

Multi-Community Partnership to Reduce Nitrogen in Upper Buzzards Bay – Fisheries Resource Analysis



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1. Introduction

1.1 Background

Communities throughout southeastern Massachusetts and Cape Cod depend on good water quality to support their local economies and quality of life. Many are also struggling with how to reduce nitrogen entering harbors and coves in an effective, affordable, and sustainable way. The “Multi-Community Partnership to Reduce Nitrogen in Upper Buzzards Bay” project capitalizes on this collective need to solve the nitrogen pollution problem in two nitrogen-impaired upper Buzzards Bay estuaries while at the same time meeting the economic development needs in the town of Bourne, and will likely save a state educational institution from investing in costly upgrades to existing wastewater infrastructure.

This partnership brings together all of the Head of Buzzards Bay communities – Wareham, Bourne, and Plymouth – together with Massachusetts Maritime Academy (MMA) and the Buzzards Bay Coalition to combine resources and municipal sewer infrastructure across town and watershed boundaries to develop a regional wastewater solution to reduce nitrogen pollution in two of upper Buzzards Bay’s nutrient impaired sub-estuaries; the Agawam/Wareham River and Buttermilk/Little Buttermilk Bay. Nitrogen reductions will be achieved by relocating the town of Wareham’s highly-performing wastewater discharge from the Agawam River to the Cape Cod Canal and expanding municipal sewer system in the region.

The Wareham/Agawam River and Buttermilk/Little Buttermilk Bay fail to meet water quality standards due to nitrogen pollution and are listed as impaired on the Final Massachusetts Year 2016 Integrated List of Waters. Water quality data developed by the Buzzards Bay Coalition documents how high levels of nitrogen have decreased the quality of coastal ecosystem habitats in these estuaries resulting in loss of ecosystem services.

Until recently, Massachusetts state law prohibited the permitting of new municipal wastewater ocean discharges in state-designated ocean sanctuaries, including Buzzards Bay. The passage of Chapter 259 of the Acts of 2014 allows the Massachusetts Department of Environmental Protection to approve ocean discharges in ocean sanctuaries when robust scientific evidence shows that there is no adverse impact to ocean water quality or groundwater quality and the new discharge receives advanced treatment for nitrogen. The goal of this study is to document the baseline conditions with respect to finfish in the area of the proposed discharge.

1.2 Objective

The location of the proposed discharge in the Cape Cod Canal is unique. It sits in an area with vigorous currents and tidal flows – it is estimated that roughly 56-80 billion gallons of water flows through the canal every day. This environment makes the Canal primarily a short-term habitat used by fish, with migrating fish passing through the Canal and the type of fish in the Canal changing over the course of the year. To assess the baseline conditions of finfish resources near the proposed discharge, trawl data was compiled for 10 years from Upper Buzzards Bay and Cape Cod Bay near the Canal exits.

2. Methods

The Massachusetts Division of Marine Fisheries (DMF) Resource Assessment Project has conducted annual spring and fall bottom trawl surveys of Massachusetts territorial waters since 1978. Each year trawl stations are randomly chosen with a sampling density of approximately 1 station per 19 square nautical miles. For this project, the areas of Buzzards Bay and Cape Cod Bay selected for trawl survey analysis are waters north of 41°33'N, south of 41°57'N and west of 70°16'W (outlined in red in Figure 1).

The trawl surveys for each season produce information on the species present at each station, the number of individuals per species at each station, and the size of fish by species (weight in kg) for each station. For statistical analysis and comparisons, the data were grouped by season and by basin (Buzzards Bay or Cape Cod Bay). Trend analysis was performed only on those species that represent a relative abundance of at least 5% for more than a single year. Standard statistical methods were applied using Microsoft Excel software. A p-value of less than 0.05 was used to determine statistical significance. The data analysis for this report was performed according to an EPA-approved Quality Assurance Project Plan (Jakuba 2020). The tows included in the analysis met DMF's standard for acceptability. Information on the methods for the trawl surveys is provided in the Annual Performance Reports available through the DMF (Available at: <https://www.mass.gov/service-details/resource-assessment-project>).

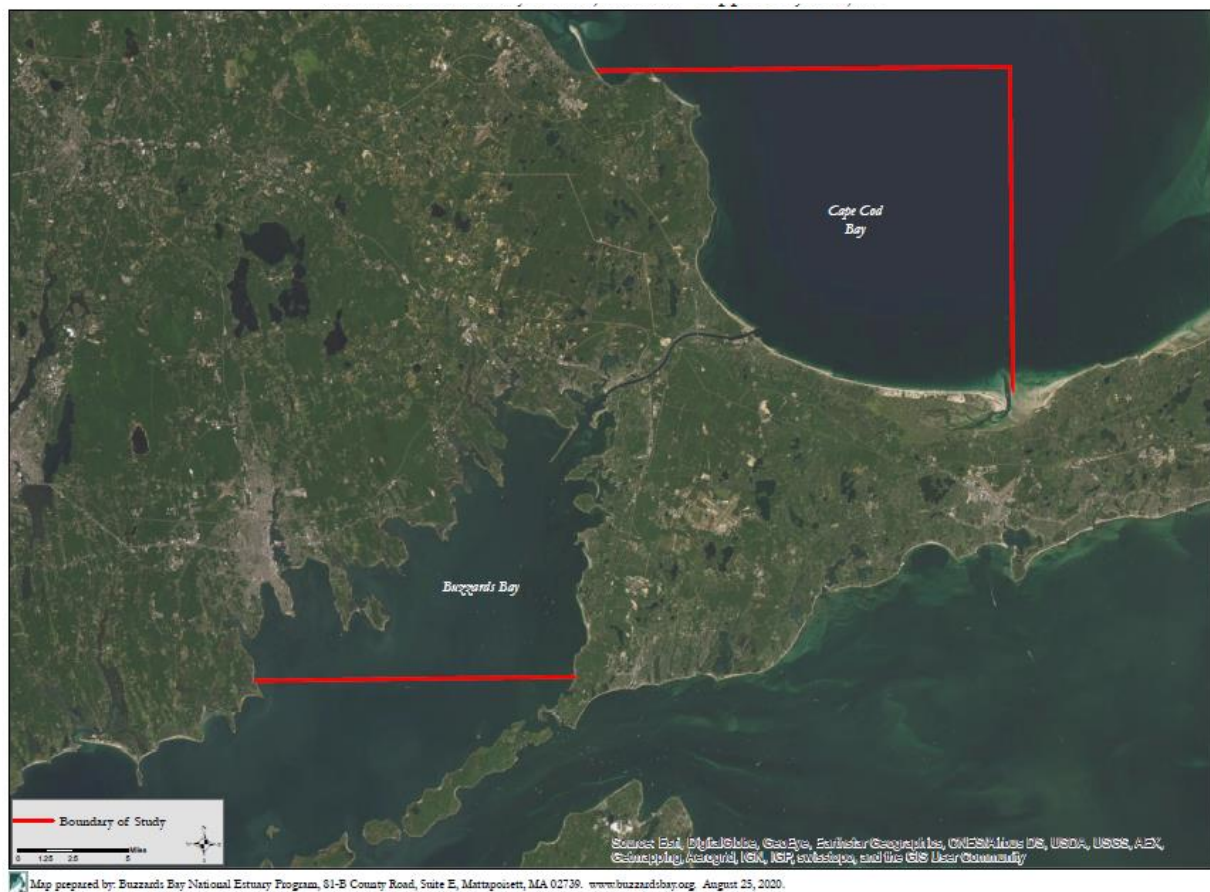


Figure 1. Map showing the areas of Buzzards Bay and Cape Cod Bay around the Cape Cod Canal that were selected for analysis.

3. Results

3.1 Available Data

Trawl survey data was compiled for the areas of interest for the 10-year time period from 2008 to 2017 (Figure 2). Data from a total of 250 trawls were analyzed (Table 1), with a roughly equal number of trawls between spring (n=129) and fall (n=121). There were a greater number of trawls performed in the Cape Cod Bay area of interest (171) than in the Buzzards Bay area of interest (79). Cape Cod Bay is a much deeper basin than that of Buzzards Bay (mean depth = 11m), which is characterized by many shallow areas with eelgrass meadows.

The distribution and location of stations is randomly selected each survey and completion rates of those stations varies by survey due to weather and other factors. Thus, the number of stations that fall in the selected area interest changes each survey (Table 1). In order to eliminate any bias caused by inconsistent effort or catches of species with patchy distributions, the analysis in this report will normalize all the data to the level of effort as quantified by the number of trawl stations.

Table 1. Number of trawl survey stations included in this analysis.

Year	Buzzards Bay		Cape Cod Bay	
	Spring	Fall	Spring	Fall
2008	4	5	8	7
2009	4	4	10	9
2010	3	4	11	8
2011	3	4	9	6
2012	5	5	8	5
2013	4	4	10	8
2014	5	2	9	9
2015	4	4	7	10
2016	3	4	12	9
2017	3	5	7	9

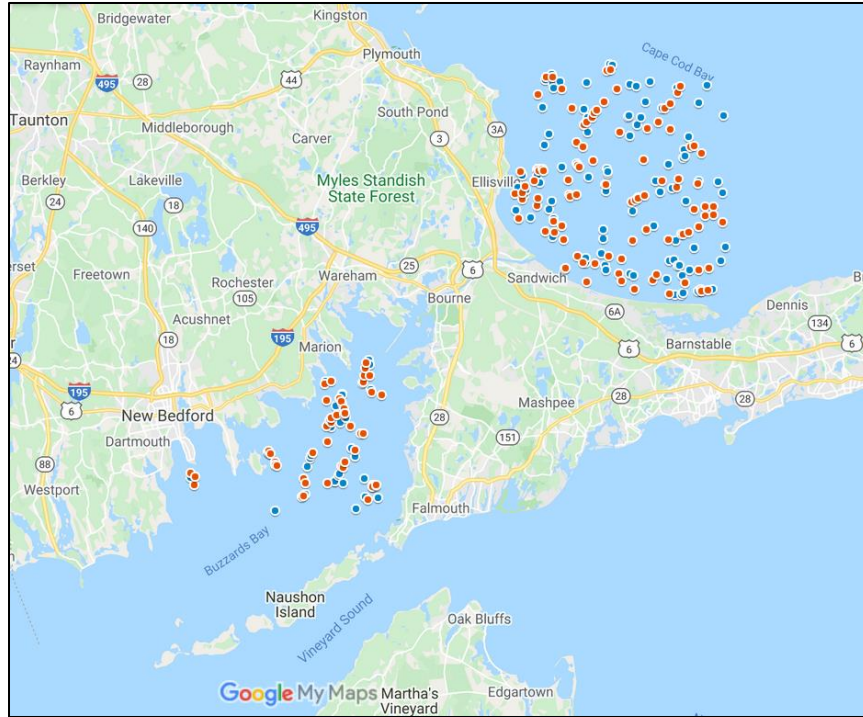


Figure 2. Beginning locations of spring (blue dots) and fall (orange dots) trawl surveys analyzed.

3.2 Total Catch

During the spring surveys, there were a total of between 190 and 2,095 total individuals caught per tow in Buzzards Bay in a single year (Figure 3) with an average of 1,002 individuals per tow. Counting all the stations for all years a total of 38,487 individuals were caught over 10 years in Buzzards Bay. During the spring surveys, lower numbers of individuals were caught in Cape Cod Bay with spring totals of between 146 and 2,130 total individuals caught per tow (Figure 3) and an average of 616 individuals per tow. Over the 10-year period, a total of 57,182 individuals were collected from all the tows done in Cape Cod Bay in the spring.

In the fall, higher numbers of individuals were caught in both basins than in the spring. There were again higher numbers of individuals caught in Buzzards Bay than in Cape Cod Bay (Figure 3). In Buzzards Bay, a total of between 2,807 and 20,248 individuals per tow were caught during each fall survey with an average of 7,046 individuals per tow for the fall surveys. A total of 291,388 individuals were collected from Buzzards Bay over the 10-year period. For Cape Cod Bay, there were between 581 and 2,037 total individuals caught per tow during the fall surveys (average = 1,405). Over the 10 years examined, a total of 111,703 individuals were caught in fall surveys of Cape Cod Bay. The overall highest density of catch was in fall in Buzzards Bay, with particularly high catch in 2015 (20,248 individuals per trawl station).

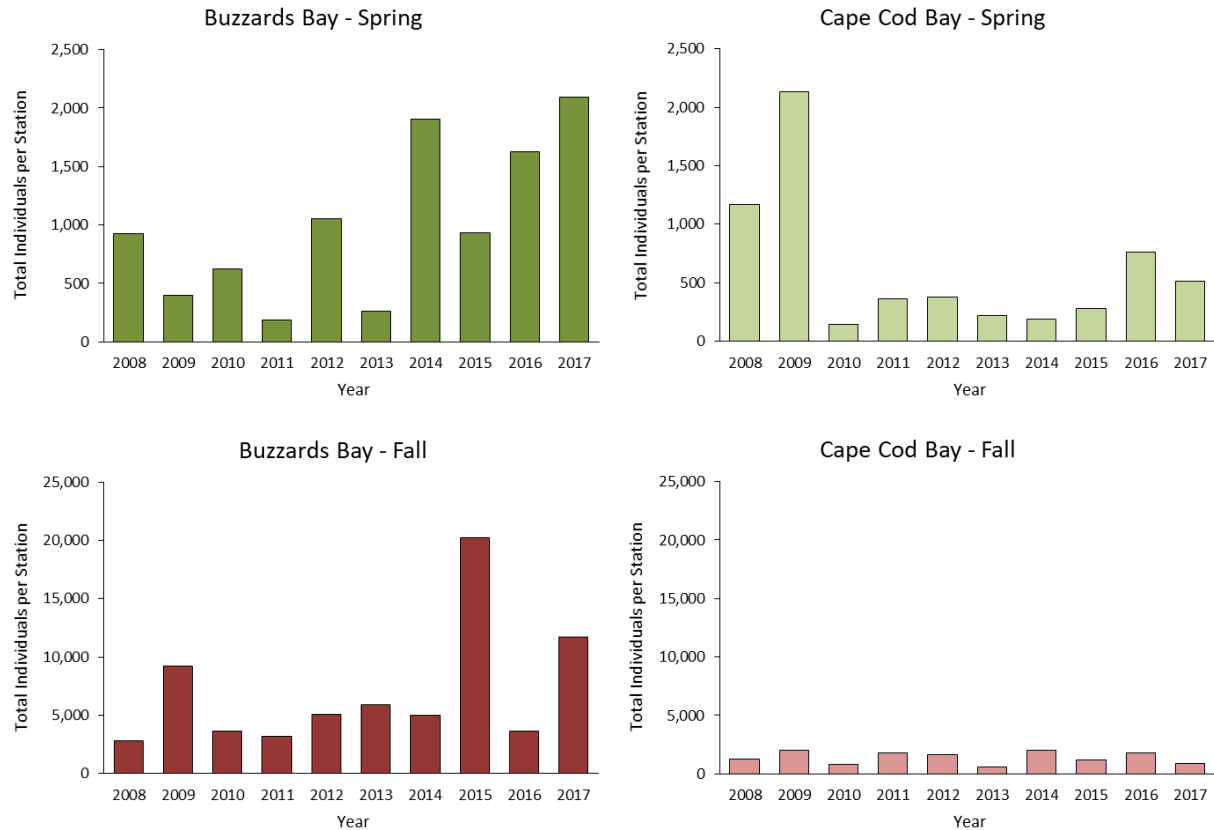


Figure 3. Total number of individuals collected per trawl station in each season. Note the y-axis for fall (lower panels) is larger than that for spring (upper panels).

3.3 Species present

There were 93 different species collected in trawl surveys between 2008 and 2017. A complete list of the species found in included in Appendix I. The majority of the species (64) were found in both spring and fall surveys. A small number of species (8) were found only during spring trawl surveys, while a larger number (21) were found only during fall trawl surveys. There were 23 species that were found exclusively in Buzzards Bay and 28 species that were found exclusively in Cape Cod Bay (see Appendix I).

The number of species found during spring surveys in Buzzards Bay ranged from 20 to 32, while the number of species found during fall surveys in Buzzards Bay ranged from 15 to 34 (Table 2). In Cape Cod Bay, there were between 22 and 48 species observed during the spring surveys and between 27 and 43 species observed during the fall surveys (Table 2).

Of the 93 species found across the total of 250 trawl stations, most species were found at four or fewer trawl stations (Figure 4).

Table 2. Number of species per survey.

Year	Buzzards Bay		Cape Cod Bay	
	Spring	Fall	Spring	Fall
2008	25	22	32	34
2009	32	30	26	37
2010	32	34	31	38
2011	20	29	36	40
2012	24	21	29	28
2013	21	23	34	30
2014	30	15	22	27
2015	25	24	29	36
2016	25	28	48	43
2017	27	30	32	32

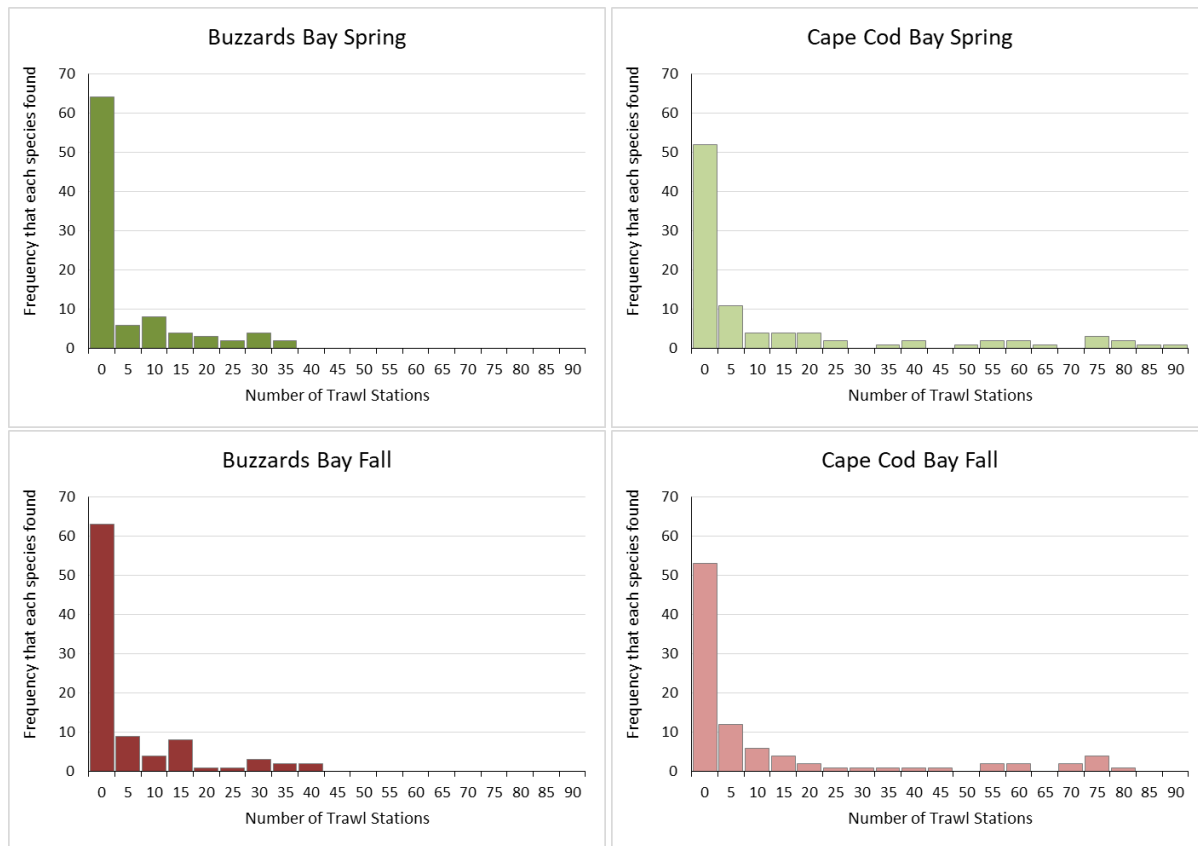


Figure 4. Histograms showing the frequency that species were found at trawl stations.

3.4 Most Abundant Species

There were clear differences between the most abundant species in Buzzard Bay versus Cape Cod Bay. In Buzzards Bay, Scup was the species that had the highest number of individuals caught in the spring for eight out of the 10 years analyzed (Table 3). In the two years that Scup did not represent the highest

Table 3. Species with the highest numbers of individuals collected in each basin each season.

	Buzzards Bay - Spring			Cape Cod Bay - Spring		
	Most abundant	2nd Most abundant	3rd Most abundant	Most abundant	2nd Most abundant	3rd Most abundant
2008	Scup	Butterfish	Longfin Squid	Atlantic Cod	Atlantic Rock Crab	Winter Flounder
2009	Scup	Cunner	Longfin Squid	Atlantic Cod	Northern Sand Lance	Winter Flounder
2010	Scup	Spotted Hake	Atlantic Herring	Winter Flounder	Silver Hake	Alewife
2011	Pollock	Scup	Longfin Squid	Alewife	Longhorn Sculpin	Winter Flounder
2012	Scup	Butterfish	Longfin Squid	Alewife	Winter Flounder	Silver Hake
2013	Atlantic Herring	Scup	Black Sea Bass	Silver Hake	Winter Flounder	Longhorn Sculpin
2014	Scup	Black Sea Bass	Atlantic Herring	Alewife	Longhorn Sculpin	Atlantic Cod
2015	Scup	Black Sea Bass	Butterfish	Silver Hake	Winter Flounder	Alewife
2016	Scup	Northern Searobin	Black Sea Bass	Silver Hake	Winter Flounder	Red Hake
2017	Scup	Black Sea Bass	Striped Searobin	Silver Hake	Atlantic Cod	Winter Flounder

	Buzzards Bay - Fall			Cape Cod Bay - Fall		
	Most abundant	2nd Most abundant	3rd Most abundant	Most abundant	2nd Most abundant	3rd Most abundant
2008	Black Sea Bass	Scup	Longfin Squid	Longfin Squid	Butterfish	Spiny Dogfish
2009	Bay Anchovy	Scup	Black Sea Bass	Butterfish	Longfin Squid	Spiny Dogfish
2010	Scup	Black Sea Bass	Cunner	Longfin Squid	Butterfish	Atlantic Herring
2011	Scup	Butterfish	Longfin Squid	Longfin Squid	Spiny Dogfish	Butterfish
2012	Butterfish	Scup	Bay Anchovy	Longfin Squid	Spiny Dogfish	Atlantic Rock Crab
2013	Bay Anchovy	Scup	Longfin Squid	Longfin Squid	Butterfish	Little Skate
2014	Butterfish	Scup	Bluefish	Longfin Squid	Butterfish	Silver Hake
2015	Scup	Bay Anchovy	Butterfish	Longfin Squid	Atlantic Rock Crab	Winter Flounder
2016	Scup	Butterfish	Black Sea Bass	Longfin Squid	Butterfish	Winter Flounder
2017	Bay Anchovy	Scup	Longfin Squid	Red Hake	Silver Hake	Winter Flounder

number of individuals during the spring survey, it was the second most abundant species caught (Table 3). Scup was only caught in spring trawls in Cape Cod Bay during a single year (2016). In the spring trawls in Cape Cod Bay there were four species that represented the most abundant species in a year (Table 3): Silver Hake (4 yrs), Alewife (3 yrs), Atlantic Cod (2 yrs), and Winter Flounder (1 yr).

In the fall trawl surveys, Scup was still often the most abundant species (4 yrs) at Buzzards Bay stations (Table 3); however there were additional species that were the most abundant species some years: Bay Anchovy (3 yrs), Butterfish (2 yrs), and Black Sea Bass (1 yr). In Cape Cod Bay fall surveys, longfin squid was the most abundant species caught for eight out of the 10 years (Table 3). Butterfish and Red Hake were each the most abundant species in a single year.

3.5 Relative Abundance

The relative abundance of each species was determined by dividing the number of individuals of that species caught in a seasonal survey by the total individuals caught in that seasonal survey. The graphs and analysis below are limited to only those species that represented more than 5% relative abundance in at least one year.

The high proportion of Scup in Buzzards Bay spring and fall trawls is evident in Figure 5 (light gray bars). For the Cape Cod Bay surveys, the relative abundance shows how the profile of species changes between spring and fall (Figure 5). In both basins, the increase in relative abundance of butterfish (black bars) and longfin squid (bright green bars) during fall surveys is apparent. There is a greater number of species in Cape Cod Bay that have a relative abundance over 5% than in Buzzards Bay.

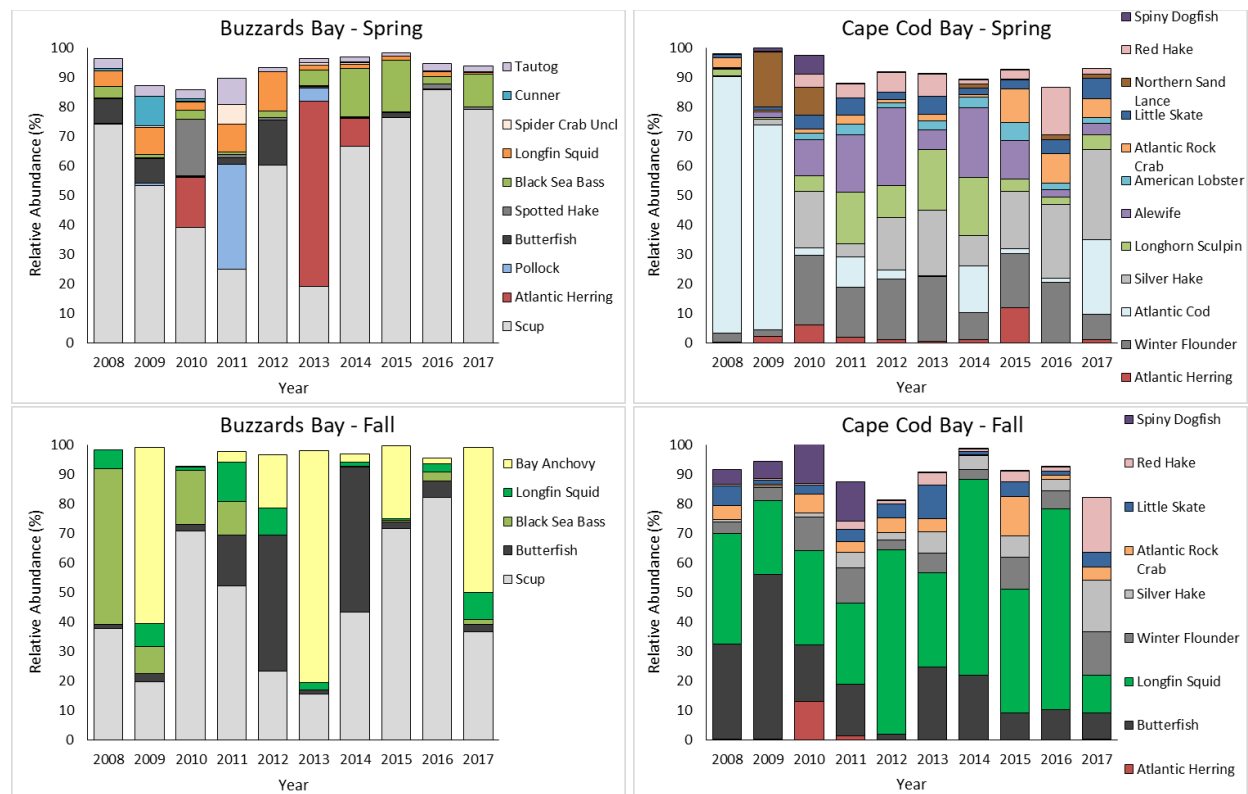


Figure 5. Relative abundance of most prevalent species.

3.6 Biomass

During the Buzzards Bay spring trawl surveys, the weight of the catch ranged from a low of 37 kg per trawl (2013) to a high of 692 kg per trawl (2017, Figure 6). In Cape Cod Bay, the weight of catch during the spring trawl surveys was lower at between 22 kg per trawl (2014) and 131 kg per trawl (2016, Figure 6).

During the fall surveys, the weight of catch was between 56 and 1,168 kg per trawl in Cape Cod Bay (Figure 6). In Buzzards Bay, that catch weighed between 59 and 288 kg per trawl (Figure 6). For the first five years examined (2008-2012), the mass of catch in Cape Cod Bay in the fall was much higher than that in Buzzards Bay, but for the last five years examined (2013-2017), the weight of catch in Buzzards Bay was similar or higher than that in Cape Cod Bay. The relatively high weight of the trawl catch in Cape Cod in the first part of the record is particularly pronounced given the lower number of individuals caught in the fall in Cape Cod Bay relative to Buzzards Bay.

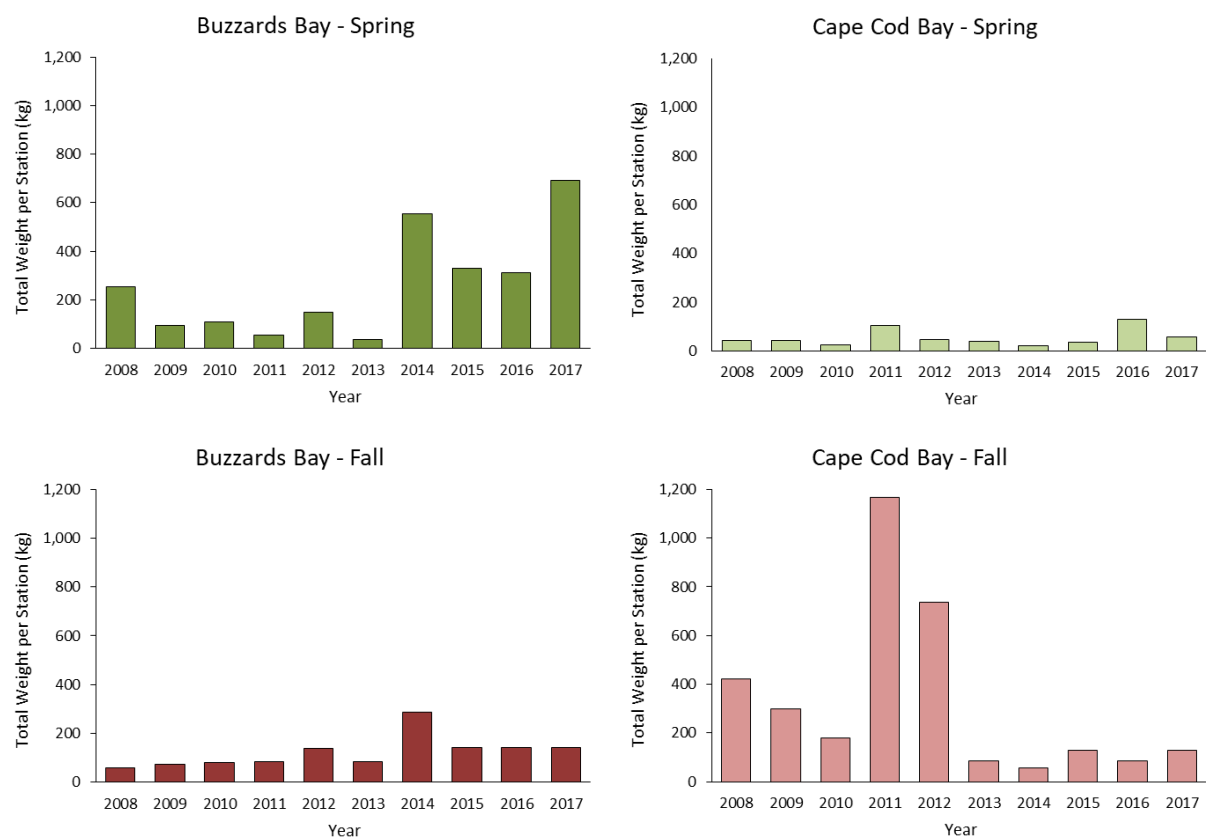


Figure 6. Total mass of catch per trawl station in each season.

The species accounting for the largest amount of biomass in the spring in Buzzards Bay was generally Scup with high levels of biomass also attributed to Tautog and Black Sea Bass. In Cape Cod Bay in the spring, the species that represented a high proportion of the biomass were Little Skate, Winter Flounder, Longhorn Sculpin, Spiny Dogfish, and Silver Hake.

In the fall in Buzzards Bay, Scup was again the species that generally was the most dominant representing the highest proportion of biomass for 8 of the 10 yrs. Other species that also accounted for a high proportion of biomass in the fall in Buzzards Bay were Butterfish, Smooth Dogfish, and Summer Flounder. In Cape Cod Bay in the fall, the species representing the highest biomass was generally Spiny Dogfish and Little Skate, with Winter Flounder also accounting for a high proportion of the biomass.

3.7 Fish Size

The size class of fish that was most abundant in both seasons and both basins was fish between 0 and 0.25 kg (Figure 7). Many of the small fish collected represent young of the year fish (fish less than one years old). These fish can have patchy distributions, often leading to high inter-annual variability in their catch. They are also highly susceptible to predation due to their small size.

During spring surveys, 95% of all the fish caught in Buzzards Bay had an average weight of 1.25 kg or less, and the median weight was 0.069 kg. The median weight of fish caught in Cape Cod Bay in spring was 0.130 kg and 95% of all fish caught had an average weight of 1.00 kg or less. During fall surveys, 95% of all the fish caught in Buzzards Bay had an average weight of 1.00 kg or less with a median weight of 0.057 kg. Whereas 95% of all the fish caught in Cape Cod Bay were 1.75 kg or less with a median weight (0.100 kg) close to double that observed in Buzzards Bay.

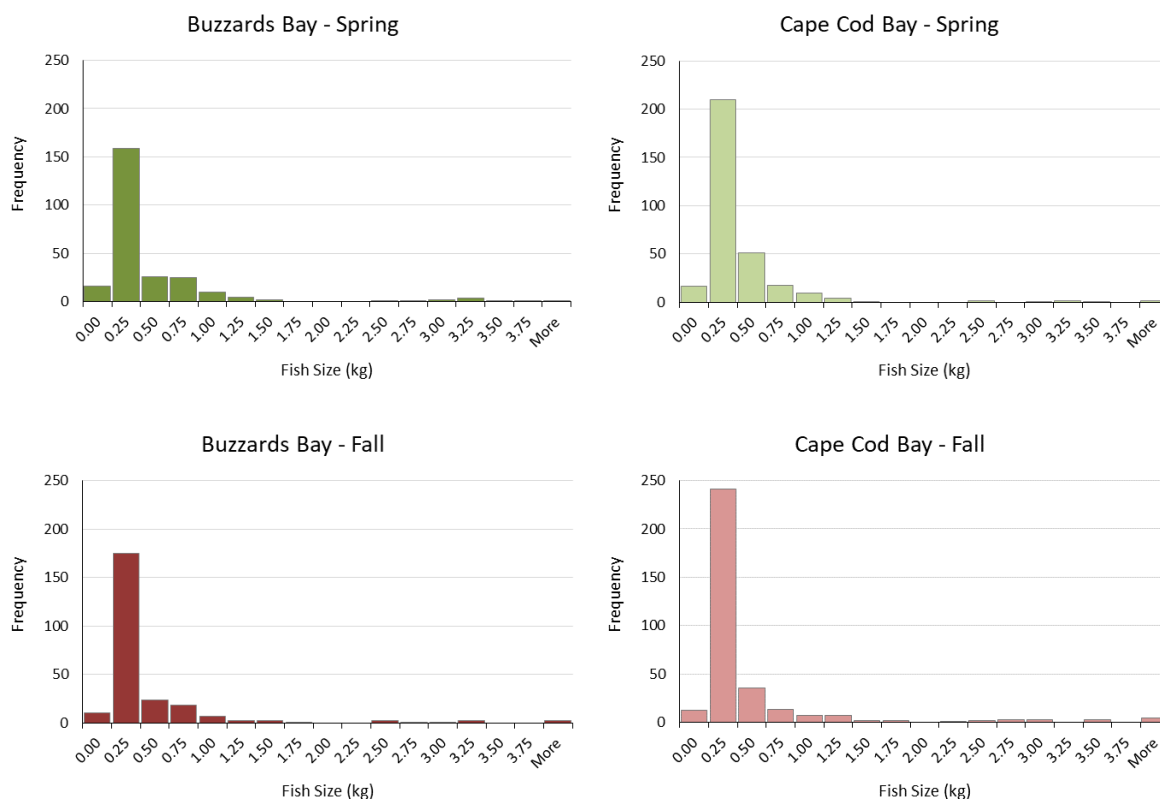


Figure 7. Histograms showing the frequency that different size classes of fish were caught.

The average fish size for the five most abundant species each season was examined (Figure 8). In Buzzards Bay during the spring, Black Sea Bass and Scup were the two species with the largest average size. These fish were heavier than the heaviest species observed in spring in Cape Cod Bay (Silver Hake and Winter Flounder).

In Cape Cod Bay in the fall, the heaviest average species were Spiny Dogfish and Winter Flounder. The average weight in Buzzards Bay in the fall was much lower than observed in the spring in Buzzards Bay or in the fall in Cape Cod Bay (Figure 8). In the fall, Buzzards Bay serves as a nursery area for all the species caught in high numbers, so many of the fish are less than a year old and consequently very small. Of the most abundant species in Buzzards Bay during the fall, Butterfish and Scup were generally the heaviest, though in 2013 and 2014, Black Sea Bass had the largest average size.

Spiny Dogfish was much heavier (~2.8 kg) than any of the other most abundant species and accounted for 70-89% of the total biomass collected in Cape Cod Bay in fall surveys for the years 2008 through 2012. The second heaviest of the most abundant species was Black Sea Bass, which averaged a quarter the size at ~0.7 kg in Buzzards Bay spring surveys.

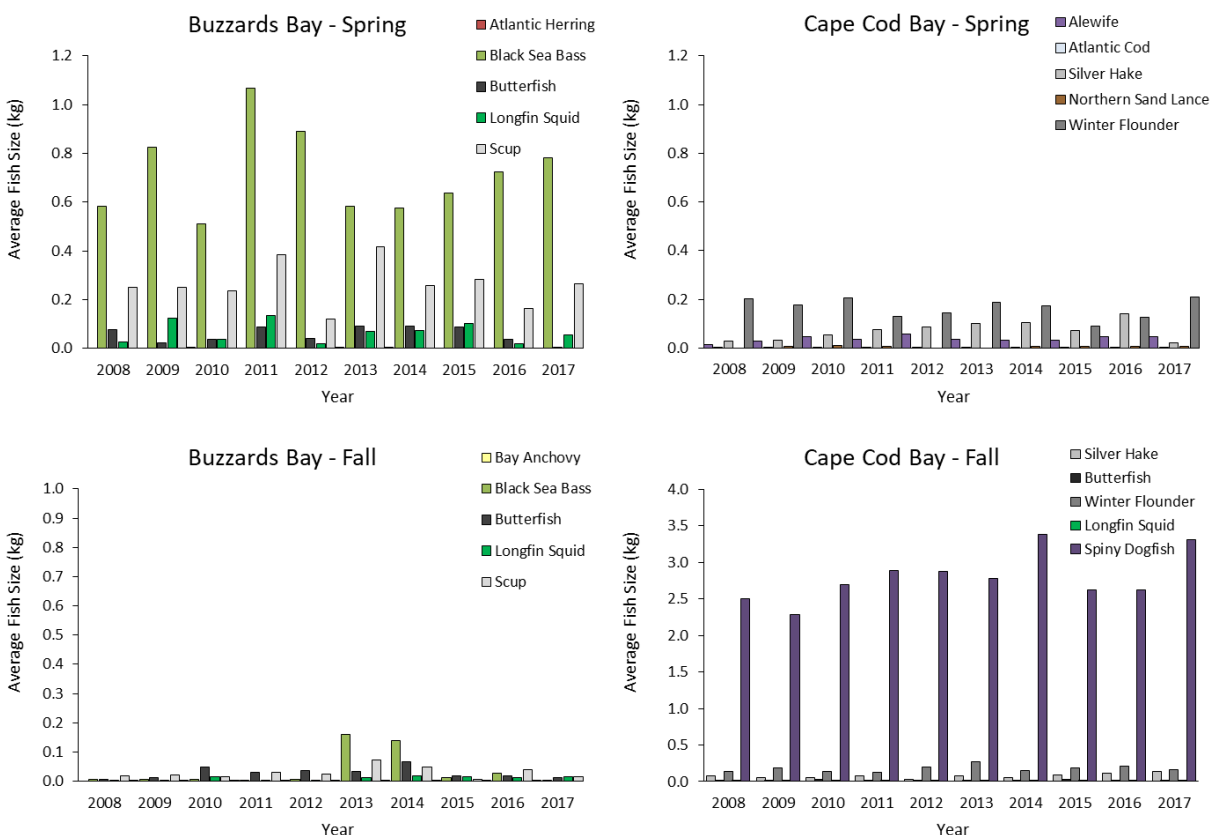


Figure 8. Average weight of individuals for the five most abundant species each season. Note the different y-axis values for Buzzards Bay and Cape Cod Bay in the fall.

4. Trend Analysis

Inter-annual variability is expected in biological surveys. To establish whether there are any temporal trends in the survey data that reflect changes over time, as opposed to inter-annual variability, linear regressions were performed.

4.1 Total Catch

There was a statistically significant increasing trend in the number of individuals caught per trawl in Buzzards Bay in the spring surveys (p -value = 0.03, Figure 9). There was no trend in the number of individuals caught per trawl in Cape Cod Bay in the spring nor in either basin in the fall (Appendix II).

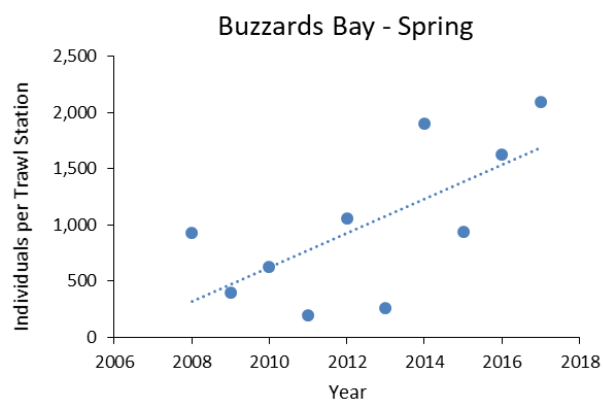


Figure 9. Number of individuals collected per trawl station during spring surveys in Buzzards Bay.

4.2 Species Present

In both the spring and fall surveys, there was no trend over time in the number of species collected per trawl in either Buzzards Bay or Cape Cod Bay (Appendix II).

4.3 Most Abundant Species

The three most abundant species in each basin during each season were analyzed to see whether the number of individuals caught of those species was changing over time. In Buzzards Bay, the species with the most individuals caught over the entire record of spring trawls were Scup, Black Sea Bass and Atlantic Herring. There was not a significant trend in the total number of individuals per trawl caught for Black Sea Bass or Atlantic Herring in spring (Appendix II). There was a significant increasing trend in the number of Scup caught per trawl over the 10-year period (p -value = 0.02) during spring surveys in Buzzards Bay (Figure 10).

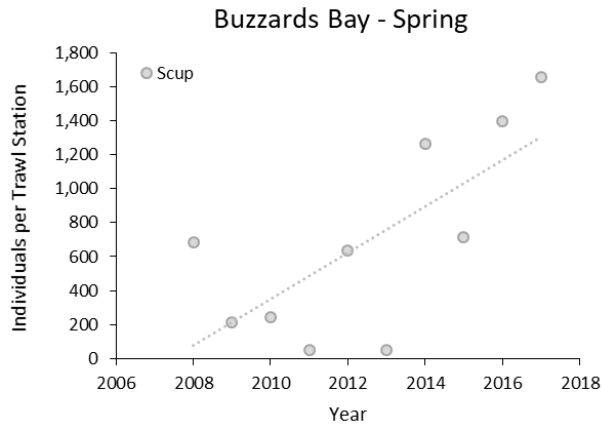


Figure 10. Number of Scup collected per trawl station during spring surveys in Buzzards Bay.

In Cape Cod Bay, the three species caught in highest numbers in the spring trawls over the entire record were Atlantic Cod, Silver Hake, and Winter Flounder. There was no trend in the total number of individuals caught per trawl for Winter Flounder (Appendix II). However, there was an increasing trend in the number of Silver Hake caught per trawl in spring trawls over time (p -value = 0.01, Figure 11). There was a significant decreasing trend in the number of Atlantic Cod caught per trawl (p -value = 0.05, Figure 11). In 2008 and 2009, there were over 1,000 Atlantic Cod caught per trawl station in spring Cape Cod Bay surveys, but there were less than 150 Atlantic Cod caught per trawl station per year for 2010 to 2017. The lower numbers of Atlantic Cod caught between 2010 and 2017 are more representative of the long-term values observed, which were similarly low between 1980 and 2000.

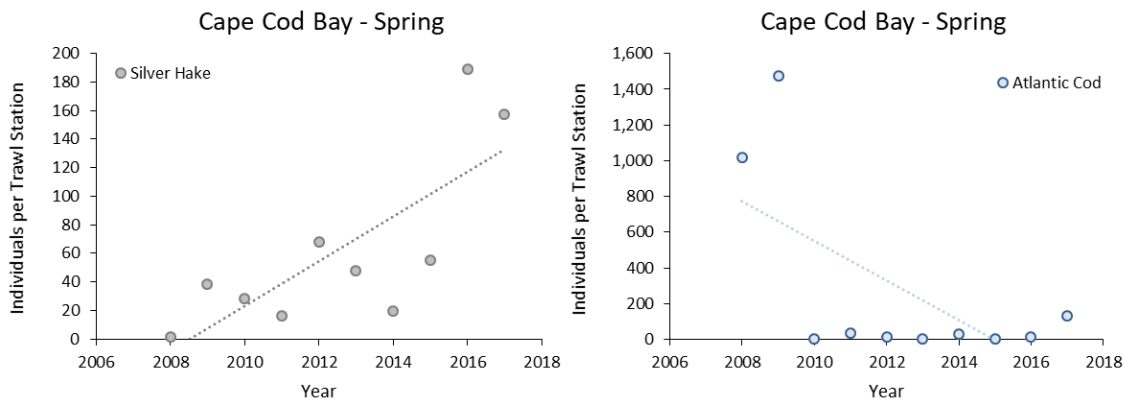


Figure 11. Number of Silver Hake (left panel) and Atlantic Cod collected per trawl (right panel) during spring surveys in Cape Cod Bay. Note the difference in y-axis scale.

During the fall trawl surveys, the three most abundant species in Buzzards Bay were Scup, Bay Anchovy, and Butterfish and in Cape Cod Bay were Longfin Squid, Butterfish, and Winter

Flounder. There were no statistically significant trends over time in the total number of these species caught per trawl station (Appendix II)

4.4 Biomass

During fall surveys, there was no significant increasing or decreasing trend in the total biomass collected per trawl in either Buzzards Bay or Cape Cod Bay (Appendix II). During fall surveys, there was no trend in total biomass in Cape Cod Bay, but there was a significant increasing trend in the biomass collected per trawl Buzzards Bay during spring trawls (Figure 12).

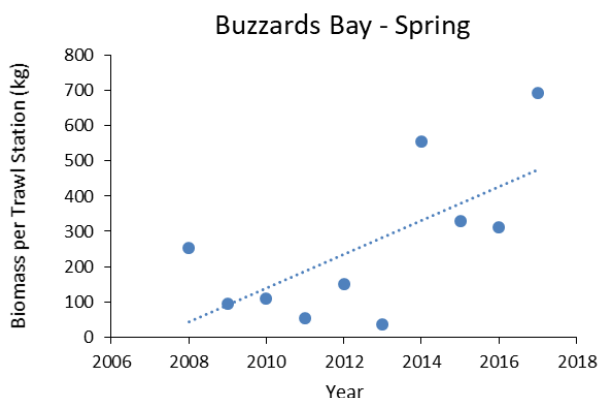


Figure 12. Weight of fish collected per trawl in Buzzards Bay during spring (left panel) surveys.

4.5 Fish Size

When the overall average fish size was calculated as the total biomass divided by the total number of individuals, there were not trends over time in the average fish size for either spring or fall surveys in either Buzzards Bay or Cape Cod Bay (Appendix II).

In each Bay, the average fish size for the five most abundant species each season was examined. During the spring surveys, there was no trend in the average size of any of the most abundant species in Cape Cod Bay (Atlantic Cod, Silver Hake, Winter Flounder, Northern Sand Lance, Alewife). In Buzzards Bay, four of the most abundant species (Scup, Black Sea Bass, Longfin Squid, Butterfish) had no significant trend in average size during spring surveys (Appendix II). However, there was a statistically significant decreasing trend in the size of Atlantic Herring caught in Buzzards Bay during the spring (Figure 13), though it is important to note that this is based on only three years of data, since Atlantic Herring were only observed in three out of the ten years.

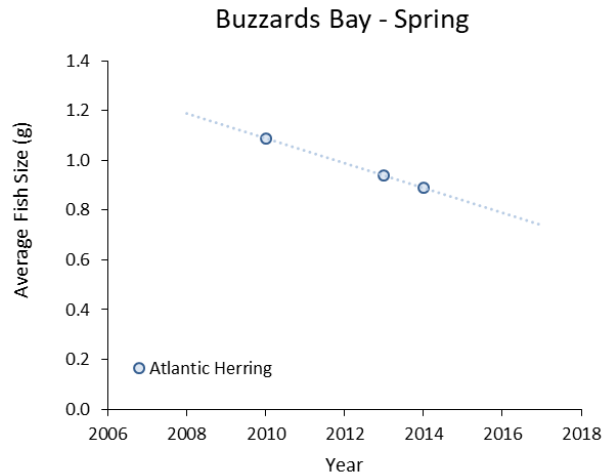


Figure 13. Average weight of Atlantic Herring caught in Buzzards Bay during spring surveys.

In Cape Cod Bay fall surveys, there were not significant trends in the average size of any of the most abundant species (Longfin Squid, Butterfish, Winter Flounder Spiny Dogfish, Silver Hake). There were not significant trends in the average size of Scup, Butterfish or Black Sea Bass in fall Buzzards Bay surveys (Appendix II). There were significant increasing trends in the size of Bay Anchovy and Longfin Squid (Figure 14).

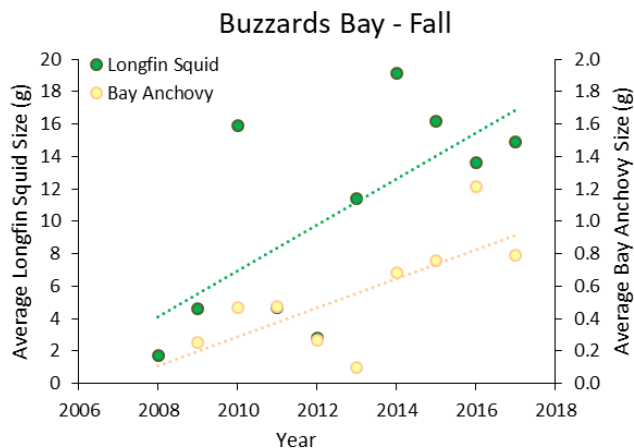


Figure 14. Average weight of Longfin Squid (left y-axis) and Bay Anchovy (right y-axis) collected during Buzzards Bay fall trawl surveys.

Summary

A ten-year analysis of data from the DMF Resource Assessment Project's long-term spring and fall trawl surveys was performed. This report documents the status of fish populations on both sides of the Cape Cod Canal between 2008 and 2017 to provide baseline information as wastewater outfall changes are proposed in the Cape Cod Canal. There were clear differences in the species and patterns observed in Buzzards Bay and Cape Cod Bay and in each season.

There were no statistically significant either increasing or decreasing trends in Buzzards Bay or Cape Cod Bay during either spring or fall for how many species were collected or the average individual fish weight.

In Cape Cod Bay, there were also no statistically significant trends in either spring or fall for how many individuals were caught per trawl or the biomass collected per trawl.

In Buzzards Bay, during the spring season only, there was an increasing trend in the number of individuals collected per trawl station, the biomass collected per trawl station, and the number of Scup collected per trawl, which was the most abundant species.

In Cape Cod Bay during the spring surveys, there was a statistically significant increasing trend in the number of Silver Hake collected per trawl and a statistically significant decreasing trend in the number of Atlantic Cod collected per trawl.

During the fall in both Buzzards Bay and Cape Cod Bay, there were not statistically significant increasing or decreasing trends in the numbers of any of the most abundant species per trawl.

In Buzzards Bay, there was a decreasing trend in the average weight of Atlantic Herring in the spring, and in the fall, there was an increasing trend in the average weight of two of the most abundant species, Longfin Squid and Bay Anchovy.

It is worth noting that, while the trends identified were statistically significant, the R^2 values were generally less than 0.7. Inter-annual variability is expected in surveys like these that take snap-shots in time. In addition, since this analysis captures many young of the year fish, high variability is also expected due to patchy distribution and high mortality. For all these reasons, it is important to look over multiple years for assessing the condition of populations.

References

Jakuba, R. (2020) Quality Assurance Project Plan for Multi-Community Partnership to Reduce Nitrogen in Upper Buzzards Bay – Fisheries Analysis. 18 pp.

Appendix I. Species Observed

The table below lists all species found in the designated area during the 2008-2017 trawl surveys. Where there is either a season or water body in parentheses after the species' common name, that species was found only in that season or water body. For example, the American Lobster was found only in Cape Cod Bay trawl surveys.

Common Name	Scientific Name
Alewife	<i>Alosa Pseudoharengus</i>
American Lobster (Cape Cod Bay)	<i>Homarus Americanus</i>
American Plaice (Cape Cod Bay)	<i>Hippoglossoides Platessoides</i>
American Shad	<i>Alosa Sapidissima</i>
Atlantic Cod	<i>Gadus Morhua</i>
Atlantic Herring	<i>Clupea Harengus</i>
Atlantic Mackerel (fall, Cape Cod Bay)	<i>Scomber Scombrus</i>
Atlantic Menhaden	<i>Brevoortia Tyrannus</i>
Atlantic Moonfish (fall)	<i>Selene Setapinnis</i>
Atlantic Rock Crab	<i>Cancer Irroratus</i>
Atlantic Silverside (spring, Cape Cod Bay)	<i>Menidia Menidia</i>
Atlantic Surfclam (spring, Cape Cod Bay)	<i>Spisula Solidissima</i>
Atlantic Tomcod (spring)	<i>Microgadus Tomcod</i>
Atlantic Torpedo (fall, Cape Cod Bay)	<i>Torpedo Nobiliana</i>
Bay Anchovy	<i>Anchoa Mitchilli</i>
Bay Scallop (Buzzards Bay)	<i>Argopecten Irradians</i>
Bigeye Scad (fall, Buzzards Bay)	<i>Selar Crumenophthalmus</i>
Black Sea Bass	<i>Centropristis Striata</i>
Blue Crab (Buzzards Bay)	<i>Callinectes Sapidus</i>
Blue Mussel	<i>Mytilus Edulis</i>
Blue Runner (fall, Buzzards Bay)	<i>Caranx Crysos</i>
Blueback Herring (Cape Cod Bay)	<i>Alosa Aestivalis</i>
Bluefish (fall)	<i>Pomatomus Saltatrix</i>
Bluespotted Cornetfish (fall, Buzzards Bay)	<i>Fistularia Tabacaria</i>
Butterfish	<i>Peprilus Triacanthus</i>
Channeled Whelk (Buzzards Bay)	<i>Busycotypus Canaliculatus</i>
Clearnose Skate (fall, Buzzards Bay)	<i>Raja Eglanteria</i>
Conger Eel (fall, Buzzards Bay)	<i>Conger Oceanicus</i>
Creville Jack (fall, Buzzards Bay)	<i>Caranx Hippos</i>
Cunner	<i>Tautogolabrus Adpersus</i>
Daubed Shanny (spring, Cape Cod Bay)	<i>Lumpenus Maculatus</i>
Fourbeard Rockling	<i>Enchelyopus Cimbrius</i>
Fourspot Flounder	<i>Paralichthys Oblongus</i>
Glasseye Snapper (fall, Buzzards Bay)	<i>Priacanthus Cruentatus</i>
Goosefish (Cape Cod Bay)	<i>Lophius Americanus</i>

Common Name	Scientific Name
Grubby	<i>Myoxocephalus Aeneus</i>
Haddock (Cape Cod Bay)	<i>Melanogrammus Aeglefinus</i>
Hogchoker (fall, Buzzards Bay)	<i>Trinectes Maculatus</i>
Horseshoe Crab	<i>Limulus Polyphemus</i>
Inshore Lizardfish (fall, Buzzards Bay)	<i>Synodus Foetens</i>
Jonah Crab (Cape Cod Bay)	<i>Cancer Borealis</i>
Knobbed Whelk (Buzzards Bay)	<i>Busycon Carica</i>
Lady Crab (Cape Cod Bay)	<i>Ovalipes Ocellatus</i>
Little Skate	<i>Leucoraja Erinacea</i>
Longfin Squid	<i>Loligo Pealeii</i>
Longfin Squid Egg Mops	<i>Loligo Pealeii Egg Mops</i>
Longhorn Sculpin (Cape Cod Bay)	<i>Myoxocephalus Octodecemspinosus</i>
Mantis Shrimp Uncl (Buzzards Bay)	<i>Stomatopoda</i>
Naked Goby (Buzzards Bay)	<i>Gobiosoma Bosc</i>
Northern Kingfish (Buzzards Bay)	<i>Menticirrhus Saxatilis</i>
Northern Moonsnail (Cape Cod Bay)	<i>Euspira Heros</i>
Northern Pipefish	<i>Syngnathus Fuscus</i>
Northern Puffer (fall)	<i>Sphoeroides Maculatus</i>
Northern Quahog	<i>Mercenaria Mercenaria</i>
Northern Sand Lance (spring, Cape Cod Bay)	<i>Ammodytes Dubius</i>
Northern Searobin	<i>Prionotus Carolinus</i>
Northern Shortfin Squid (fall, Cape Cod Bay)	<i>Illex Illecebrosus</i>
Ocean Pout (Cape Cod Bay)	<i>Macrozoarces Americanus</i>
Ocean Quahog (Cape Cod Bay)	<i>Arctica Islandica</i>
Orange Filefish (fall, Buzzards Bay)	<i>Aluterus Schoepfi</i>
Oyster Toadfish (Buzzards Bay)	<i>Opsanus Tau</i>
Planehead Filefish (fall, Buzzards Bay)	<i>Monacanthus Hispidus</i>
Pollock	<i>Pollachius Virens</i>
Rainbow Smelt (spring, Cape Cod Bay)	<i>Osmerus Mordax</i>
Red Hake	<i>Urophycis Chuss</i>
Rock Gunnel	<i>Pholis Gunnellus</i>
Rough Scad (fall, Buzzards Bay)	<i>Trachurus Lathamii</i>
Roughtail Stingray (fall, Buzzards Bay)	<i>Dasyatis Centroura</i>
Scup	<i>Stenotomus Chrysops</i>
Sea Raven (Cape Cod Bay)	<i>Hemitripterus Americanus</i>
Sea Scallop (Cape Cod Bay)	<i>Placopecten Magellanicus</i>
Sea Urchin And Sand Dollar Uncl	<i>Echinoidea</i>
Silver Hake	<i>Merluccius Bilinearis</i>
Silver Rag (fall, Cape Cod Bay)	<i>Ariomma Bondi</i>
Smallmouth Flounder	<i>Etropus Microstomus</i>
Smooth Dogfish	<i>Mustelus Canis</i>
Snakeblenny (Cape Cod Bay)	<i>Lumpenus Lumpretaeformis</i>
Spider Crab Uncl	<i>Majidae</i>

Common Name	Scientific Name
Spiny Dogfish	<i>Squalus Acanthias</i>
Spot (fall, Buzzards Bay)	<i>Leiostomus Xanthurus</i>
Spotted Hake	<i>Urophycis Regia</i>
Striped Bass (spring)	<i>Morone Saxatilis</i>
Striped Searobin	<i>Prionotus Evolans</i>
Summer Flounder	<i>Paralichthys Dentatus</i>
Tautog	<i>Tautoga Onitis</i>
Weakfish (Buzzards Bay)	<i>Cynoscion Regalis</i>
White Hake (Cape Cod Bay)	<i>Urophycis Tenuis</i>
Windowpane	<i>Scophthalmus Aquosus</i>
Winter Flounder	<i>Pseudopleuronectes Americanus</i>
Winter Skate (Cape Cod Bay)	<i>Leucoraja Ocellata</i>
Witch Flounder (spring, Cape Cod Bay)	<i>Glyptocephalus Cynoglossus</i>
Wrymouth (Cape Cod Bay)	<i>Cryptacanthodes Maculatus</i>
Yellowtail Flounder (Cape Cod Bay)	<i>Limanda Ferruginea</i>

Appendix II. Trend Analysis Statistical Data

	Basin	Season	Regression Slope	R ²	p-value
Total Catch					
Individuals per Trawl Station					
	Buzzards Bay	Spring	152	0.460	0.03
	Buzzards Bay	Fall	790	0.193	0.20
	Cape Cod Bay	Spring	-94	0.213	0.18
	Cape Cod Bay	Fall	-20	0.012	0.76
Species Present					
Species per Trawl Station					
	Buzzards Bay	Spring	0.02	0.001	0.93
	Buzzards Bay	Fall	0.00	0.000	0.98
	Cape Cod Bay	Spring	0.10	0.180	0.22
	Cape Cod Bay	Fall	-0.16	0.184	0.22
Most Abundant Species					
Atlantic Herring per Trawl	Buzzards Bay	Spring	1	0.002	0.91
Black Sea Bass per Trawl	Buzzards Bay	Spring	22	0.365	0.06
Scup per Trawl	Buzzards Bay	Spring	136	0.505	0.02
Atlantic Cod per Trawl	Cape Cod Bay	Spring	-111	0.406	0.05
Silver Hake per Trawl	Cape Cod Bay	Spring	16	0.582	0.01
Winter Flounder per Trawl	Cape Cod Bay	Spring	5	0.131	0.30
Bay Anchovy per Trawl	Buzzards Bay	Fall	258	0.088	0.40
Butterfish per Trawl	Buzzards Bay	Fall	44	0.021	0.69
Scup per Trawl	Buzzards Bay	Fall	595	0.197	0.20
Longfin Squid per Trawl	Cape Cod Bay	Fall	29	0.041	0.58
Winter Flounder per Trawl	Cape Cod Bay	Fall	4	0.044	0.56
Butterfish per Trawl	Cape Cod Bay	Fall	-56	0.275	0.12
Biomass					
Biomass per Trawl Station					
	Buzzards Bay	Spring	48	0.441	0.04
	Buzzards Bay	Fall	13	0.334	0.08
	Cape Cod Bay	Spring	3	0.079	0.43
	Cape Cod Bay	Fall	-51	0.181	0.22
Fish Size					
Total Biomass per Individual					
	Buzzards Bay	Spring	0.007	0.068	0.47
	Buzzards Bay	Fall	0.001	0.028	0.65
	Cape Cod Bay	Spring	0.006	0.062	0.49
	Cape Cod Bay	Fall	-0.031	0.239	0.15
Average Weight Atlantic Herring	Buzzards Bay	Spring	0.000	1.000	0.00
Average Weight Black Sea Bass	Buzzards Bay	Spring	-0.001	0.000	0.98
Average Weight Scup	Buzzards Bay	Spring	-0.002	0.005	0.85
Average Weight Longfin Squid	Buzzards Bay	Spring	-0.002	0.017	0.72
Average Weight Butterfish	Buzzards Bay	Spring	-0.002	0.021	0.69
Average Weight Atlantic Cod	Cape Cod Bay	Spring	0.000	0.032	0.62

	Basin	Season	Regression Slope	R ²	p-value
Average Weight Silver Hake	Cape Cod Bay	Spring	0.005	0.167	0.24
Average Weight Winter Flounder	Cape Cod Bay	Spring	-0.004	0.095	0.39
Average Weight Northern Sand Lance	Cape Cod Bay	Spring	0.000	0.145	0.41
Average Weight Alewife	Cape Cod Bay	Spring	0.002	0.214	0.18
Average Weight Scup	Buzzards Bay	Fall	0.0008	0.016	0.73
Average Weight Bay Anchovy	Buzzards Bay	Fall	0.0001	0.509	0.02
Average Weight Butterfish	Buzzards Bay	Fall	0.0003	0.002	0.90
Average Weight Black Sea Bass	Buzzards Bay	Fall	0.0043	0.046	0.55
Average Weight Longfin Squid	Buzzards Bay	Fall	0.0014	0.452	0.03
Average Weight Longfin Squid	Cape Cod Bay	Fall	-0.0001	0.026	0.65
Average Weight Butterfish	Cape Cod Bay	Fall	0.0016	0.302	0.10
Average Weight Winter Flounder	Cape Cod Bay	Fall	0.0048	0.110	0.35
Average Weight Spiny Dogfish	Cape Cod Bay	Fall	0.0646	0.332	0.08
Average Weight Silver Hake	Cape Cod Bay	Fall	0.0065	0.391	0.05