OCS Study
BOEM 2021-036

New York Bight Fish, Fisheries, and Sand Features: Data Review
Volume 2: Data Synthesis and Analysis

US Department of the Interior
Bureau of Ocean Energy Management
Headquarters (Sterling, VA)

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DISCLAIMER

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REPORT AVAILABILITY

To download a PDF file of this report, go to the US Department of the Interior, Bureau of Ocean Energy Management Data and Information Systems webpage (http://www.boem.gov/Environmental-Studies-EnvData/), click on the link for the Environmental Studies Program Information System (ESPIS), and search on 2021-036. The report is also available at the National Technical Reports Library at https://ntrl.ntis.gov/NTRL/.

CITATION

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ABOUT THE COVER

Contents of a trawl aboard the commercial trawler *FV Viking II* during a study on bycatch along a shoreface sand ridge off Little Egg Inlet, New Jersey. Clearnose Skate, Windowpane Flounder, clams, Channeled Whelk, and Atlantic Horseshoe Crab represent resources that utilize sand habitat in this area.

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Phil Politis and Paul Kostovick manage and provided access to the NEFSC trawl surveys. Kevin Hassell, Lindy Barry, Jeffrey Brust, and Joe Ciminio, and Gregory Kinks of the New Jersey Department of Environmental Protection, Bureau of Marine Fisheries manage and provided access to the clam and Ocean Stock Assessment survey data. Thomas Ertle, Miranda Rosen, and Margaret Shaw helped extract data from literature to provide the guild classifications and trophic crosswalk tables.

Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

ACCSP	Atlantic Coastal Cooperative Statistics Program
ASMFC	Atlantic States Marine Fisheries Commission
BOEM	Bureau of Ocean Energy Management
CC1	canonical component 1
CC2	canonical component 2
CCA	canonical correspondence analysis
CF	Climate-Forecast
CPUE	catch-per-unit-effort
CSV	comma-separated values
CTD	conductivity, temperature, depth
DOI	Department of the Interior
EFH	essential fish habitat
ERDDAP	An information technology platform name following an obsolete acronym
FGDC	Federal Geographic Data Committee
FOO	frequency of occurrence
FVTR	Fishing Vessel Trip Report
GARSA	Greater Atlantic Region Statistical Areas
GUI	graphic user interface
ISO	International Organization for Standardization
MAB	Mid-Atlantic Bight
MARCO	Mid-Atlantic Regional Council on the Ocean
MMIS	Marine Minerals Information System
MMP	Marine Minerals Program
MSA	Magnuson-Stevens Act
NEFSC	Northeast Fisheries Science Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NJDEP	New Jersey Department of Environmental Protection
NYB	New York Bight
OCS	Outer Continental Shelf
PC1	principal component 1
PC2	principal component 2
PCA	principal components analysis
RSS	Really Simple Syndication (data feed subscription)
SMAST	University of Massachusetts Dartmouth School of Marine Science and Technology
US	United States
USGS	United States Geological Survey
VMS	Vessel Monitoring System
VTR	Vessel Trip Report

1 Introduction

1.1 Statement of Need

The Bureau of Ocean Energy Management (BOEM) is receiving increased interest in Outer Continental Shelf (OCS) sand resources for shore protection, beach and wetland restoration, and construction projects. Worldwide, sand and mineral aggregates are the second most exploited natural resource behind water, and expected demand far outpaces supply (United Nations Environmental Programme 2015). Sand includes aggregates of differing chemical composition, shape, grain size, fracture angle, and sorting, and not all sand is suitable for all tasks that require sand (Owen 2017).

Sand is an important habitat for many benthic organisms. Sand is indirectly linked to epibenthic and pelagic organisms through food web dynamics. Sand provides temporary refuge from predators or other adverse conditions, and facilitates ambush predation (Byrnes et al. 2004; Diaz et al. 2003; Diaz et al. 2004; Mahon et al. 1998; Vasslides and Able 2008; Walsh et al. 2006). Yet, details about the mechanisms, scale, and specificity of dependency on sand for fishes is not well documented, including for the Northeast Large Marine Ecosystem, the seafloor of which is dominated by soft unconsolidated substrate.

In recognition of the importance of specific habitats in the completion of life cycles for fishes and key invertebrates, the habitat of managed fish species is under legal protection by the Magnuson-Stevens Fishery Conservation and Management Act (also referenced as Magnuson-Stevens Act, or MSA, 16 U.S.C. 1801 et seq.). The 1996 amendment to the MSA requires the identification, description, and designation of essential fish habitat (EFH), which is inclusive of managed and commercially important invertebrates. EFH, the “waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity,” is identified so that it can be managed and protected from other activities.

Sand substrate may be an important character of habitat. For marine species, the value of sand as habitat can change with its environmental, temporal, and ontological context. For example, migrant species of fish that rely on sand substrate on the coast are not there throughout the year, and some even migrate inland to freshwater (Able and Fahay 1998; 2010; Collette and Klein-MacPhee 2002). Fishes with adaptations to unconsolidated benthic habitat, such as having chemosensitive barbels or fin elements for probing sand, are common along the US East coast. However, ecology along this stretch responds to marked regional differences in climatic, oceanographic, geologic, and bathymetric character, and in the nature of anthropogenic pressure. Intra-regional structuring of fish habitat use and seasonal distribution, such as estuarine entry or shoal occupation and range extent, has influenced geopolitical and cultural boundaries, such as the growth and character of historical fisheries-based communities (Hardin 1960; Kunzig 1995; Safina 1990).

There is limited definitive information on ecological function and biological significance of sand features in the Mid-Atlantic region and the New York Bight (NYB). The extraction of sand potentially conflicts with healthy functioning and continuation of marine ecosystems and fisheries. Considerations of the potential impacts of sand dredging and transport to shore include cumulative impacts, space/use conflicts with fisheries extraction, and EFH conflicts.

1.2 Understanding Extraction as Perturbation

Sand resource extraction, or dredging, removes sand substrate and infauna, produces turbidity plumes, and changes bathymetric contours (Pickens et al. 2020). Contours and texture (i.e., bottom roughness) influence topographic steering including upwelling (Dalyander et al. 2013; Glenn et al. 2004), see reviews by Michel et al. (2013), Pickens et al. (2020), and Wenger et al. (2017). When sand is extracted, damage to the community that depends on it is expected through removal or screening of infauna, exposure to hypoxic sediment horizons and thinning of the oxygenated sediment layer suitable as habitat, resorting of sediment sizes appropriate for different infauna, burial of epibenthic fauna and fish eggs from sediment plumes, clogging of fish gills, behavioral response such as movement, and the consequent depletion of infaunal prey and their trophic transfer to fishes (Nairn et al. 2004; Pickens et al. 2020; United States Army Corps of Engineers 2015). However, similar to the case for natural disturbances, such communities should be expected to recover (see review by Nairn et al. (2004) and Waye-Barker et al. (2015)). Recovery can vary in mechanism, timing, or trajectory following a successional dynamic and relative to the type of extraction equipment, substrate, and location (Grassle and Sanders 1973; Pickens et al. 2020). These disturbances occur within a background of diurnal and seasonal photoperiod and production cycles, upwelling, seasonal and advective temperature changes, storms, disease and predation dynamics, migrations, and successional community dynamics that introduce natural variability in the system. Sand resource extraction may emulate aspects of other anthropogenic disturbances such as bottom trawling or clam suction harvest or scallop dredging (Sullivan et al. 2003). Disturbance, defined as “any discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment” (Pickett and White 1985) or more generally and unbiased, perturbation, is an important ecological structuring mechanism. It is particularly important as a driver of diversity through interruption of community succession by the suppression of otherwise dominant species (Grassle and Sanders 1973; Hardin 1960). This data synthesis focuses on a contextual view of spatial and temporal dynamics as perturbations that influence fish and macro invertebrate production and distribution in the NYB.

1.3 Purpose

The purpose of this report is to twofold: 1) compile and 2) analyze available data. Compilation gathers and serves data to facilitate assessments of lease requests for dredging at specific times and areas. Analysis examines latent and canonical habitat and fish distribution trends, as well as commercial and recreational fishing activity, to formulate a baseline understanding of spatial temporal dynamics from which predictions can be made and perturbations understood.

1.4 Report Structure

This report is a companion volume to **New York Bight Fish, Fisheries, and Sand Features: Data Review, Volume 1: Literature Synthesis and Knowledge Gaps**. Redundancy in the Introduction and Geographic definition sections provide continuity with that volume while providing information that allows this report to be read as a stand-alone document. Following those sections, sections are delineated as semi-independent but cohesive tasks: 1) data inventory; 2) data parsing and serving; 3) examination of latent trends in habitat and fish, scallop, and clam distribution; 4) examination of canonical trends, i.e., fish distribution correlated with spatial and temporal habitat trends and their relative explanatory power as perturbations; 5) autecological trends for important species; 6) analysis of fishing data in the study area; 7) a predator/prey crosstab; and 8) general conclusions. The specific purpose, methods, and results of each task are provided in their respective sections.

2 Geographic Definition

For this study, the NYB is a region geographically defined on the west and north by the bowed US coastline and to the east and south as a line drawn between Block Island, RI, and Cape Henlopen, DE (**Figure 1**). The apex of the NYB is the entrance to the Hudson River estuary. The Hudson River's historical channel continues across the apex of the NYB as the submarine Hudson Shelf Valley (Beardsley and Boicourt 1981; Castelao et al. 2010; Chen 2018; Chen et al. 2018; Epifanio and Garvine 2001) with important influence on the regional benthic structure and circulation, and therefore on composition of fish and invertebrate communities and on fisheries. The NYB and its apex are concentric with the broader Mid-Atlantic Bight (MAB) defined from Cape Cod, MA, to Cape Hatteras, NC. The NYB must be understood within the context of the MAB's features. However, the geomorphology differs and, despite a MAB-wide circulation driver, a strong zonal temperature cline shapes ecological communities and dynamics of the NYB relative to the MAB (see **Volume 1: Literature Synthesis and Knowledge Gaps**).

Due to technological constraints, sand extraction normally occurs in depths of 30 m (98 ft) or less. This study area extends to 50 m (164 ft) to encompass a buffer should technology advance dredging into deeper waters. This depth corresponds to an offshore distance of about 16.7 km (9 nm). The study region is bounded shoreward by Federal jurisdiction beginning at 3 nm (**Figure 1**). This area focuses the synthesis. Select data collected in adjacent State waters were reviewed for comparison.

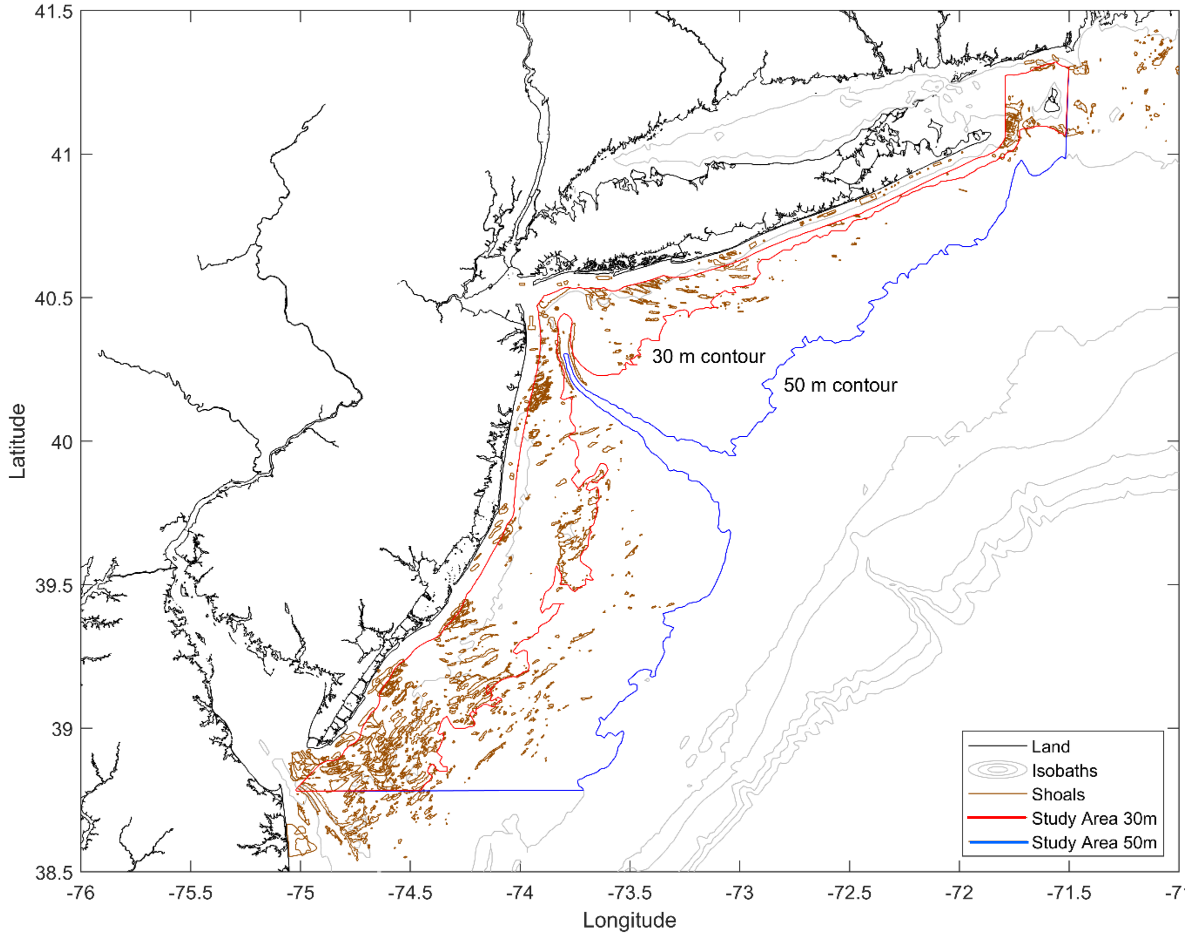


Figure 1. BOEM marine minerals study area in the NYB

Shoals depicted in this feature class include both identified sand resource and modeled shoals. Sand resources were characterized from data collected during various reconnaissance- and design-level studies where geological (e.g., sediment cores, sediment profile images, etc.) and geophysical (e.g., high-resolution swath bathymetry, side-scan sonar, seismic reflection profiles, magnetometer surveys) data were collected, at least in part, to evaluate OCS sand resources. Delineations mainly consist of approximate delineations based on interpretations of data, drawings, and or descriptions found in related study reports. Sand resource polygons were provided by BOEM in ArcGIS shapefile format and follow-up discussions were made with Marine Minerals Program (MMP) scientists to assign the evaluation stage associated with each polygon in regards to the presence of restoration quality sand and gravel. The most current version of this dataset can be downloaded via the Marine Minerals Information System (MMIS) viewer at https://mmis.doi.gov/boemmmis/. The modeled shoals feature class fall within US Federal waters seaward of the US Submerged Lands Act Boundary (3 nmi in the NYB) to a depth of 50 m in the Gulf of Mexico and Atlantic Ocean. Much of the attribution comes from the Coastal and Marine Ecological Classification Standard (https://www.cmecscatalog.org/cmecs/). The modeled shoals data set is available https://portal.midatlanticocean.org/data-catalog/maritime-industries/#layer-info-modeled-shoals-in-federal-waters4552

3 Data Synthesis

3.1 Data Inventory and Metadata

3.1.1 Purpose

To quickly identify what data sets are available in terms of factors, species and their spatial and temporal spans, quality estimators, format, storage size, and origin. The inventory tabulation provides a way to make quick assessments of whether data is readily available to address specific questions on future assessments.

3.1.2 Method

Data were gathered from sources at Rutgers University, BOEM, Mid-Atlantic Regional Council on the Ocean (MARCO), MMIS, New Jersey Department of Environmental Protection (NJDEP), and National Marine Fisheries Service (NMFS); data was also extracted from printed tables in peer-reviewed literature. Much of the data is gathered on an ERDDAP (a name based on a historical but obsolete acronym) server (https://nybsand.marine.rutgers.edu/erddap/index.html). ERDDAP was built by the National Oceanographic and Atmospheric Administration (NOAA) for projects such as this one and is hosted by Rutgers University (see https://nybsand.marine.rutgers.edu/erddap/information.html for additional information).

ERDDAP also "passes" some large data sets that are already served elsewhere. This ensures that updates at the source sites are served.

Data are served by ERDDAP through two simple landing pages—one for "griddap" format data products such as gridded bathymetric and sediment charts, and one for "tabledap" format data products, such as point time series or trajectory data, which are fundamentally described in terms of unstructured geospatial coordinates and an observation value. ERDDAP standardizes times and geospatial coordinate information so that all data sets can be searched and downloaded using consistent code that requires only a change to the ERDDAP data set URL pointing to a particular data collection. ERDDAP provides graphic user interface (GUI) tools (e.g., slider bars, drop downs, dialog boxes) for parsing, filtering, combining, mapping, and exporting data (**Figure 2**).

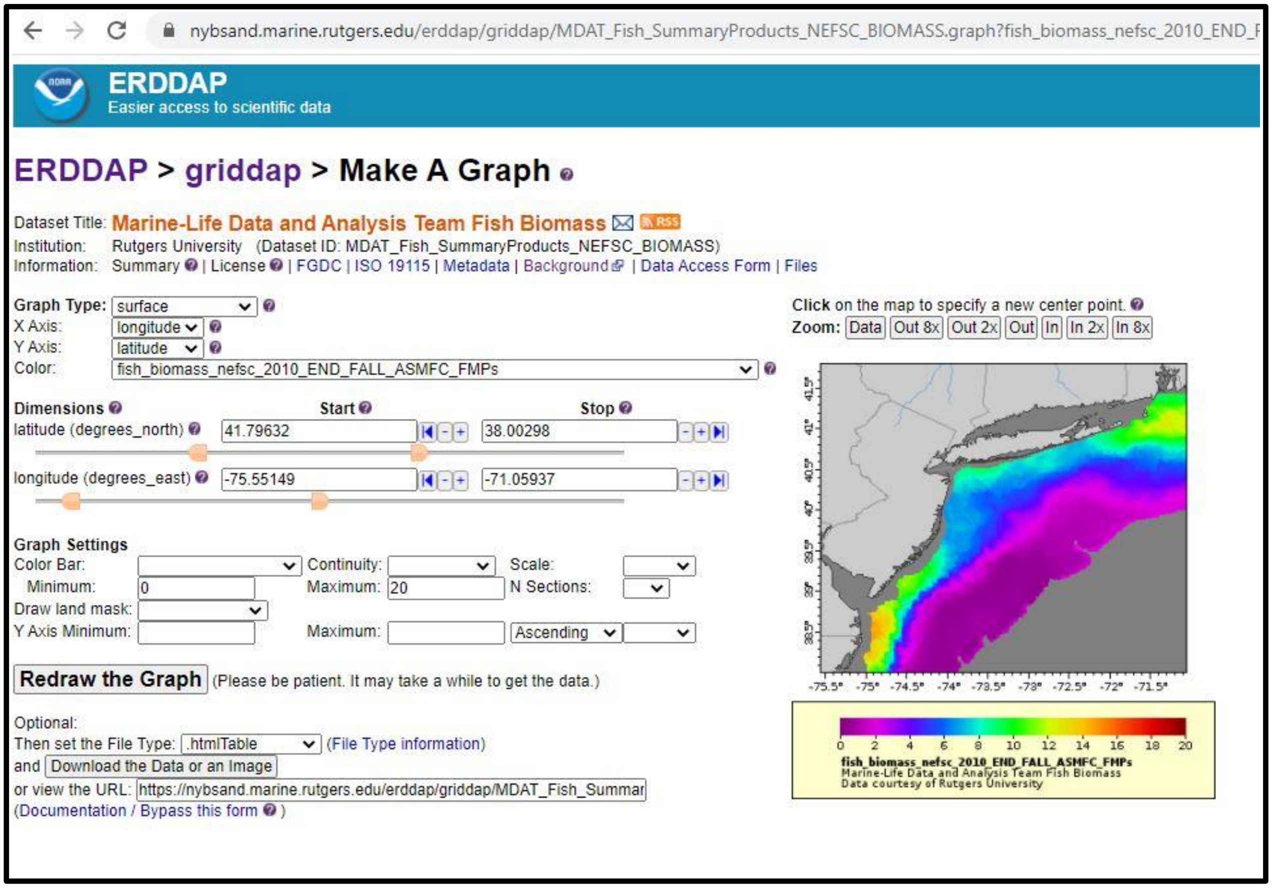


Figure 2. ERDDAP user interface

A screen grab of the project ERDDAP shows a map output of the Marine-Life Data and Analysis Team Fish Biomass, limited to an area similar to the study area by means of the GUI sliders, with the color scale set by dialog box input to maximize discernment at the local scale. Click boxes for choices on downloading data format (here .html) or generating a URL specific to the selected parameter settings for use in coding are also shown. The map itself can also manipulated by GUI or downloaded in many formats. A similar page assists with parsing and downloading the underlying data.

Data extracted from ERDDAP services can be delivered in a wide variety of file types, including simple ASCII or comma-separated values (CSV) formats for spreadsheets. A few of the types relevant to this project are noted in **Table 1**.

Table 1. Some ERDDAP data extraction formats

Data file type	Description
.asc	Download as OPeNDAP-style ISO-8859-1 comma-separated text
.csv	Download as ISO-8859-1 comma-separated text table
.esriAscii	Download as ISO-8859-1 ESRI ASCII file
.fgdc	View the dataset's UTF-8 FGDC .xml metadata
.htmlTable	View a UTF-8 .html web page with the data in a table
.json	View a table-like UTF-8 JSON file (suitable for web page applications)
.mat	Download a MATLAB binary file
.nc	Download a NetCDF-3 binary file with COARDS/CF/ACDD metadata (readable in ArcGIS 10+, R, Python, etc.)

Data served by ERDDAP do not need to be downloaded but can instead be accessed directly by programs such as MATLAB or Java through RESTful Web Services (see https://nybsand.marine.rutgers.edu/erddap/rest.html) by including URLS in the code.

ERDDAP also serves metadata. Variable names and metadata descriptions follow community best practice, e.g., by assigning variable names from the glossary of agreed-upon standard_name attributes in the Climate-Forecast (CF) Conventions and adding all Federal Geographic Data Committee (FGDC) metadata as required.

The ERDDAP inventory is also exported to hard disk and delivered to BOEM MMP as a product of this data synthesis. Additional data not well served by ERDDAP (e.g., data that cannot be gridded or tabulated) is linked to a repository within the ERDDAP landing page. The identity, location, and metadata for any data that is not well served by the ERDDAP is provided in the output table.

Password protection is provided for ERDDAP access to the State and Federal trawl and clam stock assessment surveys in accordance with the terms of use.

Instructions on how to use the ERDDAP are provided as a video at https://www.youtube.com/watch?v=18xZoXu1USM.

3.1.3 Products

There are 30 data sets served through the project ERDDAP (**Table 2**), including some that are already posted on other servers. Additional data available through MARCO, which itself mirrors the BOEM Marine Cadastre (https://marinecadastre.gov/) and the National Centers for Environmental Information server (https://www.ncei.noaa.gov/) could be useful to assessments of sand features as fish habitat but are not mirrored on the ERDDAP. They are listed in **Table 3**. Some maps are plotted as image (*.png) files in MARCO for data that are not downloadable but can be queried through the server app.

Table 2. List of all data sets served by the NYB Sand ERDDAP
Additional columns (not shown for fit) include linked names of the source institution, a link to subscribe to the Really Simple Syndication (RSS) feed, and a linked email address for the responsible person for each data set. The link to background includes data on the history and conventions used for ingesting the data to the ERDDAP. A “yes” in the Accessible column indicates that a user is logged on with permission to a password restricted data set.

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	Web Map Service	Source Data Files	Acces-sible	Title	FGDC, ISO, Metadata	Back-ground Info	Dataset ID
-	set	data	graph	-	-	public	* The List of All Active Datasets in this ERDDAP *	M	background	allDatasets
-	set	data	graph	-	-	public	Compiled Benthic Invertebrate Surveys	F I M	background	Benthic_Surveys
-	set	data	graph	-	files	public	ECOMON CTD data	F I M	background	ECOMON_CTD_DATA
data	-	-	graph	M	files	public	Marine-Life Data and Analysis Team Fish Biomass	F I M	background	MDAT_Fish_SummaryProducts_NEFSC_BIOMASS
data	-	-	graph	M	files	public	Marine-Life Data and Analysis Team Fish Species Core Biomass	F I M	background	MDAT_Fish_SummaryProducts_NEFSC_COREBIOMASS
data	-	-	graph	M	files	public	Marine-Life Data and Analysis Team Fish Species Richness	F I M	background	MDAT_Fish_SummaryProducts_NEFSC_RICHNESS
-	-	data	graph	-	-	public	Median of wave-current bottom shear stress in the Mid-Atlantic Bight	F I M	background	MAB_median_bottom_stress
-	set	data	graph	-	-	yes	Mid-Atlantic Bight Wreck position information	F I M	background	WRECK_COORDS
-	-	data	graph	-	-	public	Northeast Fisheries Science Center (NEFSC) Resource Survey Report Atlantic Surfclam/Ocean: 3 August - 15 August 2018	F I M	background	NEFSC_CLAM_SURVEY
-	-	data	graph	-	-	public	NEFSC Sea Scallop Biomass	F I M	background	NEFSC_SCALLOP
-	set	data	graph	-	-	yes	NJDEP Ocean Stock Assessment	F I M	background	NJDEP_trawl_surveys
-	set	data	graph	-	-	yes	NJDEP Clam Survey	F I M	background	NJDEP_CLAMSURVEY
data	-	-	graph	-	-	public	NEFSC "Fish Species Through Time" Trawl Dataset	F I M	background	NEFSC_FISH_SPECIES_THROUGH_TIME

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	Web Map Service	Source Data Files	Acces-sible	Title	FGDC, ISO, Metadata	Back-ground Info	Dataset ID
data	-	-	graph	M	files	public	Normalized Avian Abundance: Crustacean Eaters	F I M	background	Avian_Abundance_Crustacean_Eaters
data	-	-	graph	M	files	public	Normalized Avian Abundance: Fish Eaters	F I M	background	Avian_Abundance_Fish_Eaters
data	-	-	graph	M	files	public	Normalized Avian Core Abundance: Crustacean Eaters	F I M	background	Avian_CoreAbund__MAB_Crustacean_Eaters
data	-	-	graph	M	files	public	Normalized Avian Core Abundance: Fish Eaters	F I M	background	Avian_CoreAbund__MAB_Fish_Eaters
data	-	-	graph	M	files	public	Normalized Avian Richness: Crustacean Eaters	F I M	background	Avian_Richness_Crustacean_Eaters
data	-	-	graph	M	files	public	Normalized Avian Richness: Fish Eaters	F I M	background	Avian_Richness_Fish_Eaters
-	set	data	graph	-	-	yes	NEFSC Fall Bottom Trawl Survey	F I M	background	NEFSC_BOTTOM_TRAWL_FALL
-	set	data	graph	-	-	yes	NEFSC Spring Bottom Trawl Survey	F I M	background	NEFSC_BOTTOM_TRAWL_SPRING
-	set	data	graph	-	-	yes	NEFSC Summer Bottom Trawl Survey	F I M	background	NEFSC_BOTTOM_TRAWL_SUMMER
-	set	data	graph	-	-	yes	NEFSC Winter Bottom Trawl Survey	F I M	background	NEFSC_BOTTOM_TRAWL_WINTER
-	-	data	graph	-	-	public	Northwest Atlantic Marine Ecoregional Assessment: Benthic Habitats	F I M	background	Benthic_HABITATS
-	-	data	graph	-	-	public	Percentage of time sediment is mobile for May, 2010, May, 2011 at select points in the MAB	F I M	background	MAB_mobility_percent
-	-	data	graph	-	-	public	Sea Scallops Abundance (SMAST)	F I M	background	SMAST_scallops
data	-	-	graph	M	files	public	Soft sediments by grain size (in mm)	F I M	background	Soft_Sediments_Size

Grid DAP Data	Sub-set	Table DAP Data	Make A Graph	Web Map Service	Source Data Files	Acces-sible	Title	FGDC, ISO, Metadata	Back-ground Info	Dataset ID
data	-	-	graph	M	-	public	Topography, ETOPO1, 0.0166667 degrees, Global (longitude -180 to 180), (Ice Sheet Surface)	F I M	background	etopo180
data	-	-	graph	M	-	public	Topography, NOAA Coastal Relief Model, 3 arc second, Vol. 1 (Atlantic Northeast)	F I M	background	usgsCeCrm1
data	-	-	graph	M	-	public	Topography, NOAA Coastal Relief Model, 3 arc second, Vol. 2 (Atlantic Southeast)	F I M	background	usgsCeCrm2

Table 3. Data available through MARCO not mirrored in ERDDAP

Information Type	Examples	Notes
Administrative	Marine Jurisdictions, Lease Blocks, National Park Service boundaries, NMFS Service regions, Submerged Lands Act boundary, Territorial Sea boundary	Digital maps
Fishing	Fathom lines, Statistical Areas, Management Areas, Commercial Fishing Vessel Monitoring System (VMS) and Vessel Trip Report (VTR), Party and charter recreational boat use areas, Recreational fishing reef expansion areas	VMS and VTR as *.lyr only and *.png; underlying data cannot be downloaded
Oceanography	Fronts probability by year and season, Net Primary Productivity by year and season, hurricane tracks	-

3.1.4 Trawl Survey Data Sets for Synthesis

Two standardized trawl surveys, the NEFSC trawl survey ("NEFSC survey") and the NJDEP Bureau of Marine Fisheries Ocean Stock Assessment survey ("NJDEP survey") have a history in the study area. Only the NEFSC survey covers the entire area, and it is the basis for much of the analysis in this report. The NJDEP survey provides important context and is treated briefly. Details for each are provided below. Data on clam distribution for suction dredge survey are treated separately.

3.1.4.1 NEFSC Trawl Survey

The NEFSC trawl survey dates to 1963, but important changes were made over the survey's history, most notably the change of vessel and net in 2008 and the addition of electronic data gathering and navigation, such as global positioning systems (Johnson and Sosebee 2014; Smith 2002). Advances in navigation electronics in particular led to greater precision in documenting trawl start and stop positions and therefore estimates of trawl swept area used to calculate catch-per-unit-effort (CPUE). Several changes were made to the protocol over its history. The trawl net used since 2008 is a 3-bridle, 4-seam survey bottom trawl rigged with a rockhopper sweep. The cod end mesh is 4.5 inches. Although there was a comparison made to the earlier net to adjust for catch rates (calibration coefficients) (Milliken and Fogarty 2009), these are not discussed here as only data from 2010 and later are used (see Section 3.2 Data Parsing). Catches evaluate relative abundance (not total abundance, since the net is not 100% efficient) and are comparable over time (Politis et al. 2014). The total survey area, from Gulf of Maine to Cape Lookout, South Carolina, and to depths greater than 200 m, is divided into depth and latitudinal strata. Sample number is assigned to each strata on an area-weighted basis and spatially randomized within that strata. Only samples within this study area are considered (see Section 3.2 Data parsing).

Conductivity, temperature, depth (CTD) sampling measured hydrographic data assigned to each trawl within the constraints that the CTD cast was made within 3 hours of the start of the trawl and within 3 nautical miles of the midpoint of the tow path (Politis et al. 2014). Tow paths are along-bathymetric contours. Each standard tow is 20 minutes from winch brake set to beginning of haulback at 3.0 kts speed-over-ground with wireout length set based on Standard NEFSC Scope Table (Politis et al. 2014). The NEFSC trawl survey is conducted only in Spring (March) and Fall (October) after summer and winter surveys were discontinued in 1999. Although the earlier winter and summer surveys are served on the ERDDAP, they are not analyzed here based on findings of temporal change (see Section 3.2 Data Parsing). Additional details are provided in Politis et al. (2014).

3.1.4.2 NJDEP Trawl Survey

New Jersey has conducted its own survey since 1988. The survey does not extend through the entire study area. Although the southern boundary is just slightly beyond that of the study area (east of Delaware), the study area is bounded northward at latitude 40.47775 (the apex of the NYB at the entrance to Hudson River estuary). The maximum depth extends only to 30 m. The survey samples approximately 186 stations per year in a random stratified design of 15 strata. Sampling takes place in five months (approximately 30 in January and 39 each April, June, August, and October). The net is a 30-m, 2-seam, 3-taper trawl. Forward netting is 12 cm (4.7 inches) stretch mesh, and rear netting is 8 cm (3.0 inches) and is lined with a 6.4 mm (0.25 inch) bar mesh liner. A 10-fathom groundwire with rubber cookies extends between the doors. The wooden doors were changed to steel doors and net monitoring acoustic gear was added in 2015. Trawls are 20 minutes from winch brake set to beginning of haulback at about 3 kts.

3.2 Data Parsing

3.2.1 Purpose

Parsing reduces the available trawl survey and related environmental data sets to subsets focused spatially on the NYB and constrained to depth of interest.

3.2.2 Method

A low-level pass of parsing fish distribution data for analysis is achieved by choice of NEFSC vs. NJDEP surveys because the (Federal) NEFSC survey does not extend into State waters (**Figures 3, 4**). However, the (State) NJDEP survey does extend into Federal waters. Many of the physical factor data sets do not have political boundaries. The study area was defined on the basis of proximity to the shoreline (3 nautical mile State waters line), a northern and southern extent by latitude, and an offshore extent on the basis of the 50-m contour. This shape was used to constrain the parsing of data sets that do not have bathymetry. In general, after the fish survey samples in the area were extracted, the [time, x, y] data was used to extract its match from environmental raster data, and that searched data does not need to be parsed first. Scripts (e.g., MATLAB) can remotely access the ERDDAP from any computer connected to the internet and execute the parse actions to retrieve the desired data as a comma separated variable (*.csv), raster, matlab (*.mat), ESRI, or other format file, with the exception of data sets that are password protected.

3.2.3 Results

The constraints set for the NEFSC survey data were:

Latitude = [38.78 41.5], Longitude = [-75.5 -71.5], maximum depth = 50 m. No minimum depth was set because shoal tops might be among the shallowest depths and are of specific interest. Temporal => 2010.

The initial temporal constraint was set at 2005 but was changed to March 1, 2010, (NEFSC Spring trawl survey) and October 1, 2010, or the NEFSC Fall survey based on analysis of latent trends (see Section 3.3 Latent Trends Quantification). Data were available for both surveys until annual survey completion for 2019 (10 years).

The NEFSC Spring trawl survey (2005–2019) provided a data set containing 631 samples. The NEFSC Fall trawl survey (2005–2016, 2018–2019) did not contain any samples in the study region from year 2017 due to mechanical problems with the survey vessel (*RV Henry B. Bigelow*). It contained 605 samples.

The time-constrained NEFSC Spring trawl survey (2010–2019) provided a data set containing 378 samples. (One of these samples was subsequently dropped because it contained none of the species of interest, see Section 3.3.3.3). The time-constrained Fall trawl survey (2010–2016, 2018–2019) parsing provided a data set containing 356 samples. A plot of the trawl centers for Spring and Fall time-constrained surveys relative to the study area and the State/Federal waters demarcation showed that 22 appeared to be in State waters but near the boundary (**Figure 3**); these were retained for analysis because they are still representative of trends in the study area.

Winter and Summer surveys contained only data between 1990 and 1995 and were not spatially representative of the study area. Furthermore, they sampled a period prior to a regime shift shown in long-term trend analysis (see Section 3.3.3.2) and may not be representative of current assemblages and/or distribution.

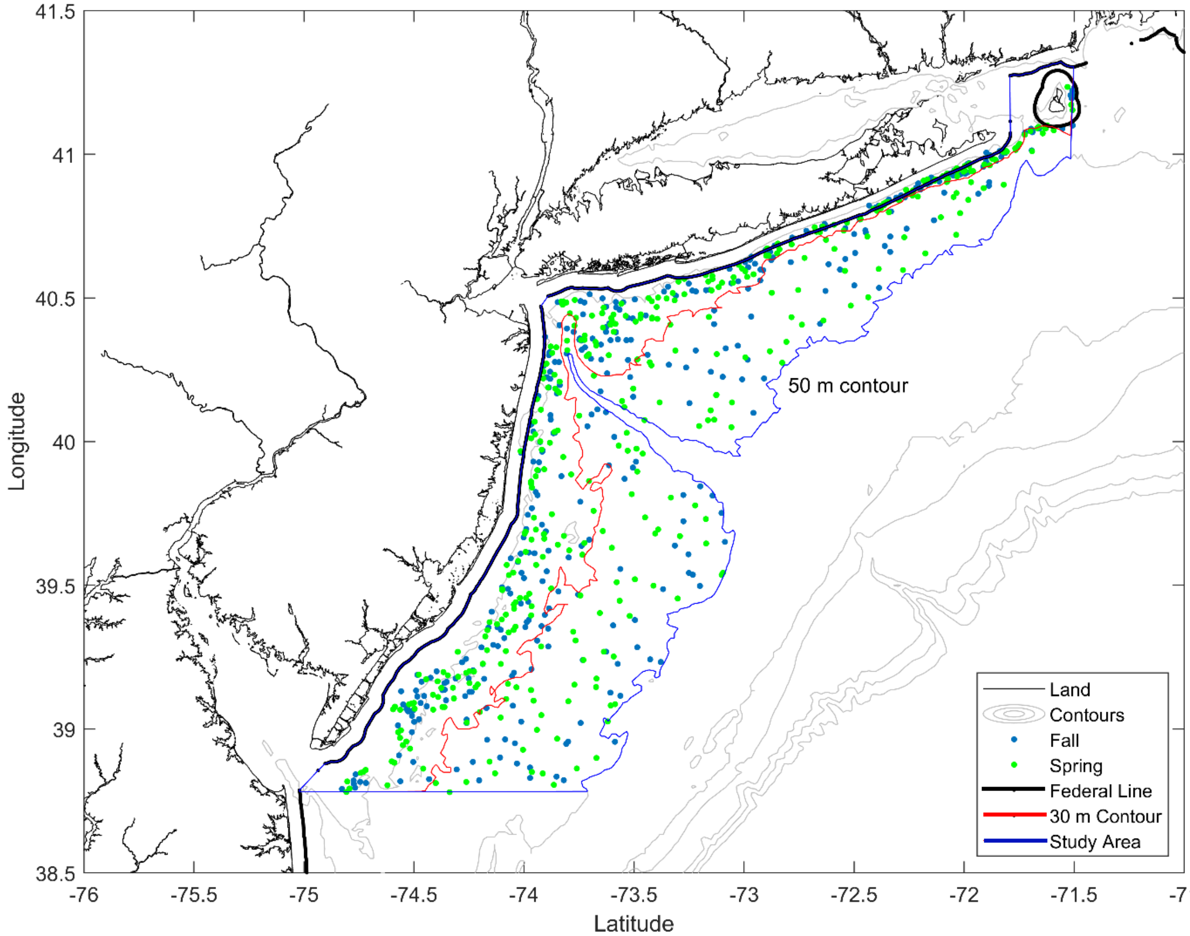


Figure 3. Plot of central trawl sample positions of the 50-m time-constrained Fall and Spring NEFSC trawl surveys relative to the State/Federal waters boundary line and the 50-m contour

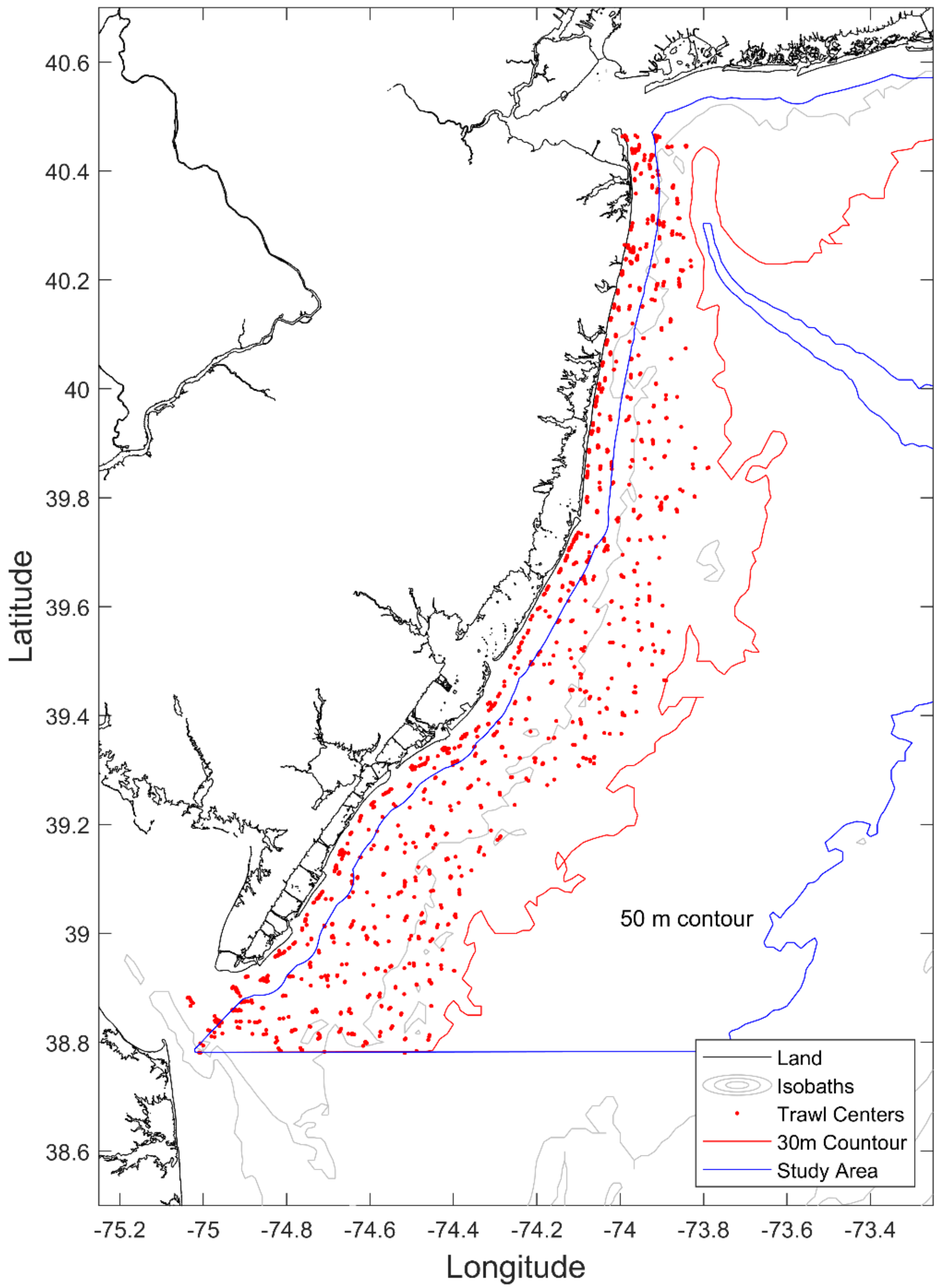


Figure 4. Plot of central trawl sample positions of the NJDEP Ocean Stock Assessment survey within the latitude bounds of the study area

3.2.4 Parsing Products

The spatial constraints were provided as two ESRI shapefiles, one bounded at the 30-m isobath and the other at the 50-m isobath (see **Figure 1**). The MATLAB scripts for data handling and graphing, including for following sections, were submitted as electronic file(s) (*.m) for use by BOEM. Parsed subsets are submitted on disk. Records for all species collected are retained in the parsed data set and contribute to calculations of richness, even if they were dropped from subsequent trends analysis.

3.3 Latent Trends Quantification

3.3.1 Purpose

Quantification and graphical presentation of latent trends provides an overall view of temporal and spatial fish and invertebrate distribution in the study area.

3.3.2 Method

Latent trends or patterns are the naturally observed distributions or groupings in space or time that are not constrained to be statistically related or ranked relative to any underlying environmental variables. They are important as the baseline to which variation explained by included factors (canonical variation) is compared. For example, two species that share a common modal temperature of occurrence will group together in a constrained ordination but might never actually co-occur in a habitat because of seasonal separation (one in Spring and one in Fall). In another example, a latent shift in sample similarity across years will warn of regime shifts that make earlier parts of the data less reliable for the assessment of current risk. Faunal (fish and invertebrate assemblages) were examined by principal component analysis (PCA), an iterative multiple regression based on co-occurrence in trawl samples. PCA reduces the dimensionality of many variables (species) and extracts and ranks the trends by strength of latent explained variance. Species were centered and standardized to unit variance. Minor (subsequent) axes in PCA can become trivial or redundant. Although this issue is very unlikely in species-rich data sets, Horn's Parallel Analysis test with 500 reshuffles and alpha = 0.05 was used to suggest retention (Ledesma and Valero-Mora 2007). Similarly, the trawl samples are grouped based on the species (and numbers thereof) that they share, which reveals habitat differences as voted on by fauna unbiased by what the observer has measured in terms of physical habitat variables. PCA was performed in Canoco 5 (ter Braak and Šmilauer 2012).

3.3.3 Results

3.3.3.1 Richness and Relative Abundance (NEFSC)

The initial Spring trawl survey data represented 92 species, while the initial Fall trawl survey data represented 167 species (**Table 4**). The union of the two sets represented 183 species. There were 76 species common to both surveys. There were 16 species unique to the Spring survey and 91 species unique to the Fall survey (**Table 4**).

3.3.3.1.1 A Note on Sand Lance Records

All sand lance collected in the NEFSC data set were identified as Northern Sand Lance (*Ammodytes dubius*) (species code 181). All sand lance collected in the NJDEP survey, which uses the same species code key, were identified as American Sand Lance (*A. americanus*), code 181 in the metadata (see Section 3.3.3.6). Codes 181 and 734 are reversed in the two keys. An email exchange with the respective listed point of contact affirmed the validity of these code-species assignments and catch.

Table 4. Abundance and frequency of occurrence for fish and invertebrate species collected in NEFSC trawl surveys in the study

Spp Code is the numerical code used by NOAA/NMFS (and also NJDEP) as a proxy for the species name. It is provided as a lookup reference for figures below and other literature. Abundance and frequency of occurrence (FOO) are shown separately for Spring and Fall, and Total of the time-constrained data set; species listed without those values occurred only previous to 2010. Species in **boldface** were included in PCA and canonical correspondence analysis (CCA) analysis (see Section 3.3.3.2 and further). Contribution Code classifies species for use in justifying inclusion in subsequent assemblage analysis (see Section 3.3.3.2). An important species may not be included in PCA/CCA because it is not well sampled by trawl (e.g., Surfclam). A = supports a substantial fishery in the MAB; B = supports a substantial fishery elsewhere or cumulative with the MAB, mutually exclusive with A; C = species of concern; D = important forage species; E = potential sand indicator species; F = not effectively sampled by trawl). Affiliation Guild refers to regional affiliation relative to the MAB as extracted from the literature (see companion Volume 1). Unclassified Taxa (Uncl.) could include several species with different ranges that were not classified.

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
13	**Smooth Dogfish**	B	5	6	348	1,792	35.3	1,798	Southern
15	**Spiny Dogfish**	A	397	19,263	79	878	47.6	20,141	Broad
19	**Bullnose Ray**	C	0	0	56	312	5.6	312	Broad
23	**Winter Skate**	A	303	3,027	122	2,580	42.5	5,607	Northern
24	**Clearnose Skate**	B	7	7	201	2,047	20.8	2,054	Southern
26	**Little Skate**	A	375	50,659	301	24,635	67.6	75,294	Southern
31	**Round Herring**	D	0	0	124	45,396	12.4	45,396	Broad
32	**Atlantic Herring**	AD	249	40,455	19	706	26.8	41,161	Northern
33	**Alewife**	B	176	5,553	1	1	17.7	5,554	MAB
34	**Blueback Herring**	B	137	1,397	4	6	14.1	1,403	MAB
36	**Atlantic Menhaden**	A	7	2,176	29	139	3.6	2,315	MAB
43	**Bay Anchovy**	D	3	33	98	14,322	10.1	14,355	Broad
44	**Striped Anchovy**	D	0	0	53	8,999	5.3	8,999	Southern
72	**Silver Hake**	A	280	55,580	179	12,176	45.9	67,756	Northern
74	**Haddock**	B	1	1	19	265	2	266	Northern
77	**Red Hake**	BE	171	1,079	37	393	20.8	1,472	MAB
78	**Spotted Hake**	BE	278	11,227	296	9,066	57.4	20,293	MAB
103	**Summer Flounder**	AE	212	834	304	3,459	51.6	4,293	MAB
104	**Fourspot Flounder**	B	53	346	163	1,423	21.6	1,769	Broad
105	**Yellowtail Flounder**	B	81	455	4	4	8.5	459	Northern
106	**Winter Flounder**	B	245	2,495	95	806	34	3,301	Northern
108	**Windowpane**	B	316	2,737	288	2,926	60.4	5,663	Northern

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
109	**Gulf Stream Flounder**	E	57	983	116	2,143	17.3	3,126	Broad
117	**Smallmouth Flounder**	E	45	308	30	178	7.5	486	Southern
121	**Atlantic Mackerel**	A	91	4,159	12	24	10.3	4,183	Northern
131	**Butterfish**	A	59	6,524	271	79,146	33	85,670	Northern
135	**Bluefish**	A	0	0	160	1,509	16	1,509	Broad
136	**Atlantic Croaker**	B	1	1	109	12,526	11	12,527	Southern
139	**Striped Bass**	A	45	281	6	233	5.1	514	MAB
141	**Black Sea Bass**	A	69	283	264	4,306	33.3	4,589	Southern
143	**Scup**	A	28	4,607	241	118,010	26.9	122,617	MAB
145	**Weakfish**	B	3	3	124	4,602	12.7	4,605	MAB
146	**Northern Kingfish**	B	0	0	82	632	8.2	632	MAB
149	**Spot**	B	0	0	71	14,833	7.1	14,833	Southern
171	**Northern Searobin**	B	187	2,305	288	67,632	47.5	69,937	MAB
172	**Striped Searobin**	B	20	62	214	2,308	23.4	2,370	MAB
181	**Northern Sand Lance**	D	50	550	23	289	7.3	839	Northern
193	**Ocean Pout**	C	123	647	11	19	13.4	666	Northern
196	**Northern Puffer**	B	0	0	135	1,366	13.5	1,366	Southern
197	**Goosefish**	A	57	124	25	47	8.2	171	Northern
211	**Round Scad**	D	0	0	38	253	3.8	253	Broad
212	**Rough Scad**	-	0	0	63	448	6.3	448	Southern
301	**American Lobster**	A	40	195	84	278	12.4	473	Northern
313	**Atlantic Rock Crab**	A	349	1,385	215	997	56.4	2,382	Northern
317	**Spider Crab Uncl.**		13	36	60	171	7.3	207	-
318	**Horseshoe Crab**	B	100	296	103	338	20.3	634	Broad
401	**Sea Scallop**	A	109	3,549	134	15,768	24.3	19,317	Northern
503	**Longfin Squid**	A	96	4,476	354	166,700	45	171,176	Northern
652	**Southern Kingfish**	B	0	0	14	404	1.4	404	Broad
794	**Etropus Uncl.**	E	151	1,140	101	745	25.2	1,885	-
2	Sea Lamprey	-	1	1	0	0	0.1	1	Northern

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
4	Roughtail Stingray	C	0	0	37	57	3.7	57	Broad
9	Sandbar Shark	CDF	0	0	2	2	0.2	2	Southern
12	Sand Tiger	CDF	0	0	1	1	0.1	1	Southern
16	Atlantic Angel Shark	C	0	0	4	4	0.4	4	Broad
18	Bluntnose Stingray	C	0	0	15	45	1.5	45	Southern
21	Atlantic Torpedo	C	0	0	0	0	0	0	Broad
22	Barndoor Skate	B	6	7	1	3	0.7	10	Northern
25	Rosette Skate	C	1	1	0	0	0.1	1	Southern
28	Thorny Skate	B	0	0	0	0	0	0	Northern
30	Herring Uncl.	-	0	0	0	0	0	0	-
35	American Shad	B	37	84	4	9	4.1	93	MAB
37	Hickory Shad	D	0	0	1	1	0.1	1	MAB
60	Eel Uncl.	-	0	0	0	0	0	0	-
63	Conger Eel	B	1	1	19	37	2	38	-
65	Margined Snake Eel	-	0	0	0	0	0	0	Southern
73	Atlantic Cod	B	28	43	0	0	2.8	43	Northern
75	Pollock	B	0	0	0	0	0	0	Northern
83	Fourbeard Rockling	-	0	0	2	6	0.2	6	Northern
87	Ling Uncl.	-	1	1	0	0	0.1	1	-
100	Pleuronectiformes	-	0	0	1	1	0.1	1	-
107	Witch Flounder	B	16	23	0	0	1.6	23	Northern
113	Atlantic Silverside	B	41	73	0	0	4.1	73	MAB
115	Threespine Stickleback	-	0	0	0	0	0	0	Northern
116	Northern Pipefish	-	5	5	0	0	0.5	5	MAB
118	Hogchoker	-	0	0	1	1	0.1	1	Southern
123	Bonito Atlantic	BF	0	0	1	1	0.1	1	Broad
124	Chub Mackerel	B	0	0	4	5	0.4	5	Southern
126	Atlantic Cutlassfish	-	0	0	5	7	0.5	7	Southern
129	Blue Runner	B	0	0	16	45	1.6	45	Broad

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
132	Atlantic Moonfish	-	0	0	61	107	6.1	107	Southern
133	Lookdown	-	0	0	0	0	0	0	-
134	Bigeye	-	0	0	0	0	0	0	-
142	Pigfish	-	0	0	0	0	0	0	Southern
147	Black Drum	B	0	0	0	0	0	0	Southern
148	Silver Perch	-	0	0	0	0	0	0	Southern
160	Sculpin Uncl.	-	0	0	0	0	0	0	-
163	Longhorn Sculpin	-	57	237	1	1	5.8	238	Northern
164	Sea Raven	-	40	54	12	16	5.2	70	Northern
166	Grubby	-	0	0	0	0	0	0	Northern
168	Lumpfish	-	0	0	0	0	0	0	-
170	Atlantic Seasnail	-	15	33	0	0	1.5	33	Northern
174	Searobin Uncl.	-	0	0	0	0	0	0	-
175	Flying Gurnard	-	0	0	3	5	0.3	5	Southern
176	Cunner	-	3	29	4	11	0.7	40	Northern
177	Tautog	A	4	7	9	11	1.3	18	Southern
179	Northern Stargazer	F	2	2	6	7	0.8	9	MAB
180	Rock Gunnel	-	0	0	0	0	0	0	Northern
187	Red Goatfish	-	0	0	8	13	0.8	13	Broad
188	Striped Cusk Eel	F	9	14	18	104	2.7	118	MAB
191	Wrymouth	-	1	1	1	2	0.2	3	Northern
195	Smooth Puffer	-	0	0	0	0	0	0	Broad
198	Striped Burrfish	-	0	0	3	7	0.3	7	Southern
201	Planehead Filefish	-	0	0	0	0	0	0	Southern
202	Gray Triggerfish	-	0	0	1	1	0.1	1	Southern
203	Greater Amberjack	F	0	0	0	0	0	0	-
204	Banded Rudderfish	F	0	0	4	4	0.4	4	Broad
205	Atlantic Saury	F	0	0	2	3	0.2	3	Northern
208	Mackerel Scad	-	0	0	0	0	0	0	-

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
209	Bigeye Scad	-	0	0	2	2	0.2	2	Southern
213	Silver Rag	-	0	0	0	0	0	0	-
249	Lumpfish Snailfish Uncl.	-	0	0	0	0	0	0	-
270	Cownose Ray	C	0	0	5	116	0.5	116	Broad
287	Sevenspine Bay Shrimp	-	2	4	0	0	0.2	4	Broad
296	Bristled Longbeak	-	5	13	1	1	0.6	14	Northern
305	Shrimp Uncl.	-	50	29	3	2	5.3	31	-
307	Shrimp Pink:Brown:White	-	2	1	2	37	0.4	38	-
311	Cancer Crab Uncl.	-	0	0	0	0	0	0	-
312	Jonah Crab	A	41	58	41	137	8.2	195	Broad
314	Blue Crab	B	4	4	18	28	2.2	32	Southern
316	Brown Rock Shrimp	-	0	0	0	0	0	0	-
319	Galatheid Uncl.	-	0	0	1	1	0.1	1	-
320	Swimming Crab Uncl.	-	0	0	2	2	0.2	2	-
321	Coarsehand Lady Crab	-	2	2	10	13	1.2	15	Southern
322	Lady Crab	-	9	19	32	74	4.1	93	Southern
323	Mantis Shrimp Uncl.	-	2	2	2	2	0.4	4	-
358	Tiger Shark	CF	0	0	1	1	0.1	1	Southern
375	Spiny Butterfly Ray	C	0	0	15	19	1.5	19	Southern
376	Smooth Butterfly Ray	C	0	0	0	0	0	0	Southern
380	Atlantic Sturgeon	C	3	4	1	1	0.4	5	Broad
390	Conger Eel Uncl.	-	7	7	8	9	1.5	16	-
403	Atlantic Surfclam	AF	9	82	2	3	1.1	85	Northern
421	Pipefish Seahorse Uncl.	-	12	15	8	9	2	24	-
425	Snake Eel Uncl.	-	1	1	0	0	0.1	1	-

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
428	Opisthonema Oglinum (Atlantic Thread Herring)	BD	0	0	19	131	1.9	131	Southern
429	Spanish Sardine	D	0	0	5	5	0.5	5	Southern
435	Inshore Lizardfish	-	0	0	40	114	4	114	Southern
439	Snakefish	-	0	0	1	4	0.1	4	Southern
458	Blotched Cusk Eel	-	1	1	3	3	0.4	4	Southern
461	Cusk Eel Uncl.	-	0	0	0	0	0	0	-
489	Red Cornetfish	-	0	0	0	0	0	0	Southern
490	Cornetfish Uncl.	-	0	0	30	39	3	39	-
492	Lined Seahorse	C	0	0	0	0	0	0	MAB
501	Squid: Cuttlefish: And Octopod Uncl.	-	0	0	1	1	0.1	1	-
502	Northern Shortfin Squid	A	0	0	10	53	1	53	Northern
504	Atlantic Brief Squid	-	0	0	0	0	0	0	-
506	Bobtail Uncl.	-	142	855	1	2	14.3	857	-
526	Bank Sea Bass	-	0	0	0	0	0	0	-
527	Rock Sea Bass	-	0	0	0	0	0	0	-
541	Gag	B	0	0	1	1	0.1	1	Southern
556	Glasseye Snapper	-	0	0	1	1	0.1	1	Southern
557	Short Bigeye	-	0	0	0	0	0	0	Broad
564	Sharksucker	-	0	0	1	1	0.1	1	Southern
567	Remora	-	0	0	0	0	0	0	-
570	Crevalle Jack	-	0	0	0	0	0	0	Southern
579	Florida Pompano	-	0	0	1	1	0.1	1	Southern
582	Jack Pompano Uncl.	-	0	0	0	0	0	0	-
584	Dolphnfish	B	0	0	1	1	0.1	1	Southern
620	Barracuda Uncl.	-	0	0	1	3	0.1	3	-
640	Pinfish	-	1	1	8	22	0.9	23	Southern
651	Banded Drum	-	0	0	1	1	0.1	1	Southern

Spp Code	Common Name	Contribution Code	Spring FOO	Spring Abundance	Fall FOO	Fall Abundance	Total FOO	Total Abundance	Affiliation Guild
657	Dwarf Goatfish	-	0	0	5	5	0.5	5	Southern
662	Spotfin Butterflyfish	-	0	0	1	1	0.1	1	Southern
694	Northern Sennet	-	0	0	16	31	1.6	31	Southern
699	Southern Stargazer	-	0	0	0	0	0	0	-
739	Goby Uncl.	-	0	0	0	0	0	0	-
743	Little Tunny	B	0	0	1	1	0.1	1	Southern
744	King Mackerel	B	0	0	1	2	0.1	2	Southern
745	Spanish Mackerel	B	0	0	5	6	0.5	6	Southern
770	Bighead Searobin	-	0	0	0	0	0	0	-
773	Righteye Flounder Uncl.	-	0	0	0	0	0	0	-
795	Lefteye Flounder Uncl.	-	0	0	0	0	0	0	-
820	Filefish And Triggerfish Uncl.	-	0	0	1	1	0.1	1	Southern
831	Unicorn Filefish	-	0	0	1	1	0.1	1	Southern
843	Marbled Puffer	-	0	0	3	3	0.3	3	Southern
851	Anchovy Uncl.	-	0	0	0	0	0	0	-
861	Puffer Uncl.	-	0	0	0	0	0	0	-
865	Silver Anchovy	-	0	0	1	1	0.1	1	MAB
866	Flounder Whiff Uncl.	-	0	0	0	0	0	0	-
877	Lesser Amberjack	-	0	0	0	0	0	0	Southern
913	Brown Shrimp	B	0	0	0	0	0	0	-
925	Thresher Shark	BF	0	0	0	0	0	0	Broad
950	Loggerhead Seaturtle	C	0	0	1	1	0.1	1	Broad

The FOO of species was inspected relative to the abundance of species (un-transformed) for the Spring and Fall surveys independently. In both cases, species that occurred infrequently also occurred in low abundance with many represented as singletons (**Table 4, Figure 5**). However, species that occurred frequently might still occur in relatively low abundance while others were abundant or hyperabundant. Schooling species of the larger herring group (clupeiforms) were a prime example such hyperabundant species. Notable large collections included those of Atlantic Herring in the Spring, Round Herring in the Fall, and Bay Anchovy in both seasons (**Table 4, Figure 5**).

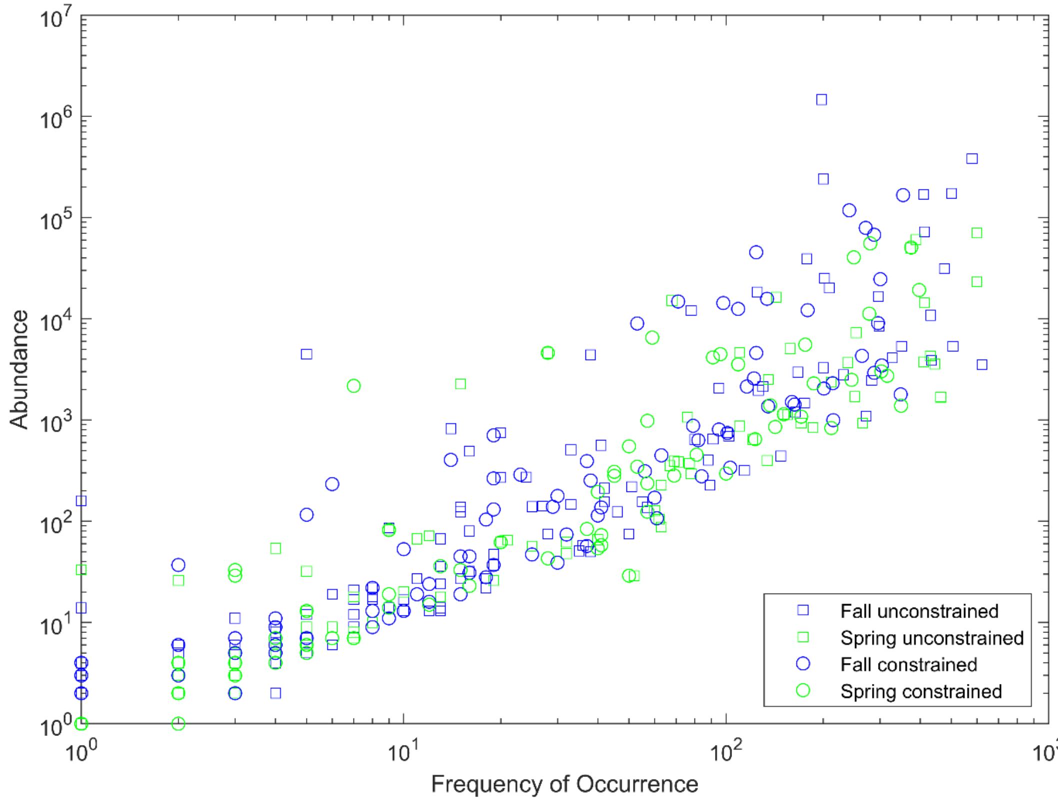


Figure 5. Individual species abundance relative to their frequency of occurrence in the initial data set

3.3.3.2 Trend in Fisheries Resource Contribution (NEFSC)

Managed species contributed roughly a third of the collected species with 61 managed (i.e., contribute to a fishery), 21 of which contribute importantly within the NYB or MAB (**Table 4,** see also Section 5 Fishing Activity Data). Trawl samples included nine species of concern, nine important forage species, and six potential indicators species based on life history traits, such as burial or chemosensory barbels. The set also included species that are not typically well sampled by bottom trawl, such as Little Tunny or Dolphinfish. These were excluded from further analysis even if they were economically or ecologically important.

Of 183 taxa, 56 were affiliated with southerly origin or spawning grounds, meaning that they recruited to the NYB as larvae or migrated into it during the warmer months (**Table 4**). Another 35 were affiliated with northerly spawning areas or retreated north during warmer months. The MAB delineates the bulk of the population for 20 taxa, even though penetrations regularly occur to the north (e.g., Massachusetts) or south (e.g., South Carolina). Another 25 are broadly distributed with ranges as wide as from Nova Scotia to Argentina. The remainder were either unknown or were not classified because they could include multiple species with different ranges.

3.3.3.3 Long-term Trend (NEFSC)

An initial PCA to inspect temporal trends used a partial species data set to prevent episodic occurrences of rare species from driving the ordination because there is little confidence that the true abundance of rare species distribution is represented by the survey. Species occurring less than 28 times (2 times a year on average) were removed. Additionally, episodically hyperabundant Atlantic Herring were removed to prevent them from driving the temporal ordination. The abundance of species retained for PCA was recalculated as CPUE as divided by the area swept by the trawl for the sample in which they were collected. Trawl swept area was not available until 2009 and was additionally missing for samples in other years. Missing swept area data were replaced by the seasonal mean for this analysis. CPUE was transformed as ln(CPUE+1). A separate Spring and Fall annual sample was then calculated as the mean transformed CPUE across all seasonal samples of that year and submitted for PCA.

In both Spring and Fall analyses, the first principal component, principal omponent 1 (PC1), explained 22% and 26% of the variance respectively. Sample score trend across time appeared to be a non-random trend (**Figure 6**). Sample scores were subjected to breakpoint analysis, which minimizes the sum of the residual squared error of the slope, mean standard deviation, or root mean square error, of each region from its local mean (MATLAB function findchangepoints.m). Breakpoint analysis using mean square deviation of score, mean score, and change of line slope and mean together all found two regions difference, cut between 2007 and 2009 (see **Appendix A** for plots of breakpoint analysis using linearity and mean). The change among score value after 2009 was more similar after 2010 and especially after 2016, but still dynamic. The variance was reflected in sum CPUE and was driven by a magnitude higher CPUE of several forage fish species. Regardless of whether this change reflected a change in sampling practice, fishing, or environment, it is clear that samples previous to 2009 represent a different condition than those in 2009 and after. Additionally, recording practices were changed in 2009, as reflected in the metadata. To allow any of these differences time to become well established and to constrain the data set to a manageable size and recent relevance, the data set was truncated prior to 2010 for further ordination analysis.

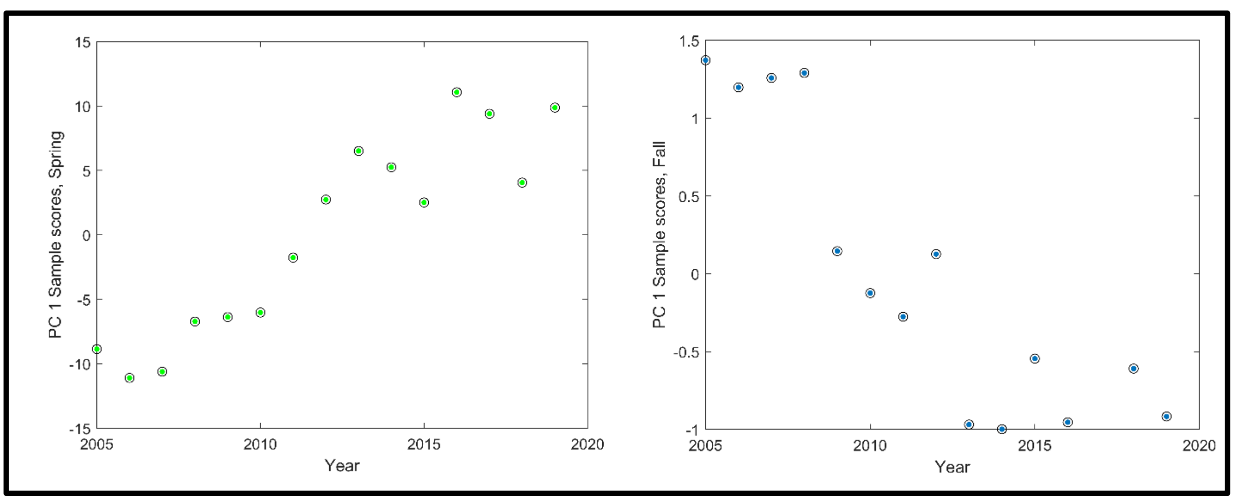


Figure 6. Long-term trend of first principal component axis scores for Spring (left) and Fall (right) NEFSC trawl samples

Following temporal parsing, species that were of no or low economic value in the MAB or elsewhere, as represented by a management plan, were excluded even if they were abundant (e.g., Bobtail) unless they were deemed to be indicator species for sand habitat based on close life history connections with substrate, such as burying or having chemosensitive feelers (see **Volume 1: Literature Synthesis and Knowledge Gaps**). Species uncommon in the trawl survey (Total FFO < 1.4 per year and Total Abundance < 200) were not included in assemblage analysis, but some were treated individually (e.g., Atlantic Surfclam, Ocean Quahog, Atlantic Sturgeon). The decision process is pictured in **Figure 7**. The effect of this on species representation is provided in **Table 2**. A single sample was eliminated as a result of having no species of interest.

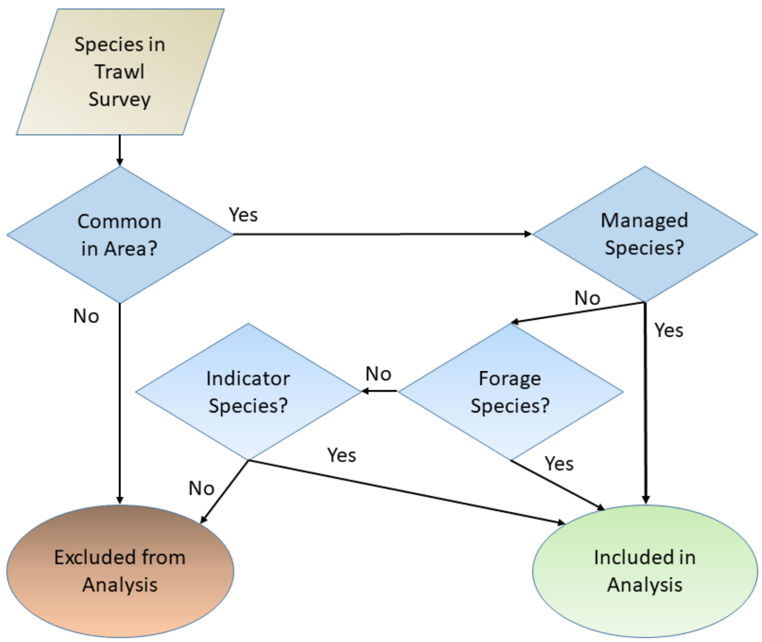


Figure 7. Decision tree for inclusion of species in assemblage analysis

3.3.3.4 Latent Assemblage Structure (NEFSC)

The time-constrained Spring trawl survey represented 75 species (**Table 2**). The time-constrained Fall trawl survey represented 127 species. The union of the two sets represented 137 species. There were 65 species common to both seasonal surveys. There were 10 species unique to the Spring survey and 62 species unique to the Fall survey.

Patterns for species FOO relative to the abundance were not substantially changed as a result of the parsing (**Figure 5**).

Analysis of the combined Spring and Fall samples (n = 733) yielded a total sum of squares in response data = 380.84050 and total standard deviation TAU (after centering/standardization) = 0.101938. The first principal component axis explained 26.2% of the variance. Additional explained variance levels off after the second principal component, with 8.7 % explained (**Table 5**). (Note: Trends are ranked by their strength, which is the percent of the total variance that each explains, also called the eigenvalue of that component. Thus, there is greater confidence in the projected position of samples along the first than second and successive components or axes.)

Parallel analysis suggested that all four computed principal components are non-trivial and could be retained. The first two are examined in detail. Scores for the 3rd and 4th are provided in **Appendix A**.

Table 5. Summary results of PCA of NEFSC trawl survey (2010–2019) Spring and Fall combined

Statistic	Axis 1	Axis 2	Axis 3	Axis 4	Total Variance
Eigenvalues	0.262	0.087	0.061	0.057	1.000
Cumulative percent variance	26.2	34.9	40.9	46.6	-

The first principal axis (PC1) clearly differentiated a seasonal (temporal) trend, and the overlap of similarity between Spring and Fall samples were largely resolved along the second mode of variation so that only about seven samples would be seasonally ambiguous on the basis of species content (**Figure 8**). This overlap and differentiation along the second, weaker axis owes to a spatial trend (see below).

Species differentiating Spring samples (Little Skate, Atlantic Herring, Spiny Dogfish, Winter Skate, Alewife, Blueback Herring, Winter Flounder, Red Hake, Silver Hake) were predominantly MAB or Northern origin guild species (**Figure 9**).

Consistent with the patterns in richness and unique species described in Section 3.3.3.1, there were more species differentiating Fall samples (Longfin Squid, Butterfish, Scup, Smooth Dogfish, Black Sea Bass, Striped Sea Robin, Clearnose Skate, Northern Puffer, Weakfish, Atlantic Croaker, Spot, Northern Kingfish, and others). These included members of Northern, Southern, MAB, Broad, and unknown origin guilds. Samples that overlapped were characterized by having relatively few fauna in general, so that the non-migratory Atlantic Sea Scallop, Gulf Stream Flounder, and Fourspot Flounder with MAB or Northern guild-affiliation were the strongest representatives.

American Lobster showed no trend, and Striped Bass, Northern Sand Lance, Smallmouth Flounder, Goosefish, Atlantic Mackerel, and Spotted Hake had relatively weak gradients in relative abundance (**Figure 9**). *Etropus* sp. flounders, Horseshoe Crab, and Windowpane did not trend strongly with season but also were not abundant in the samples that were similar among seasons. This may be interpreted as spatial segregation (see below and also canonical trends section). Coordinates (component scores) for all samples and species are provided in **Appendix A** along with values of fit for each species along each axis.

3.3.3.4.1 A Note on Interpreting PCA Biplots

Sample (individual trawl) scores (amplitudes along multivariate gradients of change or principal components, collectively coenospace) are plotted closer or further from each other in PCA plots based on the expected similarity of their catch (species composition) along a component axis (similar to the expected $\hat{y}$ position along a linear trend line of abundance but for many species at once). A particular species does not have to occur in a particular close sample at all. The expectation, a regression result, is calculated on the basis that fish that it commonly co-occurs with, or shares environment with, do occur in that sample. Fish are patchy even within their niche environments. The sign of the score (-/+ representing up or down) is arbitrary so that a flipped image of a biplot conveys the same information. Scores from the first two major trends (principal component 1 and 2, PC1 and PC2, respectively) are plotted against each other here, allowing sample similarity on two different uncorrelated trends to be viewed simultaneously. The trends in relative (centered and standardized) fish abundance (as CPUE) that account for sample similarity can be plotted as vectors over the samples; the place where a sample falls along the increasing direction of the species trends (shown by arrow direction) of the various species indicates the likelihood that those species typify that sample. It follows that species with opposing or orthogonal trends are not likely to co-occur in samples, or at least are few in samples where the other is abundant (and vice versa).

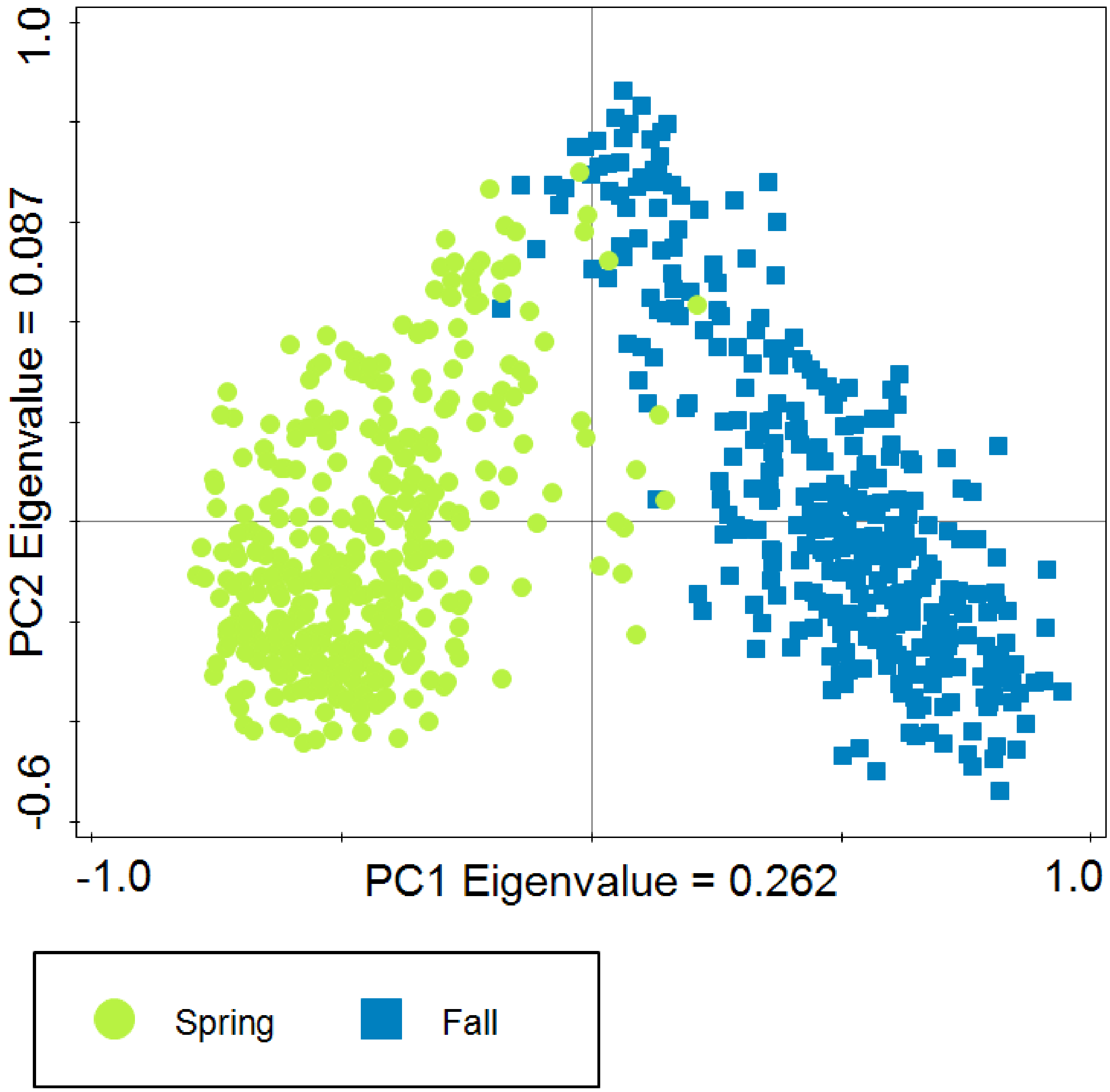


Figure 8. Scatter plot of NEFSC trawl survey sample similarity from PCA
Samples are from 2010–2019 Spring and Fall surveys and are in the same coenospace as the species plot (**Figure 9**). Samples in lower left are typified by species appearing in lower left of that figure. Separation of samples as accounted for by change in species composition (**Figure 9**) clearly differentiates a seasonal grouping along PC1, but not along PC2, indicating that species that plot opposite each other along the horizontal axes in **Figure 9** have a strong seasonal trend in abundance while those that differentiate along the vertical axes do not, and must therefore segregate in response to some other factor (including possibly each other's presence).

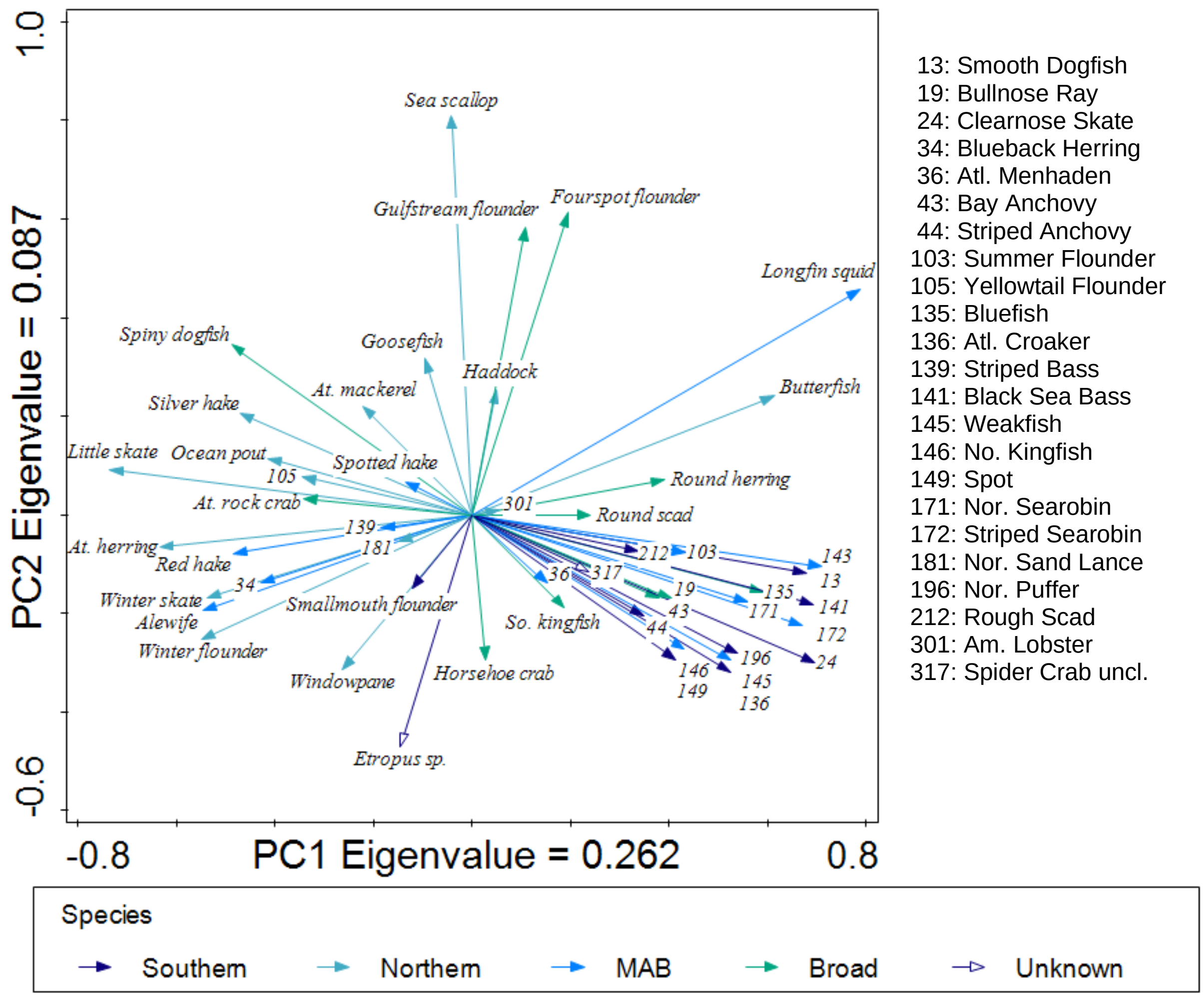


Figure 9. Species distribution through sample coenospace from PCA of both Spring and Fall
Analysis included samples from NEFSC Spring and Fall trawl survey, 2010–2019, shown in **Figure 8**. Vectors point in the direction of increasing relative abundance of species among samples plotted in **Figure 8** with lowest values in the opposite direction and median at the center. Species vectors are color coded to origin guild. NOAA species codes and abbreviations replace species name labels for some to improve legibility.

Plotting the sample scores to a map shows latent spatial structure among samples. Sample score values from PC1, which aligned with seasonal overturn, are spatially mixed because both Spring and Fall sampling occurred throughout the study area. In contrast, the weaker PC2 shows an on-offshore (or depth) trend (**Figure 10**). Atlantic Scallop, Fourspot Flounder, Goosefish, Gulfstream Flounder, and Haddock were more likely to occur in deeper samples, while numerous species—especially *Etropus* sp. flounders, Windowpane, American Horseshoe Crab, kingfishes, Spot, and Weakfish—were collected in nearshore (shallower) samples. These trends are quantified explicitly in Section 3.4 (Canonical Trends).

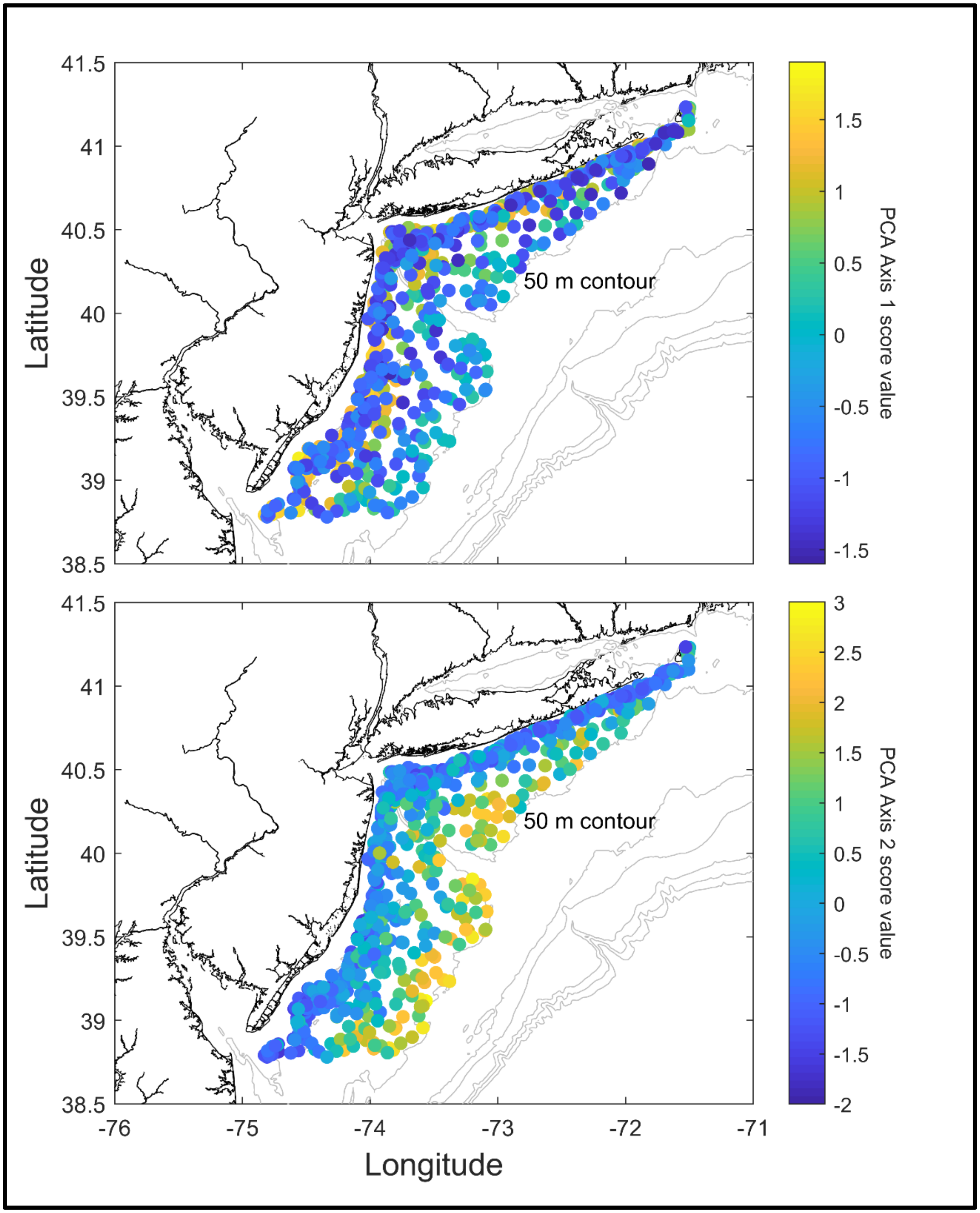


Figure 10. Spatial distribution of principal component scores for PC1 (upper) and PC2 (lower)

Dividing the Spring and Fall surveys for further independent scrutiny allows a focus on spatial co-occurrence among species given that the seasonal modes are isolated and the interannual trend from 2010–2019 was previously shown to be weak.

Spring

Spring samples were poorly differentiated overall, with PC1 only explaining 15% of the total variance among these samples (**Table 6**). Parallel analysis suggested that all four computed axes are non-trivial and could be retained. The first two are examined in detail. Scores for the 3rd and 4th are provided in **Appendix A**. Total sum of squares in response data was 13,608.00000. This quantified a trend in species composition with samples on one end of the trend (shown as the left or negative side of the horizontal axis in **Figure 11**) being typified by American Horseshoe Crab and Northern Sand Lance, and little else. Other samples contained a varying mix of Longfin Squid, Butterfish, Fourspot Flounder, Silver Hake, Summer Flounder, Black Sea Bass, Northern Sea Robin, and Silver Hake, pictured as a spread along PC2 (vertical axes) with a weak eigenvalue (**Table 6**, **Figure 11**). The species in those samples that were not typified by just Northern Sand Lance and American Horseshoe Crab were clearly related to depth, but with two depth modes (at ~ 25-m and ~ 47-m depth) for high PC1 scores (**Figure 12**). PC2 explained less than 10% of the variance and showed no convincing pattern relative to depth and a weak along-shore gradient, with hakes, Windowpane, and Winter Flounder being typical of species that were more likely to occur in samples north of the Hudson Shelf Valley (**Figure 13**). There was no strong grouping among Spring samples but rather a gradual trend (sample scatter plot not shown). There was no apparent sorting of species by origin guild within Spring trawl samples, possibly because only species of the northern origin were well represented.

Table 6. Summary results of PCA of NEFSC Spring trawl survey (2010–2019).

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.1544	0.0961	0.0793	0.0628
Cumulative Percent Variance	15.44	25.02	32.45	38.73

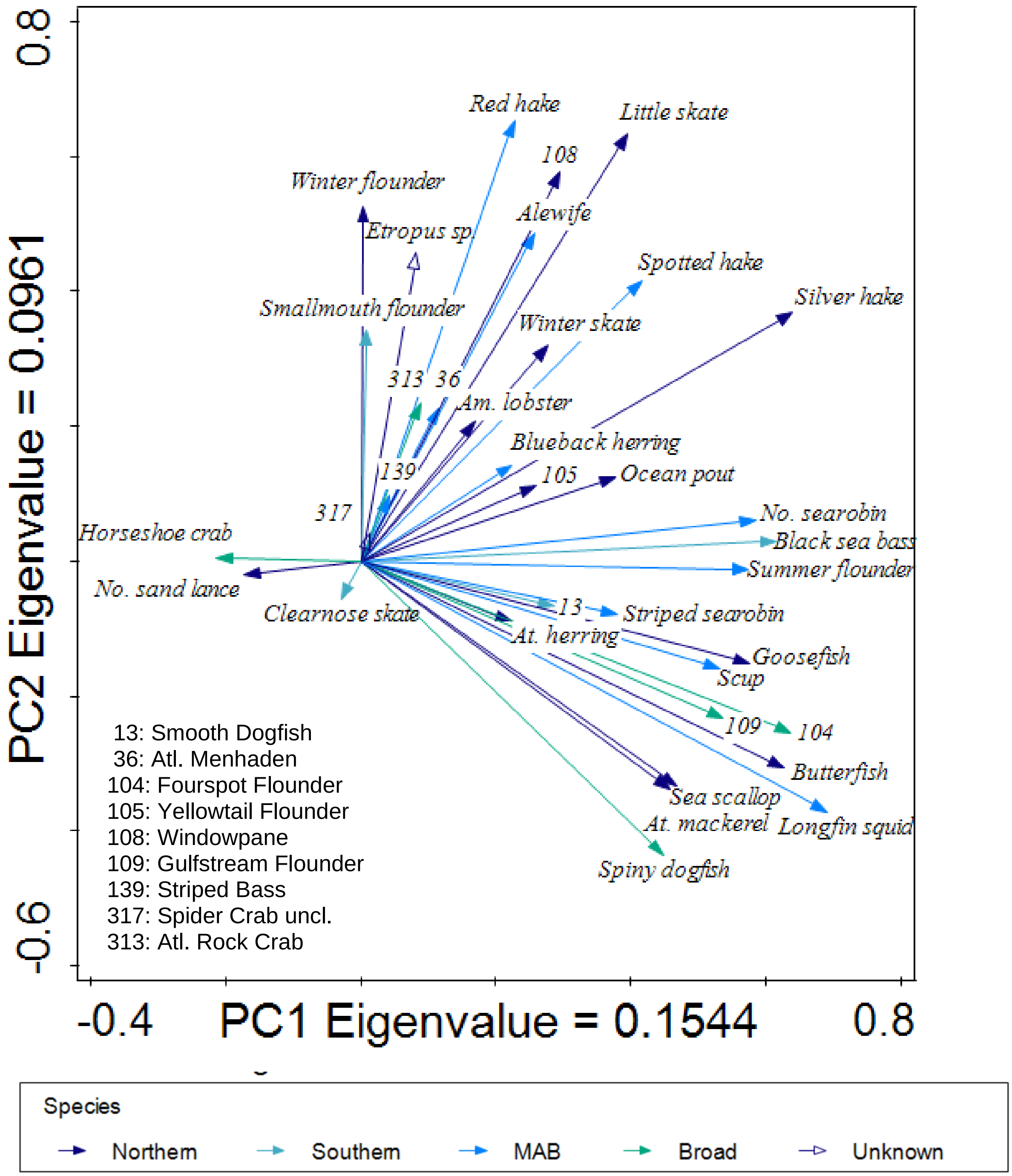


Figure 11. Species distribution through sample coenospace from PCA (Spring only)
Analysis included samples from NEFSC Spring trawl survey, 2010–2019. Vectors point in the direction of increasing relative abundance among samples and can be understood to decrease in the opposite direction. Species vectors are color coded to origin guild. NOAA species codes and abbreviations replace species name labels for some to improve legibility.

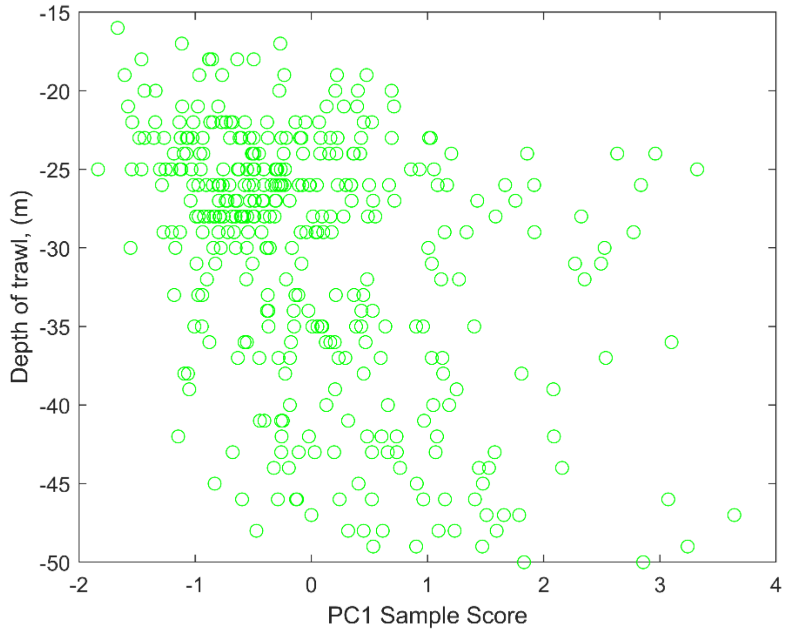


Figure 12. PC1 sample scores (NEFSC Spring trawl survey) relative to depth

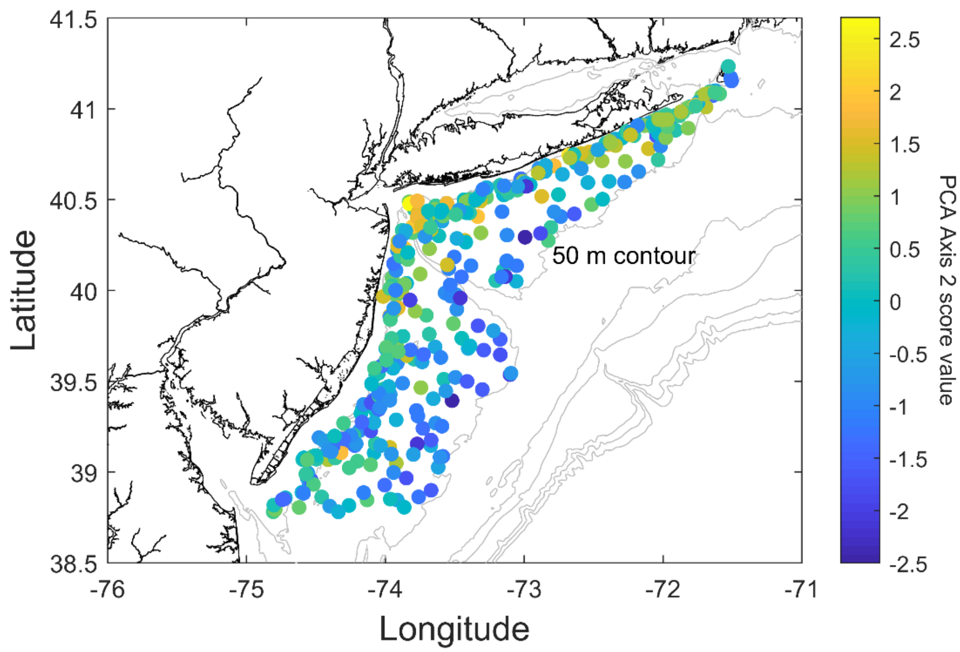


Figure 13. Spatial distribution of principal component scores for PC2 (NEFSC Spring trawl survey)

Fall

Although there were more species in Fall samples, PCA revealed a similar pattern with total sum of squares in response data = 16,732.00000 and similar distribution of explained variance among principal components (**Table 7, Figure 14.**). Parallel analysis suggested that all four computed axes are non-trivial and could be retained. The first two are examined in detail. Scores for the 3rd and 4th are provided in a digital file. During Fall, spatial distribution relative to depth was pronounced along PC1 (**Figure 14**), with negative (left side) scores being associated with deeper samples; the second axis (PC2) corresponded to a latitudinal trend (**Figure 14, 15, 16**). Atlantic Croaker, Bullnose Ray, Clearnose Skate, Spot, Weakfish, Northern Puffer, and Striped Searobin were among the strongest associated with samples taken from shallow inshore waters, while Atlantic Sea Scallop, Gulfstream Flounder, Fourspot Flounder, and Little Skate most strongly associated with the deeper samples (**Figure 14**).

Table 7. Summary results of PCA of NEFSC Fall trawl survey (2010–2019)

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.1653	0.0955	0.0672	0.0547
Cumulative Percent Variance	16.53	26.08	32.80	38.27

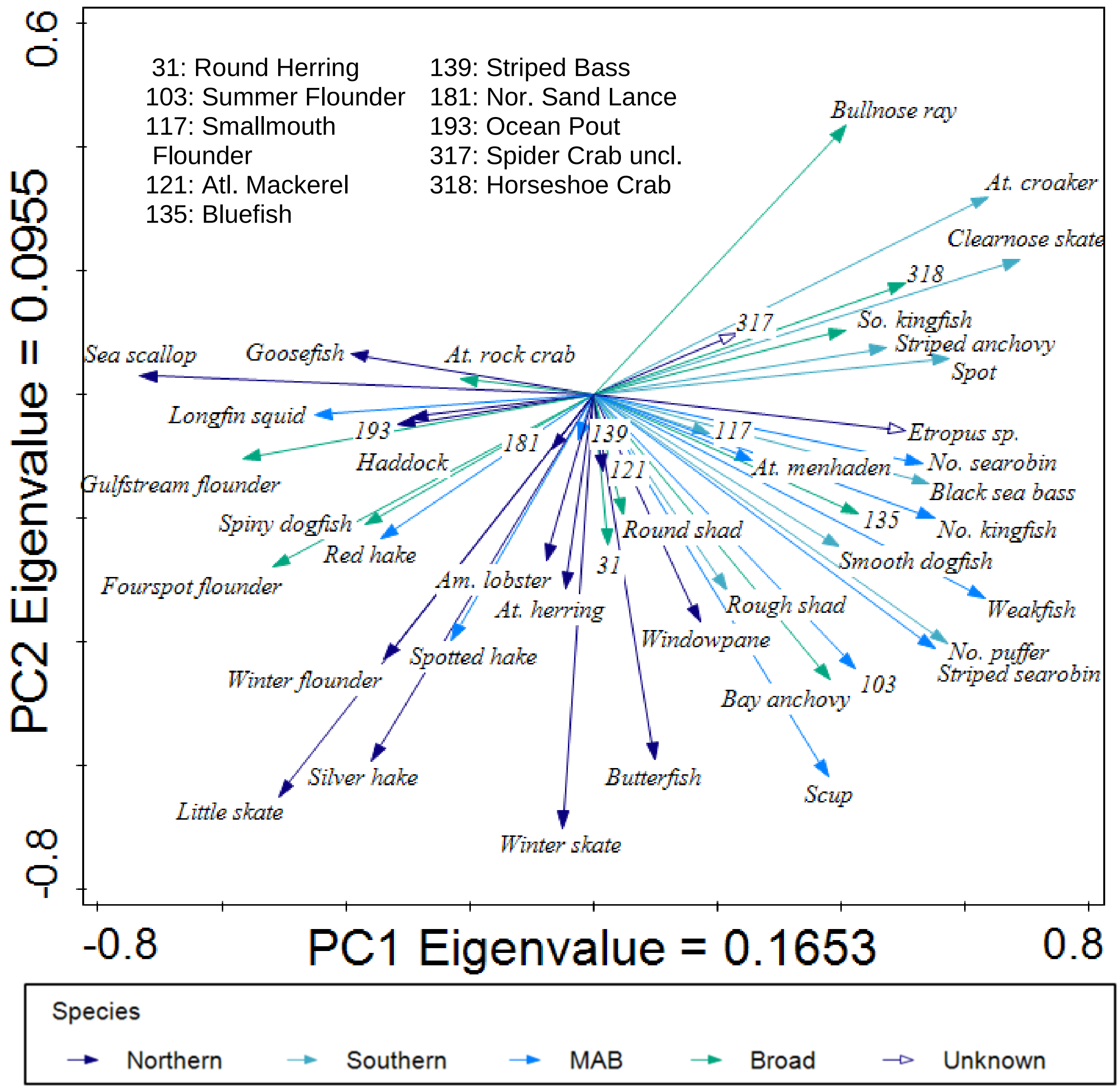


Figure 14. Species distribution through sample coenospace from PCA (Fall only)
Analysis included samples from NEFSC Fall trawl survey. Vectors point in the direction of increasing relative abundance among samples and can be understood to decrease in the opposite direction. Species vectors are color coded to origin guild. NOAA species codes and abbreviations replace species name labels for some to improve legibility.

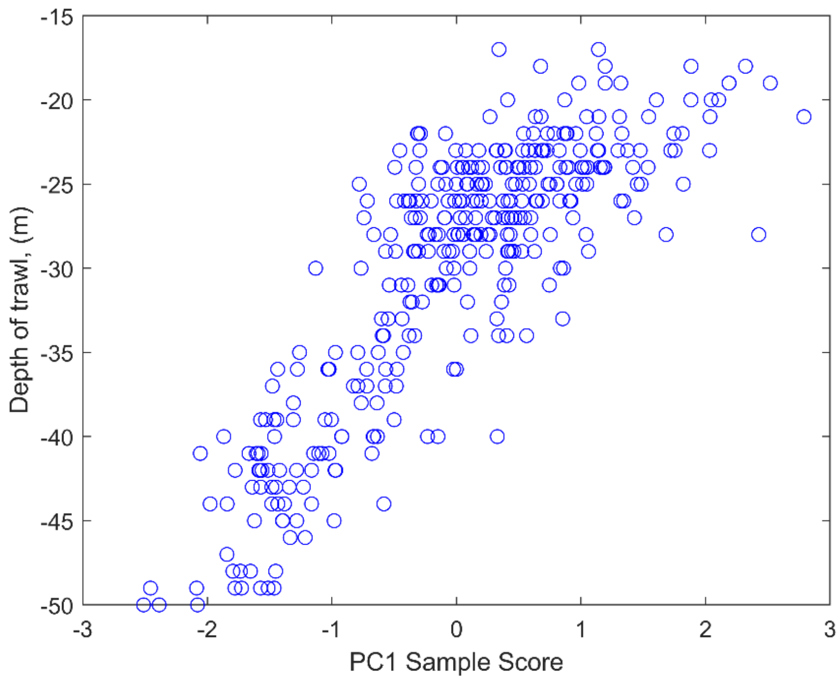


Figure 15. PC1 sample scores (NEFSC Fall trawl survey) relative to depth

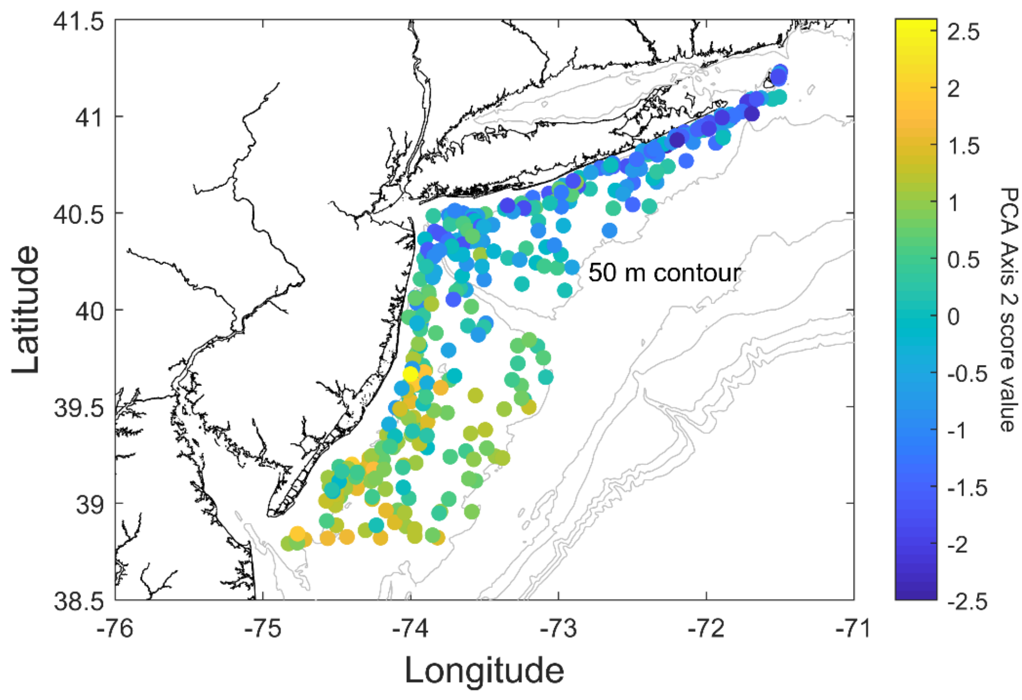


Figure 16. Spatial distribution of principal component scores for PC2 (NEFSC Fall trawl survey)

3.3.3.5 Scale Reduction

Spatial scale reduction examines whether fishes and invertebrates distribution is better explained by narrowly defined (micro) habitats or by larger areas that include possibly fragmented habitats (habitat mosaic) or frequent events. Scale reduction of the NEFSC trawl survey was achieved by assigning each sample to a common grid of 0.1-degree longitude and latitude and averaging the catch (CPUE) for all samples across years to the nearest neighbor grid node. Spring and Fall surveys were treated separately. PCA was repeated on the rescaled data set using the same data treatment protocol as before.

Despite the lower sample size, explained variance was marginally to moderately improved on both of the first two major axes for both Spring (total variation = 13,608.000) and Fall (total variation = 8,050.000) (**Table 8, 9**). Increased spatial coherence (compared to the original PCAs) is evident when plotting first and second axes scores to the map on both latitudinal and offshore/depth gradients (**Figures 17, 18**). Large-scale habitat features or regional concentrations of smaller scale habitat features are as or more important than those seen explicitly during when a sample was taken. Scores of aggregated Spring trawls for PCI suggest a regional or latitudinal pattern with similar assemblages off the Hudson River estuary and at the entrance to Long Island Sound, while the PC2 scores show a trend with depth/distance off shore (**Figure 17**). In Fall, the depth trend is strengthened for PC1, while the along-shore trend (or bimodality) is strengthened along PC2 (**Figure 18**). Thus, regional scale is more important to structuring distribution in Spring, while depth is more important in Fall, possibly due to a restructuring of hydrography (see Section 3.3.3.8) A complete scaling study would approach this through iterative resampling to find the scale of maximum explained variance and consider the rescaling of underlying (canonical) variation as well (see Mashintonio et al. 2014 and **Volume 1: Literature Synthesis and Knowledge Gaps**).

Table 8. Summary results of rescaled PCA of NEFSC Spring trawl survey (2010–2019)

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.1794	0.0982	0.0717	0.0595
Explained Variation (Cumulative)	17.94	27.76	34.93	40.88

Table 9. Summary results of rescaled PCA of NEFSC Fall trawl survey (2010–2019)

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.2322	0.1243	0.0534	0.0521
Explained Variation (Cumulative)	23.22	35.65	40.99	46.20

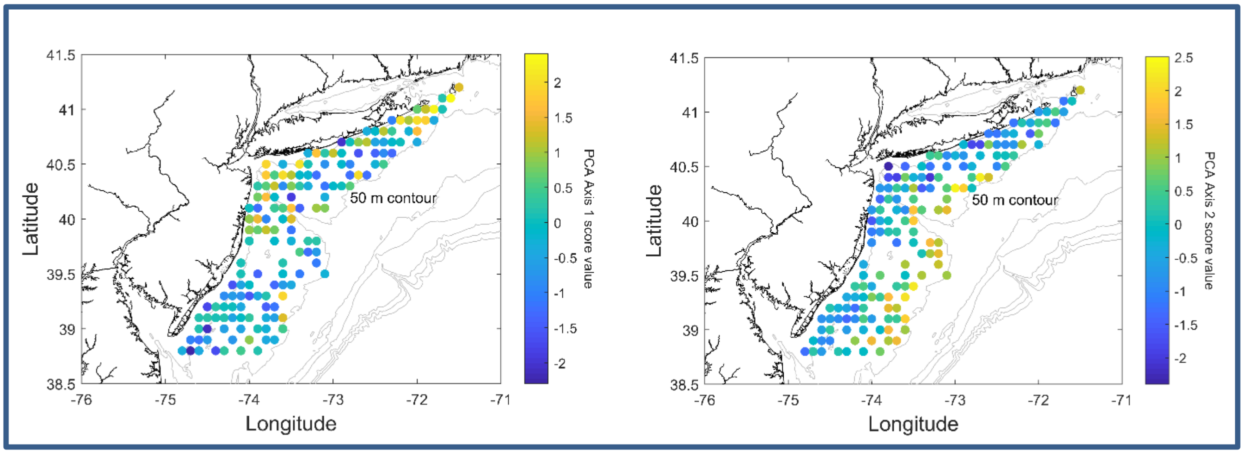


Figure 17. Spatial distribution of principal component scores for rescaled PC1 (left) and PC2 (right) (NEFSC Spring trawl survey)

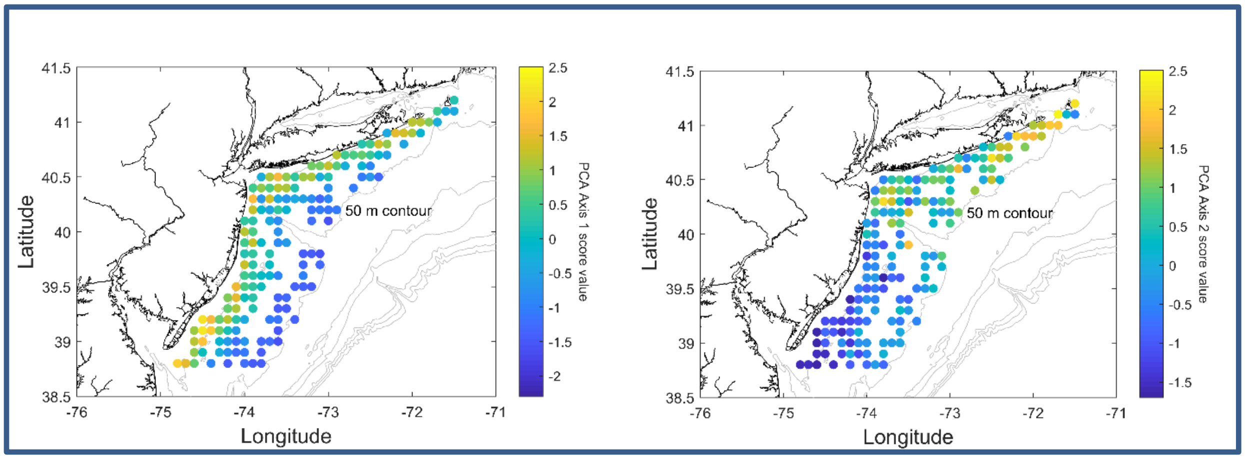


Figure 18. Spatial distribution of principal component scores for rescaled PC1 (left) and PC2 (right) (NEFSC Fall trawl survey)

3.3.3.6 Richness and Relative Abundance (NJDEP)

A total of 201 taxa were classified in NJDEP survey data within the study area from 2010 to 2019 (1,453 samples) (**Table 10**). More than half of these (57%, 115 taxa) were in common with the NEFSC data for the same period, while 86 were unique to the NJDEP survey (**Table 10**). Species unique to the NJDEP survey included those that are closely related to inshore, and especially estuarine, waters (e.g., White Perch, Silver Perch, Black Drum, Gizzard Shad) or do not appear to be counted in the NEFSC survey (e.g., Sand Dollar). Lower level classification (e.g., Common Spider Crab vs. Uncl. Spider crab) also account for some of the difference. The occurrence of rare species in the NJDEP but not NEFSC samples can be accounted for by rarefaction; there were 33 species, with just 1 or 2 occurrences over 10 years (**Table 10**). There were 22 taxa in the NEFSC survey that were not collected in the NJDEP survey (**Table 11**).

Table 10. Species list, frequency of occurrence (FOO), and abundance in constrained NJDEP survey

Species in **Bold** were unique to the NJDEP trawl survey. Species codes used by NJDEP are the same for NEFSC.

Species	Species Code	FOO	Abundance
Atlantic Herring	32	417	NaN
Bay Anchovy	43	553	2.36E+06
Butterfish	131	958	4.06E+05
Longfin Squid	503	1,152	3.78E+05
Northern Searobin	171	846	3.24E+05
Striped Anchovy	44	303	2.65E+05
Scup	143	746	2.07E+05
Weakfish	145	478	1.72E+05
Spotted Hake	78	1,041	1.01E+05
Little Skate	26	1,208	76391
Spot	149	212	71857
Round Herring	31	108	70453
Atlantic Croaker	136	321	53830
Clearnose Skate	24	950	49914
American Sand Lance	181	226	45424
Spiny Dogfish	15	574	36250
Sliver Hake	72	573	28339
Windowpane	108	1,360	28160
Bluefish	135	451	27004
Silver Perch	**148**	**151**	**26340**
Southern Kingfish	652	284	24416
Atlantic Moonfish	132	244	22062
Smooth Dogfish	13	786	21571
Uncl. Sand Dollar	**330**	**535**	**18867**
Blueback Herring	34	365	15833
Lady Crab	322	487	15638
Black Sea Bass	141	660	11930
Winter Skate	23	755	11754
Northern Kingfish	146	529	11596
Summer Flounder	103	1157	10856
Horseshoe Crab	318	636	10394
Atlantic Silverside	113	193	9307
Alewife	33	316	9202
Dusky Anchovy	**859**	**65**	**8694**
Striped Searobin	172	670	8044
Rough Scad	212	227	7425
Rock Crab	313	825	6956
Atlantic Menhaden	36	271	6502
Bullnose Ray	19	418	6145
Winter Flounder	106	571	6120
American Shad	35	258	5109
Common Spider Crab	317	600	4695
Smallmouth Flounder	117	576	4108
Uncl. Skate	**20**	**399**	**3755**
Brief Squid	**504**	**115**	**3752**
Red Hake	77	222	3621
Northern Puffer	196	319	3113
Chub Mackerel	124	40	2916

Species	Species Code	FOO	Abundance
Atlantic Mackerel	121	109	2872
Uncl. Starfish	**332**	**422**	**2622**
Uncl. Sea Urchin	**331**	**111**	**2097**
Gulf Shrimp (pink, brown, white)	307	131	1886
Blue Crab	314	214	1843
Shortfin Squid	502	68	1689
Striped Bass	139	253	1605
Hogchoker	118	118	1201
Round Scad	211	125	1166
Surf Clam	403	139	1147
Northern Sand Lance*	**734**	**5**	**814**
Northern Moon Snail	**348**	**189**	**807**
Northern Pipefish	116	91	704
Tautog	177	116	662
Northern Sennet	694	123	636
Cownose Ray	270	48	633
Fourspot Flounder	104	162	632
Roughtail Stingray	4	208	623
Uncl. Swimming Crab	320	76	606
Inshore Lizardfish	**435**	**156**	**602**
Banded Drum	651	31	477
Atl. Thread Herring	428	48	469
Striped Cusk Eel	188	69	443
Southern Stingray	**29**	**28**	**433**
Blue Runner	129	96	415
Knobbed Whelk	**337**	**124**	**411**
American lobster	301	145	380
Striped Burrfish	198	91	327
Bigeye Scad	209	36	303
Sea Scallop	401	60	295
Ocean Pout	193	75	247
Jonah Crab	312	91	229
Black Drum	**147**	**59**	**227**
Spiny Butterfly Ray	375	105	215
Pinfish	640	65	198
Lobed Moon Snail	**349**	**76**	**194**
Dwarf Goatfish	657	76	189
Gizzard Shad	**426**	**27**	**179**
Banded Rudderfish	204	56	167
Harvestfish	**749**	**30**	**164**
Pastel Swimming Crab	321	36	150
Gulf Stream Flounder	109	36	128
Atlantic Sturgeon	380	65	118
Hickory Shad	37	40	117
Channeled Whelk	**336**	**66**	**102**
Spotfin Mojarra	**872**	**38**	**98**
Loligo Egg Mop	**520**	**89**	**90**
Lined Seahorse	**492**	**60**	**85**
Cunner	176	24	77
Rough Scad	**122**	**5**	**67**
Northern Stargazer	179	53	66
Atlantic Cutlassfish	126	26	60

Species	Species Code	FOO	Abundance
Blotched Swimming Crab	**516**	**20**	**58**
Uncl. Calico Crab	**315**	**14**	**55**
Atl. Angel Shark	16	31	49
Atl. Sharpnose Shark	**360**	**21**	**44**
Bluntnose Stingray	18	30	43
Atl. Cod	73	22	40
Conger Eel	63	32	39
Mantis Shrimp	323	13	38
Sea Lamprey	2	19	33
Dusky Shark	**3**	**18**	**32**
Goosefish	197	28	32
Bluespotted Cornetfish	**120**	**22**	**31**
Sheepshead	**631**	**9**	**30**
Threespine Stickleback	**115**	**17**	**29**
Chestnut Astarte	**420**	**19**	**25**
Sand Tiger (Shark)	12	19	23
Spanish Sardine	429	6	22
Uncl. Squid	501	19	22
Thresher Shark	**925**	**19**	**21**
Gray Triggerfish	202	17	19
Striped Mullet	**689**	**9**	**18**
Bigeye (Catalufa)	**134**	**16**	**17**
American Eel	**384**	**4**	**17**
Planehead Filefish	**201**	**15**	**16**
Naked Goby	**738**	**8**	**15**
Sandbar Shark	9	9	14
Red Cornetfish	489	13	14
Witch Flounder	107	8	13
Haddock	74	12	12
Uncl. Moon Snail	**338**	**10**	**11**
Crevalle Jack	**570**	**8**	**11**
Spanish Mackerel	745	8	11
Fourspine Stickleback	**488**	**4**	**10**
Cobia	**563**	**9**	**10**
Blackcheek Tonguefish	**825**	**4**	**10**
Uncl. Ray	**5**	**2**	**9**
Uncl. Octopus	**510**	**8**	**9**
Pollock	**75**	**7**	**8**
Uncl. Hake	**80**	**4**	**8**
Sea Raven	164	8	8
Waved Whelk	**344**	**5**	**8**
African Pompano	**568**	**7**	**8**
Uncl. Dogfish	**10**	**1**	**7**
Spotfin Butterflyfish	662	7	7
Lookdown	**133**	**5**	**6**
Flying Gurnard	175	5	6
Uncl. Shrimp	305	5	6
Tilefish	**151**	**1**	**5**
Red Goatfish	187	5	5
Barndoor Skate	22	4	4
White Perch	**140**	**3**	**4**
Pigfish	**142**	**2**	**4**

Species	Species Code	FOO	Abundance
Longhorn Sculpin	163	4	4
Oyster Toadfish	185	2	4
Dog Whelk	347	3	4
Snakefish	439	4	4
Atlantic Tomcod	453	3	4
Sharksucker	564	4	4
Ridley Turtle	**954**	**4**	**4**
Rock Gunnel	**180**	**2**	**3**
Atlantic Needlefish	**471**	**3**	**3**
Striped Killifish	**474**	**2**	**3**
Remora	**567**	**3**	**3**
Florida Pompano	579	3	3
Permit	**580**	**1**	**3**
Atlantic Spadefish	**659**	**3**	**3**
Bigeye Cigarfish	**876**	**3**	**3**
Green Turtle	**951**	**3**	**3**
Atlantic Bonito	123	2	2
Seasnail	170	2	2
Unclassified Cancer Crab	**311**	**1**	**2**
Margined Seastar	**334**	**2**	**2**
Box Crab Uncl.	**339**	**2**	**2**
Hard Clam	**413**	**2**	**2**
Common Razor Clam	**416**	**2**	**2**
Blotched Cusk Eel	458	2	2
Uncl. Cornetfish	490	1	2
Short Bigeye	**557**	**2**	**2**
Red Drum	**654**	**1**	**2**
White Mullet	**690**	**1**	**2**
Uncl. Combtooth Blenny	**733**	**2**	**2**
Loggerhead Turtle	950	2	2
White Hake	**76**	**1**	**1**
Fourbeard Rockling	83	1	1
Uncl. Flounder	100	1	1
Yellowtail Flounder	105	1	1
Armored Searobin	**173**	**1**	**1**
Smooth Puffer	**195**	**1**	**1**
Greater Amberjack	**203**	**1**	**1**
White Shark	**351**	**1**	**1**
Smooth Butterfly Ray	**376**	**1**	**1**
Speckled Worm Eel	**393**	**1**	**1**
Snowy Grouper	**537**	**1**	**1**
Horse-Eye Jack	**571**	**1**	**1**
Atlantic Pomfret	**585**	**1**	**1**
Bullet Mackerel	**701**	**1**	**1**
Uncl. Goby	**739**	**1**	**1**
Little Tunny	743	1	1
Dotterel Filefish	**830**	**1**	**1**
Uncl. Butterflyfish	**855**	**1**	**1**
Finetooth Shark	**928**	**1**	**1**

*****See Section 3.3.3.1.

Table 11. Species occurring in the NEFSC but not NJDEP survey of the study area (2010–2019)

Species Code	Species
25	Rosette Skate
87	Uncl. Ling
191	Wrymouth
205	Atlantic Saury
287	Sevenspine Bay Shrimp
296	Bristled Longbeak
319	Galatheid spp.
358	Tiger Shark
390	Uncl. Conger Eel
421	Uncl. pipefish/seahorse
425	Uncl. Snake Eel
506	Bobtail Squid
541	Gag
556	Glasseye Snapper
584	Dolphin(fish)
620	Uncl. Barracuda
744	King Mackerel
794	Uncl. *Etropus* flounder
820	Uncl. Triggerfish/Filefish
831	Unicorn Filefish
843	Marbled Puffer
865	Silver Anchovy

3.3.3.7 Bathymetry

The distribution of isobaths was estimated by an evenly spaced grid of 39,524 samples extracted from the Atlantic-Cadastral data set (https://www.boem.gov/oil-gas-energy/mapping-and-data/atlantic-cadastral-data) on the same Cartesian and depth parameters used to parse the trawl data (**Figure 19**). Samples were binned and distribution represented by histogram (**Figure 20**). The depth distribution of trawl samples was likewise represented by histogram and compared to the total depth distribution (**Figure 21**). The sample distributions were similar in that both overrepresented shallow depths with a peak in the frequency that the 25-m bin was sampled about double that of this bin's relative representation in the latent depth distribution; in both cases, a second minor mode was present around 40 m.

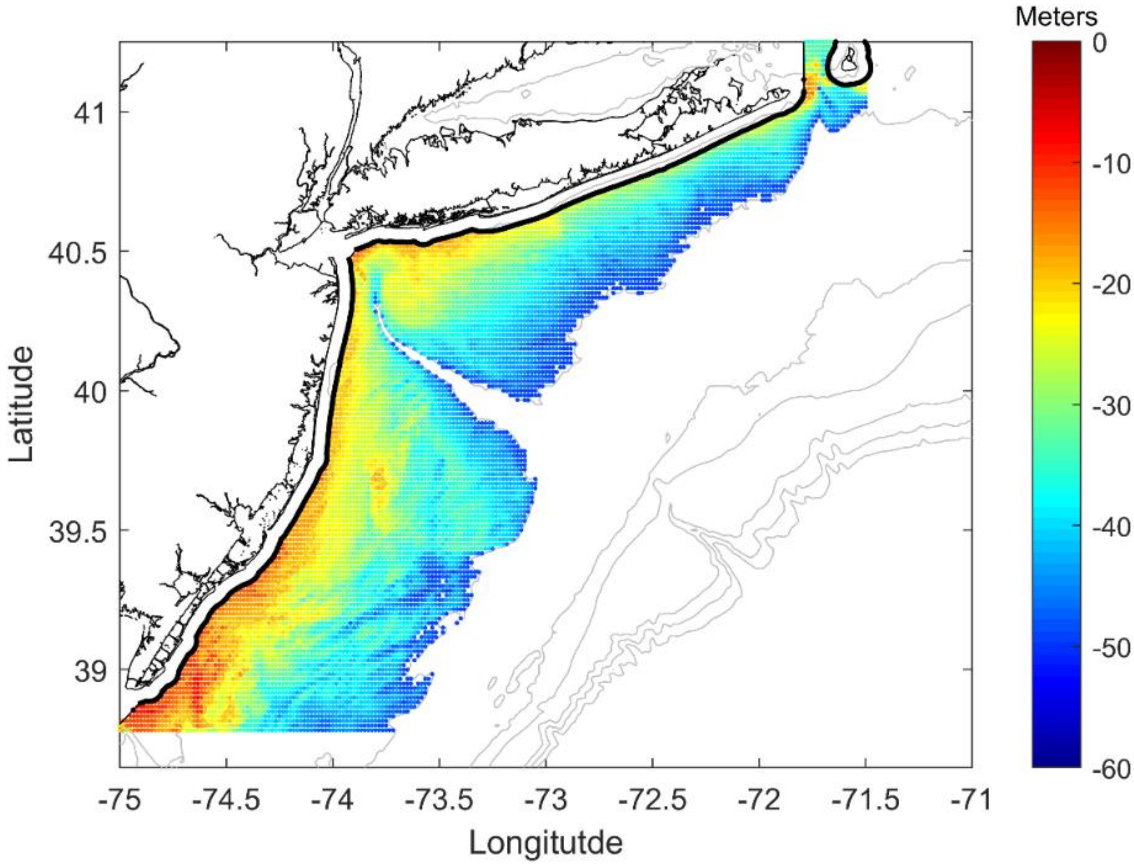


Figure 19. Rasterized bathymetry of the NYB study area used to calculate depth frequency

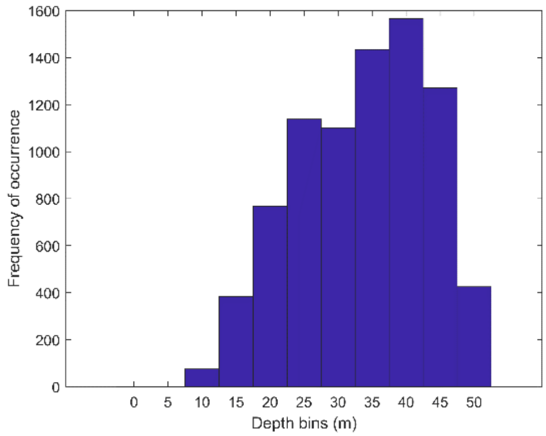


Figure 20. Latent depth frequency distribution of the NYB study area to 50 m

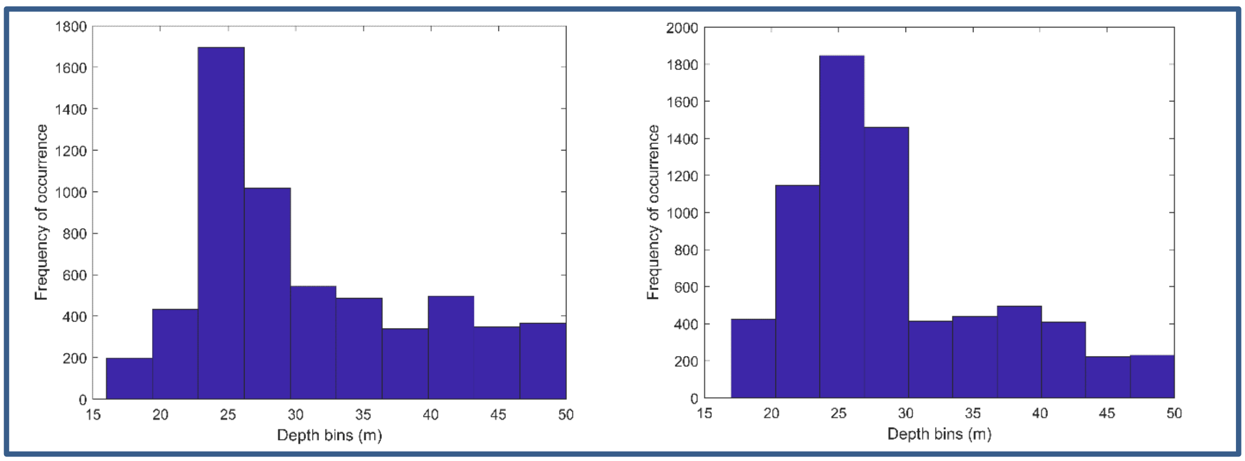


Figure 21. NEFSC Spring (left) and Fall (right) trawl sample depth distribution down to 50 m

3.3.3.8 Hydrography

Hydrography, as characterized by temperature and salinity, differed among aggregated (2010–2019) Spring and Fall NEFSC trawl survey samples (**Figure 22**). Bottom temperatures were much warmer in Fall surveys, ranging from 8.8 to 23.9 °C with a mean of 17.5 °C, while in Spring samples bottom temperature ranged from 2.6 to 9.4 °C with a mean of 5.5 °C. Stratification was apparent in both seasons, but more so in Spring, as surface temperatures were similar among Spring and Fall. Stratification was stronger in Spring (during which the Cold Pool is forming, see **Volume 1: Literature Synthesis and Knowledge Gaps**) and more variable in Fall, when bottom temperature differed as much as 18 °C among samples. Salinity was similar, but for a dozen Fall samples that encountered slightly fresher (29.5 to 31 psu) water.

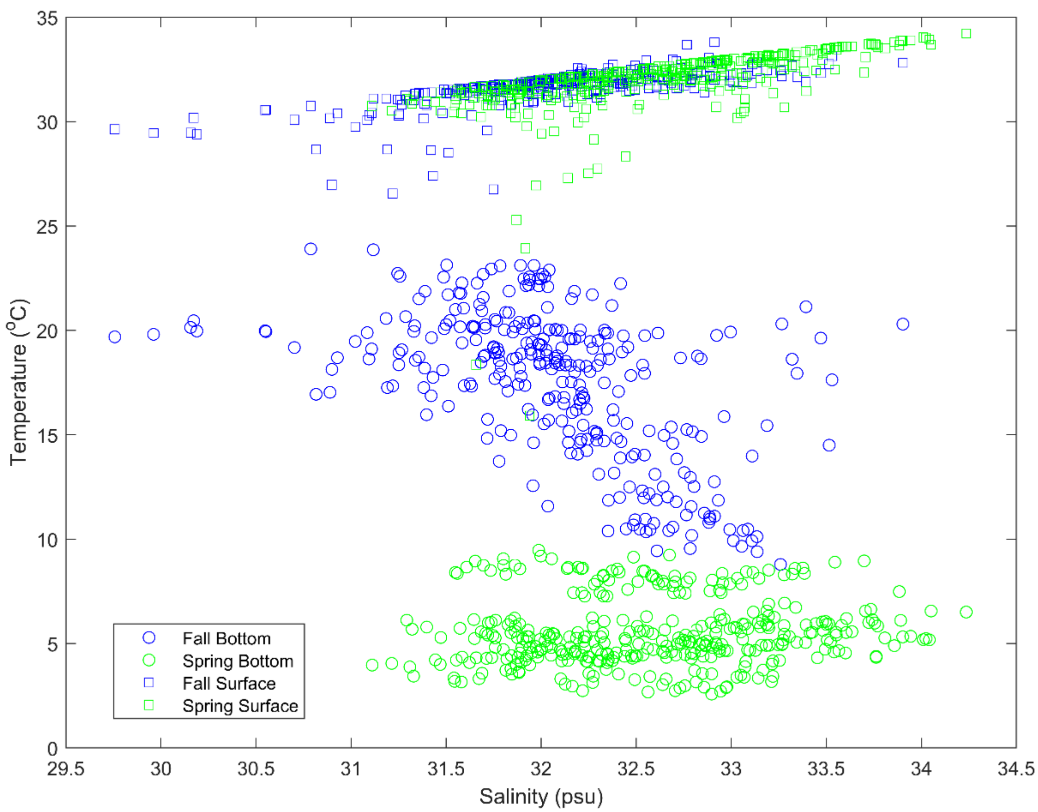


Figure 22. Temperature vs. salinity plot from constrained NEFSC Spring and Fall trawl survey

3.3.3.9 Fish Biomass and Richness

The biomass of fish and shellfish species managed under Atlantic States Marine Fisheries Commission (ASMFC) for the Mid-Atlantic region (Core Biomass_FMPs) plans are interpolated to grid (rasterized) from NEFSC trawl data survey (Fall 2010–2016 and Spring 2010–2017) using inverse distance weighting by the Marine-Life Data Analysis Team Fish v3.0 (Curtice et al. 2019; Ribera et al. 2019). Biomass distribution was calculated individually and for all species summed. Richness data were also rasterized. These data are served on the MARCO portal and mirrored through the NYB Sand ERDDAP. A graph of the summed biomass for Fall is reproduced from ERDDAP below using the geographical constraints of the study area and scaled to the maximum within the study area (**Figure 23**). This scale identifies important variation within the study area that could be hidden by broader regional scaling. Note that broader scaling is necessary to understand the relative contribution of habitats to biomass in the study area in terms of cumulative impact. Also, total biomass is weighted by species that are not necessarily tied to sand features, such as herrings. Biomass for Spring and biomass for all species (not just managed species) for both Spring and Fall are also available. Biomass within the study area in Fall is concentrated on the inside of the continental shelf and especially near the Delaware Bay and Long Island Sound outlets. The southern concentration coincides with a concentration of identified sand resources. Biomass in Spring (not shown) is shifted offshore of the 50-m contour.

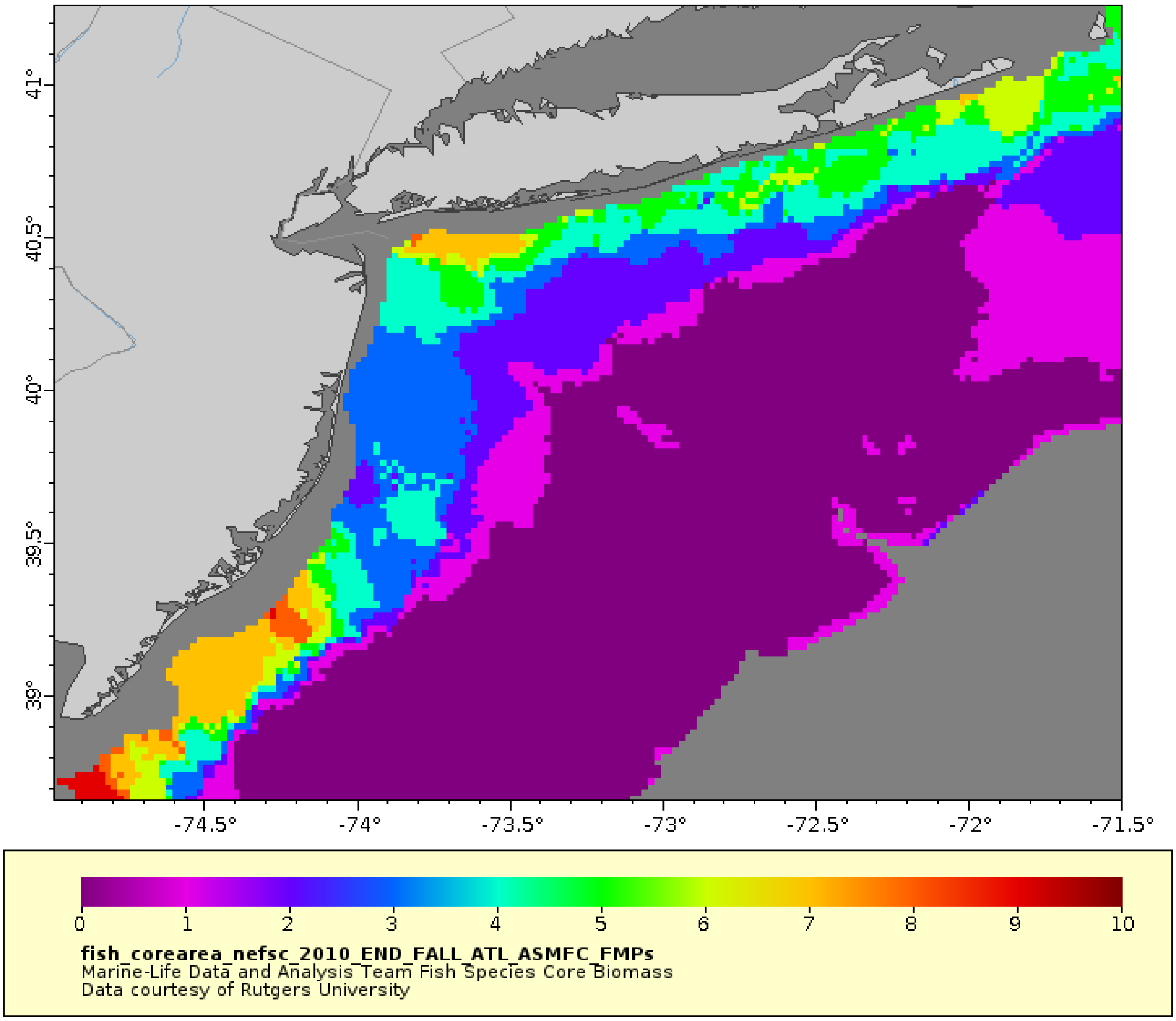


Figure 23. Cumulative biomass distribution of managed fish and shellfish in the study area
Scale is natural logarithm and unitless as relative concentration. Figure was generated in ERDDAP https://nybsand.marine.rutgers.edu/erddap/griddap/MDAT_Fish_SummaryProducts_NEFSC_COREBIOMASS.largePng?fish_corearea_nefsc_2010_END_FALL_ATL_ASMFC_FMPs%5B(41.25727):(38.66182)%5D%5B(-74.99247):(-71.4986)%5D&.draw=surface&.vars=longitude%7Clatitude%7Cfish_corearea_nefsc_2010_END_FALL_ATL_ASMFC_FMPs&.colorBar=%7C%7C%7C%7C10%7C&.bgColor=0xffccccff

The pattern of richness (number of species) distribution calculated from the same data set departs from that of core biomass abundance (**Figure 24**). The Hudson River Shelf valley at the apex of the study area is a notable richness hotspot.

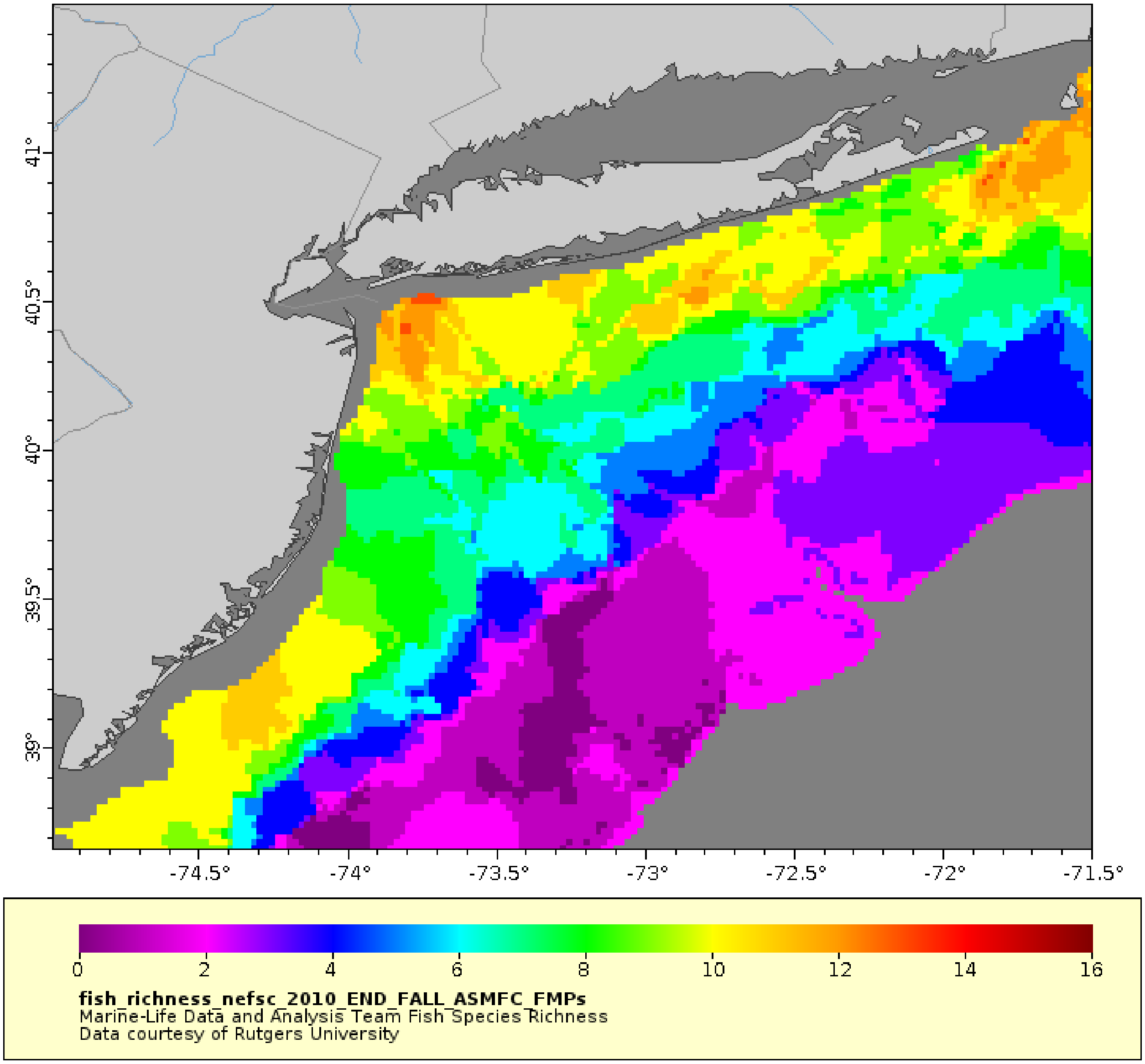


Figure 24. Species richness in the study area as represented by NEFSC Fall trawl survey
Figure was generated in ERDDAP
https://nybsand.marine.rutgers.edu/erddap/griddap/MDAT_Fish_SummaryProducts_NEFSC_RICHNESS.largePng?fish_richness_nefsc_2010_END_FALL_ASMFC_FMPs%5B(41.25727):(38.66182)%5D%5B(-74.99247):(-71.4986)%5D&.draw=surface&.vars=longitude%7Clatitude%7Cfish_richness_nefsc_2010_END_FALL_ASMFC_FMPs&.colorBar=%7C%7C%7C%7C16%7C&.bgColor=0xffccccff

3.3.4 Products

Digital files (*.xlsx) of the species FOO and abundance tables are provided to BOEM to allow sorting and searching. Digital output files (txt format) from PCA are also provided to allow electronic sorting.

3.4 Canonical Trends Quantification

3.4.1 Purpose

Canonical patterns of faunal distribution are those that significantly correlated with measured underlying variables. In the following analyses, these are hydrographic and bathymetric variables measured coincident with each trawl, as well as modeled and extrapolated benthic data (see Sections 3.4.2.2–3.4.2.5). Examining them all together answers the question of relative explained variance of the environmental factors, including the possibility/likelihood of mutual attraction to a resource (aggregation) and the influence of fauna on each other's distribution through competition, predation, or facilitation. This method quantifies the concept of realized ecological niche for the included variables and taxa. It also is meant to directly aid evaluators in assessing the risk of sand extraction as a perturbation relative to the influence of other environmental drivers or correlates.

3.4.2 Method

3.4.2.1 Canonical Correspondence Analysis (CCA)

The same data trawl survey that were used in the individual and independent latent trends analyses for environment and biota were combined in a direct gradient analysis, CCA, to quantify the relationship between their distributions as interset-correlation values (i.e., fauna-environment) for the major trends. As in PCA, CCA eigen axes are ranked by the strength of the variance (eigenvalue) that each explains, but in the case of CCA, this is only the explained variance (out of the total variance) that is correlated with the included environmental data. Extrapolation is conducted by quantifying the association of physical factors (substrate, bedform, depth) and their derivatives (slope, proximity to features such as shoals or wrecks) with biological species presence or abundance (depending on the underlying distribution parameters) through multivariate regression techniques. Eigenvectors (axes with direction and strength of change in species composition among sample stations that are stretched by the data transformation) in these analyses are calculated as the best fit regressions of linear combinations of the included variables and allow both continuous and fixed categorical variables. As such, the model that best fits the data is solved to form predictions about how all the species making up a community are distributed in space and time relative to a number of variables. Variables without strong predictive power are not necessarily unimportant; rather, strong covariance with another variable may account for it mathematically, but not mechanistically. The CCA was run with forward selection, in which iterations are run first on single variables and are then added sequentially to the model in decreasing order of strength (explained variance); the change in the explained variance is tested at each step. "Discarded" variables that do not significantly increase fit are addressed as covariate.

Canonical analysis was run on Spring and Fall trawls separately based on results of the latent analysis that demonstrated strong seasonal segregation, which is due to a combination of unmeasured or unmeasurable factors, some of which (such as gonad maturation, spawning activity, and overwinter dynamics) happen outside the study area (see **Volume 1: Literature Synthesis and Knowledge Gaps**).

3.4.2.2 Hydrographic Variables

Surface and bottom temperature, surface and bottom salinity, and depth were collected by NEFSC at each trawl sample station by CTD at the time of the trawl; these data best reflect the hydrography experienced by the fish and invertebrates during collection. Because the trawl samples mostly the bottom of the water column (except in very shallow water) the bottom temperature and salinity were entered into the analysis. The difference between the bottom and surface temperature (delta temperature) and likewise for salinity (delta salinity) were calculated separately as derivatives and also entered. These are proxy variables for water column stratification arising from different mechanisms and are potential drivers or predictor of numerous other dynamics.

3.4.2.3 Soft Sediment Grain Size Variable

Grain size was extracted from an available raster layer served by MARCO (mirrored on the ERDDAP). The raster was based on extrapolation of point collection data of the US Geological Survey (USGS) usSeabed: Atlantic Coast offshore surficial sediment data (Data series 118, version 1.0) and the USGS East Coast Sediment Texture Database (2005), Woods Hole Coastal and Marine Science Center (https://portal.midatlanticocean.org/data-catalog/SeafloorHabitat/) for the value at a particular trawl sample.

Grain size distribution as extracted from this raster had a mode at 0.25 to 0.5 with a range from 0.0182 to 4.2765 mm (**Figure 25**). The few samples with coarse sand class were close to shore (**Figure 26**).

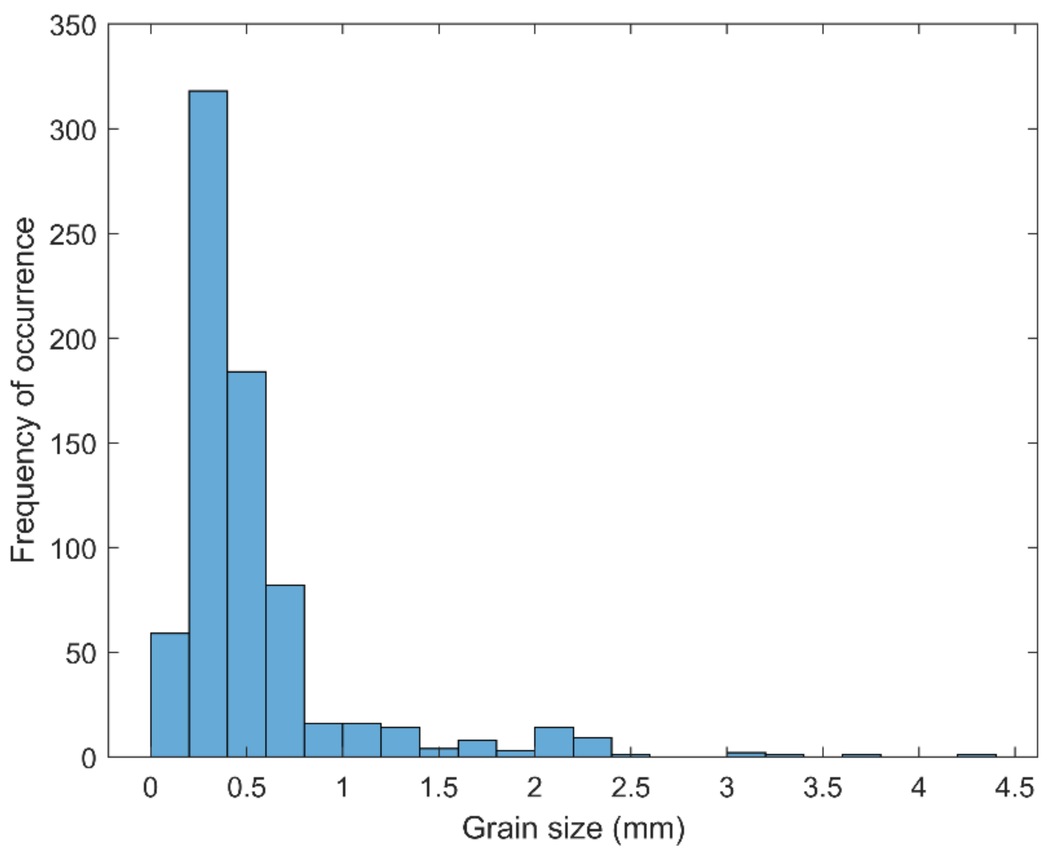


Figure 25. Frequency distribution of grain size at individual trawl sample locations

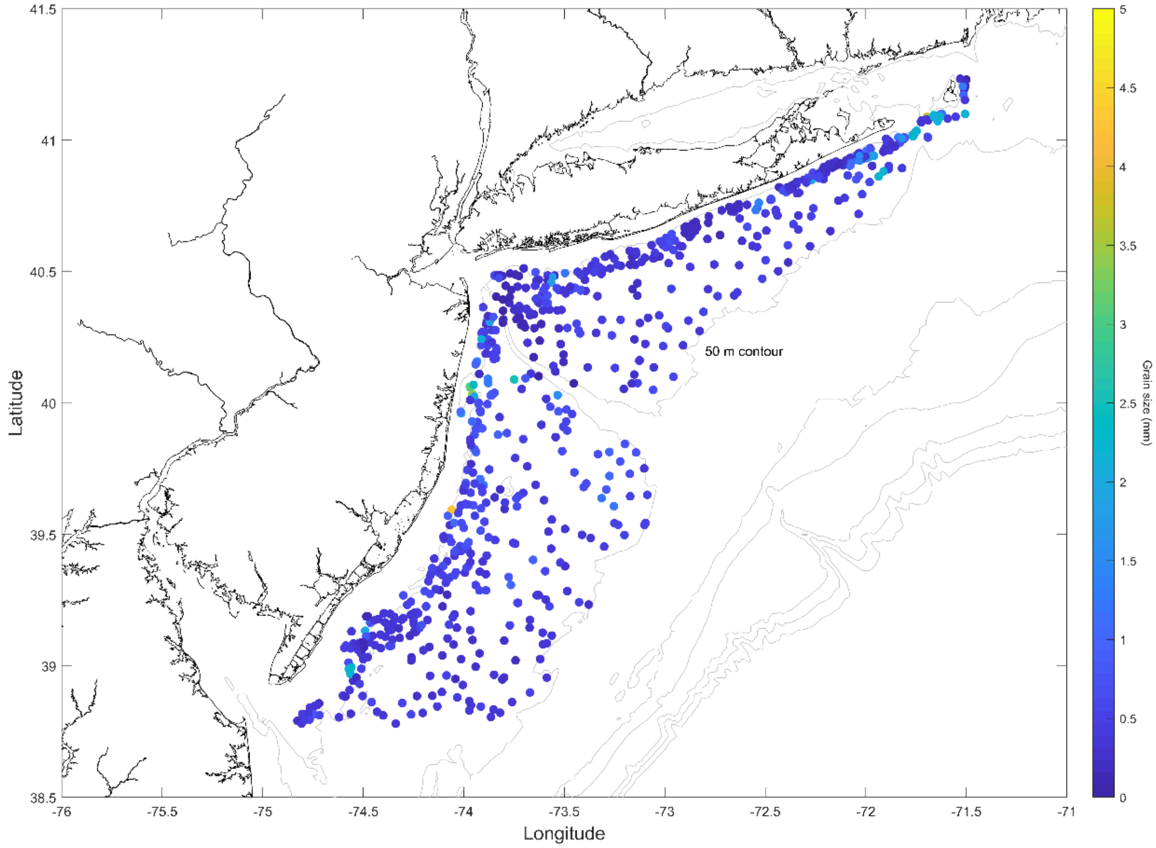


Figure 26. Physical distribution of grain size at individual trawl sample locations

3.4.2.4 Shoal Proximity Variable

The location and perimeter of modeled shoals were extracted from the MMIS (https://mmis.doi.gov/boemmmis/) Modeled Shoals layer (also mirrored on ERDDAP). Shoals delineated in this feature class as polygons are modeled on the basis of direct and indirect data including bathymetry, surficial backscatter, grain size point samples (Pickens et al. 2019). A number of the modeled shoals are redundant with the Sand Resources layer (also from MMIS) in that the latter adds additional information on accessibility to the modeled shoals to produce another classification. Due to the redundancy, the Sand Resource layer was not queried for this analysis.

In an effort to provide multi-labeling classification of the shoals for further differentiation as value to fish habitat, a cluster analysis (Spearmans's Rank distance, complete linkage) was run using the attribute values shoal area, percent sand, percent fines, grain size, depth class, minimum slope, maximum slope, and rugosity. Analysis returned no clear high level differences to justify classification, and a consensus PCA showed very little explained variance, most likely because these are the variables on which the shoal classification (as opposed to flat or no shoal) was originally based. Therefore, trawls were classified only on the location relative to a shoal as follows.

The center of each trawl location was checked against each modeled shoal polygon (n = 1,383 shoals in the study area) to see if it fell within or outside of the polygon. Trawls (n = 25) that fell inside the polygon were assigned the class "On Shoal." Trawls that did not fall within a modeled shoal polygon were then checked to see if they were within a modeled shoal polygon's bounding box. Because many of the shoals have a similar diagonally oriented long axis (Northeast-Southwest), the bounding box of each encompassed an area as much as twice that of the shoal polygon. Trawl samples (n = 126) that fell inside the bounding box but outside of the shoal polygon were classified "Near Shoal." All other trawls (n = 582) were classified as "Off Shoal." Because most trawls that are not Near Shoal are Off Shoal (with a few being On Shoal instead), these three variables are mutually exclusive, and Off Shoal and Near Shoal are highly inversely collinear. All three of these mutually exclusive factors were entered into CCA.

3.4.2.5 Habitat Classification Variable

Benthic habitats based on Ecological Marine Units created as part of the Northwest Atlantic Marine Ecoregional Assessment (https://portal.midatlanticocean.org/data-catalog/conservation/) were examined as a potential input variable. Habitats are coded into 43 classes of "habitat" and 53 classes of "ecological code." The classes within a code are mutually exclusive, meaning that they would be entered as (minimum) 43 different binary variables (i.e., the codes do not correspond to a rank or gradient value). A brief examination in consideration of class reduction to a lower order showed this to be impractical within the scope of this study; further, some of the variables on which the classifications are based are already included in the analysis as "depth," "grain size," and rugosity summarized with "modeled shoals." Therefore, Benthic Habitat class variables were not used in CCA.

3.4.3 Results

3.4.3.1 A Note on Interpreting CCA plots

Interpretation of CCA (tri)plots has important similarities and differences to that of PCA biplots. Ranking of relative importance by explained variance (eigenvalue) is that of the canonical explained variance, not the total variance. Sample (individual trawl) scores (amplitudes along multivariate gradients of canonical components, collectively coenospace) are plotted closer or further from each other (as in PCA) plots based on the expected similarity of their catch (species composition) along a component axis. The sign of the score (-/+ representing up or down) is arbitrary so that a flipped image of a triplot conveys the same information. Scores from the first two major trends (canonical component 1 and 2, CC1 and CC2, respectively) are plotted against each other here, allowing sample similarity on two different uncorrelated trends to be viewed simultaneously. The trends in relative (centered and standardized) fish abundance (as CPUE) that account for sample similarity are also plotted. The species-specific centers decline in all directions from the plot point in an assumed Gaussian distribution. Species are likely to occur in the greatest abundance in the environment of samples that plot near them (and vice versa) with decreasing abundance with distance in any direction. The environment of the samples is shown by plotting the trends (as arrows in the direction of increasing value) through the sample and species plot. Thus, a sample plotting near the arrow head for Bottom temperature along with Species A caught high relative abundance of Species A in warm water and had a similar environment and species composition to other samples plotted near it and different to those plotted on the opposite side of the graph, which would indicate cold water. The angle between environmental vectors is the correlation coefficient between the two, while the length of the vector along a particular canonical axis relates to the explained variance by that variable for that axis. Thus, vectors that line up are co-linear (or covary inversely if they line up but in opposite direction). In this report, triplots were separated into a biplot layer (species and environment) and scatterplot (samples only) for legibility.

Depth and grain size are likely to be proxies for much more complicated relationships, including causative factors of light penetration, oxygen content, connectivity, energy (flow and oscillation), and refuge. The realized niches are not necessarily the metabolic optimum, but a compromise with unmeasured factors. It is also is important to remember that these analyses are correlative, not causative, although first principles of ecology and metabolic theory provide confidence that the relationships with temperature are causative.

3.4.3.2 A Note on Interpreting Van Dobben Circles

Because the canonical axes calculated to provide the best fit are synthetic (i.e., are multiple regressions that provide better fit than using just a single variable), the predictive capacity of single variables for individual species is hidden in a triplot. Although environmental factors may always be covariate in natural settings, the effect of individual variables is useful as a predictor of fish distribution. These effects were tested using Van Dobben circles (also called T-value biplots) in Canoco5. A positive response circle of radius 2T is drawn from the plot origin. Vectors of increase in species-specific CPUE that fall inside the circle (at least 50 of the rendered arrowhead) are calculated to have a significant (alpha = 0.05) correlation with that tested factor because the T-value statistic from a (multiple) regression is predicted to have value greater than 2. A circle drawn in the other direction (-2T) identifies species with a significant inverse correlation with that factor (based on the T-value less than -2).

3.4.3.3 Spring Trawl Survey

Variation (5.95240) accounted for by explanatory variables in CCA of the Spring (2010–2019) data set was 11.5% of the total variation. The first canonical axis explained 33.7% of that variance, and the second explained an additional 16.8% (**Table 12**). The relationship between the variables on each axis and the synthetic axis itself, called the pseudo-canonical correlation, was fairly high at 0.76 and 0.62 for CC1 and CC2 respectively.

Table 12. Summary results of CCA (Spring)

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.3365	0.1680	0.0895	0.0429
Explained Variation (Cumulative)	5.65	8.48	9.98	10.70
Pseudo-canonical Correlation	0.7627	0.6237	0.4642	0.3541
Explained Fitted Variation (Cumulative)	49.28	73.87	86.98	93.26

Forward selection retained six of the input variables as contributing significant (at alpha = 0.05) additional explained variance (**Table 13**). Bottom temperature and bottom salinity had the strongest explanatory power, followed by factor near shoal, sample depth, delta temperature, and grain size. Factor Off Shoal was dropped from the model as not providing any additional information because of inverse collinearity with Near Shoal (i.e., most trawls that were not "Near" were "Off"), while the factor On Shoal did not significantly change the explained variance. Delta salinity was dropped because of collinearity with delta temperature.

Table 13. Forward selection results (Spring)

Explains % is the explanatory contribution of each variable at the moment of its selection, related to the total variation (after accounting for a priori covariates, if any). The Contribution % relates this contribution to the whole set of explanatory variables considered during the selection and thus approaches 100%.

Name	Explains %	Contribution %	pseudo-F	P
Bottom temperature	5.0	42.1	19.4	0.002
Bottom salinity	2.8	23.9	11.4	0.002
Near shoal	1.5	12.5	6.0	0.002
Depth	1.1	9.1	4.4	0.002
Delta temperature	0.6	5.1	2.5	0.062
Grain size	0.5	4.3	2.1	0.046

Fishes and invertebrates of the OCS in Spring sorted themselves first along a trend in hydrography that contributed the most to explained variation in CC1, in which warmer bottom temperature (and to a much lesser extent larger grain size) and stratification were inversely correlated (colder bottom temperature occurred when the difference between surface and water temperature was greater) (**Figure 27**). They secondarily sorted along a trend in bottom salinity and depth that was inversely related to factor Near Shoal, along CC2. The taxa typifying salty, deep, and (relatively) warm water in Spring were especially Gulf Stream Flounder, Fourspot Flounder, and Weakfish, while Atlantic Sea Scallop were in deep but somewhat cooler water (**Figure 27**). Taxa typifying warm shallower water were Bay Anchovy, Smooth Dogfish, Scup, Butterfish, and, to a lesser extent, Striped Searobin. In Spring, the shallower nearshore water was cooler, and this included a number of samples collected in close proximity to shoals (**Figures 27, 28**); these samples were typified by Northern Sand Lance, Winter Flounder, Red Hake, Smallmouth Flounder, Clearnose Skate, Winter Skate, and Striped Bass, and in warmer shoal water by Atlantic Horseshoe Crab and Atlantic Menhaden. Only Haddock typified cold, saline, deep, and stratified water. Spiny Dogfish, Summer Flounder, Blueback Herring, Alewife, Spotted Hake and others were fairly centralized in their distribution relative to these trends; however, such distributions could be either central and broad, so that they occurred as similar relative CPUE in trawls from across the hydrographic spectrum, or central and tight, meaning that they occurred in few samples that were very similar in their environment. This central tendency of a species is measured as the root mean square deviation from its centroid, or “tolerance.” The centroid and tolerance together define the realized niche. Tolerance is standardized by the effective sample size (N2) because more abundant species are more likely to be encountered at some ecological distance from their central niche.

Tolerance and tolerance/N2 for each species is provided in **Appendix A**. Species with especially narrow (< 0.028) tolerance/N2 along the CC1 in NEFSC Spring trawl samples, a potential impact assessment factor, were in (ascending order) Haddock, Little Skate, Windowpane, Winter Flounder, Winter Skate, Summer Flounder, *Etropus* sp. flounders, Red Hake, Spotted Hake, Spiny Dogfish, Atlantic Herring, Goosefish, and Longfin Squid. By comparison, the highest was 0.7722 for Atlantic Menhaden. Species with narrow tolerance/N2 (< 0.025) for CC2 were many of the same: Haddock, Winter Flounder, Windowpane, Little Skate, Winter Skate, Summer Flounder, *Etropus* sp. flounders, Spotted Hake. Haddock had 0 tolerance on both axis because they were collected in only a single sample. For comparison, the highest standardized tolerance along CC2 was 0.3566 for Spider Crab (unclassified).

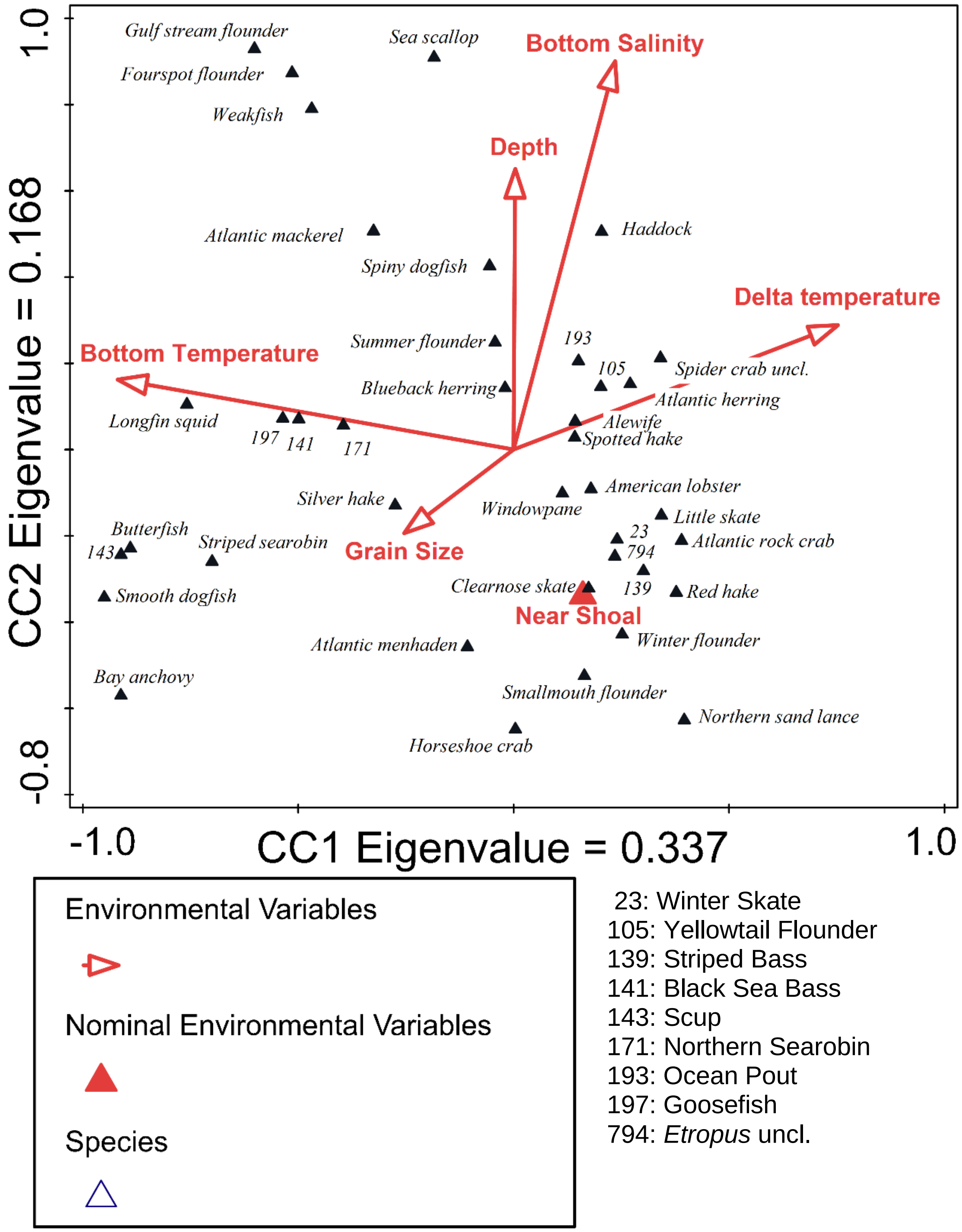


Figure 27. Biplot of species and environmental variables for Spring trawl survey
Symbols mark the estimated center of a species abundance in sample space (**Figure 28**), and abundance declines in all directions from that center. Vectors point in the direction of increasing value of each variable through the sample and species space. Vector length is proportional to the strength (explained variance) of the trend. This figure occupies the same coenospace as **Figure 28** but is separated for legibility.

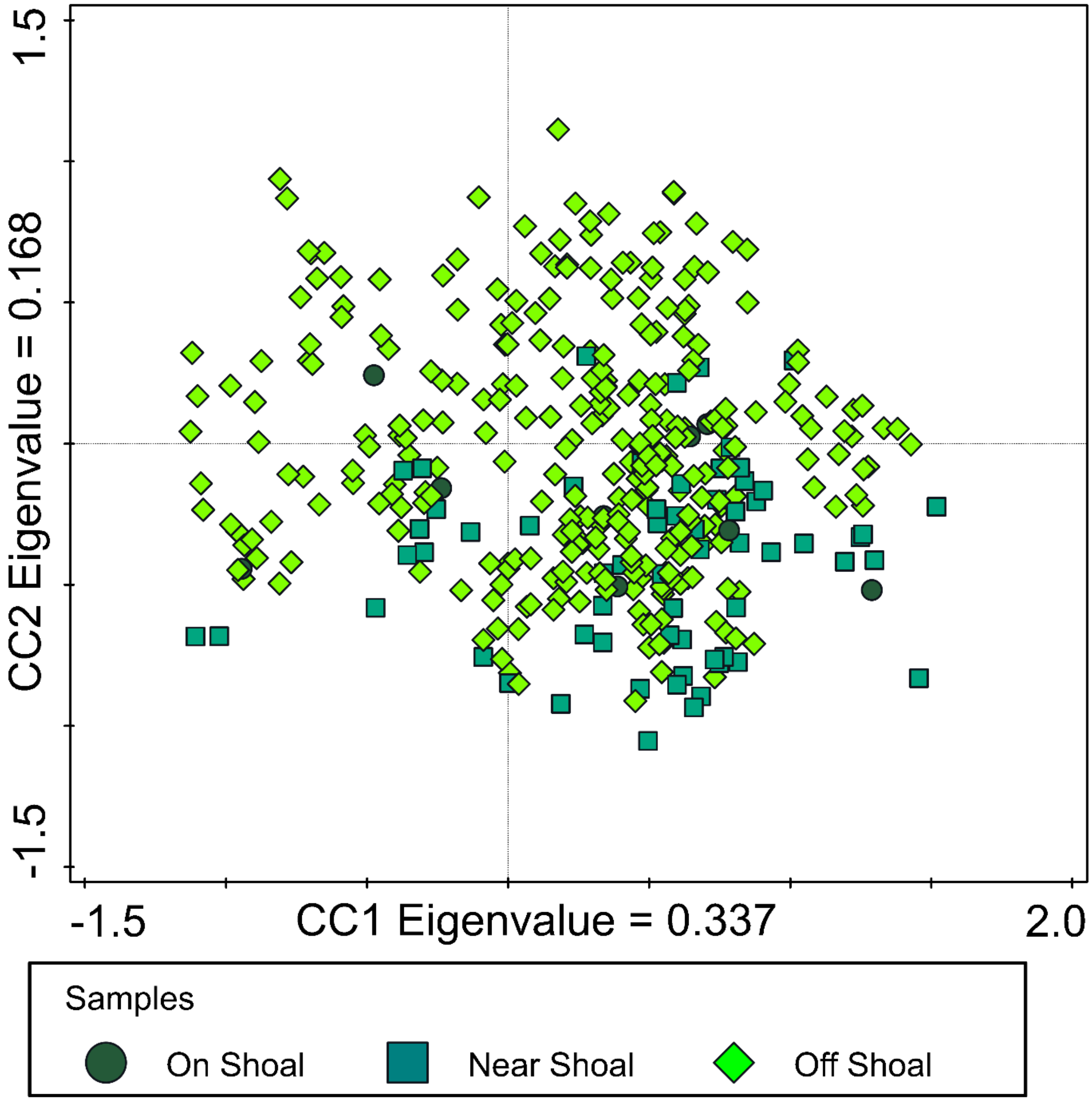


Figure 28. Spring trawl (2010–2019) sample distribution classified by shoal proximity
“Shoal” refers to modeled shoals. This plot shares coenospace with the biplot in **Figure 27**. Species in **Figure 27** are more likely to appear in higher abundance in samples that plot near them and together with other species that plot near them. Trends in variables shown by the vectors in **Figure 27** reflect changes through this sample distribution.

As an example of interpretation, no species vectors fall entirely within the positive circle of a T-value biplot for grain size, but Little Skate fall within the negative circle, meaning that Little Skate sort significantly along a gradient towards finer sediment in these samples in the absence of other information about them, though no species can be significantly predicted to be found in coarser grains on that information alone. However, grain size variation in combination with another environmental trend may still form a better prediction of distribution than that other variable alone.

The results of the Van Dobben circle testing for taxa in the NEFSC Spring trawl survey are summarized in **Table 14**. Given that this is a threshold-type test that may be influenced by rendering (is the arrowhead entirely or partially inside the circle), in some (few) cases, additional species may have been included as a judgement call, or are close enough that the tested factors may yet be useful predictors[1] (see Dushoff et al. (2019)). Therefore, the individual raw T-value biplots are provided for scrutiny in **Appendix A**.

Table 14. Results of Van Dobben Circle analysis for species collected in NEFSC Spring trawl survey

Environmental Variable	Species with Positive Fit	Species with Negative Fit
Bottom temperature	Smooth Dogfish, Goosefish, Fourspot Flounder, Atl. Mackerel, Gulf Stream Flounder, Scup, Black Sea Bass, Butterfish, Silver Hake, Longfin Squid	Little Skate, Winter Skate, Atl. Herring, Red Hake, Winter Flounder, *Etropus* sp. flounders
Bottom salinity	Spiny Dogfish, Atl. Herring, Summer Flounder, Atl. Sea Scallop Fourspot Flounder, Gulf Stream Flounder	Silver Hake, Winter Flounder, Smallmouth Flounder, Butterfish, Scup
Near shoal	Little Skate, Winter Flounder	Fourspot Flounder, Atl. Sea Scallop, Gulf Stream Flounder
Depth	Fourspot Flounder, Gulf Stream Flounder, Longfin Squid, Atl. Sea Scallop	Little Skate, Red Hake, Winter Flounder
Delta temperature	none	none
Grain size	none	Little Skate

3.4.3.4 Fall Trawl Survey

Variation (6.72393) accounted for by explanatory variables in CCA of the Fall (2010–2016, 2018, 2019) data was 11.8% of the total variation. The first canonical axis explained 35.8% of that variance, and the second explained an additional 19.7% (**Table 15**). The relationship between the variables on each axis and the synthetic axis itself, called the pseudo-canonical correlation, was fairly high at 0.77 and 0.55 for CC1 and CC2 respectively.

Table 15. Summary results of CCA (Fall)

Statistic	Axis 1	Axis 2	Axis 3	Axis 4
Eigenvalues	0.3582	0.1966	0.0909	0.0887
Explained Variation (Cumulative)	5.33	8.25	9.60	10.92
Pseudo-canonical Correlation	0.7738	0.5539	0.4214	0.4148
Explained Fitted Variation (Cumulative)	45.19	69.98	81.45	92.63

[1] The use of an arbitrary alpha level for absolute acceptance or rejection of a hypothesis or test of confidence has recently been challenged by numerous papers.

Forward selection retained six of the input variables as contributing significant (at alpha = 0.05) additional explained variance (**Table 16**). Bottom temperature and inversely correlated sample depth and delta temperature had the strongest explanatory power along CC1, while delta salinity, factor Near Shoal, and inversely correlated grain size, explained variation along CC2 (**Figure 26**). The factor Off Shoal was dropped because of collinearity with Near Shoal, while the factor On Shoal did not significantly change the explained variance. Bottom salinity was dropped because of collinearity with bottom temperature.

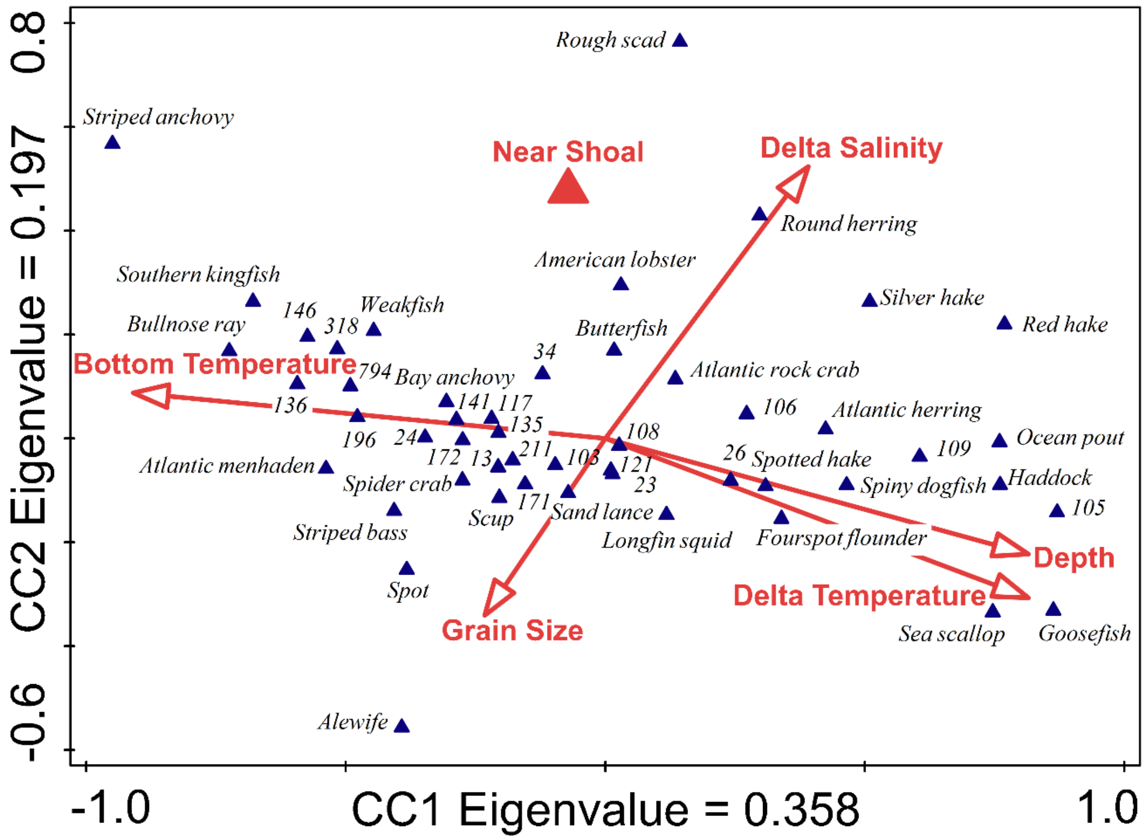
Table 16. Forward selection results Fall

Explains % is the explanatory contribution of each variable at the moment of its selection, related to the total variation (after accounting for a priori covariates, if any). The Contribution % relates this contribution to the whole set of explanatory variables considered during the selection and thus approaches 100%.

Name	Explains %	Contribution %	pseudo-F	P
Bottom temperature	4.6	37.8	14.6	0.002
Delta temperature	2.4	19.6	7.7	0.002
Depth	1.6	13.4	5.4	0.002
Near Shoal	1.4	11.4	4.6	0.006
Grain size	1.3	10.4	4.3	0.006
Delta salinity	0.6	5.1	2.1	0.026

Fishes of the OCS in Fall sorted themselves first along a trend in hydrography defined by bottom temperature and, inversely, depth and the delta temperature. Shallower samples were warmer and less stratified (**Figures 29, 30**). They secondarily sorted along a trend characterized on one end by being near a shoal and being high in salinity and having small grain size. The taxa typifying the shallow warm water near shoals were Striped Anchovy, Southern Kingfish, Weakfish, Bullnose Ray, Atlantic Croaker, and Atlantic Horseshoe Crab, while samples near shoals—but in deeper, cooler, and more stratified water—tended to consist especially of Butterfish, American Lobster, and Atlantic Herring. The deepest samples from cooler stratified water were represented especially by Atlantic Sea Scallop, Goosefish, Haddock, Ocean Pout, Spiny Dogfish, and Gulfstream Flounder. Only Alewife characterized the truly coarse grain sample, which was at moderate warm temperature and moderate depth, but Alewife were also found elsewhere. Numerous species characterized the modal environment, being distributed either broadly or narrowly from there (as shown by Tolerance). Species-characterizing samples typified by a modal environment or broadly distributed during Fall included especially Windowpane, Atlantic Mackerel, Winter Skate, Round Scad, Summer Flounder, Smooth Dogfish, Northern Sand Lance, and Bluefish.

Tolerance and tolerance/N2 for each species is provided in **Appendix A**. Species with especially narrow (< 0.02) tolerance/N2 along the first canonical axis in NEFSC Fall trawl samples were (in ascending order) Alewife, Windowpane, Striped Searobin, Longfin Squid, Little Skate, Northern Puffer, Northern Kingfish, Scup, and Winter Skate. For comparison, the highest standardized tolerance on CC1 was for Atlantic Herring at 0.48. Species with narrow (< 0.025) standardized along canonical axis 2 were Alewife, Summer Flounder, Little Skate, Windowpane, Longfin Squid, Striped Searobin, Northern Searobin, and Fourspot Flounder. For comparison, the broadest standardized tolerance along CC2 was 0.4199 for Striped Bass. Alewife had 0 tolerance on both axis because they were collected in only a single sample.



Environmental Variables

Nominal Environmental Variables

Species

13: Smooth Dogfish
23: Winter Skate
24: Clearnose Skate
26: Little Skate
34: Blueback Herring
103: Summer Flounder
105: Yellowtail Flounder
106: Winter Flounder
108: Windowpane
109: Gulf Stream Flounder
117: Smallmouth Flounder
121: Atlantic Mackerel
135: Bluefish
136: Atlantic Croaker
141: Black Sea Bass
146: Nor. Kingfish
171: Nor. Searobin
172: Striped Searobin
196: Nor. Puffer
211: Round Scad
318: Horseshoe Crab
794: *Etropus* uncl.

Figure 29. Biplot of species and environmental variables for Fall trawl survey
Symbols mark the estimated center of a species abundance in sample space (**Figure 30**), and abundance declines in all directions from that center. Vectors point in the direction of increasing value of each variable through the sample and species space. Vector length is proportional to the strength (explained variance) of the trend. This figure occupies the same coenospace as **Figure 30** but is separated for legibility

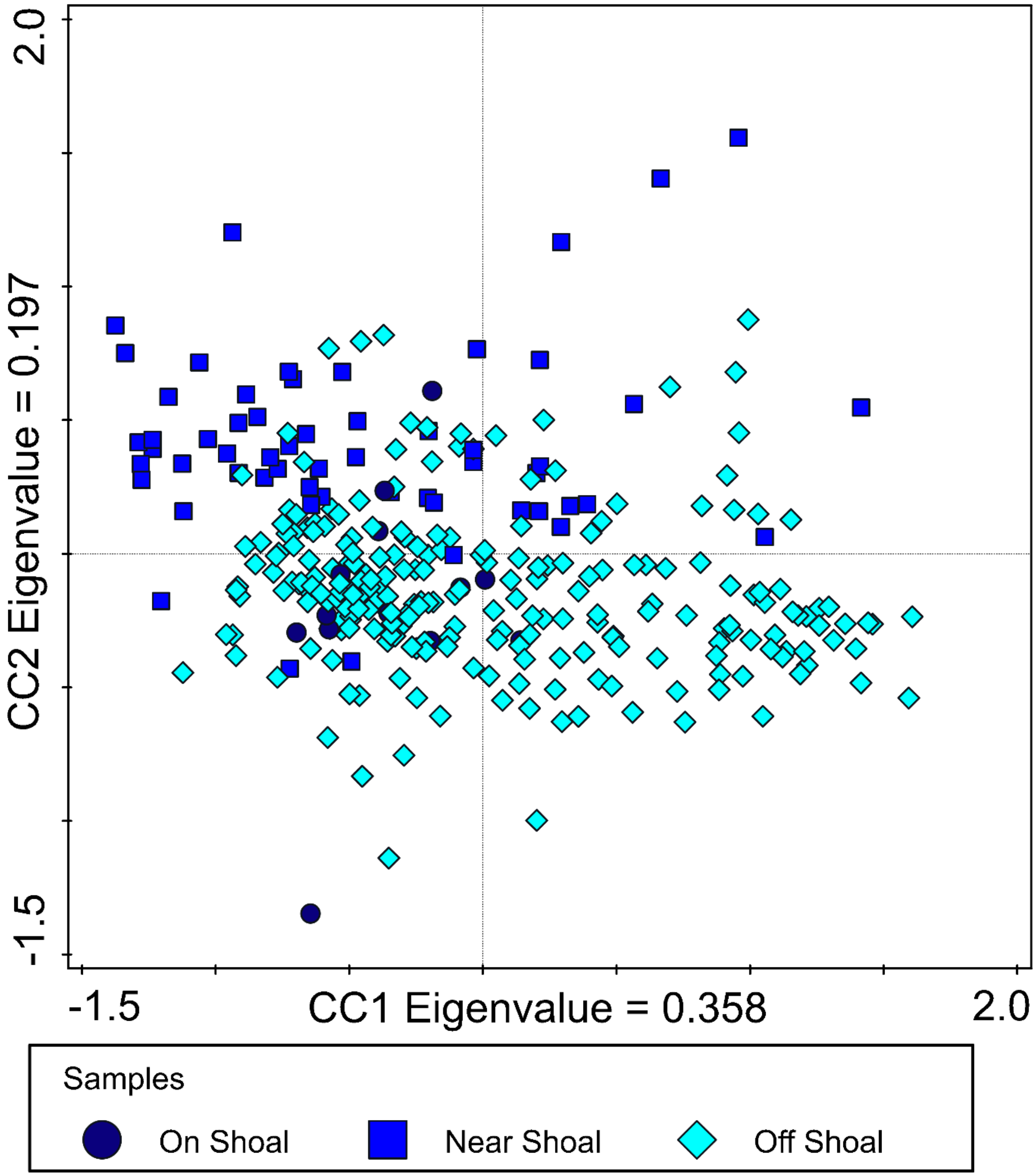


Figure 30. Fall trawl sample distribution classified by shoal proximity
"Shoal" refers to modeled shoals. This plot shares coenospace with the biplot in **Figure 29**. Species in **Figure 26** are more likely to appear in higher abundance in samples that plot near them and together with other species that plot near them. Trends in variables shown by the vectors in **Figure 29** reflect changes through this sample distribution.

The results of the T-value biplot testing for taxa in the NEFSC Fall trawl survey are summarized in **Table 17**. Given that this is a threshold-type test that may be influenced by rendering (is the arrowhead entirely or partially inside the circle), in some (few) cases, additional species may have been included as a judgement call, or are close enough that the tested factors may yet be useful predictors. Therefore, the individual raw T-value biplots are provided for scrutiny in **Appendix A**.

Table 17. Results of Van Dobben Circle analysis for species collected in NEFSC Fall trawl survey

Environmental Variable	Species with Positive Fit	Species with Negative Fit
Bottom temperature	Scup, Longfin Squid	Round Herring, Rough Scad
Delta salinity	Atl. Sea Scallop, Longfin Squid	Stripped Anchovy
Near shoal	Round Herring, Striped Anchovy, Rough Scad	Atl. Sea Scallop, Longfin Squid
Depth	Round Herring	none
Delta temperature	Scup, Atl. Sea Scallop, Longfin Squid	Round Herring, Striped Anchovy, Butterfish, Rough Scad
Grain size	Scup, Longfin Squid	Round Herring, Rough Scad

3.5 Atlantic Sturgeon Distribution

3.5.1 Purpose

Atlantic Sturgeon are an endangered species, and their distribution is of special concern. The species was not well represented in NEFSC surveys between 2010 and 2019 and were not included in the assemblage analysis.

3.5.2 Methods

The distribution of Atlantic Sturgeon in the study area NEFSC trawl data and in the study areas in State waters from NJDEP trawl data was examined and presented by scatter plot.

3.5.3 Results

A total of 13 Atlantic Sturgeon were collected in the study area in Spring NEFSC trawl surveys between 2010 and 2019, and another 19 were collected in Fall surveys (despite the fact that Fall data contained fewer years). All Atlantic Sturgeon were in nearshore samples except for one individual collected off the mouth of the Delaware Bay in Spring. No more than two individuals were collected together in Spring. No more than four were collected together in Fall, but given the scarcity of these fish in general, the two trawls with four fish and single trawl with three fish may indicate hotspots (although they may also be an artifact of social behavior). Social behavior of Atlantic Sturgeon on marine feeding grounds is not documented. Sturgeon were distributed more to the north in Fall than in Spring (**Figure 31**).

Sturgeon were much better represented in NJDEP trawl surveys, with a total of 412 individuals collected. As in NEFSC surveys, all were close to shore (NJDEP trawls were in State and OCS waters), with the exception again of several collected well off the mouth of the Delaware Bay (**Figure 32**). Most trawls collected only singletons, but the distribution was highly skewed with several catches between 2 and 12 individuals and a single trawl each with 16 and with 21. Hotspots were at the apex of the study area and to a lesser extent off Cape May, NJ.

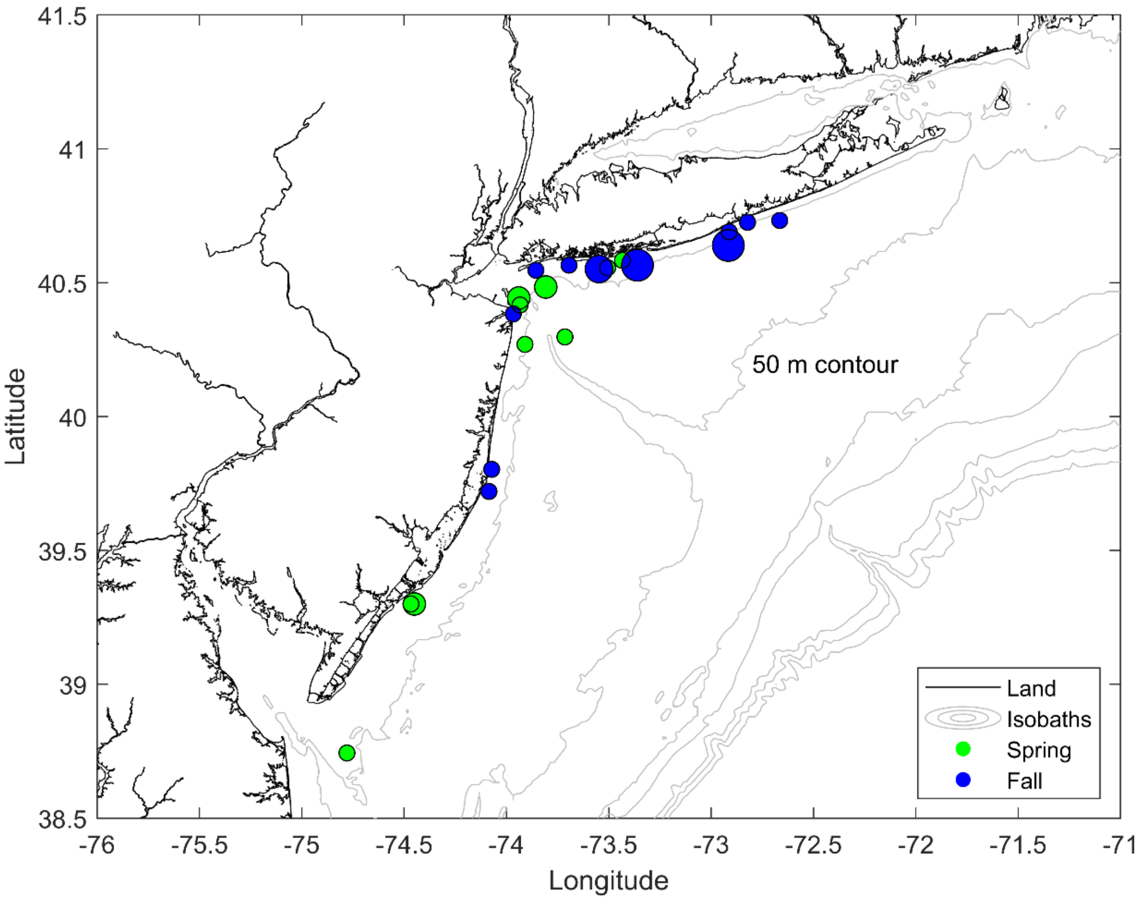


Figure 31. Distribution of sturgeon in the study area from NEFSC trawl surveys
Larger marker sizes correspond to four individuals, smallest to one individual.

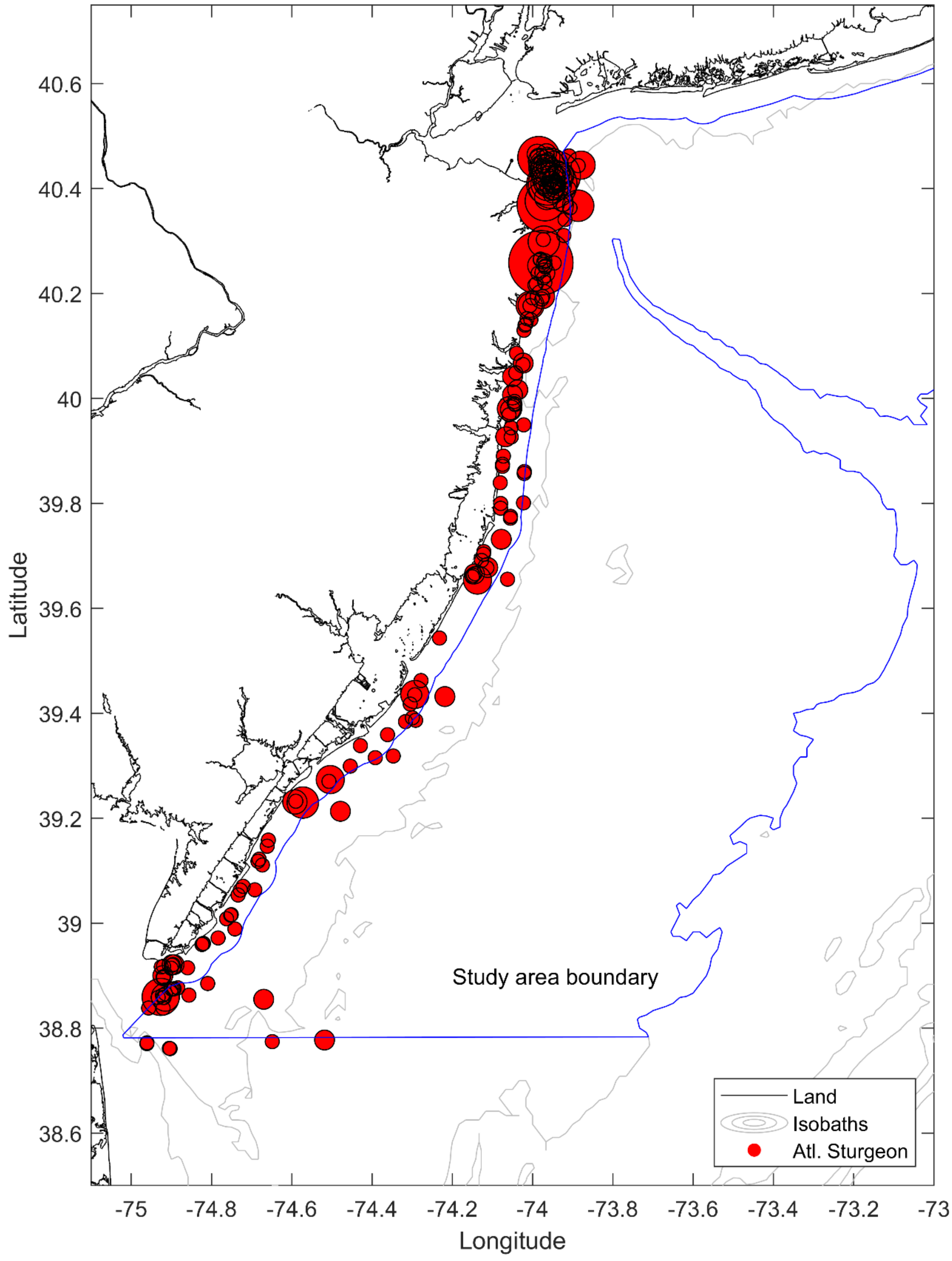


Figure 32. Distribution of sturgeon in the study area from NJDEP trawl surveys
Larger marker sizes correspond to 21 individuals, smallest to one individual.

Sturgeon were centered at salinity 30–32 psu but at two temperature modes (as a consequence of seasonal sampling bias), one near 6 ºC and again near 16 ºC, but broadly anywhere between 2.1 and 21.1 ºC (**Figure 33**). Sturgeon were collected throughout the year in NJDEP trawls, but least in summer (**Figure 34**).

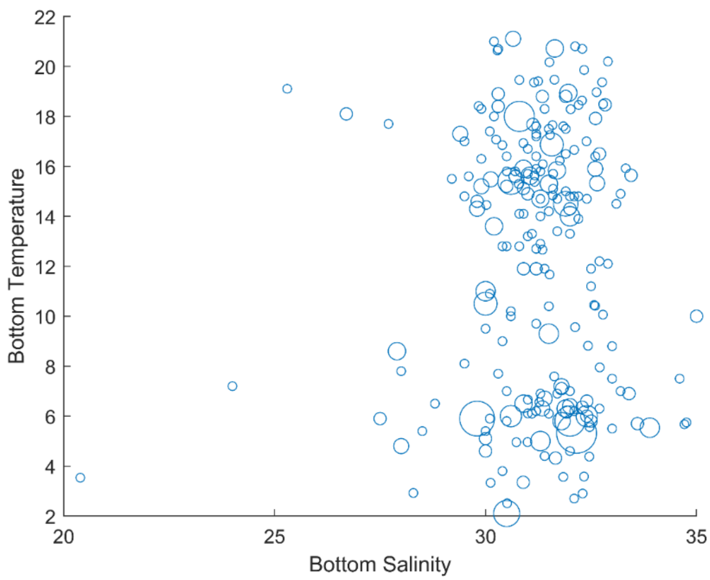


Figure 33. Distribution of Atlantic Sturgeon relative to hydrography
Data are extracted from in NJDEP and NEFSC trawl surveys from 2010–2019. Bubble size is scaled between 1 and 21 fish per trawl. Methods differ between NJDEP and NEFSC surveys, and number is not scaled to trawl swept area as CPUE and should be viewed as rank order.

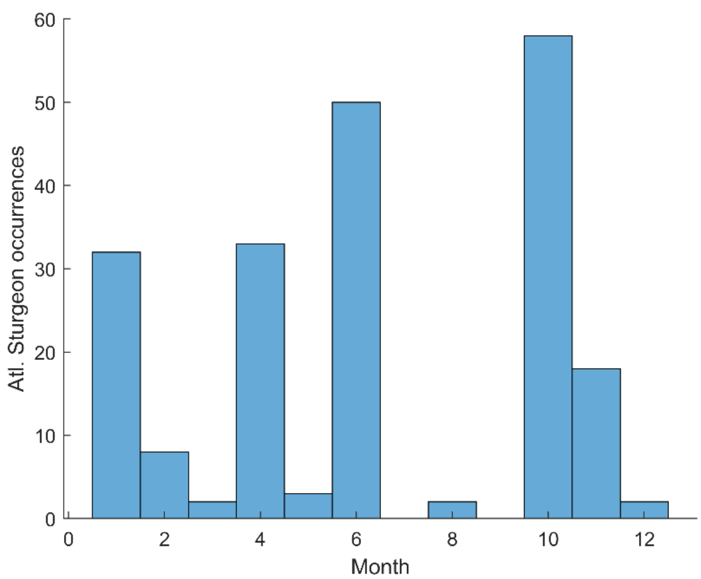


Figure 34. Distribution of Atlantic Sturgeon by month from NJDEP trawl survey

3.6 Benthic Invertebrate Distribution and Trends

3.6.1 Ocean Quahog and Atlantic Surfclam

3.6.1.1 Purpose

New Jersey and New York State waters have historically been excellent habitat for Atlantic Surfclam and Ocean Quahog and both supported robust fisheries. There is evidence of declining recruitment to the fishable population and mortality of large clams in New Jersey and New York based on size frequencies and total biomass estimates) (Northeast Fisheries Science Center 2017).

3.6.1.2 Methods

Data on Ocean Quahog distribution were extracted from the NEFSC Resource Survey Report, Atlantic Surfclam/Ocean Quahog, Delmarva Peninsula–Nantucket Shoals, August 3–15, 2017 (NEFSC 2018). The survey collects both species but reports separately on Ocean Quahog and Atlantic Surfclam. Therefore, plot locations of samples are identical for the two species. Scientific surveys of abundance are based on a 13-foot commercial-style hydraulic dredge towed for 5 minutes at 3.0 kt.

The median depth (depth at which half of the cumulative total clams caught the annual NEFSC survey) was regressed against year with a linear model.

3.6.1.3 Results

Ocean Quahog are sparsely distributed inshore of the 30-m bathymetric contour in the study area, especially in the south of the NYB apex (**Figure 35**). Abundance increased markedly seaward, with a maximum of 4,025 per sample. The distribution of Atlantic Surfclam is less well characterized and more widely distributed with regards to depth than their name implies. Highest densities were also seaward of the 30-m contour (**Figure 36**). Abundance was lowest to the south and inshore.

Although the maximum local density was roughly twice as high for Ocean Quahog as for Atlantic Surfclam, the more even distribution of the latter yielded a similar total count of 30,865 for Atlantic Surfclam vs. 29,784 for Ocean Quahog in the same survey.

The southern distribution of Atlantic Surfclam is shifting into deeper water south of the NYB apex off New Jersey (slope = -0.48 m per year, adjusted $R^2 = 0.8604$, $p < 0.0001$) but not off Long Island, New York (slope = -0.05 m per year, adjusted $R^2 = 0.0240$, $p = 0.581$) (**Figure 37**). This is thought to be due to warming in nearshore habitats (see **Volume 1: Literature Synthesis and Knowledge Gaps**). Atlantic Surfclam populations distribution and warming bottom temperatures cause previously suitable nearshore habitat to decrease and offshore habitat to increase, particularly in the MAB. Recent declines in abundance of Atlantic Surfclam in the most southern portion of their range on the MAB continental shelf has been attributed to warming bottom waters (Kim and Powell 2004; Weinberg 2005; Weinberg et al. 2002) and increased frequency of conditions that result in episodic warming events of bottom waters (Narváez et al. 2015). As ocean temperatures increase, the distribution and biology of Atlantic Surfclam are potentially changing, with likely effects on fishery productivity (Munroe et al. 2016).

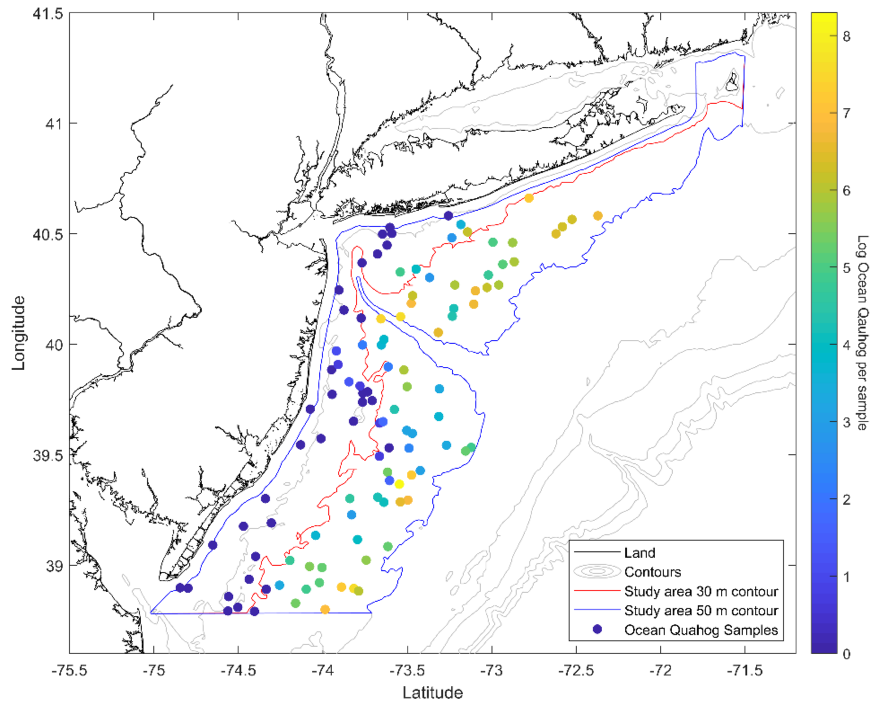


Figure 35. Distribution of Ocean Quahog in the study area in 2018
Log(8.303) corresponds to the maximum catch of 4,025 clams in a sample.

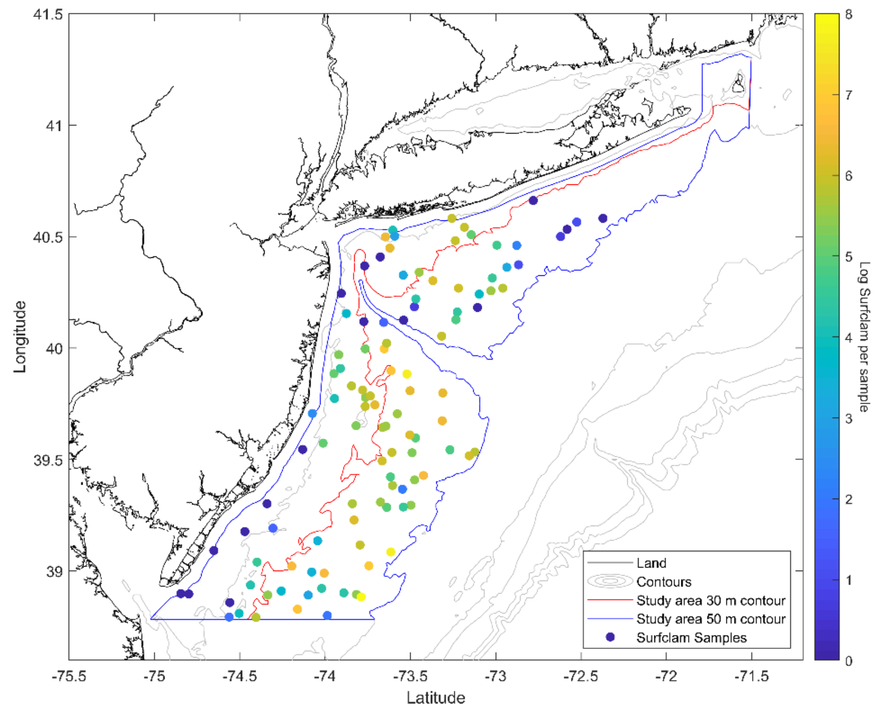


Figure 36. Distribution of Surfclam in the study area in 2018
Log(7.96) corresponds to the maximum catch of 2,873 clams in a sample.

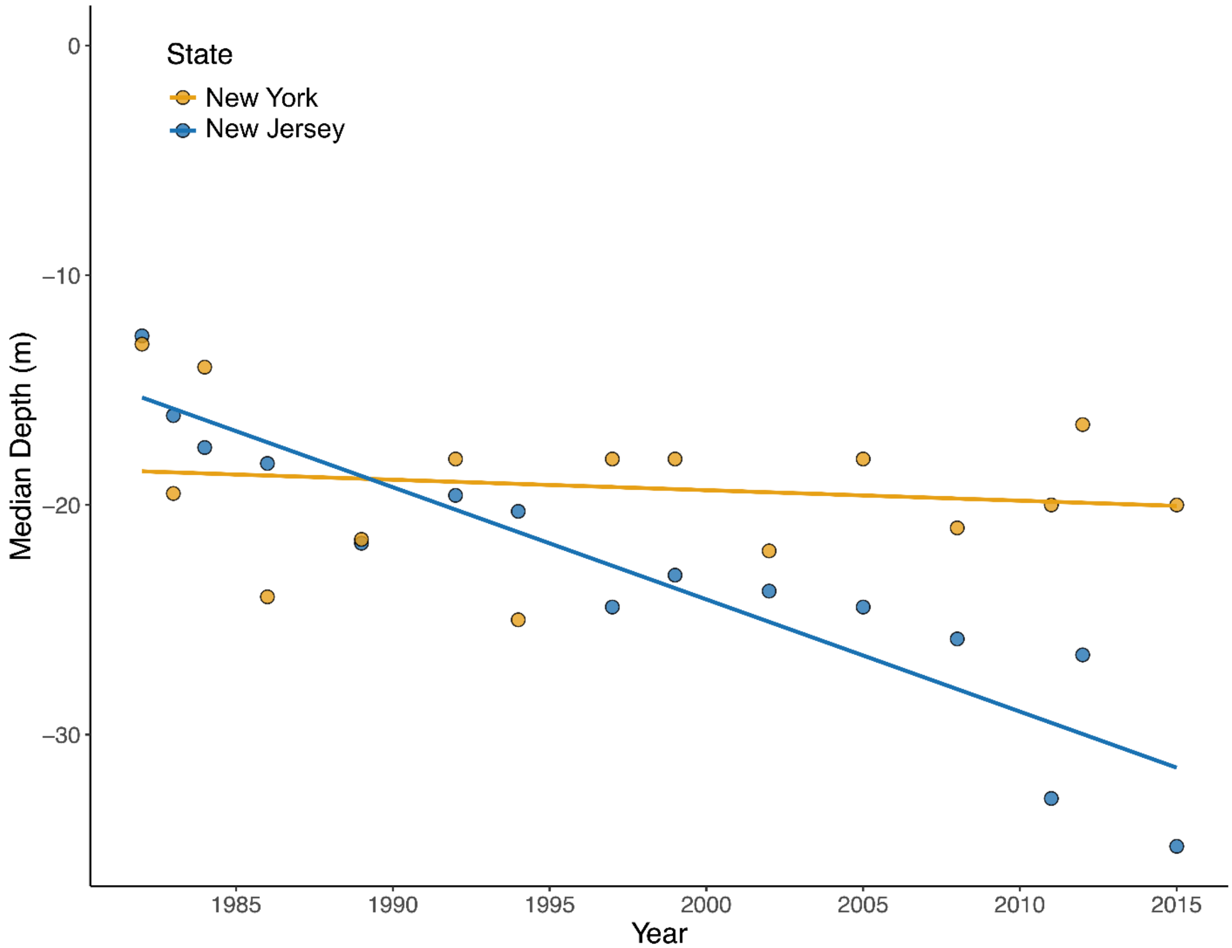


Figure 37. Change in depth distribution of New Jersey and New York, 1983–2015
The median depth (m) of Atlantic Surfclam by year, separated by Surfclam stock assessment regions. A negative slope indicates that a higher proportion of the total Surfclams in a region were caught in deeper water in recent years. Data summarized from 61st Northeast Regional Stock Assessment Workshop Report (NEFSC, 2017).

3.6.2 Atlantic Sea Scallop

3.6.2.1 Purpose

The NYB has historically been excellent habitat for Atlantic Sea Scallop. This invertebrate is sampled independently of the NEFSC trawl survey at higher resolution using photo-imaging methods. Distribution relative to the study area is of interest due to the high revenue generated from this resource.

3.6.2.2 Methods

The distribution of Atlantic Sea Scallop was mapped on the basis of average abundance per video sample cell from the University of Massachusetts Dartmouth School of Marine Science and Technology (SMAST) video survey from 2003 through 2012. Data were extracted from the ERDDAP.

3.6.2.3 Results

Atlantic Sea Scallop were absent within the 30-m isobaths of the study area and low (between 0 and 4) between the 30- and 50-m isobaths (**Figure 38**). Abundance increased with depth, including at the edges of the Hudson Shelf Valley.

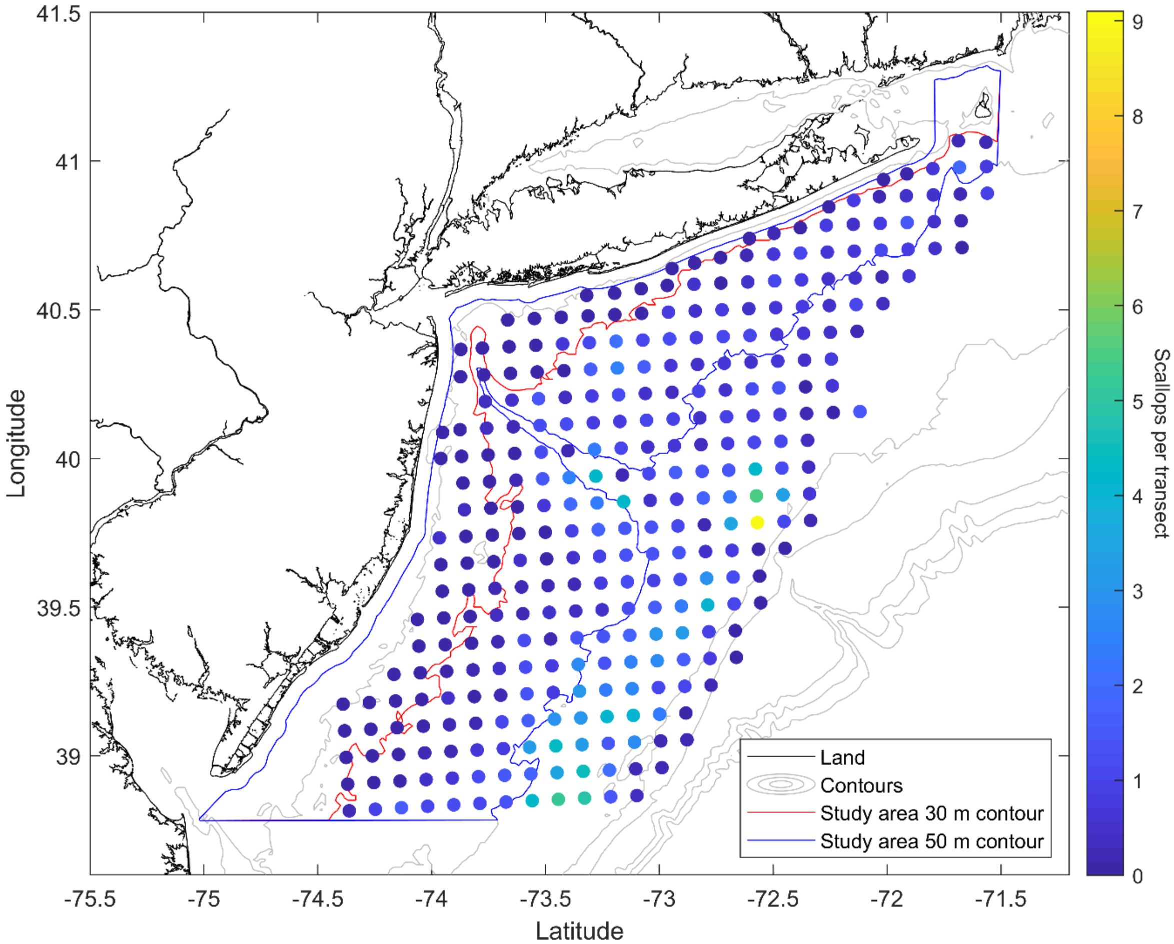


Figure 38. Average number of scallops from 2003 to 2012 per video transect cell

4 Trophic and Life History Crosswalk

4.1 Purpose

As part of this study, we created a large electronic (and therefore sortable) table for easy lookup of species that might be unaffected by disturbance in one place but be indirectly affected by disturbance to other species through trophic cascade or cumulative effects. The table includes a species-by-prey matrix that is annotated on the basis of known predator/prey association, as well as reproductive guilds.

4.2 Method

Of regional species, 88 were characteristic of, or important to, the NYB OCS and were therefore included in the table. The list includes species that are not treated in analysis of the trawl data because they are not well sampled by trawls, such as tunas and sharks, but are addressed in **Volume 1: Literature Synthesis and Knowledge Gaps**. A simplification of the complex trophic relationship classified species into Benthivores (primary focused on benthic infauna or epifauna, including scallops), Generalists (those that preyed on a wide variety of taxa and forms), Piscivores (those that focused primarily on fishes and squids), and Planktivores (focused primarily on plankton, but included small forage and larval fish and potentially large jellies). Benthivores were the most common, with 25 representatives, followed by Piscivores (21 representatives), while generalists and planktivores were both represented by 18 species.

Broadcast spawners were the best represented among spawning guilds with 43 representatives, followed by Live Birth (Sharks, 19), Egg Capsule (Skates, 8), and Anadromous (6), but included species that lay adhesive eggs, brooded clutches, and others.

4.3 Results

A printed table in appears in **Volume 1, Appendix A.** A digital table with embedded annotation is submitted.

5 Fishing Activity Data

5.1 Identified Prime Fishing Grounds

5.1.1 Purpose

This task involved identifying aggregations of fishing behavior as ecological hotspots expressing the cumulative effects of hidden factors (latent trends) such as cost-return benefits.

5.1.2 Method

Prime Fishing Grounds are locations within 20 nautical miles of the coast identified on the basis of NOAA charts annotated through NJDEP staff interviews of 28 party boat captains, 47 charter boat captains, and 22 private boat captains from all ports along the Atlantic Coast of New Jersey. Original charts from 1982–1984 were updated in 2018 to include artificial reef sites and digitized. Layers are served and managed by NJDEP. Attributes for named Prime Fishing Grounds (n = 313) constrained to the study area latitude and longitude were extracted from MARCO and examined for attributes relative to understanding the role of sand shoals in defining the area. The attribute "Profile Area" contained as basic descriptor of the main bottom profile feature with values defined as 1) Lump: positive elevation change from the surrounding area, 2) Slough: negative elevation change from the surrounding area, and 3) Plain: level area. The attribute Site Type contained a basic descriptor of surficial features such as the presence of wrecks or reefs. Each site was also identified as being a place to fish certain species, with binary (presence or absence) values for 15 targets (Summer Flounder, Black Sea Bass/Tautog, Cod/Pollock, Bluefish, Weakfish, Striped Bass, Tuna, Sharks, Billfish, Bonito/Albacore, Scup, Red Hake, American Lobster, Other.
(https://www.arcgis.com/sharing/rest/content/items/df7de8c132a749d680ae415b30322fc8/info/metadata/metadata.xml?format=default&output=html). Based on a query with the data manager Peter Clarke, "Albacore" refers to Little Tunny (commonly called False Albacore).

Similarity among prime fish grounds was calculated (function "dist") using Euclidean distance metric on a matrix of the binary species identifiers and clustered (function "hclust") with a complete linkage rule in R (R Core Team 2020). Similarity was depicted as a dendrogram (function "as.dendrogram").

5.1.3 Results

The most common Profile Area value for prime fishing grounds in the study area was "Unclassified" (47%). "Lump" was by far the most common classified profile at 30% (**Table 18**). "Lump" was part of the description for an additional 1.6% of profile types (or 3% of classified profile types). Site Types attributes were not well populated, with 82.4% remaining "unclassified." "Wreck" was the most common (6.4%) value of Site Type (36.4% of the classified Site Types) followed by "Other" (4.8%) (**Table 19**).

Cluster analysis revealed no discernable grouping of prime fishing grounds (based on target species attraction) that aligned with profile type (dendrogram not shown). Both Unclassified and classes inclusive of Lump appeared in all clusters, but the few sites inclusive of Dropoff grouped to some extent due to an affinity with targets Tuna, Sharks, and Billfish. Summer Flounder were identified as the target in 126 of the 313 sites, followed by Bluefish (93), and then Bonito/Albacore. Summer Flounder was the most frequently (49) identified target for Lumps, followed by Bluefish (44).

Table 18. Frequency distribution of Profile Area attributes for Prime Fishing Grounds in the study area

Profile Area	Count	Percent
Dropoff	7	2.2%
Lump	94	30%
Lump, Slough	3	1%
Lump, Slough, Dropoff	1	0.3%
Plain	30	9.6%
Plain, Lump	1	0.3%
Slough	29	9.3%
Unclassified	148	47%

Table 19. Frequency distribution of Site Type attributes for Prime Fishing Grounds in the study area

Site Type	Count	Percent
Hill	1	0.3%
Reef	1	0.3%
Dump Site	2	0.6%
Inlet	2	0.6%
Mussel Bottom	4	1.3%
Wreck, Others	4	1.3%
Canyon	6	1.9%
Other	15	4.8%
Wreck	20	6.4%
Unclassified	258	82.4%

5.2 Commercial Fishing Activity

5.2.1 Purpose

This activity quantified commercial fishing effort within the study area and identified fish and invertebrate species of commercial importance as a means for assessing relative value and overlap with resource extraction.

5.2.2 Method

A fisheries-oriented reference map of the NYB was generated within ArcMap. This reference map included the following: a raster layer of regional bathymetry containing data compiled by The Nature Conservancy from NOAA’s Coastal Relief Model and Atlantic margin bathymetry data compiled in turn by the Center for Coastal and Ocean Mapping Joint Hydrographic Center at the University of New Hampshire; a polygon layer of prime recreational fishing grounds compiled by the NJDEP, which identified features such as lumps, sloughs, plains, wrecks, and artificial reefs; a polygon layer contained both modeled shoals and sand resources from MMIS; a polygon layer of marine minerals lease areas from BOEM MMIS; demarcations of the NOAA Greater Atlantic Region Statistical Areas (GARSA); and polygons of the study area at both the 30-m and 50-m depth contour.

Geospatial PNG tiles created from Vessel Monitoring System (VMS) data (satellite tracking of individually identified vessel movements) for commercial fishing vessels travelling under 4 knots and targeting Atlantic Sea Scallop, Goosefish, Surfclam, Ocean Quahog, the multispecies groundfish complex, and the herring-mackerel-squid pelagics complex were extracted from MARCO. A vessel speed of under 4 knots nominally corresponds to active fishing effort; it should be noted that "hotspots" also appear next to inlets and fishing ports, which represent vessels leaving and returning to port. These tiles were overlaid on maps of the NYB within ArcMap (ESRI 2019) containing demarcations of NOAA Statistical Areas and polygons of the study area at the 30-m and 50-m depth contours. This permitted the visual estimation of the degree of overlap between commercial fishing and potential dredging activity, and thus an estimate of the potential for space-use conflict between these activities (**Figures 39–45**).

Non-confidential data for annual landings and the top three species in terms of landings and revenue harvested via traps and pots, trawls, dredges, purse seines, and gill nets within the NOAA GARSAs encompassing the study area (612, 613, 614, and 615) were acquired from the Atlantic Coastal Cooperative Statistics Program (ACCSP). These gear types were specified to best reflect commercial fishing dependent on sand features, i.e., bottom-oriented commercial fisheries. By evaluating fishing effort by Statistical Area instead of by NYB-local landings (i.e., NJ and NY landings), a more complete picture of fishing effort within the NYB can be obtained (**Figures 46–48**). For example, if a commercial vessel from NC were to fish within the NYB, the resulting landings and revenues would be captured within the ACCSP data, but not the NYB-local landings. For confidentiality reasons, data no finer than annual summaries at the scale of the Statistical Areas containing the study area could be provided. Thus, the resulting summaries may contain some landings and revenues from outside the formal study area; this is particularly true for Statistical Areas 613 and 615. Data was processed and plotted within R (R Core Team 2020).

5.2.3 Results

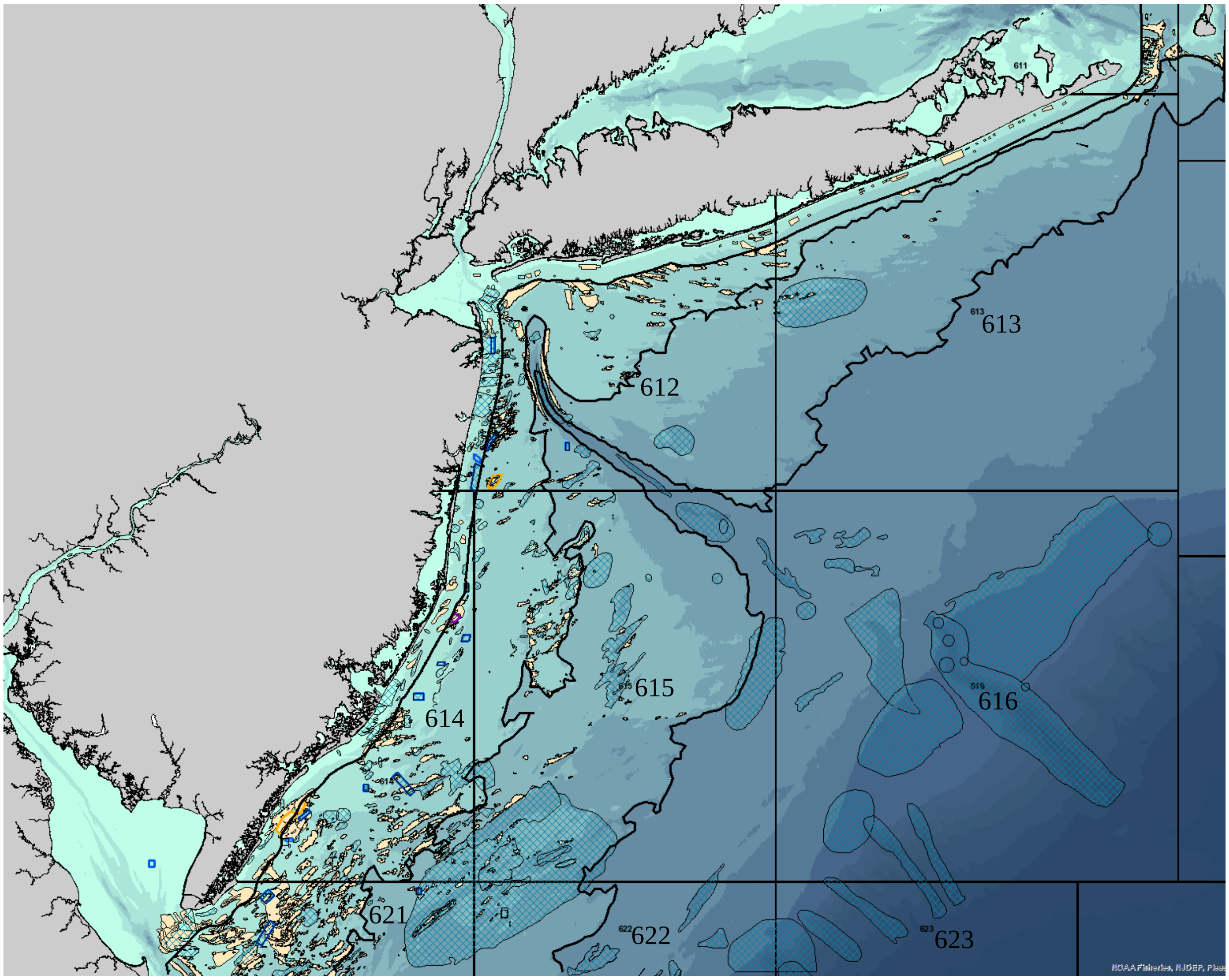


Figure 39. A reference map of the NYB to accompany fisheries analysis
Modeled shoals and sand features in beige. NJDEP prime recreational fishing grounds demarcated by blue-hatched polygons; artificial reefs identified as prime fishing grounds demarcated by blue-edged polygons. Marine minerals lease areas demarcated by orange- and purple-edged polygons. Large format numbers identify the statistical area designations.

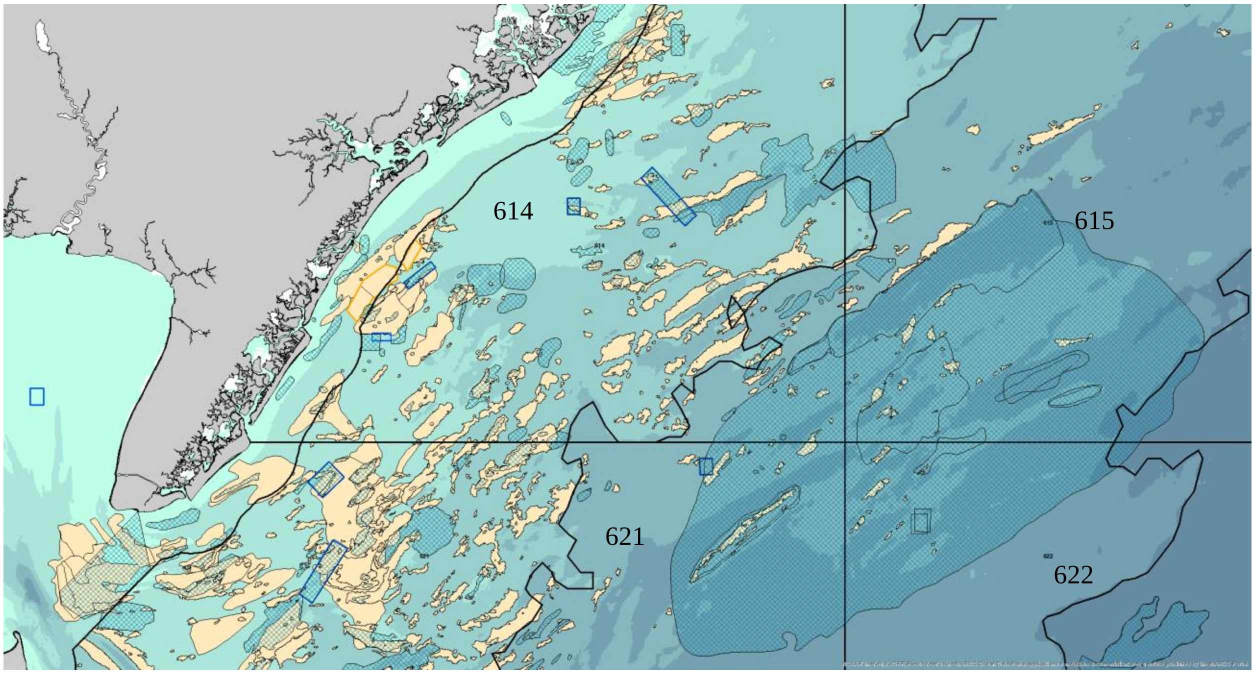


Figure 40. A reference map of the study area off Cape May and Atlantic counties, New Jersey, to accompany fisheries analysis

Modeled shoals and sand features in beige. NJDEP prime recreational fishing grounds demarcated by blue-hatched polygons; artificial reefs identified as prime fishing grounds demarcated by blue-edged polygons. Marine minerals lease areas demarcated by orange- and purple-edged polygons. Large font numbers identify statistical areas.

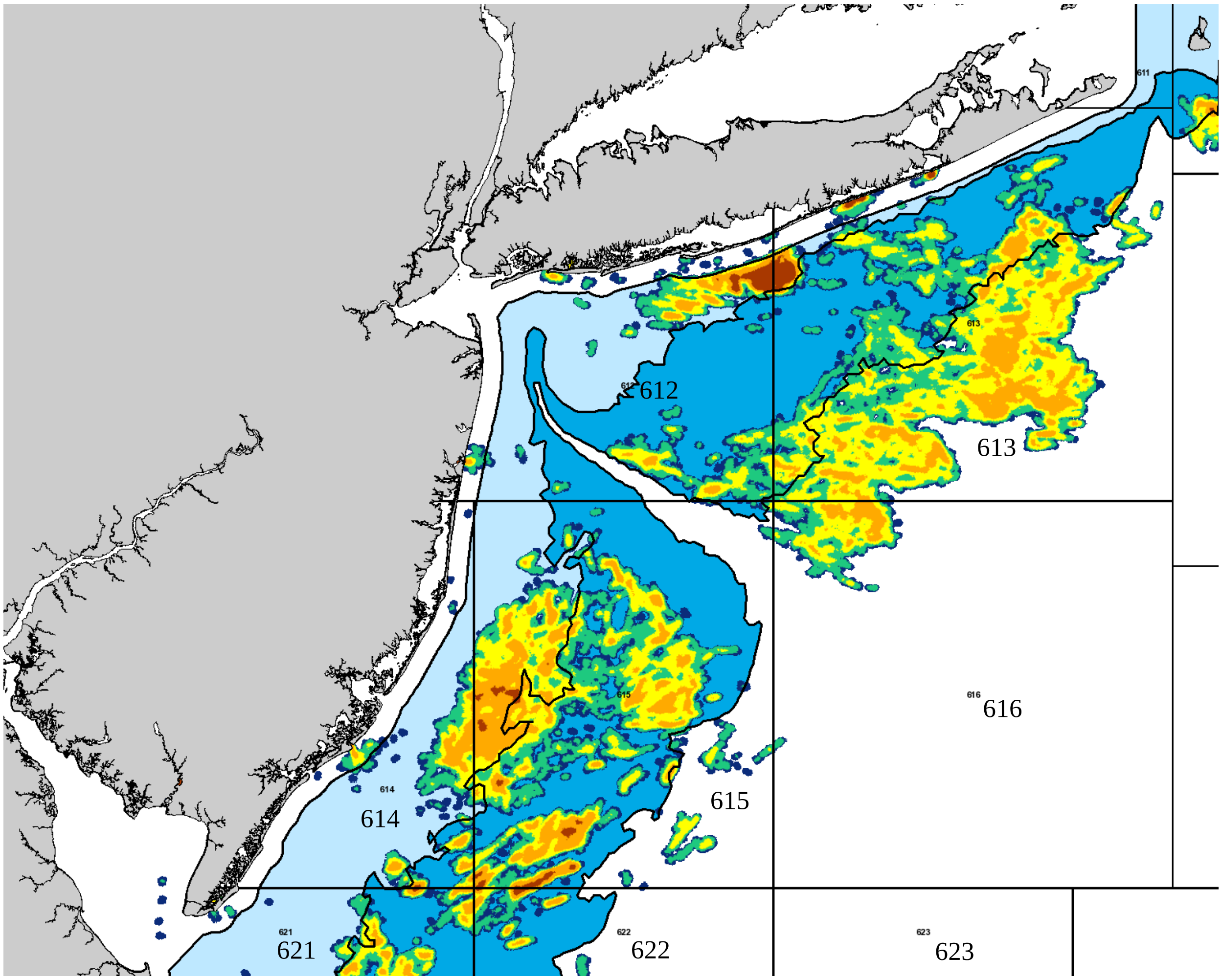


Figure 41. Distribution of commercial fishing activity for Surfclam and Ocean Quahog within the study area, 2015–2016
Large font numbers identify statistical areas.

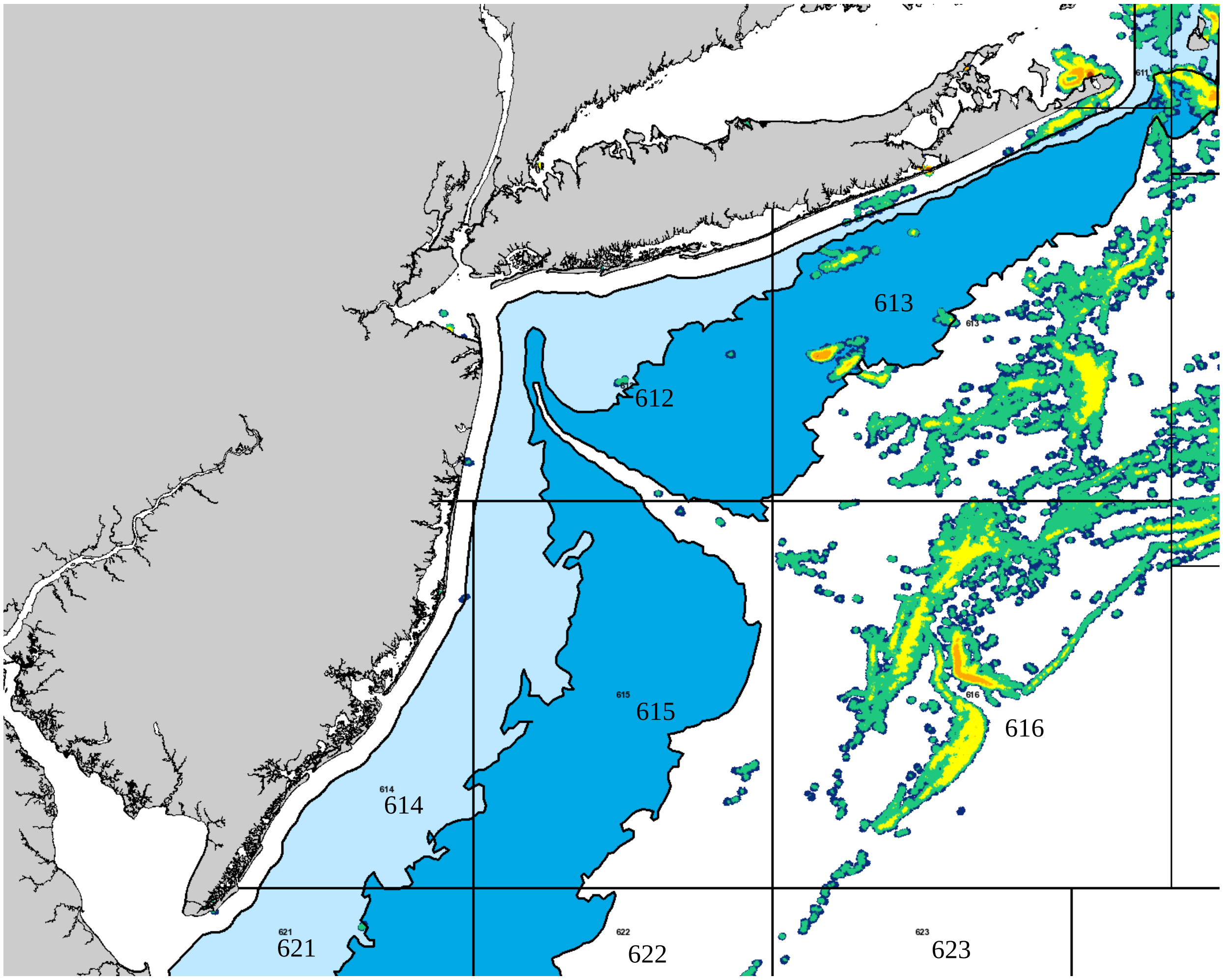


Figure 42. Commercial fishing activity for the multispecies groundfish complex within the study area, 2015–2016
Large font numbers identify statistical areas.

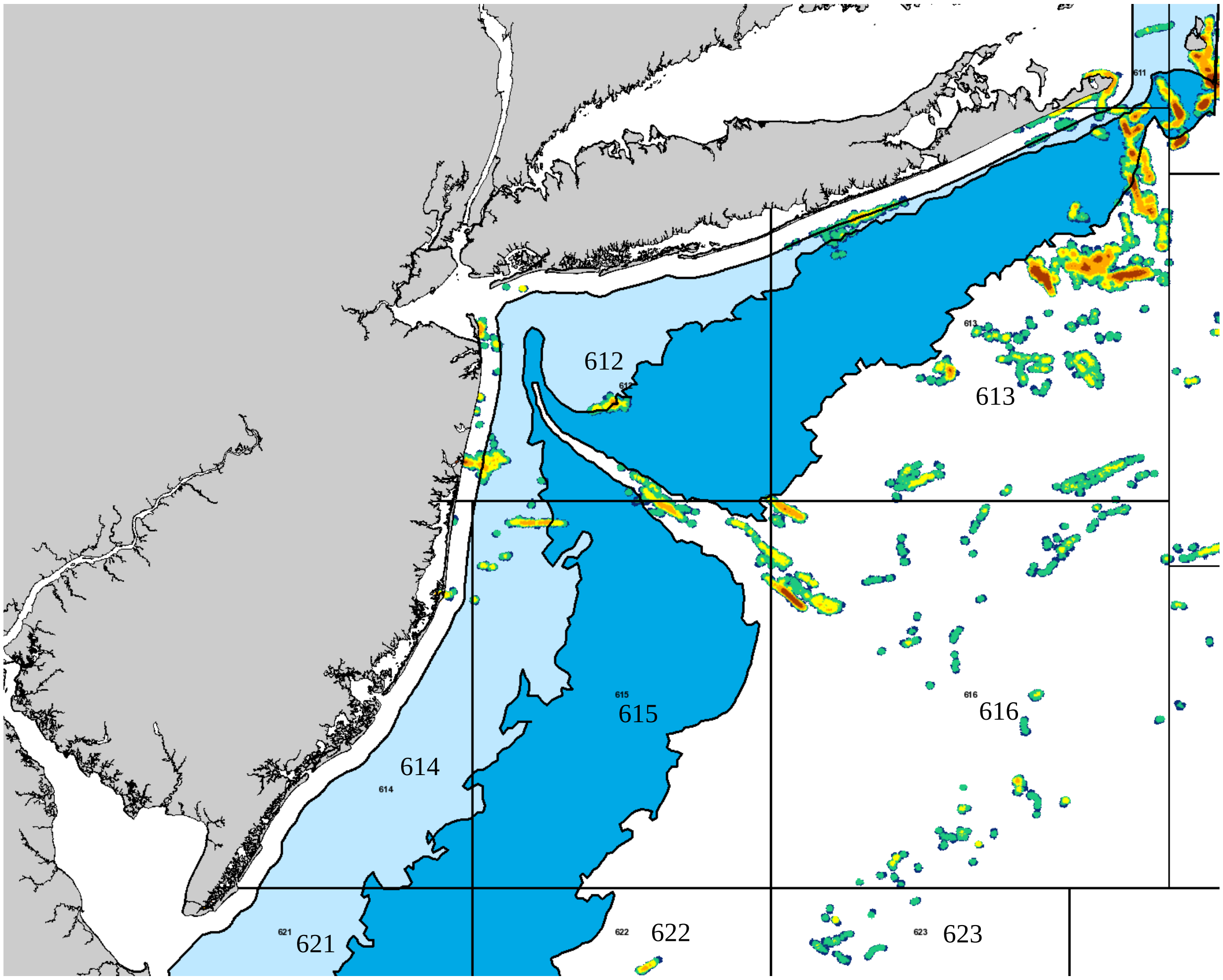


Figure 43. Commercial fishing activity for Goosefish within the study area, 2015–2016
Large font numbers identify statistical areas.

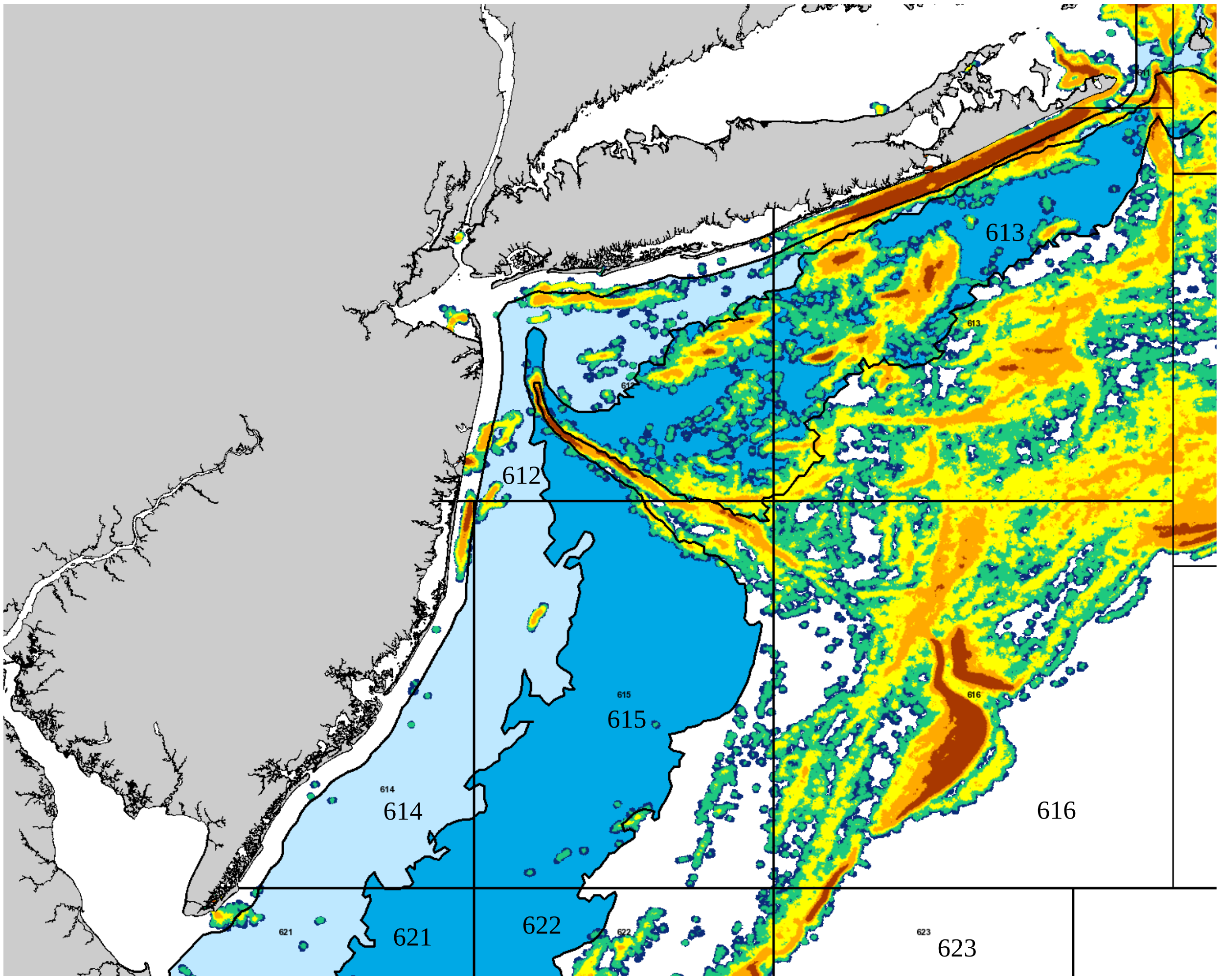


Figure 44. Commercial fishing activity for the herring-mackerel-squid pelagics complex within the study area, 2015–2016
Large font numbers identify statistical areas.

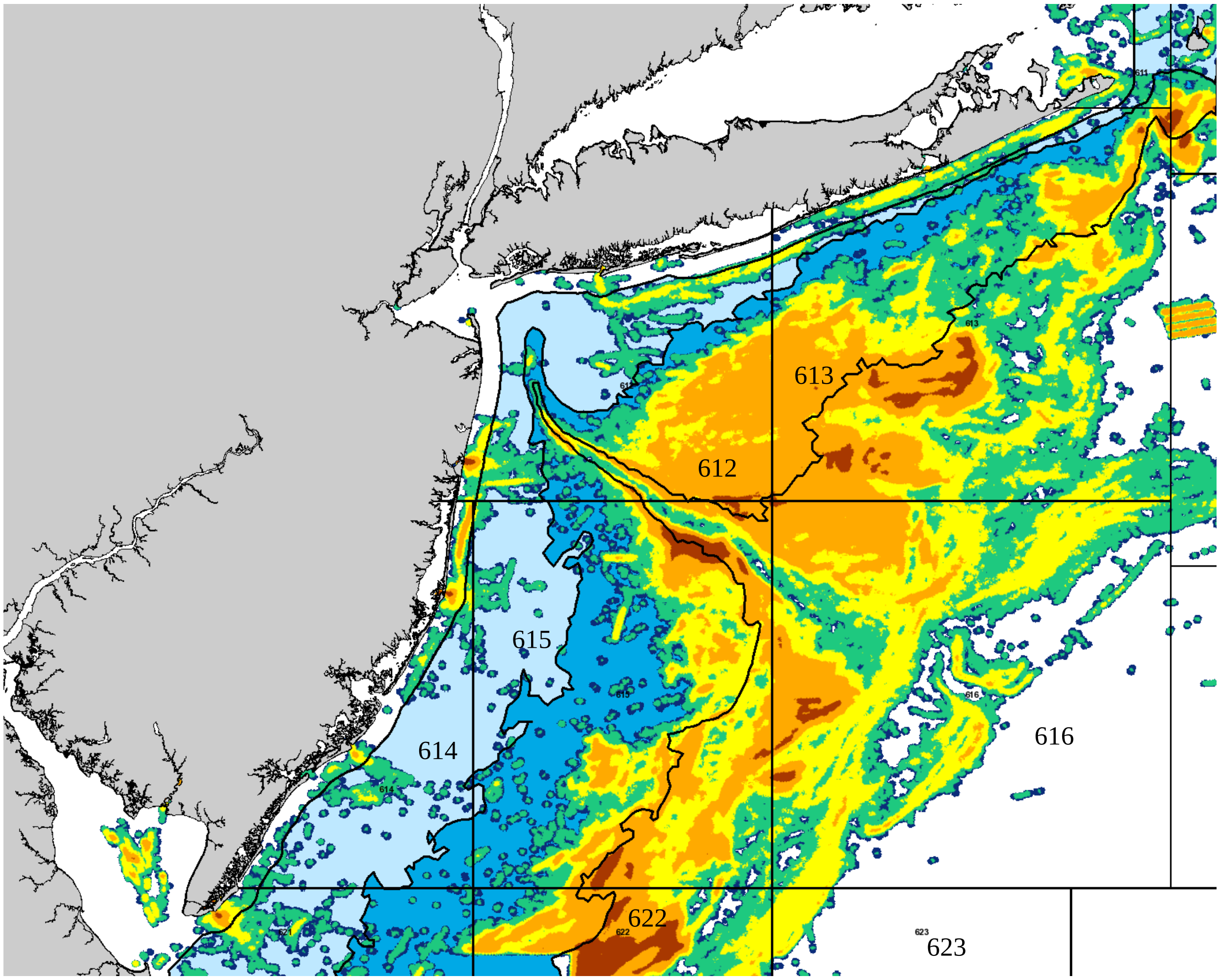


Figure 45. Commercial fishing activity for Atlantic Sea Scallop within the study area, 2015–2016
Large font numbers identify statistical areas.

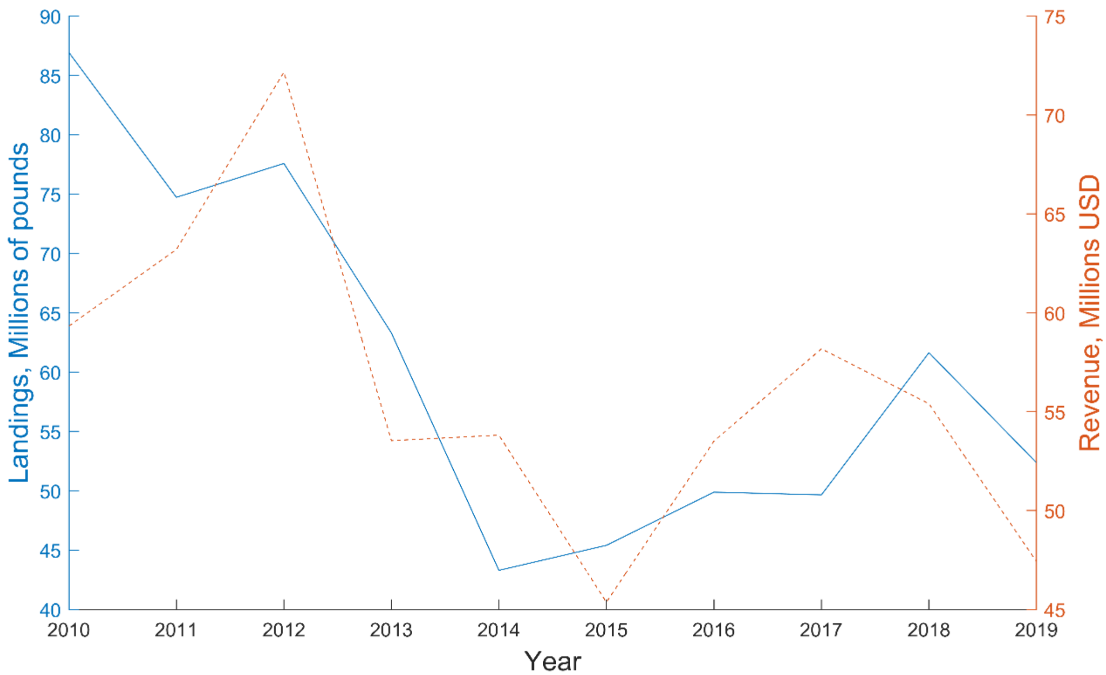


Figure 46. Total commercial landings (trap and pot, trawl, dredge, purse seine, and gill net fishing) and revenues within the Statistical Areas containing the study area, 2010–2019

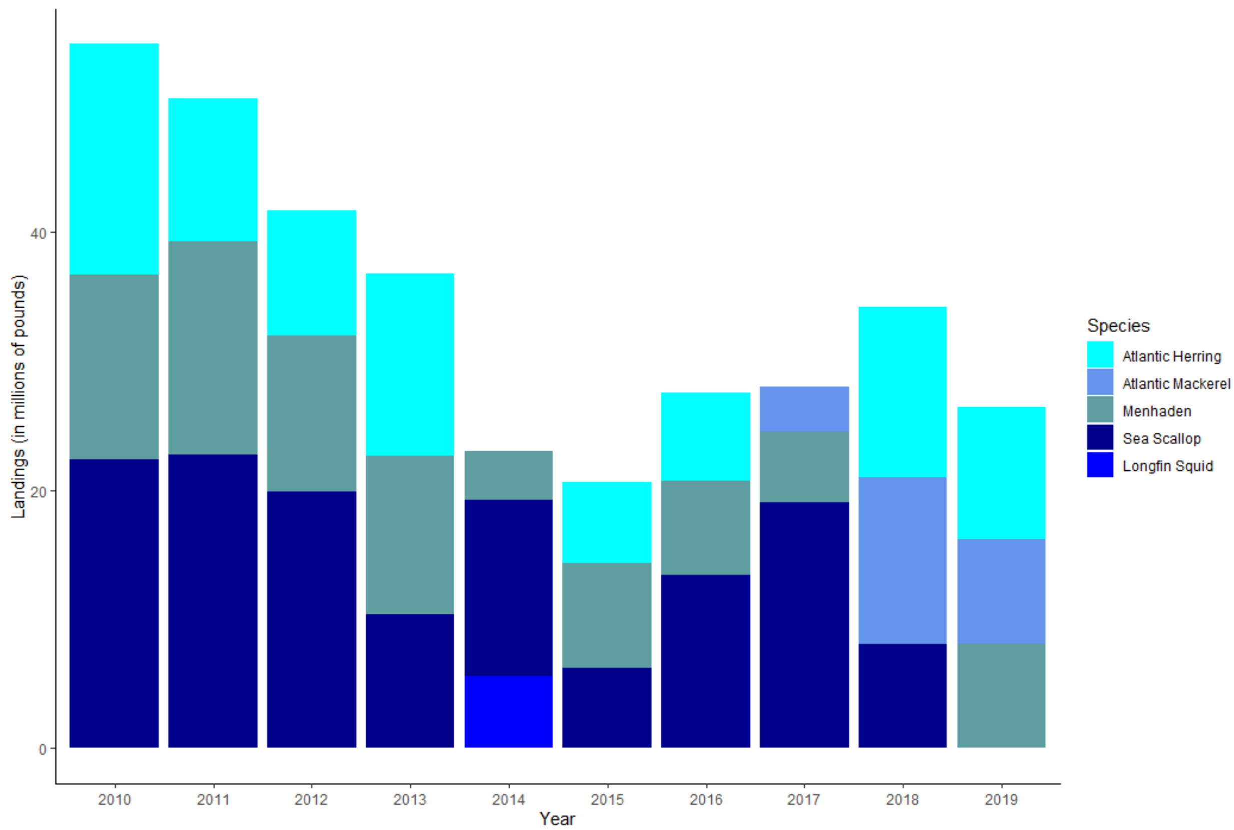


Figure 47. Commercial landings of the top three species by landings volume within the Statistical Areas containing the study area, 2010–2019

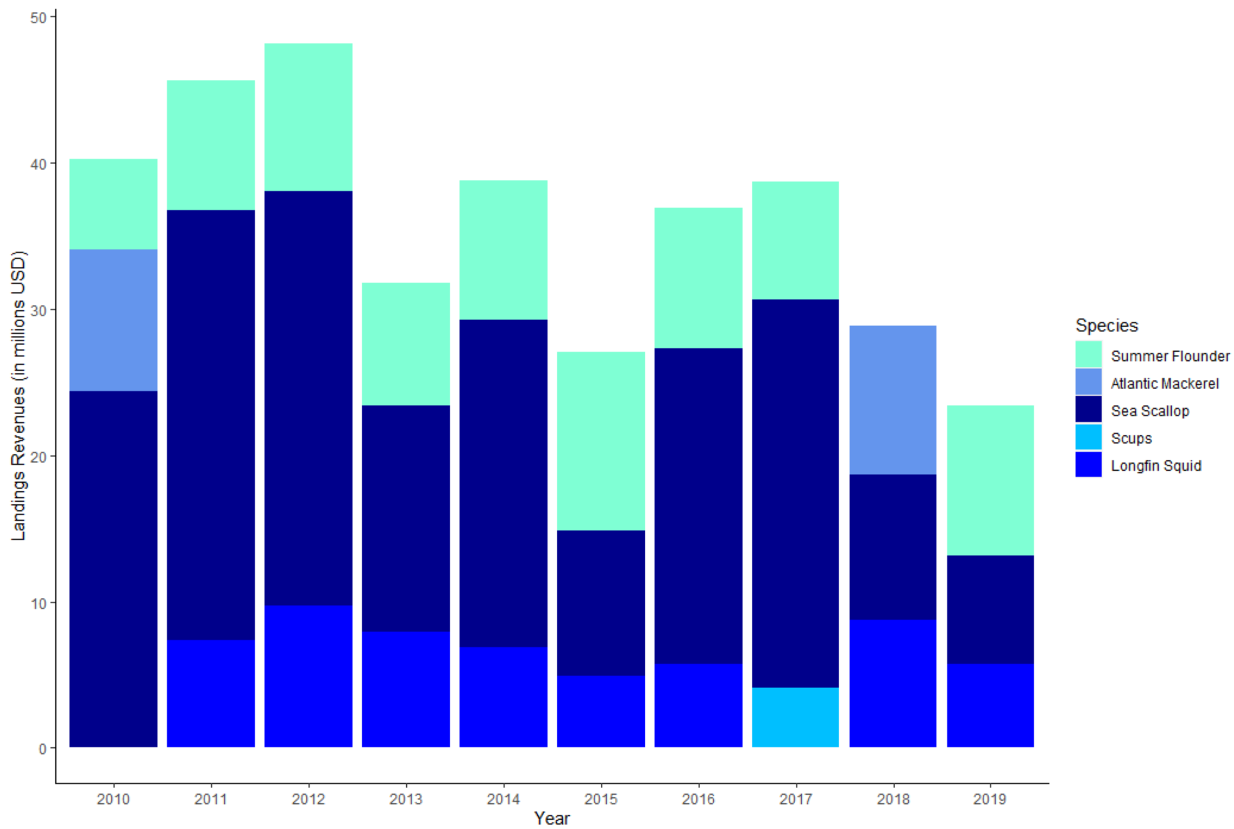


Figure 48. Commercial revenues of the top three species by revenue value within the Statistical Areas containing the study area, 2010–2019

5.3 Recreational Fishing Activity

5.3.1 Purpose

For this task, we quantified recreational (private and charter) fishing effort within the study area and identified sand features of recreational importance.

5.3.2 Method

Geospatial raster tiles containing Vessel Trip Report (VTR) data from 2000–2009 for recreational party and charter boat trips compiled by The Nature Conservancy were retrieved from MARCO, along with a polygon layer of prime recreational fishing grounds compiled by the NJDEP. Fishing Vessel Trip Report (FVTR) tiles were shaded based on total number of trips within each tile relative to the mean. These two layers were overlaid on a map of the NYB containing polygons of the study area at the 30-m and 50-m depth contours (**Figure 49**).

5.3.3 Results

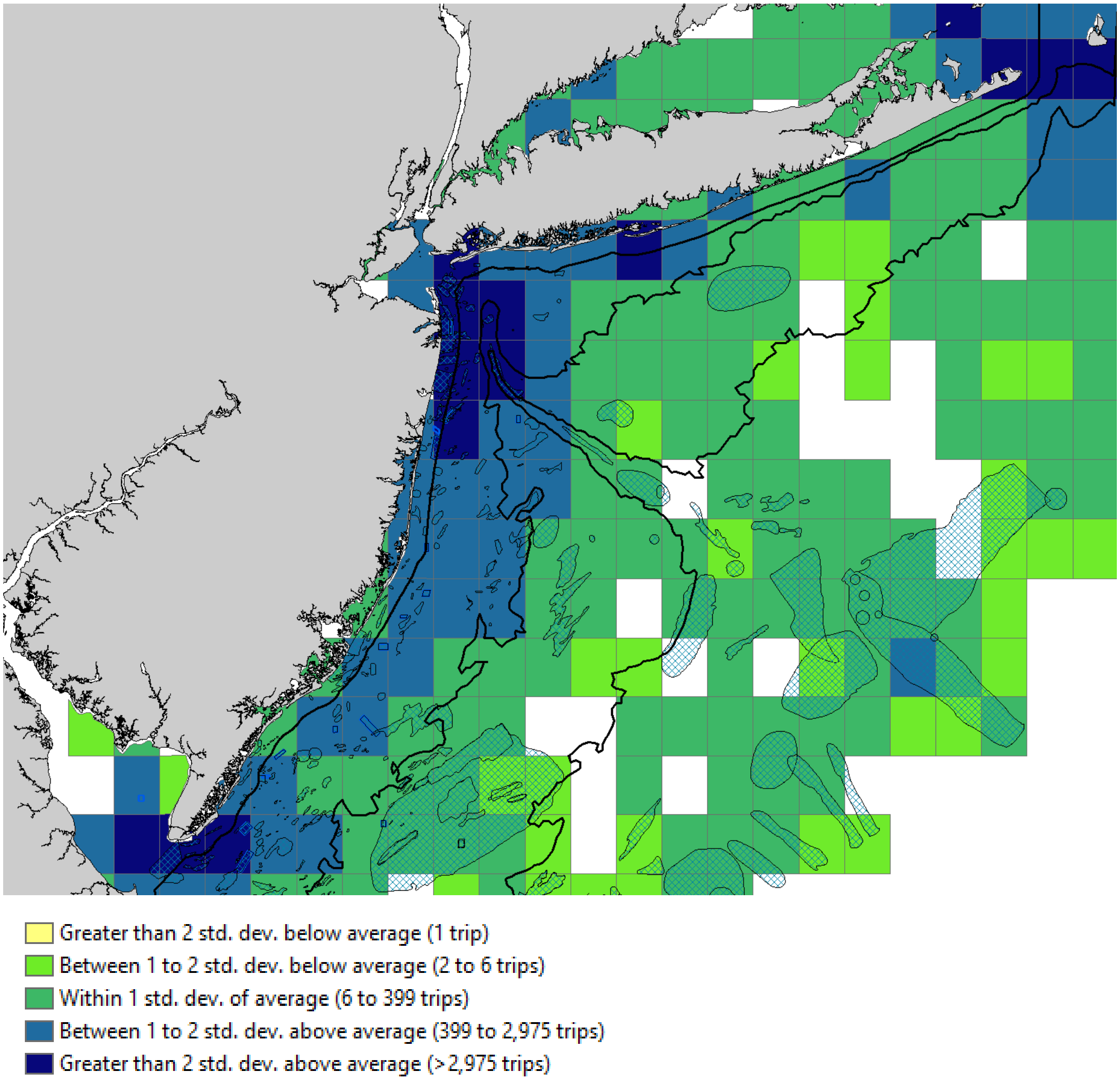


Figure 49. Recreational party and charter boat fishing activity within the study area, 2000–2009

6 Conclusions

This project gathered and summarized available data for ready access by resource managers reviewing a marine minerals lease application. It also calculated modes of variation (spatial temporal gradients) that may be forcing species distribution. This project took the approach of understanding fish and invertebrate ecology in the study area as a response to many different kinds of perturbations (including each other) and measuring the relative impact that dredging could be expected to have among these. This complements the approach of the companion **Volume 1: Literature Synthesis and Knowledge Gaps**.

6.1 Summary of Findings on Fish Habitat Use

Findings on fish habitat use, as measured by relative abundance and co-occurrence, are summarized in **Table 20**. Patterns of temporal/spatial variation are ranked in order of the scale of their importance in structuring assemblage turnover (beta diversity), measured as explained variation in the preceding analyses for comparison to possible dredging effects on the NYB OCS. Summarized finds are expanded upon following the table.

Table 20. Summary of finding on relative variation scales in the distribution of fishes relative to OCS habitat

Pattern	Relative Variation Rank	Implication
Stochastic	1	Most of the variation in faunal distribution is stochastic at the examined scale and cannot be attributed to any underlying variables.
Inter-decadal	2	Fish distribution data from the last decade can be combined for robust sample size. Habitat association patterns should be revisited on 10-year or less scale. Older data for mobile species may have lost some relevance.
Seasonal	3	Short-term (days–months) impacts of dredging will affect different species in different seasons. Which species will be affected in a season, and their affinity to a season, have been documented.
Temperature	4	Within season, temperature is the strongest measured factor structuring habitat use.
Depth	5	Within and across season, OCS habitat use trends relative to depth for both mobile and sessile species. Although the trend remains in both seasons, its strength relative to other spatial trends decreases in Spring. Temperature trends with depth but is more important than depth when trends diverge. Atlantic Sturgeon distribution is strongly skewed towards nearshore shallow water. Nearshore waters (inside the State waters boundary) have a richer faunal fish assemblage with more unique species than OCS waters.

Pattern	Relative Variation Rank	Implication
Latitude	6	There is no clear separation of mobile species with latitude, but there is a weak overturn in relative abundance across the Hudson Shelf Valley. The Atlantic Surfclam abundance population center is shifting deeper south of the Hudson Shelf Valley, but not north of it.
Hydrography	7	Hydrography (including co-varying temperature), salinity, and stratification have a significant measurable effect on structuring relative abundance within broader spatial variation.
Profile	8	Bathymetric relief characterized as Modeled Shoals, Sand Resources, or Lumps have weak but measurable effects on most species distribution, and important effects for a few. These features are valued by recreational anglers for good fishing.
Grain size	9	Sediment grain size frequency is highly skewed, with a mode towards fines over much of study area, but corresponds weakly with relative abundance of a few species.

Less than 50% of total variance in beta diversity was explained by the first four orthogonal eigenvalues of PCA. This means that, despite some common individual trends in species that could be synthesized as principal components, there were numerous less well defined trends among which variance was parsed. This result is not surprising given that there are factors that are difficult to account for: sampled fauna comprise mobile species, resources are patchy and dynamic within the NYB, fish respond to each other dynamically, fishing selectively removes considerable biomass, and social behavior, such as schooling, of the most abundant species occur on scales that are hit or miss to scientific trawl transects. Downscaling moderately improved statistical fit to spatial distribution as seen on a map, and this can reveal effects of scale in future studies. An implication of this is that signals from dredging may be difficult to detect when measured as relative abundance on an annual or interannual and study area-wide sampling scale.

The major modes of explained variation in relative species abundance were temporal. These include inter-decadal and seasonal variation. A major change in the NYB OCS fish and benthic invertebrate assemblage as measured by trawl survey occurred in 2009. A shift in species associations and range has been predicted and documented and attributed to a regional warming trend (see **Volume 1: Literature Synthesis and Knowledge Gaps**). However, the decadal-scale trend documented in this data synthesis cannot be attributed to a particular cause through the current analysis; it was explored only as a latent trend. Possible explanatory factors include regional temperature change; fishing impacts (particularly on forage species, as they were among the highly weighted species in the unconstrained PCA); habitat impacts elsewhere in the population range; and a change in the survey vessel, net, and methods.

The major implication of this finding for the practitioner is that data on the spatial distribution of fishes of the NYB OCS up to a decade in age can be combined to create a robust dataset that treat year as a random factor relative to other impacts. This implication is important because the trawl survey coverage of the OCS within any given year is sparse relative to questions of habitat structure as is intended and best suited to measuring stock size change among years. It is quite likely that there are meaningful interannual fluctuations of interest to ecologists, but these were not explored as being relevant to understanding the relative impact of dredging. For example, the impact of a storm would be hard to measure given the spacing and paucity of samples within any single year relative to the width of the storm track (except for the largest storms). The time between storm passage and trawling (an uncontrolled factor), would make this task even more difficult due to recovery with elapsed time. The NJDEP survey would be much better suited to this in timing and density of sampling, but it does not cover the study area.

Another major latent trend was the seasonal overturn in OCS occupation. The first principal linear mode of variation through a 10-year combined Spring and Fall data set resolved slightly more than 26% of variation and clearly differentiated seasonal assemblages, except for relatively few samples that did not collect many specimens other than non-migratory scallops and fish. In comparison, the second mode of variation resolved only about 9% of total variation and was very clearly a spatial trend; Spring and Fall samples overlapped completely along this mode and mapped more to an on-offshore trend than to a zonal gradient. A latent zonal mode and offshore/depth mode are evident, but very high variability remains unexplained even after fourth modes.

An important implication is that inquiries into potential effects should consider season. Based on the temperature-salinity diagrams, life histories, and oceanography reviewed in **Volume 1: Literature Synthesis and Knowledge Gaps**, Fall assemblage structure would be the better proxy for Summer assemblages and Spring for Winter assemblages in the absence of robust sampling for those seasons. Furthermore, they are partially imprinted by the previous season.

Measured factors could only explain less than 12% of total variation in both Spring and Fall. Of this canonical variation, temperature explained the most (roughly 37–42% by season, or 5% of total variation in the absence of other factors), even though it was already considered only with a season. Ambient temperature is closely tied to physiology for poikilotherms (**Volume 1: Literature Synthesis and Knowledge Gaps**), and it factors not just in the basic function of respiration but in competition, predation, and evasion capacity, which are relative to co-occurring species. Warm bottom temperatures, especially in Fall, could occur both shallow and deep but were inversely correlated with highly stratified samples, which must necessarily have cold bottom water. These are samples near or in the Cold Pool, which is known to be an important habitat structuring factor (see **Volume 1: Literature Synthesis and Knowledge Gaps**). Depth was subordinate to temperature and stratification, explaining roughly 1–2% of total variation, while proximity to shoals and sand grain size explained roughly 1%.

6.2 Summary of Findings on Trophic Interactions

Understanding the trophic structure of fishes and macroinvertebrates in the NYB is challenged due to spatial and temporal dynamics. Much of the fauna migrates in and out of the study area zonally (north-south) or on-offshore and eats or becomes prey elsewhere. Relative abundance of prey and predator fluctuate with season, fishing pressure, climate change, and stochastic recruitment factors (also often happening elsewhere). Furthermore, diet studies are expensive and difficult to produce, and diets are reported to different levels of identification, or different measures for quantification, in different studies. However, there are some general patterns that are useful to understanding dredging effects.

First, diet and trophic position change greatly with ontogeny. The focus here is on adult or subadult fishes. Fishes grow extremely fast in the early life, doubling in size daily in the first days to weeks and typically reaching at least a third of maximum size, and often sexual maturity, within the first year. Therefore, the biomass and consumptive impact of young-of-the-year for fish that live many years is trivial in comparison to consumption by adults. Knowledge of young-of-the-year diet is important for understanding recruitment but does converge ultimately on very small organism, either plankton or infauna, over a wide range of taxa (see **Volume 1: Literature Synthesis and Knowledge Gaps**).

Second, there are generalities as feeding guilds, and these can be further parsed by life history and seasonality of habitat use in the NYB. Guilds are apparent as groups that focus primarily on 1) infauna, 2) sessile or epibenthic fauna, 3) fish or squid, 4) plankton, and 5) opportunity (generalist).

6.3 Summary of Findings on Fisheries Space Use

Total annual commercial fisheries revenues for bottom-oriented fisheries with the NOAA GARSAs encompassing the study area ranged from ~$45–75 million USD between 2010 and 2019, with a mean annual revenue of ~$56 million USD. Total annual commercial landings ranged from ~43–86 million pounds, with a mean of ~60 million pounds. Atlantic Sea Scallop is the most valuable fishery within the NYB, being consistently within the top three species in terms of both landings and revenues and generally accounting for the largest species-specific share of each on an annual basis. Two other commercially important species in terms of both landings and revenue are Atlantic Mackerel and Longfin Squid. In general, commercially important species in terms of landings were pelagic (with the notable exception of Atlantic Sea Scallop). Within the top three species by revenue, Summer Flounder is a sand-dwelling species. Summer Flounder are also one of the most recreationally important species within the NYB (Bochenek et al. 2010).

Within several commercial fisheries—namely those for Atlantic Surfclam, Ocean Quahog, Atlantic Sea Scallop, and squid—distinct fishing effort patterns emerge north and south of the Hudson River Canyon. These patterns may result from differences in commercial fishing regulations north and south of the canyon, in addition to differences in species distributions. Of the commercial fisheries evaluated, Surfclam and Ocean Quahog fisheries are most likely to face space-use conflicts with sand dredging activity. A significant portion of fishing activity for these species takes place within the 30-m depth contour of the study area, i.e., the depth range within which current sand dredging happens. Furthermore, almost all fishing activity for these species within NJ falls within the study area; within NY, additional fishing activity occurs within the 50–60-m range. As dredging technology advances, the commercial fisheries for Atlantic Sea Scallop and squid may also begin to experience space-use conflicts with sand dredging. From 2011 to 2016, substantial Atlantic Sea Scallop fishing activity occurred within NJ and NY in the 40–60-m depth range. In addition, substantial fishing activity for squid took place in patches between 20–50-m depths north of the Hudson Shelf Valley between 2014 and 2016.

The most intense party and charter boat-based recreational fishing activity within the NYB occurred nearshore, within the 30-m depth contour of the study area. Much of that activity occurs within tiles containing artificial reefs and other bottom features, such as sand lumps and shoals. Data for private recreational fishing vessels—a significant portion of overall recreational fishing activity within the NYB—was not publicly available. Data in this report cannot not provide a comprehensive picture of recreational fishing activity within the NYB.

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Appendix A: Ordination Statistics

A.1 Temporal Breakpoint Analysis

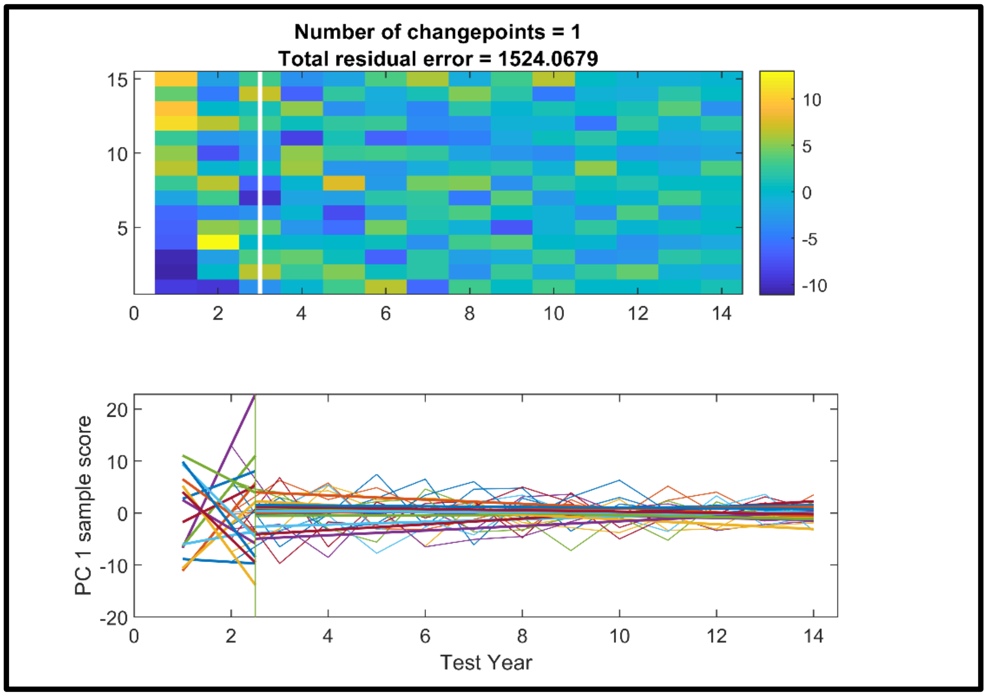

Figure A-1. Breakpoint analysis (linear) plot for Spring PC 1 axis sample scores

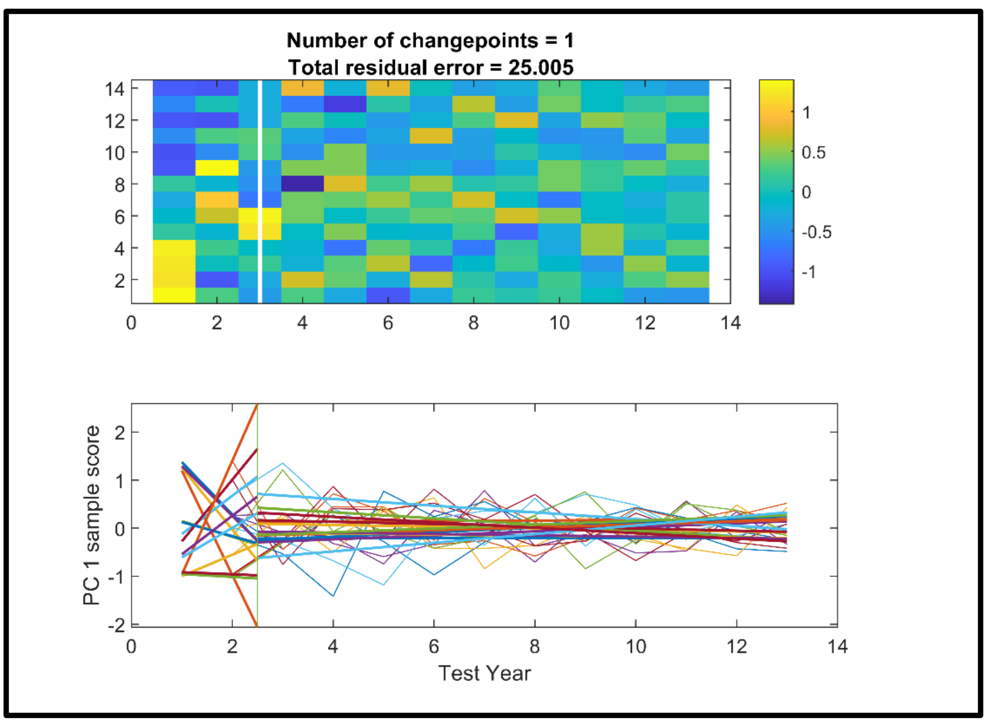

Figure A-2. Breakpoint analysis (linear) plot for Spring PC 1 axis sample scores

A.2 CCA

Table A-1. Table of species tolerance for CCA (Spring)

Name	Species Code	RespN2	Tol.1	Tol.2	Tol.3	Tol.4	Tol4
SMOOTH DOGFISH	13	4.5015	0.2406	0.2537	0.1608	0.3004	24.4104
SPINY DOGFISH	15	40.8204	0.835	1.108	0.9096	0.5701	87.712
BULLNOSE RAY	19	NA	NA	NA	NA	NA	NA
WINTER SKATE	23	95.7416	0.9283	0.9831	0.9087	0.9206	93.5607
CLEARNOSE SKATE	24	6.9487	0.6677	1.4303	1.3468	0.8401	111.9269
LITTLE SKATE	26	113.7309	0.8375	1.1239	1.0594	1.1826	105.8978
ROUND HERRING	31	NA	NA	NA	NA	NA	NA
ATLANTIC HERRING	32	36.6164	0.8584	0.962	0.8291	1.0212	92.0931
ALEWIFE	33	9.1332	0.981	0.8504	1.1749	1.4971	115.1859
BLUEBACK HERRING	34	12.4711	1.0595	1.0573	1.1961	0.9681	107.3369
ATLANTIC MENHADEN	36	1.0922	0.8434	0.3194	0.792	0.2178	60.9915
BAY ANCHOVY	43	2.2164	0.2783	0.325	0.2347	0.2482	27.376
STRIPED ANCHOVY	44	NA	NA	NA	NA	NA	NA
SILVER HAKE	72	20.4989	0.779	0.6295	1.0755	0.945	87.365
HADDOCK	74	1	0	0	0	0	0
RED HAKE	77	41.3092	0.7929	1.2085	1.0326	2.6106	157.8835
SPOTTED HAKE	78	49.6014	1.0056	1.0571	1.1272	0.7493	99.5089
SUMMER FLOUNDER	103	95.9678	1.0373	1.1552	0.9305	0.6811	96.7005
FOURSPOT FLOUNDER	104	6.3584	0.8844	0.9756	0.8053	0.5693	82.2584
YELLOWTAIL FLOUNDER	105	32.1372	0.9916	0.9935	0.8334	0.767	90.1833
WINTER FLOUNDER	106	115.5632	1.0984	0.7647	0.997	1.4965	112.0797
WINDOWPANE	108	120.873	1.0247	1.047	1.0856	0.87	101.0161
GULF STREAM FLOUNDER	109	5.8344	0.695	0.8017	0.4646	0.5723	64.5967
SMALLMOUTH FLOUNDER	117	17.9815	1.1866	0.8748	1.3681	1.9831	141.2242
ATLANTIC MACKEREL	121	14.1995	0.6984	0.8076	0.6141	0.4805	66.1081
BUTTERFISH	131	3.2168	0.4311	0.922	0.3624	0.463	58.7705
BLUEFISH	135	NA	NA	NA	NA	NA	NA
ATLANTIC CROAKER	136	NA	NA	NA	NA	NA	NA
STRIPED BASS	139	5.8335	0.8087	0.7531	1.0026	0.9367	88.0871
BLACK SEA BASS	141	19.369	0.957	1.2282	0.771	0.7616	94.8521
SCUP	143	2.9489	0.2923	0.3306	0.2517	0.3425	30.6339
WEAKFISH	145	2.9763	0.7376	0.107	0.5503	0.2746	48.3153
NORTHERN KINGFISH	146	NA	NA	NA	NA	NA	NA
SPOT	149	NA	NA	NA	NA	NA	NA
NORTHERN SEAROBIN	171	18.706	1.0935	0.9099	0.9776	0.6801	92.7609
STRIPED SEAROBIN	172	4.7253	0.8888	1.0531	0.9695	0.7145	91.5066
NORTHERN SAND LANCE	181	4.6995	0.3903	0.3979	1.1335	1.2306	88.1736

Name	Species Code	RespN2	Tol.1	Tol.2	Tol.3	Tol.4	Tol4
OCEAN POUT	193	24.3732	0.8016	1.09	0.9943	2.6476	156.7535
NORTHERN PUFFER	196	NA	NA	NA	NA	NA	NA
GOOSEFISH	197	35.162	0.8376	0.961	1.0244	0.6919	88.7854
ROUND SCAD	211	NA	NA	NA	NA	NA	NA
ROUGH SCAD	212	NA	NA	NA	NA	NA	NA
AMERICAN LOBSTER	301	5.6695	0.6878	1.1545	1.217	3.6958	205.827
ATLANTIC ROCK CRAB	313	31.1848	1.1219	0.9297	1.1829	1.3653	116.0428
SPIDER CRAB UNCL	317	2.919	0.8765	1.0411	0.8823	2.165	135.2569
HORSESHOE CRAB	318	19.9693	1.3166	0.8155	1.3375	1.2357	119.5204
SEA SCALLOP	401	20.2974	0.966	0.719	0.5272	0.4213	69.0208
LONGFIN SQUID	503	17.7978	0.4917	1.0218	0.9534	0.5629	79.2421
SOUTHERN KINGFISH	652	NA	NA	NA	NA	NA	NA
ETROPUS SP.	794	56.9959	1.0076	0.9312	1.071	0.6832	93.4881

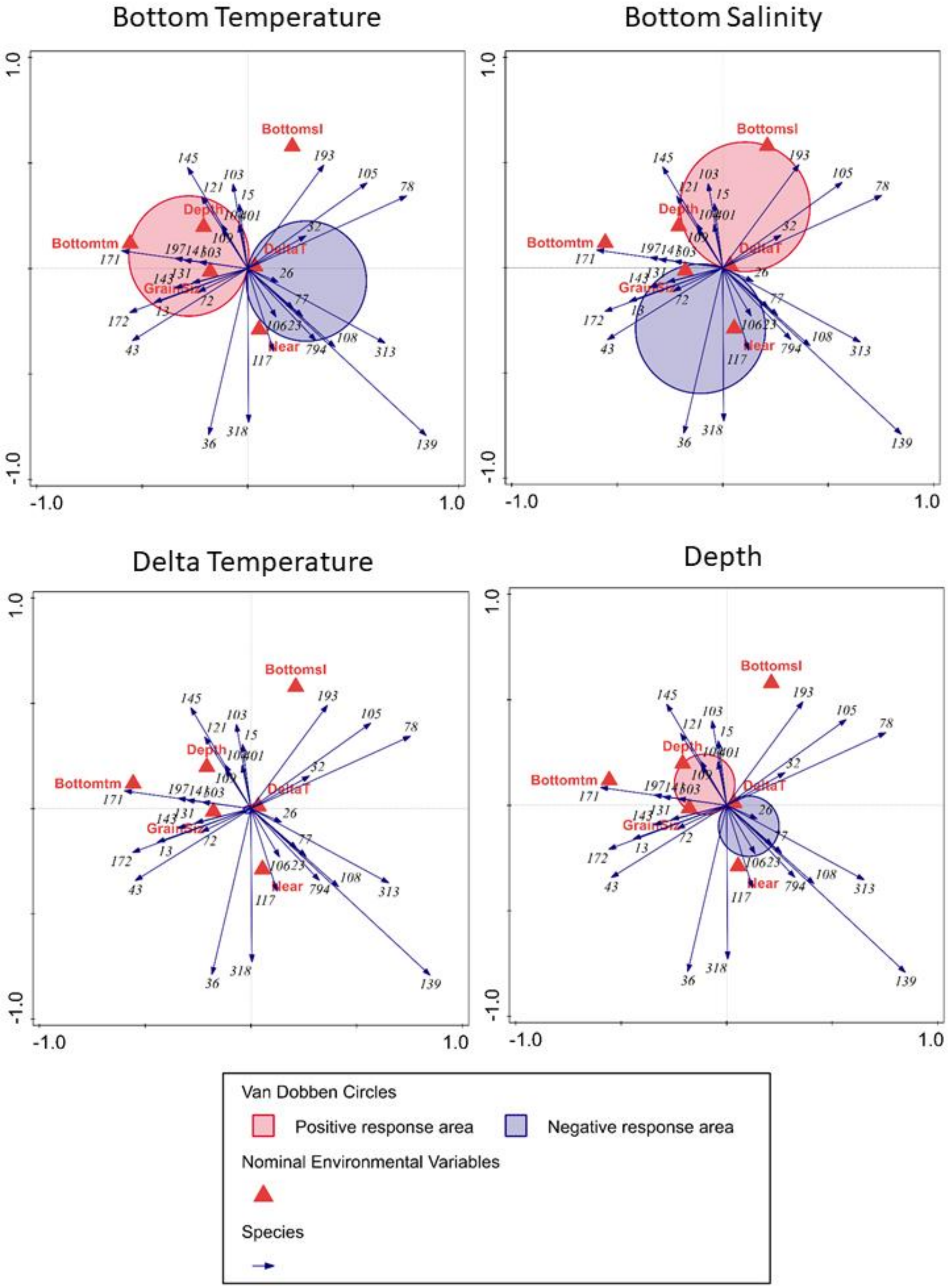

Figure A-3a. Van Dobben circle plots, Spring CCA

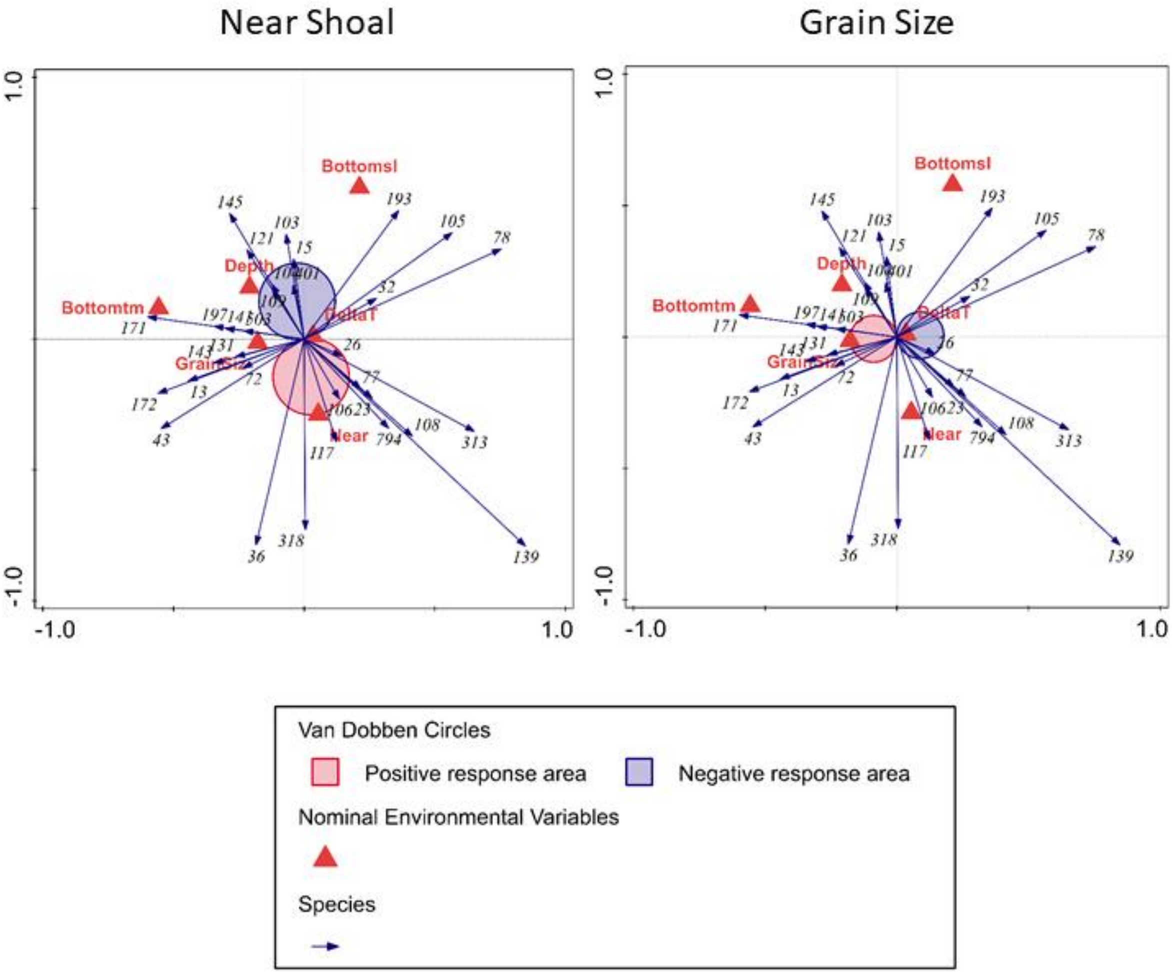

Figure A-3b. Van Dobben circle plots, Spring CCA

Table A-2. Table of species tolerance for CCA (Fall)

Name	Species Code	RespN2	Tol.1	Tol.2	Tol.3	Tol.4	Tol4
SMOOTH DOGFISH	13	39.4171	0.9106	0.9062	0.9918	1.2955	103.8306
SPINY DOGFISH	15	13.6316	1.1557	0.7687	0.8999	0.6249	88.4132
BULLNOSE RAY	19	12.2161	0.6867	0.7306	0.7519	0.9314	78.0722
WINTER SKATE	23	36.0932	0.7015	0.8534	1.0076	1.0515	91.3973
CLEARNOSE SKATE	24	35.849	0.839	0.9135	1.0812	1.123	99.6038
LITTLE SKATE	26	72.9904	1.0375	0.8318	0.9624	1.0961	98.6903
ROUND HERRING	31	5.4295	0.8161	1.4394	1.047	0.7001	103.9745
ATLANTIC HERRING	32	1.6548	0.8026	0.5841	1.1994	1.5771	110.8041
ALEWIFE	33	1	0	0	0	0	0
BLUEBACK HERRING	34	3.6373	1.641	0.9595	1.8379	0.7658	137.6413
ATLANTIC MENHADEN	36	8.4506	0.3605	0.8021	0.8186	1.1687	83.8068
BAY ANCHOVY	43	8.1151	0.6034	0.8062	0.844	0.7004	74.4489
STRIPED ANCHOVY	44	4.0595	0.4402	0.9666	0.6607	0.7086	71.8815
SILVER HAKE	72	6.6085	1.303	0.8563	1.3706	1.0471	116.2551
HADDOCK	74	3.3786	0.5147	0.5316	0.5651	0.7729	60.5029
RED HAKE	77	3.9176	1.119	1.0072	1.0233	1.2369	110.0422
SPOTTED HAKE	78	37.5261	1.2109	0.7996	1.1324	1.3991	115.6016
SUMMER FLOUNDER	103	114.8297	0.8134	0.9102	1.009	1.1925	99.125
FOURSPOT FLOUNDER	104	40.1964	1.1478	0.733	0.7513	1.2003	98.2322
YELLOWTAIL FLOUNDER	105	3.9145	0.5863	0.6196	0.5073	1.1521	76.0319
WINTER FLOUNDER	106	10.1475	0.9859	1.3503	1.2724	0.8684	113.67
WINDOWPANE	108	79.302	0.9977	0.9228	1.1568	1.3415	111.6325
GULF STREAM FLOUNDER	109	10.5451	1.2347	0.9344	0.8477	1.3158	110.0845
SMALLMOUTH FLOUNDER	117	7.9477	0.9132	1.0461	1.4799	0.7077	107.4636
ATLANTIC MACKEREL	121	7.2758	0.9627	0.5645	0.5762	1.2454	88.4405
BUTTERFISH	131	5.0242	0.631	0.8142	1.1885	0.691	85.8967
BLUEFISH	135	13.0397	0.7249	0.8345	0.9724	0.8608	85.2715
ATLANTIC CROAKER	136	16.031	0.5003	0.6966	0.9565	1.1269	85.4431
STRIPED BASS	139	1.1777	0.2709	0.4946	0.3538	0.664	47.0117
BLACK SEA BASS	141	39.518	0.8963	0.9261	1.2619	1.1858	107.9313
SCUP	143	33.589	0.6237	0.9787	0.9798	1.0281	91.7059
WEAKFISH	145	26.7201	0.5649	0.9168	1.482	0.8292	100.5428
NORTHERN KINGFISH	146	29.417	0.4838	0.9698	1.6079	0.8547	105.953
SPOT	149	5.0192	0.5688	0.6879	0.603	0.8032	67.1837
NORTHERN SEAROBIN	171	40.8441	0.8405	0.7236	1.1001	1.3691	103.8576
STRIPED SEAROBIN	172	55.5752	0.7208	0.8636	1.0782	1.0941	95.1976
NORTHERN SAND LANCE	181	9.6312	0.5998	0.6162	0.8805	1.3949	93.0108
OCEAN POUT	193	7.8963	0.8698	0.8626	0.9136	0.8571	87.6072
NORTHERN PUFFER	196	33.5359	0.5391	0.8782	1.0977	0.9317	88.5281

Name	Species Code	RespN2	Tol.1	Tol.2	Tol.3	Tol.4	Tol4
GOOSEFISH	197	6.4774	1.1796	0.7246	0.634	1.1631	95.806
ROUND SCAD	211	8.4058	0.6633	0.7383	0.5985	0.7656	69.4505
ROUGH SCAD	212	9.687	1.1231	1.8119	1.2536	0.9054	131.6763
AMERICAN LOBSTER	301	13.9202	1.2169	1.0639	1.3235	1.5808	130.9895
ATLANTIC ROCK CRAB	313	18.5064	1.341	0.8668	1.0862	1.081	110.6586
SPIDER CRAB UNCL	317	14.4456	0.76	1.1037	1.6513	1.4327	128.2102
HORSESHOE CRAB	318	28.8145	0.7118	0.6799	0.7982	1.1352	85.0687
SEA SCALLOP	401	17.7688	0.7965	0.4878	0.5235	0.7489	65.3305
LONGFIN SQUID	503	76.736	1.0058	0.9064	0.8653	1.0067	94.8075
SOUTHERN KINGFISH	652	2.4471	0.3149	0.5623	0.6856	0.8854	64.6003
ETROPUS SP.	794	18.3498	0.7422	0.7995	1.3825	1.3196	110.0309

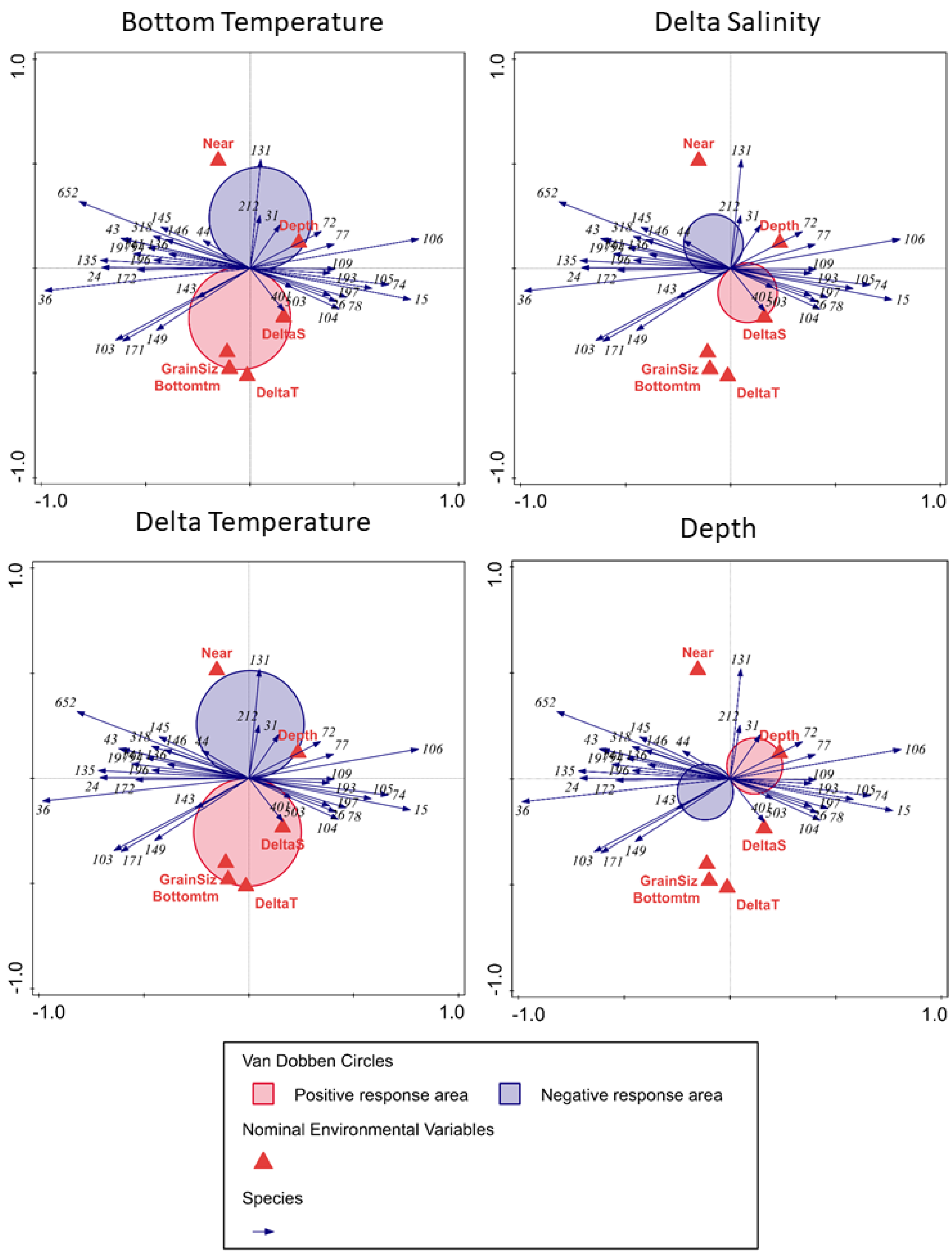

Figure A-4a. Van Dobben circle plots, Fall CCA

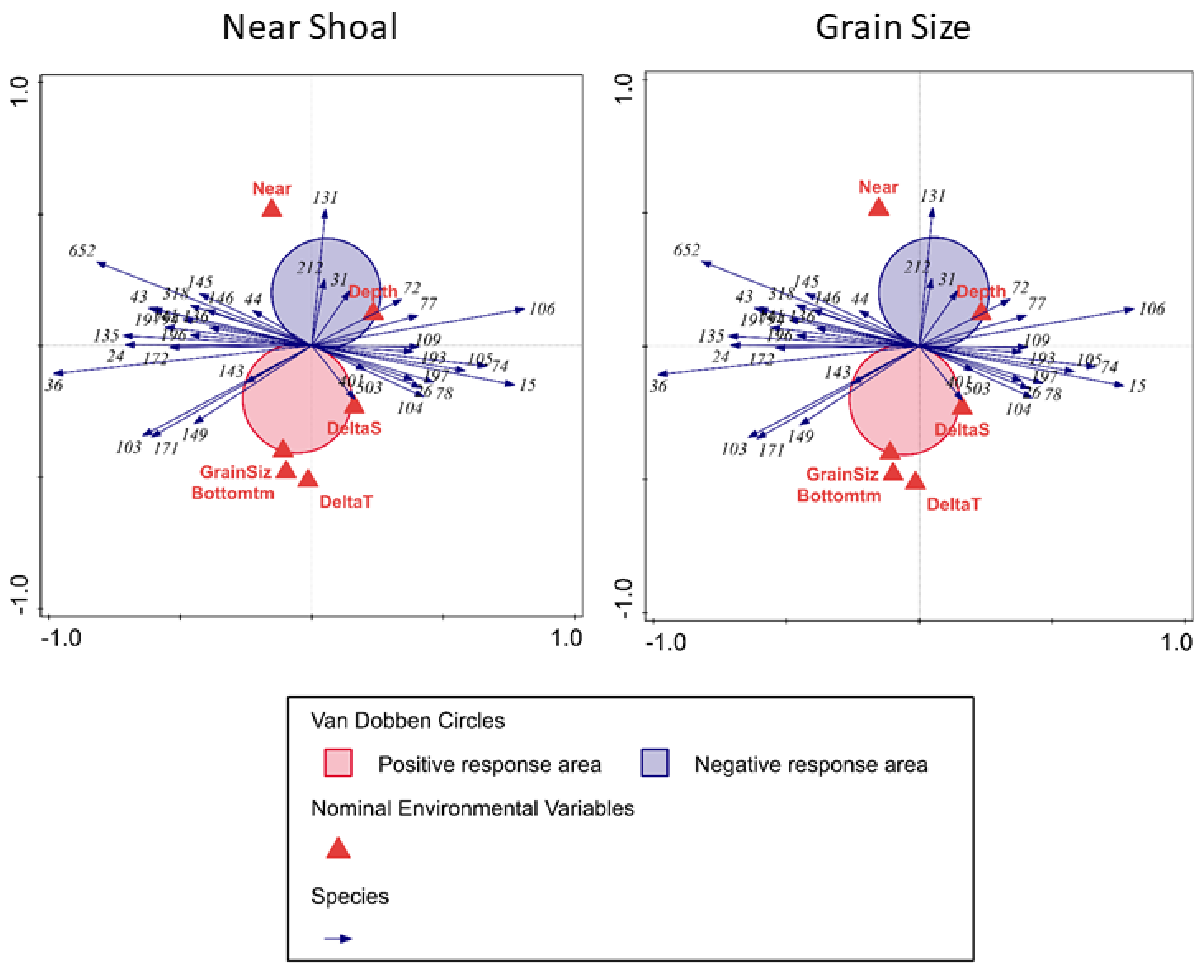

Figure A-4b. Van Dobben circle plots, Fall CCA

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