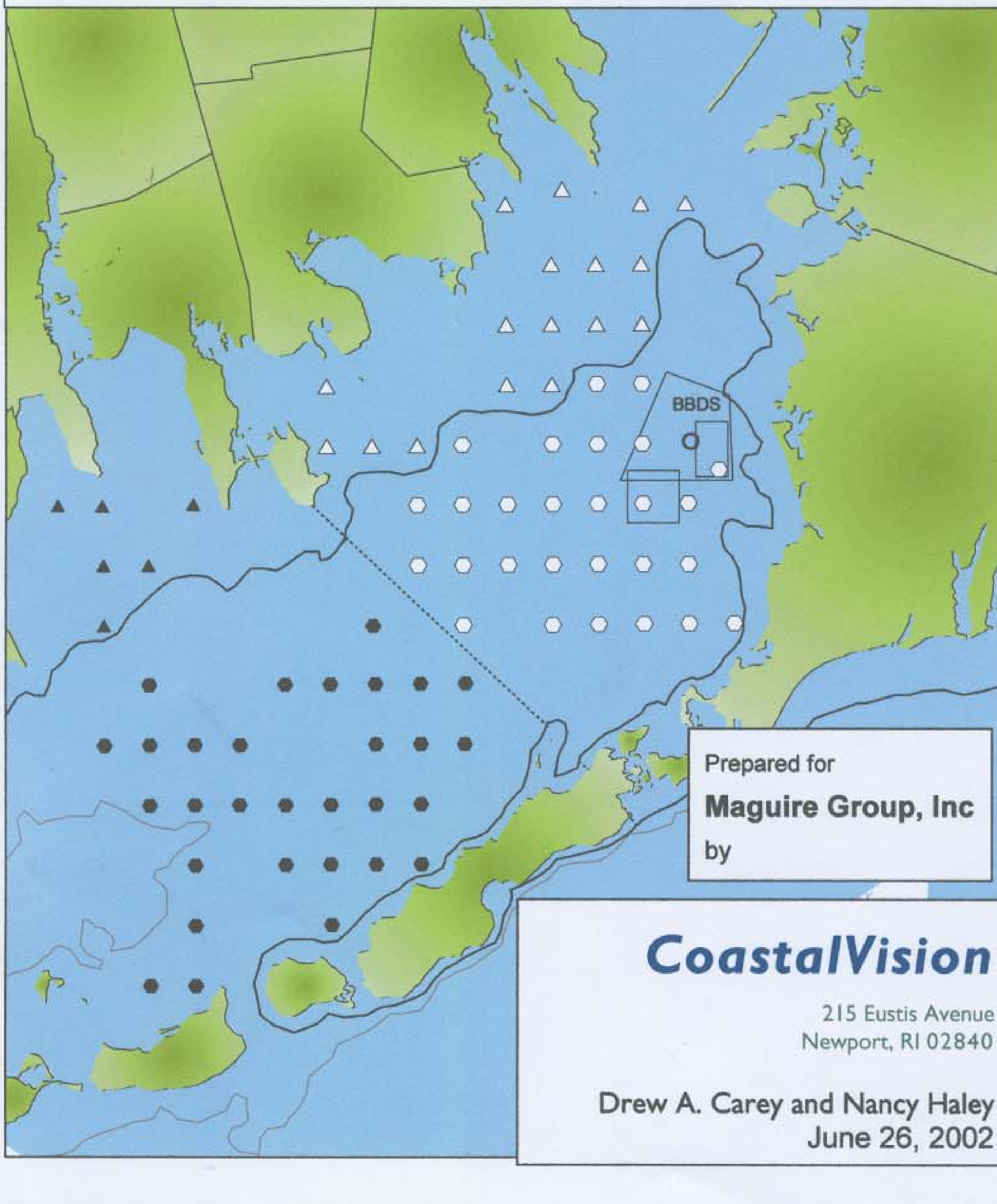
Buzzards Bay Disposal Site Report

MASSACHUSETTS DIVISION OF MARINE FISHERIES TRAWL DATA ANALYSIS

Report submitted to the

Massachusetts Executive Office of Environmental Affairs Coastal Zone Management



Prepared for

Maguire Group, Inc

by

CoastalVision

215 Eustis Avenue
Newport, RI 02840

Drew A. Carey and Nancy Haley

June 26, 2002

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EXECUTIVE SUMMARY

Long-term fisheries data collected by the Massachusetts Division of Marine Fisheries (DMF) in Buzzards Bay was compiled and analyzed to characterize the existing habitats and associated fish and mobile invertebrate communities in the Bay. Specific attention was given to determine the distribution and abundance of nekton within and around two candidate dredged material disposal sites in eastern Buzzards Bay.

The trawl data includes spring and fall finfish and mobile invertebrate (primarily squid, crab and lobster) collections from 1978 to 2000. Data were grouped by season, depth strata, geographical section (north or south), and by approximately one square nautical mile areas (station) in order to examine patterns of abundance (expressed in catch per unit effort, CPUE), biomass (weight), species richness (number of species), and length frequency (juvenile or adult).

The Massachusetts Office of Coastal Zone Management (CZM) has initiated a set of studies to determine baseline conditions in Buzzards Bay in support of an Environmental Impact Report to designate a dredged material disposal site in Buzzards Bay. The results of physical surveys indicated two candidate disposal sites with water depths greater than 12 m (Site 1 and Site 2) were most likely to be preferred disposal locations, because such areas have the potential to limit sediment resuspension and maximize long-term capacity while accommodating access by deep draft hopper dredges. This study was initiated to evaluate fisheries resources across Buzzards Bay, including these sites.

Site 1 is located in a broad topographic depression south of the old Cleveland Ledge Disposal Site (CLDS). Site 2 includes a more constrained basin on the eastern margin of the CLDS immediately adjacent to the former Buzzards Bay Disposal Site (BBDS). Both sites contain a mix of shallow muddy sands (<12 m) and deeper soft mud (> 12 m). These sites are located within a portion of Buzzards Bay with sampling stations assigned to a nearshore moderate depth stratum (9120; 9.1 – 18.3m). Only two of the stations were located within the candidate sites and these were only trawled once during the twenty-three year collection period. These data do not allow discrimination in suitability between Site 1 and Site 2 as fisheries habitat or between them and the habitat as a whole. However, the data presented here provide a baseline of seasonal and spatial

nekton distribution for comparison and monitoring of potential effects of dredged material disposal in Buzzards Bay.

This study found, in general, seasonal assemblages of finfish species within the Bay; and spatial distribution patterns based on depth strata. Catch per unit effort (CPUE) and catch weight (biomass) were relatively consistent throughout the collection period with higher CPUE in the fall and higher biomass in the spring reflecting the movement of spawning adults into the estuary in spring and recruitment of juveniles in the fall. The one exception to this pattern was the distinct decline in spring biomass after 1990 due to a decline in tautog and scup size.

The distribution of CPUE and biomass within and between each stratum was fairly even apart from concentrations of large finfish in the northern portion of 9110 and invertebrates in the southern portion of 9120 in spring. Large invertebrates were scarce in the southern portion of 9110 in the fall but congregated in the northern portion of this stratum. The analysis of CPUE by strata and geographical section for the eighteen select species indicated specific zones of seasonal concentration for most species.

To evaluate the general area of Site 1 and Site 2, the northern portion of the depth stratum 9120 (>9.1m, <18.3 m) was evaluated relative to the characteristics of three other sub regions of the Bay: south 9120; north 9110 (< 9.1 m depth); and south 9110. Both sites are located in the northern 9120 sub region, which may provide a general characterization of their baseline finfish resource conditions. The habitat represented by these deeper portions of northern Buzzards Bay is widely distributed and appears to be relatively uniform in character and finfish distribution. Those portions of the candidate disposal sites that contain unconsolidated mud and water depths greater than 9.1 m (30 feet) are consistent with this habitat.

Species that concentrate within the northern extent of stratum 9120 vary seasonally. During the spring, the season of lowest finfish abundance in the bay, only Atlantic herring and striped anchovy appear to concentrate within this region. Both species are pelagic, schooling fish and their high relative occurrence in spring trawls might be due to a few very high catches or could signify more extended use of this stratum. Other species have notable abundances or biomass in this sub region in spring including: black sea bass, tautog, windowpane, and winter flounder. In the fall, a more diverse assemblage of demersal and pelagic species concentrate in the northern extent of the deep stratum indicating that the area provides suitable habitat for a variety of species.

Although fish may regularly move among the bay's four sub regions, the long time-series of CPUE data in this bottom trawl survey can be used to highlight species that have the greatest potential to be affected by disposal activity at one of the proposed sites. Spring concentrations of herring and striped anchovy may move through the areas proposed for disposal but are not expected to be dependent on specific benthic habitats. Black sea bass, northern sea robin, scup, tautog and windowpane are important species that inhabit this sub region in spring. Fall species of note that concentrate in this sub region are the pelagic species: blueback herring, bluefish (YOY), long-finned squid, striped anchovy, and weakfish; and the demersal species, northern searobin, and summer flounder. Other important species widely distributed but present in this sub region include scup, tautog, and winter flounder. The fall pelagic species may not have strong benthic affinity, but clearly use this sub region. Northern searobin and to a greater degree summer and winter flounder might be expected to have greater sensitivity to disturbances in benthic habitat. The data in this report do not provide any measure of relative sensitivity to disturbance from dredged material disposal; they merely provide an indication of the species most likely to inhabit the sub region with proposed disposal sites.

1.0 INTRODUCTION

1.1. DREDGED MATERIAL MANAGEMENT

The Massachusetts Office of Coastal Zone Management (CZM) is developing an Environmental Impact Report (EIR) to designate a dredged material disposal site in Buzzards Bay. CZM is collecting data to determine the baseline physical and biological characteristics of any proposed disposal site(s), including bathymetry, sediment grain size and chemistry, benthic community structure, bottom currents, fisheries, and water column chemistry. An initial goal was to determine the best potential sites for locating a disposal site in Buzzards Bay based on physical features.

High-resolution bathymetry and side-scan sonar was collected across a relatively large area encompassing the southern half of the historic Cleveland Ledge Disposal Site [Under contract to CZM, SAIC conducted a survey for Maguire Group Inc., in May 1998 (SAIC, 1998)]. The objective of this reconnaissance survey was to gather data on the physical characteristics of the seafloor to facilitate optimal siting of the proposed BBDS.

In general, the May 1998 study identified areas with water depths greater than 12 m as preferred disposal locations, because such areas have the potential to limit sediment resuspension and maximize long-term capacity while accommodating access by deep draft hopper dredges. The May 1998 bathymetric data revealed two locations in the surveyed area having water depths greater than 12 m: a basin located near the eastern boundary of the historic Cleveland Ledge Disposal Site ("eastern basin") and an area near the southern boundary ("southern basin"; Figure 1-1). SAIC conducted a second bathymetric survey in October 2000 to characterize in detail the bottom topography near the southern basin (SAIC 2001). The two candidate disposal sites selected for further study are located over the southern and eastern basins and designated as Sites 1 and 2, respectively (Figures 1-1 and 1-2).

The deeper parts of the southern basin occur just outside the southern boundary of the Cleveland Ledge Disposal Site (Figures 1-1 and 1-2). Since deeper areas within Buzzards Bay have the greatest potential to act as containment sites for deposited dredged material, a decision was made to establish candidate Site 1 (a square area measuring 1600 m × 1600 m) over this deeper part of the southern basin. Site 2 is a rectangular area with dimensions 1000 m × 1700 m (Figure 1-2). It is under consideration as a potential disposal site because it has been affected by past dredged material disposal at the historic Cleveland Ledge Disposal Site and appears to have sufficient water depth and capacity.

Following definition of proposed sites, a series of site characterization studies were initiated. This report provides an analysis of existing data collected throughout Buzzards Bay to characterize the nekton (fish and large mobile invertebrates) based on trawl surveys conducted by the Division of Marine Fisheries (DMF). This analysis is a complement to site-specific trawl data collected by DMF and CZM in 2001 (Wilbur personal communication). By providing an examination of relative abundance of nekton throughout the Bay for a long time series (1978-2000), the importance of fish and invertebrate resources potentially affected by disposal can be evaluated in a larger context.

Disposal of dredged material in Buzzards Bay has occurred over many years with peak activities during the construction and maintenance of the Cape Cod Canal. From 1979 to 1984, dredged material from small harbors and marinas was placed at the Buzzards Bay Disposal Site (BBDS) with average disposal volumes of 22,500 cubic yards per year. In 1985, 73,800 cubic yards from the Mass Maritime Academy were disposed at BBDS (SAIC 1989). In 1986 2,200 cubic yards was disposed and finally, 800 cubic yards was disposed in 1989, the last year of disposal at the site (Dr. Thomas Fredette, personal communication).

The environmental effects of disposal activities have been studied extensively in New England estuaries (see SAIC 1995 for review). Providing that the material disposed at an open water site has passed testing requirements for unconfined disposal, effects can be predicted with considerable accuracy. Material considered suitable for unconfined aquatic disposal must pass tests based on biological standards (toxicity tests of direct exposure to sediments relative to reference sediments). The presumption of the tests is that the disposed sediments have equivalent effects on benthic resources as reference sediments collected from near the disposal site. Immediately after disposal, benthic resources buried by more than 10-15 cm of material are killed and the fresh dredged material is available for recolonization by larvae and mobile organisms. This initial response is frequently a strong attractant for demersal fish who feed on the recolonizing benthos and utilize the uneven bottom for refuge. Over time (1-3 years), the surface of the dredged material approaches the ambient conditions due to reworking by larger benthic organisms and may reach equilibrium with the surrounding sediments. If the dredged material is finer or coarser than the surrounding sediments, the habitat may be altered for much longer periods, at least until sediment deposition (fines) or migration (coarse) modifies the surface material to equilibrate with the surrounding sediments. If deposition rates or coarse sediment supply is low, equilibration could take many years.

From a fisheries resource perspective, dredged material disposal has several potential impacts: habitat modification, local increase in food supply, bioaccumulation of contaminants contained in harbor sediments (Michael Ludwig, personal communication). While effective management of the disposal activities has proven effective in minimizing negative impacts, it is important to characterize baseline conditions at proposed sites in relation to usage by fish and invertebrate resources. To complete the site assessment, the nature and abundance of nekton using the area in northern Buzzards Bay will be characterized and compared to comparable areas in southern Buzzards Bay.

The nekton is an important component of the Buzzards Bay ecosystem that has been recognized for its commercial, recreational and ecological importance from the earliest observations and studies of Buzzards Bay to the present (Buzzards Bay Project, In press). Trawling and fixed nets (e.g. gillnets) were banned from Buzzards Bay in 1893, in part due to the efforts of former president Grover Cleveland, an enthusiastic sport fisherman. Subsequently the State legislature ordered a study of the fisheries of the Bay conducted by Dr. David Belding from 1913-1915. He observed, "…In the early days the abundance of fish afforded a cheap and valuable food supply at the very door of the inhabitants. Within the last two hundred years conditions have radically changed. The present supply is but a small portion of the great natural production described by historical writers – a condition which has been brought about by a variety of causes both local and general…" (Belding 1916). Belding's studies showed that alewife runs (the food source of many migratory fish) had decreased drastically from pollution, dams and overfishing. While the fisheries have not recovered from this early restriction on spawning and recruitment, the resource in Buzzards Bay is still a major recreational and commercial fishery for the region (Colburn et al. 2002). Of these fisheries, commercial lobstering, fish potting (scup and black sea bass), and charter and sportfishing (scup, striped bass, flounder, bluefish) dominate the activities in the Bay.

Many of the fish in Buzzards Bay are migratory, moving along the Southeastern New England coast and into the Bay in summer and often through the Cape Cod Canal into Cape Cod Bay. Some resident species also move throughout the Bay (winter flounder, tautog, skate). As a result, the nekton of Buzzards Bay is connected to a much larger population of fish and invertebrates affected by regional conditions of stress and opportunity. The analysis of trawl data is in many ways a snapshot of these populations in space and time as they respond to food availability, temperature and requirements for spawning throughout the region.

1.2. DIVISION OF MARINE FISHERIES RESOURCE ASSESSMENT

The DMF inshore bottom trawl survey covers the territorial sea from the New Hampshire border to Rhode Island waters (seaward to three nautical miles). The survey area is stratified into geographic zones (strata) based on depth and area. Predetermined trawl sites are allocated in proportion to the area of each stratum and chosen randomly within the stratum. Trawl surveys have been conducted in May and September each year since 1978 (in a few instances, cruises extended into June or October). The objectives of the cruises are to determine the distribution and relative abundance of fish species in state waters; collect biological samples; and to collect physical data (depth, surface and bottom temperatures and salinity). Data are aggregated and analyzed by strata and region (Howe et al., 2000).

The Statewide assessment results are important to place the characterization of Buzzards Bay in context. Although the DMF would not ordinarily examine spatial distribution in the same detail as this report, their sampling regime produces a robust randomized sample of nekton population and biomass within the Bay that can provide an indication of relative location of resources within the Bay for comparative analysis.

1.3. STUDY OBJECTIVES

The primary objective of the study reported here was to characterize the baseline distribution of nekton in Buzzards Bay by analyzing trawl data collected by the Massachusetts Division of Marine Fisheries (DMF). Secondary objectives were to characterize the existing fisheries habitats and associated fish communities known or anticipated (based on historical data) to be present within the two candidate disposal sites and in the immediate surrounding area.

2.0 METHODS

2.1. SCOPE OF STUDY

In order to characterize the distribution of finfish and selected invertebrates in Buzzards Bay and evaluate the relative habitat value of the proposed disposal sites, the study area was restricted to the inshore waters of Buzzards Bay (less than 18.3 m water depth inside of bay closure line between Cuttyhunk Island and Gooseberry Neck, Massachusetts). We aggregated trawl data from 255 tows within this area into 80 “stations” for geographical analysis of the location of resources within Buzzards Bay (Figure 2-1). Trawls were conducted by the DMF based on a random stratified design that assigns tow locations based on a grid with over 100 potential locations with Buzzards Bay. These locations are not fixed stations because the design of the DMF sampling effort is to compare catch from regional strata much larger than Buzzards Bay and does not attempt to describe localized distribution patterns. In order to meet our study objectives we aggregated data from all tows within a grid cell and assigned the station location to the center of the grid cell (Figure 2-1).

The stations in Buzzards Bay form only a portion of the statewide depth-strata sampling regime but provide an excellent characterization of the distribution of nekton within the Bay. Of these stations only three fall within either the historic CLDS or one of the two proposed disposal sites. Because of this small sample size, we did not attempt direct comparison of stations within or near the disposal sites (historic or proposed) with stations from similar habitats (Figure 2-2). The aggregated sampling stations were grouped by depth strata ($0 \leq 9$ m; 9.1 – 18.3 m) and geographic section of the Bay (North; South) to facilitate comparison of the species abundance and biomass from habitats near the disposal sites with those more isolated from the disposal sites (Figure 2-1). The division into North and South was an arbitrary separation along a line with relatively few tows, effectively “clumping” a group of tows in the North and a group of tows in the South. The purpose was to compare habitats near disposal activity (North section) with similar habitats more remote from disposal activity (South section). Both proposed disposal sites and the historic disposal areas fall within the North sub region of “9120” strata (stations 9.1 – 18.3 m deep). Therefore any potential historical impacts present in the time series should be most evident in this sub region and the baseline characteristics of this sub region most closely reflect the conditions present at the proposed sites.

2.2. DATA COLLECTION

The data were collected by DMF during inshore bottom trawl surveys of Buzzards Bay between 1978 and 2000. The following is a synopsis, taken from Howe et al. (2000), of the methods used by DMF to sample Buzzards Bay. The bottom trawl survey is conducted biannually; sampling occurs during three-week sampling periods in May (Spring sampling) and September (Fall sampling). Among the objectives of the DMF inshore bottom trawl survey program are to: 1) determine the distribution and relative abundance of fish species in state waters, and 2) collect physical data - geographic location, depth, and hydrographic information - from sampling locations.

DMF employs a stratified random sampling design to conduct the trawl survey. Coastal areas are stratified by region and depth and predetermined trawl sites are identified within each depth strata. The numbers of individual trawl locations within a given stratum are proportional to the stratum's area, resulting in weighted, or stratified, abundance measures. Certain regions of Buzzards Bay are not sampled due to the potential for gear damage to the trawl. Trawl sites are selected randomly for each cruise. During each cruise, DMF completes at least two tows per stratum to permit calculations of catch variance.

A trawl sample consists of deploying a 3 / 4 size North Atlantic type two seam otter trawl (11.9 m headrope – 15.5 m footrope) for a 20-minute tow at 2.5 knots from a chartered research vessel (Howe et al. 1999). DMF records the total weight (kg) and length frequency (cm) for each species captured in a trawl sample. When practicable, all fish captured are measured. If sample sizes are too large then standard subsampling procedures are followed to obtain length frequencies for each species in the catch (R. Johnston, DMF, personal communication). At each station, DMF also measures the surface salinity and bottom temperature.

2.3. APPROACH TO DATA ANALYSIS

The portion of the DMF trawl survey database needed to conduct this analysis was imported into a Microsoft Excel spreadsheet. The study area of upper Buzzards Bay contained two depth strata: 9110 (<9.1 meters) and 9120 (9.1 – 18.3 meters). The depth strata represent a DMF designation of potential tow locations for their inshore trawl survey; the area included in Buzzards Bay is only a portion of the depth strata sampled in their surveys.

Data tables were organized to permit spatial analysis in two ways: 1.) through compilation of summary data of spatial groups, and 2.) through presentation of data summaries for each station on maps. The spatial groups included: the two depth strata; the two regional geographical sections (North and South); sampling stations. The geographical sections are an arbitrary division of Buzzards Bay into a northern region and southern region (Figure 2-1). The division was selected on a line between West Island and the Weepecket Islands based on an existing grouping of tow locations. These sections are further divided into sub regions based on the distribution of the strata in each section. The individual tows comprised the unit of randomized sampling design and represented the base unit for compiling averages. The tow locations were classified into 80 "stations" (not a DMF designation) and catch statistics were compiled for each station (e.g. Figure 2-2 displays the total number of tows collected at each station). Tow locations were classified as stations to facilitate data processing, mapping and compilation of summary statistics. Each station had a stratum and geographical section designation and summary statistics were compiled for these spatial groups and for each sampling season (Spring and Fall).

The bottom trawl survey catch data were grouped into two categories: Total Catch and Select Species. The total catch consisted of all finfish and invertebrate species collected in the bottom trawl survey from strata 9110 and strata 9120 within the Buzzards Bay study area (Table 1-1). Select species included long-finned squid in addition to 17 finfish species that met the following criteria: in numerical abundance they were within the top 80% of the total catch in either season and were determined to be representative species of Buzzards Bay. Biologists from CZM and the DMF collaborated on finalizing this list of species (Table 2-1). Results of the total catch analyses were summarized by season as total finfish or total invertebrates while results for each of the select species were presented individually. Length frequency data were analyzed for five of the 17 finfish species (Black sea bass, Scup, Summer Flounder, Tautog, and Winter Flounder), which permitted more detailed results by lifestage for these species (Table 2-2).

Summary statistics were calculated in Microsoft Excel with the use of “PivotTables”, a utility that permits rapid compilation of summaries by fields present in a spreadsheet. This simple database function permitted detailed analysis for all the complex groupings of the data (strata, season, section, station) and export into mapping software. Station data was linked to location files and displayed on maps with a Geographic Information System (GIS) (ArcView 8, ESRI, Redlands, CA). Data presentation was standardized to show the existing BBDS circle, the historic CLDS polygon, the potential disposal sites, the strata boundaries, and town boundaries (Figure 2-1).

2.4. DESCRIPTIVE STATISTICS

The Buzzards Bay catch data were analyzed for the following parameters: average catch-per-unit-effort (CPUE), average biomass, and richness. Average CPUE, which provides a measure of relative abundance, is the average number of fish caught per unit of effort (King 1995). One 20-minute tow was chosen as the unit of effort. Biomass is the weight, in kg, of fish caught in the trawl survey. Average biomass was determined by dividing the total weight of the total catch or a particular species by the total number of tows in a given season or region. Richness is the mean number of species caught per tow. Richness was calculated by summing the mean number of species per station by season, stratum, and section.

The data were summarized by season (Spring, Fall), station (1-80), strata (9110, 9120), and section (North, South) for each parameter. For the total catch only, the parameters were also summarized by year and season to provide an overview of temporal data patterns.

Average total CPUE and average total biomass were calculated for all finfish and invertebrate species captured in the trawl survey (Table 1-1). Average CPUE and average biomass were also calculated for each of 18 species selected for individual analyses by CZM and DMF biologists (Individual Species CPUE) (Table 2-1). For black sea bass, scup, summer flounder, tautog, and winter flounder, mean CPUE of both juvenile and adult fish were calculated based on length frequency data (see below, Table 2-2).

Length frequencies were plotted for black sea bass, scup, summer flounder, tautog, and winter flounder. For each species, all length data that were collected between 1978 and

2000 were aggregated and plotted by season and stratum. Due to the wide range in length frequencies for most species, lengths were plotted on a logarithmic scale. Adult and juvenile fish were distinguished within the length frequency figures and adult, age 1+ juveniles, and young-of-the-year (YOY) fish were discussed within the text. General species synopses (e.g., NOAA Technical Memoranda), which referred to age and growth studies in the primary literature, were used to define length ranges for lifestages of the 5 species listed above (Table 2-2). Minimum lengths for adults were based on the length at which 50% of the population (both sexes combined) had attained sexual maturity. Maximum lengths for YOY fish were largely taken from age and growth studies in the mid-Atlantic region where growth rates may vary with respect to Buzzards Bay. Therefore, the length ranges used to denote YOY and juvenile lifestages should be viewed with caution and should not be interpreted as absolute length ranges for species inhabiting Buzzards Bay. Growth rates for individual species vary, sometimes greatly, from system to system depending on a multitude of environmental and ecological factors. For the species chosen, the lengths used to define each life stage help discern general seasonal patterns of juvenile and adult distribution and occurrence in Buzzards Bay.

For each select species the average CPUE (catch per tow) and biomass (weight per tow) for each season by station was calculated and plotted on distribution maps. The range of catch and weight per tow is typically quite high for inshore finfish and this presents a problem for display of distribution. We fit the data to predefined ranges of catch number and weight and assigned a standard symbol size to each range (Table 2-3). The standard symbol size allows comparison between species and seasons but it can obscure specifics of distribution within those ranges. To alleviate this problem, we display the actual range of results next to each bullet for species and season. In many cases, only a few stations had average catches within the range and the actual result provides a better indication of distribution than the standard range. Particularly high outliers (more than double the next lowest result) are indicated with a red circle around the bullet except where the outlier is obvious on the map.

3.0 RESULTS

3.1. SUMMARY OF DATA

The data analyzed in this study represented the compilation of 255 tows collected in the spring (n=131) and fall (n=124) from 1978-2000. Fall finfish catch dominated the abundance totals with 572,879 fish representing 69 species. Spring finfish catch was an order of magnitude lower in abundance with 50,356 fish representing 49 species. The fall catch of invertebrates was also much larger than spring with 87,412 organisms representing 15 species. Spring catch was lower (12,377 organisms) but represented a larger number of species (19).

The dominance of the fall finfish CPUE was consistent throughout the survey period (1978-2000) with particularly high average catches in 1988 and 1998 (Figure 3-1a). This relationship also held for fall invertebrate CPUE with high average catches in 1986, 1988 and 1993 (Figure 3-1b). However, the biomass time series revealed a shift in seasonal dominance because of a precipitous drop in spring finfish biomass after 1990 (Figure 3-2a). In 1990, the spring biomass was dominated by a high catch (abundance and biomass) of scup. In subsequent years, scup catch returned to previous levels but tautog catch declined from 1990 lowering the spring biomass average (Figure 3-3a). Fall biomass did not show a specific trend with most of the variation from scup and butterfish catch. Apart from low years in 1982, 1990 and 1995, fall scup catch weight was high throughout the survey. Fall tautog catch did decline after a peak in 1989, but butterfish catch increased. The invertebrate biomass results show a few anomalous years with unusually high weights in either spring or fall (1988, 1993, 1995, 1997) but in general the spring and fall weights are comparable (Figure 3-2b). Species richness (mean number of species per tow) does not show any distinct pattern over time apart from an apparent drop in spring species richness between 1987 and 1993 followed by a recovery (Figure 3-4). This corresponds to a period of relatively high fall catch for finfish and invertebrates.

3.2. SPATIAL ANALYSIS OF HABITAT UTILIZATION

In spring, finfish are more abundant in the northern portion of the bay, in particular, within the shallow depth strata north of the disposal site (Figure 3-5a). There are also peaks in average abundance along the shoreline in the southern region of the Bay around the Elizabeth Islands. While the standard deviations around the means indicate very wide variances, this is typical of trawl data where catch numbers can vary over a wide range within a relatively small area (Figure 3-6). Spring finfish biomass reflected even more concentration of catch in the northern shallow strata (Figure 3-5b). This indicates larger fish associated with the high CPUE in this area (Figure 3-6).

In contrast with the spring, fall finfish CPUE was evenly distributed throughout the Bay with some indication of concentrations in the northern sub region of strata 9120 around the disposal site and in the southernmost part of the Bay (Figure 3-5c). Fall finfish biomass closely mirrored the CPUE distribution with some increased dominance of weight in the northerly deep stations around the disposal site (Figures 3-5d, 3-6).

The spring finfish pattern is not reflected in the invertebrate abundance distribution (Figure 3-7a). Invertebrate species were more abundant in the southernmost stations in the central region of Buzzards Bay and may represent individuals migrating into the shallower waters. Spring invertebrate biomass was skewed toward the larger catch weights but mirrored the regional distribution of CPUE (Figures 3-7b, 3-8). Fall invertebrate CPUE was more evenly distributed and dominant within the deeper strata (Figures 3-7c, 3-8). Fall invertebrate biomass was more evenly distributed than CPUE, but catch weight in the shallow stations along the northern edge of the 20 m contour was relatively high (Figures 3-7 d, 3-8).

In spring, a total of 49 species of finfish and 19 species of invertebrates were captured throughout the Bay in contrast to fall when 69 species of finfish and 15 invertebrate species were captured. The average number of species in the southern part of the Bay in spring was greater than the species richness of stations in the northern section with higher species richness in the deep stratum (Figure 3-9). By fall this disparity appears to have evened out in the deep stratum and reversed in the shallow stratum with more species present in the deep stratum (Fig 3-9). A similar pattern was seen in the distribution of species with high abundance. In spring, eleven species were concentrated in the south compared to seven in the north (Table 3-1). In fall, ten species were concentrated in the south and eleven in the north (Table 3-2).

In spring the shallow north sub region had the highest finfish catch and biomass but the lowest species richness (Table 3-3). Spring invertebrate catch and biomass was highest in the south 9120 sub region, which had the highest species richness. In fall, the south 9120 sub region had the highest finfish catch and high biomass, while the north 9120 sub region had the highest finfish biomass and invertebrate catch (Table 3-4).

3.3. SELECT SPECIES

Like any sampling method, bottom trawl surveys are not equally effective over all habitats or for all species. The catch per unit of fishing effort (CPUE) in a bottom trawl survey is influenced not only by the catchability of fish by the trawl but also by the density of fish in the sampling area (Sissenwine and Bowman 1978). A low number of fish collected per tow may not necessarily reflect reduced abundance of certain species but may be due to the variable effectiveness of bottom trawls in collecting certain species and operating in specific habitats. Some fast-swimming species of fish, like bluefish and weakfish, can evade capture in active sampling gear with their speed (Hayes 1983). Similarly, the characteristic schooling behavior of clupeid species (e.g., alewives, Atlantic herring, bay anchovy, blueback herring, and striped anchovy) leads to large variations in the catch size of these species because active sampling gear often may miss large concentrations of fish (Nielson and Johnson 1983). Bottom trawls are less effective over high relief bottoms and, generally, are not deployed in highly structured habitats where there is a strong potential for gear damage. Thus, fish that primarily occur in structured habitats (i.e., cunner, tautog, black sea bass) are likely to be less common in the bottom trawl survey than fish that occur in pelagic and less structure-oriented regions. These inherent limitations of trawl sampling should be noted when interpreting the survey results concerning the relative abundance of the following select species.

Alewife (*Alosa pseudoharengus*)

Alewives were moderately abundant in the bottom trawl survey. Slightly more fish were collected in the spring than in the fall (Table 2-1). As a pelagic species, alewives are less vulnerable to capture in bottom trawls than more demersal species. Total sample sizes observed in the survey may therefore underestimate the abundance of alewives in Buzzards Bay during either season. Alewives are an anadromous species that enter the Bay in late spring to spawn within tidal rivers and tributaries of Buzzards Bay (Howes and Goehringer 1996). Young-of-the-year and juvenile alewives use the bay as nursery habitat throughout the year.

Alewives were widely, though not evenly, distributed in the trawl survey during the spring and fall. Highest average catches of alewives during both seasons occurred at only a few stations within the deeper sampling stratum (Figure 3-10 a, c). During both seasons, alewives were relatively more abundant in the southern extent of Buzzards Bay, at stations within stratum 9120 (Figure 3-11 a, c). An average of more than 100 alewives per tow were collected from two of these stations in the spring. Conversely, the highest average catch of alewives at stations in the northern section of the bay during either season was 20 fish per tow (Figure 3-11 a, c). As expected, the stations and sections with higher mean catch contained a greater mean biomass of alewives (Figure 3-10 b, d).

Alewives were not collected in great abundance in the shallower stratum during either season. Although alewives travel through this reach of Buzzards Bay to spawn in several bay tributaries, their spring spawning runs occur earlier than the spring trawl survey. In the fall, the alewives' return migration to sea occurs over a more protracted period and consists of smaller groups of fish.

Atlantic herring (*Clupea harengus*)

Atlantic herring were fairly numerous during spring sampling (n = 3,715) but quite rare in the fall survey (n = 78 fish). The high number of fish collected per tow in the spring is due to large catches of post-larval (brit) herring. Aside from being relatively more abundant in the spring trawl survey; Atlantic herring were also more widely distributed in Buzzards Bay during this season. In the spring, much higher catches of the species were collected at one station within the northern extent of Buzzards Bay in stratum 9120 (Figure 3-12 a, 3578 herring per tow). Similarly, mean biomass of Atlantic herring was also higher at this station (Figure 3-12b, 6 kg). Only one station sampled in the fall, in the southern portion of the bay in stratum 9120, yielded an average of more than one herring per tow (Figure 3-12 c). Few fish were collected in stratum 9110 during either sampling season (Figure 3-13 a, b).

Bay anchovy (*Anchoa mitchilli*)

Although bay anchovies were not collected during spring sampling, the species was commonly collected during the fall (Figure 3-14). Bay anchovies ranked third in numerical abundance (n = 13,086), behind scup and butterfish, among all species captured in fall sampling. The catch of bay anchovy varied widely in this survey (range = 0 – 1659 fish). The distribution of bay anchovy observed in the trawl survey is consistent with other reports of the species' preference for nearshore, mud habitats (Bigelow and Schroeder 1953; Whitehead et al. 1988). Bay anchovy were mainly collected in the northern extent of Buzzards Bay and were relatively more abundant in the shallow stratum (Figure 3-15). Relatively large catches of bay anchovy were also obtained in the northern extent of stratum 9120 (Figure 3-14 c). The highest average catch of bay anchovies occurred in the northern extent of stratum 9110 (mean of 243 fish per tow) as compared to a low mean of 20 fish per tow collected in the southern extent of stratum 9120 (Figure 3-15).

Black sea bass (*Centropristes striata*)

Black sea bass exhibited strong seasonal variation in abundance in Buzzards Bay (Table 2-1, Figures 3-16, 3-17). By far, most black sea bass collected in the trawl survey are YOY fish (≤ 10 cm TL) that were taken in fall tows (Figure 3-18). In the spring, nearly all black sea bass collected were adult fish (Figure 3-18).

In both seasons, average catches of black sea bass were greatest at shallower stations in the northern extent of the Bay (Figure 3-16). In the spring, relatively higher catches of adult black sea bass were also taken at deeper stations within the southeastern quadrant of Buzzards Bay (Figure 3-16b). The region with the lowest CPUE for black sea bass in the spring was the southern end of stratum 9110 (Figure 3-17).

Although black sea bass were also collected at similar stations in the fall, the species was more widely distributed in stratum 9110 during this season. Most of the juvenile black sea bass captured in the fall were YOY (Figure 3-18). Spring and fall sample sizes of adult black sea bass was nearly equal. A shift in the size distribution of adult black sea bass between the two strata indicates that larger fish tend to occur at greater depths during this season (Figures 3-17, 18). Adult black sea bass are typically found at greater depths than juveniles during the summer and early fall (Howes and Goehringer 1996; Steimle et al. 1999a).

The distribution of YOY black sea bass in the fall survey was similar to the distribution of adult black sea bass. Like the adults, YOY fish were differentially distributed within stratum 9110 in the fall. While the highest CPUE recorded for this species in the fall occurred within the northern extent of stratum 9110 (mean of 264 YOY per tow), an average catch of only two fish per tow was obtained from trawls in the southern range of the stratum (Figure 3-17). Relatively high catches of YOY black sea bass were also taken at several stations throughout stratum 9120 (Figure 3-16), however, they were not as highly concentrated within this stratum.

Blueback herring (*Alosa aestivalis*)

Blueback herring were collected in moderate abundance in the bottom trawl survey. Bluebacks were more abundant in spring (n = 483) versus fall sampling (n = 111) (Table 2-1). The highest average catch of blueback herring at any station sampled in the fall was 32.5 fish per tow compared to a high spring mean of 166 blueback herring per tow (Figure 3-19). In the spring, stations along the southeastern shore of Buzzards Bay, in strata 9120, yielded the highest mean catches of blueback herring (Figures 3-19, 3-20). Few fish were collected in trawls in the northern extent of the Bay or within the shallow stratum during spring sampling.

Blueback herring were more widely distributed in the fall albeit with lower numbers (Figure 3-19). Relatively greater catches occurred in the northern region of the deeper stratum (mean of 2.3 fish per tow) as compared to the other quadrants of the bay (Figure 3-20). Like alewives, blueback herring are a pelagic, anadromous species that spawn in tidal tributaries of Buzzards Bay during the spring. Howes and Goehringer (1996) report that bluebacks are abundant in Buzzards Bay in late summer and fall. Blueback herring were more broadly distributed in the bay during the fall even though they were less abundant in the trawl samples during this season (Figure 3-20). As a pelagic species, blueback herring are less vulnerable to capture in bottom trawls and, therefore, may be under sampled in the trawl survey.

Bluefish (*Pomatomus saltatrix*)

Bluefish are a fast moving, warm water pelagic species that spawns offshore in late spring and summer (Bigelow and Schroeder 1953). Therefore, as expected, bluefish were rarely captured in spring trawls in Buzzards Bay (Figure 3-21). Only two fish were collected in 131 spring tows. Bluefish were much more abundant in fall sampling when YOY bluefish (“snappers”) are common in southern New England waters, including Buzzards Bay. The broad distribution of bluefish captured in the fall (Figure 3-21) reflects a period when juvenile bluefish actively chase smaller prey species throughout the bay. Still, during this season, some regions show higher relative concentration and biomass of bluefish than others. The tendency for juvenile bluefish to school while foraging results in large individual catches of this species and, hence, the broad range in the number of bluefish caught per tow.

Stations with the highest CPUE and greatest biomass of bluefish were those within the northern section of stratum 9120 (Figures 3-21, 3-22). The southern section of the deeper stratum and the northern section of stratum 9110 ranked second and third, respectively, in relative abundance of juvenile bluefish. Previous analyses of juvenile bluefish distribution in inshore waters of Massachusetts showed that juveniles were most common at depths ranging from 5 to 10m (Fahay et al. 1999).

Butterfish (*Peprilus triacanthus*)

Butterfish were abundant in both the spring and fall trawl sampling, although they were considerably more abundant in fall samples (Table 2-1). Next to scup, butterfish were the most abundant species collected in Buzzards Bay during the fall. Butterfish were widely distributed in the deeper stratum during both seasons and were virtually ubiquitous in fall (Figure 3-23). Butterfish reportedly exhibit a preference for sandy bottoms over mud or rocky bottoms (Bigelow and Schroeder 1953, Cross et al., 1999). The species' greater relative abundance in the middle section of the bay, away from rocky nearshore habitat, appears to support this pattern of habitat preference but the population in fall is sufficiently numerous to occupy most habitats.

The southern extent of stratum 9120 supported the highest average catches and the greatest biomass of butterfish in the study area. Relatively fewer butterfish were collected from shallow stations of the bay in the spring as compared to the fall (Figure 3-24), probably due to the seasonal increase in juvenile butterfish abundance in the fall. Within the shallower stratum, higher mean catches of butterfish occurred in the northern section. The region with the lowest mean catch of butterfish during both seasons was the south section of stratum 9110 (Figure 3-24).

Cunner (*Tautogolabrus adspersus*)

Cunner is a nearshore, benthic species known to occur among eelgrass and over rocky bottoms. Due to the preference of cunner for habitats containing structure, where trawl gear is infrequently deployed, the species is likely to be under sampled in the survey. Cunner were distributed mainly within stratum 9110 during both seasons (Figure 3-40a, Figure 3-41a). This species was three times more abundant in stratum 9110 in the fall, while in the spring; they were seven times more abundant in the shallower stratum. This pattern was more evident in the spring when nearly ten times as many cunner were collected in the survey (Table 2-1).

In the spring, the highest mean catches of cunner (mean of 50 fish per tow) occurred at stations along the southwestern shore of Buzzards Bay. In contrast, the southern section of stratum 9120 yielded an average of only two cunner per tow (Figure 3-26). Overall, the highest mean catch of cunner in the fall occurred in the northern extent of stratum 9110, due to a few individual tows with large catches. The average catch of cunner in this region, however, was only slightly higher than average catches obtained in the rest of the bay during this season (Figure 3-26).

Little skate (*Raja erinacea*)

Little skate were abundant during both survey seasons, although more than twice as many skate were collected in the spring than in the fall (Table 2-1). In the spring, little skate were widely distributed and were collected from all regions of Buzzards Bay (Figure 3-27). Little skate were relatively more abundant at the southern end of Buzzards Bay in the spring, with nearly equivalent average catches between the two sampling strata (Figure 3-28).

In the fall, when relatively fewer little skate were captured in the trawl survey, little skate were mainly caught in the deeper stratum (Figure 3-27). Similar to their spring distribution, skate captures in the fall were higher, on average, in the southern extent of Buzzards Bay (Figure 3-28). Little skate were least abundant, in both seasons, in the northern end of stratum 9110. The predominance of rocky habitat in this region probably limits the occurrence of this species in this area. Little skate are more commonly found over sand, pebbly or mud bottoms (Bigelow and Schroeder 1953).

Long-finned squid (*Loligo pealeii*)

Long-finned squid were highly abundant in both seasons of the trawl survey. In the spring, squid were the second most abundant species collected and they were the third most abundant species collected in the fall trawls (Table 2-1). Squid were broadly distributed in Buzzards Bay during both seasons although they were most abundant in the deeper sampling stratum and in the fall (Figure 3-29 a, c). In the spring, the highest average catches of squid occurred in the southern extent of stratum 9120 (mean of 132 squid per tow, Figure 3-30). The CPUE for squid in the fall was high across the deep stratum (mean of 925 in the north and 861 in the south, Figure 3-20) indicating broad and even distribution of large numbers of squid. Squid were least abundant at shallow stations in the north during both seasons.

Although length-frequency data was not analyzed for squid in this study, the relative biomass results suggest that spring catch was dominated by relatively large individuals (average weight 0.09 kg) while the fall catch was dominated by small individuals (average weight 0.01 kg). Many of the stations in the north 9110 sub region had relatively high average weight despite low average abundance. These results are consistent with size-frequency analyses for Massachusetts inshore waters that indicate fall catch is composed of large numbers of pre-recruits (≤ 8 cm mantle length) while spring is dominated by recruits (≥ 9 cm) (Cargnelli, et al. 1999). Recruit refers to the minimum mantle length for exploitation of 9 cm. Long-finned squid are known to migrate offshore in late fall and overwinter on the continental shelf before coming inshore in the spring to spawn (Cargnelli et el. 1999).

Northern searobin (*Prionotus carolinus*)

As a demersal fish, northern searobin were moderately abundant in the trawl survey. Although their abundance varied little from season to season, they were slightly more numerous in the spring (Table 2-1). The distribution of northern searobin was also more discrete during this season (Figure 3-31). Stations with the highest average catches of searobin were located in the shallow stratum at the northern end of Buzzards Bay. Stations with the next highest abundance of northern searobin were located in deeper water along the southeastern shore of Buzzards Bay (Figures 3-31, 3-32). Relatively few searobins were collected in spring sampling in the shallow stratum in the southwestern section of the bay or within deeper water in the northeastern section of the bay.

In the fall, northern searobin are more widely distributed in Buzzards Bay. During this sampling period, the deeper stations in the northern extent of the bay supported the highest average catches of northern searobin (mean of 20 fish per tow, Figures 3-31, 3-32). As in the spring, northern searobin were rarely found at the shallow stations in the southwestern section of the bay.

Scup (*Stenotomus chrysops*)

Scup were the most numerous species collected during each season of the bottom trawl survey (Table 2-1). Although scup were plentiful in spring sampling, there were nearly 13 times as many scup collected in fall sampling (Figures 3-33, 3-34). This marked increase in fall abundance of scup represents recruitment of YOY scup to the trawl sampling. The vast majority of scup collected in fall sampling were YOY and juvenile fish (Figure 3-35); while adults constituted only a minor component of the fall catch.

Adult scup slightly outnumbered juvenile scup in the spring samples (Figure 3-35). As expected, the majority of the juveniles collected in the spring were age 1+ fish (10.1 – 15.4cm TL). Some smaller yearling fish (< 10cm TL) were also taken during this sampling period. Most adult scup were collected in the shallow stratum in the north end of the Buzzards Bay (Figure 3-34). In contrast, an average of only five adult scup per tow were collected at stations in the southern end of the shallow stratum. The southern extent of stratum 9110 also yielded relatively low catches of juvenile scup in the spring. Highest spring catches of juvenile scup (mean of 219 fish per tow) were taken at stations in the southeastern region of the bay in stratum 9120 (Figure 3-34). The next highest region for juvenile scup abundance was the north section of stratum 9110. Smaller juveniles were found within this stratum as compared to the size range of juvenile fish collected from stratum 9120 (Figure 3-35).

The distribution of adult scup in the fall was comparable to their spring distribution. Unlike the spring, however, average catches of adult scup in north end of stratum 9110 were not notably higher than other regions of the bay (Figure 3-34), indicating a more uniform occurrence during this season. The largest adult scup in the fall trawl survey were taken in stratum 9110 (Figure 3-35). As in the spring, adult scup were least abundant at stations in the southern extent of the shallow stratum.

Juvenile scup were evenly distributed throughout Buzzards Bay in the fall (Figures 3-33, 3-34). Most of the juveniles collected in this season were YOY fish (≤ 10 cm TL) (Figure 3-35). In contrast to adult scup, stations in the southern extent of stratum 9110 yielded the highest mean catches of YOY scup (mean of 3858 fish per tow). The lowest mean catch of YOY scup in the fall (2569 scup per tow) occurred at stations in the northern end of stratum 9120. There does not appear to be any notable differences in the size classes of juvenile scup inhabiting deep versus shallow strata in the fall. Only slightly more of the smallest fish measured (3 cm TL) were collected in stratum 9110 (Figure 3-35).

Striped anchovy (*Anchoa hepsetus*)

Striped anchovy increase in abundance in Buzzards Bay as the summer progresses. By far, most striped anchovy are collected in fall samples (Table 2-1). In the spring, when striped anchovy abundance is lower, the species has only been collected at stations in the north end of stratum 9120 (Figure 3-36). Striped anchovy are more widely distributed in the fall, occurring at nearly all sampling stations in the bay (Figure 3-37). As is the case for other schooling fish species collected in the trawl survey, the size of striped anchovy catches were highly variable due to the “hit or miss” phenomenon associated with trawl sampling tightly concentrated pelagic fish. The southern section of stations in stratum 9110 yielded the greatest concentration of striped anchovy in the fall (mean of 485 fish per tow), followed by the northern extent of stratum 9120 (mean of 144 fish per tow) (Figure 3-37). Striped anchovy were least abundant at stations in the northern end of stratum 9110 (mean of 11 fish per tow).

Summer flounder (*Paralichthys dentatus*)

Summer flounder abundance varied seasonally in Buzzards Bay; three times as many fish were collected in fall samples than in the spring (Table 2-1, Figures 3-38, 3-39). Most of the summer flounder captured in both seasons were adults (≥ 37 cm TL). The size distribution of summer flounder varied little between the two sampling strata (Figure 3-40). Adult summer flounder were broadly distributed in Buzzards Bay in the spring, though very few fish (mean of 0.5 summer flounder per tow) were collected among the northern stations of stratum 9120 (Figure 3-38). Northern stations in stratum 9110 yielded relatively greater concentrations of adult summer flounder (mean of 2.3 fish per tow) in the spring than other regions of the bay.

In contrast to the adults, more juvenile summer flounder were captured in the spring in stratum 9120 (Figure 3-40). Most of the juvenile summer flounder collected in this season were age 1+ or older fish. The size distribution of juvenile fish, like the adults, exhibited little variation between the depth strata suggesting that size classes of summer flounder do not segregate by depth. Highest CPUE for juvenile summer flounder in spring trawls occurred at stations in the southern end of stratum 9120 (Figure 3-39). Like the catches of adult summer flounder, average catches of juvenile summer flounder were lowest at stations in the northern end of stratum 9120.

In the fall, when adult summer flounder abundance increased, adult fish were more uniformly distributed. The adult size distribution indicated only slight variation between the sampling strata (Figure 3-40). Although there were only slight differences in average CPUE of adult summer flounder among the four different regions of the bay during the fall, this lifestage was relatively more abundant at stations in the northern end of stratum 9120 (Figure 3-39). Thus, the distribution of adult summer flounder in this region varies seasonally. Overall, adult catches in the fall were three times greater than in the spring.

The number of juvenile summer flounder taken in Buzzards Bay in the fall was only slightly larger than the number collected in the spring. Juvenile summer flounder were uniformly distributed between the depth strata with respect to size (Figure 3-40). Although the total fall catch of juvenile summer flounder was nearly equal between the depth strata, the average catch of juvenile summer flounder was higher in stratum 9110 (mean of 1.4 fish per tow) than in stratum 9120 (mean of 0.77 fish per tow) (Figure 3-39). The northern end of stratum 9110 yielded the highest CPUE of juvenile summer flounder while roughly equivalent average catches of juvenile summer flounder were obtained within the other three regions of the bay.

Tautog (*Tautoga onitis*)

Tautog were more numerous in the spring versus the fall sample (Figures 3-41, 3-42). Adult tautog were more abundant than juveniles, especially during the spring (Figure 3-43). Very few YOY tautog were collected in either spring or fall sampling; thus the majority of the juvenile fish were age 1+ fish. An even size distribution for both lifestages was observed between the two strata in each season, indicating that the size of tautog captured does not vary with depth.

In the spring, adults were most concentrated in the shallow stratum (Figure 3-41). Trawl sampling at stations in the north end of stratum 9110 yielded the highest average catch of adult tautog (mean of 57 fish per tow) (Figure 3-42). Adult tautog were least abundant, in the spring, at stations in the southern extent of stratum 9120 (mean of 1 tautog per tow). Adult tautog were also collected at stations in the north of stratum 9120 although CPUE was nearly seven times lower than the CPUE observed at shallow stations within Buzzards Bay. Fewer juvenile tautog were taken in the spring as compared to the adult catch. Higher catches of juveniles were also taken in stratum 9110 during this season. In contrast to the spring distribution of adult tautog within this stratum, however, juvenile fish were more abundant in the south end of stratum 9110 (Figure 3-42). On average, twice as many juveniles were collected at stations within the southern extent of stratum 9110 than at stations in the north.

Fewer adult tautog were collected in the fall sampling; thus, the fall CPUE was lower relative to spring CPUE. The distribution of adult tautog shifted in the fall. In this season, stations in the southern end of stratum 9110 yielded the highest average catches of adult fish (mean of 8.1 adult tautog per tow) (Figure 3-42). As in the spring, tautog were least abundant at deeper stations in the southern portion of the bay. Overall, the fall CPUE of juvenile tautog was quite low in all regions of Buzzards Bay (n = 98) (Figure 3-43). Juvenile tautog occupied a similar distribution in the fall as they had in the spring (Figure 3-42). Juveniles were only slightly more abundant in the southern extent of stratum 9110 than at stations in the north. Overall, the average fall catch of juvenile tautog at shallow sites (mean of 1.6 fish per tow) was four times greater than the CPUE of juvenile tautog at deeper stations.

The distribution observed for tautog is consistent with earlier records of the species occurrence in Buzzards Bay. Howes and Goehringer (1996) report that tautog move into inshore in the spring and inhabit weedy, inshore regions of the bay. Spawning occurs within eelgrass beds among the bay’s numerous embayments and coves. The high concentration of adult tautog in the spring trawl survey within the northeastern portion of the bay supports this pattern of movement and habitat preference. Like cunner, tautog are common among ledges and rocky shoreline habitat where preferred invertebrate prey species are abundant (Bigelow and Schroeder 1953). The southerly shift seen in the distribution of tautog from spring to fall within the shallow stratum suggests a transition away from spawning habitat towards more productive feeding areas.

Weakfish (*Cynoscion regalis*)

Weakfish were collected in relatively low abundance in the trawl survey (Table 2-1). The vast majority of captures of this species occurred in the fall survey. During this period, weakfish were most common at stations within the northern extent of the stratum 9120 (mean of 3.8 fish per tow, Figures 3-44, 3-45). Although weakfish were taken in all other regions of the bay, average catches were low and roughly equal among each stratum/section (mean of less than 1 fish per tow).

Weakfish are seasonal migrants to southern New England; appearing in estuaries like Buzzards Bay in late spring or early summer after water temperature rises. Therefore, the nearly absolute lack of captures in the spring is not surprising. Weakfish are less vulnerable to capture in bottom trawls while they are feeding on pelagic prey species. Like bluefish, weakfish are swift swimmers and capable of evading capture in trawl gear. Bigelow and Schroeder (1953) describe weakfish as an inshore species during their summer residence in the New England waters, rarely occurring in water deeper than 20 meters. This distribution pattern is consistent with the distribution of weakfish observed in the trawl survey.

Windowpane (*Scophthalmus aquosus*)

Windowpane were broadly distributed in Buzzards Bay in the spring when most individuals were collected (Figure 3-46, Table 2-1). The region with the highest mean catch of windowpane was the southern section of stratum 9110 (mean of 15.5 fish per tow, Figure 3-47). In addition to this region, a few stations at the northern end of stratum 9120 yielded relatively high catches and biomass of this species, indicating localized abundance along the CLDS in late spring (Figure 3-46). Average catches of windowpane during the spring were comparable elsewhere in Buzzards Bay, although relatively few fish were found in the northern extent of stratum 9110.

There was little seasonal variation in the distribution of windowpane. A smaller number of windowpane were collected in the fall and, therefore, their CPUE during this season was relatively low. As in the spring, the region with the highest CPUE of windowpane in the fall was the southern extent of the shallow stratum (mean of 2 fish per tow). Unlike the spring, however, stations in stratum 9120 that border the CLDS did not yield high catches of windowpane in the fall (Figure 3-47).

Winter flounder (*Pseudopleuronectes americanus*)

In general, winter flounder were widely distributed in Buzzards Bay in the spring (Figure 3-48). The highest average catches of adult winter flounder (mean of 55 fish per tow) in the spring were taken in the southern extent of stratum 9110 (Figure 3-49). Adult winter flounder were also concentrated at many stations in the southern range of stratum 9120 (mean of 23 fish per tow) Winter flounder are among the group of Buzzards Bay fish that undergo a seasonal inshore-offshore migration. Thus, winter flounder are more abundant in the bay during the spring before they move out of the bay to deeper water offshore. Nearly as many juveniles as adults were collected in spring trawl samples (Figure 3-50). Adult winter flounder were evenly distributed in number and size between the two depth strata during this season. The CPUE of adult winter flounder in the northern end of Buzzards Bay was lower than in the south although high numbers of winter flounder were taken at a few stations in this region (Figure 3-48).

The spring distribution of juvenile winter flounder resembled the distribution of adult fish. Although the size distribution of juvenile fish was comparable between strata, the total number of juveniles collected from each stratum varied (Figure 3-50). More juvenile winter flounder were captured in the deep stratum than in the shallow region. On average, however, stations in the southern range of stratum 9110 supported the largest catches of juvenile winter flounder (Figure 3-49). The region with the lowest mean catch of juvenile winter flounder in the spring was the northern extent of the shallow stratum. Juveniles were equally abundant within both regions of stratum 9120 (mean 17 fish per tow).

As water temperatures increase during the summer winter flounder, predominantly adults, move offshore to deeper water (Bigelow and Schroeder 1953; Pereira et al. 1999). Accordingly, very few adult winter flounder were collected in fall samples (Figure

3-50). The small numbers of adults remaining in the bay during this season were smaller fish than those taken in the spring. The CPUE of adult winter flounder in the fall was very low (mean < 1 fish per tow), however average catches were highest in the southern extent of the deep stratum (Figure 3-49).

Juvenile winter flounder were also less abundant in the fall, yet their numbers did not drop off as considerably between seasons. Stratum 9120 supported most of the juvenile fish in this season (Figure 3-49). Among the four major regions of the bay, stations within the south and north of stratum 9120 had the highest mean catches of juvenile winter flounder in fall sampling (mean of 9 and 6 fish per tow, respectively) (Figure 3-49). Within the northern extent of stratum 9120, juvenile winter flounder were most abundant at one station within the CLDS (Figure 3-48). Young winter flounder are known to occur in deeper regions of coastal bay waters during the summer months to escape thermal stress (Howes and Goehringer 1996; Pereira et al. 1999). The seasonal distribution patterns exhibited by adult and juvenile winter flounder in the trawl survey is consistent with other studies of the species in northeast embayments (Pereira et al. 1999). While the highest CPUE recorded for this species in the fall occurred within the northern extent of stratum 9110 (mean of 264 fish per tow), an average catch of only two YOY per tow was obtained among stations in the southern range of the stratum.

4.0 DISCUSSION

The nature of fish distribution, community structure, abundance and biomass in Buzzards Bay and other New England estuaries can be attributed to many factors (e.g., temperature Jeffries and Terceiro 1985, Ayvazian et al. 1992, Deegan et al. 1997; habitat degradation and overharvest Deegan et al. 1997; vegetation Dorf and Powell 1997; habitat type Meng and Powell 1999; eelgrass density and biomass Hughes et al. 2002a and 2002b; eelgrass complexity Wyda et al. 2002). This analysis does not attempt to explain relative distribution or abundance of nekton in Buzzards Bay; the objective is to provide a descriptive baseline of nekton distribution in the Bay and compare geographic sub regions relative to potential dredged material disposal sites.

4.1. DMF TRAWL DATA RESULTS

Analysis of the DMF trawl data provided a comprehensive, statistically robust method for characterizing the distribution of nekton in Buzzards Bay. The trawl data does not reflect a complete sampling of the entire spectrum of macroorganisms present in benthic and pelagic habitats (seafloor and water column). However, it does provide a representative sample of the most significant commercial and recreational fish resources. Further, this dataset is structured to provide geographic information about finfish and invertebrate seasonal distributions over a relatively long sampling period (twenty-three years; 1978-2000). By analyzing data summarized from a randomized, stratified sampling conducted over many years, this baseline characterization is substantial and much more than a “snapshot”. It represents a history of geographic distribution that overlaps with periodic disposal activities at BBDS and reflects an integrated picture of long-term community structure and overall abundance in resources. If changes in habitats or regional conditions are sufficient to affect the population distribution of nekton, this analysis should provide the basis for detection of change.

Despite changes in abundance of individual species, the overall trawl CPUE (#/tow) and average biomass (weight/tow) was remarkably consistent over the survey period. Declines in tautog and scup biomass in spring were the most noticeable changes over time (Figure 3-3a). Peaks in fall finfish CPUE were almost entirely driven by large catches of small butterfish, scup and striped anchovy and peaks in invertebrate CPUE and biomass were driven by long-finned squid catches (Figures 3-1, 3-2, 3-3b).

This study provided possible evidence of temporal changes in the Buzzards Bay fish community. The scope of this study did not allow rigorous examination of the potential shift in fish community structure. However, changes have been reported in other New England estuaries (Jeffries and Terceiro 1985; Meng and Powell 1999; Hughes et al. 2002; Wyda et al. 2002) and oceanic systems (Fogarty and Murawski 1998), and discussion of the possible shifts in relative abundance and composition of fishes warrants mention.

Pelagic species replaced demersal species in nearshore habitats (Hughes et al. 2002; Wyda et al. 2002), and oceanic environments showed the replacement of gadids and flounders by elasmobranchs (Fogarty and Murawski 1998). The strongest evidence of this type of trend is seen in the decline in tautog and winter flounder catch, increase in butterfish and little skate and stability of scup (Figure 3-3a,b). Fall catches of butterfish increased since the mid-to-late 1980s. Fall biomass of scup was consistent, and spring relative abundance of older juvenile and adult fish varied through the study. Higher scup relative abundance and biomass in spring appears recurring since study commencement (1978), with larger catches found in the late 1970s to early 1980s, 1990 and 2000. Tautog relative abundance and biomass decreased in the late 1980s to a stable lower level during the 1990s. Winter flounder numbers appear to be decreasing since the early 1980s. An elasmobranch demersal species, little skate, increased in catch, including number and biomass, in the later part of the survey (Figure 3-3a, b).

Observations during this study are not conclusive, and we can not distinguish between community shift and natural variation. Large-scale environmental change, such as water temperature, will influence catches (Jeffries and Terceiro 1985) and could alter the distribution and seasonal presence of species. Long-term fluctuation in the abundance and biomass of fishes, beyond the duration of this study, may be occurring. Further investigation of community, including relatively abundant and scarce species, may elucidate the trend of community shift.

Based on the average CPUE by region and strata it is difficult to consider any part of the Bay more or less productive than any other in the fall (Figures 3-5, 3-6, Tables 3-4, 3-5). In the spring, the north shallow sub region (9110) had higher finfish catch and weight per tow than the other sub regions (Table 3-4). This high catch was centered over the sand flats west of Cleveland Ledge (Figure 3-5).

4.2. LIFE HISTORY AND HABITAT USE

The species selected for individual analysis (Table 1-1) showed common and distinct patterns of seasonal occurrence and distribution. Summarizing these observed patterns by respective life history characteristics provides a broader understanding of Buzzards Bay finfish assemblages (McHugh 1967). Species life histories were assigned for Waquoit Bay finfish by Ayvazian et al. (1992) based on biological data and personal observation. We accepted their classification and amended it for species and life history features found in Buzzards Bay (Bigelow and Schroeder 1953; Murdy et al. 1997; Able and Fahay 1998; Cross et al. 1999). While Ayvazian's study used nearshore seine nets and small otter trawls, the classification was applied to the results from trawl surveys of Narragansett Bay (Oviatt and Nixon 1973) that used similar gear, sampled comparable depth and substrate strata and showed a similar distribution of species and life histories as this study. The life history organization provided a reasonable system to discuss ontogenetic characteristics and ecological functions of Buzzards Bay. Zones were identified for each species that indicate the predominant association with the pelagic or benthic environment. Four life history groupings were represented among the select finfish species in Buzzards Bay and will be discussed here: nursery, diadromous, marine, and resident species. Adventitious visitors were also represented in the total catch (Table 1-1).

Adventitious visitors (17 species) included species found at the northern limits of their range (e.g., spot) or fishes, such as filefishes and gag, that were moved north by the Gulf Stream to Buzzards Bay. Diadromous fishes (6 species), such as alewife and blueback herring, were frequently collected in large schools. The combination of marine, nursery and resident species dominated catches. Nearly 60% of the fishes were classified as marine. Marine species (29 species) included fishes that were collected in relatively low numbers, such as American plaice, ocean pout and scads. Many marine species were additionally classified as nursery species. Fishes solely found during early life history stages (e.g., Atlantic herring and weakfish) were labeled nursery (4 species). Marine-nursery species (10 species) represented a substantial portion of the Buzzards Bay fish community. Marine-nursery fishes, such as bay anchovy, black sea bass, butterfish and scup, were dominant during the fall sampling. Residents (11 species), including northern pipefish and rock gunnel, and resident-nursery species (e.g., Atlantic silverside, cunner and tautog) were found throughout the study. Marine populations of cunner and tautog that migrate to the bay may also exist in the study area. Species that were representative of life history categories and numerically dominant (with the exception of adventitious visitors) were selected for additional analyses (Figure 3-3 through Figure 3-50) and discussion.

Finfish species, such as Atlantic herring, cunner, tautog, winter flounder, windowpane, and little skate, were relatively more abundant in the spring and were less numerous in the fall. These species presumably move to deeper and/or less trawl accessible areas or other habitats beyond the range of the survey. This group of species was more widely distributed in the spring and had more clumped distributions in the fall. Not surprisingly, the average CPUE (#/tow) of these species in the four sub regions of Buzzards Bay was smaller in the fall than in the spring.

The wide variability in average catches of Atlantic herring is due to the pelagic schooling nature of this species that, on occasion, produces extremely large catches. The high number of herring taken per tow, during the spring, was due to the trawl intercepting large schools of post larval size Atlantic herring (i.e., young-of-the-year; brit), an indication of the use of Buzzards Bay as a nursery. Atlantic herring were nearly absent from the fall trawl survey other than in collections at a single station in the southwest quadrant of the bay.

The lower relative abundance (i.e., CPUE) of cunner and tautog in the fall was consistent with their known seasonal and life history behavior, such as movement to shallower waters and juvenile habitat requirements. Cunner and tautog overwinter on the continental shelf and migrate toward shallow water habitat in the spring and early summer (Auster 1989; Steimle and Shaheen 1999). The spring samples were predominantly comprised of adults and older juveniles that were apparently moving toward shallow waters, found in an area of vertical relief (e.g., drift algae, rock and ledge or marine debris), or were collected in wintering grounds (which may exist in nearshore areas; Dew 1976). The biomass of tautog particularly observed in the spring indicated a substantial potential source of spawning adults. Juvenile tautog and cunner prefer complex habitats, such as eelgrass beds and macroalgae, and demonstrate site fidelity (reviewed by Auster 1989; Able and Fahay 1998; Steimle and Shaheen 1999). Juveniles, especially early benthic phase, are most abundant in summer and early fall and inhabit these shallow water habitats. These areas were not assessed by the resource assessment and older fishes were not found at particularly high abundance in the study area, resulting in lower CPUE and biomass in the fall.

Winter flounder were more abundant in the spring, similar to tautog and cunner, but have different seasonal patterns of movement and development. Adult winter flounder move inshore during colder months and offshore as water temperatures increase (Bigelow and Schroeder 1953), as seen in higher spring CPUE and biomass. Spawning occurs during their stay in nearshore waters from winter to early spring (Bigelow and Schroeder 1953). Juveniles were also collected in the spring and fall, indicating suitable environmental conditions. Young-of-the-year inhabit shallow waters, such as coves (Able and Fahay 1998; Pereira et al. 1999) and harbors (Normandeau Associates Inc. 1998), for the first year of life and are encountered less frequently in open bay waters (Able and Fahay 1998). As early juveniles develop, they move from nearshore areas to deeper waters in the following spring – in concurrent areas with older fish (Able and Fahay 1998) – contributing to the spring collection. The combination of young fish moving to deeper water and older fish migrating shoreward in the winter and early spring was consistent with higher spring CPUE and biomass.

Windowpane juveniles and adults were found and broadly distributed in Buzzards Bay during the spring. Long Island Sound produced similar seasonal findings of occurrence. Windowpane were collected on the continental shelf and in Narragansett Bay throughout the year with no apparent seasonal change in distribution (Chang et al. 1999). Windowpane appeared to have seasonal movements in Buzzards Bay (e.g., in and out of the bay or within Buzzards Bay but out of the study area).

Little skate are a dominant component of the northwest Atlantic demersal fish community, and inshore populations migrate onshore and offshore with temperature change (Packer et al. 2000). This dominance was more apparent during spring in Buzzards Bay. Spring relative abundance and biomass was greater than fall, supporting the trend of seasonal movement. Little skate were widely distributed in the southern portions of the bay in spring and found in the deeper strata in the fall. The variation in distribution indicated seasonal preference of areas within Buzzards Bay.

Bay and striped anchovy were nearly absent in spring and abundant in fall. The bay anchovy was the third most numerically abundant fish collected, with all of these fish caught in the fall. Anchovies enter the bay as waters warm and migrate to the inner continental shelf in the fall (Able and Fahay 1998). Their distribution appeared ubiquitous throughout the study area. The absence (or relatively lower abundance) of anchovies in spring samples supports identified migration patterns and demonstrated that bay and striped anchovy enter Buzzards Bay in the summer.

Bluefish and weakfish are migratory species that move into the bay in summer and remain until fall (Mercer 1989; Fahay et al. 1999). Fall collections were dominated by juveniles, commonly found in large schools. The presence of juvenile bluefish, and to a lesser extent weakfish (southern Massachusetts is the northern boundary of range), indicated the seasonal function of Buzzards Bay as nursery and foraging habitat.

As expected, amongst the diadromous species, anadromous clupeids (alewives and blueback herring) were caught in relatively higher abundance in the spring. A relatively smaller number of alewives and blueback herring were collected in the fall; all of these fish are presumably YOY or older fish that are gradually moving out of Buzzards Bay for the winter.

Colvocoresses and Musick (1984) identified black sea bass, butterfish, scup, summer flounder and northern searobin as part of a recurrent warm temperate, demersal species group. This species group was evident in Buzzards Bay and showed distinct life history and behavior characteristics.

Summer flounder and northern searobin exhibit inshore-offshore migration (i.e., marine species) (Bigelow and Schroeder 1953; Packer et al. 1999). Seasonal abundance and biomass of summer flounder and northern searobin were not as variable as other fishes. Fall collections of summer flounder were, however, substantially larger than spring. Summer flounder migrate to nearshore waters in the spring and leave in the fall (Packer et al. 1999). The difference in spring and fall catches suggested that the majority of summer flounder move into Buzzards Bay in late-spring to early summer. Summer flounder catch was composed of adults and older juveniles, and they were distributed throughout the bay during spring and fall. Northern searobin (including adult and juvenile) were found more in shallow water during spring and northern deeper waters in the fall. Settlement to the benthic environment occurs on the continental shelf in areas with suitable nursery conditions (Able and Fahay 1998). Early juveniles were found in Buzzards Bay, demonstrating movement to nearshore waters with suitable nursery habitat for development.

Scup and butterfish were described as the spring dominants of the warm temperate species group (Colvocoresses and Musick 1984). Their dominance of the Buzzards Bay fish community (particularly in fall) was very evident, ranking one and two in numeric abundance. Black sea bass had similar seasonal occurrence as scup and butterfish. Adults and older juveniles (i.e., 1+ year) were found in the spring. During the spring, scup appeared more frequently in the northern, shallow waters, and butterfish were widely distributed in the deeper waters.

The fall collections marked the recruitment of young-of-the-year scup, butterfish and black sea bass to Buzzards Bay. These species were highly abundant and broadly distributed in the fall survey. Butterfish do not drastically change from larvae to juveniles, occur in schools, and move from the continental shelf to bays in early summer (Able and Fahay 1998). Trawl collections show butterfish were found near the seafloor and more frequently in deeper waters. It is unknown if scup directly settle from the plankton to the seafloor or migrate to nursery areas. Newly settled scup (based on total length) were found in a Buzzards Bay embayment (Geoghegan and Wilbur in preparation) and deeper portions of the bay (Camisa and Wilbur personal observation), and subsequent collections showed modal progression of length frequency. This indicates that scup were settling to the seafloor or quickly moving into Buzzards Bay to find suitable nursery habitat. Scup collections in the fall of this study appeared evenly distributed in shallow and deep waters. Black sea bass were collected more in the shallow northern section of the bay, although they were found throughout the study area. Early life history stages of black sea bass prefer structured habitats (Able et al. 1995), so this study may underestimate the importance of Buzzards Bay as nursery habitat.

Long-finned squid, the only invertebrate species in the list of species selected for individual analysis, exhibited a seasonal abundance pattern typical of this species (Cargnelli et al. 1999). Squid are relatively short-lived and, like many invertebrates, are highly prolific. The substantial increase in squid numbers in the fall reflects their high rate of recruitment. Squid were also broadly distributed in Buzzards Bay during the fall, although their abundance tended to increase with depth, consistent with temperature related observations (Cargnelli et al. 1999).

Marine species, which include mostly juvenile fishes and squid, were by far the most abundant species in the trawl survey. The relative abundance of young fishes demonstrates the value of nursery habitat in the bay. The seasonal occurrence of adult fishes and other species collected at lower abundance (but frequently at higher biomass) provides a better understanding of the fish community in Buzzards Bay.

4.3. DREDGED MATERIAL DISPOSAL SITES

The spatial structure and intensity of the sampling did not support a site-specific analysis of the finfish and mobile invertebrate communities associated with the historic or proposed dredged material disposal sites. However, these sites are consistent with the characteristics of the north sub region of stratum 9120 (deeper waters; 9.1-18.3 m). We examined the groupings of stations within this sub region for comparison with the other sub regions in Buzzards Bay. With few exceptions, this sub region did not support a community distinct from, or different in scale from, the comparable habitats in south sub region of stratum 9120.

However, the detailed spatial analysis of this time series of spring and fall fisheries-independent catch does allow for an explicit baseline characterization of fish resources in the sub region of Buzzards Bay with potential dredged material disposal sites (Carey et al. 2001). This baseline characterization is necessary to provide a starting point for evaluation of potential impact on fish resources following selection of any location for dredged material disposal.

Specific habitat characteristics of these potential disposal sites (water depth, grain size, structure) were reviewed from data compiled during site surveys to provide a more detailed predictive comparison. A combination of habitat characterization (e.g., SAIC 1998 and 2001) and documentation of species distributions provides a clear indication of the potential affected populations from disposal activity. Both Site 1 and Site 2 had benthic habitats well correlated with depth (SAIC 2001). Below 12-13 m the sites contained unconsolidated soft mud and relatively undisturbed benthic infauna. Above 12 m the sites, contained very fine sand mixed with mud and in the shallowest areas the benthic infauna and sediments reflected some physical disturbance, including erosion due to currents. Both of these benthic habitats contain finfish and mobile invertebrates. They may use these finer sediments for feeding, and some demersal species may use them for refuge or spawning. It is these deeper sediments that define the North 9120 sub region. The historic disposal area was not sampled directly by DMF because it has long been marked on nautical charts as a disposal area with no information on depth or potential hangs. The shallower sediments would be consistent with the North 9110 stratum (i.e., ≤9.3 m) and reflect the conditions of a nearshore supply of fine sand and higher wave and current energies.

The habitat conditions represented by the deeper portions of northern Buzzards Bay is widely distributed and appears to be relatively uniform in character and finfish distribution. Those portions of the candidate disposal sites that contain unconsolidated mud and water depths greater than 30 feet (> 9.1 m) are consistent with this habitat. These data do not allow discrimination in suitability of each site as fisheries habitat or between them and the habitat as a whole. However, we can note that the presence of vertical structure in the form of shallow rock ledges or shoals in the midst of this habitat that is likely provide suitable habitat for a variety of creatures, such as scup, tautog, and black sea bass.

In general, squid and finfish species were distributed in Buzzards Bay according to known habitat preferences (e.g., nearshore species were concentrated in stratum 9110). The analysis of CPUE and biomass by strata and geographic section for the select species indicated specific zones of seasonal concentration for most species (Table 2-1, Table 3-2). Although fish may regularly move among the bay's four sub regions, the long time-series of CPUE data in this bottom trawl survey can be used to highlight species that would be most affected by disposal activity at the BBDS. Species that concentrate within the northern extent of stratum 9120 vary seasonally. During the spring, the season of lowest finfish abundance and relatively high biomass in the bay, Atlantic herring and striped anchovy appeared to concentrate within this region. Both species are pelagic, schooling fish and their high relative occurrence in spring trawls is due to a few very high catches (post-larval brit herring). However, other important species were also present with notable biomass in this sub region including black sea bass (Figures 3-16, 3-17), tautog (Figures 3-41, 3-42) and windowpane (Figures 3-46, 3-47). In the fall, a more diverse assemblage of demersal and pelagic species concentrate in the northern extent of the deep stratum indicating that the area provides suitable habitat for a variety of species (Table 3-2). Species with notable biomass in this sub region in the fall include: blueback herring (Figures 3-36, 3-37), long-finned squid (Figures 3-29, 3-30), northern searobin (Figures 3-31, 3-32), scup (Figures 3-33, 3-34), striped anchovy (Figures 3-36, 3-37), summer flounder (Figures 3-38, 3-39), and tautog (Figures 3-41, 3-42).

4.4. SUMMARY

This report represents the first characterization of Buzzards Bay nekton on time and spatial scales sufficient to evaluate potential impacts of dredged material disposal. It can complement parallel studies on the habitat characteristics and distribution at the potential disposal sites as well as nearshore studies on impacts of habitat degradation on fish communities (e.g., Hughes et al. 2001a, b, Wyda et al. 2001). Habitat type and condition influence community structure and may dictate productivity. Buzzards Bay supports a productive and diverse assemblage of fishes and crabs that vary geographically and seasonally. This study provides the means to identify potential deleterious effects and determine changes in community structure associated with dredged material disposal.

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Table 1-1

List of species collected in strata 9110 and strata 9120 and their seasonal occurrence in the MA DMF Trawl survey, 1978-2000. Species in bold type selected for individual analyses. Zone indicates the species predominant association with the benthic (B) or pelagic (P) zone. Life history classification after Ayvazian et al., (1992).
D - diadromous, R- residents, N- Nursery, M- Marine, A- Adventitious visitors, I - invertebrate. Bold indicates species selected for detailed analysis. Total species do not count duplicate genera when species are identified (e.g., Urophycis spp. is not counted as a separate species).

Common name	Scientific name	Occurrence	Zone	Life History
Alewife	***Alosa pseudoharengus***	Spring, Fall	P	D
American eel	*Anguilla rostrata*	Spring, Fall	B	D
American lobster	*Homarus americanus*	Spring, Fall	B	I
American plaice	*Hippoglossoides platessoides*	Fall	B	M
American shad	*Alosa sapidissima*	Spring	P	D
Atlantic cod	*Gadus morhua*	Spring	B	M
Atlantic herring	***Clupea harengus***	Spring, Fall	P	N
Atlantic mackerel	*Scomber scombrus*	Spring	P	M
Atlantic menhaden	*Brevoortia tyrannus*	Spring	P	N
Atlantic moonfish	*Selene setapinnis*	Fall	P	A
Atlantic rock crab	*Cancer irroratus*	Spring, Fall	B	I
Atlantic seasnail	*Liparis atlanticus*	Fall	B	R
Atlantic silverside	*Menidia menidia*	Spring	P	R, N
Atlantic tomcod	*Microgadus tomcod*	Spring	B	R, N
Banded rudderfish	*Seriola zonata*	Fall	P	A
Bay anchovy	***Anchoa mitchilli***	Fall	P	N, M
Bay scallop	*Argopecten irradians*	Spring, Fall	B	I
Bigeye	*Priacanthus arenatus*	Fall	B	A
Bigeye scad	*Selar crumenophthalmus*	Fall	P	M

Common name	Scientific name	Occurrence	Zone	Life History
Black sea bass	***Centropristis striata***	Spring, Fall	B	M, N
Blue crab	*Callinectes sapidus*	Spring, Fall	B	I
Blue runner	*Caranx crysos*	Fall	P	A
Blueback herring	***Alosa aestivalis***	Spring, Fall	P	D
Bluefish	***Pomatomus saltatrix***	Spring, Fall	P	M, N
Bluespotted cornetfish	*Fistularia tabacaria*	Fall	P	A
Butterfish	***Peprilus triacanthus***	Spring, Fall	P-B	M, N
Channeled whelk	*Busycotypus canaliculatus*	Spring, Fall	B	I
Conger eel	*Conger oceanicus*	Spring, Fall	B	M
Cornetfish spp.	*Fistularia spp.*	Fall	P	A
Crevalle jack	*Caranx hippos*	Fall	P	A
Cunner	***Tautogolabrus adspersus***	Spring, Fall	B	M, R, N
Fourbeard rockling	*Enchelyopus cimbrius*	Spring, Fall	B	M
Gag	*Mycteroperca microlepis*	Fall	B	A
Glasseye snapper	*Priacanthus cruentatus*	Fall	B	A
Goby spp.	*Gobiidae* (family)	Fall	B	R
Gray triggerfish	*Balistes capriscus*	Spring	B	A
Grubby	*Myoxocephalus aeneus*	Spring	B	R
Guanguanche	*Sphyraena guachancho*	Fall	P	A
Gulf Stream flounder	*Citharichthys arctifrons*	Fall	B	M
Hake spp.	*Urophycis spp.*	Spring	B	M
Hermit crab spp.	*Pagurus spp.*	Spring	B	I
Hogchoker	*Trinectes maculatus*	Fall	B	M, R
Horseshoe crab	*Limulus polyphemus*	Spring, Fall	B	I

Common name	Scientific name	Occurrence	Zone	Life History
Inshore lizardfish	*Synodus foetens*	Fall	B	M, A
Jonah crab	*Cancer borealis*	Spring, Fall	B	I
Knobbed whelk	*Busycon carica*	Spring, Fall	B	I
Lady crab	*Ovalipes ocellatus*	Spring, Fall	B	I
Little skate	***Raja erinacea***	Spring, Fall	B	M
Lizardfish spp.	*Synodus spp.*	Fall	B	M, A
Longfin squid	***Lologi pealeii***	Spring, Fall	P-B	I
Longhorn sculpin	*Myoxocephalus octodecemspinosus*	Spring, Fall	B	M
Mackerel scad	*Decapterus macarellus*	Fall	P	M
Mantis shrimp spp.	*Stomatopoda*	Spring, Fall	B	I
Naked goby	*Gobiosoma bosci*	Fall	B	R
Northern kingfish	*Menticirrhus saxatilis*	Fall	B	N
Northern pipefish	*Syngnathus fuscus*	Spring, Fall	B	R
Northern puffer	*Sphoeroides maculatus*	Fall	B	M
Northern quahog	*Mercenaria mercenaria*	Fall, Spring	B	I
Northern sand lance	*Ammodytes americanus*	Spring	B	M
Northern searobin	***Prionotus carolinus***	Spring, Fall	B	M, N
Northern sennet	*Sphyraena borealis*	Fall	P	M
Northern shortfin squid	*Illex illecebrosus*	Spring	P-B	I
Ocean pout	*Macrozoarces americanus*	Spring, Fall	B	M
Ocean quahog	*Arctica islandica*	Spring, Fall	B	I
Orange filefish	*Aluterus schoepfi*	Fall	B	A
Oyster toadfish	*Opsanus tau*	Spring, Fall	B	M, R

Common name	Scientific name	Occurrence	Zone	Life History
Planehead filefish	*Monacanthus hispidus*	Fall	B	A
Pollock	*Pollachius virens*	Spring	B	M
Rainbow smelt	*Osmerus mordax*	Spring	P	D
Red goatfish	*Mullus auratus*	Fall	B	A
Red hake	*Urophycis chuss*	Spring, Fall	B	M, N
Red porgy	*Pagrus pagrus*	Fall	B	A
Rock gunnel	*Pholis gunnellus*	Spring, Fall	B	R
Rough scad	*Trachurus lathami*	Fall	P	M
Scup	***Stenotomus chrysops***	Spring, Fall	B	M, N
Sea raven	*Hemitripterus americanus*	Spring, Fall	B	M
Sea scallop	*Placopecten magellanicus*	Spring	B	I
Short bigeye	*Pristigenys alta*	Fall	B	A
Silver hake	*Merluccius bilinearis*	Spring, Fall	B	M
Smallmouth flounder	*Etropus microstomus*	Spring, Fall	B	M
Smooth dogfish	*Mustelus canis*	Spring, Fall	B	M
Snakefish	*Trachinocephalus myops*	Fall	B	M
Spanish mackerel	*Scomberomorus maculatus*	Fall	P	M
Spider crab spp.	*Libinia spp.*	Spring, Fall	B	I
Spiny dogfish	*Squalus acanthias*	Spring	B	M
Spot	*Leiostomus xanthurus*	Fall	B	M, A
Spotted hake	*Urophycis regia*	Spring, Fall	B	M, N
Striped anchovy	***Anchoa hepsetus***	Spring, Fall	P	M
Striped bass	*Morone saxatilis*	Spring	P	D
Striped cusk-eel	*Ophidion marginatum*	Spring	B	M

Common name	Scientific name	Occurrence	Zone	Life History
Striped searobin	*Prionotus evolans*	Spring, Fall	B	M, N
Summer flounder	***Paralichthys dentatus***	Spring, Fall	B	M
Tautog	***Tautoga onitis***	Spring, Fall	B	M, R, N
Weakfish	***Cynoscion regalis***	Spring, Fall	B	N
White hake	*Urophycis tenuis*	Spring, Fall	B	M
Windowpane	***Scophthalmus aquosus***	Spring, Fall	B	M
Winter flounder	***Pseudopleuronectes americanus***	Spring, Fall	B	N, M
Winter skate	*Raja ocellata*	Spring, Fall	B	M

TOTAL # OF FISH SPECIES	78
TOTAL # OF INVERTEBRATE SPECIES	17
TOTAL # OF SPECIES	95

Freshwater – those species normally confined to inland waters.

Diadromous – anadromous and catadromous.

Residents- species that spawn in the estuary and spend all or a significant portion of their life there.

Nursery – species which use the estuary as a nursery ground, either spawning in the estuary or offshore. The majority of adults move offshore in the winter.

Marine – species indigenous to the local neritic waters (such as the adjacent sounds) and which usually visit estuaries as adults.

Adventitious visitors – species which appear irregularly, have no apparent estuarine or coastal requirements, and are at the limit of the normal bounds of their range.

Invertebrate – species of invertebrates not covered by the life history classification.

(from Ayvazian et al. 1992 and adapted from Bigelow and Schroeder 1953; Murdy et al. 1997; Able and Fahay 1998).

Table 2-1a

Total relative abundance (number) of selected species collected during each season of the trawl survey from 1978-2000.

Species	Spring	Fall	Species	Spring	Fall
Alewife	581	439	Long-finned squid	9,044	85,849
Atlantic herring	3,715	78	Northern searobin	1,140	996
Bay anchovy	0	13,086	Scup	28,642	366,313
Black sea bass	152	11,239	Striped anchovy	103	11,528
Blueback herring	483	111	Summer flounder	288	670
Bluefish	2	2,066	Tautog	3,221	363
Butterfish	1,215	161,830	Weakfish	1	157
Cunner	1,243	130	Windowpane	757	84
Little skate	1,406	587	Winter flounder	5,275	834

Table 2-1b

Total biomass (kg) of selected species collected during each season of the trawl survey from 1978-2000.

Species	Spring	Fall	Species	Spring	Fall
Alewife	18	8	Long-finned squid	622	781
Atlantic herring	10	1	Northern searobin	200	91
Bay anchovy	0	11	Scup	3,819	5,149
Black sea bass	97	103	Striped anchovy	1	12
Blueback herring	9	3	Summer flounder	251	539
Bluefish	6	66	Tautog	6182	510
Butterfish	87	2150	Weakfish	5	7
Cunner	26	1	Windowpane	218	19
Little skate	880	354	Winter flounder	1,674	96

Table 2-2

Length ranges used to designate lifestages for species included in length frequency analyses.

Species	Length Range		
	YOY	1+ Juvenile	Adult
Black sea bass	≤ 10 cm[1]	10.1 – 18.9 cm[2]	≥ 19 cm[2, 3]
Scup	≤ 10 cm[4]	10.1 – 15.4 cm[4]	≥ 19 cm[3,4]
Summer Flounder	≤ 30 cm[1,5]	30.1 – 36.9 cm[5]	≥ 37 cm[3,5]
Tautog	≤ 13 cm[1]	13.1 – 25.9 cm[6]	≥ 26 cm[3,6]
Winter Flounder	≤ 16 cm[1]	16.1 –25.9 cm[7]	≥ 26 cm[3,7]

[1] Able and Fahay 1998

[2] Steimle et al. 1999a

[3] O'Brien et al. 1993

[4] Steimle et al. 1999b

[5] Packer et al. 1999

[6] Steimle and Shaheen 1999

[7] Pereira et al. 1999

Table 2-3

Bullet sizes used to designate ranges in average CPUE and biomass per station for maps of select species distribution.

CPUE		Biomass	
Bullet size	Range	Bullet size	Range
8	0.1 – 5	8	0.1 – 1
15	5-10	15	1-5
22	10.1-50	22	5.1-10
29	50.1-250	29	10.1-50
36	250.1-1000	36	50.1-100
43	1000.1-3000	43	100.1-500
50	>3000	50	>500
Added red circle	High outlier	Added red circle	High outlier

Note the ranges displayed on the maps reflect the actual catch number and weights within these ranges. Presenting the actual numbers clarifies the specific distribution of catch more accurately while the range limits permit comparison between seasons and species.

Table 3-1

Regions and highest spring relative abundance (CPUE; #/tow) among squid and select finfish species in Buzzards Bay

9110 North Black sea bass (A) Northern sea robin Scup (A) Summer flounder (A) Tautog (A)	**9120 North** Atlantic herring Striped anchovy
9110 South Cunner Little skate Tautog (J) Windowpane Winter flounder (A,J)	**9120 South** Alewife Winter Flounder (A) Blueback herring Butterfish Long-finned squid Little skate Scup (J) Summer flounder (J)

Table 3-2

Regions and highest fall relative abundance (CPUE; #/tow) among squid and select finfish species in Buzzards Bay

9110 North Bay anchovy Black sea bass (A, YOY) Cunner Scup (A) Summer flounder (J)	**9120 North** Blueback herring Bluefish (YOY) Long-finned squid Northern searobin Striped anchovy Summer flounder (A) Weakfish
9110 South Little skate Scup (YOY) Striped anchovy Tautog (A, J) Windowpane	**9120 South** Alewife Atlantic herring Butterfish Little skate Winter Flounder (A, J)

A – Adult J- Juvenile YOY- Young of the Year

Table 3-3

Distribution of Spring average CPUE (#/tow), biomass (weight/tow) and richness (# species/tow) of finfish and invertebrates by sub region in Buzzards Bay.

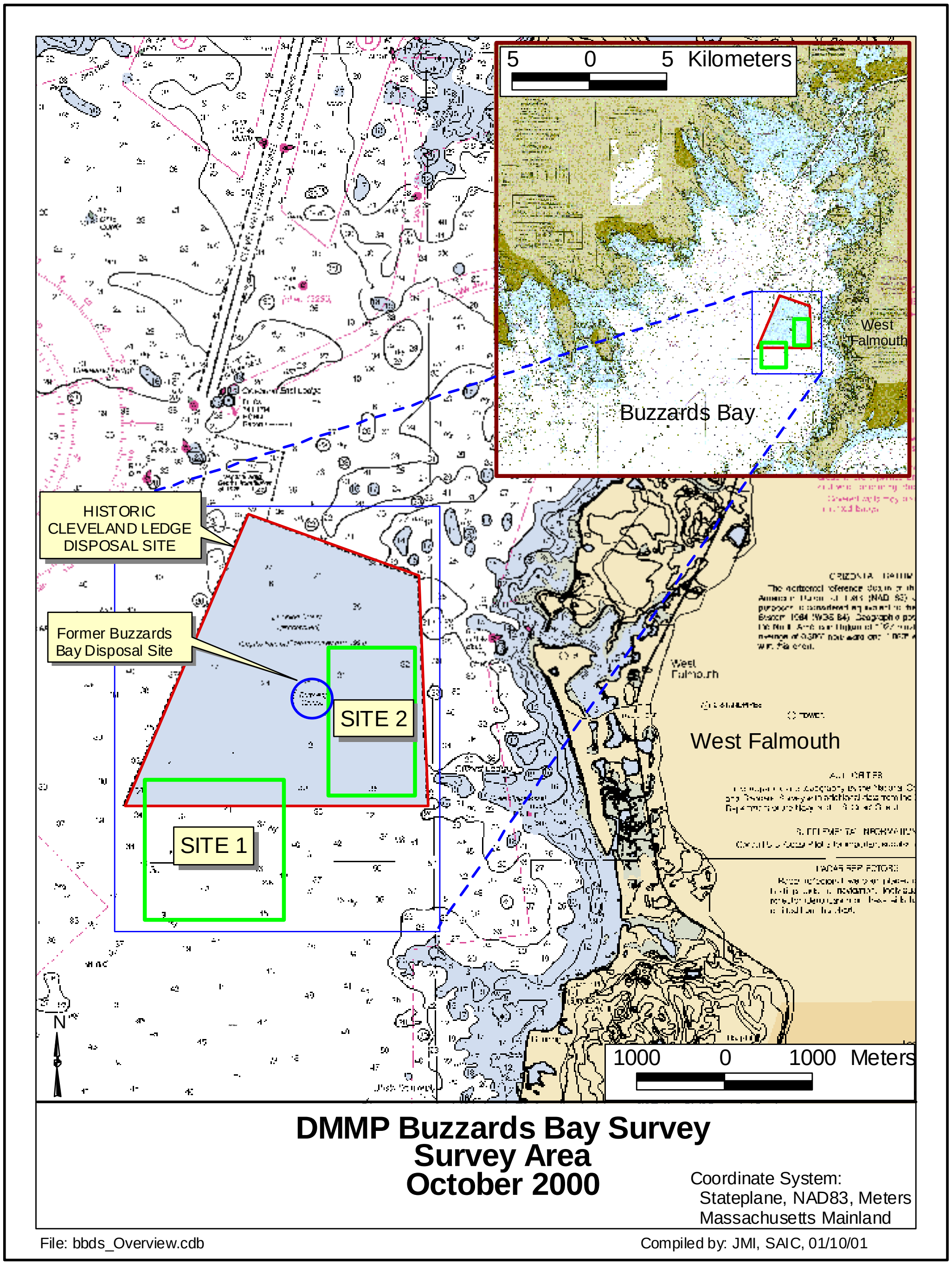
9110 North		**9120 North**	
Finfish CPUE	640	Finfish CPUE	260
Finfish Biomass (kg)	223	Finfish Biomass (kg)	86
Invertebrate CPUE	34	Invertebrate CPUE	44
Invertebrate Biomass (kg)	4	Invertebrate Biomass (kg)	5
Species Richness	11	Species Richness	12
9110 South		**9120 South**	
Finfish CPUE	252	Finfish CPUE	383
Finfish Biomass (kg)	151	Finfish Biomass (kg)	61
Invertebrate CPUE	75	Invertebrate CPUE	168
Invertebrate Biomass (kg)	7	Invertebrate Biomass (kg)	15
Species Richness	13	Species Richness	16

Table 3-4

Distribution of Fall average CPUE (#/tow), biomass (weight/tow) and richness (# species/tow) of finfish and invertebrates by sub region in Buzzards Bay.

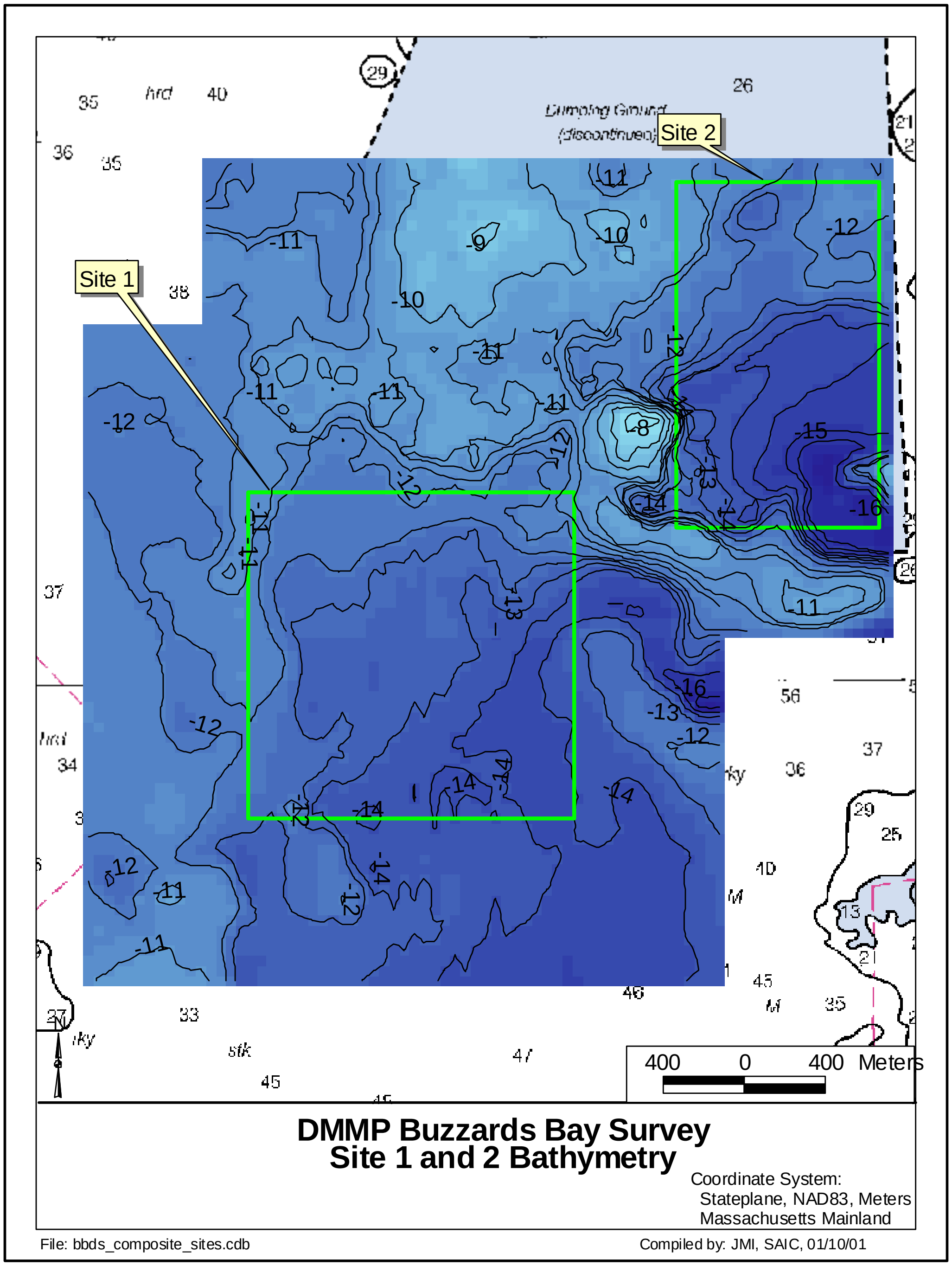
9110 North		**9120 North**	
Finfish CPUE	3892	Finfish CPUE	4267
Finfish Biomass (kg)	62	Finfish Biomass (kg)	90
Invertebrate CPUE	244	Invertebrate CPUE	948
Invertebrate Biomass (kg)	8	Invertebrate Biomass (kg)	9
Species Richness	14	Species Richness	15
9110 South		**9120 South**	
Finfish CPUE	4560	Finfish CPUE	5255
Finfish Biomass (kg)	71	Finfish Biomass (kg)	83
Invertebrate CPUE	387	Invertebrate CPUE	877
Invertebrate Biomass (kg)	4	Invertebrate Biomass (kg)	9
Species Richness	12	Species Richness	15

Figure 1-1



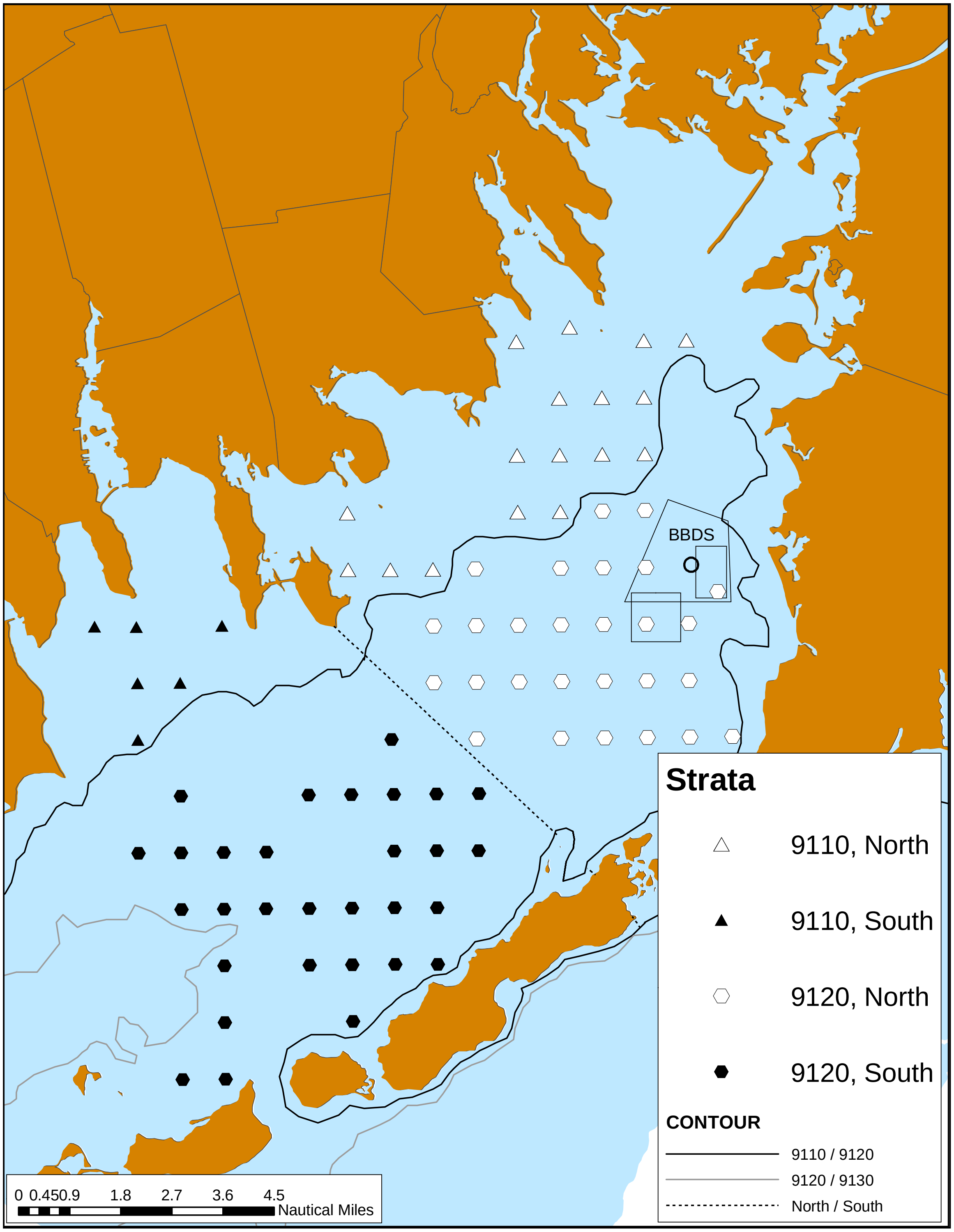
Buzzards Bay Site Investigations Survey Areas (from SAIC)

Figure 1-2



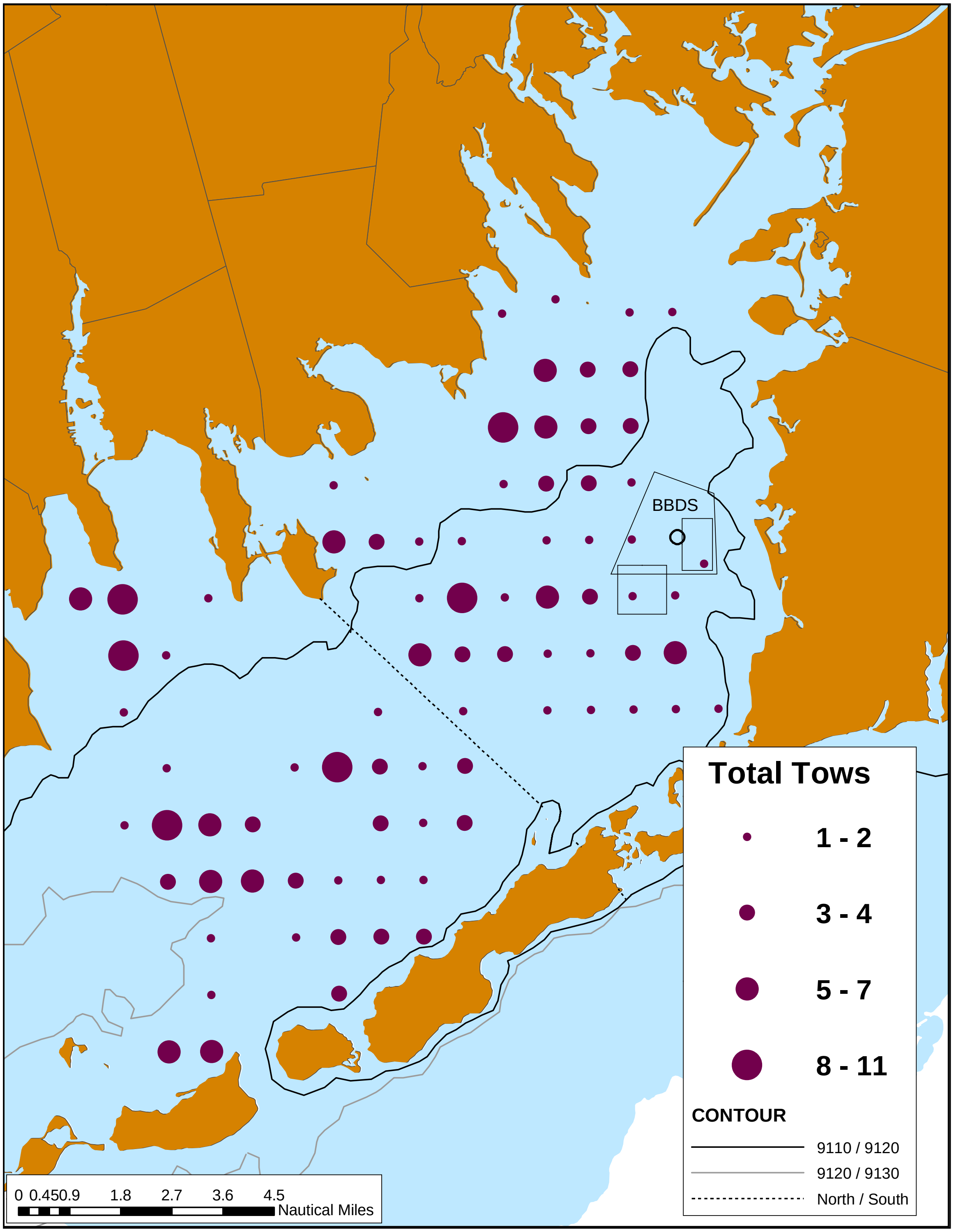
Buzzards Bay Bathymetry Sites 1 and 2 (from SAIC)

Figure 2-1



Trawl Stations In Buzzards Bay

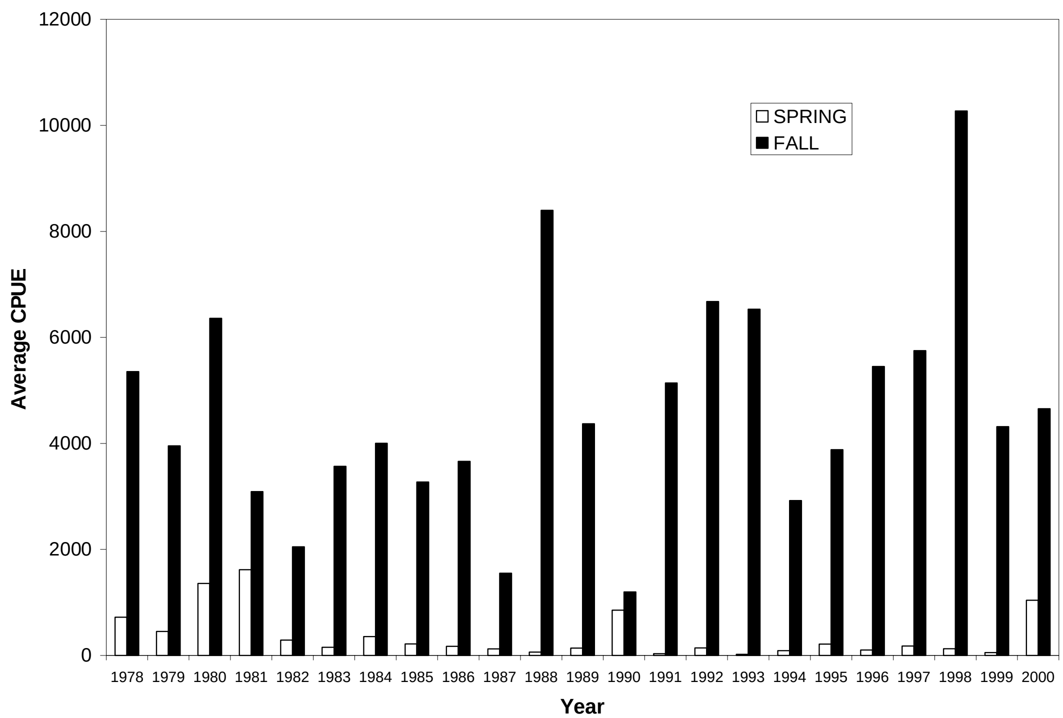
Figure 2-2



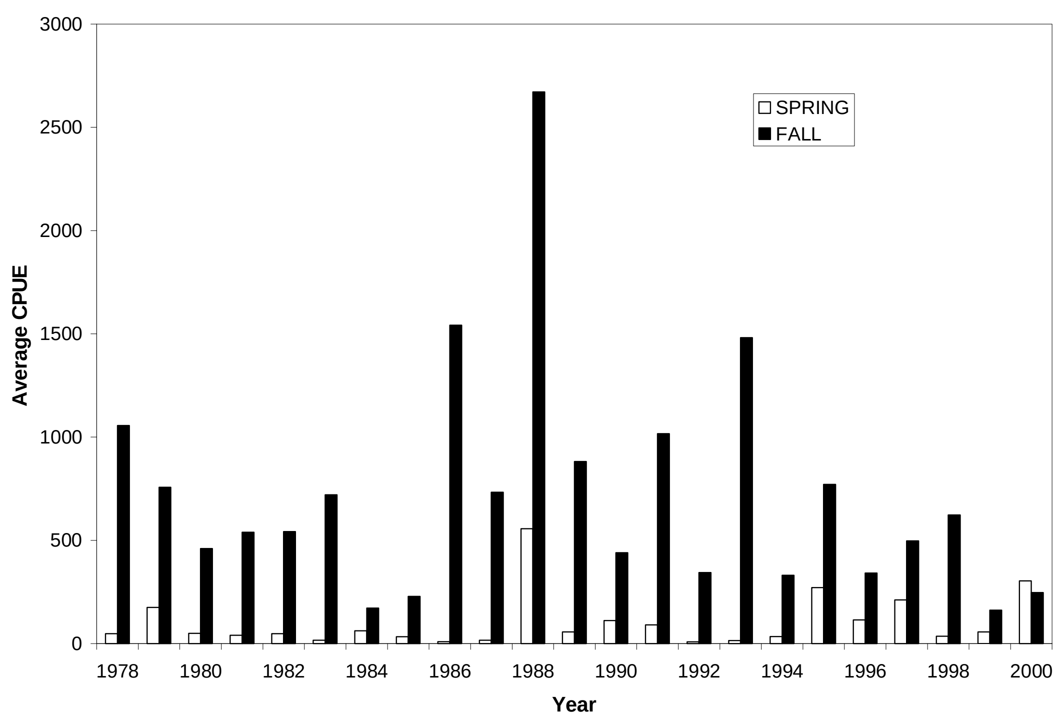
Tow counts for Trawl Stations 1978-2000

Figure 3-1

a. Finfish CPUE

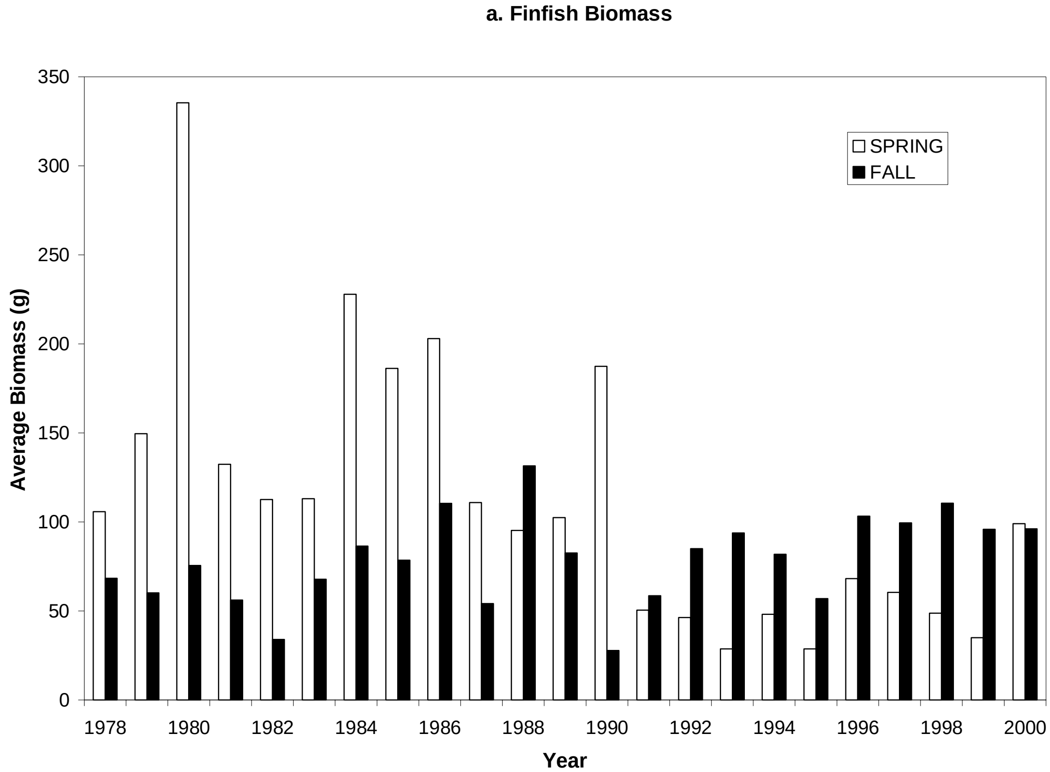


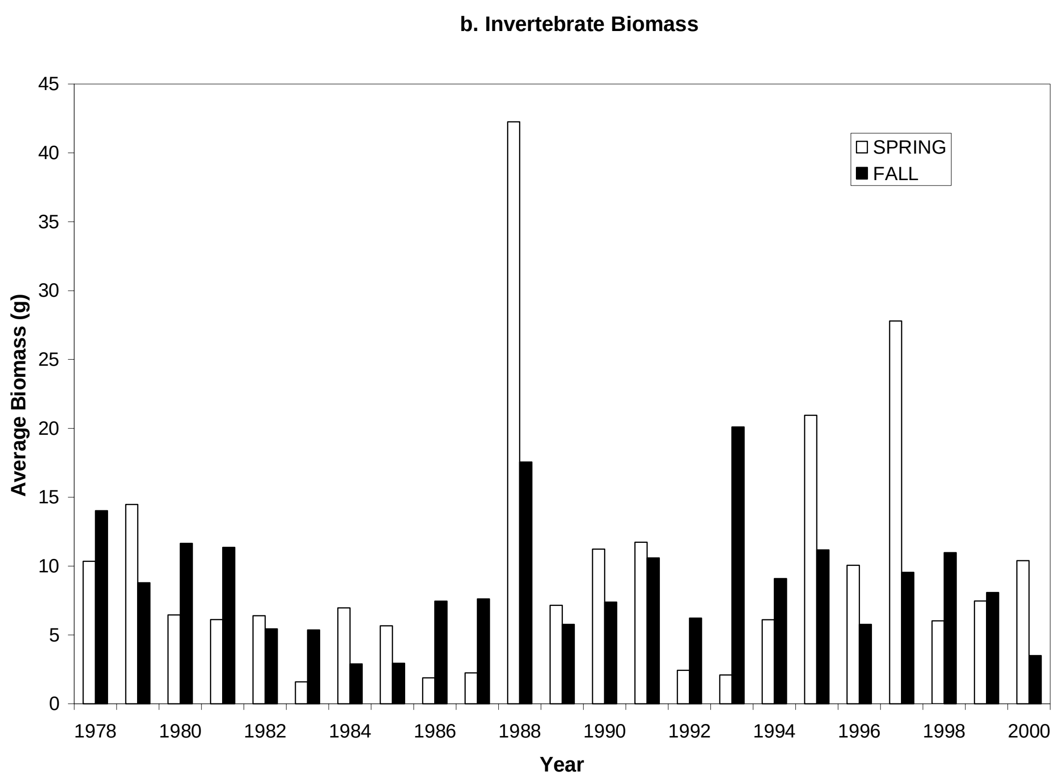
b. Invertebrate CPUE



Average Abundance CPUE by season & year

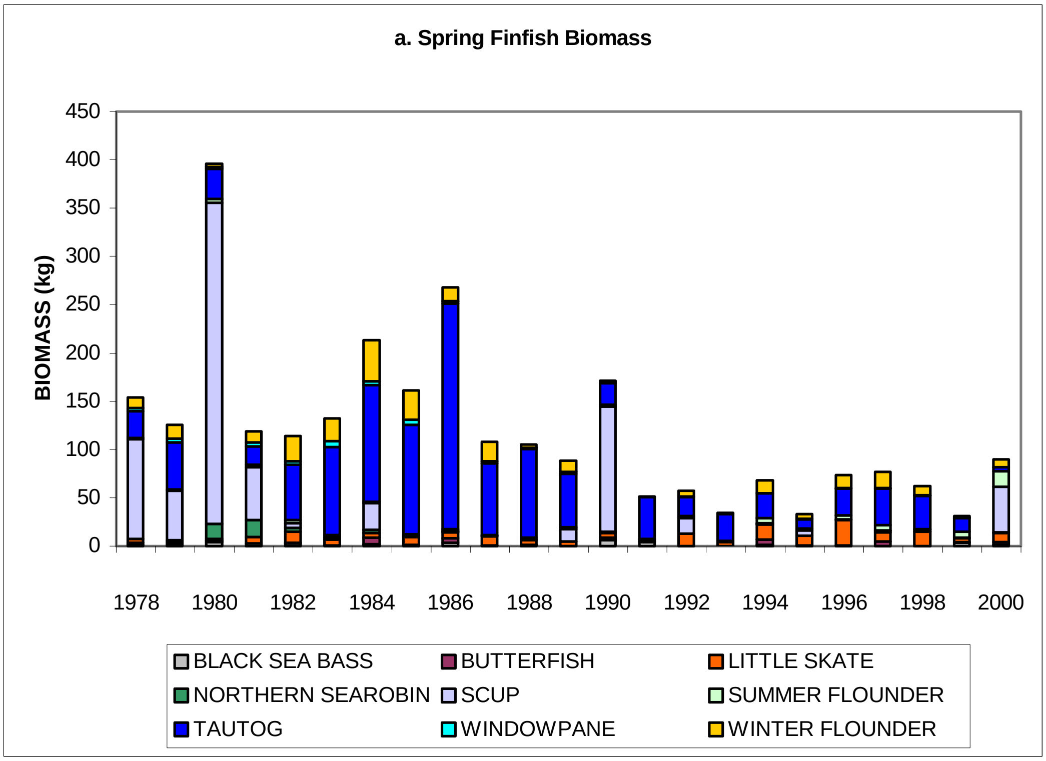
Figure 3-2

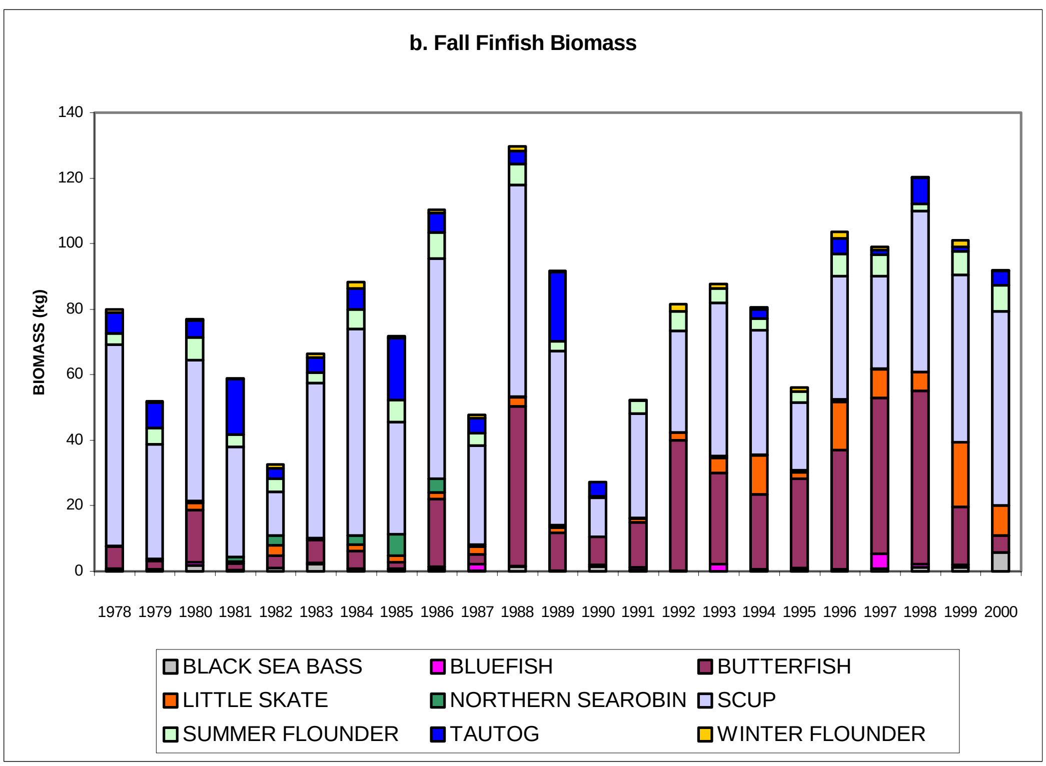




Average Biomass per tow by season & year

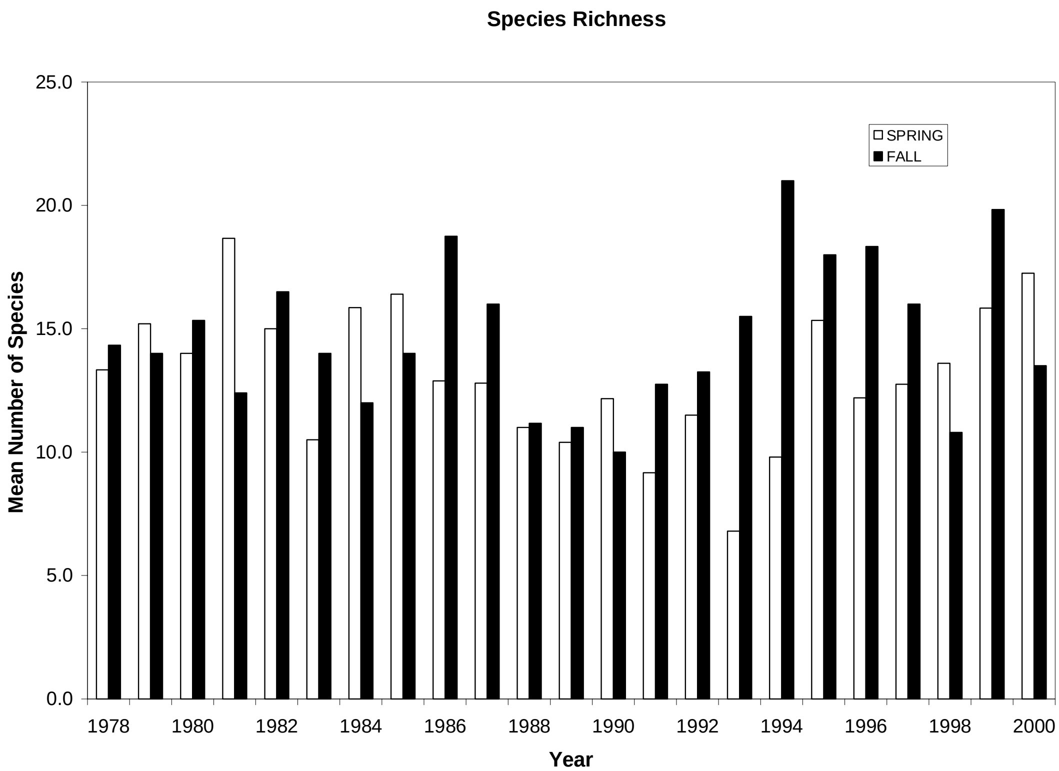
Figure 3-3





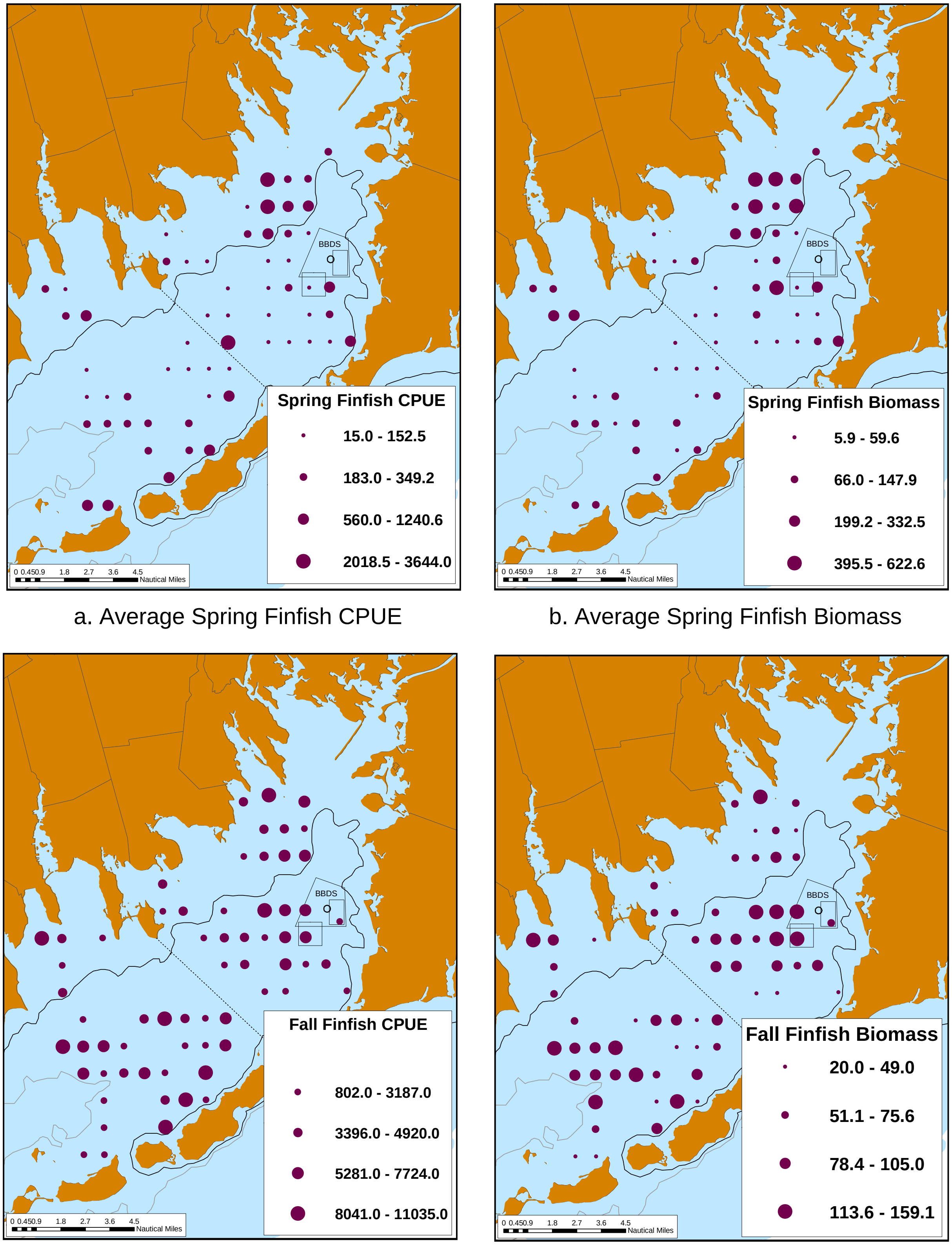
Biomass of top nine finfish species by year. a. Spring. b. Fall.

Figure 3-4



Average Species Richness per tow by season & year

Figure 3-5



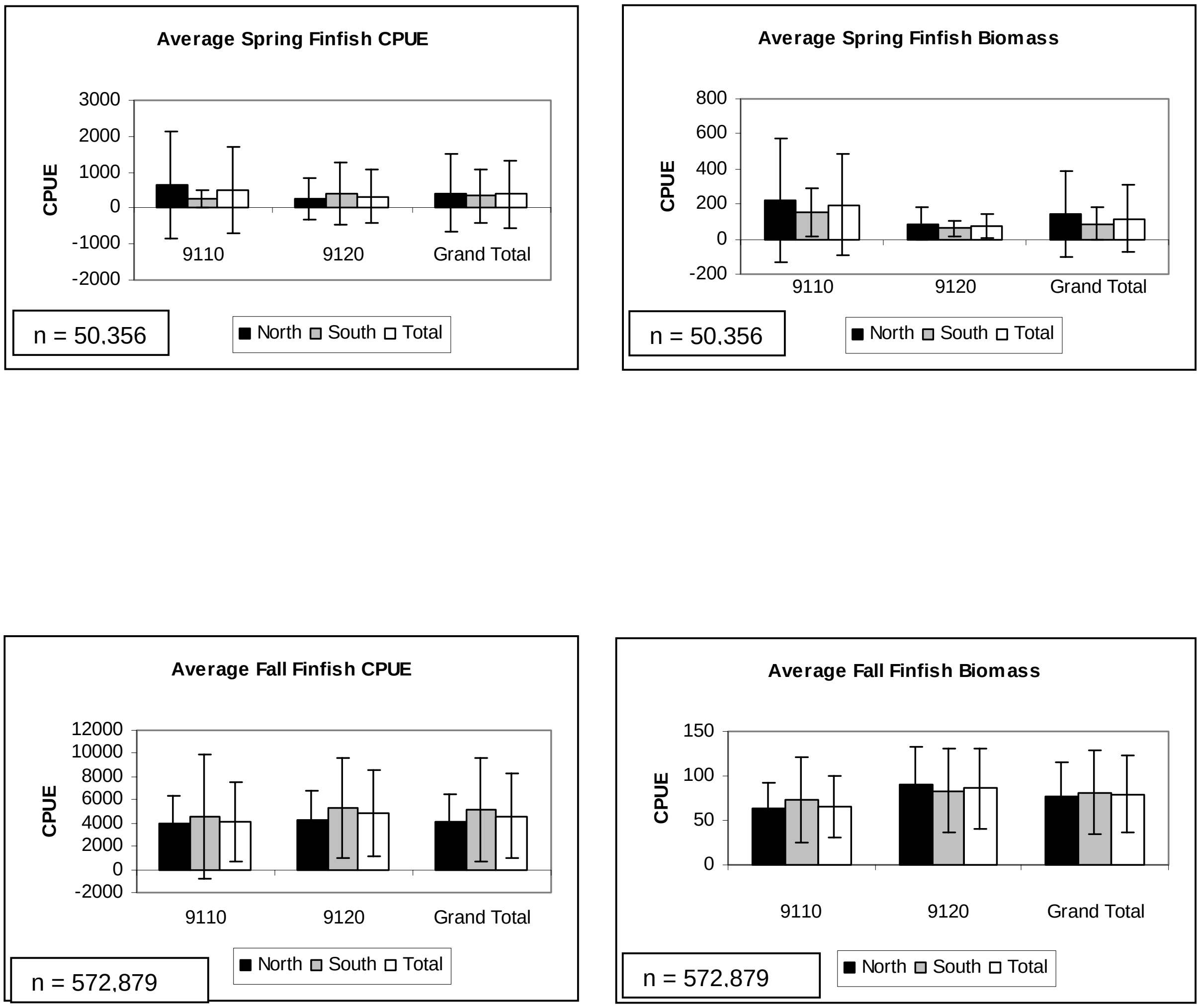
a. Average Spring Finfish CPUE

b. Average Spring Finfish Biomass

c. Average Fall Finfish CPUE

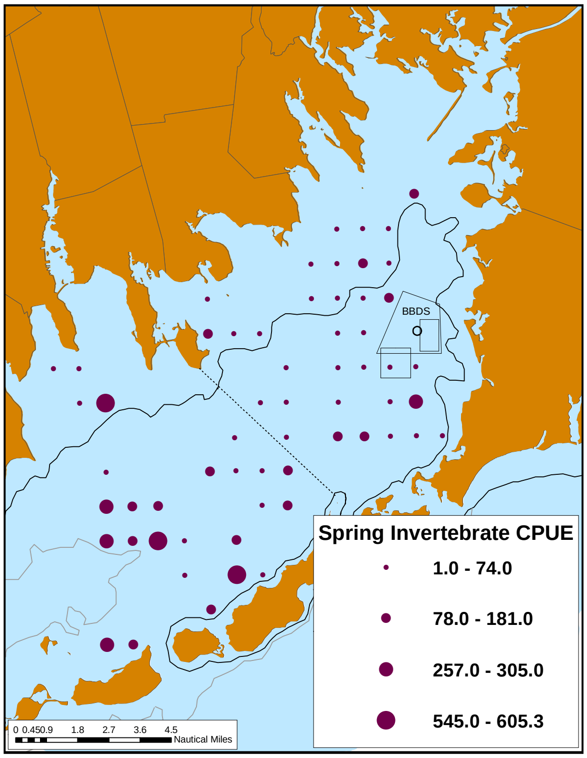
d. Average Fall Finfish Biomass

Figure 3-6

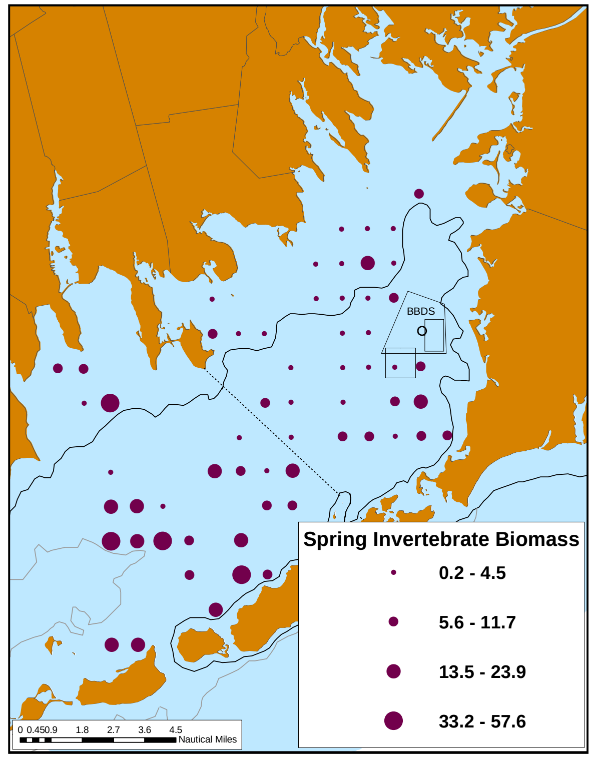


Finfish results by sub region
Error bars are plus and minus one standard deviation from the mean.

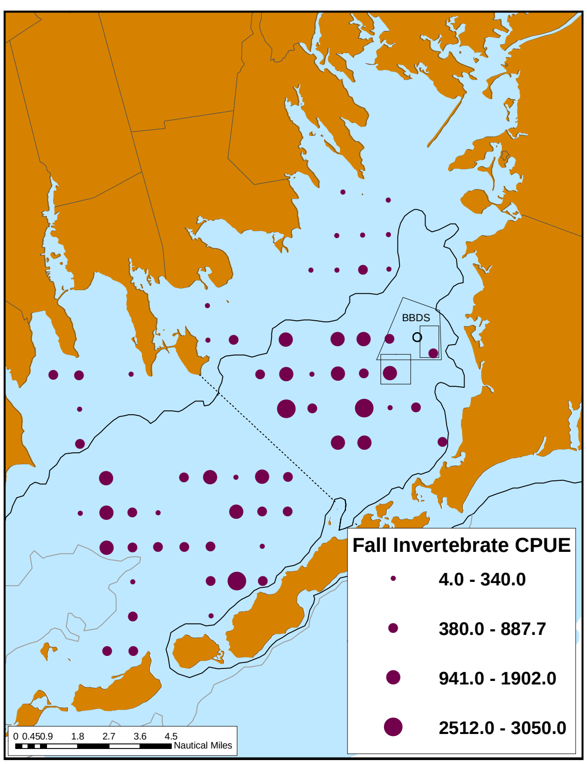
Figure 3-7



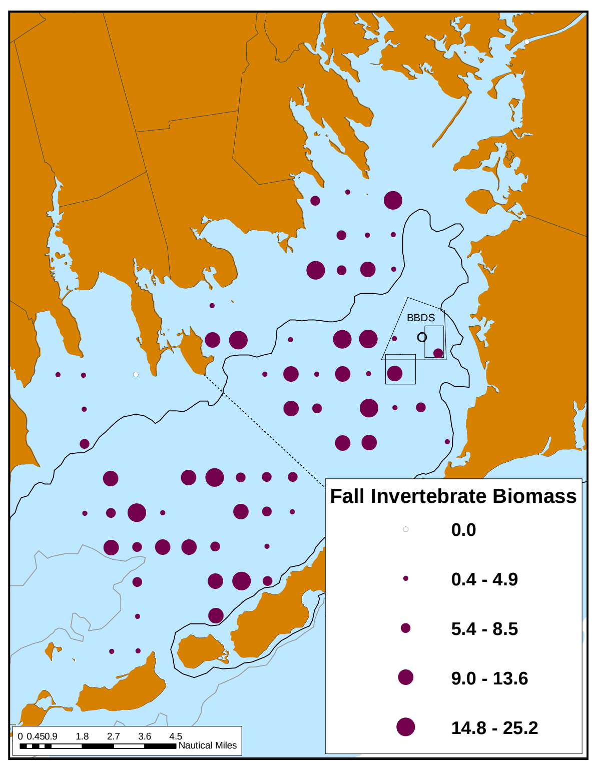
a. Average Spring Invertebrate CPUE



b. Average Spring Invertebrate Biomass

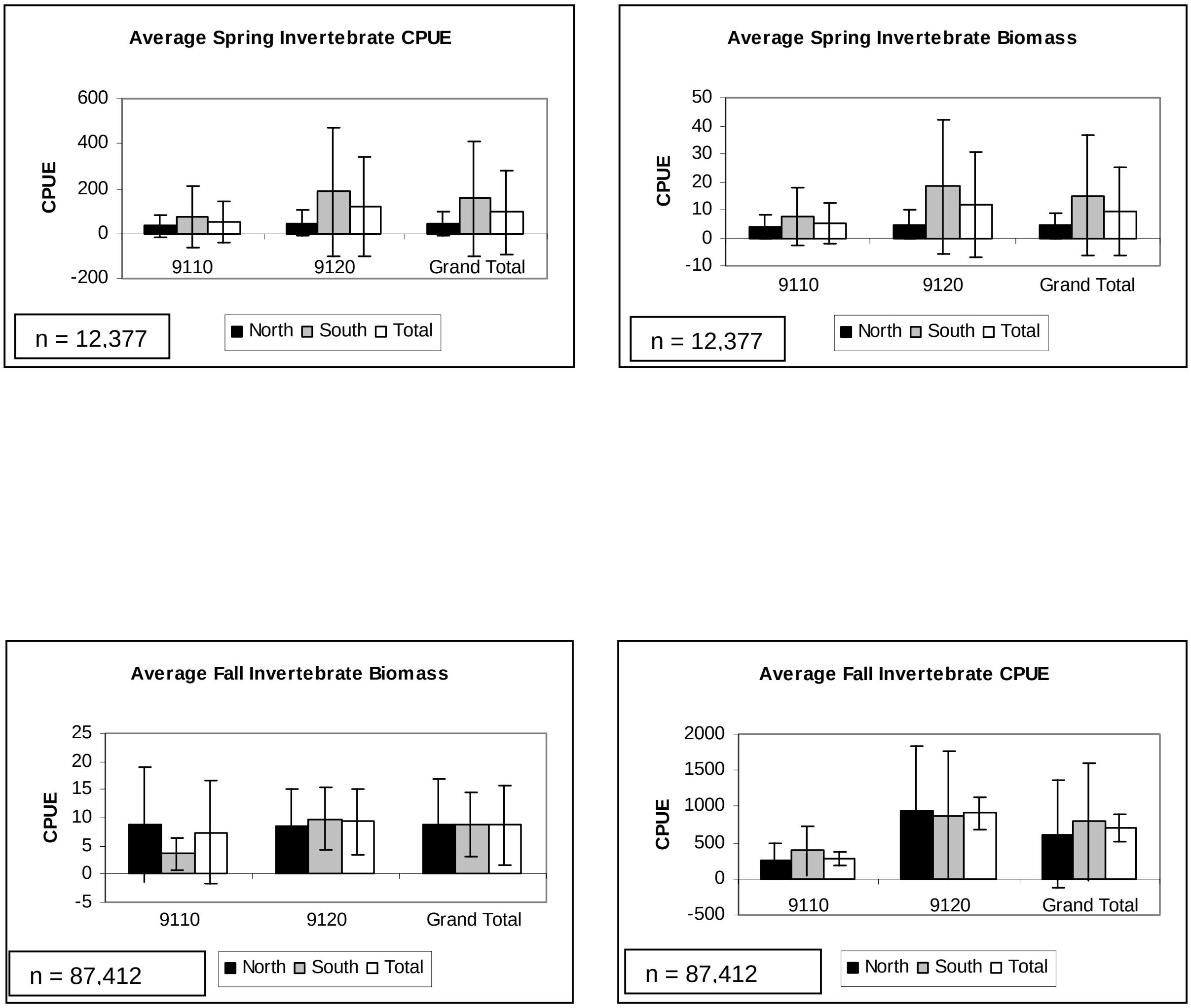


c. Average Fall Invertebrate CPUE



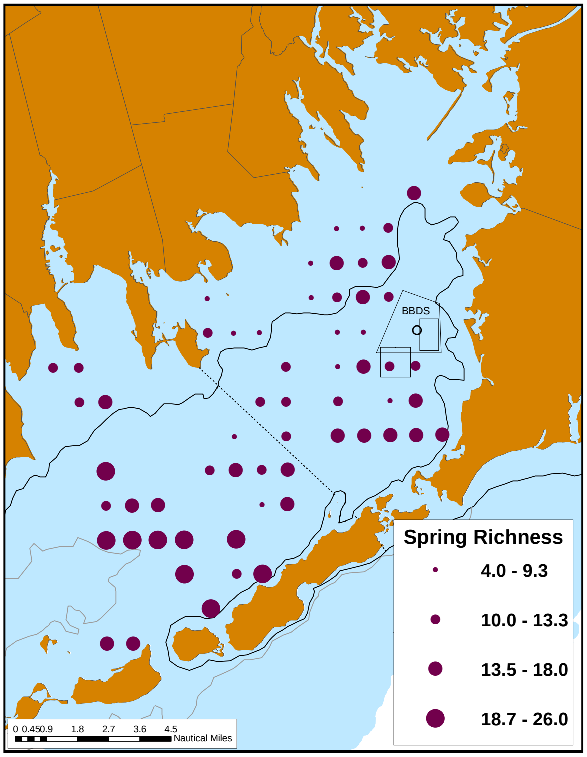
d. Average Fall Invertebrate Biomass

Figure 3-8

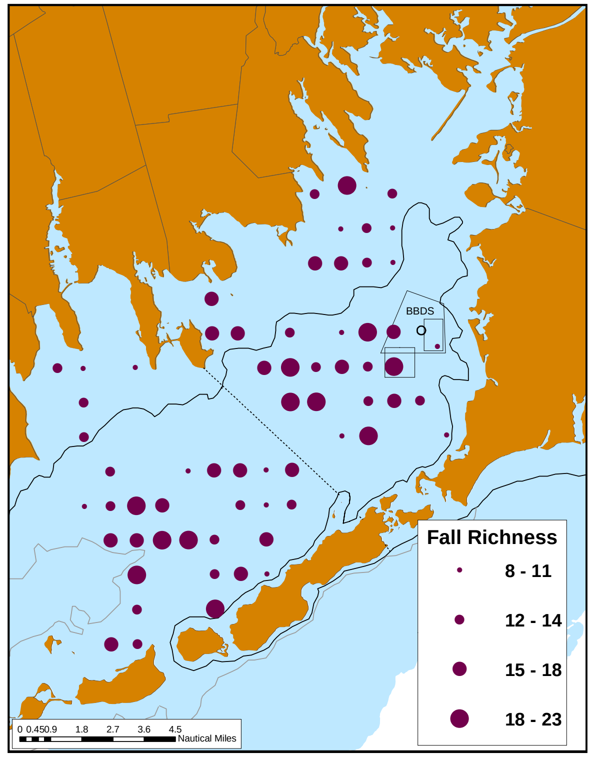


Invertebrate results by sub region
Error bars are plus and minus one standard deviation from the mean.

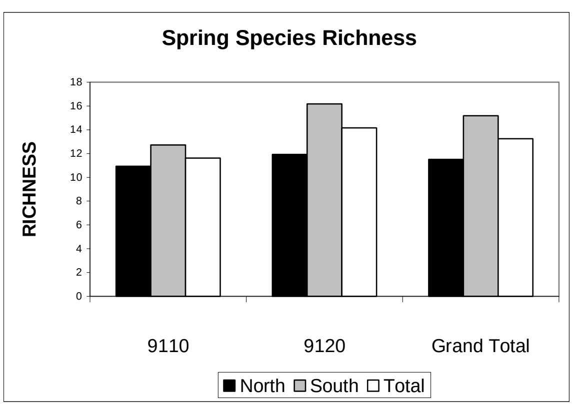
Figure 3-9



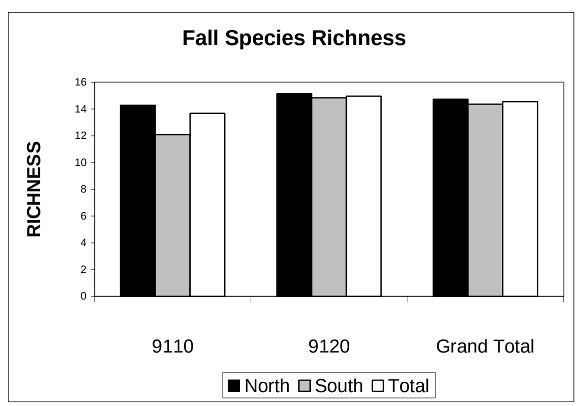
a. Average Spring Richness for all stations



b. Average Fall Richness for all stations

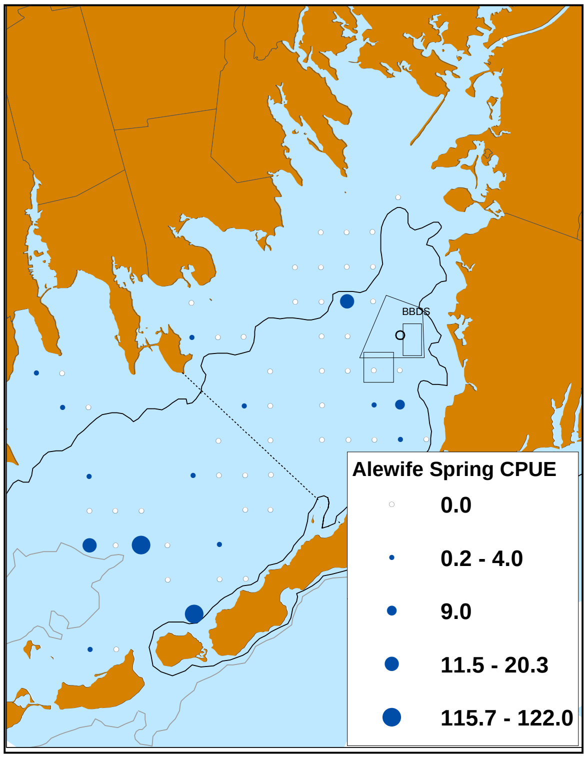


c. Average Spring Richness for all stations by sub region

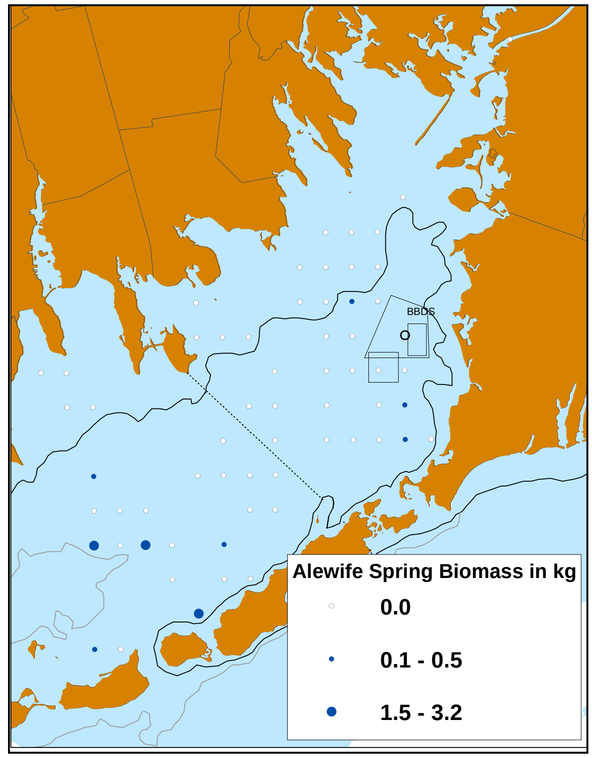


d. Average Fall Richness for all stations by sub region

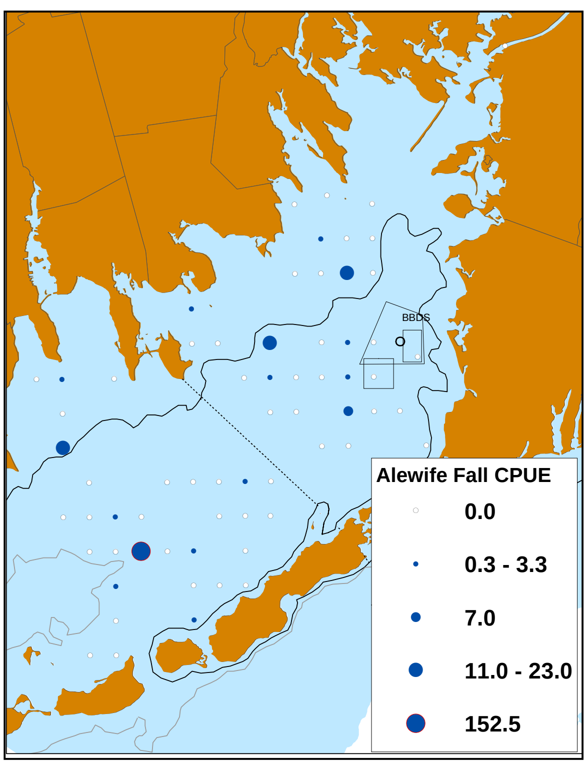
Figure 3-10



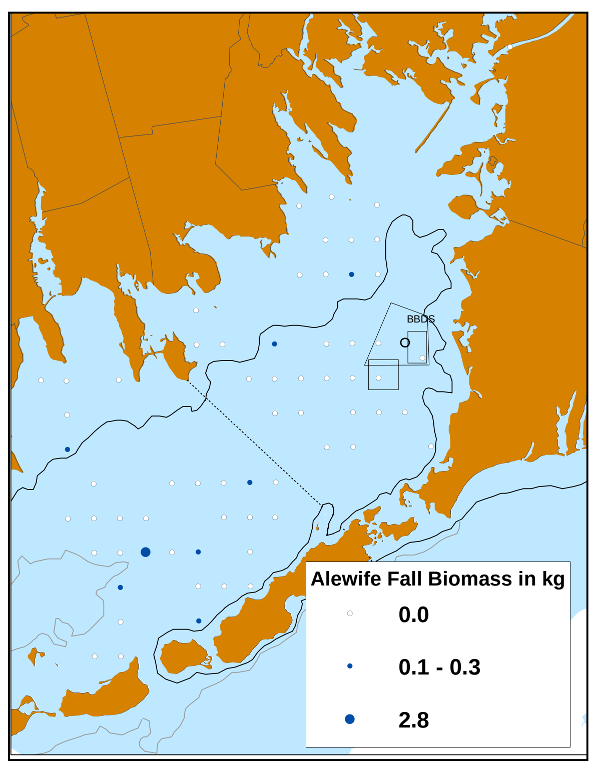
a. Average Spring CPUE of Alewife



b. Average Spring Biomass of Alewife

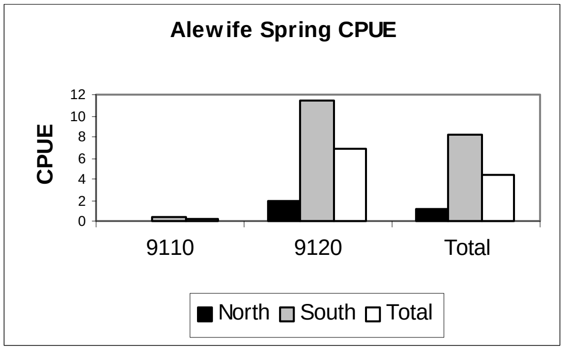


c. Average Fall CPUE of Alewife

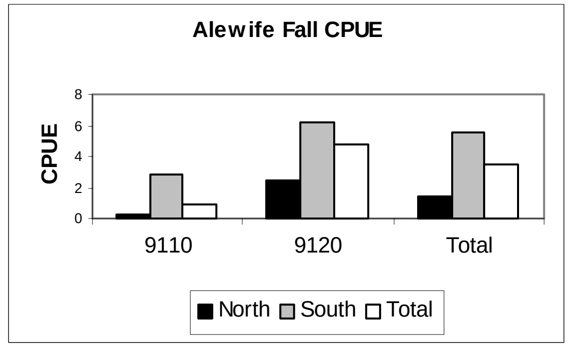


d. Average Fall Biomass of Alewife

Figure 3-11

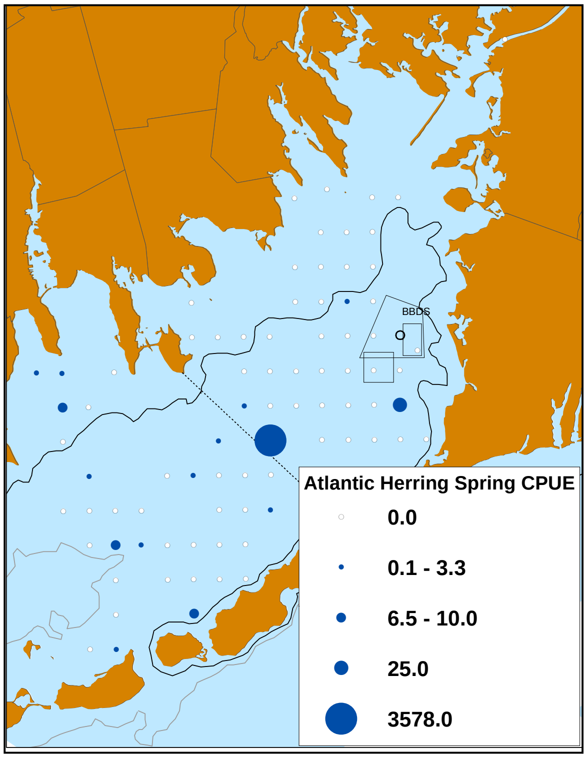


a. Average Spring CPUE of Alewife by sub region

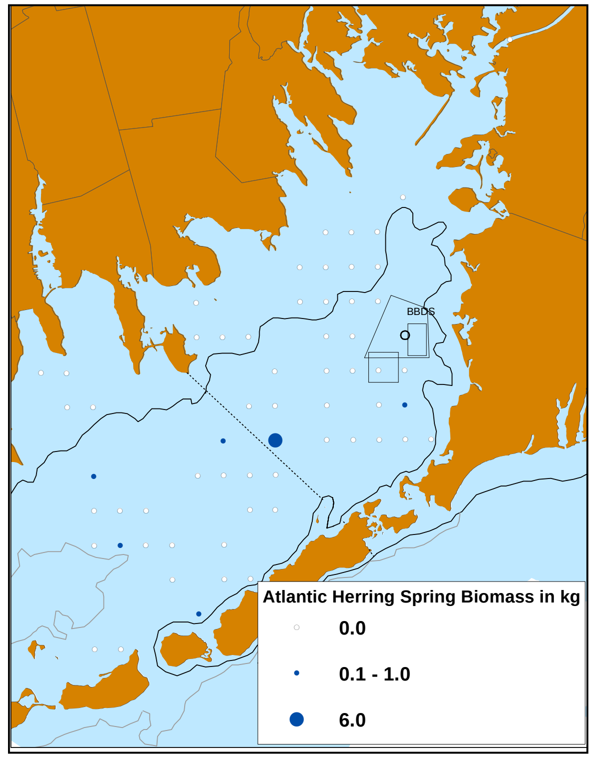


b. Average Fall CPUE of Alewife by sub region

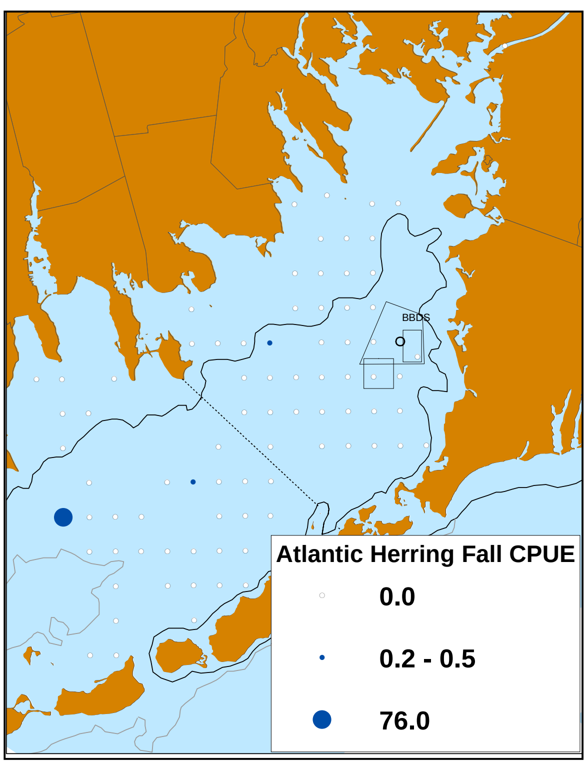
Figure 3-12



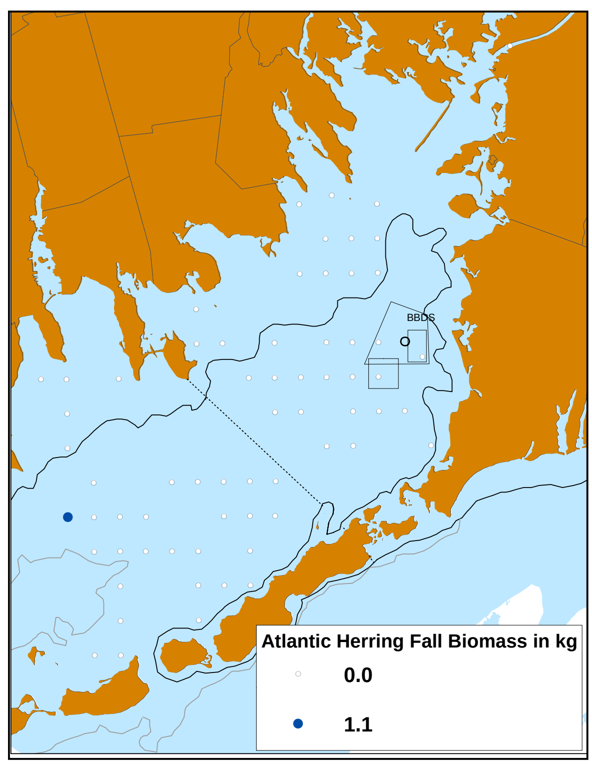
a. Average Spring CPUE of Atlantic Herring



b. Average Spring Biomass of Atlantic Herring

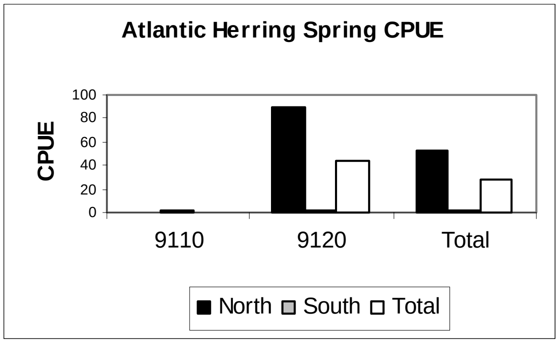


c. Average Fall CPUE of Atlantic Herring

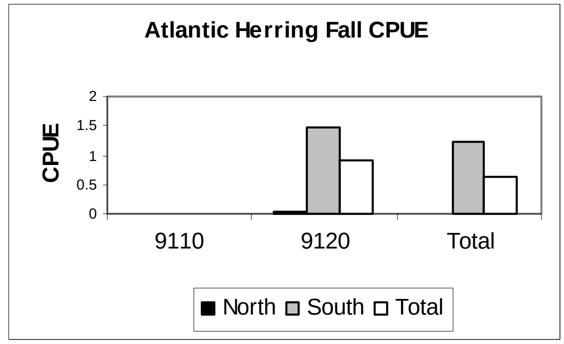


d. Average Fall Biomass of Atlantic Herring

Figure 3-13

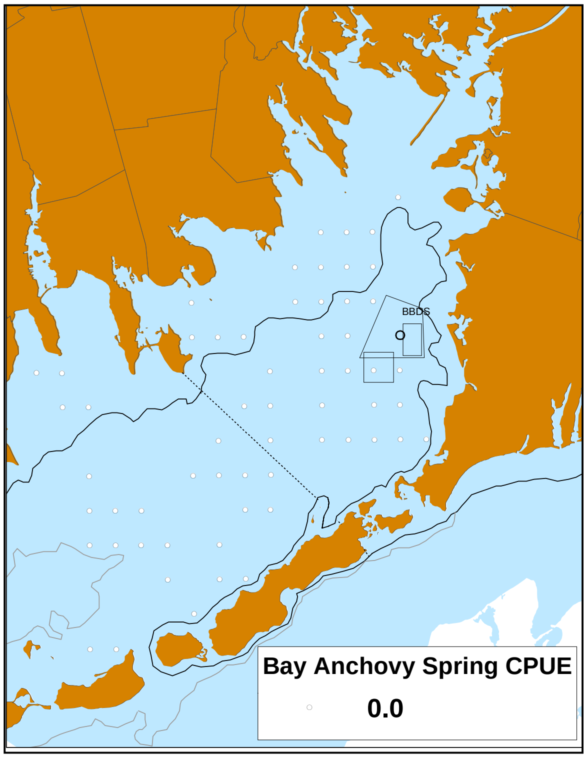


a. Average Spring CPUE of Atlantic Herring by sub region

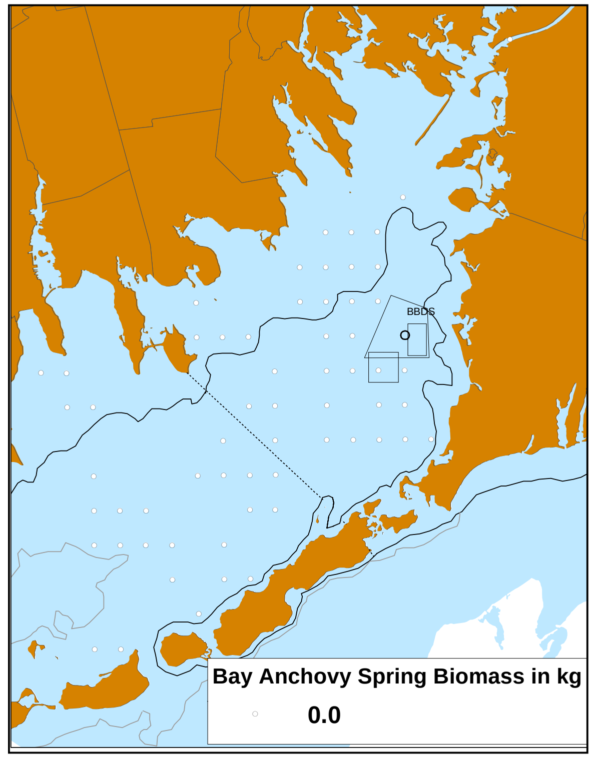


b. Average Fall CPUE of Atlantic Herring by sub region

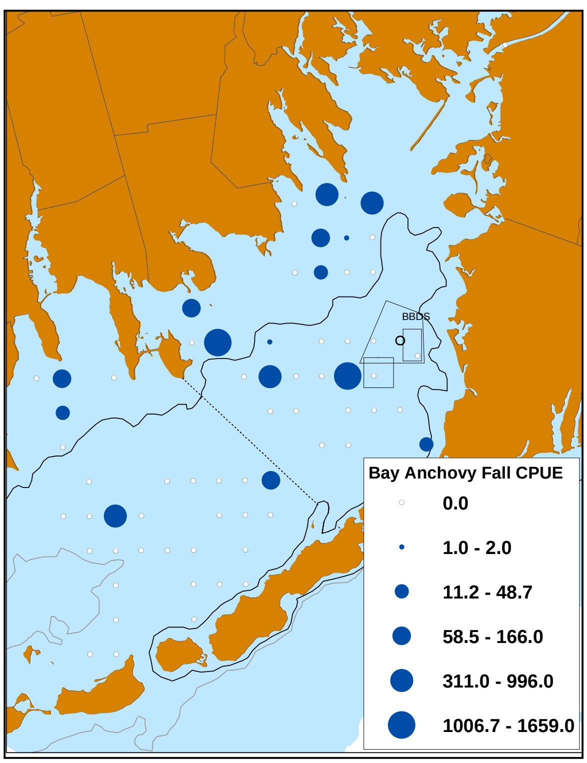
Figure 3-14



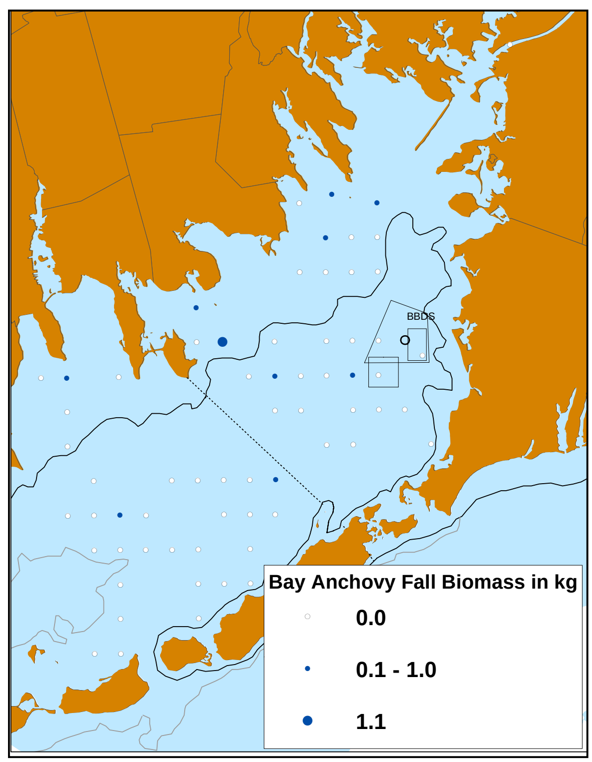
a. Average Spring CPUE of Bay Anchovy



b. Average Spring Biomass of Bay Anchovy

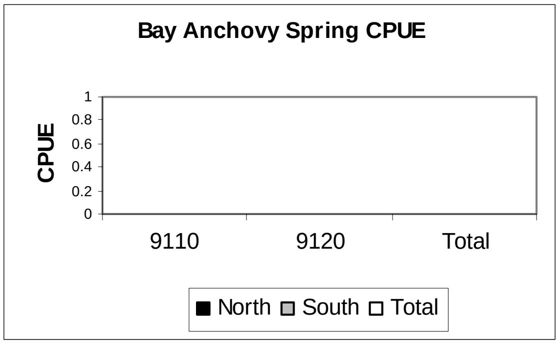


c. Average Fall CPUE of Bay Anchovy

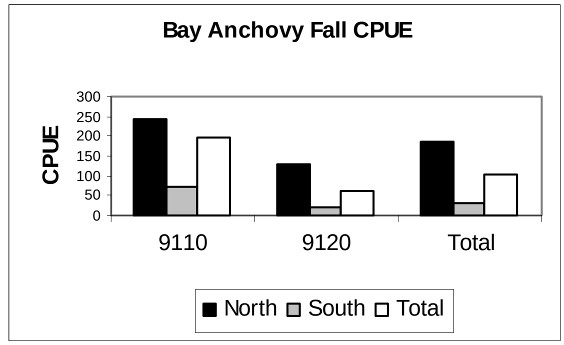


d. Average Fall Biomass of Bay Anchovy

Figure 3-15

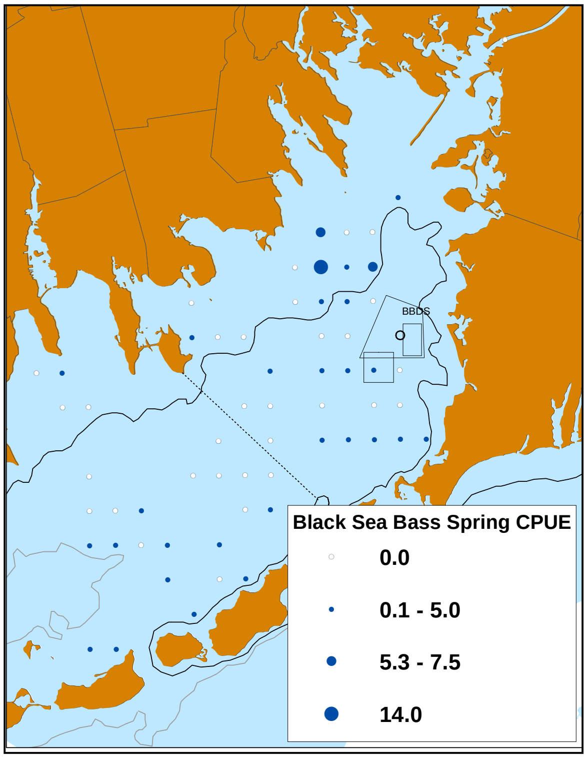


a. Average Spring CPUE of Bay Anchovy by sub region

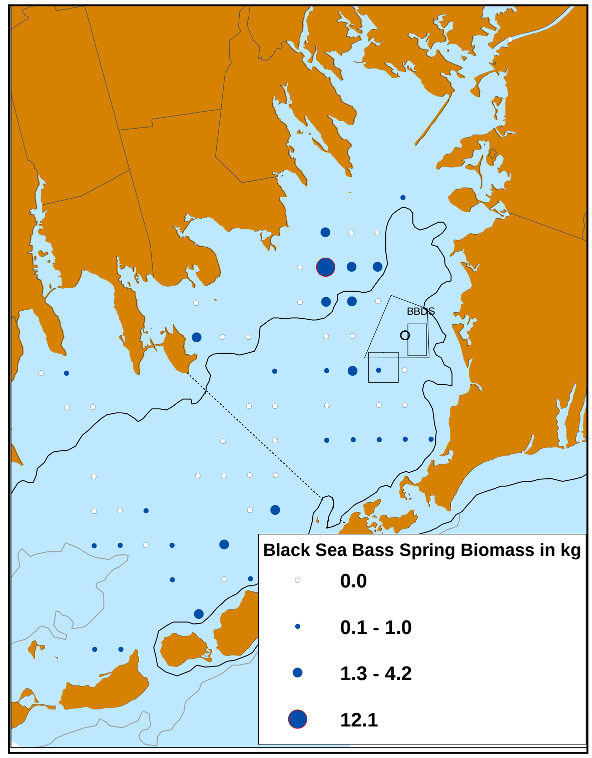


b. Average Fall CPUE of Bay Anchovy by sub region

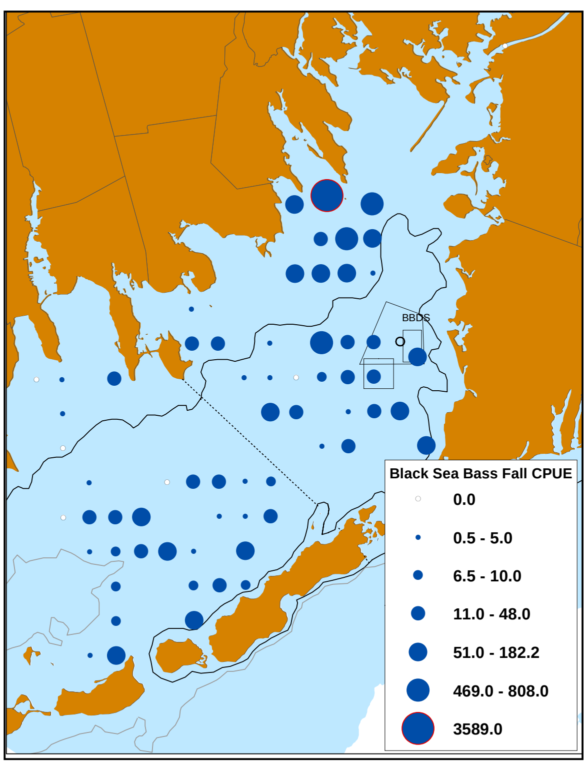
Figure 3-16



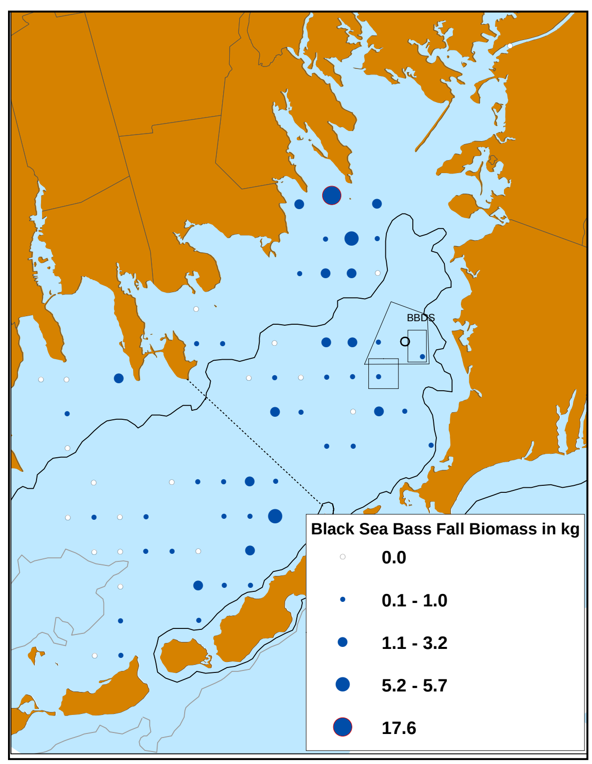
a. Average Spring CPUE of Black Sea Bass



b. Average Spring Biomass of Black Sea Bass

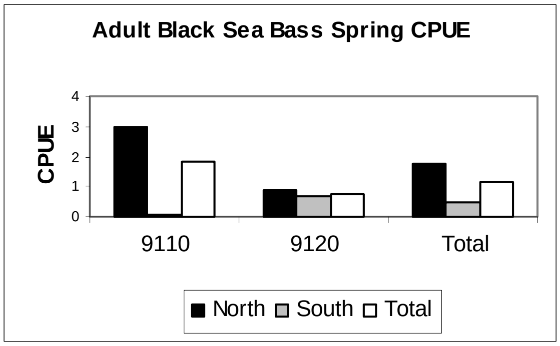


c. Average Fall CPUE of Black Sea Bass

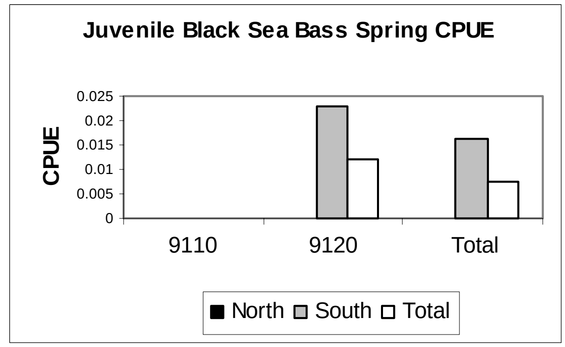


d. Average Fall Biomass of Black Sea Bass

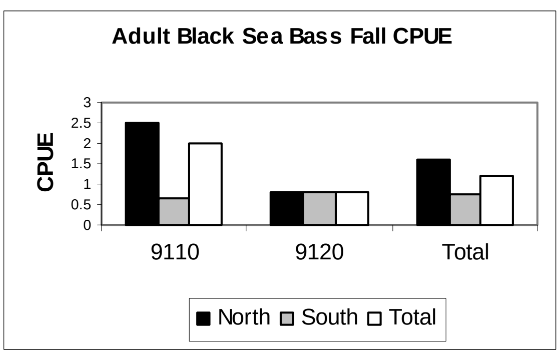
Figure 3-17



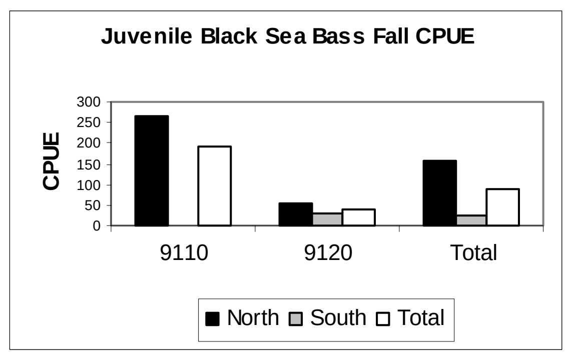
a. Average Spring CPUE of Adult Black Sea Bass by sub region



b. Average Spring CPUE of Juvenile Black Sea Bass by sub region

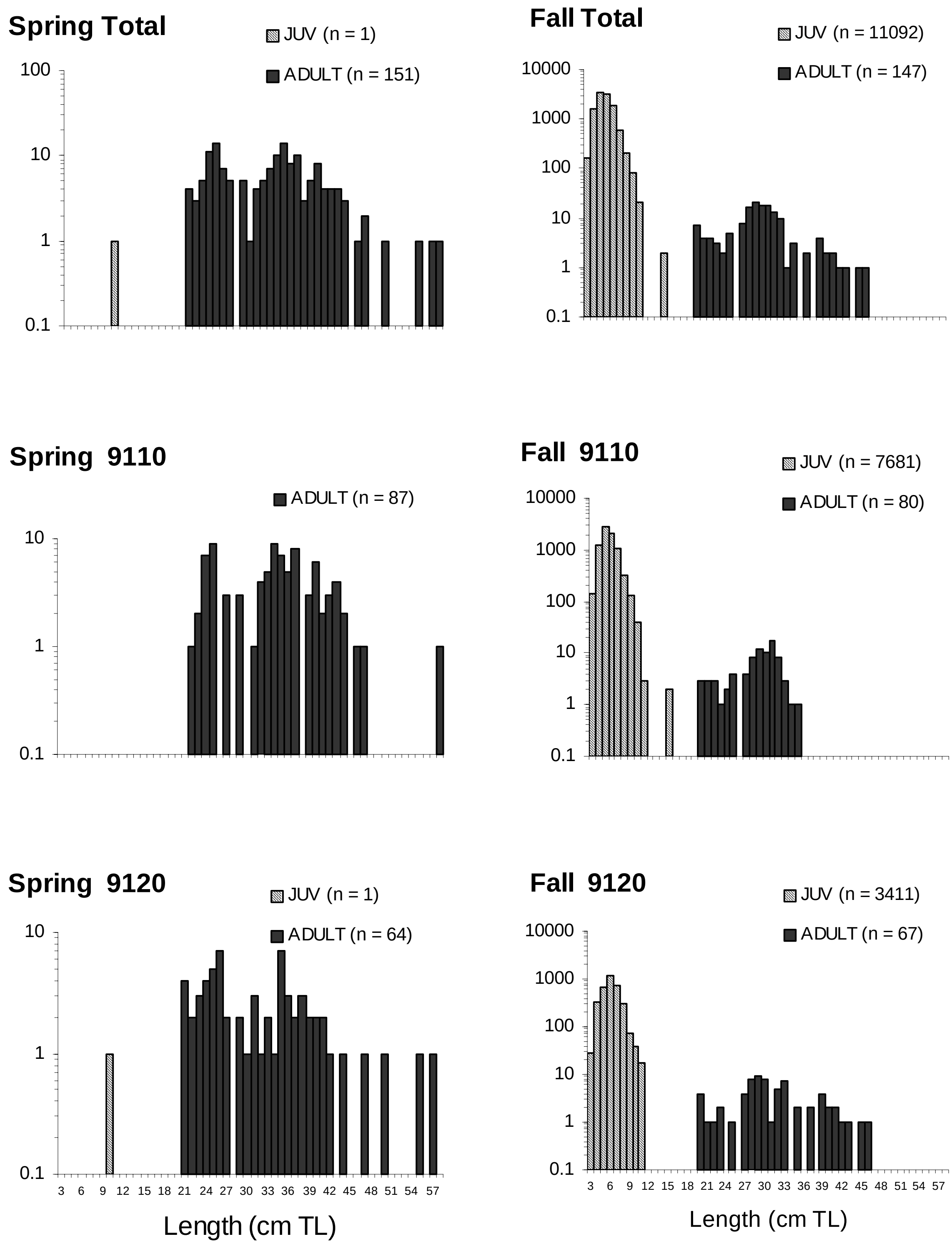


c. Average Fall CPUE of Adult Black Sea Bass by sub region



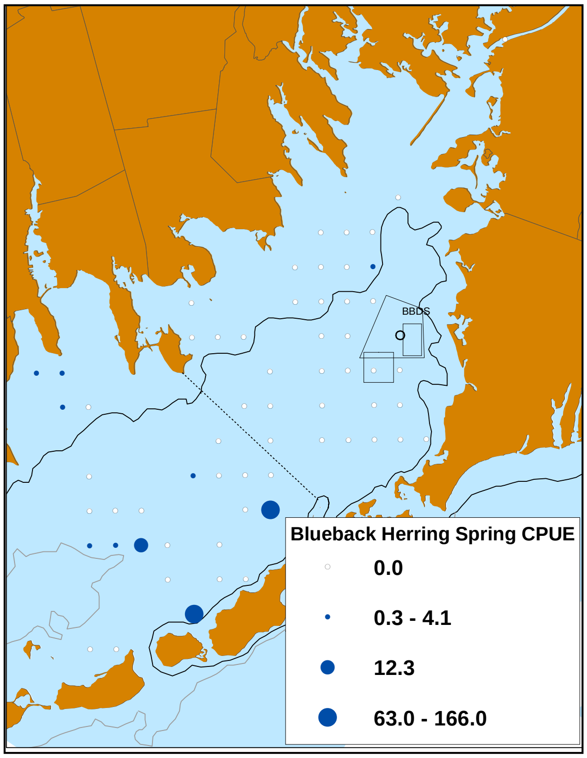
d. Average Fall CPUE of Juvenile Black Sea Bass by sub region

Figure 3-18

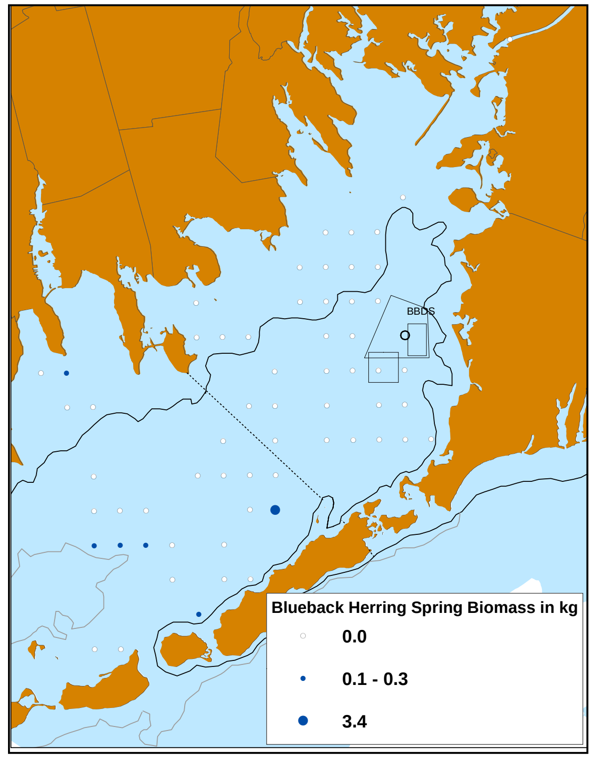


Seasonal Black Sea Bass (*Centropristes striata*) log10 length frequencies (cm TL) by strata based on 11, 239 fish captured between 1978 –2000.

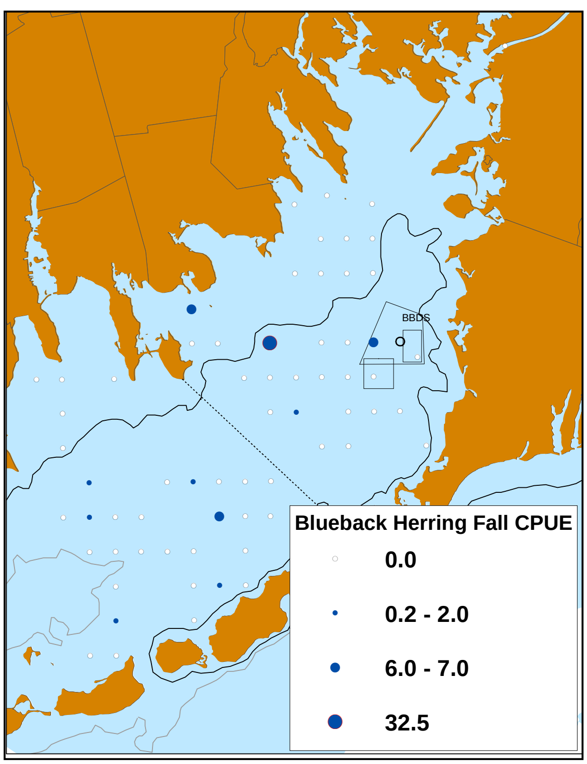
Figure 3-19



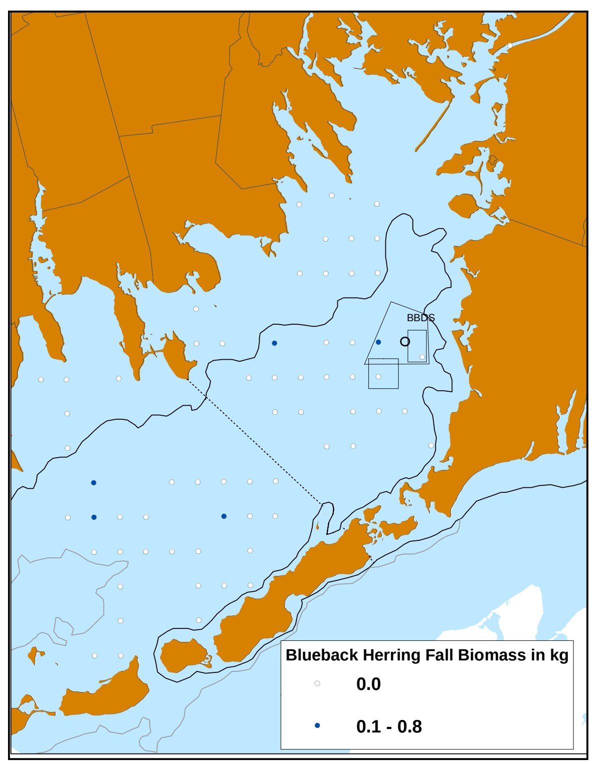
a. Average Spring CPUE of Blueback Herring



b. Average Spring Biomass of Blueback Herring

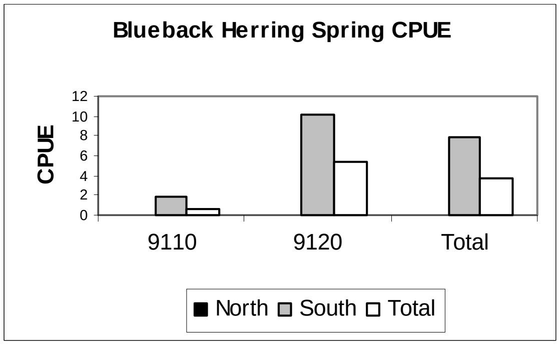


c. Average Fall CPUE of Blueback Herring

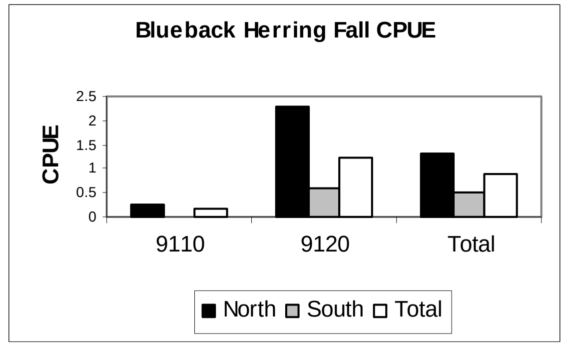


d. Average Fall Biomass of Blueback Herring

Figure 3-20

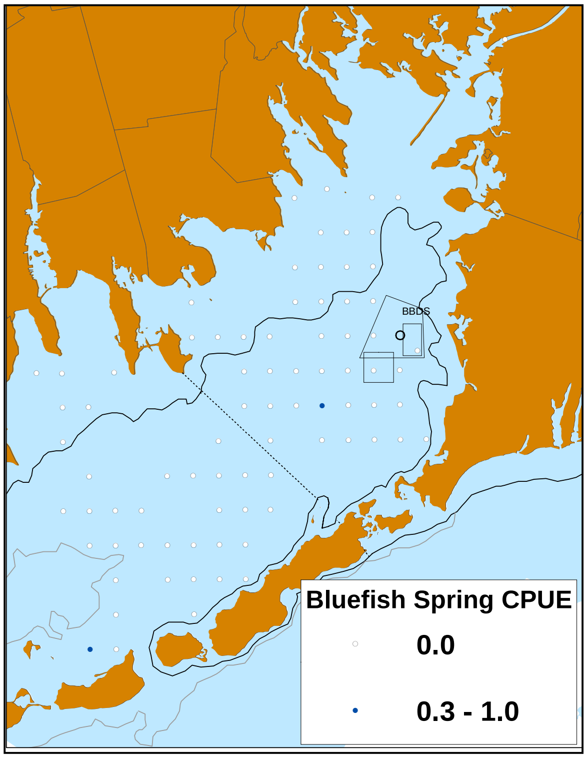


a. Average Spring CPUE of Blueback Herring by sub region

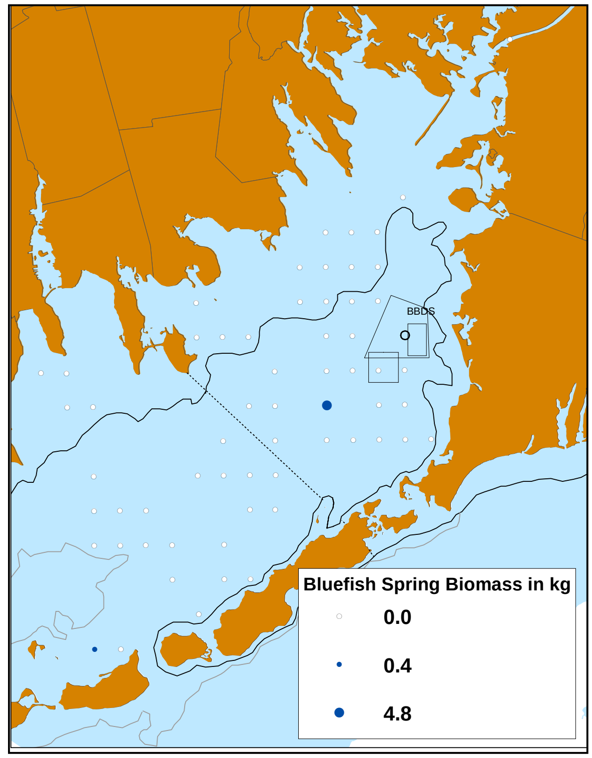


b. Average Fall CPUE of Blueback Herring by sub region

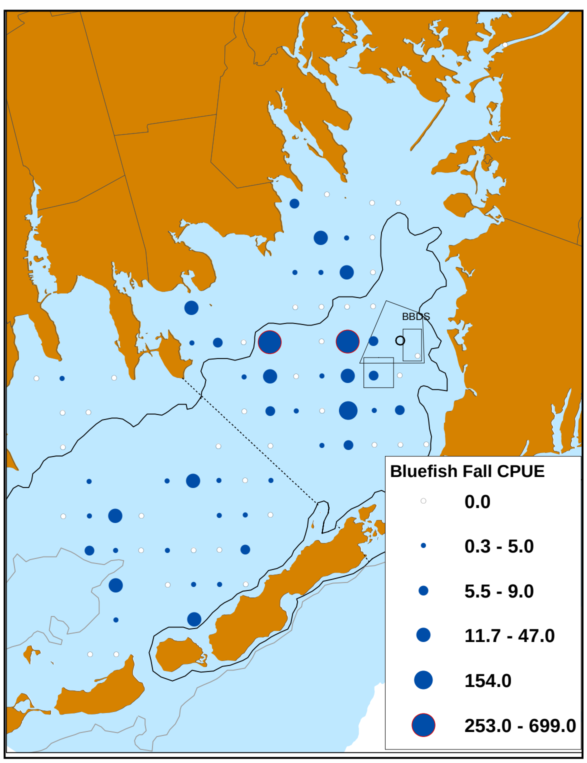
Figure 3-21



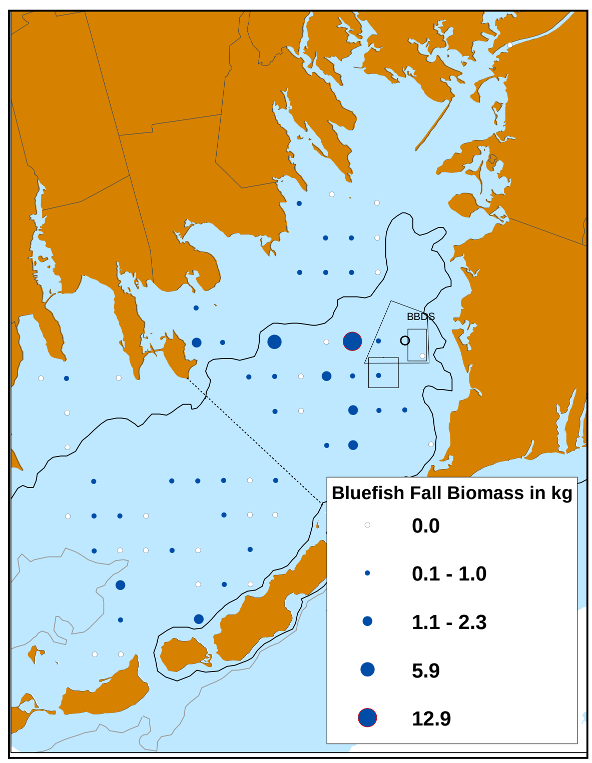
a. Average Spring CPUE of Bluefish



b. Average Spring Biomass of Bluefish

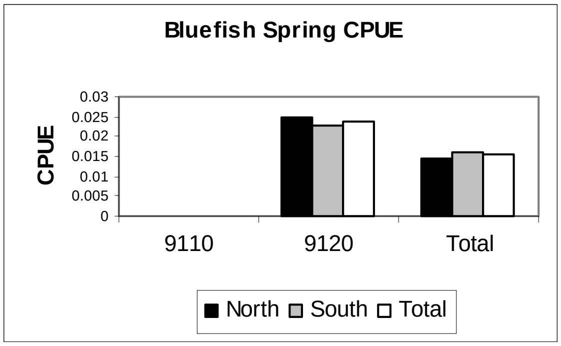


c. Average Fall CPUE of Bluefish

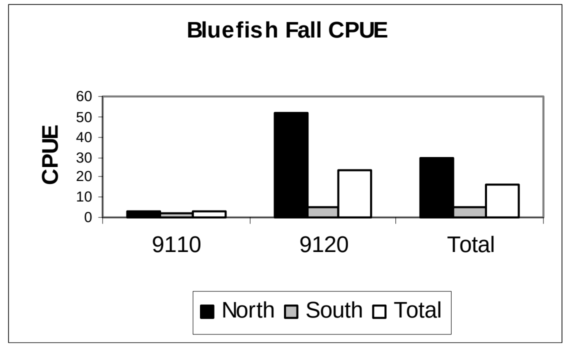


d. Average Fall Biomass of Bluefish

Figure 3-22

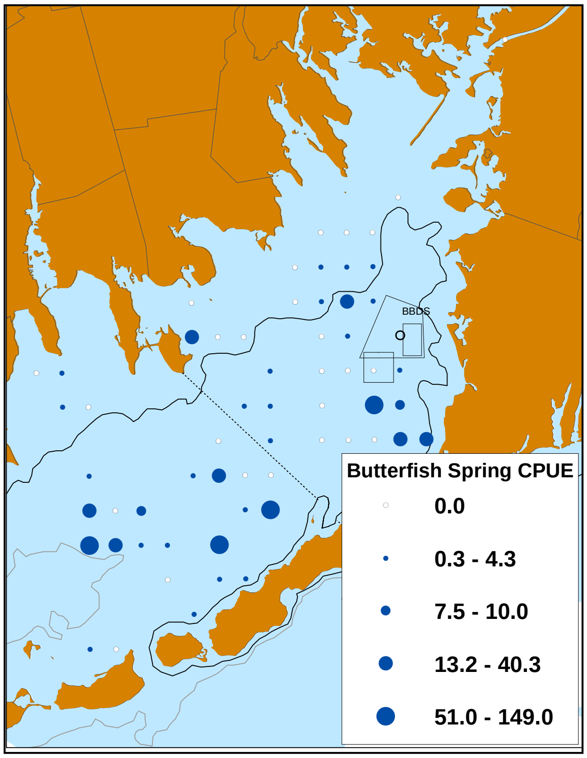


a. Average Spring CPUE of Bluefish by sub region

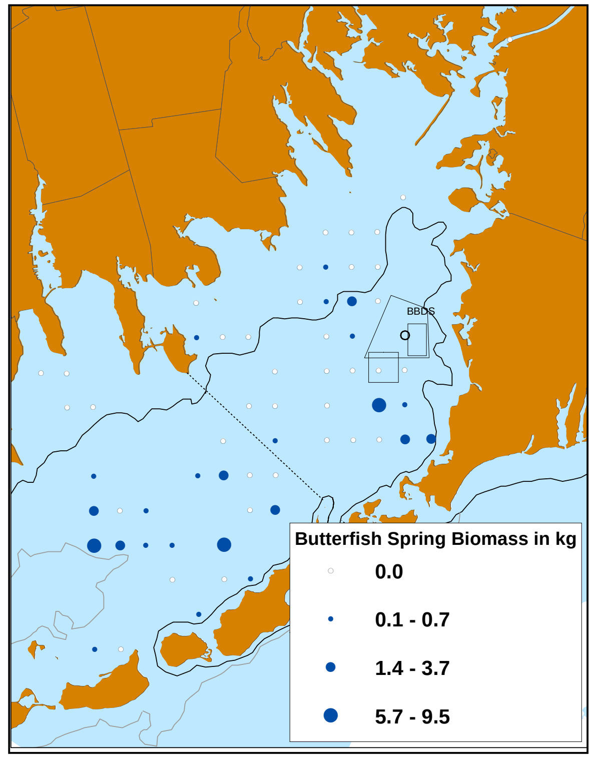


b. Average Fall CPUE of Bluefish by sub region

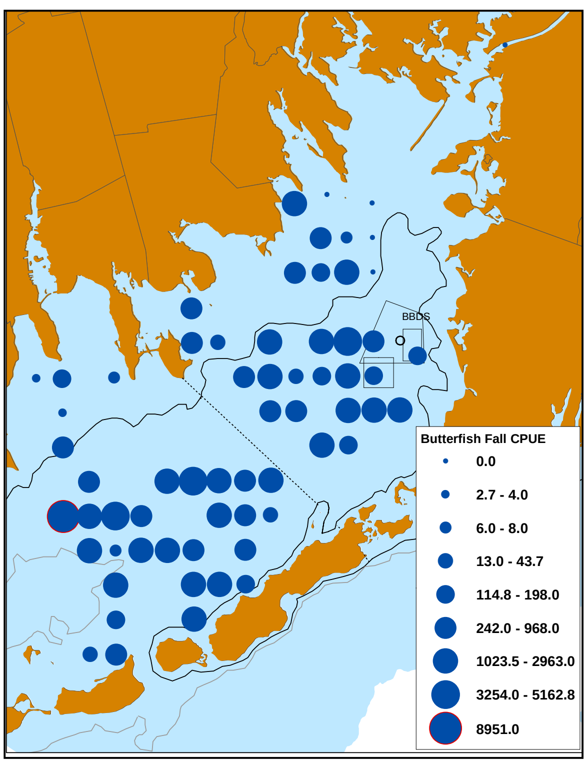
Figure 3-23



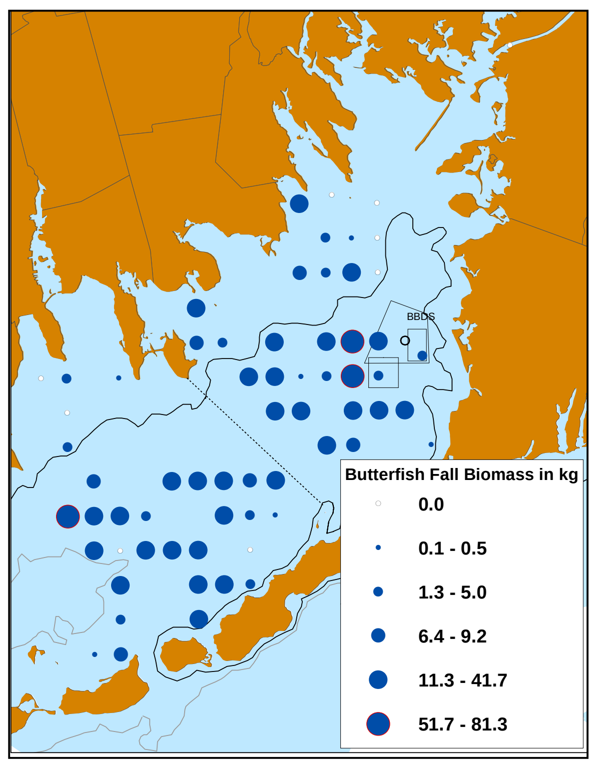
a. Average Spring CPUE of Butterfish



b. Average Spring Biomass of Butterfish

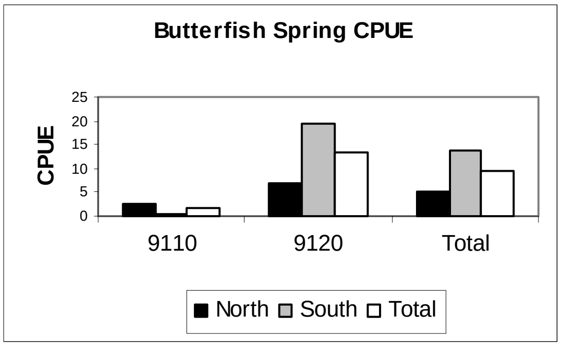


c. Average Fall CPUE of Butterfish

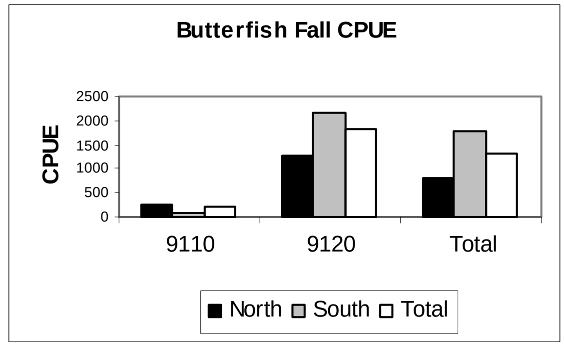


d. Average Fall Biomass of Butterfish

Figure 3-24

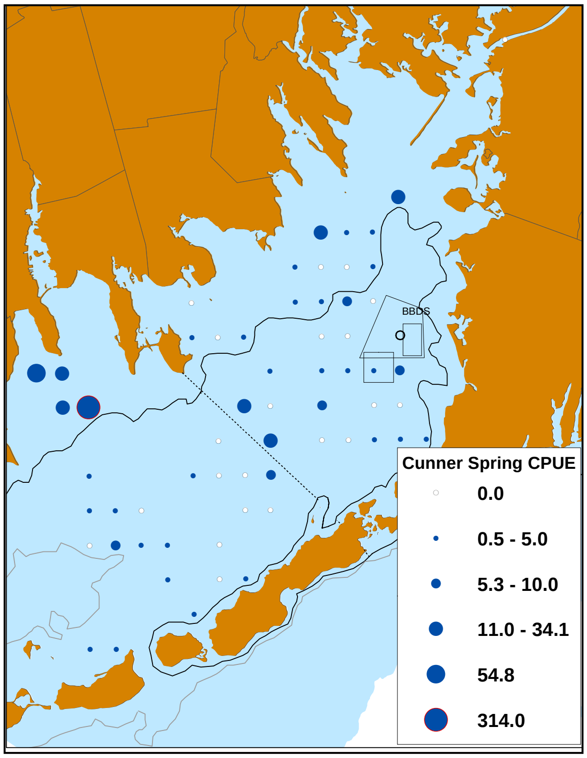


a. Average Spring CPUE of Butterfish by sub region

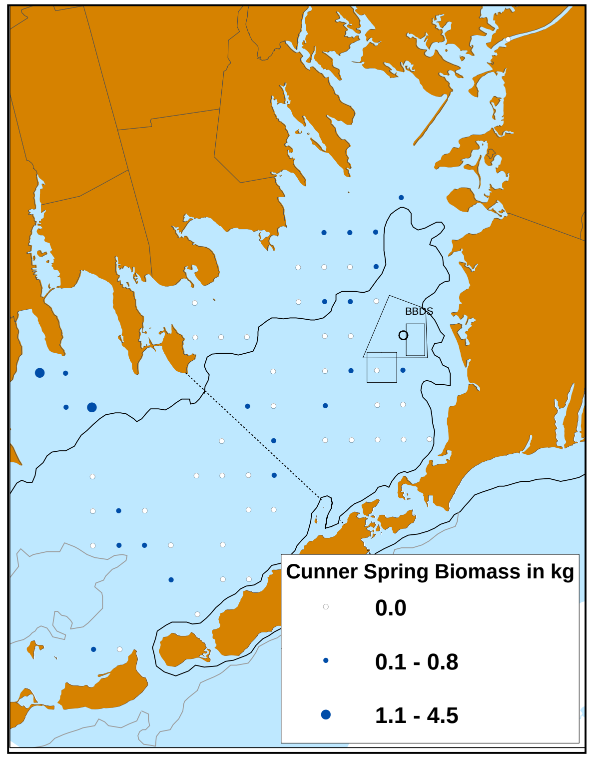


b. Average Fall CPUE of Butterfish by sub region

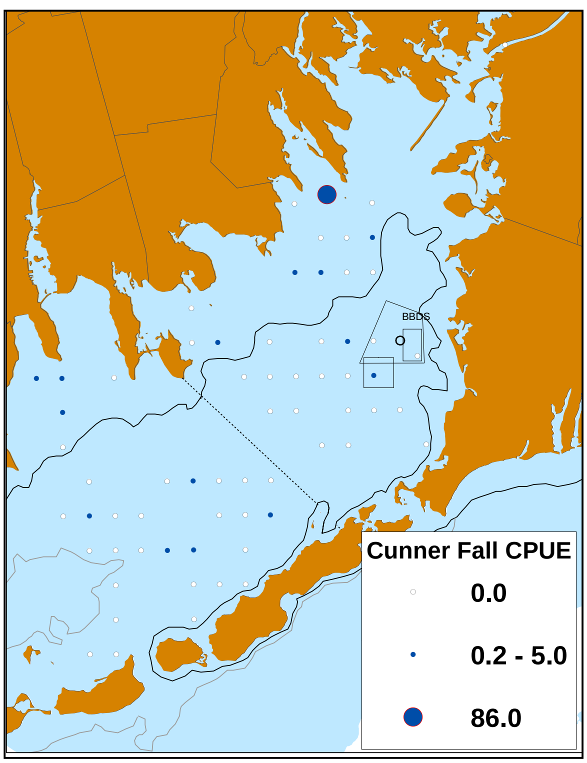
Figure 3-25



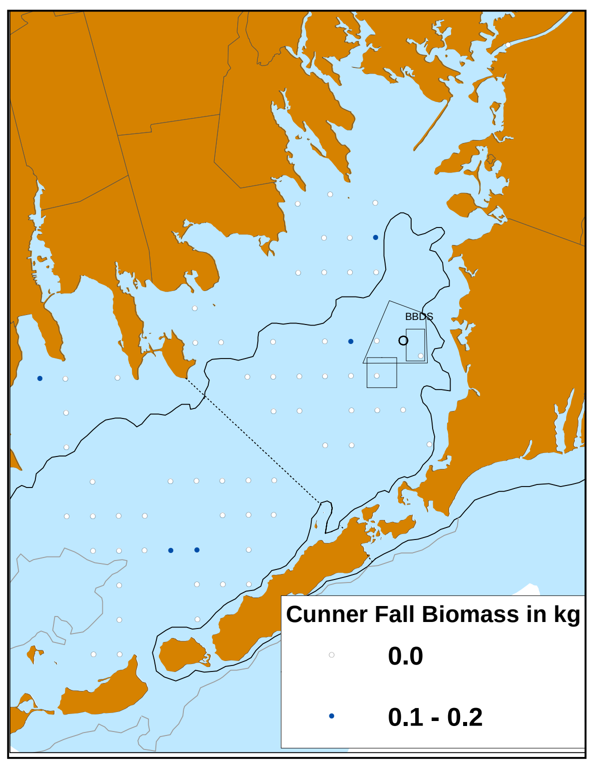
a. Average Spring CPUE of Cunner



b. Average Spring Biomass of Cunner

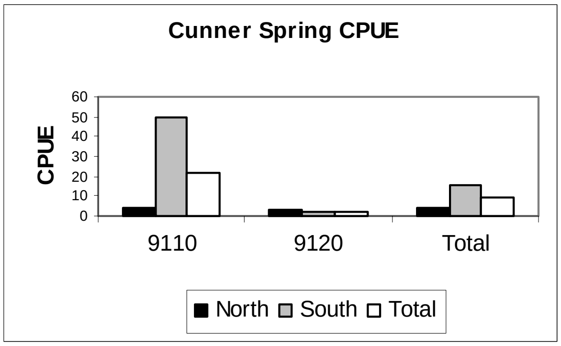


c. Average Fall CPUE of Cunner

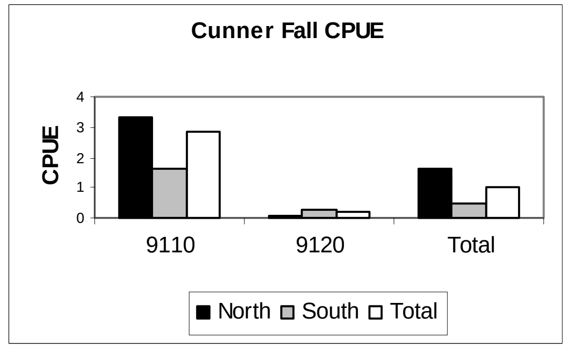


d. Average Fall Biomass of Cunner

Figure 3-26

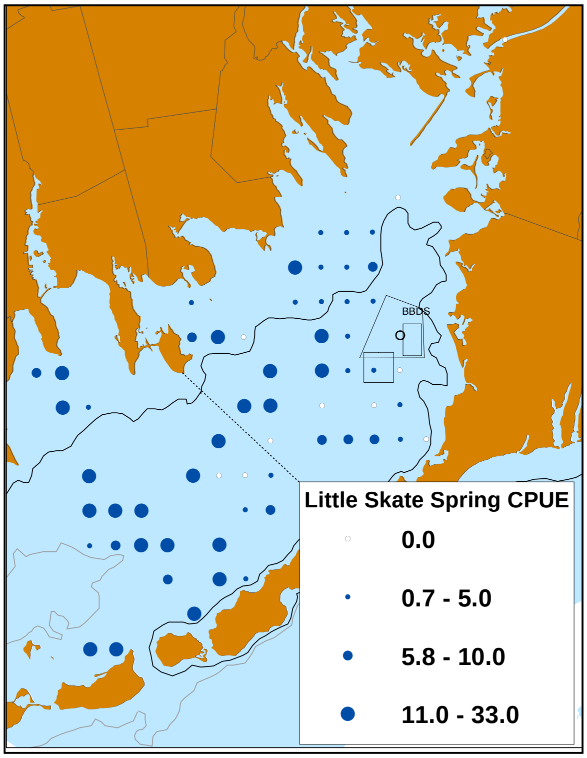


a. Average Spring CPUE of Cunner by sub region

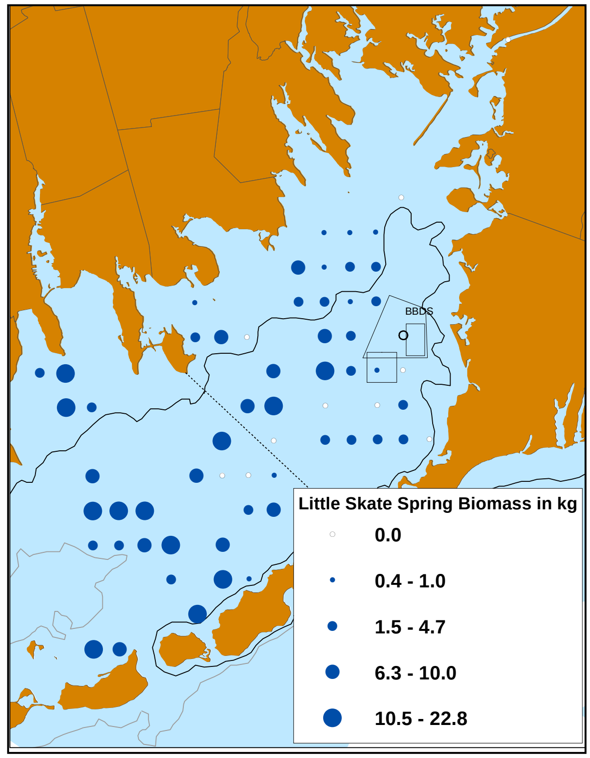


b. Average Fall CPUE of Cunner by sub region

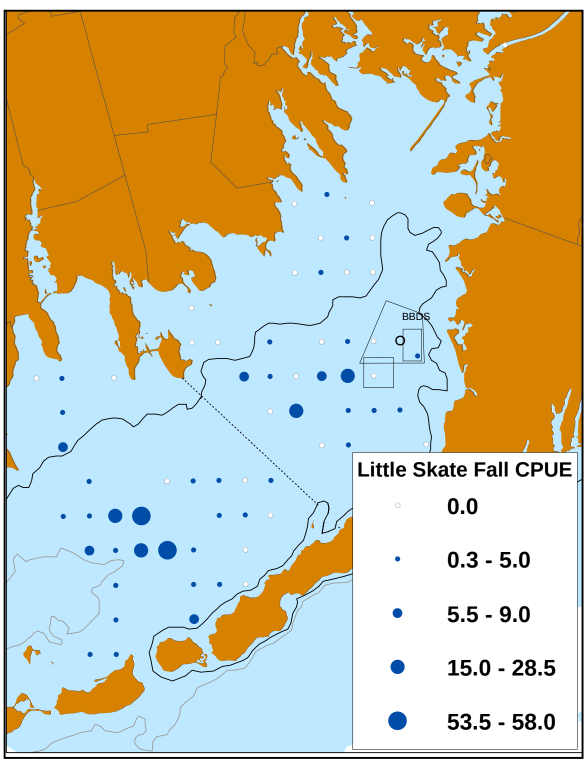
Figure 3-27



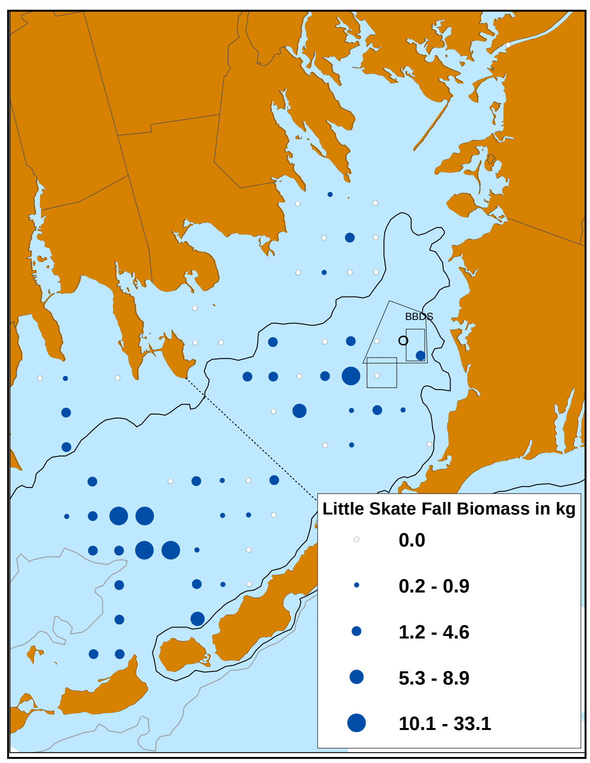
a. Average Spring CPUE of Little Skate



b. Average Spring Biomass of Little Skate

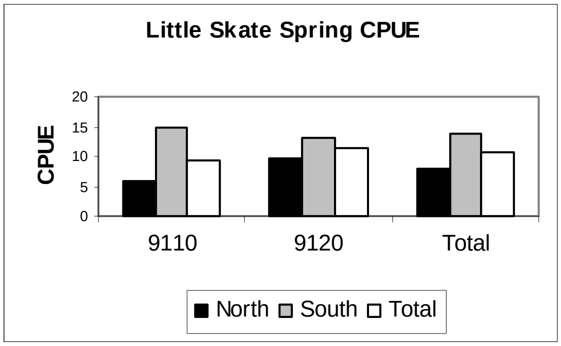


c. Average Fall CPUE of Little Skate

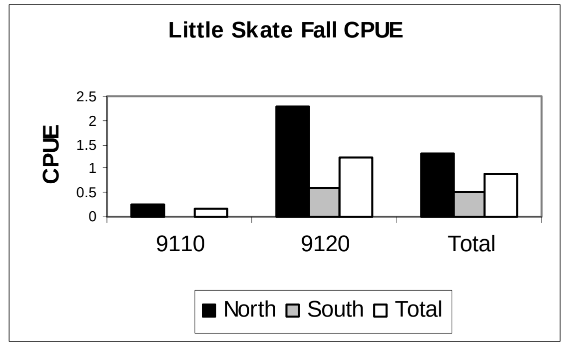


d. Average Fall Biomass of Little Skate

Figure 3-28

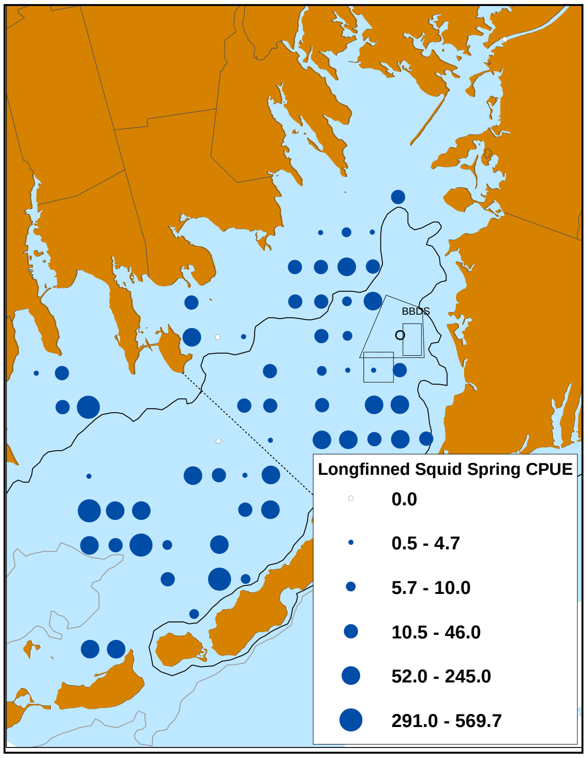


a. Average Spring CPUE of Little Skate by sub region

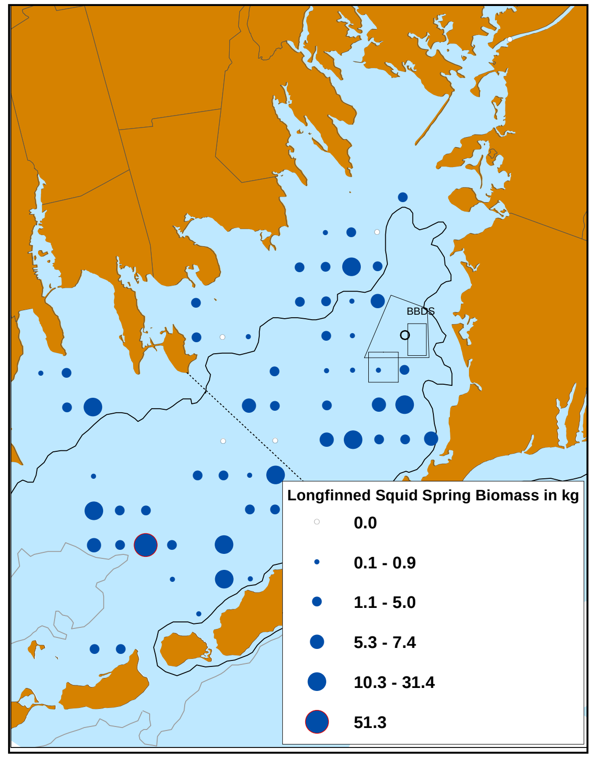


b. Average Fall CPUE of Little Skate by sub region

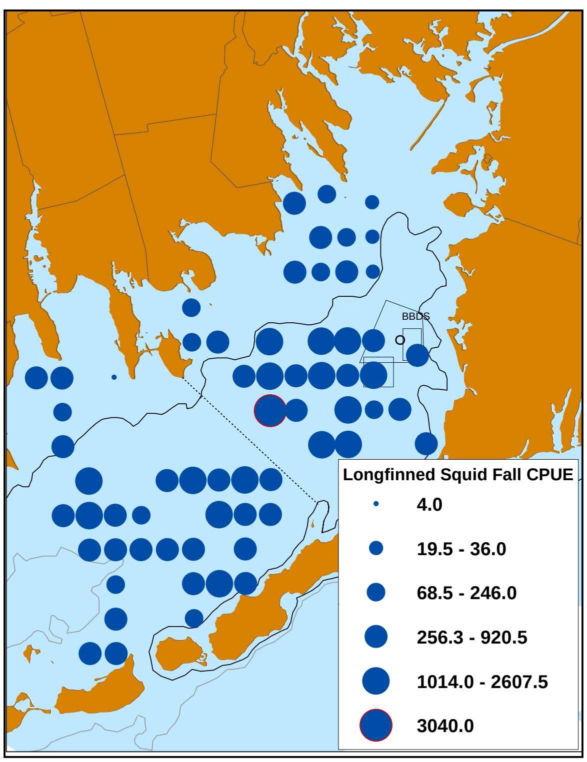
Figure 3-29



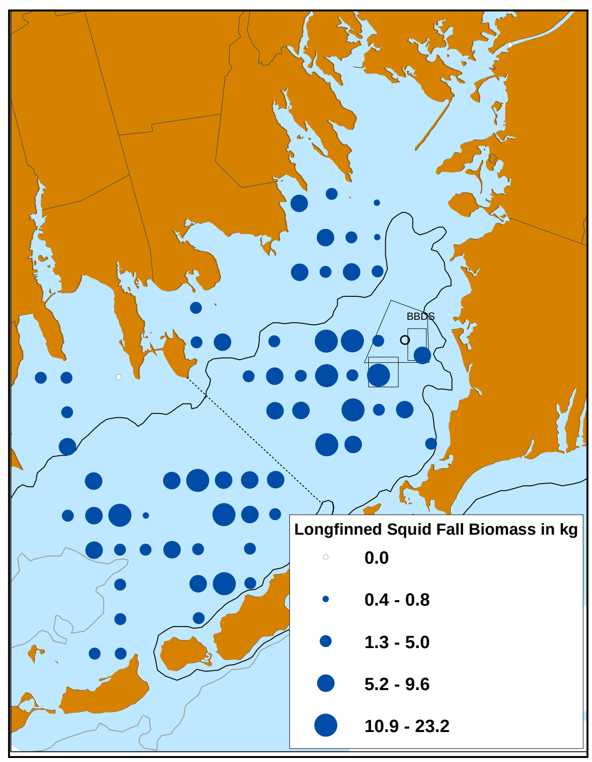
a. Average Spring CPUE of Long-finned Squid



b. Average Spring Biomass of Long-finned Squid

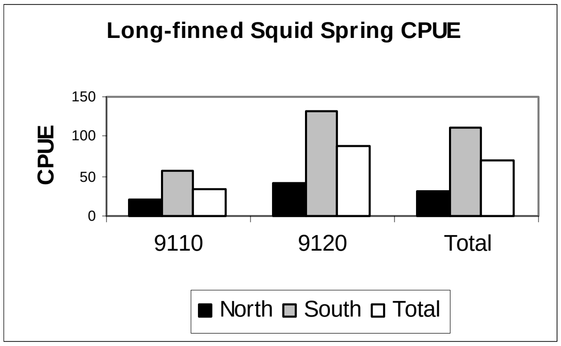


c. Average Fall CPUE of Long-finned Squid

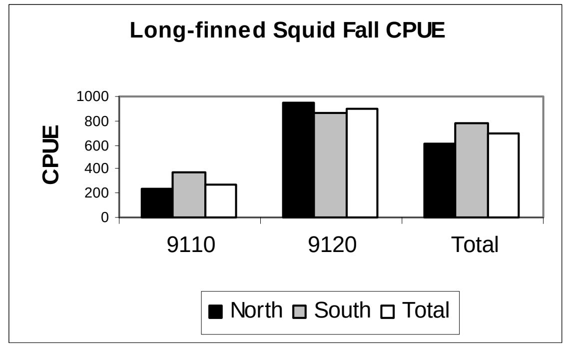


d. Average Fall Biomass of Long-finned Squid

Figure 3-30

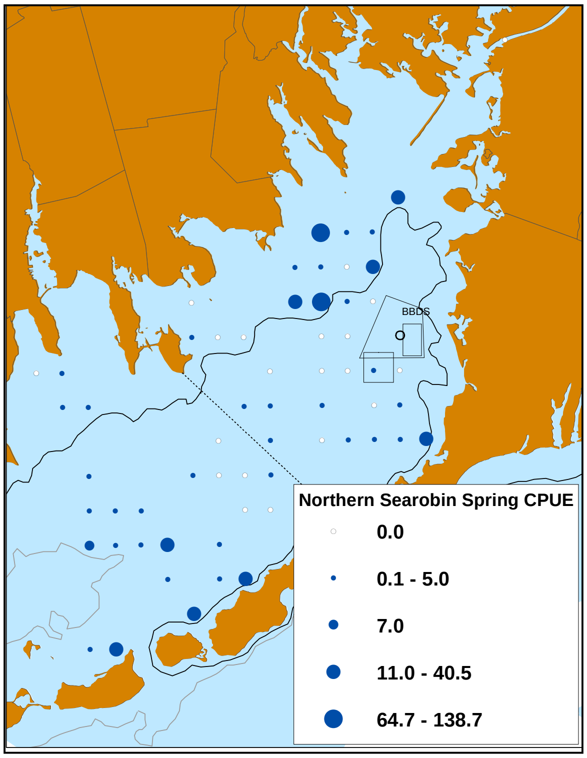


a. Average Spring CPUE of Long-finned Squid by sub region

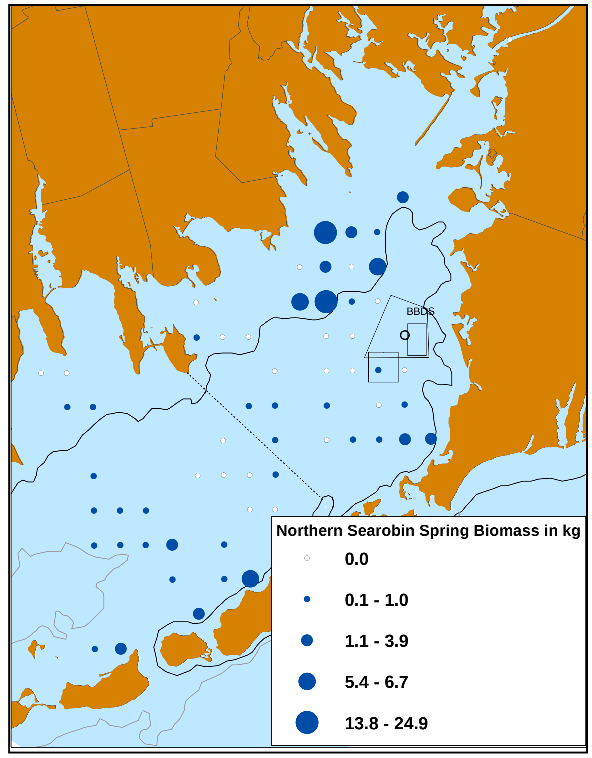


b. Average Fall CPUE of Long-finned Squid by sub region

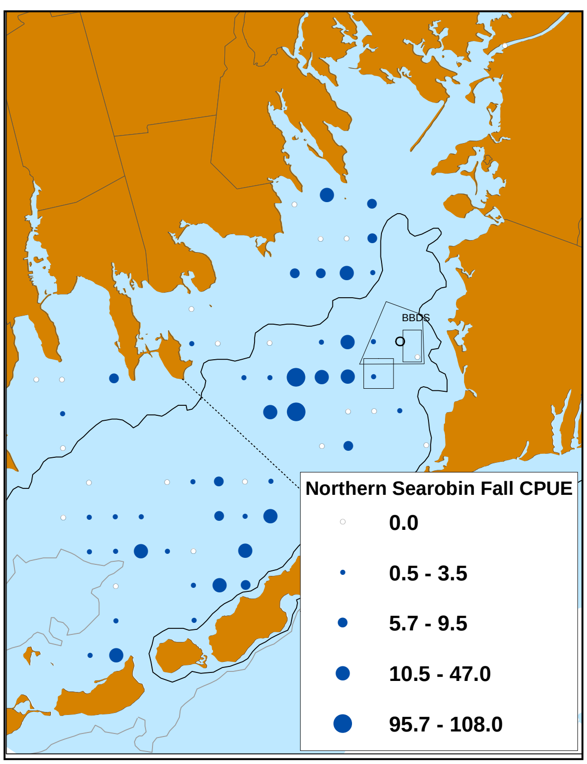
Figure 3-31



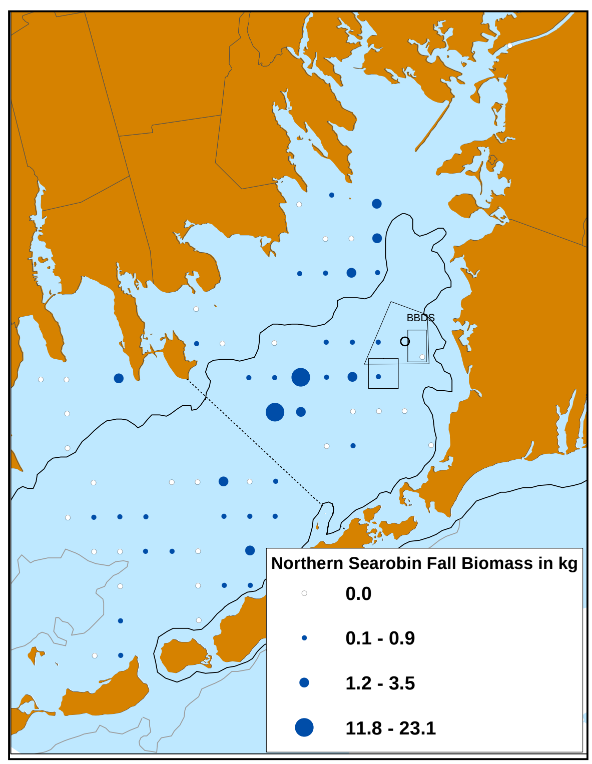
a. Average Spring CPUE of Northern Searobin



b. Average Spring Biomass of Northern Searobin

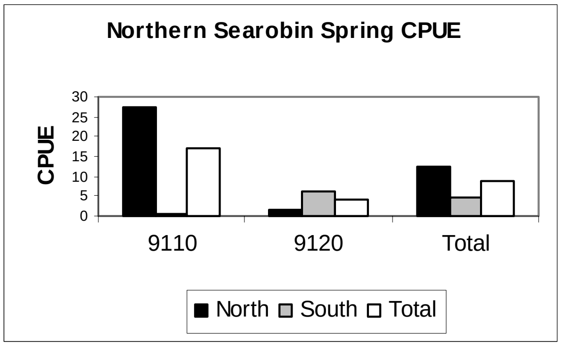


c. Average Fall CPUE of Northern Searobin

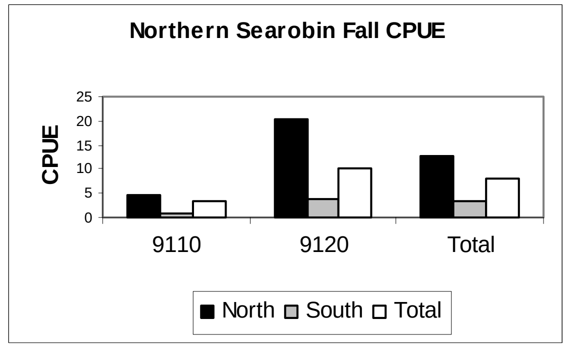


d. Average Fall Biomass of Northern Searobin

Figure 3-32

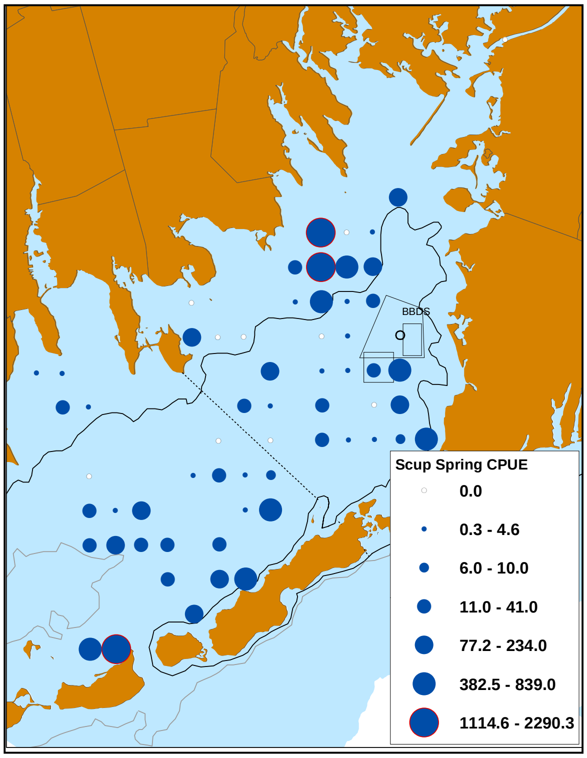


a. Average Spring CPUE of Northern Searobin by sub region

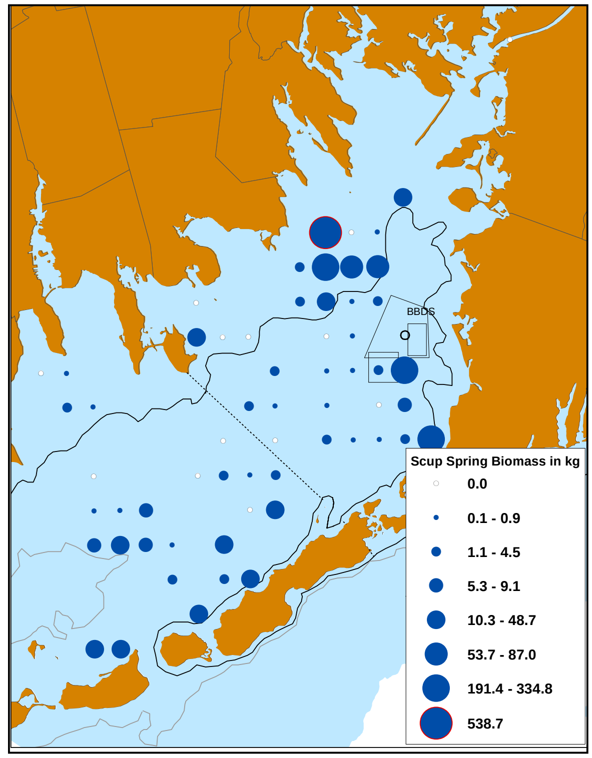


b. Average Fall CPUE of Northern Searobin by sub region

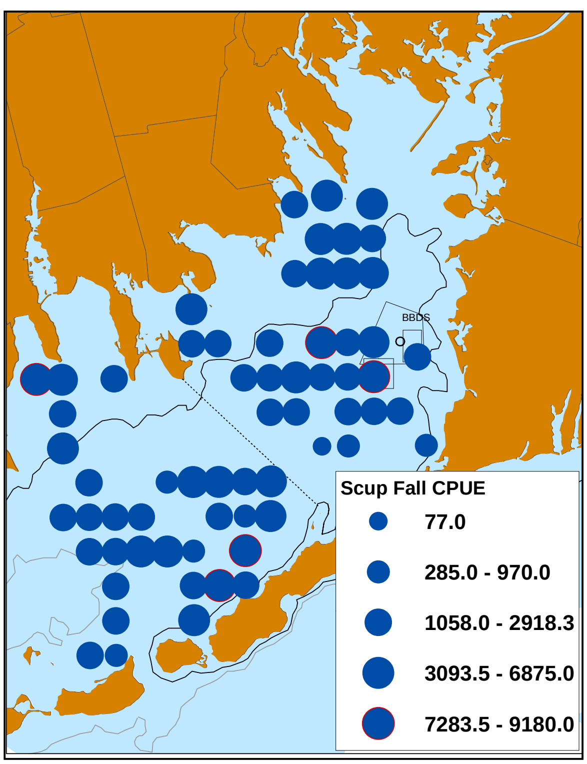
Figure 3-33



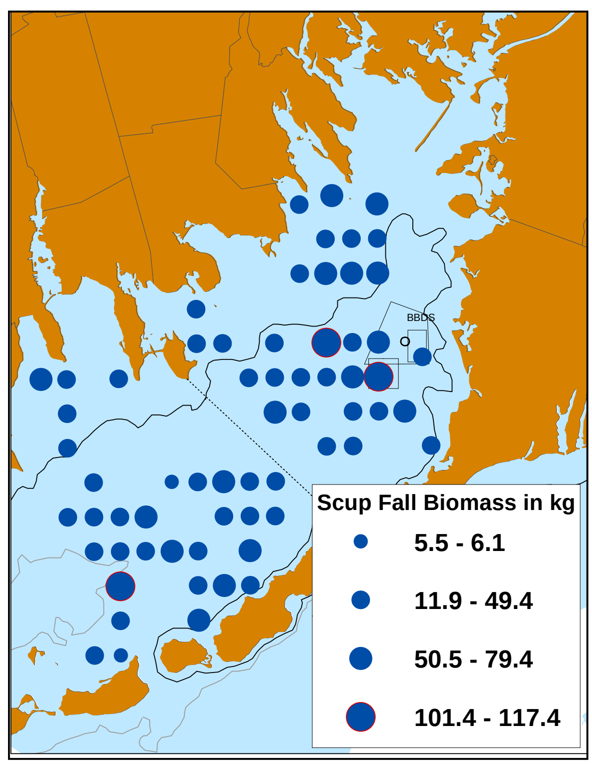
a. Average Spring CPUE of Scup



b. Average Spring Biomass of Scup

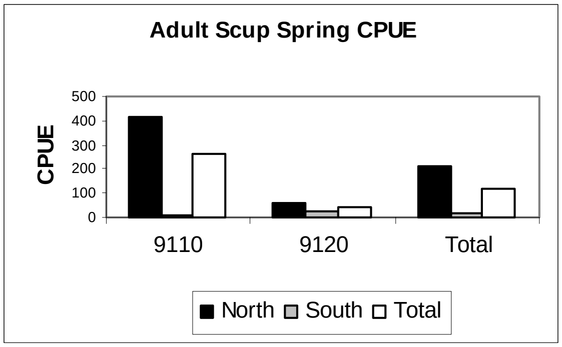


c. Average Fall CPUE of Scup

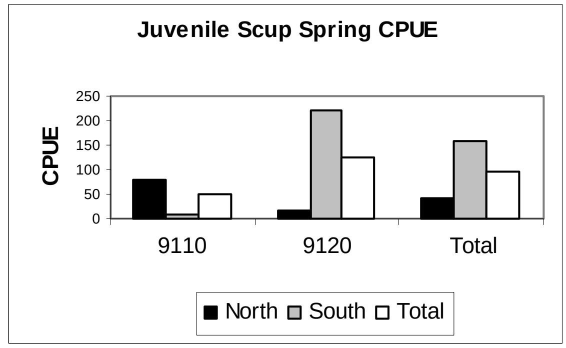


d. Average Fall Biomass of Scup

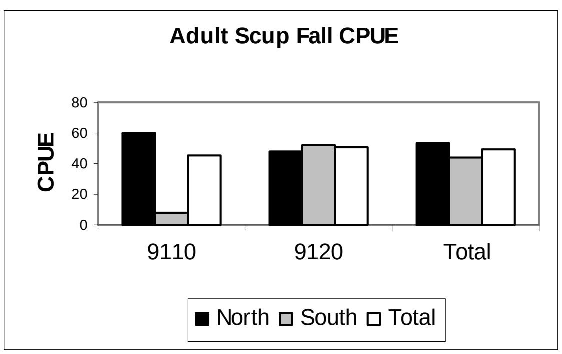
Figure 3-34



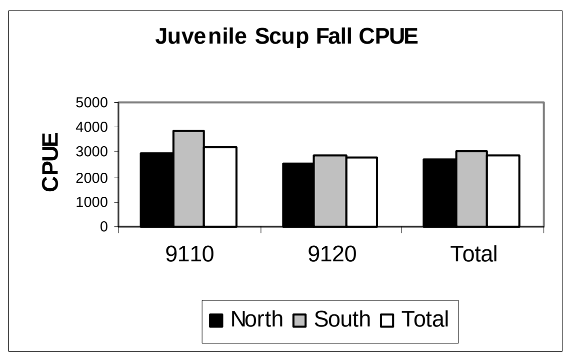
a. Average Spring CPUE of Adult Scup by sub region



b. Average Spring CPUE of Juvenile Scup by sub region

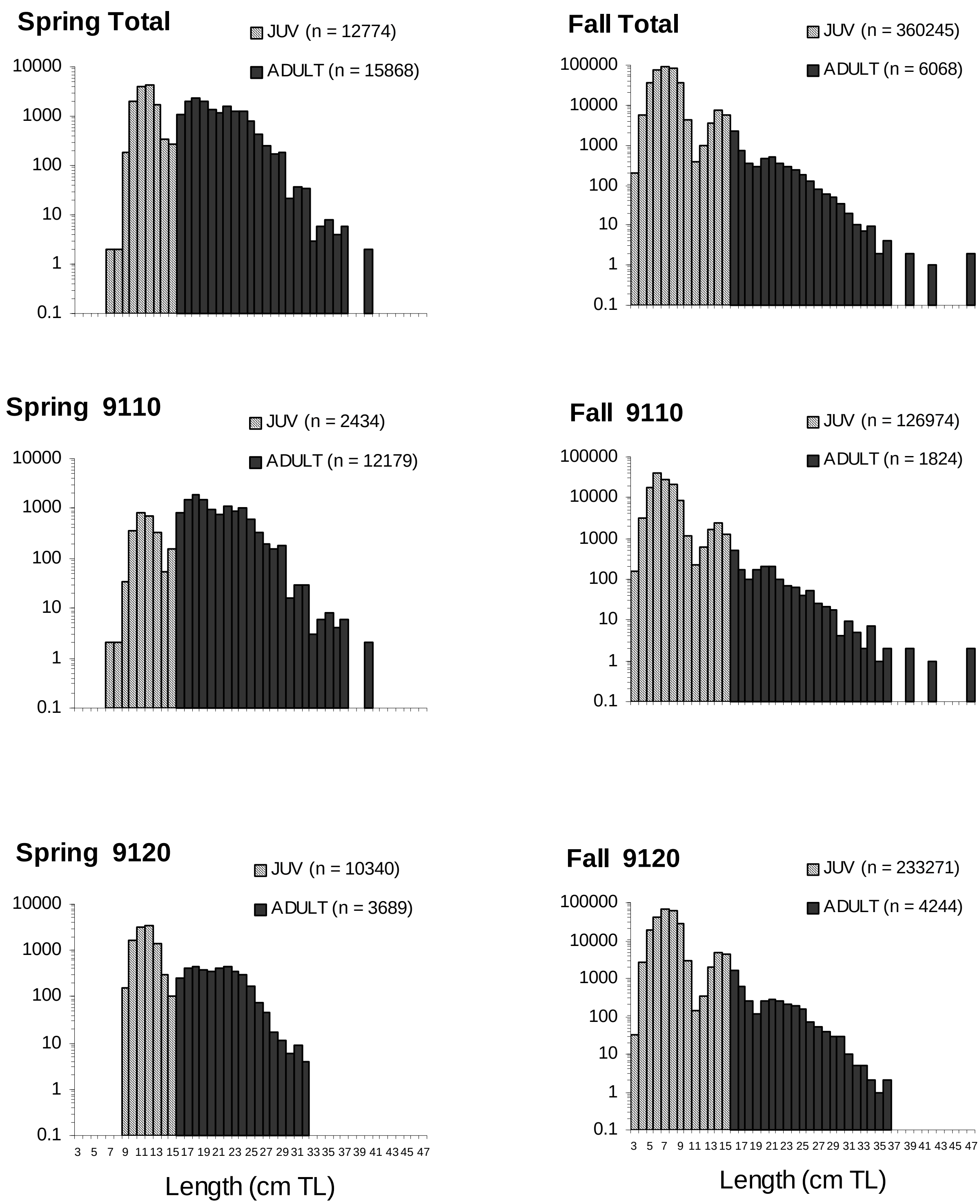


c. Average Fall CPUE of Adult Scup by sub region



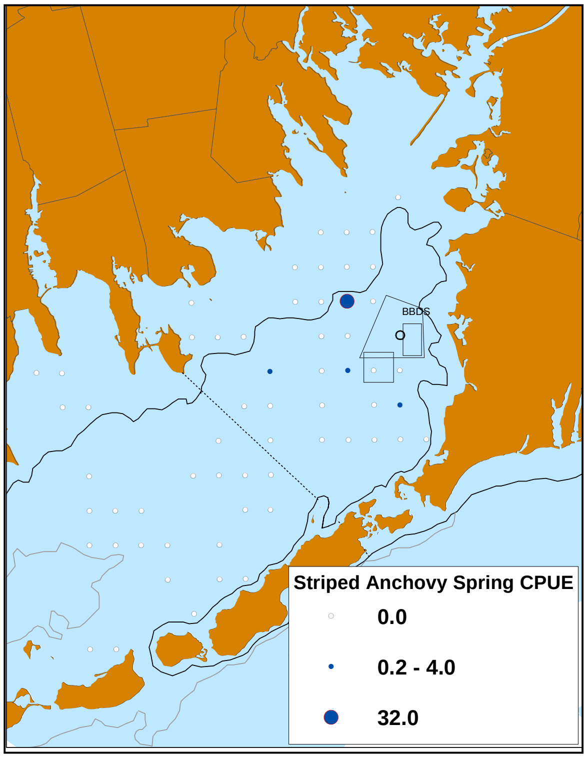
d. Average Fall CPUE of Juvenile Scup by sub region

Figure 3-35

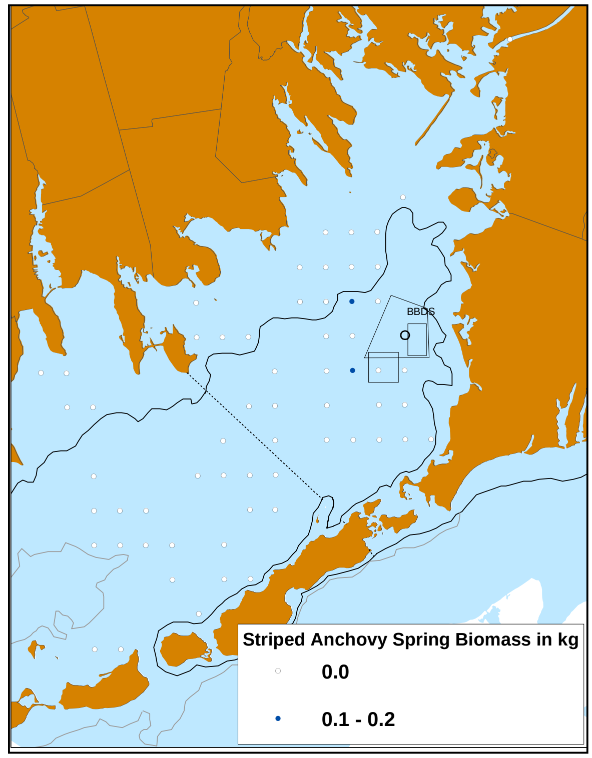


Seasonal Scup (*Stenotomus chrysops*) log10 length frequencies (cm TL) by strata based on 394.955 captured between 1978 and 2000.

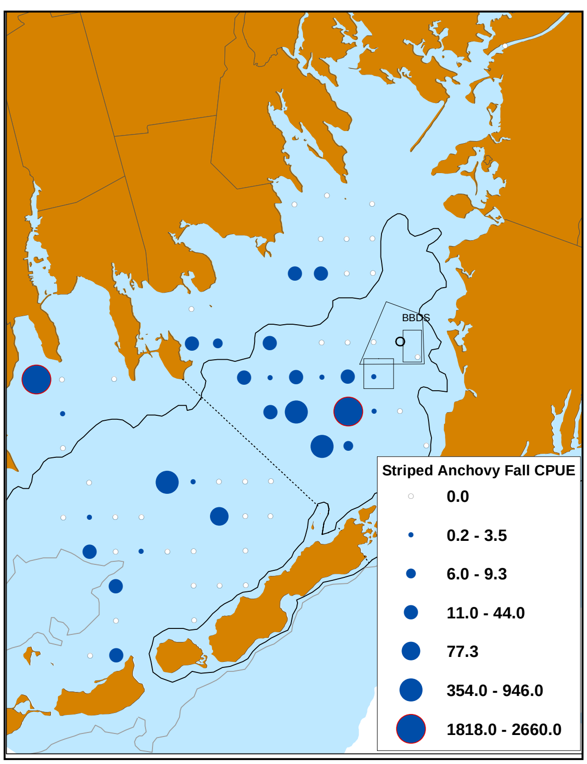
Figure 3-36



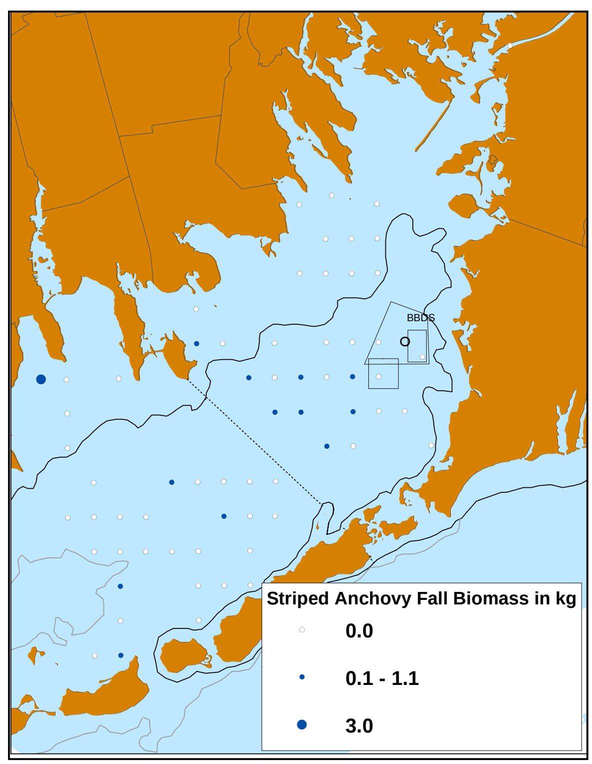
a. Average Spring CPUE of Striped Anchovy



b. Average Spring Biomass of Striped Anchovy

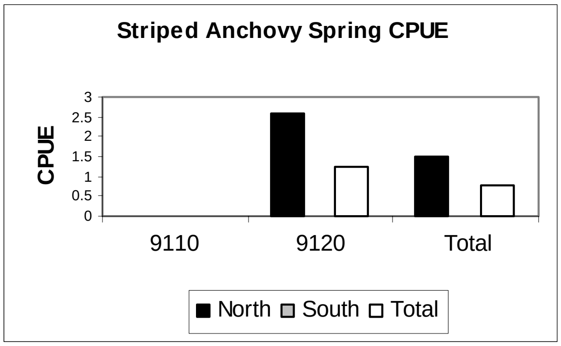


c. Average Fall CPUE of Striped Anchovy

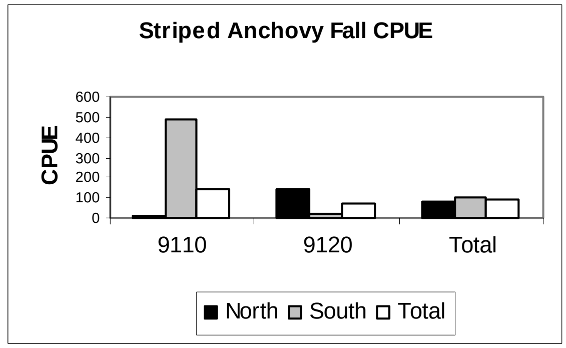


d. Average Fall Biomass of Striped Anchovy

Figure 3-37

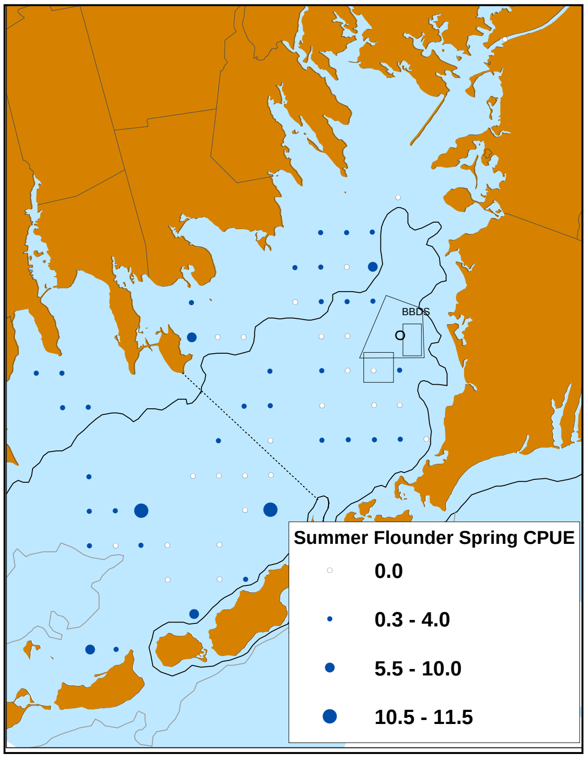


a. Average Spring CPUE of Striped Anchovy by sub region

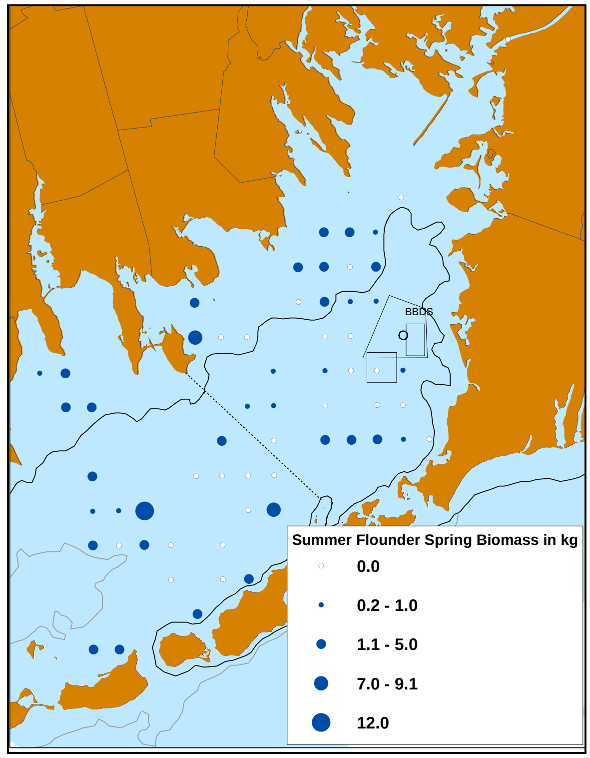


b. Average Fall CPUE of Striped Anchovy by sub region

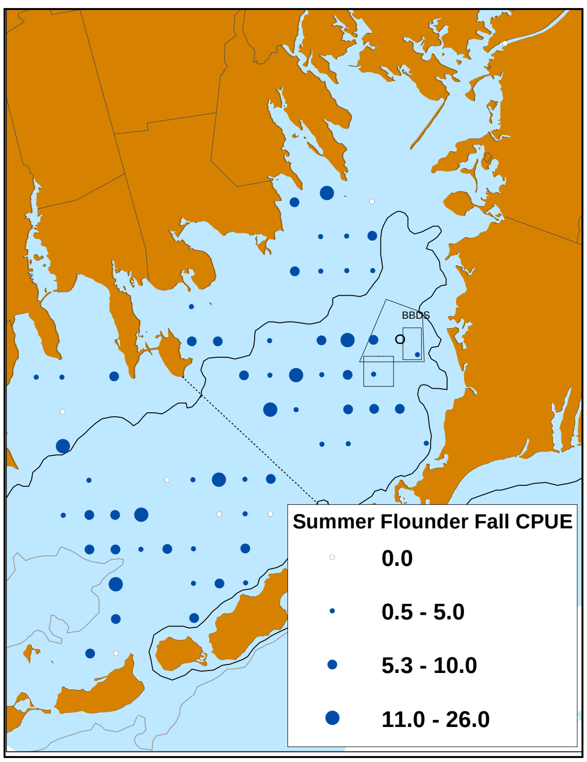
Figure 3-38



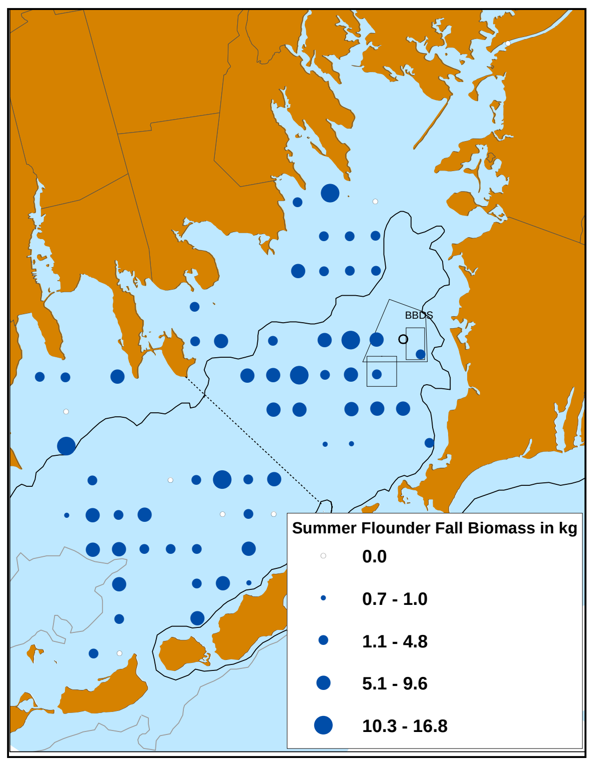
a. Average Spring CPUE of Summer Flounder



b. Average Spring Biomass of Summer Flounder

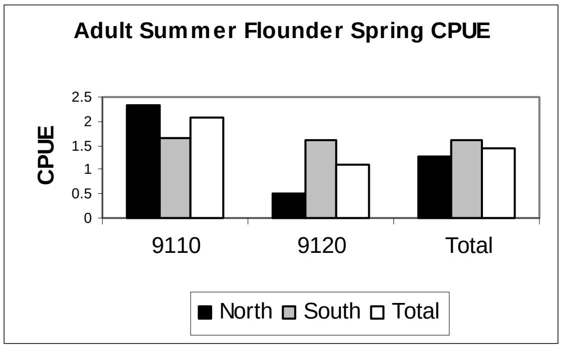


c. Average Fall CPUE of Summer Flounder

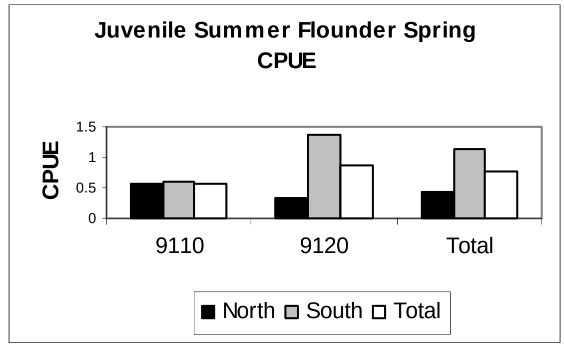


d. Average Fall Biomass of Summer Flounder

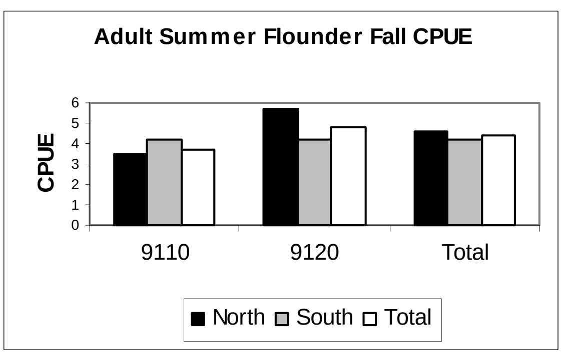
Figure 3-39



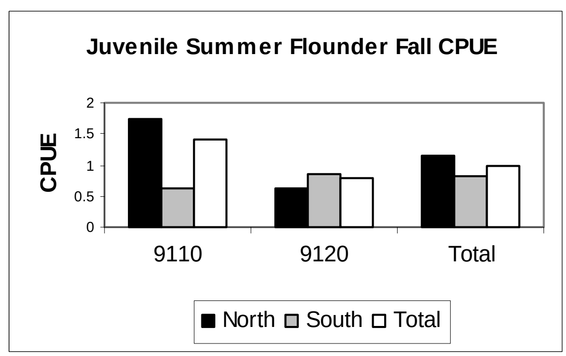
a. Average Spring CPUE of Adult Summer Flounder by sub region



b. Average Spring CPUE of Juvenile Summer Flounder by sub region

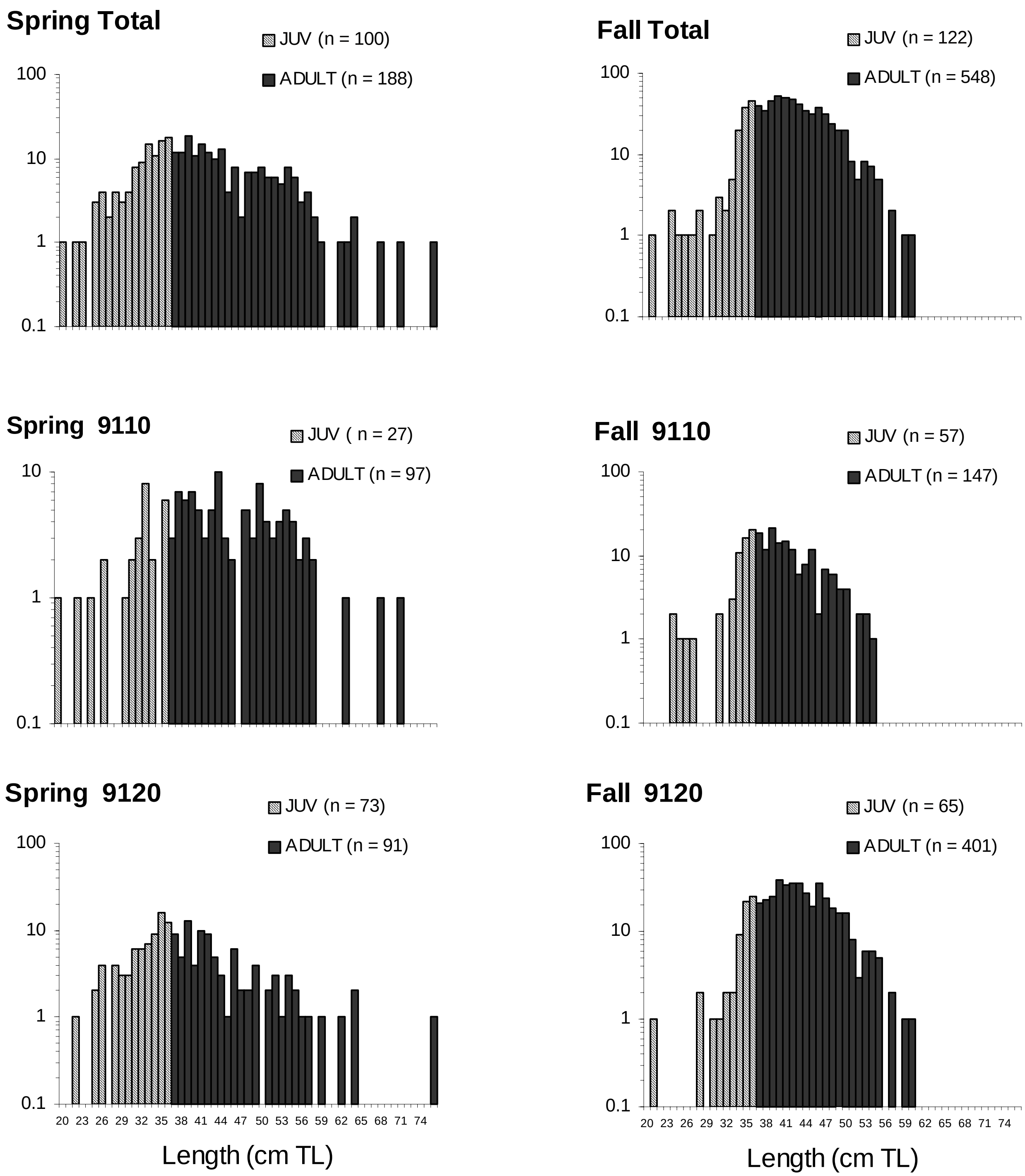


c. Average Fall CPUE of Adult Summer Flounder by sub region



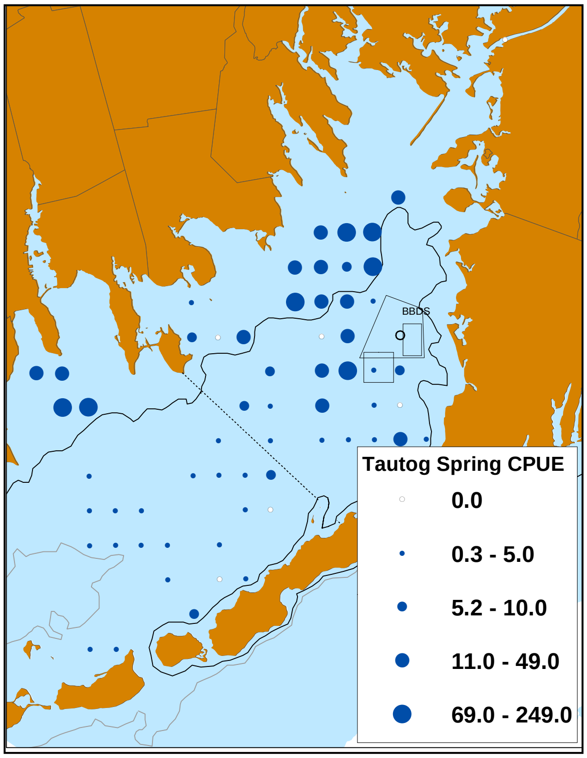
d. Average Fall CPUE of Juvenile Summer Flounder by sub region

Figure 3-40

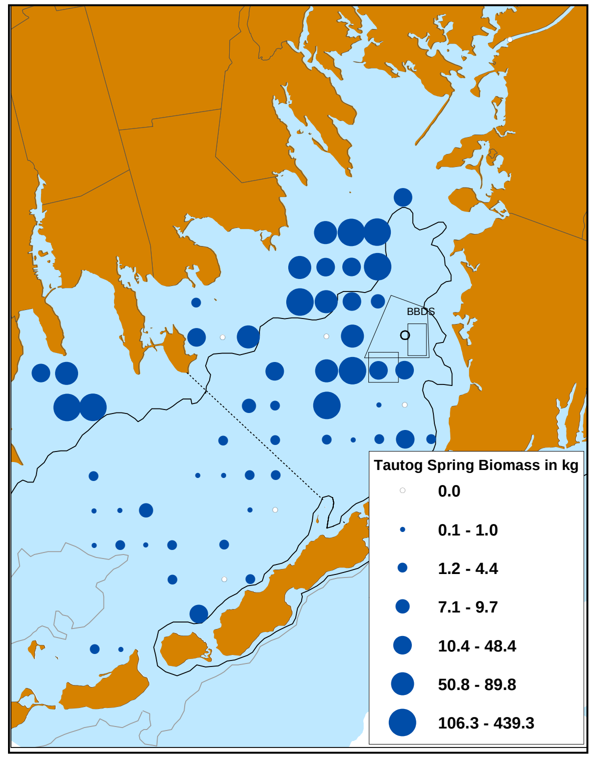


Seasonal Summer Flounder (*Paralichthys dentatus*) log10 Length Frequencies (cm TL) by strata based on 958 fish captured between 1978 and 2000.

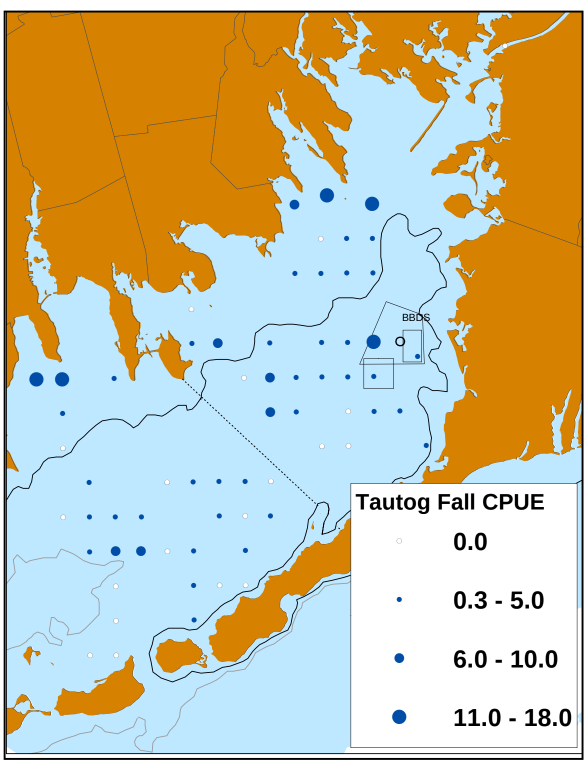
Figure 3-41



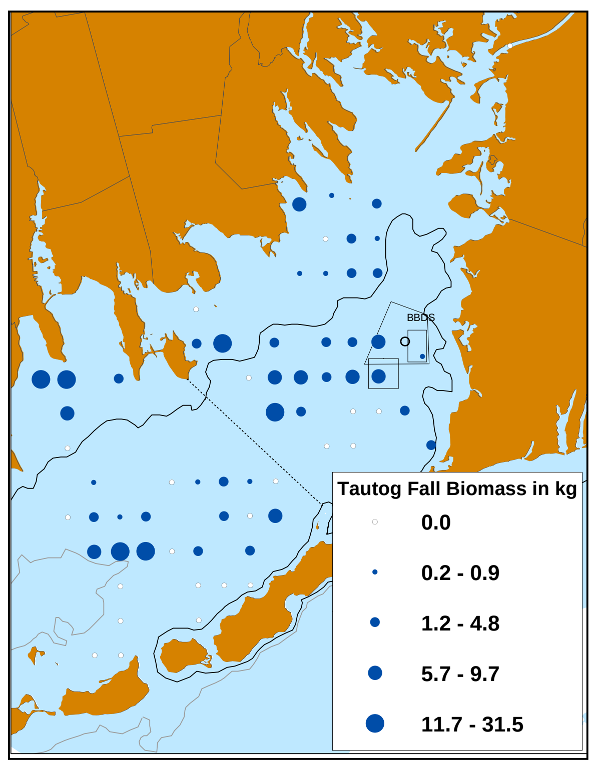
a. Average Spring CPUE of Tautog



b. Average Spring Biomass of Tautog

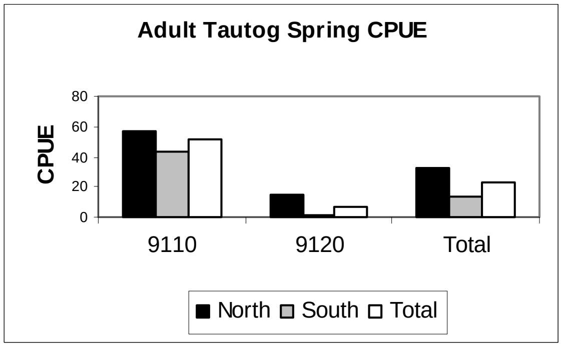


c. Average Fall CPUE of Tautog

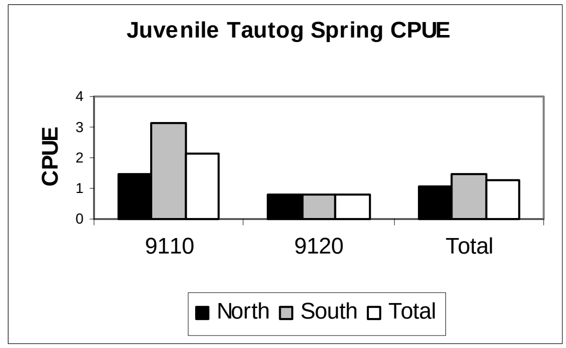


d. Average Fall Biomass of Tautog

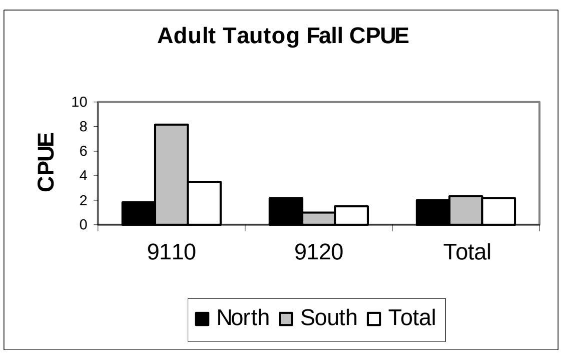
Figure 3-42



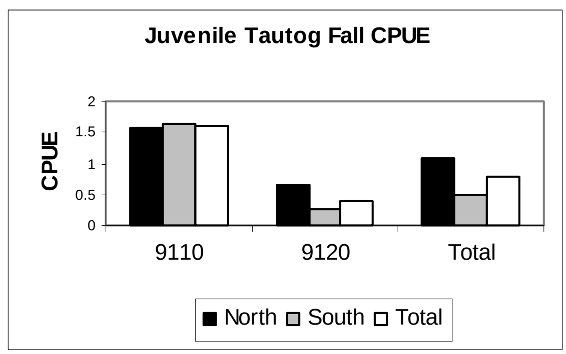
a. Average Spring CPUE of Adult Tautog by sub region



b. Average Spring CPUE of Juvenile Tautog by sub region

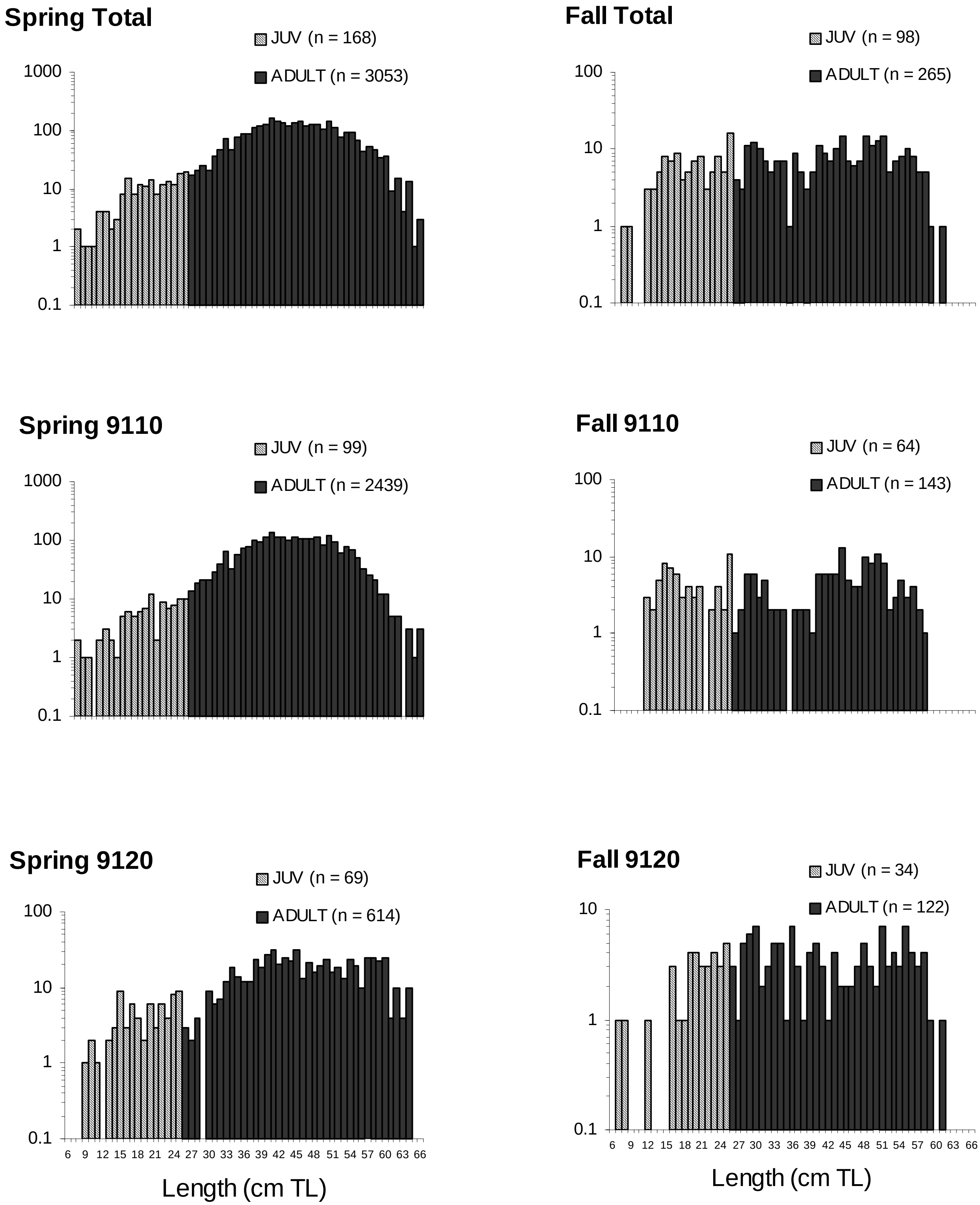


c. Average Fall CPUE of Adult Tautog by sub region



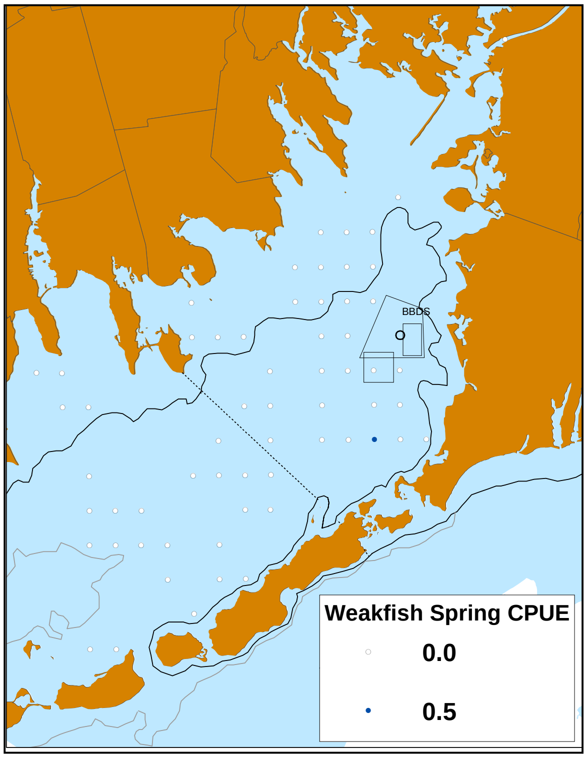
d. Average Fall CPUE of Juvenile Tautog by sub region

Figure 3-43

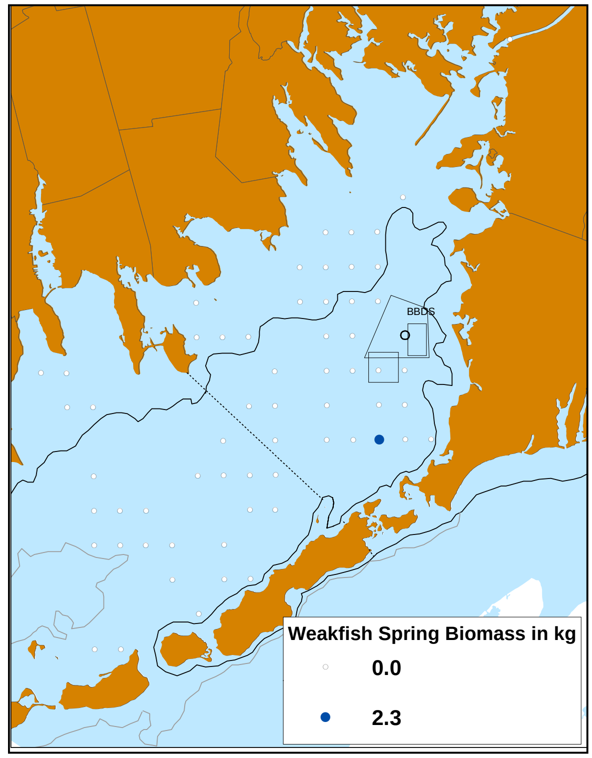


Seasonal Tautog (*Tautoga onitis*) log10 Length Frequencies (cm TL) by strata based on 3,584 fish captured between 1978 and 2000.

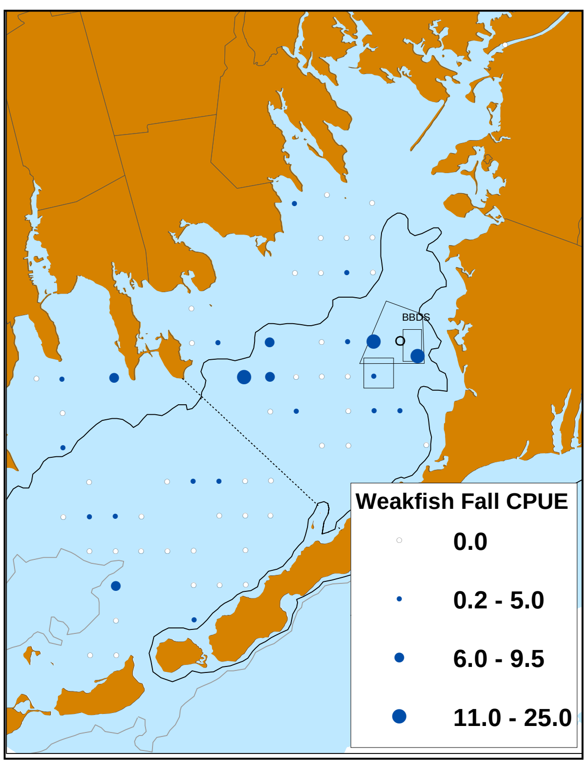
Figure 3-44



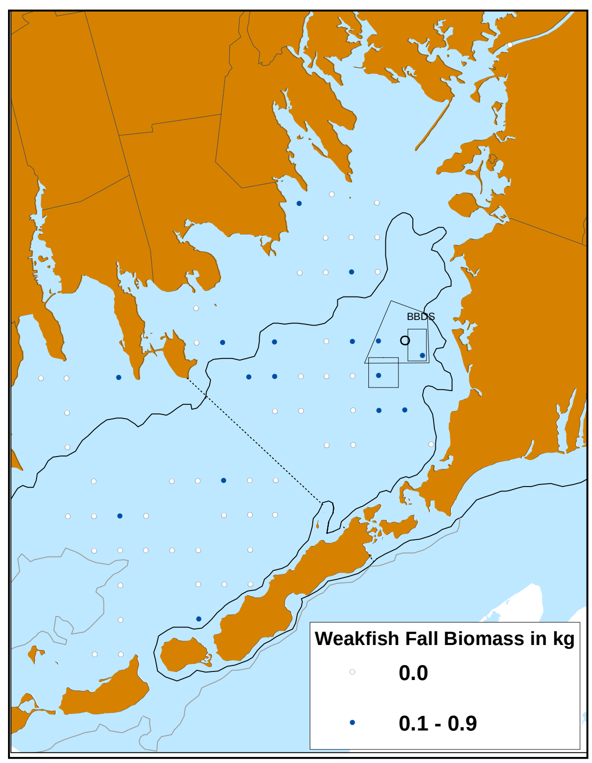
a. Average Spring CPUE of Weakfish



b. Average Spring Biomass of Weakfish

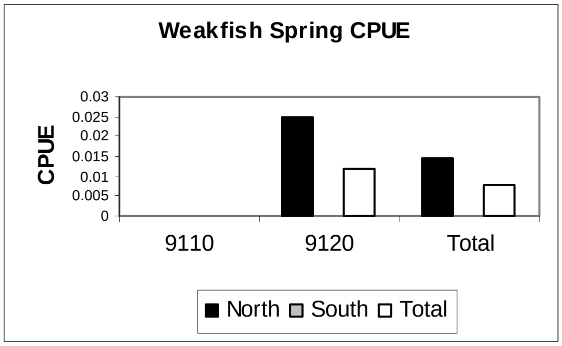


c. Average Fall CPUE of Weakfish

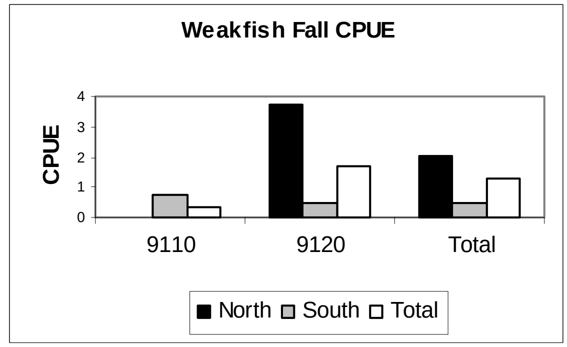


d. Average Fall Biomass of Weakfish

Figure 3-45

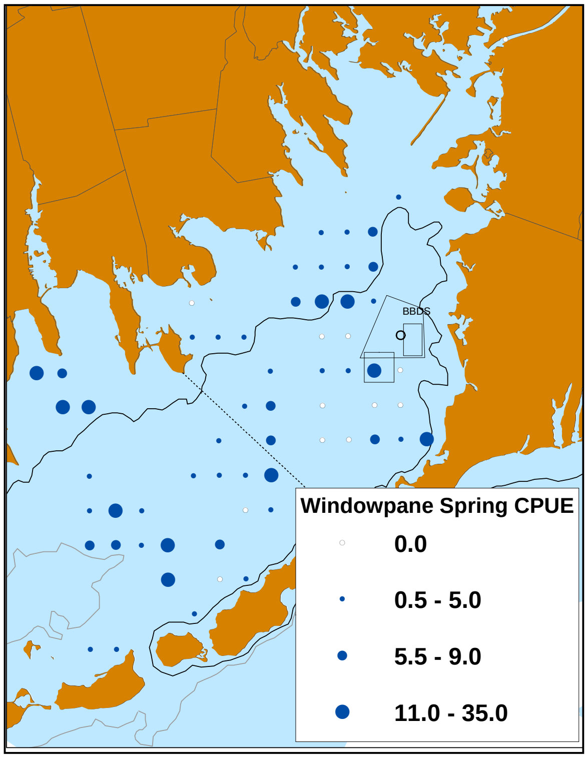


a. Average Spring CPUE of Weakfish sub region

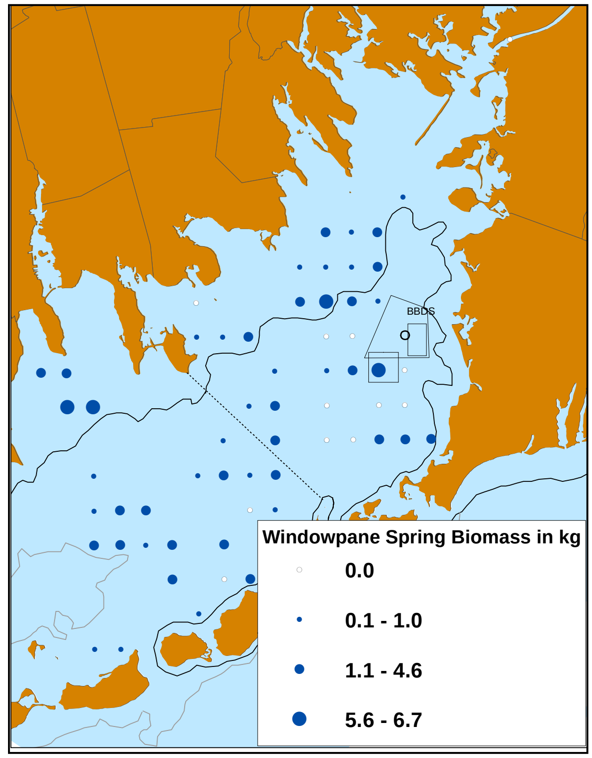


b. Average Fall CPUE of Weakfish by sub region

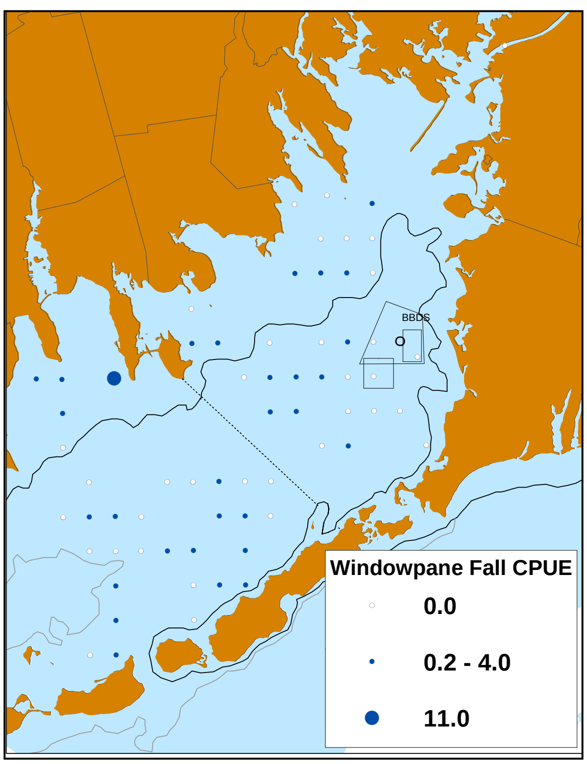
Figure 3-46



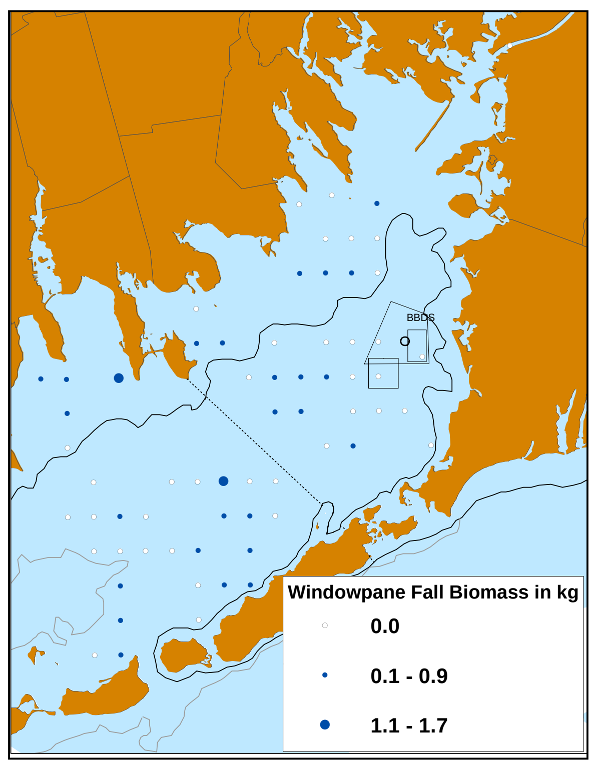
a. Average Spring CPUE of Windowpane



b. Average Spring Biomass of Windowpane

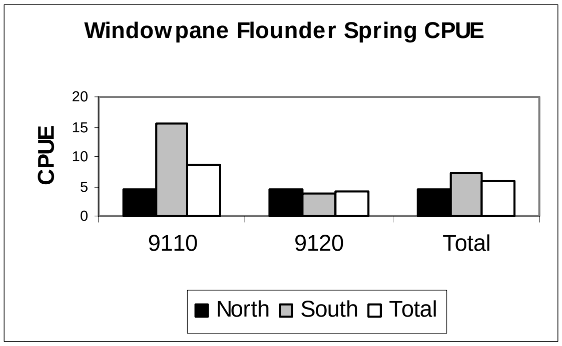


c. Average Fall CPUE of Windowpane

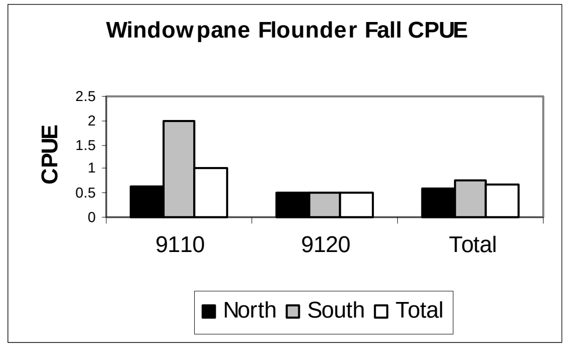


d. Average Fall Biomass of Windowpane

Figure 3-47

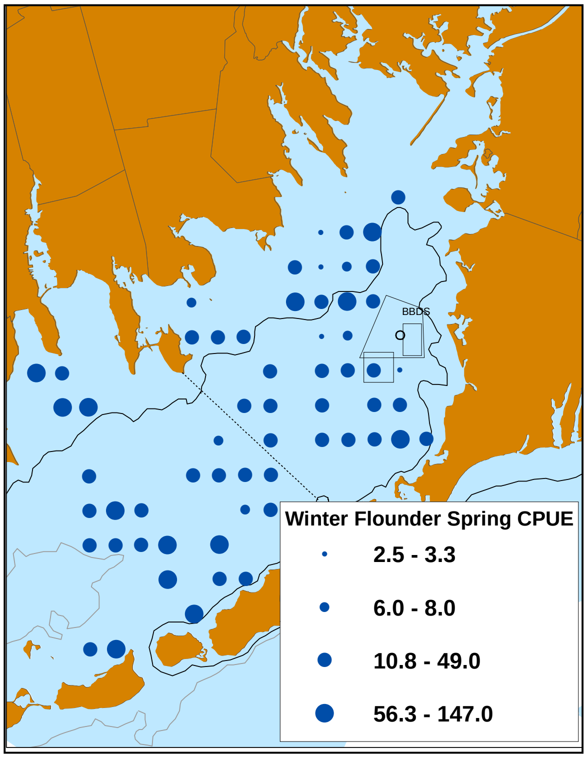


a. Average Spring CPUE of Windowpane by sub region

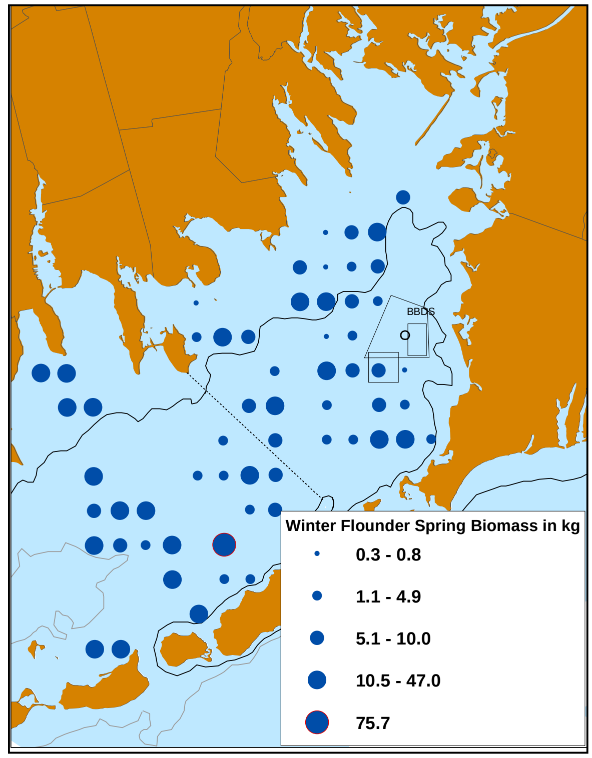


b. Average Fall CPUE of Windowpane by sub region

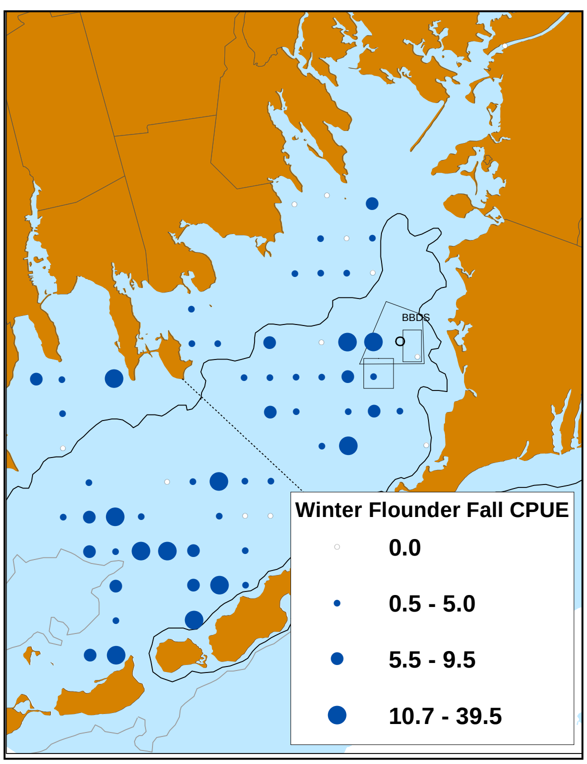
Figure 3-48



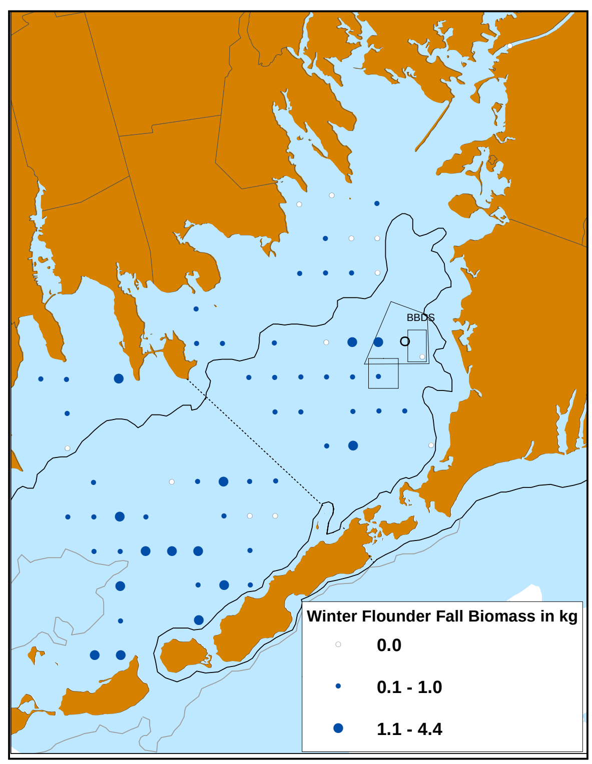
a. Average Spring CPUE of Winter Flounder



b. Average Spring Biomass of Winter Flounder

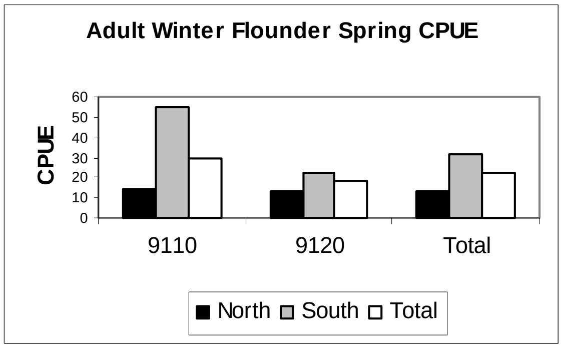


c. Average Fall CPUE of Winter Flounder

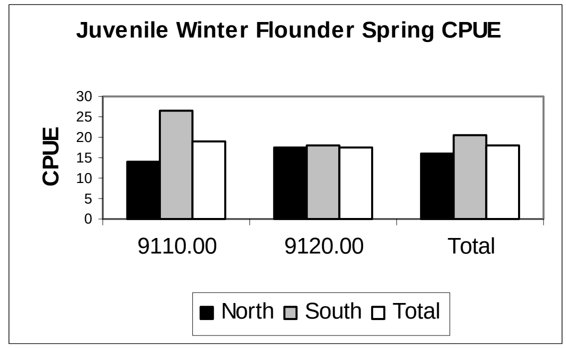


d. Average Fall Biomass of Winter Flounder

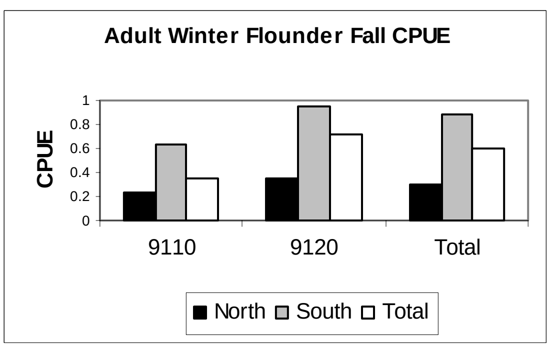
Figure 3-49



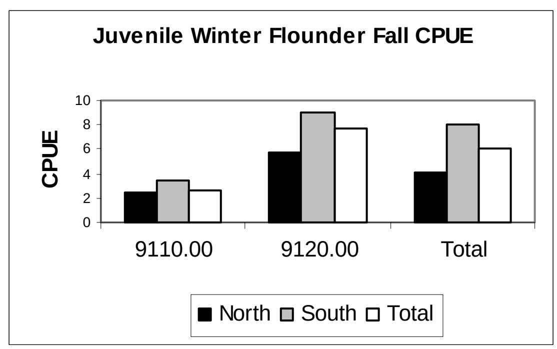
a. Average Spring CPUE of Adult Winter Flounder by sub region



b. Average Spring CPUE of Juvenile Winter Flounder by sub region

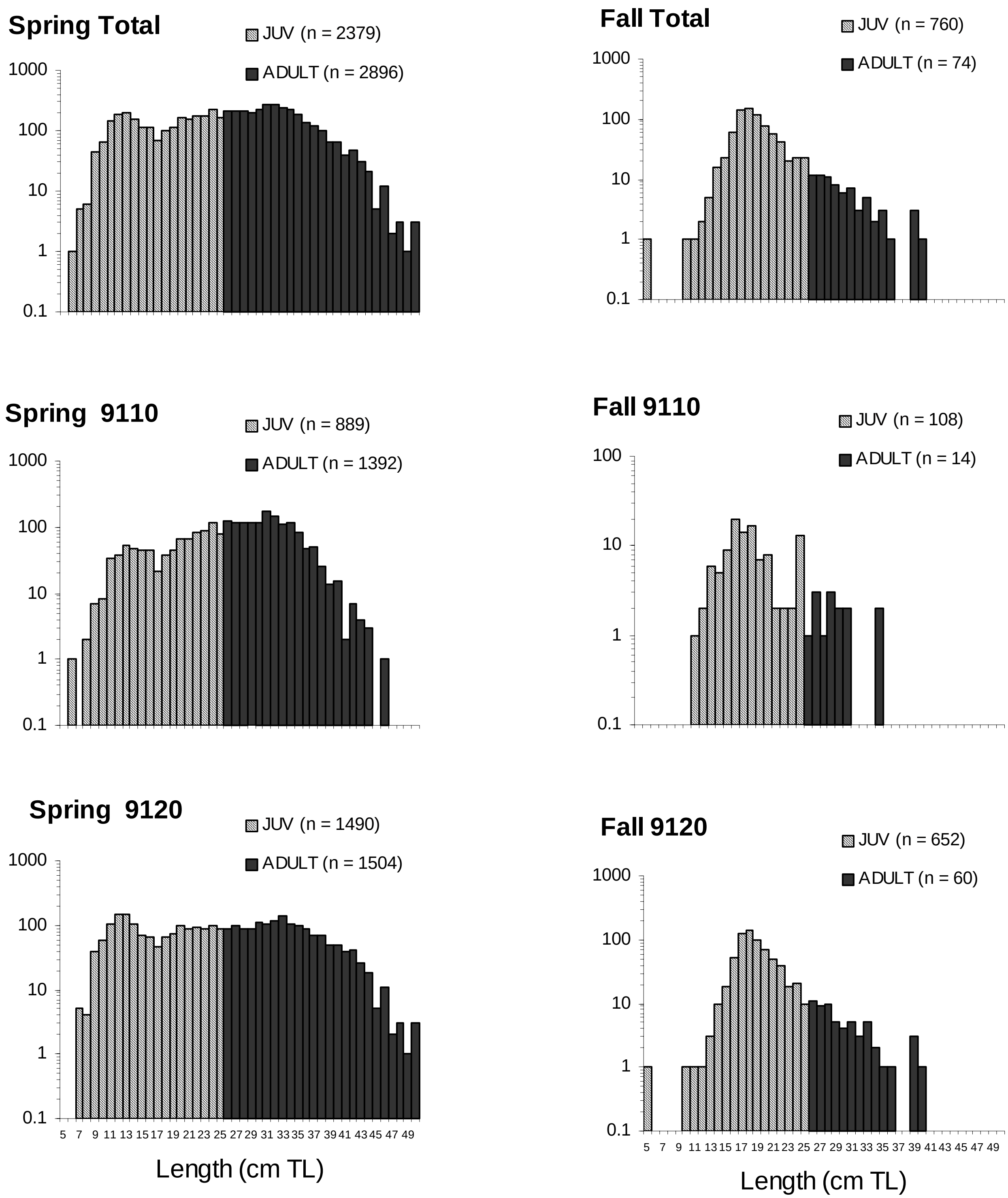


a. Average Fall CPUE of Adult Winter Flounder by sub region



c. Average Fall CPUE of Juvenile Winter Flounder by sub region

Figure 3-50



Seasonal Winter Flounder (*Pseudopleuronectes americanus*) log10 Length Frequencies (cm TL) by strata based on 6,109 fish taken in spring tows between 1978 and 2000.