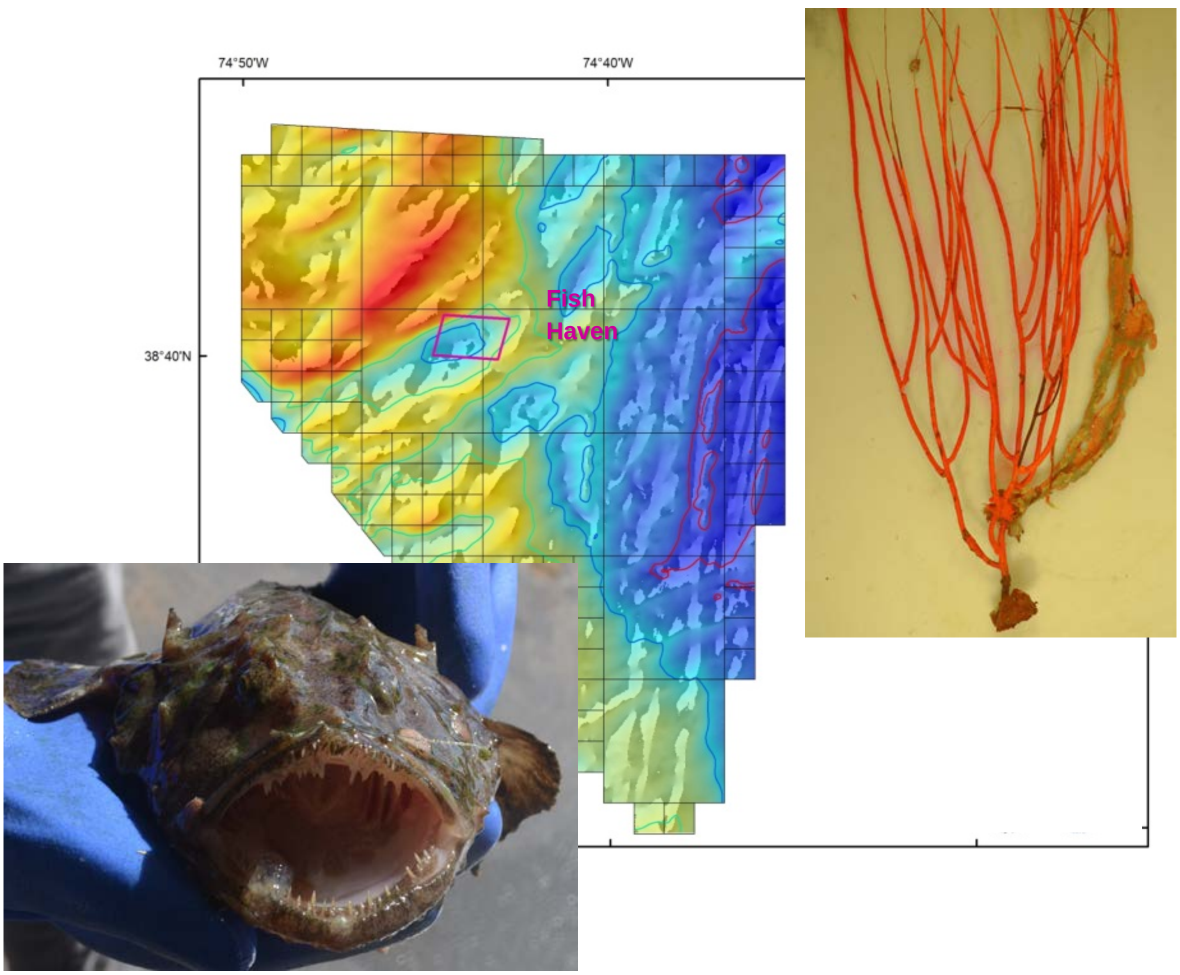
OCS Study
BOEM 2017-088

Habitat Mapping and Assessment of Northeast Wind Energy Areas



U.S. Department of Interior
Bureau of Ocean Energy Management
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ABOUT THE COVER

The cover is a compilation of images highlighting various work conducted as part of the habitat assessment project including surveys of fish (beam trawls), geophysical mapping (multibeam ecosounder surveys), and assessment of benthic habitat, both physical and biological. The images are from left to right are of a monkfish (*Lophius piscatorius*), multibeam imagery of the Delaware Wind Energy Area featuring Delaware artificial reef site #11, and a sea whip (*Leptogorgia virgulata*).

ACKNOWLEDGMENTS

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HABITAT MAPPING AND ASSESSMENT OF NORTHEAST WIND ENERGY AREAS

EXECUTIVE SUMMARY

Background:

The U.S Department of Interior, Bureau of Ocean Energy Management (BOEM) has issued leases in eight Wind Energy Areas (WEA) along the Northwest Atlantic Outer Continental Shelf (OCS) from Massachusetts to North Carolina, encompassing >7,000 square km of seafloor for offshore renewable energy (ORE) development. While BOEM is responsible for regulating the development of offshore energy within each of these areas, the National Oceanic and Atmospheric Administration (NOAA) Fisheries is charged with managing and protecting the nation's living marine resources. At the intersection of these two responsibilities, BOEM and NOAA Fisheries are working closely to ensure that offshore resources are sustainably managed as nascent ORE industries develop.

Project Goals and Objectives:

To that end, the NOAA Northeast Fisheries Science Center (NEFSC), in collaboration with Woods Hole Oceanographic Institution and the University of Massachusetts-Dartmouth School for Marine Science and Technology (SMAST), has developed a comprehensive multi-scale benthic assessment of the eight Atlantic OCS WEAs. The goal of this partnership is to increase the understanding of the current benthic structure, function and valued resources within the Atlantic WEA network, prior to development. From new and existing data sources, NOAA NEFSC has established a contemporary and comprehensive benthic habitat database that can serve as a baseline for evaluating the potential impacts of ORE construction, operation and decommissioning to benthic marine resources. Being implemented in three phases, this study characterizes the 1) abiotic components, 2) biotic components and 3) abiotic-biotic relations (between habitat and fauna) that will support ecosystem-level assessments and cumulative impact analyses for all eight WEAs. The following report describes a broad-brush assessment of benthic habitats within eight proposed WEAs in the National Marine Fisheries Service Greater Atlantic Region (BOEM Northeast and Mid-Atlantic Planning Areas).

The goal of this project is to provide the data necessary to establish a contemporary and comprehensive benthic habitat database for the Bureau of Ocean Energy Management (BOEM) Wind Energy Areas (WEAs) in the northeastern region of the United States in order to provide insight into benthic environmental issues and potential impacts associated wind power development on the continental shelf. Our investigations included the following WEAs: Massachusetts (MA), Rhode Island – Massachusetts (RIMA), New York (NY), New Jersey (NJ), Delaware (DE), Maryland (MD), Virginia (VA), and North Carolina – Kitty Hawk (NC-KH). The database is established at the J.J. Howard Laboratory of the Northeast Fisheries Science Center.

Summary of Observations on Individual WEAs:

Massachusetts Wind Energy Area (MA WEA): The MA WEA covers about 743,000 acres of nearly flat, primarily sandy bottom south of Cape Cod. The WEA has been divided NE-SW into four lease areas. Bottom temperatures in the period 2003-2016 ranged from 1-18°C and a strong thermo-haline tidal front (Nantucket Shoal Front) borders it on the east. Sandy sediments predominate, but become muddy toward the southern end of the area and gravelly toward the northwest corner. The same topographic features occupy all four lease areas: a sediment wave field dissected by several dendritic shelf valley tributaries. Grab sampling yielded 151 infaunal taxa, numerically co-dominated by amphipods and polychaetes, in that order. Sand shrimp and sand dollars comprised 88% of benthic epifaunal (beam trawl) samples; 58 taxa in all were collected by this method. Megafauna, assessed from fourteen years (2003-2014) of Northeast Fisheries Science Center (NEFSC) Seasonal Trawl Survey records, included 101 taxa, of which 40 support managed fisheries. Little skate, winter skate, and silver hake were dominant catches year-round. These were joined by additional dominant taxa during the warm season (summer and fall): longfin squid, scup, and spiny dogfish, and by Atlantic herring during the cold season (winter and spring). Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass (warm season), Atlantic cod (cold season), sea scallop, and ocean quahog (both year-round).

Rhode Island-Massachusetts Wind Energy Area (RIMA WEA): The RIMA WEA covers about 165,000 acres of gently-sloping bottom at the southern end of Rhode Island Sound and adjacent to the northwest corner of the MA WEA. It is divided into two lease areas: one covering the north and central portions of the WEA and the other in the south, adjoining the MA WEA. Bottom temperatures ranged 2-18°C during the period 2003-2016. Sediments are primarily sandy, but are muddy in the north, at the site of an ancient glacial lake. A platform harboring a moraine deposit with a mix of sand, gravel, cobble, and rock (glacial till) is in the center. The western part of this platform is called Cox Ledge. The south slopes seaward from the edge of the moraine platform and contains a sandy glacial outwash fan and a shelf valley tributary with sediments ranging from sand to muddy and gravelly sand. Grab samples (37 infaunal taxa) were numerically co-dominated by amphipods and polychaetes, in that order. Sand shrimp and sand dollars comprised 97% numerically of benthic epifaunal (beam trawl) samples; 20 taxa were collected by this method. Megafauna were assessed from fourteen years (2003-2014) of Northeast Fisheries Science Center (NEFSC) Seasonal Trawl Survey records. This yielded 59 taxa, of which 33 support managed fisheries. Little and winter skates were dominant catches year-round. These were joined by longfin squid, scup, and spiny dogfish in the warm season (fall), and by Atlantic herring, ocean pout, and yellowtail flounder during the cold season (winter and spring). Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass (warm season), Atlantic cod (cold season), sea scallop, and ocean quahog (year round).

New York Wind Energy Area (NY WEA): The NY WEA covers about 79,000 acres of nearly flat, almost exclusively sandy bottom south of western Long Island and constitutes a single lease area. Its contours consist entirely in a series of low megaripples. Bottom temperatures ranged 2-22°C between

2003 and 2016. Grab sampling yielded 85 infaunal taxa, numerically co-dominated by polychaetes and amphipods, in that order. Sand shrimp and sand dollars numerically dominated benthic epifauna (beam trawl) samples here in March (97%, 19 taxa) and in August (99%, 60 taxa). Little skate dominated the 14-year megafauna (NEFSC seasonal trawl survey) records year-round (71 taxa, 33 with managed fisheries), joined by longfin squid and sea scallop in the warm season, and by Atlantic herring in the cold season. Taxa for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass and longfin squid egg mops (warm season), and sea scallop, surfclam, ocean quahog (year-round).

New Jersey Wind Energy Area (NJ WEA): The NJ WEA covers about 344,000 acres of nearly flat, almost exclusively sandy bottom east of southern New Jersey and is divided into northern and southern lease areas. Bottom water temperatures can range 2-23°C between 2003 and 2016. Most of the northern lease area is occupied by a platform, while most of the southern one is occupied by a field of megaripples with a shelf valley cutting across it. Sediments are primarily sand with some gravelly sand in the north and center and muddy sand in the south. Grab sampling yielded 94 infaunal taxa, numerically dominated by polychaetes. Sand shrimp, sand dollars, and dwarf warty sea slugs were the numerical dominants (96%) among the 24 taxa of epibenthic (beam trawl) fauna. There were no year-round dominants among the 113 taxa of megafauna (39 with managed fisheries) during the 14 years of NEFSC seasonal trawls examined. Atlantic croaker, longfin squid, and scup dominated the warm season fauna, while Atlantic herring, little skate, and spiny dogfish dominated the cold season. Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass (warm season), sea scallop, and surfclam (year-round).

Delaware Wind Energy Area (DE WEA): The DE WEA covers about 96,000 acres, is located off the coast of ocean coast of Delaware, southeast of the mouth of Delaware Bay, and constitutes a single lease area. Bottom water temperatures ranged 3-23°C between 2003 and 2016. Bottom topography and habitat distribution are strongly influenced by proximity to the tidal flow from Delaware Bay. Bottom features include a series of N-S-oriented megaripples in the east and a second, larger set of NE-SW-oriented megaripples in the west, including a very large ridge in the NW corner of the WEA. An artificial reef area (“Fish Haven”) of about 1,000 acres lies near the center of the WEA. At least one natural blue mussel reef lies near the NW corner of the WEA. Sediments are primarily sandy with gravelly areas in the east and northwest. Polychaetes dominated the 53 taxa of benthic infauna from grab samples, while blue mussels, longclaw hermit crabs, New England dog whelk snails, and sand dollars numerically dominated (84%) epibenthic (beam trawl) catches. There were no year-round dominants among the 82 taxa (42 with managed fisheries) of megafauna during the 14 years of NEFSC seasonal trawls examined. Atlantic croaker, northern searobin, and scup dominated the warm season fauna, while Atlantic herring, little skate, and spiny dogfish dominated the cold season. Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass (warm season), sea scallop, and surfclam (year-round). In addition, habitats that may be may be in jeopardy include mussel reefs in the northwest and communities dominated by star coral (hard corals) and sea whips (soft corals) in the troughs between the larger megaripples in the western part of the WEA, plus the artificial reef community, also located in a megaripple trough.

Maryland Wind Energy Area (MD WEA): The MD WEA covers about 80,000 acres, is located off the Maryland Coast near Ocean City, MD, and is divided into northern and southern lease areas. Bottom water temperatures can range 3-23°C between 2003 and 2013. Most of the WEA is occupied by NE-SW trending megaripples. Sediments are primarily sand, gravelly in the north and with muddy pockets in the center and south. The 72 taxa of benthic infauna taken in grabs were dominated by polychaetes, and the 38 taxa of benthic epifauna were dominated (84%) by sand shrimp, New England dog whelk snails, and sand dollars. The 43 taxa (23 with managed fisheries) of megafauna from the NEFSC seasonal trawl survey showed no year-round dominants, but Atlantic croaker, weakfish, and spot dominating in the warm season, and little skate, spotted hake, and spiny dogfish dominating in the cold season. Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass (warm season), sea scallop, and surfclam (year-round). In addition, sea whip (soft coral) habitats may be vulnerable.

Virginia Wind Energy Area (VA WEA): The VA WEA covers about 113,000 acres, is located off Virginia Beach, VA and southeast of the mouth of Chesapeake Bay. It constitutes a single lease area. Bottom water temperatures can range 4-22°C between 2003 and 2016. Tidal flows from the mouth of the Chesapeake may have some influence on topography, hydrography, and fauna, but this WEA does not appear to be close to the influence of the main tidal channel, unlike in the case of the DE WEA. Topographic features include a NE-SW-oriented sediment wave field, a sedimentary fan, a series of shelf valley tributaries to the north and east and isolated patches of mud in the west and center and gravel in the east. Sediments are primarily sandy, but include a muddy patch in the center and gravelly sand in the east. The infauna was dominated by polychaetes in March 2014 and in August 2015, with 85 and 28 taxa, respectively. Benthic epifauna were dominated by sand shrimp, unclassified snails, and dwarf surfclams (71% of numerical catch) in March 2014, and by calico scallops, longclaw hermit crabs, New England dog whelk snails, and dwarf warty sea slugs (60%) in August 2015. Megafauna (46 taxa, 25 supporting managed fisheries) from 2003-2016 had no year-round dominants, but were dominated by black sea bass, northern searobin, and scup in the warm season and clearnose skate, spiny dogfish and summer flounder in the cold season. Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass and longfin squid egg mops (warm season), and sea scallop, ocean quahog, and surfclam (year-round).

North Carolina – Kitty Hawk Wind Energy Area (NC-KH): The NC-KH WEA covers about 122,000 acres and is located on the shelf east of Kitty Hawk, NC, north of Cape Hatteras. Bottom temperatures ranged 6-23°C between 2003 and 2016. Its topography includes a series of N-S megaripples in the east, a sediment fan in the west, and isolated muddy patches and one gravelly patch. Sediments are otherwise sand. The benthic infauna (21 taxa) was dominated by polychaetes. The benthic epifauna was dominated by sea scallops, sand shrimp, and calico scallops (91% numerically). Megafauna from the NEFSC seasonal trawl survey 2003-2016 (78 taxa, 35 with managed fisheries) was dominated year-round by longfin squid, joined during the warm season by spotted hake, and during the cold season by clearnose skate and spiny dogfish. Species for which there may be concern regarding possible habitat disturbance from offshore wind construction and operation activities include black sea bass (warm season), sea scallop, and surfclam (year-round).

General Considerations

Benthic habitats in the BOEM-designated WEAs represent a subset of those in the encompassing Northeast U.S. Continental Shelf Large Marine Ecosystem (NE LME) and share many common features, processes, and faunas. Physical features and processes were investigated in terms of hydrographic regimes, bottom topography, and sediment characteristics. Faunal investigations included benthic infauna (within sediments), benthic epifauna (on bottom surfaces), and demersal nekton (swimmers on or just above the bottom). Data were gathered from a wide variety of sources, internal and external to the National Oceanic and Atmospheric Administration (NOAA), including data from historical sources and from dedicated sampling cruises to the WEAs, to provide the best datasets possible for creating benthic habitat definitions and their relationships to important species and Essential Fish Habitat (EFH) for all of the northeast U.S. WEAs. The NOAA Coastal and Marine Ecological Classification System (CMECS) was employed for habitat classification.

Common features shared by all of the WEAs and indeed, much of the LME, included relatively flat (low profile) topography with overall (large scale) slopes never exceeding one degree and local (small scale) slopes only rarely reaching four degrees. Sediments in all WEAs were primarily sand or sand-dominated (e.g. muddy sand, gravelly sand), many with indication of sediment mobility such as ripples and megaripples. All WEAs were subject to small ranges of salinities within the euhaline range, but large annual ranges in water temperature (12-15°C seasonal ranges on the bottom), and with substantial variation in actual temperatures and the timing of stratification and turnover events from year to year.

The faunas that have developed around these conditions have many common features, and share many common taxa across physical habitats and across WEAs. A common suite of polychaete worms typical of sandy bottoms played dominant to sub-dominant roles in the infauna of all WEAs. Being sandy bottom fauna adapted to disturbances where sediment mobility and temperature change are important factors, these communities tend to recover quickly from disturbances. The same was generally true of members of the epibenthic fauna, generally including sand shrimp, sand dollars, various crabs and snails. The more mobile elements of the epifauna and the demersal nekton, mainly fish and squid taxa, showed strong patterns of seasonal change due to migratory patterns. Resistance to disturbance and the ability to either recolonize quickly or move in response to disturbance renders these kinds of faunal assemblages relatively resilient in the face of anthropogenic changes.

Possible exceptions to this generalization regarding resilience are species of concern that require structured habitats or create or enhance structured habitats. Physical habitats dominated by structural geological or biogenic substrates: rock, boulder, cobble, mussel beds, and corals are relatively rare on this continental shelf. We found gravel to be somewhat more common, but not often as the dominant sediment type. Gravel was usually mixed with other elements, e.g. muddy gravel or sandy gravel.

Settlement habitat for Atlantic cod and refuge habitat for black sea bass, particularly young-of-the-year, may depend on habitats of this type. Populations of such species may be limited by the availability of such habitats, so their possible disturbance by offshore wind development is of concern. Atlantic cod were detected by us in small numbers in the MA and RIMA WEAs, and black sea bass, sometimes in large numbers, in all of the WEAs. Species that create or enhance structured species: blue mussels, and hard corals were detected only in the DE WEA. Soft coral habitats (stands of sea whips) were found in both DE and MD WEAs. They are of some concern in particular because they appear to create or enhance black sea bass habitat.

Other species of concern are ones that are immobile or nearly so during at least one life stage and are thus unable to escape from habitats subject to possible anthropogenic disturbance. This includes juvenile and adult shellfish: sea scallops, calico scallops, surfclams, ocean quahogs. It also includes the egg mops (bottom-attached egg masses) of longfin squid. Sea scallops occurred in all WEAs, surfclams in all but RIMA, and ocean quahogs in all but DE. Longfin squid egg mops were found in NY and VA. These distributions call into question some EFH designation maps, as the indicated WEAs have little or no overlap with sea scallop EFH or squid egg mop EFH as currently plotted. In the case of the sea scallop this is related to low or inconsistent densities and/or failure to survive to market size in areas outside the EFH zone. In the case of longfin squid egg mops, there is a paucity of data.

Contrary to expectations, we did not find strong relationships between physical habitat types based upon topographic and sediment texture characterization and the distributions of species of concern. This was not surprising for species like sea scallop and surfclam that may have broad habitat requirements, but perplexing in the case of Atlantic cod and black sea bass, whose distributions are suspected to be habitat-limited. We believe that at least the young stages of these fishes may be using shell hash, which has a widespread distribution on sandy bottoms, as a substitute for structural geological substrates like gravel, cobble, and boulders.

HABITAT MAPPING AND ASSESSMENT OF NORTHEAST WIND ENERGY AREAS

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LIST OF ACRONYMS AND ABBREVIATIONS

ASMFC	Atlantic States Marine Fisheries Commission
BOEM	Bureau of Ocean Energy Management
BPI	Bathymetric Position Index
BTM	Benthic Terrain Modeler
CB&I	Chicago Bridge and Iron
CINAR	Cooperative Institute for North Atlantic Research
CMECS	Coastal and Marine Ecological Classification System
CPUE	Catch per Unit Effort
CSC	Coastal Services Center
CTD	Conductivity-Temperature-Depth (instrument)
D.O.	Dissolved Oxygen
DEM	Digital Elevation Model
EFH	Essential Fish Habitat
EPAct	Energy Policy Act
FGDC	Federal Geographic Data Committee
GEBCO	General Bathymetric Chart of the Oceans
GIS	Geographic Information System
GPS	Global Positioning System
IMAG	Image Modeling and Analysis Group
IOOS	Integrated Ocean Observing System
LMRCSC	Living Marine Resources Cooperative Science Center
MAB	Mid-Atlantic Bight
MD WEA	Maryland Wind Energy Area
MESH	Mapping European Seabed Habitats
NAD	North American Datum
NASC	Nautical Area Scattering Coefficient
NCEI	Nautical Centers for Environmental Information
NGDC	National Geophysical Data Center

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
ORE	Offshore Renewable Energy
psu	practical salinity units
R/V	Research Vessel
RI SAMP, SAMP	Rhode Island Special Area Management Plan
SMAST	School of Marine Science and Technology
Ts	Target strength
UMASS	University of Massachusetts
UMES	University of Maryland Eastern Shore
UNOLS	University National Oceanographic Laboratory System
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WEA	Wind Energy Area
WHOI	Woods Hole Oceanographic Institution

1 Project General Introduction

1.1 Background

There is great national interest and benefit in the development of renewable energy. Under the Energy Policy Act of 2005 (EPAct), the U.S. Department of Interior, Bureau of Ocean Energy Management (BOEM) is responsible for issuing leases, easements, and rights of way to enable renewable energy development on the Outer Continental Shelf (OCS). EPAct requires BOEM to coordinate with relevant federal, state, and local government agencies to ensure that renewable energy development proceeds in a safe and environmentally responsible manner. In this capacity, BOEM is tasked with overseeing development plans and environmental analyses for commercial wind facilities within eight proposed Wind Energy Areas (WEA) in the Atlantic OCS, encompassing offshore lease sites from Massachusetts to North Carolina. As a collaborating agency, the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) is responsible for the stewardship of the nation's living marine resources and their habitats, ensuring productive sustainable fisheries, safe sources of seafood, recovery and conservation of protected resources, and healthy ecosystems, backed by sound science and an ecosystem-based approach to management. The NMFS Northeast Fisheries Science Center (NEFSC), in particular, conducts ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf (the Canadian border south to Cape Hatteras, North Carolina), to promote the recovery and long-term sustainability of these resources, and to generate social and economic opportunities and benefits from their use. Clearly, the interests of the two agencies are aligned.

NOAA already undertakes and maintains spatially and temporally extensive datasets from offshore Federal waters (from 3 miles offshore to the continental slope) in support of their resource management responsibilities. In addition to satellite and large-scale oceanographic and climate monitoring, different offices within NOAA also collect data at spatially smaller scales to support particular regulatory mandates (NOAA 2017a). NEFSC, for example, has conducted randomized trawl surveys to assess fish populations on an annual basis for the last fifty years, the results of which are part of the Integrated Ocean Observing System (NOAA, NEFSC Oceanography Branch 2017). The NEFSC has also conducted the only large scale macrobenthic survey to span the entire northeast continental shelf (including parts of BOEM designated WEAs) (Wigley and Theroux, 1981, Theroux and Wigley, 1998). This particular data set must now be considered historic and possibly unrepresentative due to its age and the dynamic nature of benthic fauna. However, NEFSC has conducted this and many other benthic surveys of more focused scope throughout BOEM's target areas (Steimle et al. 1995). In recent years, state agencies and academic institutions have also conducted more limited benthic surveys in the region. UMass Dartmouth (UMASS Dartmouth) has, for example, conducted photographic assessments of the northeast's scallop resources (Harris and Stokesbury, 2010), while the University of Maryland Eastern Shore (Tewes, 2013) and the University of Rhode Island have conducted benthic and/or sediment surveys in their states' proposed WEAs. NEFSC has also carried out intensive site-specific benthic surveys of offshore dumpsites and deeper ocean canyon habitats, as well as its own photographic scallop survey. Together these works contribute to our understanding of the benthic communities within WEAs but will likely be insufficient to meet the requirements established by BOEM for evaluating potential wind energy impacts. For this reason, NEFSC has surveyed all of the currently identified Atlantic WEAs north of Cape Hatteras to establish a contemporary and comprehensive benthic database that will serve as the background against which BOEM and NOAA can assess impacts of wind energy development on natural resources.

Among the issues of mutual interest to BOEM and NOAA is the potential for impacts from construction and operation of offshore wind facilities to benthic (bottom) habitats and the valued fisheries they support. The concept of habitat utilized here is defined as "…a spatially recognizable area characterized by physical and environmental conditions that support a particular biological community together with the community itself" (Valentine et al. 2005, Foster-Smith et al. 2007, FGDC 2012). The term is synonymous with "biotope", emphasizing the association between physical elements and biological assemblages, including demersal fisheries stocks. Analysis of the character and distribution of existing benthic habitats, as so defined, is important from both statutory and stewardship perspectives, but has not been undertaken previously. The distribution of benthic fauna, including demersal fisheries species, depends on a combination of biological, chemical, physical oceanographic, geological (i.e. sediments) and geographic (i.e. terrain) conditions.

It is generally acknowledged that most of the northeast shelf benthic habitat is dominated by sandy habitats (Stevenson et al. 2006). As a consequence, many of its marine species are highly mobile, well-adapted to life on sandy substrate. These are readily capable of moving from habitats disturbed by human activities, including offshore wind development, and likely not limited by the availability of habitats of suitable bottom type. There are notable exceptions, however.

Diverse studies have shown that certain species have affinities for certain types of bottom, such as hard-bottom for reef-dependent species, e.g. corals and black sea bass (Wilson et al. 2007, Pitman and Brown 2011, Kostylev 2013, Cameron et al. 2014, Guinotte and Davies 2014). Relatively small natural hard bottom reef areas are known to be scattered across the OCS (Steimle and Zetlin 2000) and there are also a number of artificial reefs (MARCO 2017). Further, rock, cobble and gravel hard-bottom habitats are important as spawning and juvenile habitats for others species, e.g. Atlantic cod (Lough 2004). Additional species have limited mobility and escape during some stage of their life cycle and are therefore more potentially vulnerable to disturbance, e.g. lobsters and bivalve mollusks.

Given that some of these potential benthic and demersal fisheries habitats may be vulnerable to disturbance, the project will focus particularly on the presence and spatial extent of such bottom-dependent and low-mobility species and their habitats.

A report on the benthic habitats of the Maryland Wind Energy Area was submitted to BOEM in January, 2015. As this was the first WEA to be examined, that report contains comparisons and evaluation of sampling and analysis techniques, some of which were not employed in subsequent WEA investigations. That report is included as section 2 of the current report with minor changes to accommodate its inclusion herein, and without updates of data or conclusions. The structure of that section of this report is therefore somewhat different from those of the subsequent WEAs and its appendices are presented as a separate series in section 12 of this report, designated as Appendix MD-xx. All data appendices to this report provide partially aggregated data from all NEFSC sampling associated with this report.

1.2 Project Rationale

1.2.1 Project Goal

The goal of this project is to provide the data necessary to establish a contemporary and comprehensive benthic habitat database for the BOEM WEAs in the northeastern region of the United States. Existing data contribute to our understanding of the benthic communities that exist in the WEAs; however, it is insufficient to meet the requirements established by BOEM for evaluating wind energy impacts. For this reason, NEFSC has assembled existing data, collected additional data where needed from the Atlantic WEAs north of Cape Hatteras, and assembled all data into a comprehensive database that accurately characterizes contemporary benthic habitats. This database will serve as a baseline that both BOEM and NOAA can use to assess the potential impacts of wind energy development on natural resources and in support of the site selection process.

1.2.2 Project Objectives

The project objectives are: 1) to acquire datasets from both existing sources and field sampling within each WEA in order to characterize important environmental, biological and ecological features of the OCS and 2) to assemble all datasets into a Geographic Information System (GIS) enabling future benthic habitat analyses and assessment. This second task is further subdivided into three phases that each address different analytical scales and components necessary to properly characterize the benthic environment of the Atlantic OCS WEAs and support Cumulative Impact Analyses.

Phase one of our study focuses on characterizing the abiotic components of the benthic environments within the specified WEAs, while Phase two focuses on the biotic components. Phase three utilizes physical, biological and chemical data to conduct ecosystem-level assessments and support cumulative impact analyses. Sampling in support of Phases one and two employed bottom imagery; acoustic mapping and sediment grab samples within WEAs. This project approach and organization provided a basis from which habitat types and extents could be interpolated to provide projections for potential impacts to those habitats (Phase three) from construction and operation of offshore renewable energy facilities.

This project utilizes the framework presented in the Coastal and Marine Ecological Classification Standard (CMECS) for habitat classification. This scheme is the national standard of habitat classification (FGDC 2012), which provides a hierarchical scheme to take into account a wide variety of physical, chemical, biological, geological and geographic factors to classify marine habitats. Different components of the research will contribute valuable information on the characteristics of the study areas, and contribute essential information on the four underlying components of the seascape as defined by CMECS: water column, geoform, substrate, and biotic components.

1.3 Location and Setting

1.3.1 BOEM Wind Energy Areas

BOEM Atlantic WEAs in the NOAA NMFS Northeast Region are located along the Atlantic coast from Massachusetts to North Carolina and encompass over 1.74 million acres (≈ 2,056 sq. nautical miles ≈7,050 km^2 or 70,500 hectares) of ocean floor (Table 1-1, Figure 1-1). A benthic assessment has been completed for each WEA listed in Table 1-1. This report focuses on all of these WEAs.

Table 1-1. Total acreage of the eight Atlantic OCS WEAs found in the NMFS Northeast Region. Source data:(BOEM 2017). Abbreviations: MA – Massachusetts WEA, RIMA – Rhode Island-Massachusetts WEA, NY – New York WEA, NJ – New Jersey WEA, DE – Delaware WEA, MD – Maryland WEA, VA – Virginia WEA, NC-KH – North Carolina-Kitty Hawk WEA.

Call Area (WEA)	Lease Area	Lease Acreage	Total WEA Acreage
MA	OCS-A-0500	187,523	742,978
MA	OCS-A-0501	166,886	
MA	OCS-A-0502	248,015	
MA	OCS-A-0503	140,554	
RIMA	OCS-A-0486	97,498	164,750
RIMA	OCS-A-0487	67,252	
NY	OCS-A-0512	79,350	79,350
NJ	OCS-A-0498	160,480	343,833
NJ	OCS-A-0499	183,353	
DE	OCS-A-0482	96,430	96,430
MD	OCS-A-0489	32,737	79,707
MD	OCS-A-0490	46,970	
VA	OCS-A-0483	112,799	112,799
NC-KH	OCS-A-0508	122,405	122,405
GRAND TOTAL			1,742,252

The combined acreage of the WEAs (1.742 Macres = 7,049 km^2) represents about 2.7% of the entire Northeast U.S. Continental Shelf Large Marine Ecosystem (NE LME) of 310,000 km^2 (Aquarone and Adams 2009). While the extent of the WEAs may appear small in comparison with the entire system, it is the largest pre-planned anthropogenic development in the coastal ocean in this region. Further, the LME is not homogeneous, so that the effects of WEA development can potentially have impacts out of proportion to its small size.

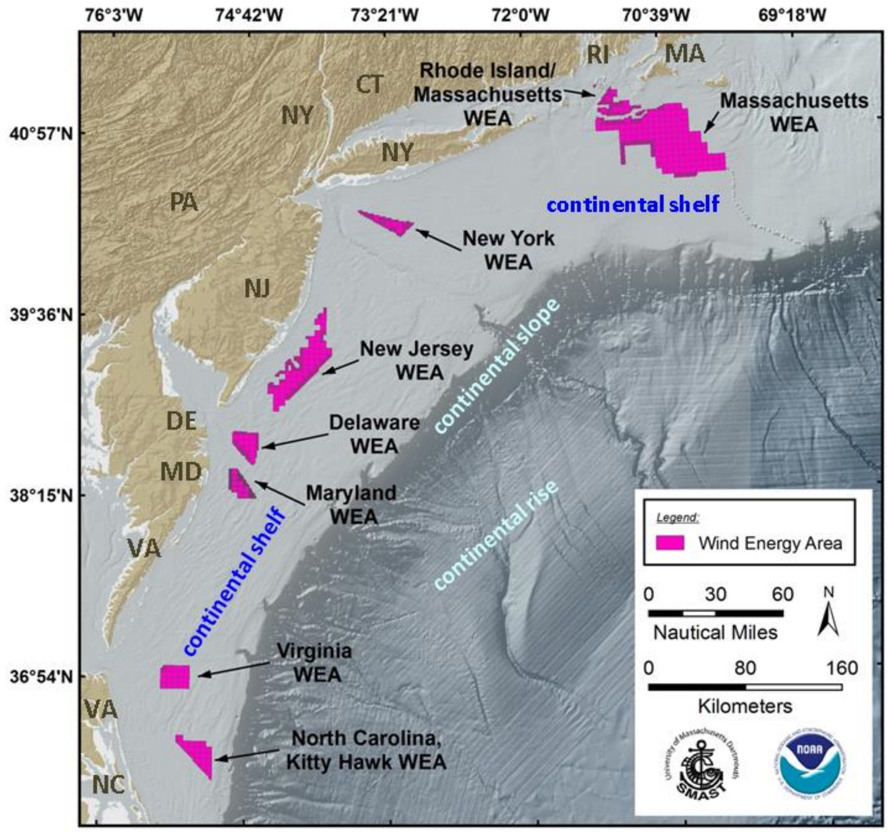

Figure 1-1. BOEM Outer Continental Shelf (OCS) wind energy areas. Source data: (BOEM 2016, GEBCO 2010, NOAA, NCEI 2017).

1.3.2 Geographic and Geological Setting

The Mid-Atlantic Bight (MAB)-Southern New England (SNE) continental Shelf subregions (Cook and Auster 2007) extend from Cape Cod, Massachusetts to Cape Hatteras, North Carolina (Figure 1-1) and owe much of their present configuration to the geologic events of the Pleistocene epoch (Uchupi 1972). The Pleistocene, also known as the last great ice age, occurred between ~ 2 million and 10,000 years ago and witnessed fluctuations in sea level due to alternating entrapment and release of water in advancing and retreating glaciers as continental ice sheets froze, advanced southward, melted, retreated northward, and refroze and re-advanced repeatedly. When the ice sheets melted, rivers flowed onto the coastal plains exposed by low sea levels resulting from glaciation and deposited their sediments (Uchupi 1972). Those sediments persisted through the most recent glacial retreat and were reworked by waves and currents as sea level rose and flooded the outer margins coastal plain, creating the broad, sediment-laden continental shelf that now exists in much of the MAB region. The topography of sediment surface in the MAB and elsewhere on the shelf has been shaped at a variety of spatial scales (e.g. sand ripples, waves and ridges at scales from cm to km) by physical oceanographic processes since the Pleistocene (Hobbs et al 2008).

The width of the Continental Shelf in the MAB and SNE subregions gradually narrows (150km – 30km) from north to south, resulting in the convergence of the Mid-Atlantic and South Atlantic Bight water masses around Cape Hatteras, North Carolina. A significant interaction between the open-ocean and Gulf Steam current also occurs on the shelf and upper slopes (Townsend et al. 2004, Rasmussen et al. 2005, Fratantoni and Pickart 2007). In addition to these two water masses converging, the MAB physical oceanography is also influenced by discharges from two large estuarine systems, the Chesapeake Bay and Hudson River. These estuarine systems have cut v-shaped canyons into the OCS from their outflows that funnel nutrient-rich water to the ocean abyss (Church et al. 1984). Delaware Bay and numerous smaller estuarine systems also have substantial impacts on topography and hydrography. Due to the constant replenishment of surficial sediments from those estuarine systems, continuous reworking of surficial sediments by wave and tidal energy, and the formation of barrier islands and other coastal landforms, sand dominates the MAB shelf region (<200 m depth), and silt and clay dominate the deeper waters of the slope and canyons (>200 m depth) (Uchupi 1972, Wigley and Theroux 1981, Gutierrez et al. 2007).

1.3.3 Physical Attributes: Regional Perspective

Overviews of the entire NE LME, within which the WEAs treated in this report, including its history, physical and biotic dimensions, climate, protected species, fisheries, and human interactions are available elsewhere (Aquarone and Adams 2009, NOAA, NEFSC 2017). Therefore, rather than attempting to reiterate them here, these issues will be treated individually as they apply to each WEA in subsequent sections of this report. A few relevant ecosystem issues are taken up in this section of the report simply to highlight them or because they need to be treated in a larger LME-wide context for purposes of evaluation in WEAs.

The temperature regimes in the NE LME feature some of the largest seasonal variations for any such system worldwide, making temperature a major driver for the activities, distribution, and movement of marine fishes and other organisms. This results in three major annual distributional patterns for many organisms: 1. latitudinal (north-south) seasonal migrations, 2. longitudinal (inshore-offshore) seasonal migrations, or 3. little or no migration, but special physiological adaptations to endure extreme local changes.

A scheme for seasonal temperature variations in the water column in a small geographic area (RI SAMP area) in the region over a 32-year period (1977-2008) is shown in Fig. 1-2. The salient features of this plot are the large temperature changes at the surface and bottom over the seasonal cycle, the isothermal (same temperature at all depths during the cold season, but progressive stratification (separation of warm and cold layers) during the warm season, and the pattern of wide variation (scatter) of temperature values for any given day of the year. While the data displayed only treats observations from Rhode Island waters, these patterns are universal for WEAs throughout the NE LME, as seen in succeeding sections of this report, and undoubtedly play a critical role in vital activities such as spawning and migration.

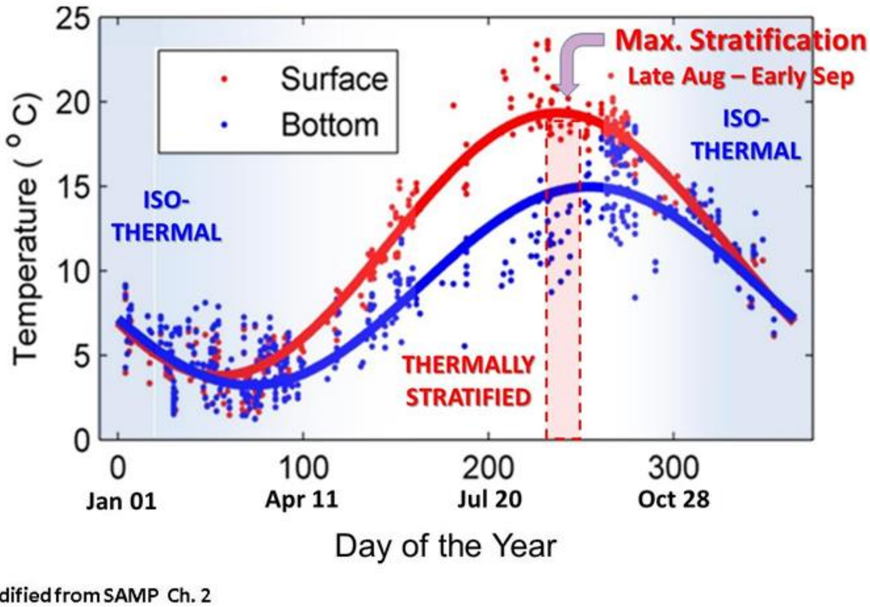

Figure 1-2. Surface and bottom water temperatures collected off Rhode Island during the NEFSC Marine Resources Monitoring, Assessment and Prediction Program (MARMAP) program. Source: SAMP 2011.

This shelf-wide seasonal temperature pattern is driven by the interaction of atmospheric climate and currents. Specifically, solar warming heats surface water in spring through fall. Simultaneously a cold current flows southward from the Gulf of Maine through the Great South Channel between the landward end of Georges Bank and Cape Cod across Nantucket Shoals into Southern New England. This current continues southwestward along the bottom down the length of the mid-Atlantic shelf (Figure 1-3). This "cool pool" water mass is maintained throughout much of the warm season over the extent of the shelf bottom via complex interactions with shelf topography (Houghton et al. 1982). Resulting stratification persists until broken in September or October by a combination of solar warming and wind-mixing. While the interactions of the cool pool and other water masses maintain seasonal temperature regimes across latitudinal and depth gradients, changes in these can these induced by cyclic (e.g. North Atlantic Oscillation or NAO) and long-term climatic change can influence the intensity and timing of local hydrographic conditions, e.g. rapid erosion of the cool pool and subsequent early fall turnover events (Fratantoni et al. 2017), that can result in the redistribution of benthic and demersal faunas. These kinds of background effects, along with fishing pressure (Fogarty et al. 2009) and the differential vulnerability of species to climate change (Hare et al. 2016), should be taken into account when assessing potential impacts of OCS development.

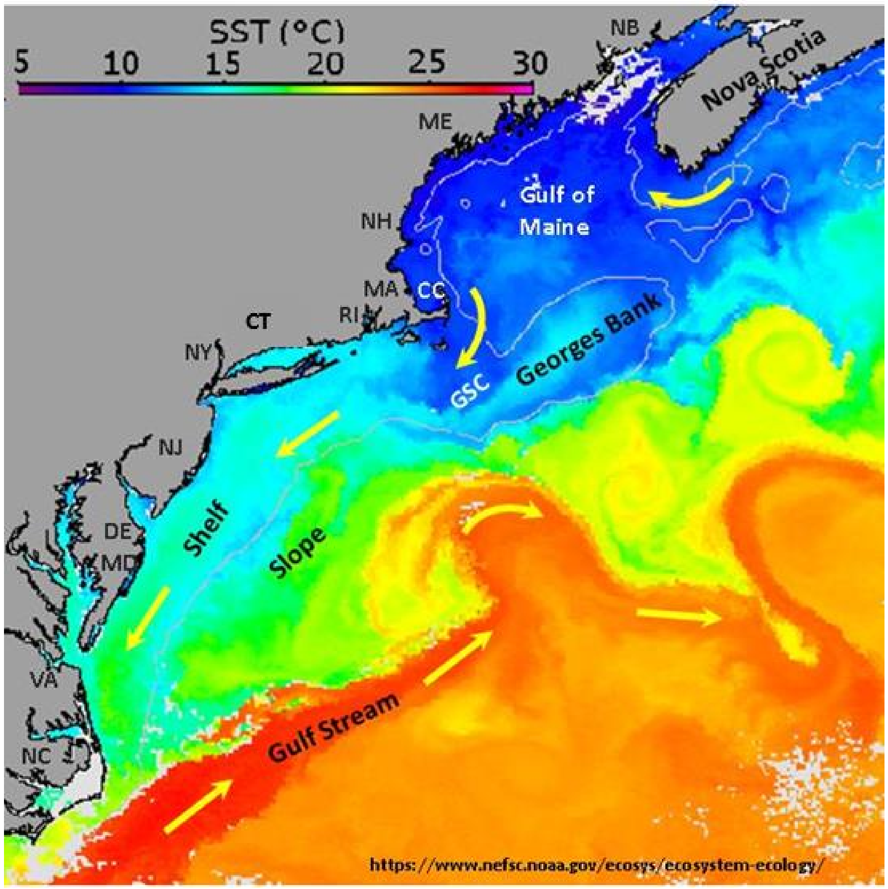

Figure 1-3. Satellite image depicting a daily snapshot of fall surface water temperature patterns on the Northeast U.S. continental margin. Cooler temperatures are represented by darker colors shading to dark blue. Warmer temperatures are represented by the warmer colors shading to red. Yellow arrows indicate current directions. Abbreviations: CC – Cape Cod, GSC – Great South Channel, U.S. States and Canadian Provinces as used in postal systems.

Where water masses of very different temperature and salinities meet, horizontal hydrographic fronts are apparent. Some of these associated with the output of low salinity water from estuaries (e.g. river plumes) tend to be ephemeral; their location and strength is weather-dependent. Though all, being water column features, have some tendency to move, strengthen and weaken, others, like those associated with temperature and salinity differences among major offshore water masses, are more persistent and predictable. Any of these hydrographic features can cause plankton to be concentrated, resulting in concentration of the marine food chain in their vicinity, but the persistent fronts probably play larger ecological roles over the long term. Most WEAs are not associated with any such prominent, persistent fronts. The exceptions are MA and NC-KH WEAs, both of which have contact with important persistent frontal systems (Nantucket Shoals and the Shelf-Slope Fronts, respectively) at their eastern ends (Figure 1-4).

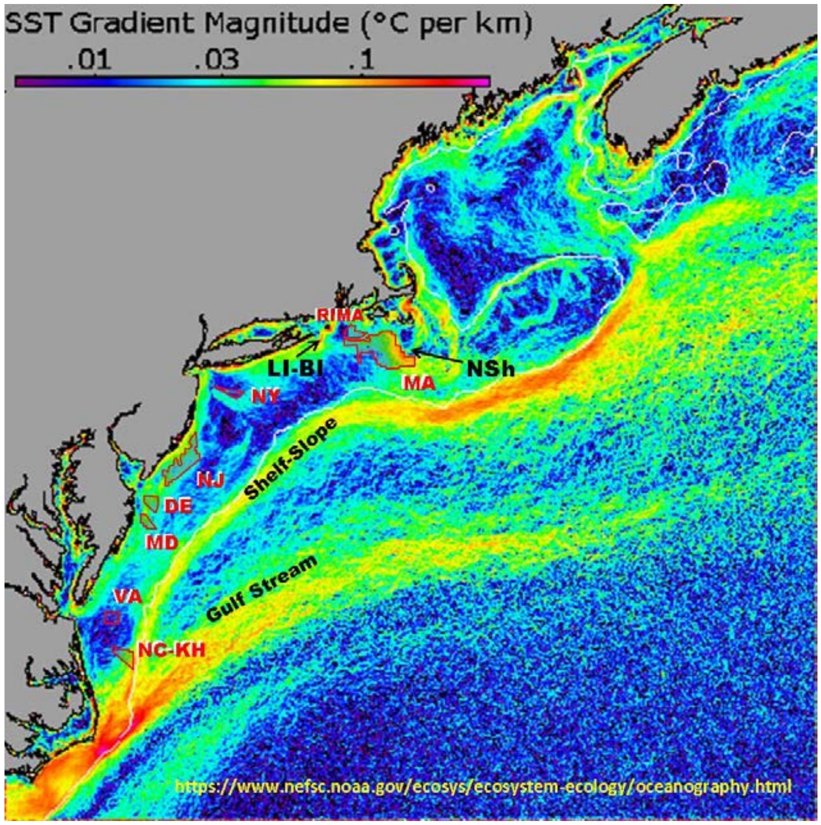

Figure 1-4. Major hydrographic fronts in the northeastern U.S. based upon satellite sea surface thermal imagery. Outlines of BOEM WEAs are superimposed to assess overlap. Abbreviations for WEAs: MA – Massachusetts, RIMA – Rhode Island-Massachusetts, NY – New York, NJ – New Jersey, DE – Delaware, MD – Maryland, VA – Virginia, NC-KH – North Carolina-Kitty Hawk. Abbreviations for fronts: LI-BI – Long Island-Block Island, NSh – Nantucket Shoal.

Aside from influencing bottom temperatures, regional current systems along with surface waves also create turbulence that influences bottom topography, sediment composition, and sediment stability, all of which are important habitat factors for benthic and demersal faunas. Bottom shear stress is a measure of the force per unit area generated across the bottom (parallel to the bottom surface). Daylander et al. (2013) have recently developed methods for predicting shear stresses generated by waves, tidal and non-tidal currents over large areas and applied these to the known sediment types in the southern New England and mid-Atlantic shelf subregions. Their results, featured in the USGS Sea Floor Stress and Sediment Mobility Database (https://woodshole.er.usgs.gov/project-pages/mobility/mid_atl_bight.html) demonstrate that the highest shear stresses are predicted for the Nantucket Shoal area, the mouths of major estuaries (tidal current stress), and projecting capes (wave stress), with elevated values along shorelines (wave stress), especially along those with a southeastern exposure (southern New Jersey and the Delmarva Peninsula) in summer, and all shorelines in winter (Daylander et al. 2013, Figures 5 and 6). Applying these predictions to the kinds of sediments found in each area, they predicted percentages sediment mobility as illustrated in Figure 1-5.

Bottom bedforms on a variety of spatial scales result from the movement of sediments driven by shear stress-induced mobility. These can play important roles in providing microhabitats for various fishes, especially juvenile fishes (Diaz et al. 2003). For this reason, we have been careful to note and record the nature and prevalence of bedforms: sand ripples, megaripples, sand waves and sand ridges as they occur in the WEAs. Most WEAs appear in areas of moderate to low sediment mobility.

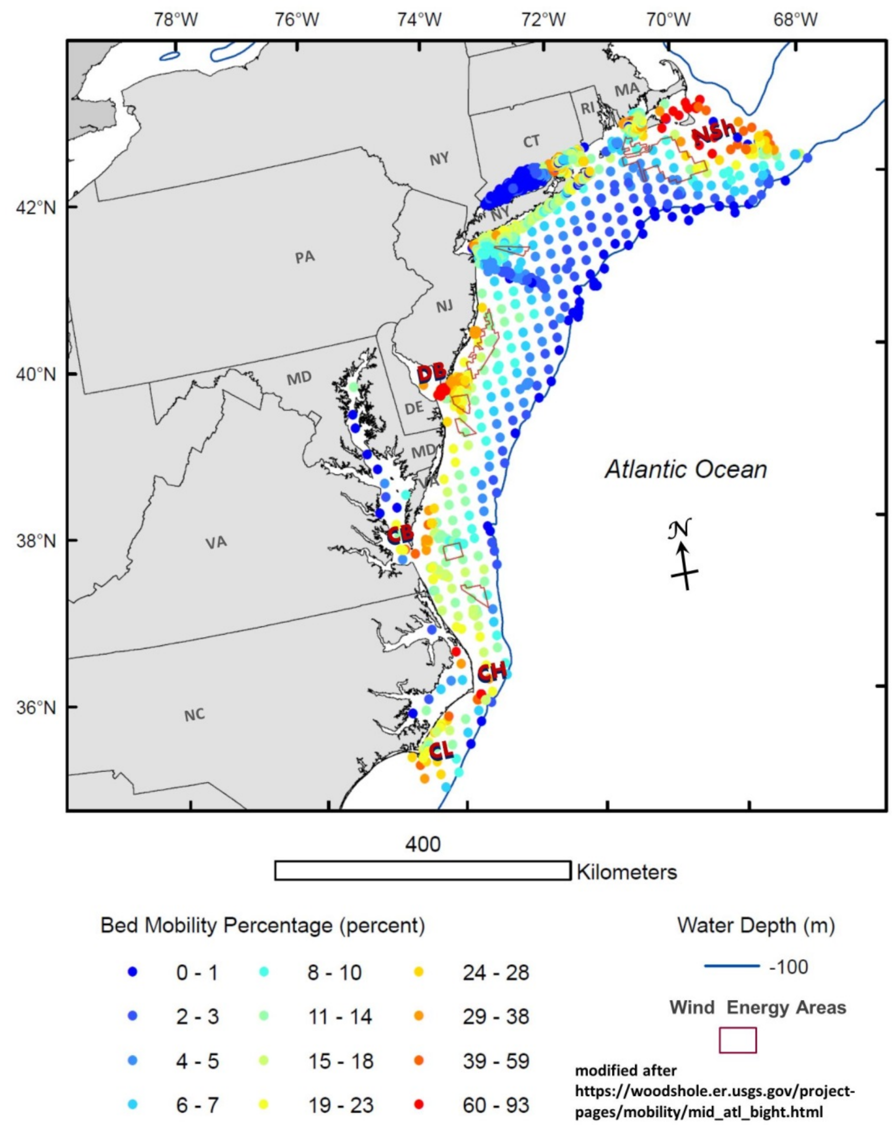

Figure 1-5. Predicted sediment bed mobility in Southern New England and the Southern Middle Atlantic Bight for the one year period May 2010 to May 2011 based upon sediment type interactions with predicted shear stresses from waves and currents. BOEM WEAs are superimposed on the original USGS map. Abbreviations: CB – Chesapeake Bay, CH - Cape Hatteras, CL – Cape Lookout, DB – Delaware Bay, Nsh – Nantucket Shoals, U.S. States – postal abbreviations.

1.3.4 Benthic/Demersal Biota: Regional Perspective

As this report is concerned mainly with benthic (bottom) and demersal (near-bottom) habitats, it is primarily concerned with benthic infauna and epifauna and demersal nekton (fishes and swimming invertebrates, e.g. squids). As the methods used for collection of these target species can capture some pelagic (mid-water) fauna (e.g. clupeioids: herring-like fishes), these are also considered when encountered. Although of paramount importance in the system, birds, marine mammals and reptiles, zooplankton, phytoplankton, meiofauna and microbiota and their habitats are not treated here.

Two adjoining bioregions (Figure 1-6) are included in the study area: Southern New England and the southern Mid-Atlantic Bight (Cook and Auster 2007) with related faunas. Many mobile species are seasonally migratory, including cold-water species that migrate south and west into the region and warm-water species that migrate north and east to take advantage of favorable thermal conditions inshore during the cold and warm seasons, respectively. Hence, cold-adapted Atlantic herring and little skate were prominent in NEFSC seasonal survey catches in Southern New England during winter and spring, while warm-adapted scup, butterfish and longfin squid became prominent in summer and fall. Seasonal faunal turnover is a major feature of the demersal nekton throughout the two subregions.

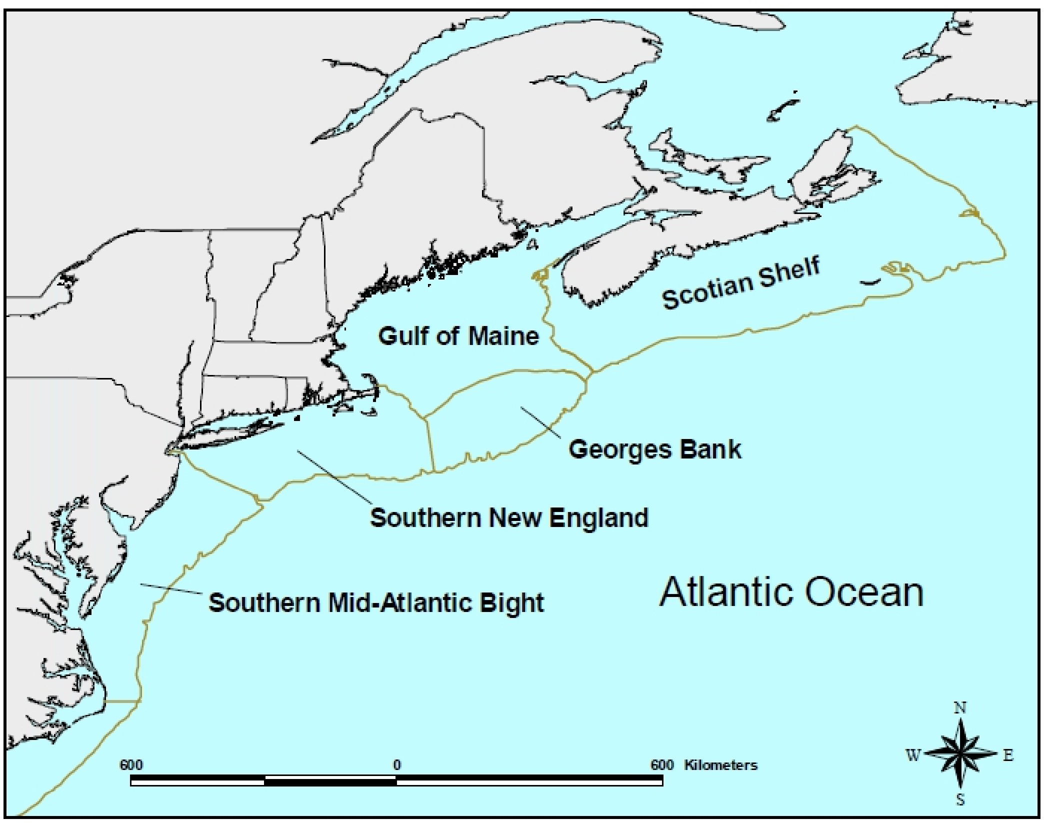

Figure 1-6. Biogeographic regions on the Northeast Continental Shelf (from Cook and Auster 2007).

There are many ways to assess the value and potential impacts on marine faunas like those of the northeast. In this report we have chosen to treat the species encompassed from two perspectives: 1. ecological diversity and 2. fisheries management value. These dual values are reflected in the descriptive metrics utilized to characterize these marine faunal assemblages and those taxa from within the faunas with which we are most concerned.

Regarding ecological diversity, we are reporting data for all taxa, whether covered under fisheries management plans or not, recorded in databases and all taxa found in physical samples regardless of perceived value or lack thereof. As our goal is to characterize area faunas rather than to assess individual populations or stocks, we have utilized raw catch numbers rather than catch-per-unit-effort (CPUE) so as to facilitate comparisons among species within samples. These numbers have been pooled by WEA so as to provide an overview of what are primarily highly mobile faunas on a whole WEA basis. Three measures of ecological importance within samples are considered: 1. total numbers of each taxon as a proportion of the total number of individuals of all taxa caught, 2. total weight of each taxon as a proportion of the total weight of the catch, and 3. frequency of capture as a proportion of all samples within a suite of samples. Recognizing that faunas may undergo large seasonal changes, suites of samples are defined as those taken within a particular WEA in a particular season (warm or cold). Thresholds were set arbitrarily to be plotted individually in graphical representations: taxa representing >10% of total numbers caught, >10% of total weight caught, and occurring in >50% of catches with the suite for benthic epifauna (beam trawl catches: 10-10-50) and >1% of total numbers, >1% of total weight, and >50% occurrence for NEFSC seasonal (otter) trawls (1-1-50). For the purposes of characterizing faunal assemblages species meeting all three criteria for their sampling regime were considered “dominants”. For purposes of graphical representation, numbers, weights and frequencies of taxa not meeting the criteria for abundance, weight, or frequency were pooled as “other” taxa. Beam trawl (epibenthic fauna) trawl data collected on NEFSC-sponsored cruises during the course of this project were treated similarly to the seasonal trawl data; the same thresholds for numbers, weight and frequency were utilized for determining importance and the same criteria were used for selecting dominants.

In the case of benthic infauna, where only numbers were collected, importance was determined solely on the basis of frequency. Organisms occurring at 80% or more of stations within a WEA were considered “core” species for that WEA. Other taxa were considered “non-core”. In most cases core taxa were those with highest overall abundance as well.

Because few NEFSC seasonal survey trawls were made in each WEA during each year, we chose to combine all data from any one season over a span of years to include enough data to be confident of a representative sample. That trawl database spans catches from the entire northeast U.S. region from the 1960s until the present. However, over that period of time large changes have occurred in the external drivers of LME condition such as climate and the responses of species to those changes. Thus, we restricted the use of the historic database to the period of 2003 to 2016 to avoid the some of the major shifts in the ecosystem prior to that time. We felt this would provide a more realistic view of the current state of each WEA than the use of all the data while providing enough data for a representative sample. In most years and in most locations NEFSC seasonal surveys have been conducted during early spring (March-April) and early fall (September-October), corresponding to the coldest and warmest times of year for bottom organisms, respectively (Figure 1-2). In a few cases where winter (January-February) data were available, it was added to spring data to create a more data-robust “cold season” dataset. Likewise data from the occasional July-August summer period were combined with fall data to create a “warm season” dataset.

1.4 Data Sources and Methods

As a first step in describing the benthic habitats of the WEAs, an intensive data mining process was undertaken in order to ensure the most recent existing data was incorporated into this report. We referred to the NOAA/National Centers for Environmental Information (NCEI), formerly the National Geophysical Data Center (NGDC) website (NOAA, NCEI 2017) for bathymetric data; NCEI compiles and distributes bathymetric data from coastal and open ocean areas. We also referred to the NOAA/NEFSC website (NOAA, NEFSC Oceanography Branch 2014), which provides extensive databases for physical and biological oceanography and the NEFSC fisheries independent trawl survey. For additional surficial sediment data, we also referred to the usSEABED United States Geological Survey (USGS) website (Reid et al. 2005).

A complete listing of the environmental data incorporated to this report is listed in Table 1-2. This table contains both pre-existing data gleaned from the data mining effort and new data gathered as part of the current project to fill gaps in the pre-existing datasets. Table 1-3 summarizes all data collection by source and WEA. Note that bathymetric data resolution varied according to its source and that UMASS SMAST data did not cover VA or NC-KH WEAs. Table 1-4 lists NEFSC-sponsored cruises on which data was gathered specifically for the purposes of this project. Swath and multibeam sonar products mentioned in this table were partial, covering only a fraction of each WEA, and were utilized as supplements to the primary sources of bathymetry and sediment characterization listed in Tables 1-2 and 1-3. The following sections describe the treatment of data from these sources.

Table 1-2. Summary of the environmental data used in this report. Subsequent sections (numbered in paretheses) treat details for each category.

Environmental Data (Section of this report)	Data Format	Source
***Bathymetry* (1.4.1)**		
Depth	Raster	from CB&I[a] ,FUGRO[b], NCEI (NGDC)[c]
***Terrain variables* (1.4.2)**		
Slope, Rugosity, Aspect[1]	Raster	Derived from Bathymetry from respective sources
Rugosity[2]	Raster	Derived from Bathymetry from respective sources
Bathymetric Position Index[1,3]/Slope[1] Benthic Zones	Raster	Derived from Bathymetry from respective sources
***Substrate texture variables* (1.4.3)**		
Predicted Surficial Sediment Mean Grain Size[4]	Points	usSEABED Atlantic Coast parsed and extracted data- bases (Reid et al. 2005)[b], NOAA-NEFSC[d], UMES[e]
Predicted Surficial Sediment: Percent Sand, Mud, Gravel[4]	Points	usSEABED Atlantic Coast parsed and extracted data- bases (Reid et al. 2005)[b],NOAA-NEFSC[d], UMES[e]
Observed Surficial Substrate Type: Sand, Sand Ripple, Shell Debris, Silt, Gravel, Cobble, Rock[5]	Points	UMASS SMAST sampling pyramid imagery[f]
***Physical/Chemical variables* (1.4.4)**		
CTD data	Points	R/V *Resolute*, NOAA-NEFSC Oceanography Branch historical database [g]
***Biological variables* (1.4.5)**		
Benthic Infauna[6]	Points	NOAA-NEFSC grab samples for this project
Benthic Epifauna[6]	Trawls	NOAA-NEFSC beam trawls for this project
Benthic-Demersal Epifauna (photographic)[6]	Points	SMAST sampling pyramid imagery[f]
Fish Density (MD only)	Points	NOAA-NEFSC sonar data, R/V *Resolute*[c]
Demersal Nekton & Megabenthos[6]	Trawls	NOAA-NEFSC seasonal bottom trawl survey

Table 1-2 footnotes:

[1] Derived using ArcGIS 10 Spatial Analyst.
[2] Derived using the ArcGIS 10 extension DEM Surface Tools (Jenness 2013).
[3] Calculated using Benthic Terrain Modeler.
[4] Derived using ArcGIS 10 Geostatistical Analyst.
[5] Data provided by UMASS SMAST
[6] Data collected and analyzed in-house specifically for this project

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[a] Provided by Chicago Bridge and Iron (CB&I: contracted for MD WEA survey by the state of MD: CB& I 2014)
[b] Provided by FUGRO for the VA WEA survey by the state of VA
[c] From National Centers for Environmental Information (NCEI) – National Geophysical Data Center (NGDC)
[d] Downloaded from http://walrus.wr.usgs.gov/usseabed
[e] Provided by U. of Maryland Eastern Shore (UMES) graduate student Emily Tewes (Tewes 2013): MD only
[f] Provided by U. of Massachusetts Dartmouth School of Marine Science & Technology (SMAST): K. Stokesbury
[g] Provided by NOAA-NEFSC

Table 1-3. Data collections summarized by source, resolution, and WEA.

	Bathymetry Source & Resolution (m)			Sediment Samples & Observations			Hydro-graphy	Biotic Samples & Observations		
WEA	CRM[1]	NOS[2]	Other[3]	usSEABED	NEFSC	SMAST	NEFSC	Infauna	Beam Tr	Trawl Surv
MA	~90[1]			X	X	X	X	X	X	X
RIMA		66		X	X	X	X	X	X	X
NY	~90[1]			X	X	X	X	X	X	X
NJ		74		X	X	X	X	X	X	X
DE		38		X	X	X	X	X	X	X
MD			2	X	X	X	X	X	X	X
VA			2	X	X		X	X	X	X
NC-KH	~90[1]			X	X		X	X	X	X

Table 1-3 Footnotes:

[1] CRM = NCEI Coastal Relief Model (3 arc-sec ≈ 93 m Lat, ≈ 70-75 m Lon, depending on Lat)
[2] NOS = NOAA National Ocean Service map grids
[3] Other = Chicago Bridge and Iron (CB&I: MD WEA), FUGRO (VA WEA)

Table 1-4. NEFSC-sponsored cruises providing data for this report.

NEFSC Program	Ship	Cruise	Dates	Data Collected	WEAs
Habitat Characterization[1]	NOAA Ship *Gordon Gunter*	GU13-04	July 5-10, 2013	CTD, Benthic Grabs	MD
HabCam Maryland Habitat[1]	R/V *Hugh Sharp*	n/a	July 22-26, 2013	HabCam Bottom Photos, Multibeam Mapping	MD
HabCam Maryland Habitat[1]	NOAA Vessel *Resolute*	n/a	July 24-27, 2013	CTD, Fish Mapping	MD
AMAPPS[1,2]	NOAA Ship *Gordon Gunter*	GU14-02 part I	March 7-31, 2014	CTD, Benthic Grabs, Beam Trawl	RIMA, MA, NY, NJ, VA
AMAPPS[1,2]	NOAA Ship *Gordon Gunter*	GU14-02 part 2	April 7 - May 1, 2014	CTD, Benthic Grabs, Beam Trawl	MA
Benthic Habitat Mapping[3]	NOAA Ship *Thomas Jefferson*	TJ15-04	June 22 - July 3, 2015	CTD, Benthic Grabs, Multibeam Mapping	NJ
Charter[3]	R/V *Connecticut*	n/a	July 27 - August 3, 2015	Benthic Grabs, Swath Sonar Mapping	MA
Habitat Characterization[3]	NOAA Ship *Henry Bigelow*	HB15-05	August 12 - August 25, 2015	CTD, Benthic Grabs, Beam Trawl, Multibeam Mapping	DE, VA, NC-KH
Habitat Characterization[3]	NOAA Ship *Pisces*	PC16-06	September 21-29, 2016	CTD, Benthic Grabs, Beam Trawl, Multibeam Mapping	NY

Table 1-4 Footnotes:

[1] BOEM Benthic Habitat Assessment data collections "piggybacked" onto other cruise goals
[2] AMAPPS = Atlantic Marine Assessment Program for Protected Species
[3] Exclusively BOEM Benthic Habitat Assessment cruise

1.4.1 Bathymetry

Bathymetry for the WEAs was collected from a variety of sources with the intent of using the highest resolution data possible. The National Ocean Service (NOS) hydrographic survey data (surveys with bathymetric attributed grids and surveys with digital sounding data) was aggregated to fully cover each WEA. When available high resolution (2m) multibeam bathymetry was used however, it was often only partially available within the WEAs. The highest resolution surveys were collected from the NOS website: http://maps.ngdc.noaa.gov/viewers/bathymetry/ and were combined into a continuous bathymetry using ordinary kriging with the first order trend removed. Output resolution was one half the average nearest neighbor distance between the input data points. The resolution and surveys used for each WEA are listed below.

The Rhode Island- Massachusetts WEA bathymetry is a 66 m horizontal grid resolution created using the following surveys: H06439, H06444, and H06445. The New Jersey WEA bathymetry is a 74 m horizontal grid resolution created using the following surveys: H09534, H09542, H09552, H09573, H11242, H11243, H11455, and H114567. The Delaware WEA bathymetry is a 38 m horizontal grid resolution created using the following surveys: H09639, H10989, and H11554. The Virginia WEA was fully covered by 2 m horizontal grid resolution bathymetric attributed grid which was created by mosaicking surveys H12309, H12201, H12502, H12503 (Table 1-2).

When the average resolution from the NOS data alone exceeded 90 m resolution, such as in the Massachusetts, New York, and North Carolina WEAs, the U.S. Costal Relief Model (CRM) was used. The CRM is based on a combination of sources resulting in a dataset depicting a 3 arc-second horizontal grid resolution. The U.S. CRM was provided by NOAA National Centers for Environmental Information, https://www.ngdc.noaa.gov/mgg/coastal/crm.html. Bathymetric data sources include the U.S. National Ocean Service Hydrographic Database, the U.S. Geological Survey (USGS), the Monterey Bay Aquarium Research Institute, the U.S. Army Corps of Engineers, and various other academic institutions. Topographic data are from the USGS and the Shuttle Radar Topography Mission (SRTM).

Supplementary bathymetry data of selected parts of WEAs using swath and multibeam sonar mapping collected aboard NEFSC-sponsored cruises could not be added readily to complete WEA mapping products of generally lower resolution, so they are treated separately from the main mapping products in sections of this report dealing with individual WEAs. Cleaning and processing of this data was performed using Caris HIPS & SIPS™.

1.4.2 Terrain Variables

Terrain metrics (i.e. slope, rugosity, and aspect) derived from bathymetry data quantify the three dimensional character of the seafloor and can be used as a proxy for topographic features (e.g. sand waves, reefs, scarps, and channels). Studies have shown various bottom-associated species inhabit different topographic structure because they have an affinity to specific types of terrain (Wilson et al. 2007, Vasslides and Able 2008). Slope is a measure of the steepness of the changes in bathymetry. Rugosity is used to infer terrain complexity. Aspect is a measure of the direction of the slope (Friedman et al. 2012), which are color-keyed to both ordinal (compass degrees) and cardinal (N-S-E-W) aspect ranges on figures in this report. The use of high resolution multibeam bathymetry to calculate terrain metrics has proven useful in predictive habitat suitability modelling for species associated with bottom terrain features (Tittensor et al. 2009, Toller et al. 2010, Yesson et al. 2012, Rengstorf et al. 2013, Guinotte and Davies 2014). For the each WEA the highest bathymetry data available was used to calculate terrain metrics for slope, rugosity, and aspect. Slope and aspect were both calculated using ArcMap 10.0 Spatial Analyst Extension-Surface Tool. Rugosity was calculated using DEM Surface Ratio

Tool Ver. 2.1.305 (Jenness 2013). We chose to further classify the WEAs into benthic zones by incorporating the slope and bathymetry data into a combined broad-scale (500 m) benthic zone map using the Benthic Terrain Modeler (BTM) Tool ver. 3.0 for ArcMap (NOAA, CSC 2013). The BTM Modeler first calculated the broad bathymetric position index (BPI) (inner radius = 25, outer radius = 250) for the study area and then incorporated the slope metric into a bathymetric zone map at a 500 m horizontal scale (NOAA CSC 2013).

1.4.3 Substrate Texture Variables

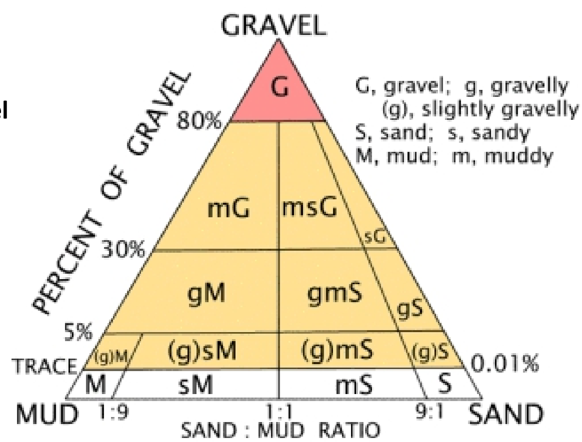
Table 1-5 presents a summary of the Wentworth and Folk sediment classification schemes used in this report. These are the same schemes used by USGS and by NOAA for CMECS classification.

Table 1-5. Grain sizes and sediment classification schemes used in this report. Source data: (Wentworth 1922, Folk 1954, USGS 2006).

Wentworth Classification for grain sizes

Size range (metric)	Phi range	Aggregate name (Wentworth Class)	
256 mm <	<-8	Boulder	
64-256 mm	-8 to -6	Cobble	
32-64 mm	-6 to -5	Very coarse gravel	**gravel**
16-32 mm	-5 to -4	Coarse gravel	**gravel**
8-16 mm	-4 to -3	Medium gravel	**gravel**
4-8 mm	-3 to -2	Fine gravel	**gravel**
2-4 mm	-2 to -1	Very fine gravel	**gravel**
1-2 mm	-1 to 0	Very coarse sand	**sand**
½ - 1 mm	0 to 1	Coarse sand	**sand**
¼ - ½ mm	1 to 2	Medium sand	**sand**
125-250 µm	2 to 3	Fine sand	**sand**
62.5-125 µm	3 to 4	Very fine sand	**sand**
3.90625-62.5 µm	4 to 8	Silt	**mud**
<3.90625 µm	>8	Clay	**mud**
<1 µm		Colloid	

Folk Classification for mixed sediments



Seabed survey point data from the usSEABED Atlantic Coast Offshore Surficial Sediment Data Release, version 1.0 was downloaded from the USGS website (Reid et al. 2005, USGS 2013b). The parsed and extracted databases (USGS 2013a) were selected and filtered to remove duplicate records and points not pertaining to surficial sediments (Reid et al. 2005). As we desired more data of the "extracted" variety, we undertook to collect additional sediment samples for grain size analysis in the WEAs.

NOAA sediment samples were obtained from samples taken with a 0.10 m^2 Young-modified Van Veen sediment grab sampler. Triplicate grab samples were taken at stations in each WEA (for numbers and locations see individual station maps for each WEA in succeeding sections of this report). Single 3 cm diameter cores were taken from each valid grab replicate and stored under refrigeration until analyzed for grain size distribution via coarse fraction sieving (Poppe et al. 2000) ashore.

Lacking full-coverage multibeam backscatter data upon which to base sediment distribution, we chose instead to create interpolation maps of sediments based on relatively large numbers of grain size analysis single point samples from usSEABED and NOAA sources. For purposes of plotting the combined usSEABED and usSEABED data, interpolations were performed using ArcMap 10.0 Geostatistical Analyst. The data were explored using histogram plots to determine data distribution and conduct trend analyses. The geostatistical method used for interpolation was ordinary kriging, which uses a weighted average of neighboring samples to estimate the ‘unknown’ value at a specific location. Since a sampling trend was detected in the data, we decided to use a second-order polynomial to correct that trend. Sediment prediction and prediction error maps were thus generated. For further details about the interpolation process, see the metadata associated with the raster layers.

The two sediment datasets (usSEABED and NOAA) were integrated to produce sediment maps. Data from each dataset was cleaned, processed and combined into a complete data set containing the fields: % mud (silt and clay), % sand (very fine sand to very coarse sand), % gravel (very fine gravel to very coarse gravel), and mean grain size. Percentages of mud, sand, and gravel were then converted to a fraction for the interpolation process and converted back to a percentage after the interpolation process for purposes of representation on maps.

Surficial sediment data from University of Massachusetts School of Marine Science and Technology (UMASS SMAST) camera pyramid surveys of 2012 and 2013 were also utilized in assessing sediment texture. These datasets consist of observations on sediment types as major categories (mud, sand, gravel, cobble, boulder) based on analysis of in situ underwater imagery as collected by the SMAST camera pyramid. Being qualitative, they could not be easily incorporated with quantitative usSEABED or NOAA grain size data, so they are herein reported separately from those datasets. The particular value of the SMAST dataset in regard to sediments is that it reports the presence of large grain sizes (cobble, boulder) that are not accessible to capture by grab samples, and hence are not reported in usSEABED or NOAA grain size data. SMAST data also reports the presence of shell debris, which is typically excluded from grain-size analysis, and also reports sand ripples in bottom sediments, which are valuable clues to bottom current regimes (see Section 1.3.3). Such microtopographic features are not evident from grab samples and only evident in multibeam or swath bathymetry of the highest resolution, for which coverage is spotty or lacking in most WEAs. UMASS SMAST camera pyramid data was available for all WEAs except VA and NC-KH.

1.4.4 Water Column Oceanographic Data

Water column data used in this report came from the NEFSC historical database (NOAA, NEFSC Oceanography Branch 2014) that includes vertical CTD (Conductivity-Temperature-Depth instrument) cast data from numerous survey and research cruises taken since its inception in the 1970s. This includes data from those NOAA cruises on which data was accumulated specifically in pursuit of this report (Table 1-3). Only data collected between 2003 and 2016 were utilized, so as to match the period for collection of NEFSC Seasonal Trawl Survey data (see Section 1.3.3 for rationale).

1.4.5 Biological Variables

Biological variables utilized in both the ecological diversity and management value portions of our biological analysis came from a combination of historical NEFSC datasets.

1.4.5.1 Historical NEFSC Datasets: Benthic Fauna and Seasonal Trawl Survey

Two sets of NEFSC historic data on benthic and demersal fauna cover the entirety of the northeast region, including the WEAs: the Wigley and Theroux study (Wigley & Theroux 1981) for benthic infauna and epifauna, and the NEFSC bottom trawl survey for demersal fauna. Each has its limitations with respect to intensity of sampling in time and space, sample size, catchability of various organisms. While comprehensive and thorough, the surveys that are the basis for the Wigley and Theroux data are up to 50 years old. Given the dynamic nature of benthic communities in general and the extent of environmental change since the time of their collection, they may be too outdated to be incorporated into the current analysis. Thus we decided to conduct our own sampling program for benthic infauna and epifauna with grab samples and beam trawls, respectively. Some more recent benthic sampling data is available in limited quantities for individual WEAs, e.g. RIMA (LaFrance et al. 2010).

As explained in section 1.3.3, only NEFSC Seasonal Trawl Survey data from 2003 to 2016 were utilized. The bottom trawl survey, which has been conducted every year since the 1960s, has in recent years been conducted semi-annually (Fall and Spring) using standardized protocols and a stratified random sampling pattern (Johnston 2013, Politis et al. 2014). We have chosen to pick out a fourteen-year period from 2003 to 2012 to represent the character of the MD WEA region in recent years. While the structure of trawl survey has remained the same over the years, the gear has not. In 2008-2009 the 36 foot Yankee otter trawl that had been used for many years prior was phased out and replaced with a more efficient four-seam otter trawl system, requiring some adjustments of trawl protocol. Among the changes was a change in the length of trawls necessary to obtain a catch adequate for statistical purposes. It is for this reason that the tracks differ noticeably in length; the longer ones are 36 Yankee (older) tracks, the shorter are the 4-seam (newer) tracks. In this region Fall Survey trawls have been performed during September and early October. Spring trawls have been performed largely in March, April, and sometimes May. Data from the few cases where winter and summer data (outside these limits) were available were combined with spring and fall, respectively to create cold season (Winter-Spring) and warm season (Summer-Fall) plots (see Section 1.3.4).

1.4.5.2 New Benthic Infauna and Epifauna Sampling and SMAST Data

Triplicate benthic grab samples were taken at stations in each WEA (for numbers and locations see individual station maps for each WEA in succeeding sections of this report). These were the same grab samples from which NOAA sediment grain-size cores were taken. At sea, the benthic grab samples were passed through 1.0 mm sieves and the remaining contents were transferred to half gallon jugs containing 10% borate-buffered formalin with Rose Bengal dye in seawater. After arrival at the NOAA James J. Howard Laboratory at Sandy Hook, NJ, formalin-fixed benthic samples were sieved again using 1.0 mm sieves, and transferred to 70% ethanol to prepare for sorting. Samples thus preserved were sent to one of two contract benthic analysis laboratories for sorting: Cove Corporation of Lusby, MD for RIMA, MA, NY (March 2014 samples only), NJ, MD and VA (March 2014 samples only) WEAs; Lotic Corporation of Belfast, ME for NY (August 2015 samples only), DE, VA (August 2015 samples only) and NC-KH WEAs. Organisms were identified to the following taxonomic levels: Sponges, Hydrozoans, Anthozoans, Bryozoans, Tunicates and Oligochaetes – to major taxon only; Polychaetes – to family; Pelecypod and Gastropod Mollusks - to species where possible; Crustaceans – to species where possible; Chordates – to major taxon only. These were then enumerated.

Beam trawl sampling employed a 2m beam trawl net with a 0.25” (0.635 cm) mesh deployed on a single 0.25” (0.635 cm) tow wire at slow speed (2 knots = 1 m/s) for periods of 10 minutes. The catch was sorted to the lowest practicable taxon and analyzed fresh. Each taxon was weighed as a group. Individual weights were not taken. Total lengths of individual fish and carapace widths of brachyuran crabs were determined to the nearest centimeter. The flat, bottom-hugging beam trawl net caught a lot of benthic epifauna not caught in grab samples, yet also not accessible to larger, faster bottom trawl survey otter trawl nets with rollers. Except in the cases of the NY and VA WEAs, benthic grab and beam trawl samples were taken in only one season as dictated by the cruise schedule.

UMASS SMAST bottom imagery annotation included organisms as well as sediment texture information. As with sediment analysis, we did not attempt to combine SMAST observations of organisms with data from NOAA sources both because of differences of scale and coarseness of the taxonomic definition. However, the SMAST data provides good data on the presence of sea scallops, its intended purpose.

1.4.5.3 Fisheries Management Value: Species of Concern

There are a large number of species of marine animals that may utilize habitats in the northeast regional WEAs at some time, including demersal and pelagic fisheries resource species primarily in federal waters, estuarine fisheries resource species that are interstate migrants, protected species, and highly migratory species. Many of these managed species are highly mobile and have broad enough habitat requirements that limited disturbance may not have measurable effects on their stocks (populations). There are some exceptions: species that have require relatively rare types of habitats for one or more life stages and those with limited mobility during one or more life stages. Such species will hereafter be referred to as “Species of Concern”. This category includes commercially valuable shellfish species with limited mobility as juveniles and adults: sea scallops (*Placopecten magellanicus*), Atlantic surfclams (*Spisula solidissima*), and ocean quahogs (*Arctica islandica*). The immobile, attached egg masses (egg mops) of the longfin squid (*Doryteuthis pealeii*) represent another such life stage (Jacobson, 2005). The category also includes juvenile Atlantic cod (*Gadus morhua*), which prefer gravelly or vegetated bottoms and adults that prefer rocky, pebbly or gravelly bottoms (Lough 2004), and black sea bass (*Centropristis striata*), which requires structured refuge habitats as juveniles and adults and show strong site fidelity toward favorable habitats (Fabrizio et al. 2013, Drohan et al. 2007). In the southern New England and the southern mid-Atlantic subregions, where sandy sediments are the overwhelming dominant type of bottom, the structured habitats preferred or required by Atlantic cod and black sea bass can be a stock-limiting ecological resource for those species. Hence, their disturbance becomes a management issue.

All species managed by the either of the two regional Fisheries Management Councils (FMCs: New England FMC or NEFMC and Mid-Atlantic FMC or MAFMC), including the species of concern in this report, have zones of Essential Fish Habitat (EFH) defined either for the species as a whole (all life stages) or as separate zones for each life stage. The definition of these zones are based upon historic detection of these species within 10 degree latitude X 10 degree longitude blocks throughout the region, so that each block in which the species/life stage has been detected becomes part of the EFH zone. The proposed conduct of non-fisheries activities in these EFH zones are reviewed by the Greater Atlantic Region Fisheries Office (GARFO) to determine what impact they might have on each species. The primary legal extent of these EFH zones is in the form of text, but for the purpose of visualizing such zones, maps are available (http://www.habitat.noaa.gov/protection/efh/efhmapper/).

EFH for the species of concern span large portions of the NE LME, overlapping with several WEAs. For this reason we have chosen to present them in a whole ecosystem perspective in this section of the report to introduce the EFH concept in relation to its overlap with the northeast regional WEAs. EFH distribution for shellfish species (sea scallop, ocean quahog, Atlantic surfclam) are shown in Figures 1-7 through 1-9.

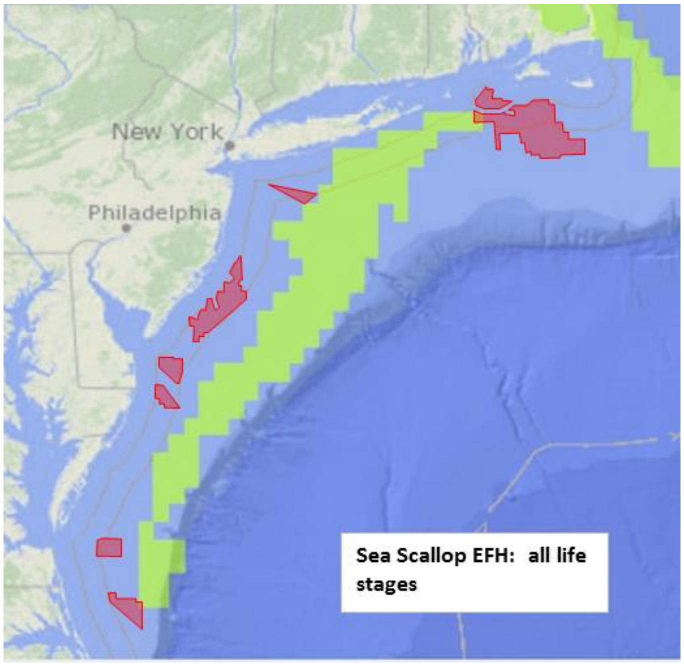


Figure 1-7. Distribution of Essential Fish Habitat (EFH) for sea scallop (*Placopecten magellanicus*) in relation to WEAs in the northeast region. EFH is yellow-green, WEAs are red. Source: NOAA, NMFS Habitat Conservation 2017.

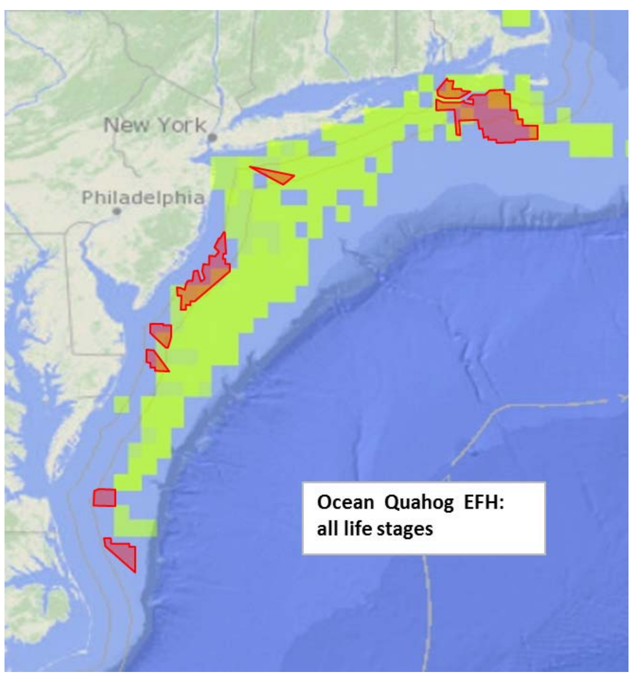


Figure 1-8. Distribution of Essential Fish Habitat (EFH) for ocean quahog (*Arctica islandica*) in relation to WEAs in the northeast region. EFH is yellow-green, WEAs are red. Source: NOAA, NMFS, Habitat Conservation 2017.

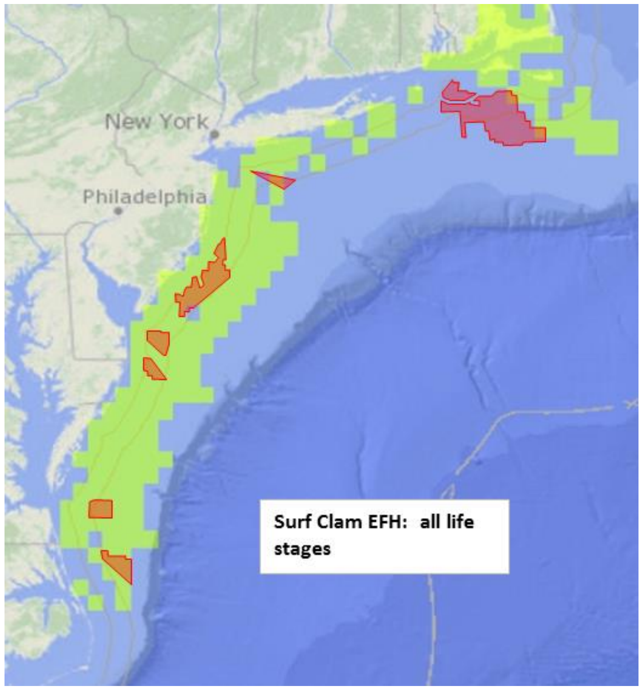


Figure 1-9. Distribution of Essential Fish Habitat (EFH) for Atlantic surfclam (*Spisula solidissima*) in relation to WEAs in the northeast region. EFH is yellow-green, WEAs are red. Source: NOAA, NMFS, Habitat Conservation 2017

It is evident from these maps that the overlap of sea scallop EFH with WEAs is small: only a small portion of the MA WEA and possibly a small portion of the NC-KH WEA show overlap. Current sea scallop EFH is located farther offshore than the other WEAs. This may change shortly if the NEFMC passes the current version of Omnibus Habitat Amendment 2 (NEFMC and NMFS 2016), in which sea scallop EFH may be redefined to include all of the RIMA and NY WEAs, most of the MA WEA, and possibly portions of the NJ WEA. Surfclam EFH already overlaps nearly all of the RIMA and NY WEAs, a substantial part of the MA WEA and most of the DE and MD WEAs. Ocean quahog EFH overlaps the MA WEA along its eastern margin, does not overlap RIMA, but completely overlaps NY, NJ, DE, ME, VA, and NC-KH WEAs. Changes in EFH for the latter two species are not pending, as they are managed by the MAFMC, and thus are not included in the NEFMC Omnibus Habitat Amendment.

The detection of fish and shellfish species of concern provided in this report result from integration of data from a variety of sampling methods with very different catch efficiencies, scales of coverage, and size selectivity. Therefore their results cannot be compared or combined quantitatively. Thus, only NEFSC seasonal survey catches are reported in quantitative terms; detections by other methods (beam trawl, benthic grab, UMASS bottom imagery) are represented on maps separately as qualitative detections.

Longfin squid egg mop EFH distribution is based upon a study by Hatfield and Cadrin (2002). Minor overlaps with all WEAs except VA and NC-KH are indicated (Figure 1-10).

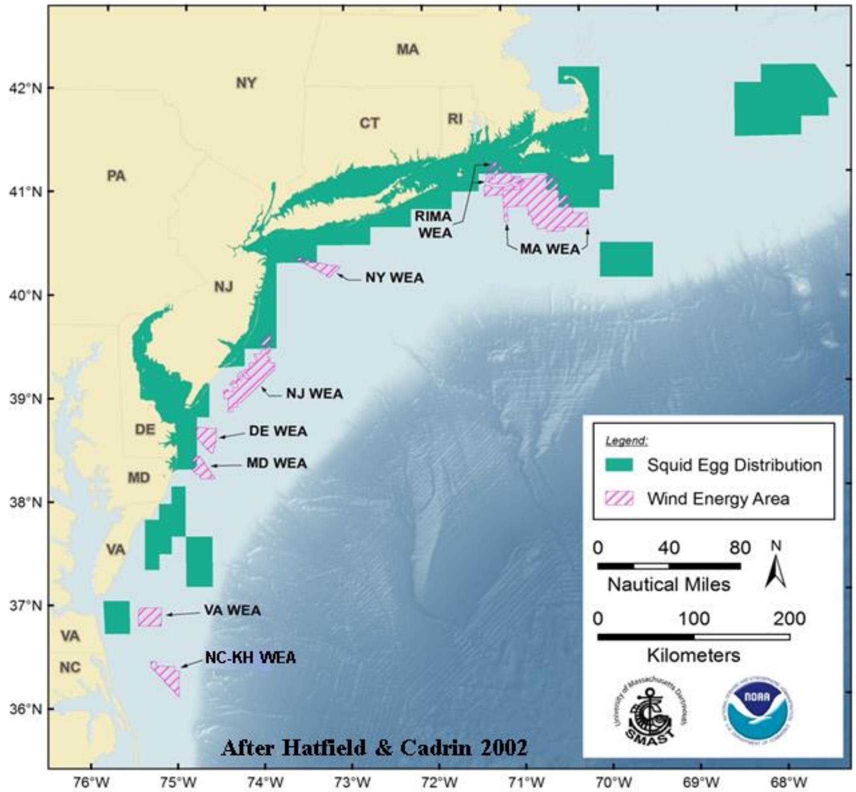


Figure 1-10. Distribution of Essential Fish Habitat (EFH) for egg mops of longfin squid (*Doryteuthis pealeii*) in relation to WEAs in the northeast region. EFH is green, WEAs are in striped pink.

EFH for juvenile Atlantic cod overlap a large portion of the RIMA WEA and a portion of the MA WEA, but does not impinge on any other WEA. Adult cod EFH, on the other hand, completely covers RIMA, about half of MA, and substantial fractions of the NJ, DE, and MD WEAs (Figure 1-11). As with sea scallops, this pattern may change substantially if proposals in Omnibus Habitat Amendment 2 are adopted by NEFMC. Overlaps with NJ, DE, and MD WEAs may be eliminated.

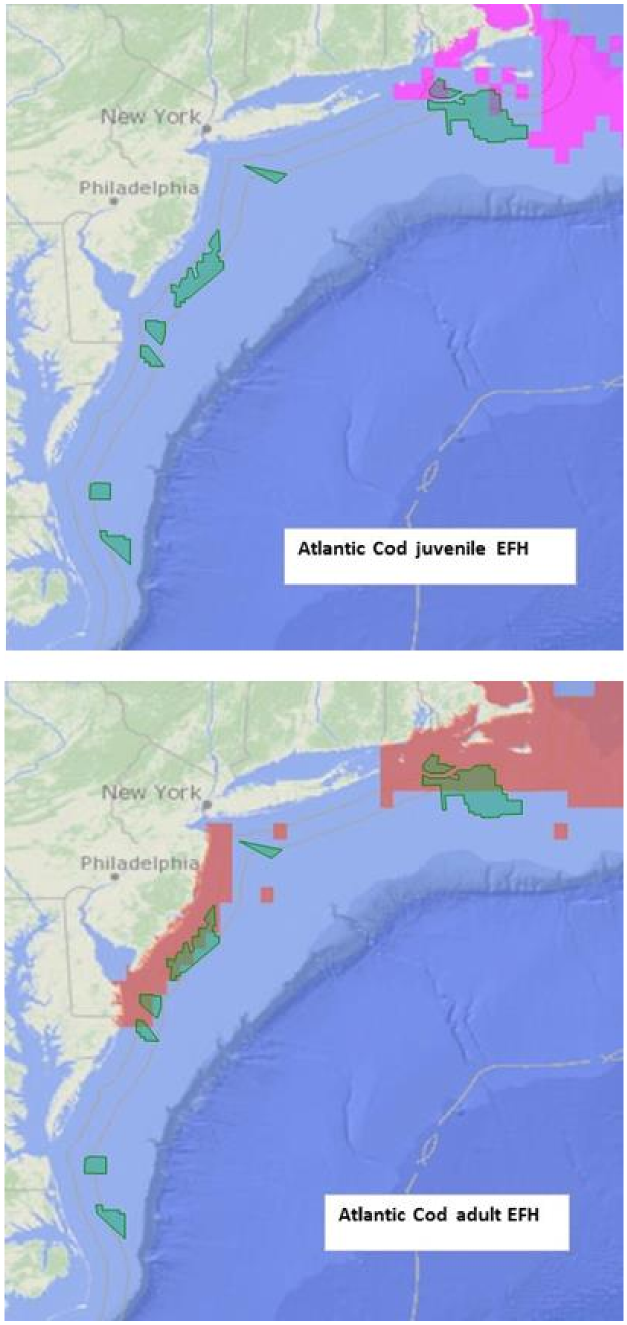


Figure 1-11. Distribution of Essential Fish Habitat (EFH) of Atlantic cod (*Gadus morhua*) in relation to WEAs in the northeast region. EFH is pink (juvenile), and maroon (adult), WEAs are in green. Source: NOAA, NMFS, Habitat Conservation 2017.

Juvenile black sea bass EFH overlaps all WEAs, including complete overlap of RIMA, VA, and NC-KH. The pattern is similar for adult black sea bass (Figure 1-12). Unlike Atlantic cod, EFH for black sea bass and also for longfin squid are not subject to changes under the Omnibus Amendment, as both are managed by MAFMC. Overlap with EFH for species of concern will be discussed in more detail in subsequent sections of this report dealing with individual WEAs.

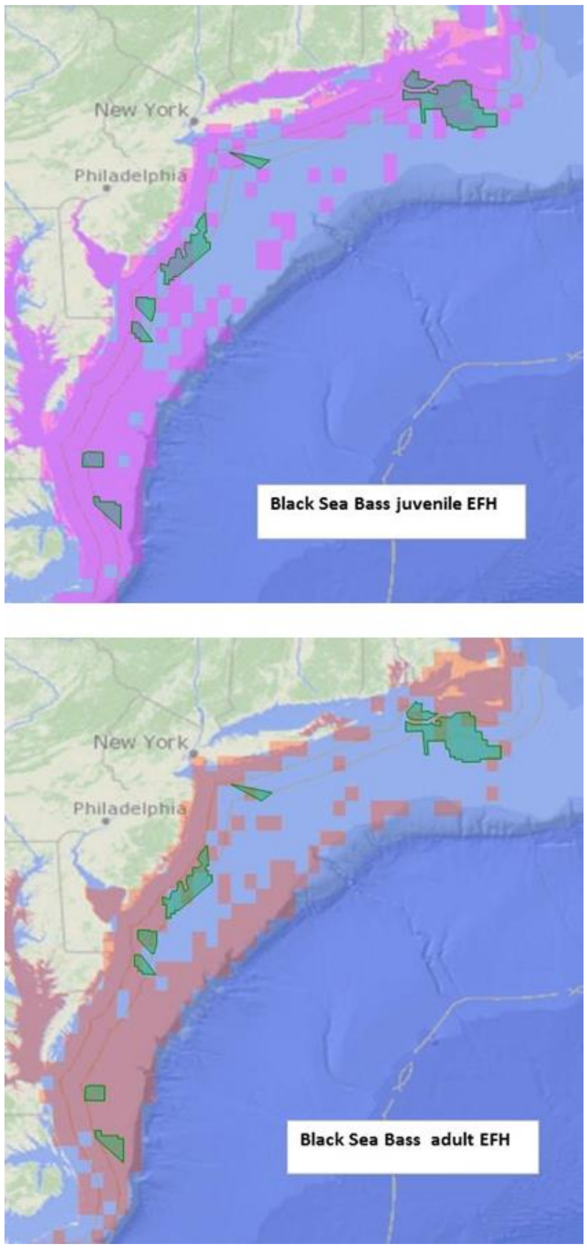


Figure 1-12. Distribution of Essential Fish Habitat (EFH) for black sea bass in relation to WEAs in the northeast region.   EFH is pink (juvenile), and maroon (adult), WEAs are in green. Source: NOAA, NMFS, Habitat Conservation 2017.

1.4.5.4   Notes on biological presentations in subsequent chapters

A number of long-standing taxonomic names for common species have been changed in recent years. We endeavored to utilize the most recent names available in this report, but understand that this can cause confusion for readers who have not necessarily kept up with name changes. For instance, the original taxonomic name for the longfin squid, *Loligo pealeii*, was established in 1821. That name appears in a large body of literature and in many species lists. That name was declared unaccepted based on taxonomic work in 1996 and changed to *Doryteuthis pealeii*, In order for such changes not to cause confusion, we have opted to represent it as "formerly *Loligo*" to give the reader a better chance for recognition. Thus, it will be represented hereafter as *Doryteuthis* (f. *Loligo*) *pealeii*. Similar "(f….)" notation will be used for other species whose long-standing taxonomic names have been changed in the past 20 years or so.

1.5 Physical Benthic Habitat Classification

From a fisheries perspective, habitat is often thought of as where a particular species lives (i.e. anywhere that it has been encountered alive), and habitats are defined in terms of single species of interest that live there, giving rise to such terms as Sea Scallop habitat or Atlantic cod habitat, whose characteristics can then be set out in terms of geological and oceanographic conditions that favor that species. This definition of habitat is the basis for the Essential Fish Habitat concept and the maps in Figures 1-7 through 1-12. Our goal here, however, is to define physical habitats: coherent areas of similar topographic, geological, and oceanographic characteristics (physical habitats) that underpin the distributions of individual living species and biotic communities. In line with this view of habitats, we are employing the CMECS classification system starting with those physical aspects that are basic to habitat function in each of the WEAs, and working toward their biological components, including managed species.

CMECS classification places habitats in two Setting (Biogeographic and Aquatic) and four Components (Water Column, Geoform, Substrate, and Biotic), which are further broken down into subcomponents, some in hierarchical manner, some not. Classification elements that are common to all the WEAs are presented in this section. Those that are specific to particular WEAs or that represent distinctions within each WEA will be presented in succeeding sections dealing with those WEAs.

There are many examples of habitat maps the have been created as a result of CMECS classification. Many of these create multiple mutually exclusive polygons that abut one another to represent areas of differing classification (FGDC 2012). We have chosen not to do this, but instead to divide WEAs into a small number of distinct zones based on topography (Topo Zones) and to superimpose features like smaller topographic features, zones of differing sediment texture, biogenic and anthropogenic structures, and hydrographic features on top of those as transparent layers so as to recognize their overlapping character and underlying similarity and continuity suggested by the broad distributions of many biotic components. We felt that a large number of very fine distinctions in habitat type were not warranted by biotic data that was not gathered using prior knowledge of habitat distribution, often from trawls that we later found collected in more than one habitat type. Most biotic data was collected in a stratified spatial randomization with strata based on latitude and distance from shore (e.g. NEFSC

Seasonal Trawl Survey) or on simple orthogonal grids (SMAST camera pyramid and dedicated NEFSC benthic habitat sampling). For this reason also we have not endeavored to use biotic data as CMECS Biotic Components to characterize habitats in most cases, but have relied primarily on physical characteristics, especially Geoform and Substrate Components.

1.5.1 CMECS Common Classification Elements

The common elements for all WEAs from among CMECS Settings and Components are as follows:

Biogeographic Setting (Spalding 2007)
- Realm: Temperate North Atlantic
  - Province: Cold Temperate Northwest Atlantic
    - Ecoregion: Virginian

Aquatic Setting (FGDC 2012)
- System: Marine
  - Subsystems: Nearshore (<30 m) and adjacent Offshore (>30 m)
    - Tidal Zone: Subtidal (both Subsystems)

Water Column Component
- Layer Subcomponent: Marine Nearshore Water Column (<30 m) and adjacent Marine Offshore Water Column (>30 m)
- Salinity Subcomponent: Euhaline

- Temperature Subcomponent: Very Cold Water to Very Warm Water, seasonally

Geoform Component
- Tectonic Setting Subcomponent: Passive Continental Margin
- Physiographic Setting Subcomponent: Continental/Island Shelf

More detailed levels of Geoform, Substrate, and Biotic Components appear in the respective sections for each WEA.

2 Maryland Wind Energy Area

2.1 Methods

2.1.1 Project location, size and subdivision

The Maryland WEA lies on the MAB shelf in a band between approximately 10 and 22 nautical miles east of Ocean City, Maryland (Figure 2-1) and is divided into north and south regions totaling nine full lease blocks and 11 partial blocks (Figure 2-2). The average water depth of the Maryland WEA is approximately 25 m and it covers approximately 79,707 acres of seafloor (BOEM 2014b).

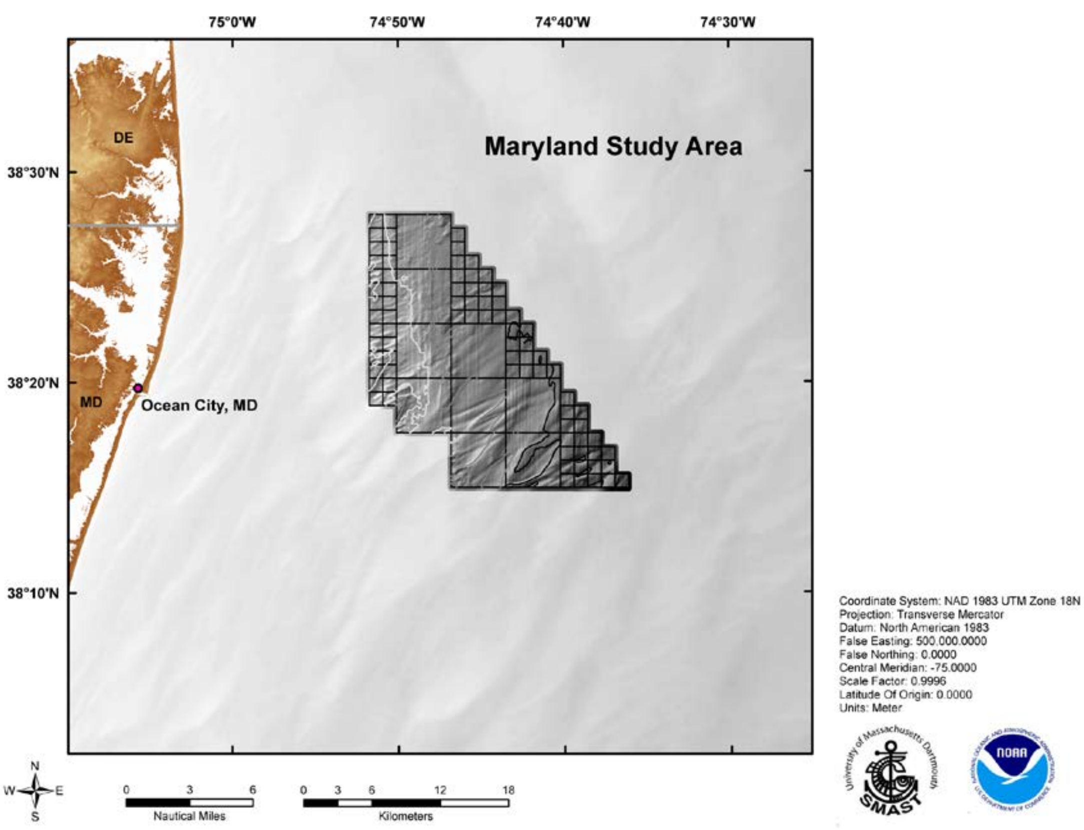


Figure 2-1. Map of Maryland study area. Source data:(CB&I 2014, NOAA, NGDC 2014).

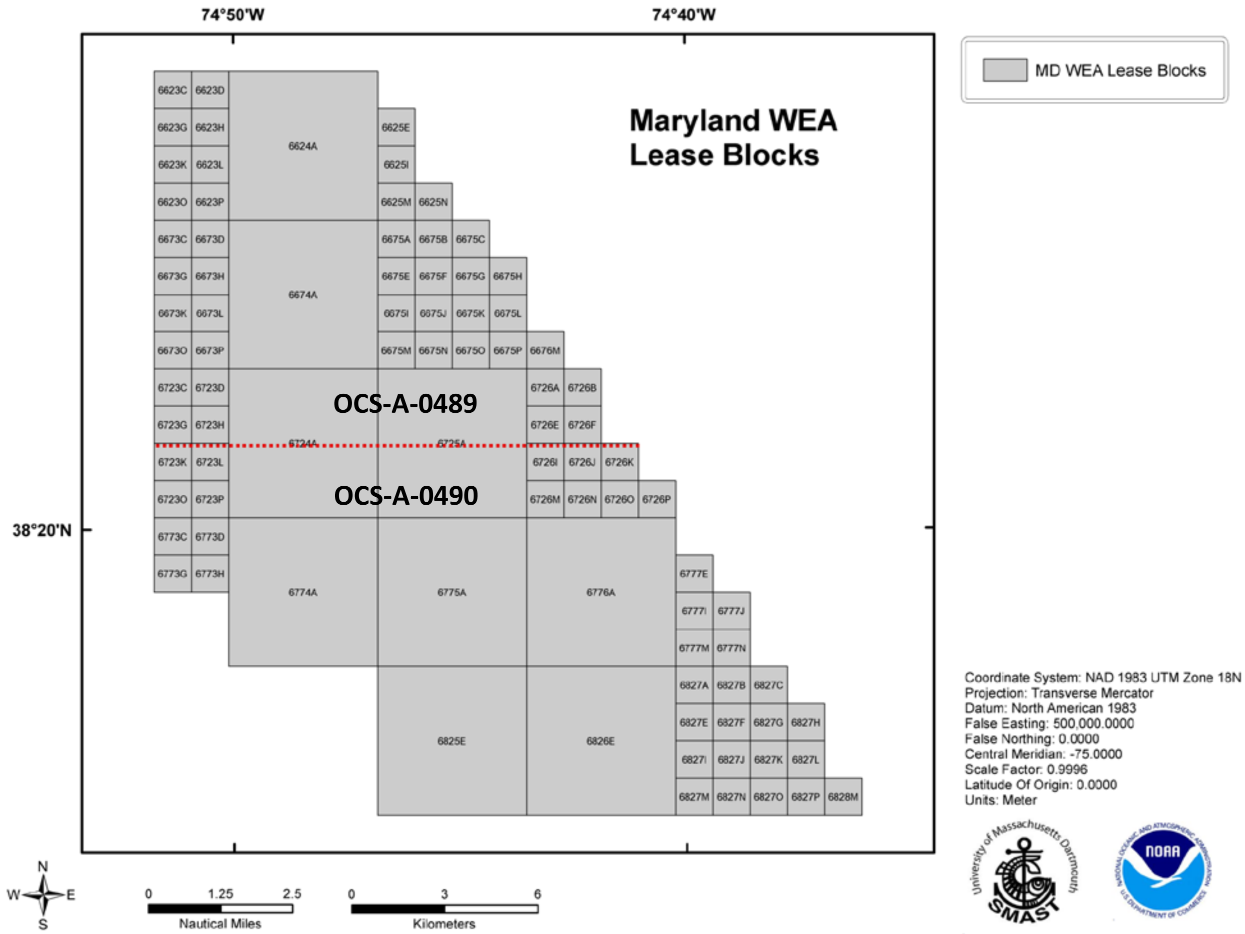


Figure 2-2. Lease block numbers for MD WEA. Dotted red line denoted the split in the north and south lease areas OCS-A-0489 (north) and OCS-A-0490 (south). Source data: (BOEM 2013).

As a first step in describing the benthic habitats of the MD WEA, an intensive data mining process was undertaken in order to ensure the most recent existing data was incorporated into this report. We referred to the NOAA/National Geophysical Data Center (NGDC) website (NOAA, NGDC 2014) for bathymetric data; NGDC compiles and distributes bathymetric data from coastal and open ocean areas. We also referred to the NOAA/NEFSC website (NOAA, NEFSC Oceanography Branch 2014), which has extensive databases for physical and biological oceanography and the NEFSC fisheries independent trawl survey. For additional surficial sediment data we also referred to the usSEABED United States Geological Survey (USGS) website (Reid et al. 2005). A complete listing of the environmental data incorporated to this report is listed in Table 2-1. This table contains both pre-existing data gleaned from the data mining effort and new data gathered as part of the current project to fill gaps in the pre-existing data. Sections following Table 2-1 provide details regarding the various data types mentioned in the table.

Table 2-1. Summary of the environmental data used in the Maryland Report.

Environmental Data	Native Resolu-tion	Source
Bathymetry		
Depth	2 m	from CB&I[a]
Terrain variables		
Slope, Rugosity, Aspect[1]	2 m	Derived from CB&I[a]
Rugosity[2]	2 m	Derived from CB&I[a]
Bathymetric Position Index[1,3]/Slope[1] Benthic Zones	2 m	Derived from CB&I[a]
Substrate variables		
Predicted Surficial Sediment Mean Grain Size[4]	points	usSEABED Atlantic Coast parsed and extracted data- bases (Reid et al. 2005)[b], NOAA-NEFSC[c], UMES[e]
Predicted Surficial Sediment: Percent Sand, Mud, Gravel[4]	points	usSEABED Atlantic Coast parsed and extracted data- bases (Reid et al. 2005)[b],NOAA-NEFSC[c], UMES[e]
HabCam-Predicted Surficial Sediment: Percent Sand-Silt, Mud, Gravel[4]	points	NOAA-NEFSC-HabCam Imagery[c]
Observed Surficial Substrate Type: Sand, Sand Ripple, Shell Debris, Silt, Gravel, Cobble, Rock[5]	points	SMAST sampling pyramid imagery[d]
Physical/Chemical variables		
HabCam CTD data (temperature, do, salinity)	points	NOAA-NEFSC HabCam CTD[c]
CTD data	points	R/V *Resolute*, NOAA-NEFSC Oceanography Branch historical database[c]
Biological variables		
Benthic Infauna[5]	points	NOAA-NEFSC grab samples, *Gordon Gunter*[c]
Benthic-Demersal Epifauna (photographic)[6,7]	points	NOAA-NEFSC HabCam Imagery[c]
Benthic-Demersal Epifauna (photographic)[5]	points	SMAST sampling pyramid imagery[d]
Fish Density[8]	points	NOAA-NEFSC sonar data, R/V *Resolute*[c]
Demersal Fish & Benthic Epifauna	trawls	NOAA-NEFSC bottom trawl survey[c]

Table footnotes:

[1] Derived using ArcGIS 10 Spatial Analyst.
[2] Derived using the ArcGIS 10 extension DEM Surface Tools (Jenness 2013).
[3] Calculated using Benthic Terrain Modeler. Broad scale (500m) using an inner radius of 25 and outer radius 250
[4] Derived using ArcGIS 10 Geostatistical Analyst.
[5] Direct observational count data.
[6] Derived by displaying the graduated percentage of animals/image along HabCam Track Map
[7] Derived by calculating the mean number of animals/image/1200m sub block

[a] Provided by Chicago Bridge and Iron (CB&I: contracted for the MD WEA survey by the state of MD)
[b] Downloaded from http://walrus.wr.usgs.gov/usseabed
[c] Provided by NOAA-NEFSC
[d] Provided by U. of Massachusetts Dartmouth School of Marine Science & Technology (SMAST): K. Stokesbury
[e] Provided by U. of Maryland Eastern Shore (UMES) graduate student Emily Tewes (Tewes 2013)

2.1.2 Bathymetry Data

The National Ocean Service (NOS) collected partial, high resolution multibeam coverage (2 m horizontal resolution) (NOAA, NESDIS, and NGDC 2014) of the MD WEA from 2006-2008. While of excellent quality, these data do not cover the southeastern corner of the MD WEA, necessitating the collection of new high-resolution (2 m horizontal resolution) multibeam data by Chicago Bridge and Iron Company (CB&I) in 2013 for the Maryland Energy Administration (MEA). CB&I conducted a geophysical survey for the entire MD WEA during July 2013, which included multibeam bathymetry (2 m horizontal resolution), sidescan sonar, magnetometer, shallow-penetration chirp sub-bottom profiler, and medium-penetration multi-channel sparker seismic-reflection geophysical systems (CB&I 2014). Unfortunately, despite efforts to obtain such data in both cases, neither the NOS nor the CB&I datasets included the multibeam backscatter data we requested.

2.1.3 Terrain Metrics Derived from Bathymetry

Terrain metrics (i.e. slope, rugosity, and aspect) derived from bathymetry data quantify the three dimensional character of the seafloor and can be used as a proxy for topographic features (e.g. sand waves, reefs, scarps, and channels). Studies have shown various bottom-associated species inhabit different topographic structure because they have an affinity to specific types of terrain (Wilson et al. 2007, Vasslides and Able 2008). Rugosity is used to infer terrain complexity. Slope is a measure of the steepness of the changes in bathymetry and aspect is a measure of the direction of the slope (Friedman et al. 2012). The use of high resolution multibeam bathymetry to calculate terrain metrics has proven useful in predictive habitat suitability modelling for species associated with bottom terrain features (Tittensor et al. 2009, Toller et al. 2010, Yesson et al. 2012, Rengstorf et al. 2013, Guinotte and Davies 2014). For the MD WEA we used the high resolution 2 m bathymetry data collected by CB&I to calculate terrain metrics for rugosity, slope and aspect. Rugosity was calculated using DEM Surface Ratio Tool Ver. 2.1.305 (Jenness 2013). Slope and aspect were both calculated using ArcMap 10.0 Spatial Analyst Extension-Surface Tool.

We utilized the Coastal and Marine Ecological Classification Standard (CMECS: FGDC 2012) to develop a scheme for benthic habitat classification of this and other WEAs. However, recognizing that CMECS criteria for slope and rugosity may not discriminate the subtle topographic distinctions that may play a part in habitat definition in the Maryland WEA, we chose to further classify the WEA into benthic zones by incorporating the slope and bathymetry data into a combined broad-scale (500 m) benthic zone map using the Benthic Terrain Modeler (BTM) Tool ver. 3.0 for ArcMap (NOAA, CSC 2013). The BTM Modeler first calculated the broad bathymetric position index (BPI) (inner radius = 25, outer radius = 250) for the study area and then incorporated the slope metric into a bathymetric zone map at a 500 m horizontal scale (NOAA CSC 2012).

2.1.4 Side-Scan Imagery

Side-scan imagery data are primarily used to detect hard-bottom, shipwrecks, and other obstructions which can be used as fish habitat (Sedberry and Van Dolah 1984, Steimle and Zetlin 2000, Drohan et al. 2007, Fabrizio et al. 2013). Side-scan imagery is not only used to define features as mentioned, but is also used as a ground-truthing tool for sediment grain size sampling. The side-scan imagery data collected by CB&I during their geophysical survey of the MD WEA was used in this report to ground-truth substrate maps in section 2.3.2.2. For further details regarding the side scan data collected by CB&I, please refer to their report submitted to the Maryland Energy Administration (CB&I 2014).

2.1.5 Sediment Sampling and Analyses

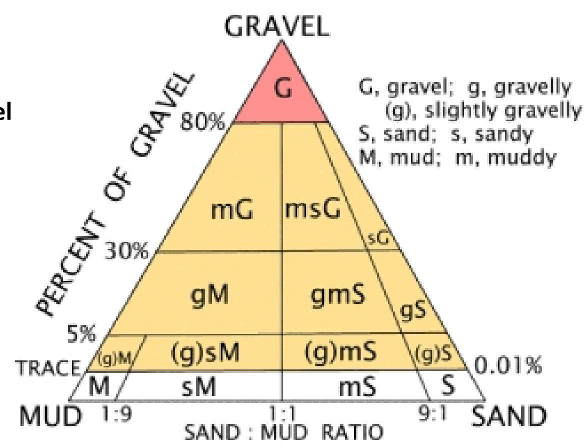
Table 2-2 presents a summary of the Wentworth and Folk sediment classification schemes used in this report. These are the same schemes used by USGS and by NOAA for CMECS classification.

Table 2-2. Grain sizes and sediment classification schemes used in this report. Source data: (Wentworth 1922, Folk 1954, USGS 2006).

Wentworth Classification for grain sizes

Size range (metric)	Phi range	Aggregate name (Wentworth Class)	
256 mm <	<-8	Boulder	
64-256 mm	-8 to -6	Cobble	
32-64 mm	-6 to -5	Very coarse gravel	
16-32 mm	-5 to -4	Coarse gravel	
8-16 mm	-4 to -3	Medium gravel	**gravel**
4-8 mm	-3 to -2	Fine gravel	
2-4 mm	-2 to -1	Very fine gravel	
1-2 mm	-1 to 0	Very coarse sand	
½ - 1 mm	0 to 1	Coarse sand	
¼ - ½ mm	1 to 2	Medium sand	**sand**
125-250 µm	2 to 3	Fine sand	
62.5-125 µm	3 to 4	Very fine sand	
3.90625-62.5 µm	4 to 8	Silt	**mud**
<3.90625 µm	>8	Clay	
<1 µm		Colloid	

Folk Classification for mixed sediments



2.1.5.1 usSEABED Sediment Data

Seabed survey point data from the usSEABED Atlantic Coast Offshore Surficial Sediment Data Release, version 1.0 was downloaded from the USGS website (Reid et al. 2005, USGS 2011). The parsed and extracted databases (USGS 2013) were selected and filtered to remove duplicate records and points not pertaining to surficial sediments (Reid et al. 2005). Only three stations (two with replicates) were found among the “extracted” usSEABED data (i.e. with complete laboratory grain size data extracted from samples) within the WEA (Table 2-3). Values for the remaining usSEABED points are based on “parsed” (word-based descriptions) or “calculated” data (based on less complete analysis). As we desired more data of the “extracted” variety, we undertook to collect additional sediment samples for analysis in the MD WEA.

2.1.5.2 NOAA and University of Maryland Eastern Shore Sediment Samples

During July 2013, the NOAA National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC) conducted a five day cruise from July 4-9, aboard the NOAA ship *Gordon Gunter* with a primary objective to train students participating in the NOAA Living Marine Resources Cooperative Science Center (LMRCSC) in fisheries science. As part of this program, students assisted in collecting bottom grab samples at nine stations within the MD WEA using a 0.04 m^2 Young-modified Van Veen grab sampler. Triplicate grabs were obtained from all nine stations from a pre-arranged grid of benthic sampling stations in the MD WEA (Figure 2-6). Sediment cores (3.175 cm diameter) taken from the benthic grab samples were analyzed for grain size utilizing the Wentworth-Folk procedure and modified techniques developed by Dr. Norbert P. Psuty, Rutgers Cooperative Extension (Wentworth 1922, Folk 1954,). Additional MD WEA sediment core data was collected in 2012 by University of Maryland Eastern Shore master’s degree candidate, Emily Tewes. Tewes’ sediment samples were also analyzed for grain size utilizing the Wentworth-Folk procedure (Wentworth 1922, Folk 1954).

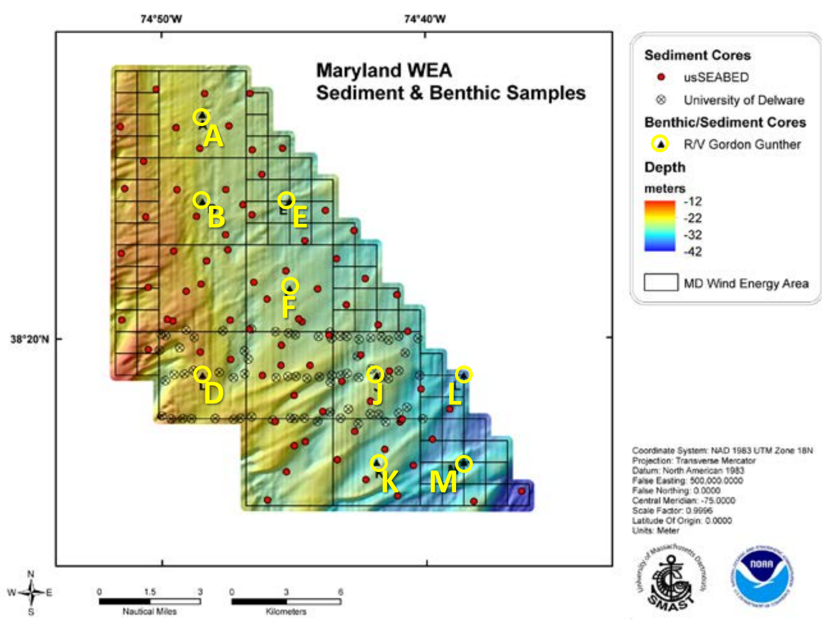


Figure 2-3. Location of benthic sediment samples. Included are cores (black triangles with station letters) taken using a 0.10 m^2 Smith-modified Van Veen grab sampler, aboard the NOAA Ship *Gordon Gunter* from July 4-9, 2013. Location of sediment samples (open circles with x inside) collected in 2012 by University of Maryland Eastern Shore graduate student Emily Tewes. Grain size distribution locations from the usSEABED dataset (red circles). Source data: (Tewes 2013, Reid et al. 2005, NOAA 2013a, CB&I 2014, BOEM 2013).

2.1.5.3 Integration of Sediment Results

Lacking multibeam backscatter data upon which to base sediment distribution, we chose instead to create interpolation maps of sediments based on relatively large number of grain size analyses (83 stations) we had available for this WEA. For purposes of plotting the combined NOAA, UMES, and usSEABED data, interpolations were performed using ArcMap 10.0 Geostatistical Analyst. The data was explored using histogram plots to determine data distribution and conduct trend analyses. The geostatistical method used for interpolation was ordinary kriging, which uses a weighted average of neighboring samples to estimate the 'unknown' value at a specific location. Since a sampling trend was detected in the data, we decided to use a second-order polynomial to correct that trend. Sediment prediction and prediction error maps were thus generated. For further details about the interpolation process, see the metadata associated with the raster layers.

The three sediment datasets (usSEABED, NOAA, and UMES: Tewes) were integrated to produce sediment maps. Data from each database was cleaned, processed and combined into a complete data set containing the fields: % mud (silt and clay), % sand (very fine sand to very coarse sand), % gravel (very fine gravel to very coarse gravel), and mean grain size. Percentages for mud, sand, and gravel were then converted to a fraction for the interpolation process and converted back to a percentage after the interpolation process for purposes of representation on maps.

Additional analysis of sediment texture and microtopography made utilizing imagery from HabCam and the University of Massachusetts School of Marine Science and Technology (UMASS SMAST) camera pyramid is described in succeeding sections.

2.1.6 Water Column Oceanographic Data

Water column data used in this report came from three sources: 1) the NEFSC historical database (NOAA, NEFSC Oceanography Branch 2014) that includes vertical CTD cast data from numerous survey and research cruises taken over the past ten years, 2) from a CTD instrument mounted on the HabCam IV vehicle aboard the R/V *Hugh Sharp* cruise (July, 2013) and operated continuously during that deployment, and 3) from vertical CTD casts made aboard R/V *Resolute* during that same period.

2.1.7 Sampling and Analysis of Benthic/Demersal Fauna

2.1.7.1 Historic NEFSC Data

Three sets of NEFSC historic data on benthic and demersal fauna cover the Maryland WEA region: the Wigley and Theroux study (Wigley & Theroux 1981), the NEFSC bottom trawl survey (NOAA, NEFSC 2014) and unpublished results of a DelMarVa beam trawl survey conducted in 2008. While comprehensive and thorough, the surveys that are the basis for the Wigley and Theroux data are up to 50 years old. Given the dynamic nature of benthic communities in general and the extent of change since the time of their collection, they are considered too outdated to be considered further in the current analysis. The others NEFSC data, which are more of recent origin are considered more likely to represent the current state of the MD WEA.

The bottom trawl survey, which has been conducted every year since the 1960s, has in recent years been conducted semi-annually (Fall and Spring) using standardized protocols and a stratified random sampling pattern (Johnston 2013, Politis et al. 2014). We have chosen to pick out a ten-year period from 2003 to 2012 to represent the character of the MD WEA region in recent years.   In this region Fall Survey trawls have been performed during September and early October. Spring trawls have been confined to March.

The 2008 DelMarVa beam trawl data was collected from the NOAA ship *Henry B. Bigelow* during a survey of fishing areas largely to the SSE of the MD WEA. It employed a 2m beam trawl net with a 0.25" (0.635 cm) mesh deployed on a single 0.25" (0.635 cm) tow wire at slow speed (2 knots = 1 m/s) for periods 10 minutes. The catch was sorted to the lowest practicable taxon. Each taxon was weighed as a group. Individual weights were not taken.   Total lengths of individual fish and carapace widths of brachyuran crabs were determined to the nearest centimeter. The flat, bottom-hugging beam trawl net caught a lot of benthic epifauna not caught in grab samples, yet also not accessible to larger, faster bottom trawl survey otter trawl nets with rollers.

2.1.7.2 Benthic Grab Sampling Aboard NOAA ship *Gordon Gunter* in 2013.

Triplicate benthic grab samples were taken at nine stations in the MD WEA (Figure 2-3). These were the same grab samples from which NOAA sediment grain-size cores were taken. At sea, the benthic grab samples were passed through 1 mm sieves and the remaining contents were transferred to half gallon jugs containing 10% buffered formalin in seawater. After arrival at the NOAA James J. Howard Laboratory at Sandy Hook, benthic samples were sieved again using 1 mm sieves and transferred to 70% ethanol to prepare for sorting. The benthic macro-infauna samples were sorted into five categories 1) worms 2) bivalves 3) amphipods 4) tubes and 5) other. The 'other' category consisted of materials not belonging in the other four categories. After sorting into categories and counting, samples were saved for more detailed taxonomic analysis (not presented in this report) by an expert subcontractor.

2.1.8 Benthic Imagery for Sediment Type and Fauna

2.1.8.1 R/V *Hugh R. Sharp* Cruise

A five day cruise was conducted from July 22-26, 2013 aboard the University of Delaware's University National Oceanographic Laboratory System (UNOLS) vessel R/V *Hugh R. Sharp* in order to characterize fish habitats on the continental shelf off the Atlantic coast of the DelMarVa Peninsula. The scientific objective for day 1 (7/22) was to collect visual data for a general assessment of the bottom habitats and associated biota within the MD WEA using the HabCam IV camera system. HabCam was originally developed to survey scallop habitat in the Northeast and Mid-Atlantic regions. The HabCam vehicle takes six images per second from stereo cameras as it is being towed by the ship (~ 5.8 kt) and maintained by a human pilot at two to three meters above the ocean floor. Rapid stream images (6 per second) were transferred from the camera system to computers aboard the ship via fiber optic cables (NOAA 2014b). The Woods Hole Oceanographic Institution (WHOI) team under Dr. Scott Gallager has developed different versions of HabCam over the past few years. The latest generation of the system, HabCam IV (owned by NOAA NEFSC since 2012), was used for this project (Figure 2-4).

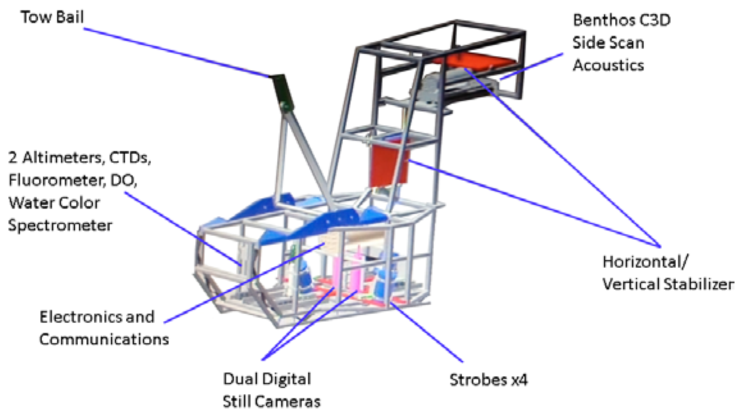


Figure 2-4. Diagram of HabCam IV vehicle. Source data: (WHOI 2014).

2.1.8.2 Site Selection and Cruise Track

A grid of N-S and E-W lines with 3 statute mile spacing, centered on BOEM 3 X 3 statute mile lease blocks, covered the MD WEA to meet the wind energy habitat investigation goal. Each line ran through the geographic center of the BOEM lease blocks within the MD WEA (Figure 2-5 A). The cruise track followed a grid of N-S and E-W lines with thirteen intersections (A through M) at the centers of each block. This pattern allowed each intersection to be visited twice to provide visual analysis comparisons from differing directions. Bottom grab samples were obtained for sediment and biological analysis from nine of these intersection points on a previous NEFSC cruise aboard the NOAA ship *Gordon Gunter* (Figure 2-5 B). The strict N-S, E-W courses of some lines were altered to capture bottom imagery at sites where previous sediment grain size analysis had been collected by E. Tewes of UMES as part of her thesis research (Figure 2-5 B). As with the grid points, three of these sediment grab points were also traversed twice from differing directions in order to provide analytic comparisons of the same points from differing aspects. All planned lines in the MD WEA were surveyed, including dual orthogonal passes over 12 nodal waypoints, 8 of which had been sampled for sediments during the LMRCSC cruise, dual orthogonal passes over 3 of E. Tewes sediment sampling sites, and single passes over 10 additional Tewes sites (40 point passes altogether). In addition, a set of 5 transects oriented roughly NNW-SSE were run through the fishing reef area in the center of the MD WEA. Of 222 ¾ X ¾ statute mile (1207 X 1207 m) sub-blocks, 160 or 72% yielded some images, although the density of coverage varied among these (Fig. 2-5 C).

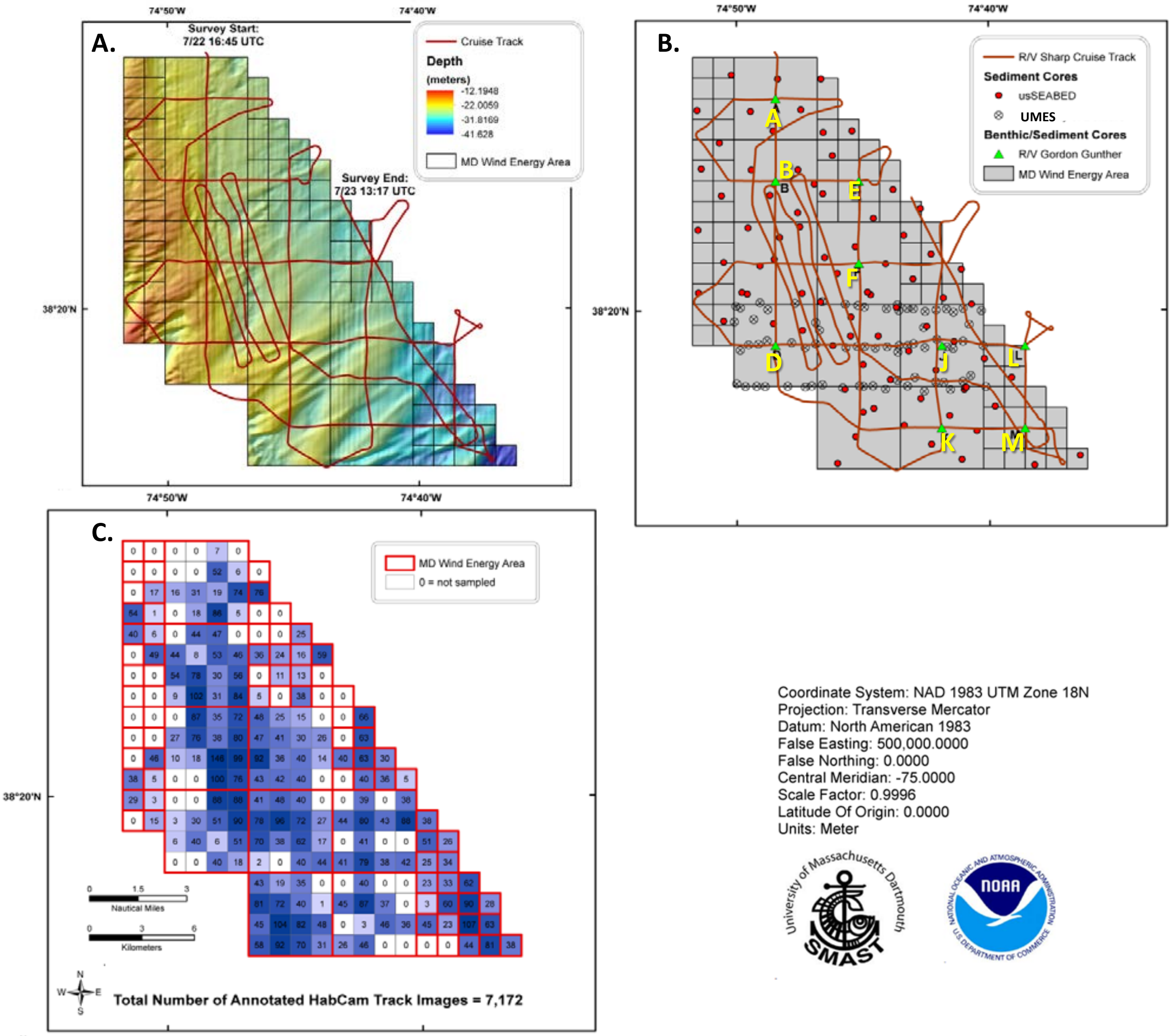


Figure 2-5. R/V *Sharp* cruise track with HabCam: A. *Sharp*/Habcam cruise track plotted on bathymetric map of MD WEA, B. *Sharp*/Habcam cruise track showing relationship to *Gordon Gunter* and UMES bottom grab sampling sites , C. *Sharp/*Habcam cruise track showing numbers of images in each ¾ mile (1207 m) sub-block in the MD WEA. There were a total of 7, 172 images annotated from the MD WEA (~ every 50th photo) for this report. White blocks are areas where HabCam did not take photos. Numbers of images are recorded in each sub-block, the depth of blue color indicates relative coverage. Source data: (Reid et al. 2005, BOEM 2013 NOAA 2013a, Tewes 2013, CB&I 2014).

2.1.8.3 Data Streams Collected

HabCam IV: Six pairs of stereo photos per second, continuous near-bottom CTD record, including conductivity, temperature, depth, dissolved oxygen, with periodic vertical excursions through the water column, continuous record of HabCam IV altitude above the bottom, and a continuous side-scan sonar record of the bottom backscatter (signal strength) along the ship's track were recorded.
R/V *Sharp*: A continuous GPS record of ship's position, and continuous record of multibeam sonar bottom topography and backscatter along the ship's track. An attempt to obtain water column backscatter (i.e. fish) data from *Sharp*'s Reson 8101 multibeam system was not successful due to digital data handling constraints. Multibeam water column data requires a higher speed for data transfer and larger capacity for data storage than were available aboard the *R/V Sharp*. We did, however, collect continuous multibeam bathymetry and backscatter data from the seafloor throughout the cruise.

2.1.8.4 HabCam IV Data Processing

HabCam IV Images: An estimated 1,600,000 images were collected by HabCam IV in the MD WEA and were processed for light mapping and color correction by the WHOI team. A subset of every 50th of those images were selected for annotation, which works out to 1 image approximately every 30 meters, totaling over 7,000 images within the WEA. We used the WHOI manual web-enabled annotation tool originally developed as part of a Gordon and Betty Moore Foundation funded initiative for ocean imaging informatics. Annotation is the process by which photos are evaluated quantitatively for small-scale topographic structure, sediment type, and epifauna. The front end of the annotation tool was collaboratively modified by IMAG and WHOI from the tool previously developed for sea scallop population surveys to one that supports the CMECS evaluation criteria. The PostgreSQL database schema supporting the annotation tool was populated by geophysical and biotic elements based on our review of post-cruise processed images. Modifications included five new classes (i.e. Topography, Bottom Type, Wentworth Surficial Sediment, and Biotic Components) covering 49 variables which were developed to align with CMECS elements and criteria. Since CMECS was originally designed primarily for Caribbean shallow reef habitats, necessary adjustments were made for the specific North Atlantic environments.

Two rounds of image processing were performed on the HabCam MD WEA images. The first image processing was done at sea aboard *R/V Sharp*, and this process was continued on shore. Processing involved color correcting, enhancement, and 3D processing and was done for all the stereo paired images from the WEA. After several weeks of attempts at annotating with these images, we found that the processed images were generally still too dark. At this point we had to send our image set back to WHOI for reprocessing, requiring several more weeks. Reprocessing was done using the left side of the paired stereo images only and involved flattening of the light field and additional color correction (without 3D processing); examples can be seen in Fig. 2-16 with map of locations in Fig. 2-17.

Despite reprocessing the images, we found some images (randomly distributed) remained unusable. An image was deemed unusable if the photo 1) was too dark to see anything , 2) had white interference flecks not attributable to plankton, detritus, or minor image artifacts, or 3) was completely white. After the 7,126 images were successfully annotated for the MD WEA, an image count map was calculated for the MD WEA. For purposes of display, we divided the MD WEA into 0.75 statute mile (1207 m) sub-blocks and calculated the sum of images (which varies) per sub-block (Figure 2-15 C).

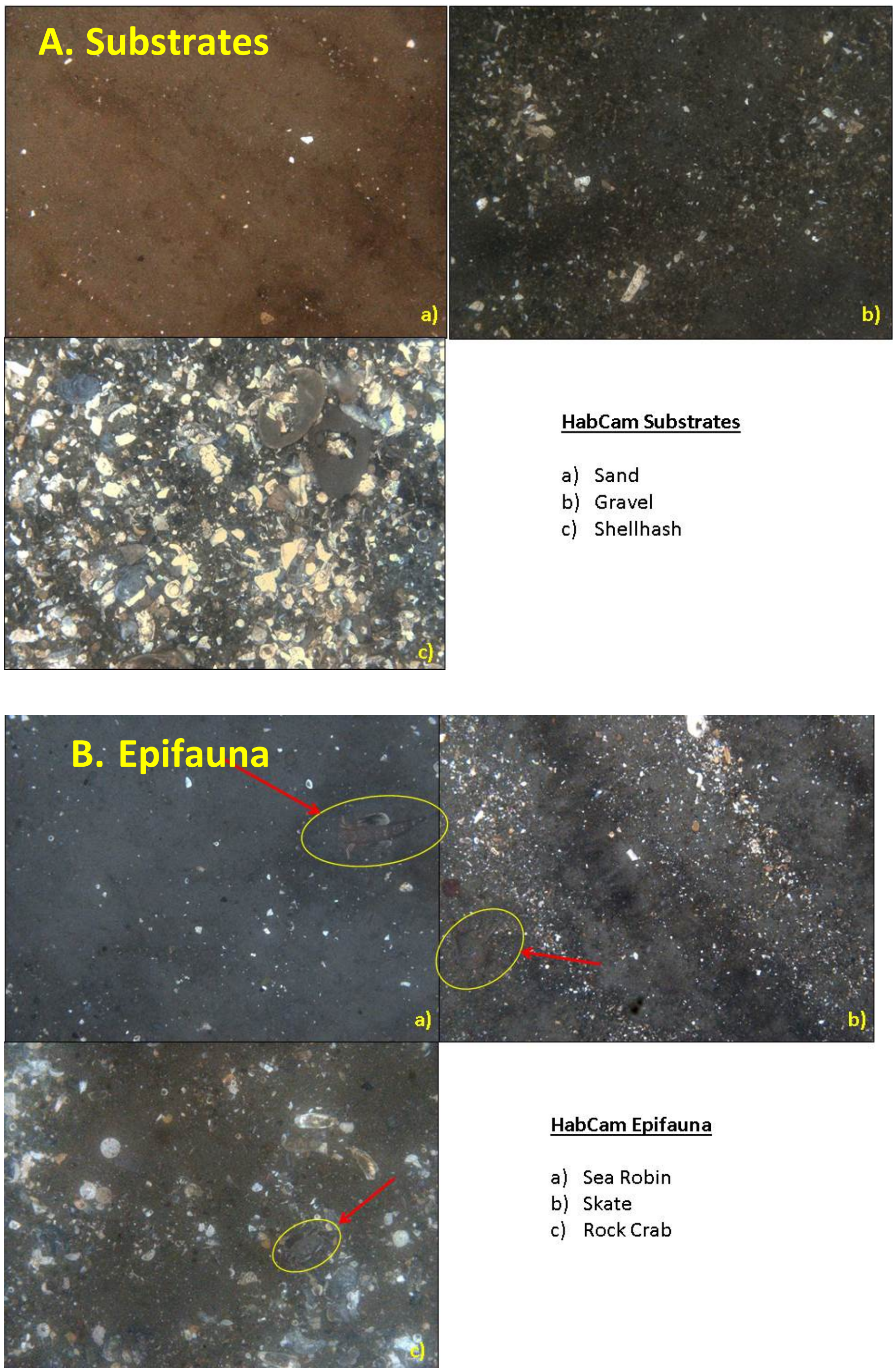


Figure 2-6. Examples of HabCam photos: substrate types (A.) and epifauna (B. & C.).

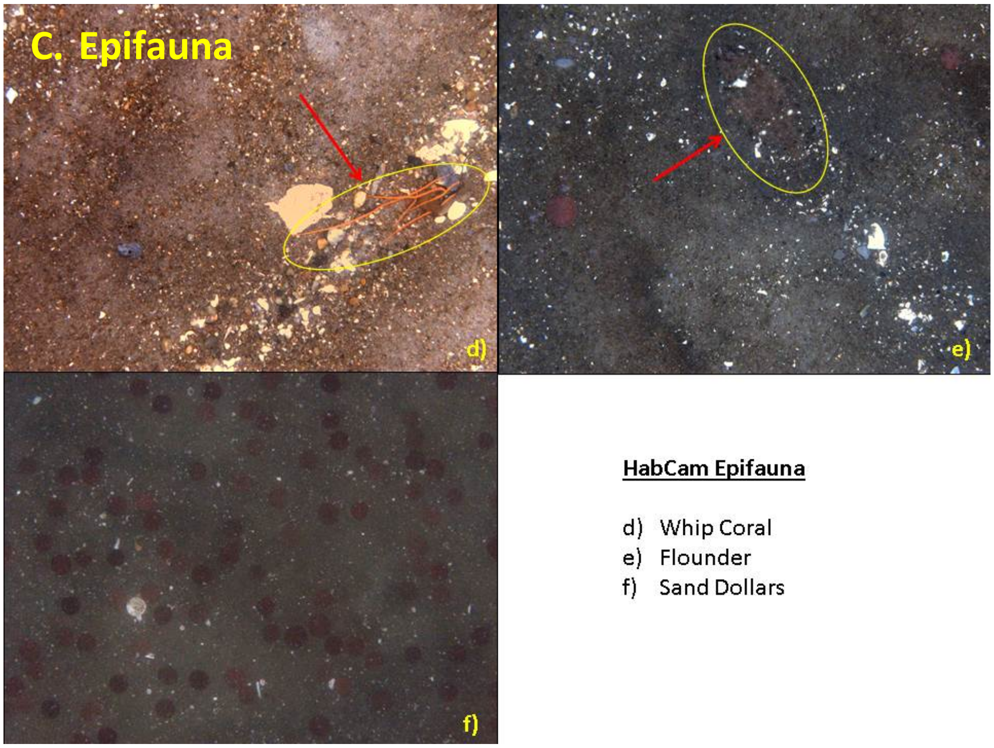


Fig. 2-6 (continued). Examples of HabCam photos: epifauna.

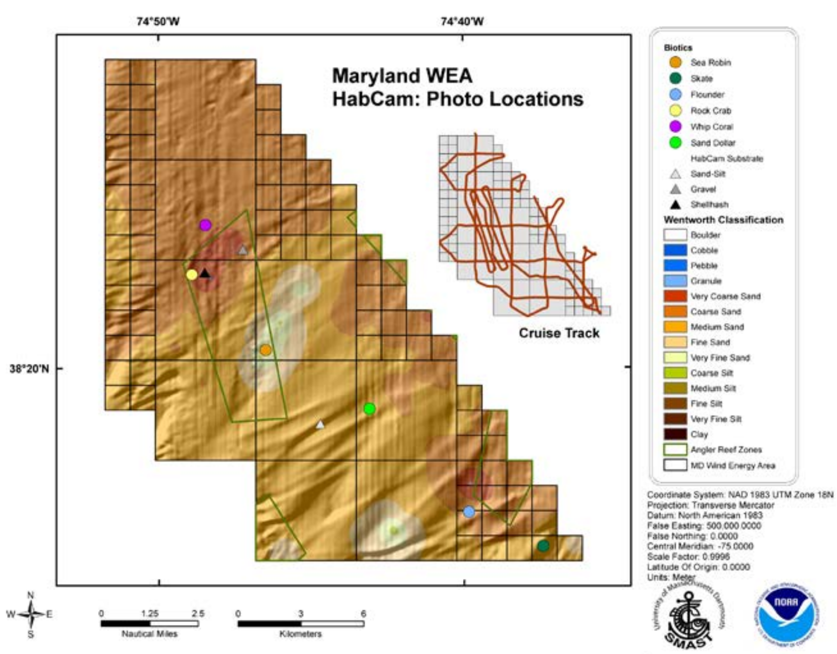


Figure 2-7. Locations of photos seen in Figure 2-6.

2.1.8.5 Extraction of Data from HabCam IV Imagery

Demersal fishes and benthic epifaunal organisms in HabCam imagery were identified and categorized into identifiable taxa that ranged from phylum to species level. Figure 2-6 B & C show selected HabCam epifaunal images. Organismal densities for methodological comparison were calculating through the use of the "catch per unit effort" (CPUE) concept. After the images were annotated for the MD WEA, we divided the WEA into 0.75 statute mile (1207 m) sub-blocks and summed the total number of images annotated for each sub-block (Figure 2-5 C), then summed the total number of benthic epifauna recorded within the same sub-block. To calculate the CPUE the total number of epifauna were divided by the total number of images per sub-block. We did not attempt to place the epifauna on an areal basis, i.e. numbers per square km, because the areas of the photos varied, depending on the variable altitude of HabCam above the bottom for each photo. Nevertheless, our CPUE calculation helped normalize the data (despite the uneven numbers of photos taken in each sub-block) and provided useful information on patterns of distribution. The CPUE values were generally low because most epifaunal groups had counts of fewer than 300 individuals total. Sand dollars were exceptional in this regard, with over 2,600 recorded.

2.1.8.6 University of Massachusetts, School of Science and Technology (SMAST) Survey

As an integral part of first year study, Dr. Kevin Stokesbury and his team of the University of Massachusetts School of Marine Science and Technology (UMASS SMAST) was subcontracted to a grant to Dr. Scott Gallager of WHOI from the NOAA-funded Cooperative Institute for North Atlantic Research (CINAR). This grant also funded Dr. Gallager and his WHOI team for operation of HabCam and set up the image annotation system for HabCam images at the NEFSC Sandy Hook Laboratory. The SMAST survey was meant to provide an alternate source of visual data that could be compared with HabCam results. A full description of the UMASS SMAST participation in the Maryland WEA survey can be found in Dr. Stokesbury's report (Appendix MD-1). Hence, only a brief description is provided below.

A survey of the MD WEA and an adjacent angler reef area was conducted by SMAST personnel from July 24^{th} to 27^{th}, 2013 (coincident with the *Sharp*-HabCam and *Resolute* fisheries acoustic cruises) aboard a commercial fishing vessel . A drop camera pyramid lander was deployed at stations on a 0.5 X 0.5 nmi (0.93 X 0.93 km) grid, collecting 12.8 m^2 of video and high resolution still camera footage at each station. A total of 455 stations were imaged, of which 320 (75%) covered the entire WEA except for three sub blocks in the southeast corner (Fig. 2-40). The SMAST team analyzed these images ashore for substrate type and biota (megabenthic epifauna), providing a basis for comparison of their results with those from HabCam and other sources.

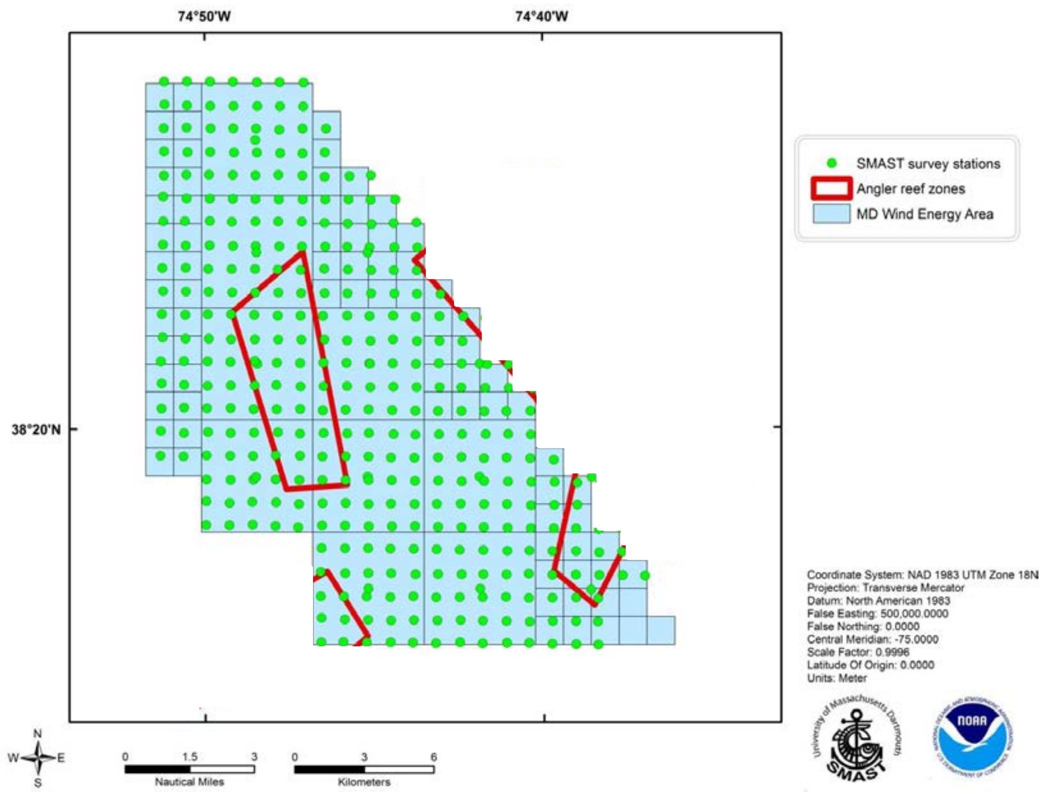


Figure 2-8. UMASS SMAST survey stations in the MD WEA. Stations outside the WEA have been excluded for clarity. Data source: Stokesbury et al. 2014 (Appendix MD-1).

2.1.9 R/V *Resolute* Fisheries Acoustics

During the five day cruise with the R/V *Sharp* (July 22-26, 2013), a fisheries hydro-acoustic survey was conducted in tandem aboard the NOAA vessel *Resolute* on portions of the MD WEA and surrounding areas. Fisheries hydro-acoustics (split beam sonar) enables researchers to estimate numbers of fish in the water column associated with benthic habitats. The survey tracks followed portions of the *Sharp*/HABCAM cruise two days later. The equipment used consisted of two pole-mount Biosonics hydro-acoustic heads, with frequencies of 38 and 120 kHz. The entire survey ran for four days of sampling (daylight hours only), but the MD WEA transect was completed in one day (July 24, 2013). All equipment was calibrated prior to the survey, using standard techniques. Real-time observations of the apparent echograms were taken aboard ship and post-processed echograms and analysis were completed with Echoview® software.

Processing and analysis of the echograms began with the cleaning and filtering of the navigational data stream, and with the verification and cleaning of the echogram bottom detection. Areas of bad data, turbulence, acoustic artifacts and interference were removed in post-processing. Background noise data was also calculated for the echograms and reduced through post-processing.

Analysis of the processed echograms was limited to single target detection and calculation of Nautical Area Scattering Coefficient (NASC) in square meters per square nautical mile (m^2/nmi^2). NASC can be thought of as un-scaled energy returned to the transducer and can be used as an index of biological potential within the water column. Higher values of NASC are related to more scattering targets within the water column, however, since they are independent of target strength (Ts), it cannot be used to determine the probable size of the scatterer. Likewise, for this analysis, single target detection was set at a level which will identify only objects from approximately 2 cm to over 1 m in size. Further analysis will need to be conducted in order to parse out scatterers of different sizes (body lengths) as well as targets that are found in different parts of the water column. The water column position suggests whether a target is a bottom-dwelling species such as black sea bass or hake, or a more pelagic species such as bluefish and menhaden, although position in the water column is not an entirely foolproof method for target identification. Fishes with swim bladders (most bony fishes) generate strong return signals were targeted, as it is gas pocket in that organ that scatters sound strongly. Elasmobranchs (sharks and skates) and invertebrates in the water column (e.g. squid) are detectable, but may have been missed because they provide weak signals as they lack swim bladders. Acoustic surveys of the bottom also experience a "dead zone" in the water column within a short distance from the bottom in which interference from the bottom substrate prevents fish detection. Thus, this method is not likely to provide good estimates for fishes that habitually lie directly on the bottom, even if they have swim bladders (e.g. flatfish). The thickness of this dead zone can vary with conditions.

2.2 Results

2.2.1 Bathymetry and Terrain Metrics

Figure 2-9 shows the MD WEA bathymetry has multiple ridges linear trending northeast-southwest towards the outer shelf and submarine canyons. Theses ridges are prominent in the southern half and along the western edge of the MD WEA, but grow faint, indicating less vertical relief, in the central and northeastern regions.

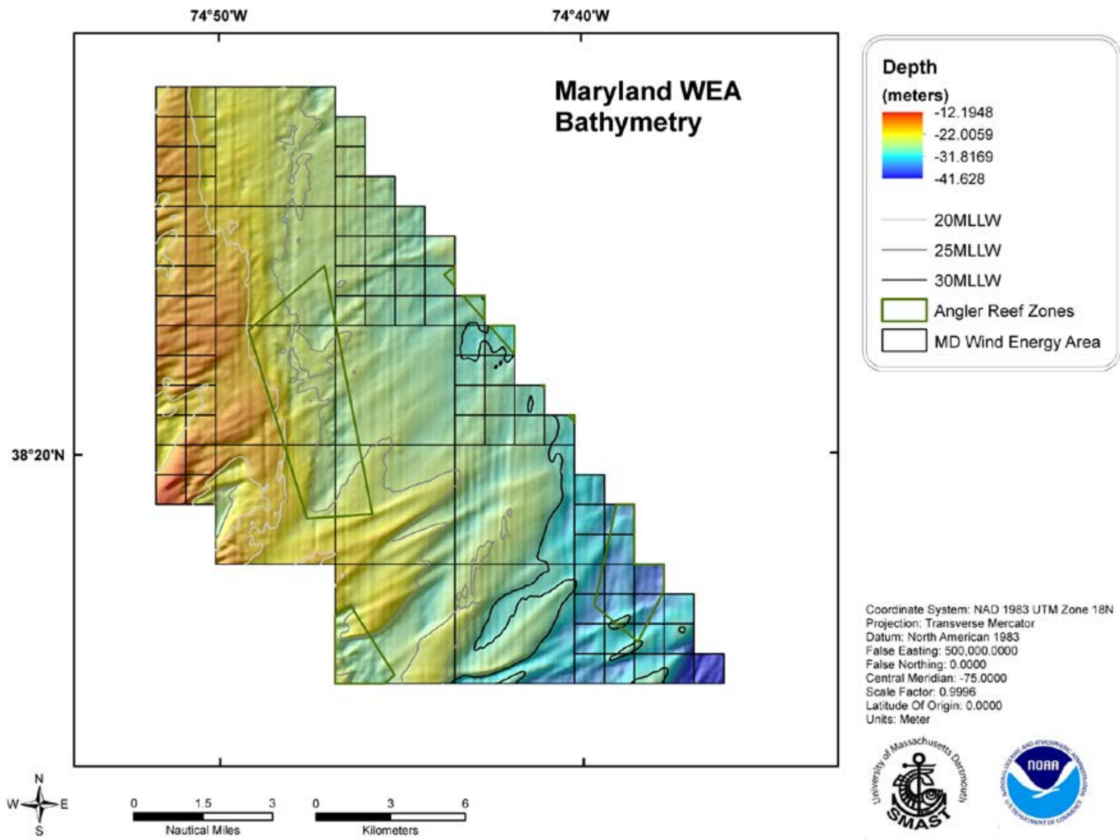


Figure 2-9. Bathymetry (2 m horizontal resolution) with isobaths contours and known angler reef zones (green polygons) in the MD WEA. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

Regarding terrain metrics, we found small variations in slope (< 2.8 degrees: Fig. 2-10A) and low rugosity values (<1.001: Fig. 2-10B). Aspect (Fig. 2-10C) was dominated by southeasterly-oriented gradients. Gradients facing directly eastward forming directly narrow, evenly spaced north-south parallel lines, also visible Fig. 2-4 A and B are probably data artifacts resulting from evenly-spaced north-south mapping transects. Overall topographic characteristics meet the CMECS criteria for flat terrain (0 to <5 degrees slope and very low rugosity: 1.0 to < 1.25)(FGDC 2012). This result is not unexpected given previous characterizations based on lower resolution bathymetry of the area: low vertical relief, minimal slope, and mostly sand substrate (Uchupi 1972, Steimle and Zetlin 2000).

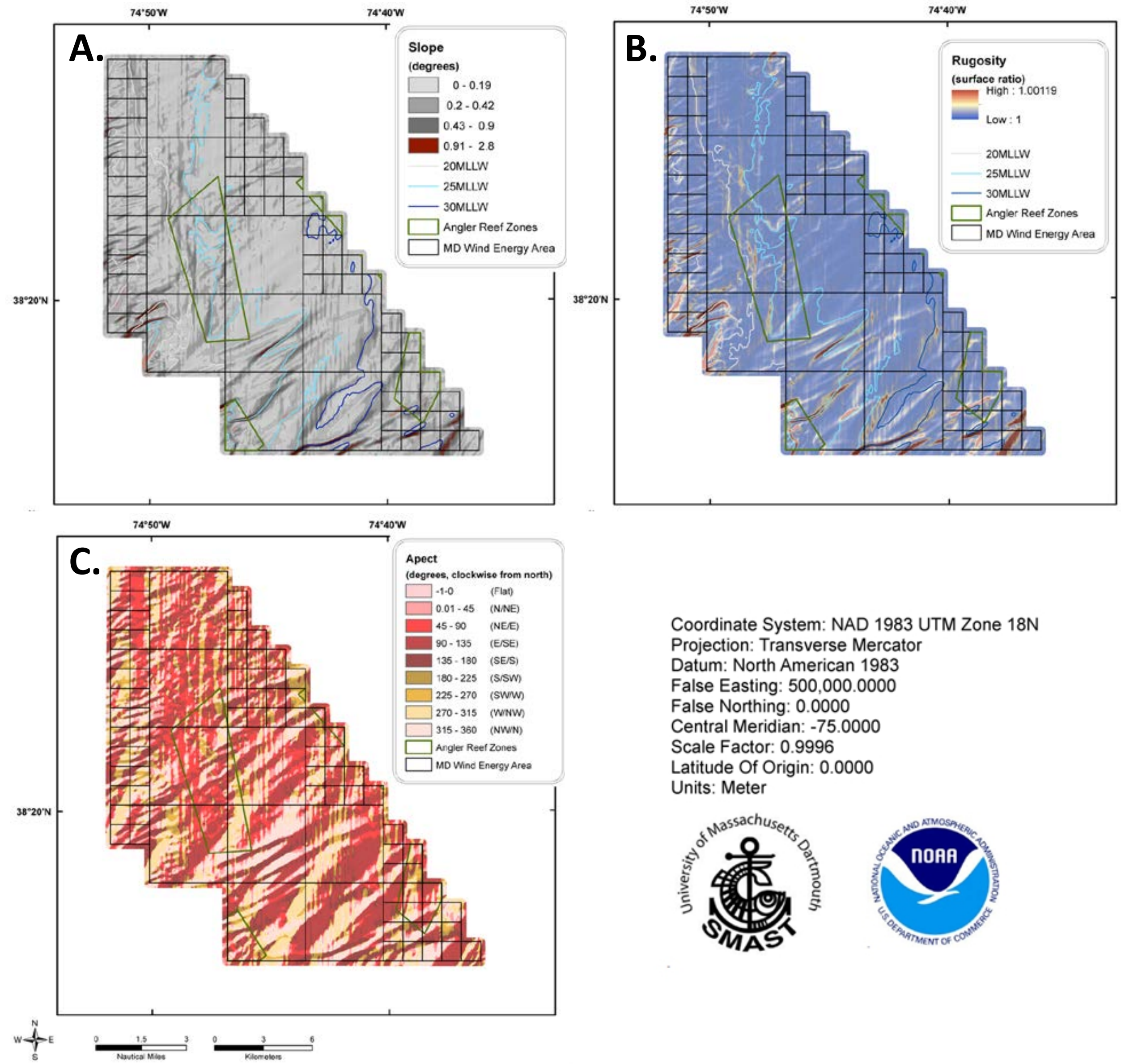


Figure 2-10. Terrain metrics (derived at a 2 m scale) and known angler reef zones (green polygons) in the MD WEA. A. Seafloor slope, B. Rugosity, C. Aspect. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

Application of the BTM Tool allowed identification of zones in the study area that are consistent with subtle, but visible bathymetry features evident in Figs. 2-10 A through C. The benthic zones (Figure 2-11) derived by this model included crests, depressions, slopes and flat areas, and are based on the BPI, slope (2 degrees), standard deviation break = 2, and depth. Figure 2-11 displays the southern section of the MD WEA containing some sloped areas, along with some crests (also called ridges in the Mid-Atlantic Bight). Linear NE-SW ridges, some with stretches of increased slope and depressions, and shorter, irregular ridges in the west and north become evident. However, most of the WEA is indeed flat. The three areas designated as angler reef zones in the MD WEA included segments of the four benthic zones as designated by the model, and the angler reef in the southwestern corner of the MD WEA did include all four zones.

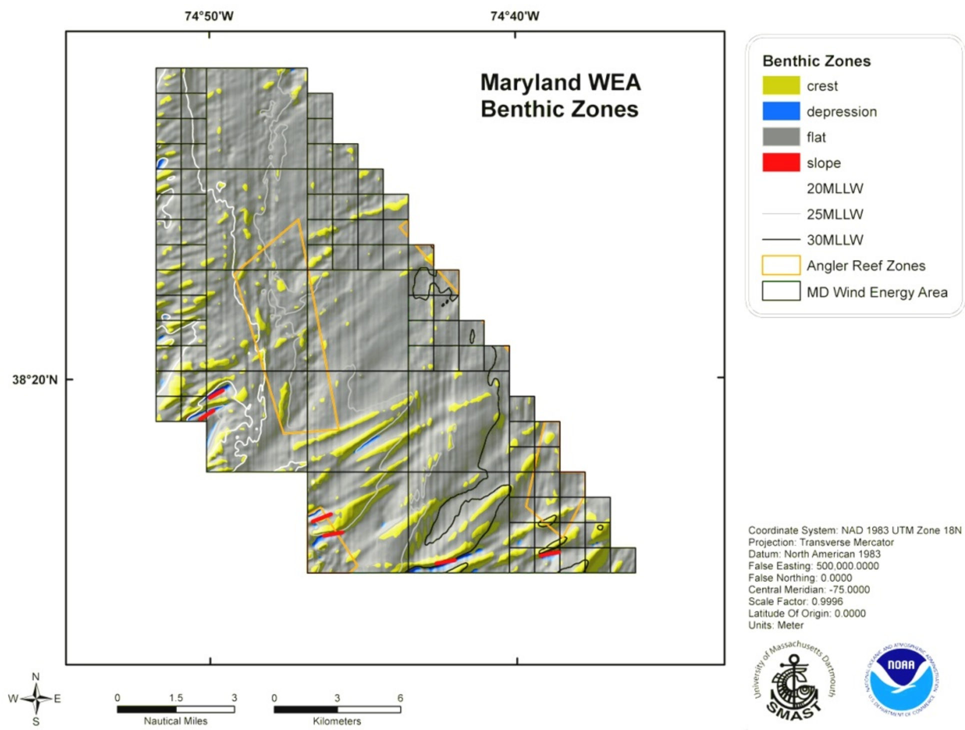


Figure 2-11. Benthic zones (500 m horizontal scale, derived from 2 m bathymetry and 2 m slope data) and known angler reef zones in the MD WEA. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

2.2.2 Sediment Characterization

2.2.2.1 Historic and 2013 Sample Data

Tables 2-4 and 2-5 and Appendices 2 and 3 present the results of the NOAA (nine triplicate samples) and UMES (71 single samples) analyses, respectively. These results demonstrate the following: 1. Sand is the primary substrate in nearly all locations; gravel-dominated samples occurred in 5 of the 27 NOAA replicates and one gravel-dominated and one mud-dominated sample occurred in the UMES dataset; and 2. there is substantial variation between in sediment composition evident among replicates at most stations in the NOAA dataset. This latter observation suggests small spatial scale (tens of m) variations in surficial sediments in much of the WEA.

Table 2-3. Summary of grain sizes and percentages from usSEABED extracted data database. Folk category abbreviations: S - sand, (g)S – slightly gravelly sand.

Station	mean phi	mean % gravel	mean % sand	mean % mud	Folk Class
K1 (8 reps)	1.1	4.3%	95.9%	0.0%	all (g)S
BLM02B_K-1 (2 reps)	1.1	2.5%	96.5%	1.0%	all (g)S
2033 (1 rep)	1.3	0.0%	100.0%	0.0%	S

Table 2-4. Summary of grain sizes and percentages from the nine benthic grab stations taken aboard the NOAA Ship *Gordon Gunter* July 5-9, 2013. Folk category abbreviations: S - sand, (g)S – slightly gravelly sand, gS – gravelly sand, sG – sandy gravel.

Site	mean phi	Folk Classifications		
		Rep. 1	Rep. 2	Rep. 3
A	0.700	(g)S	gS	(g)S
B	0.177	(g)S	sG	gS
D	1.355	(g)S	S	(g)S
E	-0.462	gS	sG	sG
F	0.487	gS	(g)S	gS
J	0.483	gS	(g)S	gS
K	1.074	(g)S	(g)S	(g)S
L	0.207	(g)S	sG	gS
M	-0.163	gS	sG	gS

Table 2-5. Summary of grain sizes and percentages from the benthic grab stations taken by Emily Tewes (UMES) during the summer of 2012. Folk category abbreviations: S - sand, (g)S – slightly gravelly sand, gS – gravelly sand, sM – sandy mud. Source data: (Tewes 2013,).

Folk Class	sample count	mean % gravel	mean % sand	mean % mud
(g)S	58	1.52%	97.74%	0.74%
gS	11	11.75%	96.22%	0.46%
sG	1	35.80%	62.45%	1.75%
sM	1	0.00%	44.03%	55.97%

Interpolated sediment distributions for the MD WEA, error estimates, and means by lease block are represented for mud, sand, and gravel are presented in Figs. 2-12, 2-13, and 2-14, respectively.

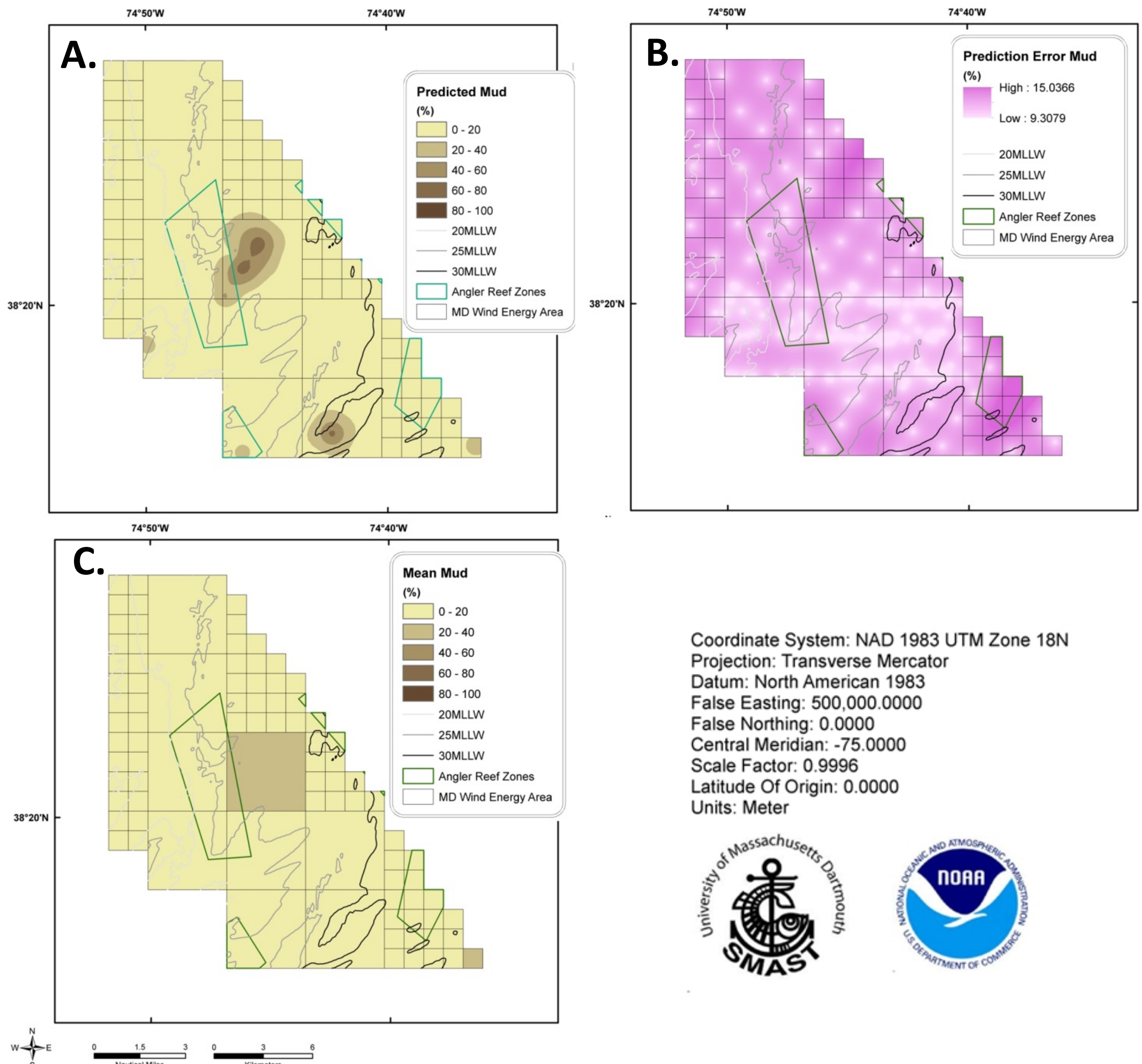


Figure 2-12. Predicted mud (silt + clay) distribution of surficial sediments in MD WEA with known angler reef zones (green polygons): A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data: (NOAA 2013a, Reid et al. 2005, Tewes 2012, Hawkins 2013, CB&I 2014, BOEM 2013).

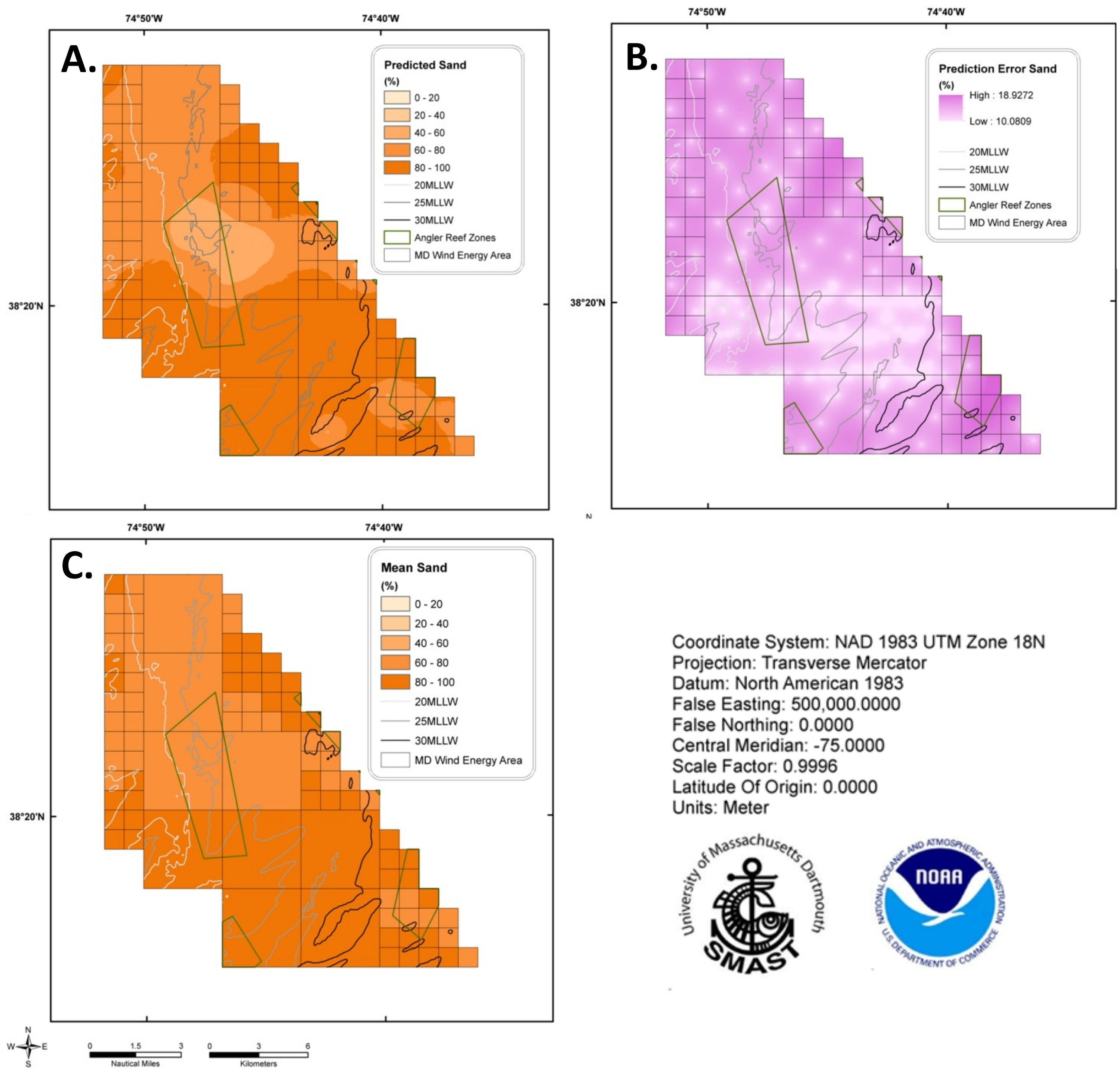


Figure 2-13. Predicted sand distribution of surficial sediments in MD WEA with known angler reef zones (green polygons): A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data: (NOAA 2013a, Reid et al. 2005, Tewes 2012, Hawkins 2013, CB&I 2014, BOEM 2013).

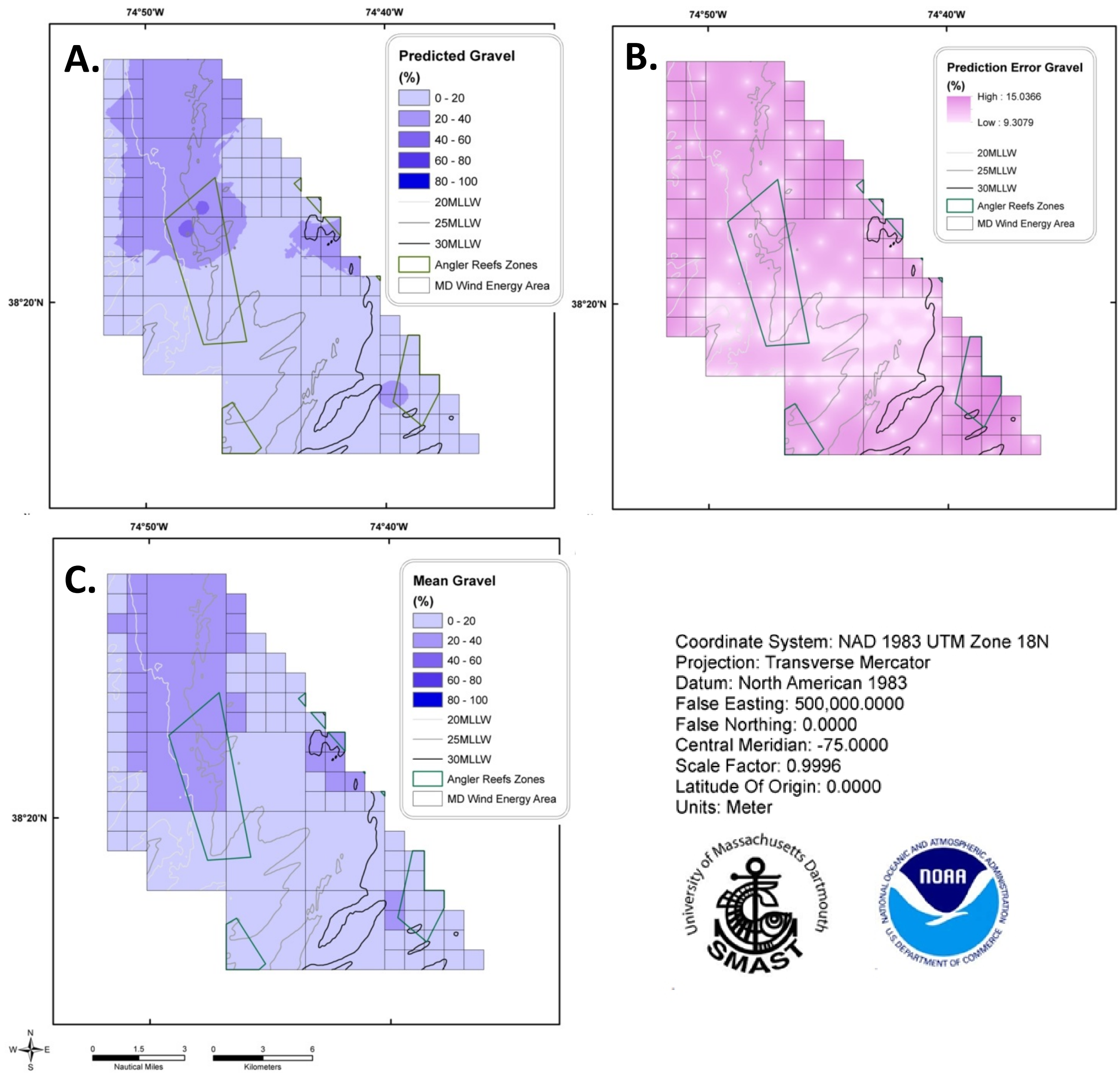


Figure 2-14. Predicted gravel distribution in surficial sediments of MD WEA with known angler reef zones (green polygons): A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data: (NOAA 2013a, Reid et al. 2005, Tewes 2012, Hawkins 2013, CB&I 2014, BOEM 2013).

The mean grain size map (Figure 2-15) shows that 50% of the MD WEA is composed primarily of sand, which includes fine thru coarse sands. Areas composed primarily of mud (≥ 50%) were found mainly in two small pockets located in the center and southern sections of the WEA. The area of muddy sediment predicted in the center of the WEA covers less than half the 4800 m^2 block and the mud section in the southern half of the WEA can be referred to as a ‘mud hole’ because it is found in a benthic zone depression (Figure 2-12). Predicted areas containing between 20% and 40% gravel (fine to very coarse) are seen mainly in the north section of the WEA (Figure 2-14) and are distributed throughout multiple lease blocks.

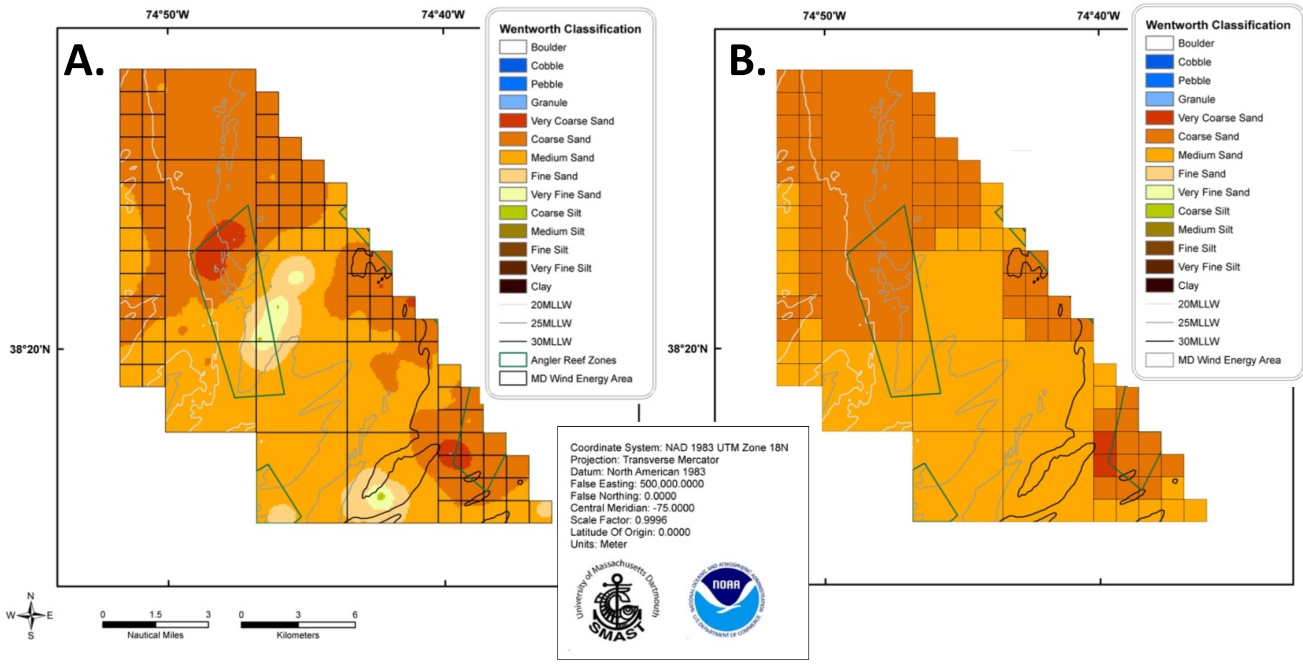


Figure 2-15. Predicted sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the MD WEA with known angler reef zones (green polygons. A. Interpolated sediment type distribution, B. Mean sediment type by whole Lease Block. Source data: (NOAA 2013a, Reid et al. 2005, Tewes 2012, BOEM 2013, CB&I 2014).

2.2.2.2 HabCam IV Sediment Observations

Percent cover of five Wentworth sediment classifications (silt, sand, gravel, cobble, and boulder) and shell hash substrates were recorded (annotated) for each HabCam IV image. Shell hash was not difficult to identify due to its bright white color, and gravel and cobble showed up fairly well in the images; no boulders were seen. However, we found that differentiating between sand and silt from the images was not always possible due to the quality of the images (Fig. 2-6). For the sake of consistency, we therefore decided to combine the sand and silt layers generated from HabCam imagery for this report. Figure 2-16 shows the percentages of substrate cover from the 7,126 HabCam images annotated within the MD WEA. Sand-silt was the dominant cover (94.26%) throughout the MD WEA. The next highest Wentworth classification was gravel (4.84%), with cobble only covering 0.04%. No boulders were seen. Shell hash covered 15.86% of the MD WEA. Though never a dominant fraction, relict estuarine shell material (blackened shells of oysters, bay scallops, and jingle shells) were commonly seen among shell hash materials, suggesting erosion from estuarine sediments laid down during a lower stand of sea level.

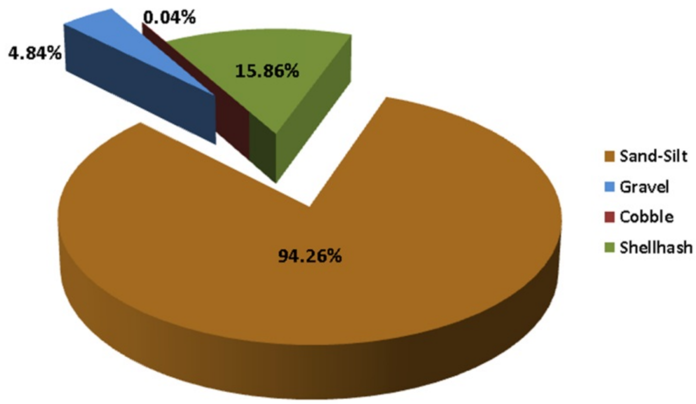


Figure 2-16. Percent of surficial sediment type identified from HabCam surveys in MD WEA. Source data: (NOAA 2013b).

Figures 2-17 through 2-19 show the graduated percent coverages along the cruise track with their corresponding interpolated prediction map based on HabCam IV observations. Percent cobble (Fig. 2-20) is presented only as a track map because so few records would yield an inaccurate interpolation. Prediction maps (ordinary kriging) for HabCam substrates were completed using the same protocols as the sediment core prediction maps described in section 2.3.2.1. Interestingly, the shell hash prediction map (Figure 2-19) showed high percentages of shell hash within the reef angler zone located in the southeast section of the MD WEA and cobble occurrences, although rarely recorded, were nearly all found within angler reef zones (Figure 2-20).

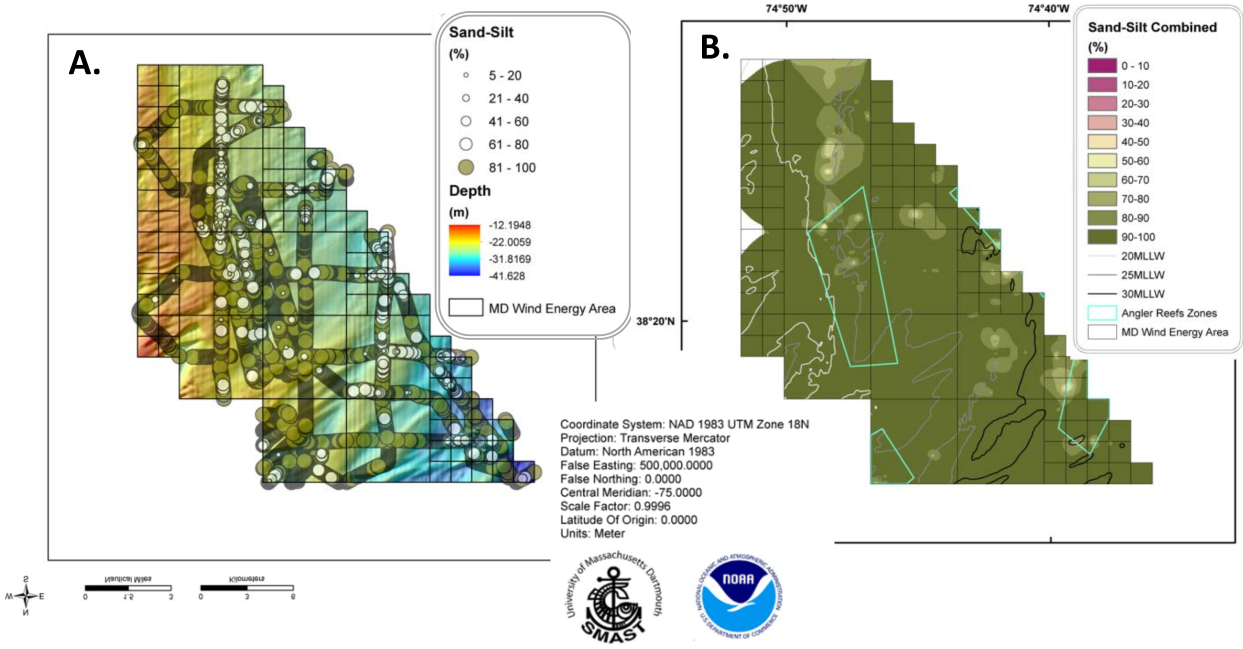


Figure 2-17. HabCam surficial sand-silt coverage: A. Graduated circles represent the percentage of sand-silt substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. B. Interpolated prediction of surficial sediment percent sand-silt based on annotated HabCam imagery. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013).

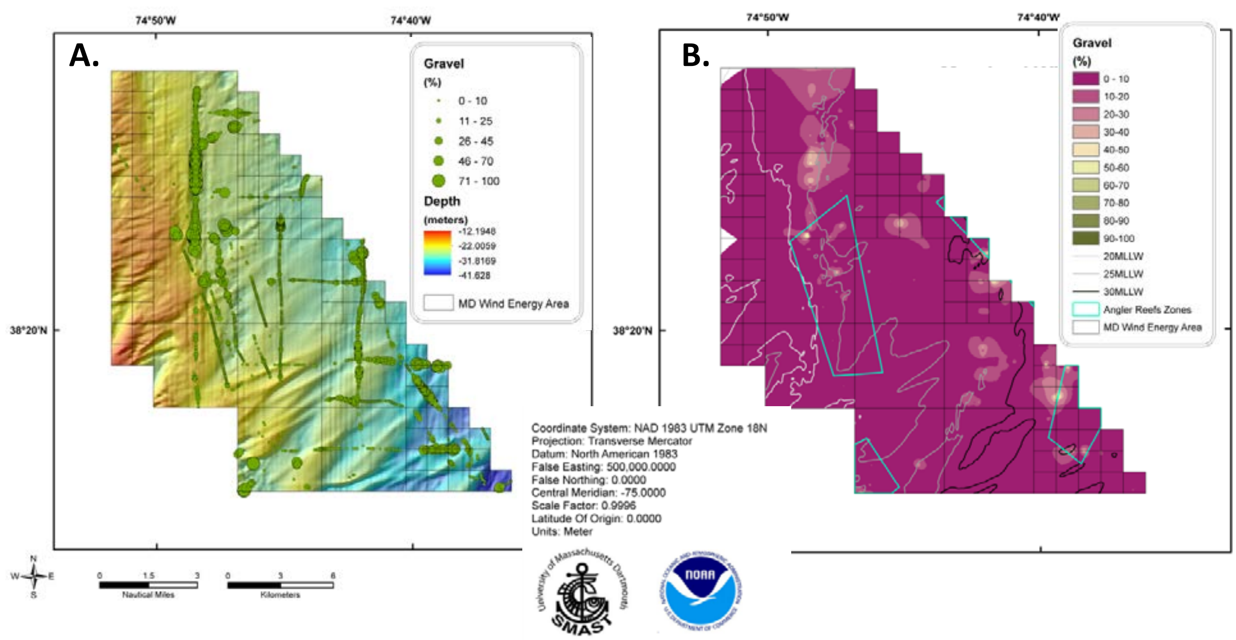


Figure 2-18. HabCam surficial gravel coverage: A. Graduated circles represent the percentage of gravel substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. B. Interpolated prediction of surficial sediment percent gravel based on annotated HabCam imagery. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013).

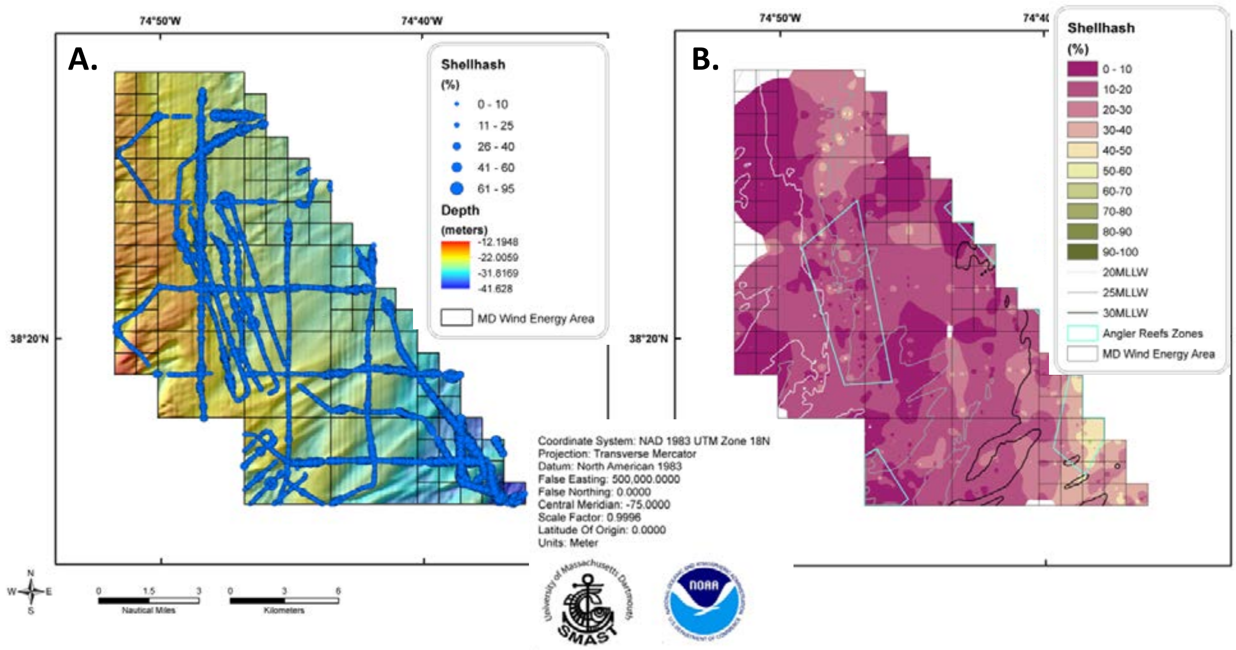


Figure 2-19. HabCam surficial shell hash coverage: A. Graduated circles represent the percentage of shell hash substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. B. Interpolated prediction of surficial sediment percent shell hash based on annotated HabCam imagery. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013).

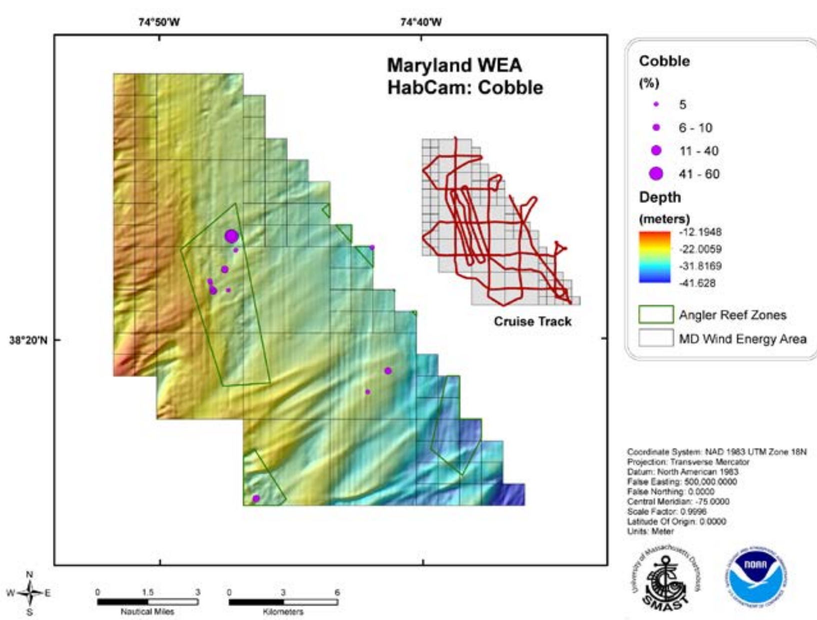


Figure 2-20. HabCam surficial cobble coverage: Graduated circles represent the percentage of cobble substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013).

2.2.2.3 UMASS SMAST Sediments in the WEA

Substrate analysis through visual imagery from the pyramid lander distinguished seven bottom sediment elements: silt, sand, sand ripple, gravel, cobble, rock, and shell debris. Presence/absence data only was recorded for each sediment type. All stations were found to have either sand or sand ripples. Indeed, sand ripples, distinguished from sand by the presence of 3-dimensional waveforms along the bottom, occurred at 85% of the stations (Fig. 2-21 A). Flat sand occurred primarily in a band in the northeast of the WEA and in patches in the south and southeast. It was largely absent in the western and central portions of the WEA. The widespread presence of ripples suggested a dynamic bottom with substantial influence by waves and/or currents over much of the WEA. In addition, silt was observed in about 43% of the stations within the WEA, gravel in 19%, cobble in 0.6% (Fig. 2-21 B, C), and rock not at all. Shell debris (not figured) was seen at 100% of stations within the WEA.

2.2.2.4 Comparison of Sediment Distribution Results

Mapping the actual sediment grain size analyses from the NOAA ship *Gordon Gunter*, Tewes, and usSEABED data (Section 2.3.2.1) along with their prediction maps (Figs. 2-12 through 2-15), allowed us to compare results against the HabCam substrate prediction maps (Figs. 2-17 through 2-20) and the UMASS SMAST observations (Fig. 2-21). First, these evaluations are not entirely comparable: analysis of samples classified surficial sediments into mud, sand, and gravel, whereas HabCam classified them into silt-sand, gravel, cobble, and shell hash and UMASS SMAST into silt, sand, sand ripple, gravel, cobble, rock, and shell debris. The dominance of sandy substrate and its presence throughout the WEA is clear in all three cases, although the variation in definitions of those substrates makes any critical comparison impossible. Differences between definitions of shell hash versus shell debris make comparisons of these sedimentary elements impossible, too. The definition of gravel in all cases, however, was the same, allowing comparison of distribution for that sediment type (Fig. 2-22).

Side-by-side comparison of gravel distribution derived from these three data sources show common features and differences. All three maps indicate low or infrequent occurrence of gravel in the southwestern third of the WEA, in the northwest, and along the western margin. All three also indicate a corridor of more concentrated or more frequent occurrence of gravel extending north to south through the middle of the WEA to about its middle (Fig. 2-22). Elsewhere gravel patches were indicated by all three methods, but with little agreement on exact locations or larger scale patterns.

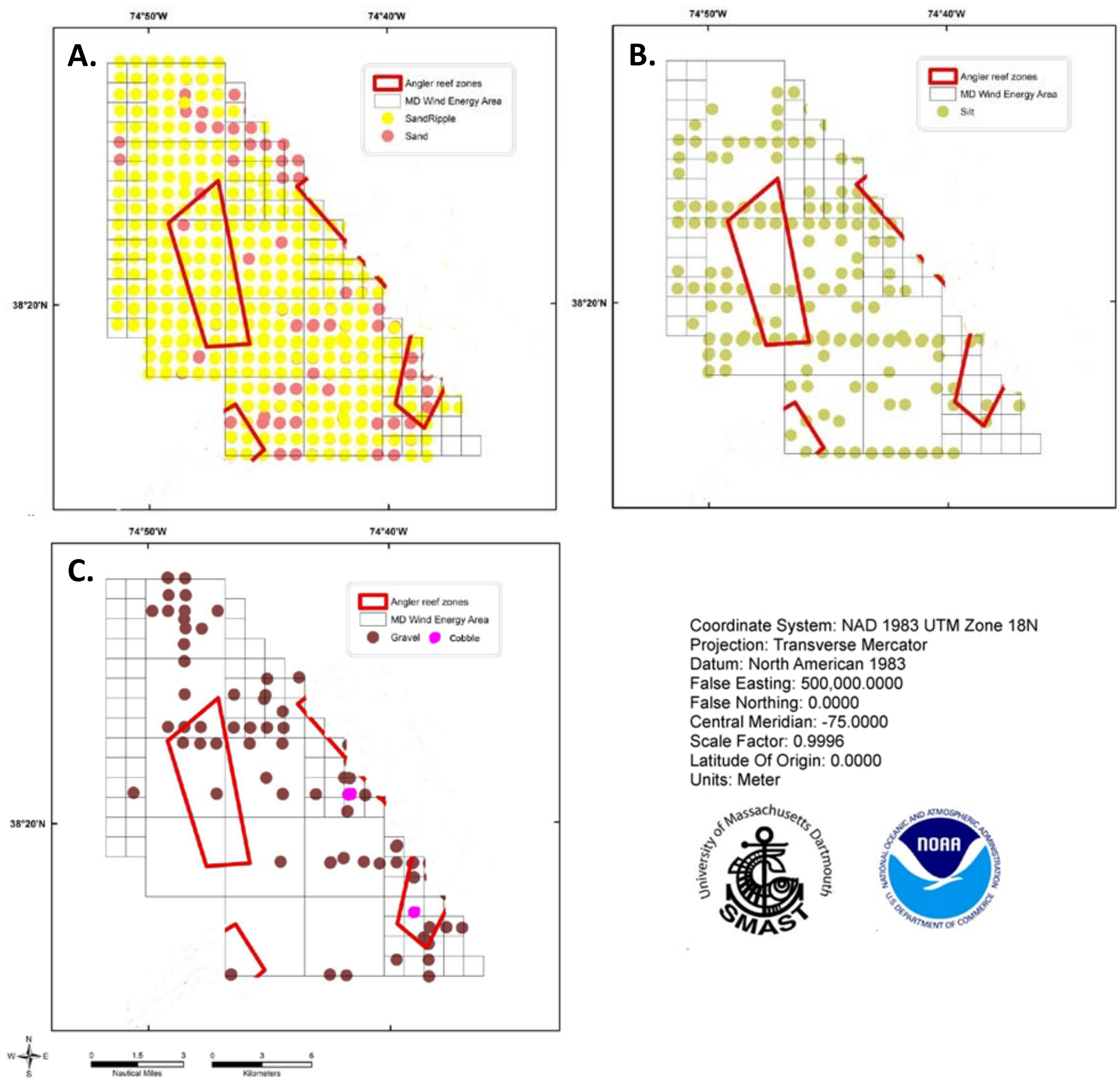


Figure 2-21. UMASS SMAST surficial sediments (presence-absence) observations: A. Sand and Sand Ripples, B. Silt, C. Gravel and Cobble. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013), Appendix MD-1.

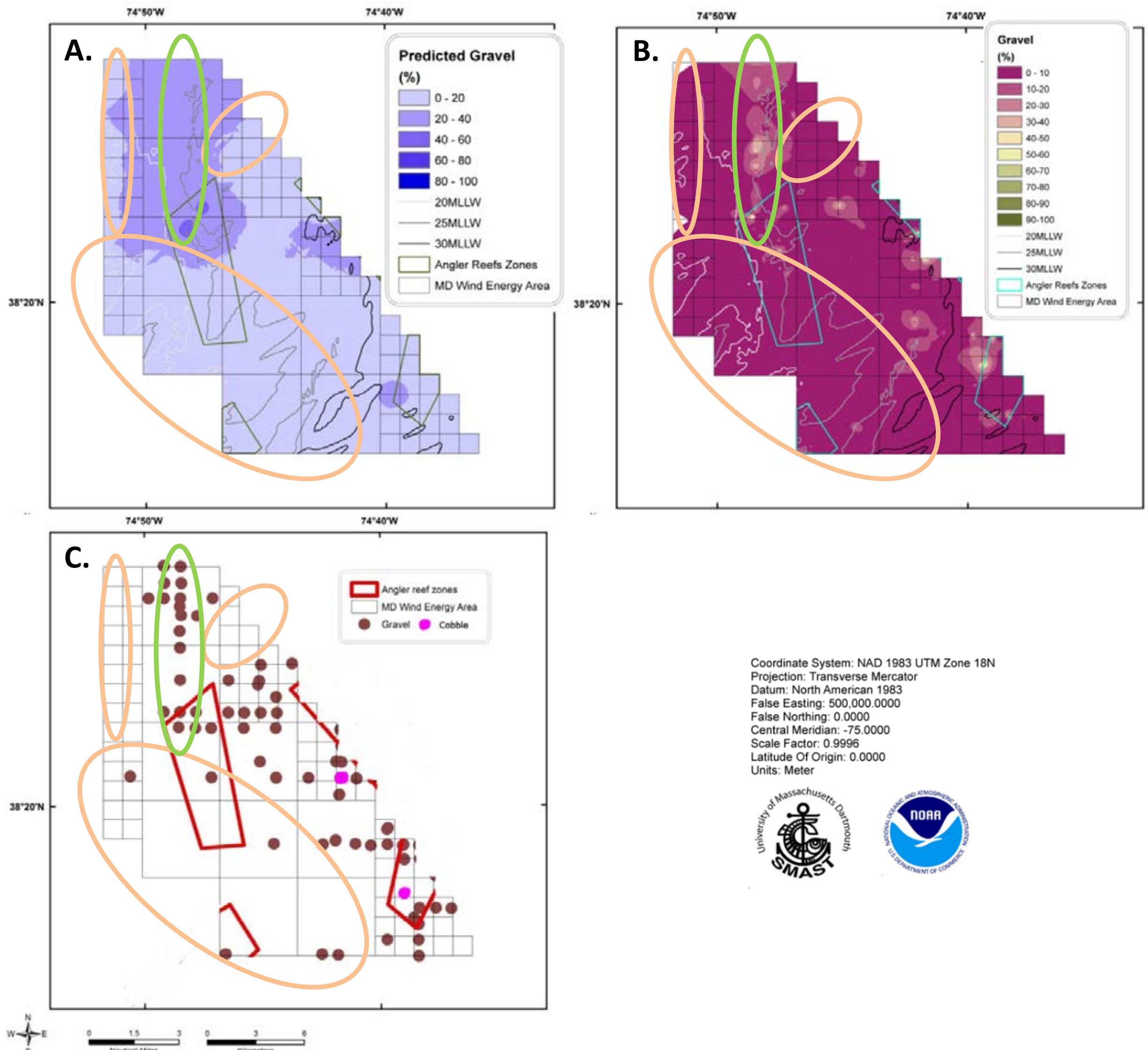


Figure 2-22. Comparison of gravel cover patterns: A. Prediction from interpolation of grab sample grain size analysis (Fig. 2-14 A), B. Prediction from interpolation of HabCam photographic annotation (Fig. 2-18 B), C. Observed presence/absence pattern from UMASS SMAST photographic annotation (Fig. 2-21 C). Orange ovals are common areas of low or infrequent gravel occurrence, green ovals are common areas of higher or more frequent gravel occurrence. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013), Appendix MD-1.

2.2.3 Water Column Oceanography

The HabCam IV CTD recorded the following water parameters: temperature (°C), dissolved oxygen (mg/L), and salinity (ppt) throughout the MD WEA. Table 2-6 lists the means and standard errors for the parameters at four depth ranges (Figure 2-23). Variations within each depth range were very small, and differences between depth ranges were only slightly larger. This short-term spatiotemporal uniformity suggests the absence of any hydrographic fronts, which can lead to sudden shifts in conditions on the bottom with implications for habitat ecology (Guida et al. 2013), within the WEA during sampling. Even though the water parameters were a 'snapshot' in time from July 22-23, 2013, the data categorized by depth range, showed the gradual decrease in temperature and dissolved oxygen and increase in salinity, which is typical of the Mid-Atlantic Bight shelf in 2012 (Fratantoni et al. 2013). No data was recorded for chlorophyll *a*, pH, or turbidity.

Table 2-6. HabCam continuous near-bottom CTD data (temperature, dissolved oxygen and salinity) mean and standard errors by depth zones.

Depth Range	T(°C)		DO (mg/L)		Salinity (ppt)	
(m)	Mean	SE	Mean	SE	Mean	SE
<20	10.58	0.03	4.88	0.01	33.10	0.00
20-25	10.35	0.01	4.85	0.00	33.12	0.00
25-30	10.01	0.01	4.81	0.00	33.13	0.00
30-40	9.31	0.01	4.73	0.00	33.20	0.00

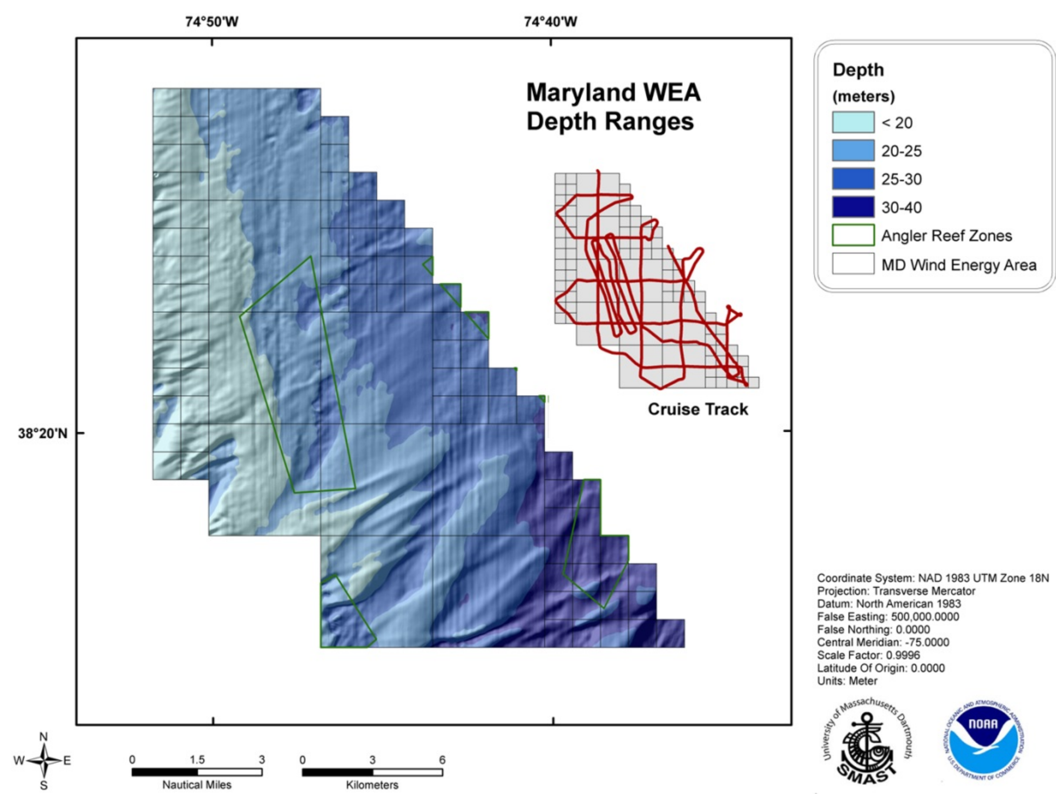
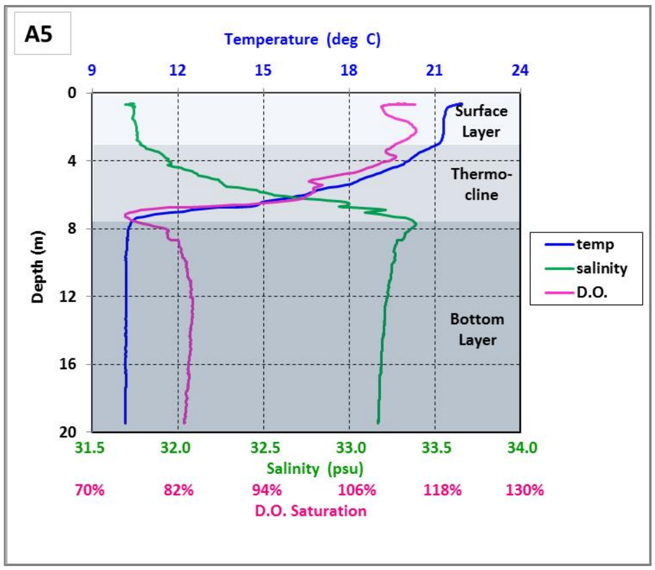


Figure 2-23. Bathymetric zones corresponding to depth ranges in Table 2-6 in the MD WEA. Data horizontal resolution is 2 m. Source data: (Hawkins 2013, BOEM 2013, CB&I 2014).

Vertical CTD casts made aboard R/V *Resolute* on July 24, 2013 in connection with an acoustic survey of the MD WEA provide a better sense of the 3-dimensional hydrographic situation during the sampling period. These CTD casts revealed a strongly-stratified water column with warm (>21° C) water in a thin surface layer, underlain by a strong thermocline and a thick bottom layer of cool water (~10° C) with a salinity about 1.5 psu higher than the surface. The decline in temperature from the surface to the bottom water layers was paralleled by a decline in dissolved oxygen (D.O.) from supersaturated (>100% saturation) at the surface layer to ~80% saturation in the bottom layer as indicated for one station in Fig. 2-24.

A.



B.

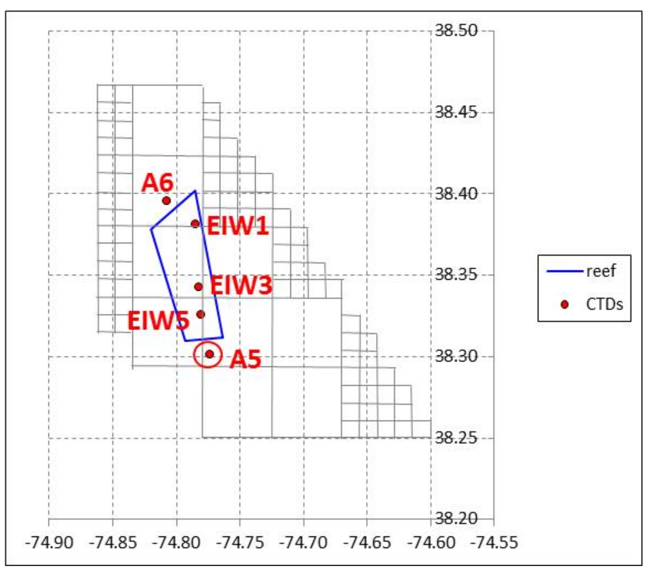


Figure 2-24. Vertical CTD casts in the MD WEA made aboard R/V *Resolute*: A. Plot of CTD parameters at Station A5; Blue line is temperature (values on blue scale); green line is salinity (values on green scale); rose line is dissolved oxygen (D.O.: values on rose scale) B. Map of MD WEA showing positions of five vertical CTD casts. A5 is circled in red. Data sources: (BOEM 2013, Hawkins 2013, NOAA, NEFSC 2014).

Statistics for the five CTD casts performed aboard *Resolute* between 11:48 and 13:33 EDST in the MD WEA are presented in Table 2-7. As with the continuous near-bottom CTD data taken two days earlier by HabCam, there is little difference in bottom temperature, salinity and D.O. from place to place, showing no evidence of horizontal frontal structures. There are, however, north to south differences in the depths of the layers, which is indicative of sloping surfaces of water masses that generate currents.

Table 2-7. Summary of water column CTD data, stations arranged north to south, obtained by R/V *Resolute* in and around the Maryland WEA (Fig. 2-24 B) on July 24, 2013. Data Source: J. Pessutti, pers. comm.

Station	Layer	depth range (m)	Temp C (mean ± SD)	Sal psu (mean ± SD)	DO sat % (mean ± SD)
A6	surface	0 - 1	21.48 ± 0.00	31.83 ± 0.00	116 ± 2.91
	thermocline	1 - 10	--	--	--
	bottom	10 - 22	10.33 ± 0.03	33.08 ± 0.01	84 ± 0.31
EIW1	surface	0 - 1	21.58 ± 0.01	31.82 ± 0.00	115 ± 2.40
	thermocline	1 - 11	--	--	--
	bottom	11 - 27	9.96 ± 0.02	33.09 ± 0.01	81 ± 0.23
EIW3	surface	0 - 2	21.51 ± 0.04	31.58 ± 0.00	114 ± 0.57
	thermocline	2 - 6	--	--	--
	bottom	6 - 24	10.08 ± 0.02	33.15 ± 0.02	81 ± 0.41
EIW5	surface	0 - 3	21.70 + 0.13	31.56 + 0.06	115 + 1.84
	thermocline	3 - 9	--	--	--
	bottom	9 - 26	10.04 ± 0.00	33.17 ± 0.09	82 ± 0.64
A5*	surface	0 - 3	21.62 ± 0.29	31.67 ± 0.02	111 ± 1.34
	thermocline	3 - 8	--	--	--
	bottom	8 - 20	10.19 ± 0.02	33.24 ± 0.05	83 ± 0.81

*Depicted in Fig. 2-24 A.

CTD data from the NEFSC Oceanography Branch survey database provides a longer view of hydrographic conditions than the brief datasets provided by the *Sharp*/Habcam and *Resolute* cruises. Twenty-nine CTD casts were made close to or within the MD WEA in various seasons during the ten year period from 2003 – 2012 (Fig. 2-25). A brief summary of these results (Table 2-8) shows that the highly-stratified condition found in July 2013 with surface temperatures near 20° C and a surface to bottom temperature difference of 9-10° C was typical of the June to August period. However, stratification largely dissipated by September, resulting in nearly isothermal (fully mixed water column) condition with temperatures exceeding 20° C surface to bottom. Winter conditions were also isothermal or nearly so with temperatures ranging ~3 to ~10° C throughout the water column.

Thermal features stand out as potentially important with regard to bottom fauna throughout the MD WEA: 1) WEA bottom water was quite uniform throughout its spatial extent in any given season. 2) summer bottom temperatures were the most consistent during and across years, 3) turnover events in September appeared to result in a sudden rise in bottom temperature, and winter bottom temperatures were usually substantially colder than summer and fall bottom temperatures. Surface temperatures were similar to bottom temperatures in winter, indicating a consistent well-mixed water column condition. Salinities, on the other hand, varied little throughout the year, particularly on the bottom (<0.3 psu variation). Surface to bottom gradients were also consistently small (<2 psu) throughout all seasons.

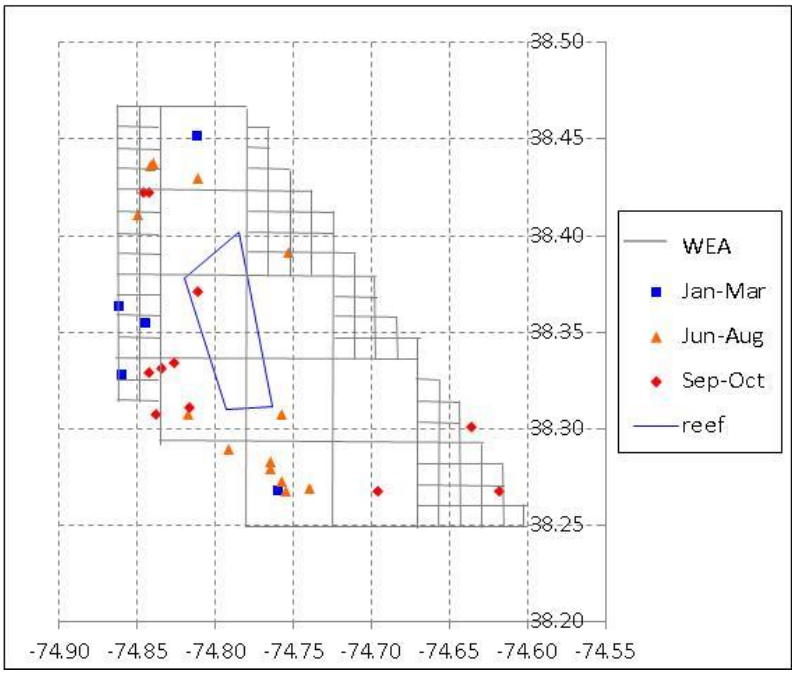


Figure 2-25. Positions of vertical CTD casts made in or near the MD WEA by NEFSC surveys in various seasons between 2003 and 2012. Data sources: (BOEM 2013, Hawkins 2013, NOAA, NEFSC 2014).

Table 2-8.   Ten years (2003 – 2012) of NEFSC CTD data from the Maryland WEA summarized by seasonal periods. Data source: NOAA, NEFSC Oceanography Branch 2014. Source: (NOAA, NEFSC 2014).

Period	Layer	Temperature (deg C)			Salinity (psu)		
		median	min	max	Median	min	max
Jun 1 - Aug 31 n = 13	surface	21.99	17.04	24.24	31.172	29.487	32.006
	bottom	10.92	9.39	17.88	32.734	31.723	32.902
Sep 1 - Oct 31 n = 11	surface	22.01	20.35	23.72	31.212	30.136	32.062
	bottom	19.76	11.57	23.42	31.576	30.191	32.758
Jan 1 - Mar 31 n = 5	surface	5.27	3.41	10.12	31.814	30.045	32.246
	bottom	5.03	3.40	10.38	31.914	30.996	32.467

2.2.4 Biota

2.2.4.1 Historic NEFSC Trawl Data

Trawl tracks with the MD WEA for the NEFSC semiannual bottom trawl survey for a ten- year period (2003 - 2012) and summaries of seasonal catches are presented in Fig. 2-26. A complete listing of catch taxa and their importance in terms of the percentage of numbers caught and frequency of catch can be found in Appendices 4 and 5.

All 18 random trawls performed over ten years were confined to the western half of the MD WEA (Fig. 2-26 A) as a result of the WEA being divided north to south between a smaller, densely sampled inshore stratum (#29) on the west and a larger, more diffusely sampled offshore stratum (#69) on the east within the larger NEFSC scheme for stratified random trawl sampling. Trawl catches were recorded in the NEFSC database farther east, but these were neither plotted here nor included in tallies since they were entirely outside of the WEA in deeper water where results could not be assumed to be representative of the WEA fauna. The uneven coverage and the long lengths of the trawl tracks of this dataset (Fig. 2-26 A) are not ideal with respect to the small scale of habitat analysis desired for this project. Nevertheless, the results is instructive in a general way.

The bottom trawl survey results from within the WEA demonstrate a large seasonal shift in benthic/demersal megafuana. It is clear that catches in fall (Sept.-Oct.) and spring (March) were quite different. Much larger catches were made in fall than in spring, both in terms of numbers of individuals caught (mean fall catch = 1,709 per trawl vs. 76 per trawl in spring) and numbers of species (39 in fall vs. 15 in spring: Fig. 2-26 B, C). Fall catches were dominated by seasonally migratory species: Atlantic croaker, weakfish, spot, and northern sea robin, whereas the much smaller spring catches were dominated by little skate, smallmouth flounder, and spotted hake. In fact, nearly all the spring trawl species were present in fall trawls (among the 32 unnamed species in Fig. 2-26 B), but their numbers were small as compared with the dominant seasonal migrants present in the warmer September-October period. Thus the spring catch species represent a year-round resident fauna. Both seasonal faunas were dominated by bottom-dwelling species (Appendices 4 and 5).

Like the NEFSC trawl survey data, the 2008 DelMarVa beam trawl data set is weak with respect to spatially defining habitat values within the WEA, as only a few of the trawls were taken inside the WEA limits (Fig. 2-27 A), but the results are also instructive in a general way, as they were taken in an adjacent region of similar depth range (15-37 m) and bottom contours. A complete listing of catch taxa and their importance in terms of the percentage of numbers caught and frequency of catch can be found in Appendix MD-6. Unlike the NEFSC survey catches, the DelMarVa beam trawl catches were heavily dominated by epibenthic invertebrates: sand dollars and a variety of gastropod mollusks, decapod crustaceans, and echinoderms poorly represented in NEFSC survey catches (Fig. 2-27 B). The most abundant fish species was the diminutive gulf stream flounder, which did not appear in NEFSC survey catches from this area at all. Fifty-seven taxa (mostly epifaunal) were identified from these samples; many more than from the NEFSC bottom trawl survey (Fig. 2-26, Appendices 4 and 5) that employed larger otter trawl nets at higher speeds. Most beam trawl taxa were not captured in grab samples, either.

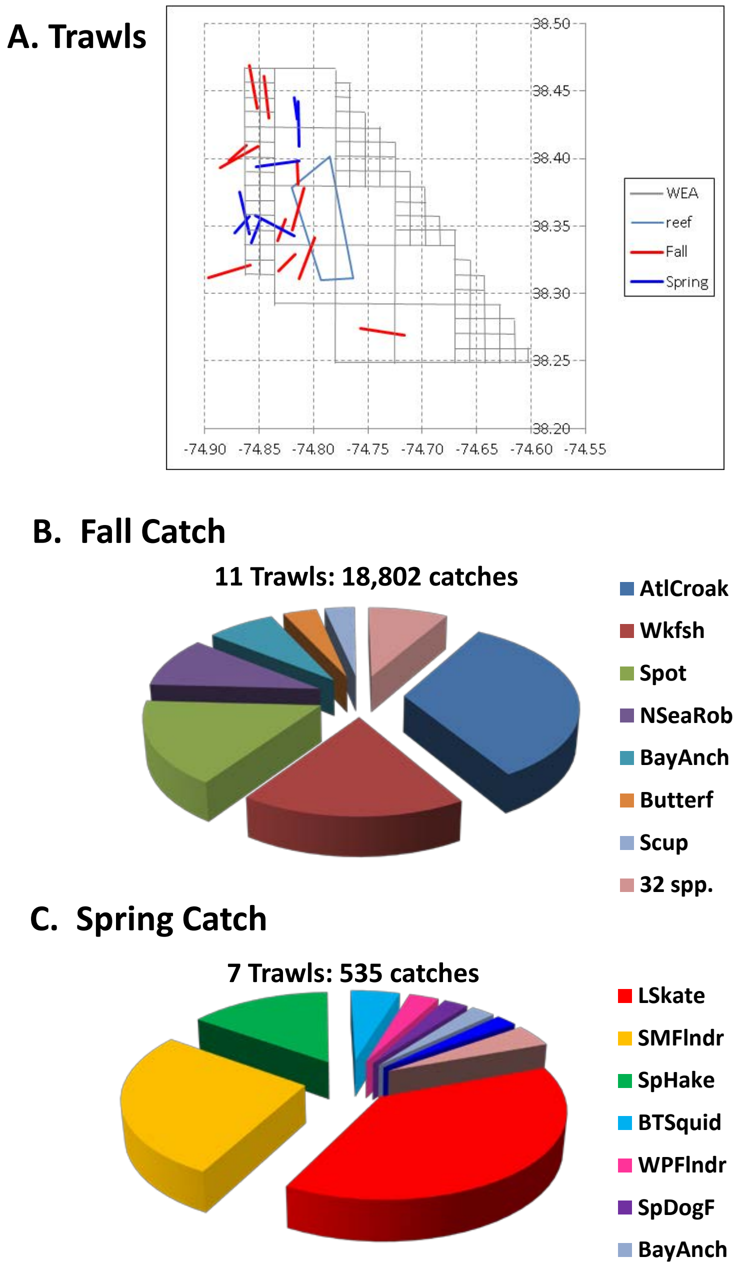


Figure 2-26. NEFSC bottom trawl surveys in the MD WEA. A. Trawl tracks impinging on the WEA, B. Summary of fall catch by percentage of individuals caught, and C. Summary of spring catch by percentage of individuals caught. Fish name abbreviations: AtlCroak – Atlantic croaker, Wkfhs – weakfish, NSeaRob – northern sea robin, BayAnch – bay anchovy, Butterf – butterfish, LSkate – little skate, SMFlndr – smallmouth flounder, SpHake – spotted hake, BTSquid – bobtail squid, WPFlndr – windowpane flounder, SpDogF – spiny dogfish, StrBass – striped bass. Source Data: (NOAA, NEFSC Oceanography 2014).

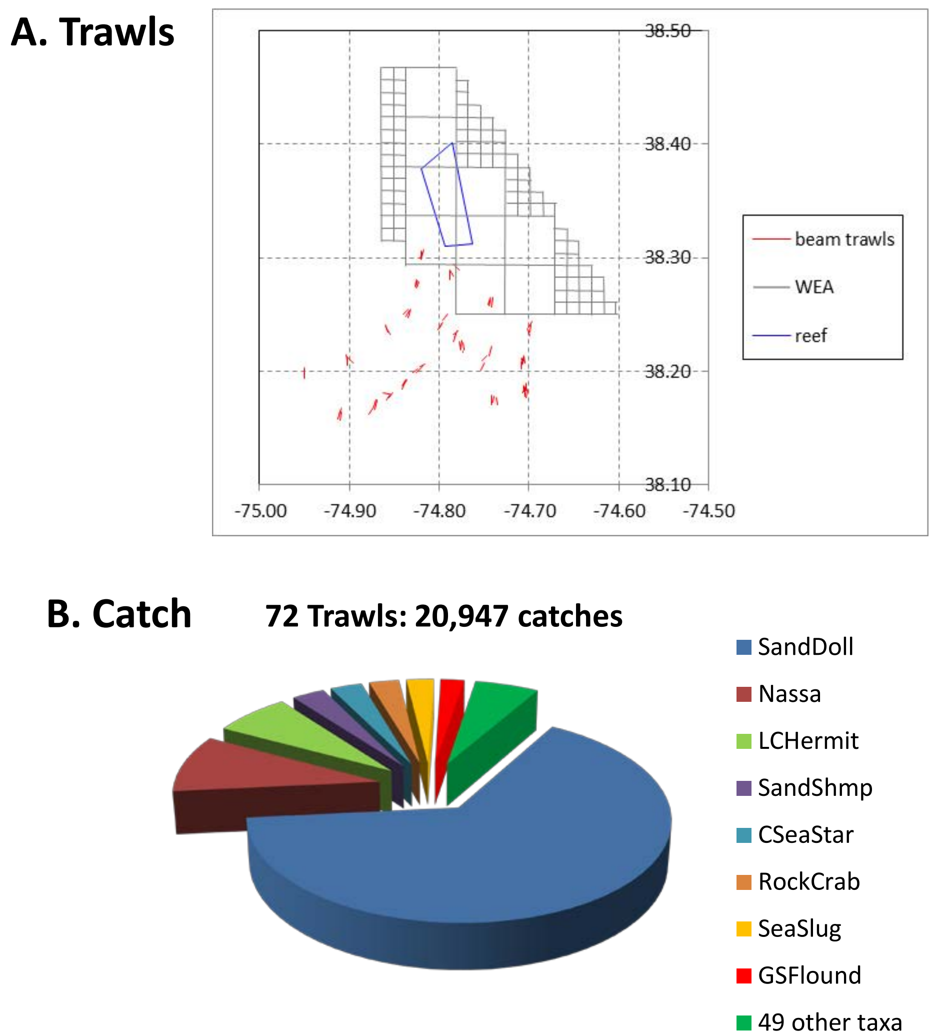


Figure 2-27. 2008 Delmarva beam trawl survey near the MD WEA: A. Trawl tracks in WEA vicinity, B. Summary of catch by percentage of individuals caught Abbreviations: SandDoll – sand dollar, Nassa - Nassa snail (dog whelk), LCHermit – long clawed hermit crab, SandShmp – sand shrimp, CSeaStar – common sea star, RockCrab – southern rock crab, SeaSlug – dwarf warty sea slug, GSFloud – Gulf Stream flounder.

2.2.4.2 HabCam IV Epifaunal/Demersal Biotic Data

A total of 3,286 organisms were observed from HabCam IV imagery and categorized into 22 identifiable taxa grouped into eight groups: fish, crabs, anemones, corals & sponges, urchins, snails, sea stars, and gelatinous fauna (Table 2-9).

Table 2-9. Summary of demersal/benthic epifauna from HabCam images (n = total number of specimens: [1] denotes epifaunal taxa not identified to genus or species).

Epifaunal *Group*/Taxon	**Scientific name**	**n**
Fish		
Sea Robin	*Prionotus* spp.	99
Ocean Pout	*Macrozoarces americanus*	1
Flounder [1]	Pleuronectiformes	2
Banded Rudderfish	*Seriola zonata*	1
Hake	*Urophycis* spp.	1
Spotted Hake	*Urophycis regia*	1
Skate[1]	Rajidae	3
Skate egg cases[1]	Rajidae	17
Fish (unidentified) [1]	Osteichthyes	9
SUBTOTAL (not including egg cases)		**117**
Crabs		
Hermit Crab	*Pagurus* spp.	102
Rock crab	*Cancer irroratus*	102
Crab (unidentified)[1]	Brachyura	28
SUBTOTAL		**232**
Anemones		
Anemone colonial [1]	Zoanthida	1
Anemone solitary [1]	Actinaria	229
SUBTOTAL		**230**
Corals & Sponges		
Sea whips	*Leptogorgia virgulata*	2
Sponge (unidentified) [1]	Demospongia	1
SUBTOTAL		**3**
Urchins		
Sand dollar	*Echinarachnius parma*	2664
SUBTOTAL		**2,664**
Snails		
Moon snail[1]	Naticidae	5
Moon snail collar[1]	Naticidae	34
SUBTOTAL (not including collars)		**5**
Sea Stars		
Sea Stars (unidentified) [1]	Asteroida	14
SUBTOTAL		**14**
Gelatinous fauna		
Jelly fish (unidentified) [1]	Schyphozoa	22
Ctenophores [1]	Ctenophora	2
SUBTOTAL		**4**
GRAND TOTAL		**3,286**

The graduated sums of the biota associated with mean grain size and benthic zones, as well as CPUEs for sea robins, identified fish, skates and their egg cases, and unidentified fish are shown in Figures 2-28 to 2-31. Seven taxa of identified fish occurred in the MD WEA. Out of a total of 117 individuals, 99 were sea robins (*Prionotus* spp.: *P. carolinus* + *P. evolans*). Sea robins were associated with varying grain sizes of sand including and throughout flat and crest areas (Figure 2-28). Three identified fish including two

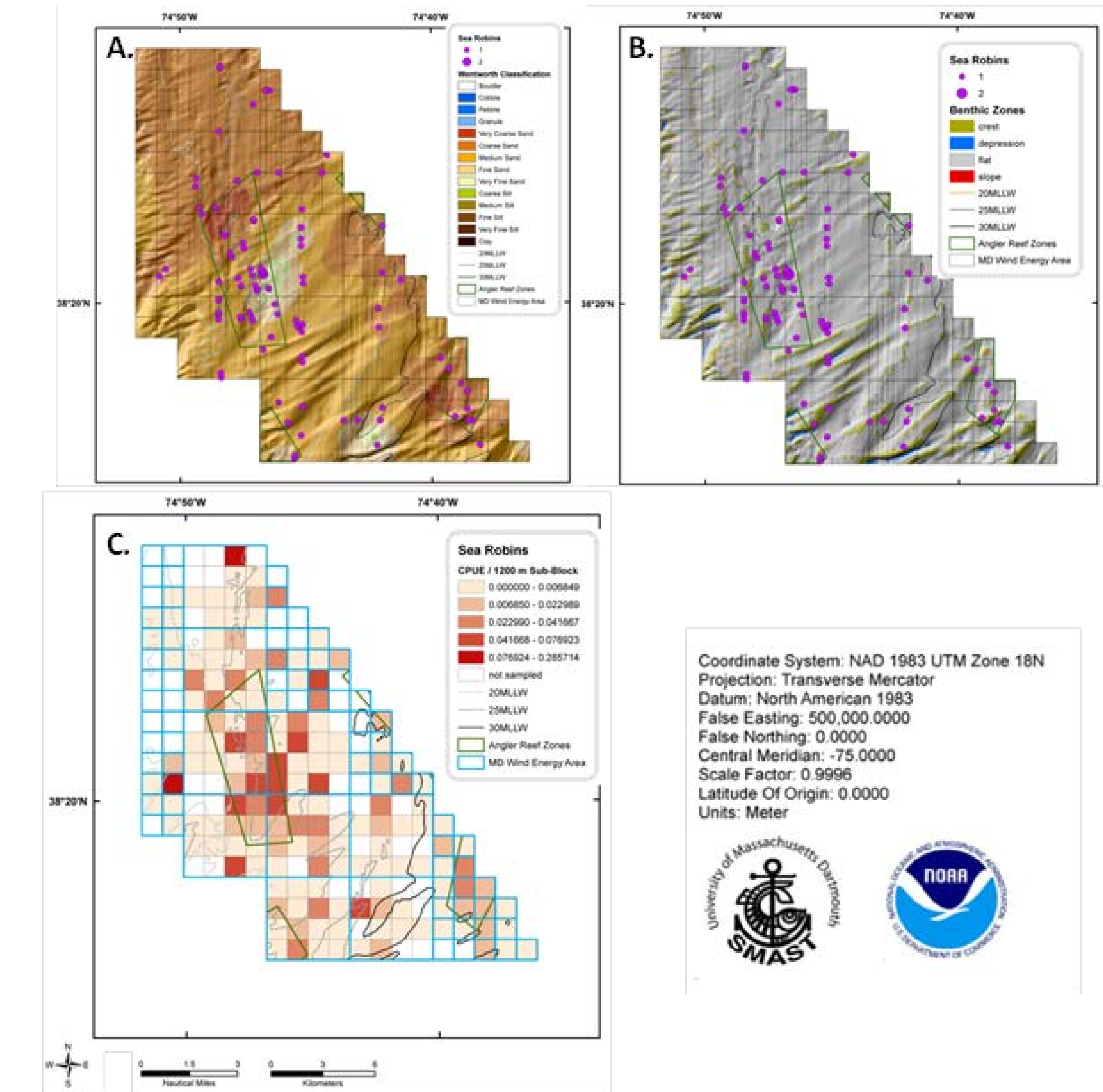


Figure 2-28. Sea robin (*Prionotus* spp.) abundance from HabCam: A total of 99 sea robins were recorded from the HabCam images in the MD WEA; A. Sea Robin counts per image overlaid on mean grain size for the MD WEA., B. Sea Robin counts per image overlaid on benthic zones for the MD WEA. C. Sea Robins CPUE/1207 m sub-block in the MD WEA. CPUE represents counts per photo for each sub-block. Note that the angler reef zone in the center of the WEA had multiple sub-blocks with high CPUE numbers. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b, CB&I 2014).

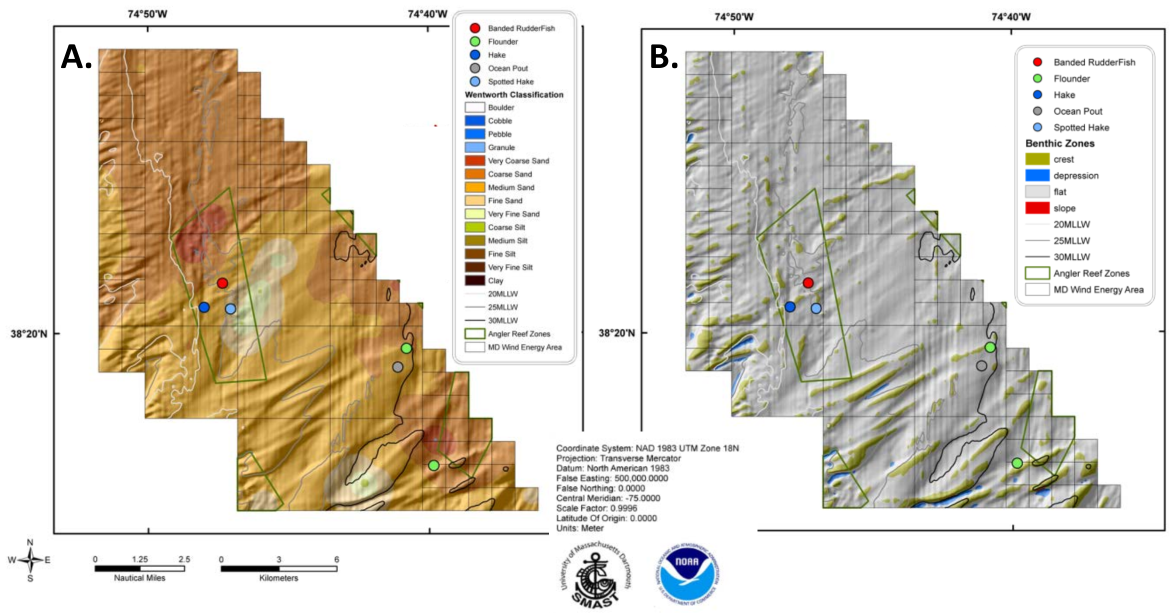


Figure 2-29. Abundance of five identified fish species from HabCam: (1) Banded rudderfish (*Seriola zonata*), (2) flounder (Pleuronectiformes), (3) unclassified hake (*Urophycis* spp.), (4) spotted hake (*Urophycis regia*), and (5) ocean pout (*Macrozoarces americanus*): A. Overlaid on mean grain size for the MD WEA, and B. Overlaid on benthic zones size for the MD WEA. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b, CB&I 2014).

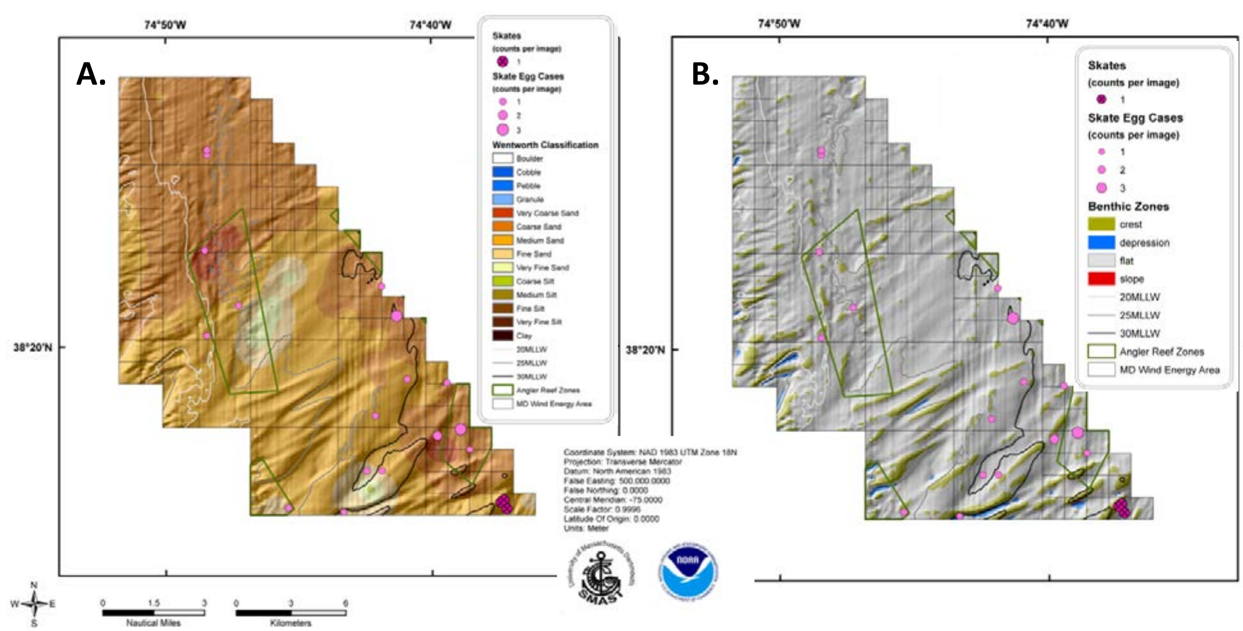


Figure 2-30. Abundance of skates (Rajidae) and egg cases from HabCam. Counts per image are overlaid on mean grain size for the MD WEA: A. Overlaid on mean grain size for the MD WEA, and B. Overlaid on benthic zones size for the MD WEA. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b, CB&I 2014).

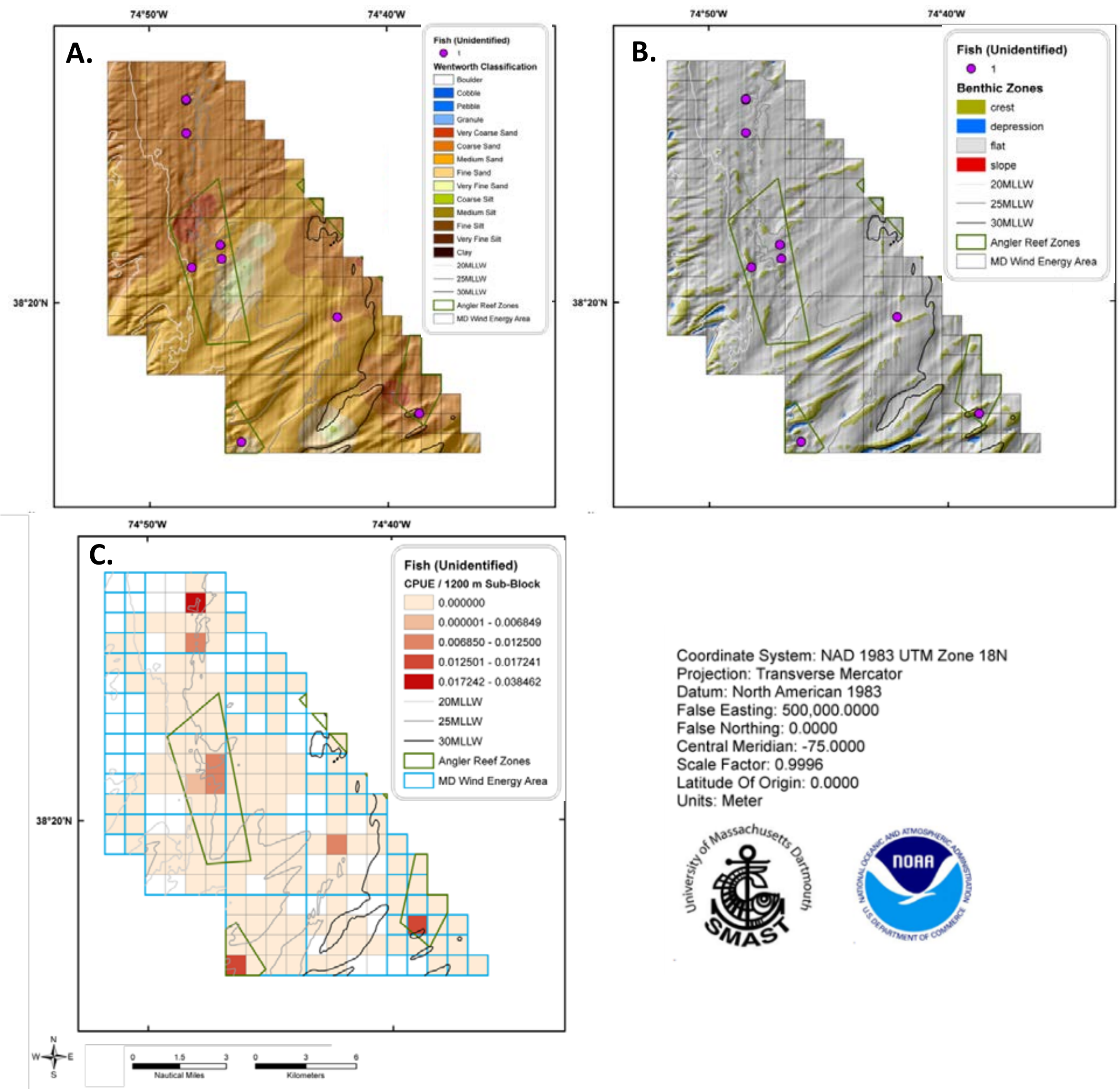


Figure 2-31. Abundance of unidentified bony fish (Osteichthyes) from HabCam: A. Counts per image overlaid on mean grain size for the MD WEA., B. Counts per image overlaid on benthic zones for the MD WEA. C. CPUE/1207 m sub-block in the MD WEA. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b, CB&I 2014).

hake taxa (spotted hake and hake sp.) were recorded in the large angler reef (middle of WEA) at depths between 20 and 30 m and associated with fine to medium sand (Figure 2-29). The three skates recorded were clustered together in the southeast corner of the WEA at depths ≥ 35 m in medium and fine sand areas (Figures 2-29). CPUE maps were calculated for sea robins (Figure 2-28 C) and unidentified fish (Figure 2-31 C) only. The higher CPUE values for sea robins are seen at depths between 20-25 m, and 25-30 m for unidentified fish. Also, unidentified fish and sea robins were recorded in angler reef zones.

Unfortunately, managed species of skates (likely little, clearnose, and winter skates) could not be reliably distinguished from HabCam imagery, nor could managed flatfish species (likely summer, smallmouth, and windowpane flounders) be distinguished from non-managed species (likely fourspot and Gulf Stream flounders), nor could managed red hake (*Urophycis chuss*) be reliably distinguished from unmanaged spotted hake (*U. regia*).

A total of 232 crabs were observed in the MD WEA and two types were identified as hermit crabs (*Pagurus* spp.: *P. longicarpus, P. pollicarus,* and *P. acadianus*) and rock crabs (*Cancer irroratus*), the rest were unidentified brachyurans (true crabs). The hermit crab graduated maps overlaid on mean grain size and benthic zones (Figure 2-32 A, B) showed a clustering of hermit crabs in two of the angler reef zones (middle and southwest corner), which range in depth between 20-25 m. The rock crab and unidentified crab graduated summation maps (Figures 2-33 A, B and 2-34 A, B) show presence in angler reef zones and deeper depths (20-30 m), unlike the hermit crabs. It is likely that all or most of the unidentified crabs were, in fact, rock crabs that could not be seen clearly enough to identify positively. The hermit crab CPUE values (Figure 2-32 C) are higher in the northwest section of the MD WEA above the middle angler reef zone, and in the far southwest corner of the WEA at 25 m depth. CPUE values for rock crabs (Figure 2-33 C) and unidentified crabs (Figure 2-34 C) had sub-blocks with high values at deeper depth ranges between 20 and 30+ m, unlike hermit crabs CPUE's, which were higher at depths of < 30 m.

A total of 230 anemones, one colonial and 229 solitary were recorded in the MD WEA. Although the solitary anemones were not identified to genus or species, they were most likely the tube anemones (*Cerianthus americanus*). The graduated summation maps associated with mean grain size and benthic zones (Figure 2-35 A, B) show that solitary anemones were associated with coarse to very fine sand at depths > 20 m in flat zones. Colonial anemones were recorded at a depth ≥ 30 m in the far southeast section of the WEA. The CPUE figure for solitary anemones (Figure 2-35 C) had higher values at depths ≥ 25 m.

A total of two whip corals (*Leptogorgia virgulata*) and one unidentified demosponge were recorded within the MD WEA at depths ≥ 25 m and both biota were associated with coarse to medium sand in mostly flat zones with no vertical relief (Figures 2-36 A, B). Since total numbers were low, a CPUE figure was not generated. These organisms are of particular interest, as they require attachments to stable, hard surfaces; their presence strongly suggests hard bottom habitat.

A total of 2, 664 sand dollars (*Echinarachnius parma*) were recorded in the MD WEA. Figure 2-37 A and B show that sand dollars were consistently found throughout the MD WEA and associated with very coarse sand to very fine sand. Typically more than one sand dollar was recorded from a photo on flat bottom and sand substrate at depths ≥ 20 m. Figure 2-37 C demonstrates high CPUE values in the angler reef zone located in the far southwest corner of the MD WEA and in sub-blocks throughout the entire cruise track at depths ≥ 20 m.

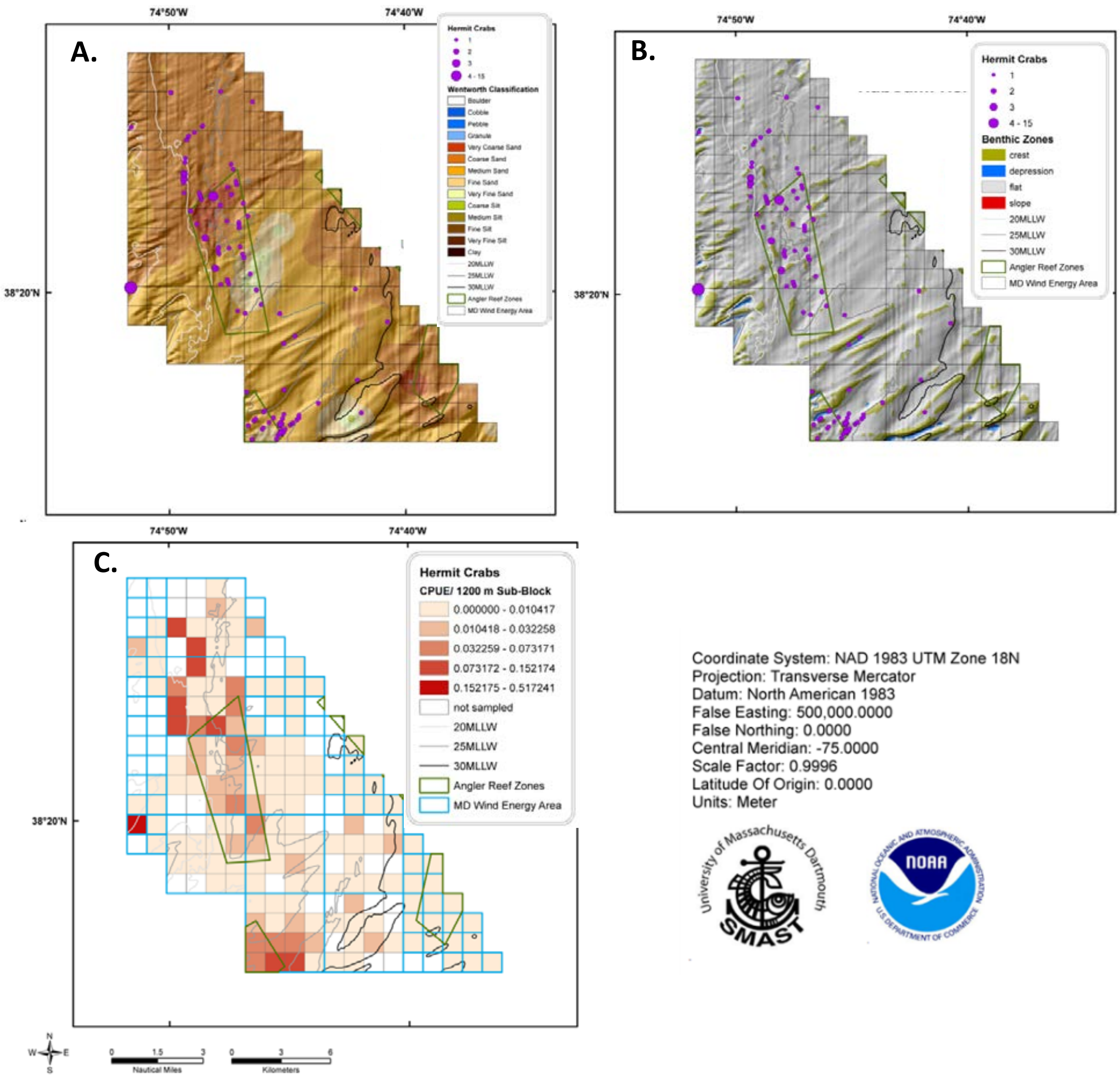


Figure 2-32. Hermit crab (*Pagurus* spp.) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. A total of 102 hermit crabs were recorded from the HabCam images. There appears to be a concentration of hermit crabs in two of the three angler reef zones. Inset box shows HabCam cruise track. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b, CB&I 2014).

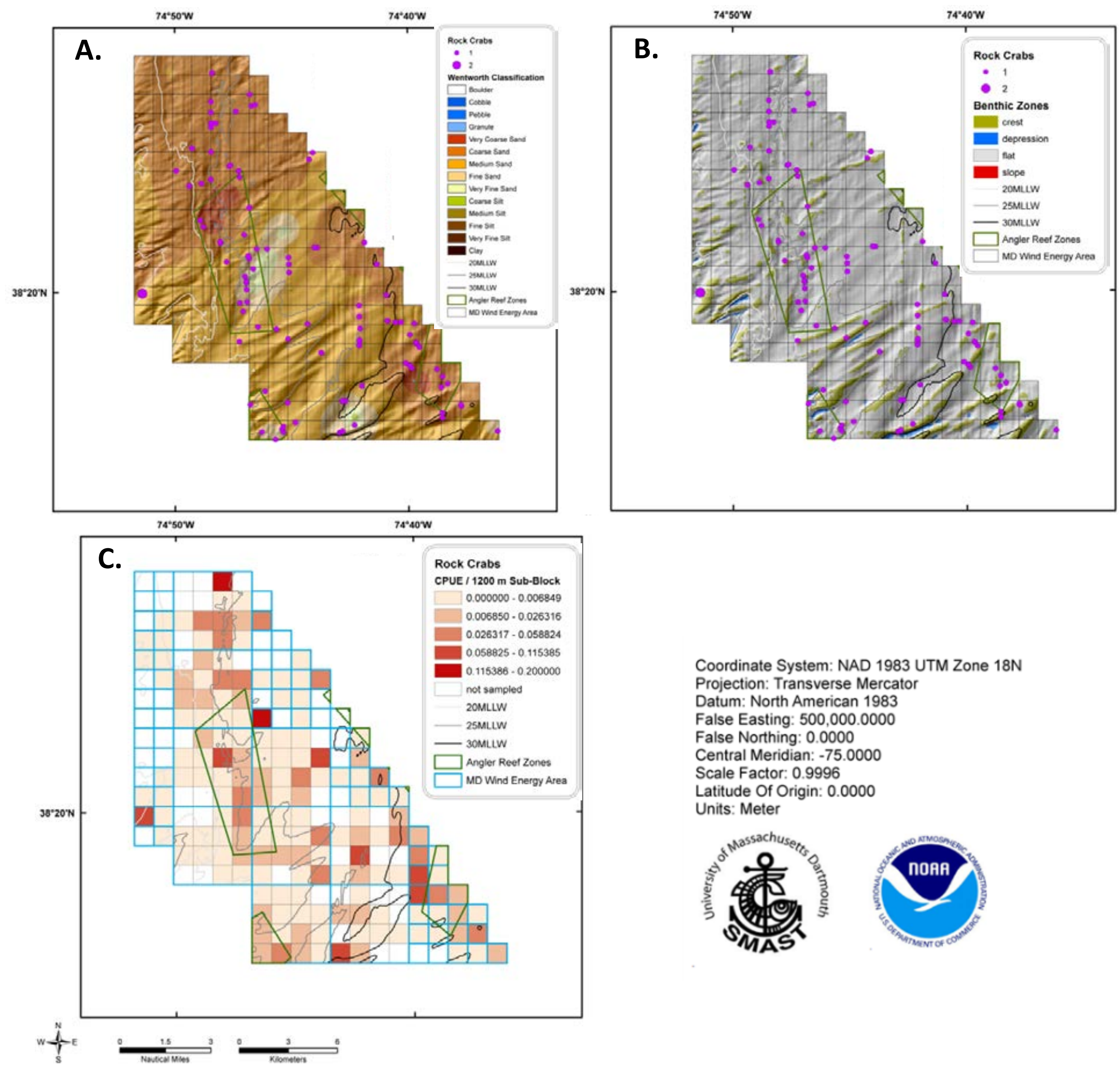


Figure 2-33. Rock Crab (*Cancer irroratus*) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

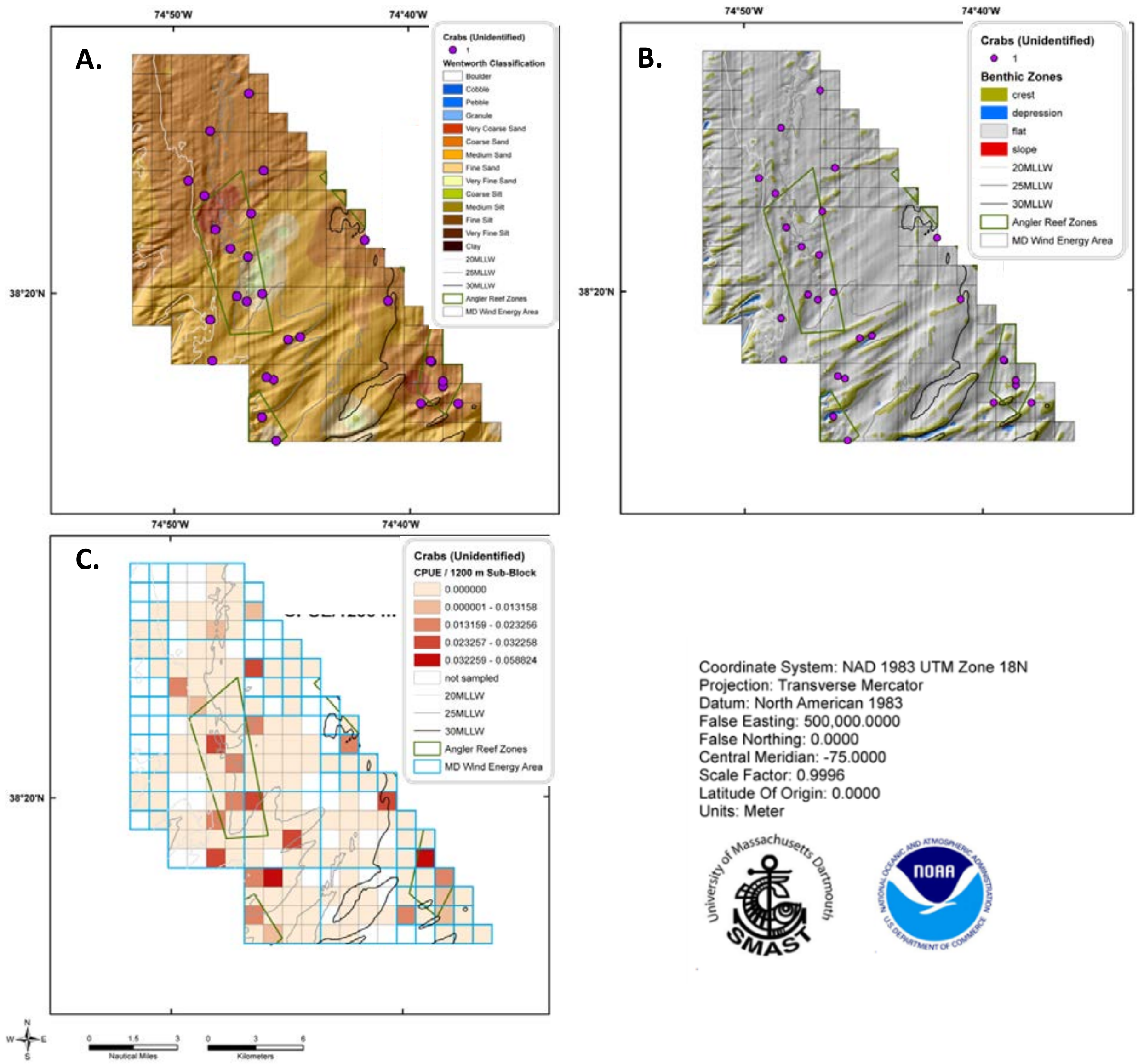


Figure 2-34. Unidentified crab (Brachyura) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

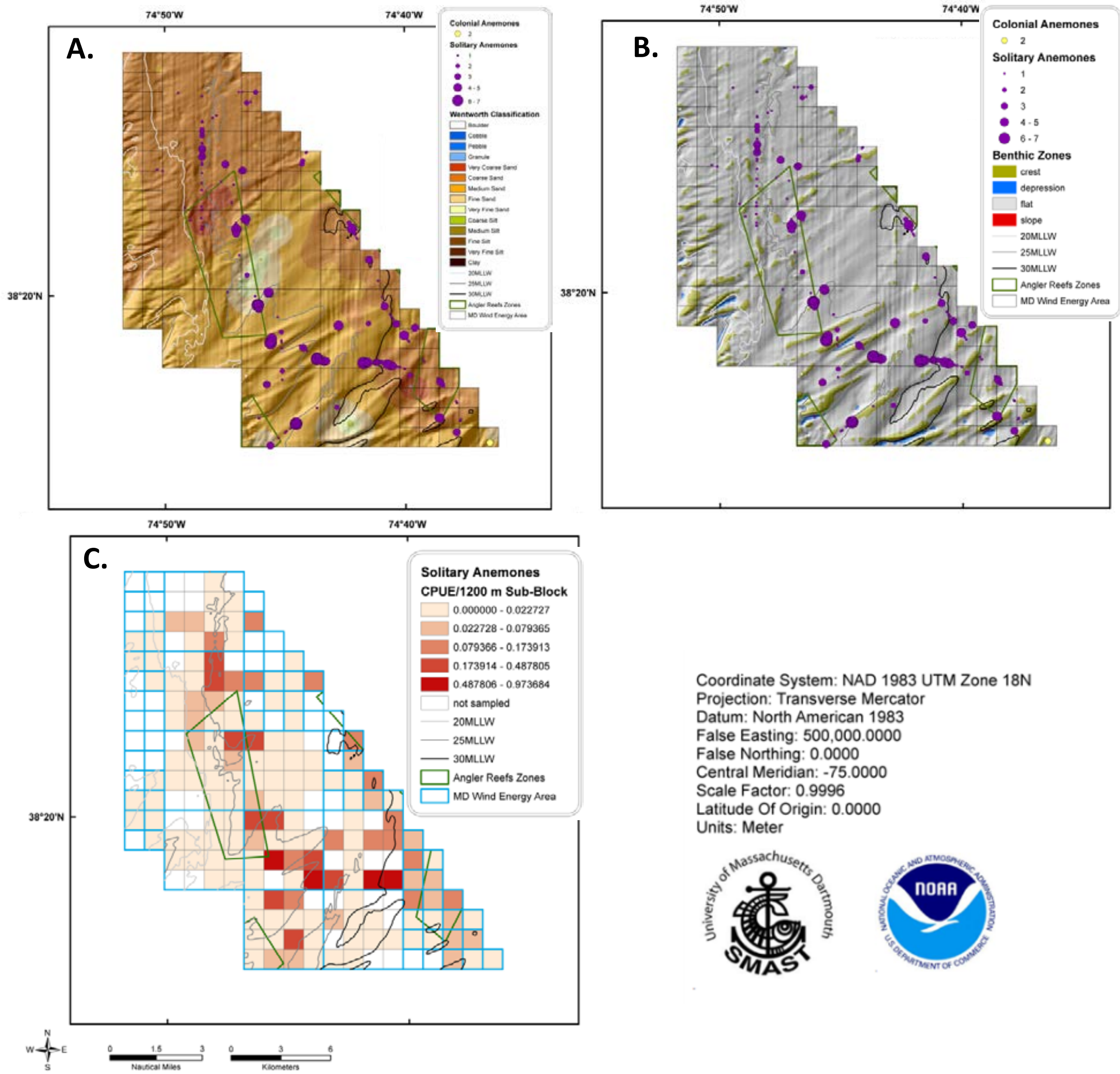


Figure 2-35. Solitary and colonial anemones abundances from HabCam: Two colonial anemones were counted (yellow dot) from the same image in the southeast corner of the MD WEA. A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

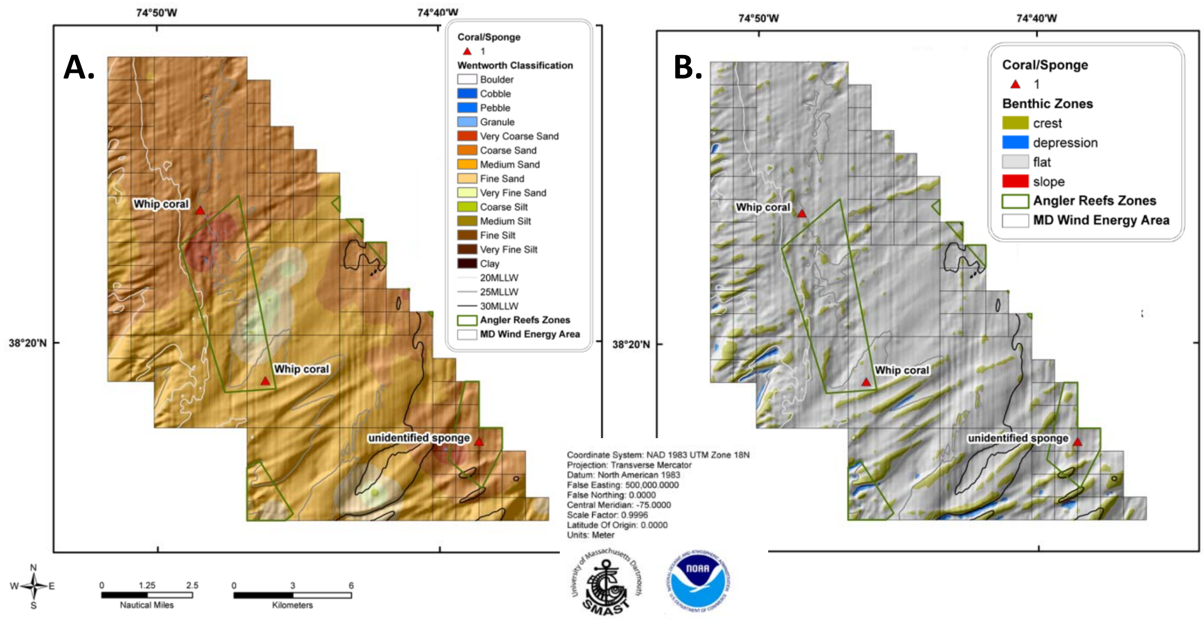


Figure 2-36. Coral and sponge abundances from HabCam: two whip corals (*Leptogorgia virgulata*) and one unidentified sponge associated with mean grain size. One of the corals and the one sponge recorded were also associated with angler reef zones. The sponge was found at a depth > 35 m. A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

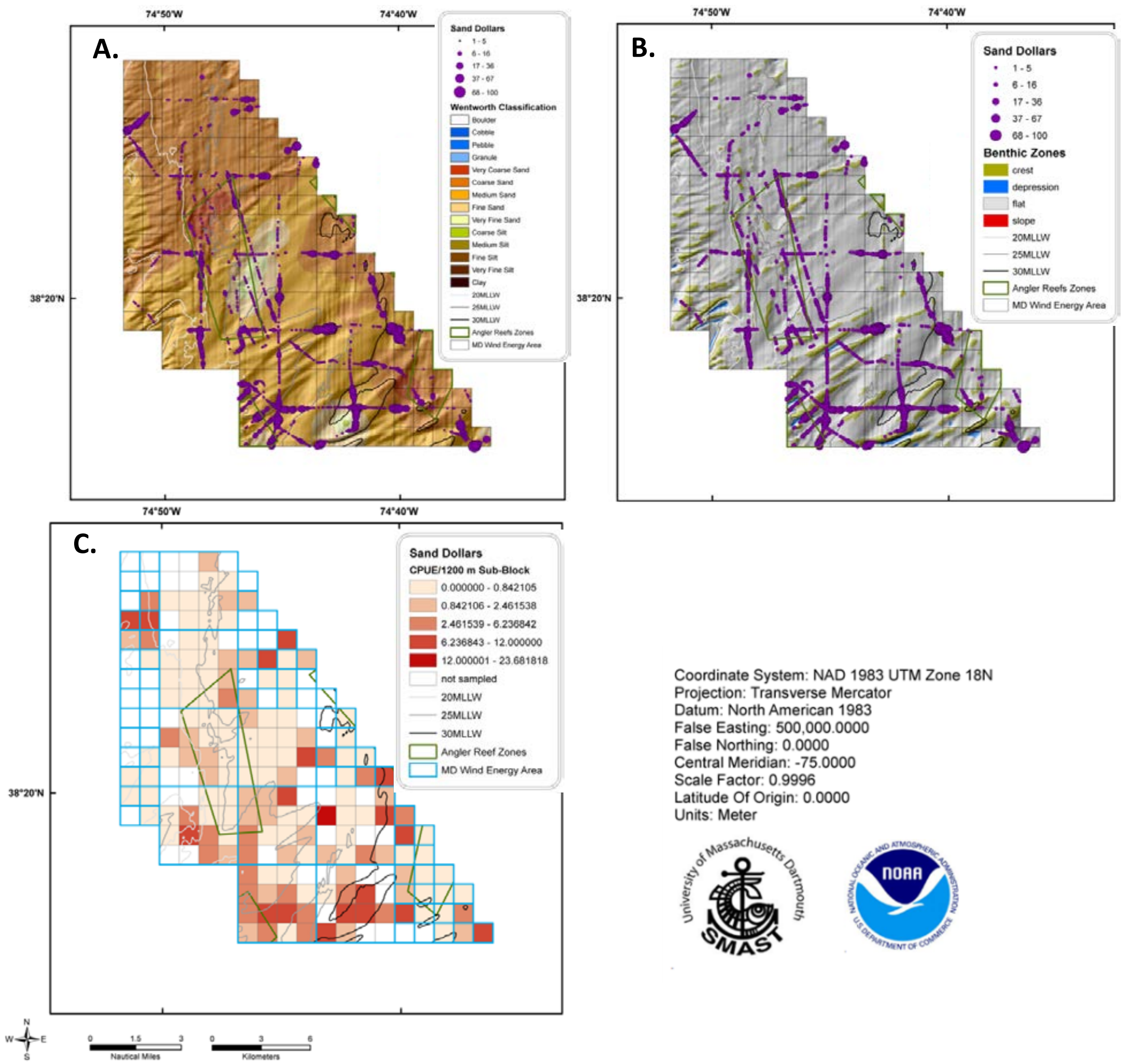


Figure 2-37. Sand dollar (*Echinarachnius parma*) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

A total of five moon snails (Naticidae spp.) and 34 moon snail collars (naticid egg cases) were recorded in the MD WEA. We were unable to distinguish from the two most probable species, *Euspira heros* and *Neverita duplicata* in the photographs. Figures 2-38 A, and B show that there were more collars than snails and the snails were found at depths ≤ 30 m and associated with course to very fine sands in mostly flat zones. Since counts were very low for snails, a CPUE figure was not calculated.
Another type of snail probably present in much greater abundance than moon snails, but not enumerated, were Nassa snails, also known as dog whelks, probably either *Nassarius trivittatus* or *N.*

vibex. They were not enumerated because while visible, they were not readily distinguishable in photos from medium to coarse gravel particles, which are in the same size range.

A total of 14 sea stars (*Asterias* sp., probably *A. forbesi*) were recorded in the MD WEA at depths ≥ 25 m on very fine to medium sand on mostly flat bottom (Figure 2-39). Since counts were low, a CPUE figure was not plotted.

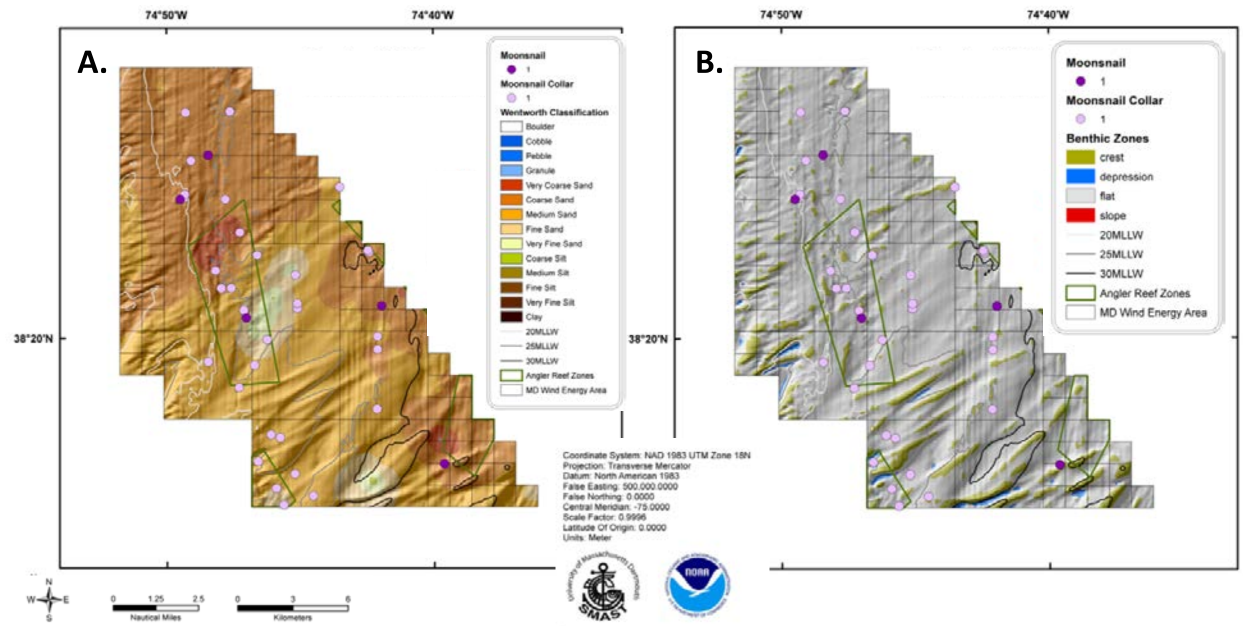


Figure 2-38. Moon snail (Naticidae) and sand collar (naticid egg cases) abundances from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

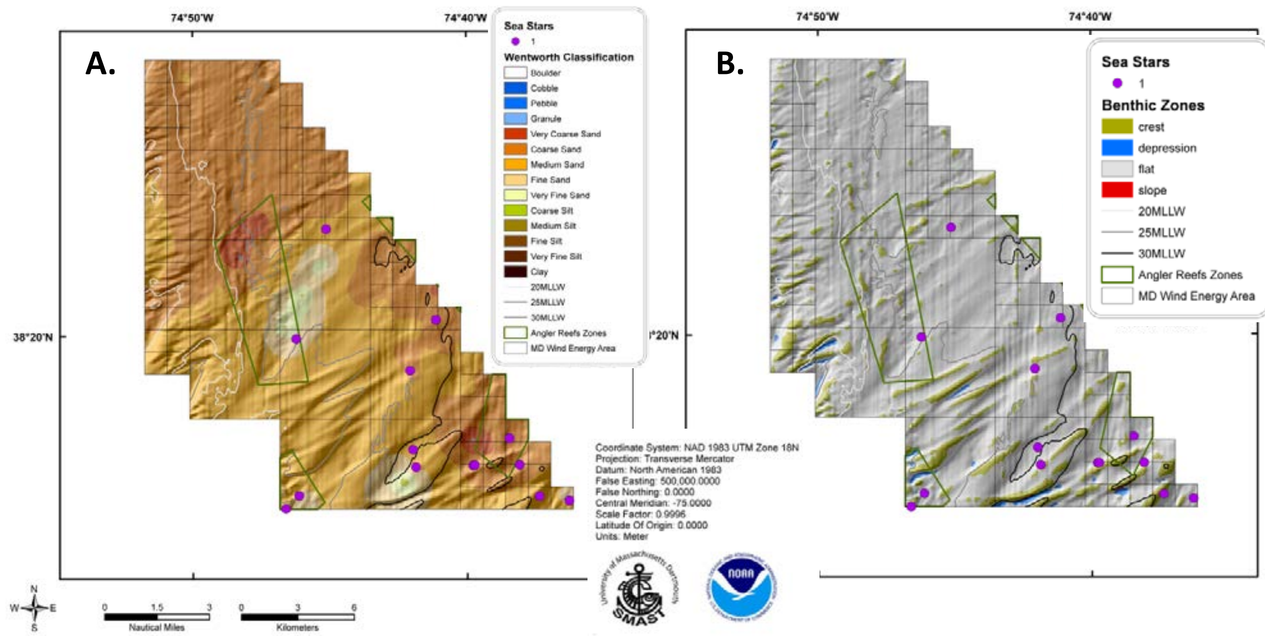


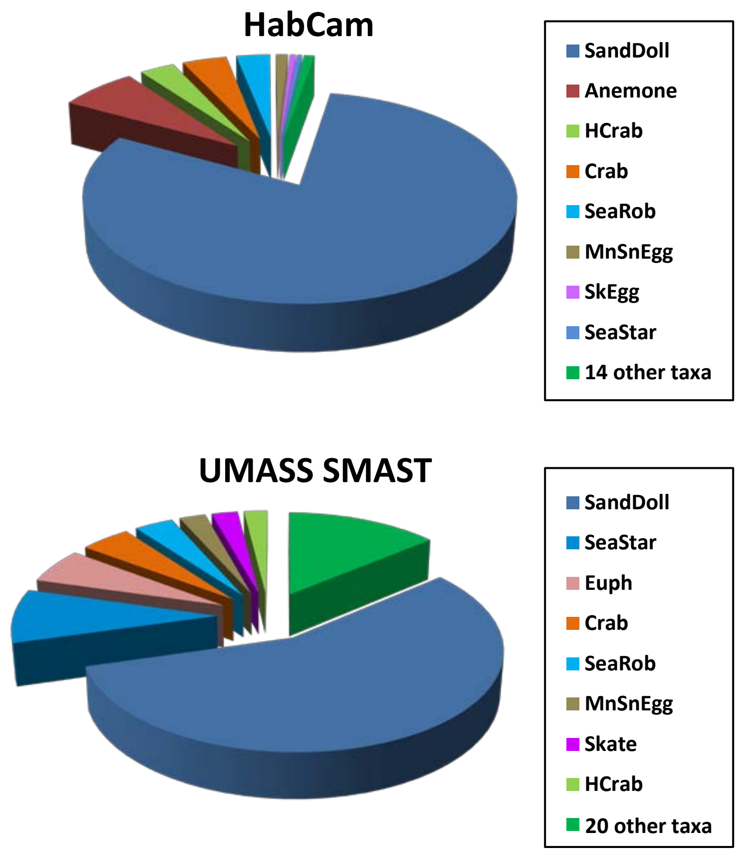
Figure 2-39. Sea star (*Asterias* sp.) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

A total of 22 jellyfish and two ctenophores were recorded in the MD WEA. These occurrences were not mapped as these gelatinous forms, although photographed near the bottom, are essentially planktonic, not benthic fauna.

2.2.4.3 UMASS-SMAST Demersal and Benthic Epifauna and Comparison of Methods

The SMAST survey of the MD WEA distinguished and enumerated 28 taxa of epifauna. Methods for use of the SMAST camera pyramid and extraction and manipulation of biotic data from images are detailed in Appendix MD-1 . Estimates of areal densities of benthic/demersal organism and plots of presence/absence are also provided. As with the HabCam image analysis, sand dollars dominated numerically and sea robins were the most abundant fish. However, the proportions and the list of major taxa differ somewhat between surveys (Fig. 2-40). Note the resemblance to the beam trawl catch (Fig. 2-27 B).

A.



B.

Figure 2-40. Comparison of proportions of epifauna by visual methods: A. HabCam, and B. SMAST surveys. Abbreviations: SandDoll – sand dollars, HCrab – hermit crabs, SeaRob – sea robins, MnSnEgg – moon snail egg cases, SkEgg – skate egg cases, SeaStar – sea stars, Euph – euphausiids.

Comparison of the distributions of organisms within the WEA plotted from HabCam and the SMAST results demonstrated both similarities and differences. The common sand dollar (*Echinarachnius parma*) was the most abundant and widespread species in both surveys and plots of its distribution (Fig. 2-41) serve to provide a comparison of methods for species with limited mobility. It is clear in both cases that this is a very widespread species. Although there is not clear agreement on its presence or absence on a block-by-block or sub block-by-sub block basis, it is clear that sand dollars are less prevalent or abundant in the northern part of the WEA and especially along the western boundary than in the south or east.

Plots for sea robin (*Prionotus* spp.), the most abundant fish (Fig. 2-42), provide a comparison of distributions for a more mobile taxon. In this the species is again widespread, but there is little resemblance between the distribution patterns displayed by the two methods, except perhaps that here again, there is little occurrence of this taxon in the western-most sub-blocks of the WEA.

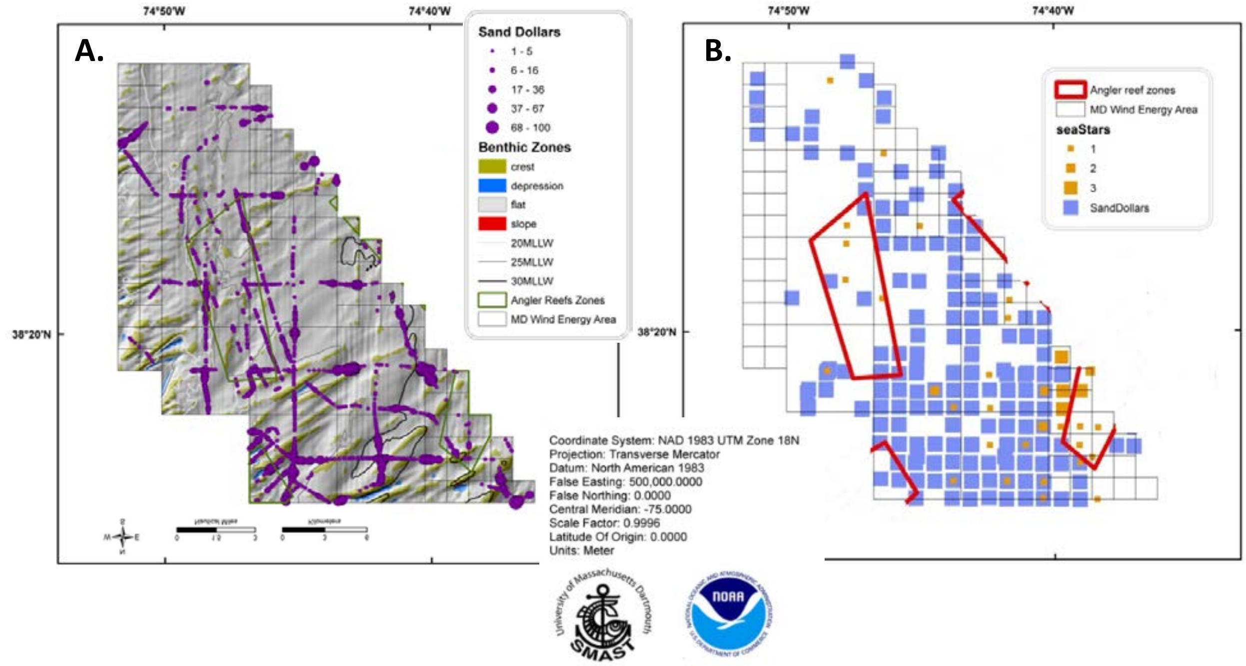


Figure 2-41. Comparative plots of sand dollar distribution in the MD WEA: based on data from A. HabCam IV (left, from Fig. 2-37 B), and from B. the UMASS-SMAST camera pyramid (Appendix MD-1, Fig. 16).

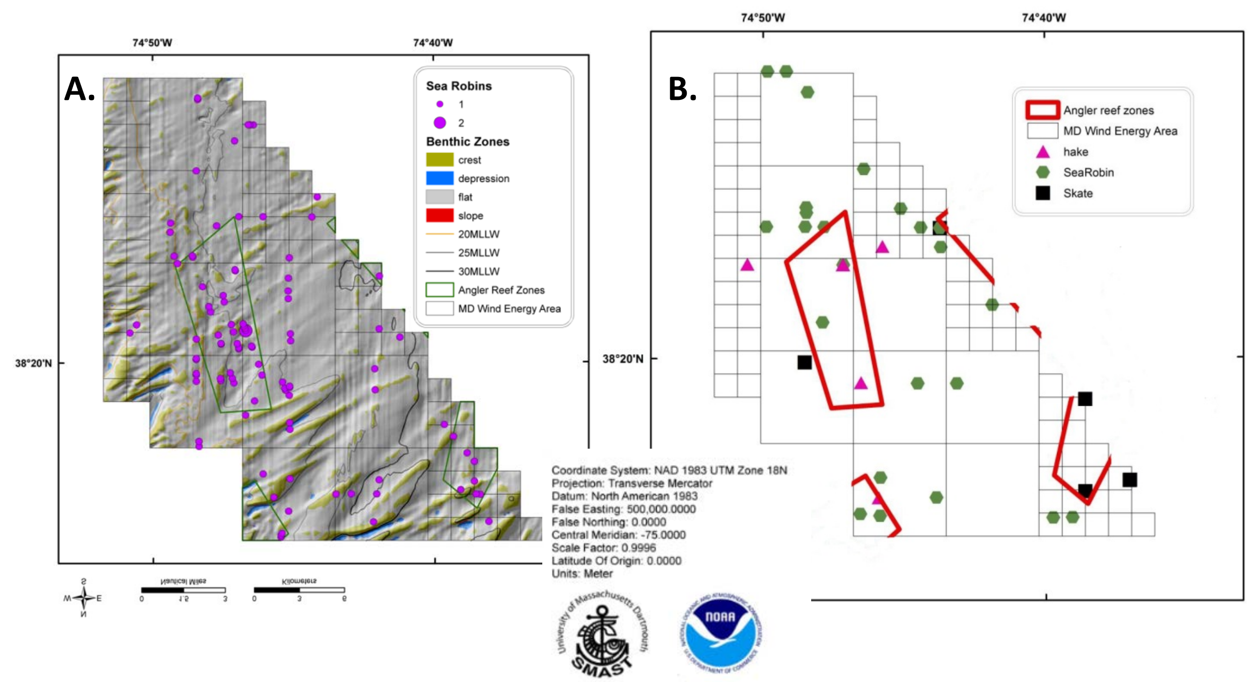


Figure 2-42. Comparative plots of sea robin distribution in the MD WEA based on data from A. HabCam IV (from Fig. 2-28 B), and from B. the UMASS-SMAST camera pyramid (Appendix MD-1, Fig. 27).

In the interest of placing these and other taxon-by-taxon comparisons on quantitative bases, the numbers of nine composite taxa were rendered into both occurrence along linear track lines (numbers per kilometer) and areal density (numbers per hectare)(Table 2-10).

Table 2-10. Comparative summaries of visual detections of demersal fauna and benthic epifauna for the MD WEA for HabCam and SMAST pyramid. All fishes and the major invertebrate taxa are included. Observations are recorded both in terms of individuals per linear unit linear transect (Linear Occurrence) and individuals per unit area (Areal Density). For this purpose HabCam image fields were assumed to be 1 m^2 = 1 X 1 m and the SMAST large camera fields (3.2 m^2 = 1.79 X 1.79 m) were used to determine metrics for the entire WEA. SMAST values are based exclusively on large camera observations from the WEA only. Some taxa have been combined in order to produce comparable lists for the two methods.

Taxon	HabCam		SMAST	
	Linear Occurrence no./km	Areal Density no./ha	Linear Occurrence no./km	Areal Density no./ha
Sea Robins	13.9	139	10.5	59
Skates	0.4	4	2.2	12
Hakes	0.3	3	2.2	12
Flounders	0.3	3	0.9	5
other fish	1.5	15	6.1	34
TOTAL FISH	16.4	164	21.9	122
Sand Dollars	373.8	3738	189.1	1057
Sea Stars	2.0	20	20.5	115
Crabs	18.2	182	6.1	34
Hermit Crabs	14.3	143	4.4	24
TOTAL INVERT	408.4	4084	220.1	1230
METRICS	7.13 km	0.713 ha	2.29 km	0.410 ha

The two methods clearly resulted in some large differences in abundance estimates for the WEA as a whole, particularly in the case of invertebrates, but at least agree in terms of orders of magnitude for the composite taxa, thus providing a basis for comparison with hydroacoustic detection.

2.2.4.4 Hydroacoustic Fish Detection

A plot of acoustic target detections within the WEA (Fig. 2-43) during a transects on July 24, 2013 shows a small number of hits within the angler reef zones in the center and southeast corner of the WEA, but few outside those zones. The total of individual acoustic hits over approximately 34 km of transit lines within the WEA was 13 (thirteen), of which 7 were within the central angling reef area. All of the hits were recorded within 8 m of the bottom, suggesting demersal fish species. Ten were within 2 m of the bottom, where they might have been subject to bottom photography had HabCam or the SMAST pyramid been there. Larger numbers of hits (27) were recorded on July 28th in the 3.2 km transect through the angler reef on the southwestern margin of the WEA (Fig. 2-43), but only eight (8) of these were within 2 m of the bottom; the rest were scattered throughout the water column. Nevertheless, the apparent density of demersal fishes was nearly an order of magnitude greater in the 7/28 survey (2.49 fish/km) than in the 7/24 survey (0.30 fish/km) further north.

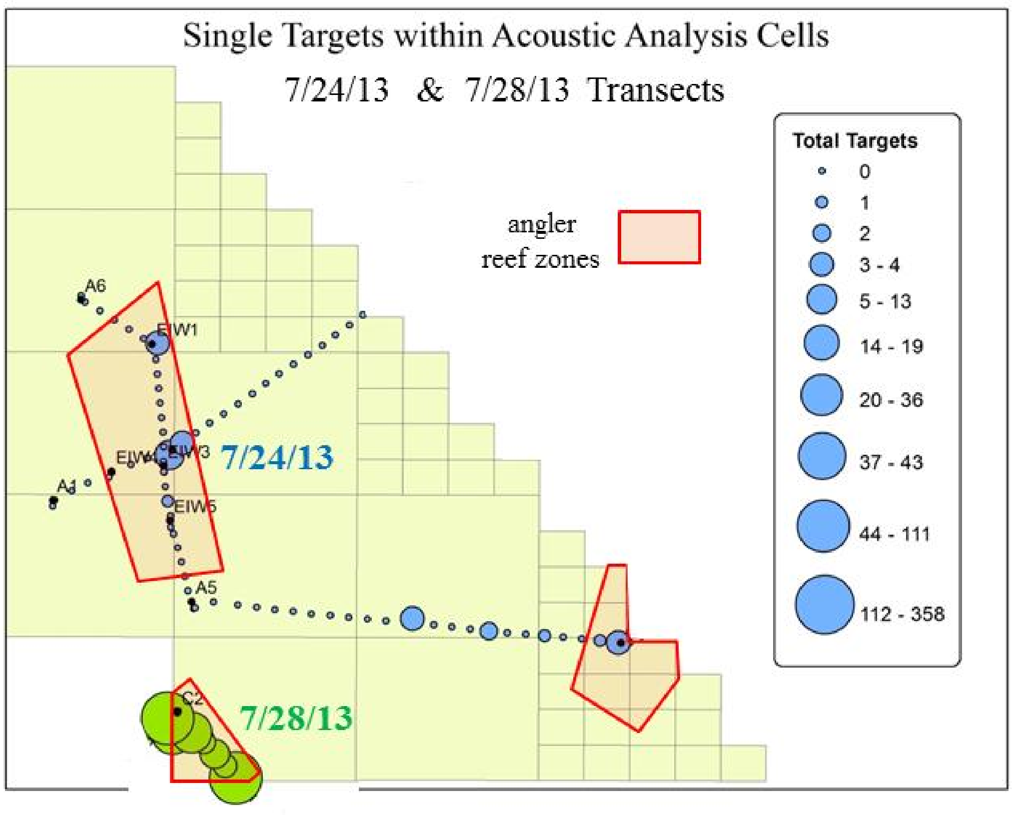


Figure 2-43. Acoustic targets detected during 7/24/13 and 7/28/13 transects on NOAA vessel *Resolute* in MD WEA. Red outlined areas show angler reef zones within the WEA. Two of these zones and the corresponding acoustic surveys also extend outside of the WEA (not shown).

This pattern was comparable to what was seen nearby during the same period. Approximately 143 km of additional acoustic transect were made outside the WEA at depths ranging 22-40 m in the vicinity (within 37 km) from July 24-28, 2013. The pattern of acoustic detections was similar to that in the WEA: either low near-bottom detection rates with nearly all detections within 2 m of the bottom as in most of the WEA, or higher near-bottom rates with much larger detection rates in the water column as in the SW corner angler reef zone.

2.2.4.5 Benthic Infauna (preliminary results)

Figure 2-44 summarizes the organisms captured in benthic grab samples from the NEFSC LMRCSC cruise aboard *Gordon Gunter* in 2013. Taxa are represented by broad category (worms, bivalves, amphipods, and other), displaying $\log_{10}$ mean and standard deviation of densities by station. Further information is provided in Appendices MD-7 & MD-8. Worms (largely oligochaete and polychaete annelids) were the numerical dominants in most cases and their numbers appeared to be responsible for most of the sample-to-sample variations in total numbers of organisms. The three stations with the highest numbers of organisms counted and largest numbers of taxa were stations B, M, and E (Fig. 2-44, Appendices MD-7 & MD-8). B and E were in adjacent lease blocks in the northern part of the MD WEA, and station M, which had the second highest overall number of individuals was located at the southeast corner of the MD WEA (Figures 2-3 and 2-5 B). These three stations had the most gravelly sediments from among the *Gordon Gunter* grab samples (mean phi < 0.177: Table 2-4). Among important commercial species, the prevalence of juvenile surf clams (*Spisula solidissima*) at all but two sites, juvenile sea scallops (*Placopecten magellanicus*) at two sites, and a single ocean quahog (*Arctica islandica*) at one site was noted (Appendix MD-8B).

2.3 Comparison of Methods and Integration of Results

2.3.1 Topographic Characterization

High resolution (2 m) bathymetry was essential in developing and providing analysis of topographic features in the MD WEA. In particular, capturing subtle features at scales of tens to hundreds of meters with terrain metrics (Fig. 2-10) demanded the broad, precise coverage provided by multibeam bathymetry. The features revealed were useful in defining benthic habitats and localizing distributions of some benthic fauna on scale similar to BOEM lease sub blocks.

Fine scale (centimeter) microtopographic features, e.g. sand ripples, were not accessible from multibeam data. They were, however evident in side scan sonar data from HabCam (not treated here) and in SMAST photos. They have proved important in suggesting the dynamics of bottom habitats, i.e. the degree of hydrographic re-working of bottom sediments (mobility). Sediment mobility has been shown to be an important characteristic for defining benthic habitats and the fauna that they support (Valentine et al. 2005). Visual detection of sand ripples, an important indicator of mobility, demands some means of recognizing three-dimensional structure. HabCam employed stereo pairs of photos with color separation suitable for viewing with 3-D glasses for this purpose. The UMASS pyramid relied on an angled photographic lighting scheme that allows bottom irregularities to cast obvious shadows. Viewing stereo images taken by HabCam could have provided this perspective through the use of 3-D images. Unfortunately, problems with processing photos precluded the use of that feature, as only one of each stereo pair of images suitable for viewing and without 3-D color separation was available. While a practiced viewer can recognize subtle shadows and linear windrows of shell or other materials in these HabCam images (Fig. 2-6), the quality of photo images were such that we did not feel that we could do this consistently for our photo annotation dataset. Therefore, microtopographic features were not recorded by us. The UMASS team was better able to recognize sand ripples (Appendix MD-1, Figs. 4, 17) and included them in their sediment classification scheme as a result.

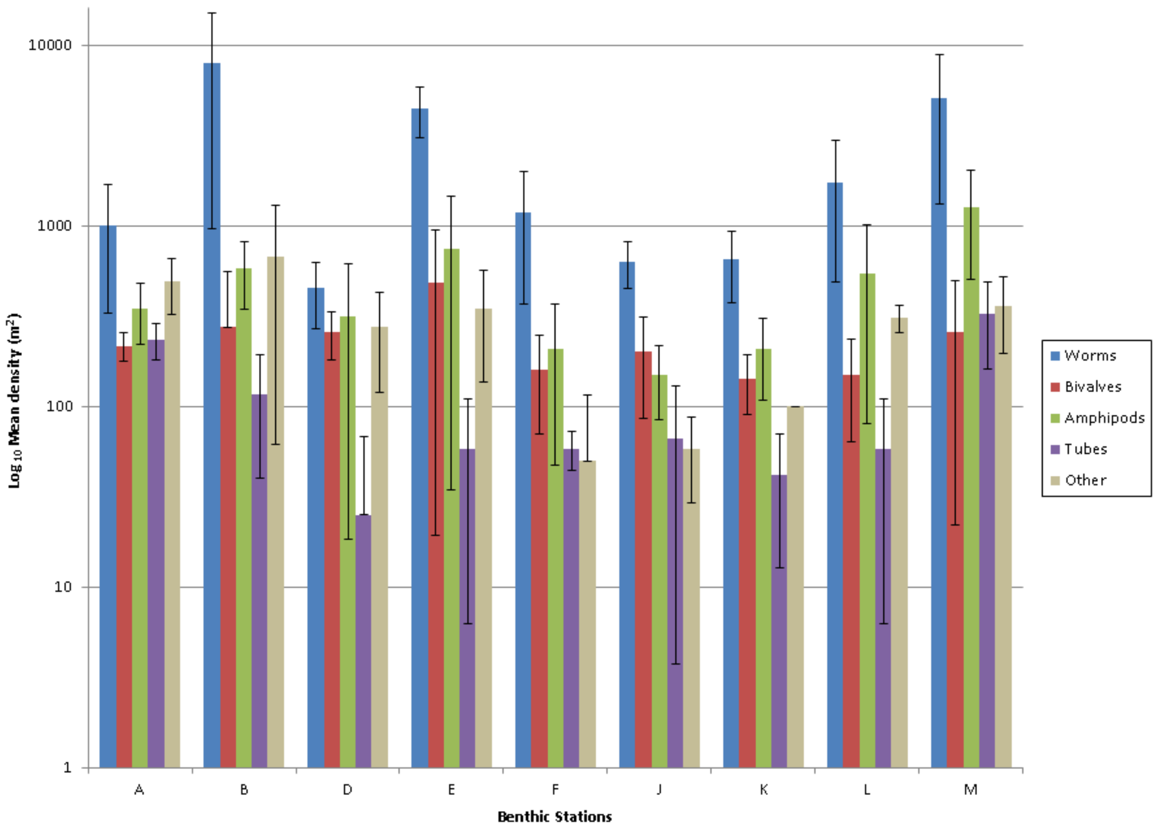


Figure 2-44. Log_{10} mean infaunal densities ± 1 standard deviation for benthic taxa. Samples were taken from nine stations aboard the NOAA ship *Gordon Gunter*, from July 4-9, 2013 in the MD WEA. Organisms were divided into five categories: worms, bivalves, amphipods, tubes, and others. Letter designations of stations refer to the lettered sites in Figs. 2-3 and 2-5 B. Source data: (NOAA 2013a).

2.3.2 Sediment Characterization

Sediment characterization in the MD WEA was dependent on point data with varying scales of coverage and degrees of precision (Table 2-1). This information was originally intended as ground-truth data for calibration of the full and continuous coverage to be provided by multibeam backscatter data. No backscatter data could be obtained from either NOS navigational mapping surveys or the CB&I acoustic survey performed under contract to the state of Maryland. Therefore the point data became the primary source for sediment information. Presentation depended upon gridded mapping of points (Figs.

2-5 C, 2-8) or interpolation (Section 2.2.5.3 above). Interpolation of data based on very different scales of sampling led to rather different results (Fig. 2-22). However, it is evident from these maps that gravelly sediments were prevalent in the northern half and eastern boundary of the WEA, and largely absent in the south and west. While agreeing in general, the maps disagree on the exact locations of gravel concentrations. HabCam results, derived from closely spaced (~30 m) photos, suggest variations on a small spatial scale (Fig. 2-18). Hence interpolated HabCam data are probably superior to the other point sources, but primarily along the narrow corridor around the vehicle path. More than a few meters away from that path, interpolations become more speculative.

Despite its more systematic coverage, the SMAST data points are more widely spaced (0.93 km), leaving the possibility of missing small scale anomalies that could represent important benthic habitats. Further, SMAST data analysis, as practiced, offered qualitative assessment of sediment types (presence-absence of types) as opposed the quantitative analysis of HabCam data, which provides percentage cover for each type of sediment component in each image, albeit without distinguishing between silt and sand. Presence-absence recording is responsible for the discrepancy in shell debris (or shell hash) evaluation between SMAST (100%: Appendix MD-1, Fig. 14) and HabCam (16%: Fig. 2-19). The SMAST team recorded all occurrences of shell debris in any amount while the HabCam team recorded the estimated degree of coverage by shell hash in each photo.

Sediment sample data, on the other hand, though very widely spaced in much of the WEA (Fig. 2-3), provided a precise quantitative definition of grain size distributions. Analysis of replicate samples at locations removed from one another by tens of meters again point to variations in sediment composition (Table 2-4) and possibly habitat type over those small spatial scales.

What all three sources (HabCam, SMAST, sediment sampling) indicate is that MD WEA benthic habitats are heavily dominated by mobile sandy bottoms. Some cobble was found in the angler's reef area in the middle of the WEA, partly as a result of more intensive coverage there since we knew it to be an angling area. Cobble was also detected by HabCam at one eastern site in the WEA and in the angler reef in the southwest corner (Fig. 2-20). SMAST also encountered cobble in two locations near the eastern boundary of the WEA (Fig. 2-21 C), not corresponding exactly to the HabCam locations. This suggests that more may be present in the coverage gaps, particularly along the eastern side of the WEA, where another angler reef area impinges. The value of cobble as hard-bottom habitat for invertebrates and fishes is conjectural; if it is dominated by relatively barren stones (Appendix MD-7, Fig. 10) with little colonization by sessile organisms (sponges, anemones, hydrozoans, bryozoans, etc.) it is probably of limited habitat value to other organisms. Barren surfaces often result from stony surfaces being subject to scouring and/or periodic burial by mobile sediments (Valentine et al. 2005).

2.3.3 Epifaunal Characterization

The results of characterization of epibenthic megafauna (including demersal fishes) are clearly very dependent on the assessment method. Large, fast moving (~4 kt. = 2 m/sec), otter trawls, with rollers (NEFSC Fall and Spring surveys) are the most efficient means for assessing large, fast-moving fish and squids, which include most species whose stocks are managed in the northeast (Appendix MD-4, MD-5). However they have some disadvantages. They are poor at catching the numerous smaller organisms (Appendix MD-6) that remain close to the bottom, as a comparison with beam trawl catch demonstrates (Fig. 2-26 C, D vs. 2-27 B). Although poor at catching large, fast swimmers, the slower (~2 kt. = 1 m/sec), flatter, smaller 2 m beam trawl is more efficient with small, slow bottom-dwellers. Due to the lengths of NEFSC survey otter trawl tracks (Fig. 2-26 A) these large trawls are not good at localizing the catch to habitat types that may span only a few meters, or even at localizing catches to lease sub-blocks. Again, beam trawl tracks lengths (Fig. 2-27 A) are closer to the scale of habitats as suggested by variations in bottom type. While they may be evenly distributed with regard to the large stratified random sampling scheme meant to assess widespread mobile fish stocks, the distribution of NEFSC otter trawl survey tracks within an area as small as the MD WEA can obviously be very skewed (Fig. 2-26 A). NEFSC bottom trawl surveys span 50 years and are seasonal, providing temporal depth to their catch data. Beam trawl surveys are one-time expeditions, which in this case, having been collected for another project four years before the start of this MD WEA investigation, matches neither the timing of the other data nor the footprint of the WEA. Nevertheless, this data provides at least a qualitative view against which to compare epifaunal data from other sources. Beam trawl data specifically taken within WEAs will be used more effectively in succeeding WEA studies.

Visual epifaunal data derived from HabCam and SMAST imagery is point data and thus has the distinct advantage of coming from precise points in space, time, and habitat. They have the disadvantages of poor visibility that does not allow precise species identification for many taxa, or renders some taxa cryptic, and the possibility that some organisms may have escaped from view by swimming over a meter above the bottom, or by fleeing the lights, noise, or pressure waves generated by the approaching camera vehicle. Specific problems with taxonomic identification to species have been previously mentioned (Sections 2.3.4.2 and 2.3.4.3 above).

The problem of cryptic species becomes obvious when comparing taxa lists from image analysis versus beam trawl catches (Table 2-9 versus Appendix MD-1, Table 3 and Appendix MD-6). Several important beam trawl catches were cryptic fauna in the sense that they were not evident with either camera system, whether due to small size, good camouflage, or partial burial: Nassa snails, sand shrimp, sea slugs, and gulf stream flounders were never seen, or at least never recognized. It is likely that longclaw hermit crabs (*Pagurus lonigicarpus*), which are small enough as adults to utilize Nassa snail shells, were not observed photographically, either: only their larger and less abundant congeners *P. acadianus* and *P. pollicarus* that commonly use the larger and more conspicuous moon snail shells (Appendix MD-7, Fig. 18). While not important in terms of managed fisheries, their sheer abundance suggests that these cryptic taxa may be important ecologically.

The small number of mobile epibenthic megafauna observed, particularly fishes, raised questions about the ability of camera vehicles to detect them. The *Resolute* acoustic survey results (Section 2.4.5) offered a comparison to address the issue of fishes that may escape visual detection either by swimming well above the bottom or by fleeing. Dividing the numbers of near-bottom (within 2 m of bottom) acoustic "hits" within the WEA by the lengths of the transects, generates linear detection rates for near-bottom fish ranging from 0.30 (7/24/13 transect) to 2.49 fish/km (7/28/13 transect). Limitations of acoustic detection, especially in near-bottom circumstances, dictate this at best represents a minimal estimate of actual fish density, but it at least provides a range against which to compare other estimates within and outside of the WEA. Nine acoustic transect legs outside the WEA (143 km total, depth range 22-40 m, within 37 km of the WEA, and taken with the same sonar equipment during daylight hours from July 24-28, 2013) provided a similar range of near-bottom detection rates: 0.35 to 2.10 fish/km. As mentioned in Section 2.4.5, the patterns of distribution were similar to those in the WEA: low total detection rates with nearly all "hits" near the bottom or much higher rates that include higher rates near the bottom, but also high rates throughout the water column.

In order to normalize visual data for comparison with acoustic data, the assumption was made that the fields of view for useable photo images averaged 1 m X 1 m (= 1 m^2 area) for HabCamIV. The actual sizes of image fields varied with the altitude of HabCam from the bottom. Linear occurrence values were then based upon each photo representing 1 m of trackline. Because the altitude of the SMAST pyramid was fixed, the areas of its camera fields were constant. The large camera field for that vehicle (3.2 m^2) was assumed to be square, yielding a trackline value of 1.79 m (= $\sqrt{3.2\ m^2}$). The results of calculations for fishes and major invertebrate taxa are presented in Table 2-8.

The linear occurrence estimates for all near-bottom fish of 16.4 and 21.9 fish/km from HabCam and SMAST, respectively (Table 2-9), are higher by more than an order of magnitude than the range of near-bottom values generated by the acoustic transects (0.30 to 2.49 fish/km). We assume that inability of acoustic methods to detect fish actually on the bottom (acoustic dead zone phenomenon) is the cause of this discrepency. In any case, acoustic detection as performed can not be used as a ground-truth method for visual detection for this study, although it does suggest an interesting relationship between overall density of fish near the bottom and higher up in the water column.

Comparison between HabCam and SMAST visual results (Table 2-9) provides values for the two methods that are similar in magnitude, but not identical. This might be expected for extrapolation from methods that actually surveyed very small fractions of the 32,256 hectares (79,707 acres) of heterogeneous MD WEA: 0.713 ha (0.0022%) in the case of HabCam and 0.410 ha (0.0013%) in the case of the SMAST pyramid (Table 2-9) based on markedly different sampling schemes.

By far the most numerous fish were unmanaged sea robins, which occurred in all habitat zones, but most prominently within the angler reef zone near the center of the WEA. No fishes normally associated with structured hard bottom habitats (e.g. black sea bass, scup, tautog) were identified by either the HabCam or SMAST pyramid analyst teams, again suggesting that there were few, if any hard bottom patches within the WEA. The acoustic data also suggested few such fish. In known areas of black sea bass habitat outside the WEA to the south, large numbers of fish were detected during the daytime both in the water column and near the bottom, although those fish were not identified. Black sea bass are well known to swim up into the water column to forage during daylight hours, and we susptect that that is the phenomenon that we were recording in the vicinity of the known black sea bass reef habitats. Indeed, the pattern seen where an angler reef impinges on block 6825 in the southwest corner of the WEA (Fig. 2-39) with relatively large numbers of fish both in the near-bottom region and up in the water column was very similar to the patterns seen over the black sea bass reefs farther south where fish were photographed. We did not see this pattern at all in the centeral part of the WEA (Fig. 2-39), suggesting no habitat in use by these hard-bottom seeking fish, probably because no suitable habitat was available.

In comparing the photographic results from HabCam and the SMAST pyramid (Table 2-9) with NEFSC survey fall catch data (Appendix MD-4), one is struck by the absence from both visual records of the three species that accounted for 61% of the catch during ten years of fall surveys (essentially late summer fauna) in the WEA. The three species of sciaenids (drum family): Atlantic croaker, spot, and weakfish, went entirely undetected while sea robins (*P. carolinus* + *P. evolans*), a distant fourth-place contender accounting for only 9% of the 10-year catch (Appendix MD-4), were by far the most numerous fish detected by both visual methods (Table 2-9). Both visual methods also reported a small number of unidentified (bony) fish, which could have included sciaenids, but far fewer of those were seen than sea robins. Three non-exclusive explanations are possible: 1. these three sciaenid species were averse to the disturbance (light, noise, pressure waves) caused by both camera vehicles and nearly all escaped before they could be photographed, 2. they were there but not on the bottom, and/or 3. they were simply not present expect perhaps in small numbers as unidentified fish. We do not have the data to make a definitive choice among these explanations. However, we do suspect that #3 is the case: sciaenids were simply not present (or present only in very small numbers) in the summer of 2013.

There are several reasons why we think that sciaenids were simply not present. First, a single trawl made by the NEFSC fall survey in September, 2013 caught only a small number of croakers, one spot, and no weakfish at all. Trawls in other years caught either small numbers (usually 0-10 individuals total) of all three or large catches of all three (hundreds to thousands). What this suggests is that these fish generally aggregate in schools. What is even more telling is that when the numbers of individuals of each species in fall trawls from the vicinity of the WEA (n=17) is regressed against the total number of sciaenids (all three species) in the same trawls, there are strong linear correlations: r^2 = 0.88, 0.74, and 0.91 respectively for numbers of Atlantic croaker, spot, and weakfish versus total sciaenids. In other words, the three species appear to be schooling together. Catches consist of either large to very large numbers of all three species or all three are missing or nearly so. By contrast, the regression of total sea robins (*P. carolinus* + *P. evolans*) against total sciaenids yields r^2 = 0.02: virtually no relationship. Sciaenids are essentially either all present or all absent. The poor trawl catch of sciaenids within the WEA in 2013 combined with the fact that despite very different modes of operation and hence disturbance generation, neither camera vehicle imaged them, and that whole stock catches of all three species along the entire Atlantic coast declined over the period 2003 – 2013 (ASMFC 2014a, 2014b, 2014c) all suggest that perhaps these fishes simply were not present at least where we looked in July, 2013: either absent entirely or in patchy schools that we missed using visual methods.

2.4 Integration of Benthic Habitat Analysis for the MD WEA

The Maryland WEA is a region of relatively flat that slopes gently from west to east whose sediments are heavily dominated by sandy substrates. A subtle northeast-southwest trending ridge and swale topography, most evident in the southern half of the WEA (blocks 6775, 6776, 6777, 6825, 6826 & 6827: Figs. 2-4 and 2-5) suggests high mobility of sediments, at least in the past. Shorter and less prominent ridges with similar orientation occur in the sub-blocks of 6623, 6673, 6723, and 6773 along the western border of the WEA. The widespread presence of minor amounts of gravel and especially of blackened oyster shells suggests reworking of pre-existing sediments at some time in the past and perhaps ongoing. The pervasiveness of sand ripples (Appendix MD-1, Fig. 5) and scarcity of silt-clay (mud: Fig. 2-7) confirms that much of this sandy sediment remains at least moderately mobile. While gravel is a common minor component of much of the sandy sediments, especially in the northern part of the WEA (Fig. 2-9), more stable gravel-dominated and cobble bottoms appeared rarely, and no boulders or rock outcrops were found within the WEA (Appendix MD-1, Fig. 12). This does not mean that there are none; without complete coverage by acoustic backscatter, patches of hard bottom can not be entirely ruled out.

East of the 20 m depth contour that cuts roughly NNW to SSE through blocks 6623, 6674 and 6724, the sand wave topography in the northern two thirds of the WEA becomes flatter and less prominent, such that ridge crest benthic zones as defined by the BTM tool become discontinuous rather than linear. The flattening continues into the southern portion of block 6675, nearly all of 6725, and the northwest third of 6775, where although there are still faint hints of sand waves, no crests are detected by the BTM tool. This latter area, just east of the angler zone in the center of the WEA, is the flattest part of the WEA. . Block 6725 is also the block where the highest mud content was predicted for the WEA (Fig. 2-12).

As sediments throughout the WEA appear to be sand-dominated and there is no evidence of strong spatial variation in physical oceanographic conditions (i.e. no strong fronts or horizontal gradients), topography appears to be the most obvious basis upon which to base habitat distinctions (Fig. 2-45). Currents, however, appear to be an important factor in the structure of the bottom. Comparison of substrate type distribution with other areas of the northeast shelf also extensively characterized by the UMASS team over multiple years of sea scallop surveys shows the MD WEA resembled Georges Bank most closely and paradoxically, the adjacent mid-Atlantic mid shelf region least closely (Appendix MD-1, Table 5). The higher prevalence of sand ripples and lower prevalence of silt in the MD WEA as compared with the adjacent shelf was taken to indicate a bottom more influenced by strong physical forces, as Georges Bank is known to be.

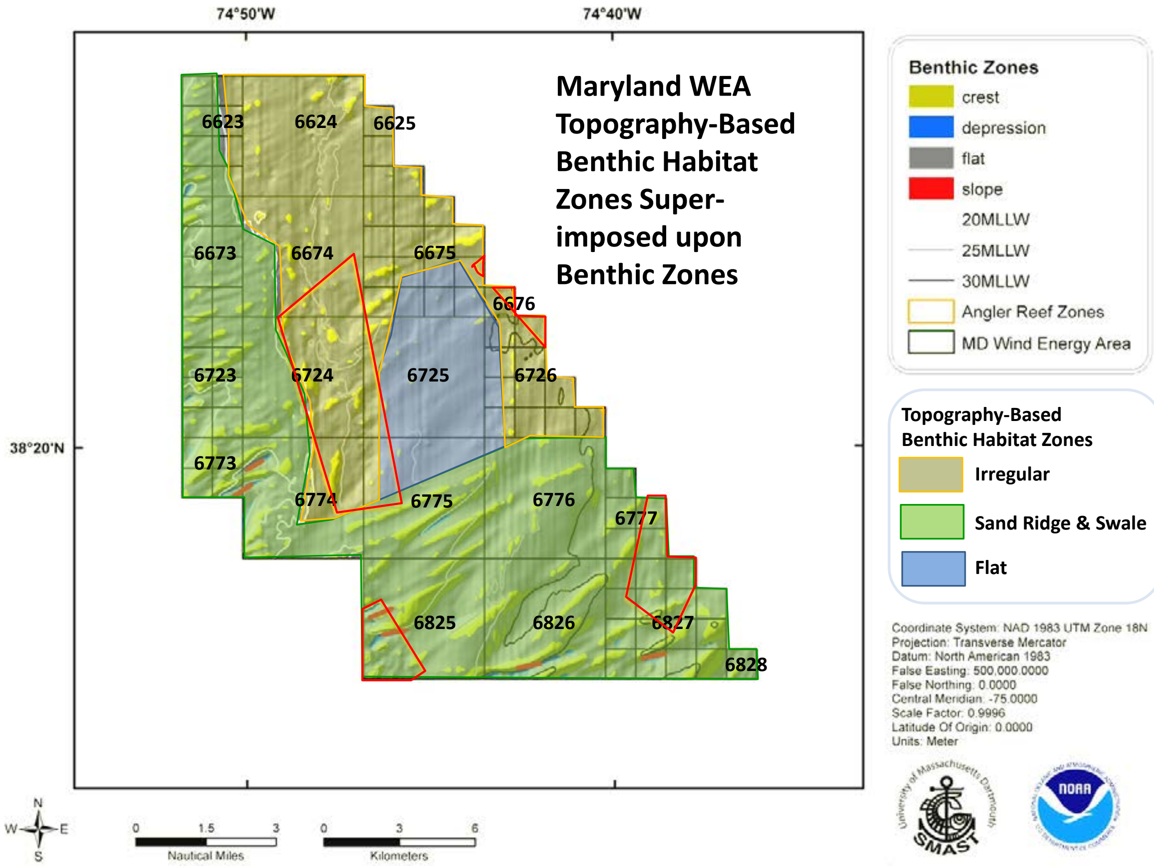


Figure 2-45. Topography-based benthic habitat zones superimposed upon benthic zones. Red lines indicate angler reef zones. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

Taxa composition among the epifauna in these regions appears to be similar, though there is some indication of preference of some taxa for some areas over others. While sand dollars were very widespread, they were more numerous in ridge and swale areas and less so in the irregular topography and gravelly sediments of the north and in the flat topographic area in the central part of the WEA. Rock, unidentified, and hermit crabs and solitary anemones were more numerous in the irregular topography areas and in the ridge and swale area in the south only. It is thought that most if not all the solitary anemones seen were ceriathids (burrowing anemones) that do not require attachment to hard substrates. Sponges and sea whips, which do require hard substrate for attachment, were quite rare. Most other invertebrates were not numerous enough to comment on their distributions.

Visually identified fish did not specifically include any managed species or ecologically important forage species, although there may have been some individuals among the unidentified fishes and the aggregated flounders, skates, and hakes. Historic NEFSC bottom trawl survey catch data was a much better indicator of the presence of those (Appendices MD-4 and MD-5**).**

2.5 CMECS Habitat Classification

The classification of MD WEA habitats according to the Coastal and Marine Ecological Classification System (CMECS) template (FGDC 2012) is as follows:

Biogeographic Setting (BS):
Realm: Temperate North Atlantic
Province: Warm Temperate Northwest Atlantic
Ecoregion: Virginian

Aquatic Setting (AS):
System: Marine
Subsystem: Marine Nearshore to Offshore[1]
Tidal Zone: Marine Nearshore Subtidal to Offshore Subtidal[1]

Water Column Component (WCC):
Water Column Layer: Marine Nearshore Lower Water Column to Offshore Subtidal Water Column[1]
Salinity Regime: Euhaline Water
Temperature Regime: Cold Water to Warm Water (seasonal)

Geoform Component (GC):
Tectonic Setting: Passive Continental Margin
Physiographic Setting: Continental/Island Shelf
Geoform Origin: Geologic
Level 1 Geoform: Sediment Wave Field[2]
Level 2 Geoform: Ripples

Substrate Component (SC):
Substrate Origin: Geologic Substrate
Substrate Class: Unconsolidated Mineral Substrate
Substrate Subclass: Coarse to Fine Unconsolidated Substrate
Substrate Group: Patchy, Mobile Gravel Mixes to Muddy Sand[3]
Co-occurring Element: Patchy Shell Hash

Biotic Component (BC):
Biotic Setting: Benthic Biota
Biotic Class: Faunal Bed
Biotic Subclass: Soft Sediment Fauna
Biotic Group: Clam Bed[4]
Co-occurring Element: Patchy Sand Dollar Bed

Notes on CMECS classifications:

[1] Nearshore to Offshore distinctions are by definition (< or > 30 m depth) only; no changes in habitat were evident across this depth transition.

[2] The Rippled Sediment Wave Field Geoform exhibits 3 different configurations: Ridges and Swales (fully formed), Irregular (partially obscured), and Flat (almost completely obscured): Fig. 2-45.

[3] Patchiness was evident over scales of tens of meters in some cases and mobility was judged based upon topographic evidence (Sediment Wave Field and Ripples Geoforms).

[4] Clam Bed designation is based on presence of bivalves in all infaunal samples at densities averaging over 100/m^2 (Fig. 2-44) and the presence of shell hash in the vast majority of images.

2.6 Essential Fish Habitat

Essential Fish Habitat (EFH) is defined as all of the locations that managed marine species inhabit, whether to spawn, breed, feed, or grow to maturity. Unlike the CMECS classification, the emphasis in EFH is on the inhabiting species rather than on the surroundings. Hence it is defined on a species-by-species basis rather than on the basis of geographic boundaries for physical and biological characteristics. The MD WEA is considered EFH for all of managed species within its boundaries, i.e. all of the federally managed (**) species in Appendices MD-4 and MD-5 plus any additional managed species that may have been caught there before or after the 10-year period of that data collection. As there were thirteen federally managed stocks represented in the 10-year catch, there are at least thirteen separate spatially overlapping EFH units to consider rather than the three spatially exclusive units with multiple species as defined in the CMECS analysis in section 2.6. Ten of these thirteen stocks represent demersal species closely associated with bottom habitats (little, winter, and clearnose skates, windowpane and summer flounders, silver and red hakes, black sea bass, scup, and monkfish). To these can be added at least juveniles of three federally managed infaunal bivalves (surf clam, sea scallop, and ocean quahog: Appendix MD-8B), bringing the total to thirteen stocks. The full extents of EFH for these and other species can be found with the NOAA Office of Habitat Conservation website (NOAA, NMFS Habitat Conservation 2014).

Perhaps the most important question with regard to EFH species is to ask which of these is likely to be affected by any habitat disruption or change associated with establishment, operation, and decommissioning of wind power installations. Most of the managed species are relevant to this report, as they have benthic or demersal life stages and are therefore associated with benthic habitats. However, not all are equally vulnerable to habitat disturbance. The most obvious vulnerabilities are for species with strong affinities to benthic habitats found in the WEA, particularly if those habitats are relatively rare. As mentioned in Section 1.0, this particularly applies to the structured hard-bottom habitats sought as shelter habitats by black sea bass. Little evidence was found of such habitats in the MD WEA, although their presence cannot be ruled out entirely. Another concern could be sandy bottom habitats for egg deposition by longfin squid, little, clearnose, and winter skates. Unfortunately, little is known about the habitat conditions favored by these species for egg deposition or even the geographic distribution of egg-deposition by them. For these and most other demersal species the WEA represents feeding habitat. As the bottom is largely a mobile sandy regime, its benthic food resources are likely to recover quickly from disturbances due to construction, vessel traffic, and decommissioning.

New hard substrate created as a result of establishment of wind energy facilities may have a small positive value by increase the amount of available hard substrate for colonization by hard bottom fauna, but the effect should be small for fishes. Hard-bottom associated fishes like black sea bass and scup seek habitats with complex shapes for shelter rather than to provide food; simple support structures with sheer faces are not likely to provide much shelter.

3 Massachusetts Wind Energy Area (MA WEA)

3.1 Location, size, and subdivision

The Massachusetts WEA lies on the Southern New England shelf in a band between approximately 12 and 40 nautical miles south of the Massachusetts coast from Buzzards Bay and Nantucket (Figure 3-1). It consists of 117 full lease blocks plus 216 sub-blocks (Figure 3-2). Water depths in the MA WEA range 35 to 65 m, with an average of approximately 50 m, and it covers approximately 742,978 acres of seafloor (BOEM 2014b). The MA WEA has been divided into four lease areas: 187,523 acres (~25%) lie in the westernmost lease area (OCS-A-0500), 166,866 acres (~23%) in the west-central lease area (OCS-A-0501), 248,015 acres (~33%) in the east-central lease area (OCS-A-0502), and 140,554 acres (~19%) in the easternmost lease area (OCS-A-0503). Figure 3-2 provides the numbering for all blocks in the WEA. This section provides data and analysis for the entire WEA (all four lease areas) as a single unit.

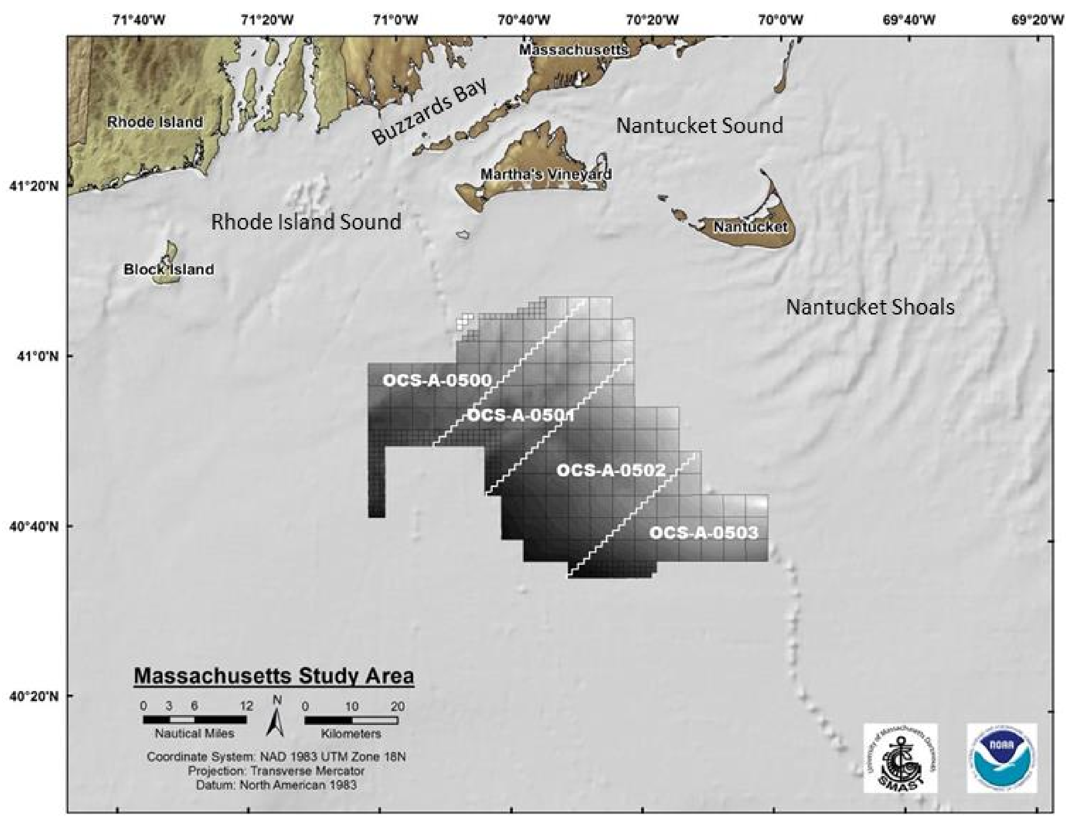


Figure 3-1. Map of Massachusetts study area. Source data:(BOEM 2016, 2017, NOAA NCEI 2017).

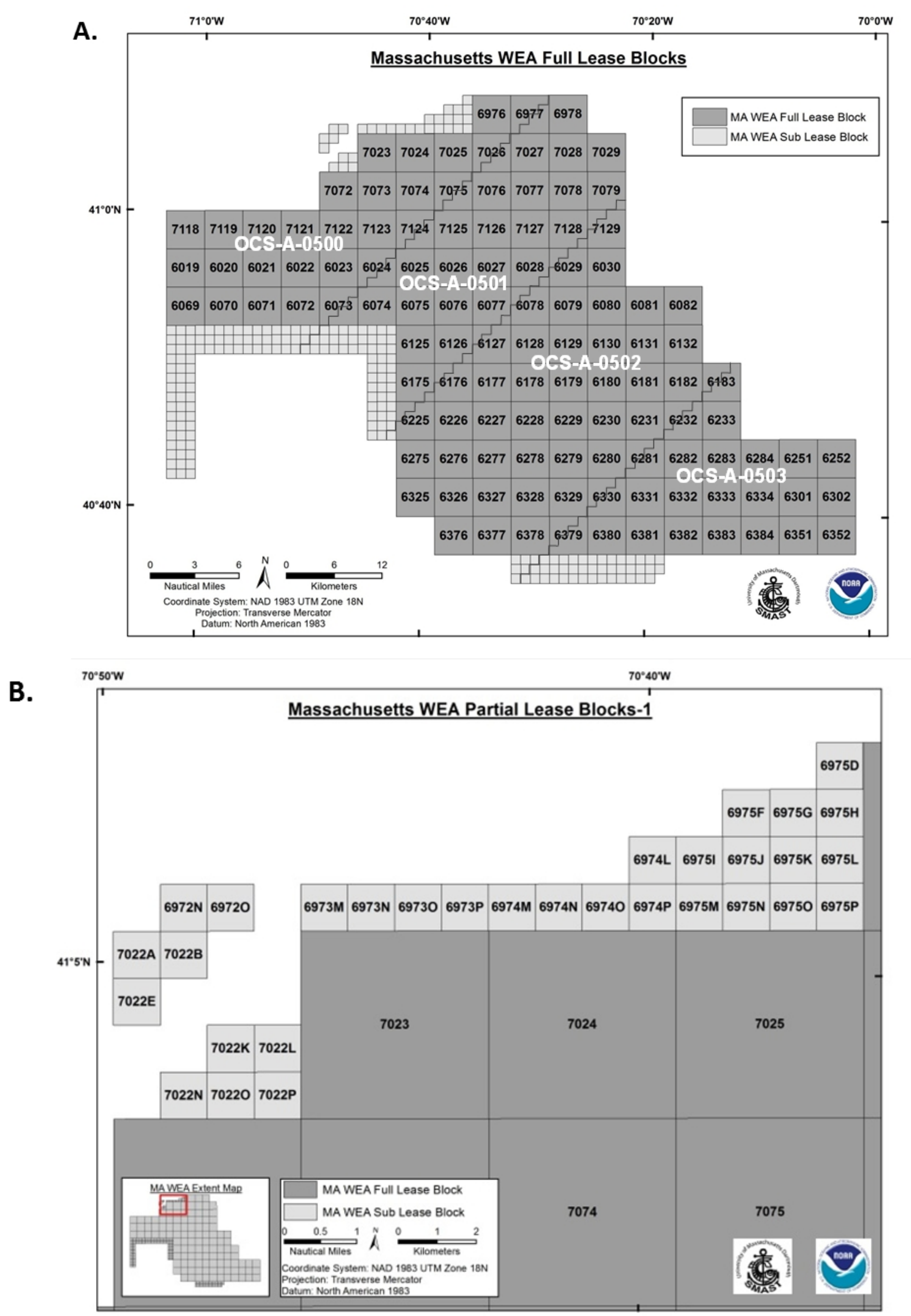
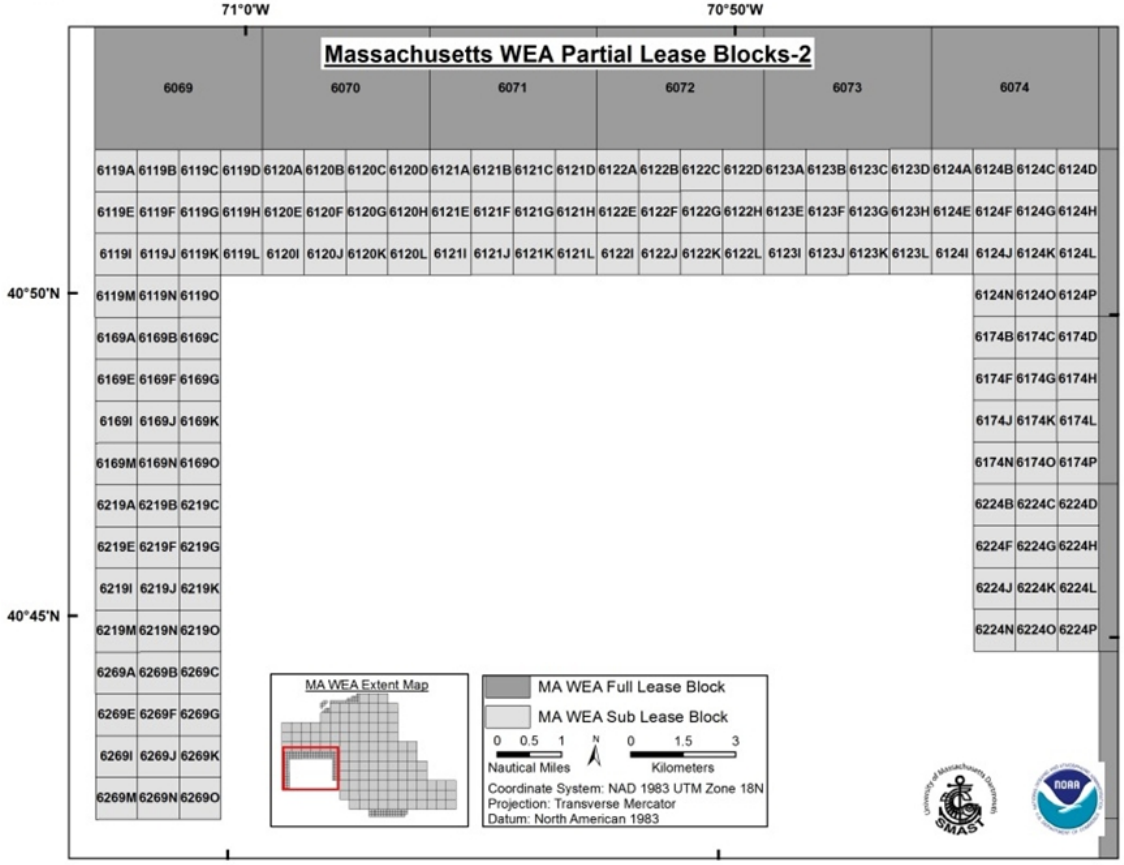


Figure 3-2. Numbered lease blocks (A.) and sub-blocks (B.-D.) included in the MA WEA (source data BOEM 2016, 2017).

C.



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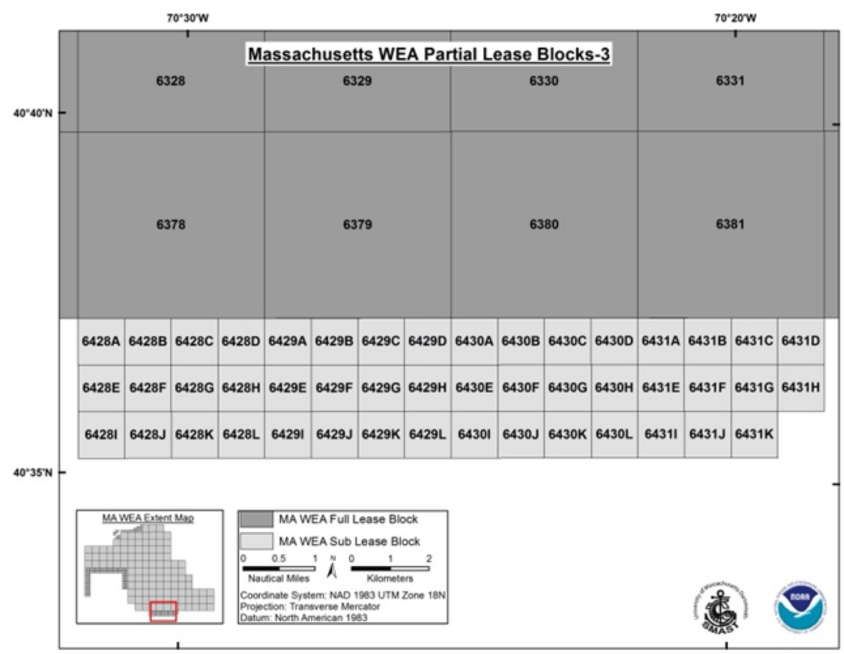

Figure 3-2. (continued) Numbered lease blocks (A.) and sub-blocks (B.-D.) included in the MA WEA (source data BOEM 2016, 2017).

3.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

3.2.1 Bathymetry

Figure 3-3 shows that the MA WEA bathymetry is relatively simple. It is essentially a flat bottom, sloping gently away from the shoreline towards the shelf edge. The depth of water increases 20 m over a distance of about 24 – 36 km, giving values in the range of 0.03 – 0.05 degrees for the general seaward slope of the bottom.

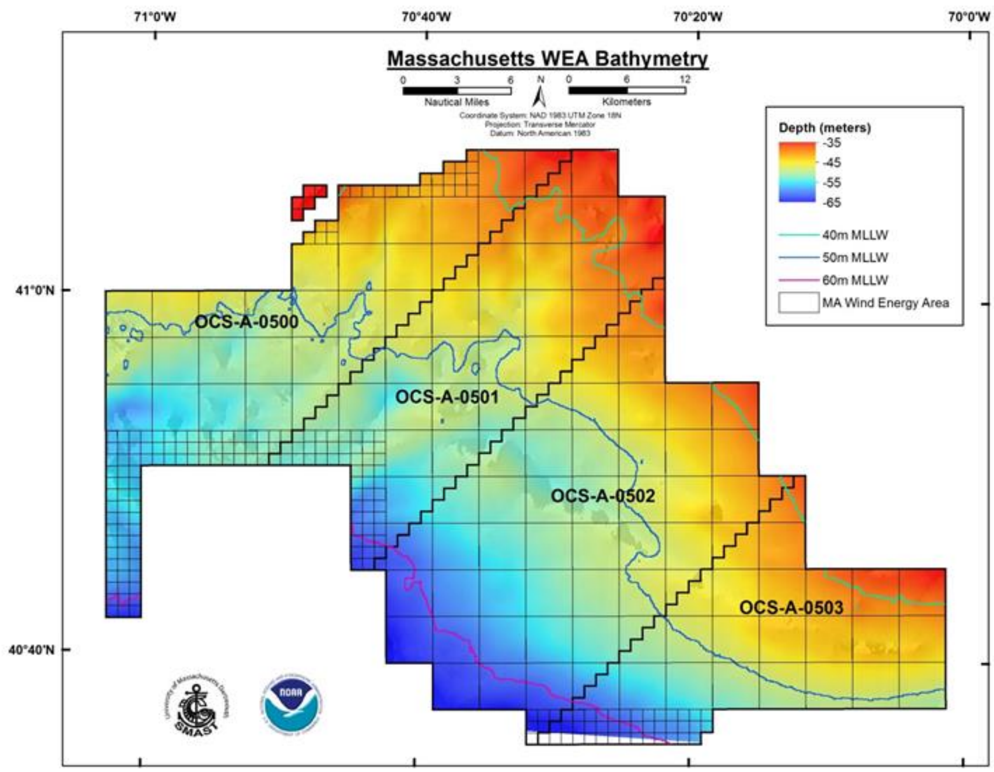

Figure 3-3. Bathymetry (3 arc-second horizontal resolution) with isobaths contours in the MA WEA. Source data: (BOEM 2017, NOAA NCEI 2017).

Close inspection of irregularities in contour lines and subtle depressions in Figure 3-3 suggests a series of branching channels eroded into the surface, possibly created by glacial drainage during lower stands of sea level (Figure 3-4). These features cross lease areas OCS-A-0500, -0501, and -0502. While such topographic features are subtle, their presence may be reflected in the distribution of surface and/or subsurface sediments and/or of organisms. The orientation of these in wider view (Ruddock 2010, Figure 1) suggests that these channels represent tributaries that fed the river that carved the Block Island Shelf Valley across the shelf to the southwest during the last low stand of sea level.

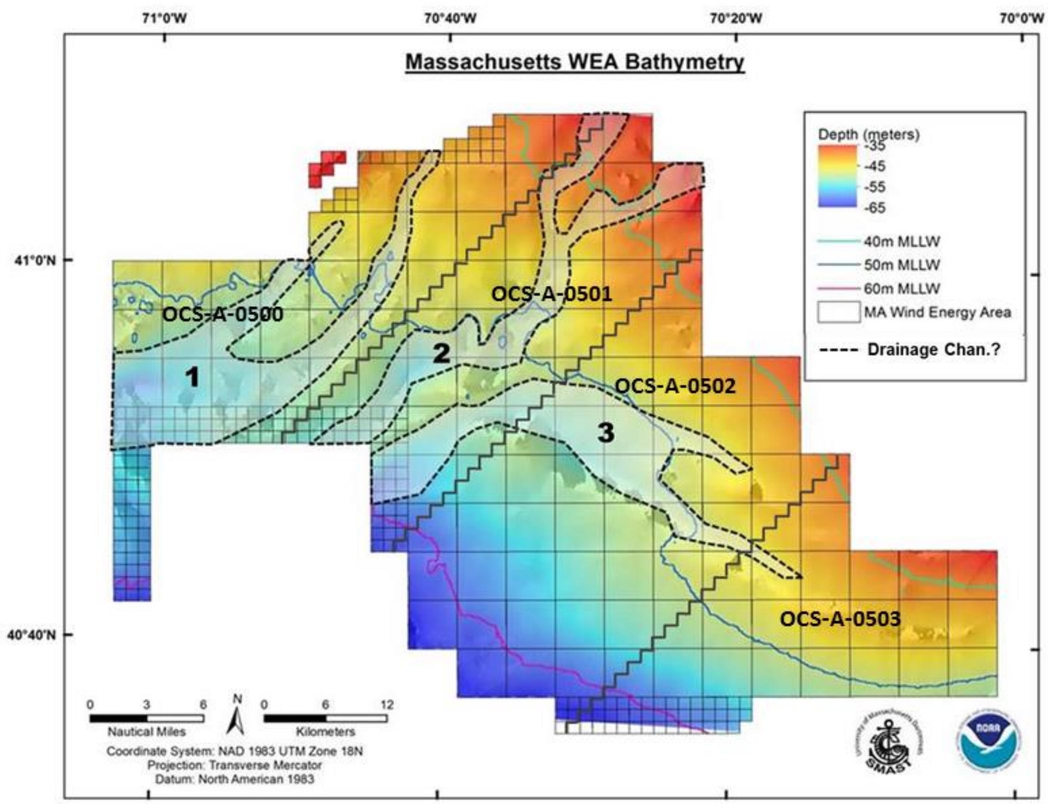

Figure 3-4. Bathymetry (3 arc-second horizontal resolution) with isobaths contours in the MA WEA with three probable erosional drainage channels emphasized.

3.2.2 Terrain Variables

Regarding terrain metrics, there was a uniformly low slope (<0.27 degrees: Figure 3-5A) and low rugosity values (<-1.0: Fig. 3-5B). Aspect (Fig. 3-5C) was largely westerly (180 to 360). Overall topographic characteristics meet the CMECS criteria for flat terrain (0 to <5 degrees slope and very low rugosity: (< 1.25)(FGDC 2012).

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 3-3) and terrain metrics (Figure 3-5). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope, standard deviation break = 2.0, and depth (Figure 3-6).

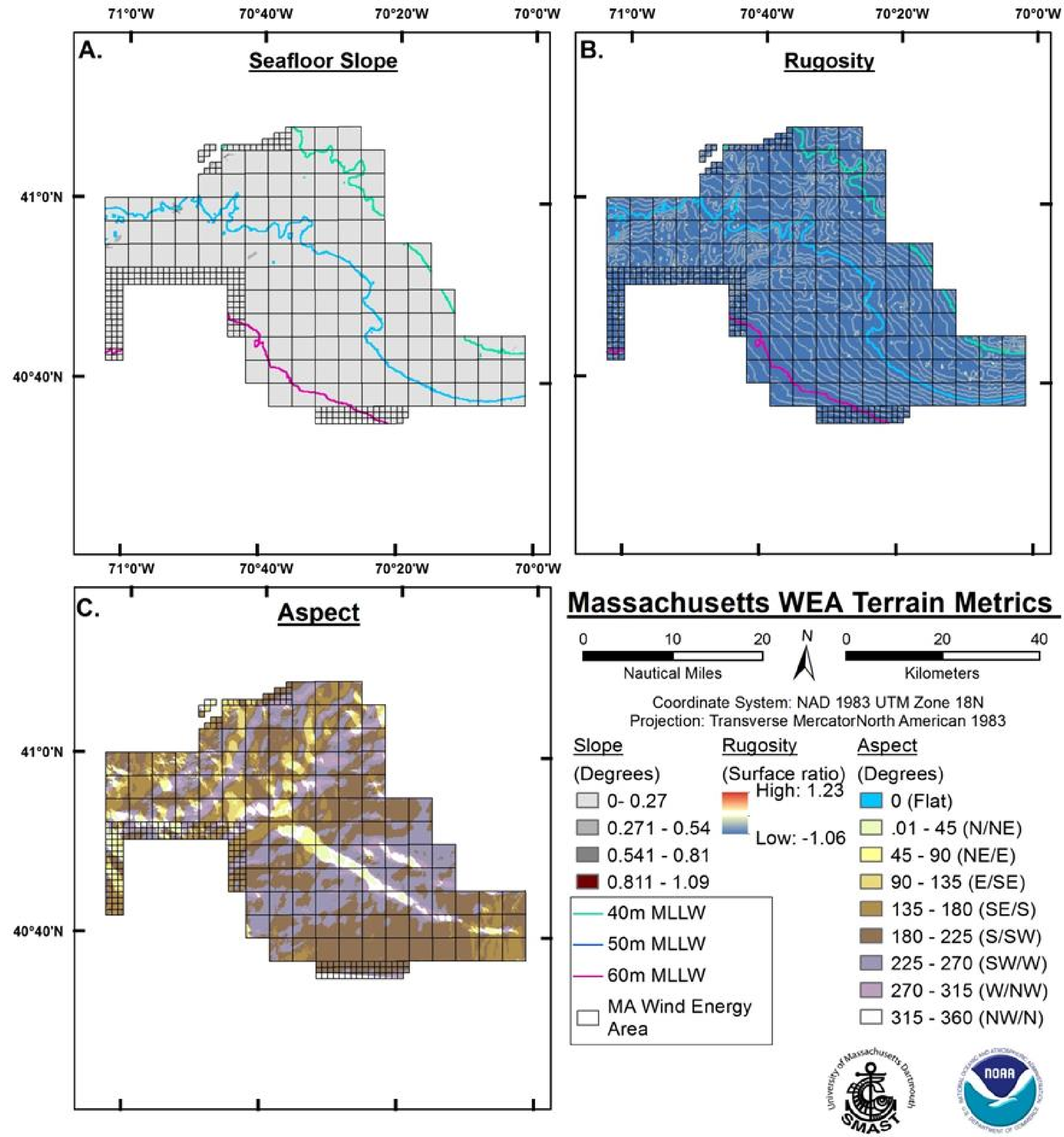

Figure 3-5. Terrain metrics derived from bathymetry for MA WEA (Figure 3-3). A. Seafloor slope, B. Rugosity, C. Aspect.

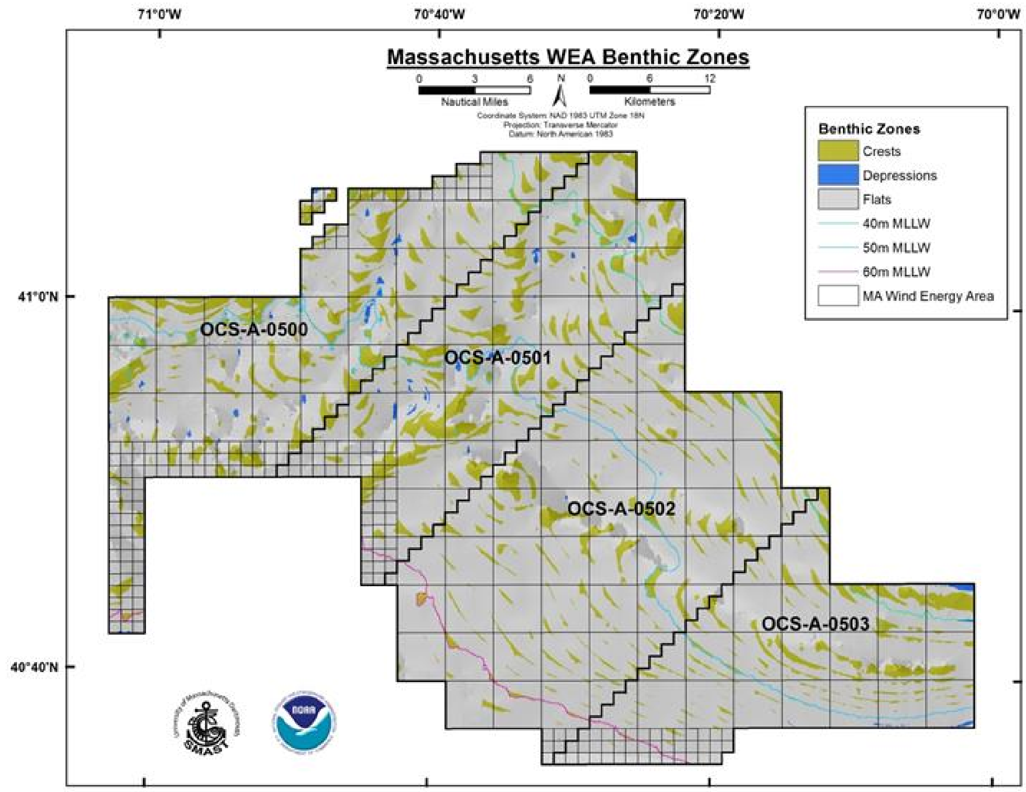

Figure 3-6. Benthic zones derived from 3 arc-sec bathymetry and derived slope data in the MA WEA.

This analysis revealed a series of elongated crests (ridges) running roughly parallel to depth contours and mostly spaced at intervals of around 1 km, but occasionally up to 4 km. These are interrupted by patterns of flats and depressions roughly corresponding to the presumed drainage channels seen in Figure 3-4. These features are presumed to be sand ridges, a common feature of sandy continental shelves worldwide. Patterns of bends and interruptions in the ridges in this figure are also reflected as sudden changes in aspect (Figure 3-5C).

3.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the MA WEA is shown in Figure 3-7. Figures 3-8, 3-9, and 3-10 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 3-7 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

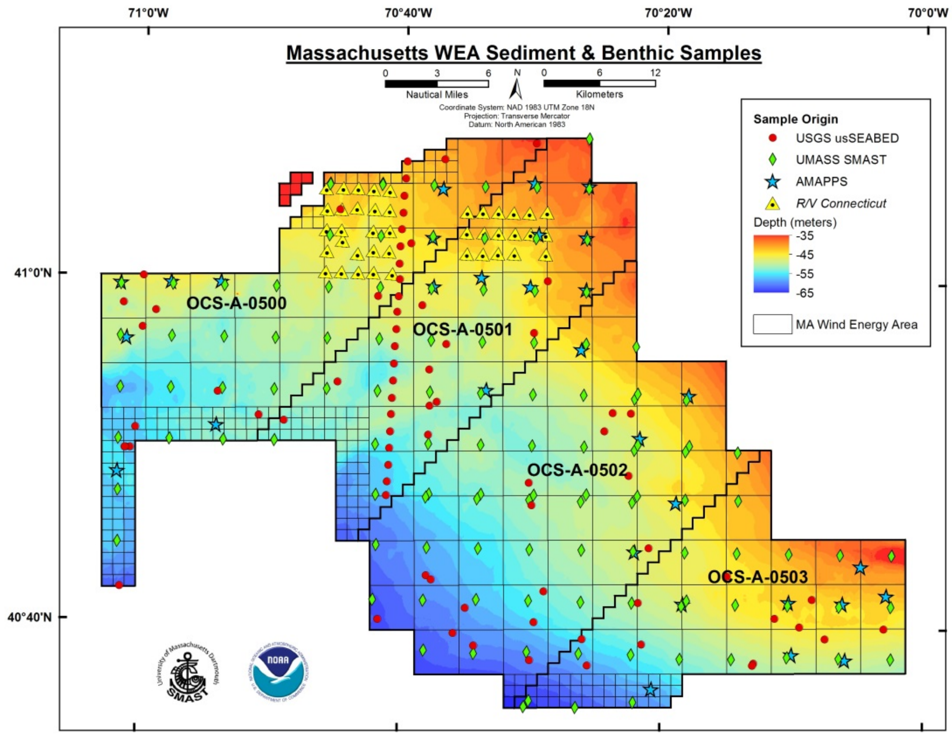

Figure 3-7. Location and source of benthic sediment samples and observations in the MA WEA. Sample include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles), cores taken from grab sampler aboard the NOAA 2014 AMAPPS cruise (green stars) and R/V Connecticut cruise (yellow triangles), and SMAST observations from camera pyramid imagery (green diamonds). Data sources - bathymetry as in Figure 3-3, sediment data: Reid et al. 2005, UMASS SMAST.

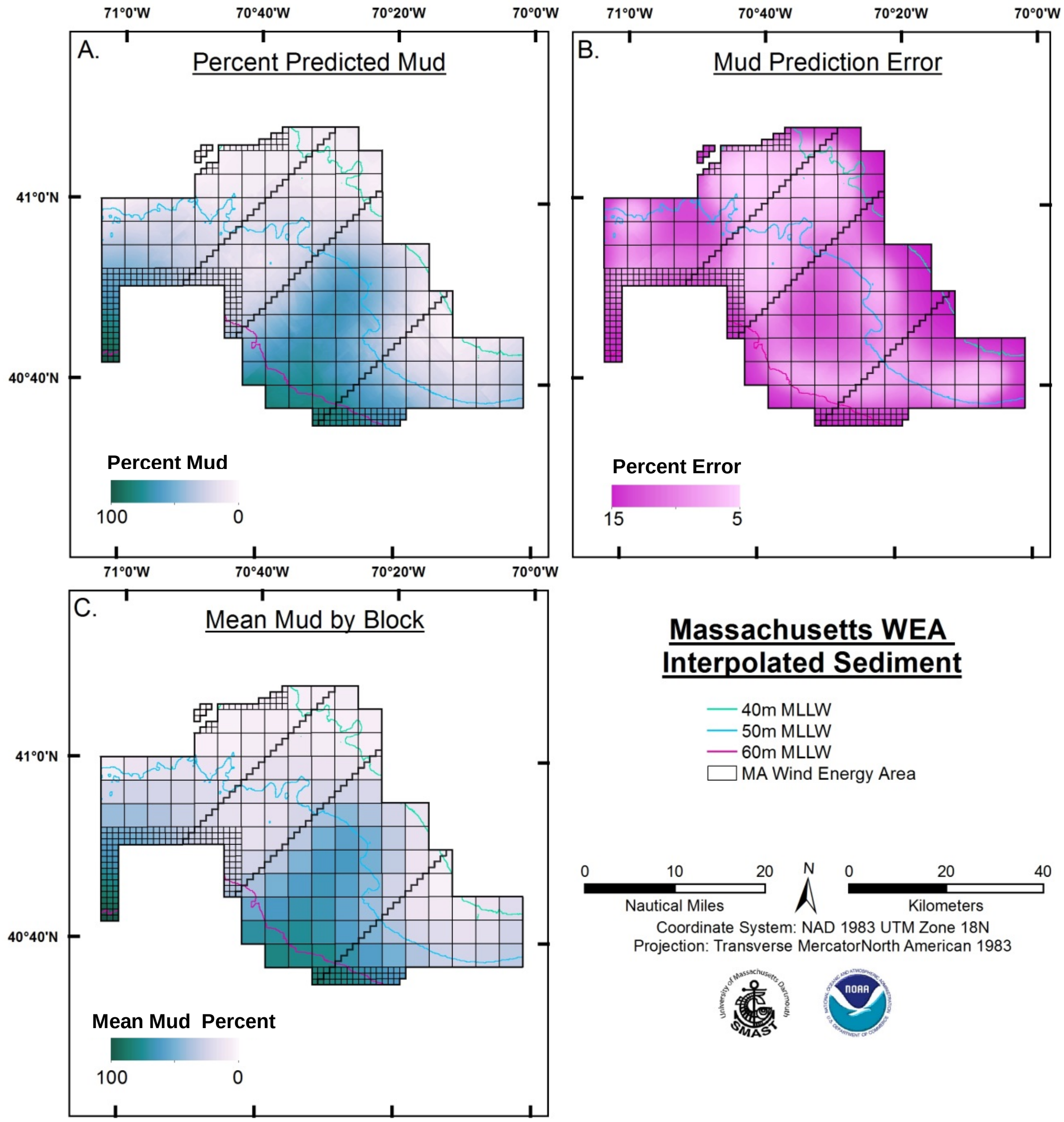

Figure 3-8. Predicted mud (silt + clay) distribution of surficial sediments in MA WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data as in Figure 3-7.

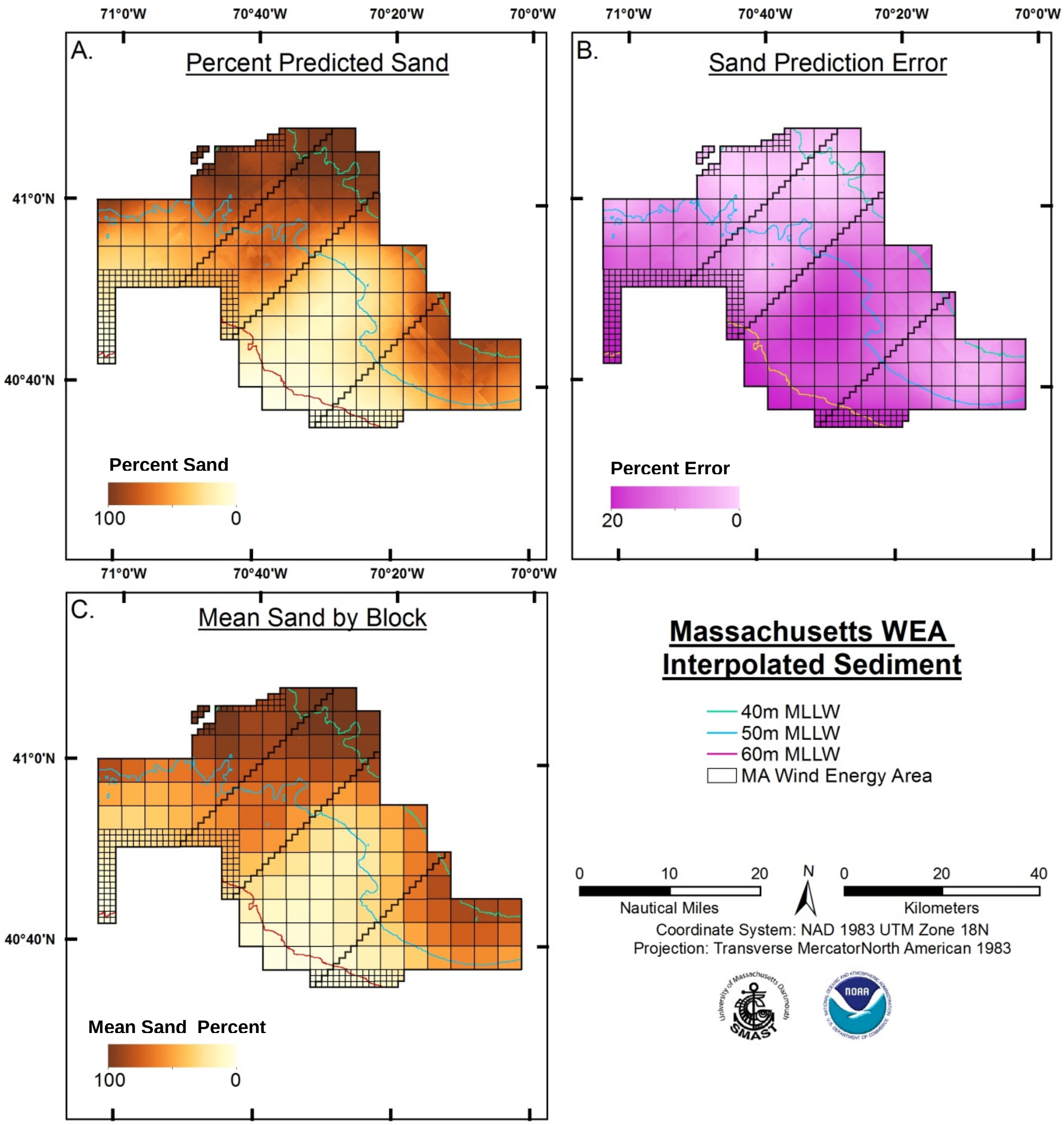

Figure 3-9. Predicted sand distribution of surficial sediments in MA WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data as in Figure 3-7.

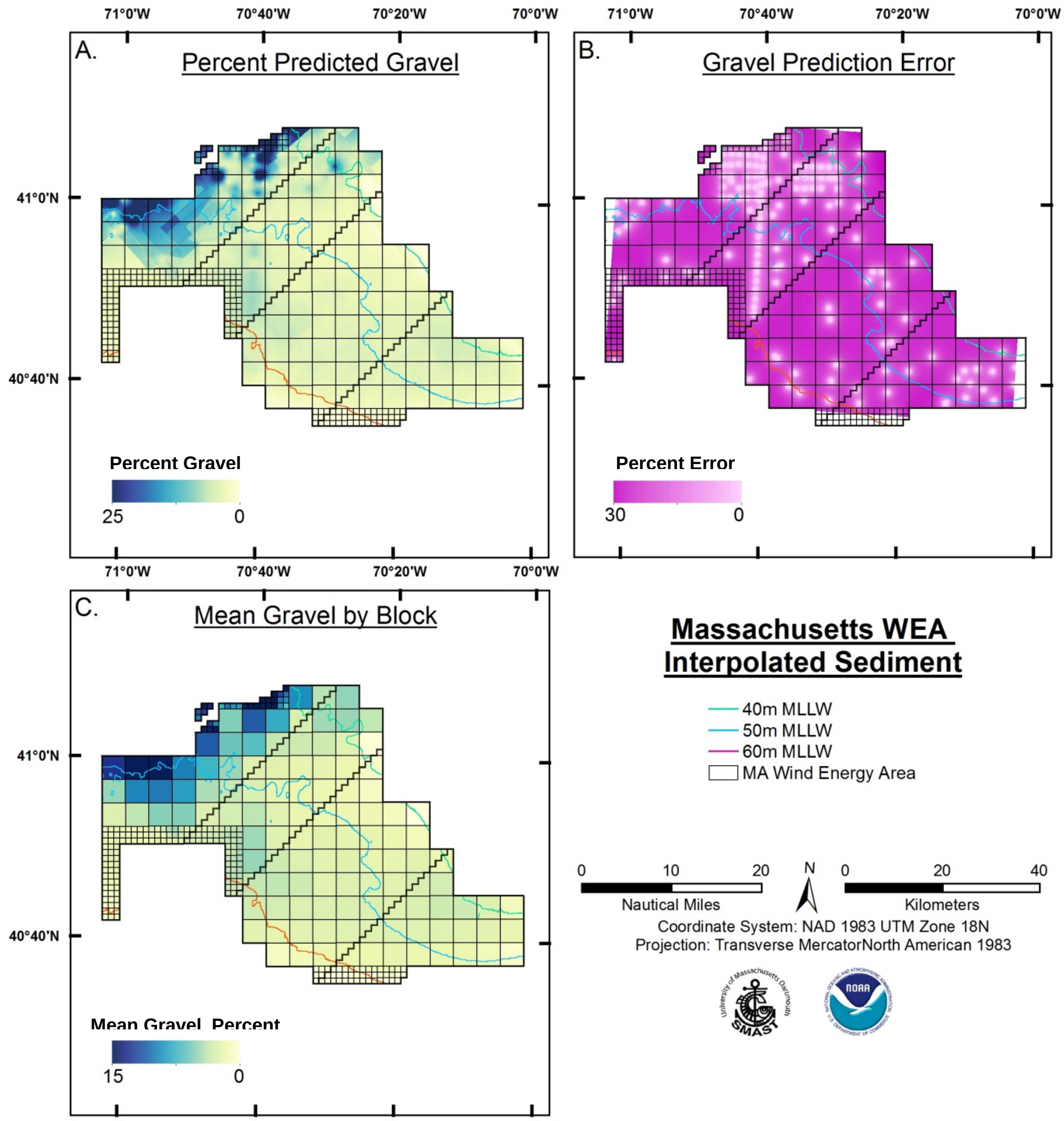

Figure 3-10. Predicted gravel distribution of surficial sediments in MA WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data as in Figure 3-7.

Together Figures 3-8 through 3-10 indicate sediments dominated by sand throughout much of the WEA, but mud-dominated in most of OCS-A-0502 and southern portions of OCS-A-500 and -503. A NE to SW gradient in mud content is evident in all lease areas. Gravel is present along in the NW blocks of OCS-A-0500 and to a lesser extent in OCS-A-501, and still less in the OCS-A-502 and -503. Nowhere in the MA

WEA is it a dominant sediment type. Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 3-11. While this represents only mean grain size without assessing the range of sediment sizes present, it does provide good characterization of sediment texture where the variation in grain sizes is not extreme. The presence of some sand and especially gravel in muddy sediments causes the mean grain size to fall within the fine sand range; minor amounts of gravel in areas in the northwestern part of the WEA register as medium to coarse sand as a result of the averaging process. Nevertheless, the dominance of fine-grain sediments throughout most of the WEA is clear.

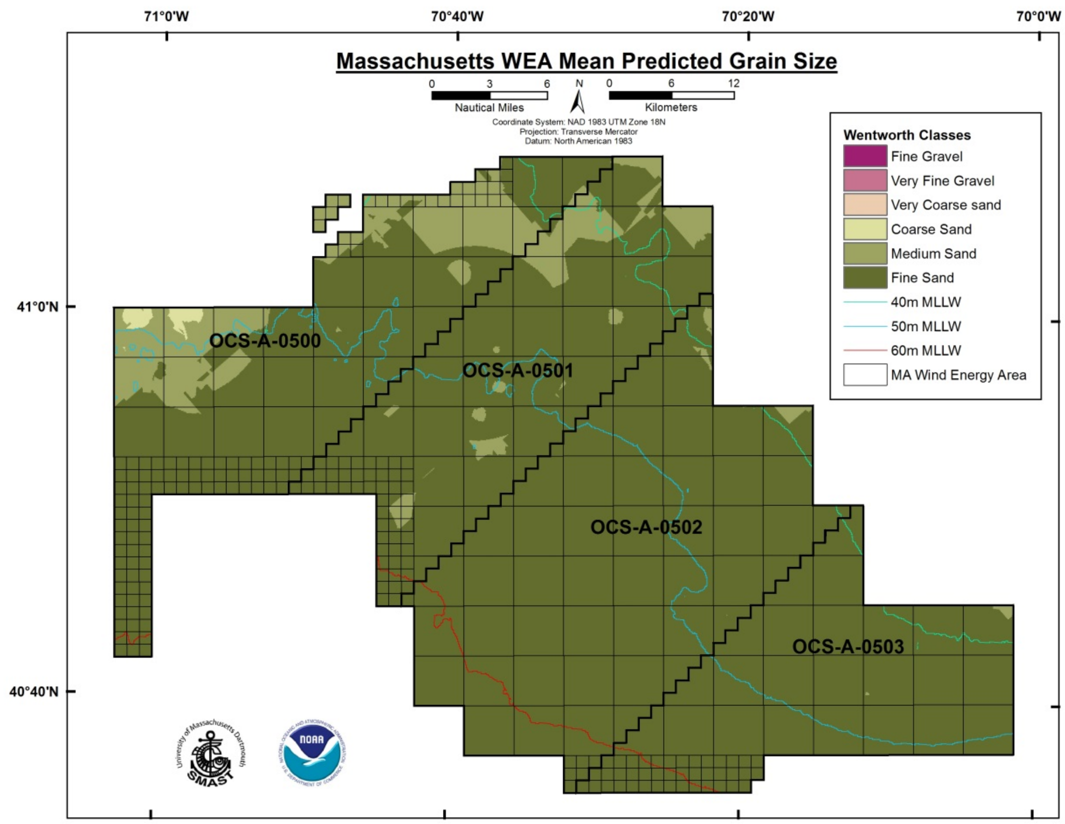

Figure 3-11. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the MA WEA physical samples. The figure displays interpolated average grain size distribution. Source data as in Figure 3-7.

SMAST image-based sediment observations, which were not incorporated into the analyses displayed in Figures 3-8 through 3-11, independently confirmed this sediment distribution pattern and supplement data from grab samples. SMAST observations include grain sizes too large for grab samples and microtopographic features too small for detection from bathymetry, e.g. sand ripples (Figure 3-12). Nearly equal numbers of observations were made of silt and sand at nearly all stations in the MA WEA.

While this does not agree with the northeast-southwest gradient in sediment grain size demonstrated with the grain-size analysis, it does show the generally fine-grained nature of sediments in this WEA. The SMAST data also shows the presence of sand ripples in a few cases. These are indicative of active movement of sediments by currents and/or waves along the bottom. The prominence of sand ripples at the eastern end of OCS-A-503 is not surprising, given the USGS prediction of relatively high sediment mobility around adjacent Nantucket Shoals (Figure 1-5).

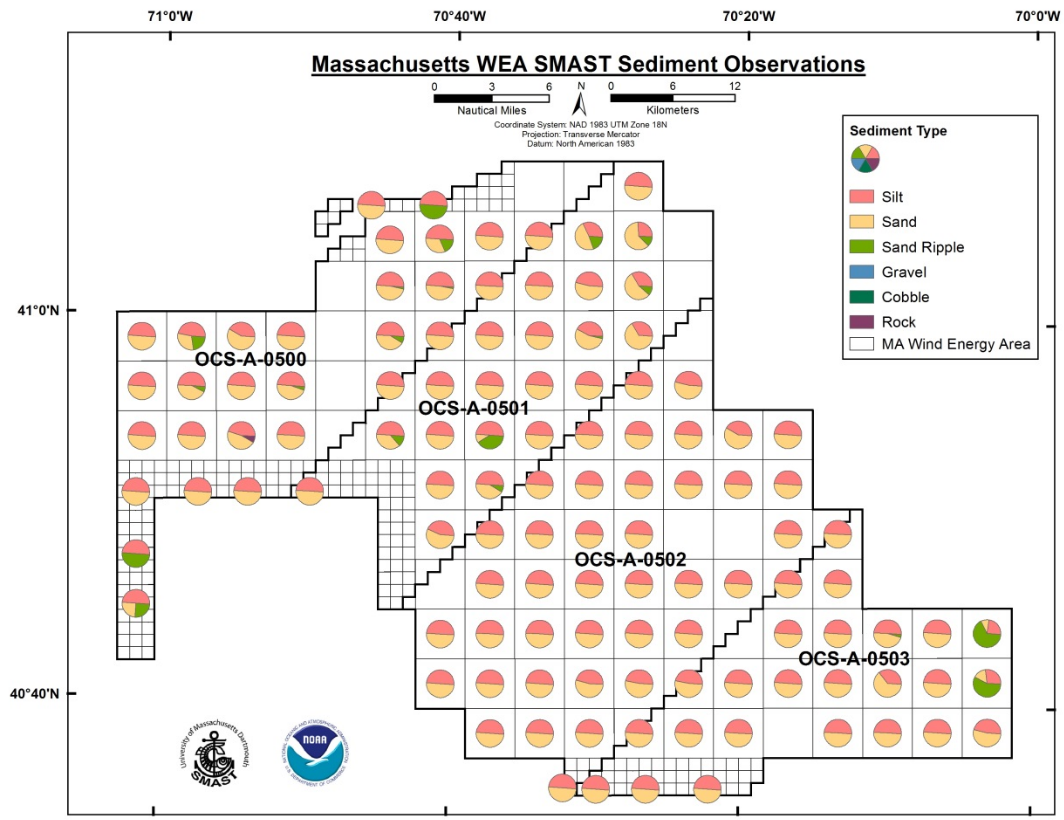

Figure 3-12. SMAST surficial sediments (presence-absence) observations. Observations proportioned in pie charts were compiled to show the ratio of sediment observations from multiple images taken at each station. Source data: UMASS SMAST.

3.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 3-13.

Median salinity measured in the MA WEA for this period, including all depths, was 32.440 g/kg with a full range spanning 30.766 to 34.385 g/kg (n=634), despite strong seasonal changes in other parameters. This range is entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 3.62 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

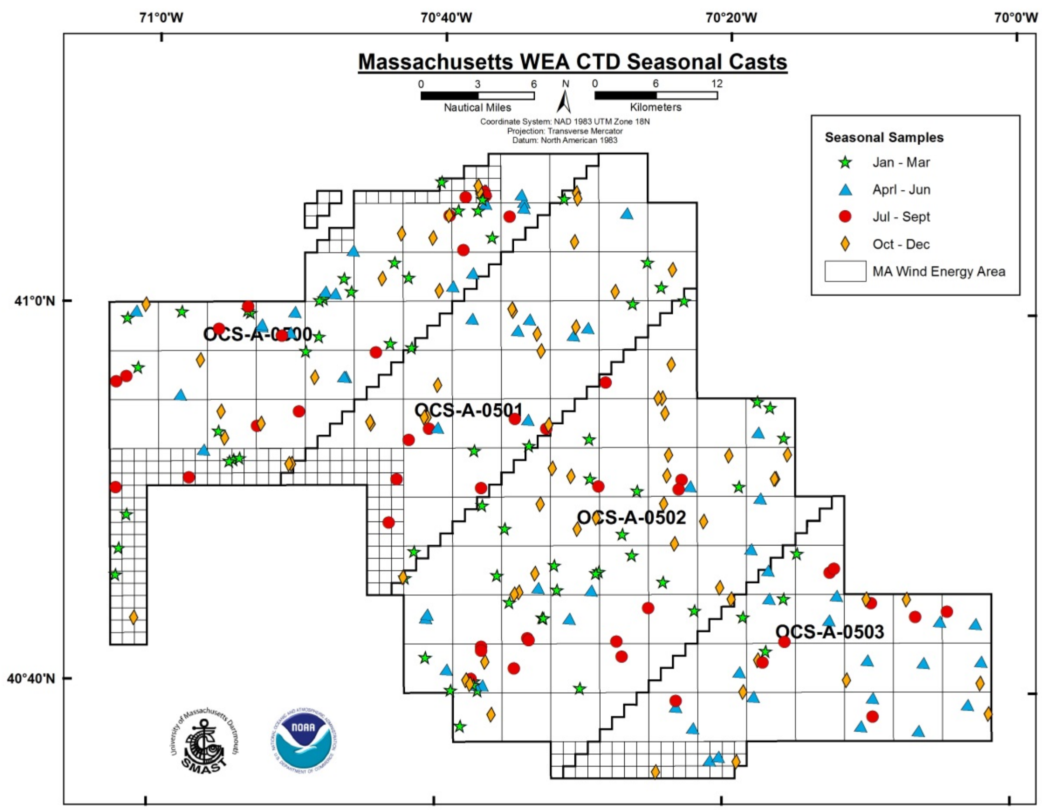

Figure 3-13. Locations for NEFSC CTD casts made between 2003 and 2016 in the MA WEA.

On the other hand, water temperatures showed large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water column structure. Figure 3-14 presents surface and bottom temperatures from CTD casts shown in Figure 3-13 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 20°C at the surface and 12°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 12°C. Then vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperatures of up to 12°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Extraordinary bottom temperatures in the 9-16 degree range were recorded in February, 2012, but have not been recorded in any other year during our target period. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton. The MA WEA has one persistent frontal system impinging upon it at its easternmost end: the Nantucket Shoal (Figure 1-4).

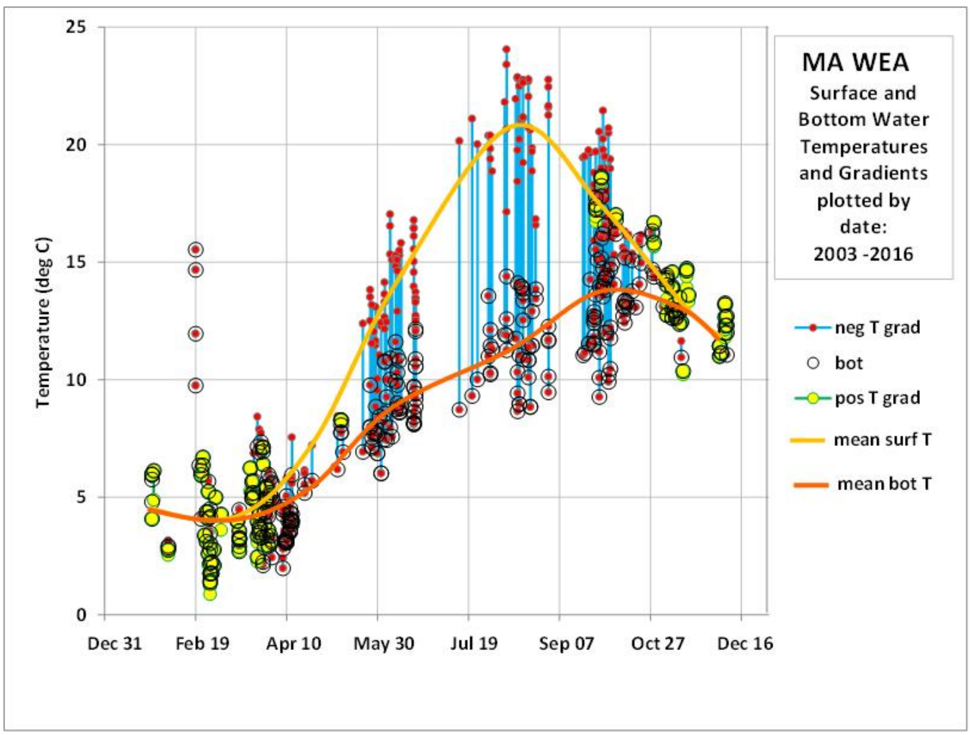

Figure 3-14. Water temperatures from CTD casts made between 2003 and 2016 in the MA WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values.

3.2.5 Biological Variables

3.2.5.1 Benthic Epifauna and Infauna

Benthic samples were collected during two NEFSC–sponsored cruises (AMAPPS GU14-02 parts 1 and 2) in the MA WEA, including 23 beam trawls for benthic epifauna and 30 triplicate Van Veen grabs for benthic infauna (Figure 3-15). Priority was given to areas with depths <50 m, as this was considered the maximum depth for placement of offshore wind facilities under present technology. Additional sampling planned for AMAPPS GU14-02 part 2 was precluded by bad weather and ship's mechanical issues. No subsequent benthic sample-capable cruises visited the MA WEA.

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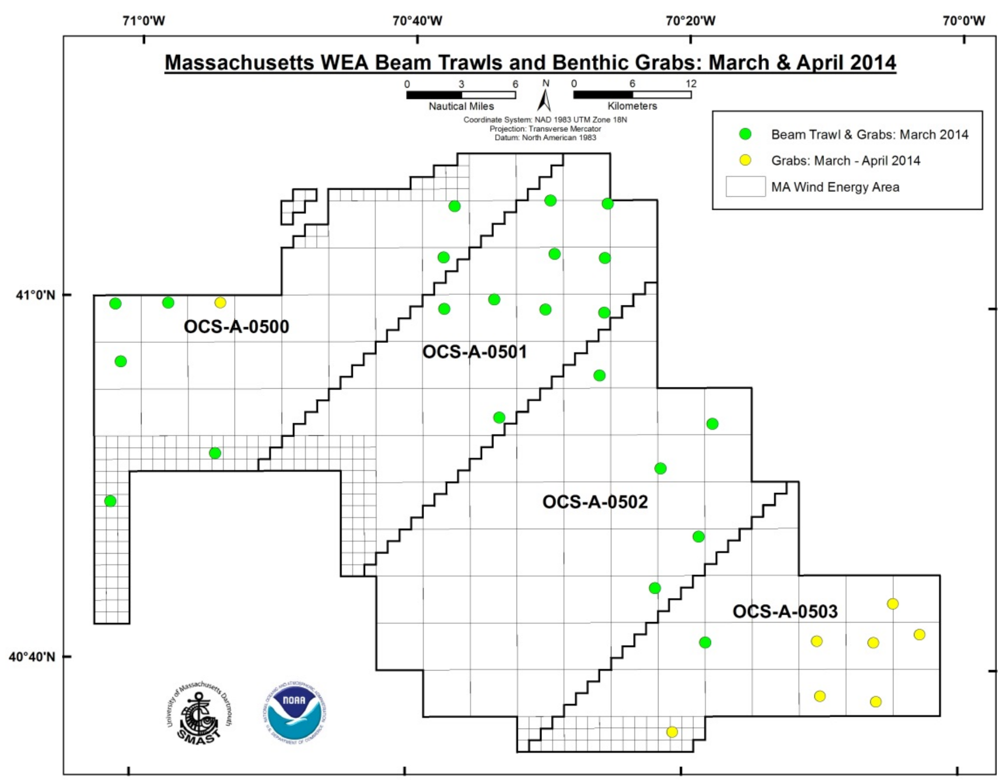


Figure 3-15. Locations of beam trawl and benthic grab samples made in the MA WEA

NEFSC beam trawl catches and the contents (58 taxa) of the benthic grab samples (151 taxa) are summarized in Figure 3-16. Among the epibenthic fauna as obtained in beam trawls, there were no dominants as defined in section 1.3.4, but sand shrimp and sand dollars came closest to meeting the criteria (Figure 3-16A). This is not surprising given the largely sandy character of sediments at most stations, which favored the sandy northern parts of the WEA.

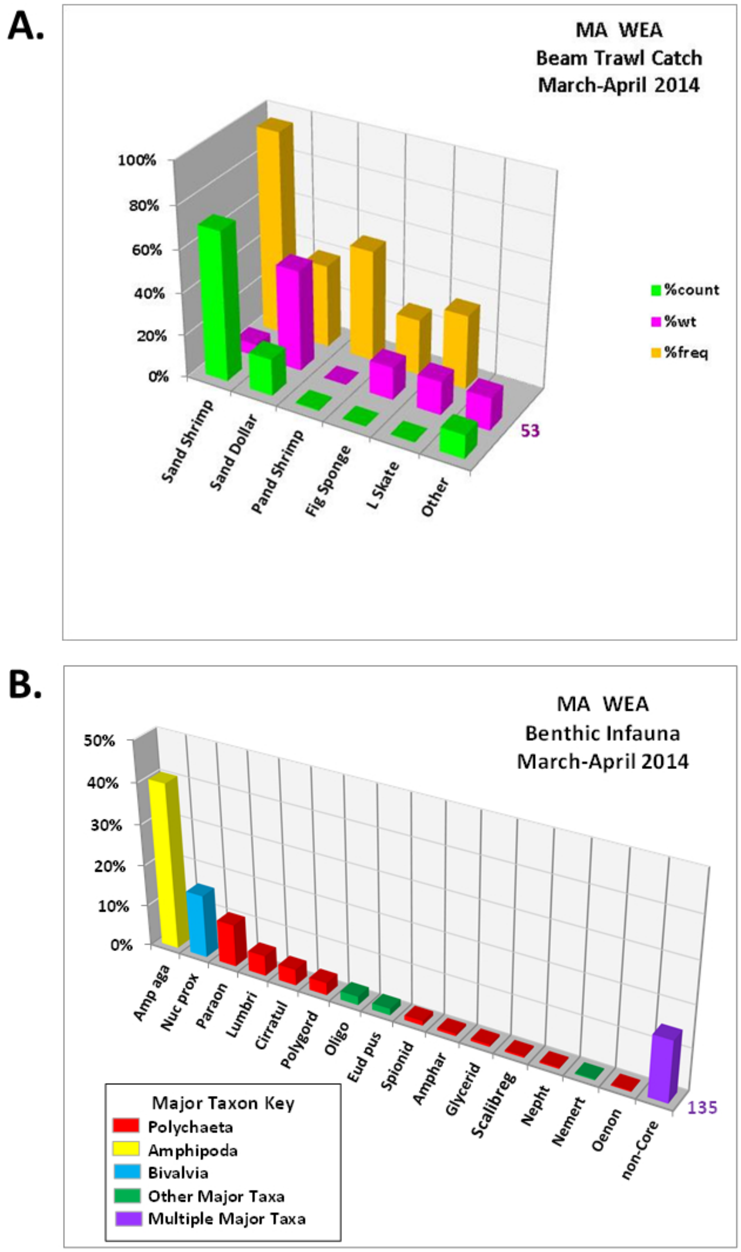


Figure 3-16. Benthic fauna caught in MA WEA by NEFSC sampling . A. Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA; B. Grab sample catch by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated common names for taxa in A.: Pand Shrimp – pandalid shrimp, L Skate – little skate. Abbreviated taxonomic names in B: Amp aga – *Ampelisca agassizi*, Nuc prox – *Nucula proxima*, Paraon – Paraonidae, Lumbri – Lumbrinereidae, Cirratul – Cirratulidae, Polygord – Polygordiidae, Oligo – Oligochaeta, Eud pus – *Eudorella pusilla*, Spionid – Spionidae, Amphar – Ampharetidae, Glycerid – Glyceridae, Scalibreg – Scalibregmatidae, Nepht - Nephtydae , Nemert – Nemertea, Oenon - Oenonidae . Numbers to the right of the “other” and “non-core” taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of “other” and “non-core” species.

One hundred and fifty one (151) taxa of infaunal benthos were captured in grab samples from the MA WEA (Figure 3-16B). The benthic infaunal assemblages resembled an assemblage common among OceanSAMP stations, described by LaFrance et al. (2010) as dominated by *Ampelisca agassizi* and *Nucula annulata* (*N. annulata* is an unaccepted synonym for *N. proxima*), and to our benthic infaunal collection from a sandy region of the RIMA WEA (section 4.2.5.1) also numerically dominated by *A. agassizi* and *N. proxima*). This pattern points to the observation that barring serious disturbance, benthic infaunal assemblages can be stable over periods of many years (LaFrance, 2010). The large number of "core" taxa in these MA WEA samples suggests that benthic assemblages from this WEA are closely related.

3.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 3-17.

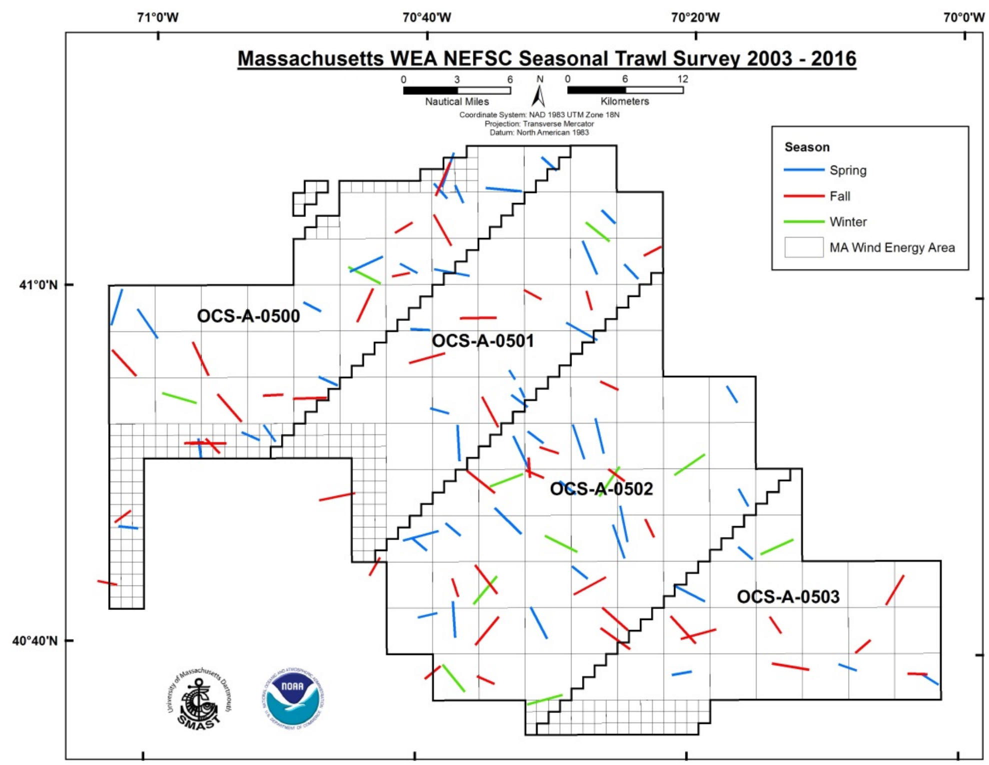


Figure 3-17. Locations of NEFSC seasonal trawls from 2003 to 2016 in the MA WEA.

Importance values among taxa captured in NEFSC Seasonal Trawl Survey catches in the MA WEA are plotted in Figure 3-18 and Table 3-1, with seasonally dominant species listed in Table 3-2.

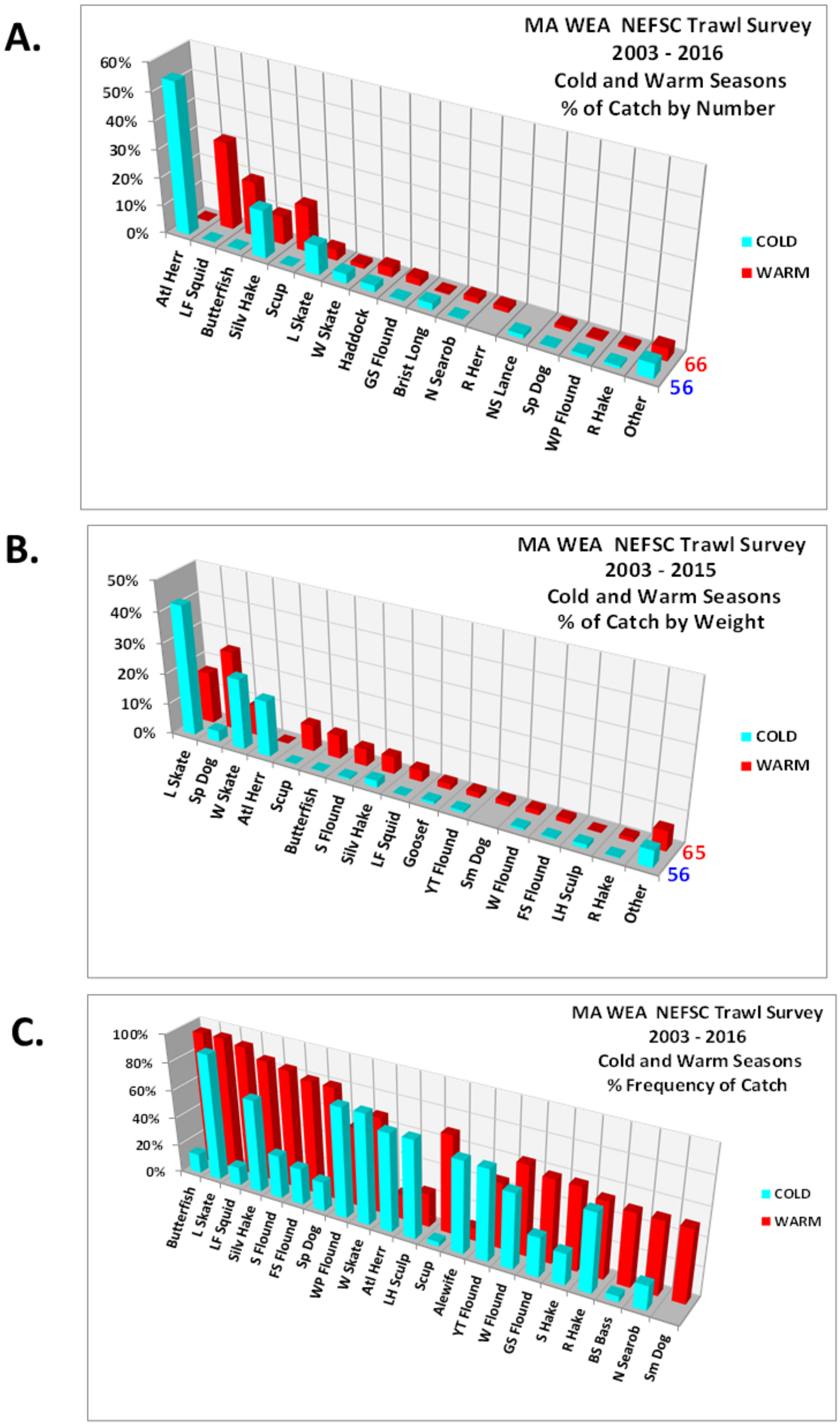


Figure 3-18. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 3-1. Blue and red numbers along the right margin of the graphs indicate the numbers of “other” species in cold and warm season catches respectively.

Table 3-1. Abbreviations for taxon names used in Fig. 3-17, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Alewife	alewife[4]	N Searob	northern searobin
Atl Herr	Atlantic herring[2]	R Hake	red hake[2]
BS Bass	black sea bass[3]	R Herr	round herring
Brist Long	bristle longbeak shrimp	Scup	scup[3]
Butterfish	butterfish[3]	Silv Hake	silver hake[2]
FS Flound	fourspot flounder	Sm Dog	smooth dogfish[5]
Goosef	goosefish (monkfish)	Sp Dog	spiny dogfish[4]
GS Flound	Gulf Stream flounder	S Hake	spotted hake
Haddock	haddock[2]	S Flound	summer flounder[3]
L Skate	little skate[2]	WP Flound	windowpane flounder[2]
LF Squid	longfin squid[3]	W Flound	winter flounder[2]
LH Sculp	longhorn sculpin	W Skate	winter skate[2]
NS Lance	northern sand lance	YT Flound	yellowtail flounder[2]

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 3-2. Dominant species in NEFSC Seasonal Trawl Survey catches within the MA WEA between 2003 and 2016.

Massachusetts WEA Dominants	
Cold Season	Warm Season
Atlantic herring	butterfish
little skate	little skate
silver hake	longfin squid
winter skate	red hake
	scup
	silver hake
	spiny dogfish
	winter skate

It is evident from this survey trawl data that this is a taxon-rich area: 81 taxa in the warm season and 71 in the cold season. It is also evident that while there is considerable overlap in the lists of taxa present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also considerable overlap among species present and dominance with the RIMA WEA (section 4.2.5.2). Of the taxa that are important in terms of numbers, biomass, and/or frequency (Table 3-1) 65% (17 out of 26) are species that are managed in the northeast region. Three species, little skate, silver hake, and winter skate were dominants in both seasons. All of the dominants other than skates were seasonal migrants. It is also notable that all of the dominants (Table 3-2) are managed fishery species.

3.2.5.3 Species of Concern

Records of shellfish species of concern in the MA WEA are illustrated in Figure 3-18. These included quantitative records of sea scallops from NEFSC seasonal trawl surveys and qualitative records from beam trawls, bottom grabs, and bottom imagery. Sea scallops were clearly widespread in this WEA, occurring in all four lease areas. Since quantitative trawl captures were located at the mid-point of the trawl track, which may lie outside the WEA limits, it is not certain whether the sea scallops near the WEA boundary were actually caught inside or outside the WEA in some cases.

Ocean quahog records (all qualitative) were also widespread, with records primarily from bottom grab samples. This distribution exceeded the limits for ocean quahog EFH in the area (Figure 1-8) in some cases. Only a single qualitative detection of surfclams was made from western extremity of OCS-A-0500, where there is no overlap with surfclam EFH (Figure 1-9).

As sea scallops and ocean quahogs were widespread and numerous, these are clearly species worth considering in terms of potential for habitat disturbance in spite of only a small overlap with the sea scallop EFH (western end of OCS-A-0500 only) as currently designated (Figure 1-7).

The egg mops of longfin squid were not detected by us in the MA WEA, but this may be attributable to our sampling in early spring (March: cold season), rather than in summer, when longfin squid lay eggs. Beam trawling is capable of catching them if they are present, but we did not encounter them so far out of season.

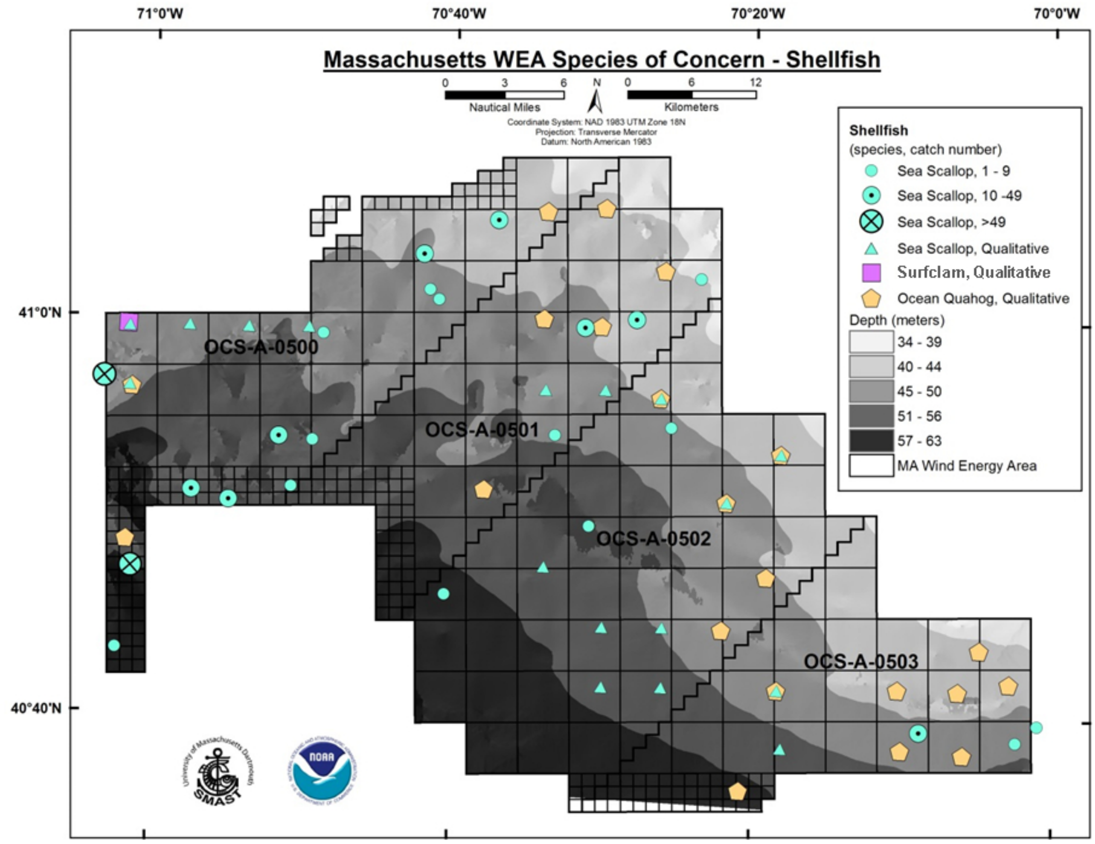


Figure 3-19. Shellfish species of concern records within and near the MA WEA.

Atlantic cod were only rarely caught by the NEFSC seasonal survey in the MA WEA between 2003 and 2016, and only in small numbers (Figure 3-20: pink circles): once in OCS-A-500, once in -502, and twice in -503. We reasoning that this rarity might be connected to the large decline in cod stocks in the 1990s. To further investigate, we added catch records from the previous 14 years, extending back to 1989 (Figure 3-20: green circles). This increased the small catches to six: 2 each in OCS-A-500, -501, and -503, and one large catch, possibly an aggregation, in OCS-A-502. Current EFH designations for adult and juvenile Atlantic cod do not include the southern half of the WEA (across all four lease areas), where some catches have been recorded. While fine sediments are likely the cause of the paucity of cod in the south and their exclusion from the cod EFH zone, this is not the cause of poor cod catches in the north, which is more gravelly and in the zone. Unless their presence is very transient or very focused on specific locations, it is unlikely that the presence of cod is being missed by the NEFSC season survey in the MA WEA. The survey regularly samples both sediment regimes during the cold season (winter and spring), averaging about twice each in the north and south during each annual cold season (Figure 3-17). Thus their low frequency (~7% of cold season trawls since 2003) and low numbers in survey catches, especially in the north, remains an open question.

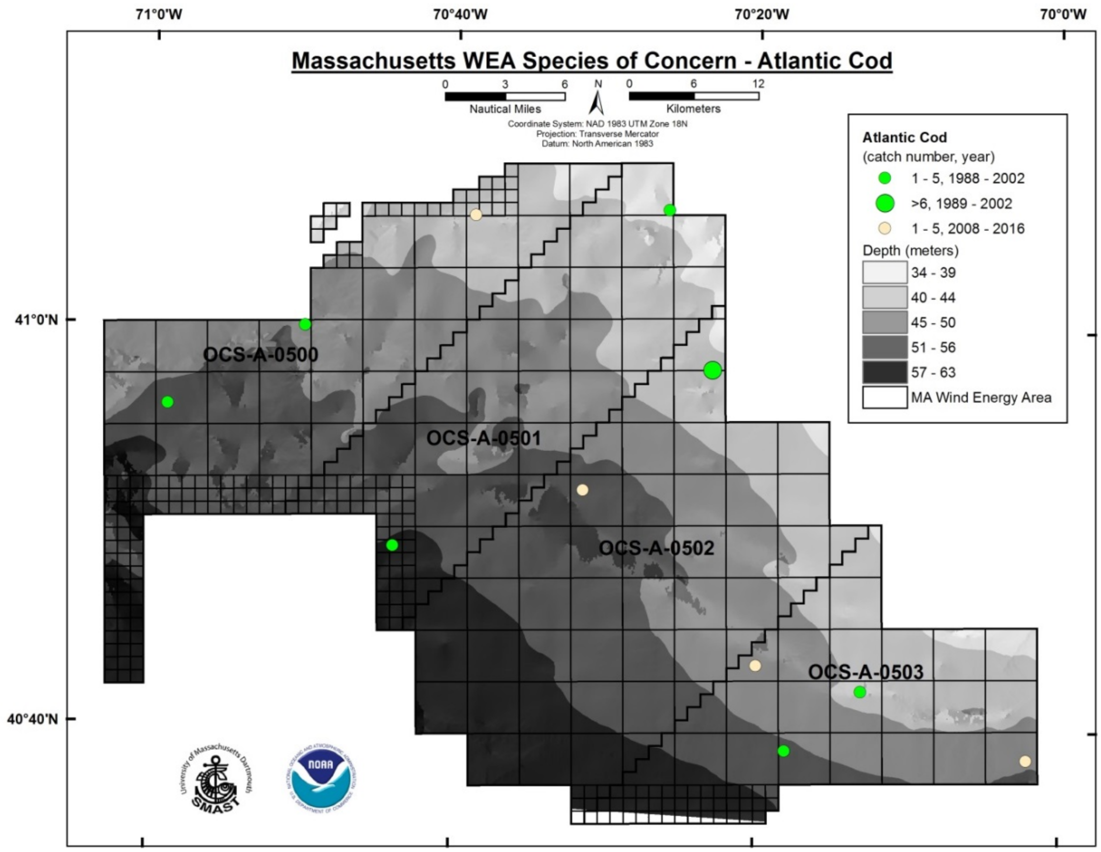


Figure 3-20. Records of Atlantic cod in the MA WEA.

Both young-of-the-year (YOY) and sub-adult to adult-sized black sea bass were also detected in the MA WEA, entirely via NEFSC seasonal survey trawl (Figure 3-21). The distinction is important because YOY black sea bass are thought to have bottom habitat refuge requirements. Their pattern of distribution suggests that adult and sub-adult black sea bass may prefer habitats at depths of 45 m or less. YOY appear to occur through a wider depth range (to at least 60 m, but may also be found at depths of 40 m in the WEA. This depth-related distribution is suggested by EFH maps for the species (Figure 1-12), although some of the records may be outside of the specific 10 minute squares indicated in those maps. This is another species where there may be potential for habitat disturbance.

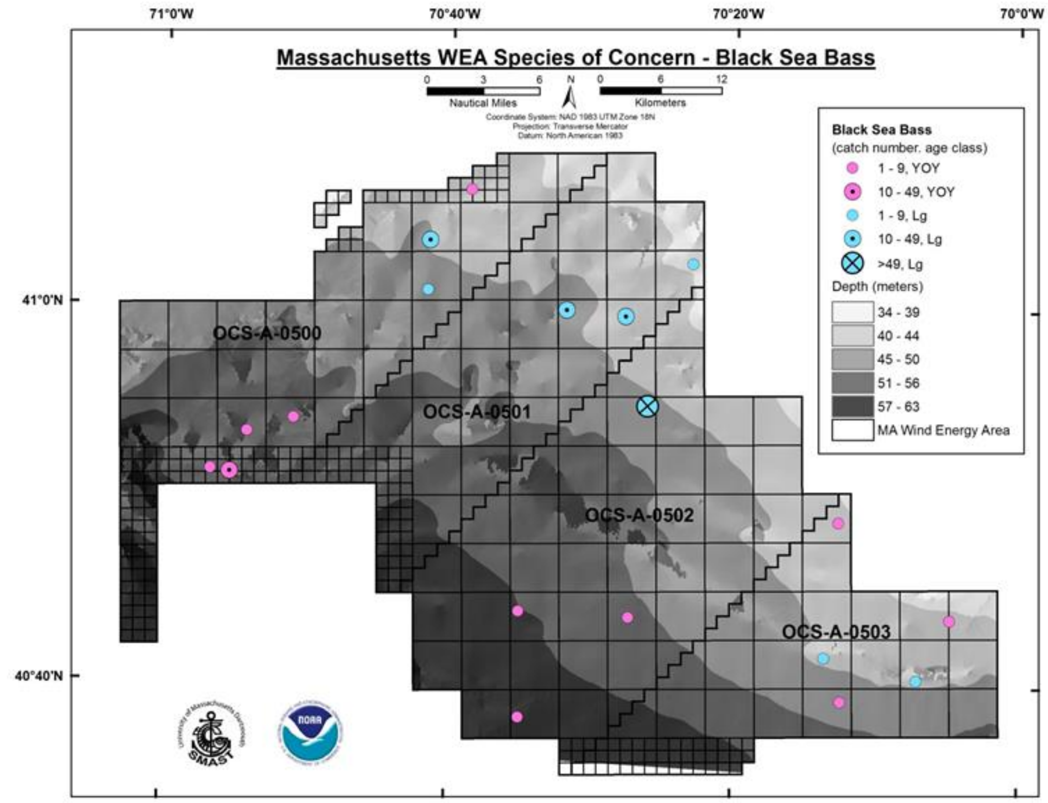


Figure 3-21. Records of young-of-the-year (YOY) and larger black sea bass in the MA WEA.

2.3 MA WEA Habitat Definition

An integrated view of the physical benthic habitat features in the MA WEA is presented in Figure 3-22. There is one major topographic zone (Topozone 1) with habitat features (shelf valley, mud to muddy patch, tidal front) superimposed upon it in various locations. The shelf valley is so designated because the faint channels (Figure 3-4) appear on a large scale map (Ruddock 2010, Figure 1) to be tributaries to the Block Island Shelf Valley that runs southward across the shelf to the southwest of the MA WEA. This was probably a large river system draining what is now the southern New England shelf during the low stand of sea level during the Wisconsin glaciation. As far as we have determined with the data at hand, the sediments and fauna of these features are not notably different from those of the surrounding shelf.

The large muddy sand to mud patch that occupies much of OCS-A-502 and smaller patches elsewhere are topographically similar to the surrounding sandy zones and there is not a clear distinction of their fauna.

Likewise, the tidal front area along the eastern border of the WEA does not demonstrate any strong difference in terms of sediment, geoform, or biota with adjacent areas. Fronts are well-known for their ability to foster intense biological activity. The frontal system is indicated along the edge of the WEA because of the known proximity and probable overlap with the Nantucket Shoal tidal front, a persistent front demonstrating large surface temperature gradients (Figure 1-4). Figure 1-4 represents a snapshot in time of surface position for this potentially dynamic, mobile feature rather than the position of a fixed feature like a geological entity. However, it should be recognized that it can influence the WEA at this eastern extremity. Such tidal fronts can extend their influence surface, where it is visible to satellite camera as in Figure 1-4 to bottom, and can also be highly mobile, even over periods of hours (Guida et al. 2015), so we felt its presence should be indicated.

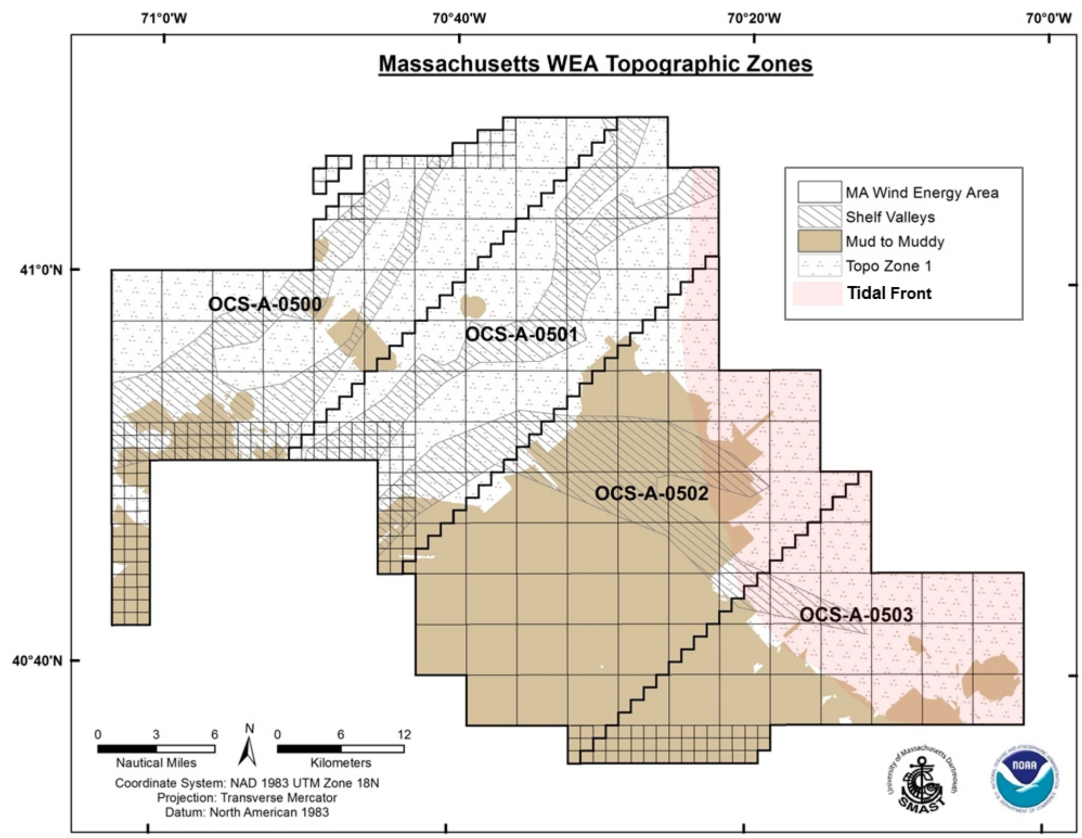


Figure 3-22. Physical benthic habitat features of the MA WEA.

3.3.1 CMECS Classifications

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Sediment Wave Field, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Sand, Slightly Muddy Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Larger Tube-Building Fauna, Scallop Bed (*Placopecten*), Clam Bed (*Arctica*)

Shelf Valley

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Shelf Valley (tributaries)
- Substrate and Biotic Components: same as for Topo Zone 1

Mud to Muddy Patch

- Geoform and Biotic Components: same as for Topo Zone 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Muddy Sand to Mud

Tidal Front

- Geoform, Substrate, and Biotic Components: same as for Topo Zone 1
- Water Column Component
  - Hydroform Class: Front
    - Hydroform: Tidal Front

4 Rhode Island – Massachusetts Wind Energy Area (RIMA WEA)

4.1 Location, size, and subdivision

The Rhode Island–Massachusetts WEA lies on the Southern New England shelf in a band between approximately 11 and 32 nautical miles south of Newport, RI (Figure 4-1) and is divided into 13 full lease blocks and 255 sub-blocks (Figure 4-2). The average water depth of the Rhode Island–Massachusetts WEA is approximately 40 m and it covers approximately 164,750 acres of seafloor (BOEM 2014b). The RIMA WEA has been divided into two lease areas: 97,498 acres (~59%) lie in a northern lease area (OCS-A-0486) and 67,252 acres (~41%) in a southern lease area (OCS-A-0487). Figure 4-2 provides the numbering for all blocks in the WEA. This section provides data and analysis for the entire WEA (both lease areas) as a single unit.

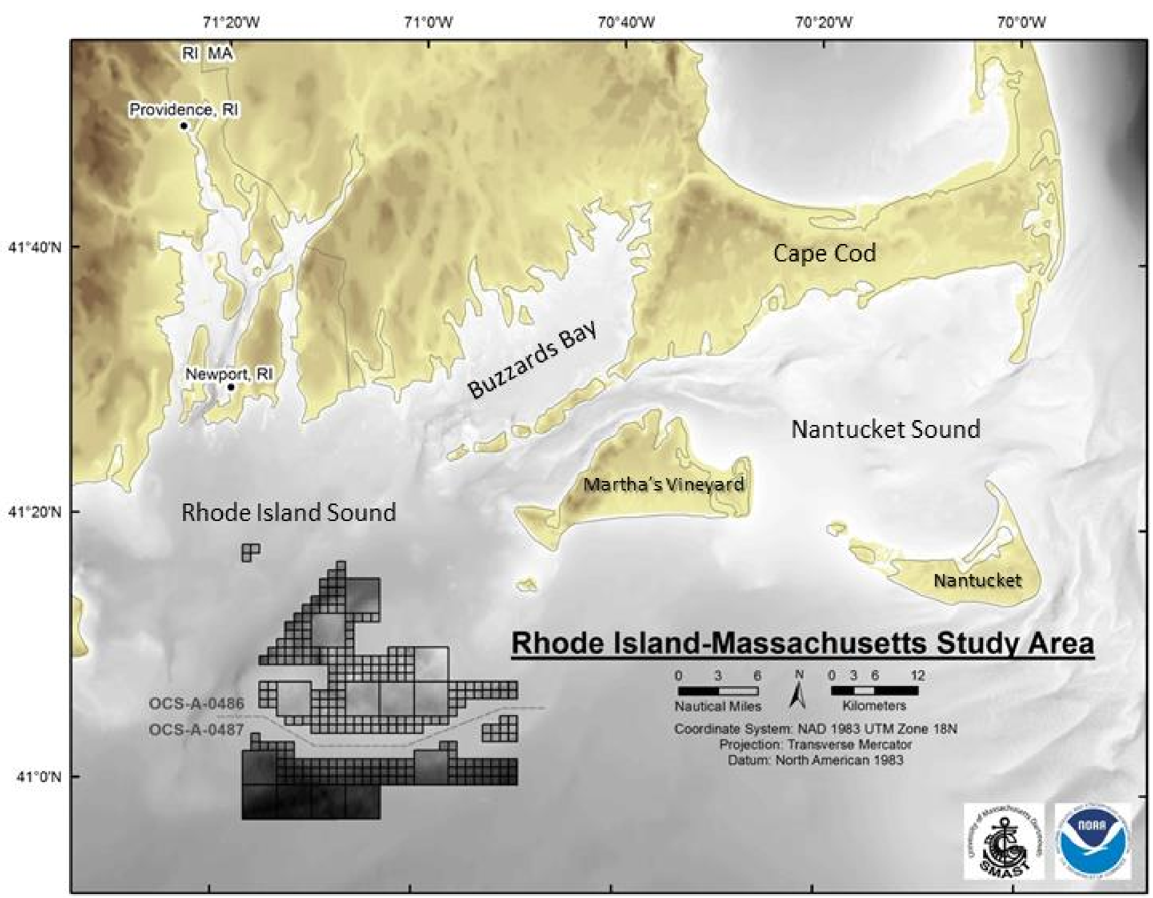


Figure 4-1. Map of Rhode Island–Massachusetts study area. Source data:(NOAA, NGDC 2014).

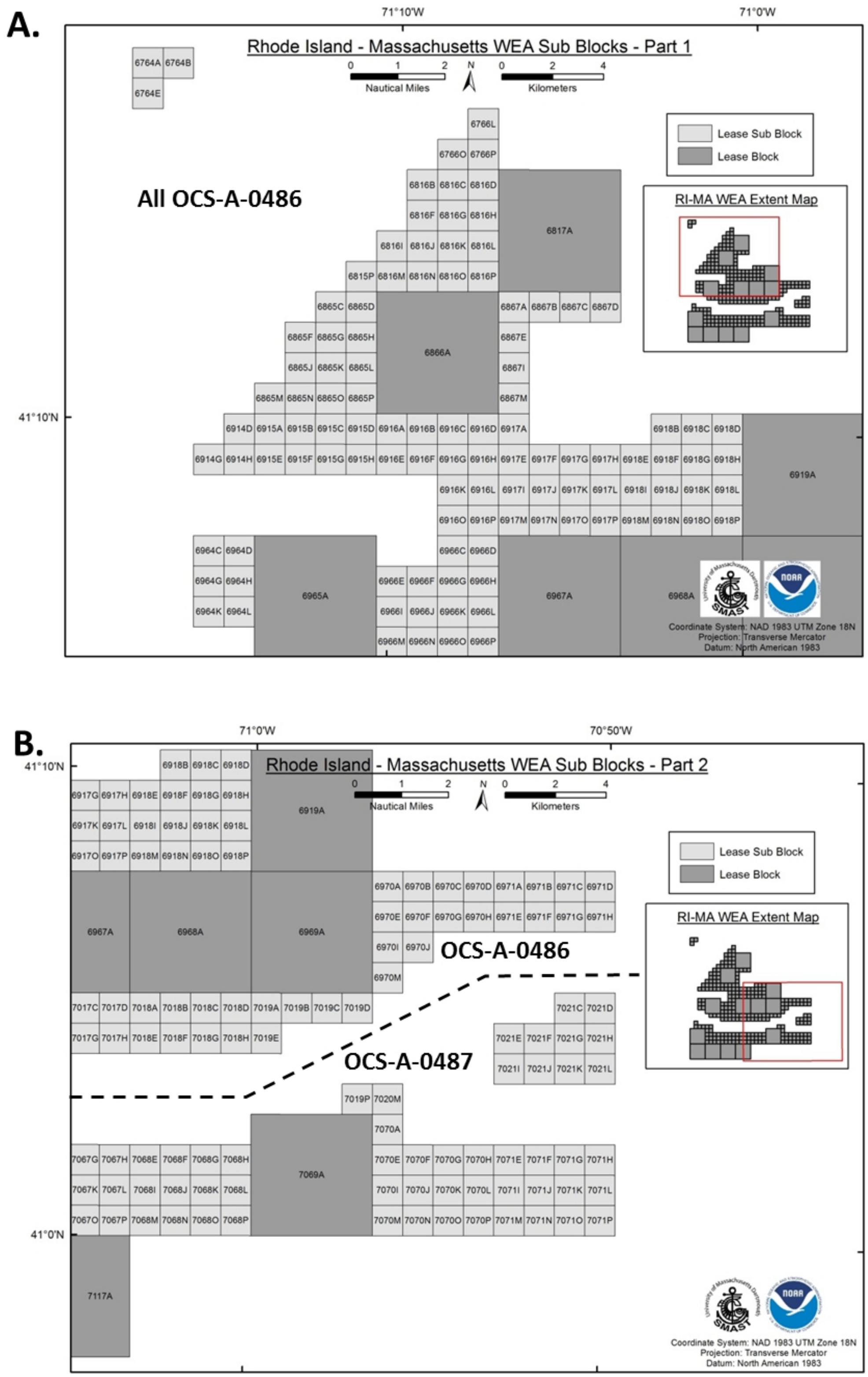


Figure 4-2. Numbered lease blocks included in the RIMA WEA (source data BOEM 2017).

C.

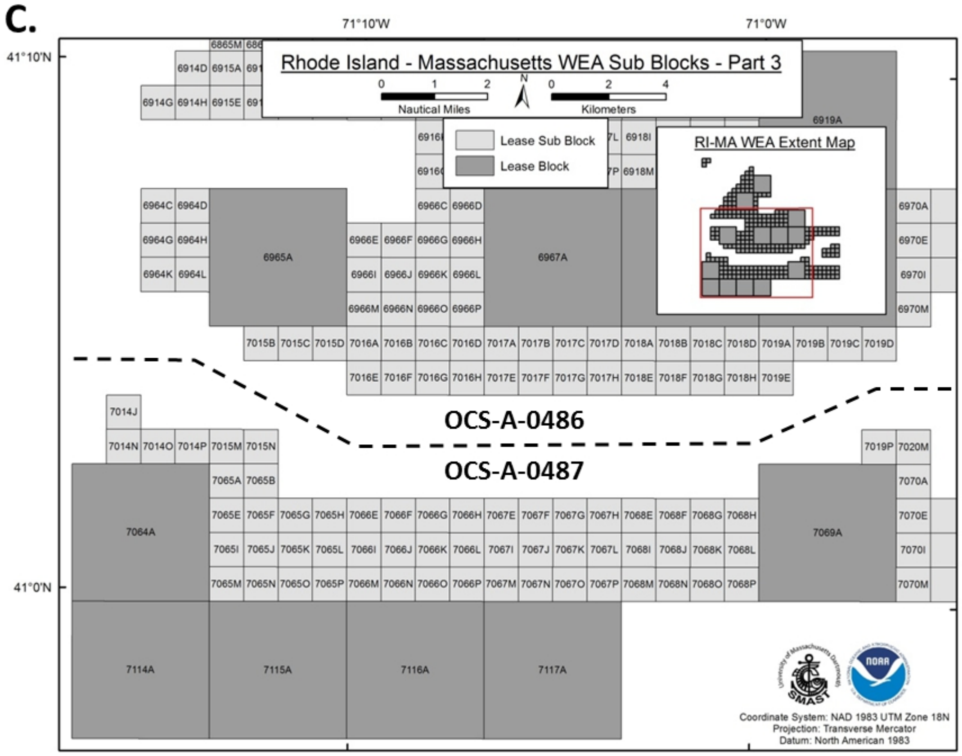


Figure 4-2 (continued). Numbered lease blocks included in the RIMA WEA (source data BOEM 2017).

4.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

4.2.1 Bathymetry

Figure 4-3 shows that the RIMA WEA bathymetry is complex. A deep channel runs along the northwestern edge of the WEA reaching a depth of 48 meters. The southernmost section of the WEA rapidly deepens to a maximum depth of 54 meters. In addition to the deep channels the central section of the WEA is marked by shallower water with several peaks and ridges shoaling at a depth of 27 meters. The flat, relatively shallow area in the southwest corner of OCS-A-0486 is known to fishermen as Cox Ledge. It appears on NOAA navigational charts as “Cox Ledge”, but on various other maps and websites as “Coxes Ledge” or “Cox’s Ledge”. Although the exact limits of this area vary with the source, part of this popular cod fishing area is inside lease area OCS-A-0486, as seen in Figure 4-3, and part is outside to the north and to the south of the southwest arm of the lease area. The fact that it is a popular cod fishing location suggests its value as habitat for at least adult and sub-adult Atlantic cod.

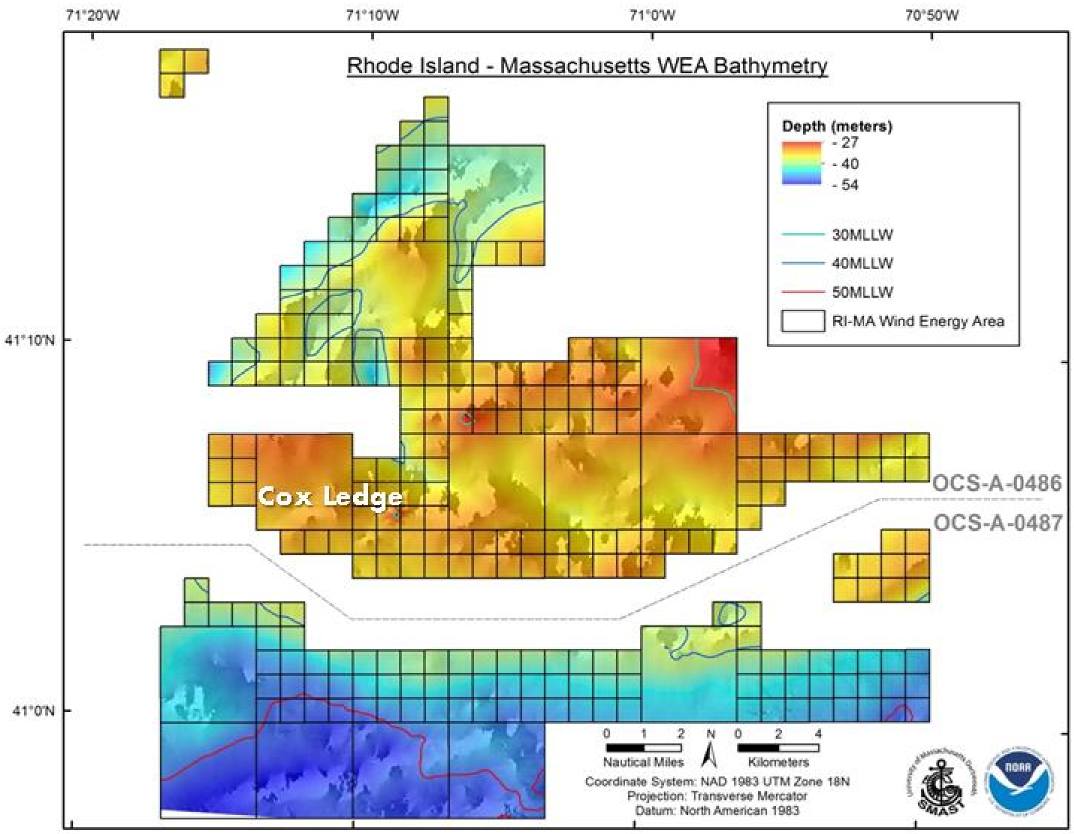


Figure 4-3. Bathymetry (38 m horizontal resolution) with isobaths contours in the RIMA WEA. Source data: (BOEM 2017, NOAA, NCEI 2017).

Bathymetric zones are apparent in this figure, including a northwestern area in OCS-A-0486 dissected by deep channels, a central, shallower zone also within OCS-A-0486 of smooth topography to the west (Cox Ledge) and more irregular topography to the east, and a gradual southward sloping zone all along the southern lease area (OCS-A-0487). Topography in the separated sub-blocks in the northwestern most corner of the WEA (OCS-0486) resembles that between channels in the nearby blocks. A large, deep NE-SW trending channel (not shown) separates these sub-blocks from the rest of the WEA. Bathymetry in the separated sub-block on the NE corner of OCS-A-0487 is similar to that of the adjoining area in OCS-A-0486 to the north: shallow and somewhat irregular.

4.2.2 Terrain Variables

Regarding terrain metrics, we found small variations in slope (< 3.15 degrees: Fig. 4-4A) and low rugosity values (<.000001: Fig. 4-4B). The areas with the greatest slope include the deep channel along the north

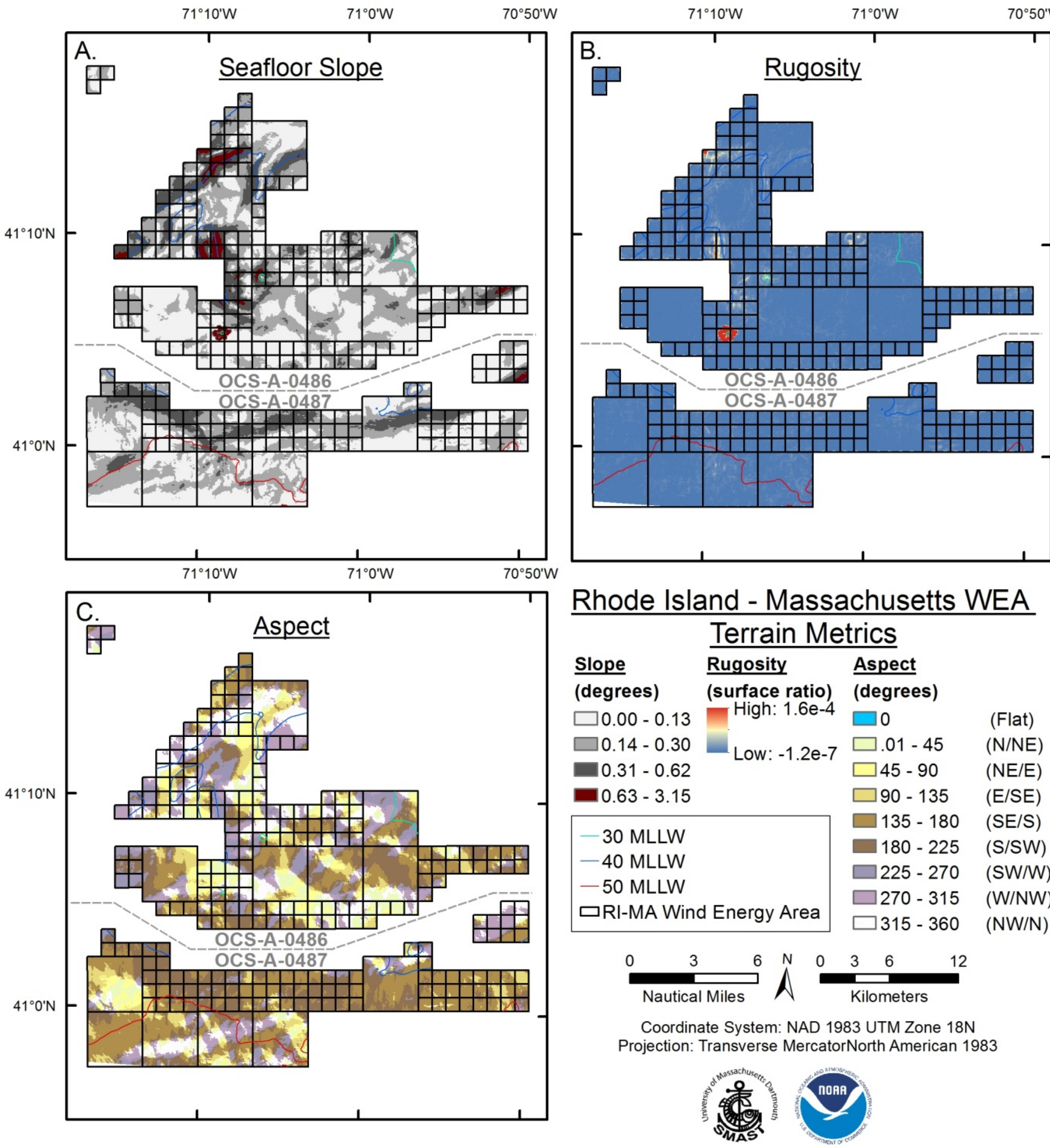


Figure 4-4. Terrain metrics derived from bathymetry for RIMA WEA (Figure 4-3). A. Seafloor slope, B. Rugosity, C. Aspect.

western edge of the WEA and the northern margin of the deepest water in the southernmost lease blocks. Areas of high slope (all within 3.15 degrees) were also noticed in areas around some peaks in the central zone. Rugosity was very low in the RIMA WEA aside from one central western peak and a few areas in the north western edge of the WEA. Aspect (Fig. 2-4C) was mixed between easterly and south westerly-oriented gradients. Overall topographic characteristics meet the CMECS criteria for flat terrain (0 to <5 degrees slope and very low rugosity: 1.0 to < 1.25)(FGDC 2012).

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 4-3) and terrain metrics (Figure 4-4). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope (2 degrees), standard deviation break = 2.0, and depth (Figure 4-5). Channels with their associated bank crests, sloping sides, and depressed bottoms are evident along the northwestern part of the WEA, the central area of peaks, slopes, and flats is also evident, all within OCS-A-0486. Also apparent is a gentle scarp (linear crest and slope) separating the shallower central area of the WEA from a deeper, flatter bottom surrounding the 50 m depth contour and punctuated with irregular rises (crests) located along the southern edge of the WEA (OCS-A-0487). The scarp appears to continue northeastward from the main body of OCS-A-0487 through that lease area's separated sub-blocks.

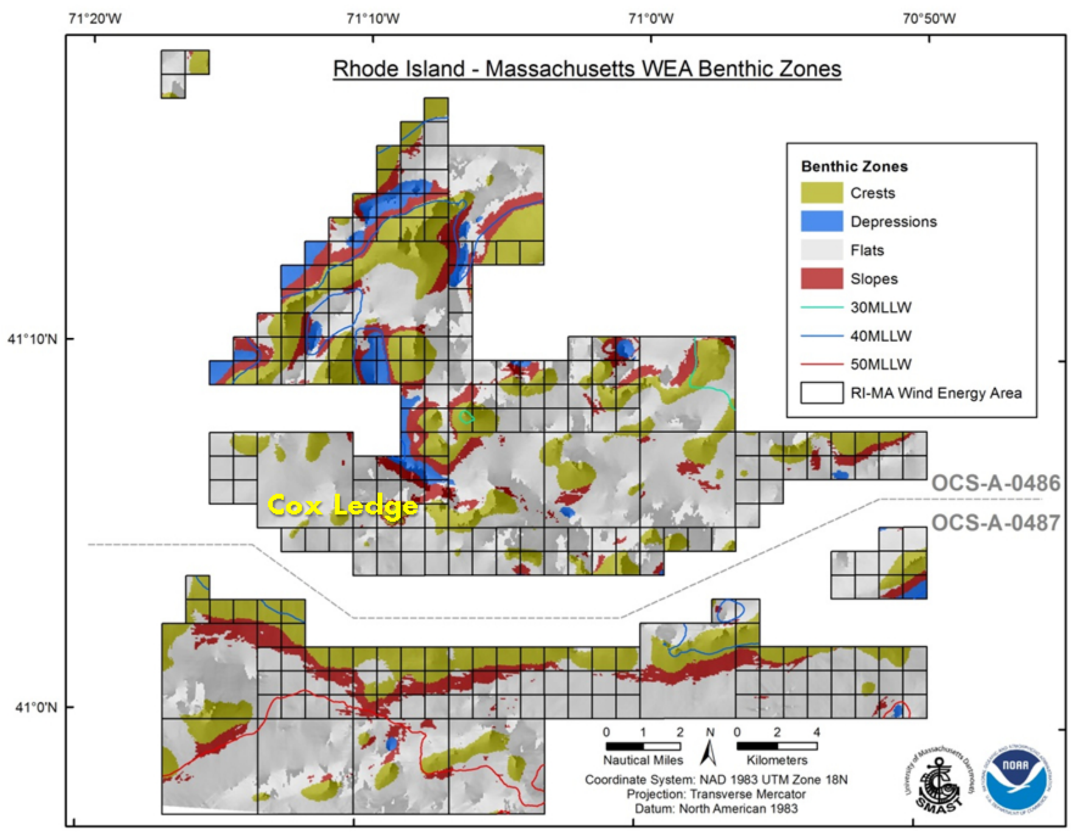


Figure 4-5. Benthic zones derived from 38 m bathymetry and derived slope data in the RIMA WEA.

4.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the RIMA WEA is shown in Figure 4-6. Figures 4-7, 4-8, and 4-9 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 4-6 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

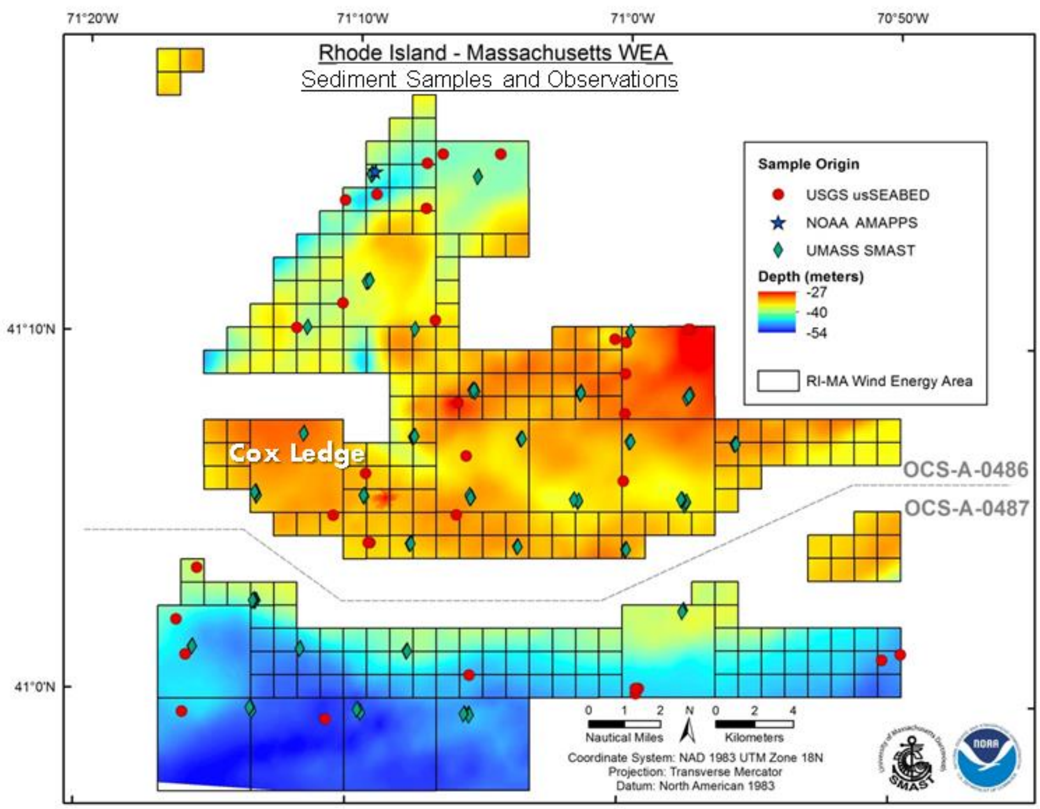


Figure 4-6. Location and source of benthic sediment samples and observations in the RIMA WEA. Sample include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles), core taken from grab sampler aboard the NOAA 2014 AMAPPS cruise (green star), and SMAST observations from imagery (green diamonds). Data sources - bathymetry as in Figure 4-3, sediment data: Reid et al. 2005, UMASS SMAST

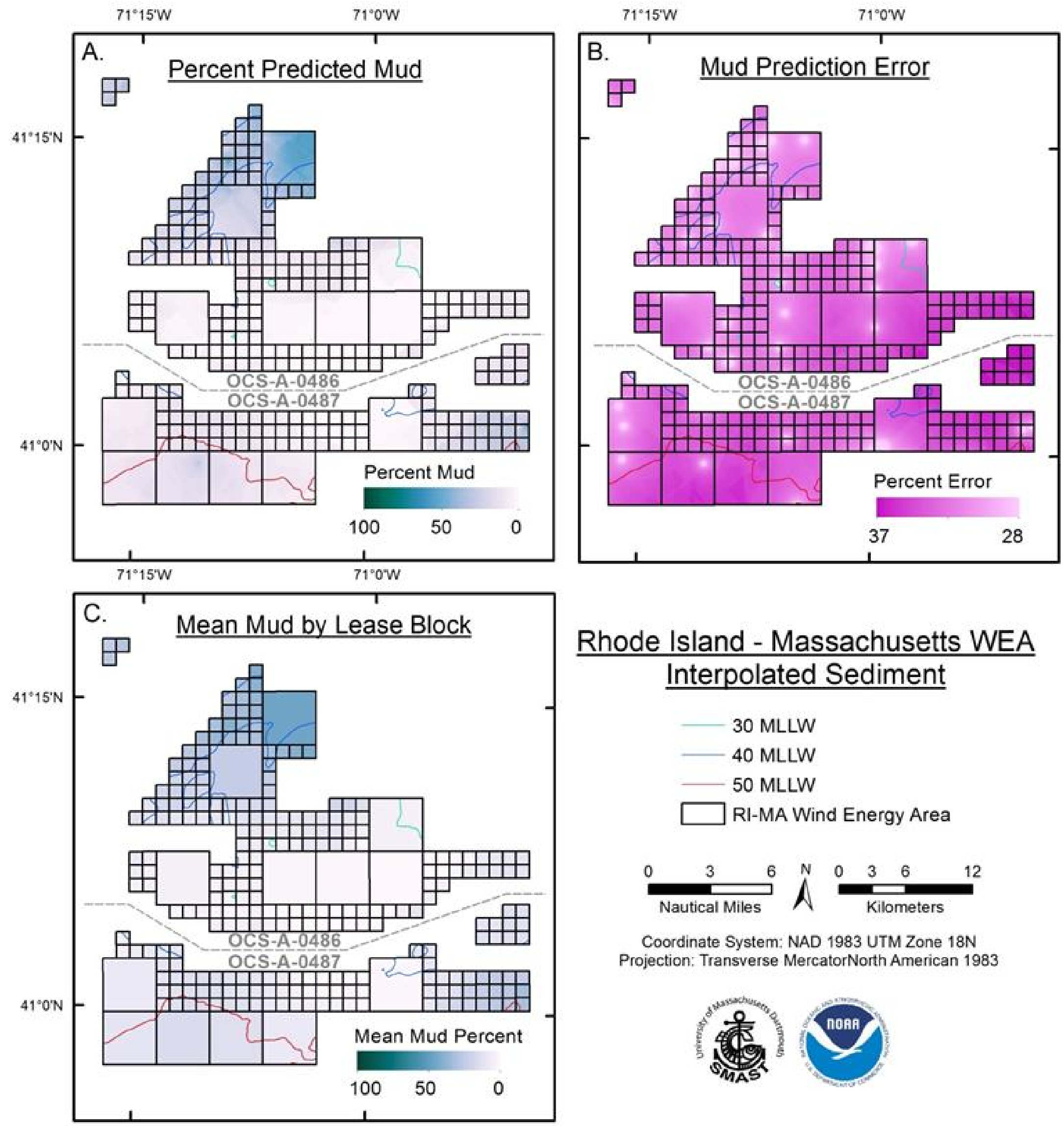


Figure 4-7. Predicted mud (silt + clay) distribution of surficial sediments in RIMA WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data as in Figure 4-6.

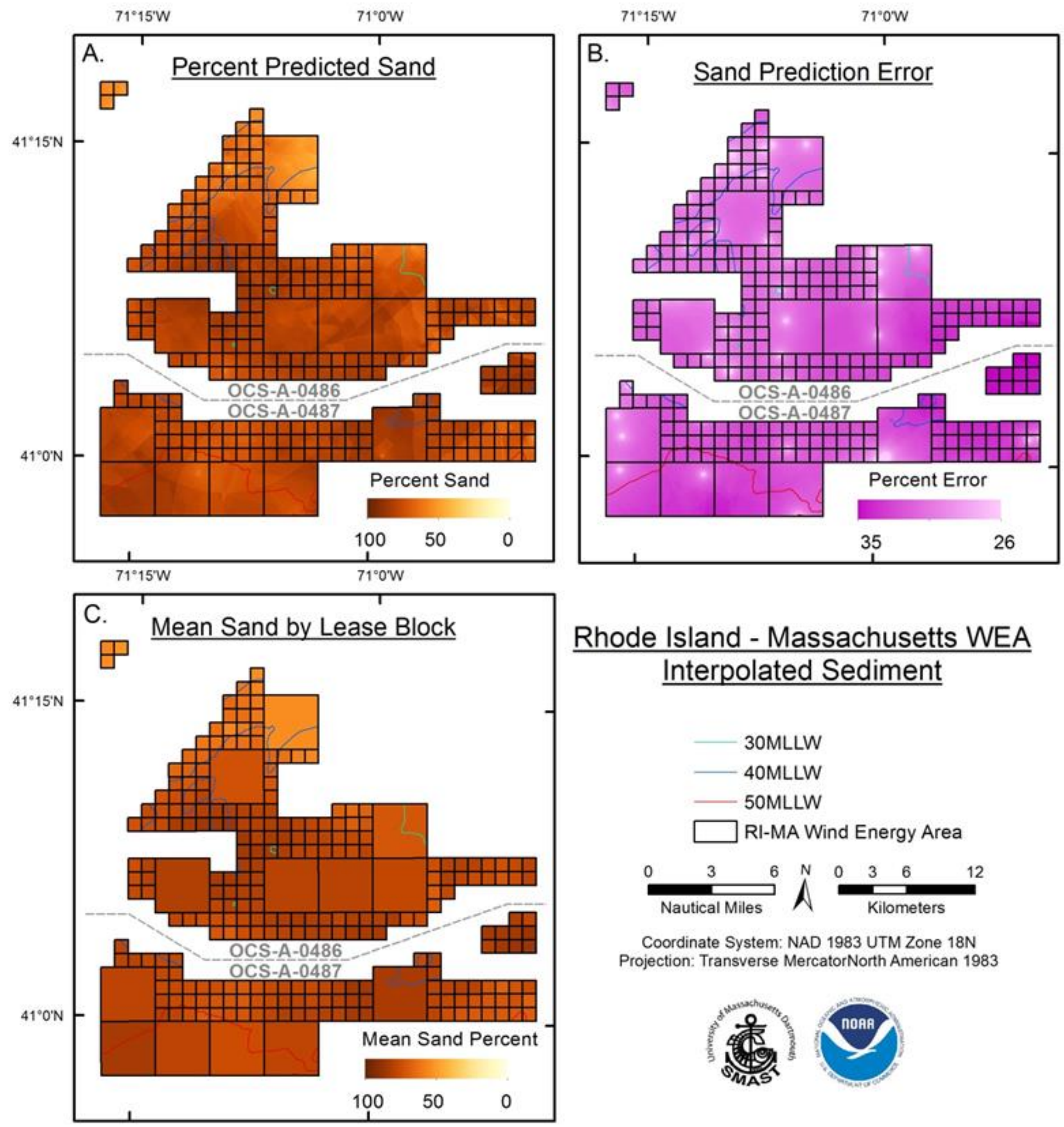


Figure 4-8. Predicted sand distribution of surficial sediments in RIMA WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data as in Figure 4-6.

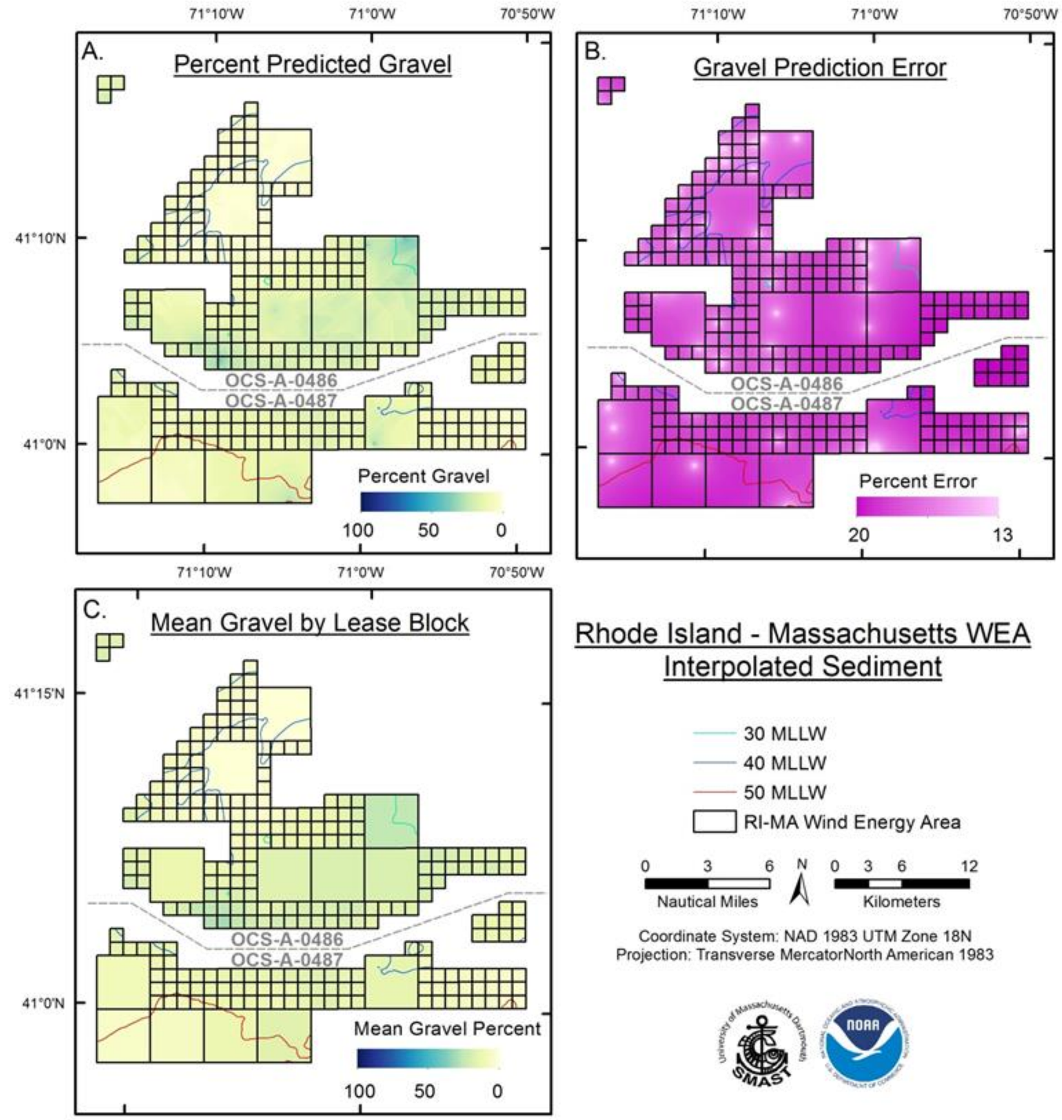


Figure 4-9. Predicted gravel distribution of surficial sediments in RIMA WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percentgravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data as in Figure 4-6.

Together Figures 4-7 through 4-9 indicate sediments dominated by sand throughout the WEA: muddy sand in the far north and in some parts of the south (Folk classification for mixed sediments: Table 1-3), and sand to gravelly sand in the central portion and some blocks in the south. Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 4-10. While this representation only represents mean grain size without assessing the range of sediment sizes present, it does give a good idea of the character of sediments where the variation in grain sizes is not extreme.

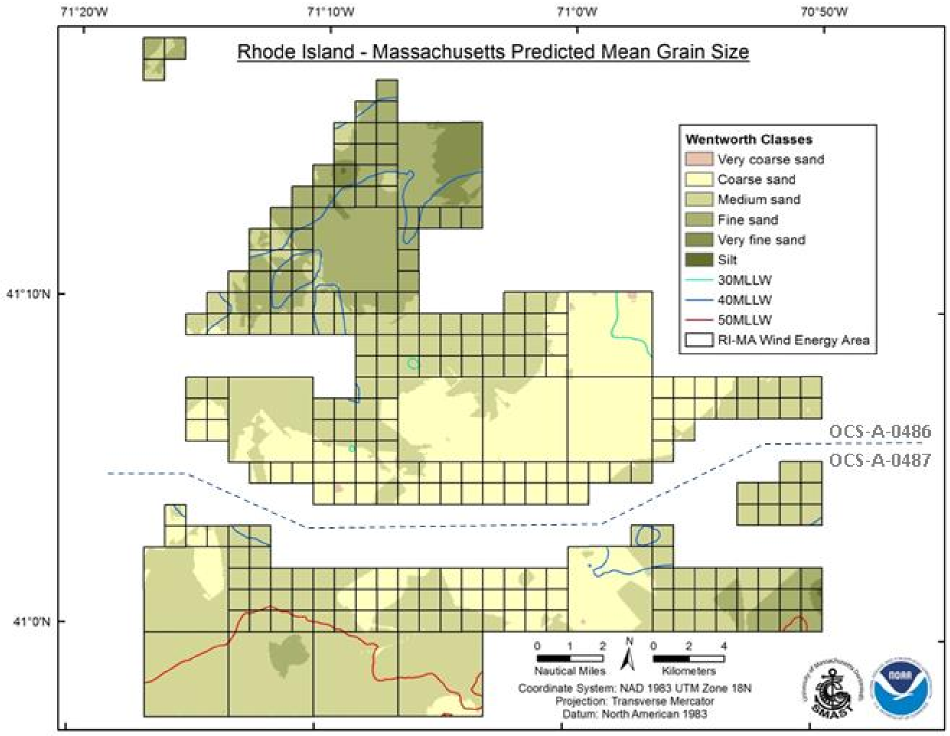


Figure 4-10. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the RIMA WEA physical samples. Figure shows interpolated average grain size distribution. Source data as in Figure 4-6.

As previously indicated surmised from the separate presentations of the distributions of mud, sand, and gravel (Figures 4-7 through 4-9) muddy sediments are restricted to the far north and patches in the far south. Everything else is sand-dominated, with the coarsest types in a band through the middle of the WEA, lapping into the south in its center. Being coarse sand on average, sediment in this central band is likely to include gravel, which we know from Figure 4-9.

UMASS SMAST image-based sediment observations, which were not included into the analyses displayed in Figures 4-7 through 4-10, independently confirmed this sediment distribution pattern and supplement data from grab samples. SMAST observations included grain sizes too large for grab samples and microtopographic features too small for detection from bathymetry, e.g. sand ripples (Figure 4-11). The silty (muddy) nature of sediments in the far north and far south of the WEA was apparent, as was the presence of gravel in the center section, but observations from the center section also included silt as a common element, and in some cases cobble and rock that were not accessible to grab sampling. Sediment diversity was greatest in this middle region. Several stations in the center section also exhibited sand ripples, an indicator of sand mobility and at least moderate bottom currents. These were absent from the sand and silt observed in the far north and south.

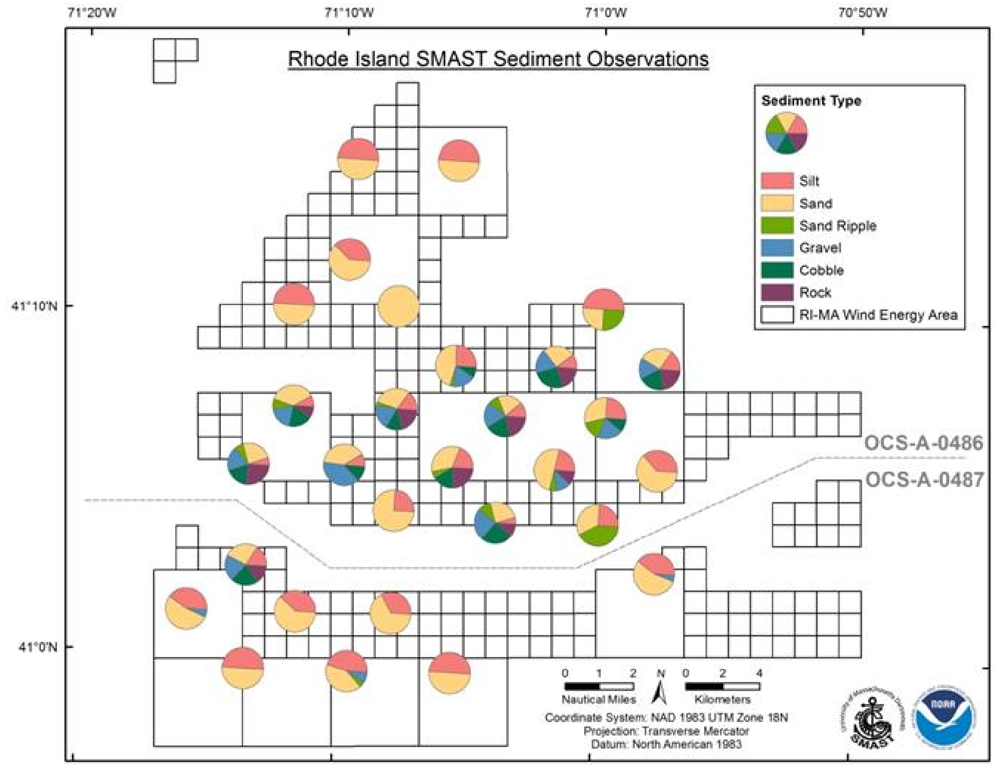


Figure 4-11. UMASS SMAST surficial sediments (presence-absence) observations. Observations proportions in pie charts were compiled to show the ratio of sediment observations from multiple images taken at each station. Source data: UMASS SMAST.

4.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 4-12.

Median salinity measured in the RIMA WEA for this period, including all depths, was 32.297 g/kg, with a full range spanning 30.939 to 33.509 g/kg (n=3,570), despite strong seasonal changes in other parameters. This range is entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 2.57 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

On the other hand, water temperatures show large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water

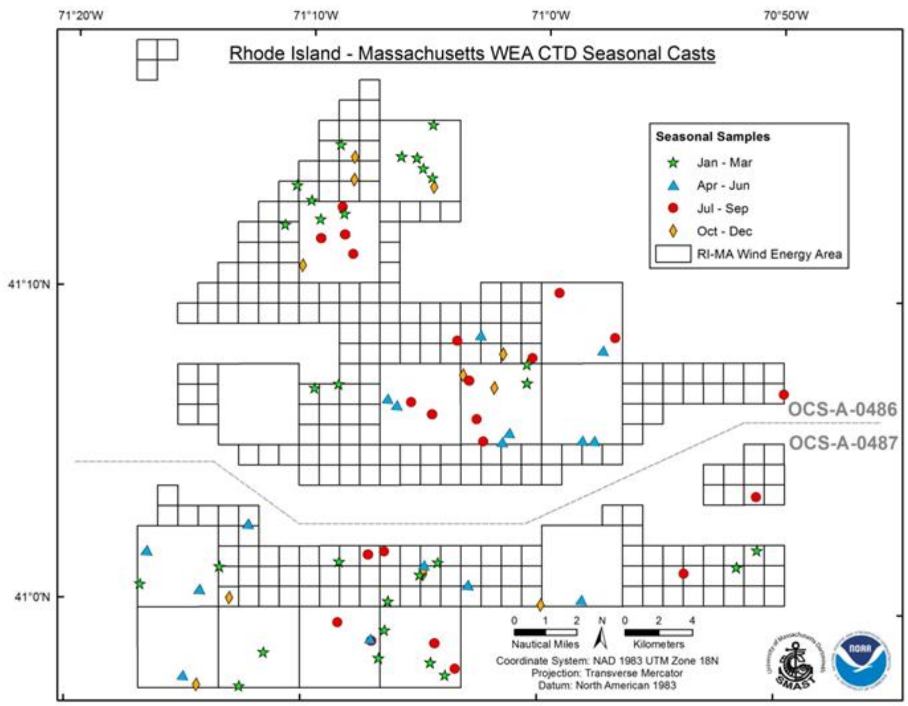


Figure 4-12. Locations for NEFSC CTD casts made between 2003 and 2016 in the RIMA WEA.

column structure. Figure 4-13 presents surface and bottom temperatures from CTD casts shown in Figure 4-12 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 20°C at the surface and 12°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 10°C. Then vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperatures of up to 12°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton. No persistent hydrographic fronts appear to impinge upon the RIMA WEA (Figure 1-4).

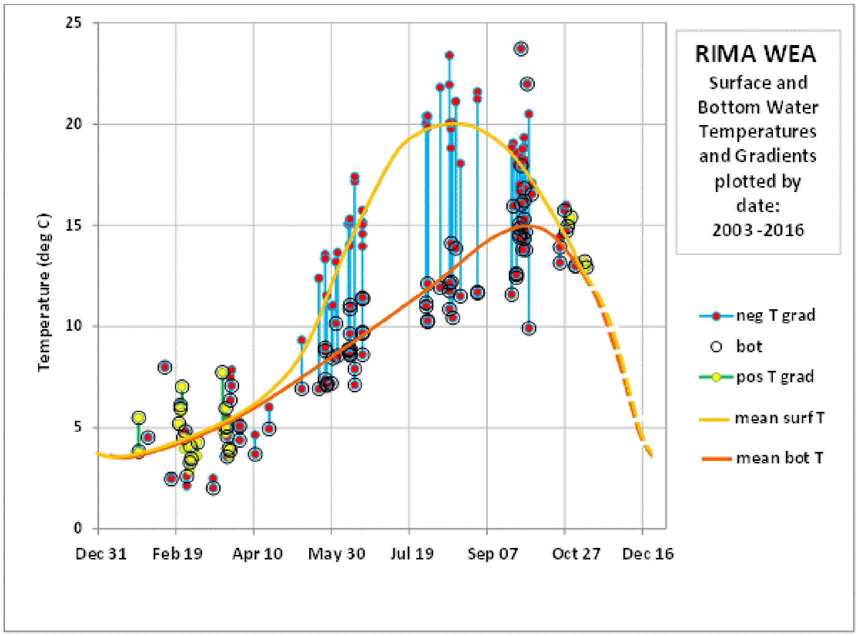


Figure 4-13. Water temperatures from CTD casts made between 2003 and 2016 in the RIMA WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values. No data was available for mid-November through mid-January, so the shapes of trend lines for that period (dashed) are conjectural.

4.2.5 Biological Variables

4.2.5.1 Benthic Epifauna and Infauna

Only a few benthic samples were collected during one of the NEFSC –sponsored cruises (AMAPPS GU14-02 part 1) in the RIMA WEA: four beam trawls for benthic epifauna and one grab for benthic infauna (Figure 4-14). All were in the northern part of OCS-A-0486. Additional sampling planned for AMAPPS GU14-02 part 2 was precluded by bad weather and ship's mechanical issues. No subsequent benthic sample-capable cruises visited the RIMA WEA. In this one WEA, since only one grab was included in the NEFSC benthic grab data, no "core" species could be determined from frequency of occurrence, so importance is represented in terms of numerical catch. Benthic sampling by the Rhode Island Ocean Special Area Plan sampling program (OceanSAMP: LaFrance et al. 2010) provided some additional coverage, but again only for the northern portion of OCS-A-0486 (Figure 4-15).

NEFSC beam trawl catches and the contents (20 taxa) of the single benthic grab sample (36 taxa) are summarized in Figure 4-16. The sole dominance of sand shrimp in beam trawl catch (all measures) and the prominence of sand dollars in biomass and frequency are not unexpected, given the sandy nature of bottom sediments (Figures 4-10, 4-11) in and near the beam trawl stations.

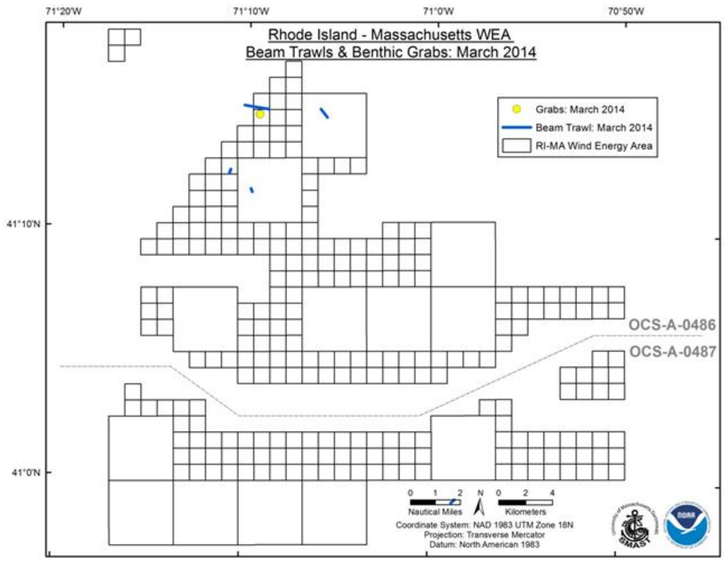
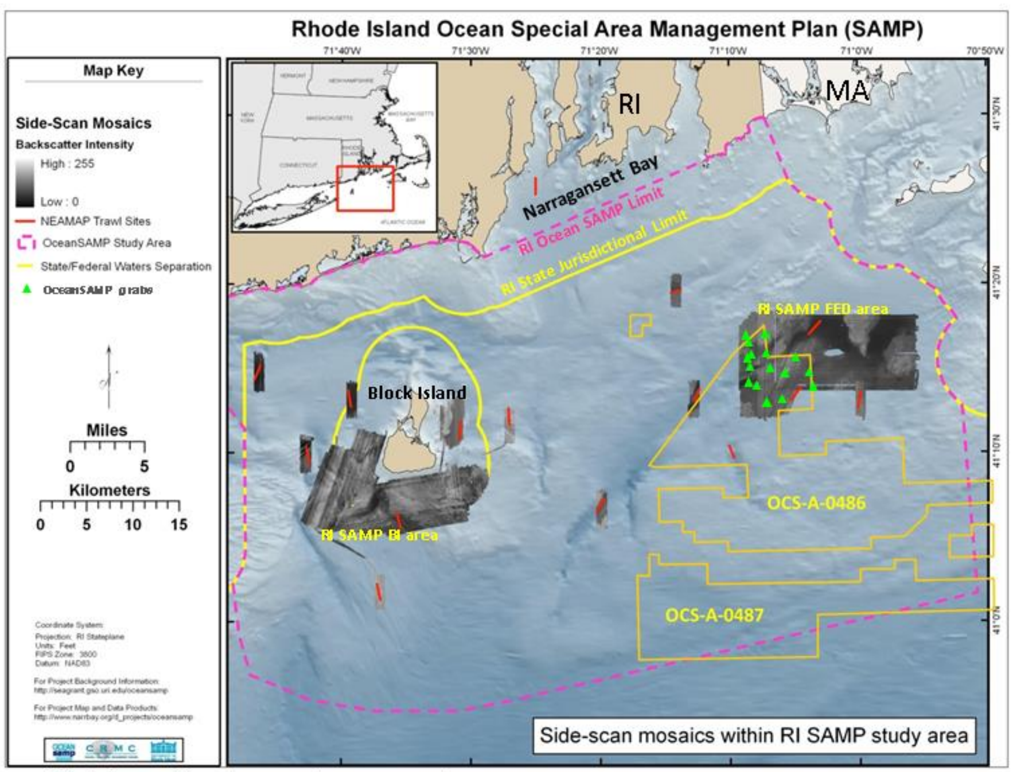


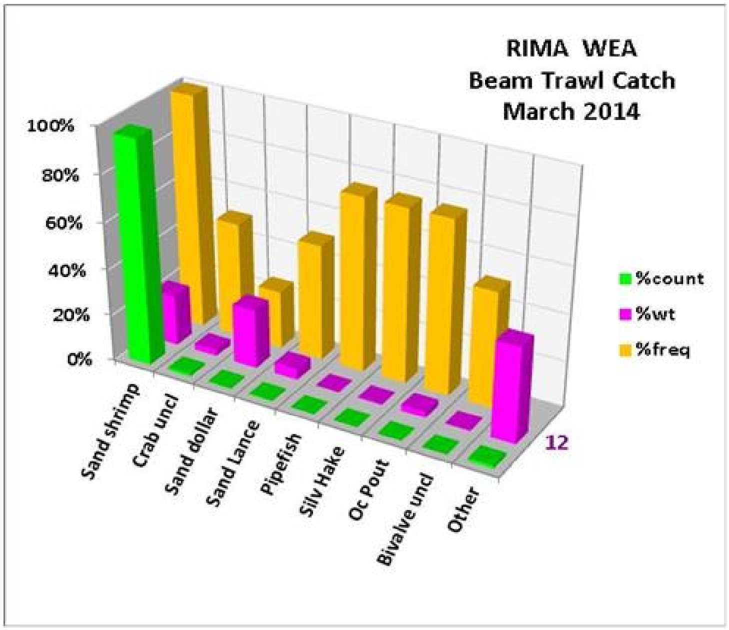
Figure 4-14. Locations of beam trawl and benthic grab samples made in the RIMA WEA.



modified after Malek et al. 2010 and LaFrance et al. 2010

Figure 4-15. Rhode Island OceanSAMP image showing program side scan sonar mapping areas and locations for benthic sampling sties that overlap with the RIMA WEA.

A.



B.

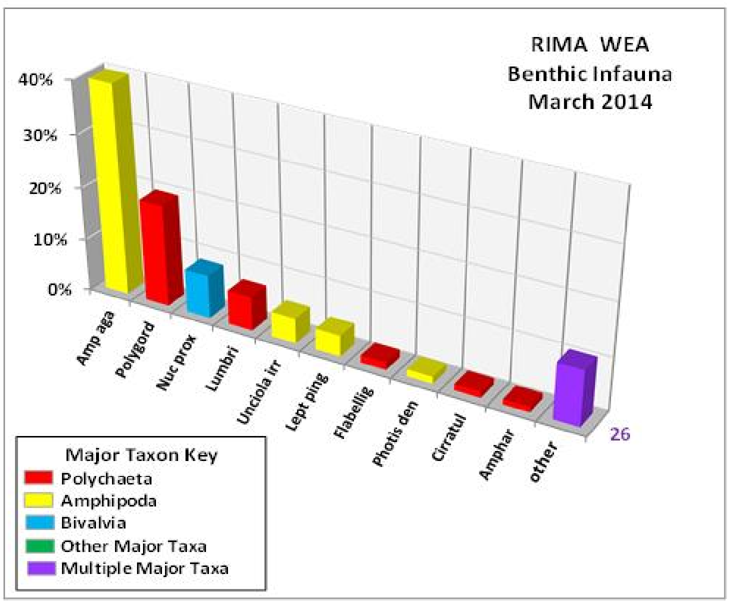


Figure 4-16. Benthic fauna caught in RIMA WEA by NEFSC sampling . A. Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA; B. Grab sample catch by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated common names for taxa in A.: Crab uncl - unclassified crabs, Silv Hake – silver hake, Oc Pout – ocean pout, Bivalve unclas – unclassified bivalve mollusks. Abbreviated taxonomic names in B: Amp aga – *Ampelisca agassizi*, Polygord – Polygordiidae, Nuc prox – *Nucula proxima*, Lumbri – Lumbrinereidae, Unciola irr – *Unciola irrorata*, Lept ping - *Leptocheirus pinguis,* Flabellig – Flabelligeridae, Photis den – *Photis dentata*, Cirratul – Cirratulidae, Amphar – Ampharetidae. Numbers to the right of the “other” and “non-core” taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of “other” and “non-core” species in these graphs.

Thirty six taxa of infaunal benthos were captured within the three replicates at the one grab station in the RIMA WEA. The benthic infauna appeared to resemble an assemblage common among adjoining OceanSAMP stations (Figure 4-15), described by LaFrance et al. (2010) as dominated by *Ampelisca agassizi* and *Nucula annulata* (*N. annulata* is an unaccepted synonym for *N. proxima*). This pattern points to the observation that barring serious disturbance, benthic infaunal assemblages can be stable over periods of many years (LaFrance, 2010).

Unfortunately, neither OceanSAMP nor our program obtained benthic samples from further south in the RIMA WEA where sediment conditions were different, likely harboring differing benthic assemblages.

4.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 4-17.

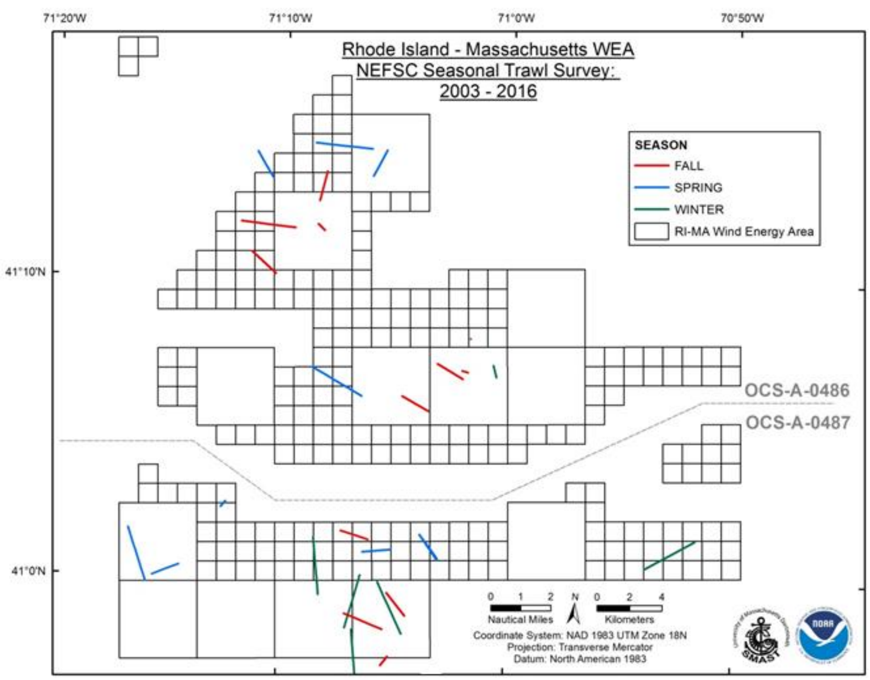
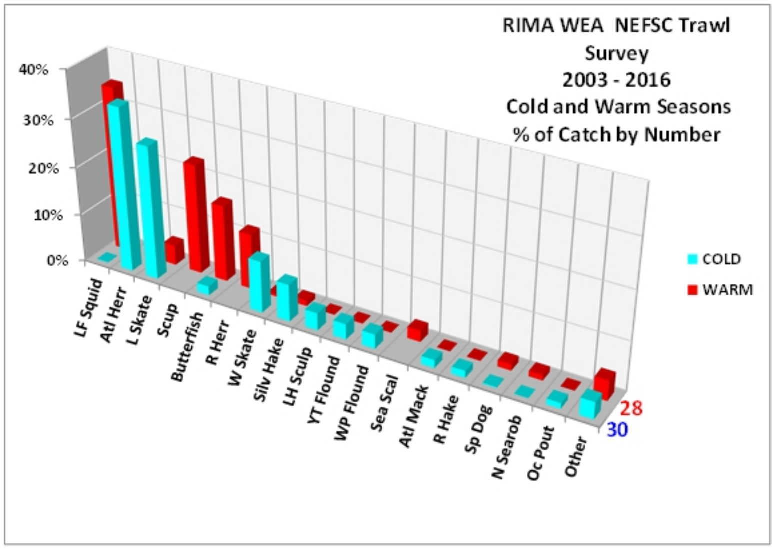


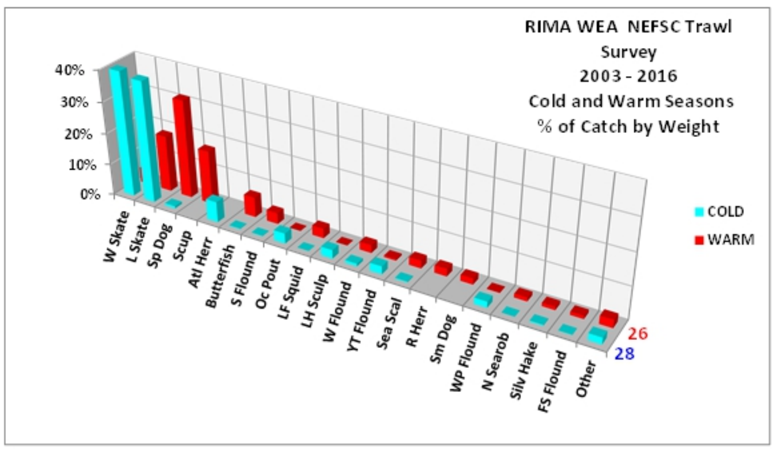
Figure 4-17. Locations of NEFSC seasonal trawls from 2003 to 2016 in the RIMA WEA.

Importance values among taxa captured in NEFSC Seasonal Trawl Survey catches in the RIMA WEA are plotted in Figure 4-18 and Table 4-1, with seasonally dominant species listed in Table 4-2.

A.



B.



C.

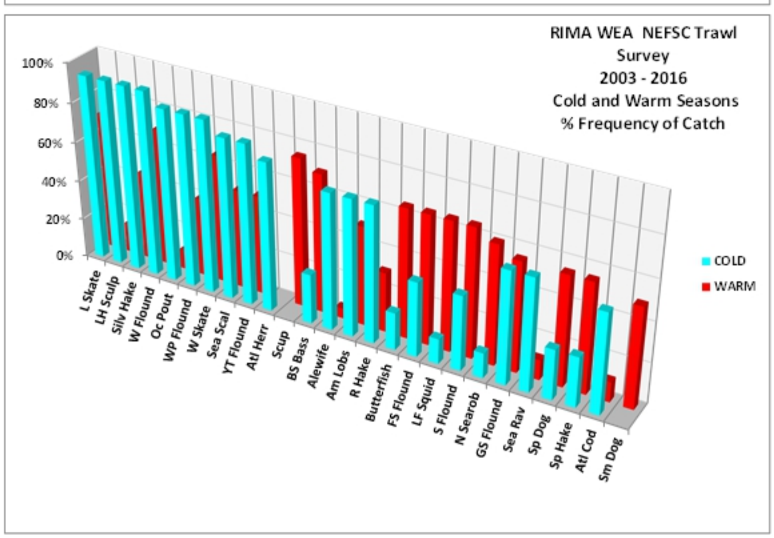


Figure 4-18. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 4-1. Blue and red numbers along the right margin of the graphs indicate the numbers of “other” species in cold and warm season catches respectively.

Table 4-1. Abbreviations for taxon names used in Figure 4-18, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Alewife	alewife[4]	R Hake	red hake[2]
Am Lobs	American lobster[1]	R Herr	round herring
Atl Cod	Atlantic cod[2]	S Flound	summer flounder[3]
Atl Herr	Atlantic herring[2]	Scup	scup[3]
Atl Mack	Atlantic mackerel[3]	Sea Rav	sea raven
BS Bass	black sea bass[3]	Sea Scal	sea scallop[2]
Butterfish	butterfish[3]	Silv Hake	silver hake[2]
FS Flound	fourspot flounder	Sm Dog	smooth dogfish[5]
GS Flound	Gulf Stream flounder	Sp Dog	spiny dogfish[4]
L Skate	little skate[2]	Sp Hake	spotted hake
LF Squid	longfin squid[3]	W Flound	winter flounder[2]
LH Sculp	longhorn sculpin	W Skate	winter skate[2]
N Searob	northern searobin	WP Flound	windowpane flounder[2]
Oc Pout	ocean pout[2]	YT Flound	yellowtail flounder[2]

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 4-2 Dominant species in NEFSC Seasonal Trawl Survey catches within the RIMA WEA between 2003 and 2016.

Rhode Island-Massachusetts WEA Dominants	
Cold Season	Warm Season
Atlantic herring	butterfish
little skate	little skate
longhorn sculpin	longfin squid
ocean pout	northern sea robin
windowpane flounder	scup
winter skate	sea scallop
yellowtail flounder	spiny dogfish

It is evident from this survey trawl data that this is a species-rich area: 45 species each in warm and in cold seasons. It is also evident that while there is considerable overlap in the lists of species present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also considerable overlap between these lists and those for the adjacent MA WEA (section 3.2.5.2). Of the taxa that are important in terms of numbers, biomass, and/or frequency (Table 4-1) 75% (21 out of 28) are species that are managed in the northeast region. Only one species, little skate, was dominant in both seasons. With the exception of the sea scallop, all others were seasonal migrants. It is also notable that all of the dominants other than longhorn sculpin and northern sea robin (i.e. 85% of dominant taxa) are managed fishery species.

4.2.5.3 Species of Concern

Records of shellfish species of concern in the RIMA WEA are illustrated in Figure 4-19. Most are quantitative records of sea scallops from NEFSC seasonal trawl surveys. Only one catch was made of an ocean quahog and no surfclams were caught here. In some cases quantitative trawl captures are located at the mid-point of the trawl track, which may lie outside the WEA limits even though the trawl did overlap the WEA. Whether the shellfish were actually caught inside or outside the WEA cannot be determined in these cases. As sea scallops were widespread and numerous and occurred in a majority of survey trawls and actually were considered a dominant species in the warm season (Table 4-2), this is a clearly a species worth considering in terms of potential for habitat disturbance in spite of only a small overlap with the sea scallop EFH (western end of OCS-A-0487 only) as currently designated (Figure 1-7). There is also a nearly complete overlap of this WEA with surfclam EFH (Fig. 1-9), although our detection methods did not find any. There is complete overlap with ocean quahog EFH with the RIMA WEA (Figure 1-8); that species was detected in our single benthic grab within the WEA.

The egg mops of longfin squid were not detected by us in the MA WEA, but this could be attributable to our sampling in early spring (March: cold season), rather than in summer (August), when longfin squid lay eggs. Beam trawling will catch them if they are present. The northernmost portion of OCS-A-0486 overlaps the EFH for this species (Figure 1-10).

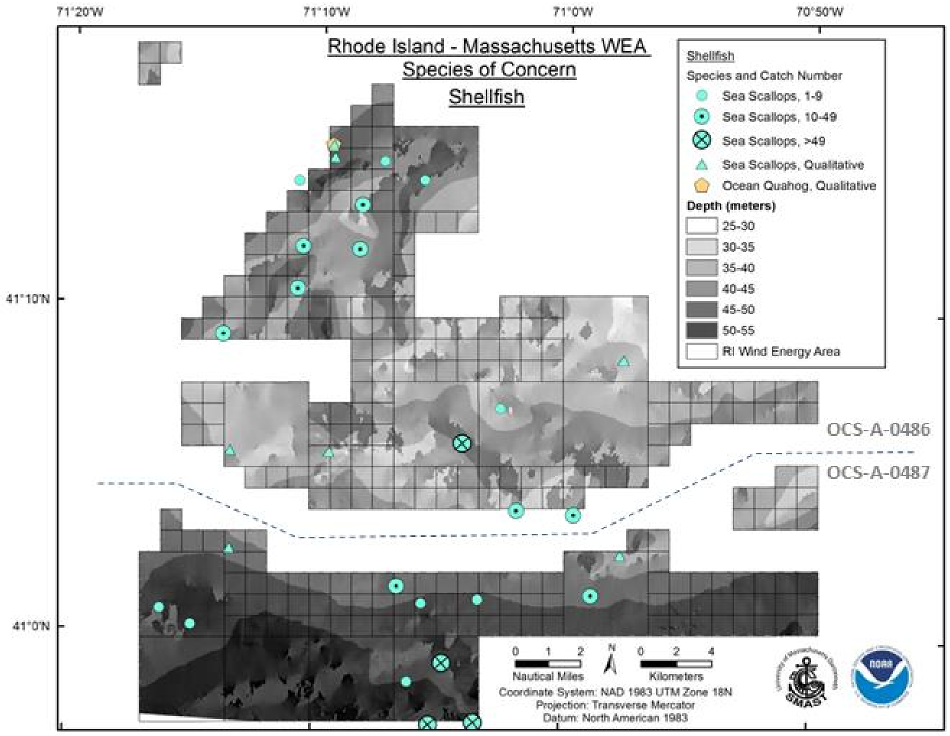


Figure 4-19. Shellfish species of concern records within and near the RIMA WEA.

Atlantic cod were only rarely caught by the NEFSC seasonal survey in the RIMA WEA between 2003 and 2016. Reasoning that this rarity might be connected to the large decline in cod stocks in the 1990s, we added catch records from the previous 14 years, extending back to 1989 (Figure 4-20), into better times for cod stocks in general, but this only increased the number of detections from 3 to 7 catches of 1-5 fish. Juvenile cod EFH covers most of OCS-A-0486 and adult cod EFH covers all of the RIMA WEA (Figure 1-11). This apparent low catch rate seems curious, as at least Cox Ledge remains a popular destination for cod anglers. In fact, the 3 catches during the period 2003-2016 represents 20% of the trawls made during the cold season, when cod are likely to be present. While not a high catch frequency, it is greater than the 7% catch frequency recorded for the cold season in the MA WEA over the same period. An explanation for the low frequency may lie in the randomness of the trawl survey. Only two cold season trawls passed through the central portion of the WEA, which probably affords the best bottom habitat type (glacial till: see section 4.3 below) for Atlantic cod. Disturbance of cod habitat remains an issue for consideration in the RIMA WEA.

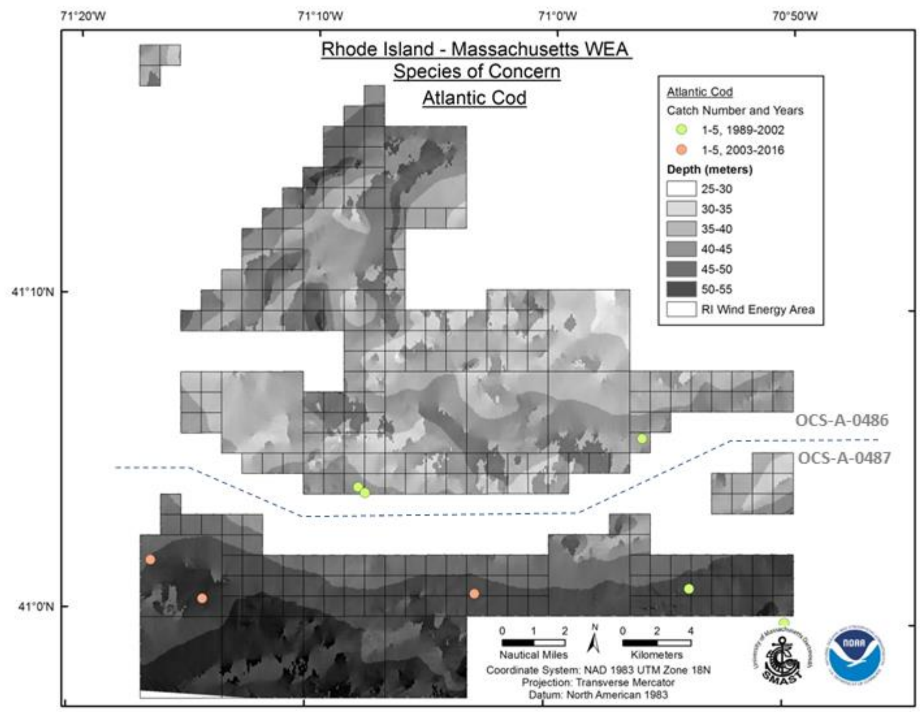


Figure 4-20. Records of Atlantic cod in the RIMA WEA.

Both young-of-the-year (YOY) and sub-adult to adult-sized black sea bass were also detected in the RIMA WEA, entirely via NEFSC seasonal survey trawl (Figure 4-21). The distinction is important because YOY black sea bass are thought to have differing requirements with respect to bottom habitat refuge requirements. Like sea scallops, both life stages are widespread throughout both lease areas in the WEA. This is reflected in the EFH map for juvenile black sea bass (Fig. 1-9A), which shows almost complete overlap with the RIMA WEA. Adult EFH (Figure 1-10B) indicates overlap only in the north (partial overlap with OCS-A-0486). This is another species where there may be potential for habitat disturbance.

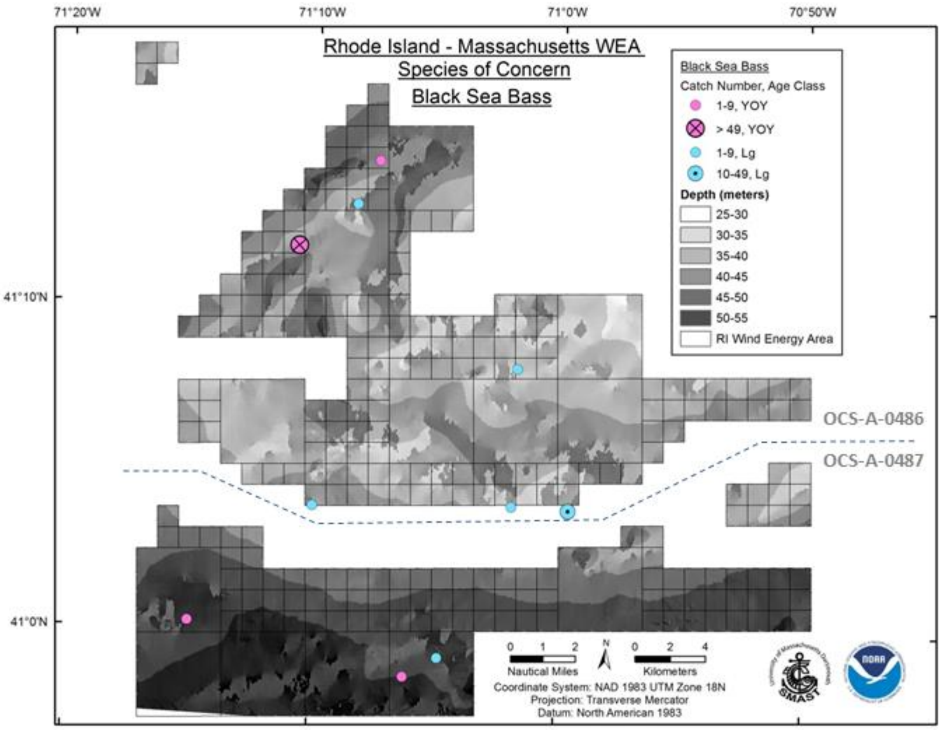


Figure 4-21. Records of young-of-the-year (YOY) and larger black sea bass in the RIMA WEA.

4.3 Habitat Definition

An integrated view of the physical benthic habitat features in the RIMA WEA is presented in Figure 4-22. The entirety of the RIMA WEA represents the southwestern tip of a bank, an elevated area above the surrounding seafloor (FGDC 2012) associated with remnants of continental glaciation during the Pleistocene epoch. There are four major topographic zones (Topo Zones 1, 2, 3, 4) with habitat features (shelf valleys, mud to muddy patches) superimposed upon it in various locations. Shelf valleys are so designated because the faint channels (Figure 4-3) appear on a large scale map (Ruddock 2010, Figure 1) to be tributaries to the Block Island Shelf Valley that runs southward across the shelf to the southwest of the RIMA WEA. This was probably a large river system draining what is now the southern New England shelf during the low stand of sea level during the Wisconsin glaciation. As far as we have determined with the data at hand, the sediments and fauna of these features are not notably different from those of the surrounding shelf.

Much of the northern lease area (OCS-A-0486) appears to be a platform with irregular contours. The northeast extension of that area includes a large mud patch with muddy sand to mud substrate. This extension overlaps the Rhode Island SAMP “Fed” area (Figure 4-15). The flat, muddy patch in the northeast corner of the RIMA WEA appears to extend much farther east of the RIMA border into the SAMP Fed area (LaFrance et al 2010). It originated from silt deposited in a glacial lake that once covered the area. The rest of OCS-A-0486 appears to have sand-dominated sediments, finer in the north and coarser in the south, with some gravel intermixed. In fact, south of the narrow neck region formed by the sub-blocks of lease blocks 6916 and 6917, SMAST indicates an admixture of cobble, boulders, and rocks with sand, silt, and rippled sediments. The fine sand north of the narrow neck is characterized by LaFrance et al. as a "hummocky moraine" deposit. The very mixed sediment to the south was not described by these authors, but they were also described as terminal moraine deposits by Stone and Borns (1986). We have thus divided OCS-A-0486 into two Topo Zones, #1 north of the narrow neck with sandy to muddy sand sediments, and #2 south of the narrow neck with very mixed silt to rock sediments and ripples. The previously mentioned shelf valley tributary channels bound this lease area along its northwest border and cut through both of these Topo Zones.

Topo Zone 3 lies along the northern margin of OCS-A-0487, where it slopes seaward in a band at angles of 0.14 – 0.62 degrees (Figure 4-4). This appears to mark the southern margin of the platform on which OCS-A-0486 is located. As this strip of bottom slopes down from the elevated region to the north we are characterizing it as a fan**,** although it does not meet the definition of any particular type of fan defined by CMECS. Sediments are slightly gravelly sand.

Topo Zone 4 lies to the south of Topo Zone 3 in OCS-A-487. It appears to be a terrace of moraine outwash material at the southern end of the bank. It is characterized by similar sediments to those of Zone 3, but lacks its uniform seaward slope. It is cut east to west by a broad shelf valley tributary.

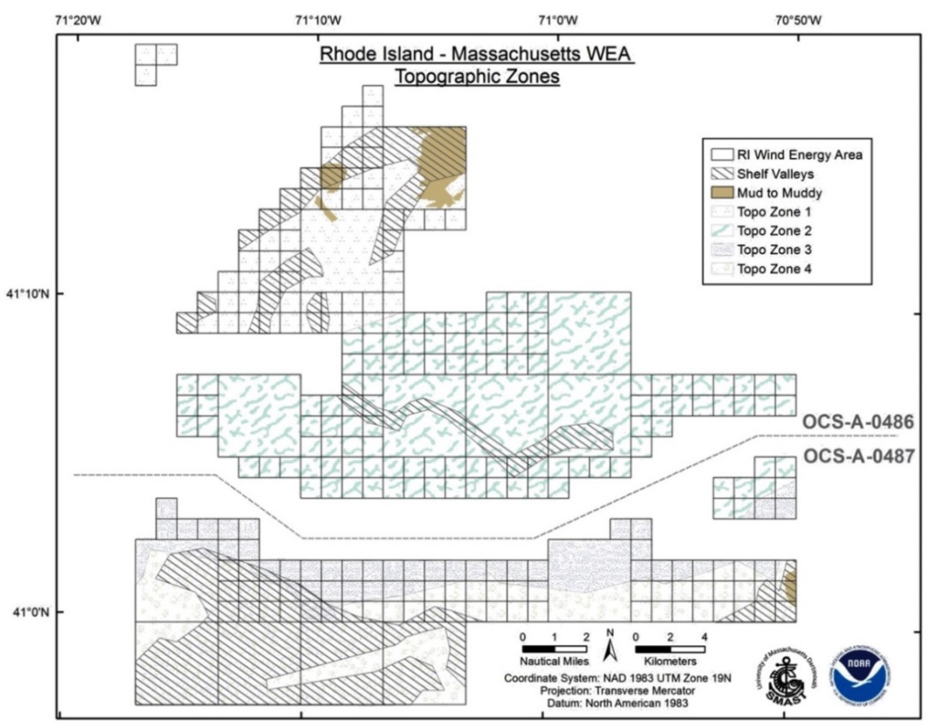


Figure 4-22. Physical benthic habitat features of the RIMA WEA.

4.3.1 CMECS Classifications:

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Moraine, Level 1
      - Geoform Type: Terminal Moraine, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Muddy Sand, Slightly Muddy Sand, Sand, Slightly Gravelly Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Larger Tube-Building Fauna, Scallop Bed

Topo Zone 2

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Moraine, Level 1, alternate Geoform: Till Surface, Level 1
      - Geoform Type: Terminal Moraine, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Coarse Unconsolidated Substrate, Fine Unconsolidated Substrate
        - Substrate Groups: Gravel Mixes, Gravelly, Slightly Gravelly, Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Larger Tube-Building Fauna, Scallop Bed

Topo Zone 3

Geoform Component

Geoform Origin: Geologic

Geoform: Fan, Level 1

Substrate Component

Substrate Origin: Geological Substrate

Substrate Class: Unconsolidated Mineral Substrate

Substrate Subclass: Fine Unconsolidated Substrate

Substrate Groups: Slightly Muddy Sand, Sand, Sand, Slightly Gravelly Sand

Biotic Components: same as for Topo Zone 1

Topo Zone 4

Geoform Component

Geoform Origin: Geologic

Geoform: Terrace, Level 1

Substrate Component

Substrate Origin: Geological Substrate

Substrate Class: Unconsolidated Mineral Substrate

Substrate Subclass: Fine Unconsolidated Substrate

Substrate Groups: Slightly Muddy Sand, Sand, Sand, Slightly Gravelly Sand

Biotic Components: same as for Topo Zone 1

Shelf Valley

Geoform Component

Geoform Origin: Geologic

Geoform: Shelf Valley (tributaries)

Substrate and Biotic Components: same as for Topo Zone 1

Mud to Muddy Patch

Geoform and Biotic Components: same as for Topo Zone 1

Substrate Component

Substrate Origin: Geological Substrate

Substrate Class: Unconsolidated Mineral Substrate

Substrate Subclass: Fine Unconsolidated Substrate

Substrate Groups: Muddy Sand to Mud

5 New York Wind Energy Area (NY WEA)

5.1 Location, size, and subdivision

The New York WEA forms a narrow wedge oriented approximately ENE by WSW lying between approximately 12 and 26 nautical miles south of Long Island's south shore and between about 16 and 42 nautical miles east of the northern New Jersey shoreline (Figure 5-1). It consists of 5 full lease blocks plus 143 sub-blocks (Figure 5-2). Not counted in this total are 5 sub-blocks at the northwest tip of the original NY WEA call area (Cholera Bank sensitive habitat area) that were removed from leasing consideration (Lease OCS A-0512). Water depths range 18 to 41 m and average approximately 30 m. The WEA covers approximately 79,350 acres of seafloor (BOEM 2014b). It lies in the Southern New England biogeographic region, just east of the Hudson Shelf Valley, that region's boundary with the Southern Mid-Atlantic Bight. Figure 5-2 provides the numbering for all blocks in this WEA. This section provides data and analysis for the entire NY WEA as a single unit.

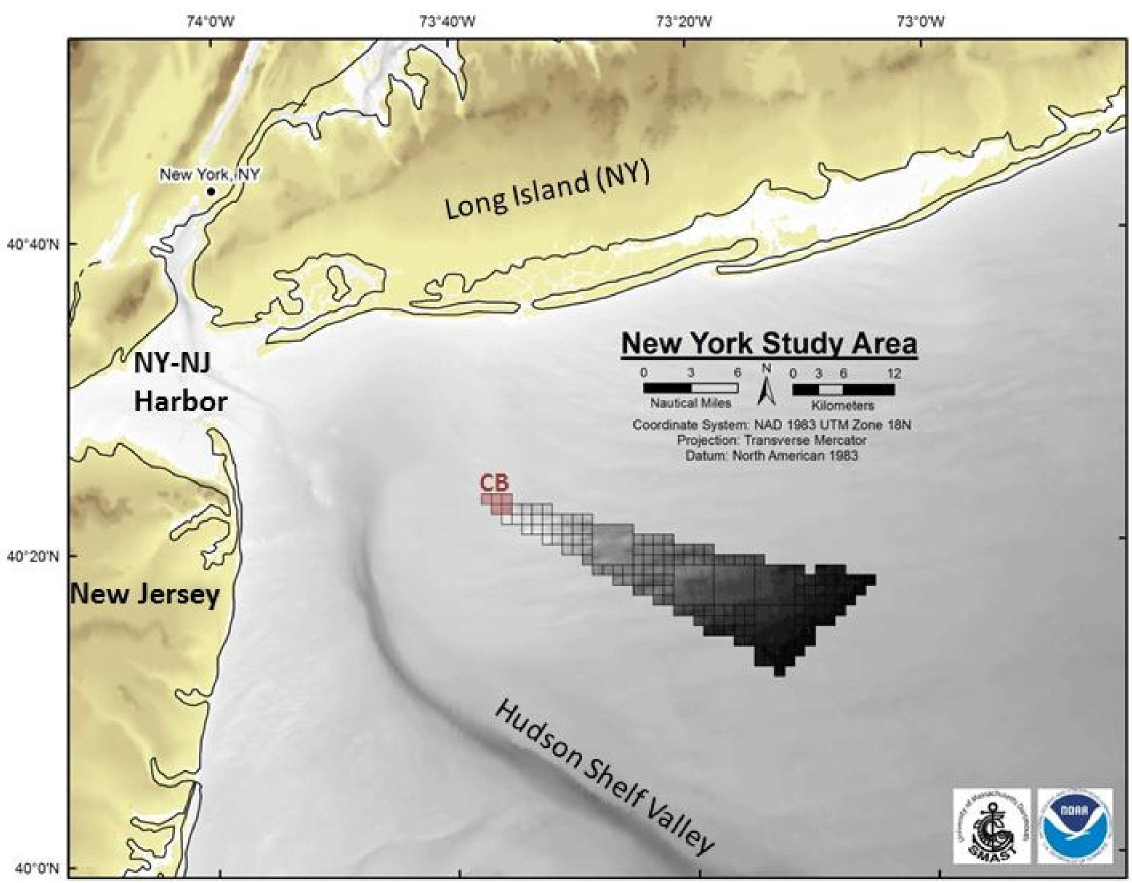


Figure 5-1. Map of New York study area. Source data:(BOEM 2017, NOAA NCEI 2017). Brown sub-blocks labeled CB represent the Cholera Bank area that was removed from Lease OCS A-0512.

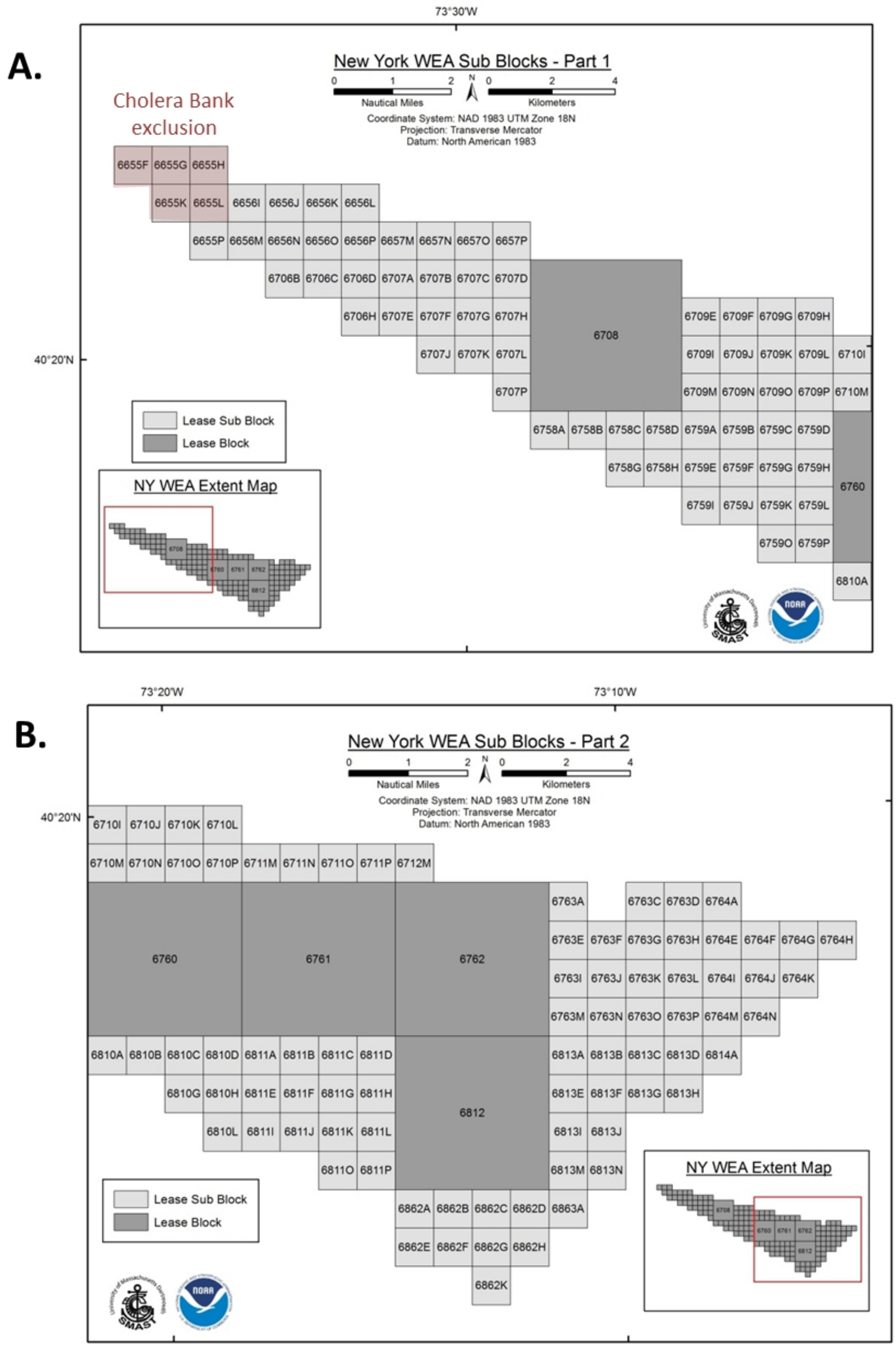


Figure 5-2. Numbered lease blocks and sub-blocks included in the NY WEA: A. Western part, B. Eastern part (source data BOEM 2017).

5.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

5.2.1 Bathymetry

Figure 5-3 shows that the NY WEA bathymetry is relatively simple. It is essentially a flat bottom, sloping gently away from land and toward the shelf edge. The depth of water increases 22 m over a distance of about 42 km, giving a value of 0.03 degrees for the general seaward slope of the bottom.

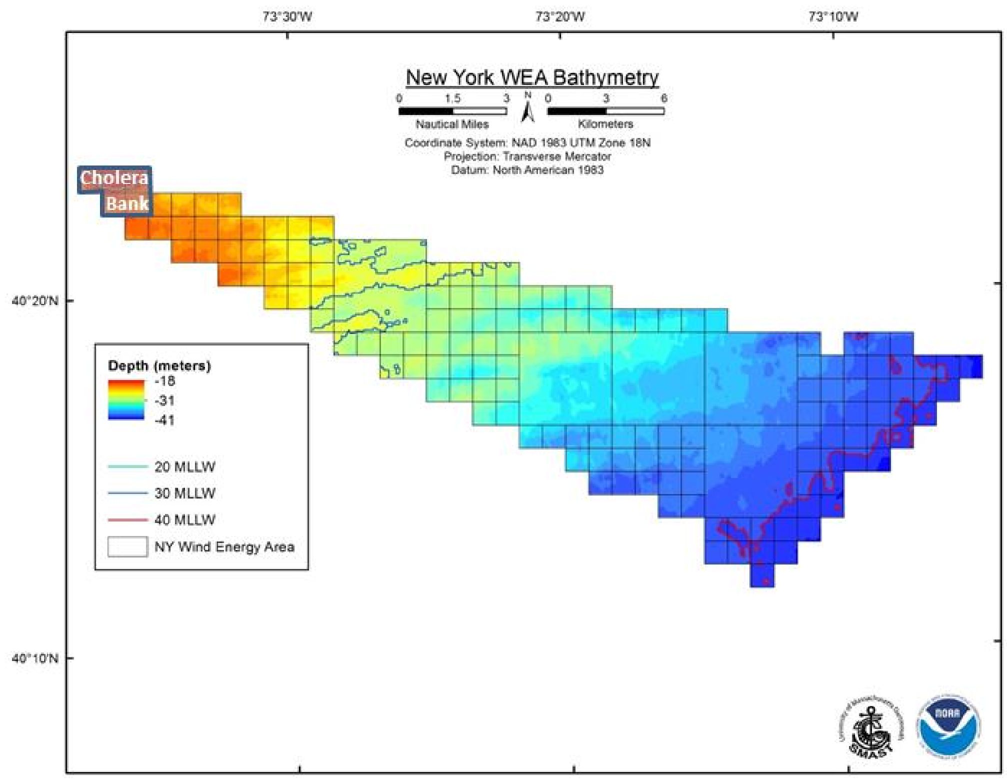


Figure 5-3. Bathymetry (3 arc-second horizontal resolution) with isobath contours in the NY WEA. Source data: (BOEM 2017).

5.2.2 Terrain Variables

Regarding terrain metrics, there was a uniformly low slope (<0.27 degrees: Figure 5-5A) and low rugosity values (<-1.0: Figure 5-5B). Aspect (Figure 5-5C) was largely westerly (180 to 360). Overall topographic characteristics meet the CMECS criteria for flat terrain (0 to <5 degrees slope and very low rugosity: (< 1.25)(FGDC 2012).

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 2-3) and terrain metrics (Figure 5-4). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope, standard deviation break = 2.0, and depth (Figure 5-5).

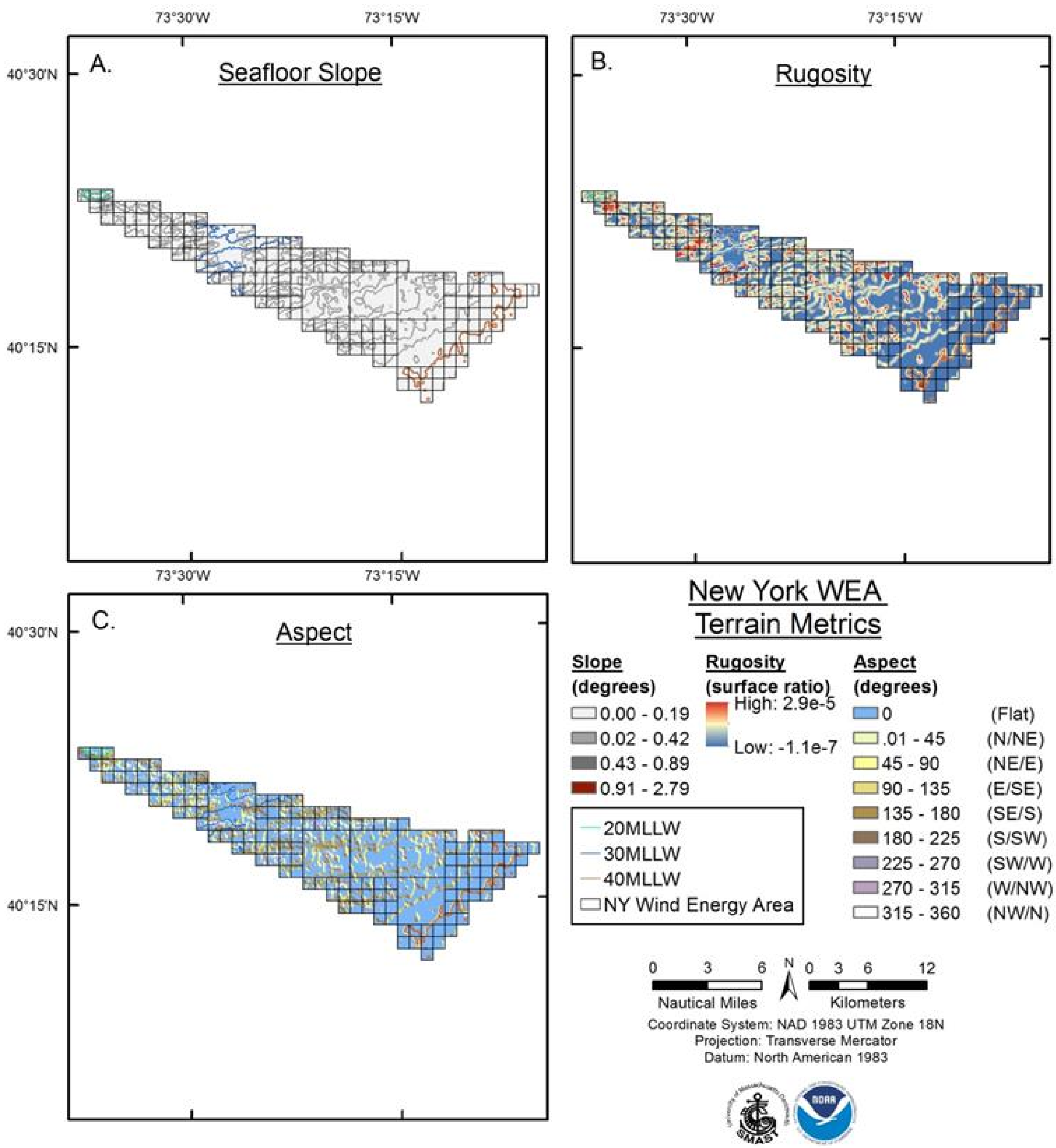


Figure 5-4. Terrain metrics derived from bathymetry for NY WEA (Figure 5-3). A. Seafloor slope, B. Rugosity, C. Aspect.

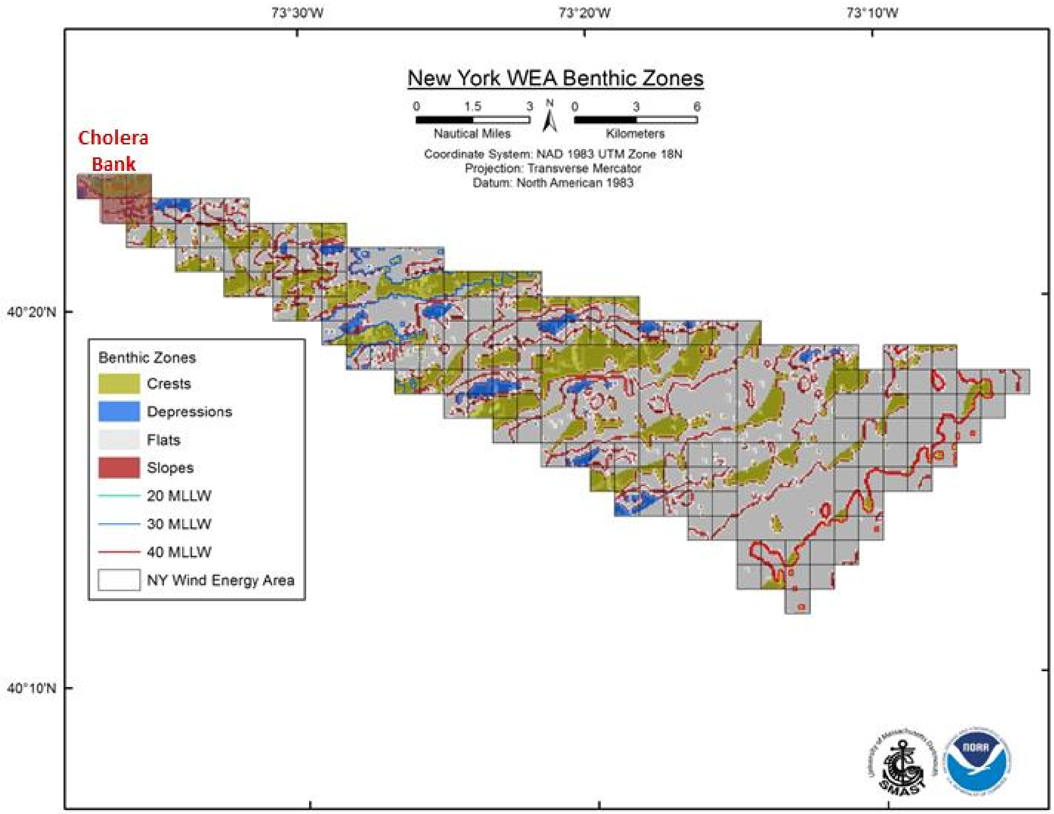


Figure 5-5. Benthic zones derived from 3 arc-sec bathymetry and derived slope data in the NY WEA.

As anticipated, these analyses revealed only very small values of slope and rugosity, and little variation in aspect (largely flat). Benthic zones appear as a series of highly irregular linear ridges and depressions running roughly SW to NE (parallel to depth contours) with crest-to-crest wavelengths in the range of 3-5 km and heights of 1-2 m. These features are presumed to be sand ridges, a common feature of sandy continental shelves worldwide.

5.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the NY WEA is shown in Figure 5-6. Figures 5-7, 5-8, and 5-9 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 5-6 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

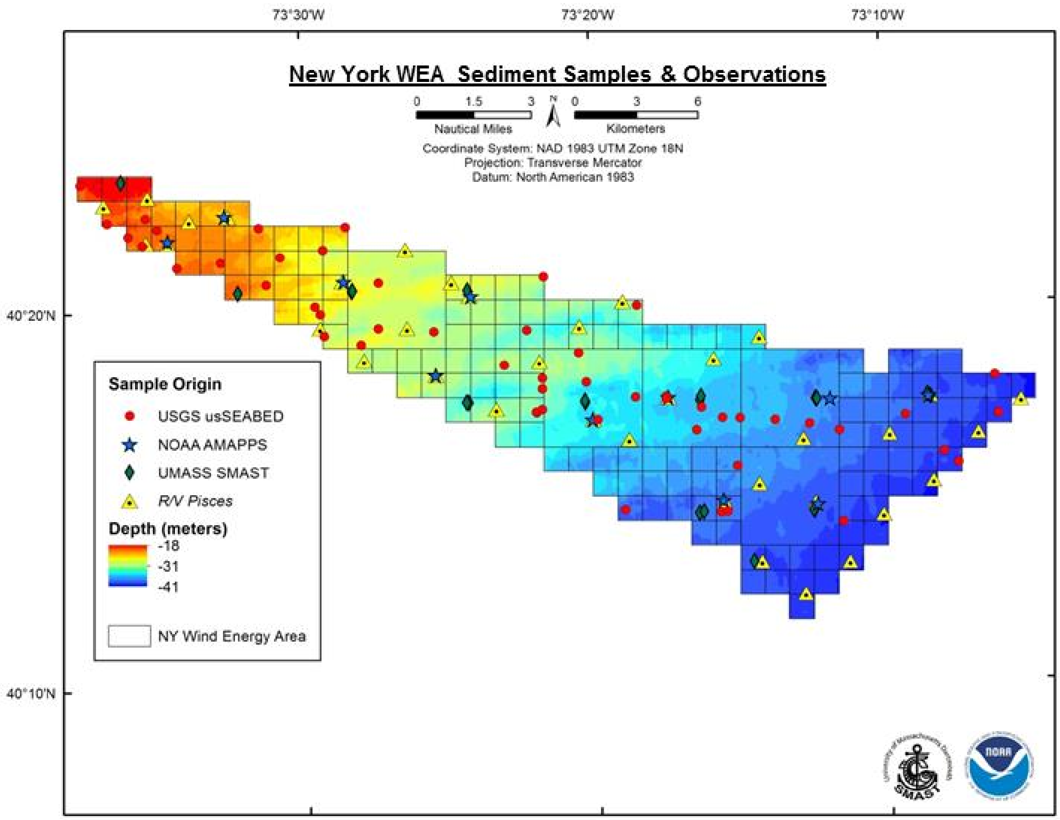


Figure 5-6. Location and source of benthic sediment samples and observations in the NY WEA. Samples include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles), cores taken from grab sampler aboard the NOAA 2014 AMAPPS cruise (green stars) and Habitat Characterization cruise PC16-06 (NOAA ship *Pisces*: yellow triangles), and SMAST observations from camera pyramid imagery (green diamonds). Data sources - bathymetry as in Figure 5-3, sediment data: Reid et al. 2005, UMASS SMAST.

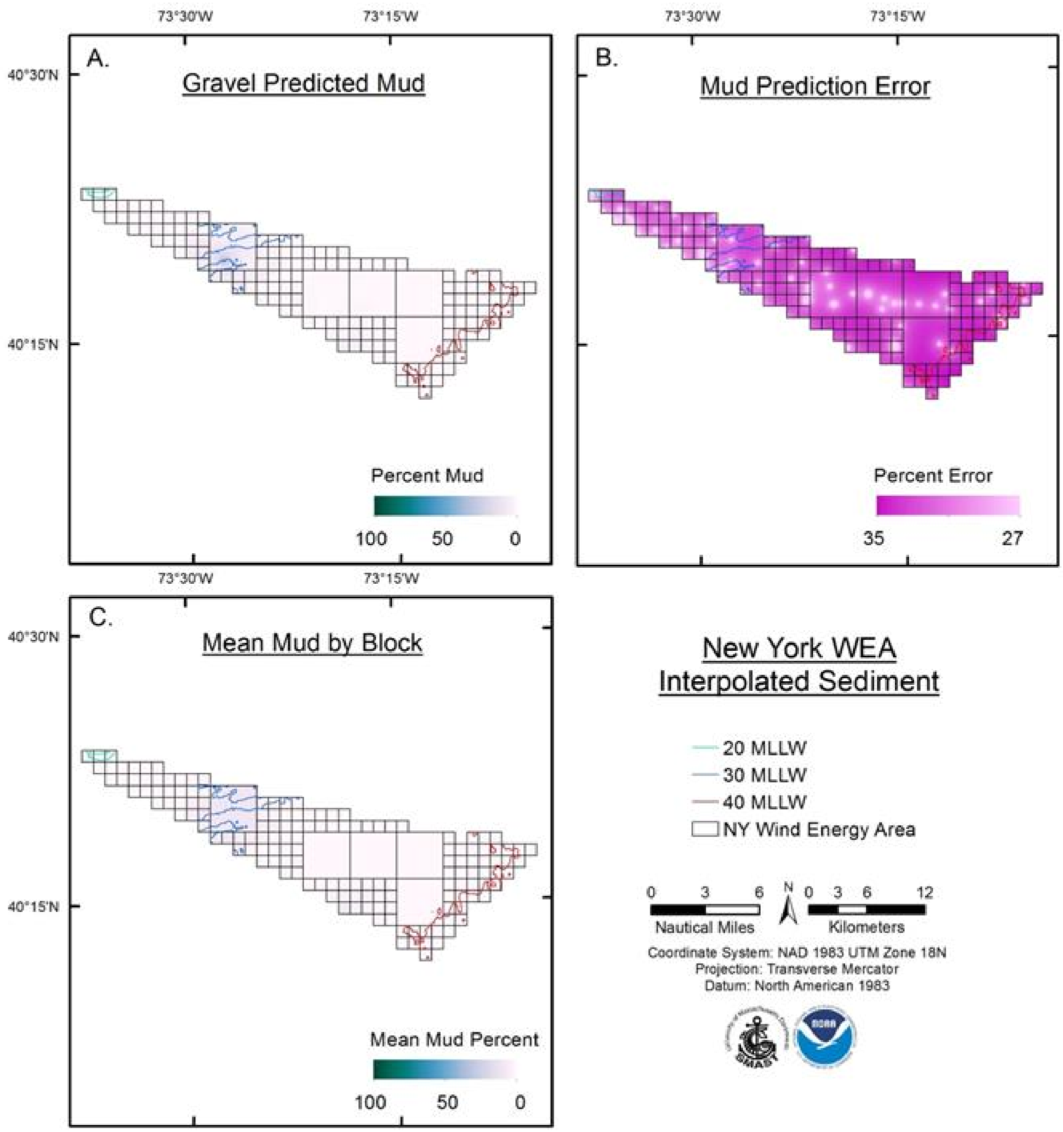


Figure 5-7. Predicted mud (silt + clay) distribution of surficial sediments in NY WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data as in Figure 5-6.

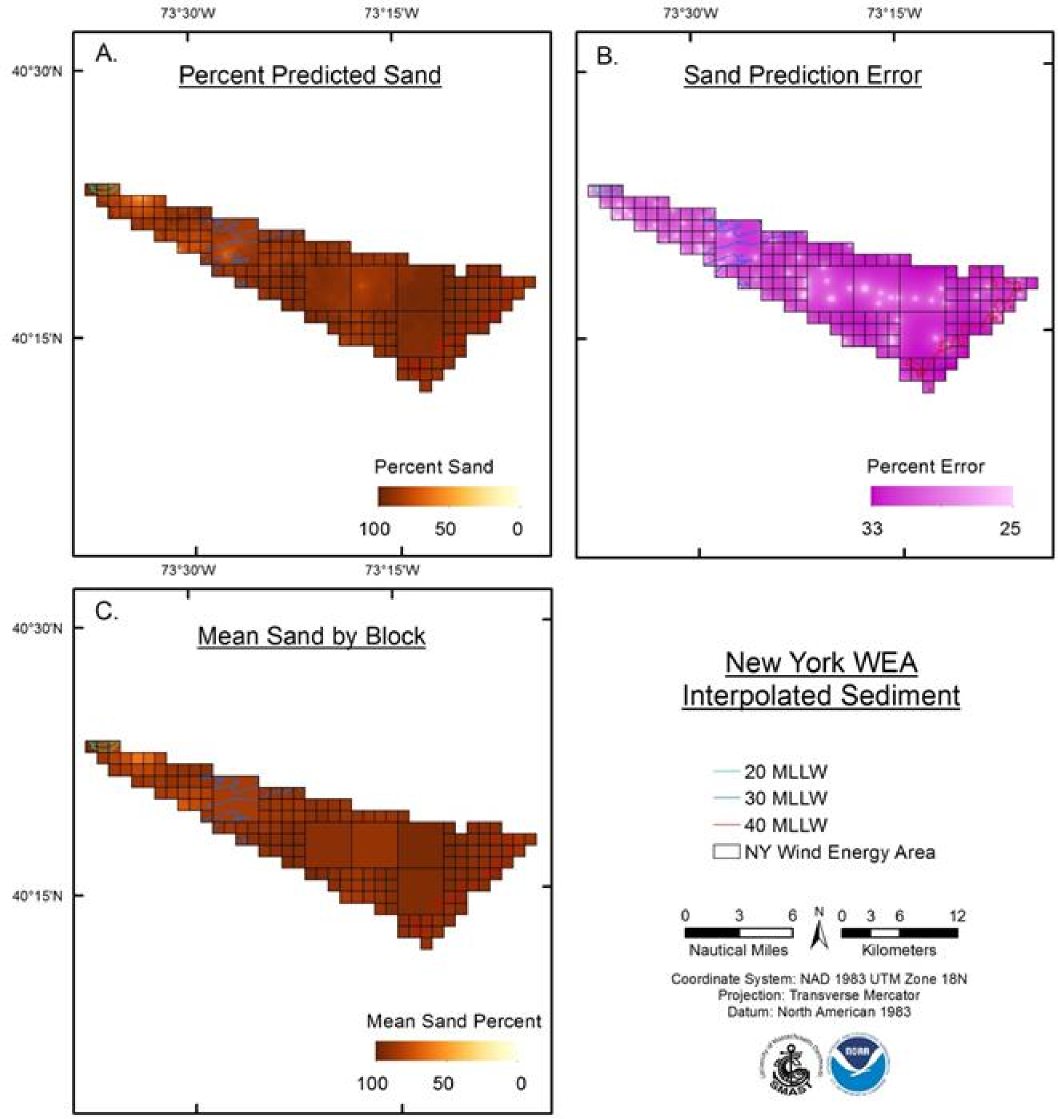


Figure 5-8. Predicted sand distribution of surficial sediments in NY WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data as in Figure 5-6.

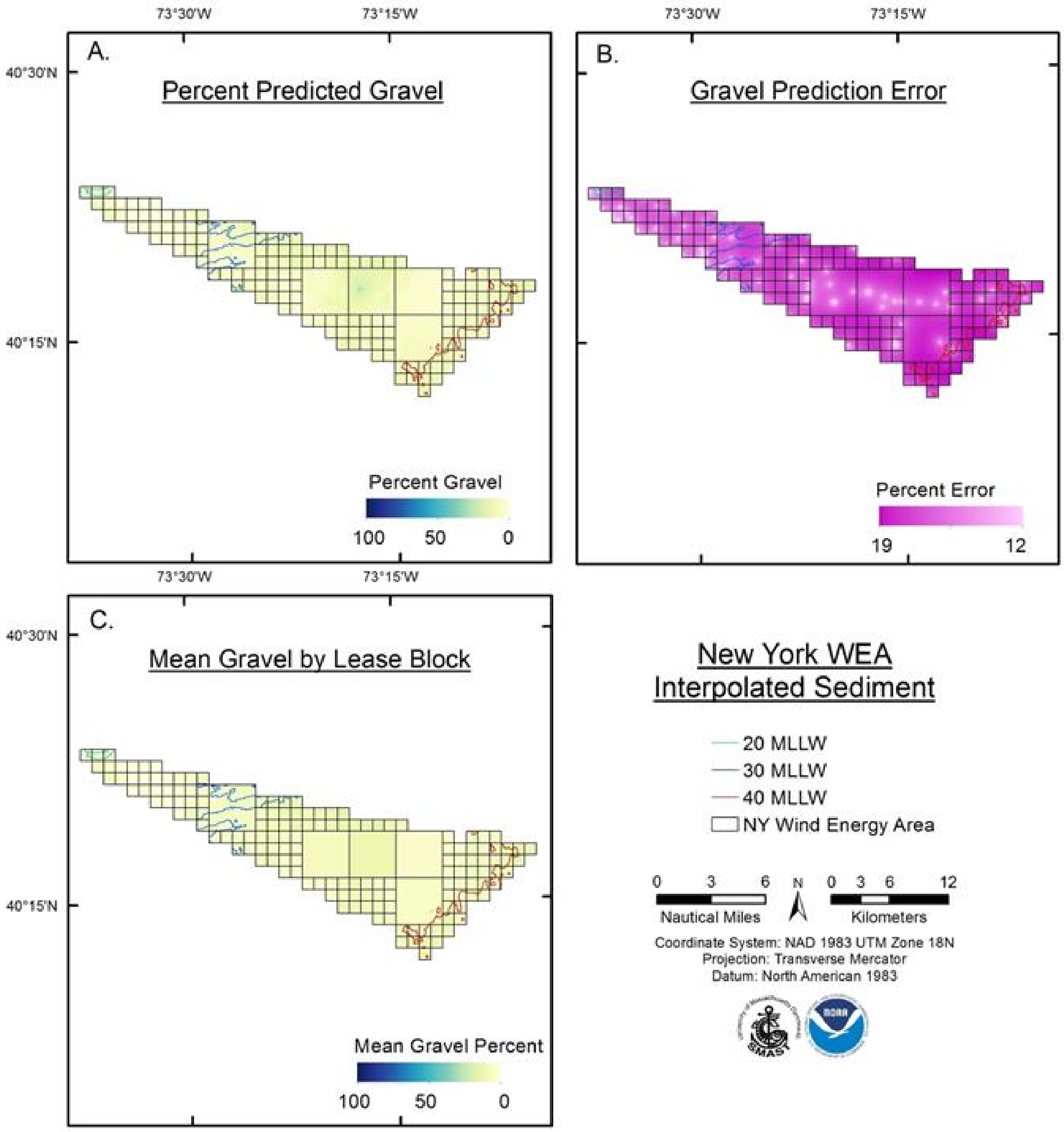


Figure 5-9. Predicted gravel distribution of surficial sediments in NY WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percentgravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data as in Figure 5-6.

Together Figures 5-7 through 5-9 indicate sediments heavily dominated by sand throughout the entire WEA, but with a patch of sediment with a minor mud content centered in block 6708 and a patch with a minor gravel content centered in block 6761. Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 5-10. While this representation only represents mean grain size without assessing the range of sediment sizes present, it does give a good idea of the character of sediments where the variation in grain sizes is not extreme. The presence of the muddy and gravelly patches is clearer in this presentation.

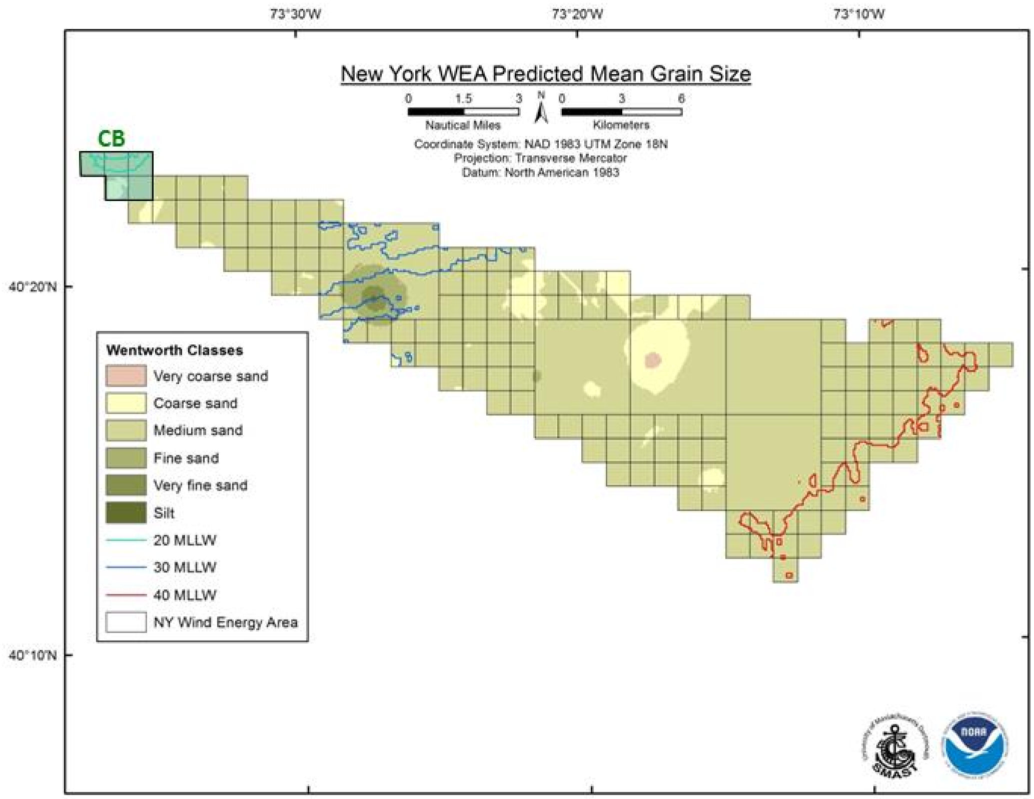


Figure 5-10. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the NY WEA physical samples. Figure shows interpolated average grain size distribution. The green shaded area marked CB is the Cholera Bank area not included in lease OCS-A-0512. Source data as in Figure 5-6.

UMASS SMAST image-based sediment observations, which were not included in the analyses displayed in Figures 5-7 through 5-10, independently confirmed this sediment distribution pattern and supplement data from grab samples. SMAST observations include grain sizes too large for grab samples and microtopographic features too small for detection from bathymetry, e.g. sand ripples (Figure 5-11). The pattern revealed in this analysis shows more widespread distribution of silt than grain size analyses, but also reveals widespread prevalence of sand ripples through the central and southeastern parts of the NY WEA. This is evidence that bottom currents are actively reworking sediments in these parts of the WEA.

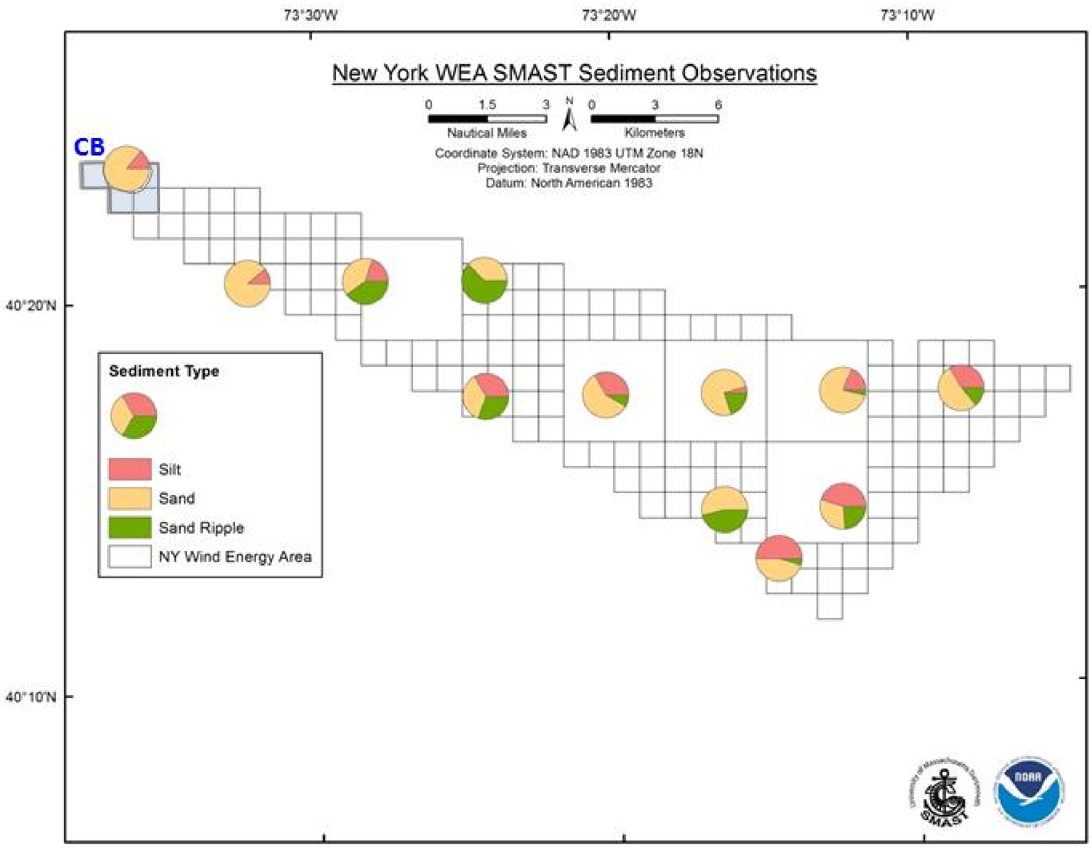


Figure 5-11. SMAST surficial sediments (presence-absence) observations. Observations proportions in pie charts were compiled to show the ratio of sediment observations from multiple images taken at each station. The blue-shaded area marked CB is the Cholera Bank are not included in lease OCS-A-0512. Source data: UMASS SMAST.

5.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 5-12.

Median salinity measured in the NY WEA for this period, including all depths, was 32.392 g/kg, with a full range spanning 29.836 to 33.917 g/kg (n=2,181), despite strong seasonal changes in other parameters. This range is nearly entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 4.08 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

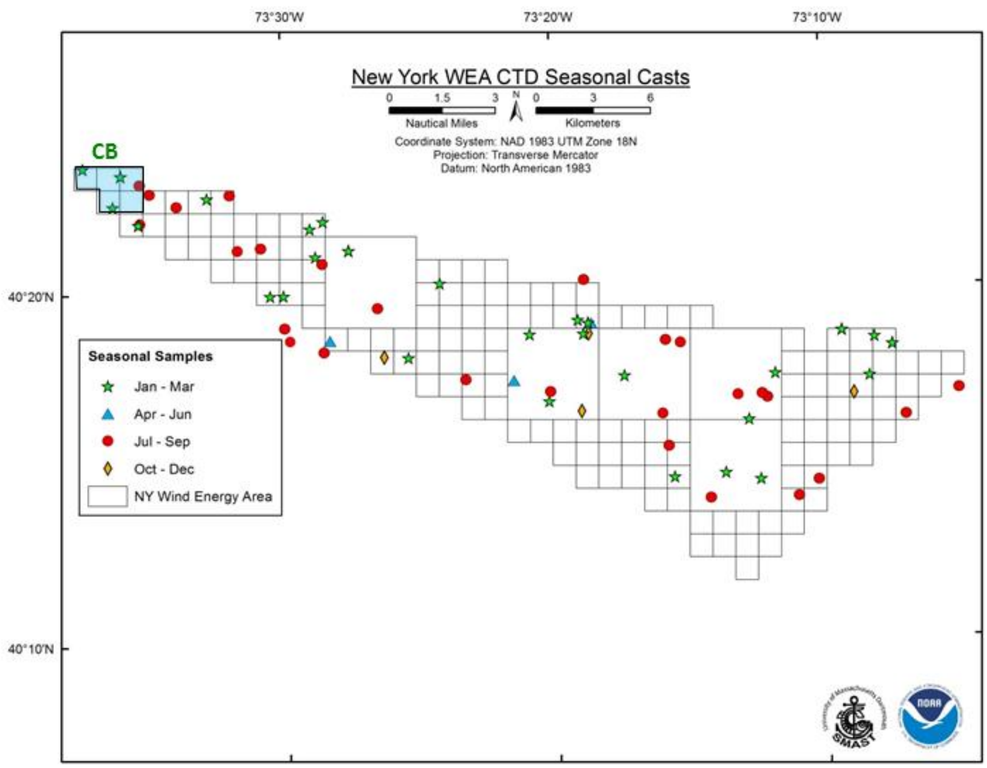


Figure 5-12. Locations for NEFSC CTD casts made between 2003 and 2016 in the NY WEA. The blue-shaded area marked CB is the Cholera Bank sensitive habitat area.

On the other hand, water temperatures showed large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water column structure. Figure 5-13 presents surface and bottom temperatures from CTD casts shown in Figure 5-12 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 25°C at the surface and 15°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 12°C. Then vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperature of up to 12°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Extraordinary bottom temperatures in the 9-16 degree range were recorded in February, 2012, but have not been recorded in any other year during our target period. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton. The NY WEA has no persistent frontal system impinging upon it (Figure 1-4).

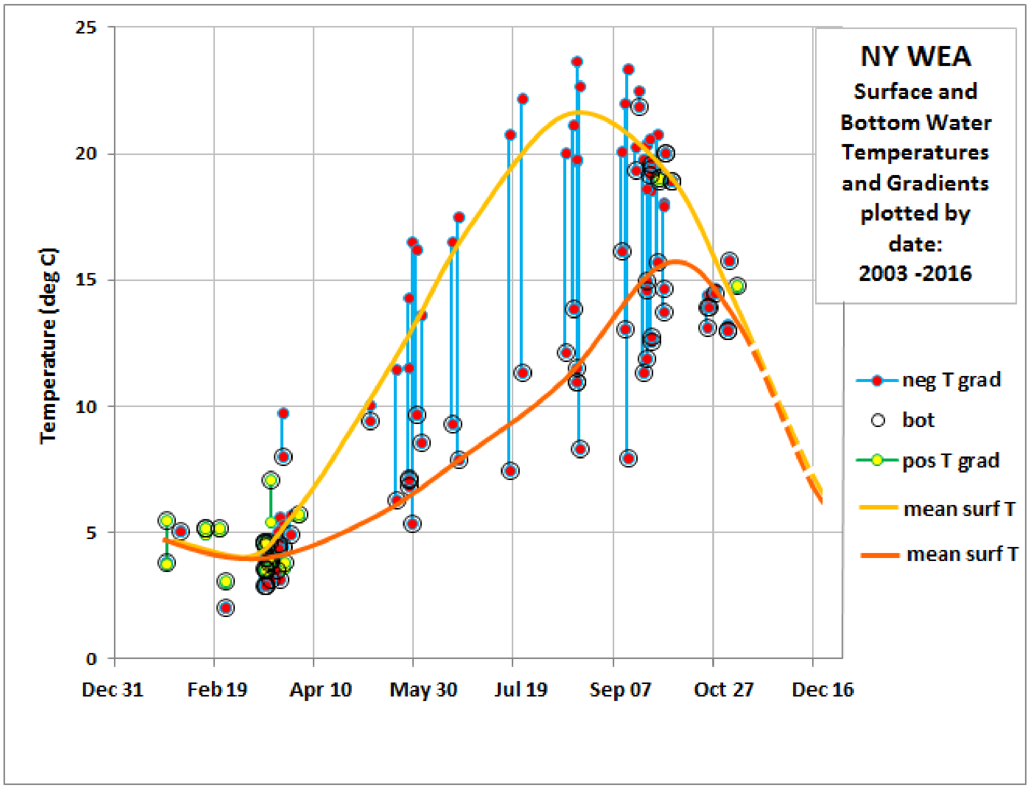


Figure 5-13. Water temperatures from CTD casts made between 2003 and 2016 in the NY WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values. No data was available for mid-November through mid-January, so the shapes of trend lines for that period (dashed) are conjectural.

5.2.5 Biological Variables

5.2.5.1 Benthic Epifauna and Infauna

Benthic samples were collected during two NEFSC–sponsored cruises (AMAPPS GU14-02 part 1 and PC16-06: March 2014 and August 2016, respectively) in the NY WEA, including 48 beam trawls (10 in March 2014, 38 in August 2016) for benthic epifauna and 11 triplicate Van Veen grabs (March 2014) for benthic infauna (Figure 5-14).

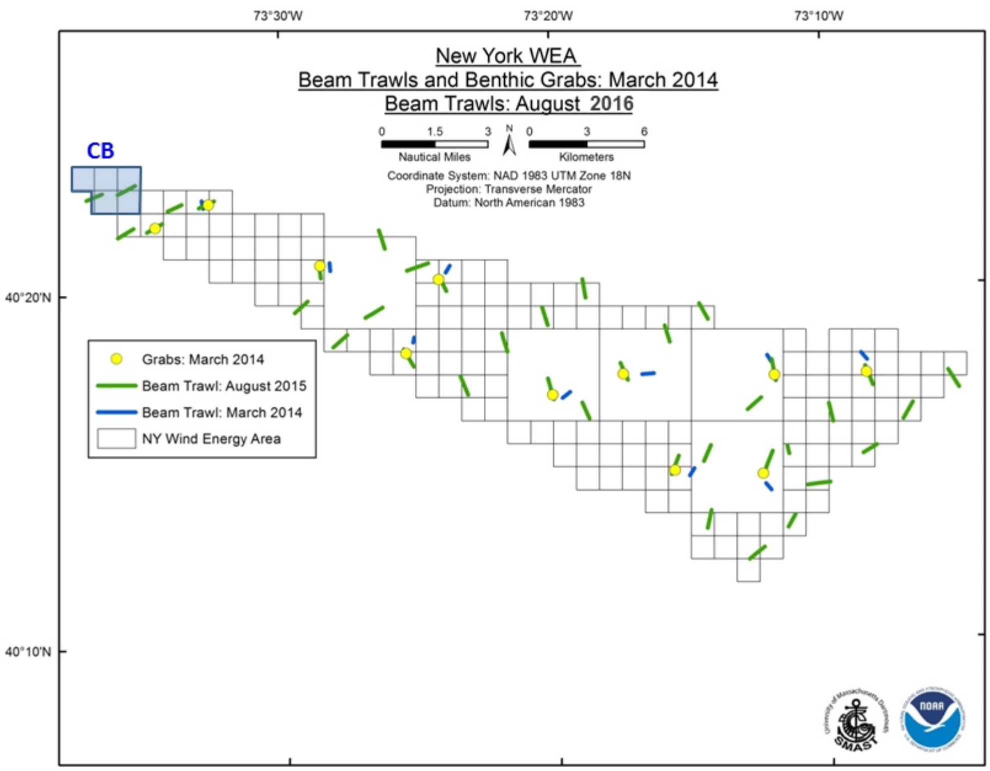
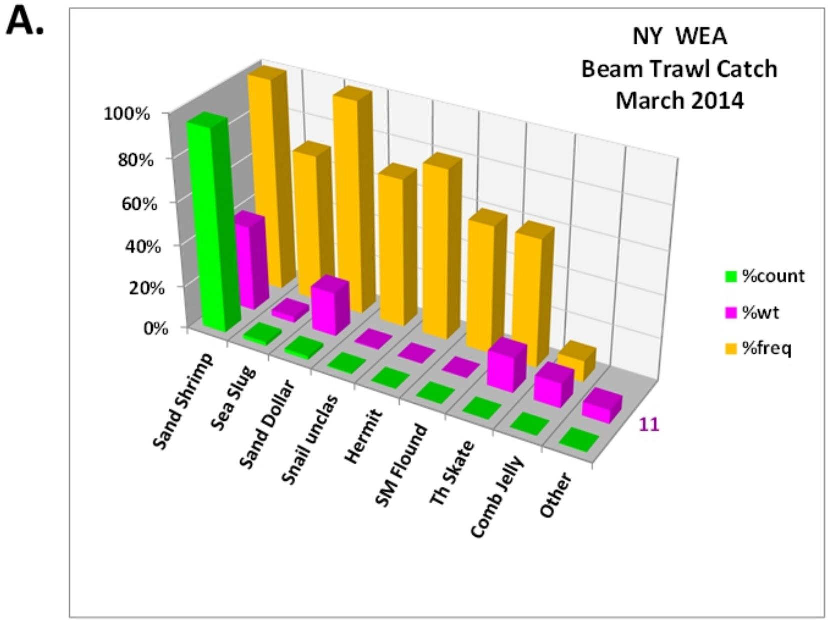


Figure 5-14. Locations of beam trawl and benthic grab samples made in the NY WEA. The blue-shaded area marked CB is the Cholera Bank sensitive habitat area.

Nineteen (19) taxa of epibenthos were captured in March 2014 and sixty (60) in August 2016 (Figure 5-15). Sand shrimp dominated in March (Figure 5-15A) and sand dollars in August (Figure 5-15B). In the latter case, sand dollar dominance stemmed from an apparent recent heavy set of new individuals (<2 cm diameter) from the plankton in southwestern stations (>35 m depth) of the WEA. Longfin squid appeared on the August list of core taxa, and hence as a separate set of bars in Figure 5-15B, on the strength of a strong set of newly-settled juveniles. Their source, longfin squid benthic egg mops, was among the other taxa recorded in those trawls. Viable skate eggs were also a frequent catch. These results point to a benthic epifauna adapted to sandy bottom conditions and while undergoing some seasonal changes of species, continually occupied by sand shrimp, sand dollars and other sand-dwelling invertebrates.

Eighty five (85) taxa of infaunal benthos were captured in grab samples from the NY WEA (Figure 5-16). Amphipods were prominent in these samples, as is typical for Southern New England infauna (Theroux and Wigley 1998), but not dominated by a single species (*Ampelisca agassizi*) as in the RIMA and MA WEAs and in the Rhode Island Ocean SAMP (La France et al. 2010). The sand dollar (*Echinarachnius parma*) stands out as a core species in these grab samples, paralleling its prominence in beam trawls catches.



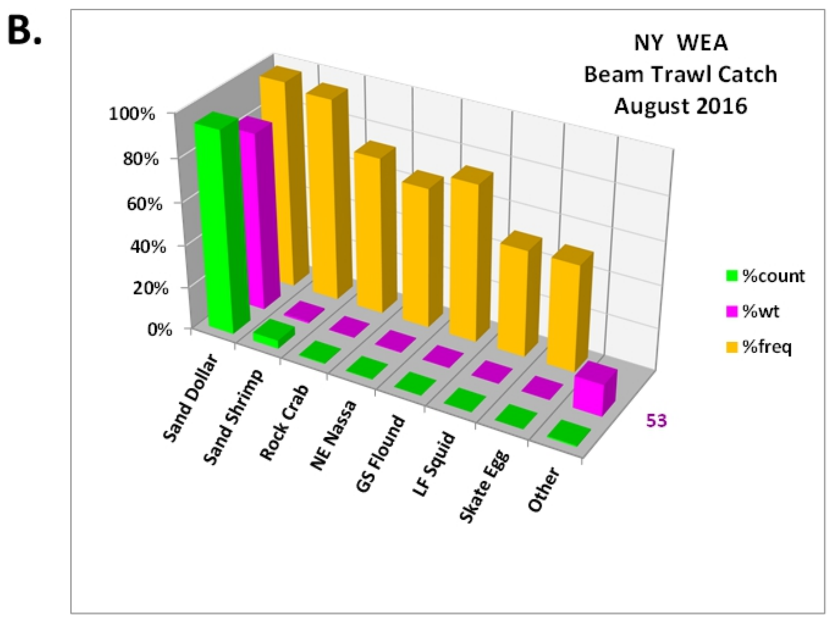


Figure 5-15. Benthic fauna caught in NY WEA by NEFSC beam trawl sampling . Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA; A. March 2014, B. August 2016. Abbreviated common names for taxa in A.: Snail unclas – unclassified shelled gastropods, Sea Slug – unclassified shell-less gastropods, Hermit – hermit crabs, SM Flounder – smallmouth flounder, Th Skate – thorny skate; in B: NE Nassa – New England nassa (dogwhelk) snail, GS Flounder – Gulf Stream flounder, LF Squid – longfin squid, Skate Eggs – viable skate eggs in egg cases. Numbers to the right of the “other” taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of “other” taxa.

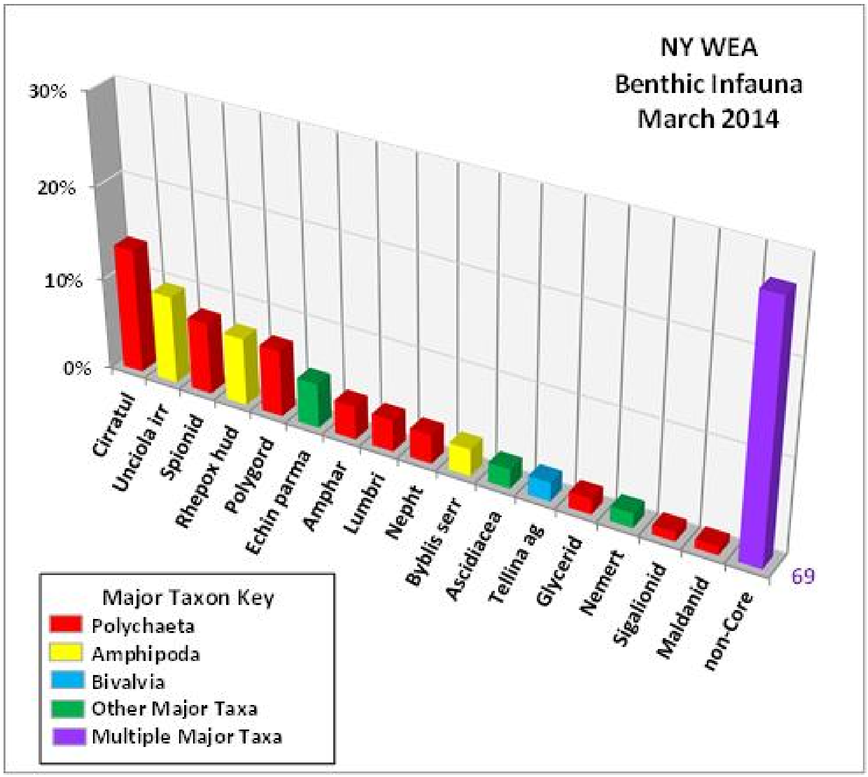


Figure 5-16. Benthic fauna caught in NY WEA by NEFSC grab sampling in March 2014. Catch is reported by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated taxonomic names: Amp aga – *Ampelisca agassizi*, Cirratul – Cirratulidae, Unciola irr - *Unciola irrorata*, Spionid – Spionidae, Rhepox hud - *Rhepoxynius hudsoni* , Polygord – Polygordiidae, Echin parma – *Echinarachnius parma*, Amphar – Ampharetidae, Lumbri – Lumbrinereidae, Nepht - Nephtydae , Byblis serr - *Byblis serrata,* Tellina ag – *Tellina agilis,* Glycerid – Glyceridae, Nemert – Nemertea, Sigalionid – Sigalionidae, Maldanid – Maldanidae. Numbers to the right of the “non-core” taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of “other” and “non-core” species.

5.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 5-17. Trawls in the period 2003-2016 were few because of the small size of the NY WEA. NEFSC seasonal trawl survey results are provided in Figure 5-18. Explanations of abbreviations for the figure and fisheries management information is provided in Table 5-1 and lists of seasonal dominant taxa are provided in Table 5-2.

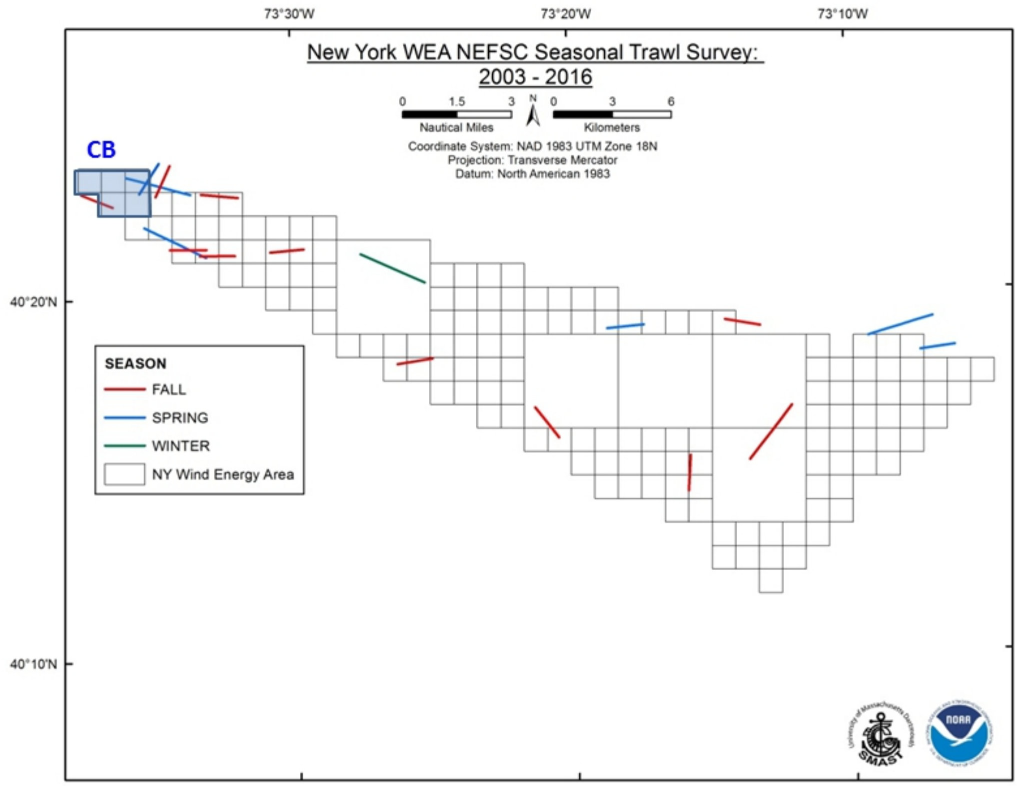


Figure 5-17. Locations of NEFSC seasonal trawls from 2003 to 2016 in the NY WEA. The blue-shaded area marked CB is the Cholera Bank area not included in lease OCS-A-0512.

A. B. C.

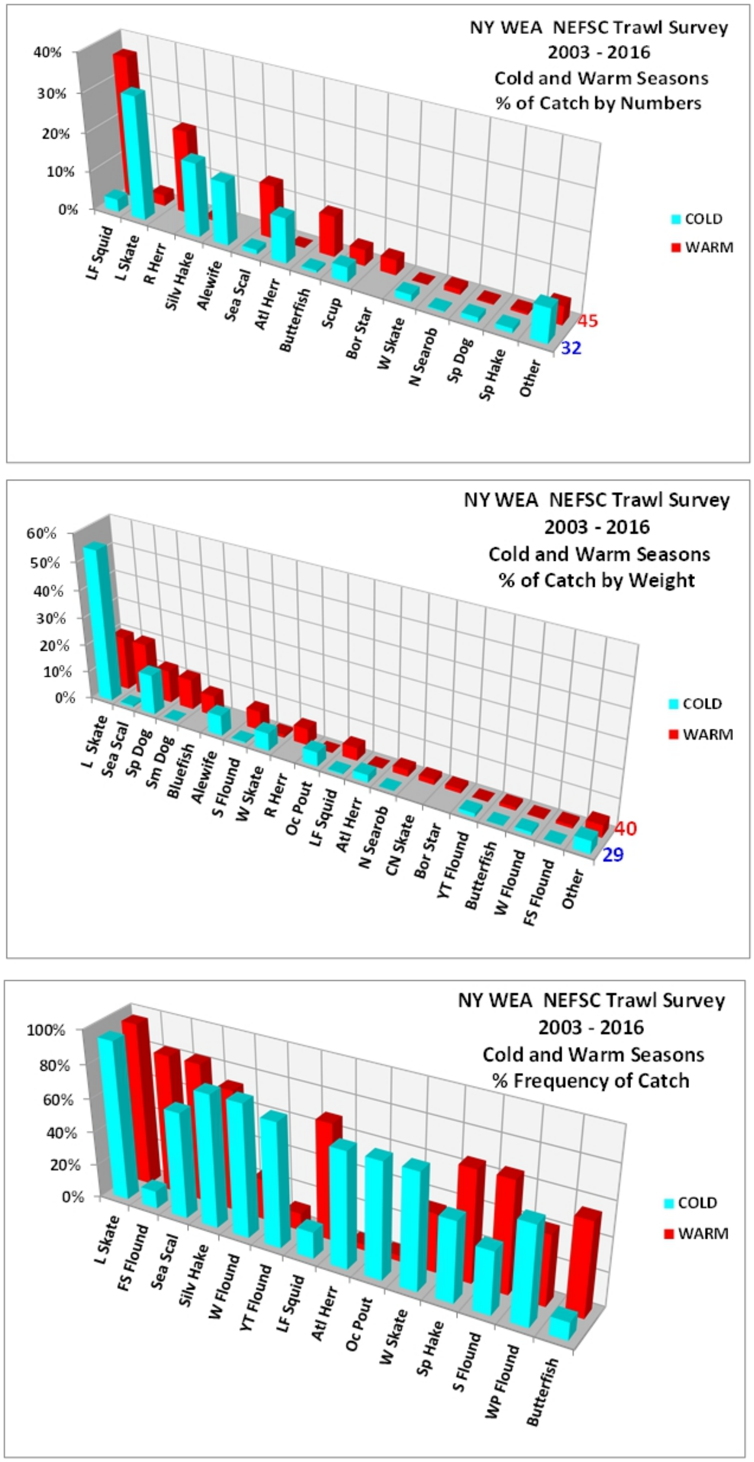


Figure 5-18. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 5-1. Blue and red numbers along the right margin of the graphs indicate the numbers of “other” species in cold and warm season catches respectively.

Table 5-1. Abbreviations for taxon names used in Fig. 5-18, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Atl Herr	Atlantic herring[2]	Scup	scup[3]
Bluefish	bluefish[3]	Sea Scal	sea scallop[2]
Bor star	boreal Asterias sea star	Silv Hake	silver hake[2]
Butterfish	butterfish[3]	Sm Dog	smooth dogfish[5]
CN Skate	clearnose skate[2]	Sp Dog	spiny dogfish[4]
FS Flound	fourspot flounder	Sp Hake	spotted hake
L Skate	little skate[2]	S Flound	summer flounder[3]
LF Squid	longfin squid[3]	WP Flound	windowpane flounder[2]
N Searob	northern searobin	W Flound	winter flounder[2]
Oc Pout	ocean pout[2]	W Skate	winter skate[2]
R Herr	round herring	YT Flound	yellowtail flounder[2]

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 5-2. Dominant species in NEFSC Seasonal Trawl Survey catches within the NY WEA between 2003 and 2016.

New York WEA Dominants	
Cold Season	Warm Season
AtlanticHerring	Butterfish
Little Skate	Little Skate
Winter Skate	Longfin Squid
	Sea Scallop

It is clear that this WEA supports a megafauna of moderate diversity: 58 taxa in the warm season and 44 in the cold season. It is also evident that while there is considerable overlap in the lists of species present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also overlap among species present and dominance with the MA and RIMA WEAs (sections 3.2.5.2 and 4.2.5.2). Of the taxa that are important in terms of numbers, biomass, and/or frequency (Table 5-1) 77% (17 out of 22) are species that are managed in the northeast region. One species, little skate, was dominant in both seasons. Dominants included both seasonal migrants (Atlantic herring, butterfish, longfin squid) and residents (little skate, winter skate, sea scallop). It is also notable that all of the dominants (Table 5-2) are managed fishery species.

5.2.5.3 Species of Concern

Records of shellfish species of concern in the NY WEA are illustrated in Figure 5-19. These included quantitative records of sea scallops from NEFSC seasonal trawl surveys and qualitative records from beam trawls, bottom grabs, and bottom imagery. Sea scallops were clearly widespread in this WEA, but more abundant in depths exceeding 35 m. Since quantitative trawl captures were located at the mid-point of the trawl track, which may lie outside the WEA limits, it is not certain whether the sea scallops near the WEA boundary were actually caught inside or outside the WEA in some cases.

Only one qualitative record of ocean quahog was made, from a bottom grab sample near the southeast corner of the WEA. This was so despite the nearly complete coverage of the NY WEA by ocean quahog EFH (Figure 1-8). Like sea scallops, surfclams were widespread, although somewhat less often encountered at depths >35 m. Catch record distribution for surfclams corresponds well to surfclam EFH (Figure 1-9), coverage of the western tip and along the central and southwestern areas, but with gaps in the western third of the WEA and along the north side of its eastern end.

As sea scallops and surfclams were widespread and numerous, these are clearly species worth considering in terms of potential for habitat disturbance.

As a consequence of performing beam trawling in the NY WEA (Habitat Characterization cruise PC16-06: Table 1-3) during August, 2016, egg mops of longfin squid containing eggs were detected. Spawning typically occurs during the warm season, though the exact time may vary and can be spread over several months (Jacobson 2005). Mops are generally attached to stable substrates ranging from rocks and gravel to seaweeds as they are being spawned. In the case of the NY WEA, which appeared to have no rocks or seaweed and little gravel, we commonly found them attached to dead mollusk shells, often surfclams. The distribution of capture for longfin squid egg mops is shown in Figure 5-20. Their distribution was widespread, spanning the depth range of the WEA and showed no tendency toward clustering or clear relationship to living bivalve mollusk distribution. We do not have enough information on the distribution and nature of shell hash that may be required for egg mop deposition to draw any relationship with that resource. The current squid egg mop EFH map (Figure 1-10) indicates only a small overlap with the NY WEA at its westernmost end. Our captures of egg mops suggest that the entire NY WEA should be included. Their presence should be examined with regard to potential impacts.

No Atlantic cod were captured within the boundaries of the NY WEA between 2003 and 2016. Indeed, the WEA is entirely outside of the EFH zones for juvenile and adult cod (Fig. 1-11).

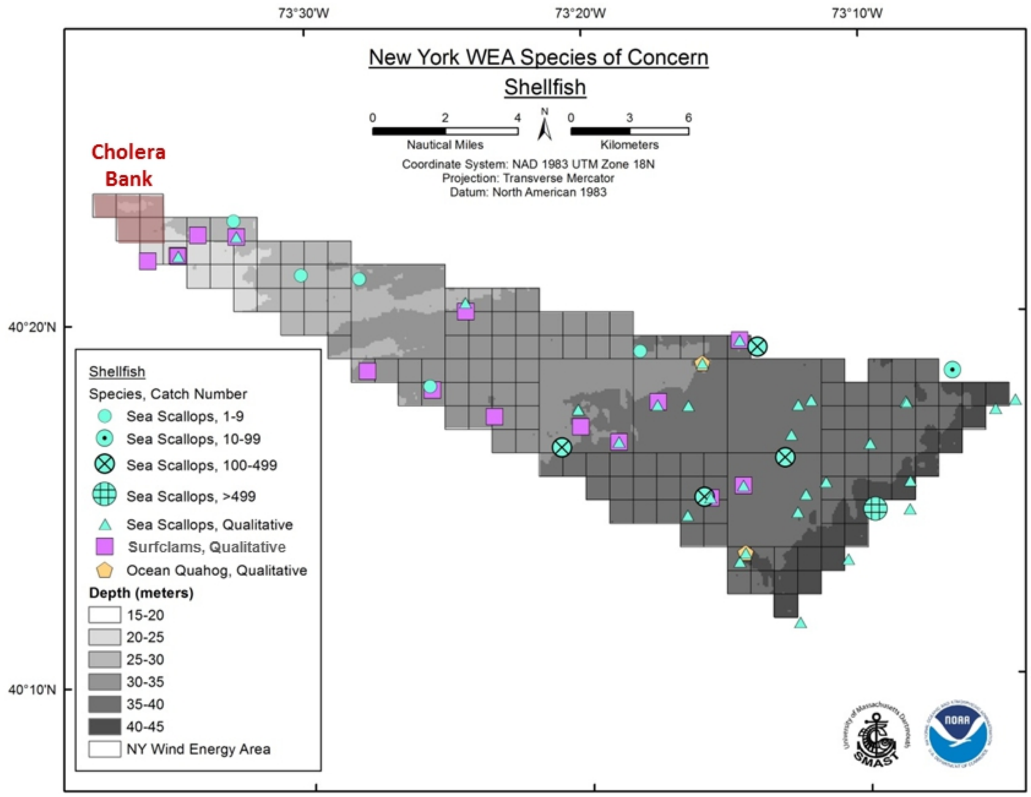


Figure 5-19. Shellfish species of concern records within and near the NY WEA.

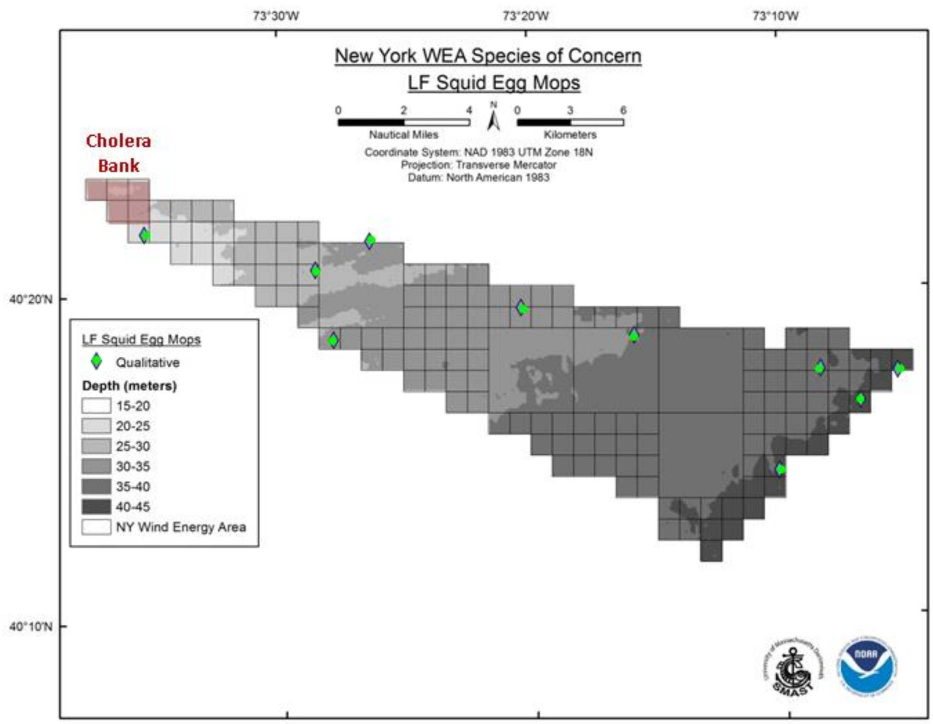


Figure 5-20. Longfin squid egg mops caught via beam trawl in the NY WEA in August 2016.

Adult and sub-adult black sea bass have been caught by the NEFSC seasonal trawl survey between 2003 and 2016 (fall survey only: quantitative) and YOY juveniles via beam trawl aboard Habitat Characterization cruise PC16-06 (August 2016: Figure 5-21). We have no records of captures of either deeper than 35 m, and most encounters were clustered in the northwest end of the WEA at depths <25 m. This includes the Cholera Bank sensitive habitat area and the adjacent area.

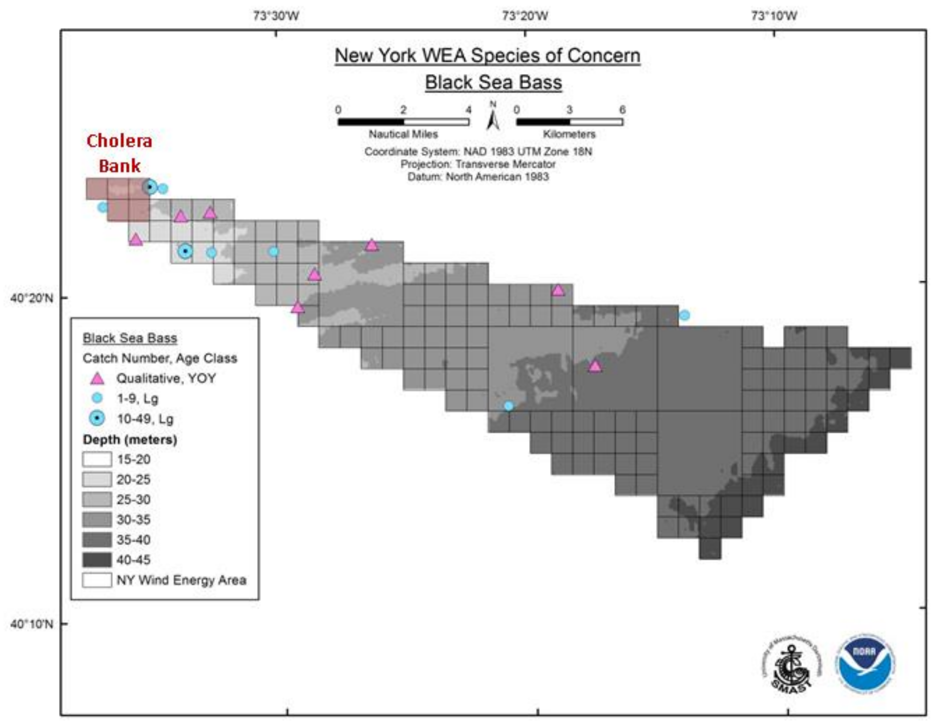


Figure 5-21. Records of young-of-the-year (YOY) and larger black sea bass in the NY WEA.

5.3 NY WEA Habitat Definition

An integrated view of the physical benthic habitat features in the NY WEA is presented in Figure 5-22. There is one major topographic zone (Topo Zone 1) with habitat features (gravelly and mud to muddy patches) superimposed upon it in various locations. That Topo Zone is characterized by megaripples (Figure 5-5) and almost exclusively sand sediments (Figure 5-10).

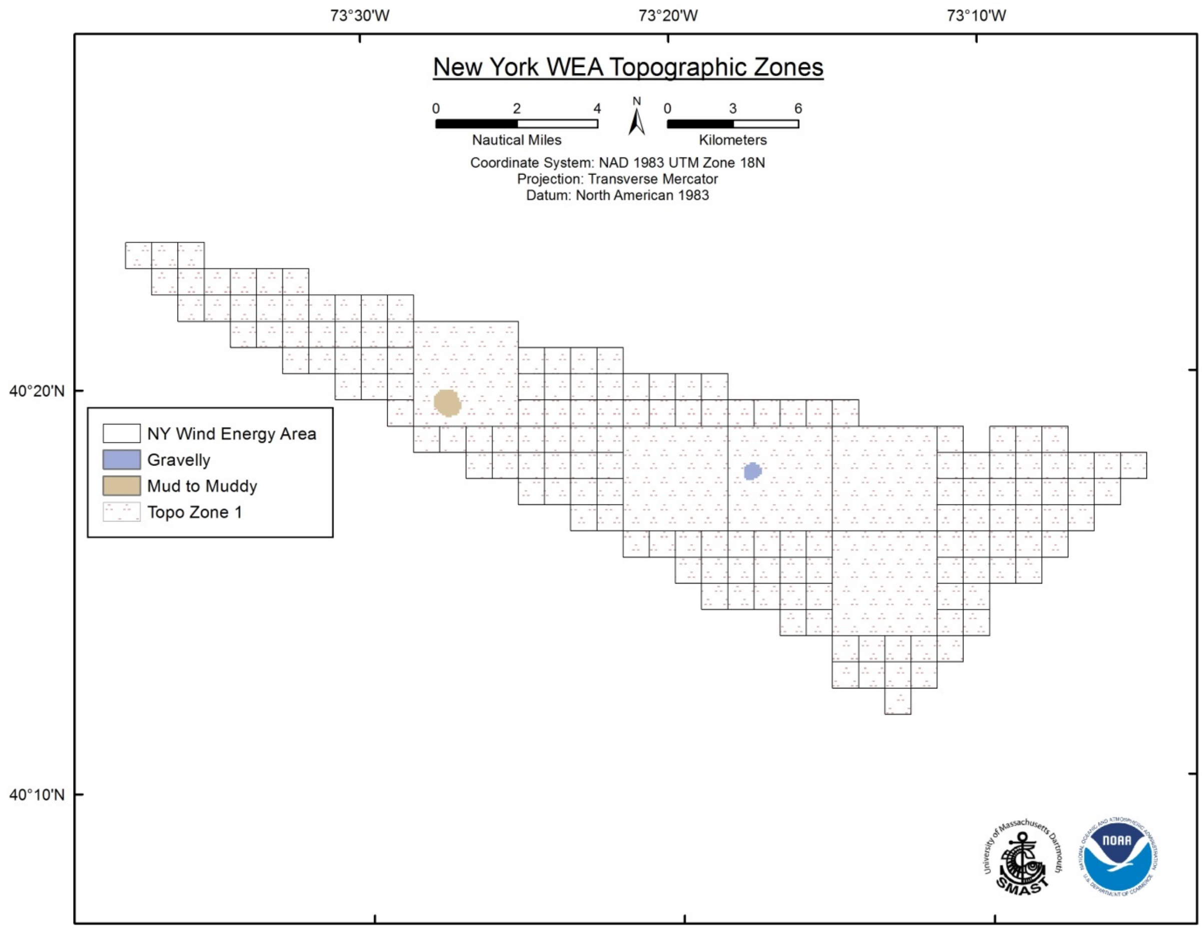


Figure 5-22. Physical benthic habitat features of the NY WEA.

5.3.1 CMECS Classifications:

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Megaripples, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Larger Tube-Building Fauna, Scallop Bed (sea scallops), Clam Bed (*Spisula*), Sand Dollar Bed (*Echinarachnius*)

Mud to Muddy Patch

- Geoform and Biotic Components: same as for Topo Zone 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Muddy Sand to Mud

Gravelly Patch

- Geoform and Biotic Components: same as for Topo Zone 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand

6 New Jersey Wind Energy Area (NJ WEA)

6.1 Location, size, and subdivision

The New Jersey WEA lies on the Southern Mid Atlantic Bight shelf in a band between approximately 8 and 21 nautical miles off the coast of southern New Jersey from Manahawkin, just south of Barnegat Inlet, to Cape May (Figure 6-1). It consists of 43 full lease blocks plus 308 sub-blocks (Figure 6-2). Water depths in the NJ WEA range 14 to 38 m, with an average of approximately 26 m, and it covers approximately 343, 833 acres of seafloor (BOEM 2014b). The NJ WEA has been divided into two lease areas: 160,480 acres (~47%) in the northern lease area (OCS-A-0498) and 183,353 acres (~53%) in the southern lease area (OCS-A-0499). Figure 6-2 provides the numbering for all blocks in the WEA. This section provides data and analysis for the entire WEA (both lease areas) as a single unit.

Figure 6-1. Map of New Jersey study area. Source data:(BOEM 2017, NOAA NCEI 2017).

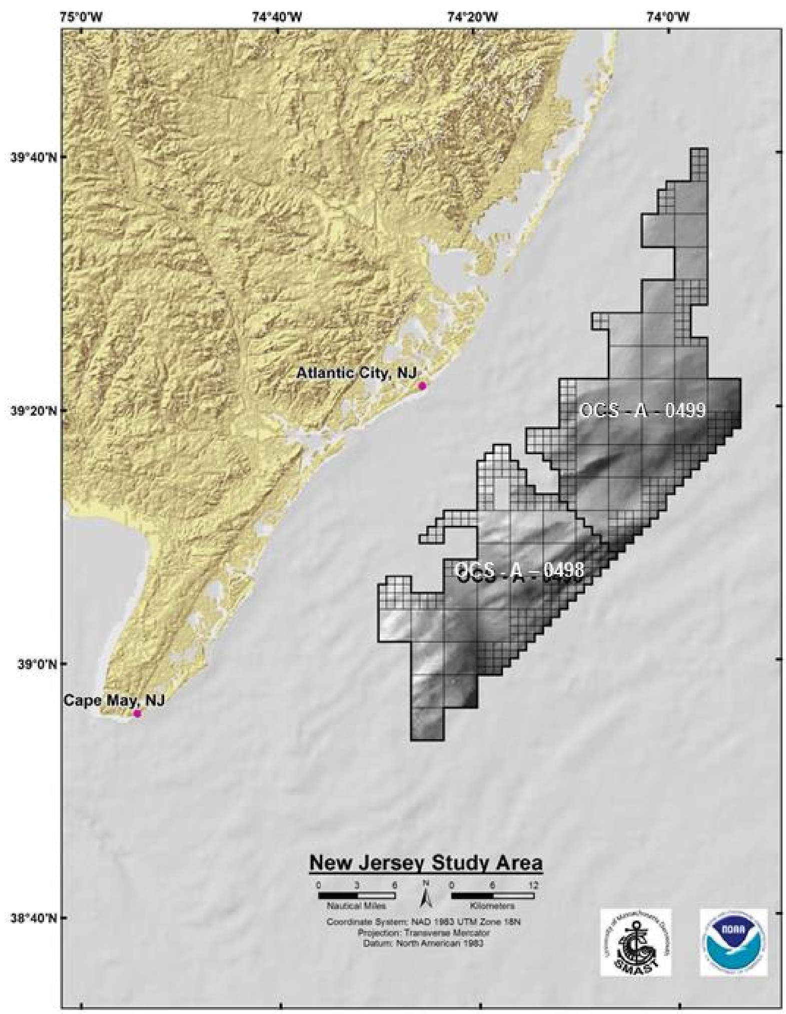


Figure 6-2. Numbered lease blocks (A.) and sub-blocks (B.-I.) included in the NJ WEA (source data BOEM 2017).

A.

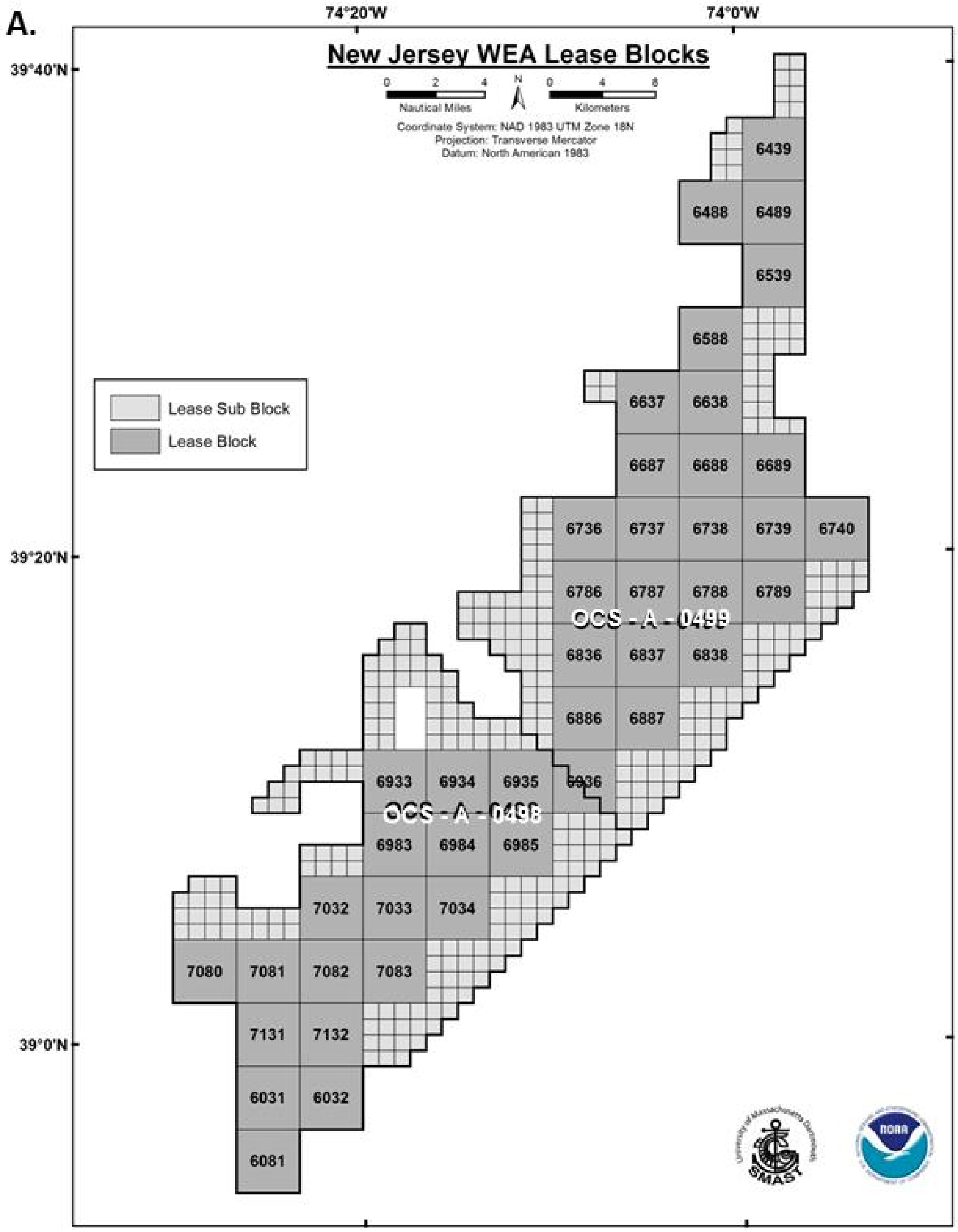
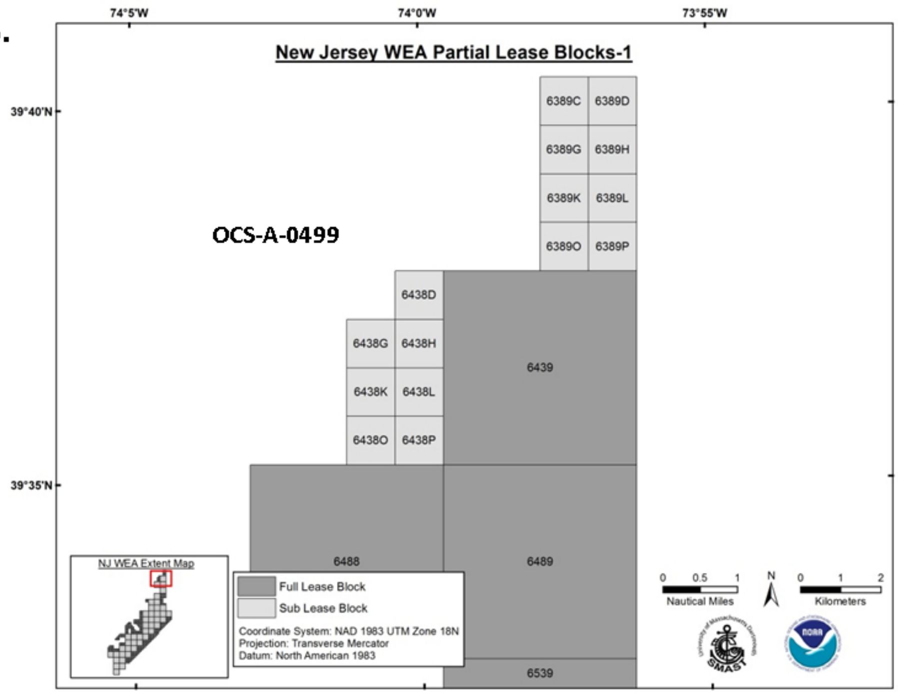


Figure 6-2 (continued). Numbered lease blocks (A.) and sub-blocks (B.-I.) included in the NJ WEA (source data BOEM 2017).

B.



C.

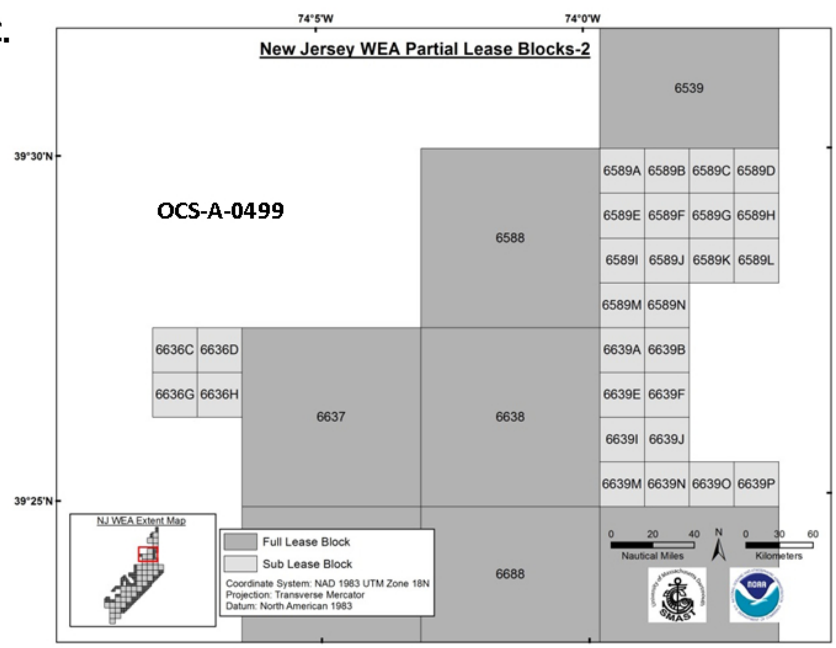
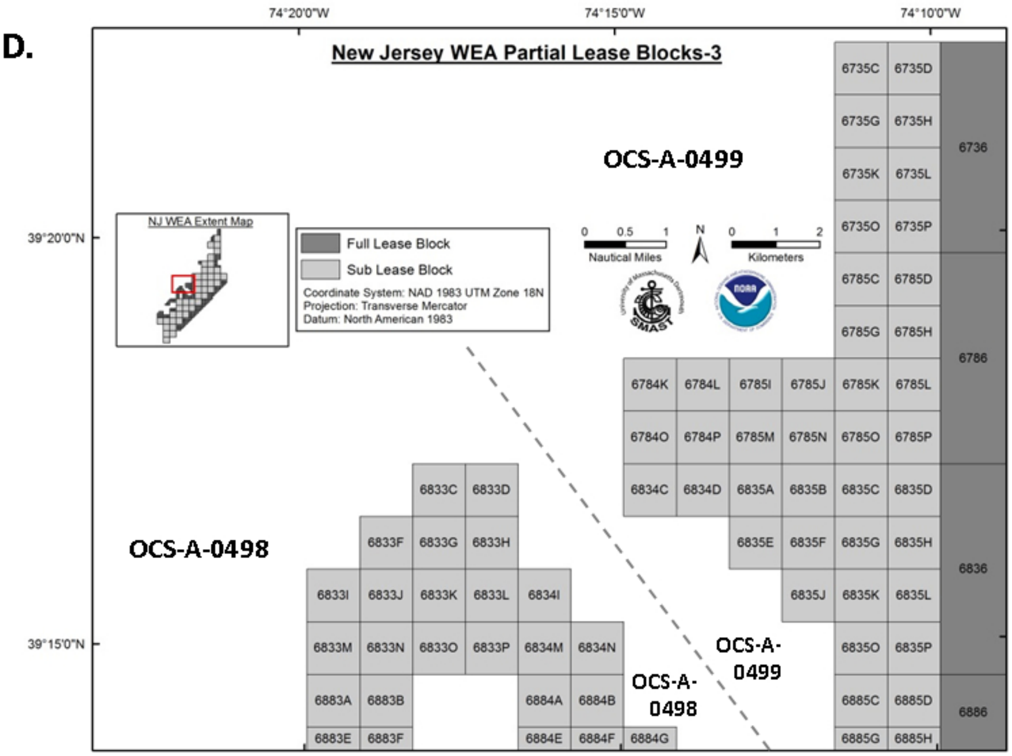


Figure 6-2 (continued). Numbered lease blocks (A.) and sub-blocks (B.-I.) included in the NJ WEA (source data BOEM 2017).

D.



E.

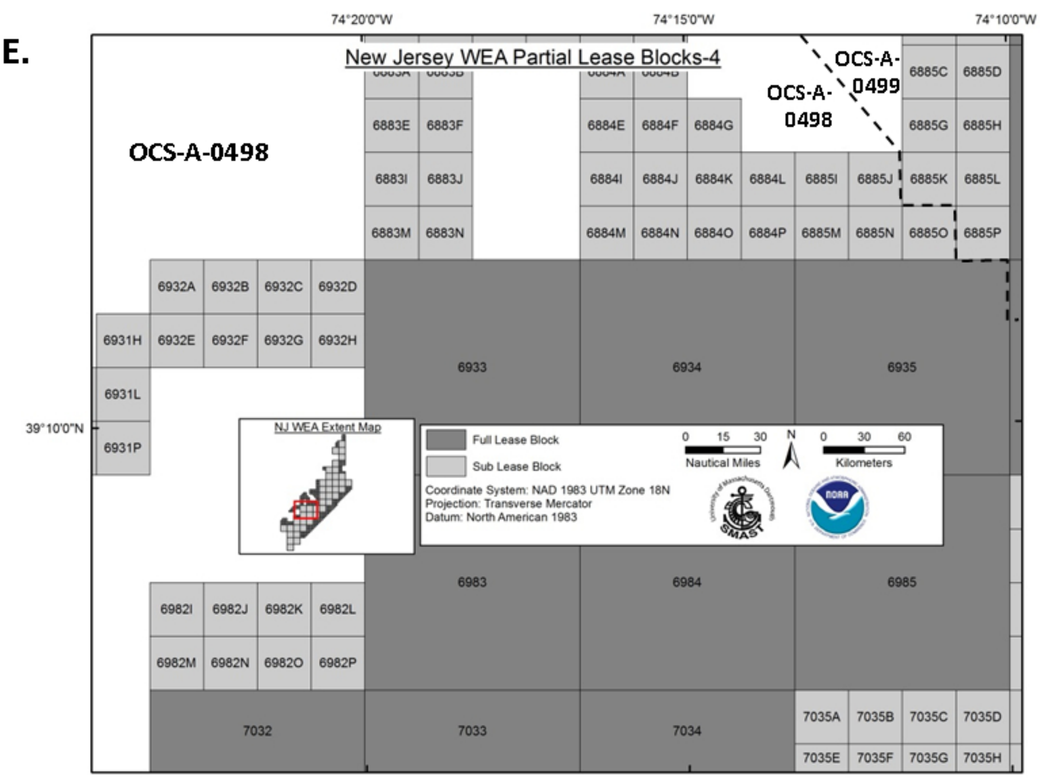
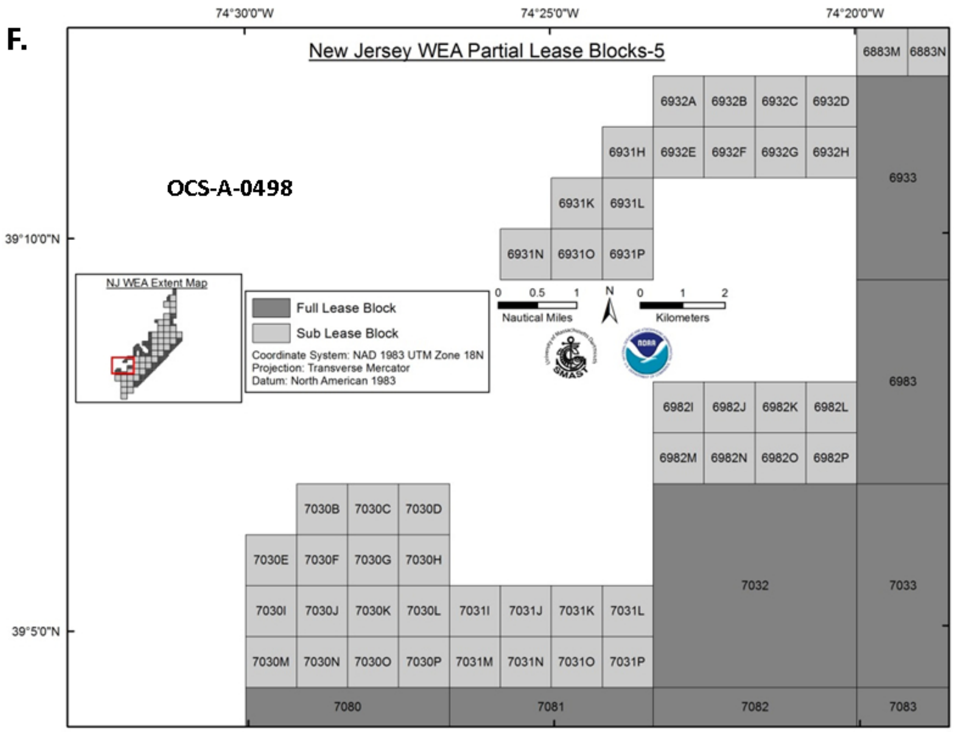


Figure 6-2 (continued). Numbered lease blocks (A.) and sub-blocks (B.-I.) included in the NJ WEA (source data BOEM 2017).



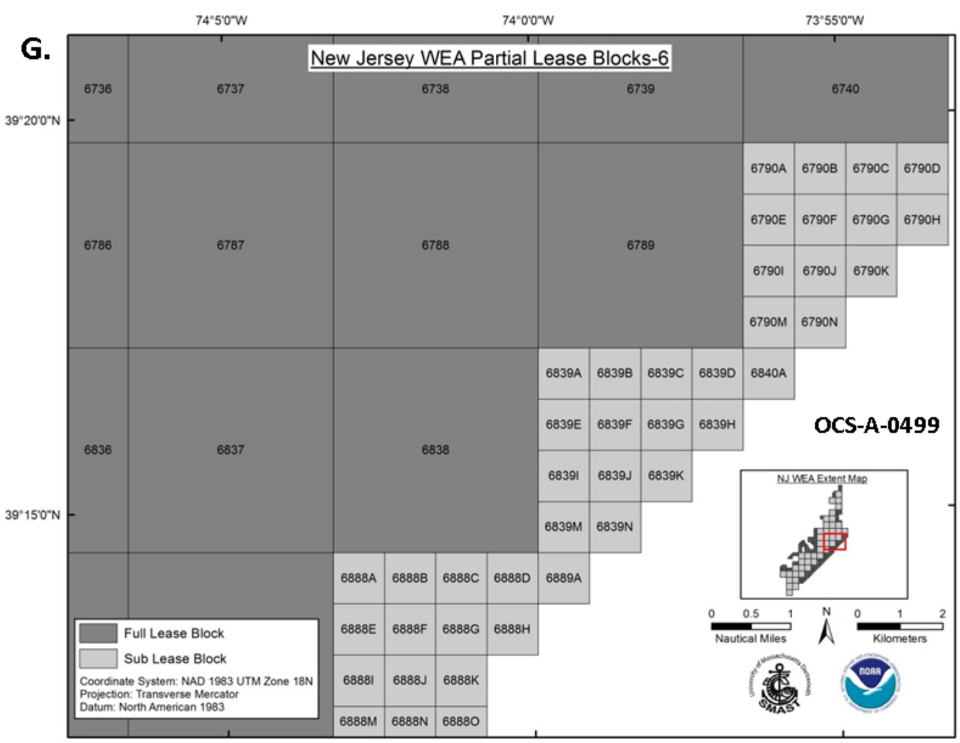
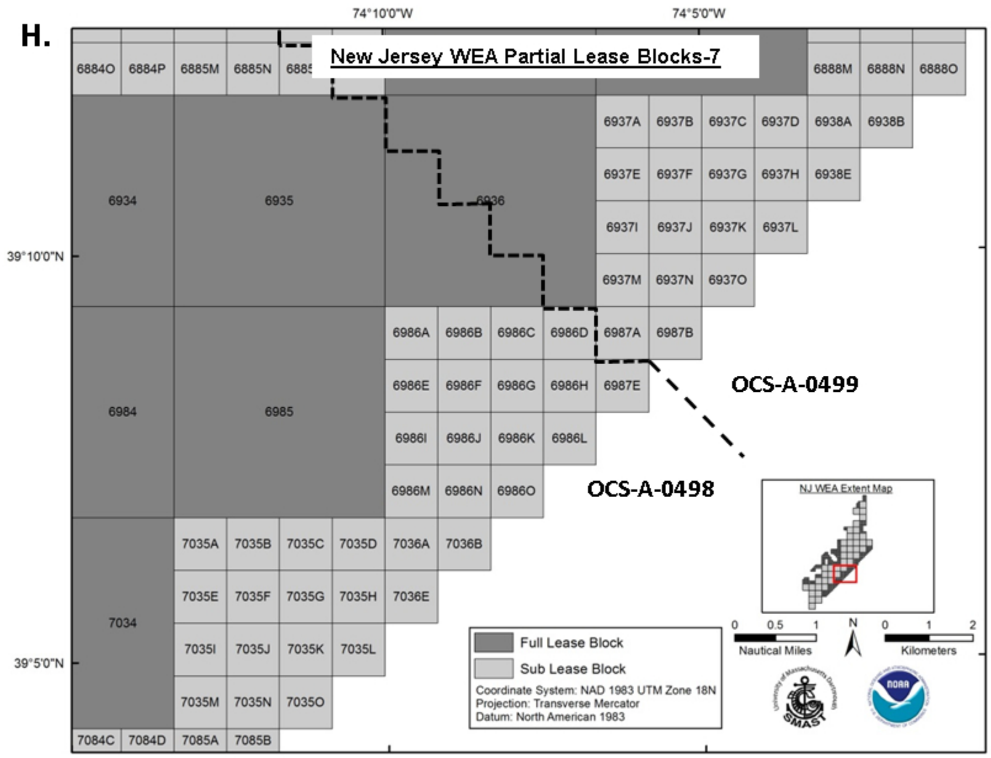
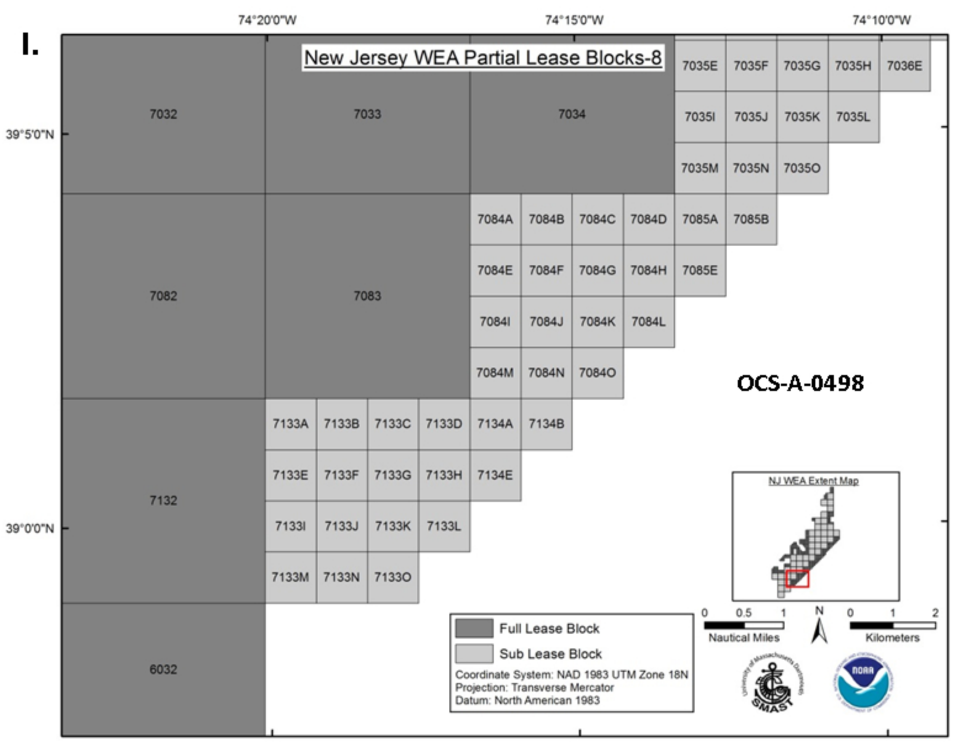


Figure 6-2 (continued). Numbered lease blocks (A.) and sub-blocks (B.-I.) included in the NJ WEA (source data BOEM 2017).

H.



I.



6.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

6.2.1 Bathymetry

Figure 6-3 shows the NJ WEA bathymetry. It essentially slopes away from landward (northwest) toward the shelf edge (southeast) with contours roughly paralleling the coast. The depth of water increases 24 m over a distance of about 24 km, giving values in the range 0.06 degrees for the overall seaward slope of the bottom. That slope is not smooth, as the bottom contours include a series of ridges and depressions with axes trending roughly NE-SW across both lease areas. A linear depression oriented roughly N-S, possibly an old drainage channel, interrupts that pattern near the southwestern corner of the WEA, in lease area OCS-A-0498.

6.2.2 Terrain Variables

Regarding terrain metrics, slope, rugosity, and aspect (Figure 6-4) all show subtle but clear patterns related to the NE-SW ridges and depressions mentioned in section 6.2.1. Nearly all slopes are less than on degree, with the general surface flat and slopes in the 0.55-1.08 degree confined to the sides of some ridges. Rugosity, a measure of surface roughness, is generally very low except in patches, particularly corresponding to the largest slopes. The largest area of higher rugosity lies in lease block 6985 and the sub-blocks of 6986 and 7035, in the easternmost corner of OCS-A-0498. Another prominent one lies in blocks 6836 and 6837 in the southern part of OCS-A-0499. Aspect, too outlines the pattern of ridges.

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 6-3) and terrain metrics (Figure 6-4). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope, standard deviation break = 2.0, and depth (Figure 6-5). Again, the pattern of ridges and depressions covering most of OCS-A-0498 and the southern third of OCS-A-0499 is evident. Also evident is relatively flat interruption of that pattern in a N-S direction through blocks 6032, 7132, 7082, 7032, and the sub-blocks of 6982, corresponding to the “drainage channel” in OCS-A-0498 and the flat topography of the northern two-thirds of OCS-A-0499.

Figure 6-3. Bathymetry (74 m horizontal resolution) with isobaths contours in the NJ WEA. Source data: (BOEM 2017, NOAA NCEI 2017).

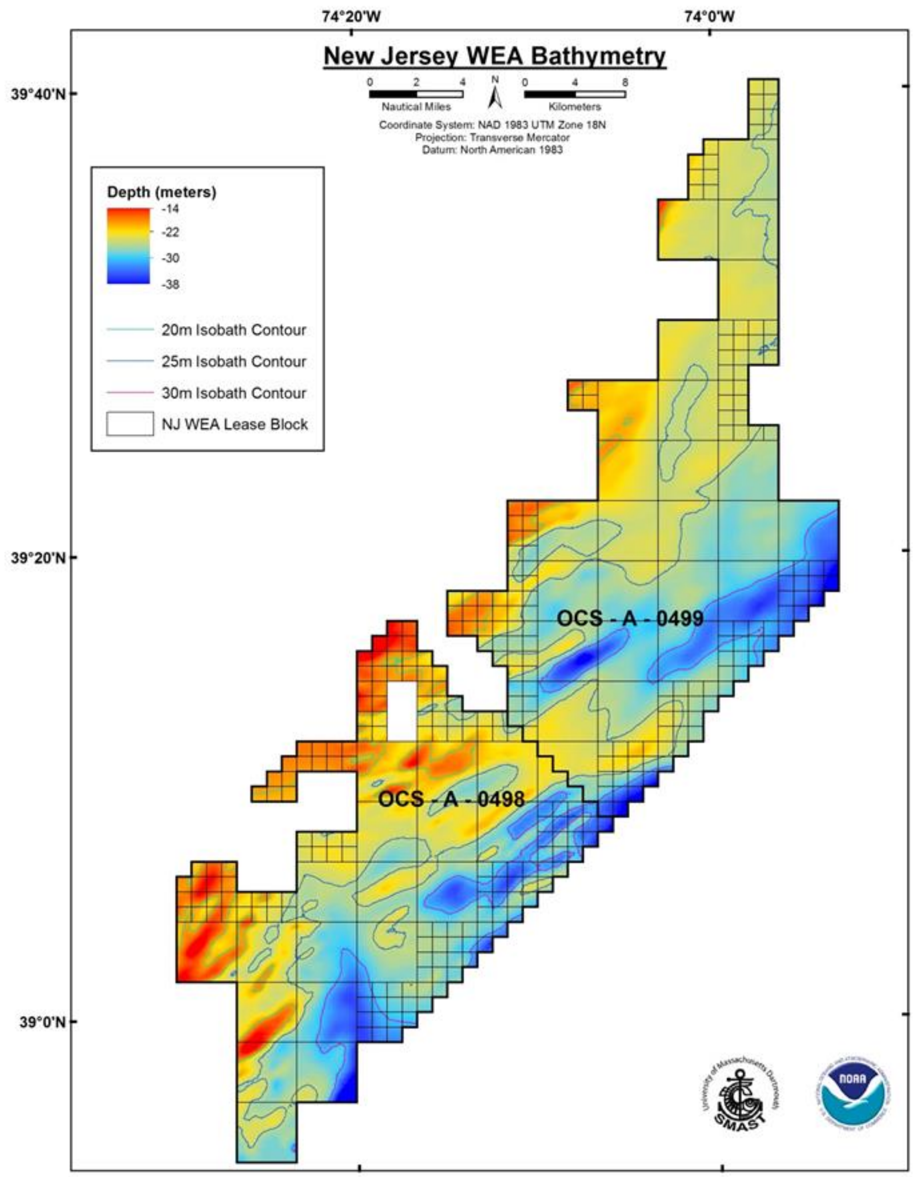


Figure 6-4. Terrain metrics derived from bathymetry for NJ WEA (Figure 6-3). A. Seafloor slope, B. Rugosity, C. Aspect.

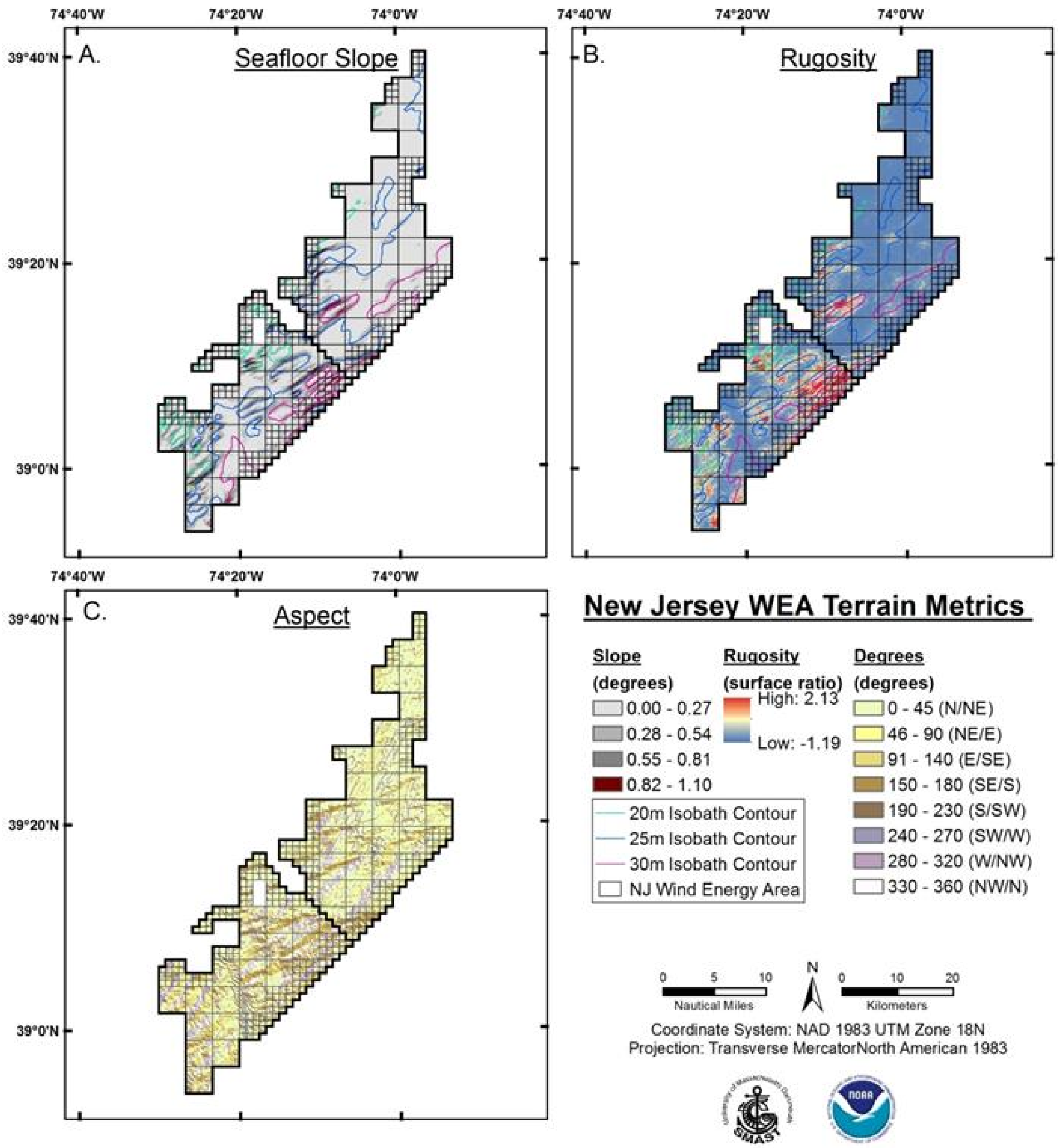
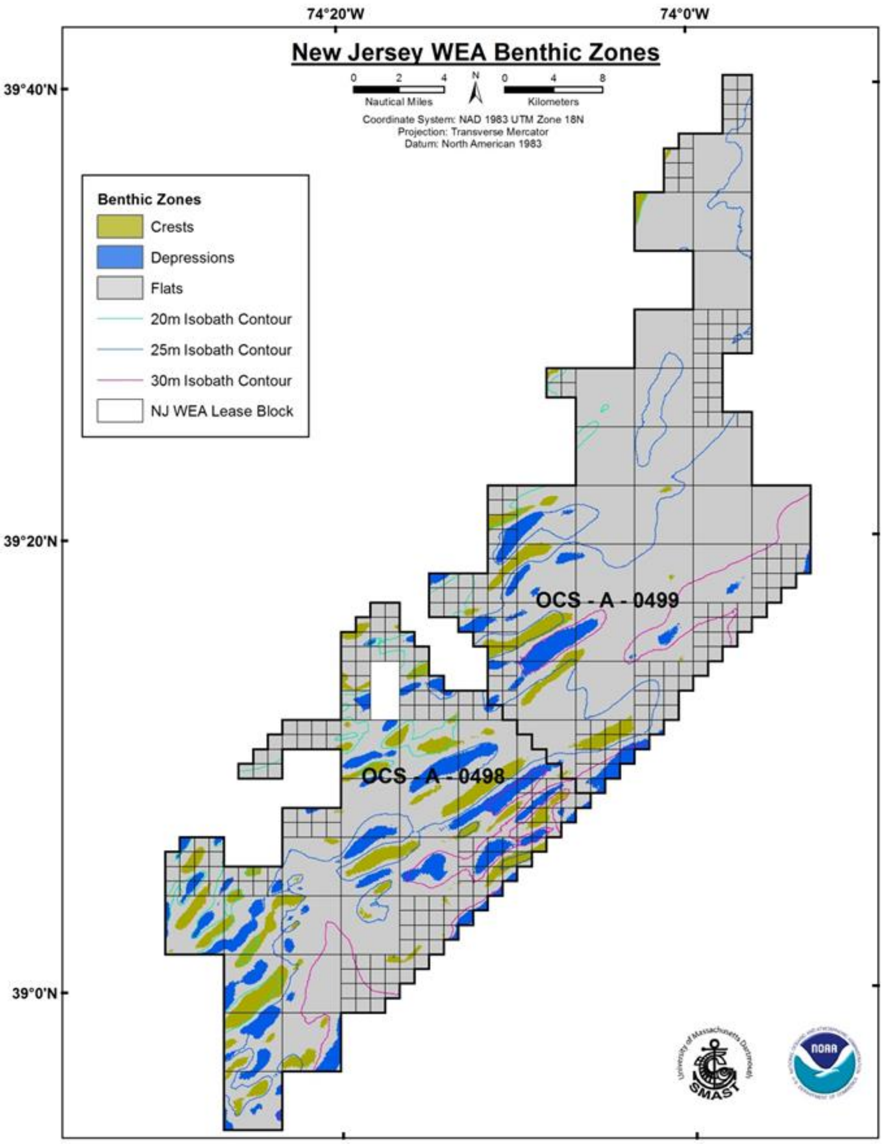


Figure 6-5. Benthic zones derived from bathymetry and derived slope data in the NJ WEA.



6.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the NJ WEA is shown in Figure 6-6. Figures 6-7, 6-8, and 6-9 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 6-6 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

Figure 6-6. Location and source of benthic sediment samples and observations in the NJ WEA. Sample include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles), cores taken from grab sampler aboard the NOAA 2014 AMAPPS cruise (green stars), and SMAST observations from camera pyramid imagery (green diamonds). Data sources - bathymetry as in Figure 6-3, sediment data: Reid et al. 2005, UMASS SMAST

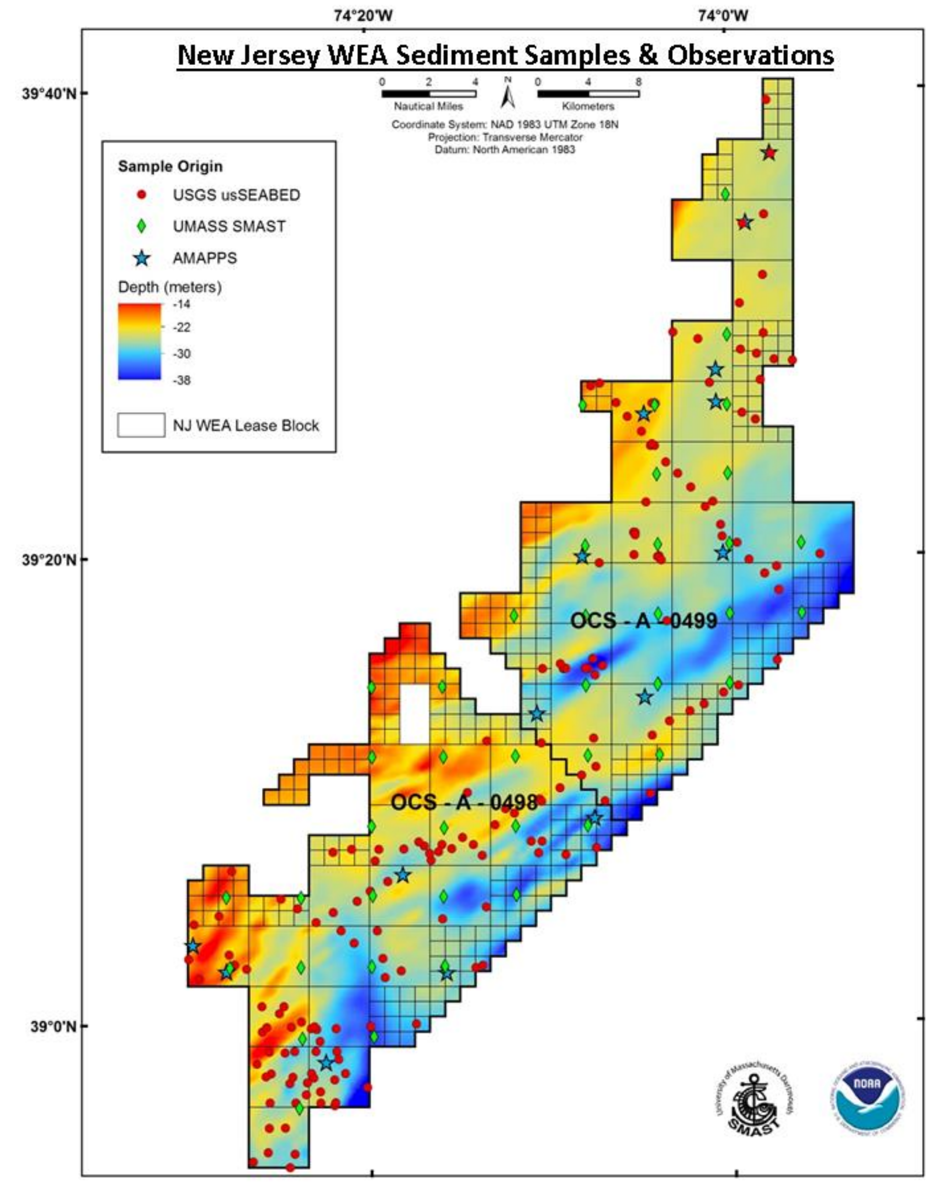


Figure 6-7. Predicted mud (silt + clay) distribution of surficial sediments in NJ WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data as in Figure 6-6.

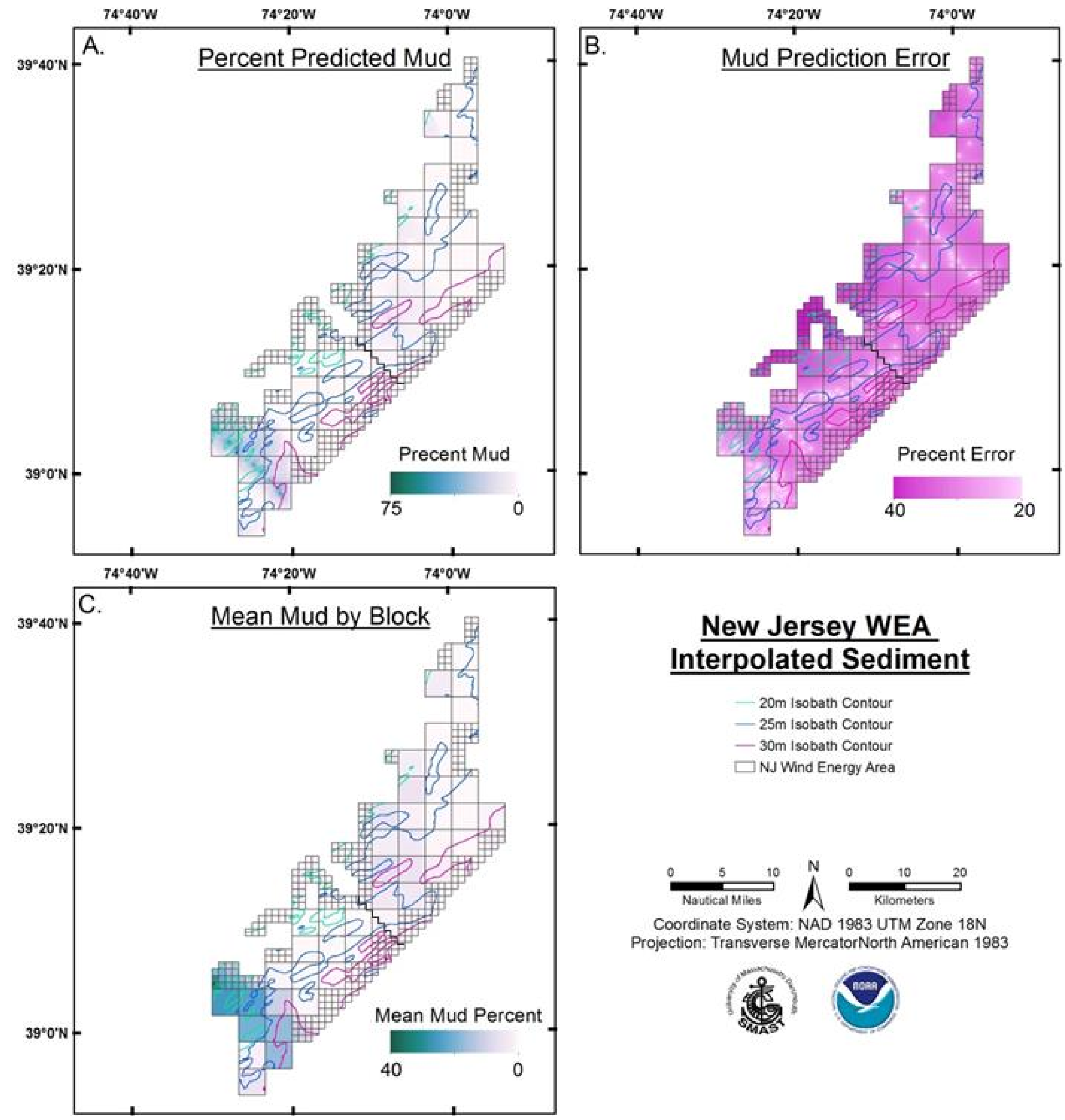


Figure 6-8. Predicted sand distribution of surficial sediments in NJ WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data as in Figure 6-6.

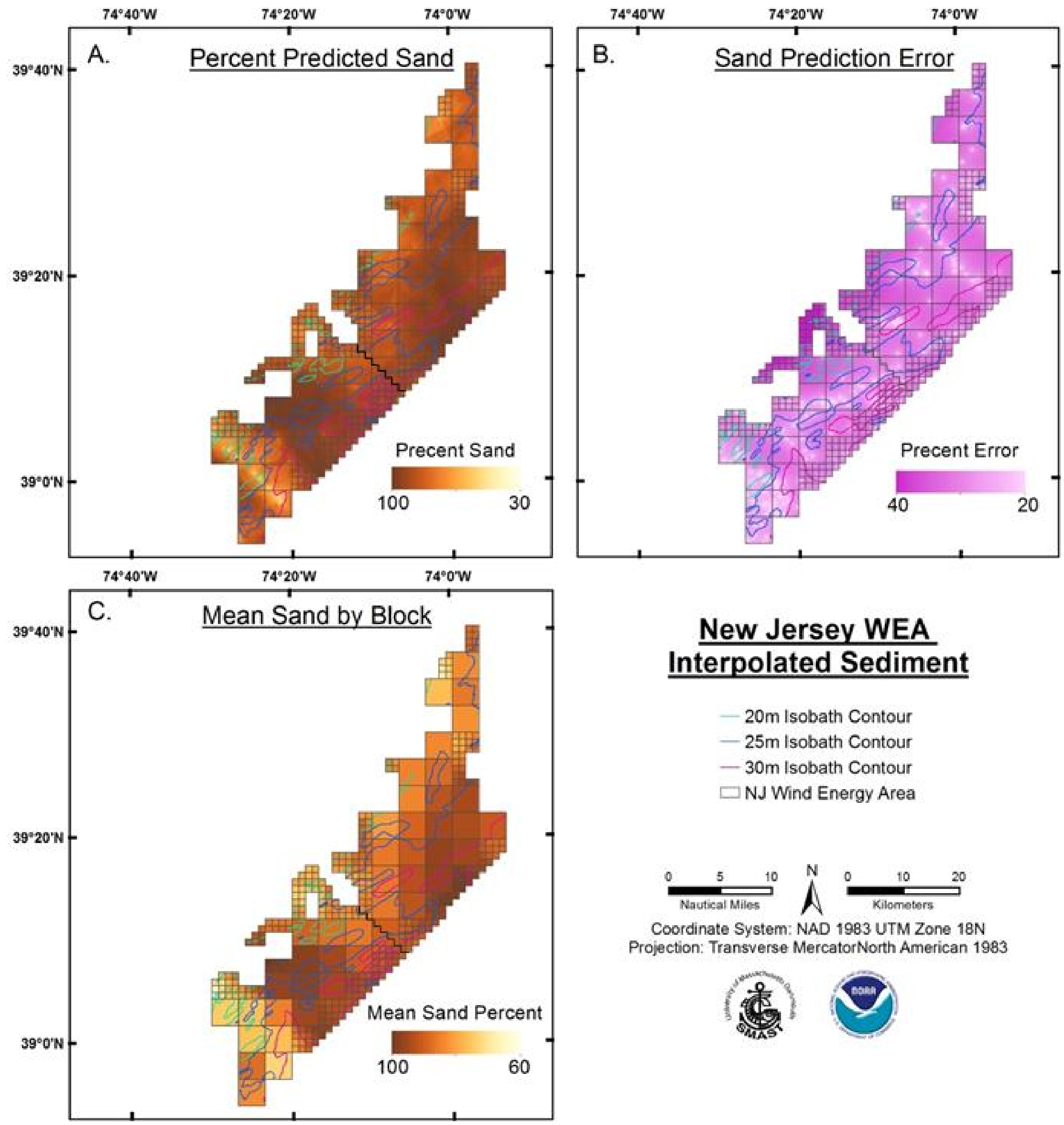
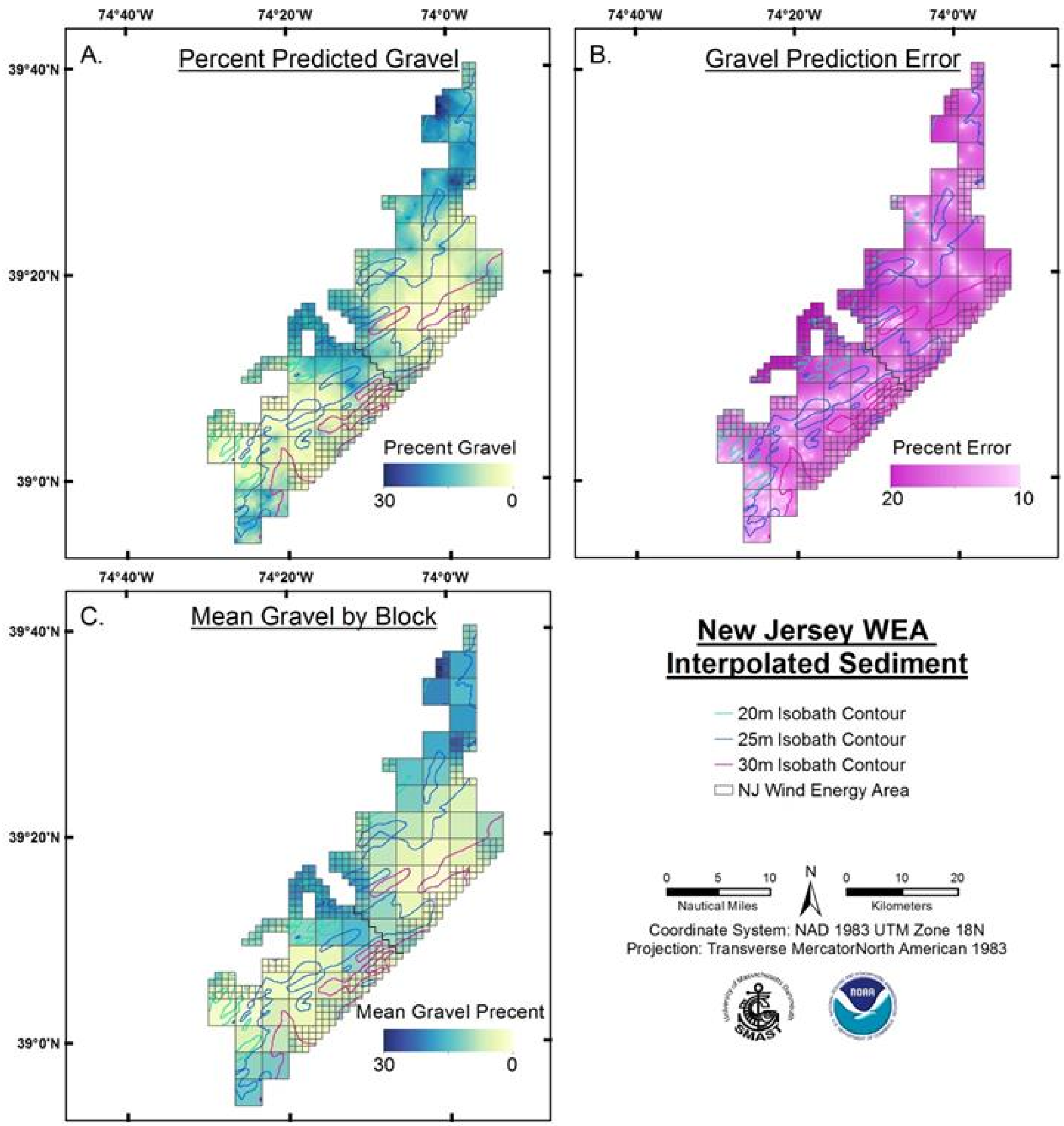


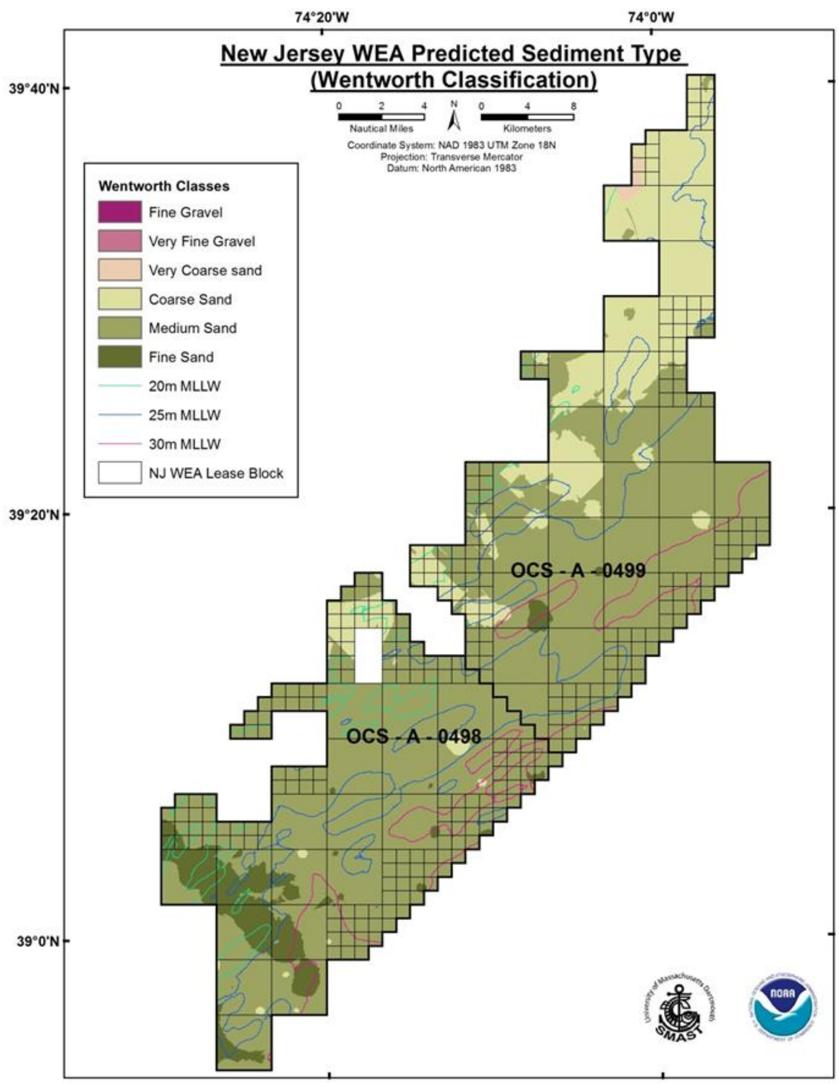
Figure 6-9. Predicted gravel distribution of surficial sediments in NJ WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data as in Figure 6-6.



Together Figures 6-7 through 6-9 indicate sediments dominated by sand throughout virtually all of the WEA. Gravel content is substantial in the north of OCS-A-0499, through the center of the WEA, spanning both lease areas, and in the far south of OCS-A-0498, but nowhere is it the dominant sediment type. Mud is minor component throughout the WEA, but only approaches dominance along a narrow NW-SE strip crossing OCS-A-0498 near its southern end.

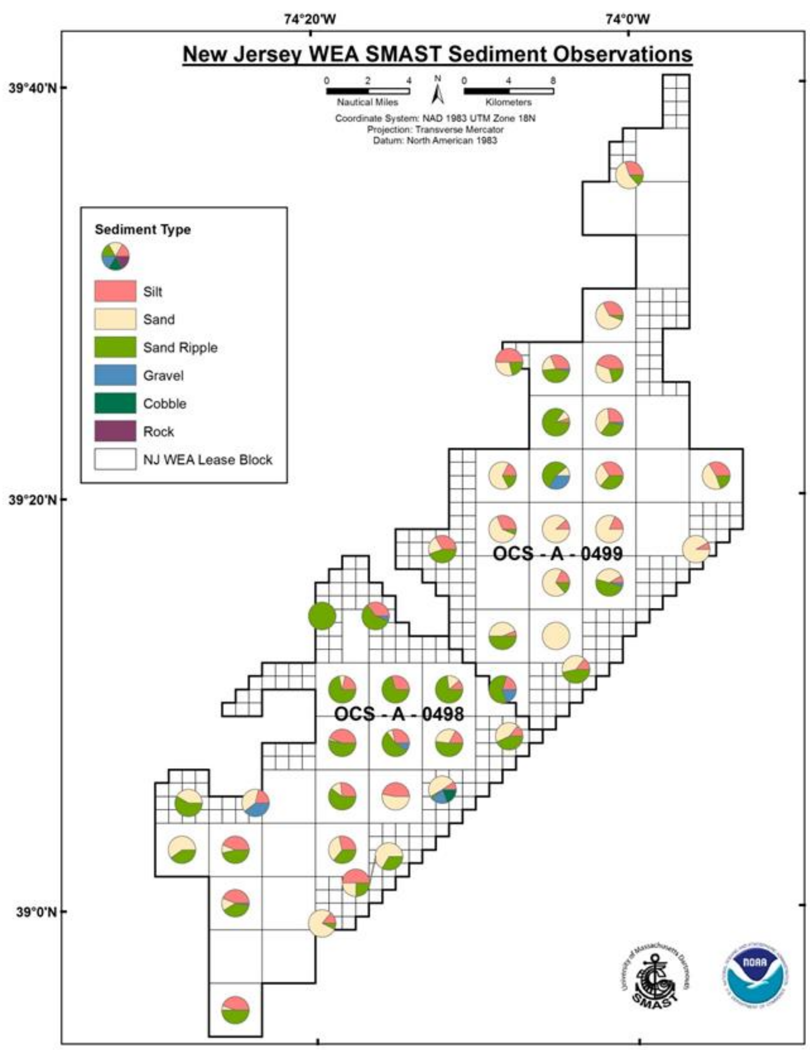
Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 6-10. While this representation only represents mean grain size without assessing the range of sediment sizes present, it does give a good idea of the character of sediments where the variation in grain sizes is not extreme. The presence of some sand and especially gravel in muddy sediments causes the mean grain size to register in the fine sand range; minor amounts of gravel in areas in the northwestern part of the WEA register as medium to coarse sand as a result of the averaging process. Nevertheless, the dominance of fine-grained sediments throughout most of the WEA is clear.

Figure 6-10. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the NJ WEA physical samples. Figure shows interpolated average grain size distribution. Source data as in Figure 6-6.



SMAST image-based sediment observations, which were not incorporated into the analyses displayed in Figures 6-7 through 6-10, independently confirmed this sediment distribution pattern and supplement data from grab samples. SMAST observations include grain sizes too large for grab samples and microtopographic features too small for detection from bathymetry, e.g. sand ripples (Figure 6-11). As in the previous analysis, sand appears to predominate and silt (mud) is widespread. Gravel appeared less often than in grain-size analysis. Of particular note is the widespread occurrence and often dominance of sand ripples throughout most of the NJ WEA. This is an indication of widespread sediment mobility, which corresponds to the high-moderate rating for that parameter for this WEA predicted from shear stress (Figure 1-5).

Figure 6-11. SMAST surficial sediments (presence-absence) observations. Observations proportions in pie charts were compiled to show the ratio of sediment observations from multiple images taken at each station. Source data: UMASS SMAST.

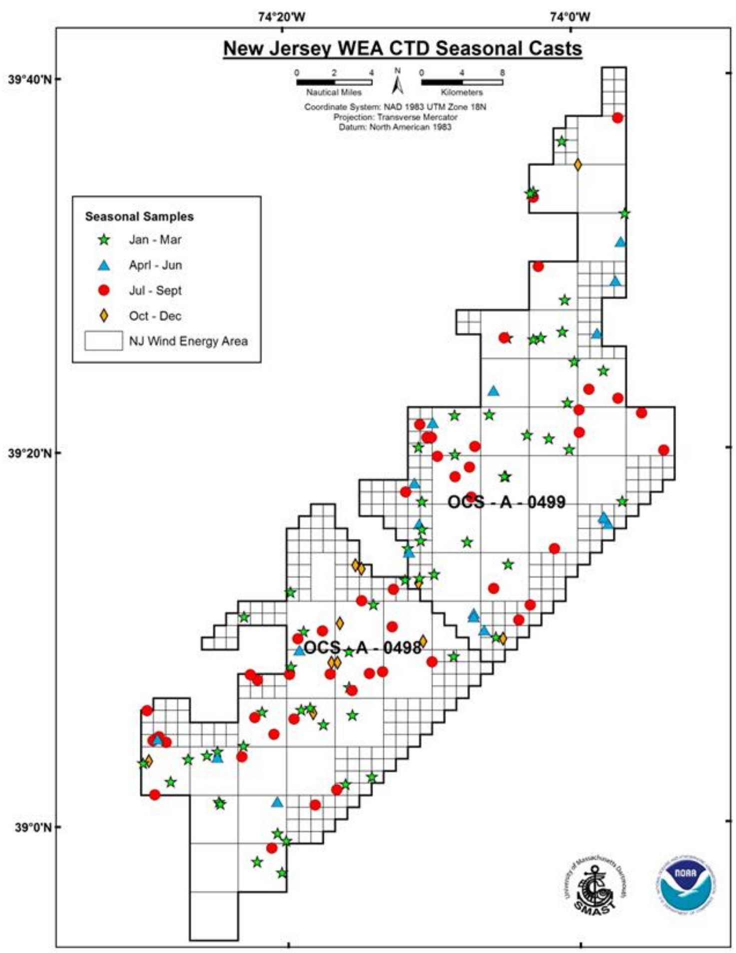


6.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 6-12.

Median salinity measured in the NJ WEA for this period, including all depths, was 32.234, with a full range spanning 29.387 to 34.362 (n=4,205), despite strong seasonal changes in other parameters. This range is entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 4.98 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

Figure 6-12. Locations for NEFSC CTD casts made between 2003 and 2016 in the NJ WEA.



On the other hand, water temperatures showed large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water column structure. Figure 6-13 presents surface and bottom temperatures from CTD casts shown in Figure 6-12 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 20°C at the surface and 15°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 15°C. Then vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperatures of up to 12°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton. The NJ WEA has no persistent frontal systems impinging upon it (Figure 1-4).

6.2.5 Biological Variables

6.2.5.1 Benthic Epifauna and Infauna

Benthic samples were collected during one NEFSC–sponsored cruise (AMAPPS GU14-02 part 1) in the NJ WEA, including 13 beam trawls for benthic epifauna and 15 triplicate Van Veen grabs for benthic infauna (Figure 6-14).

NEFSC beam trawl catches and the contents (58 taxa) of the benthic grab samples (94 taxa) are summarized in Figure 6-15. Among the epibenthic fauna as obtained in beam trawls, there were no dominants as defined in section 1.3.4, but sand shrimp came closest to meeting the criteria and sand dollars were prominent (Figure 6-16A). This is not surprising given the largely sandy character of sediments at all stations. Among the benthic infauna spionid polychaetes were most prominent. This taxon and four other polychaete families were represented among the core species, along with sand dollars (*Echinarchnius parma*) , nemertean worms, and Ascideaceans (sea squirts). Amphipods were present, but as non-core species (frequency <80%), unlike the benthic infaunal assemblages of MA, RIMA, and NY WEAs. The shift in dominance of amphipods to polychaetes from southern New England to the Mid Atlantic was also noted by Theroux and Wigley (1998). The prominent position of sea squirts was surprising, given the general paucity of gravel and lack of other stable geological substrates for attachment of these sessile invertebrates. Shell hash may be serving that purpose in this WEA.

Figure 6-13. Water temperatures from CTD casts made between 2003 and 2016 in the NJ WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values. No data was available for mid-November through mid-January, so the shapes of trend lines for that period (dashed) are conjectural.

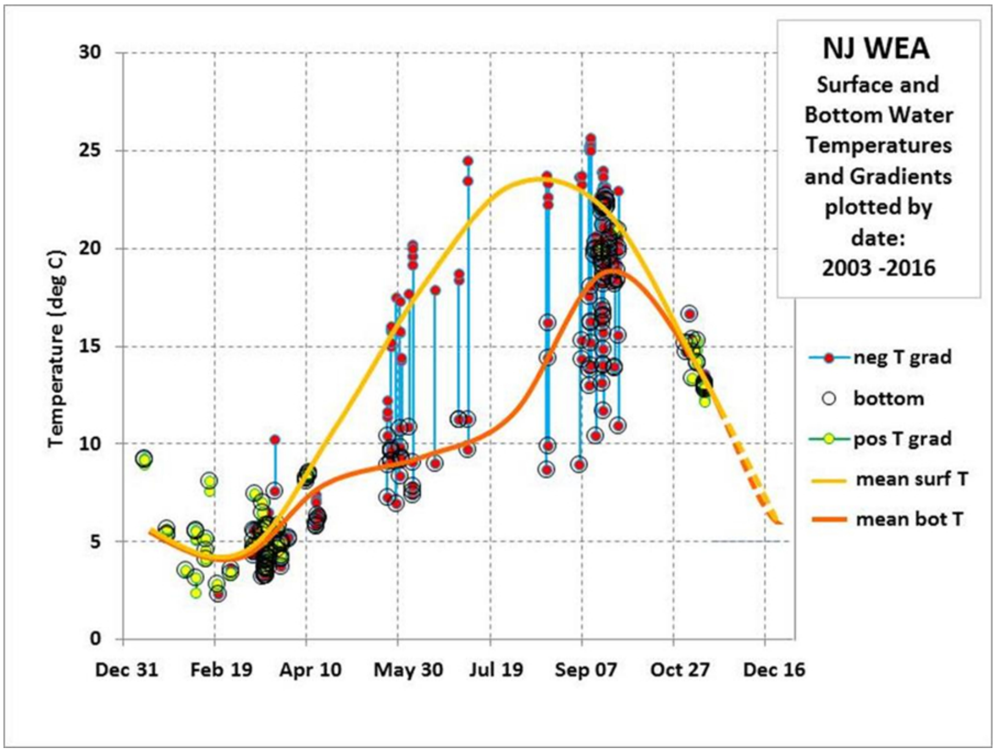


Figure 6-14. Locations of beam trawl and benthic grab samples made in the NJ WEA.

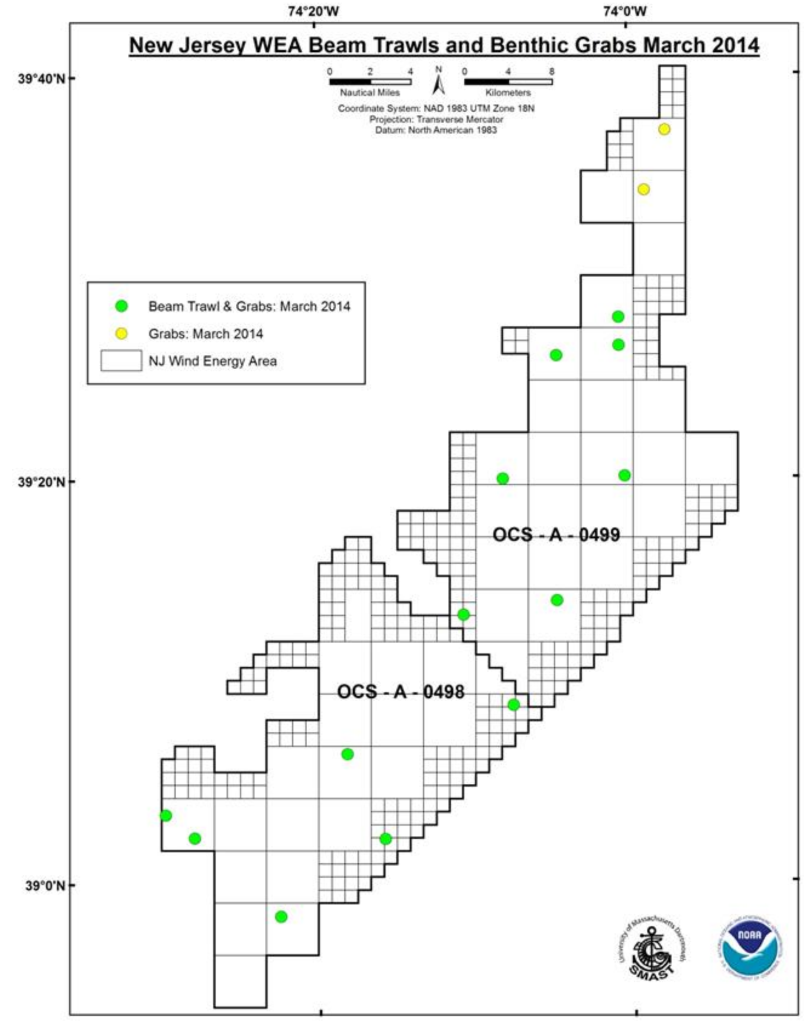
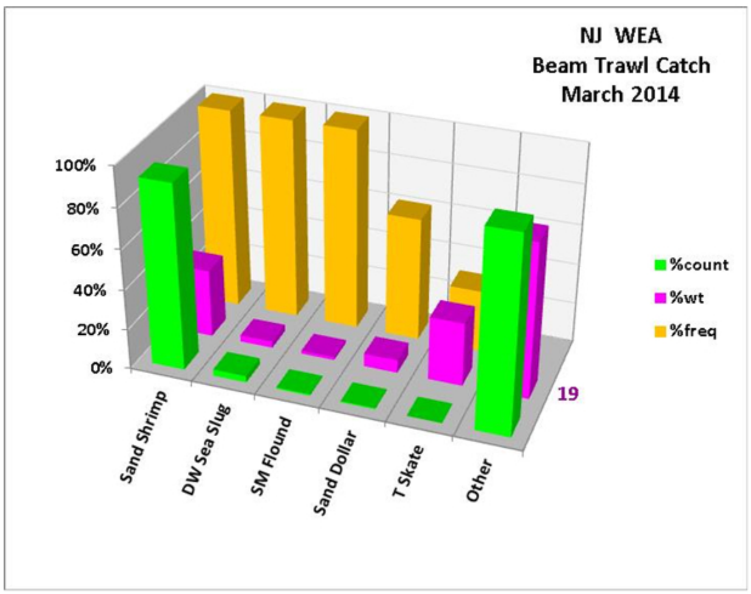
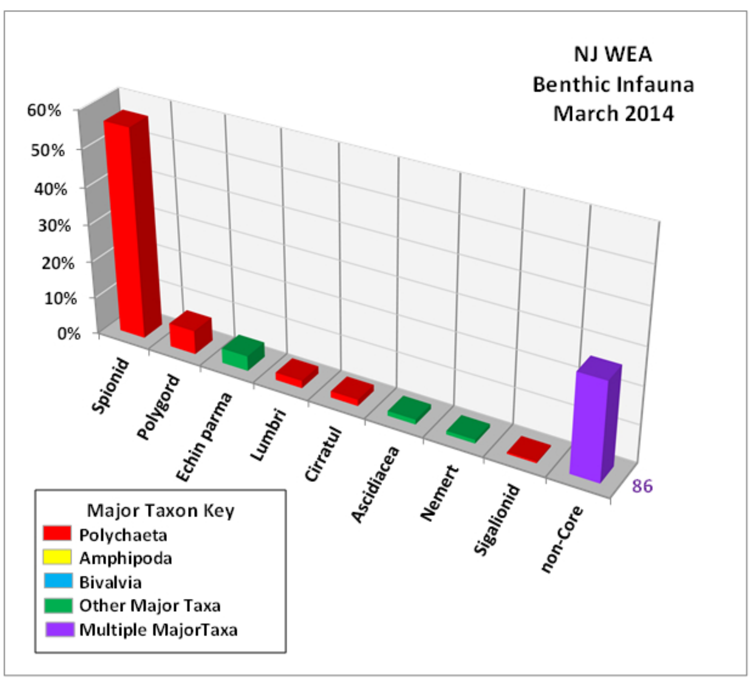


Figure 6-15. Benthic fauna caught in NJ WEA by NEFSC sampling . A. Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA; B. Grab sample catch by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated common names for taxa in A: DW Sea Slug – dwarf warty sea slug, SM Flound – smallmouth flounder, T Skate – thorny skate. Abbreviated taxonomic names in B: Spionid – Spionidae, Polygord – Polygordiidae, Echin parma – *Echinarachnius parma*, Lumbri – Lumbrinereidae, Cirratul – Cirratulidae, Nemert – Nemertea, Sigalionid - Sigalionidae. Numbers to the right of the "other" and "non-core" taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of "other" and "non-core" species.

A.



B.



6.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 6-16. Importance values among taxa captured in NEFSC Seasonal Trawl Survey catches in the NJ WEA are plotted in Figure 6-16 and Table 6-1, with seasonally dominant species listed in Table 6-2.

Figure 6-16. Locations of NEFSC seasonal trawls from 2003 to 2016 in the NJ WEA.

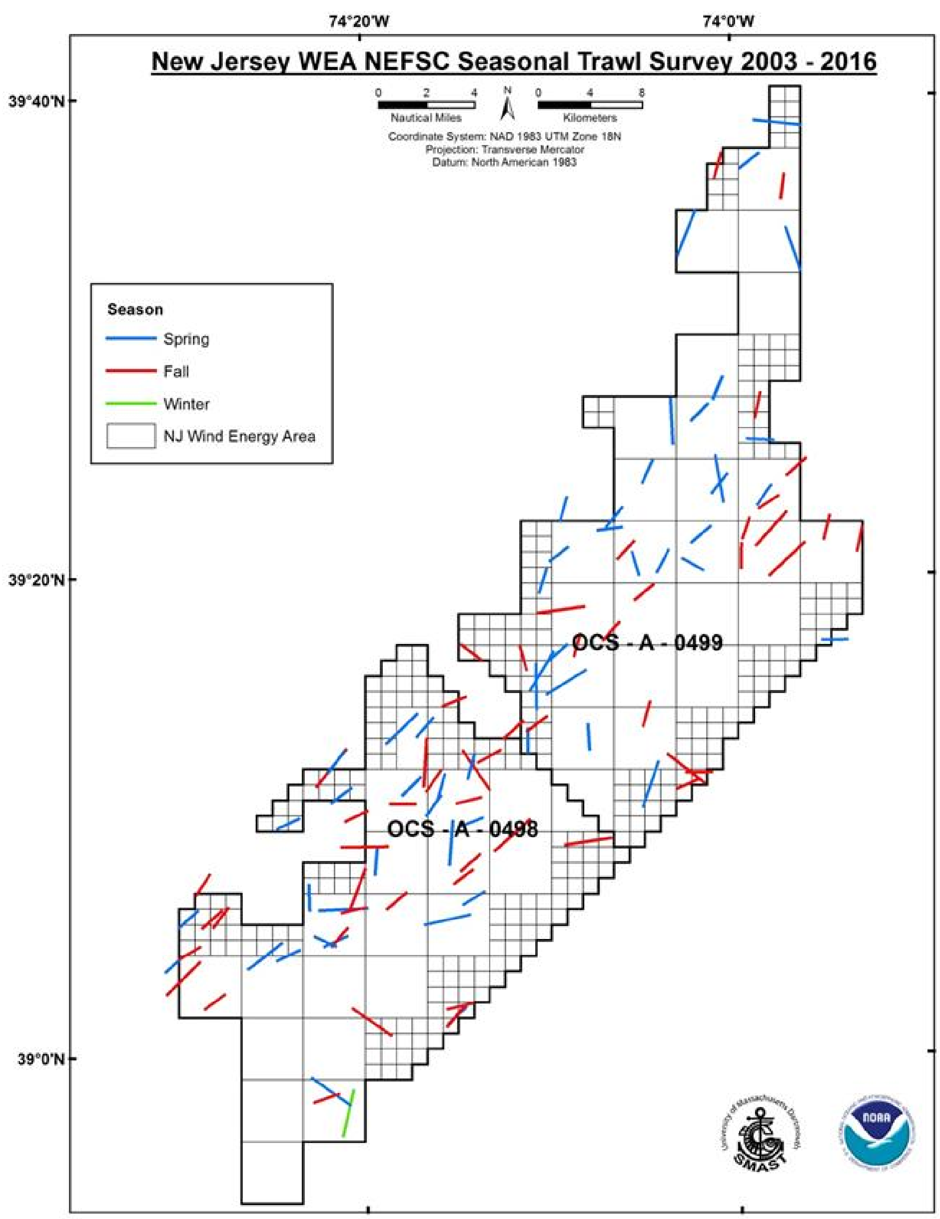
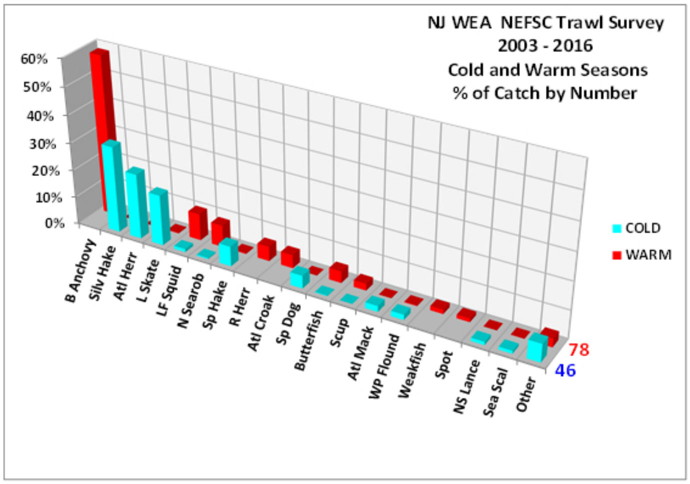
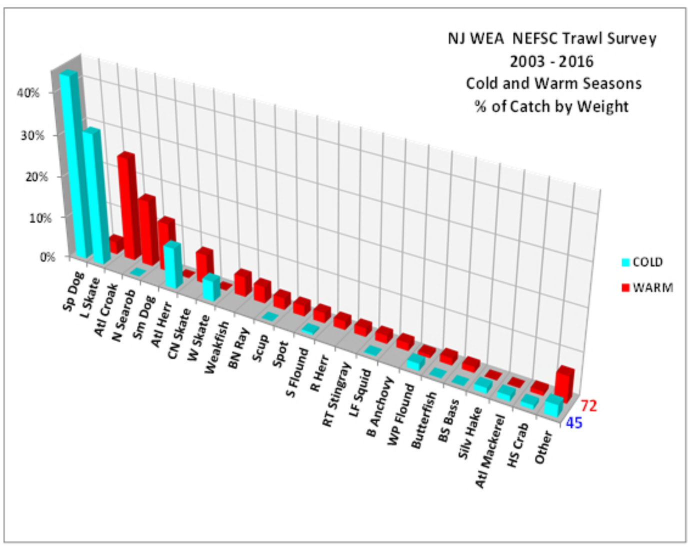


Figure 6-17. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 6-1. Blue and red numbers along the right margin of the graphs indicate the numbers of “other” species in cold and warm season catches respectively.

A.



B.



C.

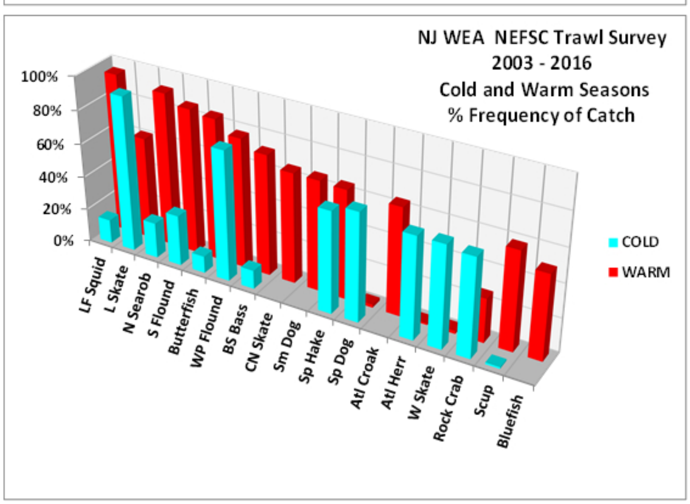


Table 6-1. Abbreviations for taxon names used in Fig. 6-16, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Atl Croak	Atlantic croaker[1]	RT Stingray	roughtail stingray
Atl Herr	Atlantic herring[2]	R Herr	round herring
Atl Mack	Atlantic mackerel[3]	Scup	scup[3]
Rock Crab	southern rock crab	Sea Scal	sea scallop[2]
B Anchovy	bay anchovy	Silv Hake	silver hake[2]
BS Bass	black sea bass[3]	Sm Dog	smooth dogfish[5]
BN Ray	bullnose ray	Sp Dog	spiny dogfish[4]
Butterfish	butterfish[3]	Spot	spot[1]
CN Skate	clearnose skate[2]	Sp Hake	spotted hake
HS Crab	horseshoe crab[1]	S Flound	summer flounder[3]
L Skate	little skate[2]	Weakfish	weakfish[1]
LF Squid	longfin squid[3]	WP Flound	windowpane flounder[2]
NS Lance	northern sand lance	W Skate	winter skate[2]
N Searob	northern searobin		

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 6-2. Dominant species in NEFSC Seasonal Trawl Survey catches within the NJ WEA between 2003 and 2016.

New Jersey WEA Dominants	
Cold Season	Warm Season
Atlantic Herring	Atlantic Croaker
Little Skate	Butterfish
Winter Skate	Longfin Squid
	Northern Searobin
	Scup

It is evident from this survey trawl data that this is a taxon-rich area: 96 taxa in the warm season and 59 in the cold season. It is also evident that while there is considerable overlap in the lists of taxa present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also considerable overlap among species present and dominance with other WEAs, especially NY (section 6.2.5.2). Of the taxa that are important in terms of numbers, biomass, and/or frequency (Table 6-1) 70% (19 out of 27) are species that are managed in the northeast region. No species were dominants in both seasons. All of the dominants other than skates were seasonal migrants. It is also notable that all but one of the dominants (Table 6-2) are managed fishery species.

6.2.5.3 Species of Concern

Records of shellfish species of concern in the NJ WEA are illustrated in Figure 6-18. These included quantitative records of sea scallops from NEFSC seasonal trawl surveys and qualitative records from beam trawls, bottom grabs, and bottom imagery. Sea scallops were clearly widespread in this WEA, occurring in both lease areas, but more commonly encountered in OCS-A-0499. In most cases they were trawled up only in small numbers; they do not appear to be abundant in this WEA. Since quantitative trawl captures were located at the mid-point of the trawl track, which may lie outside the WEA limits, it is not certain whether the sea scallops near the WEA boundary were actually caught inside or outside the WEA in some cases. Current sea scallop EFH does not intersect the NJ WEA (Figure 1-7).

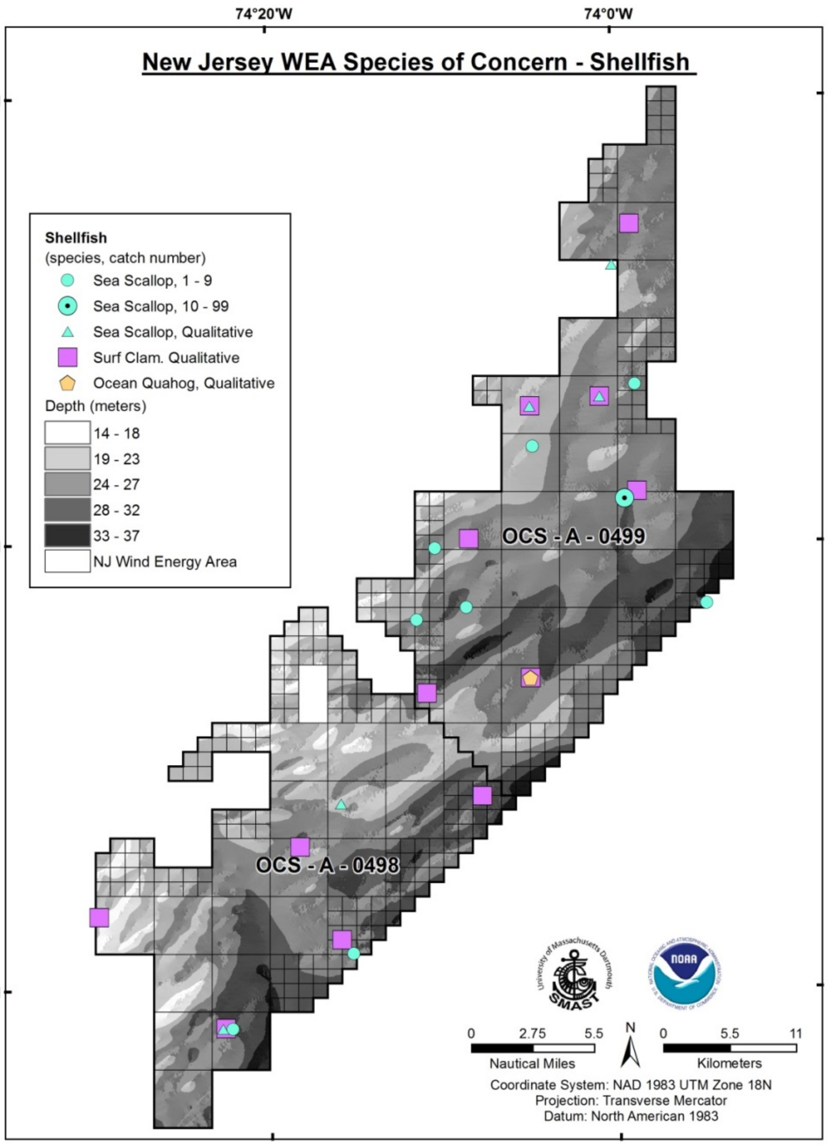
Ocean quahog EFH intersects the NJ WEA broadly (Figure 1-8), but our records show only a single qualitative catch there (Figure 6-18). Surf clam EFH overlaps this WEA completely (Figure 1-9), and surf clams were widespread there in our benthic beam trawls and grab samples (Figure 6-18).

As sea scallops and surf clams were widespread, these species might be worth considering in terms of potential for habitat disturbance in spite of only a no overlap with current sea scallop EFH.

The egg mops of longfin squid were not detected by us in the NJ WEA, but this could be attributable to our sampling in early spring (March: cold season), rather than in summer, when longfin squid lay eggs. Beam trawling will catch them if they are present, but we did not encounter them so far out of season. NJ lies largely outside the EFH zone for longfin squid egg mops (Figure 1-10).

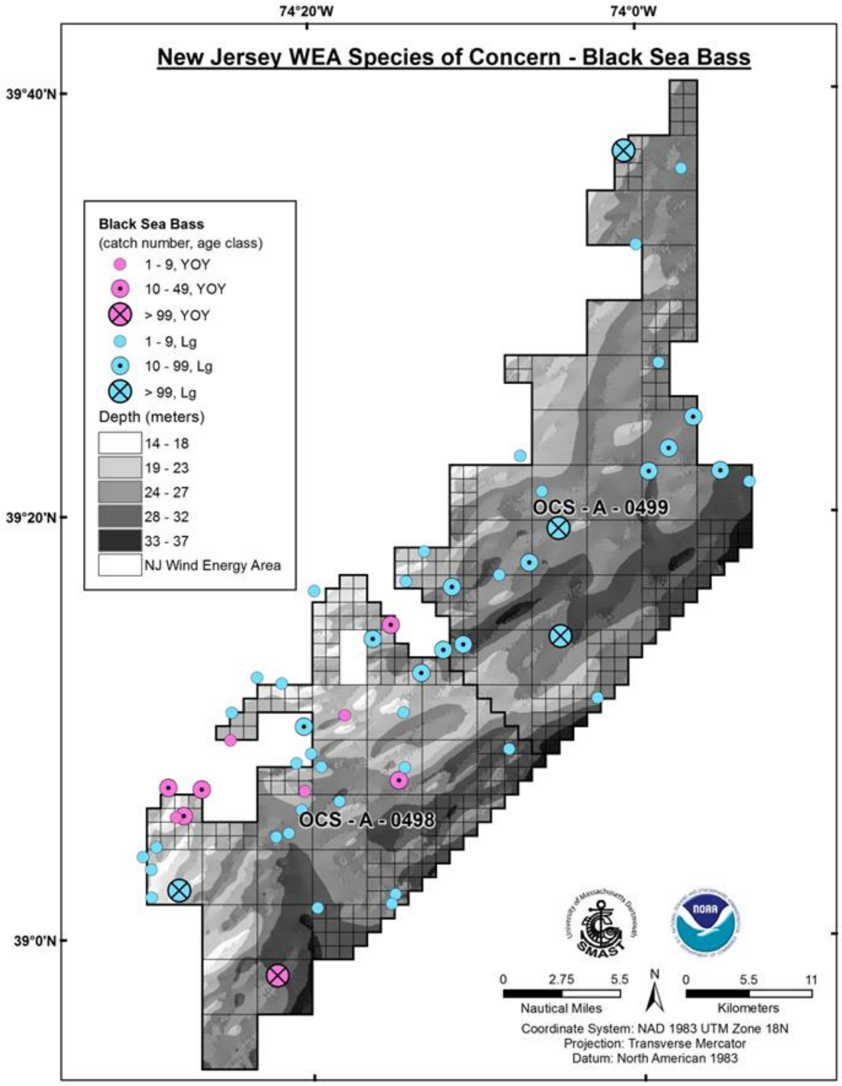
No Atlantic cod were captured within the boundaries of the NJ WEA between 2003 and 2016 despite this WEA being entirely within the current adult cod EFH zone (Fig. 1-11).

Figure 6-18. Shellfish species of concern records within and near the NJ WEA.



Both young-of-the-year (YOY) and sub-adult to adult-sized black sea bass (BSB) were widespread, common, and abundant in the NJ WEA (Figure 6-19), although YOY records were restricted to OCS-A-0498. This is despite the highest concentrations of gravel, which is supposedly favorable substrate for juvenile BSB, is in the north (OCS-A-499). Our records are entirely from NEFSC seasonal survey trawls, as our beam trawl survey, which is effective in detecting juvenile BSB, was performed during the cold season, when migratory black sea bass are absent. The distinction between YOY and larger BSB is important because YOY are thought to have differing requirements with respect to bottom habitat refuge requirements. This is a species where there is potential for habitat disturbance.

Figure 6-19. Records of young-of-the-year (YOY) and larger black sea bass in the NJ WEA.



The EFH map (Fig. 1-12) for juvenile does broadly overlap the southern half of the NJ WEA, as this data suggests it should. The map for adults, however, shows only minimal overlap occurring in the north and central parts of the WEA, so may be in need of revision.

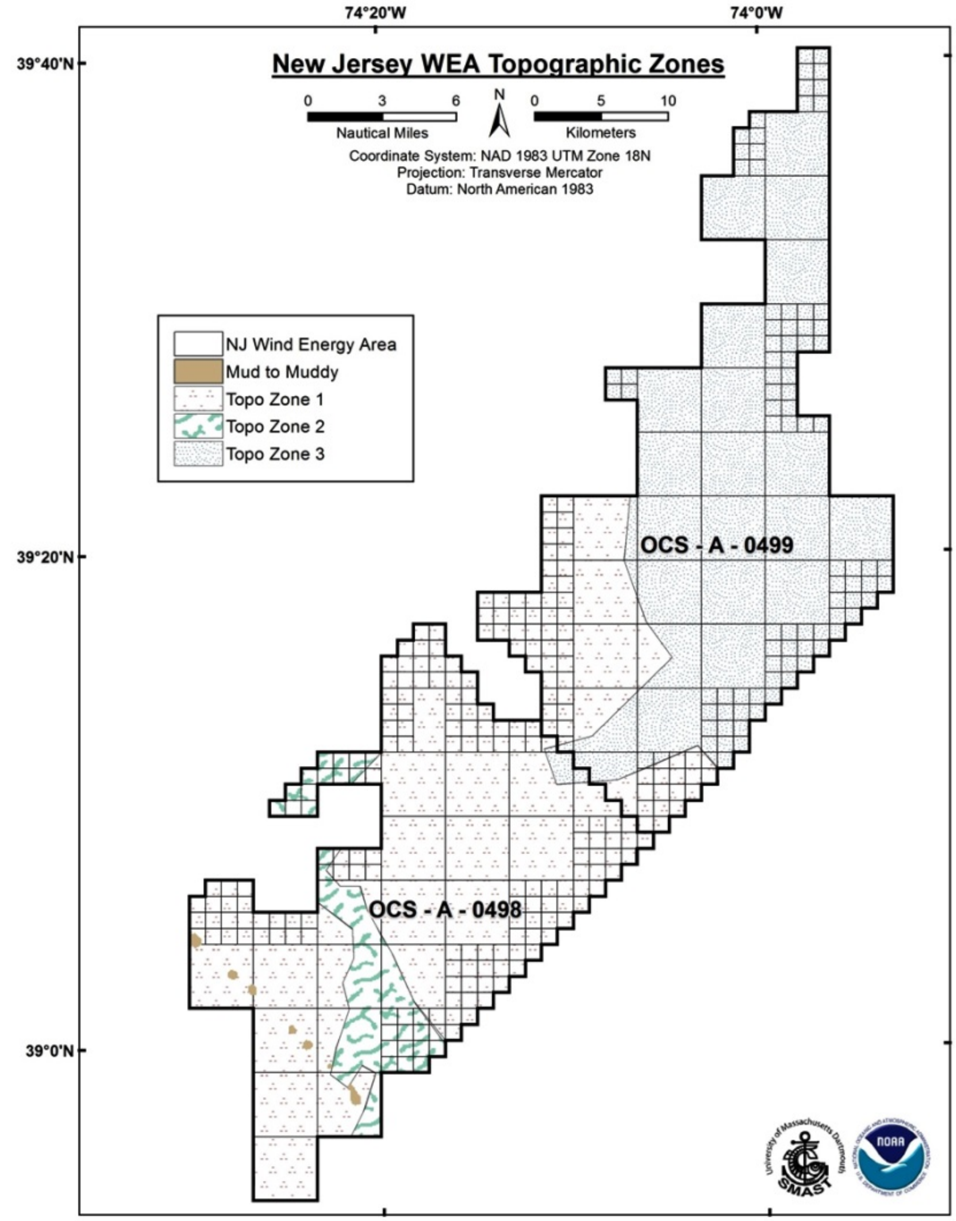
6.3 NJ WEA Habitat Definition

An integrated view of the physical benthic habitat features in the MA WEA is presented in Figure 6-20. There are three major topographic zones (Topo Zones 1, 2, 3) with habitat features (mud to muddy patches) superimposed upon it locations.

Topo Zone 1 consists of a series of megaripples oriented approximately NE-SW (Section 6.2.2, Figure 6-5). It occupies most of lease area OCS-A-0498 and the southern third of OCS-A-0499. Unlike the cases of the MA and RIMA WEAs, an apparent shelf valley as seen in larger perspective in Ruddock 2010, Figure 1), is designated as a separate topo zone (Topo Zone 3) rather than a superimposed feature, because it cuts across and fully masks the surrounding megaripple topography (Figures 6-4, 6-5). It is located entirely within OCS-A-0498. This was probably a large river system draining what is now the New Jersey coast during the low stand of sea level during the Wisconsin glaciation. As far as we have determined with the data at hand, the sediments and fauna of these features are not notably different from those of the surrounding shelf. Topo Zone 2 is flat and nearly featureless at the scale of existing acoustic mapping and occupies the northern two-thirds of OCS-A-0499. We have characterized it as a platform: a wave-cut platform submerged by rising sea level (FGDC 2012). Subsequent reworking by waves and tidal currents have been sufficient to generate sand ripples (Figure 6-11), but not the megaripples as seen in Topo Zone 1 (Figure 6-5).

Based on data from a linear transect in the USseabed database, a series of muddy patches was detected crossing Topo Zone 1 NW to SE near its southern end in OCS-A-0498.

Figure 6-20. Physical benthic habitat features of the NJ WEA.



6.3.1 CMECS Classifications:

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Megaripples, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Slightly Gravelly Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Small Surface-Burrowing Fauna, Small Tube-Building Fauna, Clam Bed (*Spisula*), Sand Dollar Bed (*Echinarachnius*)

Topo Zone 2

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Platform, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Slightly Gravelly Sand
- Biotic Component same as for Topo Zone 1

Topo Zone 3

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Shelf Valley
- Substrate and Biotic Components: same as for Topo Zone 1

Mud to Muddy Patch

- Geoform and Biotic Components: same as for Topo Zone 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Muddy Sand to Mud

7 Delaware Wind Energy Area (DE WEA)

7.1 Location, size, and subdivision

The Delaware WEA lies on the Southern Mid Atlantic Bight shelf in a band between approximately 11 and 23 nautical miles off the coast of Delaware, approximately from Rehoboth Beach to the Maryland border (Figure 7-1). It lies about 12 nautical miles southeast of the mouth of Delaware Bay. It consists of 11 full lease blocks plus 100 complete and 17 partial sub-blocks (Figure 7-2). Water depths in the DE WEA range 10 to 34 m, with an average of approximately 25 m, and it covers approximately 96,430 acres of seafloor (BOEM 2014b). The Delaware Department of Natural Resources and Environmental Control (DNREC) established an artificial reef area (Site 11 or Redbird Reef) to attract fish in the 1990s and has been adding material since then. Registered with NOAA and labeled "Fish Haven" on navigational charts, it is located near the center of the DE WEA and encompasses about 1,043 acres. Its contents include 12 shipwrecks, 1950 tons of ballasted tires, 106 military vehicles, and 714 subway cars, at least some of which are NYC "Redbird" cars (DE DNREC 2015). Figure 7-2 provides the numbering for all blocks in the WEA. This section provides data and analysis for the entire WEA as a single unit.

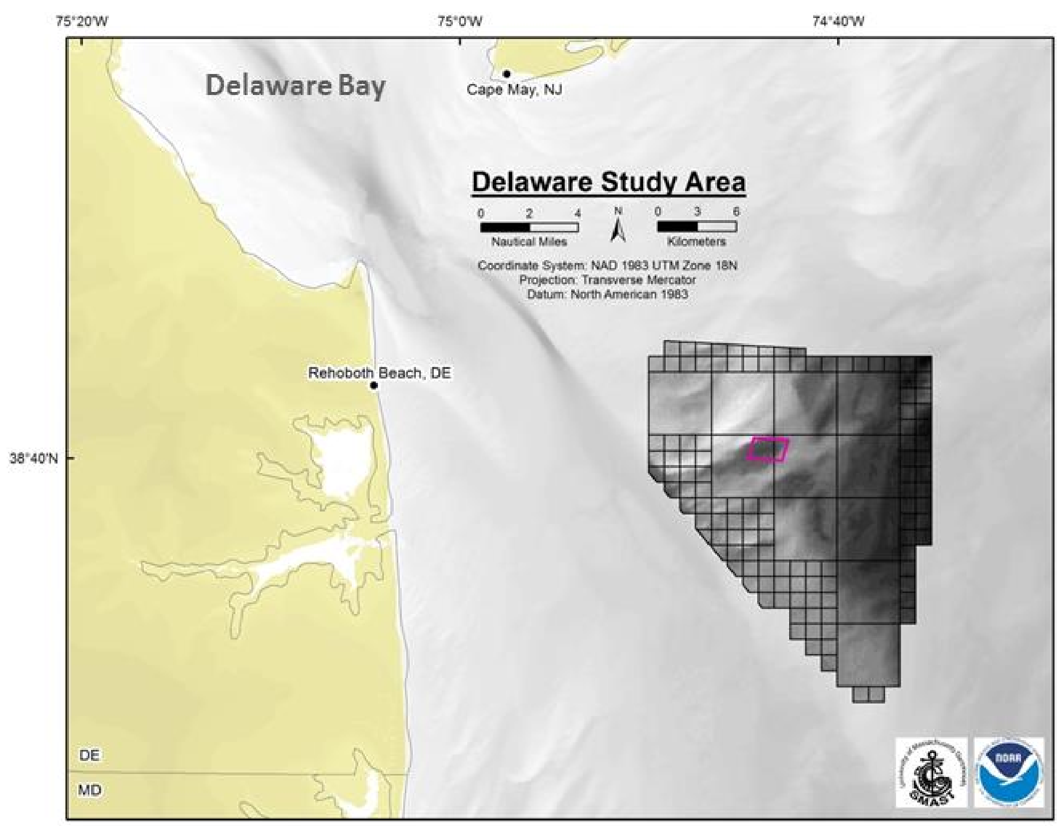


Figure 7-1. Map of Delaware study area. The DNR Site 11 (Redbird Reef) Fish Haven is outlined in magenta. Source data:(BOEM 2017, NOAA NCEI 2017, DE DNREC 2015).

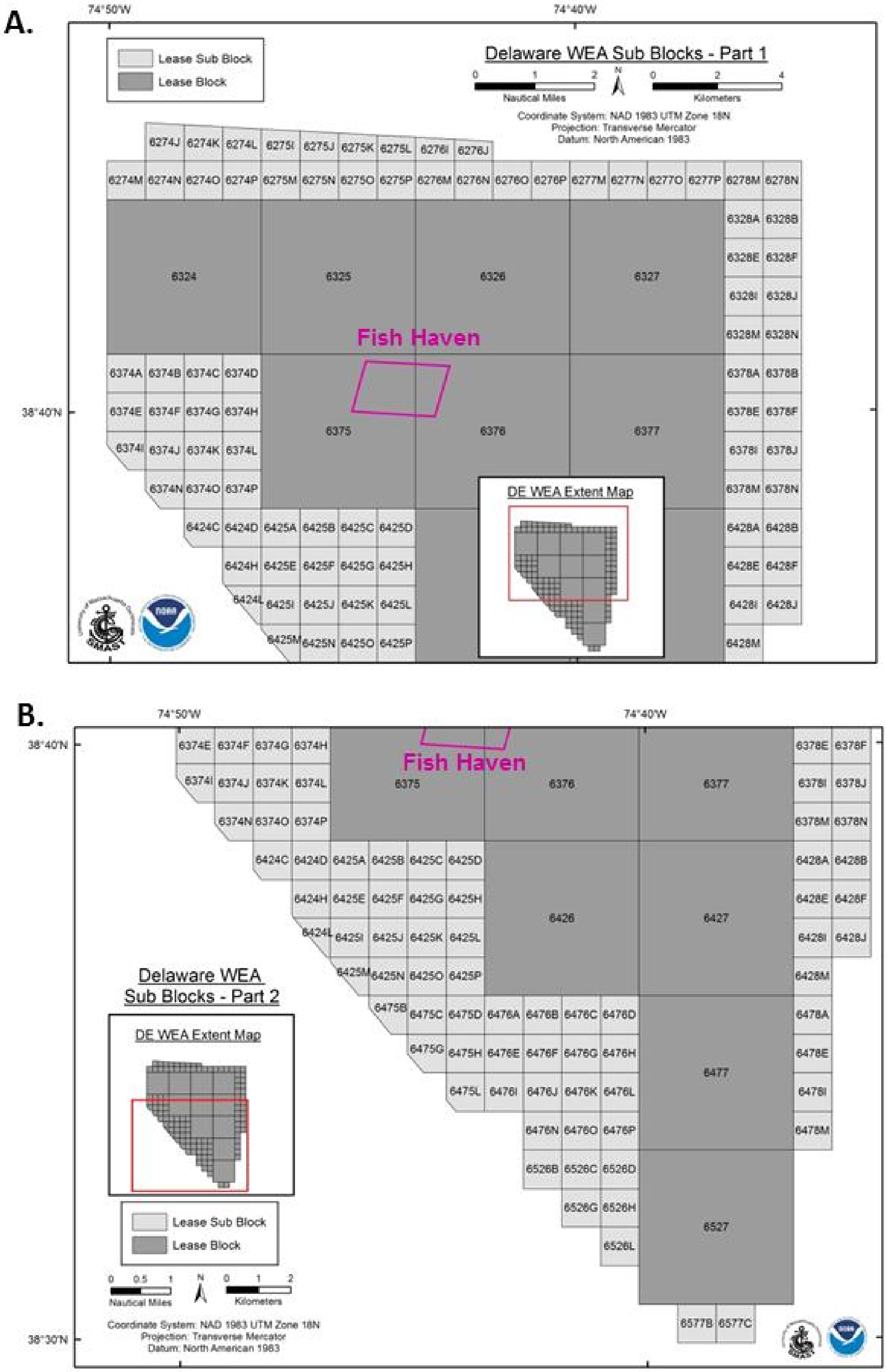


Figure 7-2. Numbered lease blocks (A.) and sub-blocks (B.-I.) included in the DE WEA (source data BOEM 2017, DE DNREC 2015).

7.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

7.2.1 Bathymetry

Figure 7-3 shows the DE WEA bathymetry. The shallower western half of the WEA's bottom topography is dominated by a series of irregular NE-SW oriented ridges and troughs with crest-to-trough heights as large as 15 m at intervals of 2-4 km crest-to-crest. The largest of these is in the northwest corner of the WEA. The eastern half of the WEA is dominated by smaller (<5 m high) N-S ridges and trough topography at intervals of 1-2 km or less. The fish haven lies in a trough between the larger western ridges.

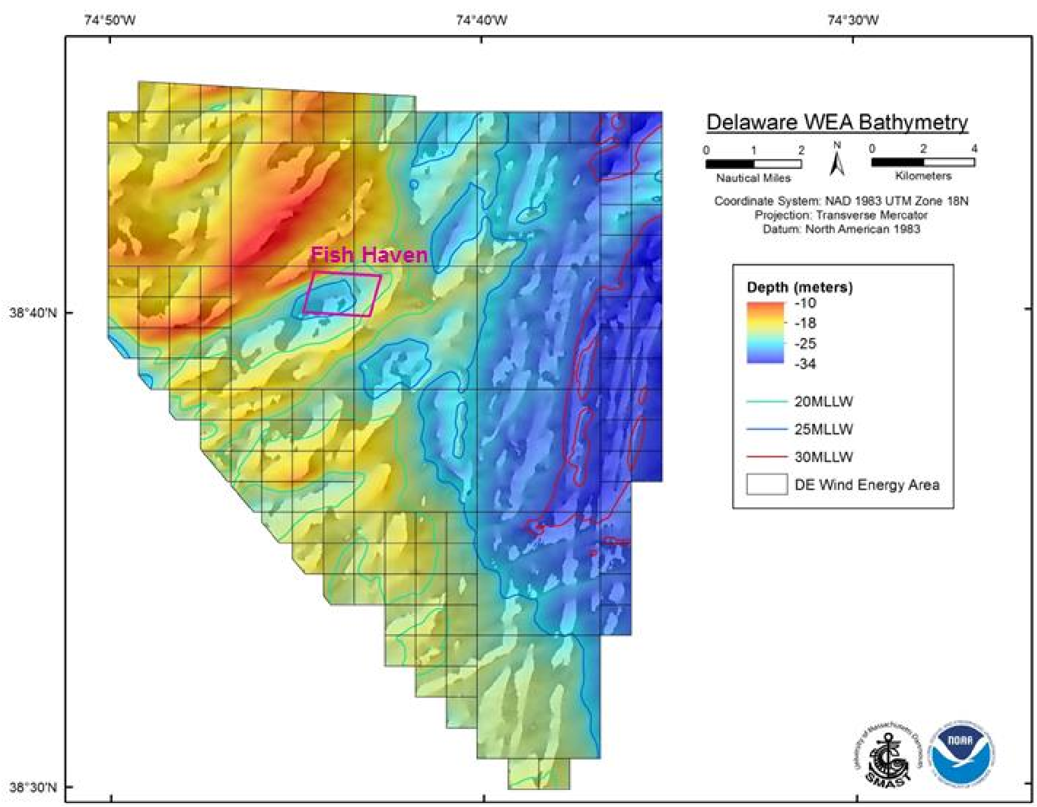


Figure 7-3. Bathymetry (38 m horizontal resolution) with isobath contours in the DE WEA. Source data: (BOEM 2017, NOAA NCEI 2017).

7.2.2 Terrain Variables

Regarding terrain metrics, slope, rugosity, and aspect (Figure 7-4) all show subtle but clear patterns related to the ridges and depression patterns mentioned in section 7.2.1. Slopes approach or exceed one degree on ridge sides in the northwest, but are generally smaller elsewhere. Rugosity, a measure of surface roughness, is generally very low except in patches, particularly corresponding to the largest slopes. Aspect also outlines the pattern of ridges.

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 7-3) and terrain metrics (Figure 7-4). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope, standard deviation break = 2.0, and depth (Figure 7-5). Again, the patterns of ridges and depressions are evident.

7.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the DE WEA is shown in Figure 7-6. Figures 7-7, 7-8, and 7-9 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 7-6 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 7-10. While this representation only represents mean grain size without assessing the range of sediment sizes present, it does give a good idea of the character of sediments where the variation in grain size is not extreme.

SMAST image-based sediment observations, which were not incorporated into the analyses displayed in Figures 7-7 through 7-10, are displayed in Figure 7-11. Sand ripples were seen at all sites, dominating most observations. Silt was noted at three sites, and gravel at three. Only one of the gravel observations corresponded with gravel detected in grain size samples along the eastern margin of the WEA. No cobbles or rocks were detected.

The prominence of sand ridges and the occurrence of sand ripples in all locations, and the general paucity of silt or mud, all point to this entire WEA being an area of strong bottom currents and sediment mobility. This agrees well with the USGS mobility prediction for this area (Figure 1-5). Indeed, the NE-SW orientation of the western sand ridges strongly suggests the influence of tidal currents from the nearby mouth of Delaware Bay, which run NW-SE: normal to the axes of the ridges, as one would expect.

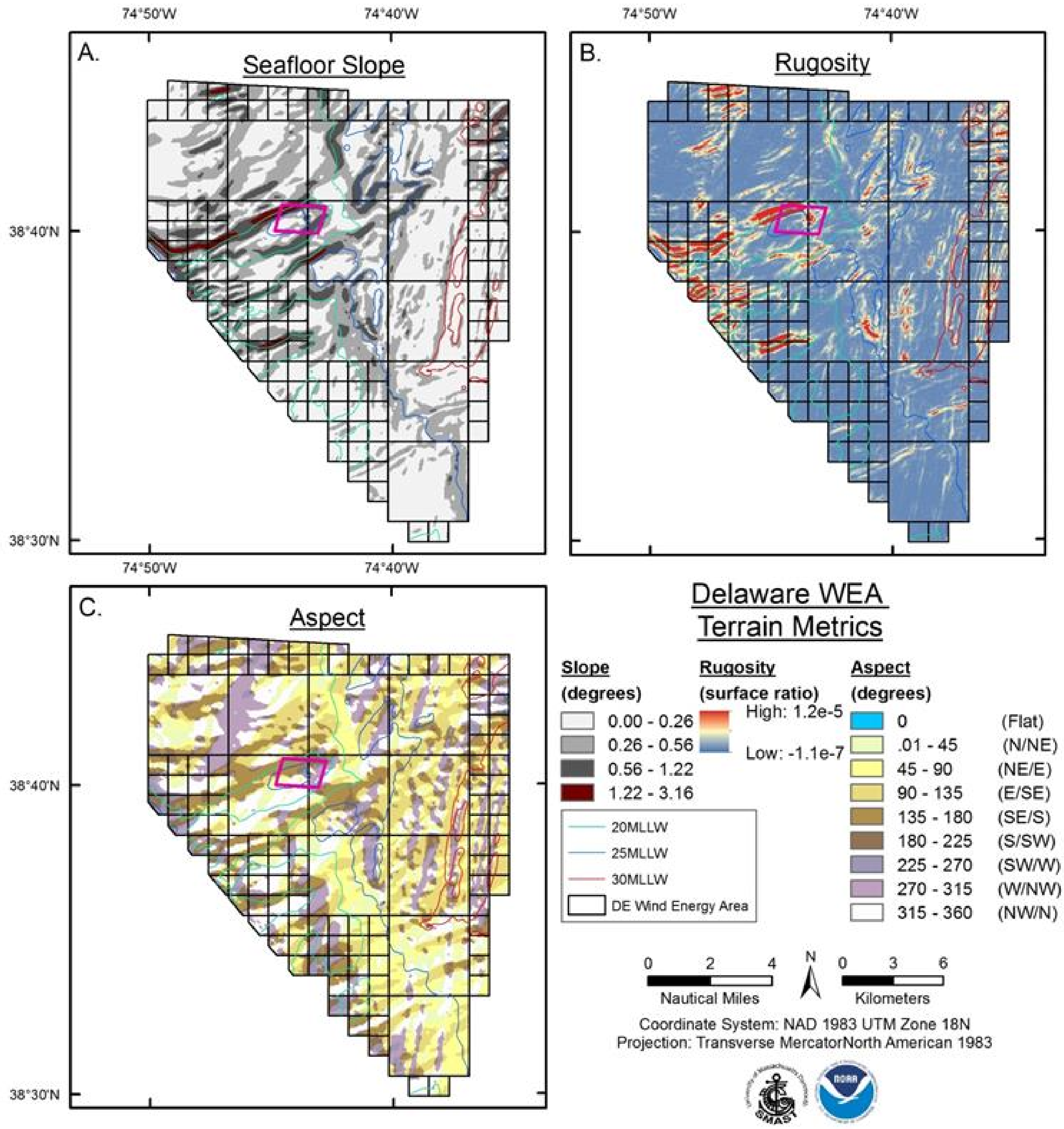


Figure 7-4. Terrain metrics derived from bathymetry for VA WEA (Figure 7-3). A. Seafloor slope, B. Rugosity, C. Aspect. The DNR Site 11 (Redbird Reef) Fish Haven is outlined in magenta.

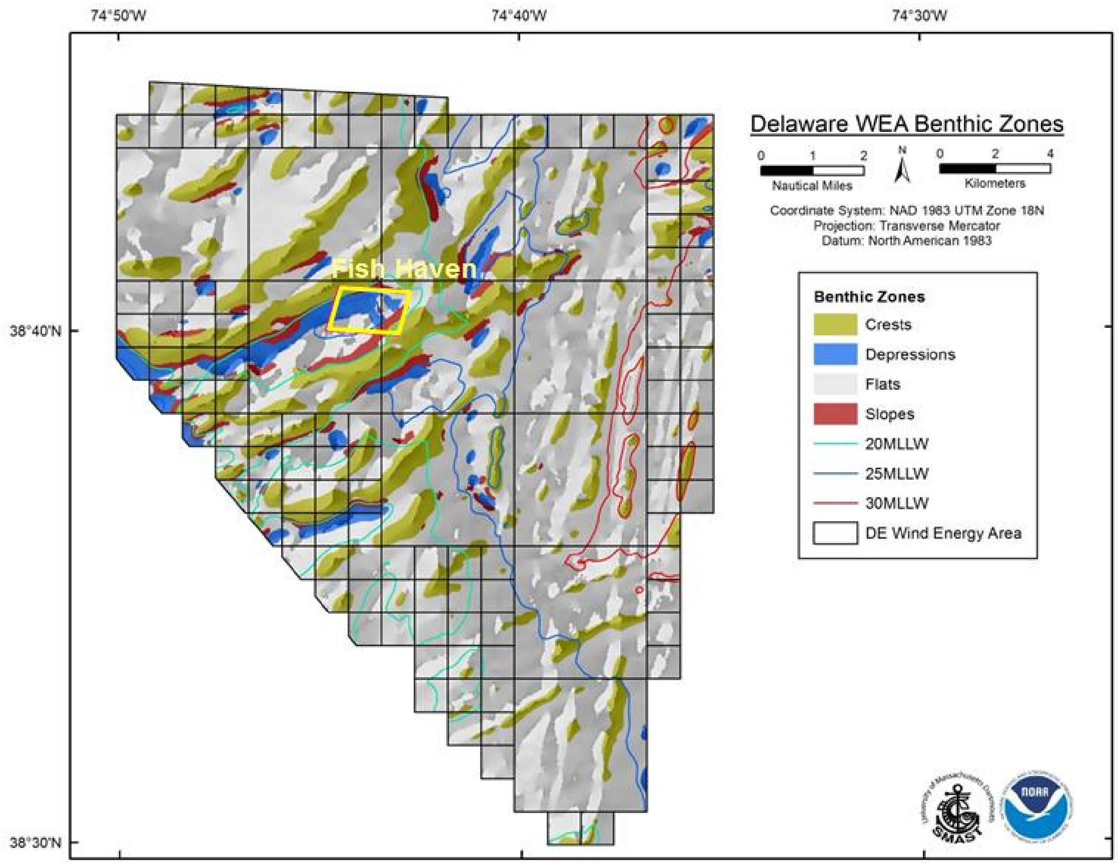


Figure 7-5. Benthic zones derived from bathymetry and derived slope data in the DE WEA.

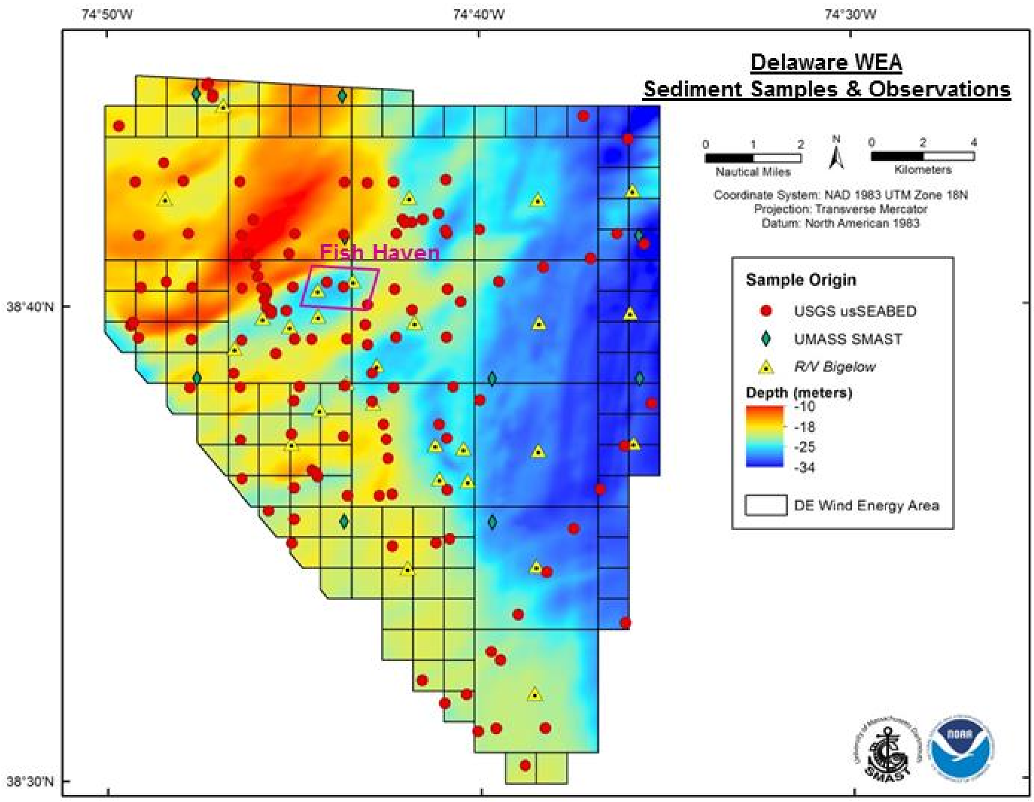


Figure 7-6. Location and source of benthic sediment samples and observations in the DE WEA. Samples include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles), cores taken from grab sampler aboard the NEFSC Habitat Characterization cruise HB15-05 (yellow triangles), and SMAST observations from camera pyramid imagery (green diamonds). Data sources - bathymetry as in Figure 7-3, sediment data: Reid et al. 2005, SMAST

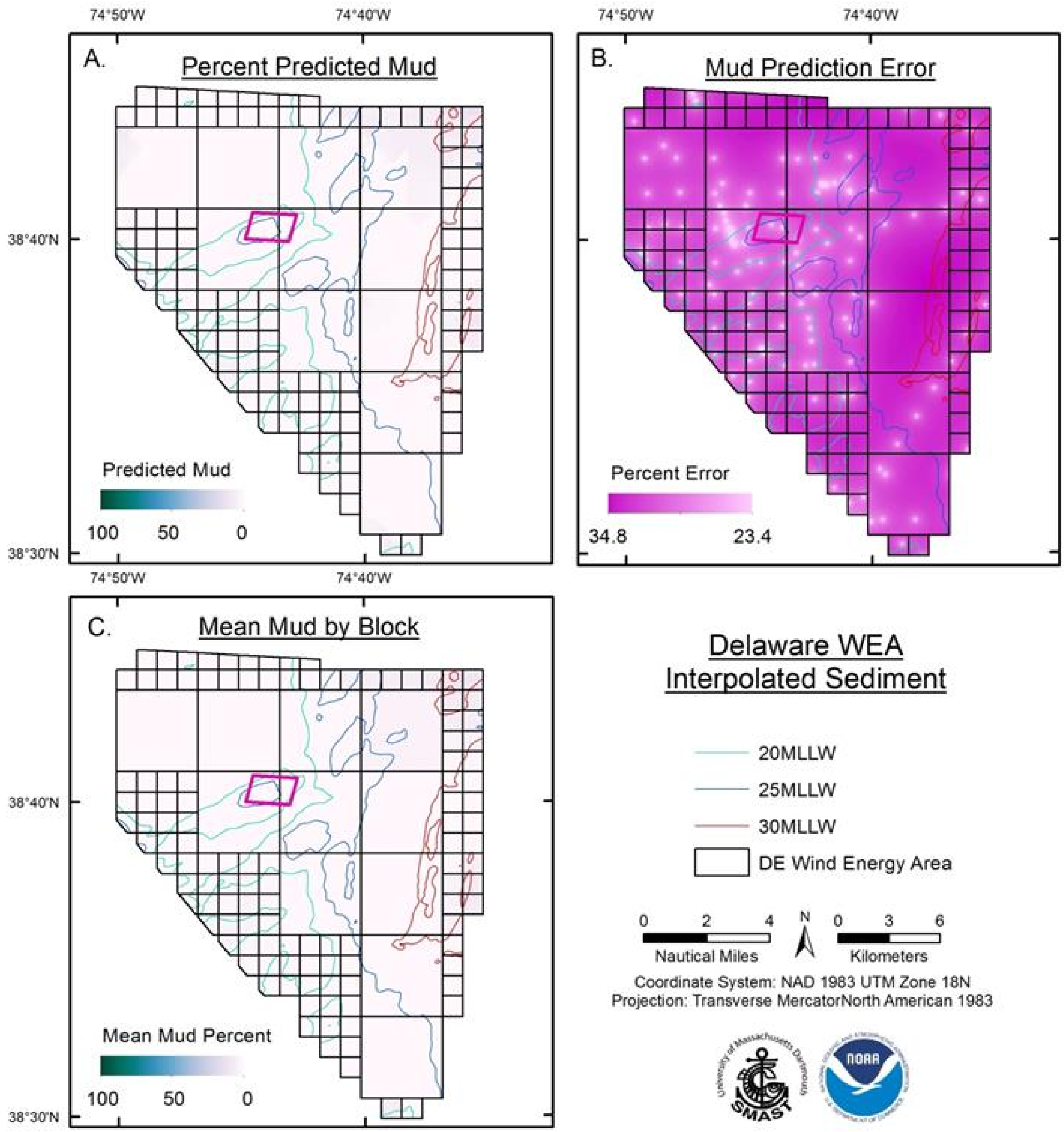


Figure 7-7. Predicted mud (silt + clay) distribution of surficial sediments in DE WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. The Fish Haven is outlined in magenta. Source data as in Figure 7-6.

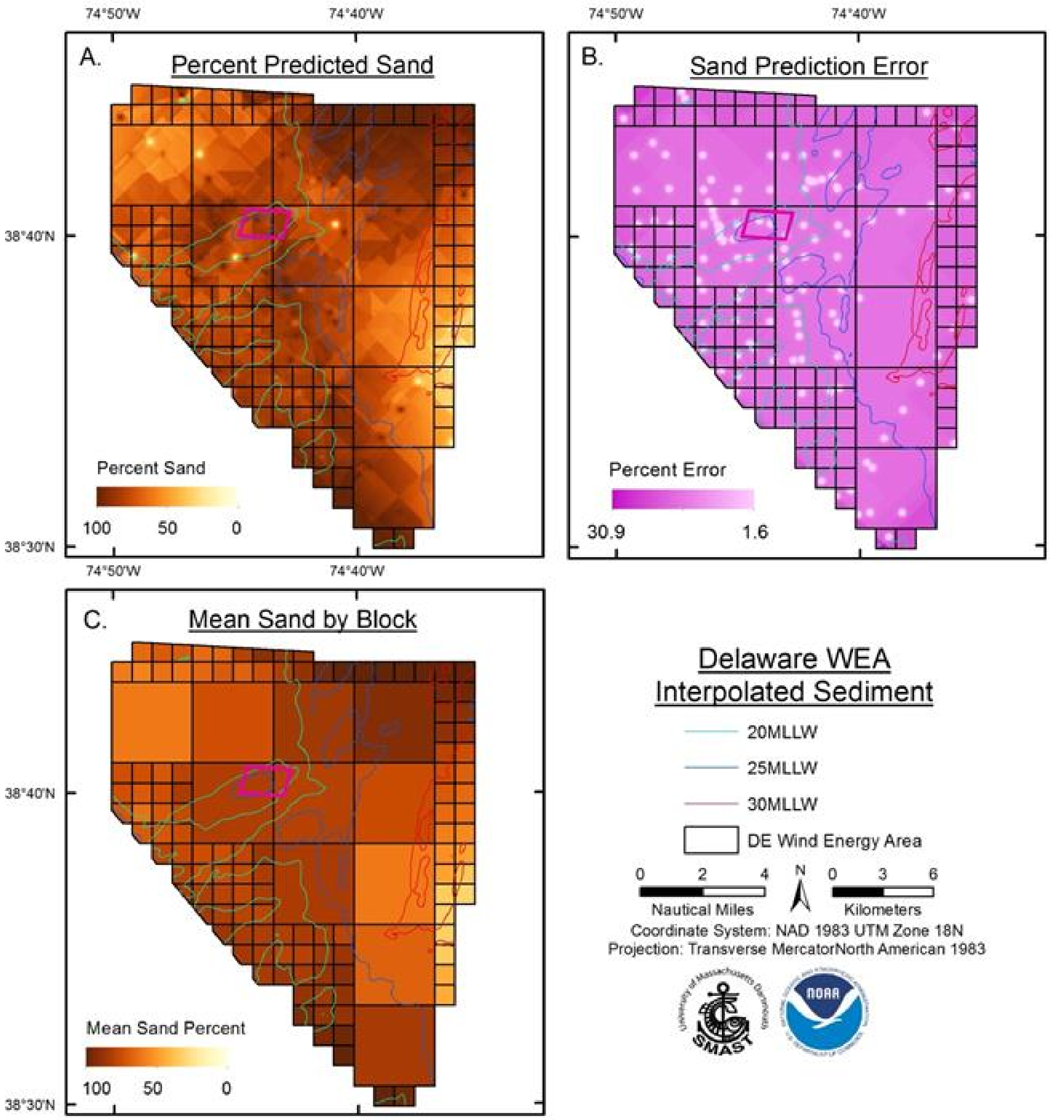


Figure 7-8. Predicted sand distribution of surficial sediments in DE WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. The Fish Haven is outlined in magenta. Source data as in Figure 7-6.

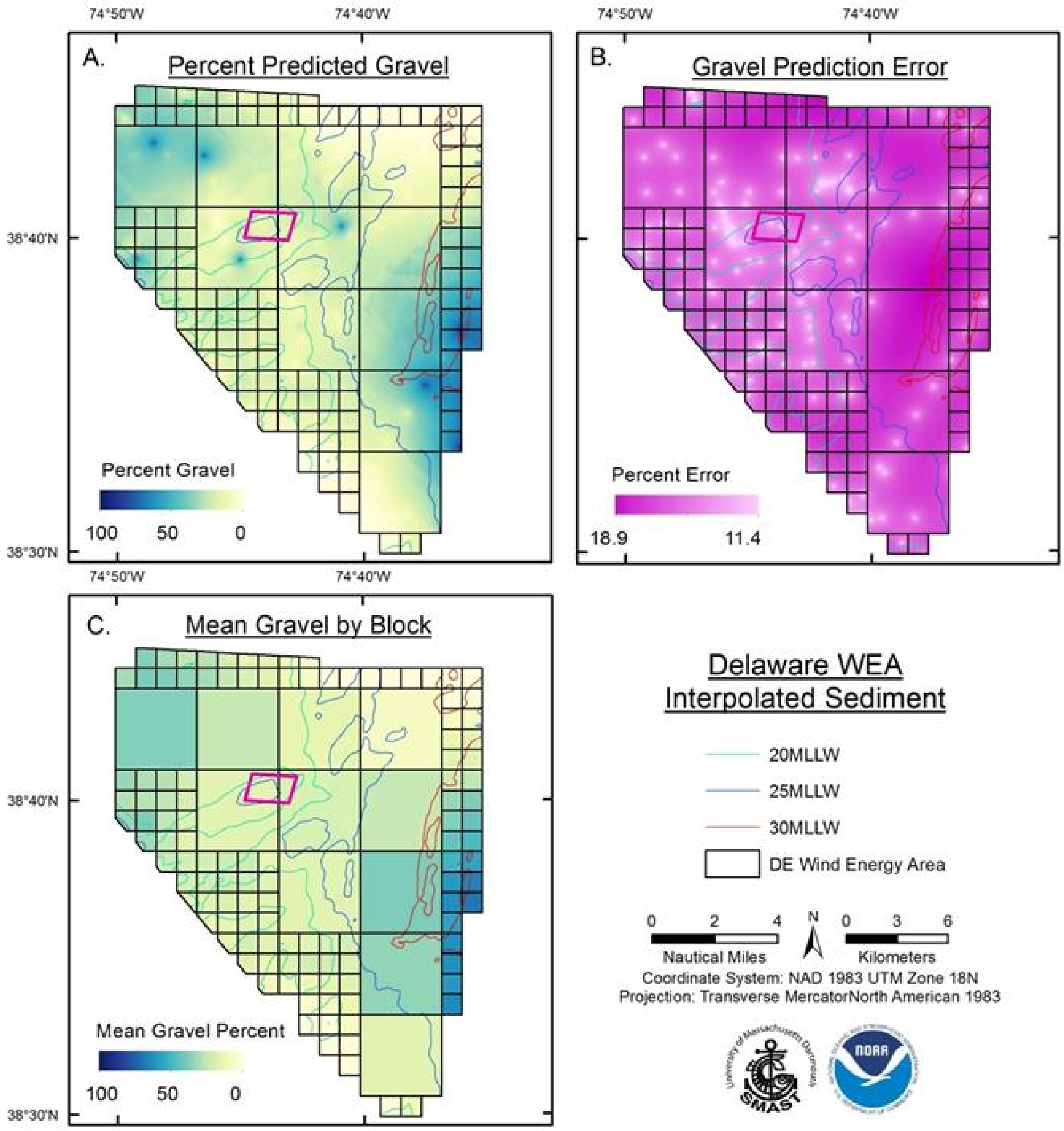


Figure 7-9. Predicted gravel distribution of surficial sediments in DE WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. The Fish Haven is outlined in magenta. Source data as in Figure 7-6.

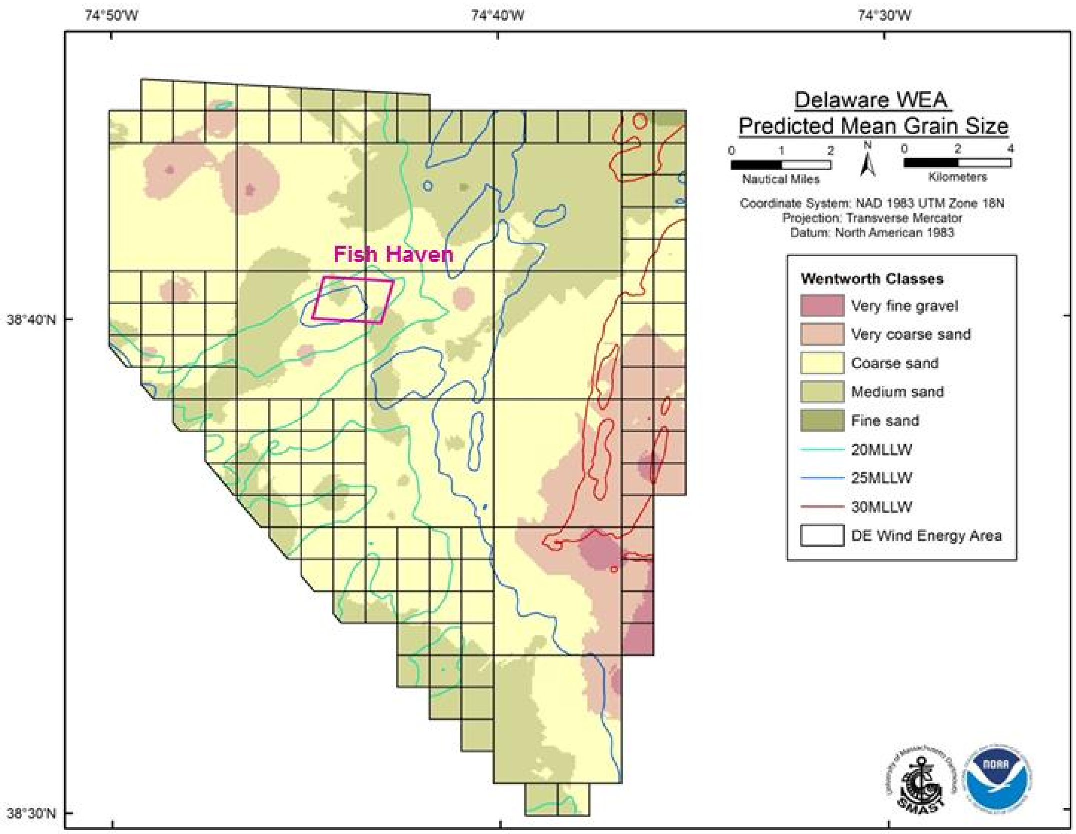


Figure 7-10. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the DE WEA physical samples. Values represent interpolated average grain size distribution. Source data as in Figure 7-6.

7.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 7-12.

Median salinity measured in the DE WEA for this period, including all depths, was 32.082 g/kg, with a full range spanning 29.499 to 33.435 g/kg (n=965), despite strong seasonal changes in other parameters. This range is entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 2.58 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

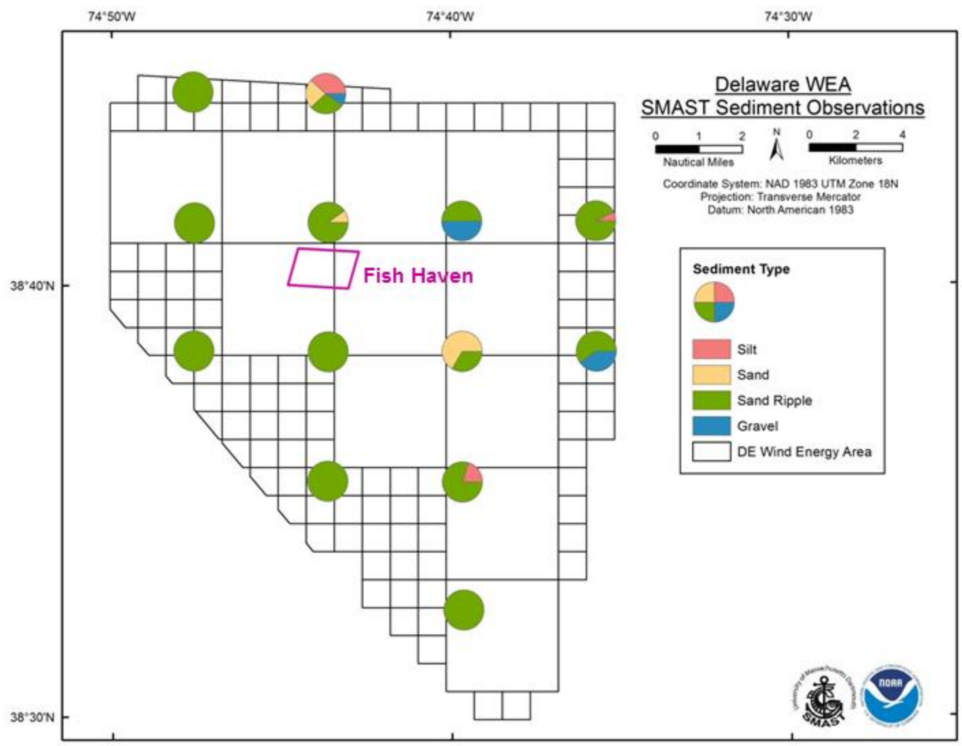


Figure 7-11. SMAST surficial sediments (presence-absence) observations. Observations proportions in pie charts were compiled to show the ratio of sediment observations from multiple images taken at each station. Source data: UMASS SMAST.

On the other hand, water temperatures showed large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water column structure. Figure 7-13 presents surface and bottom temperatures from CTD casts shown in Figure 7-12 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 20°C at the surface and 15°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 15°C. Then vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperatures of up to 12°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton. The DE WEA has no persistent frontal systems impinging upon it (Figure 1-4).

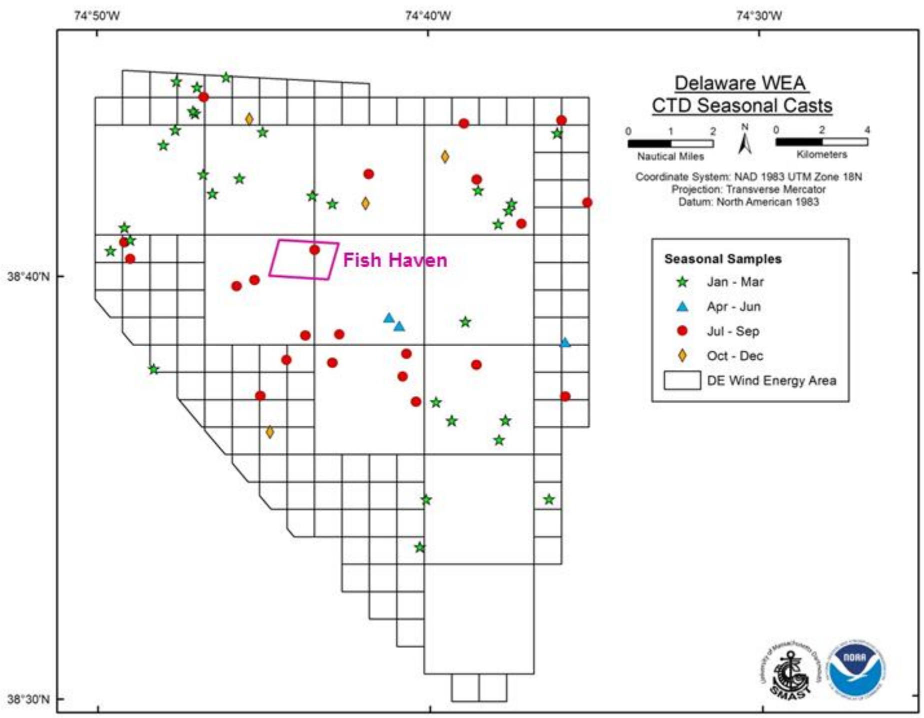


Figure 7-12. Locations for NEFSC CTD casts made between 2003 and 2016 in the DE WEA.

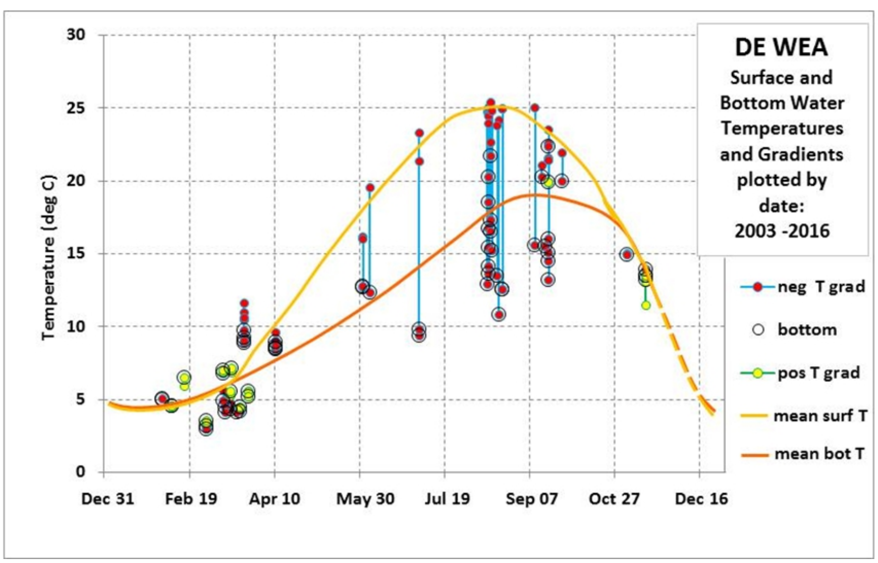


Figure 7-13. Water temperatures from CTD casts made between 2003 and 2016 in the DE WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values. No data was available for mid-November through mid-January, so the shapes of trend lines for that period (dashed) are conjectural.

7.2.5 Biological Variables

7.2.5.1 Benthic Epifauna and Infauna

Benthic samples were collected during one NEFSC–sponsored cruise (HB15-05: August 2015) in the DE WEA, including 30 beam trawls for benthic epifauna and 28 triplicate Van Veen grabs for benthic infauna (Figure 7-14).

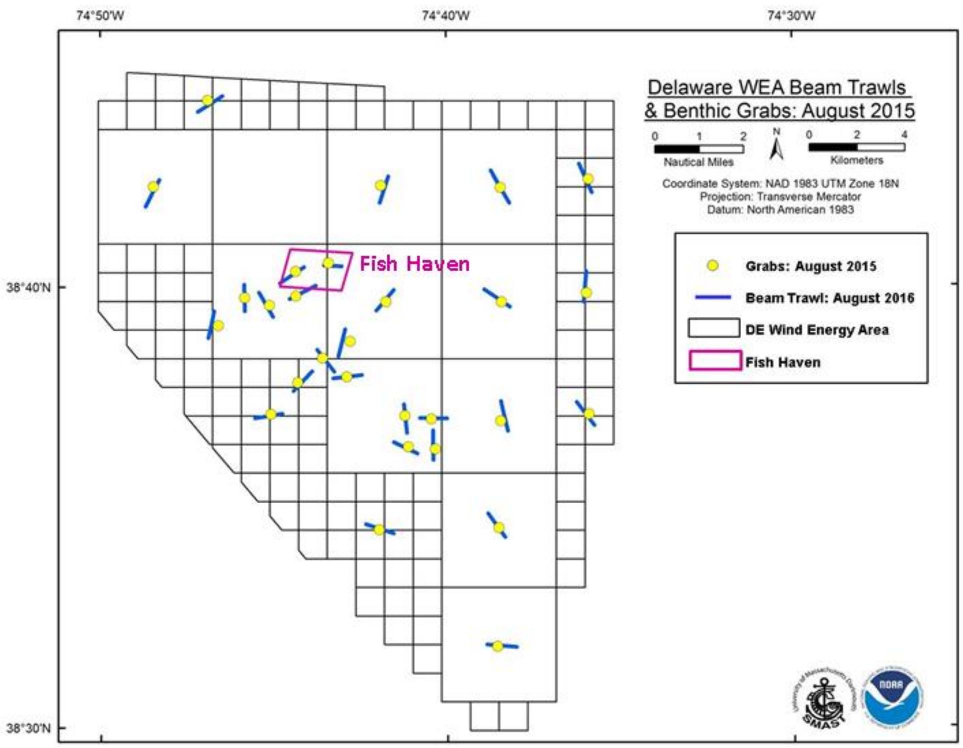


Figure 7-14. Locations of beam trawl and benthic grab samples made in the DE WEA.

NEFSC beam trawl catches and the contents (61 taxa) of the benthic grab samples (53 taxa) are summarized in Figure 7-15. Among the epibenthic fauna as obtained in beam trawls, there were no dominants as defined in section 1.3.4 (Figure 7-16A), but blue mussels were present in by far the largest numbers (68% of all catches) and largest biomass (60% of total weight). However, nearly 99.9% of all the mussel numbers and 99.7% of their biomass were taken in the single station closest to the northwestern corner of the WEA. Other epibenthic taxa were typical of sandy bottoms. The benthic infauna (53 taxa) was dominated by polychaetes, but few were core species, i.e. few occurred at 80% or more of grab sample stations. Over 60% of taxa were non-core, i.e. not occurring in 80% of the samples, suggesting a lot of variation (or diversity) among that fauna here, unlike the situation in some other WEAs.

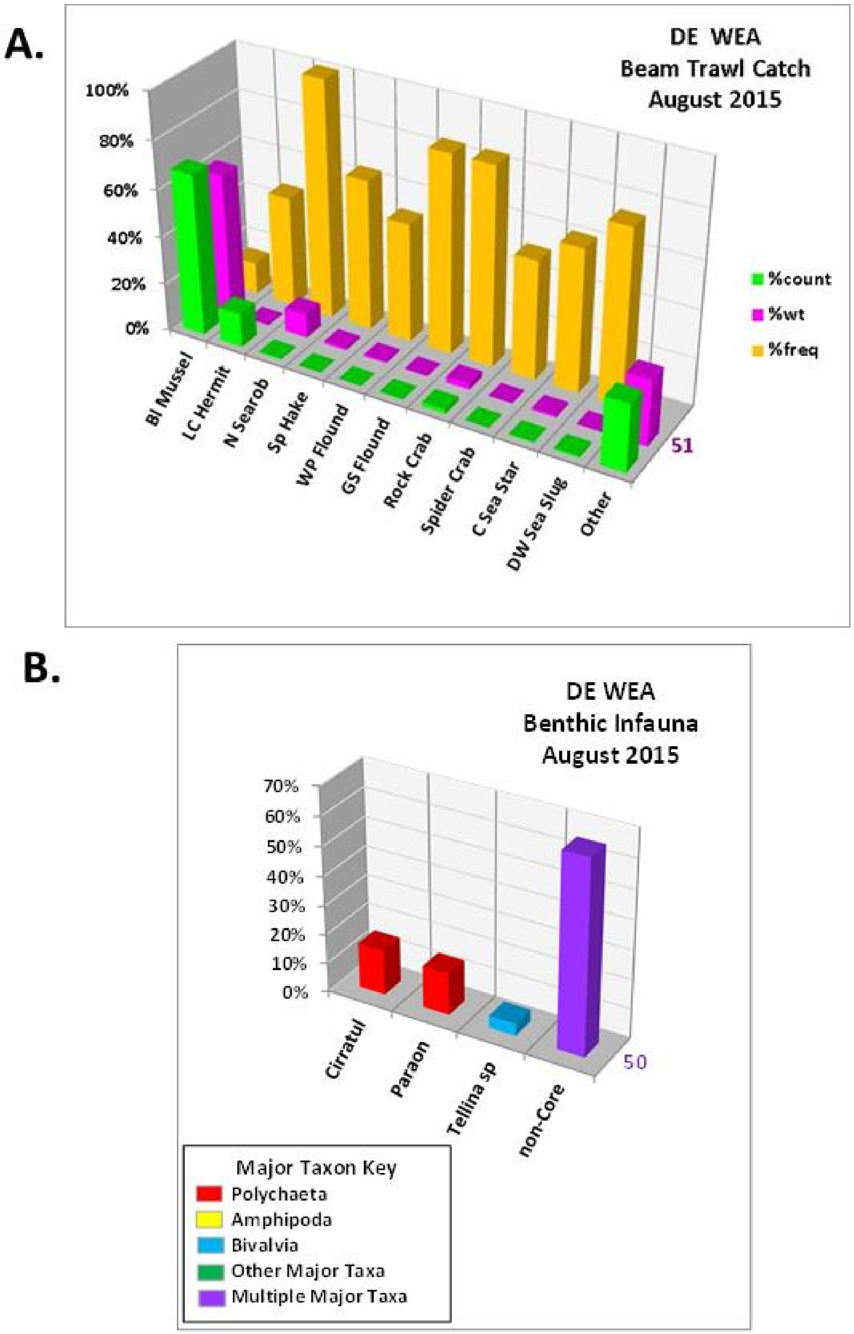


Figure 7-15. Benthic fauna caught in DE WEA by NEFSC sampling . A. Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA; B. Grab sample catch by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated common names for taxa in A: Bl Mussel – blue mussel, LC Hermit – longclaw hermit crab, N Searob – northern searobin, Sp Hake – spotted hake, WP Flound – windowpane flounder, GS Flound – Gulf Stream flounder, Rock Crab – Atlantic rock crab, C Sea Star – common sea star, DW Sea Slug – dwarf warty sea slug. Abbreviated taxonomic names in B: Cirratul – Cirratulidae, Spionid – Spionidae, Telllin sp – *Tellina* sp. Numbers to the right of the “other” and “non-core” taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of “other” and “non-core” species.

7.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 7-16. Importance values among taxa captured in NEFSC Seasonal Trawl Survey catches in the DE WEA are plotted in Figure 7-17 and Table 7-1, with seasonally dominant species listed in Table 7-2. NEFSC seasonal trawls were relatively few due to the small size of this WEA.

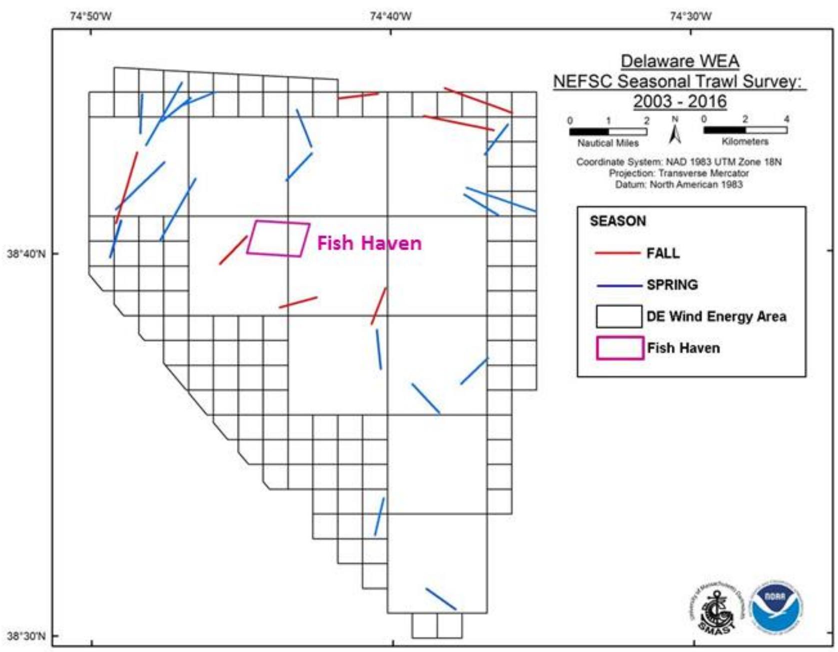


Figure 7-16. Locations of NEFSC seasonal trawls from 2003 to 2016 in the DE WEA.

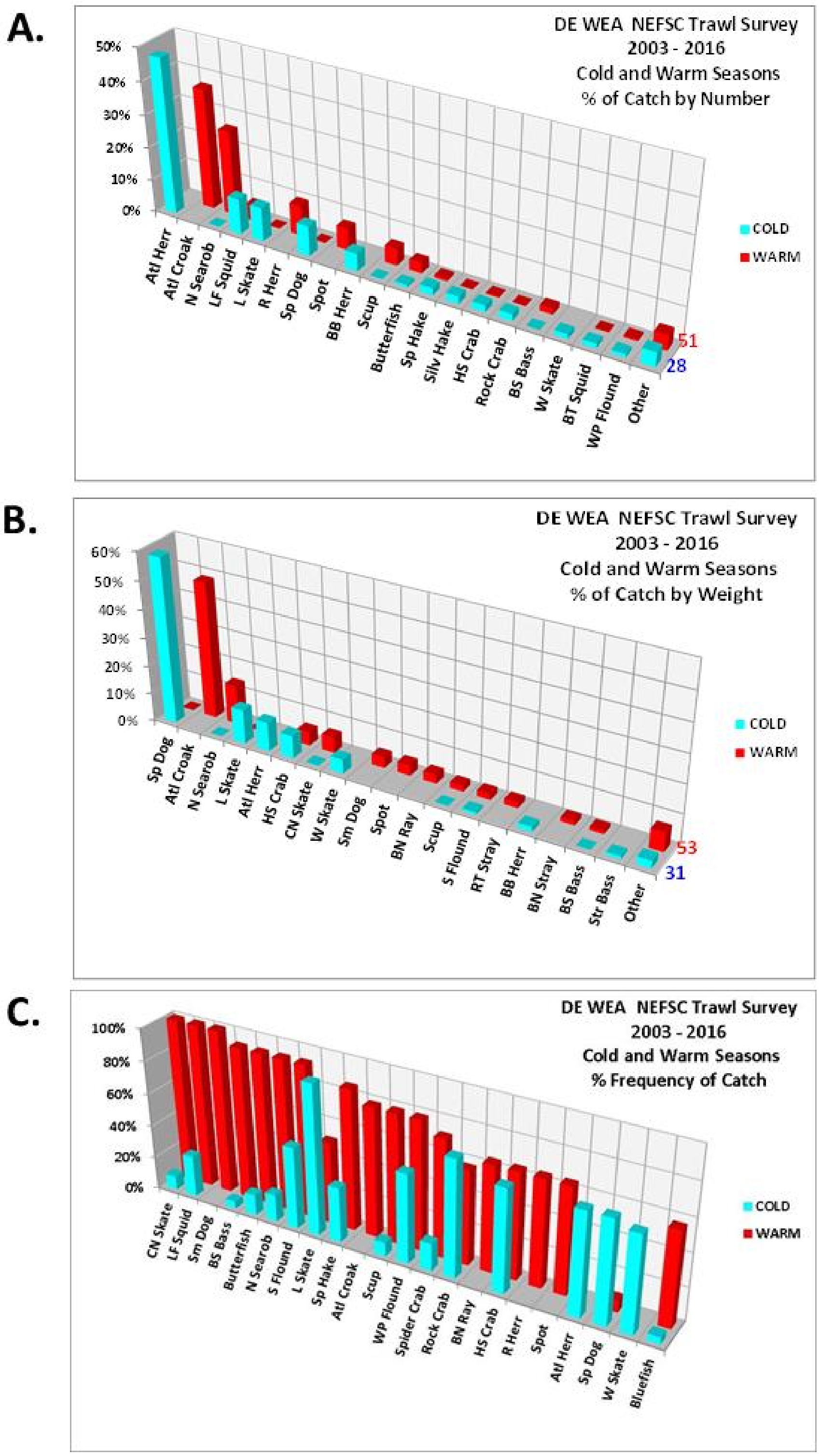


Figure 7-17. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 2-1. Blue and red numbers along the right margin of the graphs indicate the numbers of “other” species in cold and warm season catches respectively.

Table 7-1. Abbreviations for taxon names used in Fig. 7-16, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Atl Croak	Atlantic croaker[1]	N Searob	northern searobin
Atl Herr	Atlantic herring[2]	RT Stingray	roughtail stingray
Rock Crab	Atlantic rock crab	R Herr	round herring
BS Bass	black sea bass[2]	Scup	scup[3]
BB Herr	blueback herring[1]	Silv Hake	silver hake[2]
Bluefish	bluefish[3]	Sm Dog	smooth dogfish[5]
BN Stray	bluntnose stingray	Spider Crab	spider crab unclassified
BT Squid	bobtail squid unclassified	Sp Dog	spiny dogfish[4]
BN Ray	bullnose ray	Spot	spot[1]
Butterfish	butterfish[3]	Sp Hake	spotted hake
CN Skate	clearnose skate[2]	Str Bass	striped bass
HS Crab	horseshoe crab[1]	S Flound	summer flounder[3]
L Skate	little skate[2]	WP Flound	windowpane flounder[2]
LF Squid	longfin squid[3]	W Skate	winter skate[2]

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 7-2. Dominant species in NEFSC Seasonal Trawl Survey catches within the DE WEA between 2003 and 2016.

Delaware WEA Dominants	
Cold Season	Warm Season
Atlantic Herring	Atlantic Croaker
Horseshoe Crab	Black Sea Bass
Little Skate	Northern Sea Robin
Spiny Dogfish	Scup
Winter Skate	Spot

It is evident from this survey trawl data that this is a taxon-rich area: 67 taxa in the warm season and 44 in the cold season. It is also evident that while there is considerable overlap in the lists of taxa present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also considerable overlap among species present and dominance with other WEAs, especially NJ (section 6.2.5.2).

No taxa were dominants in both seasons. All of the dominants other than skates were seasonal migrants. It is also notable that 64% (18 out of 28) of the taxa in Table 7-1, and indeed all but one of the dominants (Table 7-2) are managed fishery species. Estuarine-associated taxa (horseshoe crab, Atlantic croaker, spot) were more prominent in this WEA than elsewhere, presumably due to the proximity of Delaware Bay.

7.2.5.3 Species of Concern

Records of shellfish species of concern in the DE WEA are illustrated in Figure 7-18. These include quantitative records of sea scallops from NEFSC seasonal trawl surveys and qualitative records from beam trawls, bottom grabs, and bottom imagery. Sea scallops were clearly in this WEA, largely in the deeper (>25 m) eastern part of the WEA. Current sea scallop EFH does not intersect with the DE WEA (Figure 1-7).

No ocean quahogs were found in the DE WEA, although ocean quahog EFH intersects the WEA broadly in the south (Figure 1-8). Surfclam EFH overlaps this WEA completely (Figure 1-9), and surfclams were widespread in benthic beam trawls (Figure 7-18).

No squid egg mops were encountered in the DE WEA. The WEA only barely intersects the longfin squid egg mop EFH in its northwesternmost extremity (Figure 1-10). Egg mops would likely have been present and would have been caught via beam trawl during the cruise in August, 2015 if they had been there.

As sea scallops and surfclams were widespread, these species might be worth considering in terms of potential for habitat disturbance in spite of no overlap with current sea scallop EFH.

No Atlantic cod were caught in the DE WEA between 2003 and 2016, although the western half of the WEA is within the adult cod EFH zone (Figure 1-11).

Both young-of-the-year (YOY) and sub-adult to adult-sized black sea bass (BSB) were detected in the northern half of the DE WEA only (Figure 7-19). In particular, juveniles were found associated with a blue mussel bed near the northwest corner of the WEA (Figure 7-19: red circle). Only a small part of the catch from the mussel bed station could be processed because of the overwhelming volume of blue mussels, but the presence of just a few YOY in the analyzed subsample suggested a large number in the sample as a whole (98% of all BSB beam trawl captures in the WEA). This is a species where there is a considerable potential for habitat disturbance.

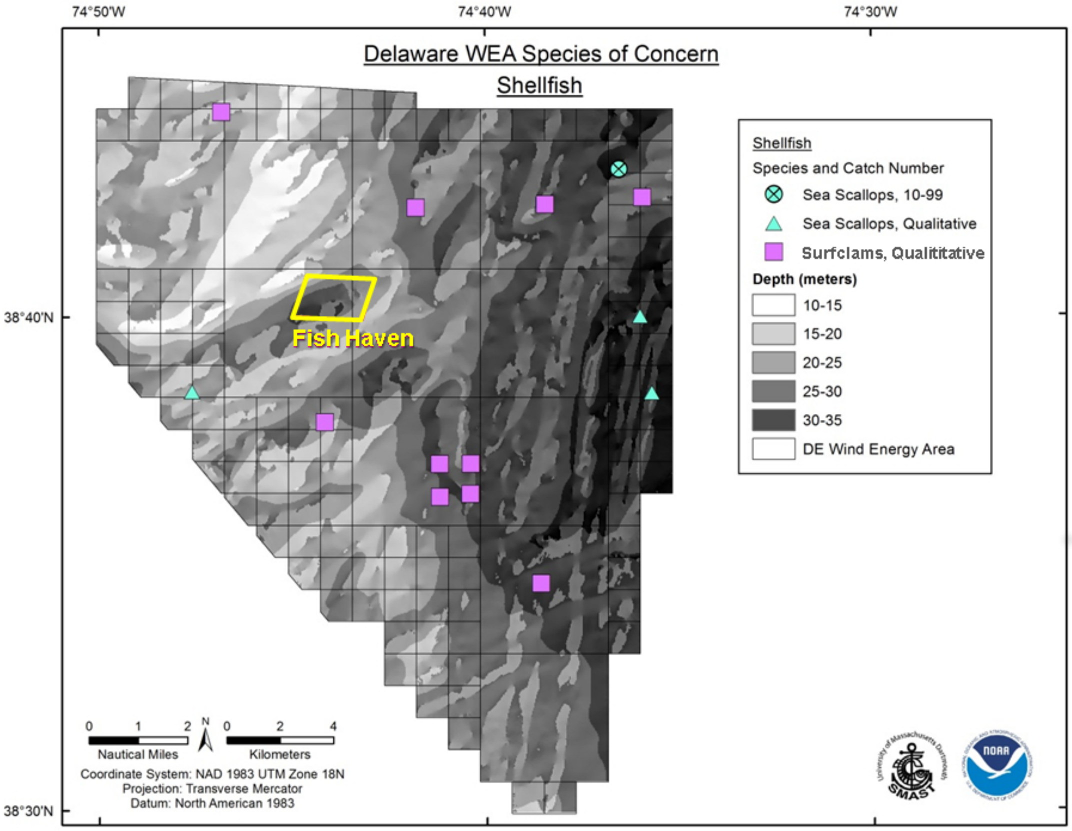


Figure 7-18. Shellfish species of concern records within and near the DE WEA.

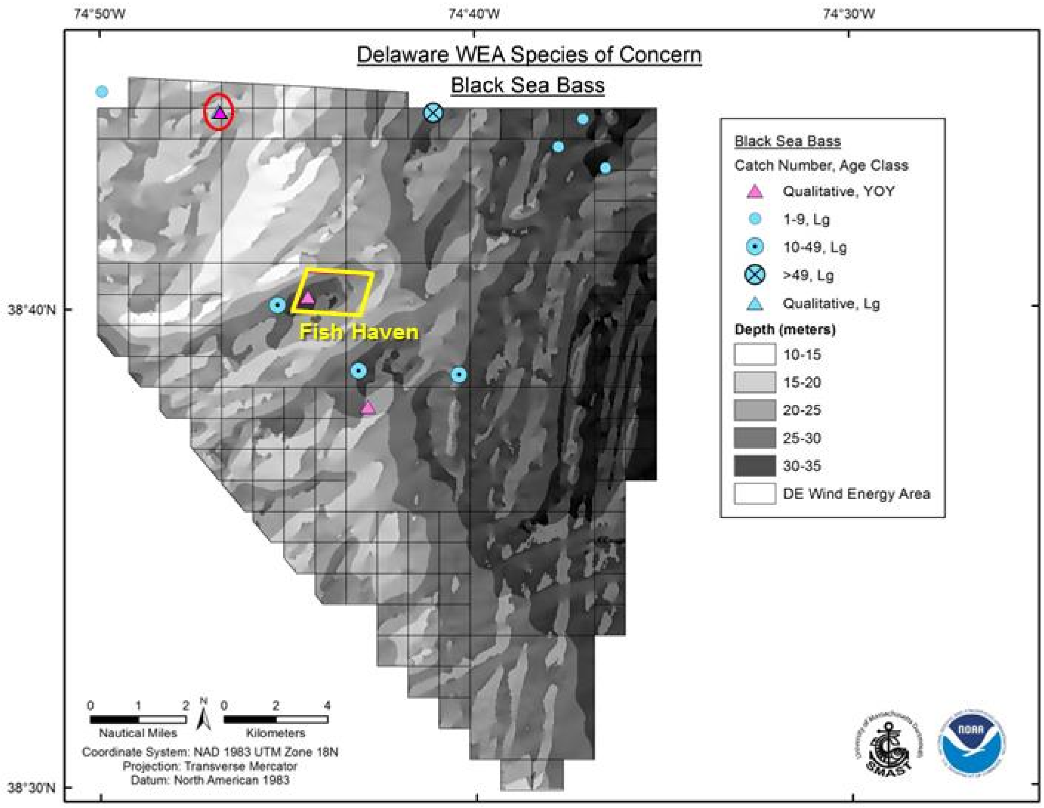


Figure 7-19. Records of young-of-the-year (YOY) and larger black sea bass in the DE WEA. The red circle marks the position of the mussel bed catch of YOY BSB that accounted for 98% of the BSB catch in this WEA.

There is one additional biological habitat issue that arose in the DE WEA and not elsewhere: structure-forming taxa. These are taxa that create structured habitats that encourage the presence of structure-seeking mobile species. Examples include hard and soft corals and beds of mussels. Two species of corals: northern star coral (*Astrangia poculata*), a hard coral, and sea whips (*Leptogorgia virgulata*), a soft coral, were encountered. Neither is reef-forming, but both enhance the value of hard substrate toward attracting other fauna where they occur. Aggregations of blue mussels (*Mytilus edulis*) that also attach themselves to hard substrates, can also enhance the structure. These structural species and the habitats they support (e.g. juvenile BSB habitat) are vulnerable to damage by anthropogenic activities.

Note that despite their presumed habitat-structuring value, neither the hard and soft corals nor their habitats found in the DE WEA have any formal legal protection. They are neither tropical reef-building corals, which fall under the Coral Reef Conservation Act of 2000, nor deep sea corals falling under the Magnuson-Stevens Act Amendment of 2006.

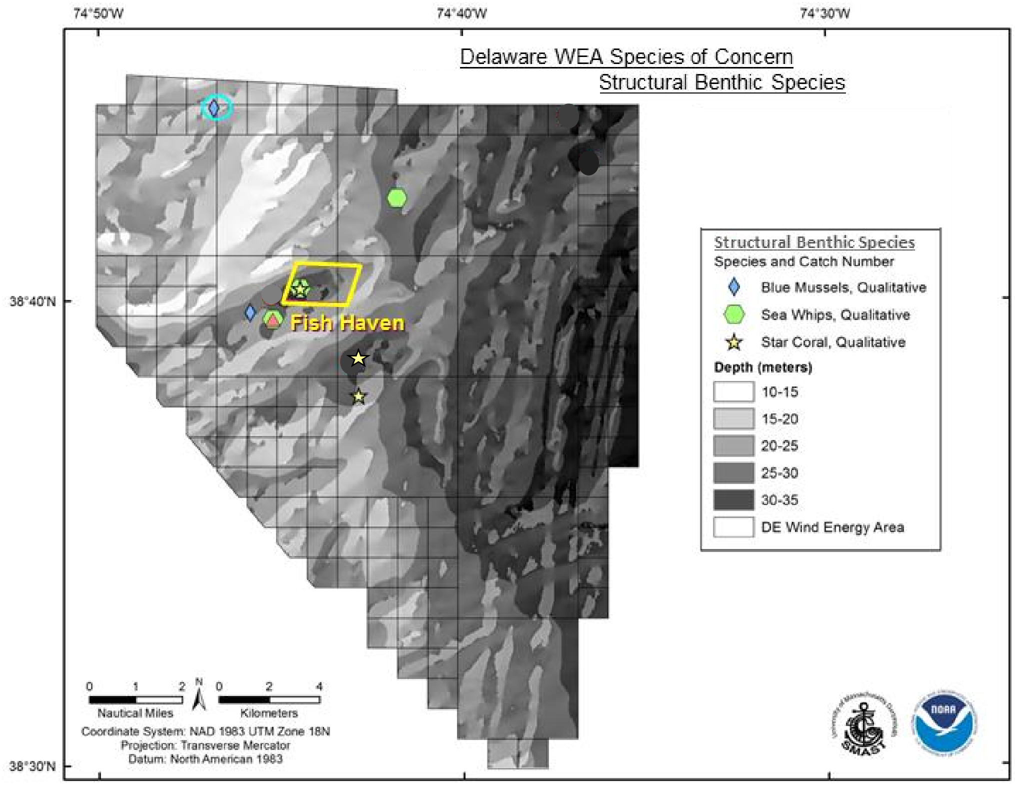


Figure 7-20. Records of structural species in the DE WEA. Cyan circle marks the blue mussel reef.

It is suspected that habitat structuring species may be more prevalent than is indicted here. In particular, strong tidal exchange in the area of the largest sand ridges in the northwest corner of the DE WEA probably favors development of blue mussel reefs and the various artificial reef materials in the Fish Haven area undoubtedly favor the establishment of corals and other sessile fauna that can serve as fish refuge habitat in addition to providing primary structure themselves. Among those users of structured habitats are black sea bass, themselves a species of concern by our definition.

7.3 DE WEA Habitat Definition

An integrated view of the physical benthic habitat features in the DE WEA is presented in Figure 7-21. There are three major topographic zones (Topo Zones 1, 2, 3) with habitat features (patch mollusk reef, gravel to gravelly patches, artificial reef, attached corals) superimposed upon their locations.

Topo Zone 1 consists of a series of megaripples oriented approximately NE-SW (Section 7.2.2, Figure 7-5). It occupies most of the western half of the WEA. The location, orientation, and size of these megaripples indicate that they result from strong tidal currents in and out of mouth of Delaware Bay to the northwest. Because of its exceptional size (covering ~62 km^2 and ~8 m high), we distinguished the largest of these megaripple crests as Topo Zone 3. It occupies most of lease block 6325 and some of the adjacent blocks. The deeper eastern half of the WEA, designated Topo Zone 2, is occupied by smaller, more closely-spaced megaripples with a N-S orientation, paralleling the Delaware coastline and probably generated by waves. The presence of rippled sediments in all SMAST stations (Figure 7-11) indicates the active reworking of surficial sediments by waves and tidal currents throughout the WEA.

Superimposed upon these Topo Zones are three habitat features. One is a patch mollusk (*Mytilus*) reef along the border between lease sub-blocks 6275N and 6275O near the northwest corner of the WEA. The reef appears to be an important habitat for YOY black sea bass; there may be others like it in the vicinity. The second habitat feature is the artificial reef complex previously described (Fish Haven: Section 7.1). This lies in a trough between two megaripple crests. Sampling in that trough, known on New Jersey's Recreational and Commercial Ocean Fishing Grounds (Long and Figley 1981) as the "Inside Mud Hole" yielded sensitive habitat-creating species, including soft corals (sea whips) and blue mussels (*Mytilus*) outside of the Fish Haven to the west. Further, the next inter-crest ripple to the south ("Middle Mud Hole") yielded equally vulnerable habitat-generating hard corals (star coral). A third depression further south ("Outer Mud Hole") yielded no such structural species. Despite their names, none of these "mud holes" yielded any muddy sediments. The full extent of coral communities in these depressions is not known, so the limits of Attached Corals areas in Figure 7-21 are based upon topography and depth of depressed areas in which they were found.

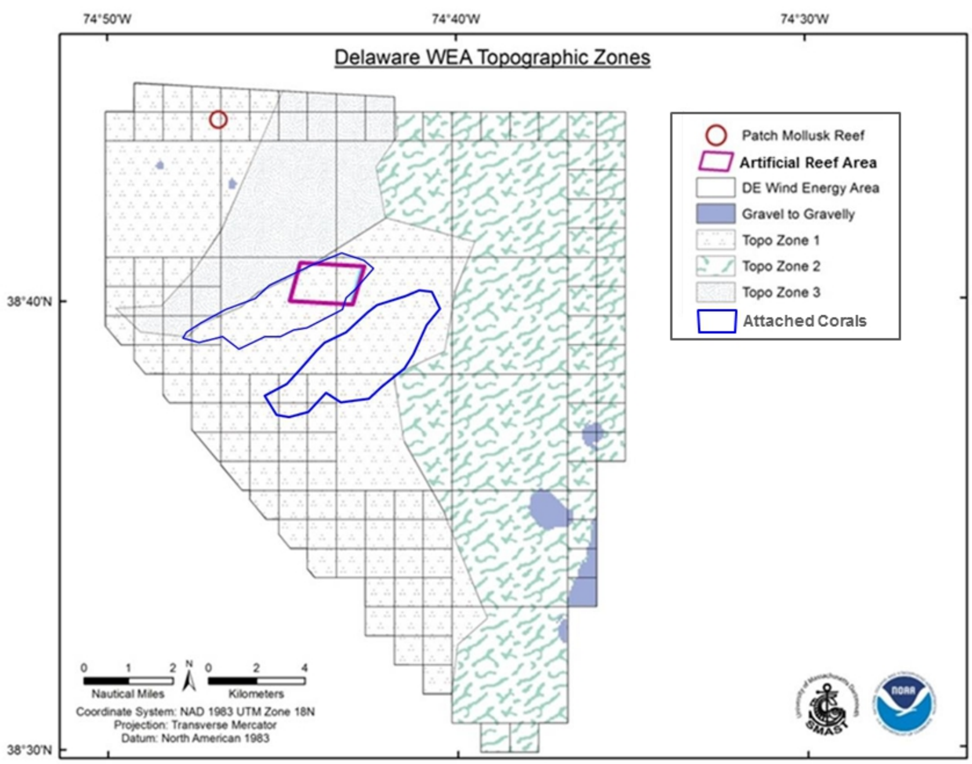


Figure 7-21. Physical benthic habitat features of the DE WEA. The Artificial Reef Area in this area is identical with the Fish Haven as plotted in other figures in this section.

7.3.1 CMECS Classifications:

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Megaripples, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate, Coarse Unconsolidated Substrate
        - Substrate Groups: Sandy Gravel, Gravelly Sand, Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Smaller Tube-Building Fauna

Topo Zone 2

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Megaripples, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate, Coarse Unconsolidated Substrate
        - Substrate Groups: Sandy Gravel, Gravelly Sand, Sand
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Smaller Tube-Building Fauna, Clam Bed (*Spisula*)

Topo Zone 3

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Ridge, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Sand
- Biotic Component: same as in Topo Zone 1

Patch Mollusk Reef

- Geoform Component
  - Geoform Origin: Biogenic
    - Geoform: Mollusk Reef
      - Geoform Type: Patch Mollusk Reef
- Substrate Component:
  - Substrate Origin: Biogenic Substrate
    - Substrate Class: Shell Substrate
      - Substrate Subclass: Shell Reef Substrate
        - Substrate Group: Mussel Reef Substrate
- Biotic Component:
  - Biotic Setting: Benthic/Attached Biota
    - Biotic Class: Reef Biota
      - Biotic Subclass: Mollusk Reef Biota
        - Biotic Group: Mussel Reef
          - Biotic Community: *Mytilus* Reef

Artificial Reef Area (Fish Haven)

- Geoform Component
  - Geoform Origin: Anthropogenic
    - Geoform: Artificial Reefs (multiple)
- Substrate Component
  - Substrate Origin: Anthropogenic Substrate
    - Substrate Class: multiple types
- Biogenic Component
  - Biotic Setting: Benthic/Attached Biota
    - Biotic Class: Faunal Bed
      - Biotic Group: Attached fauna
        - Biotic Group: multiple types including Attached Corals

Attached Corals Areas

Geoform and Substrate Components: same as for Topo Zone 1

Biotic Component

- Biotic Class: Faunal Bed
  - Biotic Subclass: Soft Sediment Fauna
    - Biotic Groups: Small Surface-Burrowing Fauna, Smaller Tube-Building Fauna, Attached Corals
      - Biotic Community:
        - Attached, Non-Reef Building Hard Corals, Attached Soft Corals

8 Virginia Wind Energy Area (VA WEA).

8.1 Location, size, and subdivision

The Virginia WEA lies on the Southern Mid Atlantic Bight shelf in a band between approximately 22 and 35 nautical miles off the coast of Virginia, east of Virginia Beach (Figure 8-1). It lies about 24 nautical miles east southeast of the mouth of Chesapeake Bay and consists of 19 full lease blocks plus 13 sub-blocks (Figure 8-2). Water depths in the VA WEA range from 18 to 41 m, with an average of approximately 30 m, and it covers approximately 112,799 acres of seafloor (BOEM 2014b). This section provides data and analysis for the entire WEA as a single unit.

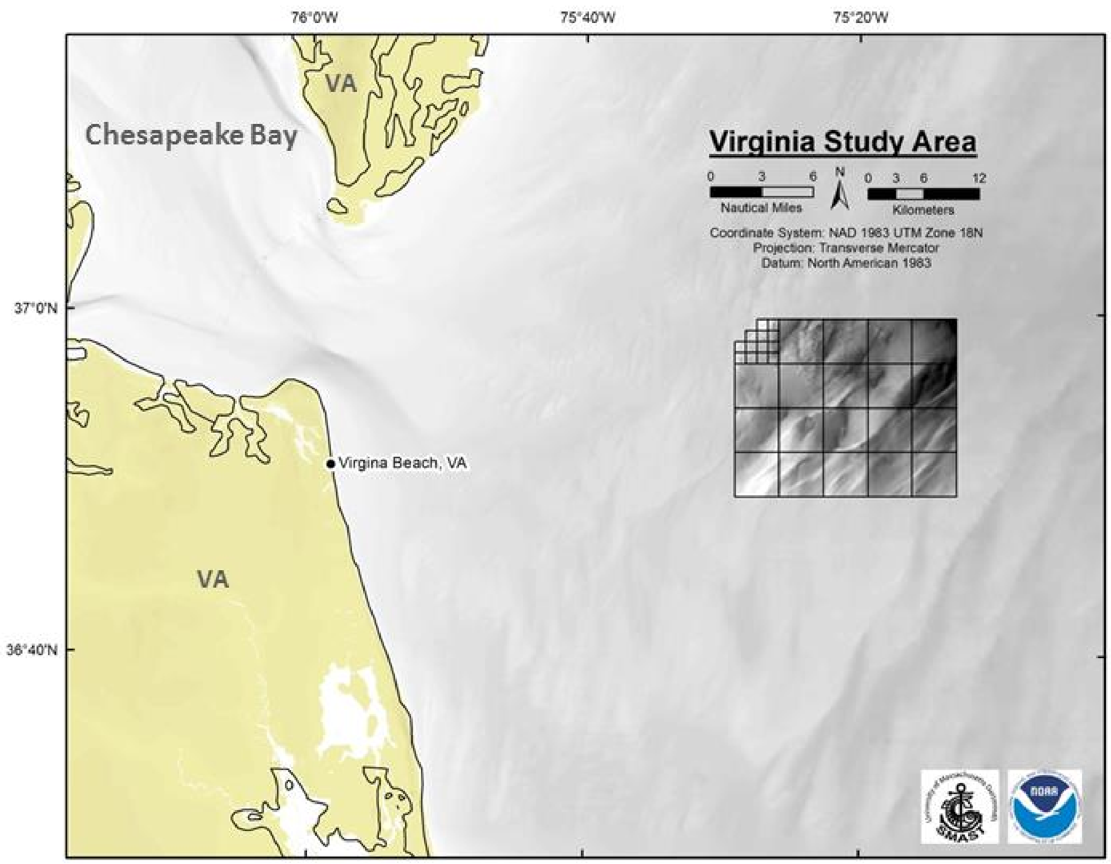


Figure 8-1. Map of Virginia study area. Source data:(BOEM 2017, NOAA NCEI 2017).

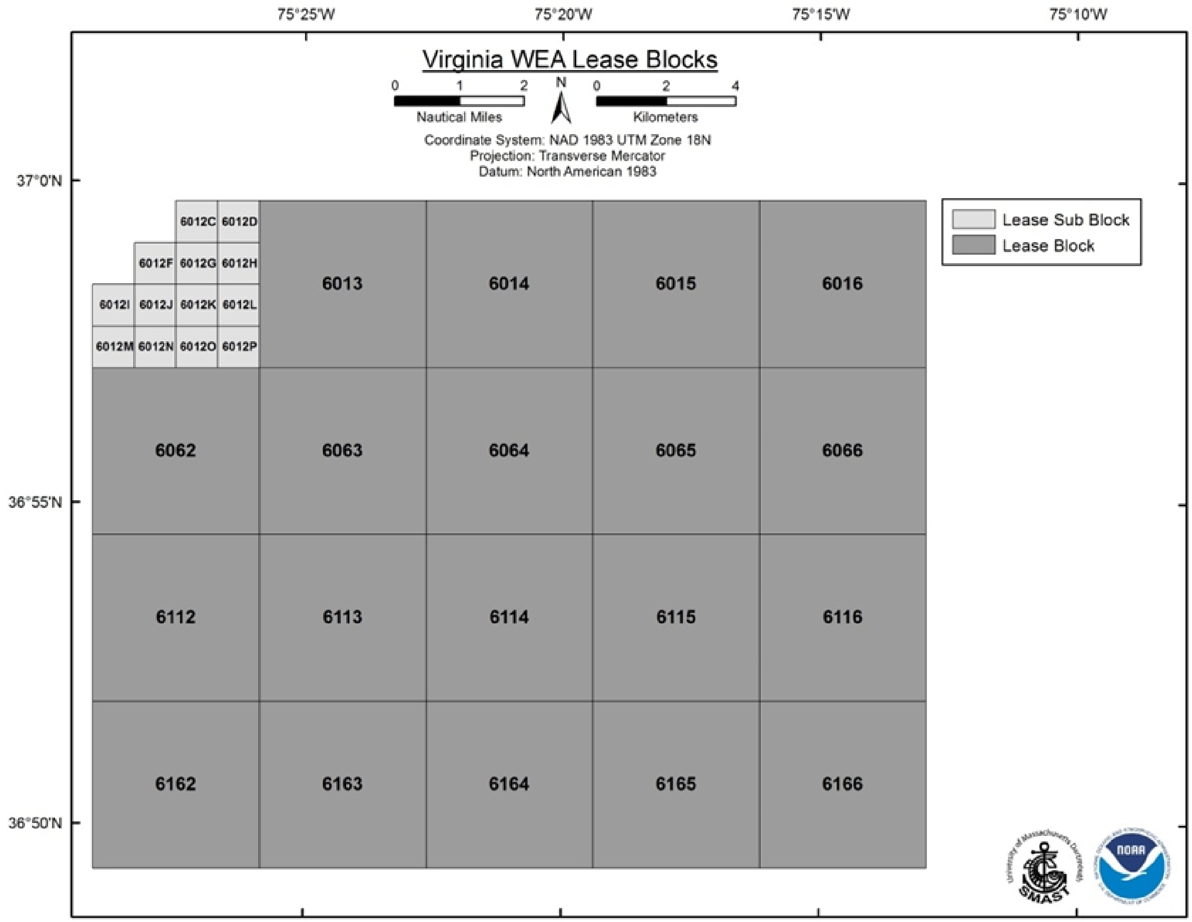


Figure 8-2. Numbered lease blocks and sub-blocks included in the VA WEA (source data BOEM 2017).

8.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

8.2.1 Bathymetry

Figure 8-3 shows the VA WEA bathymetry. Depths increase along a roughly southwest to northeast gradient, with the shallowest areas in the northwestern and southwestern corners and deepest in the northeast corner. Bottom topography is characterized by a series of southwest to northeast trending sand ridges with irregular frequencies ranging 0.5 to 5 km crest-to-crest.

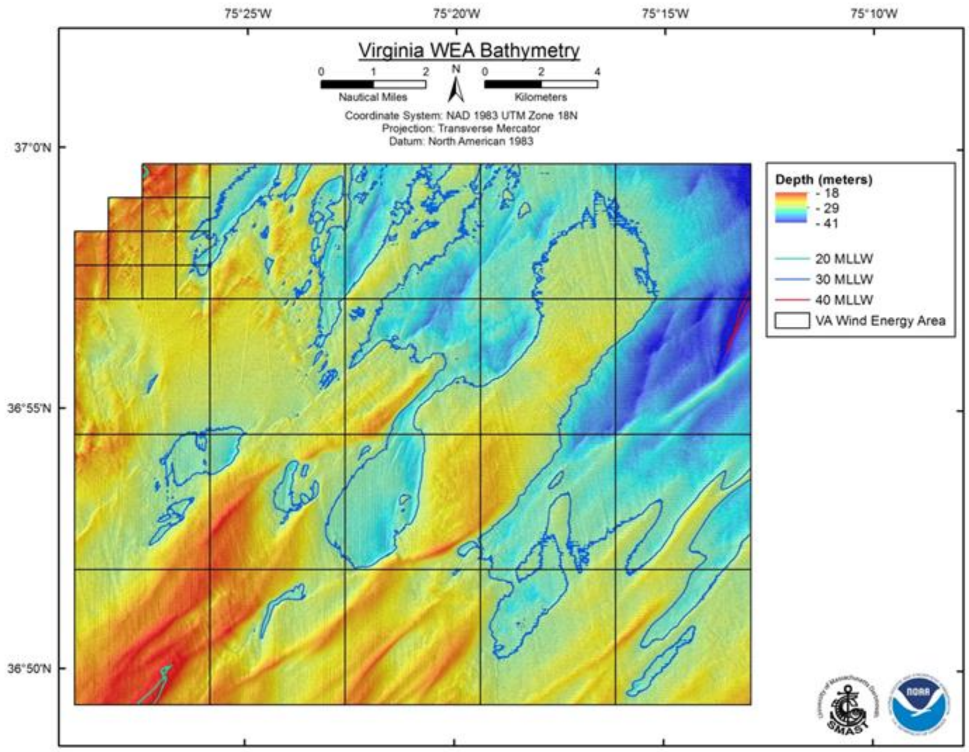


Figure 8-3. Bathymetry (2 m horizontal resolution) with isobaths contours in the VA WEA. Source data: (BOEM 2017).

8.2.2 Terrain Variables

Regarding terrain metrics, slope, rugosity, and aspect (Figure 8-4) all show subtle but clear patterns related to the ridges and depression patterns mentioned in section 8.2.1. Slopes are generally low, exceeding 1.2 degrees only on some ridge sides. Rugosity, a measure of surface roughness, is virtually nonexistent everywhere. Aspect also outlines the pattern of ridges.

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 8-3) and terrain metrics (Figure 8-4). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope, standard deviation break = 2.0, and depth (Figure 8-5). Again, the pattern of ridges separated by flat areas is evident.

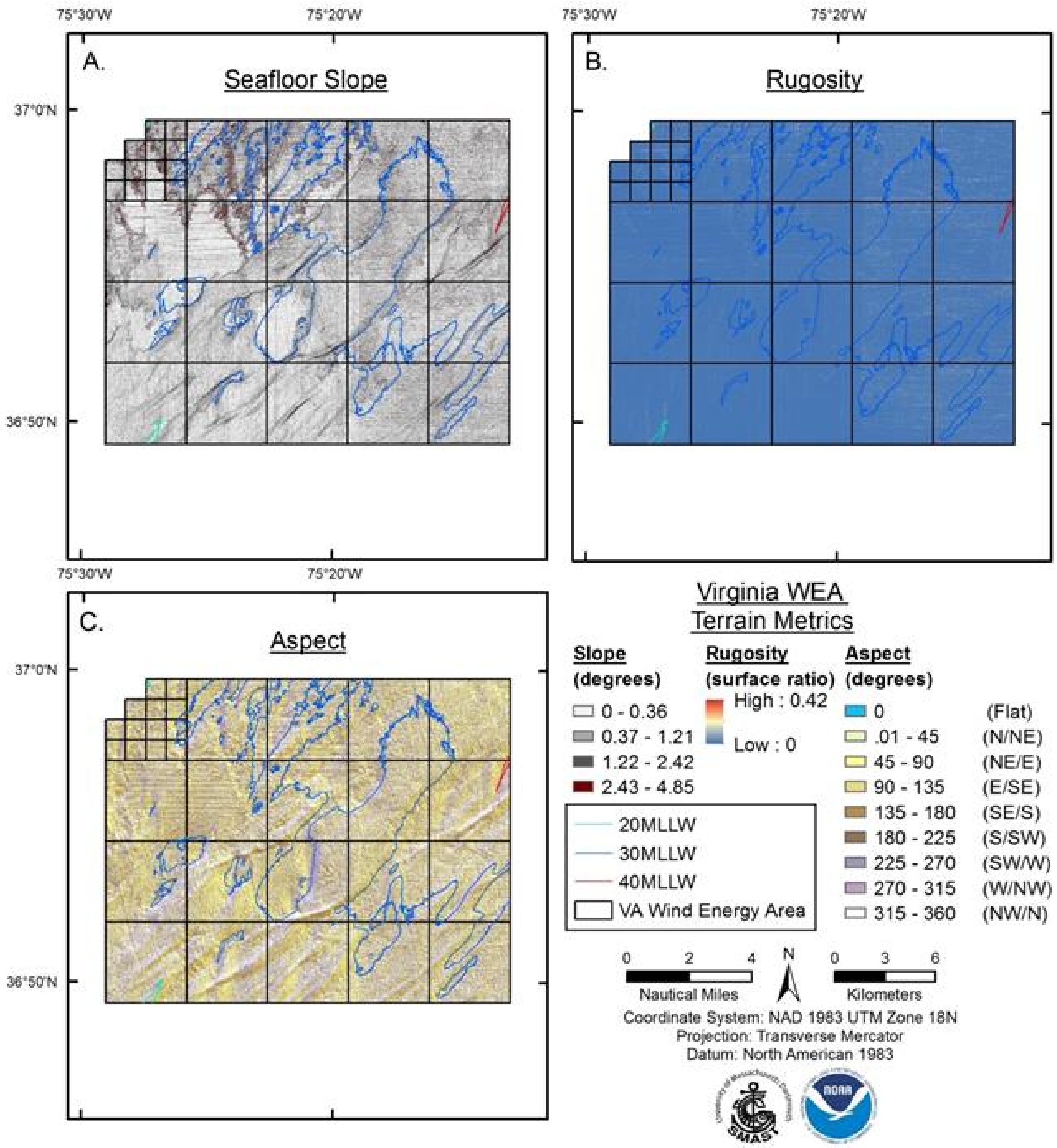


Figure 8-4. Terrain metrics derived from bathymetry for VA WEA (Figure 8-3). A. Seafloor slope, B. Rugosity, C. Aspect.

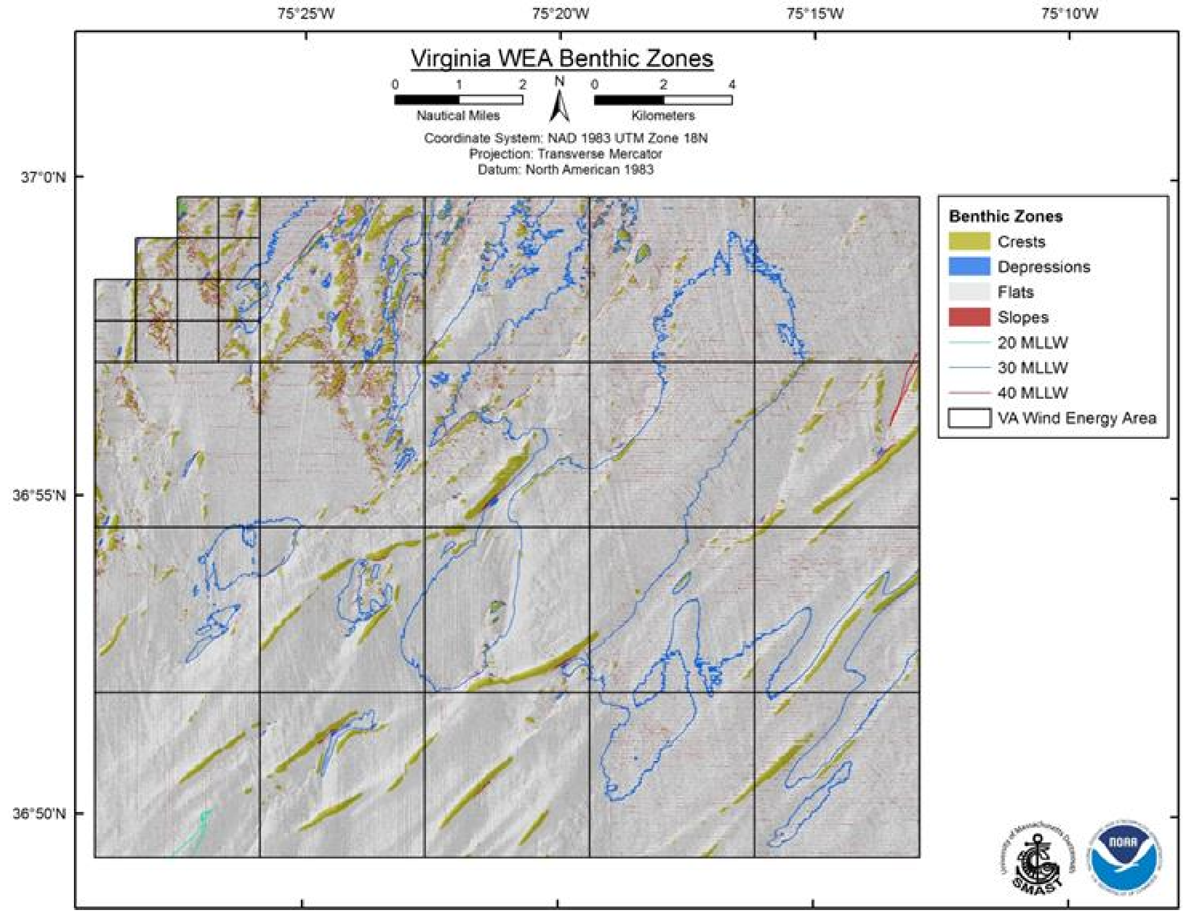


Figure 8-5. Benthic zones derived from bathymetry and derived slope data in the VA WEA.

8.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the VA WEA is shown in Figure 8-6. Figures 8-7, 8-8, and 8-9 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 8-6 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 8-10. While this representation only represents mean grain size without assessing the range of sediment sizes present, it does give a good idea of the character of sediments where the variation in grain sizes is not extreme.

No SMAST sampling was performed in the VA WEA, so there is no record of grain size larger than gravel and no record of sediment ripples.

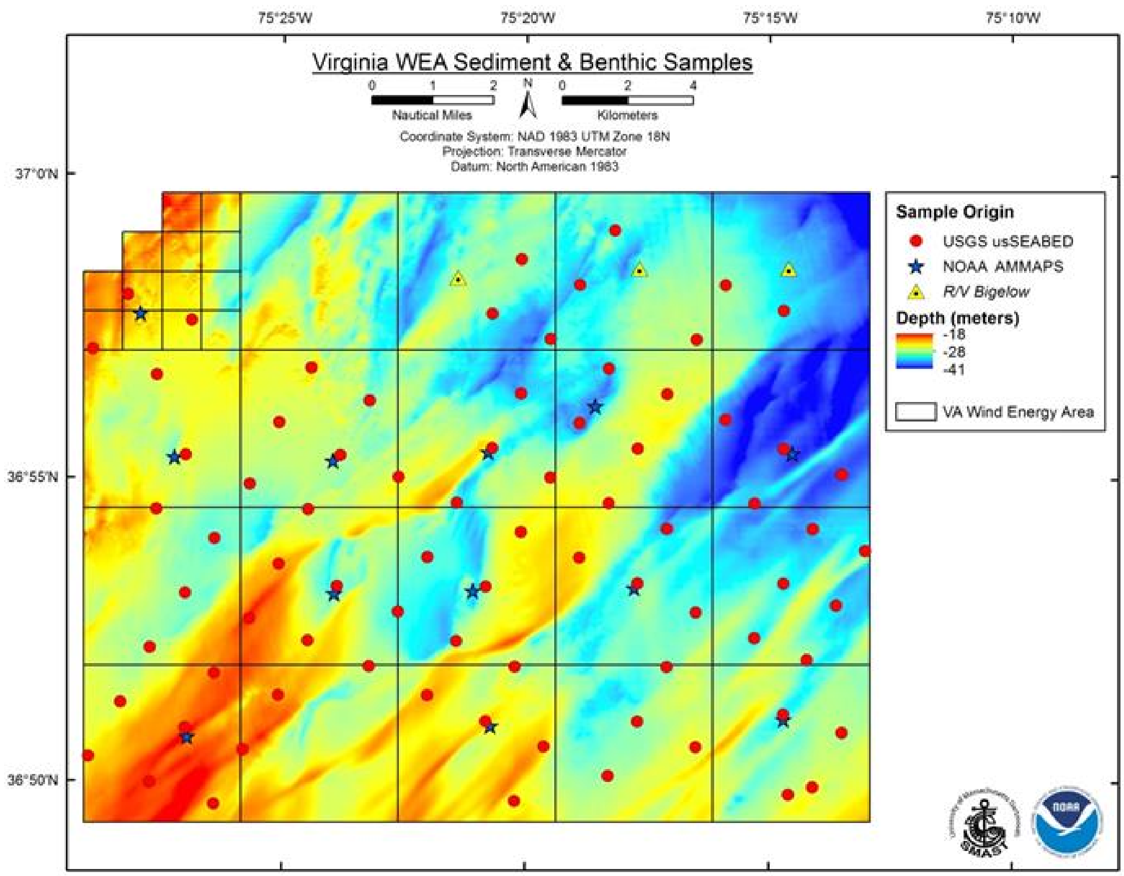


Figure 8-6. Location and source of benthic sediment samples and observations in the VA WEA. Samples include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles), cores taken from grab sampler aboard the 2014 AMAPPS cruise (green stars) and NEFSC Habitat Characterization cruise HB15-05 (yellow triangles). Data sources - bathymetry as in Figure 8-3, sediment data: Reid et al. 2005.

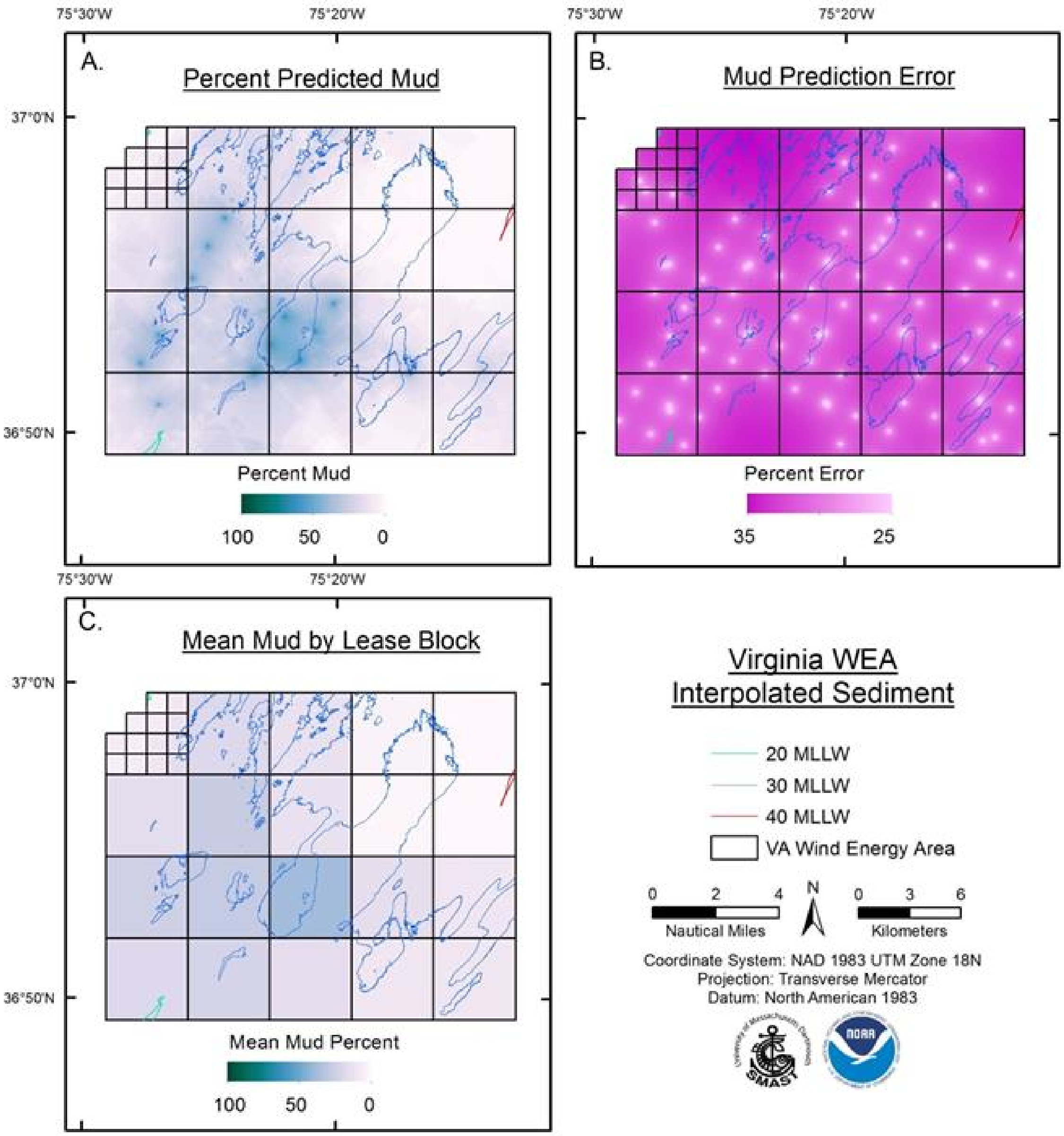


Figure 8-7. Predicted mud (silt + clay) distribution of surficial sediments in VA WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data as in Figure 8-6.

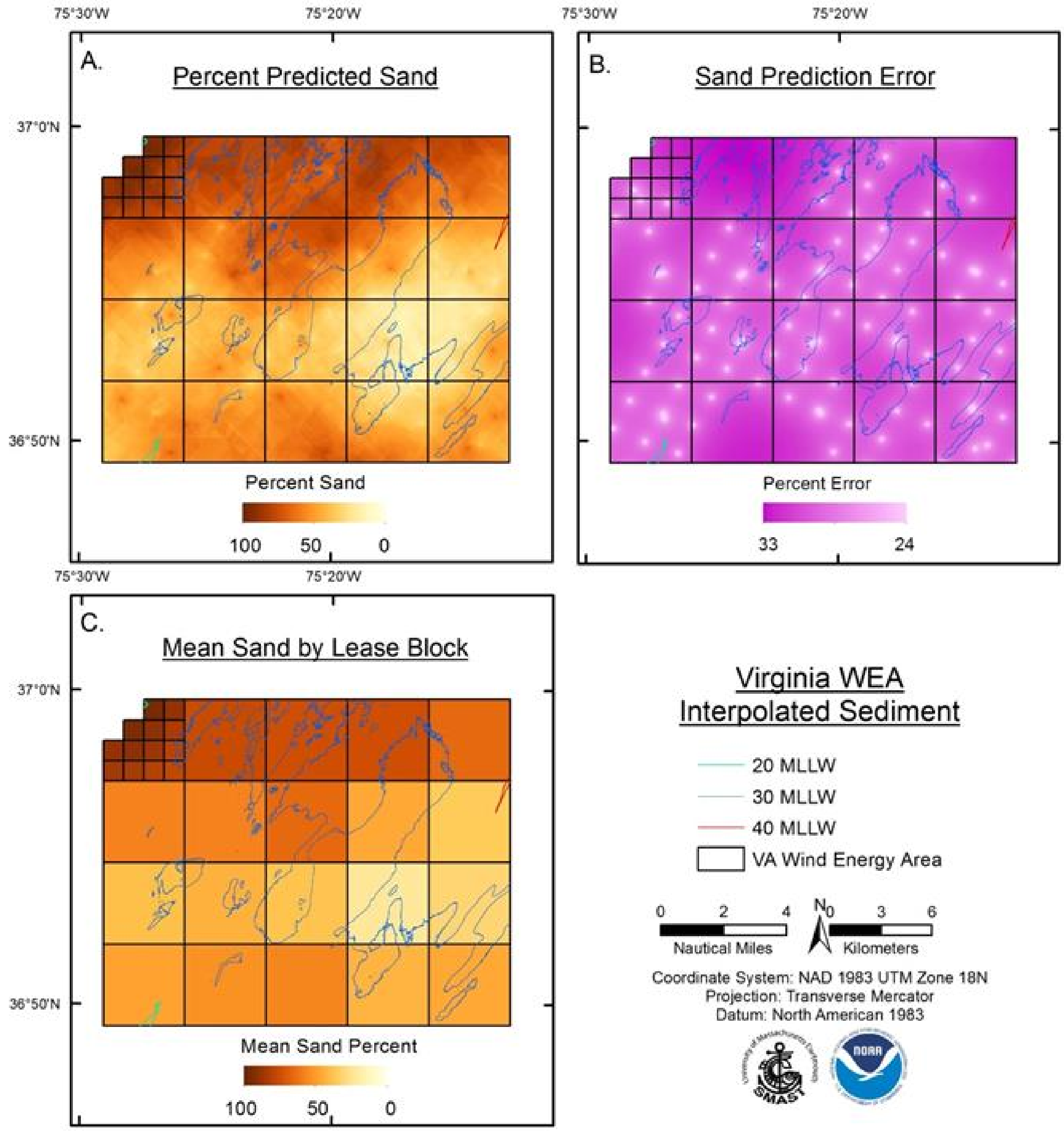


Figure 8-8. Predicted sand distribution of surficial sediments in VA WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data as in Figure 8-6.

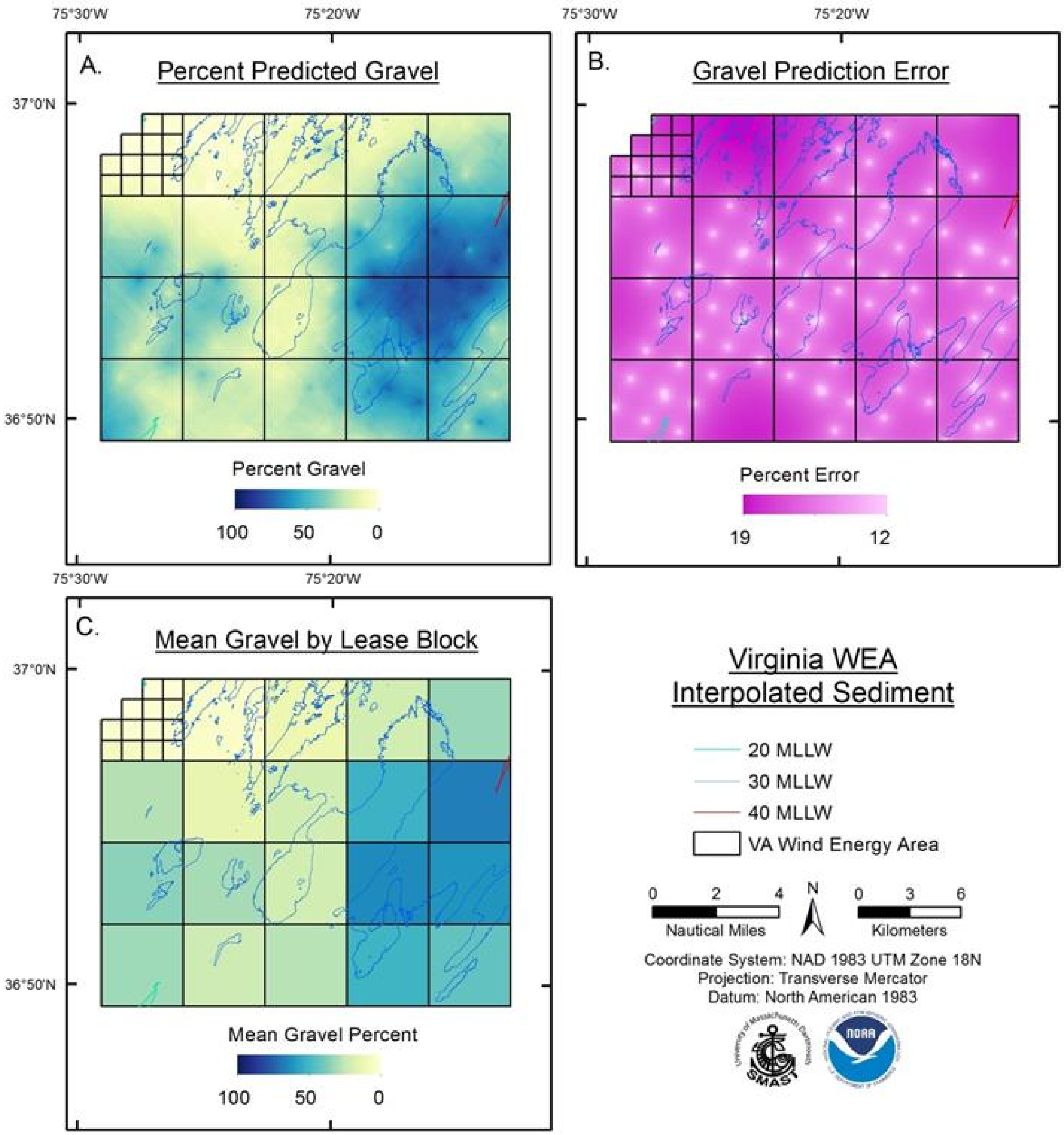


Figure 8-9. Predicted gravel distribution of surficial sediments in VA WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data as in Figure 8-6.

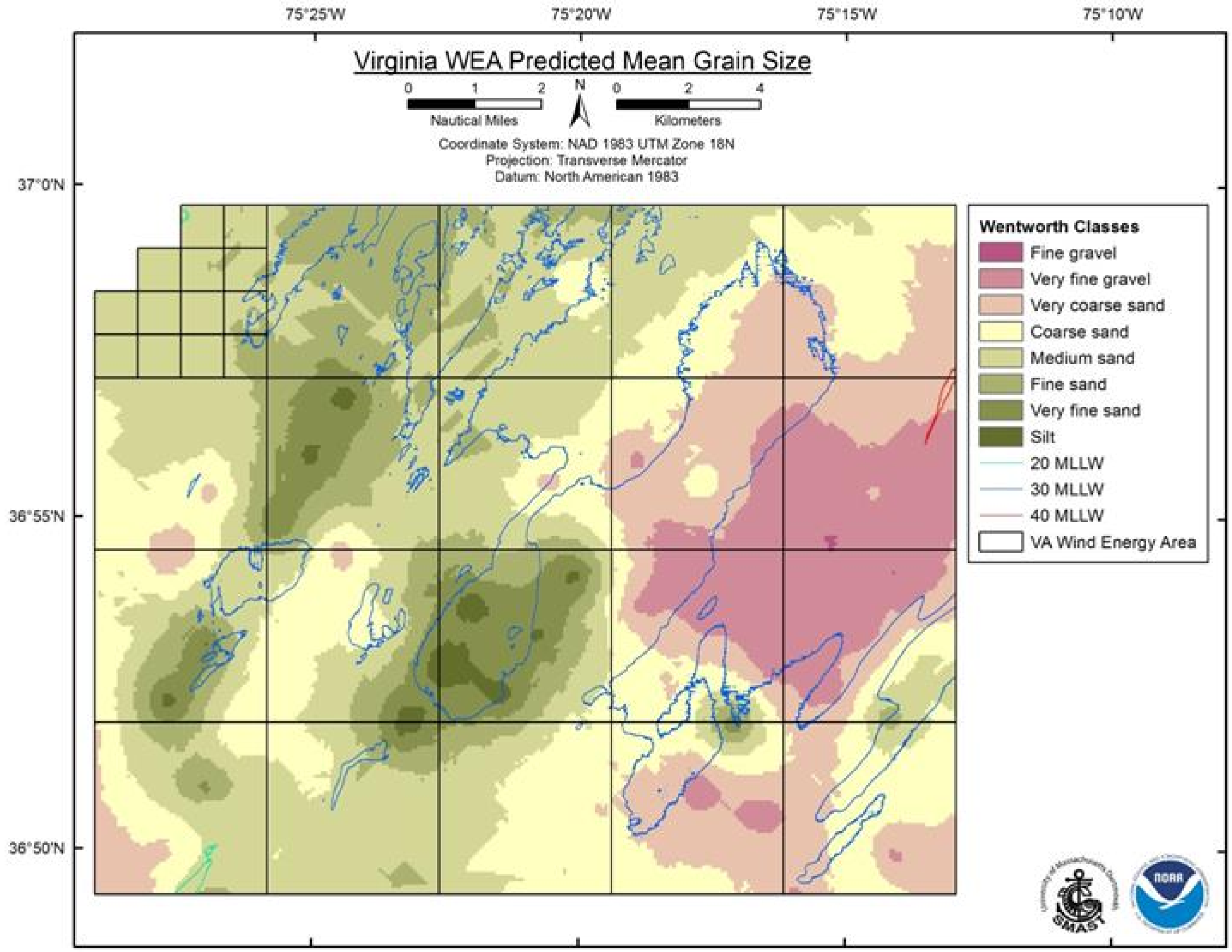


Figure 8-10. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the VA WEA physical samples. Values represent interpolated average grain size distribution. Source data as in Figure 8-6.

Sediments in the VA WEA are primarily sandy, but there are large pockets of muddy sand sediments, including one in a local depression filling most of block 6114 in the center of the WEA and a linear feature to the west running NE-SW through blocks 6112 and 6063. A large gravel-dominated patch was found in the east, occupying much of blocks 6065, 6066, 6115, and 6116. Without SMAST observations, no information was available on sand ripples or cobbles, boulders, or rock.

8.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 8-11.

Median salinity measured in the VA WEA for this period, including all depths, was 32.082 g/kg, with a full range spanning 29.764 to 33.996 g/kg (n=875), despite strong seasonal changes in other parameters. This range is entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 3.65 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

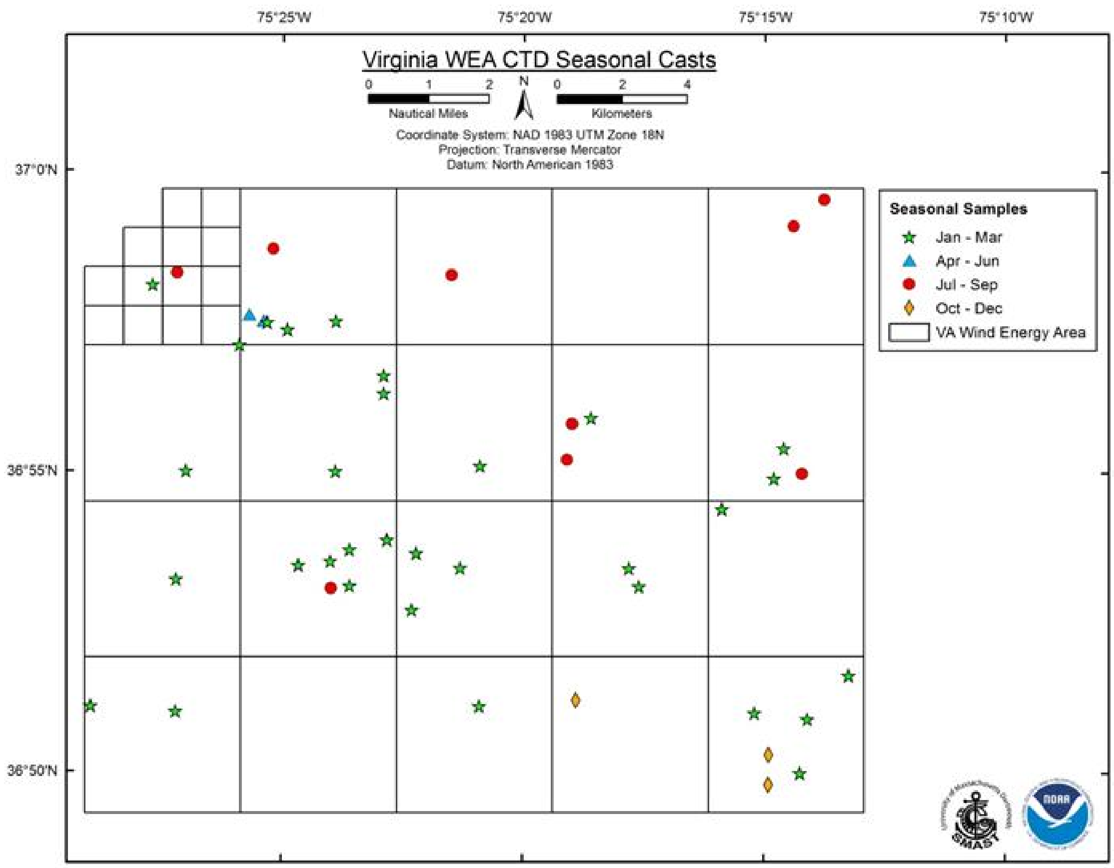


Figure 8-11. Locations for NEFSC CTD casts made between 2003 and 2016 in the VA WEA.

On the other hand, water temperatures showed large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water column structure. Figure 8-12 presents surface and bottom temperatures from CTD casts shown in Figure 8-11 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 20°C at the surface and 15°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 15°C. Vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperatures of up to 12°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton.

Figure 8-12 gives the appearance that fall warming of the bottom as a result of the turnover of the water column occurs at a higher rate in the VA WEA than in other WEAs, resulting in a skewed bottom temperature trend curve. This may be the result of utilizing relatively few data spread over a long period of time (14 years) to define the long-term trend in a season of highly variable behavior. The pattern set out in Figure 1-2 remains clear.

The VA WEA has no persistent frontal systems impinging upon it (Figure 1-4).

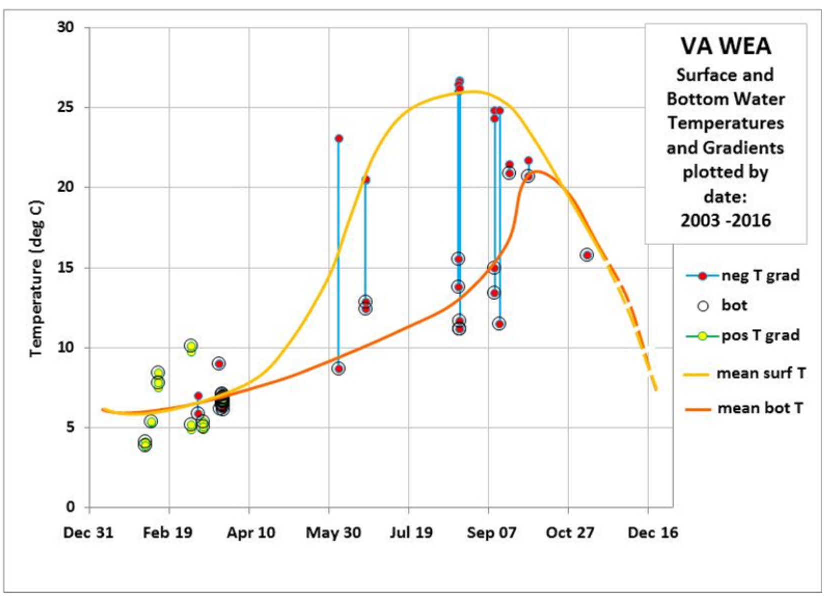


Figure 8-12. Water temperatures from CTD casts made between 2003 and 2016 in the VA WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values. No data was available for mid-November through mid-January, so the shapes of trend lines for that period (dashed) are conjectural.

8.2.5 Biological Variables

8.2.5.1 Benthic Epifauna and Infauna

Benthic samples were collected during two NEFSC–sponsored cruises: AMAPPS part 1 (March 2014) and HB15-05 (August 2015) in the VA WEA. The March cruise obtained 12 beam trawls for benthic epifauna and 12 triplicate Van Veen grabs for benthic infauna, and the August cruise obtained 7 beam trawls and 3 grabs (Figure 8-13). Catches for these two types of collections taken in each of two seasons are illustrated in Figures 8-14 and 8-15.

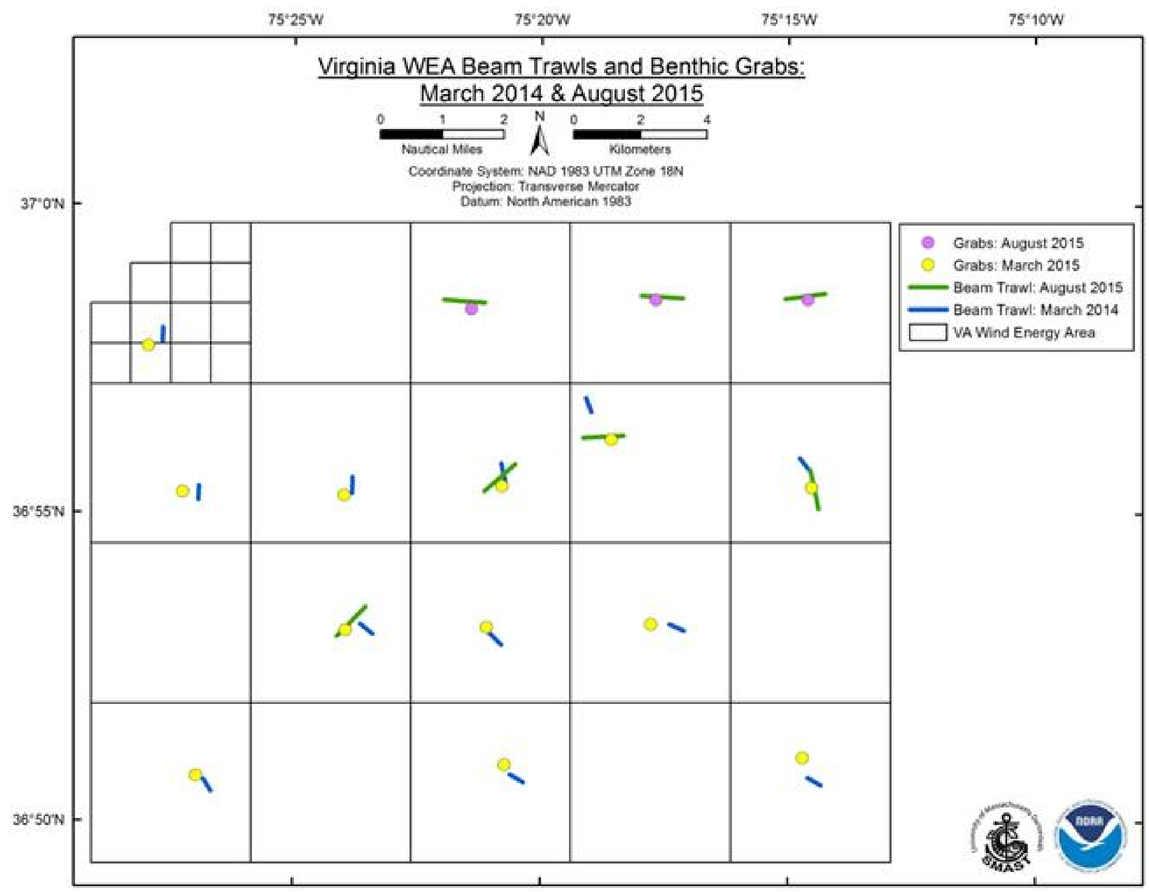
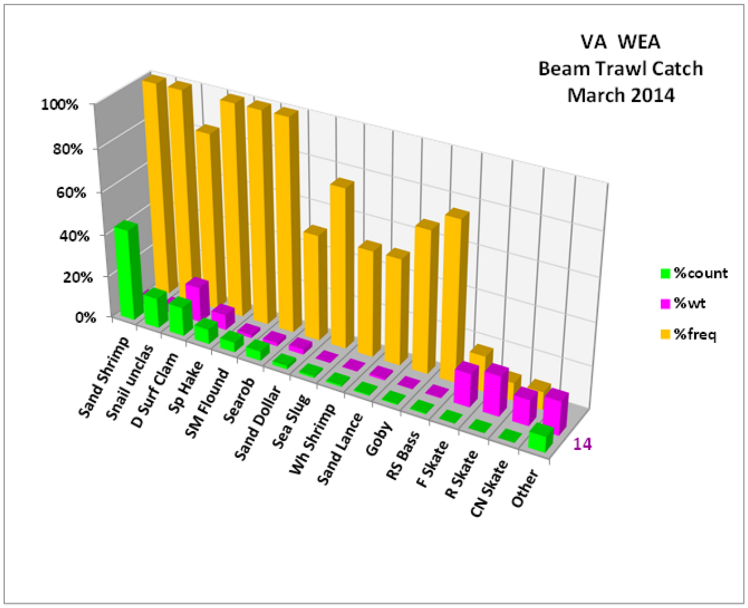


Figure 8-13. Locations of beam trawl and benthic grab samples made in the VA WEA.

A.



B.

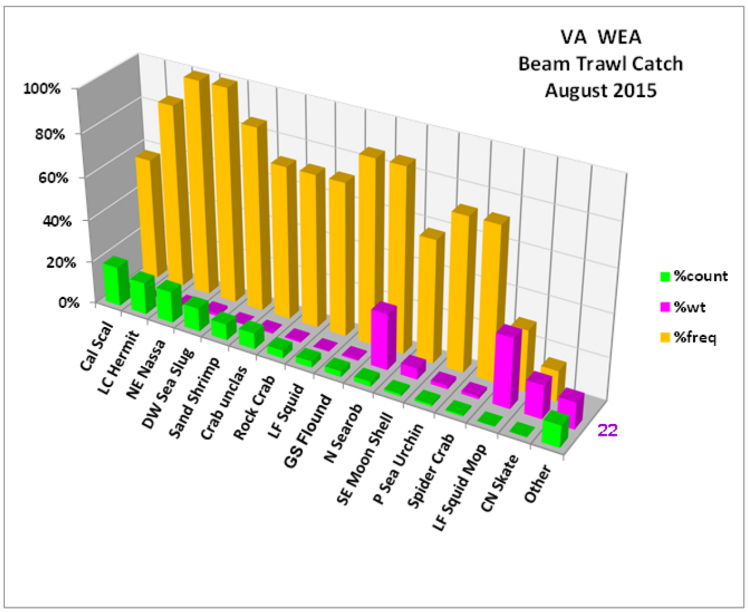
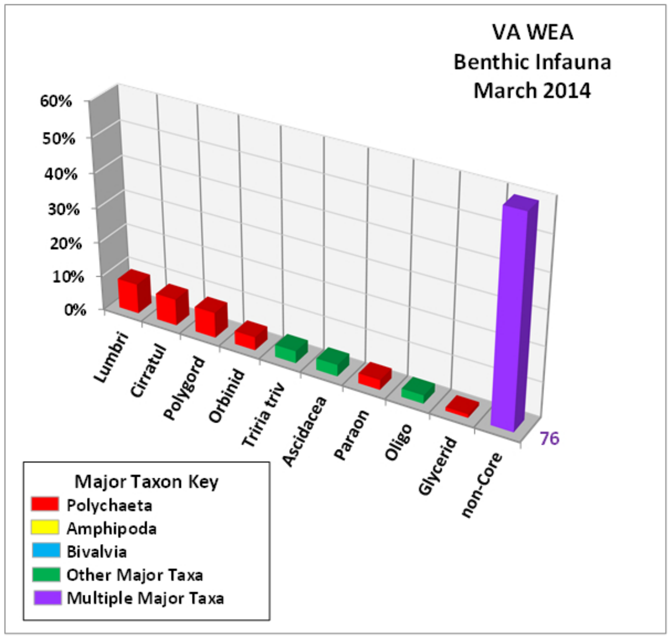


Figure 8-14. Benthic fauna caught in VA WEA by NEFSC beam trawl sampling . Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA: A. March 2014, B. August 2016. Abbreviated common names for taxa in A.: Snail unclas – unclassified shelled gastropods, D Surf Clam – dwarf surfclam, Sp Hake – spotted hake, SM Flound – smallmouth flounder, Searob – searobin unclassified, Sea Slug – unclassified shell-less gastropods, Wh Shrimp – white shrimp, RS Bass – rock sea bass, F Skate – freckled skate, R Skate - rosette skate, CN Skate – clearnose skate. Taxa in B: Cal Scal – calico scallop, LC Hermit – longclaw hermit crab, NE Nassa – New England nassa (dogwhelk) snail, DW Sea Slug – dwarf warty sea slug, Crab Unclas – unclassified crab, LF Squid – longfin squid, GS flound – Gulf Stream flounder, N Searob – northern searobin, SE Moonshell – shark's eye moonshell snail, P Sea Urchin – purple sea urchin, LF Squid Mop – longfin squid egg mop, CN Skate – clearnose skate. Numbers to the right of the "other" taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of "other" taxa.

A.



B.

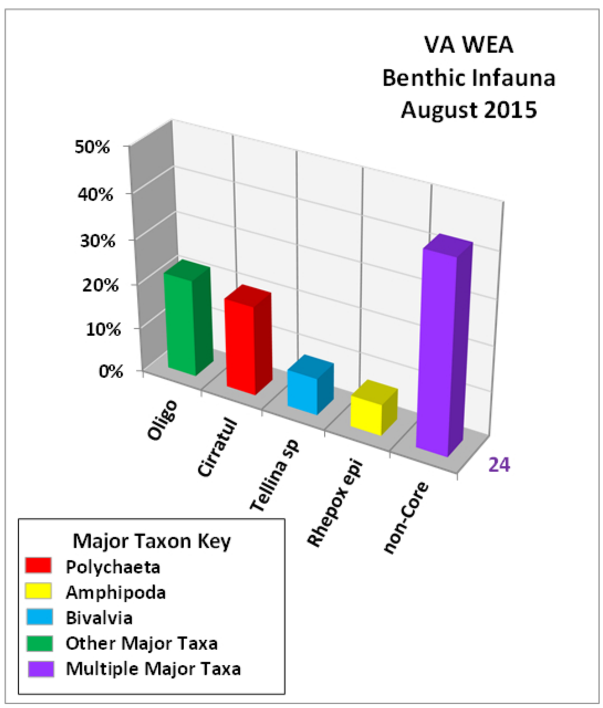


Figure 8-15. Benthic fauna caught in VA WEA by NEFSC grab sampling in March 2014 and August 2015. Catch is reported by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated taxonomic names: A. Lumbri – Lumbrinereidae, Cirratul – Cirratulidae, Polygord – Polygordiidae, Orbin – Orbinidae, Tritia triv – *Tritia* (f. *Nassarius*) *trivitata,* Paraonid – Paraonidae, Oligo – Oligochaeta, Glycerid – Glyceridae; B. Oligo, Ciratul – same as in A, Tellina sp – *Tellina* sp., Rhepox epi - *Rhepoxynus epistomus*. Numbers to the right of the "non-core" taxa bars represent additional taxa in samples not displayed individually. See section 1.3.4 for explanation of "non-core" species.

NEFSC beam trawl catches and the contents (29 and 37 taxa in March and August, respectively, 56 overall) of the benthic grab samples (85 and 28 taxa in March and August, respectively, 95 overall) are summarized in Figures 8-14 and 8-15. Among the epibenthic fauna as obtained in beam trawls, there were no dominants as defined in section 1.3.4 in either season, but sand shrimp were present in by far the largest numbers (68% of all catches) in March (Figure 8-14A), and calico scallops were first in numbers among a series of taxa with similar abundance in August (Figure 8-14B) . Other epibenthic taxa were typical of sandy bottoms. Benthic infaunal taxa were dominated by polychaetes and oligochaetes in March (Figure 8-15A), but a variety of taxa in August (Figure 8-15B). In both cases over 40% of taxa were non-core, i.e. not occurring in 80% of the samples, suggesting a lot of variation (or diversity) among that infaunas in both cold and warm seasons.

8.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 8-16. Importance values among taxa captured in NEFSC Seasonal Trawl Survey catches in the VA WEA are plotted in Figure 8-17 and Table 8-1, with seasonally dominant species listed in Table 8-2. NEFSC seasonal trawls were relatively few due to the small size of this WEA.

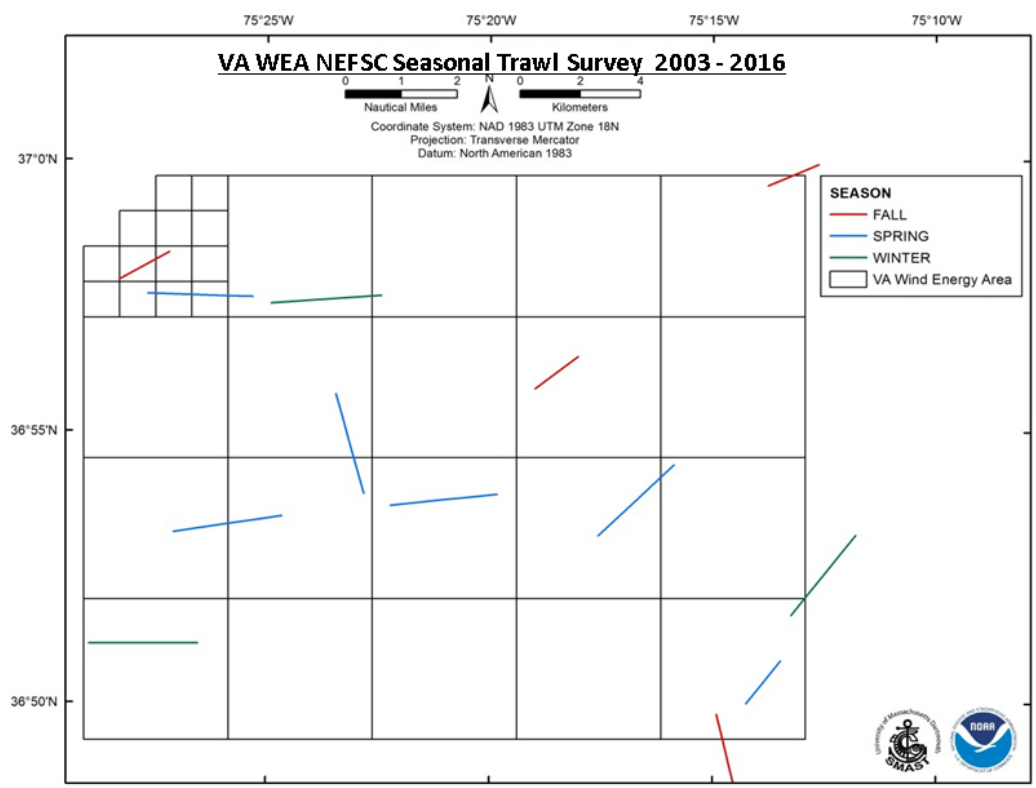


Figure 8-16. Locations of NEFSC seasonal trawls from 2003 to 2016 in the VA WEA.

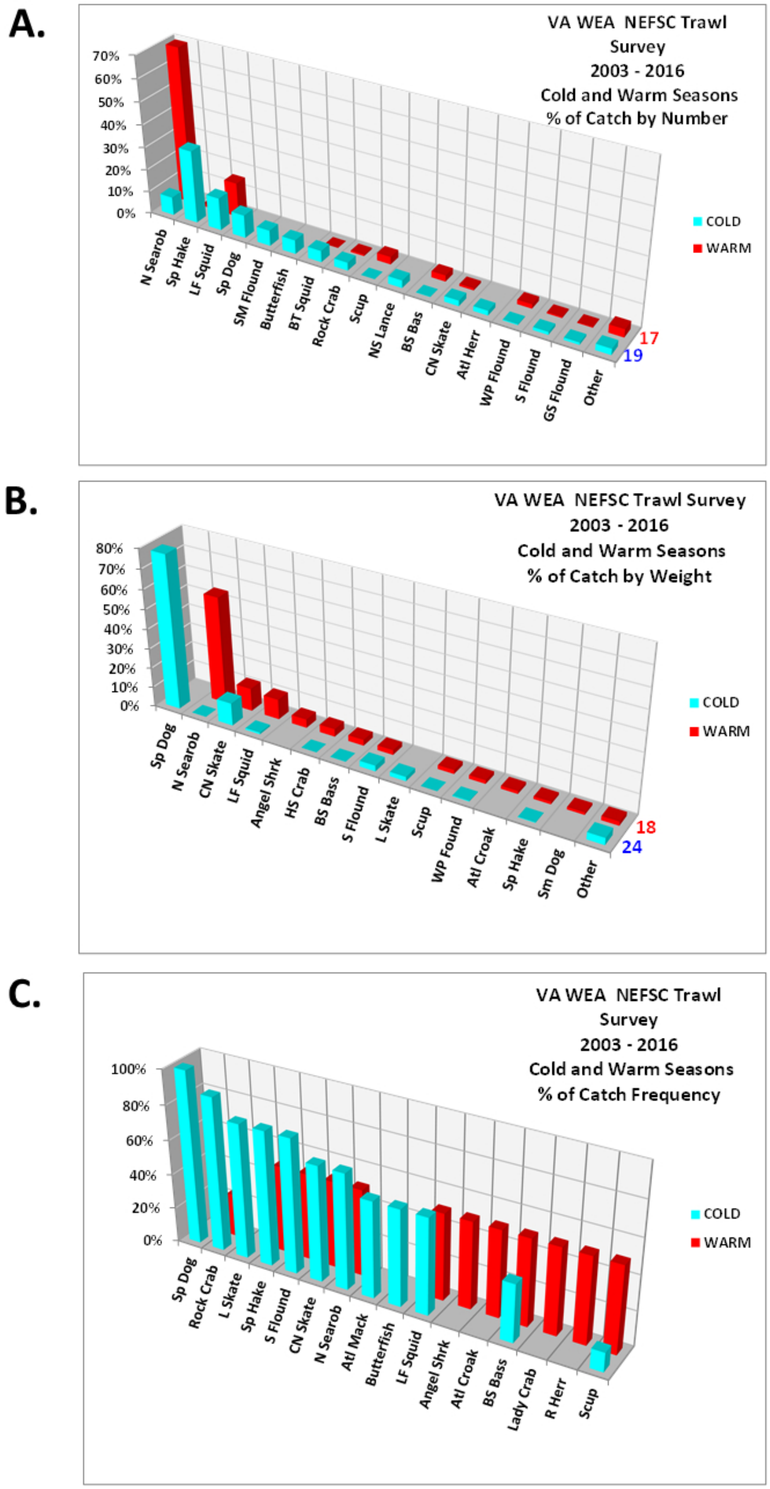


Figure 8-17. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 8-1. Blue and red numbers along the right margin of the graphs indicate the numbers of “other” species in cold and warm season catches respectively.

Table 8-1. Abbreviations for taxon names used in Figure 8-17, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Angel Shrk	Atlantic angel shark[5]	L Skate	little skate[2]
Atl Croak	Atlantic croaker[1]	LF Squid	longfin squid[3]
Atl Mack	Atlantic mackerel[3]	NS Lance	northern sand lance
Atl Herr	Atlantic herring[2]	N Searob	northern searobin
Rock Crab	Atlantic rock crab	R Herr	round herring
BS Bass	black sea bass[2]	Scup	scup[3]
BT Squid	bobtail squid unclassified	SM Flound	smallmouth flounder
Butterfish	butterfish[3]	Sm Dog	smooth dogfish[5]
CN Skate	clearnose skate[2]	Sp Dog	spiny dogfish[4]
GS Flound	Gulf Stream flounder	Sp Hake	spotted hake
HS Crab	horseshoe crab[1]	S Flound	summer flounder[3]
Lady Crab	lady crab	WP Flound	windowpane flounder[2]

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 8-2. Dominant species in NEFSC Seasonal Trawl Survey catches within the VA WEA between 2003 and 2016.

Virginia WEA Dominants	
Cold Season	Warm Season
Clearnose Skate	Black Sea Bass
Spiny Dogfish	Longfin Squid
Summer Flounder	Northern Sea Robin
	Scup
	Spotted Hake

It is evident from this survey trawl data that this is a moderately taxon-rich area: 28 taxa in the warm season and 35 in the cold season. It is also evident that while there is considerable overlap in the lists of taxa present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also considerable overlap among species present and dominance with other WEAs, especially DE (section 7.2.5.2) and North Carolina-Kitty Hawk (section 9.2.5.2). Of the taxa that are important in terms of numbers, biomass, and/or frequency (Table 8-1) 63% (15 out of 24) are species that are managed in the northeast region. No taxa were dominants in both seasons. All of the dominants other than skates were seasonal migrants. It is also notable that 75% of the species in Table 8-1 represent managed fishery species.

8.2.5.3 Species of Concern

Records of shellfish species of concern in the VA WEA are illustrated in Figure 8-18. These include quantitative records of sea scallops from NEFSC seasonal trawl surveys and qualitative records from beam trawls, bottom grabs, and bottom imagery. Although not common or numerous in our records, sea scallops were clearly present in this WEA, in the deeper (>30 m) northern and northeastern parts of the WEA. Current sea scallop EFH does not intersect at all with the VA WEA (Figure 1-7).

Ocean quahogs were found in two grab samples from the central portion of the VA WEA, although ocean quahog EFH does not intersect this WEA (Figure 1-8). Surfclam EFH overlaps this WEA completely (Figure 1-9), and surfclams were indeed widespread there in both benthic beam trawl and grab samples (Figure 8-18).

Another shellfish species encountered exclusively in August beam trawl samples was the calico scallop, *Argopecten gibbus*: 169 juveniles were caught between four sites in the WEA. This mollusk has no fisheries status in the northeast region, but is fished commercially in the southeast. If it became established locally and began to support a fishery, there may be some concern as regards to habitat, but with no status and no known fishery at this time, they are not a management issue.

Longfin squid egg mops were captured in the VA WEA in August 2015 at two stations via beam trawl (Figure 8-18). They accounted for nearly 33% of the August beam trawl biomass for the entire WEA. All this despite no overlap of the WEA with the longfin squid egg mop EFH zone (Figure 1-10).

Surfclams and longfin squid egg mops are probably the largest concerns with regard to disturbance of mollusks in this WEA. Sea scallops are present, but this is probably a marginal habitat area for them.

No Atlantic cod were caught in the VA WEA between 2003 and 2016. Juvenile and adult cod EFH zones are far removed from this WEA (Figure 1-11).

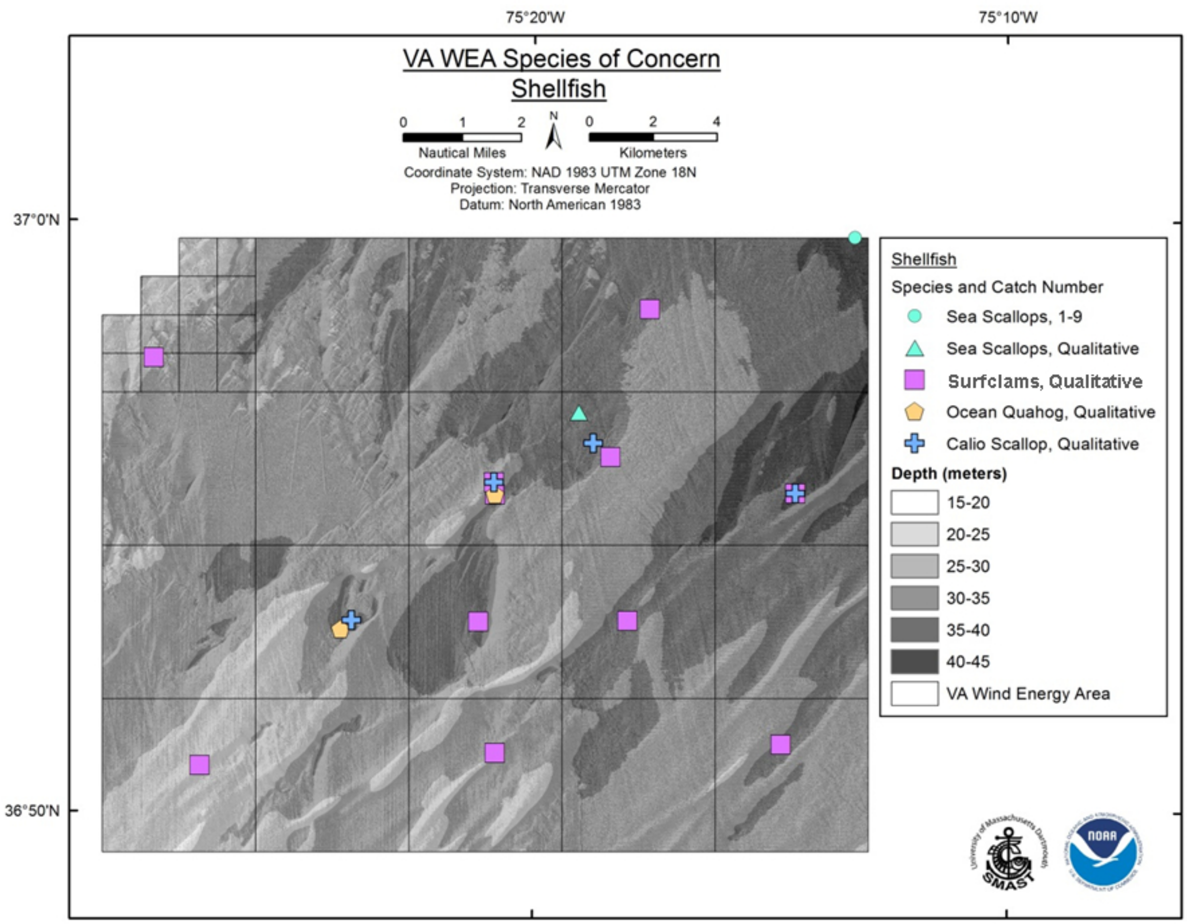


Figure 8-18. Shellfish species of concern records within and near the VA WEA.

Both young-of-the-year (YOY) and sub-adult to adult-sized black sea bass (BSB) were detected in the VA WEA (Figure 8-19), including quantitative catches indicating some abundance there. No mussels, corals, or other structure-forming fauna were detected here. Black sea bass and their habitats, however, need to be considered with respect to possible impacts in this WEA.

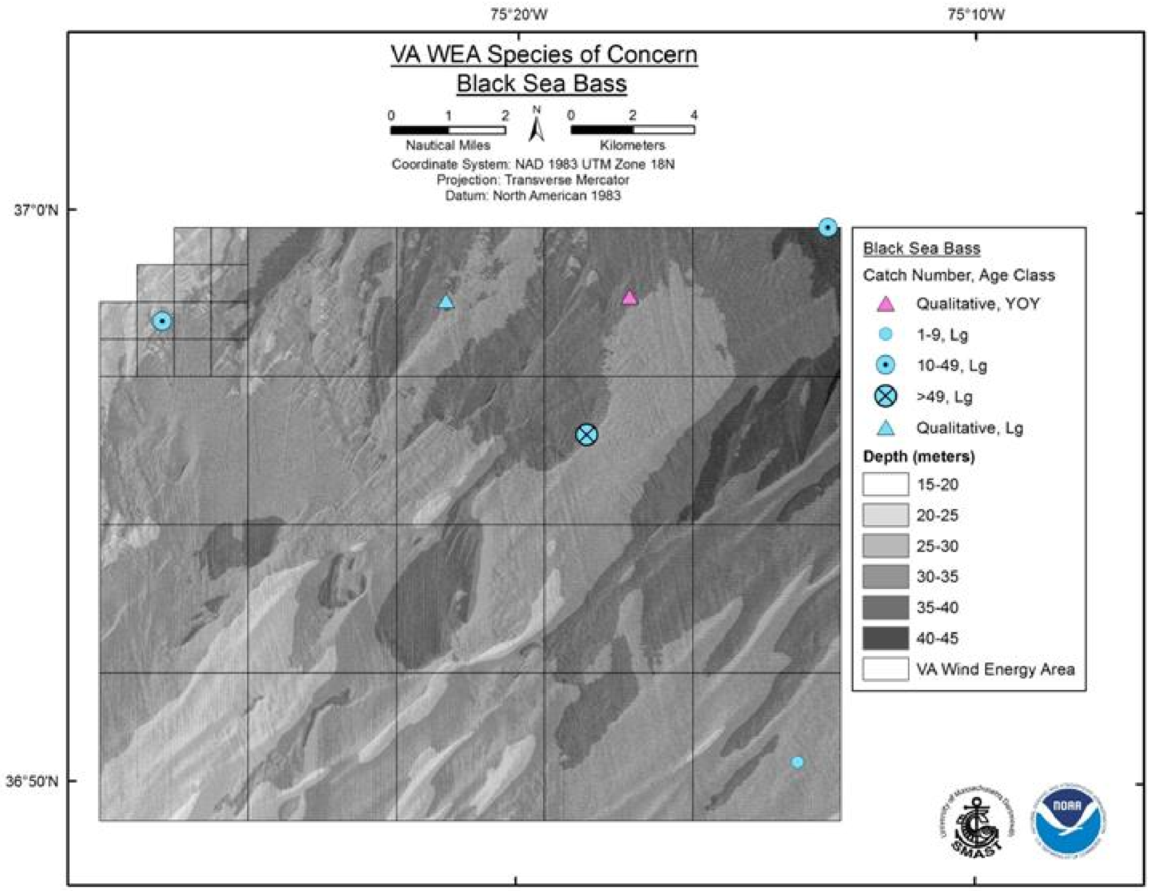


Figure 8-19. Records of young-of-the-year (YOY) and larger black sea bass in the VA WEA.

8.3 VA WEA Habitat Definition

An integrated view of the physical benthic habitat features in the VA WEA is presented in Figure 8-20. There are three major topographic zones (Topo Zones 1,2,3) with habitat features (shelf valleys, gravel to gravelly and mud to muddy patches) superimposed upon them in various locations. The shelf valleys are so designated because the faint channels (Figure 8-3) appear on a large scale map (Ruddock 2010, Figure 1) to be linear channels running southwest to northeast across the VA WEA. These probably represent a drainage system for what is now the Virginia shelf during the low stand of sea level during the Wisconsin glaciation. As far as we have determined with the data at hand, the sediments and fauna of these features are not notably different from those of the surrounding shelf.

The large muddy sand to mud patches in the western half of the WEA and the gravel to gravelly sand patches in the eastern half are topographically similar to the surrounding sandy zones and there is not a clear distinction of their fauna based on the available data.

Unlike the DE WEA, the VA WEA does not intersect the main tidal channel from the adjacent major estuary. The Chesapeake Bay channel bends southward as it passes Cape Henry, VA, thus passing south of the WEA (http://www.noaanews.noaa.gov/stories2007/s2804.htm). A smaller channel off Cape Charles at the tip of the Delmarva Peninsula, however, does trend further northward toward the WEA and may influence its topography.

Topo Zone 1, covering all but the northwest corner of the WEA, features a sediment wave field with sand ridges trending NE-SW (Figures 8-4, 8-5). The waves may be either formed by waves or tidal currents. Topo Zone 2 in blocks 6012, 6062, 6063, and 6112, is very flat and expands in the seaward direction, suggesting a sediment fan, possibly formed as a result of flows from the Cape Charles channel previously mentioned. Topo Zone 3 has a topography which we could not recognize as belonging to the CMECS classification scheme, being of low relief and rugosity, but supporting slopes of over 2.4 degrees in a pattern that was not recognizable as belonging to a described geoform feature. Topo Zone 3 covers much of the northwest third of the WEA not occupied by Topo Zone 2.

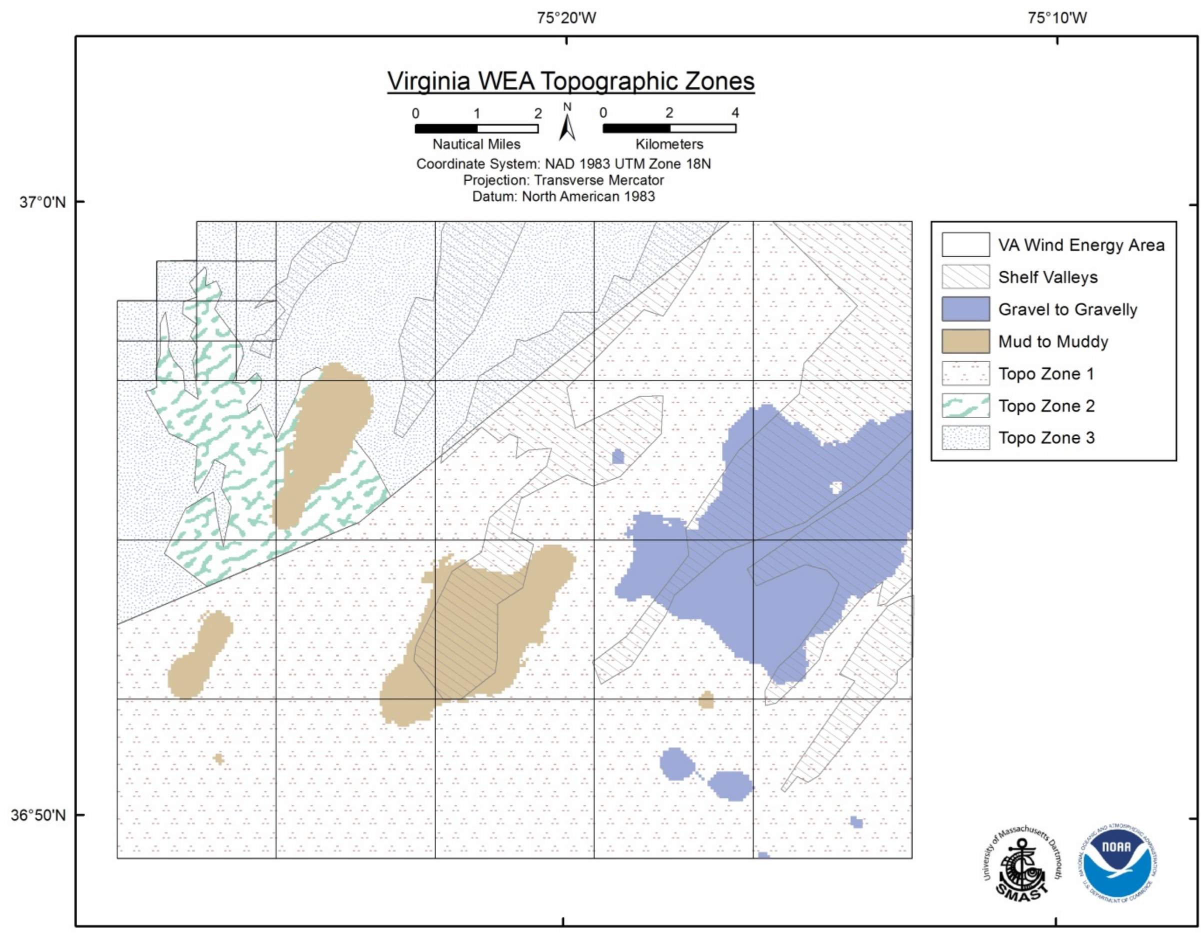


Figure 8-20. Physical benthic habitat features of the VA WEA.

8.3.1 CMECS Classifications

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Sediment Wave Field, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate, Coarse Unconsolidated Sediment
        - Substrate Groups: Sandy Gravel, Gravelly Sand, Sand, Muddy Sand, Sandy Mud
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Clam Bed (*Spisula*)

Topo Zone 2

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Fan, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Sand, Muddy Sand, Sandy Mud, Mud
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna

Topo Zone 3

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Undefined
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Sand, Muddy Sand, Sandy Mud, Mud
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna

Shelf Valley

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Shelf Valley (tributaries)
- Substrate and Biotic Components: same as for Topo Zone 1

Mud to Muddy Patch

- Geoform and Biotic Components: same as for Topo Zone 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Muddy Sand to Mud

Gravel to Gravelly Patch

- Geoform and Biotic Components: same as for Topo Zone 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Coarse Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand to Sandy Gravel

9 North Carolina – Kitty Hawk Wind Energy Area (NC-KH WEA).

9.1 Location, size, and subdivision

The North Carolina-Kitty Hawk WEA lies near the southern extremity of the Southern Mid Atlantic Bight shelf in a band between approximately 24 and 36 nautical miles off the coast of North Carolina north of Cape Hatteras, spanning the coast approximately from Corolla, NC in the north to Kitty Hawk, NC in the south (Figure 9-1). It consists of 15 full lease blocks plus 104 sub-blocks (Figure 9-2). Water depths in the NC-KH WEA range 15 to 45 m, with an average of approximately 20 m, and it covers approximately 122,405 acres of seafloor (BOEM 2014b). This section provides data and analysis for the entire WEA as a single unit.

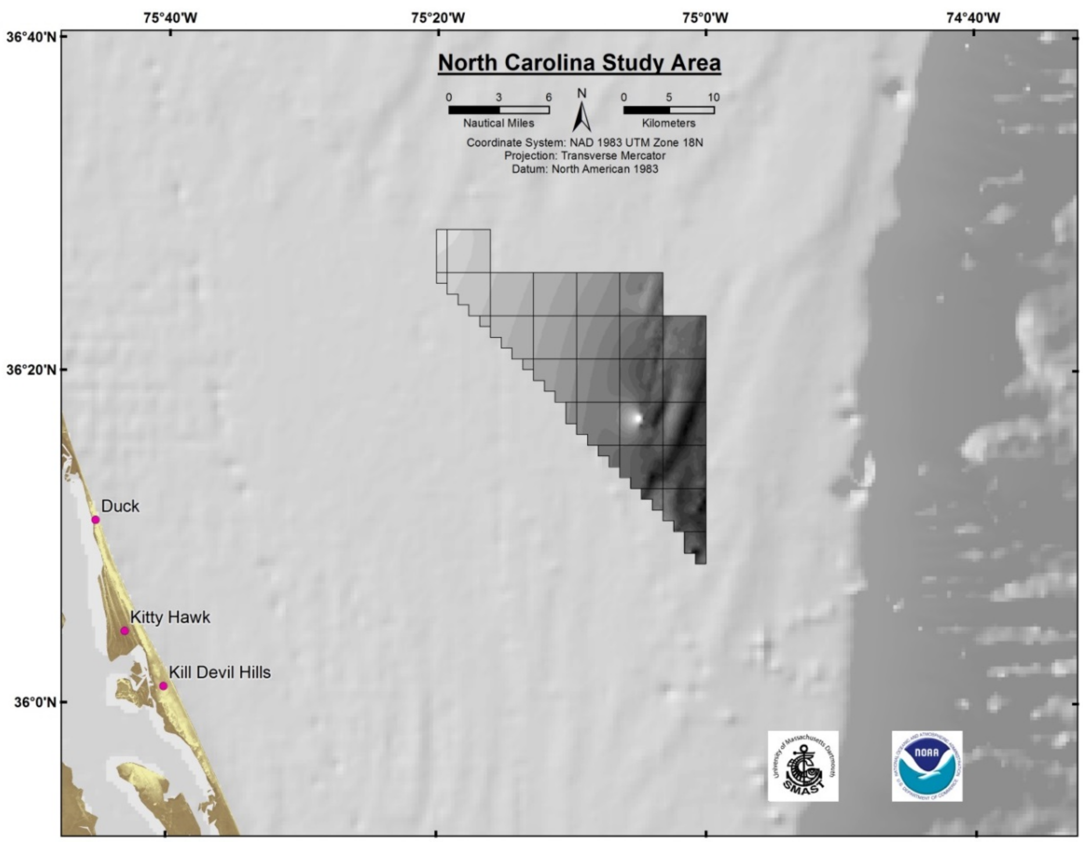


Figure 9-1. Map of North Carolina-Kitty Hawk study area. Source data:(BOEM 2017, NOAA NCEI 2017).

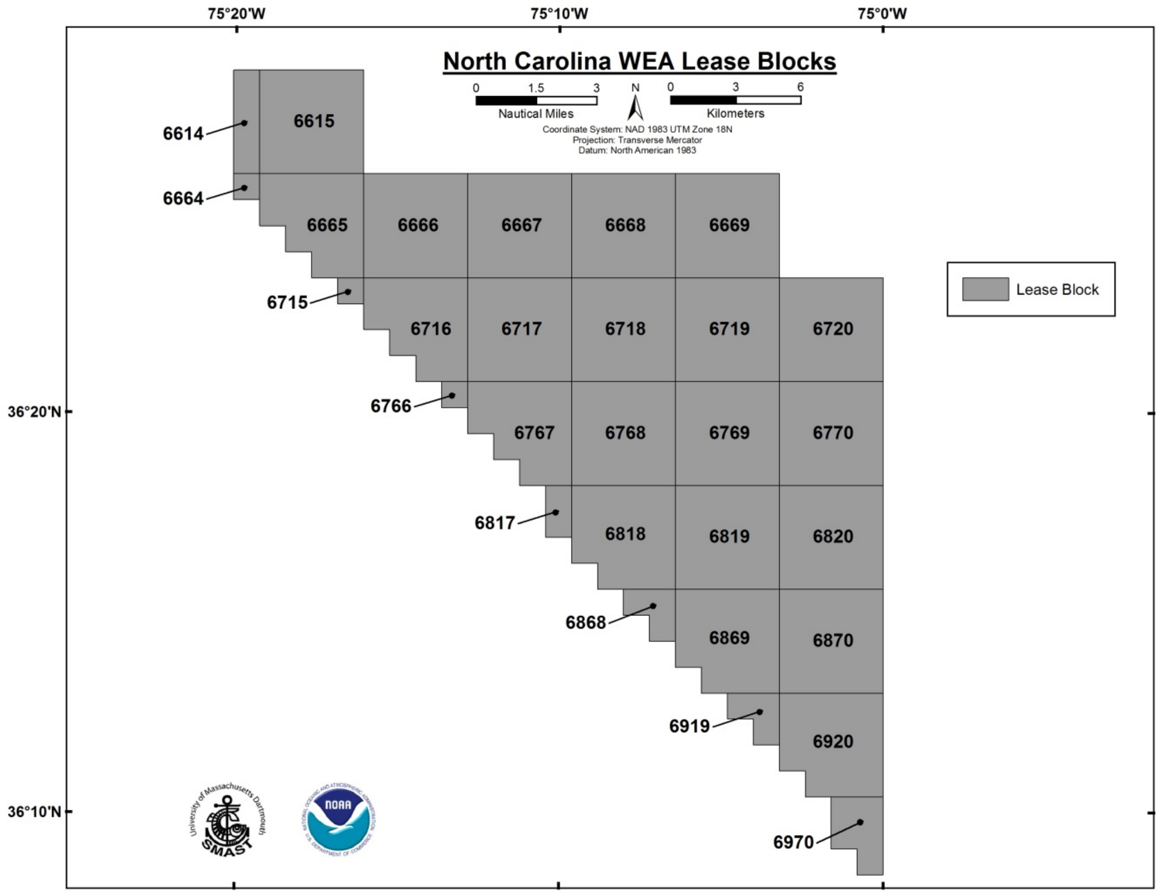


Figure 9-2. Numbered lease blocks and sub-blocks included in the NC-KH WEA (source data BOEM 2017).

9.2 Environmental Data

Environmental data describing the conditions within the WEA are provided below within the same categories and in the same order as set out in Table 1-1.

9.2.1 Bathymetry

Figure 9-3 shows the NC-KH WEA bathymetry. Depths increase along a roughly northwest to southeast gradient. Bottom topography in the western half of the WEA appears flat, gently sloping seaward (southeastward) at an able of approximately 0.02 degrees (depth changes 9 m over 24 km). The eastern half of the WEA is characterized by a series of linear ridges oriented approximately north-northeast by south-southwest separated by 2-4 km crest-to-crest distances. The deepest largest amplitude of these waves appears to be in the range of 15-20 m crest-to-trough. There is also an anomalous round hillock (knob) of about 2 km width and 7-10 m in height in lease block 6819.

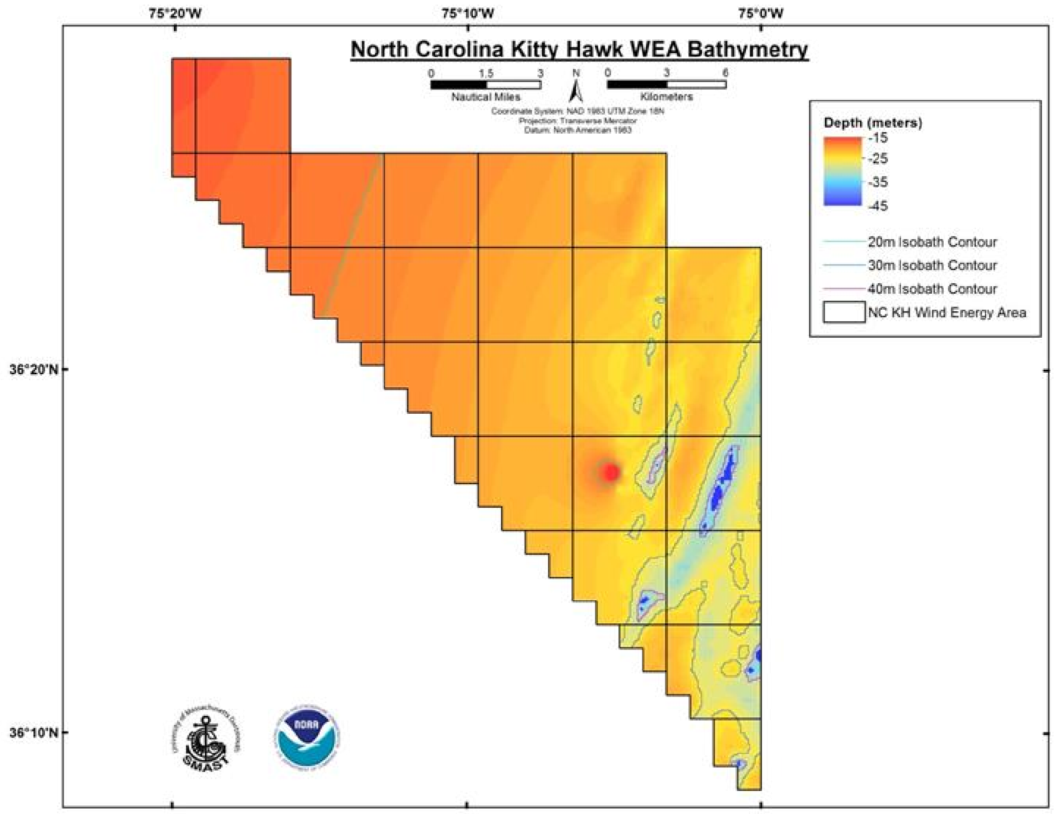


Figure 9-3. Bathymetry (3 arc-second horizontal resolution) with isobaths contours in the NC-KH WEA. Source data: (BOEM 2017).

9.2.2 Terrain Variables

Regarding terrain metrics, slope, rugosity, and aspect (Figure 9-4) all show subtle but clear patterns related to the ridges and depression patterns mentioned in section 9.2.1. Slopes are generally very low (<0.27 degrees), but approaching or exceeding 1.0 degrees on the seaward side of the anomalous hillock in block 6819. Rugosity, a measure of surface roughness, is virtually nonexistent everywhere. Aspect clearly outlines the pattern of ridges with alternating eastward and westward facing strips trending north-northeast by south-southwest.

Application of the BTM Tool allowed better definition of zones in the study area that are consistent with the previously mentioned bathymetry features (Figure 9-3) and terrain metrics (Figure 9-4). The benthic zones derived by this model included crests, depressions, and flat areas, and are based on the BPI, slope, standard deviation break = 2.0, and depth (Figure 9-5). The result is a clarification of the pattern previously described: a smooth surface in the west and a pattern of ridges and depressions in the east.

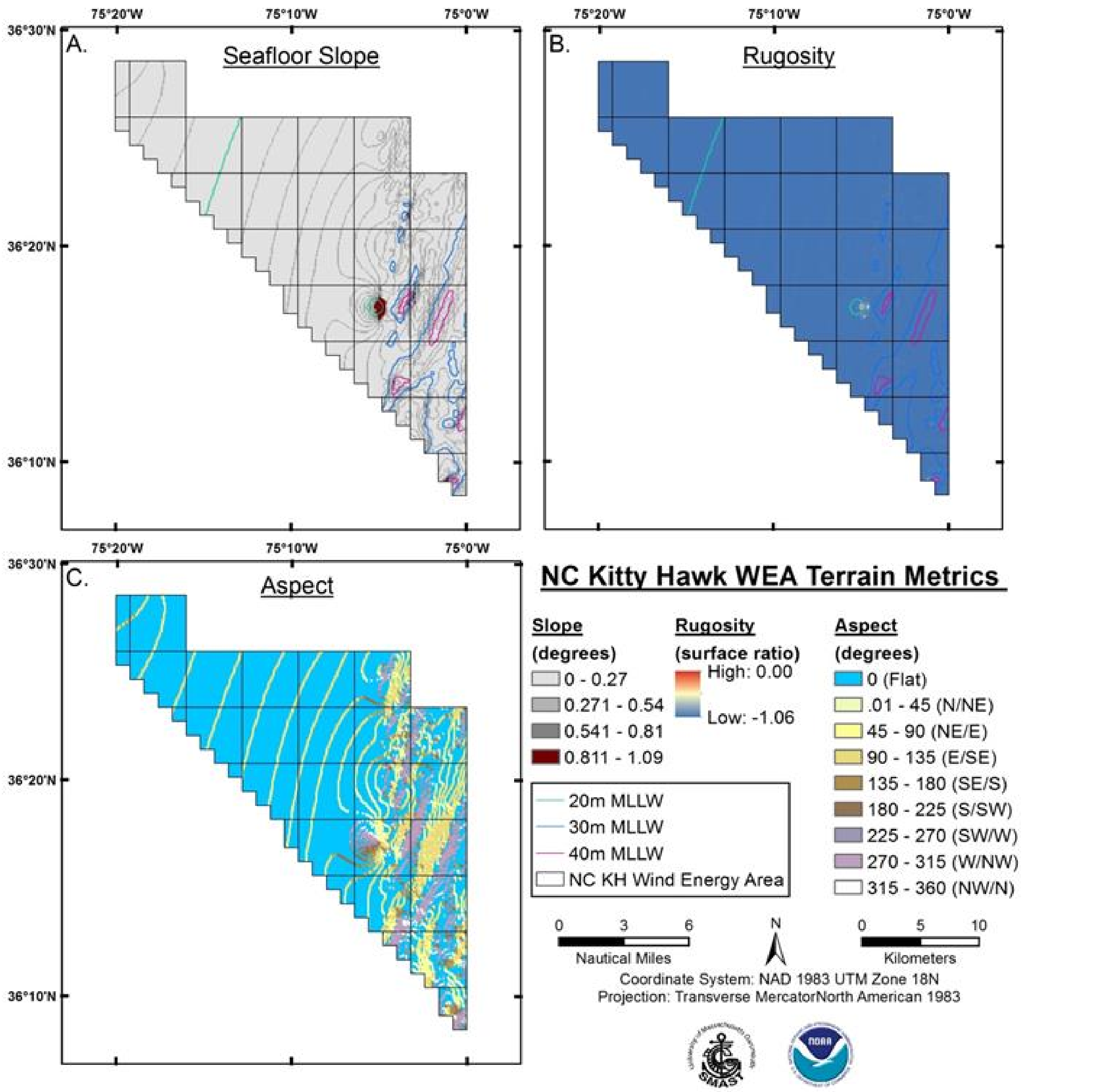


Figure 9-4. Terrain metrics derived from bathymetry for NC-KH WEA (Figure 9-3). A. Seafloor slope, B. Rugosity, C. Aspect.

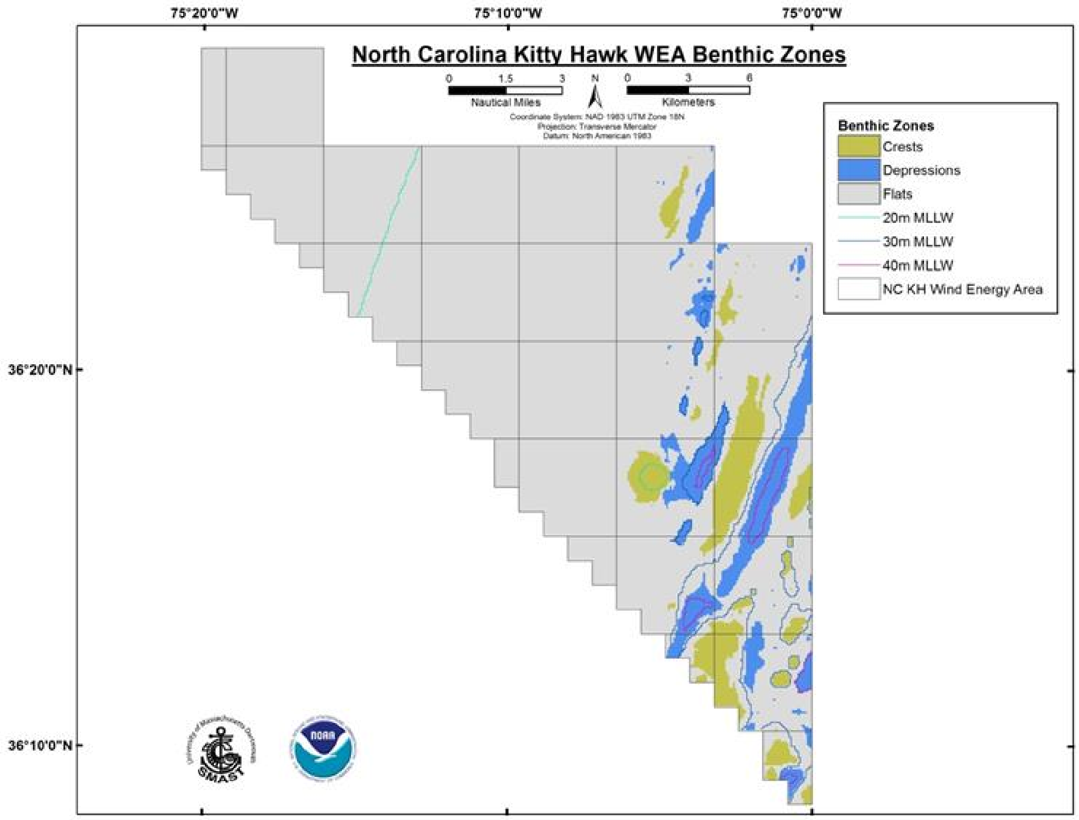


Figure 9-5. Benthic zones derived from bathymetry and derived slope data in the NC-KH WEA.

9.2.3 Substrate Texture Variables

The distribution and origin of samples utilized in sediment texture in the NC-KH WEA is shown in Figure 9-6. Figures 9-7, 9-8, and 9-9 show results from grain size analysis from the USGS and AMAPPS samples shown in Figure 9-6 in the form of % mud, % sand, and % gravel, respectively. The three divisions (A, B, C) of these three figures show the following: A. smooth interpolation of percentage values of the sediment component based on kriging point values from samples, B. a representation of error values for the sediment component inherent in the interpolation of point values, and C. kriged values averaged for each lease block and sub-block.

Averaging predicted grain sizes for the entire WEA resulted in the map of Wentworth classification (single value average grain size: Table 1-3) in Figure 9-10. While this representation only represents mean grain size without assessing the range of sediment sizes present, it does give a good idea of the character of sediments where the variation in grain sizes is not extreme.

No SMAST sampling was performed in the NC-KH WEA.

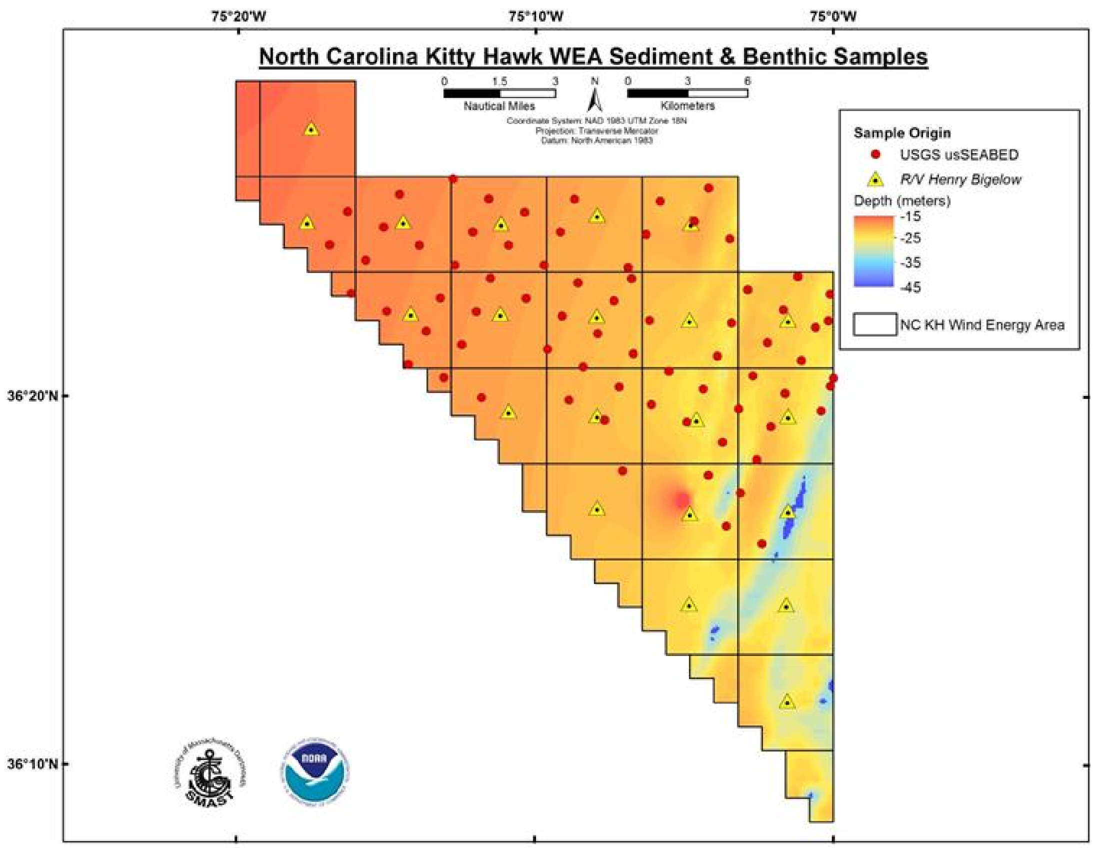


Figure 9-6. Location and source of benthic sediment samples and observations in the NC-KH WEA. Sample include grain size distribution locations from the usSEABED parsed and extracted datasets (red circles) and cores taken from grab sampler aboard the NEFSC Habitat Characterization cruise HB15-05 (yellow triangles. Data sources - bathymetry as in Figure 9-3, sediment data: Reid et al. 2005.

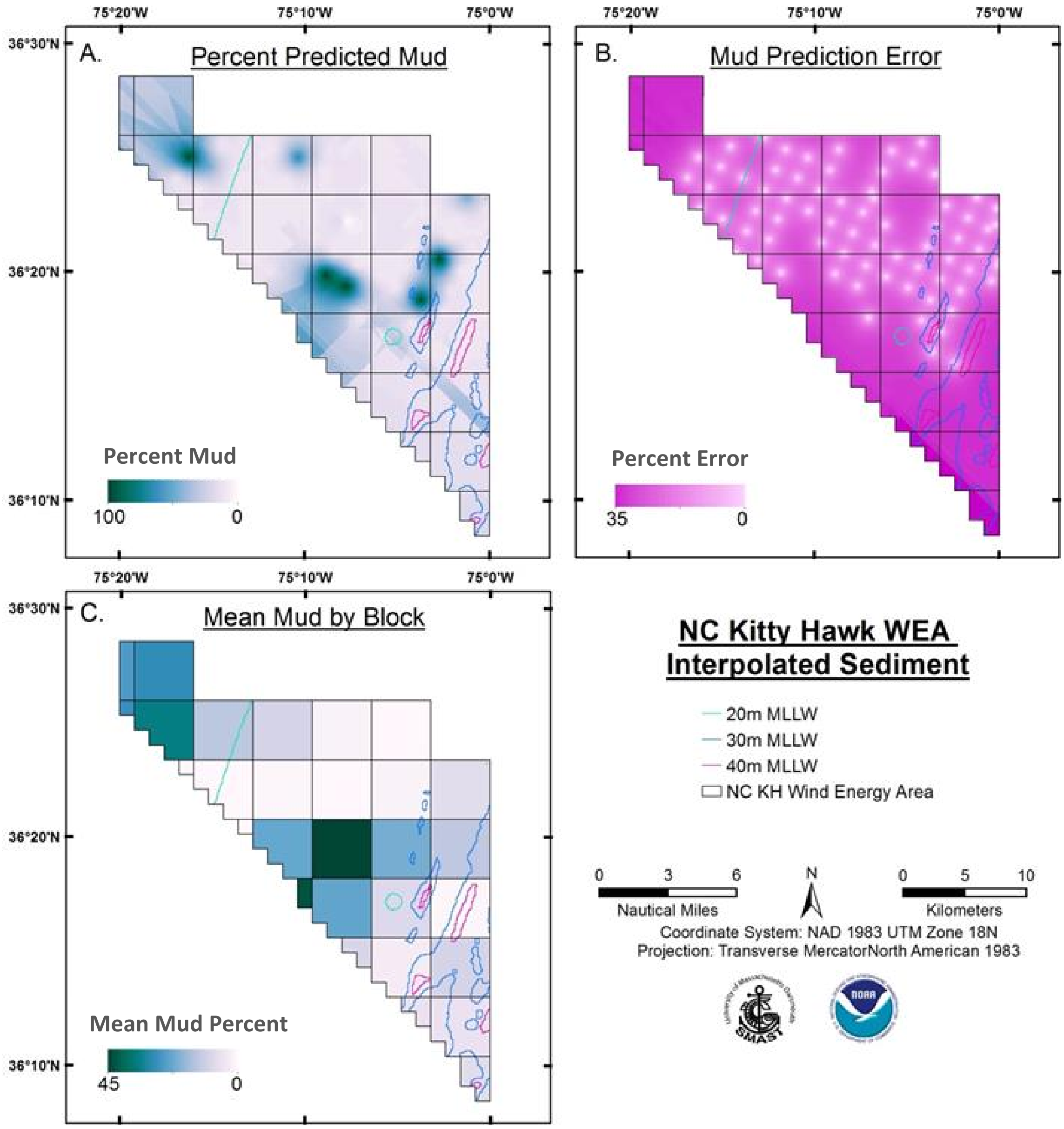


Figure 9-7. Predicted mud (silt + clay) distribution of surficial sediments in NC-KH WEA based on physical samples: A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data as in Figure 9-6.

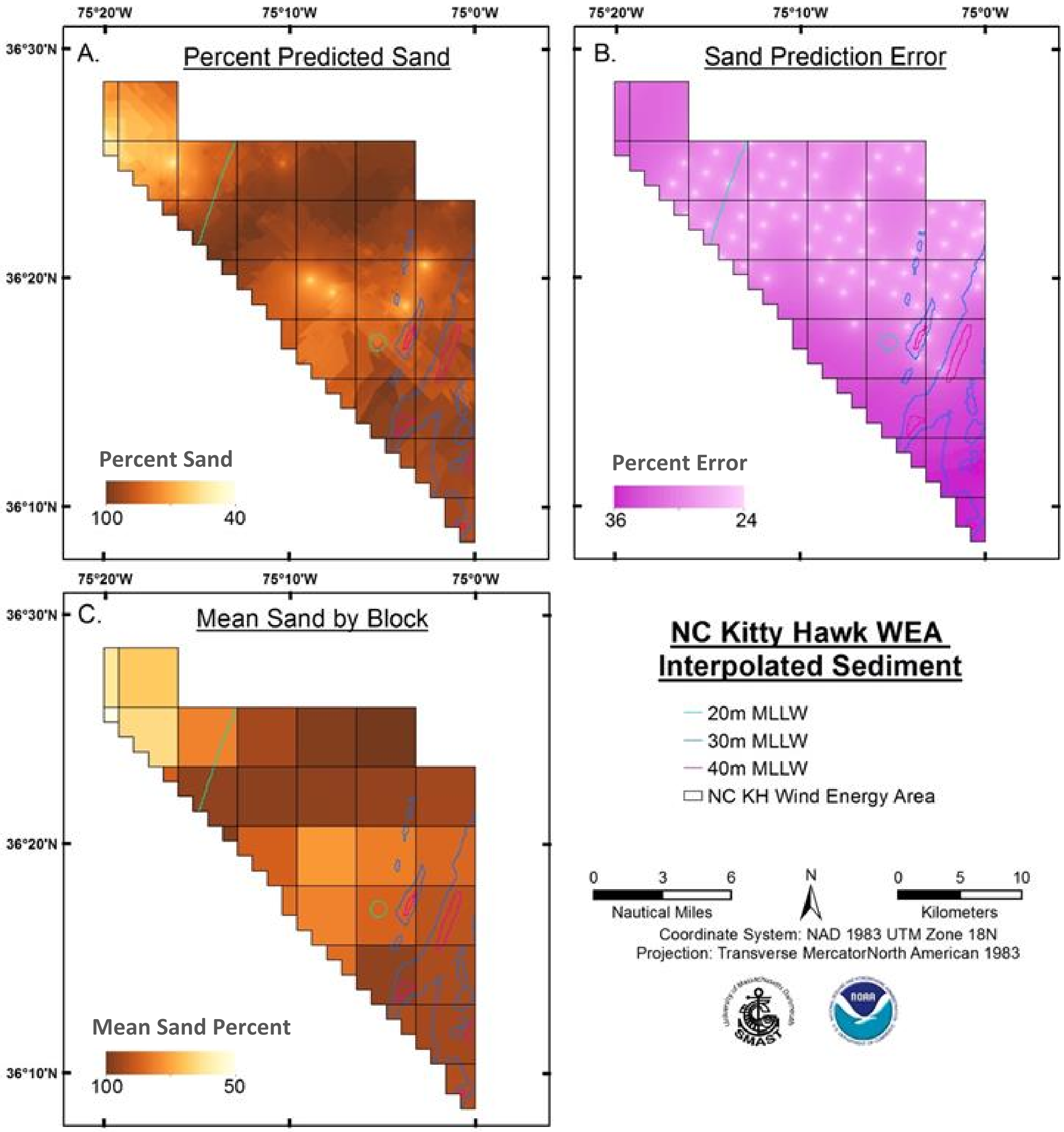


Figure 9-8. Predicted sand distribution of surficial sediments in NC-KH WEA based on physical samples: A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data as in Figure 9-6.

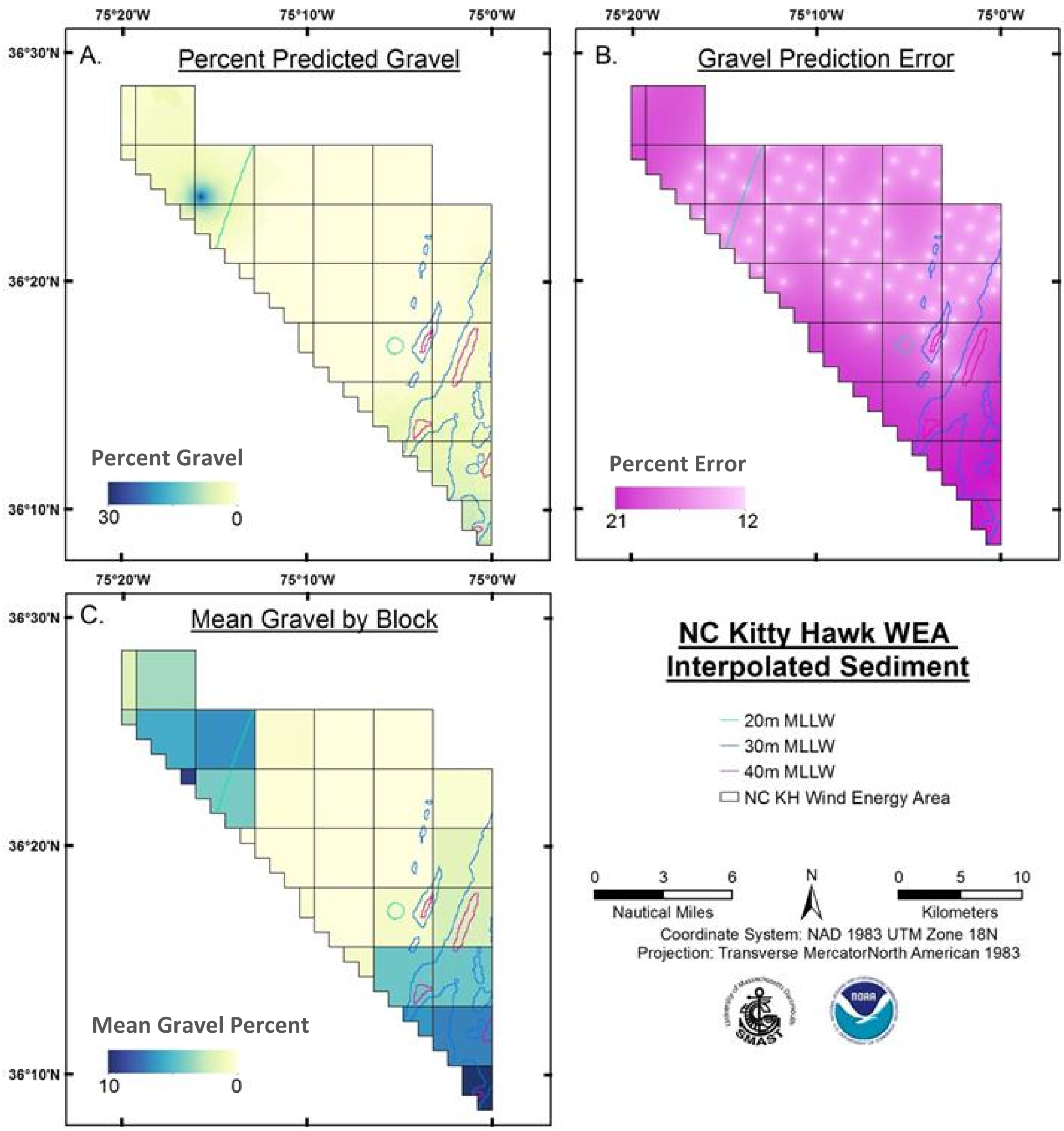


Figure 9-9. Predicted gravel distribution of surficial sediments in NC-KH WEA based on physical samples: A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data as in Figure 9-6.

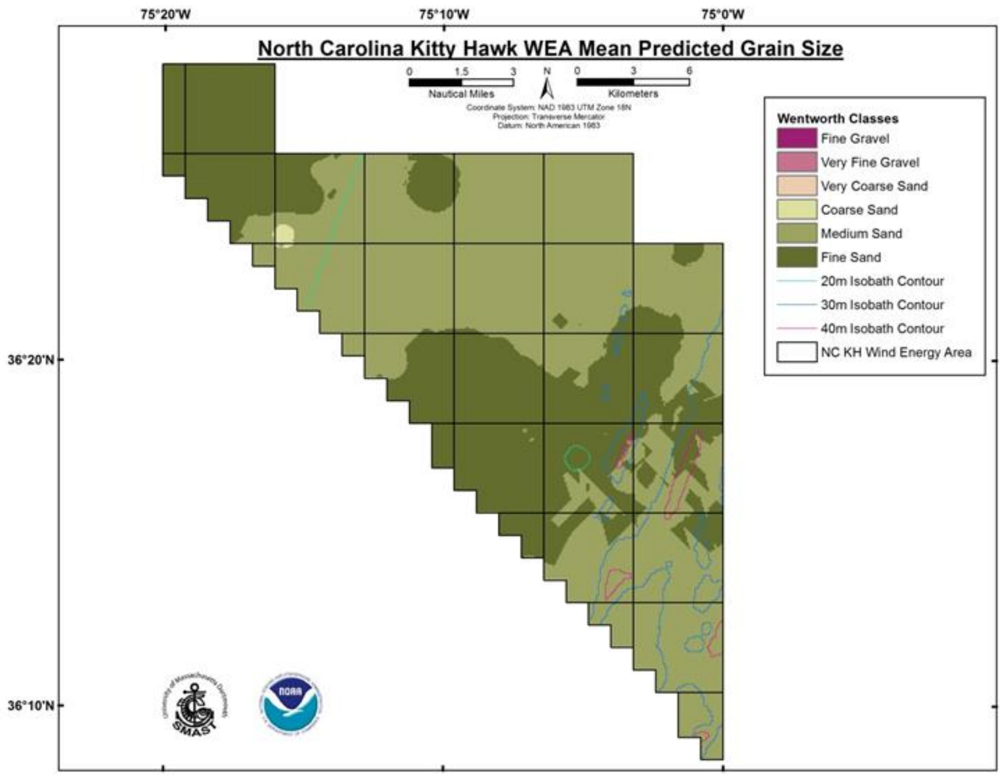


Figure 9-10. Predicted average sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the NC-KH WEA physical samples. Values represent interpolated average grain size distribution. Source data as in Figure 9-6.

Sediments in the NC-KH WEA are primarily sandy, but there are pockets of mud or sandy mud sediments, including in the north (blocks 6665-6666 and 6667) and in the center of the WEA (blocks 6768, 6769, and 6770). A single small gravel-dominated patch was found in the northwest (block 6666), and some gravelly sand in the southern tip of the WEA. Otherwise, coarse sand dominated most of the WEA. Without SMAST observations, no information was available on sand ripples or cobbles, boulders, or rock.

9.2.4 Physical/Chemical Variables: Hydrography

An NEFSC oceanographic database contains CTD records with full profiles of water column salinity and temperature at 1 m intervals gathered from various NEFSC cruises, including seasonal trawl surveys. Those from the period 2003-2016, corresponding to the chosen interval for presenting seasonal trawl data in this report (see section 1.4.5.1) are plotted by three-month intervals in Figure 9-11.

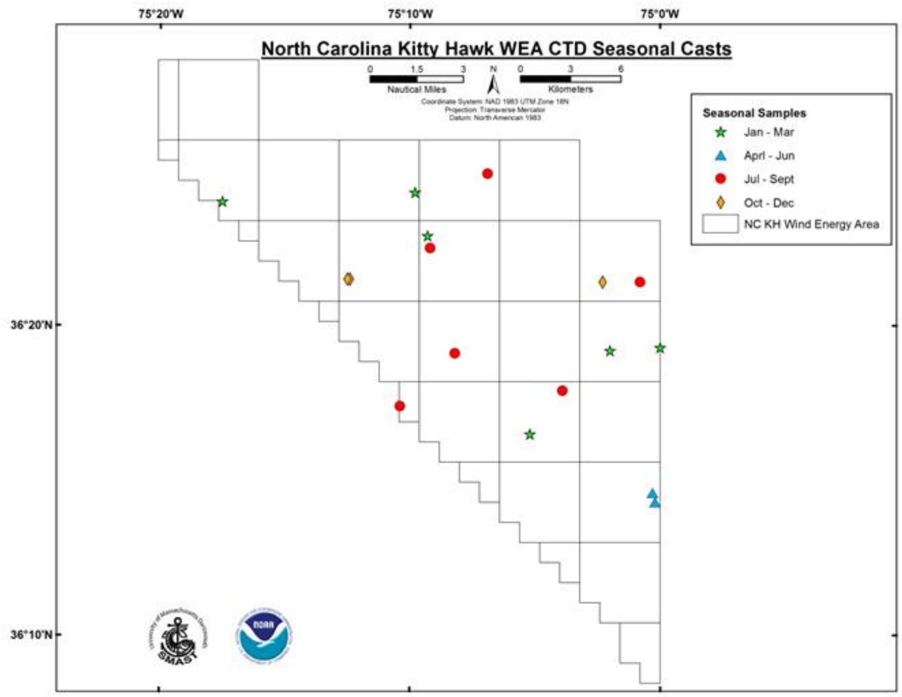


Figure 9-11. Locations for NEFSC CTD casts made between 2003 and 2016 in the NC-KH WEA.

Median salinity measured in the NC-KH WEA for this period, including all depths, was 33.432 g/kg, with a full range spanning 30.020 to 35.744 g/kg (n=1,090), despite strong seasonal changes in other parameters. This range is entirely within the euhaline range (Venice salinity classification system: Anon. 1958). While precise values within that range are critical for determining seawater density and water column structure, the small range of 5.72 units within the euhaline range is relatively unimportant as regards organismal physiology, and gradients or changes within this range probably play little if any role in habitat suitability for most coastal marine organisms.

On the other hand, water temperatures showed large changes that have important physiological and behavior consequences, e.g. inducing migrations, in addition to influencing seawater density and water column structure. Figure 9-12 presents surface and bottom temperatures from CTD casts shown in Figure 9-11 plotted against the day of the year in which they were taken. The general pattern seen in the model annual temperature cycle in Figure 1-2 is borne out in this plot specifically for the WEA. Seasonal fluctuation spanned as much as 20°C at the surface and 12°C at the bottom, with thermal stratification beginning in April and increasing into August, when maximum surface to bottom gradients reached up to 12°C. Then vertical turnover occurred in September or October, maximizing bottom temperatures, followed by a precipitous drop in temperatures of up to 10°C throughout the water column by the next January. Actual surface and bottom temperatures varied substantially from year to year, particularly during the fall turnover period, as did the date of that turnover event. Surface to bottom temperature gradients were invariably negative (warmer at the surface, cooler at the bottom) and often large in spring and summer (stratified condition), but usually nonexistent to positive and small following the fall turnover and during the winter (isothermal or nearly so). This temperature pattern is likely the major driver for seasonal migrations and re-distribution of highly mobile demersal nekton and mobile epibenthos and perhaps the settlement of new demersal and benthic organisms of all types from the plankton.

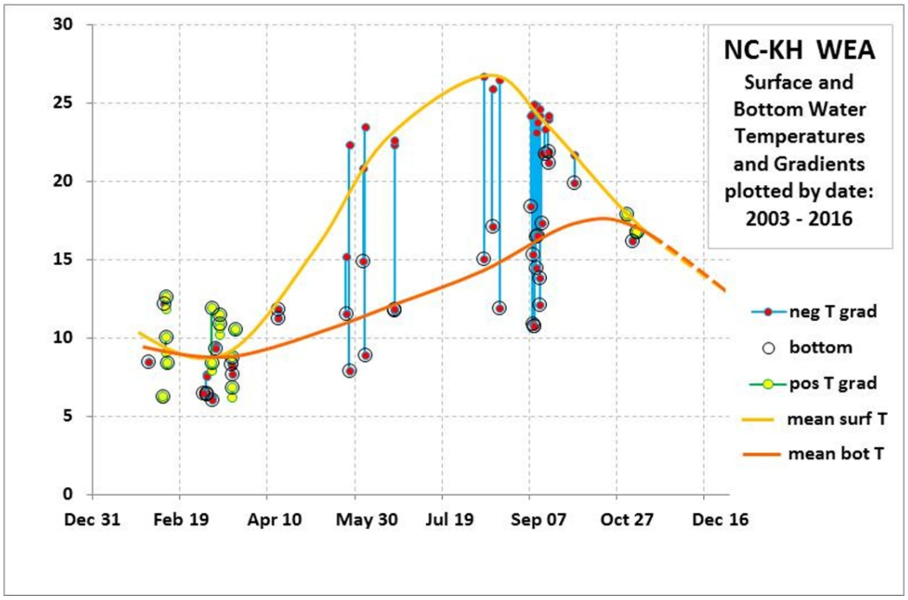


Figure 9-12. Water temperatures from CTD casts made between 2003 and 2016 in the NC-KH WEA. Red symbols with cyan lines indicate casts with negative temperature gradients (neg T grad) with depth: surface temperature (not circled) warmer than bottom (circled in black). Yellow symbols with green lines indicate casts with positive or no temperature gradients (pos T grad) with depth: surface temperature (not circled) cooler than bottom (circled in black). Annual trend lines for surface (gold) and bottom temperatures (orange) are based on segmented mean values. No data was available for mid-November through mid-January, so the shapes of trend lines for that period (dashed) are conjectural.

9.2.5 Biological Variables

9.2.5.1 Benthic Epifauna and Infauna

Benthic samples were collected during one NEFSC–sponsored cruise: HB15-05 (August 2015) in the NC-KH WEA. The cruise collected samples from 22 beam trawls and 21 grabs (Figure 9-13). Catches for these two types of collections taken in each of two seasons are illustrated in Figures 9-14.

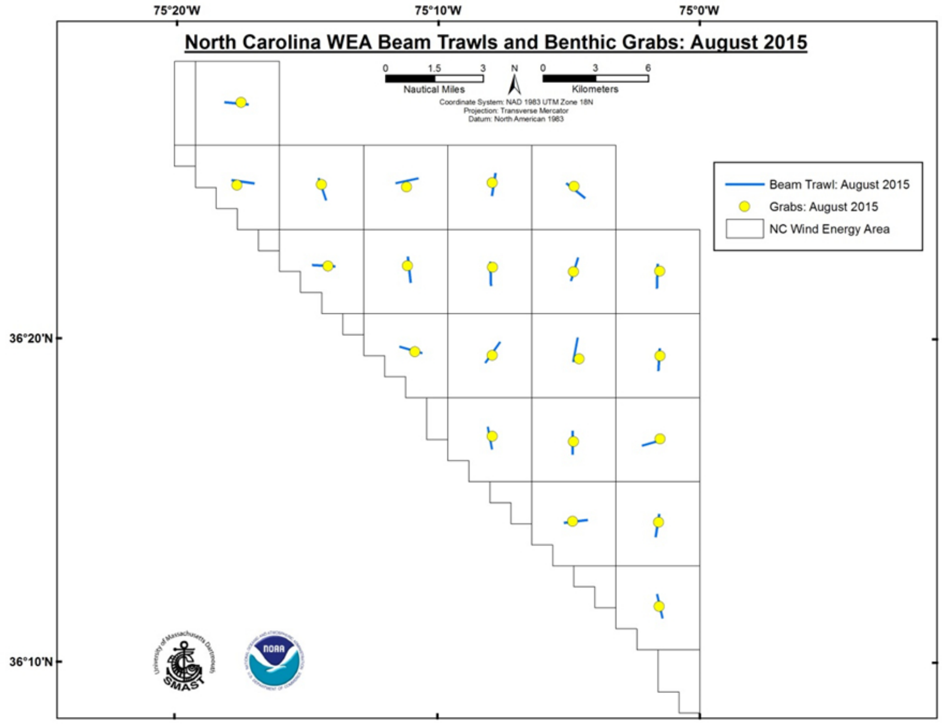
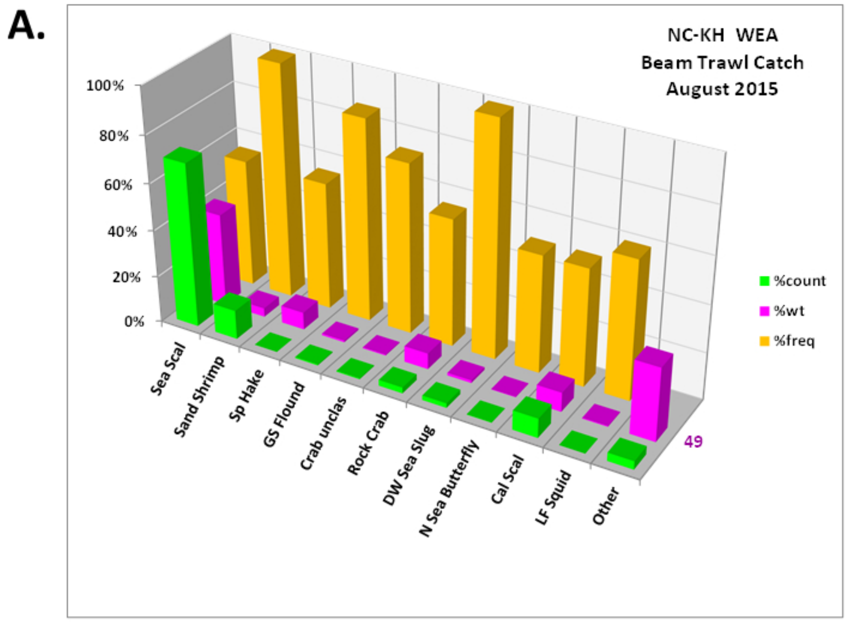


Figure 9-13. Locations of beam trawl and benthic grab samples made in the NC-KH WEA.



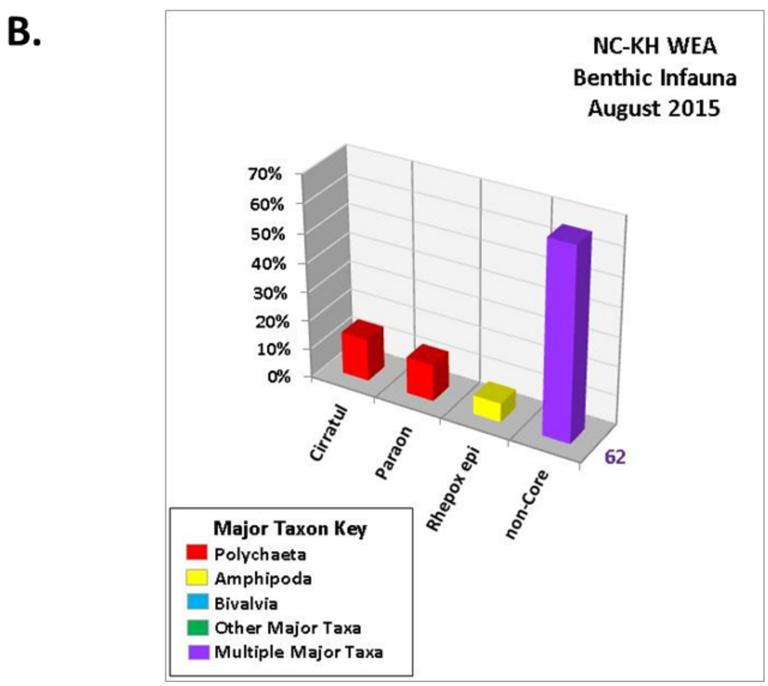


Figure 9-14. Benthic fauna caught in NC-KH WEA by NEFSC sampling . A. Beam trawl catches by percentage of total catch numbers, weights, and frequency within WEA; B. Grab sample catch by percentage of total catch numbers, color-coded by major taxonomic group. Abbreviated common names for taxa in A: Sea Scal – sea scallop, Sp Hake – spotted hake, GS Flound – Gulf Stream flounder, Crab unclas – unclassified crabs, DW Sea Slug – dwarf warty sea slug, N Sea Butterfly – naked sea butterfly, Cal Scal – calico scallop, LF Squid – longfin squid. Abbreviated taxonomic names in B: Cirratul – Cirratulidae, Paraon – Paraonidae, Rhepox epi – *Rhepoxynius epistomus*. Numbers to the right of the “other” and “non-core” taxa bars represent additional taxa in samples not displayed individually among the bars. See section 1.3.4 for explanation of “other” and “non-core” species.

NEFSC beam trawl catches and the contents (59 taxa) of the benthic grab samples (65 taxa) are summarized in Figure 9-14A. Among the epibenthic fauna as obtained in beam trawls, sea scallops were the only dominant as defined in section 1.3.4, although sand shrimp and calico scallops were not far from meeting the criteria. Other epibenthic taxa were typical of sandy bottoms. The benthic infauna (Figure 9-14B) was dominated by polychaetes, but few were core species, i.e. few occurred at 80% or more of grab sample stations. Over 60% of taxa were non-core, i.e. not occurring in 80% of the samples, suggesting a lot of variation (or diversity) among that fauna here, unlike the situation in some other WEAs.

9.2.5.2 NEFSC Seasonal Trawl Survey

The locations of seasonal trawls in the NEFSC seasonal trawl survey between 2003 and 2016 are illustrated in Figure 9-15. Importance values among taxa captured in NEFSC Seasonal Trawl Survey catches in the NC-KH WEA are plotted in Figure 9-16 and Table 9-1, with seasonally dominant species listed in Table 9-2. NEFSC seasonal trawls were relatively few due to the small size of this WEA.

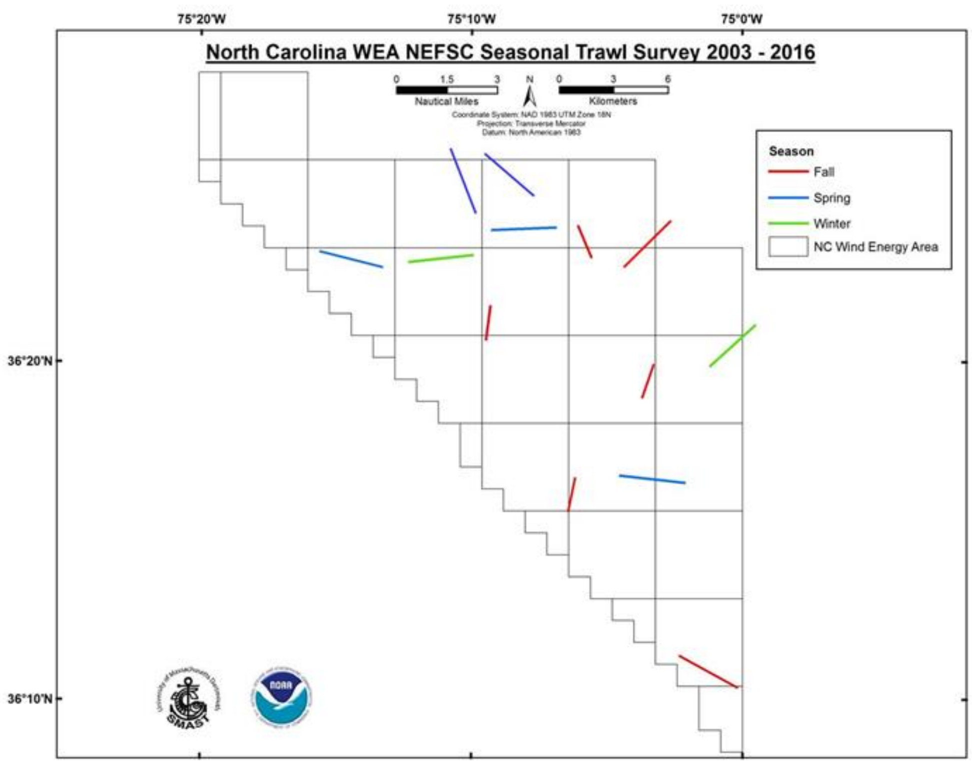


Figure 9-15. Locations of NEFSC seasonal trawls from 2003 to 2016 in the NC-KH WEA.

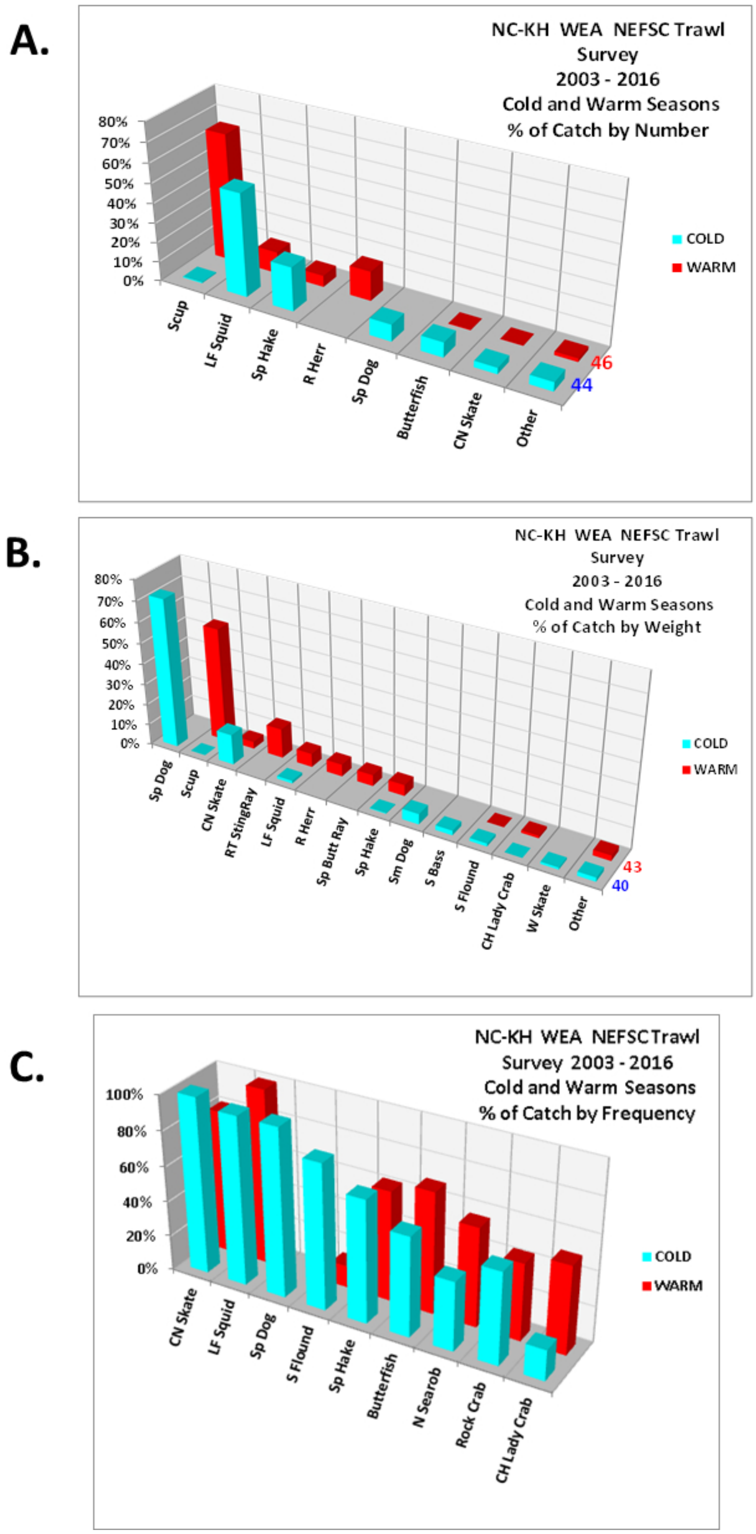


Figure 9-16. Importance of taxa in NEFSC Seasonal Trawl Survey catches between 2003 and 2016 in cold and warm seasons A. by number, B. by weight, and C. by frequency in catches. Taxon abbreviations for this figure appear in Table 8-1. Blue and red numbers along the right margin of the graphs indicate the numbers of "other" species in cold and warm season catches respectively.

Table 9-1. Abbreviations for taxon names used in Figure 9-17, with footnotes on fishery management authority for managed species.

abbrev	common name	abbrev	common name
Rock Crab	Atlantic rock crab	Scup	scup[3]
Butterfish	butterfish[3]	Sm Dog	smooth dogfish[5]
CN Skate	clearnose skate[2]	Sp Butt Ray	spiny butterfly ray
CH Lady Crab	coarsehand lady crab	Sp Dog	spiny dogfish[4]
LF Squid	longfin squid[3]	Sp Hake	spotted hake
N Searob	northern searobin	S Bass	striped bass[1]
RT StingRay	roughtail stingray	S Flound	summer flounder[3]
R Herr	round herring	W Skate	winter skate[2]

Fishery management authority notes:

[1]states under Atlantic States Marine Fisheries Commission (ASMFC)
[2]New England Fishery Management Council (NEFMC)
[3]Mid Atlantic Fishery Management Council (MAFMC)
[4]Jointly by NEFMC and MAFMC
[5]National Marine Fisheries Service, Highly Migratory Species Division

Table 9-2. Dominant species in NEFSC Seasonal Trawl Survey catches within the NC-KH WEA between 2003 and 2016.

North Carolina-Kitty Hawk WEA Dominants	
Cold Season	Warm Season
Clearnose Skate	Longfin Squid
Longfin Squid	Spotted Hake
Spiny Dogfish	

It is evident from this survey trawl data that this is a moderately taxon-rich area: 52 taxa in the warm season and 50 in the cold season, 78 overall. It is also evident that while there is considerable overlap in the lists of taxa present in the two seasons, the distributions of biomass, numbers, and frequency of catch for the two seasons are quite different. There is also considerable overlap among species present and dominance with other WEAs, especially VA (section 8.2.5.2). Of the taxa that are important in terms of numbers, biomass, and/or frequency (Table 9-1) 56% (9 out of 16) are species that are managed in the northeast region. Only one taxon was dominant in both seasons: longfin squid (Table 9-2). This differs from the situation in other WEAs, where this squid is dominant in the warm season, but absent or nearly so in the cold season. It appears that this species may be resident here rather than being a warm-season migrant, as it is in other WEAs. It is also notable that 75% of the species in Table 9-1 represent managed fishery species.

9.2.5.3 Species of Concern

Records of shellfish species of concern in the NC-KH WEA are illustrated in Figure 9-17. These include quantitative records of sea scallops from NEFSC seasonal trawl surveys and qualitative records from beam trawls, bottom grabs, and bottom imagery. Although not common or numerous in NEFSC trawl survey records and absent from our grab samples, sea scallops were clearly widespread and abundant, even dominant, in beam trawls from this WEA (Figure 9-14A), with no clear pattern in relation to depth as in other WEAs. Between 12 beam trawls over 91,000 were caught; all of them in the range of 5-20 mm shell diameter: likely all young-of-the-year based on size and known growth rates (Hart and Chute 2004). It is questionable whether they would survive the warming of bottom waters with the fall turnover based on known data on their temperature tolerance and the historical pattern of annual bottom temperatures in this WEA (Figure 9-12). Current sea scallop EFH intersects this WEA only slightly on its northeast corner (Figure 1-7).

Ocean quahogs were found in one grab samples from the northeast corner of NC-KH WEA, although ocean quahog EFH does not intersect this WEA (Figure 1-8). Surfclam EFH overlaps this WEA completely (Figure 1-9), and surfclams were indeed widespread in beam trawl samples (Figure 9-17).

Another shellfish species encountered exclusively in August beam trawl samples was the calico scallop, *Argopecten gibbus*. About 11,000 juveniles, ranging 5-45 mm shell diameter were caught between 11 sites in the WEA. This mollusk has no fisheries status in the northeast region, but is fished commercially in the southeast. That fishery, however, is notoriously variable, subject to “boom and bust” cycles. If it became established locally and began to support a viable fishery, there may be of some concern as regards to habitat, but with no status and no known fishery in the northeast at this time, they are not a management issue.

No longfin squid egg mops were captured in the NC-KH WEA in August 2015. There is no overlap of the WEA with the longfin squid egg mop EFH zone (Figure 1-10).

Surfclams are probably the largest concern with regard to disturbance of shellfish in this WEA. Sea scallops are present, but this is probably a marginal habitat area for them.

No Atlantic cod were caught in the NC-KH WEA between 2003 and 2016. Juvenile and adult cod EFH zones are far removed from this WEA (Figure 1-11).

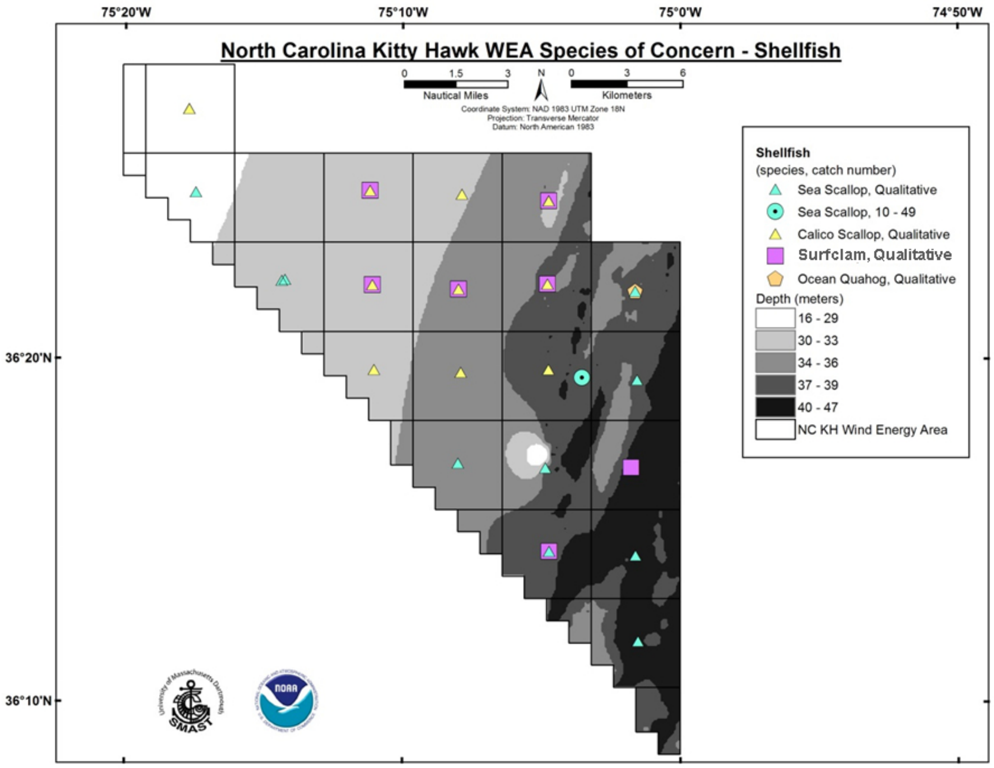


Figure 9-17. Shellfish species of concern records within and near the NC-KH WEA.

Both young-of-the-year (YOY) and sub-adult to adult-sized black sea bass (BSB) were detected in the NC-KH WEA (Figure 9-18), in NEFSC trawl survey records, but in small numbers and a diffuse pattern. No mussels, corals, sponges, or other structure-forming fauna were encountered here. Black sea bass and their habitats, however, need to be considered with respect to possible impacts in this WEA.

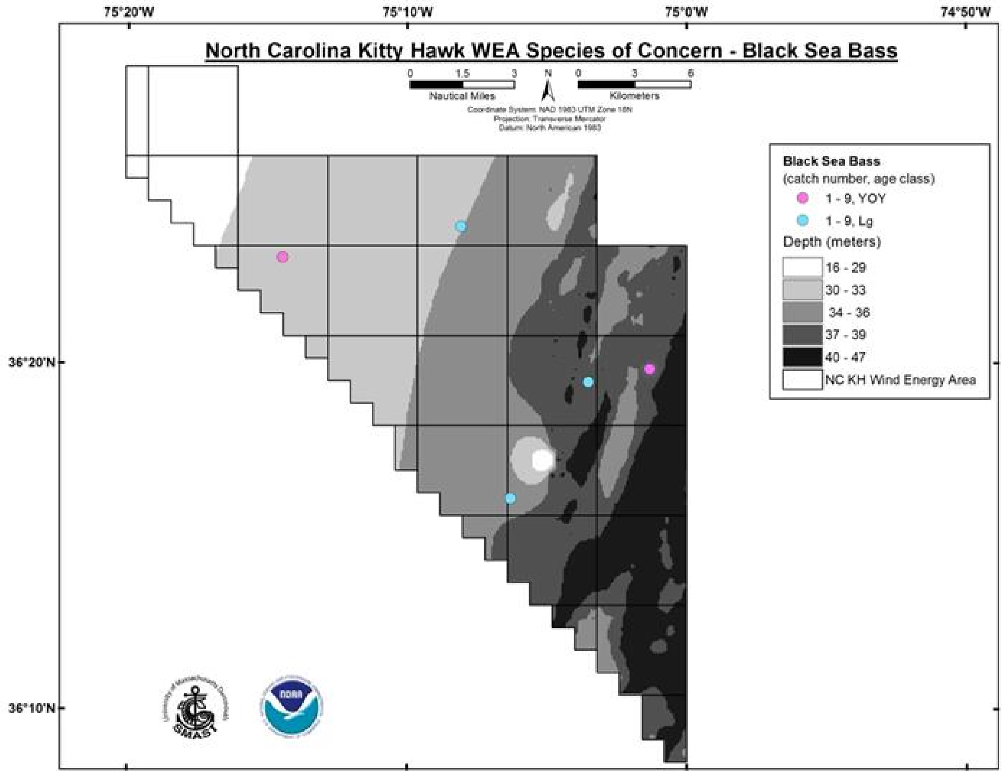


Figure 9-18. Records of young-of-the-year (YOY) and larger black sea bass in the NC-KH WEA.

9.3 NC-KH WEA Habitat Definition

An integrated view of the physical benthic habitat features in the NC-KH WEA is presented in Figure 8-19. There are two major topographic zones (Topo Zones 1,2) with habitat features (mud to muddy patches and knob) superimposed upon it in various locations. As far as we have determined with the data at hand, the sediments and fauna of these features are not notably different from those of the surrounding shelf.

Topo Zone 1 is a featureless flat area sloping gently seaward and covering the western two-thirds of the NC-KH WEA. It does not appear to correspond well with any CMECS-defined geoform, so we have characterized it as a fan for lack of a better term. Fans are flat, sloping surfaces of loose material carried by a flow of water from a narrower or steeper gradient into a broader area. Unfortunately, there are no obvious sources of sediment nearby to account for such a deposition. NCEI data for this area and the region immediately to the west of the WEA show depth contour lines that are very smoothly curved, lacking any irregularities, while the region to the east, including Topo Zone 2 (Figures 8-4 and 8-5) and the region to the south of the WEA have far more complex contours and clear megaripple patterns. We believe that the apparent smoothness of Topo Zone 1 stems from the age of the data on which the 3 arc second grid is based in this zone: 1930s and pre-acoustic. Surveys to the west and south are much more recent. It is likely that the N-S trending megaripples of Topo Zone 2 and the area south of the WEA actually continue across Topo Zone 1, but without more modern high resolution mapping we cannot say for sure. Thus we have two contrasting topo zones in the WEA.

The large muddy sand to mud patches in the WEA are topographically similar to the surrounding sandy zones and there is not a clear distinction of their fauna based on the available data.

The anomalous round hillock (section 8.2.1 and Figure 8-3) is termed a “knob” in CMECS terminology. It is located in lease block 6819 and its origin and sediment composition are unknown, although a USseabed sample along its southeastern margin (Figure 8-6) yielded slightly muddy sand similar to other nearby samples.

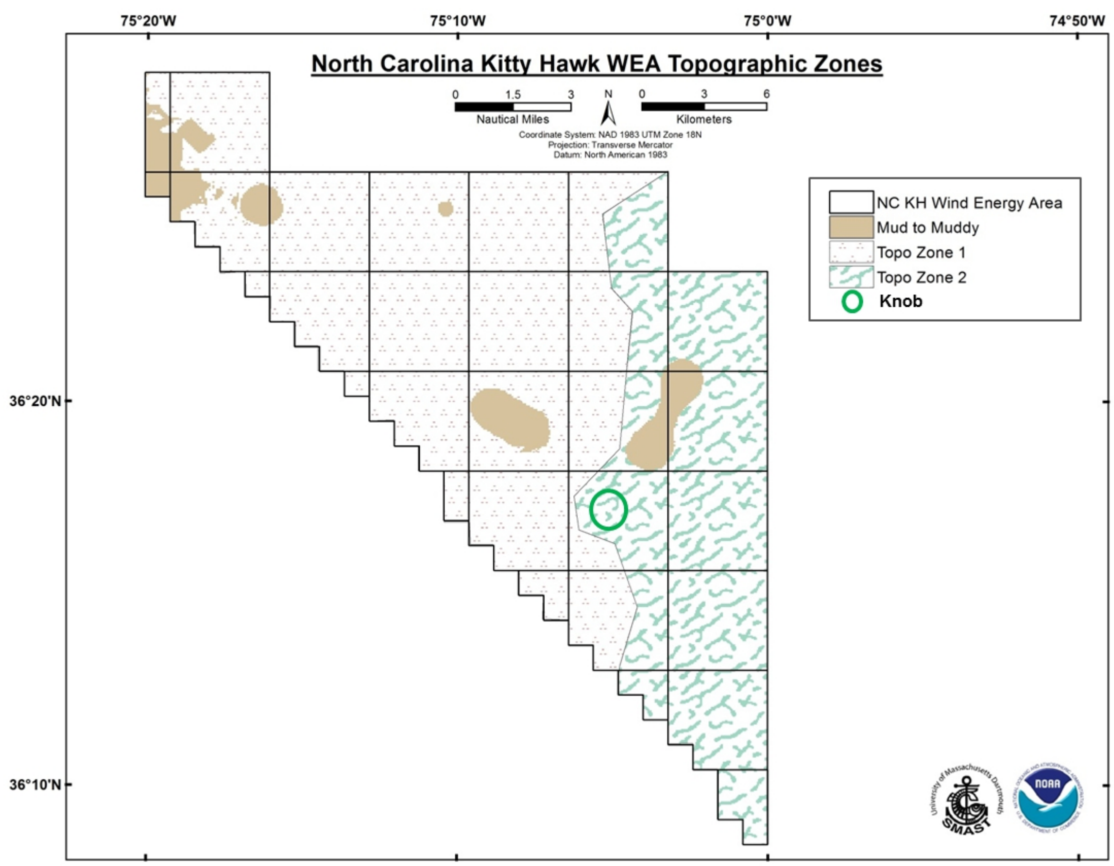


Figure 9-19. Physical benthic habitat features of the NC-KH WEA

9.3.1 CMECS Classifications

Topo Zone 1

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Fan, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Sand, Muddy Sand Mud
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Clam Bed (*Spisula*), Scallop Bed (*Argopecten*)

Topo Zone 2

- Geoform Component
  - Geoform Origin: Geologic
    - Geoform: Megaripples, Level 1
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Gravelly Sand, Sand, Muddy Sand Mud
- Biotic Component
  - Biotic Class: Faunal Bed
    - Biotic Subclass: Soft Sediment Fauna
      - Biotic Groups: Larger Deep-Burrowing Fauna, Small Surface-Burrowing Fauna, Clam Bed (*Spisula*), Scallop Bed (*Placopecten*)

Mud to Muddy Patches

- Geoform and Biotic Components: same as in Topo Zones 1 & 2, depending on location
- Substrate Component
  - Substrate Origin: Geological Substrate
    - Substrate Class: Unconsolidated Mineral Substrate
      - Substrate Subclass: Fine Unconsolidated Substrate
        - Substrate Groups: Mud, Muddy Sand

Knob

Geoform Component

Geoform Origin: Geologic

Geoform: Knob

Substrate Component

Substrate Origin: unknown

Biotic Component

Biotic Class: unknown

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