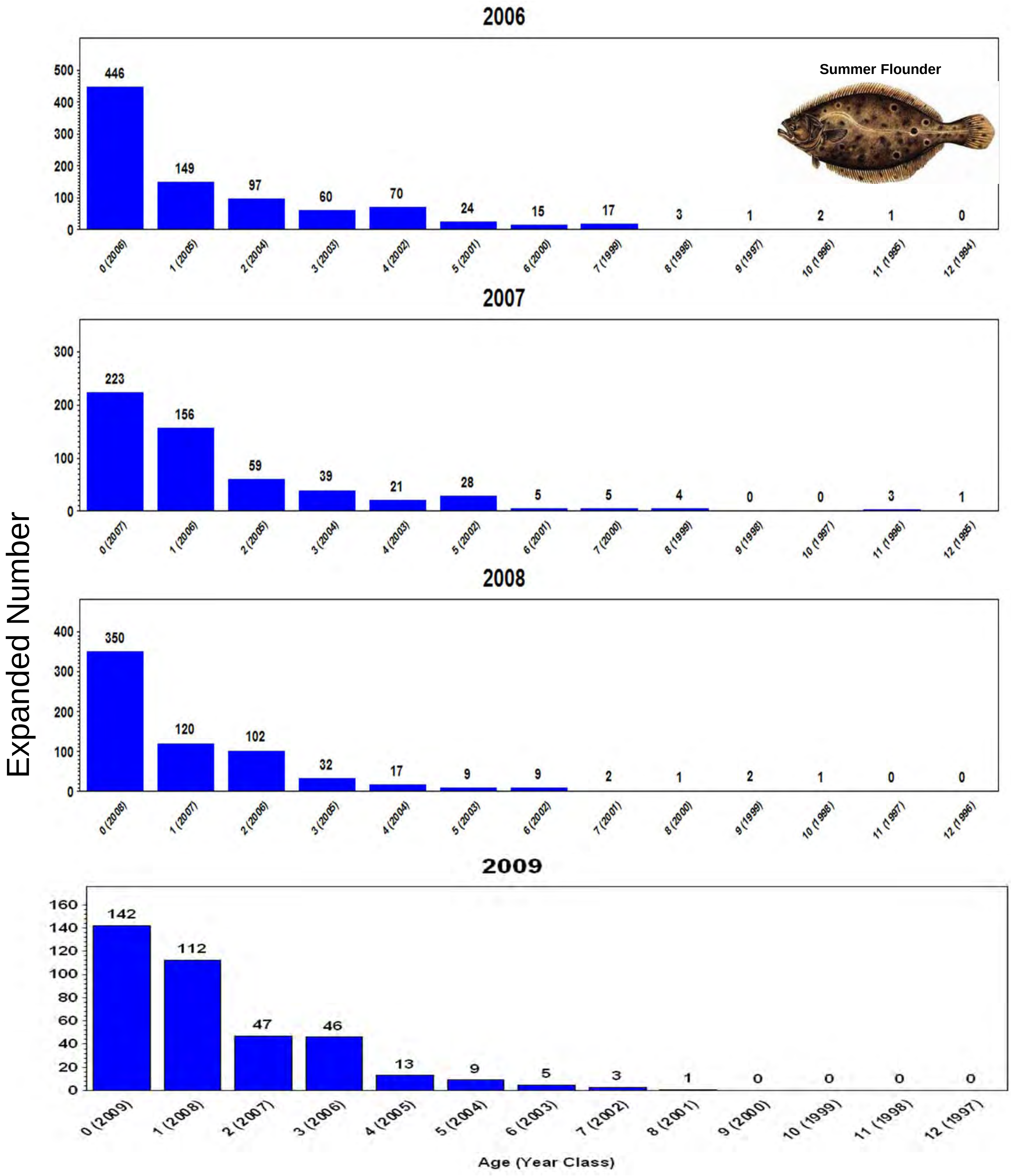


Figure 47. Abundance (kg per hectare swept) of summer flounder in Chesapeake Bay, 2010.

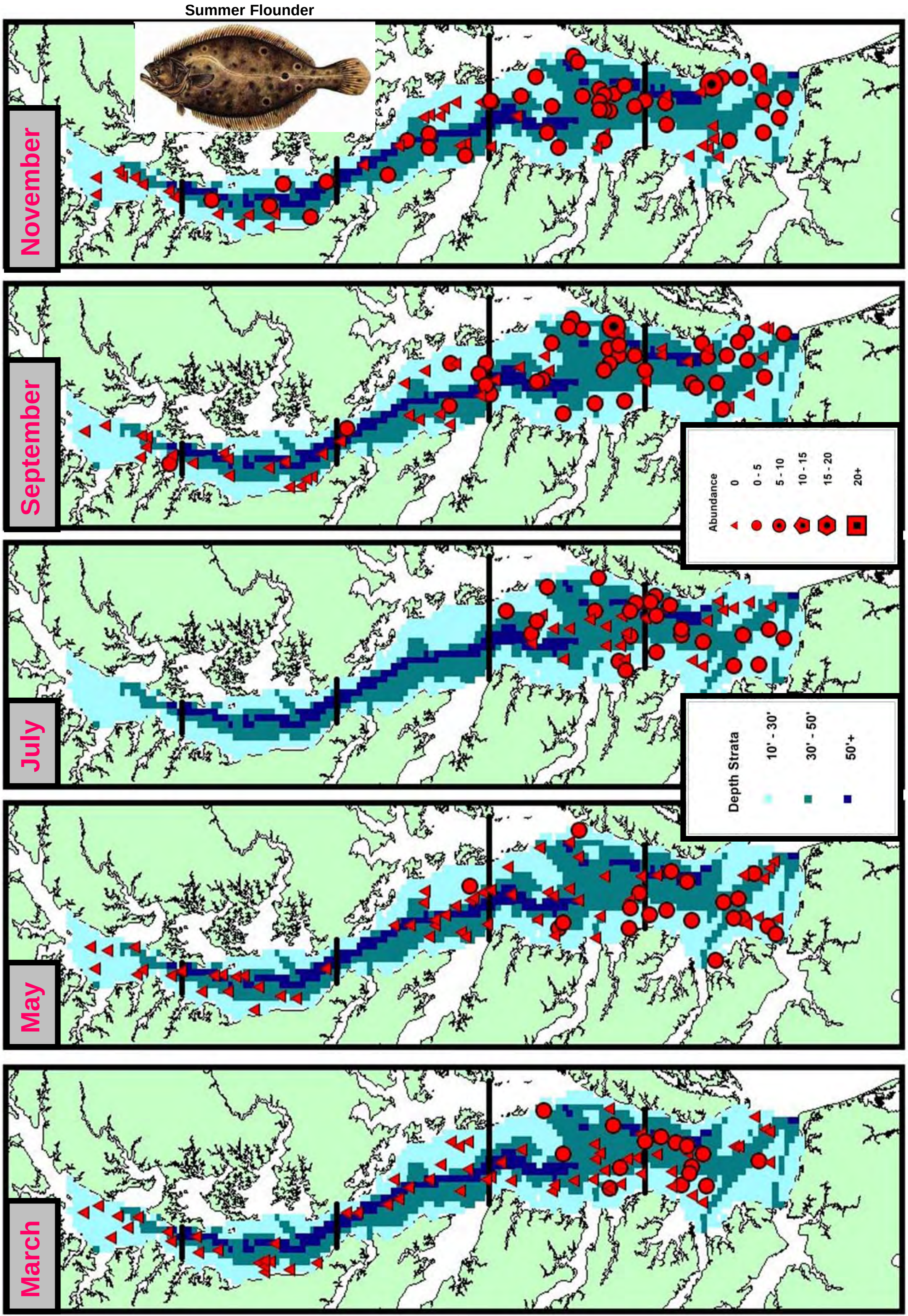


Figure 48. Diet composition, expressed as percent by weight (A) and percent by number (B) of summer flounder collected during ChesMMAP cruises in 2002-2010 combined.

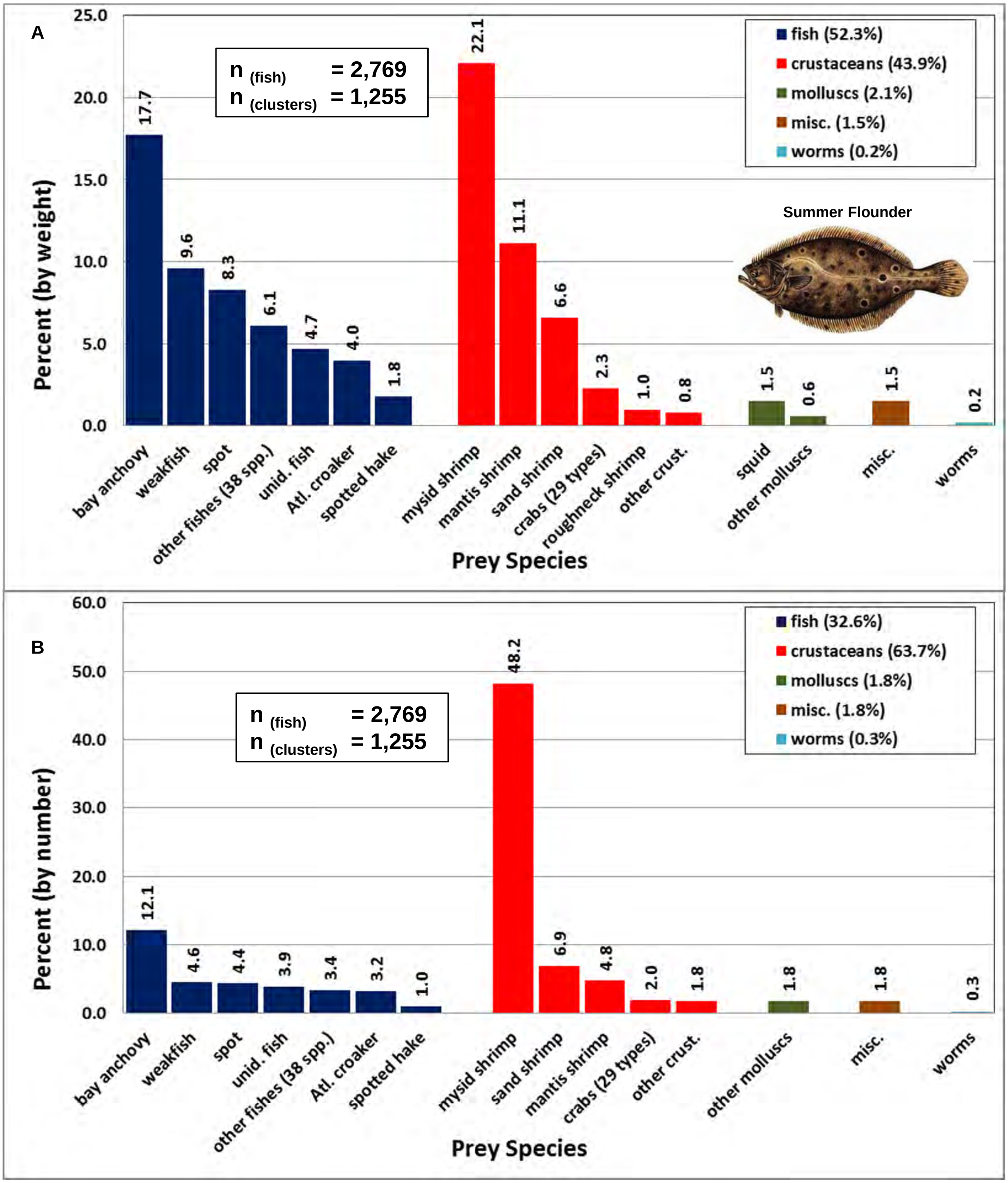
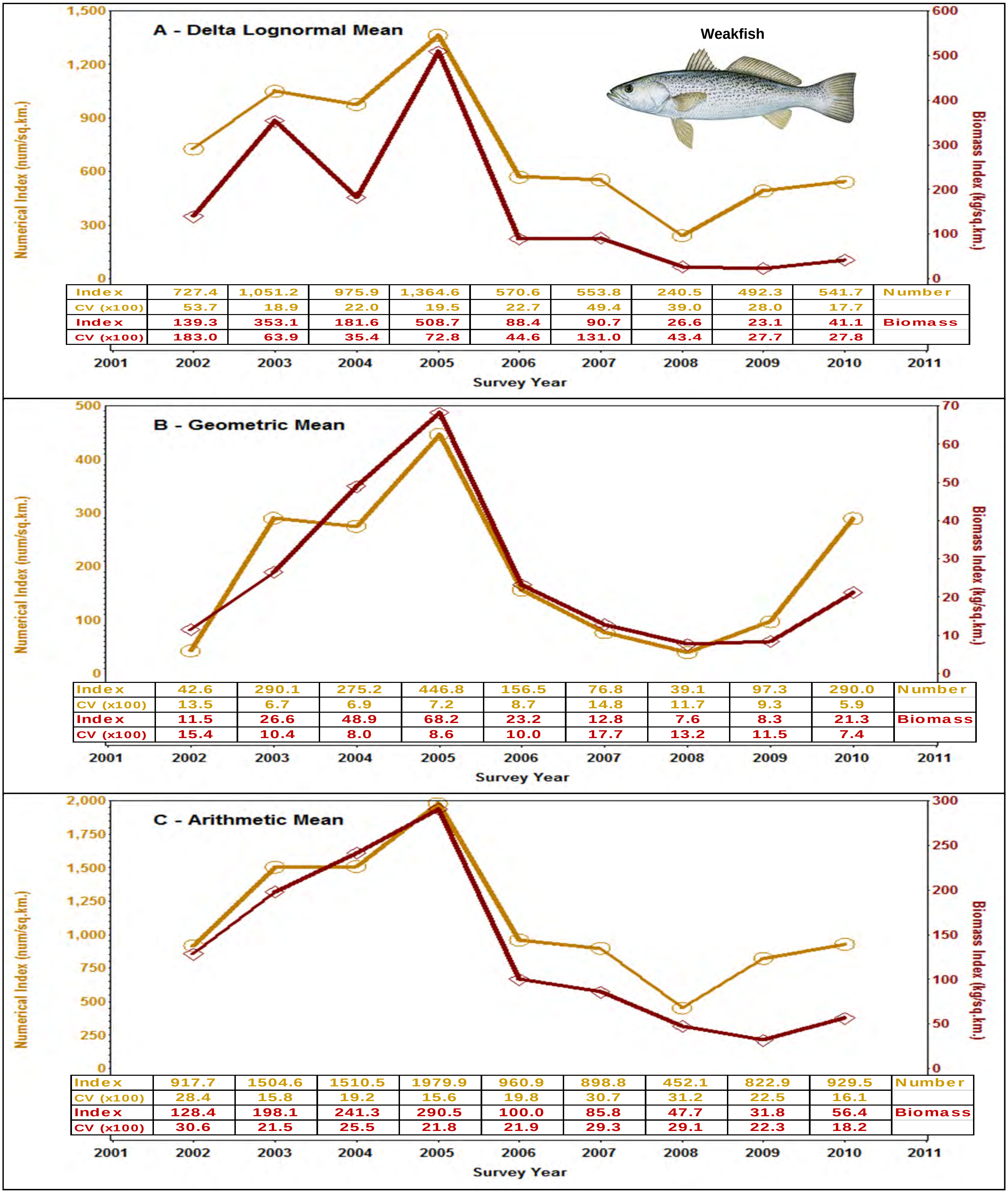


Figure 49. Abundance indices (number and biomass) for weakfish based on delta lognormal (A), geometric (B) and arithmetic (C) means.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	727.4	1,051.2	975.9	1,364.6	570.6	553.8	240.5	492.3	541.7	Number
CV (x100)	53.7	18.9	22.0	19.5	22.7	49.4	39.0	28.0	17.7	
Index	139.3	353.1	181.6	508.7	88.4	90.7	26.6	23.1	41.1	Biomass
CV (x100)	183.0	63.9	35.4	72.8	44.6	131.0	43.4	27.7	27.8	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	42.6	290.1	275.2	446.8	156.5	76.8	39.1	97.3	290.0	Number
CV (x100)	13.5	6.7	6.9	7.2	8.7	14.8	11.7	9.3	5.9	
Index	11.5	26.6	48.9	68.2	23.2	12.8	7.6	8.3	21.3	Biomass
CV (x100)	15.4	10.4	8.0	8.6	10.0	17.7	13.2	11.5	7.4	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	917.7	1504.6	1510.5	1979.9	960.9	898.8	452.1	822.9	929.5	Number
CV (x100)	28.4	15.8	19.2	15.6	19.8	30.7	31.2	22.5	16.1	
Index	128.4	198.1	241.3	290.5	100.0	85.8	47.7	31.8	56.4	Biomass
CV (x100)	30.6	21.5	25.5	21.8	21.9	29.3	29.1	22.3	18.2	

Figure 50. Weakfish length-frequency in Chesapeake Bay, 2002-2010.

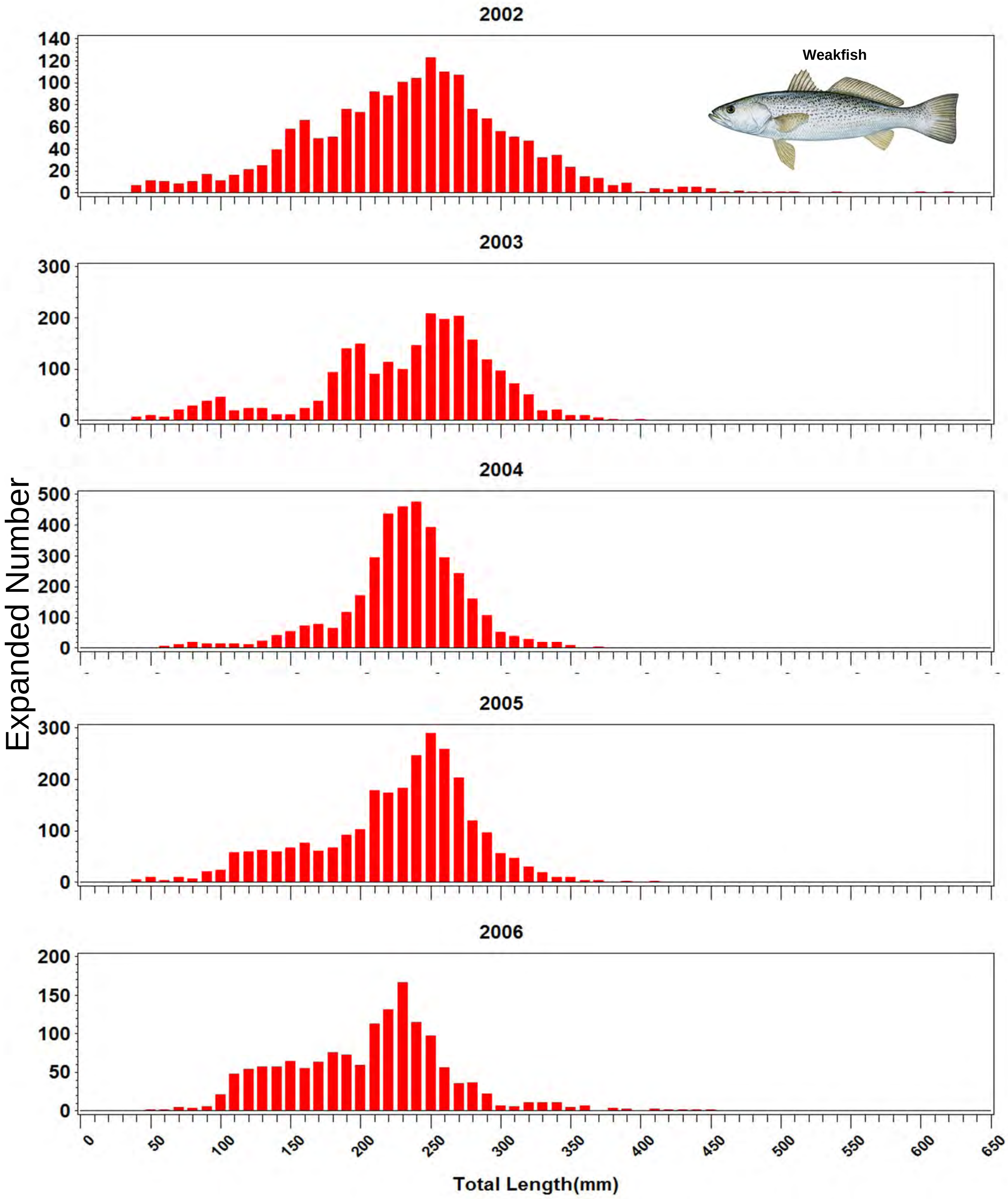


Figure 50. continued.

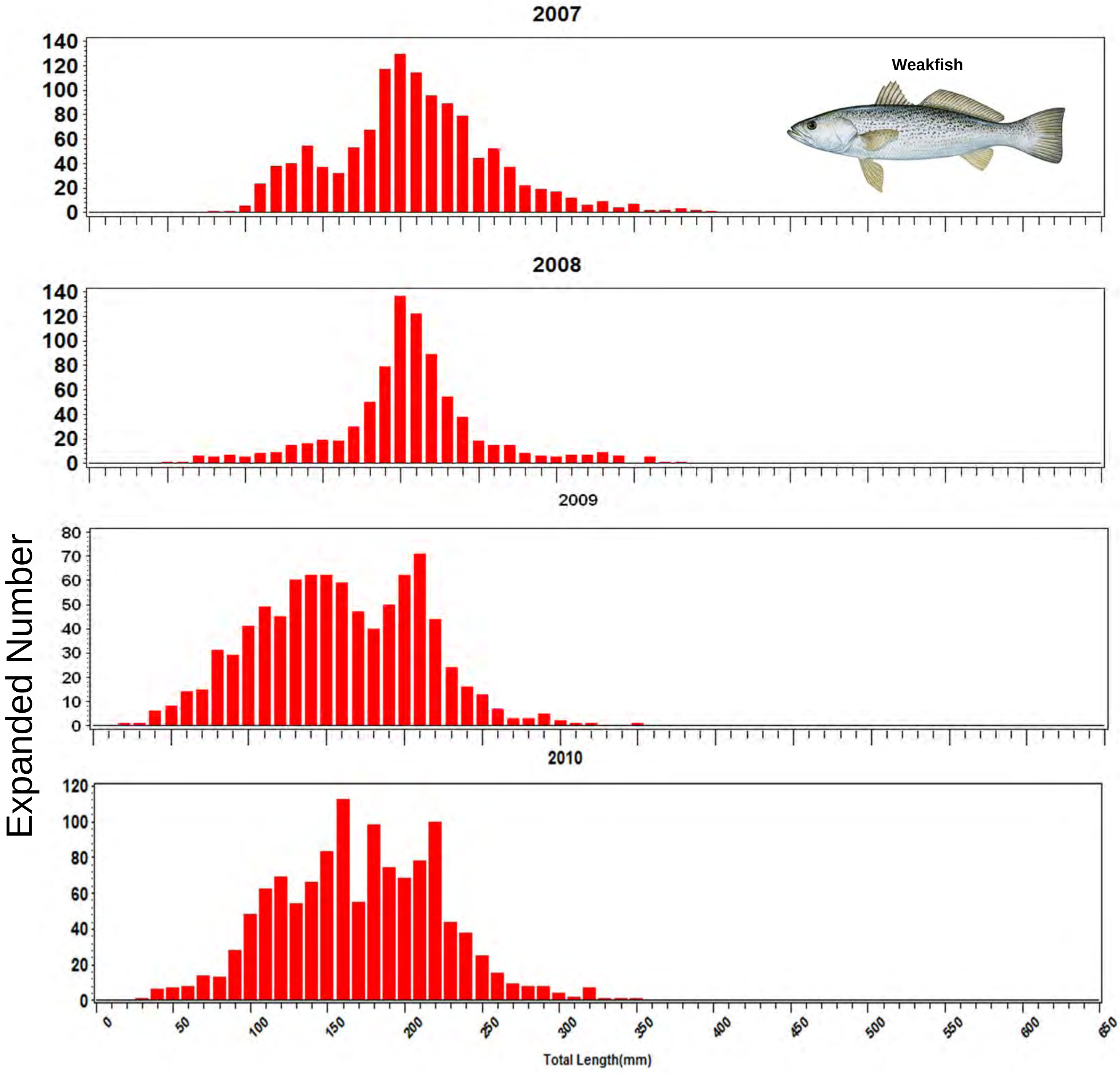


Figure 51. Weakfish age-structure in Chesapeake Bay, 2002-2009.

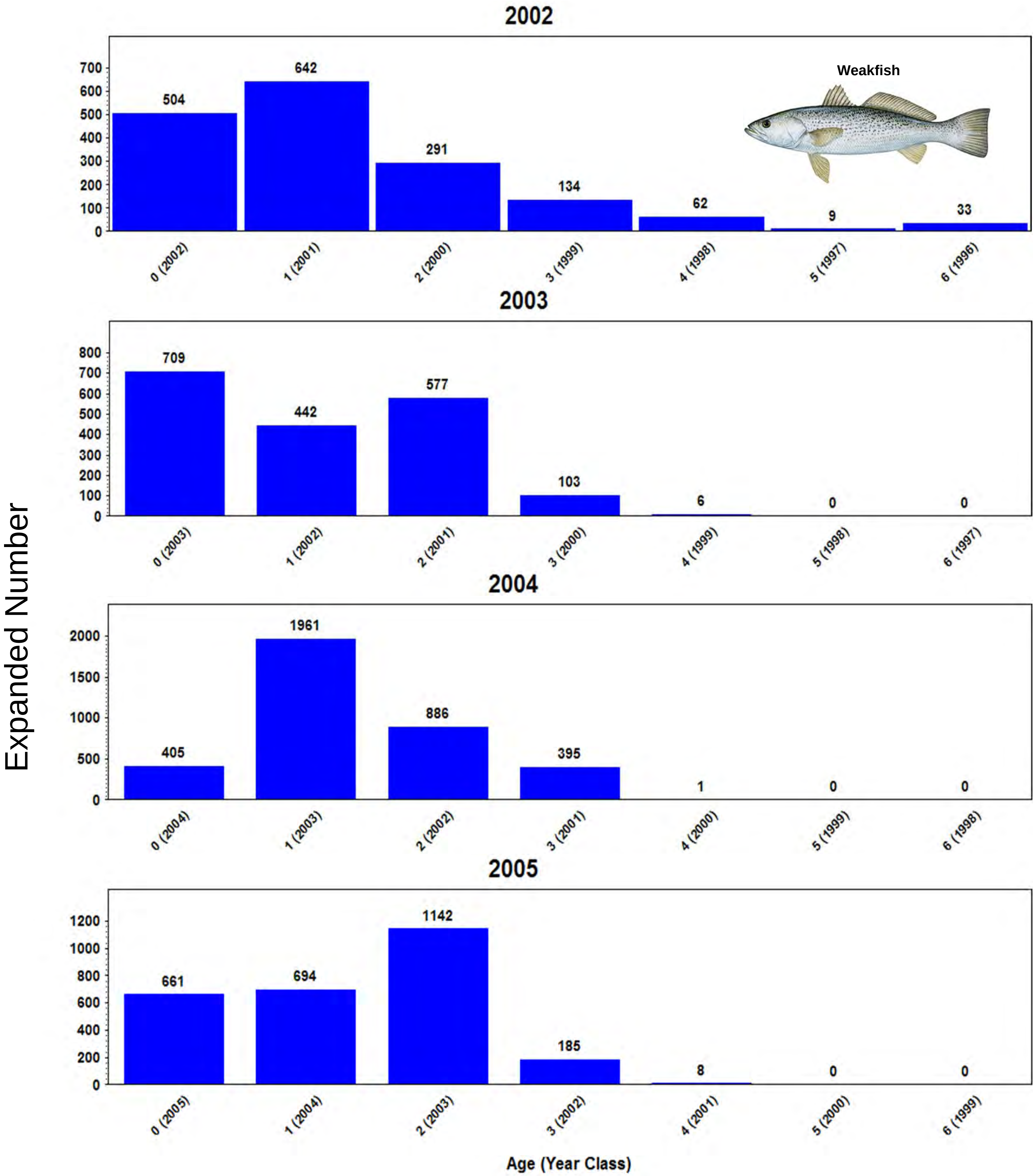


Figure 51. continued.

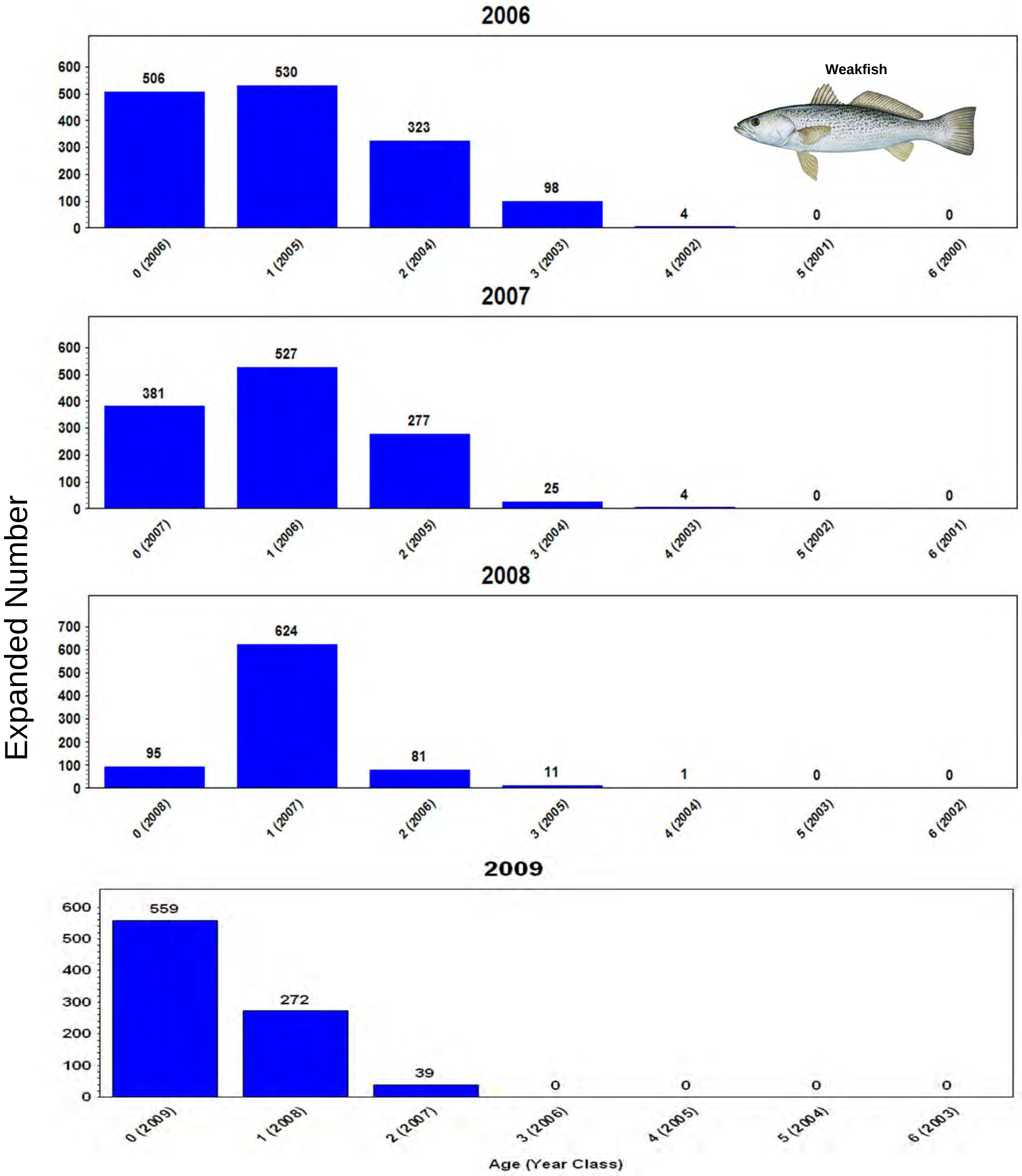


Figure 52. Abundance (kg per hectare swept) of weakfish in Chesapeake Bay, 2010.

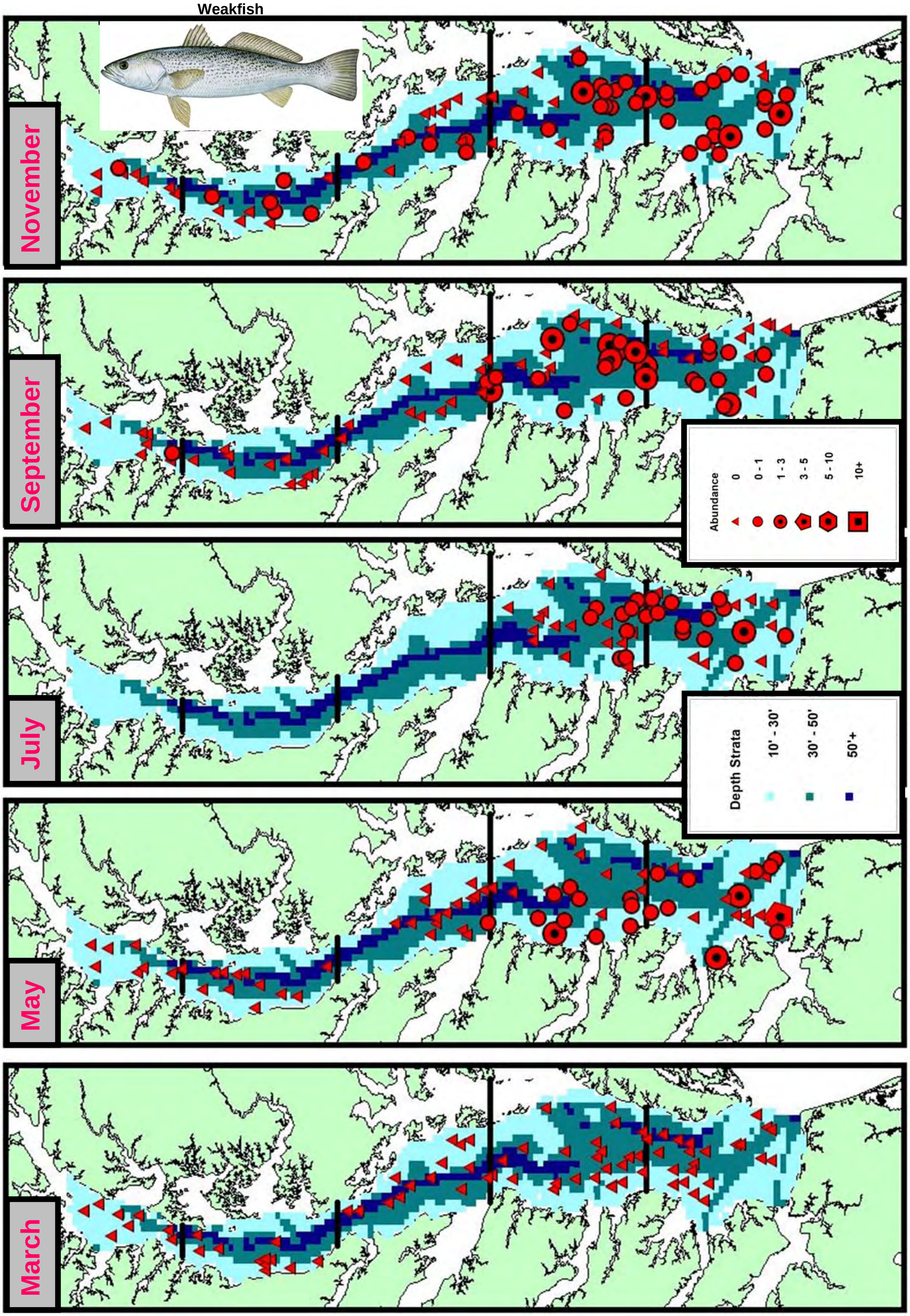


Figure 53. Diet composition, expressed as percent by weight (A) and percent by number (B) of weakfish collected during ChesMMAP cruises in 2002-2010 combined.

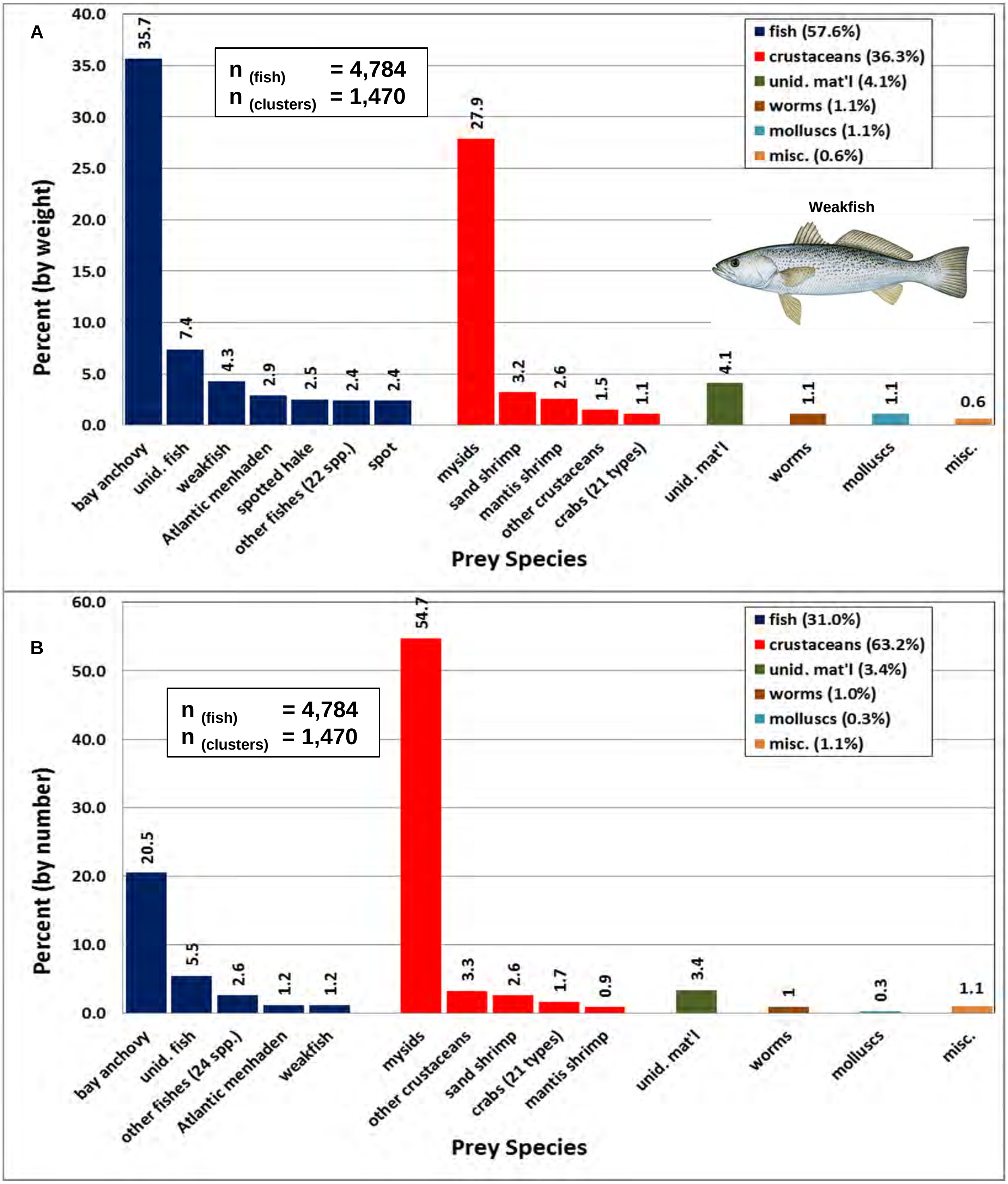
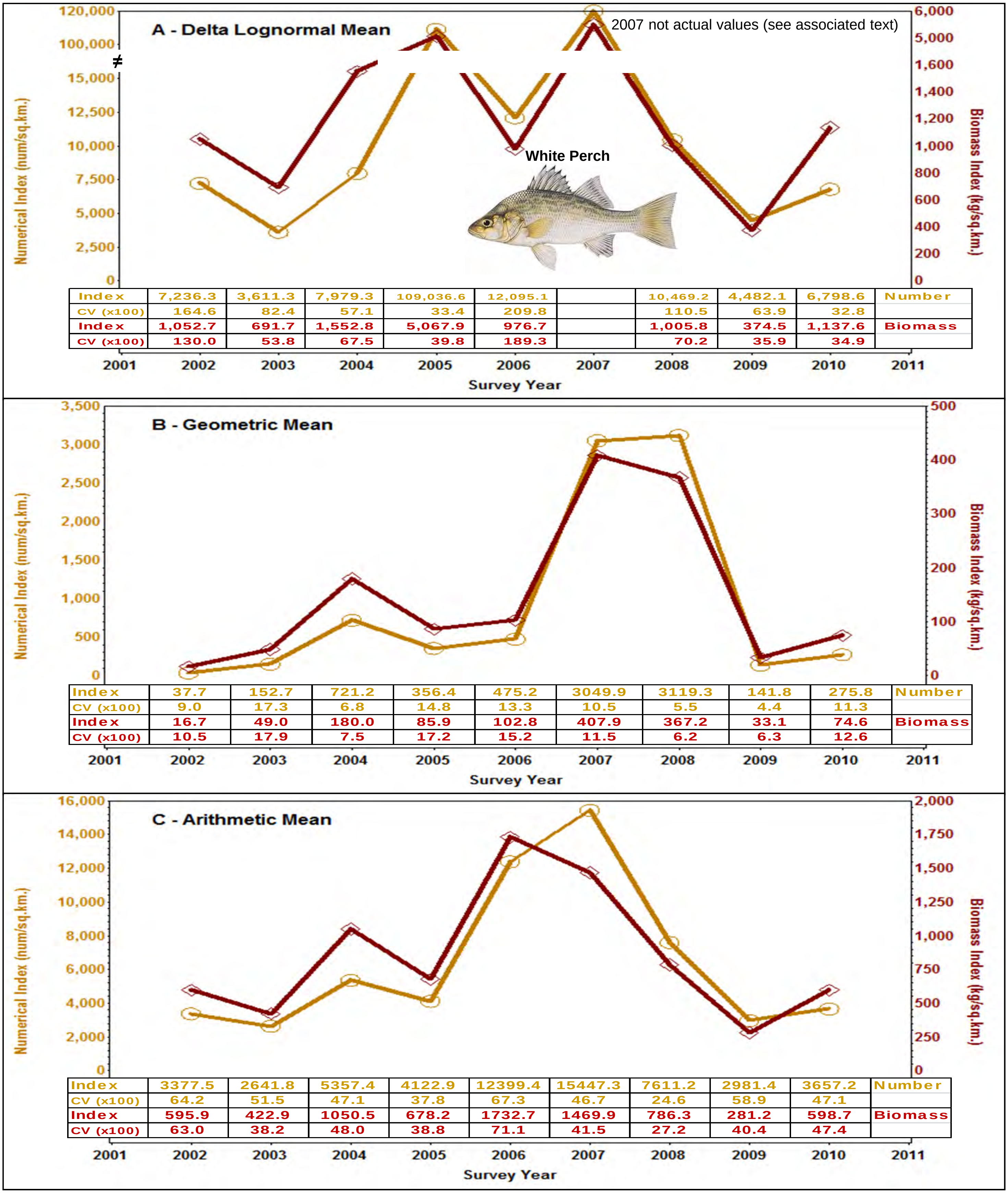


Figure 54. Abundance indices (number and biomass) for white perch (March) based on delta lognormal (A), geometric (B) and arithmetic (C) means.

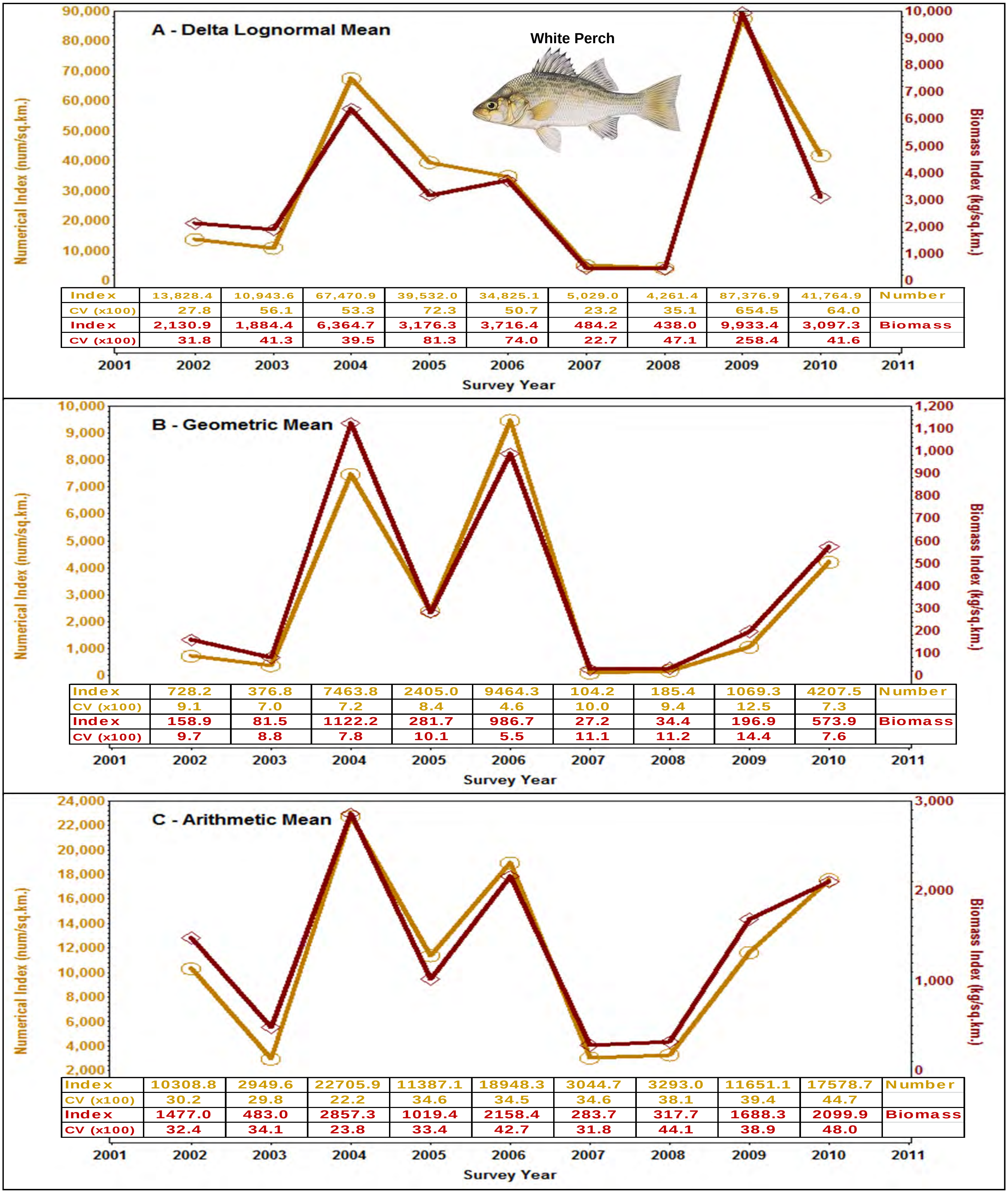


	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	7,236.3	3,611.3	7,979.3	109,036.6	12,095.1		10,469.2	4,482.1	6,798.6	Number
CV (x100)	164.6	82.4	57.1	33.4	209.8		110.5	63.9	32.8	
Index	1,052.7	691.7	1,552.8	5,067.9	976.7		1,005.8	374.5	1,137.6	Biomass
CV (x100)	130.0	53.8	67.5	39.8	189.3		70.2	35.9	34.9	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	37.7	152.7	721.2	356.4	475.2	3049.9	3119.3	141.8	275.8	Number
CV (x100)	9.0	17.3	6.8	14.8	13.3	10.5	5.5	4.4	11.3	
Index	16.7	49.0	180.0	85.9	102.8	407.9	367.2	33.1	74.6	Biomass
CV (x100)	10.5	17.9	7.5	17.2	15.2	11.5	6.2	6.3	12.6	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	3377.5	2641.8	5357.4	4122.9	12399.4	15447.3	7611.2	2981.4	3657.2	Number
CV (x100)	64.2	51.5	47.1	37.8	67.3	46.7	24.6	58.9	47.1	
Index	595.9	422.9	1050.5	678.2	1732.7	1469.9	786.3	281.2	598.7	Biomass
CV (x100)	63.0	38.2	48.0	38.8	71.1	41.5	27.2	40.4	47.4	

Figure 55. Abundance indices (number and biomass) for white perch (November) based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	13,828.4	10,943.6	67,470.9	39,532.0	34,825.1	5,029.0	4,261.4	87,376.9	41,764.9	Number
CV (x100)	27.8	56.1	53.3	72.3	50.7	23.2	35.1	654.5	64.0	
Index	2,130.9	1,884.4	6,364.7	3,176.3	3,716.4	484.2	438.0	9,933.4	3,097.3	Biomass
CV (x100)	31.8	41.3	39.5	81.3	74.0	22.7	47.1	258.4	41.6	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	728.2	376.8	7463.8	2405.0	9464.3	104.2	185.4	1069.3	4207.5	Number
CV (x100)	9.1	7.0	7.2	8.4	4.6	10.0	9.4	12.5	7.3	
Index	158.9	81.5	1122.2	281.7	986.7	27.2	34.4	196.9	573.9	Biomass
CV (x100)	9.7	8.8	7.8	10.1	5.5	11.1	11.2	14.4	7.6	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	10308.8	2949.6	22705.9	11387.1	18948.3	3044.7	3293.0	11651.1	17578.7	Number
CV (x100)	30.2	29.8	22.2	34.6	34.5	34.6	38.1	39.4	44.7	
Index	1477.0	483.0	2857.3	1019.4	2158.4	283.7	317.7	1688.3	2099.9	Biomass
CV (x100)	32.4	34.1	23.8	33.4	42.7	31.8	44.1	38.9	48.0	

Figure 56. White perch length-frequency in Chesapeake Bay, 2002-2010.

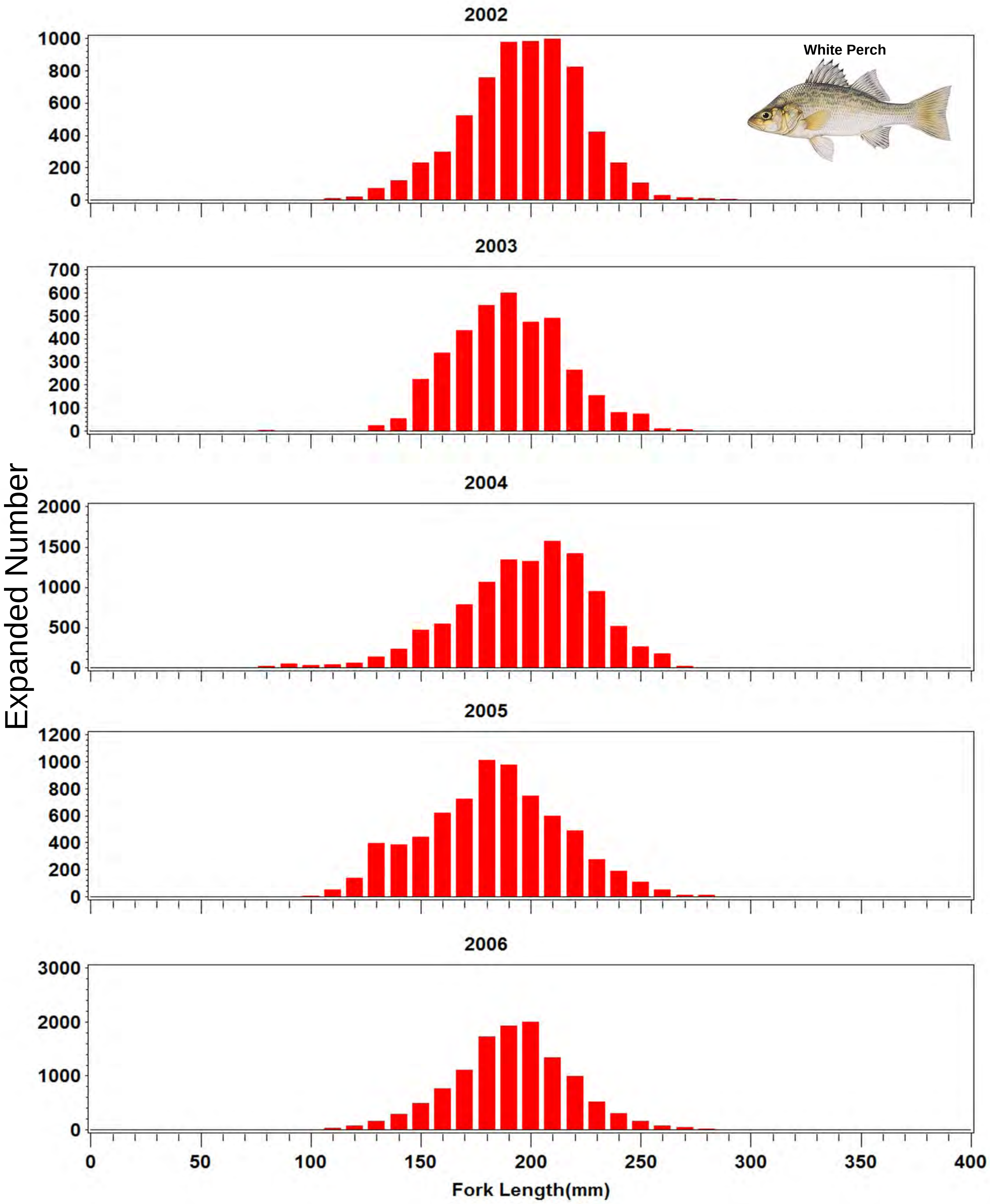


Figure 56. continued.

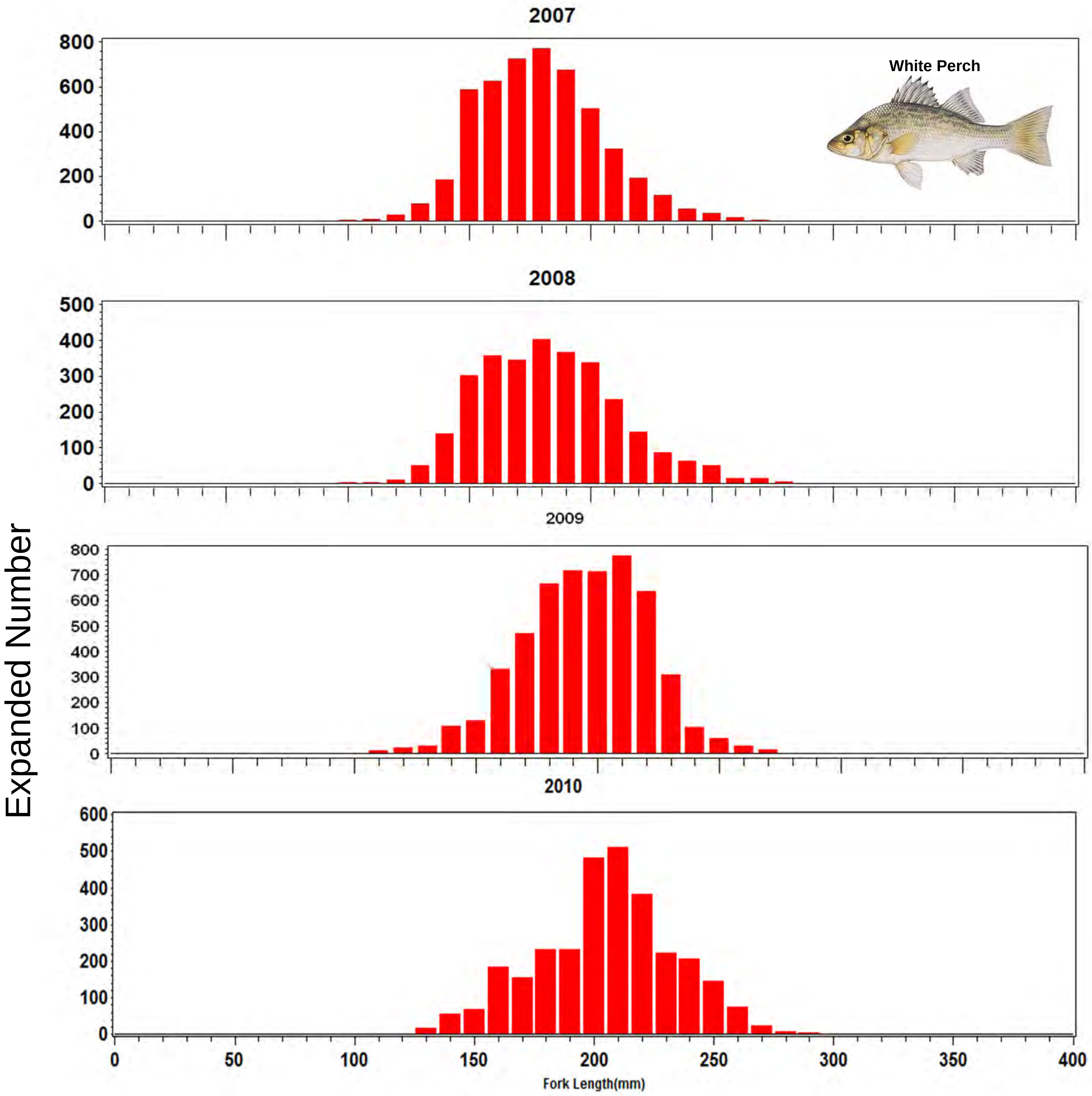


Figure 57. White perch age-structure in Chesapeake Bay, 2002-2009.

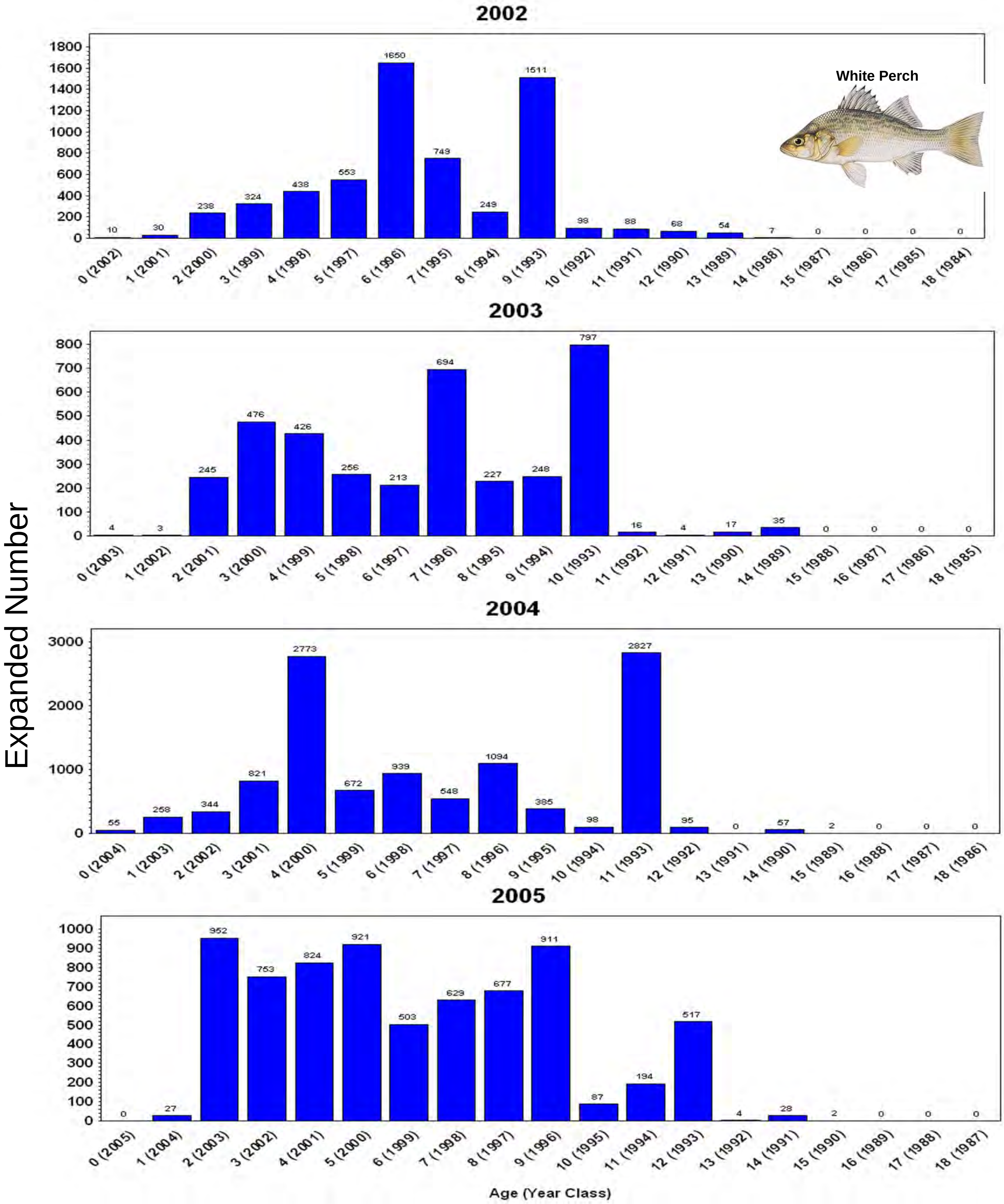


Figure 57. continued.

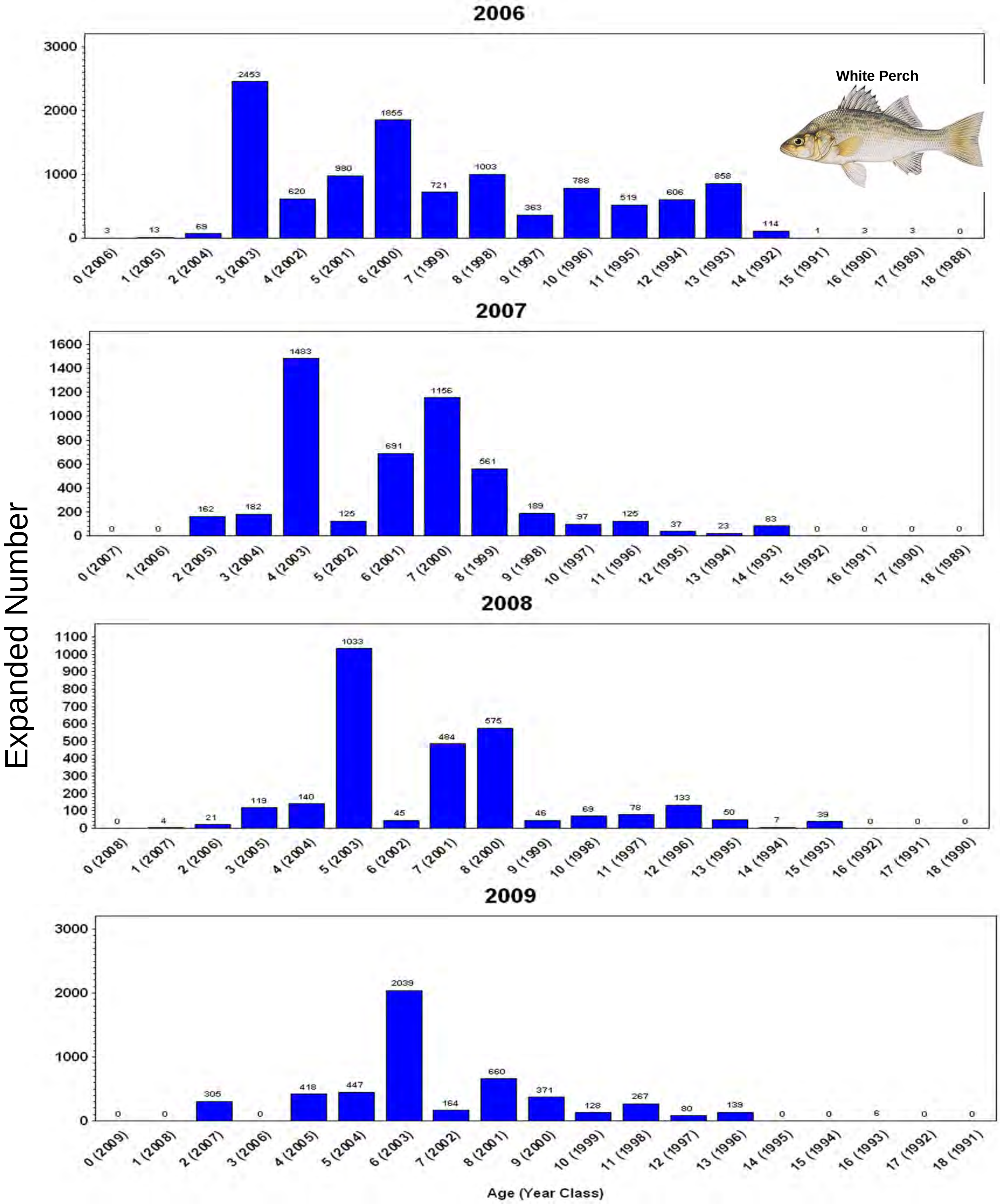


Figure 58. Abundance (kg per hectare swept) of white perch in Chesapeake Bay, 2010.

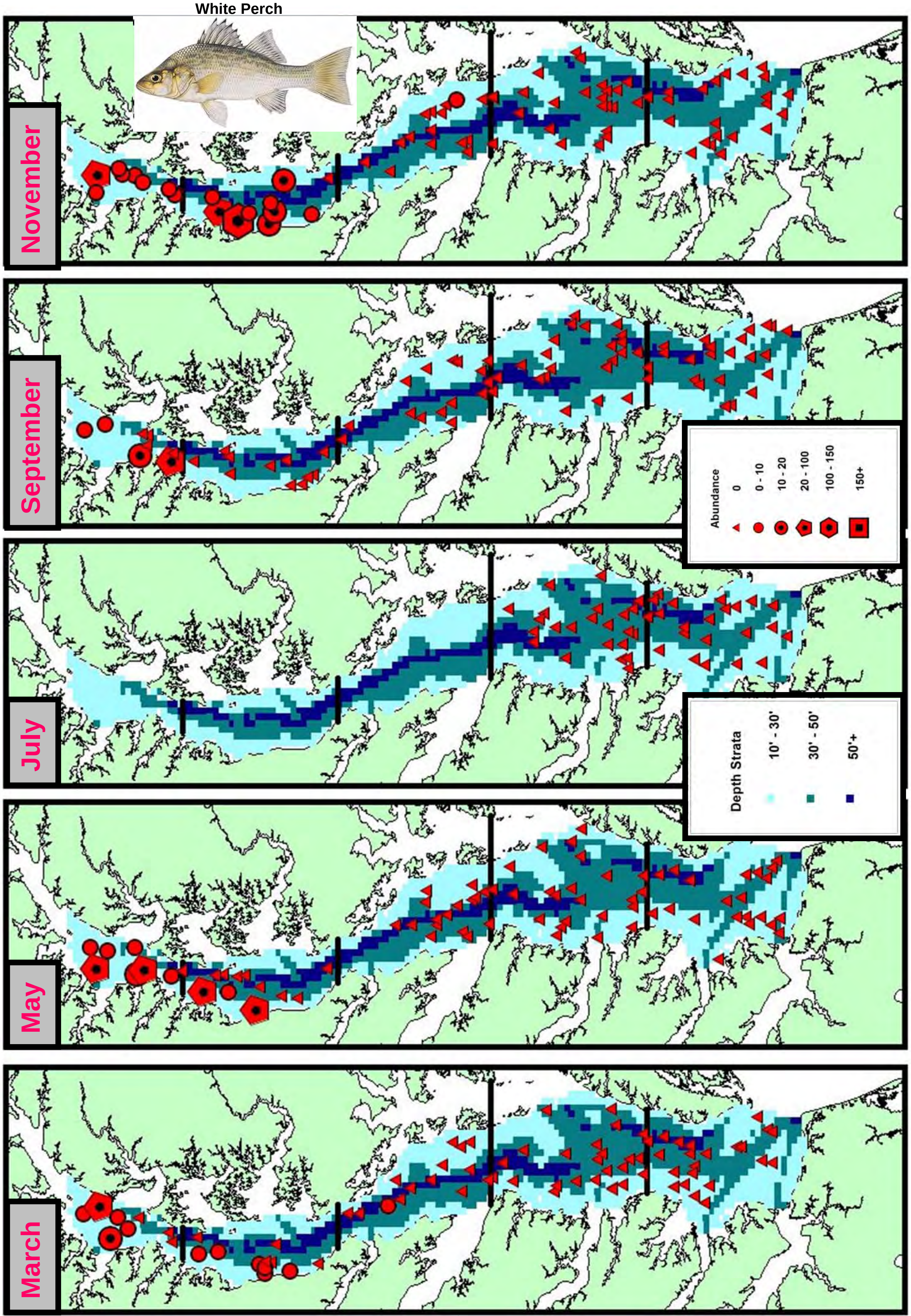


Figure 59. Diet composition, expressed as percent by weight (A) and percent by number (B) of white perch collected during ChesMMAP cruises in 2002-2010 combined.

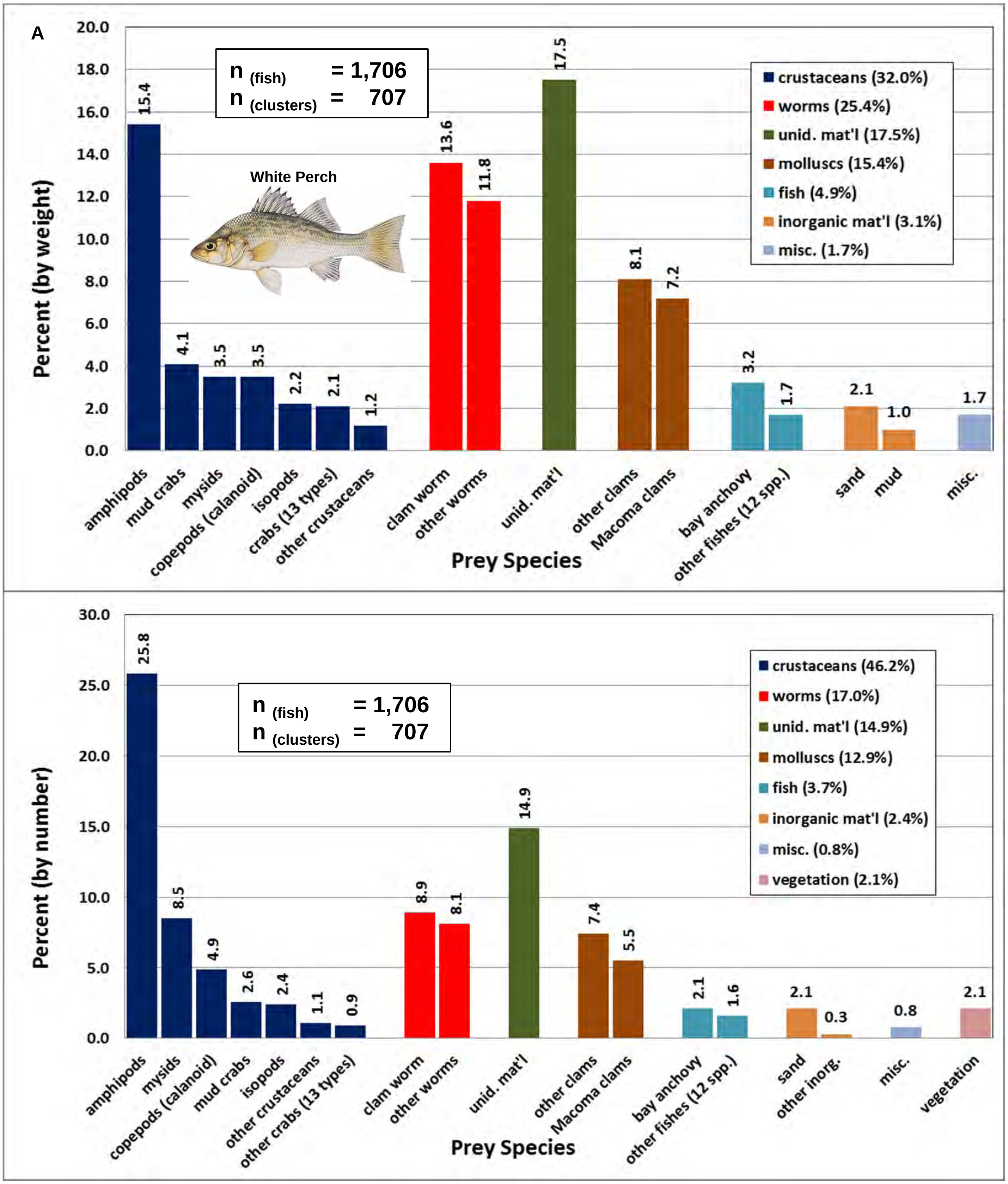


Figure 60. Surface temperature in Chesapeake Bay, 2010.

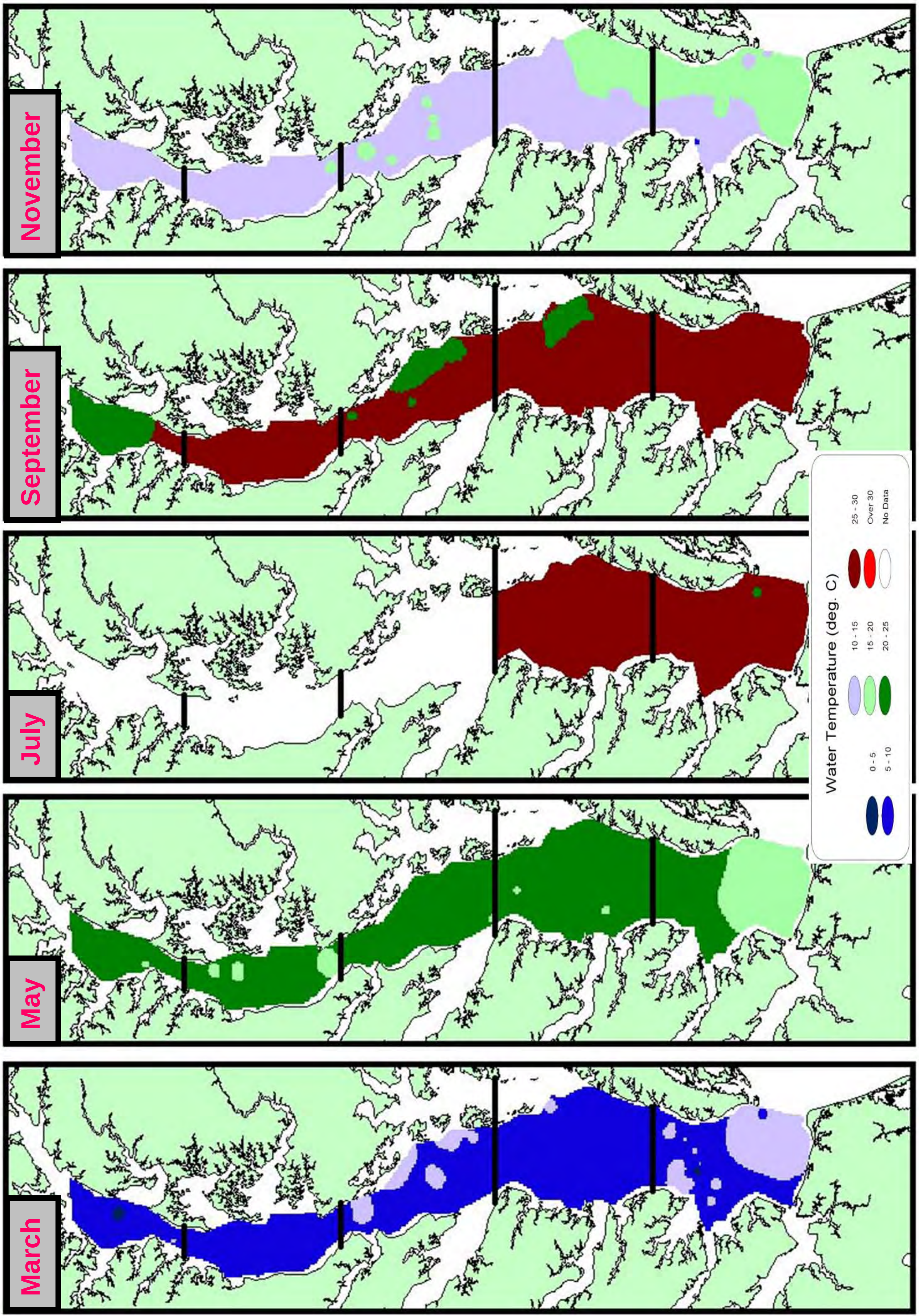


Figure 61. Bottom temperature in Chesapeake Bay, 2010.

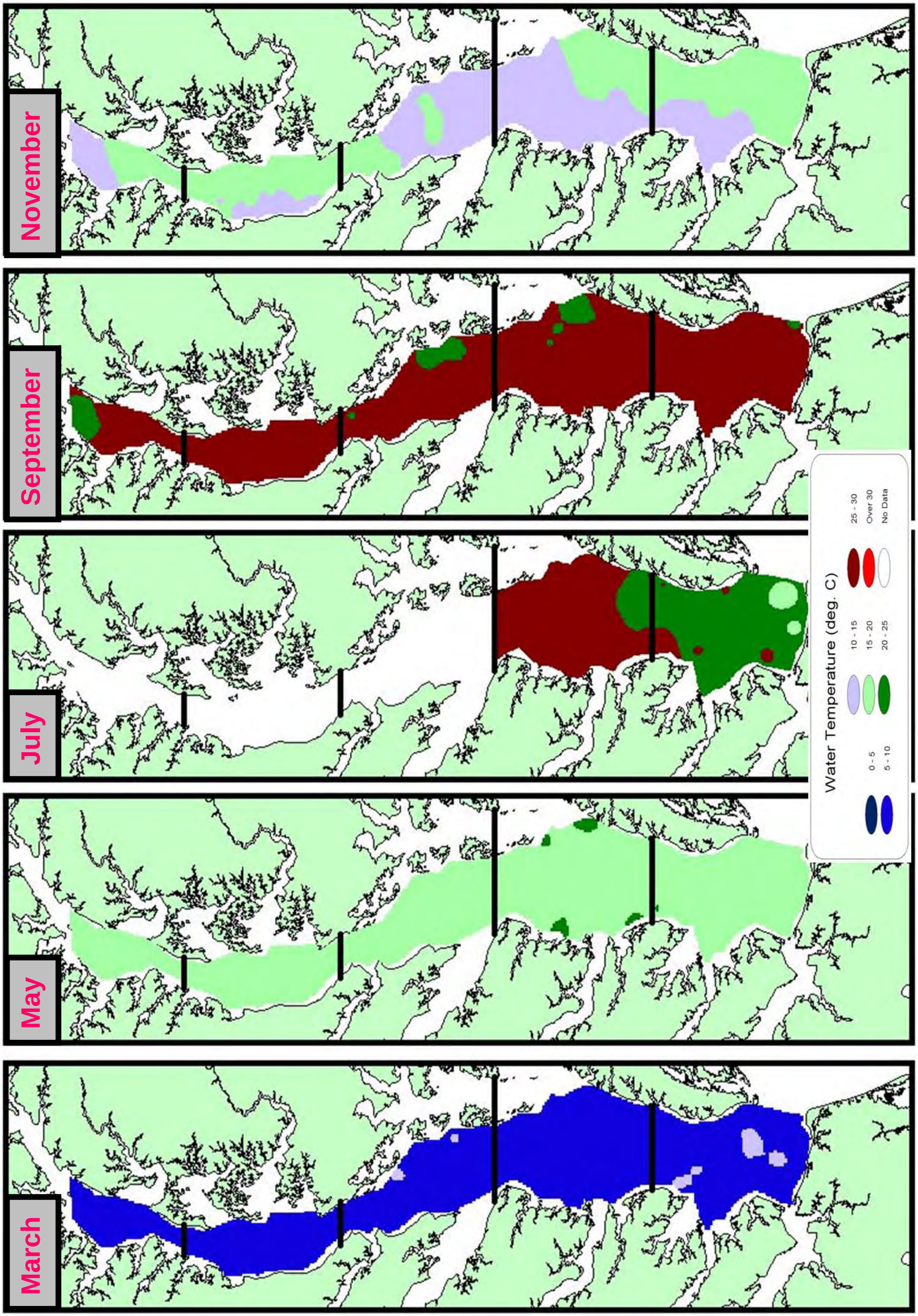


Figure 62. Surface salinity in Chesapeake Bay, 2010.

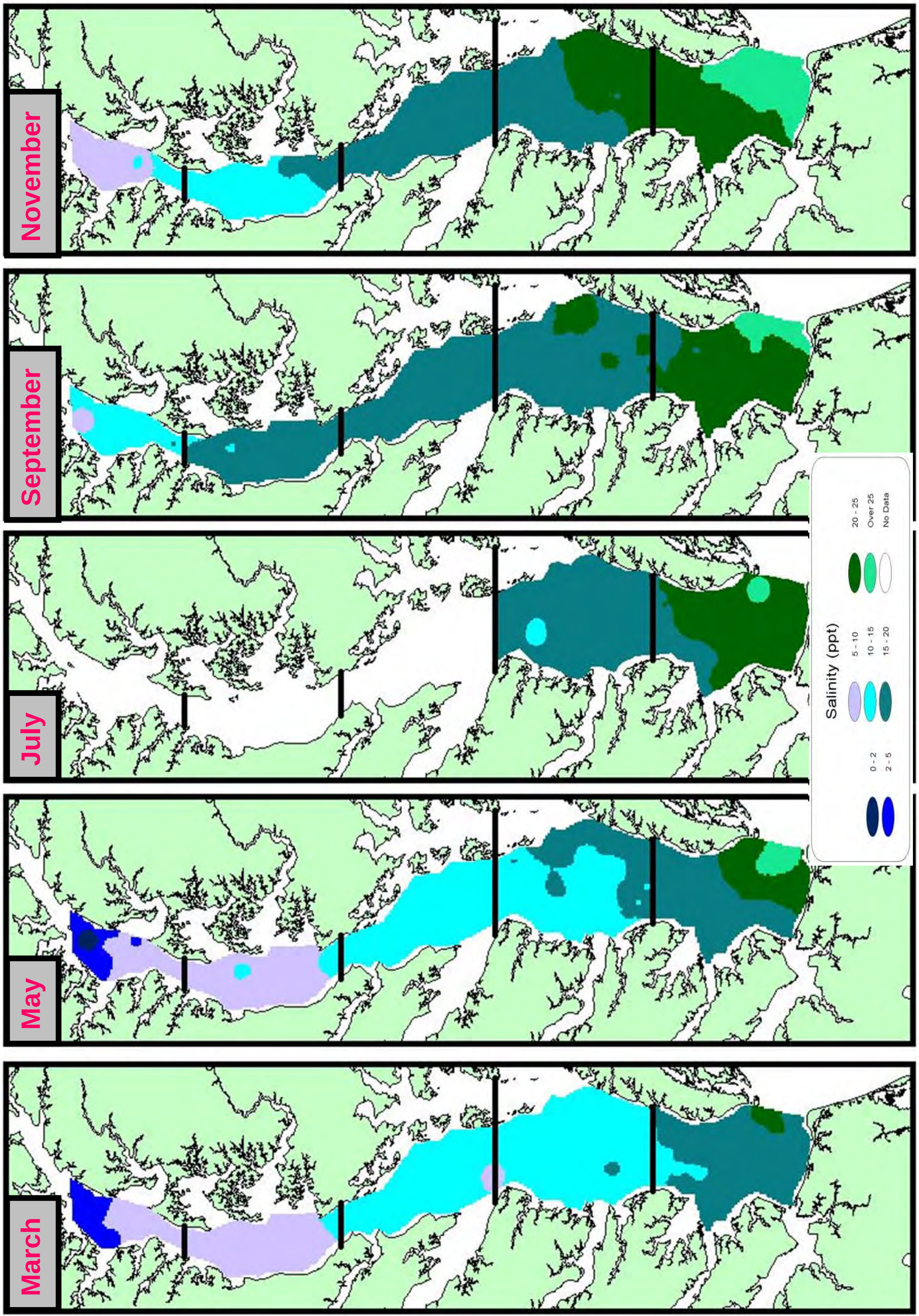


Figure 63. Bottom salinity in Chesapeake Bay, 2010.

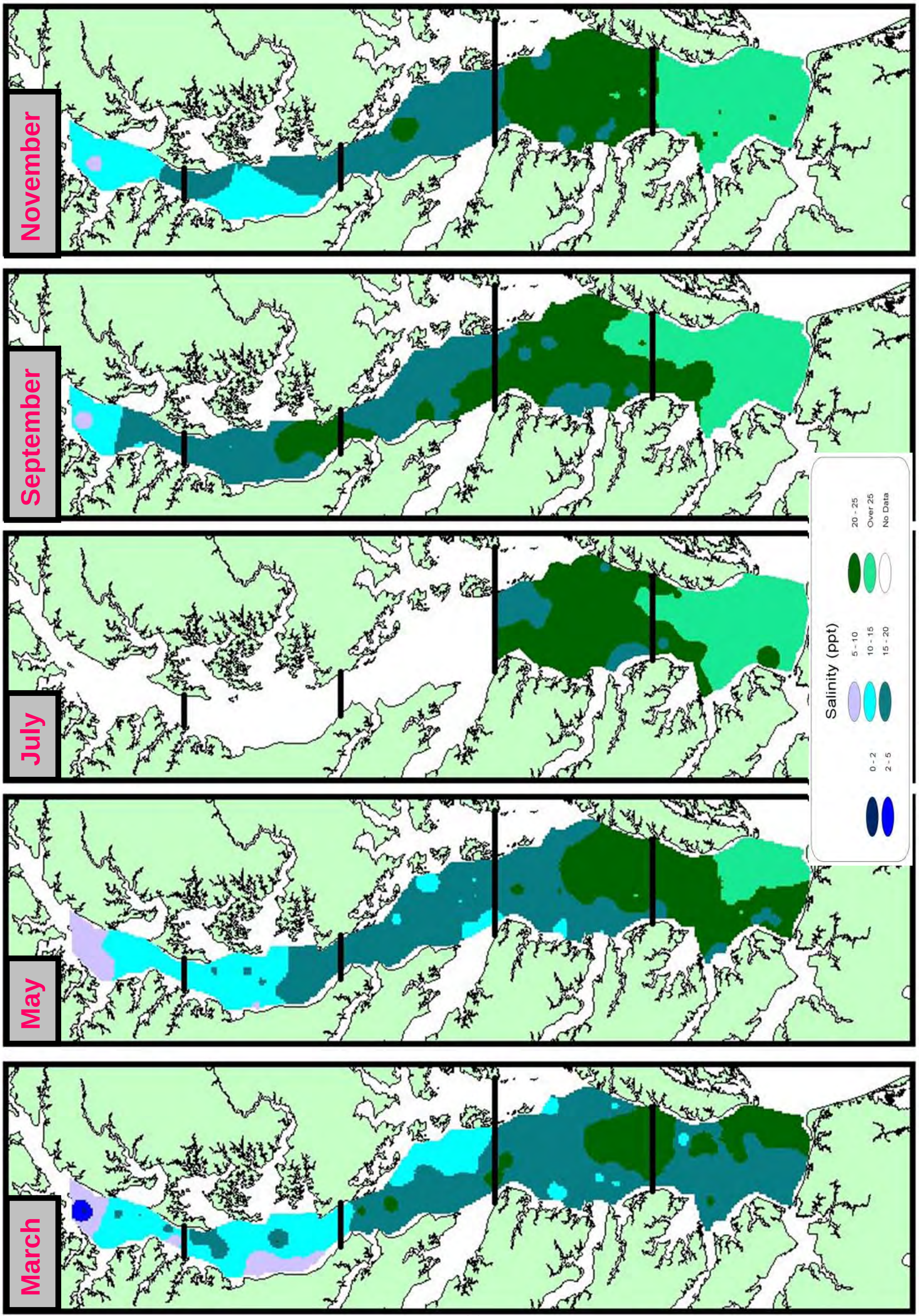


Figure 64. Surface dissolved oxygen in Chesapeake Bay, 2010.

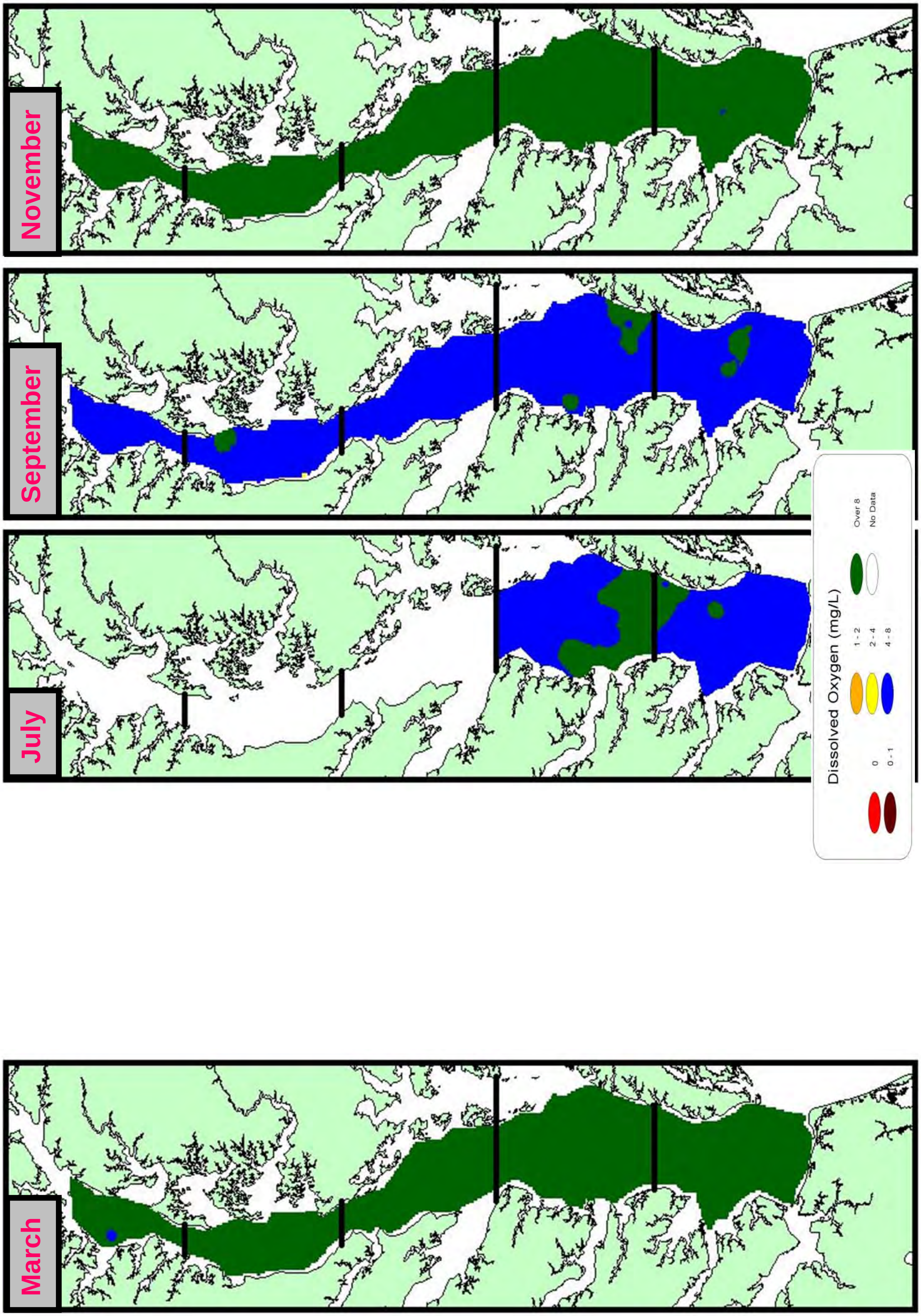


Figure 65. Bottom dissolved oxygen in Chesapeake Bay, 2010.

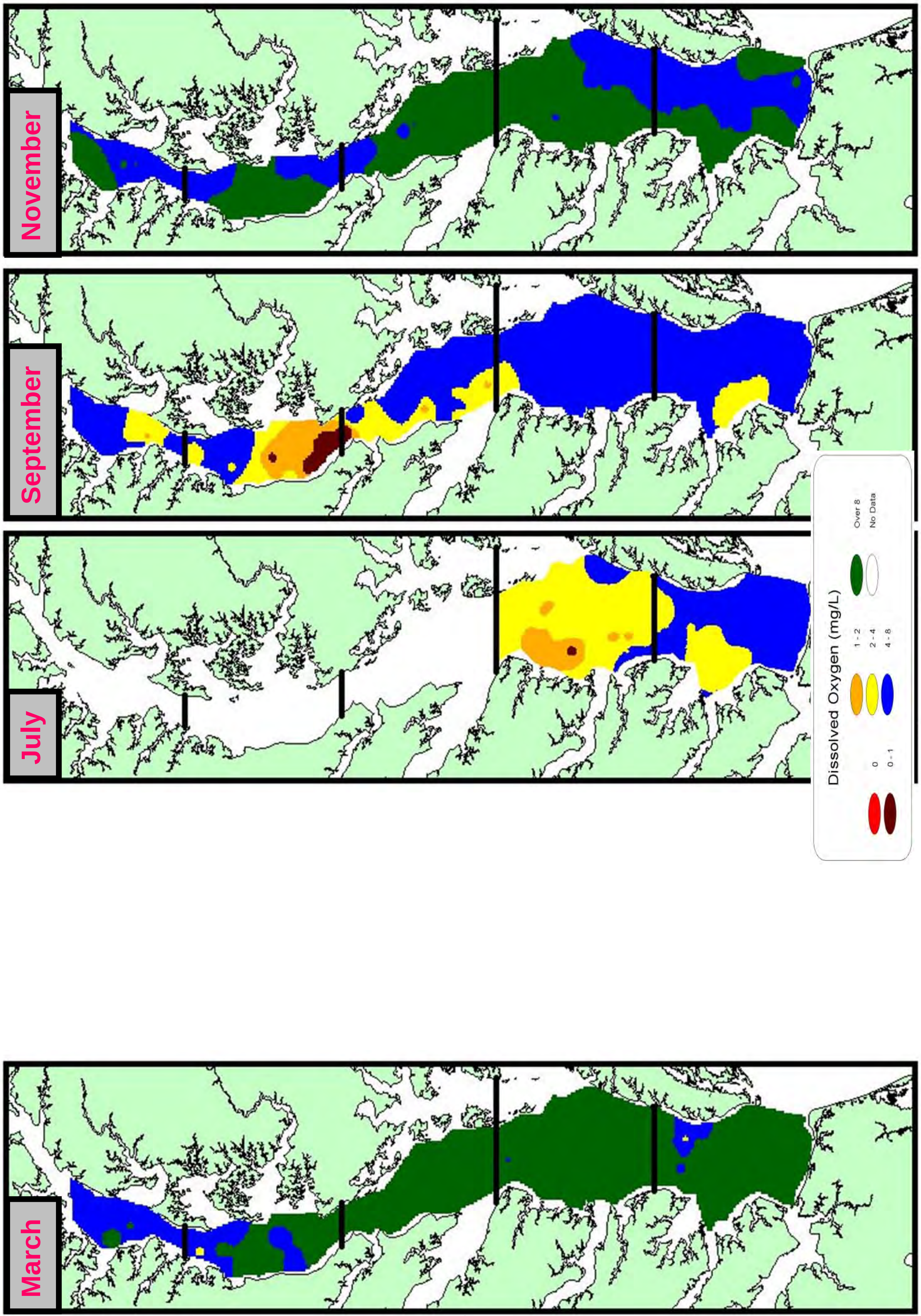


Figure 66. Design plans for a three-bridle, four-seam, 200 x 12cm (fishing circle) trawl proposed as a replacement sampling gear for the ChesMMAP Trawl Survey.

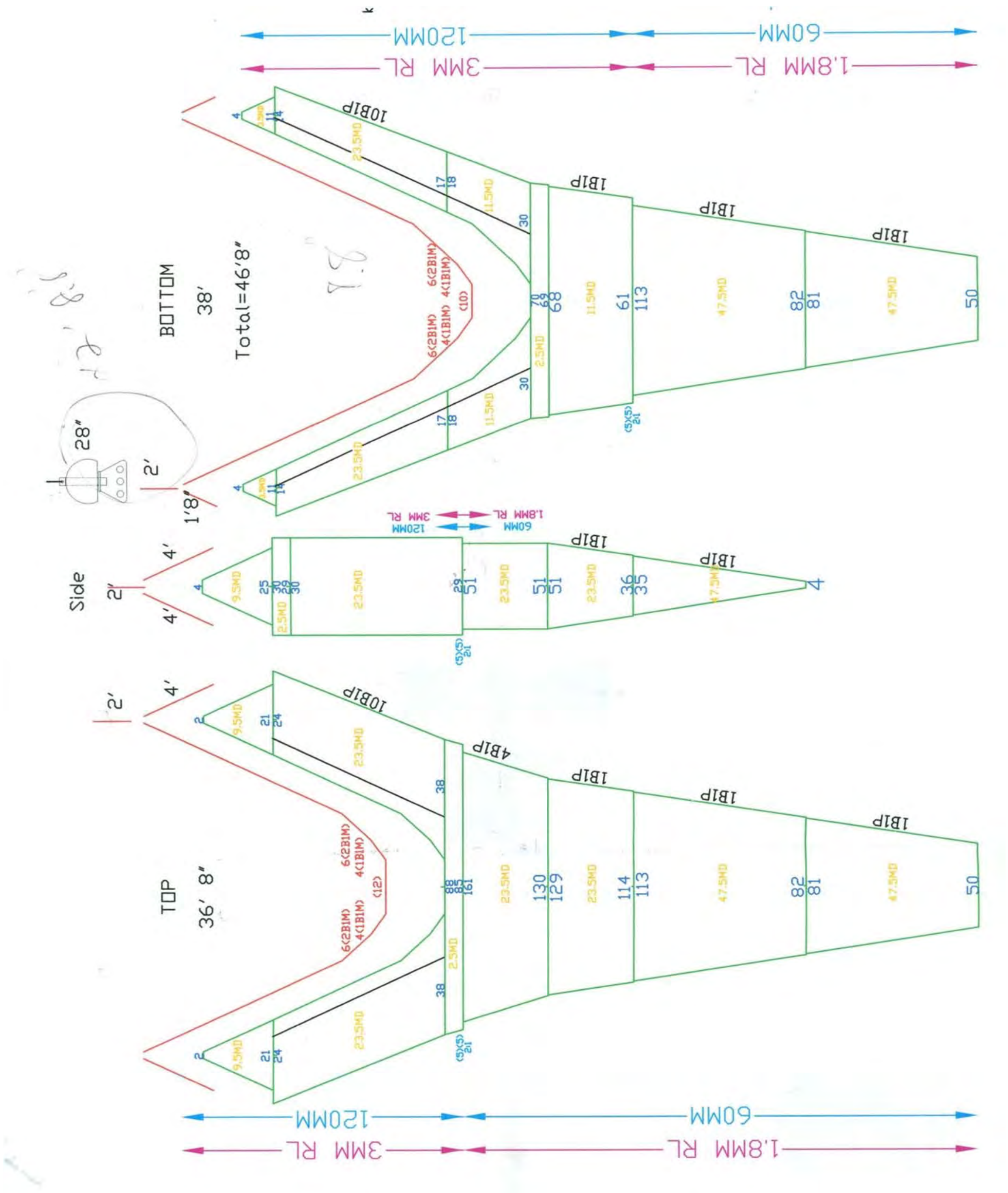


Figure 67. (A) #2 Bison door used by the ChesMMAP Trawl Survey during the field trials of the three-bridle, four-seam, 200 x 12cm bottom trawl in 2010. The surface area of these doors is $0.86m^2$, and each weighs 90kg. (B) The three-point backstrap chain system used with the #2 Bison doors during the field trials of the three-bridle, four-seam, 200 x 12cm bottom trawl in 2010. (C) Picture of the measurement of the 150^0 angle between the lower aft backstrap chain and Bison door. This angle ensured that the backstrap chains were each of appropriate length and therefore that the door would remain relatively stable during fishing operations. (D) View of towing bracket with associated washers used to raise and lower the towing point on the door. Changing the relative height of the towing point changes the balance of the door.

Figure 68. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the first tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.

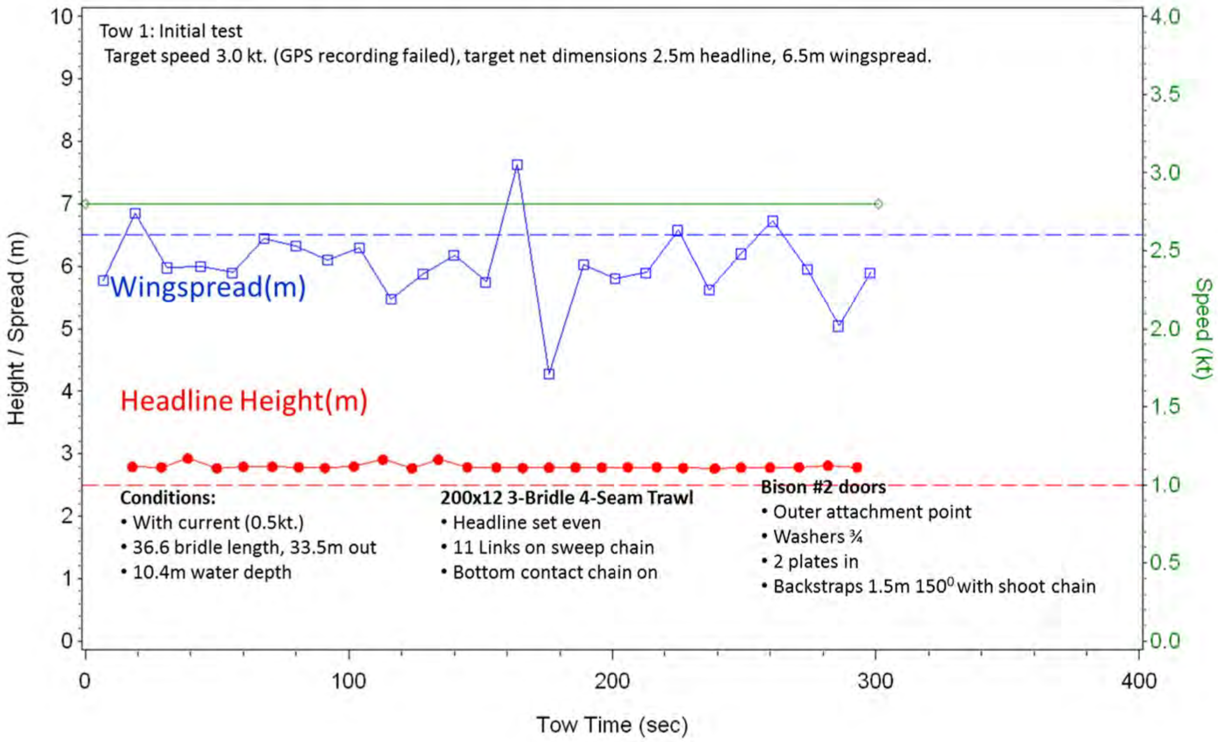


Figure 69. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the second tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.

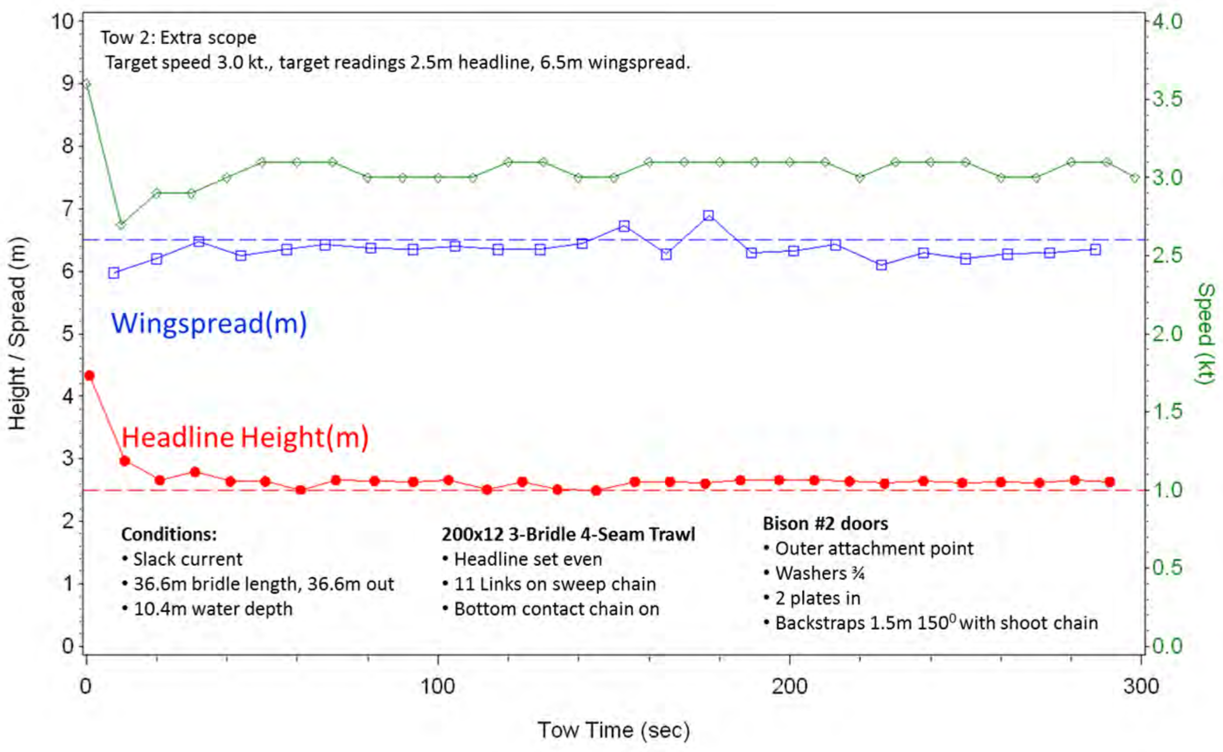


Figure 70. Photograph showing the wear pattern on the shoe of the #2 Bison door following an adjustment of the relative height of the towing bracket in an attempt to balance the door. The even wear pattern across the width of the shoe indicates that the adjustment did correct the balance.

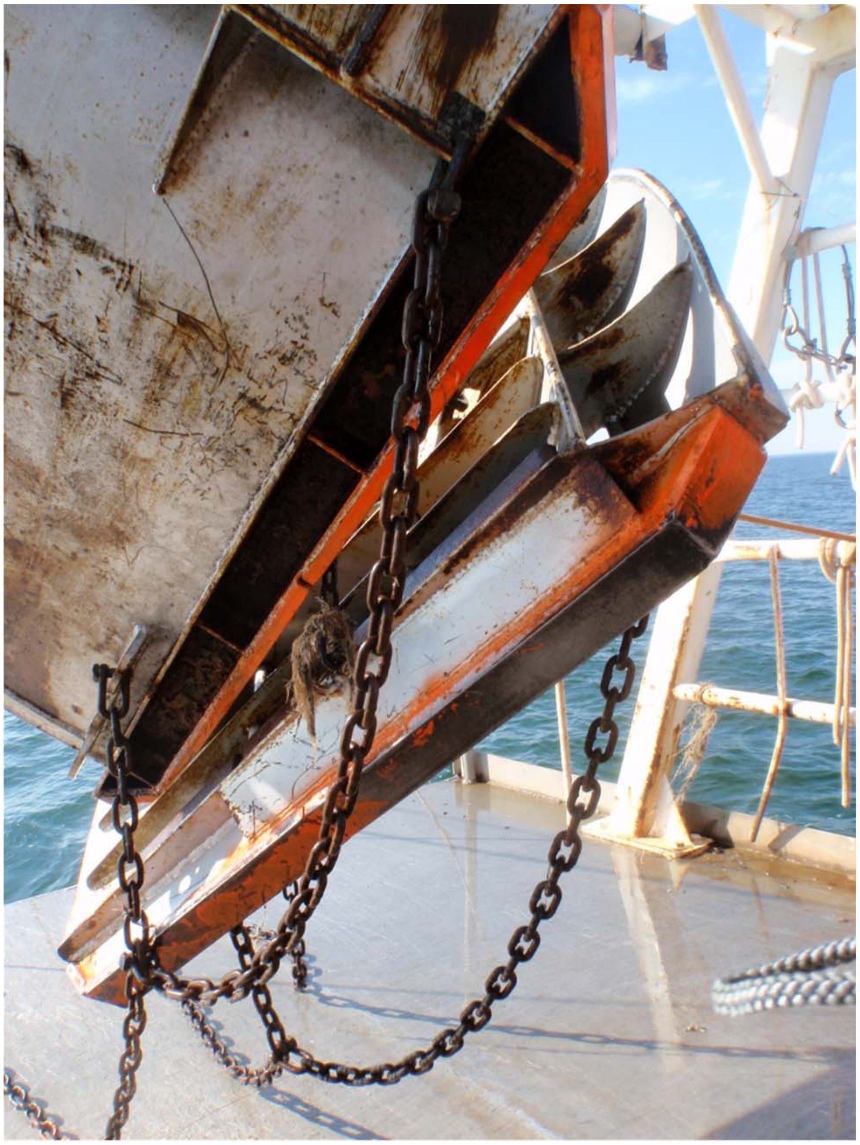


Figure 71. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the third tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.

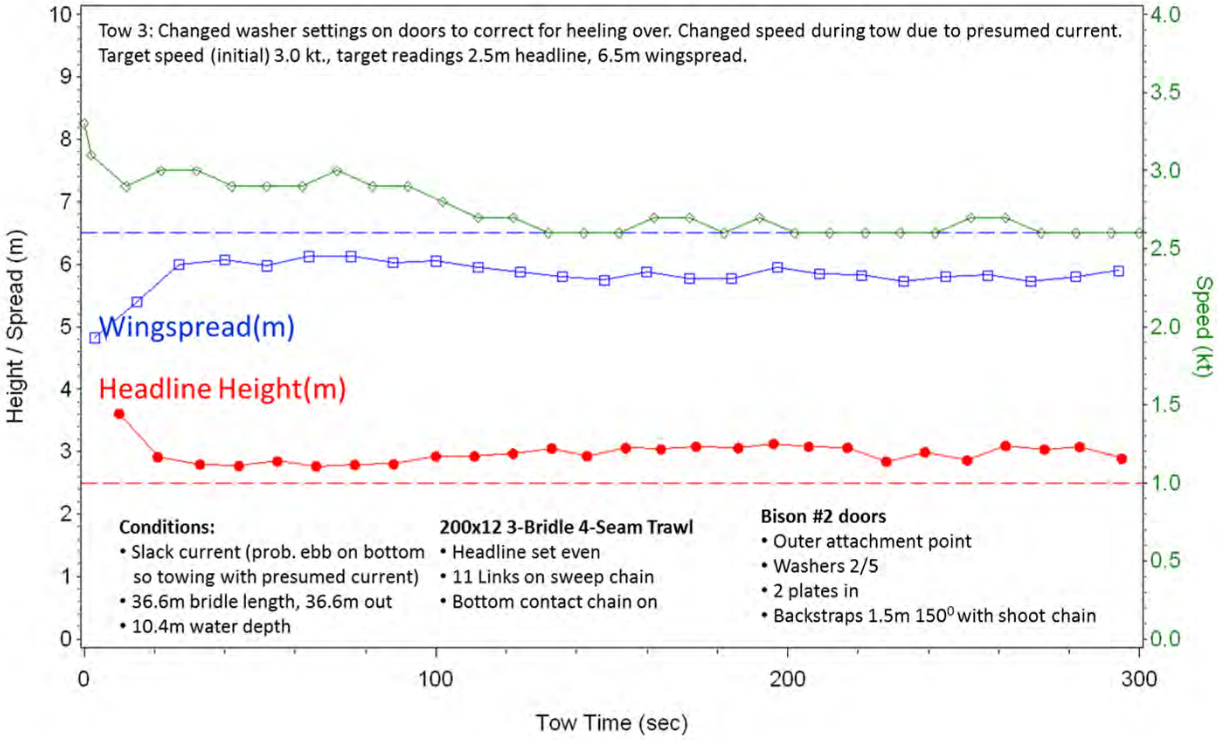


Figure 72. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the fourth tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.

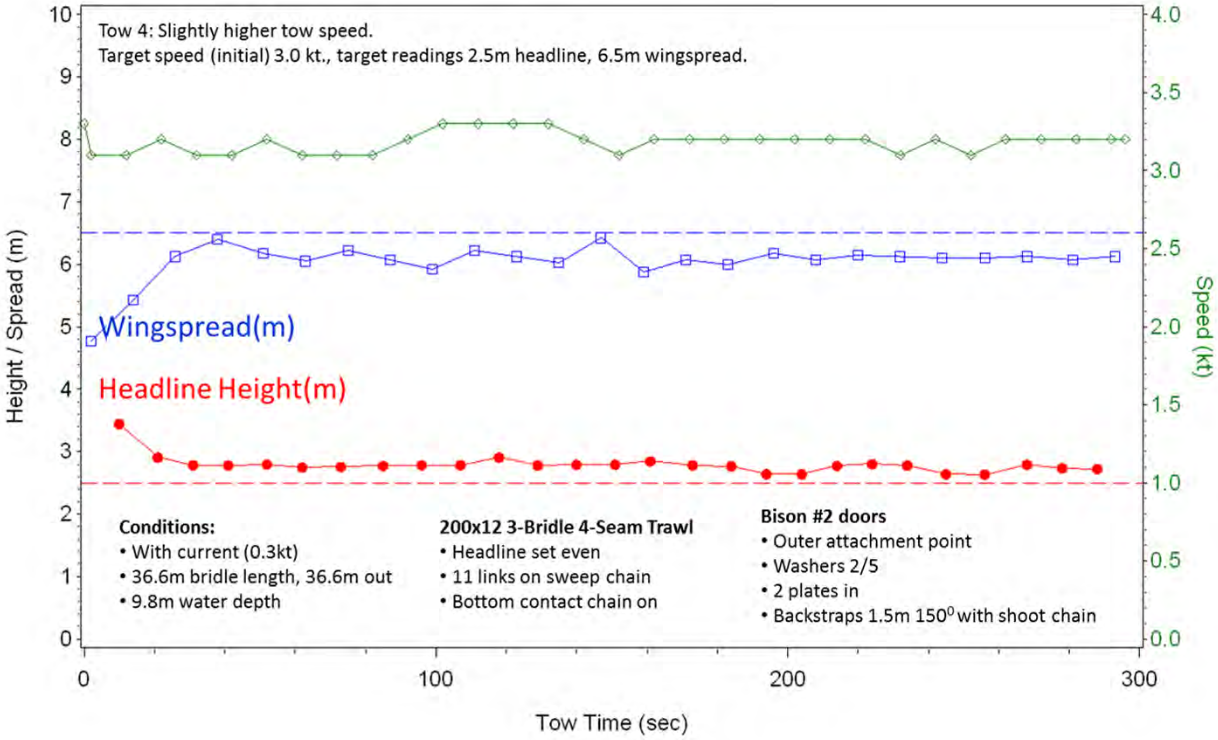
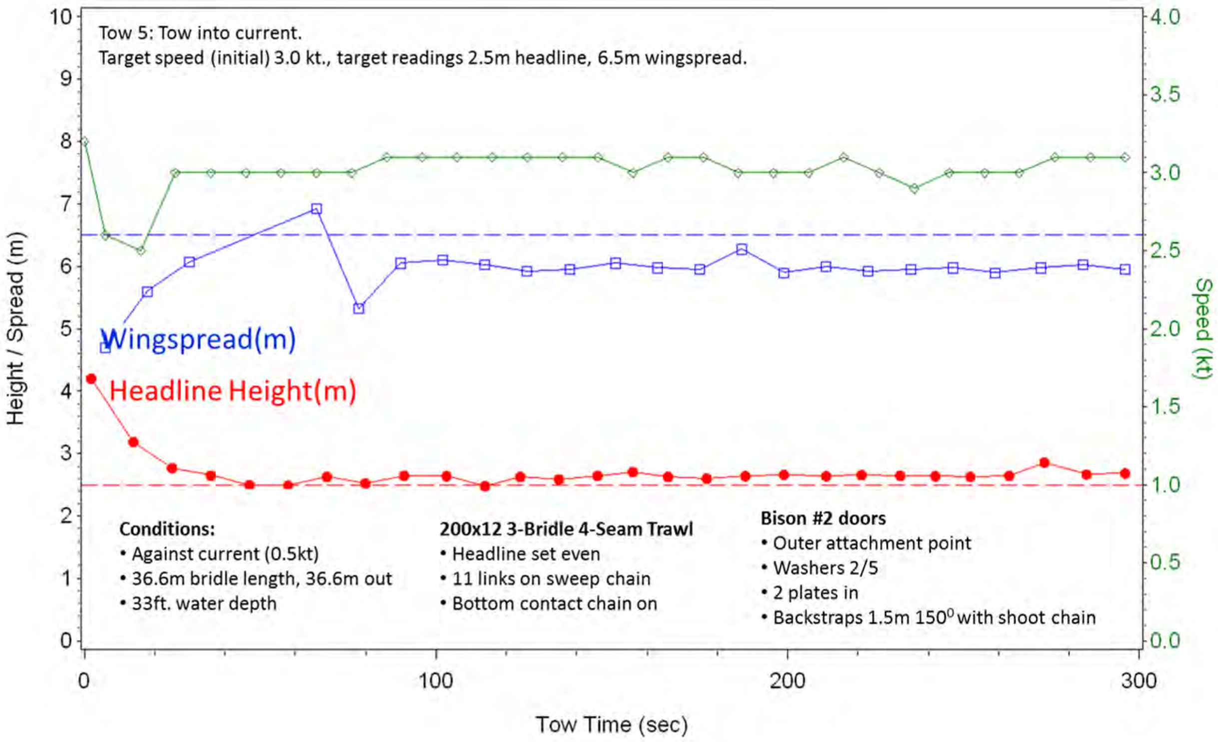


Figure 73. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the fifth tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.



Tow 5: Tow into current.
Target speed (initial) 3.0 kt., target readings 2.5m headline, 6.5m wingspread.

Conditions:
- Against current (0.5kt)
- 36.6m bridle length, 36.6m out
- 33ft. water depth

200x12 3-Bridle 4-Seam Trawl
- Headline set even
- 11 links on sweep chain
- Bottom contact chain on

Bison #2 doors
- Outer attachment point
- Washers 2/5
- 2 plates in
- Backstraps 1.5m 150^0 with shoot chain

Figure 74. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the seventh tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph. Note that changes in bridle length during the tow are denoted by vertical black lines.

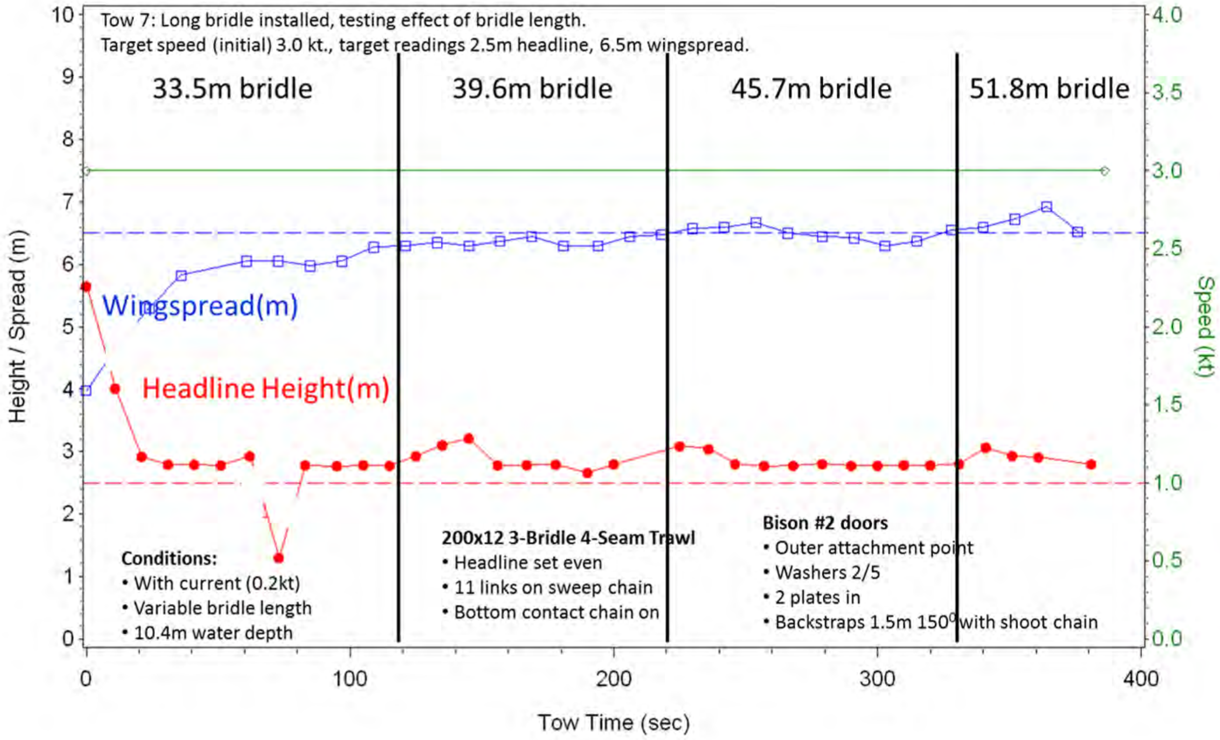


Figure 75. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the ninth tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph. Note that changes in vessel speed during the tow are denoted by vertical black lines.

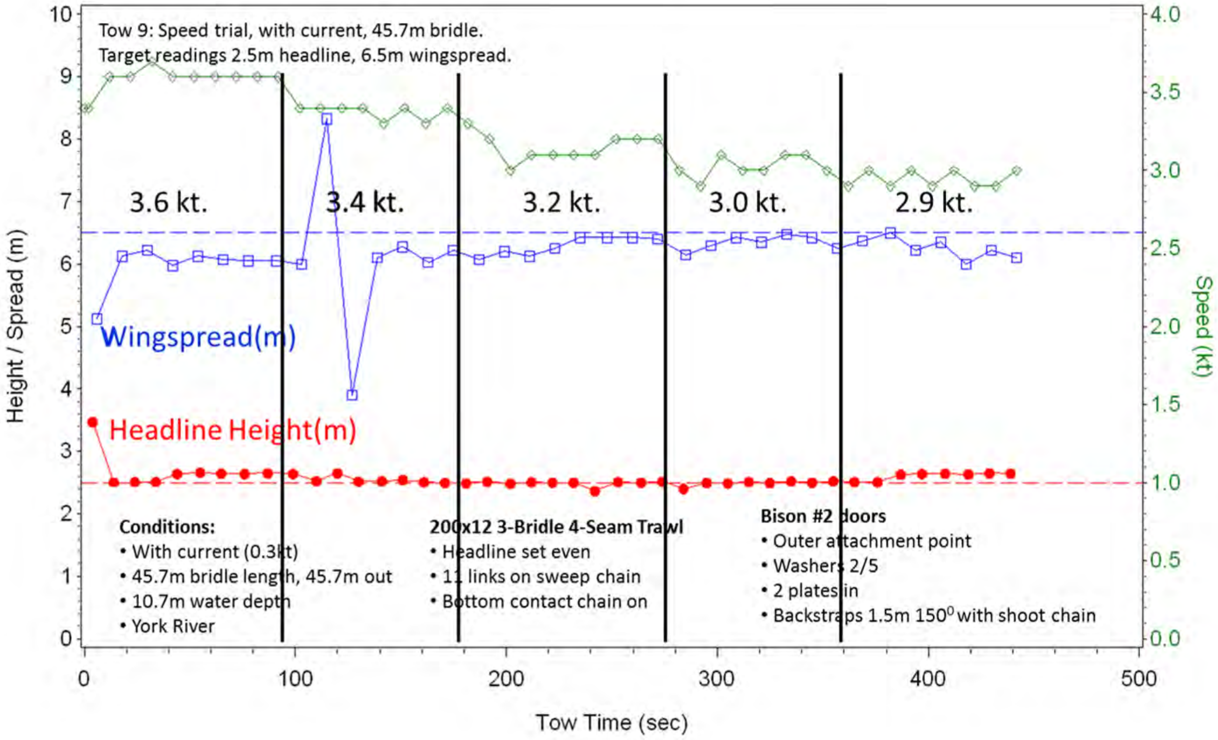


Figure 76. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the tenth tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph. Note that changes in vessel speed during the tow are denoted by vertical black lines.

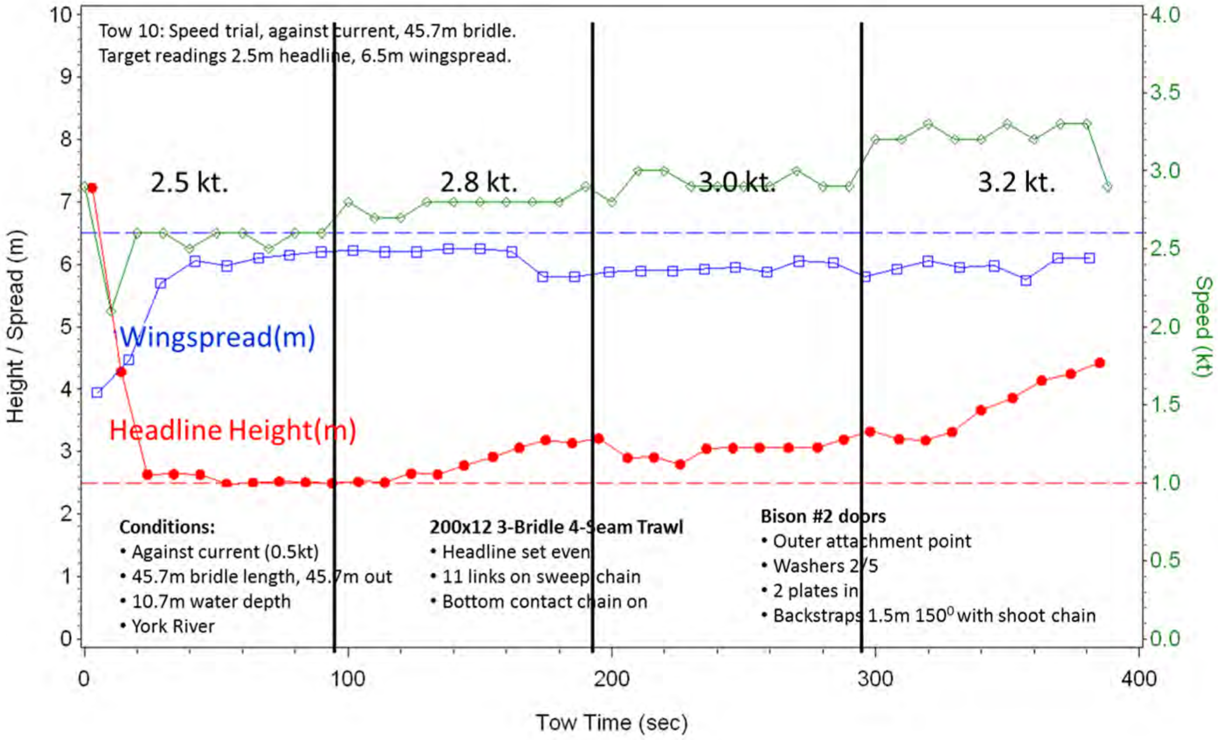
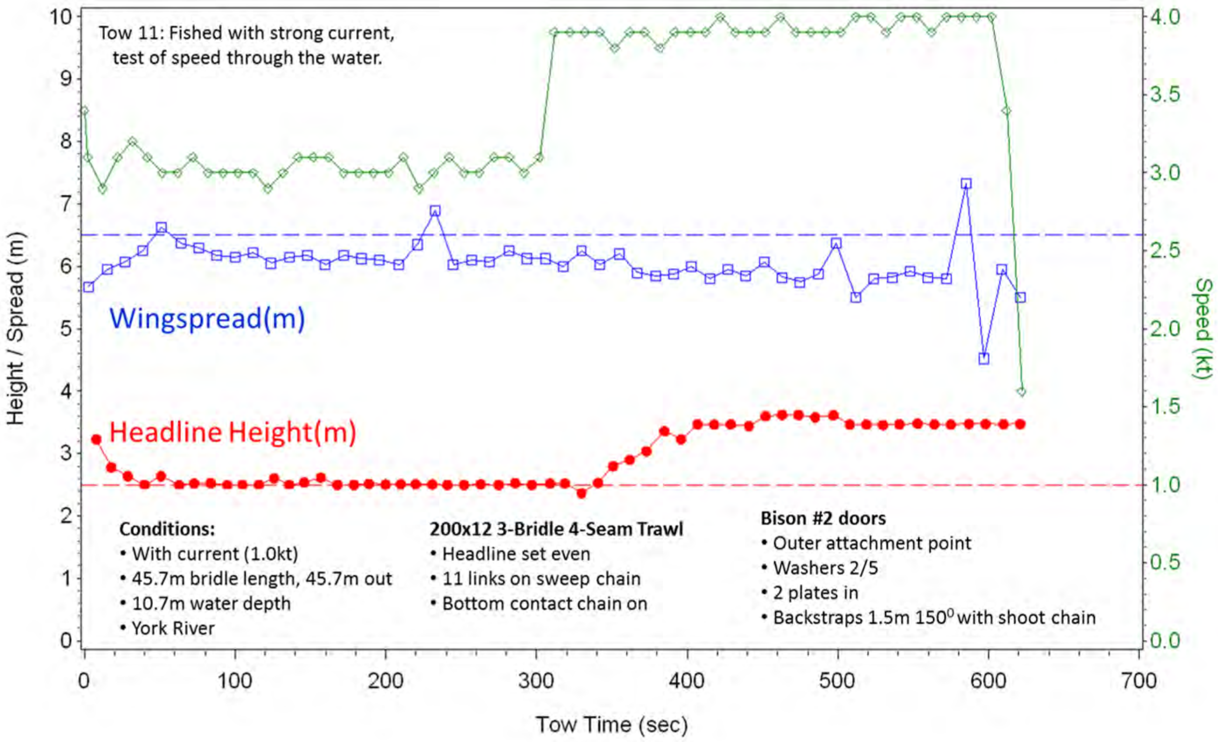


Figure 77. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the eleventh tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.



Conditions:
- With current (1.0kt)
- 45.7m bridle length, 45.7m out
- 10.7m water depth
- York River

200x12 3-Bridle 4-Seam Trawl
- Headline set even
- 11 links on sweep chain
- Bottom contact chain on

Bison #2 doors
- Outer attachment point
- Washers 2/5
- 2 plates in
- Backstraps 1.5m 150^0 with shoot chain

Figure 78. Headline height (m) and wingspread (m) measurements for the 200 x 12cm net/Bison #2 door combination during the twelfth tow. Headline heights are given in red and wingspread measurements are in blue. The optimal values for each are given in the dotted lines of the respective colors. Vessel speed (kts) over ground is given in green, while tow times (in seconds) is provided on the x-axis. Pertinent information regarding rigging adjustments, towing parameters, and prevailing conditions is given in the graph.

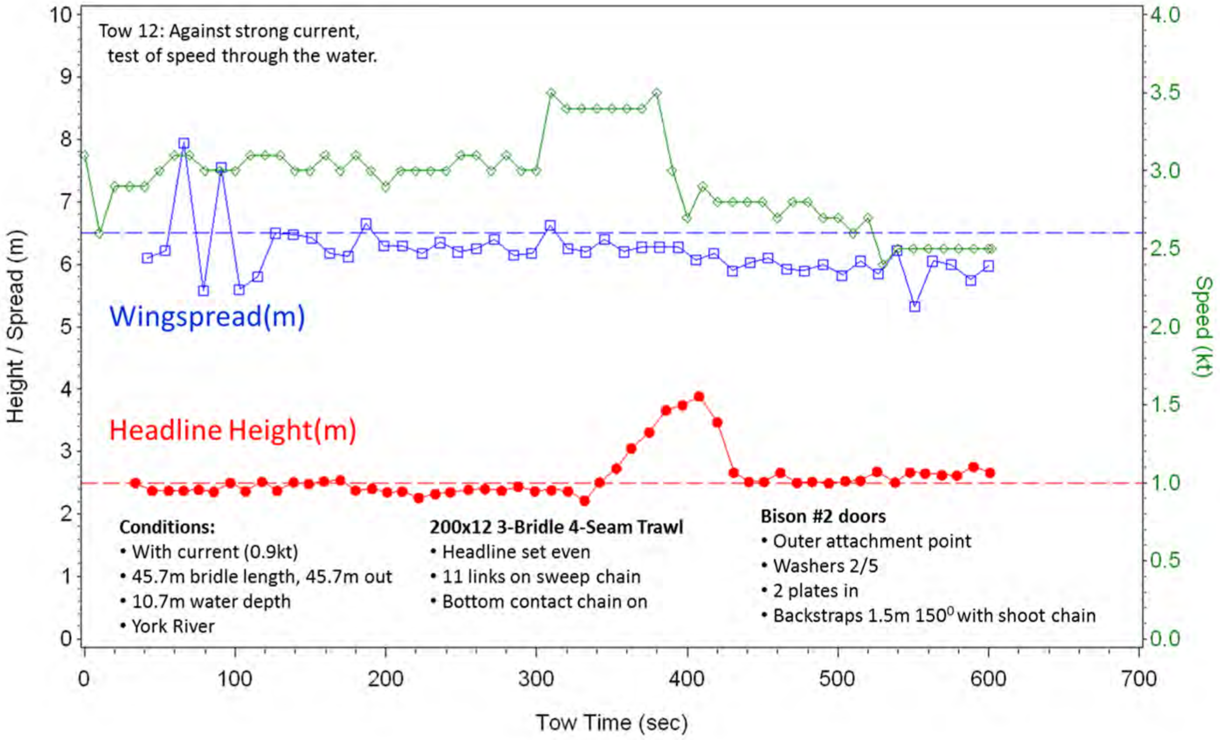


Figure 79. Thyboron, Type IV 44” doors that are to be paired with the three-bridle, four-seam, 200 x 12cm net in 2011.

A. Front view

B. Back view

Figure 80. Locations of those stations that were towed by the ChesMMAP Trawl Survey in November 2010 using both the current survey gear (two-bridle, four-seam, semi-balloon trawl) and the alternate trawl (three-bridle, four-seam, 200 x 12cm net).

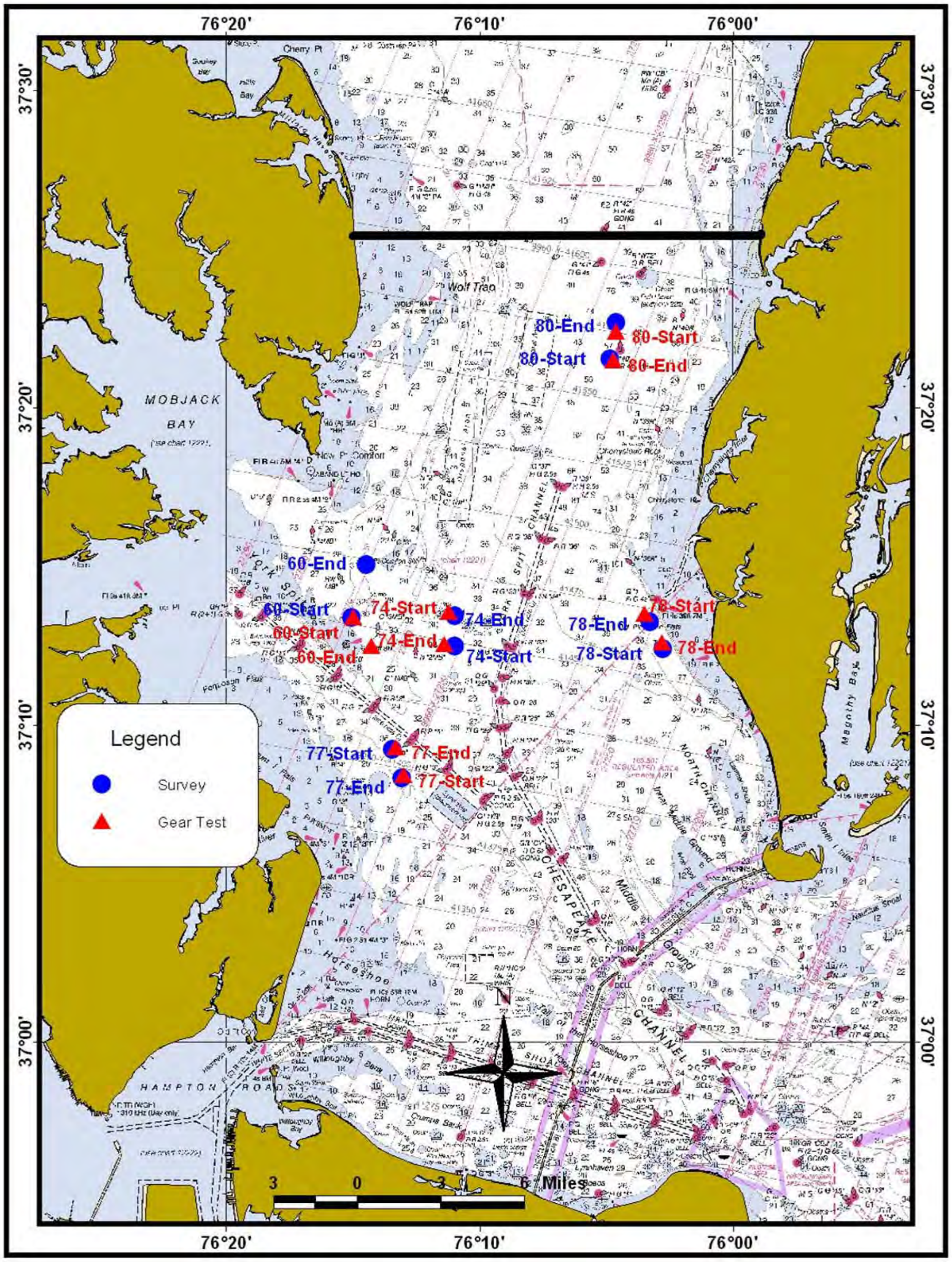
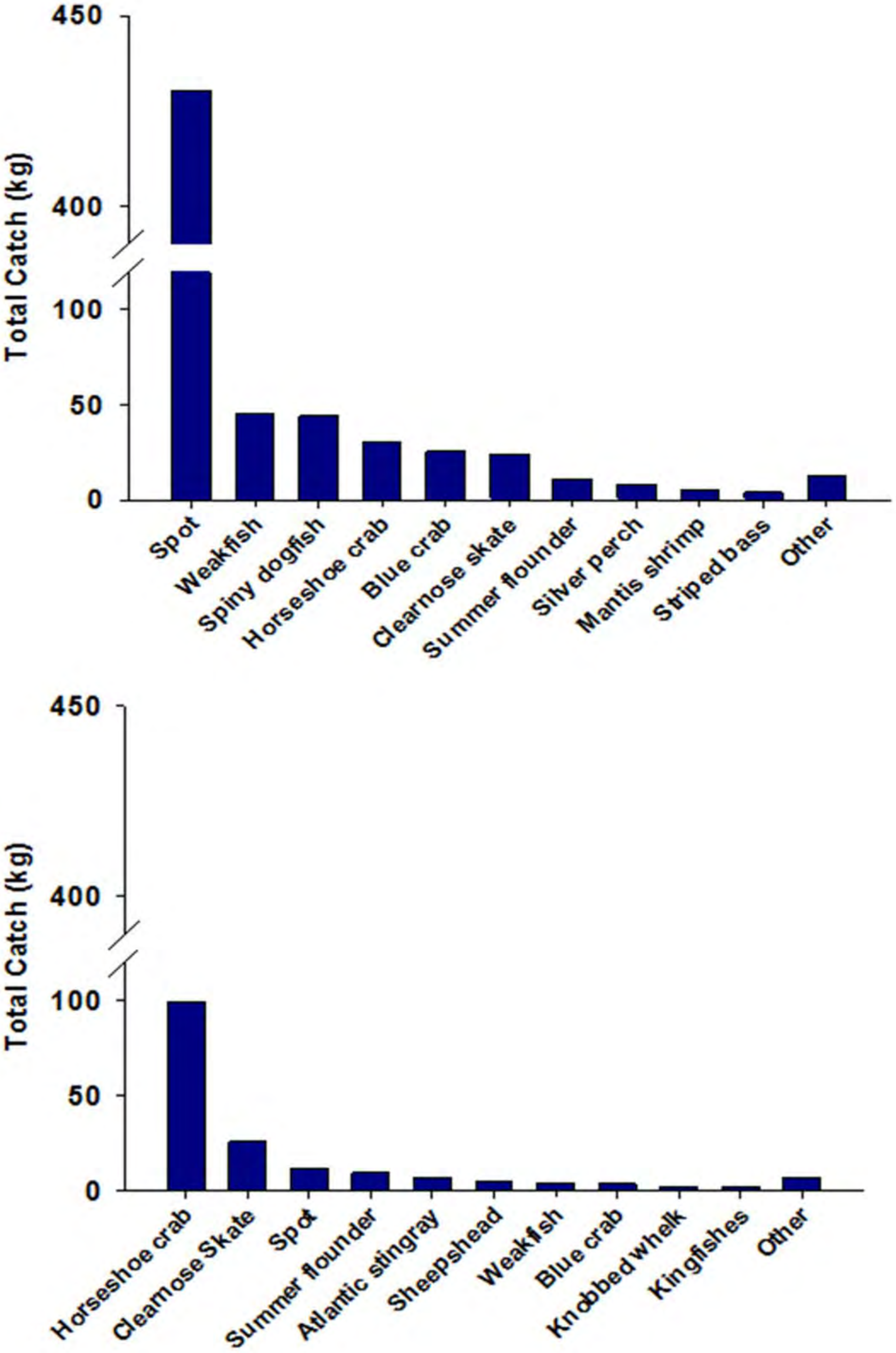


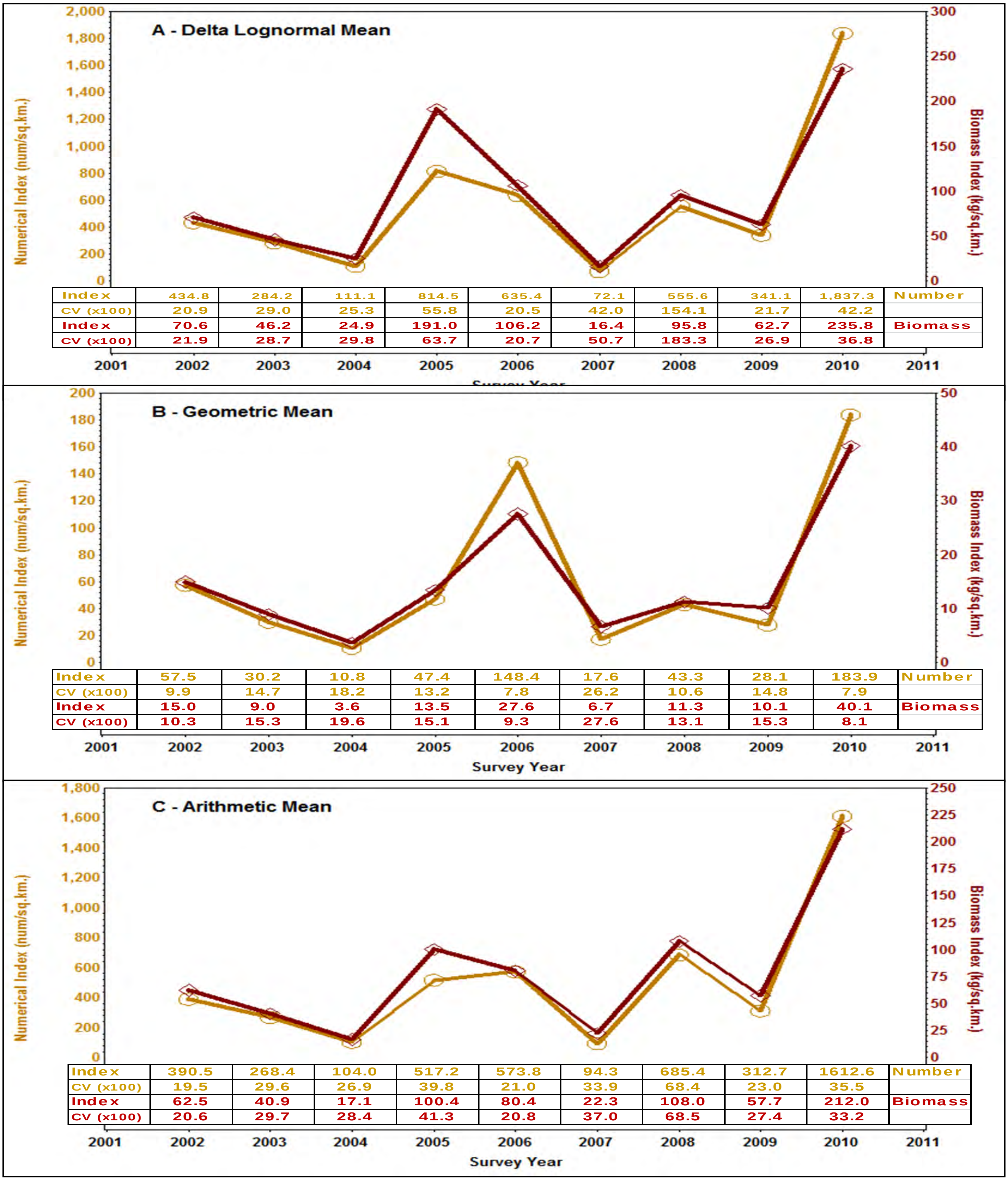
Figure 81. Total catch, in kilograms, by species for both the (A.) 200 x 12cm trawl and (B.) current ChesMMAP Survey net. The top ten species collected by gear (overall) at Stations 74, 77, 78, & 80 in November 2010 are given on the x-axis. All other species are combined into the 'Other' category. Total catch of each, in kilograms, is given on the y-axis. An axis break was inserted between 120kg and 390kg due to the large catch of spot by the 200 x 12cm net.



Appendix 1

Blue Crab and Clearnose Skate Abundance

Figure A1. Abundance indices (number and biomass) for male blue crabs based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	434.8	284.2	111.1	814.5	635.4	72.1	555.6	341.1	1,837.3	Number
CV (x100)	20.9	29.0	25.3	55.8	20.5	42.0	154.1	21.7	42.2	
Index	70.6	46.2	24.9	191.0	106.2	16.4	95.8	62.7	235.8	Biomass
CV (x100)	21.9	28.7	29.8	63.7	20.7	50.7	183.3	26.9	36.8	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	57.5	30.2	10.8	47.4	148.4	17.6	43.3	28.1	183.9	Number
CV (x100)	9.9	14.7	18.2	13.2	7.8	26.2	10.6	14.8	7.9	
Index	15.0	9.0	3.6	13.5	27.6	6.7	11.3	10.1	40.1	Biomass
CV (x100)	10.3	15.3	19.6	15.1	9.3	27.6	13.1	15.3	8.1	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	390.5	268.4	104.0	517.2	573.8	94.3	685.4	312.7	1612.6	Number
CV (x100)	19.5	29.6	26.9	39.8	21.0	33.9	68.4	23.0	35.5	
Index	62.5	40.9	17.1	100.4	80.4	22.3	108.0	57.7	212.0	Biomass
CV (x100)	20.6	29.7	28.4	41.3	20.8	37.0	68.5	27.4	33.2	

Figure A2. Abundance (kg per hectare swept) of male blue crab in Chesapeake Bay, 2010.

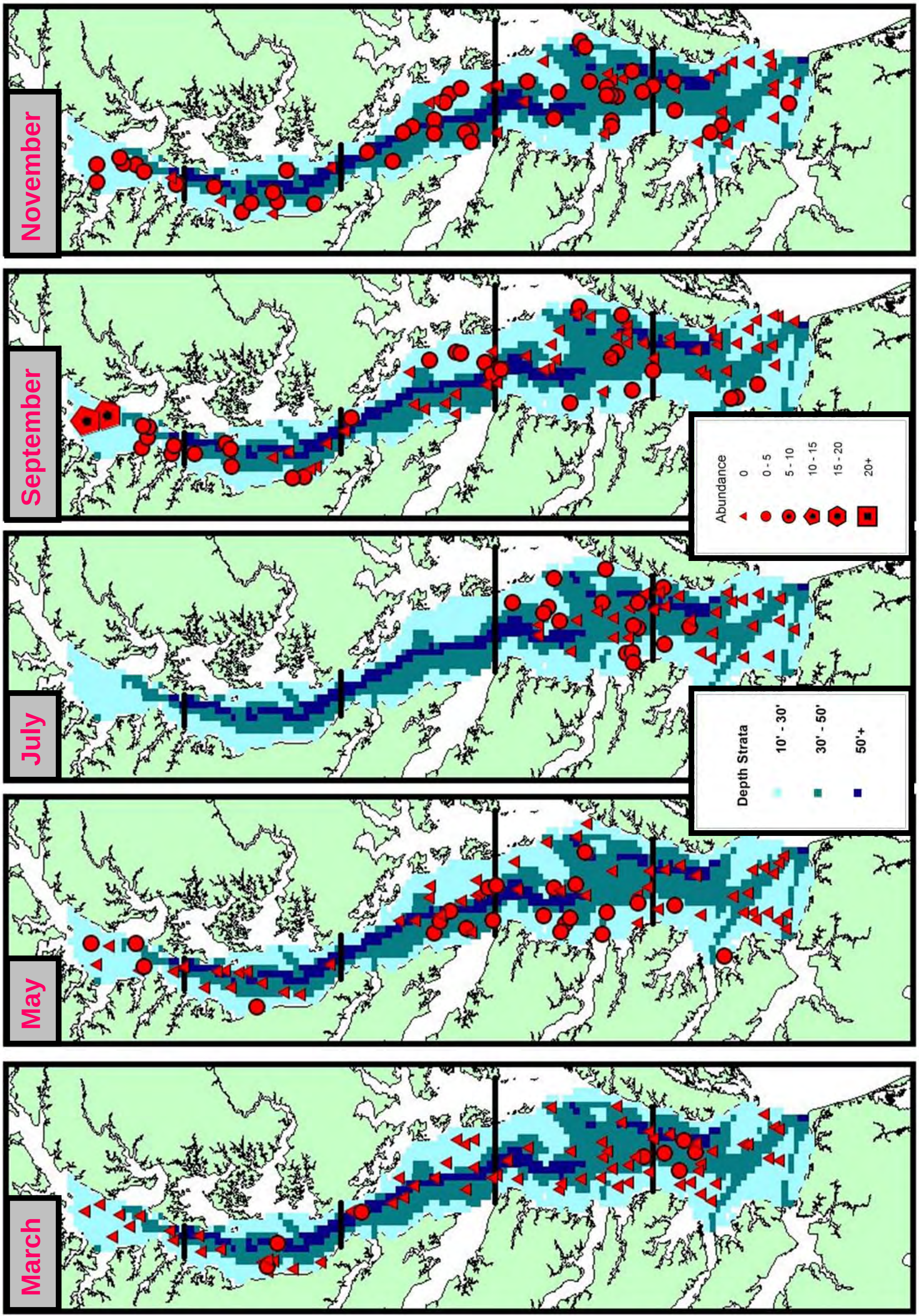
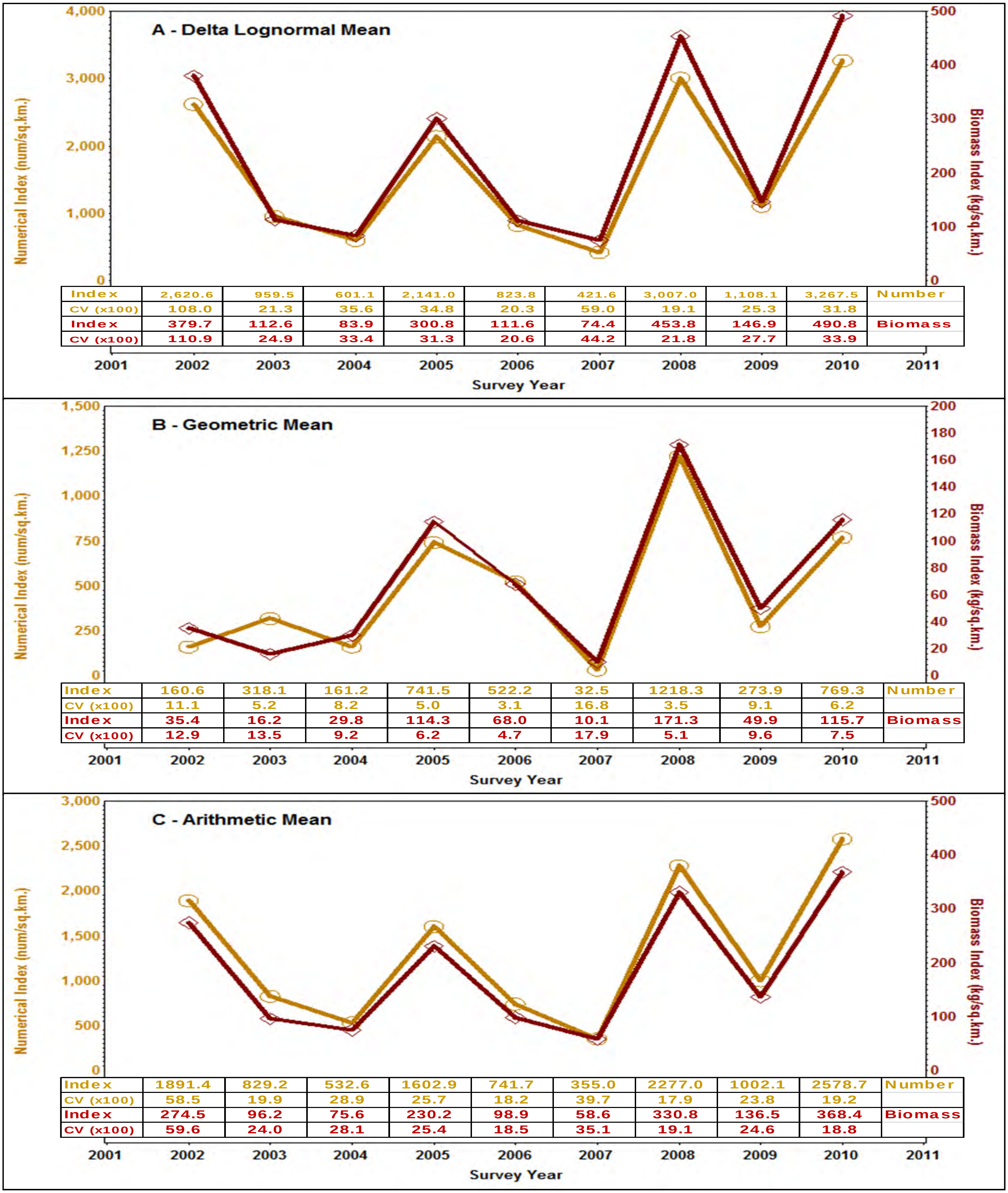


Figure A3. Abundance indices (number and biomass) for mature female blue crabs based on delta lognormal (A), geometric (B) and arithmetic (C) means.



A - Delta Lognormal Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	2,620.6	959.5	601.1	2,141.0	823.8	421.6	3,007.0	1,108.1	3,267.5	Number
CV (x100)	108.0	21.3	35.6	34.8	20.3	59.0	19.1	25.3	31.8	
Index	379.7	112.6	83.9	300.8	111.6	74.4	453.8	146.9	490.8	Biomass
CV (x100)	110.9	24.9	33.4	31.3	20.6	44.2	21.8	27.7	33.9	

B - Geometric Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	160.6	318.1	161.2	741.5	522.2	32.5	1218.3	273.9	769.3	Number
CV (x100)	11.1	5.2	8.2	5.0	3.1	16.8	3.5	9.1	6.2	
Index	35.4	16.2	29.8	114.3	68.0	10.1	171.3	49.9	115.7	Biomass
CV (x100)	12.9	13.5	9.2	6.2	4.7	17.9	5.1	9.6	7.5	

C - Arithmetic Mean

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	1891.4	829.2	532.6	1602.9	741.7	355.0	2277.0	1002.1	2578.7	Number
CV (x100)	58.5	19.9	28.9	25.7	18.2	39.7	17.9	23.8	19.2	
Index	274.5	96.2	75.6	230.2	98.9	58.6	330.8	136.5	368.4	Biomass
CV (x100)	59.6	24.0	28.1	25.4	18.5	35.1	19.1	24.6	18.8	

Figure A4. Abundance (kg per hectare swept) of mature female blue crab in Chesapeake Bay, 2010.

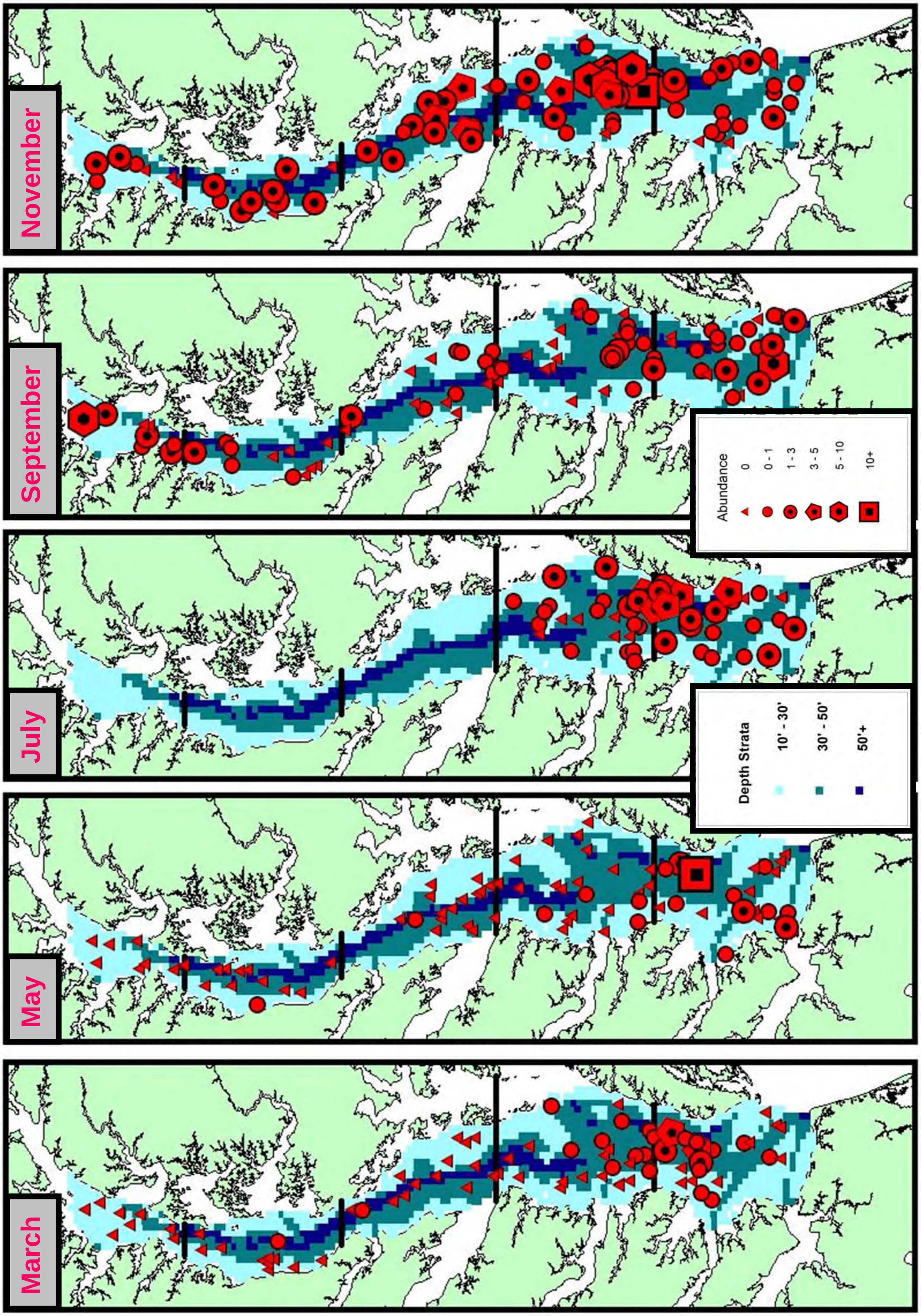
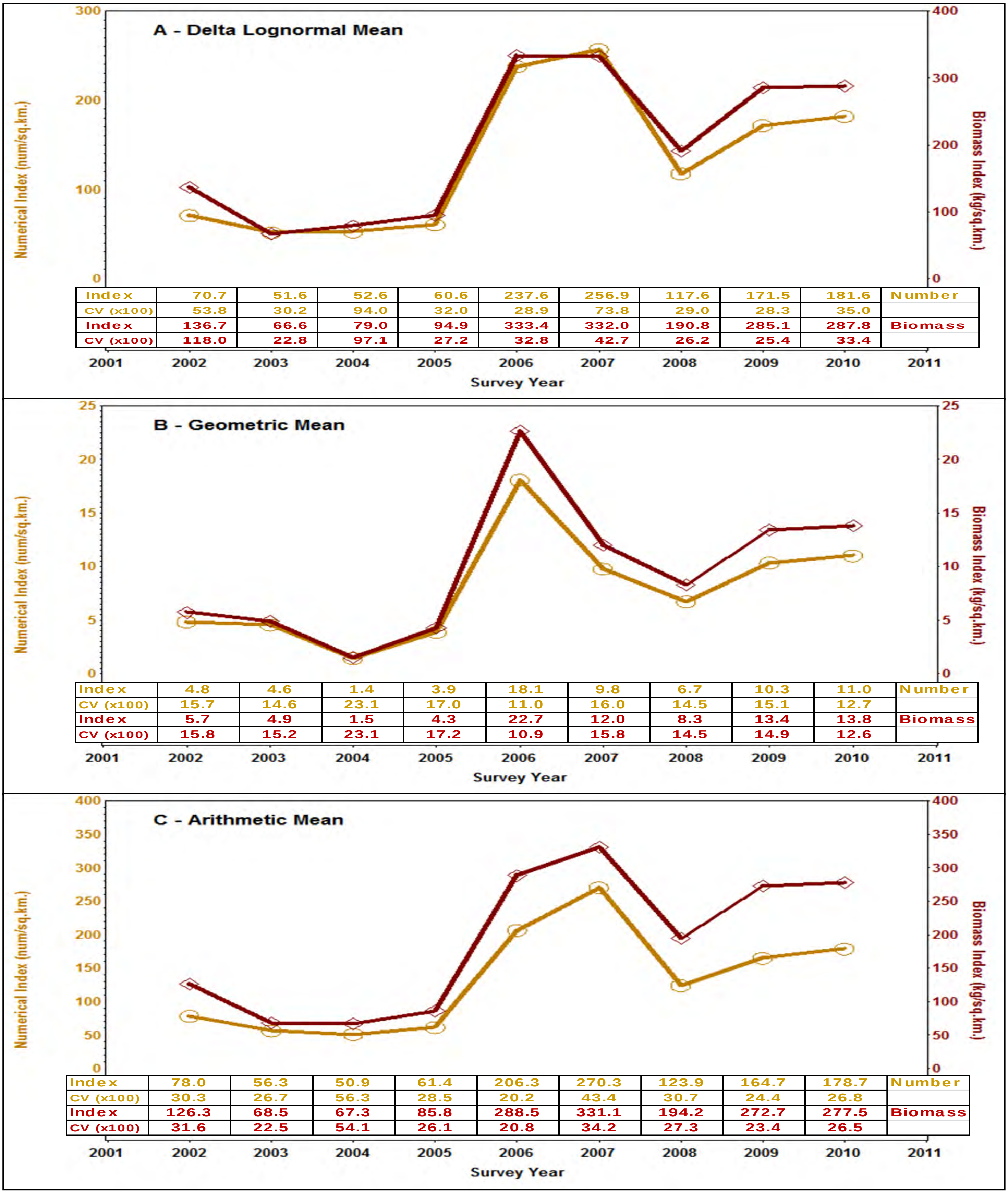


Figure A5. Overall abundance indices (number and biomass) for clearnose skate based on delta lognormal (A), geometric (B) and arithmetic (C) means.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	70.7	51.6	52.6	60.6	237.6	256.9	117.6	171.5	181.6	Number
CV (x100)	53.8	30.2	94.0	32.0	28.9	73.8	29.0	28.3	35.0	
Index	136.7	66.6	79.0	94.9	333.4	332.0	190.8	285.1	287.8	Biomass
CV (x100)	118.0	22.8	97.1	27.2	32.8	42.7	26.2	25.4	33.4	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	4.8	4.6	1.4	3.9	18.1	9.8	6.7	10.3	11.0	Number
CV (x100)	15.7	14.6	23.1	17.0	11.0	16.0	14.5	15.1	12.7	
Index	5.7	4.9	1.5	4.3	22.7	12.0	8.3	13.4	13.8	Biomass
CV (x100)	15.8	15.2	23.1	17.2	10.9	15.8	14.5	14.9	12.6	

	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Index	78.0	56.3	50.9	61.4	206.3	270.3	123.9	164.7	178.7	Number
CV (x100)	30.3	26.7	56.3	28.5	20.2	43.4	30.7	24.4	26.8	
Index	126.3	68.5	67.3	85.8	288.5	331.1	194.2	272.7	277.5	Biomass
CV (x100)	31.6	22.5	54.1	26.1	20.8	34.2	27.3	23.4	26.5	

Figure A6. Abundance (kg per hectare swept) of clearnose skate in Chesapeake Bay, 2010.