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Report on Benthic Habitats in the Maryland Wind Energy Area

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This document and attachments constitutes the first report to the U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM) on the progress of investigations in the BOEM Wind Energy Areas (WEAs) in coastal ocean waters of the northeast region of the United States in fulfillment of a funded obligation under Interagency Agreement M13PG00019/02. This report deals with the first WEA investigated: the Maryland WEA (MD WEA).

ASSESSMENT OF BENTHIC HABITATS IN ATLANTIC OCS WIND ENEREGY AREAS: MARYLAND WIND ENERGY AREA REPORT

EXECUTIVE SUMMARY

Background:

The U.S Department of Interior, Bureau of Ocean Energy Management (BOEM) has designated eight Wind Energy Areas (WEA) along the Northwest Atlantic Outer Continental Shelf (OCS) from Massachusetts to North Carolina, encompassing >3056 square nautical miles of seafloor as potential lease sites 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 ocean 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), is developing 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 deployment. From new and existing data sources, NOAA NEFSC will establish 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 will characterize 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 the proposed WEA off of Maryland, as well as a comparison of methods used, to date.

Conclusions Regarding the MD WEA:

The Maryland WEA area is relatively flat, sloping gently from west to east, and is heavily dominated by sandy substrates. The overlying watercolumn is also relatively uniform across its horizontal extent, with no evidence of sharp changes in physical oceanographic properties (e.g. no strong fronts). However, there are small variations in the topography throughout the WEA, likley reflecting pervailing current patterns and affecting the distribution of benthic fauna. For example, a flat pocket of fine-grained mud characterizes the center of the WEA (e.g. half of block 6724 and minor parts of 6674, 6624,6724), suggesting an area of reduced current. Meanwhile more dynamic "sand-ripple" and gravel-cobble dominated "irregular" bottom characterize the southern and northern WEA, respectively. In general, benthic epifaunal species composition was similar throughout the Maryland WEA, with no managed species stocks identified in our sampling within the WEA aside from juvenile surf clams, sea scallops, and

ocean quahogs. Historic data suggests the presence of 16 federally-managed species in the WEA, of which 11 are bottom-dwelling, although most are not associated with very specific types of benthic habitats. Black sea bass represent an exception to the lack of habitat specificity among stocks detected in the WEA. They specifically require complex (usually rocky) habitats for shelter, although little of this kind of feature was observed by us.

Among those species actually encountered in our sampling (including non-managed species), there appeared to be at least a weak association of some taxa with specific types of benthic habitats. Areas of gravel-cobble dominated bottom and irregular topography, including rock, unidentified, and hermit crabs, as well as solitary anemones and sea robins. Gravelly bottoms (gravelly sand and sandy gravel) also showed a tendancy to support more numerous and diverse annelid-dominated infauna.

Topography was the most obvious basis for habitat classificaiton within the WEA, and future analyses and modeling will confirm such assocations. A classification scheme is proposed under the NOAA Coastal and Marine Ecological Classification System (CMECS) and potential impacts on Essential Fish Habitat (EFH) are discussed.

Conclusions Regarding Sampling and Data Sources for Use with Succeeding WEAs:

Definition of topography and terrain metrics was critical in trying to define habitat areas in the MD WEA. In particular, high resolution (2m horizontal) from multibeam sonar coverage was essential in defining major topographic regimes within the WEA, and microtopography (cm scale) from side scan sonar and visual sampling were important to help assess the influence of currents on the habitats. This kind of data will also be needed for analysis of succeeding WEAs.

Regarding sediment characterization, in the absence of multibeam backscatter, we used kriging of existing USGS and project-collected data from physical samples plus visual analysis from HabCam IV, and the SMAST camera pyramid imagery. We seek backscatter data where available in other WEAs, and utilize data on analysis of physical samples and visual imagery as ground-truthing tools (preferred alternative). Where backscatter data or other extensive acoustic coverage (e.g. side scan sonar) is not available, it will again be necessary to rely on kriging new and historic grain size analyses and visual imagery to define sediment characteristics. While HabCam imagery has some scale advantages, we plan to utilize SMAST data only in subsequent WEA analysis, as most of those areas have already been covered by that method.

Benthic faunas were assessed through a combination of historic large net (NEFSC survey) catches for highly mobile megafauna, small net (beam trawl) for smaller megafauna, and grab samples for infauna. This combination provided a relatively complete view of benthic communities, including managed fisheries species and the background living epifaunal and infaunal communities that support them. We anticipate employing the same set of datasets for other WEAs.

CMECS classifications will continue to be utilized as a tool for standardized description of benthic habitats, and the overlap of stock EFH will be noted.

ACKNOWLEDGEMENTS

We wish to thank the U.S. Department of Interior, Bureau of Ocean Energy Management for making this work possible both by their generous funding of the NEFSC Wind Energy Benthic Habitat project and by their aid in coordinating with other agencies to obtain needed data. We wish to thank Richard Langton and Jennifer Samson of NEFSC for their foresight in conceiving this project and their efforts to obtain the funding and organizing the J.J. Howard project team. We also thank Captain Monty Hawkins for providing reef data and early discussions that helped us formulate this study. We are grateful to Emily Tewes of the University of Maryland Eastern Shore for making available sediment data from her thesis work. We thank the captains and crew that supported our work on the NOAA vessels *Resolute* and *Gordon Gunter*, the R/V *Sharp* and Prof. Bradley Stevens and the students of the University of Maryland, Living Marine Resources Cooperative Science Center (LMRCS) for their assistance with sediment and grab samples. We would also like to thank Linda Stehlik for her expertise opinion and help with fish and crab identifications. We gratefully acknowledge Barry and Chris Shafer for their professional expertise and significant contribution of sediment and benthic infaunal analyses and photo annotations, as well as guidance during early discussions formulating this report. We also acknowledge the late Joseph Vitaliano, David Dowds, and Shannon Pace for their advice and efforts with image, benthic sample, and data analyses and preparing this report.

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New Jersey Wind Energy Area

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Virginia Wind Energy Area

Kitty Hawk, North Carolina Wind Energy Area

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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
NEFSC	NorthEast Fisheries Science Center
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
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

1.0 Introduction

Great interest exists nationwide in the development of renewable energies. Under the Energy Policy Act of 2005 (EPAct), The U.S. Department of Interior, Bureau of Ocean Energy Management (BOEM) has been tasked with the responsibility 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 agencies, state, and local governments to ensure that renewable energy development proceeds in a safe and environmentally responsible manner. In this capacity, BOEM is currently overseeing development plans and environmental analyses for commercial wind facilities within eight proposed Wind Energy Areas (WEA) in the Atlantic OCS, from Massachusetts to North Carolina. As a collaborating agency, The U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) Fisheries is responsible for the stewardship of the nation's living marine resources and their habitats, and for ensuring productive sustainable fisheries, for safe sources of seafood, for the recovery and conservation of protected resources, and for healthy ecosystems, backed by sound science and an ecosystem-based approach to management. The NOAA Fisheries Northeast Fisheries Science Center, in particular, conducts ecosystem-based research and assessments of living marine resources, with a focus on the Northeast Shelf (North Carolina to the Canadian border), 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 2014a). The NOAA Northeast Fisheries Science Center (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 2014). 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 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 (UMD) 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 WEA's. NOAA Fisheries 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 be insufficient to meet the requirements established by BOEM for evaluating potential wind energy impacts. For this reason we have proposed to survey 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 not only biological, chemical, physical oceanographic, but also geological (i.e. sediments) and geographic (i.e. terrain) conditions. Indeed, diverse studies have shown that certain species have affinities for certain types of bottom, such as hard-bottom for reef species (i.e. corals) (Wilson et al. 2007, Pitman and Brown 2011, Kostylev 2013, Cameron et al. 2014, Guinotte and Davies 2014). It is generally acknowledged that most of the northeast shelf benthic habitat is dominated by sandy habitats (Stevenson et al. 2006), however natural hard bottom reef areas are known to be scattered across the OCS (Steimle and Zetlin 2000). It has also recently become evident that the small size and diffuse distribution of these has caused them to be overlooked by habitat science despite the knowledge of them among fishermen. 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 hard bottom communities.

1.1 Overall 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 we have proposed to assemble existing data, collect additional data where needed from the Atlantic WEAs north of Cape Hatteras, and assemble 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 Overall Project Objectives

This project tasks are: 1) to acquire data from existing sources and field sampling within each Wind Energy Area (WEA) to characterize important environmental, biological and ecological features of the OCS and 2) to assemble all data layers into a Geographic Information System (GIS) to be available for future benthic habitat analyses and assessment. In particular, the second task is broken down into three phases that will 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 1 of our study focuses on characterizing the abiotic components of the benthic environments within the specified WEAs, while Phase 2 focuses on the biotic components. Phase 3 utilizes physical, biological and chemical data to conduct ecosystem-level assessments and support cumulative impact analyses. This report addresses the first two phases of the work for the Maryland WEA. A subsequent report will deal with these same phases for the remaining WEAs and Phase 3. Sampling in support of Phases 1 and 2 will employ bottom imagery, acoustic mapping and sediment grab samples within BOEM Atlantic OCS WEAs. This will provide a basis from which habitat types and extents could be interpolated to provide projections for potential impacts to those habitats (Phase 3) from construction and operation of offshore renewable energy facilities.

This project utilizes the framework presented in the Coastal and Marine Ecological Characterization Standard (CMECS) for habitat classification. This scheme is the recently adopted 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 proposed 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.

1.3 Overall Project Location

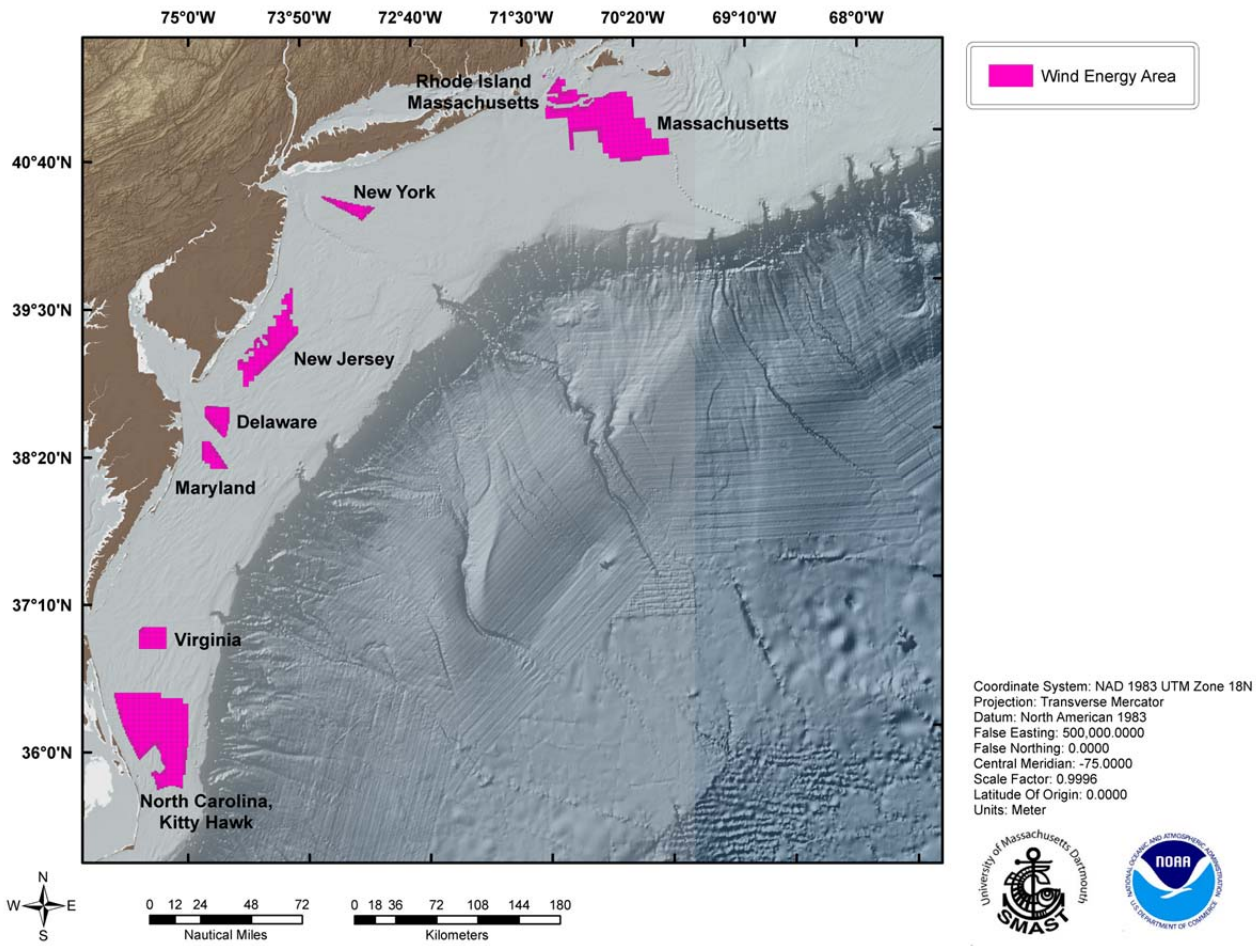
The BOEM Atlantic WEAs are located along the Atlantic coast from Massachusetts to North Carolina and encompass over 2.62 million acres (>10,600 km^2) of ocean floor (Table 1-1, Figure 1-1). A benthic assessment will be done for each wind energy area listed in Table 1-1. This report focuses only on the Maryland WEA assessment.

Table 1-1. Total acreage of the eight WEAs found in the Atlantic OCS found in the NMFS Northeast Region. Source data:(BOEM 2014b).

Wind Energy Area	Approximate Area (acres)
Massachusetts WEA	826,241
Rhode Island / Massachusetts Lease Areas	164,750
New York Proposed Lease Area	81,500
New Jersey Call Area / WEA	354,408
Delaware Commercial Lease Area	103,323
Maryland Call Area (North & South) / WEA	*79,707**
Virginia Commercial Lease Area	138,788
North Carolina Call Area (Kitty Hawk)	877,836
TOTAL	2,626,553

*subject of this report

Figure 1-1. BOEM Outer continental shelf wind energy areas. Source data: (BOEM 2013, GEBCO 2010, NOAA, NGDC 2014).



2.0 Maryland Wind Energy Area

2.1 Project Setting

2.1.1 Northeast Continental Shelf, Mid-Atlantic Bight

The Mid-Atlantic Bight (MAB) Continental Shelf extends from southern New England to Cape Hatteras, North Carolina and owes its 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, melted, and refroze. 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 shape of the Continental Shelf in the Mid-Atlantic Bight (MAB) region gradually narrows (150km – 30km) from north to south, resulting in the convergence of the Mid-Atlantic and South Atlantic Bight water masses. 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, which have cut v-shaped canyons into the outer shelf from their outflows that funnel nutrient-rich water to the ocean abyss (Church et al. 1984). Due to the constant replenishment of surficial sediments from the river systems, continuous reworking of surficial sediments from 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).

2.1.2 Project Goal and Objectives

The goal of this study was to characterize the Maryland Wind Energy Area (MD WEA) benthic environment with respect to its habitat characteristics: bathymetric features, sediment composition and biological communities. This was done by means of collecting, compiling, and updating baseline data using high-resolution imagery, grab samples, and bathymetric maps in order to delineate important offshore fishery habitats in the Maryland WEA (MD WEA).

Objectives used to reach this goal were to 1) find and acquire existing data for the MD WEA, 2) perform field work to acquire new data, 3) develop the database and analysis tools needed to assemble and analyze the WEA data with regard to benthic habitats and the resources that they support, and 4) compare and evaluate various sources of habitat data for use in succeeding WEA investigations. This includes a comparison of substrate evaluation methods, the utility of NEFSC biological surveys and fisheries acoustics, and a comparison of HabCam and the SMAST camera pyramid as tools for obtaining visual ground truth data. This report to BOEM covers only the MD WEA, for which field work was completed in 2013. A subsequent report will cover the other WEAs.

2.2 Methods

2.2.1 Project Location and Data Sources

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).
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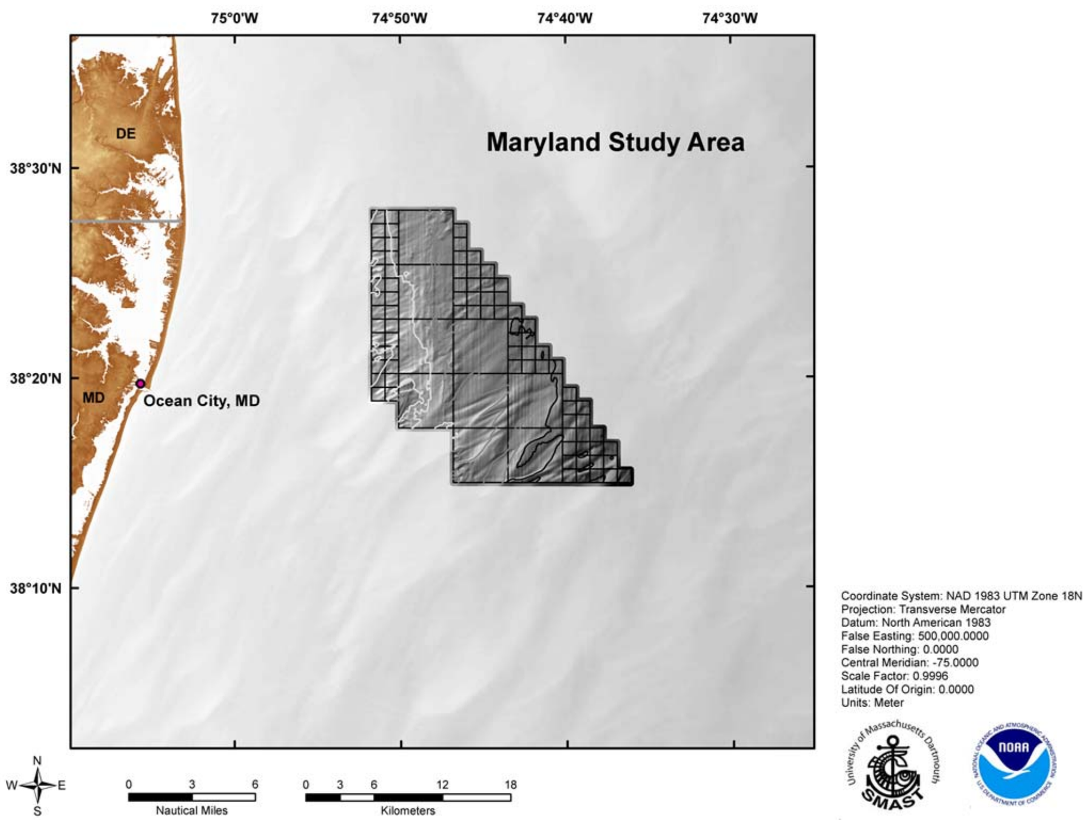


Figure 2-1. Map of Maryland study area. Source data:(CB&I 2014, NOAA, NGDC 2014).

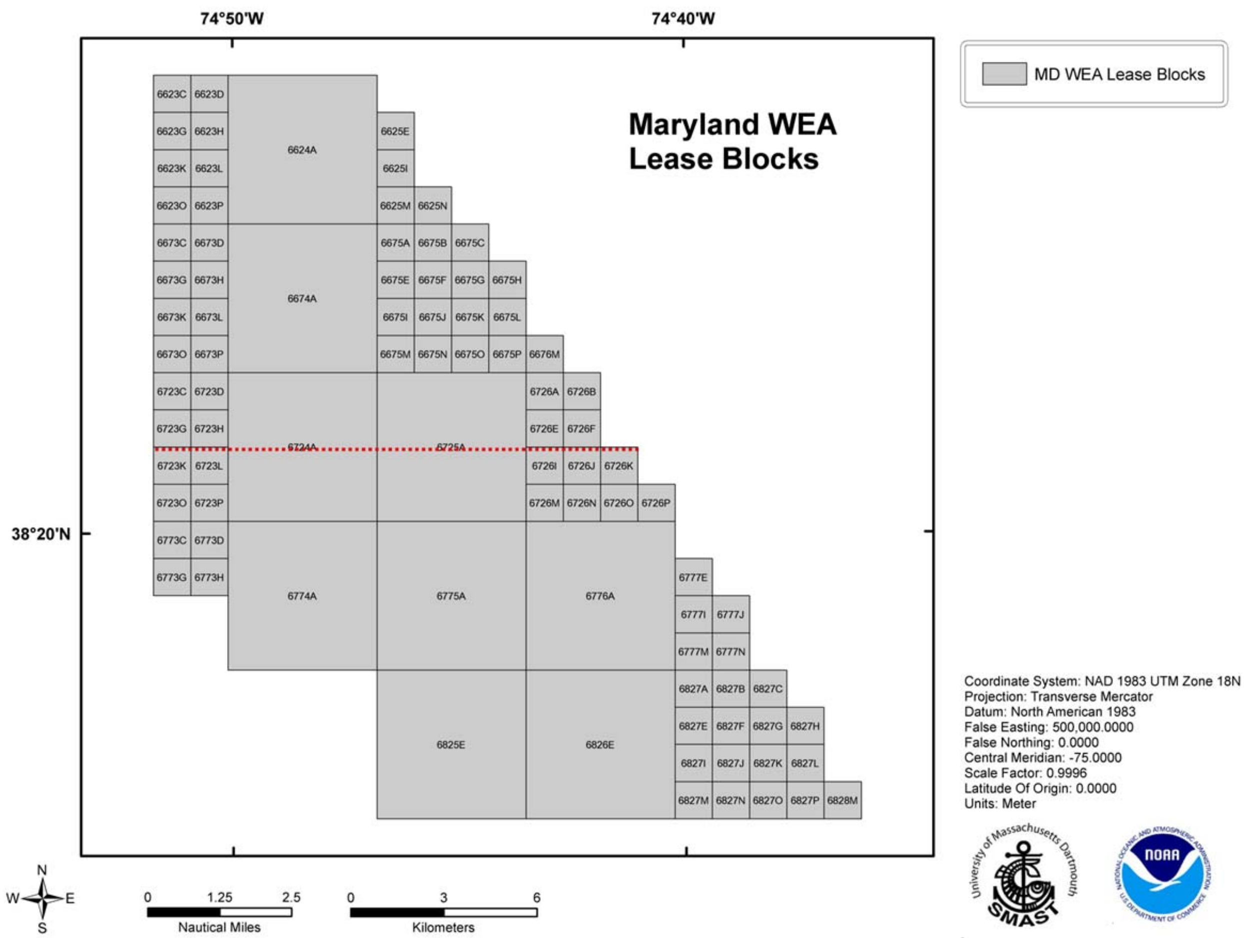


Figure 2-2. Lease block numbers for MD WEA, dotted red line denoted the split in the north and south lease areas. Source data: (BOEM 2013).

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 Resolution	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)

2.2.2 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.

2.2.3 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).

2.2.4 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).

2.2.5 Sediment Sampling and Analyses

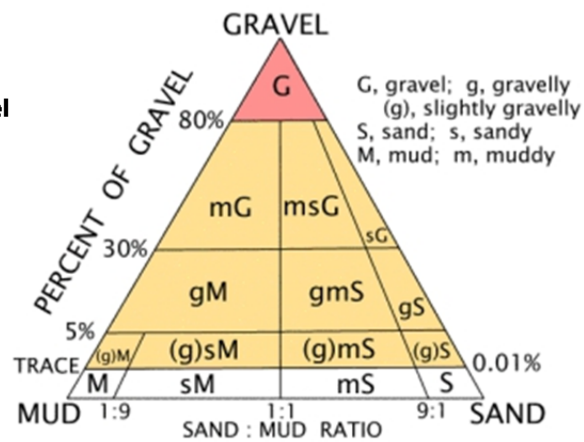
Table 2-2 presents a summary of the Wentworth and Folk sediment classification schemes used in this report. These are the same schemes used by USGS and by NOAA for CMECS classification.

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



2.2.5.1 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.

2.2.5.2 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).

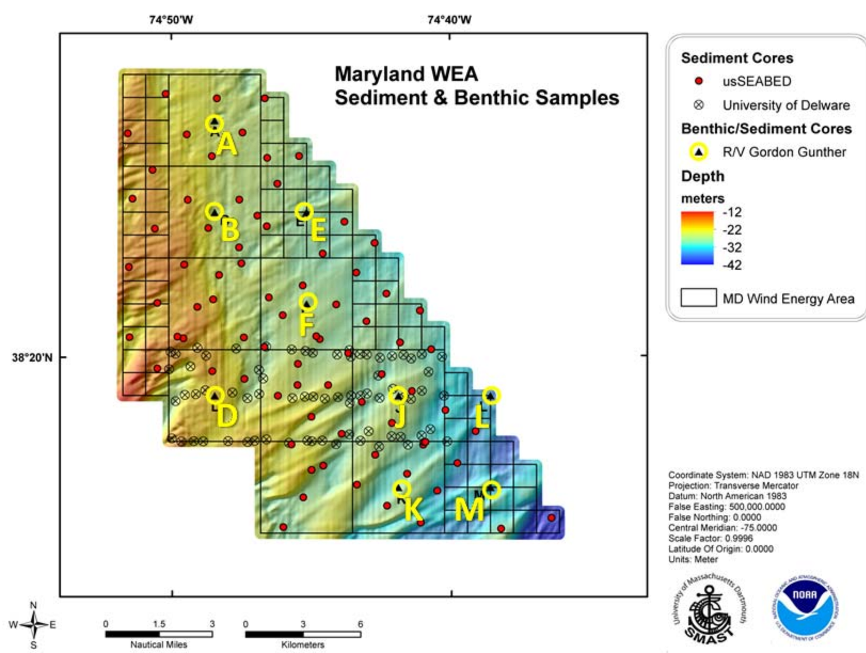


Figure 2-3. Location of benthic sediment samples. Included are cores (black triangles with station letters) taken using a 0.10 m^2 Smith-modified Van Veen grab sampler, aboard the NOAA Ship *Gordon Gunter* from July 4-9, 2013. Location of sediment samples (open circles with x inside) collected in 2012 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).

2.2.5.3 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.

2.2.6 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.

2.2.7 Sampling and Analysis of Benthic/Demersal Fauna

2.2.7.1 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.

2.2.7.2 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.

2.2.8 Benthic Imagery for Sediment Type and Fauna

2.2.8.1 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).

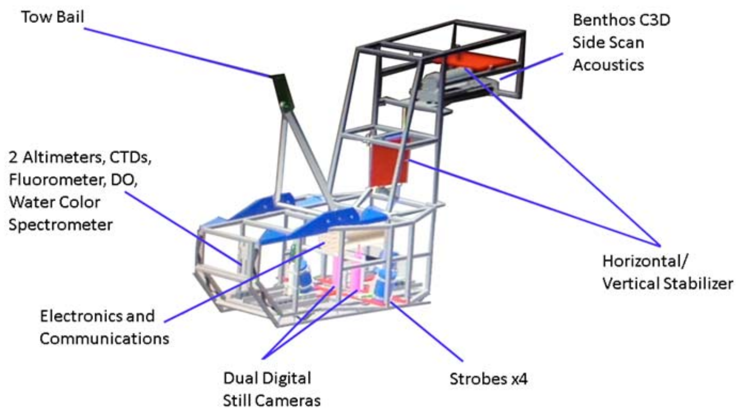


Figure 2-4. Diagram of HabCam IV vehicle. Source data: (WHOI 2014).

2.2.8.2 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).

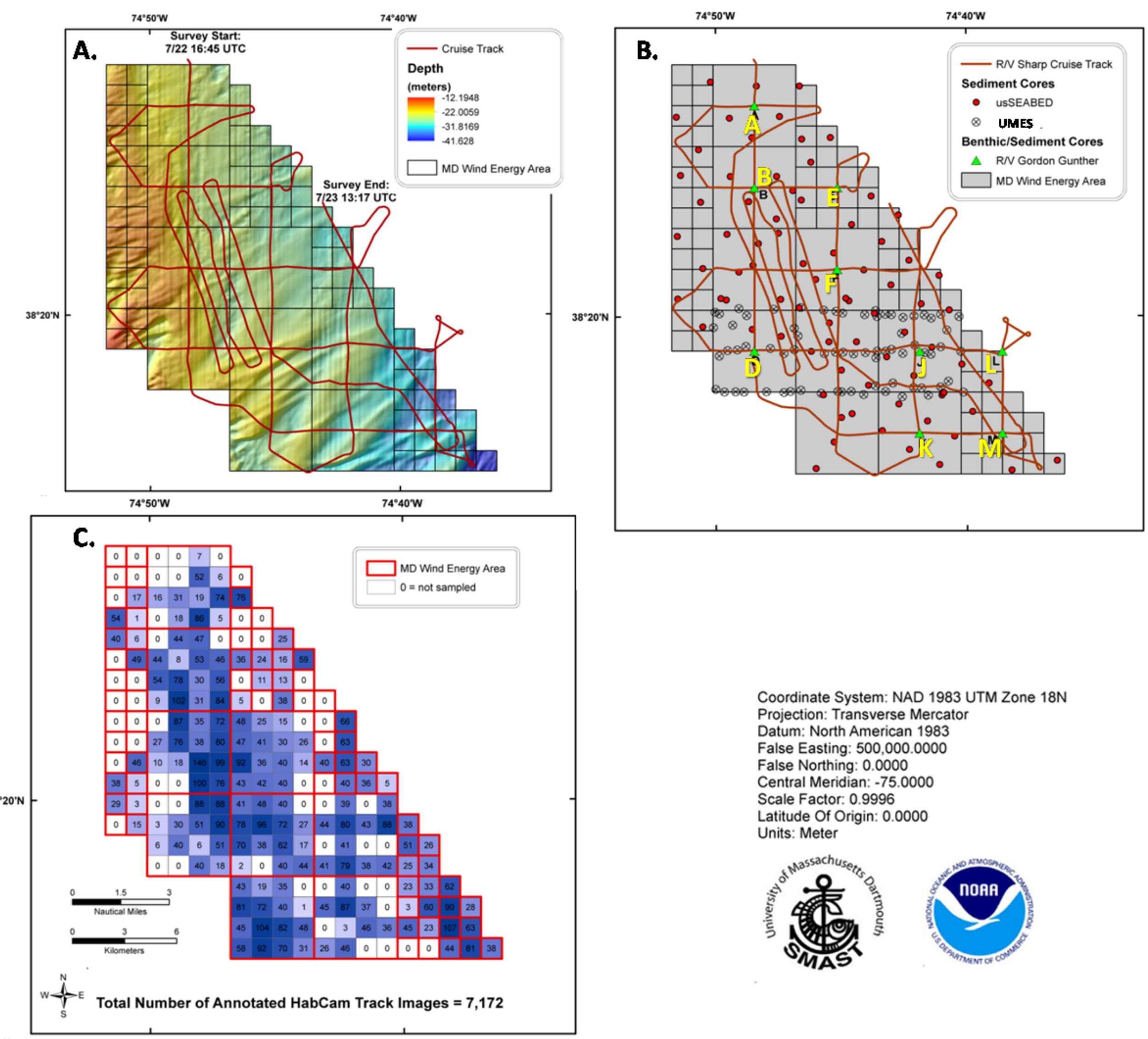


Figure 2-5. R/V *Sharp* cruise track with HabCam: A. *Sharp*/Habcam cruise track plotted on bathymetric map of MD WEA, B. *Sharp*/Habcam cruise track showing relationship to *Gordon Gunter* and UMES bottom grab sampling sites , C. *Sharp/*Habcam cruise track showing numbers of images in each ¾ mile (1207 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).

2.2.8.3 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.

2.2.8.4 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).

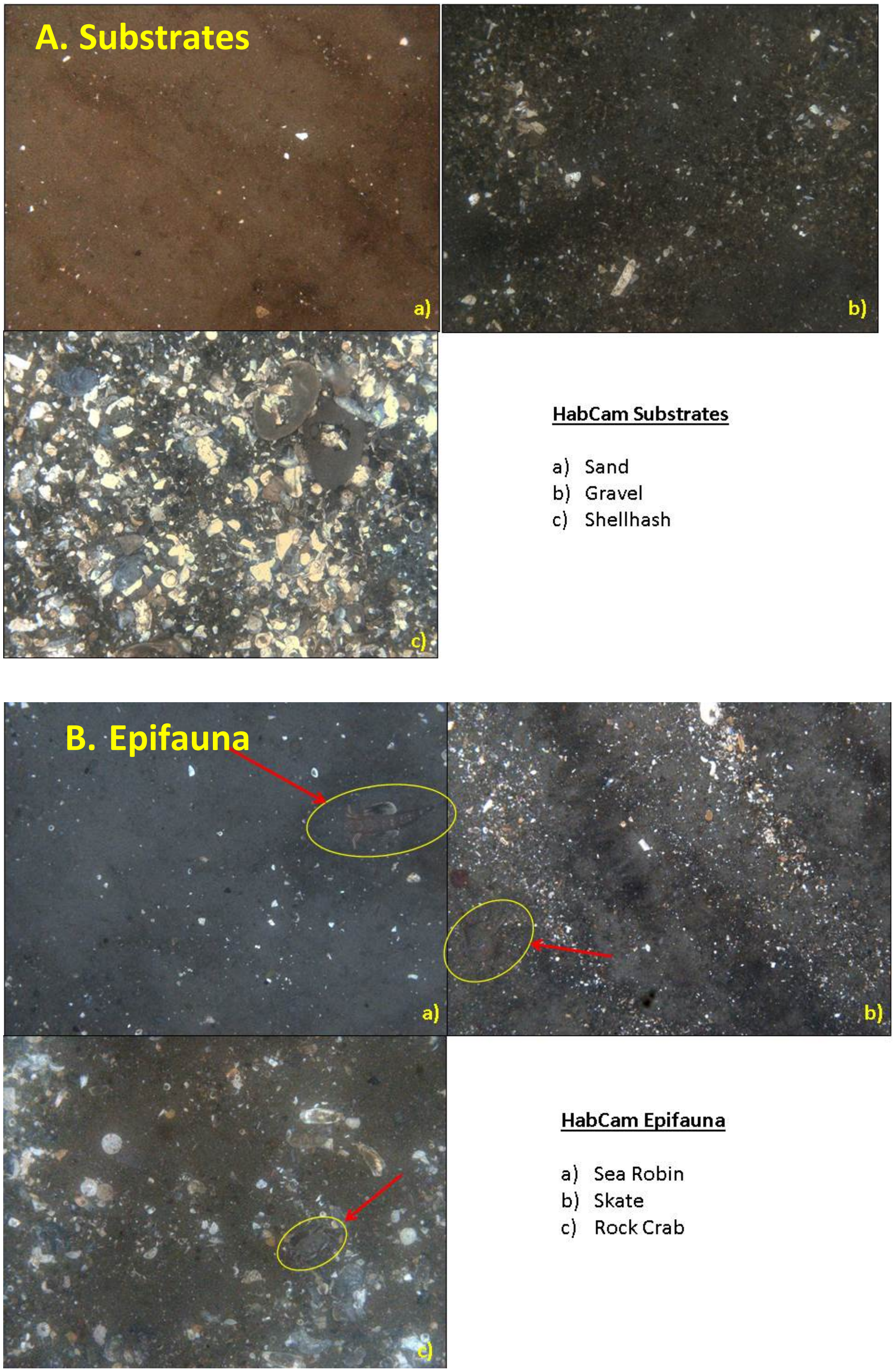


Figure 2-6. Examples of HabCam photos: substrate types (A.) and epifauna (B. & C.).

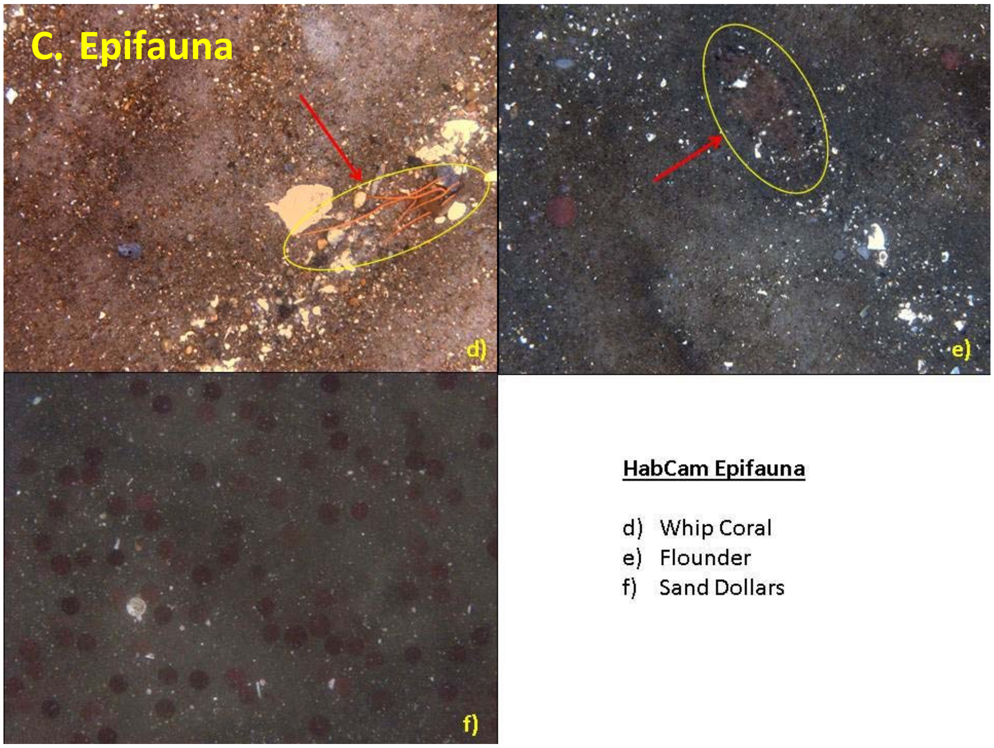


Fig. 2-6 (continued). Examples of HabCam photos: epifauna.

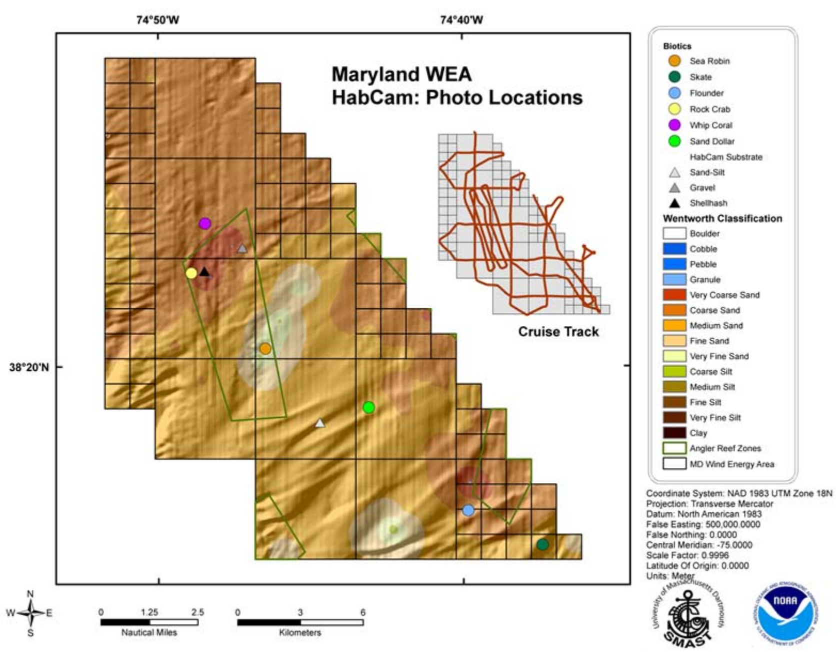


Fig. 2-7. Locations of photos seen in Fig. 2-6.

2.2.8.5 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.

2.2.8.6 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 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 24th to 27th, 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.

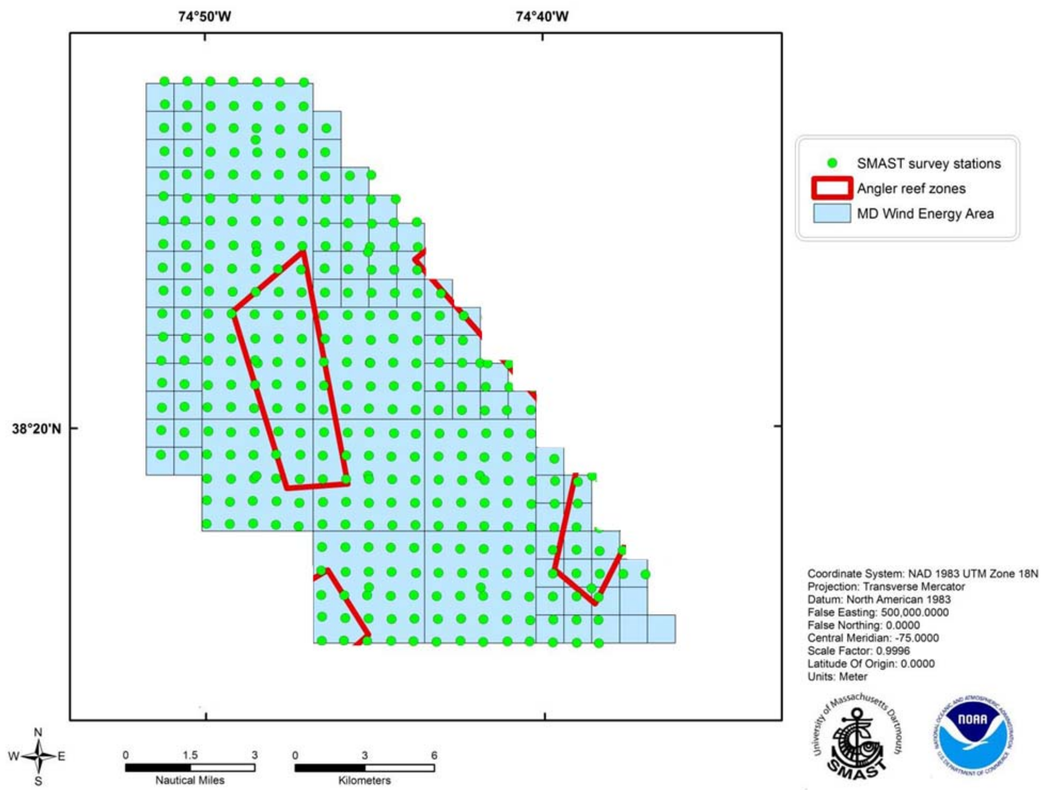


Figure 2-8. UMASS SMAST survey stations in the MD WEA. Stations outside the WEA have been excluded for clarity. Data source: Stokesbury et al. 2014 (Appendix 1).

2.2.9 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.

2.3 Results

2.3.1 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.

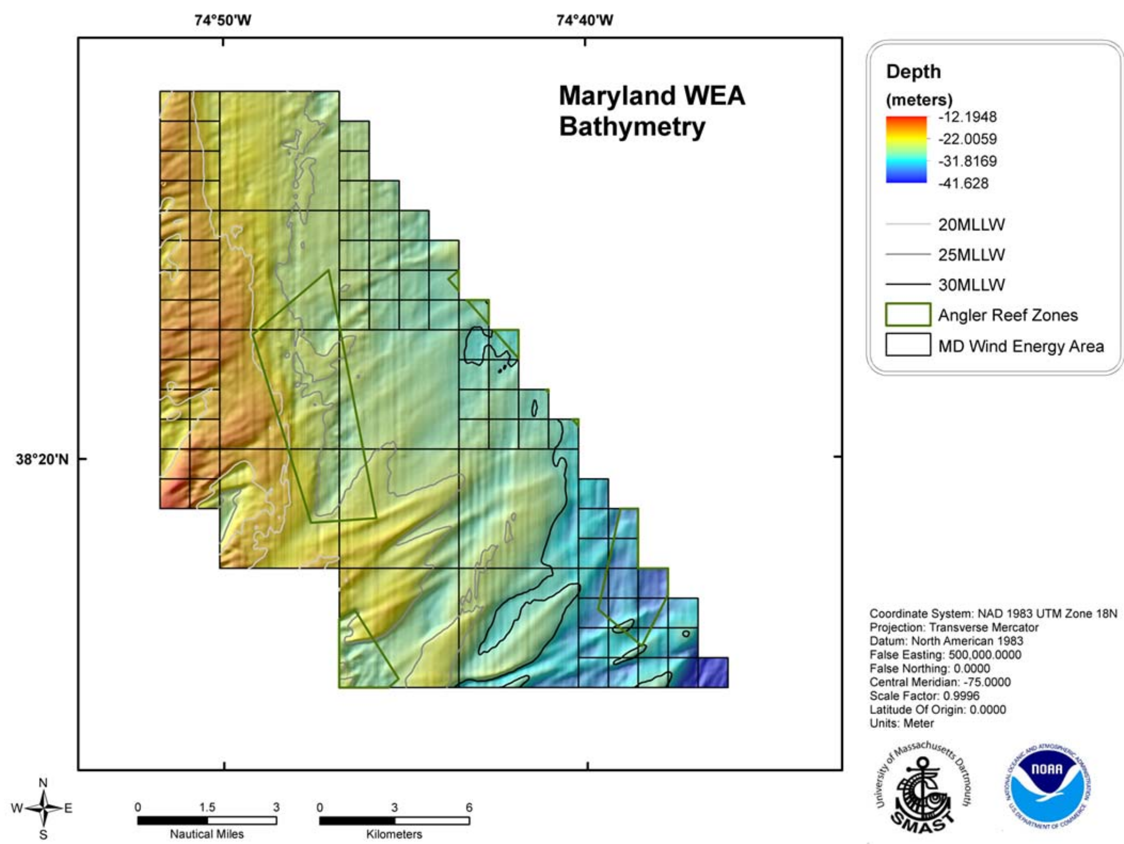


Figure 2-9. Bathymetry (2 m horizontal resolution) with isobaths contours and known angler reef zones (green polygons) in the MD WEA. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

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).

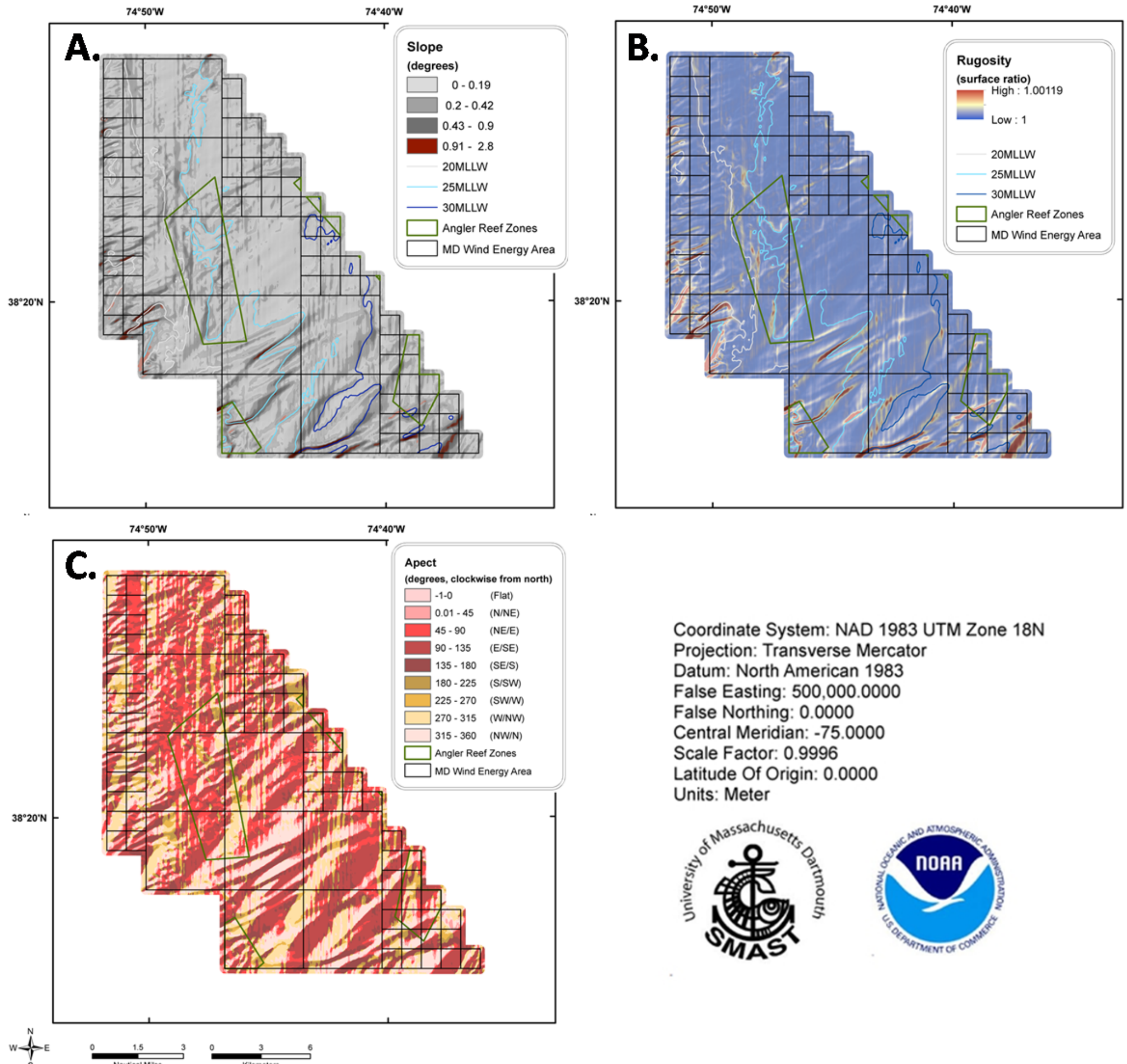


Figure 2-10. Terrain metrics (derived at a 2 m scale) and known angler reef zones (green polygons) in the MD WEA. A. Seafloor slope, B. Rugosity, C. Aspect. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

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.

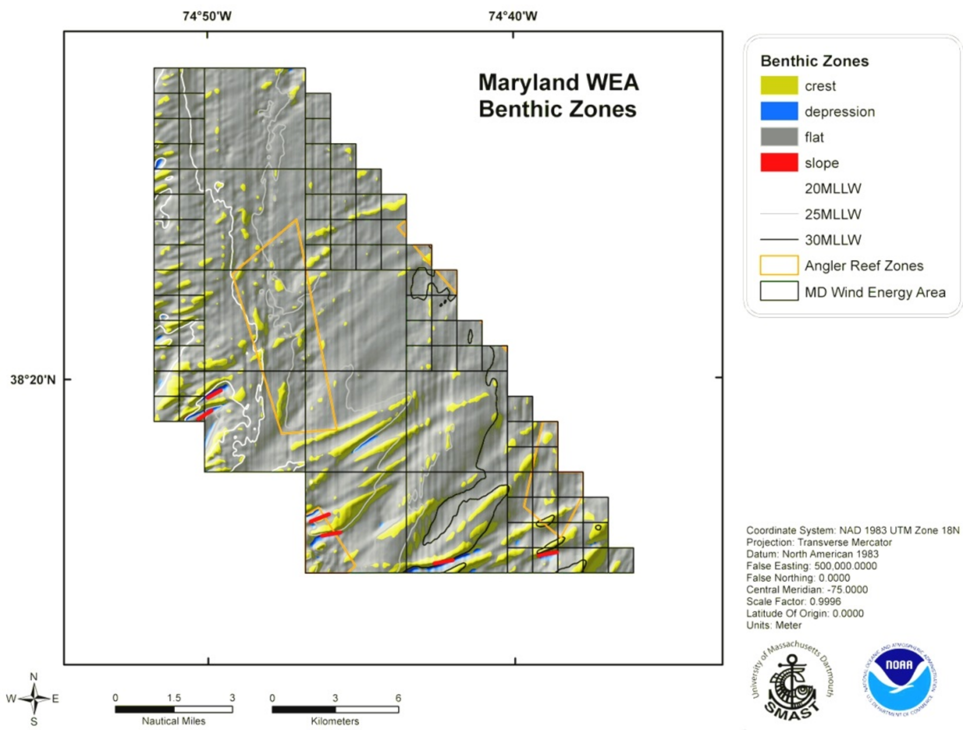


Figure 2-11. Benthic zones (500 m horizontal scale, derived from 2 m bathymetry and 2 m slope data) and known angler reef zones in the MD WEA. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

2.3.2 Sediment Characterization

2.3.2.1 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.

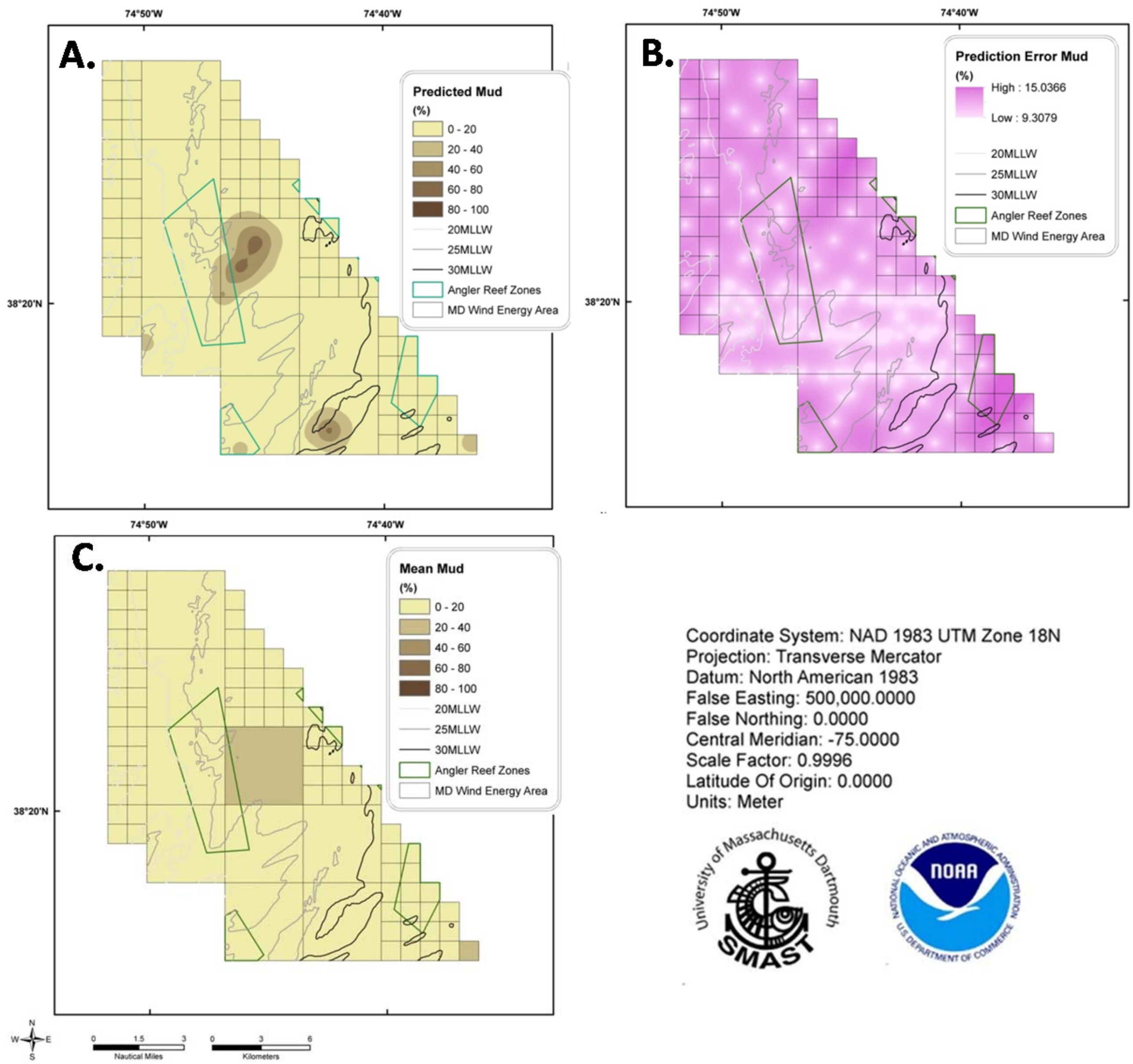


Figure 2-12. Predicted mud (silt + clay) distribution of surficial sediments in MD WEA with known angler reef zones (green polygons): A. Predicted percent mud distribution, B. Prediction error in sediment percent mud, C. Predicted mean percent mud in surficial sediments by whole Lease Block. Source data: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

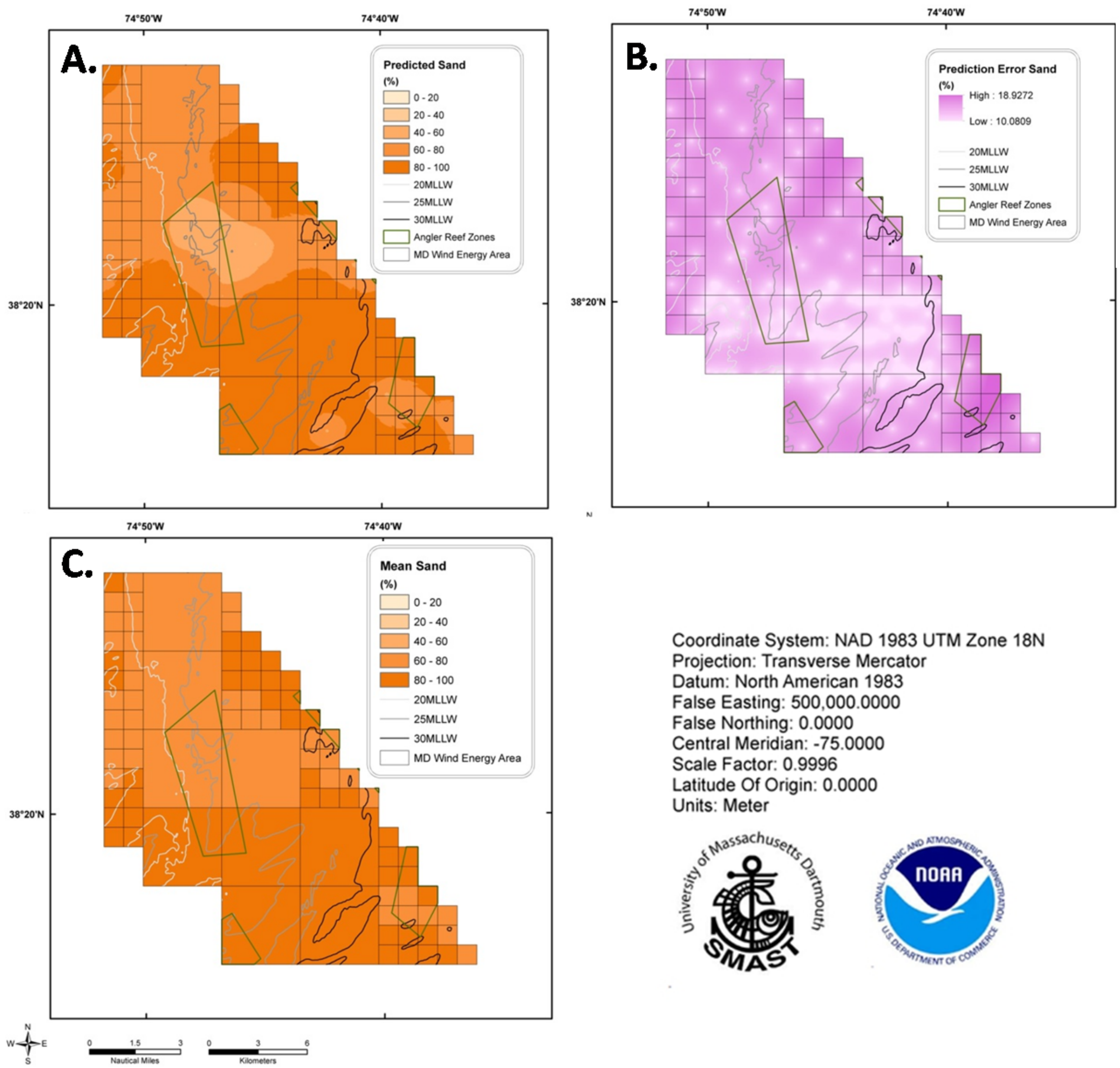


Figure 2-13. Predicted sand distribution of surficial sediments in MD WEA with known angler reef zones (green polygons): A. Predicted percent sand distribution, B. Prediction error in sediment percent sand, C. Predicted mean percent sand in surficial sediments by whole Lease Block. Source data: (NOAA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

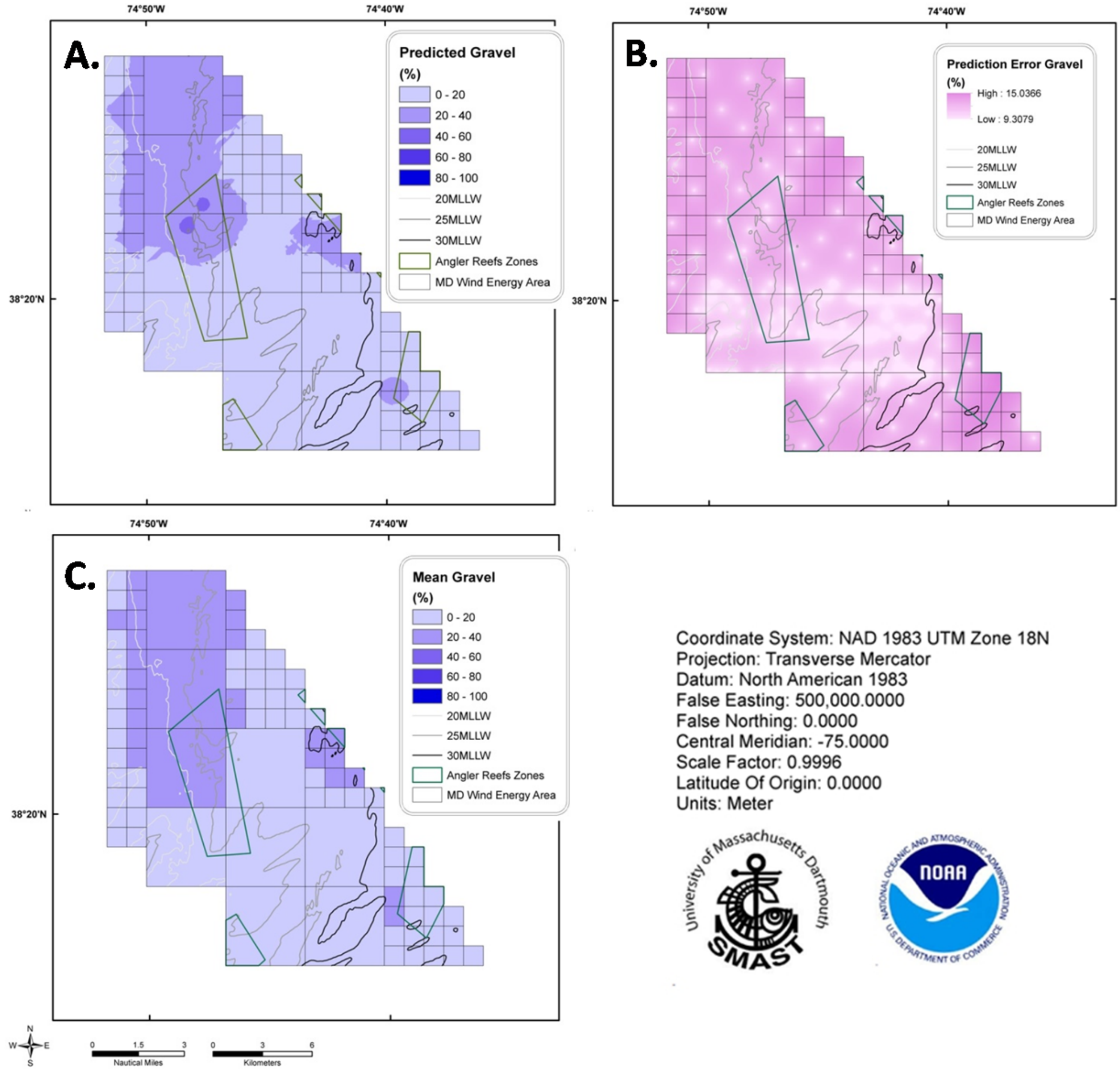


Figure 2-14. Predicted gravel distribution in surficial sediments of MD WEA with known angler reef zones (green polygons): A. Predicted percent gravel distribution, B. Prediction error in sediment percent gravel, C. Predicted mean percent gravel in surficial sediments by whole Lease Block. Source data: (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.

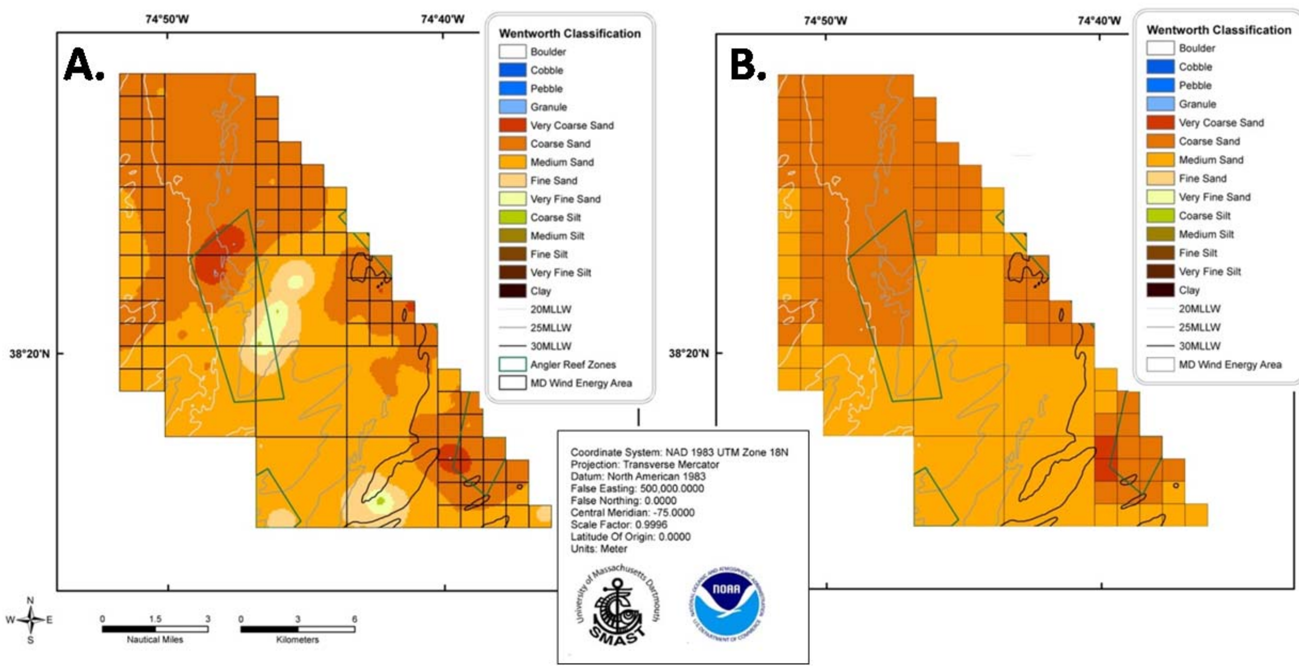


Figure 2-15. Predicted sediment type (Wentworth Classification) of surficial sediments based on mean grain size for the MD WEA with known angler reef zones (green polygons. A. Interpolated sediment type distribution, B. Mean sediment type by whole Lease Block. Source data: (NOAA 2013a, Reid et al. 2005,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

2.3.2.2 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.

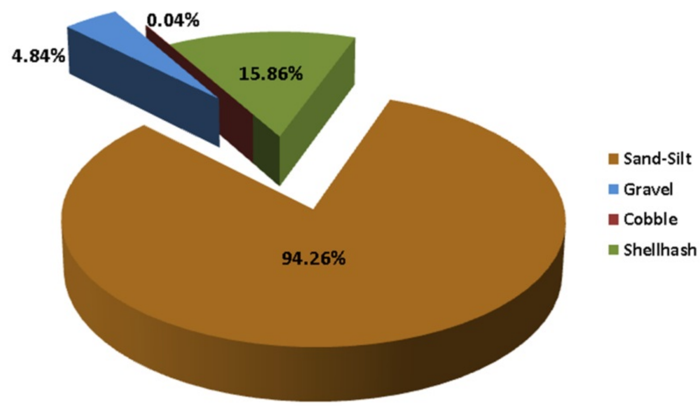


Figure 2-16. Percent of surficial sediment type identified from HabCam surveys in MD WEA. Source data: (NOAA 2013b).

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).

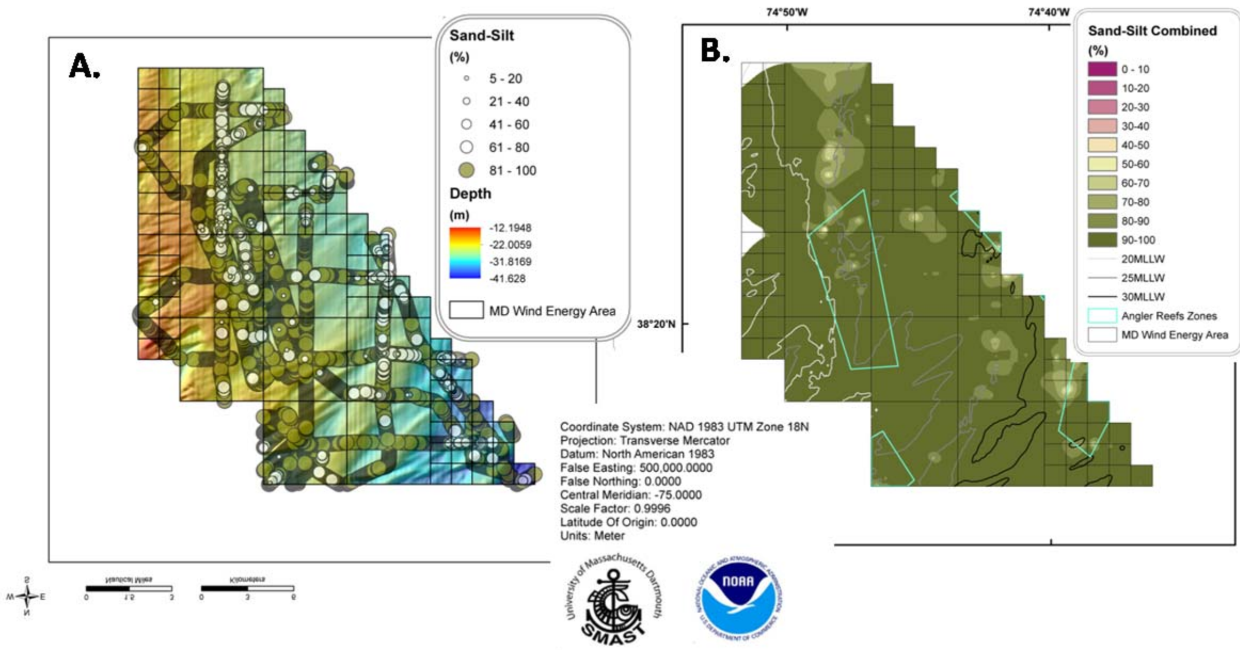


Figure 2-17. HabCam surficial sand-silt coverage: A. Graduated circles represent the percentage of sand-silt substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. B. Interpolated prediction of surficial sediment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

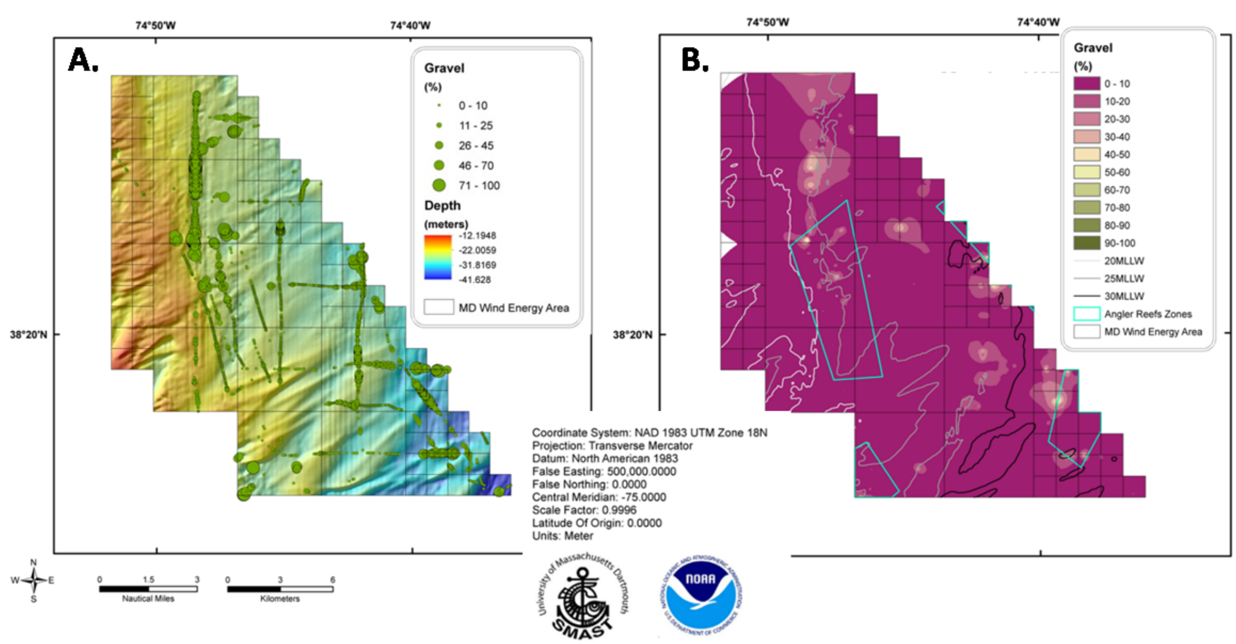


Figure 2-18. HabCam surficial gravel coverage: A. Graduated circles represent the percentage of gravel substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. B. Interpolated prediction of surficial sediment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

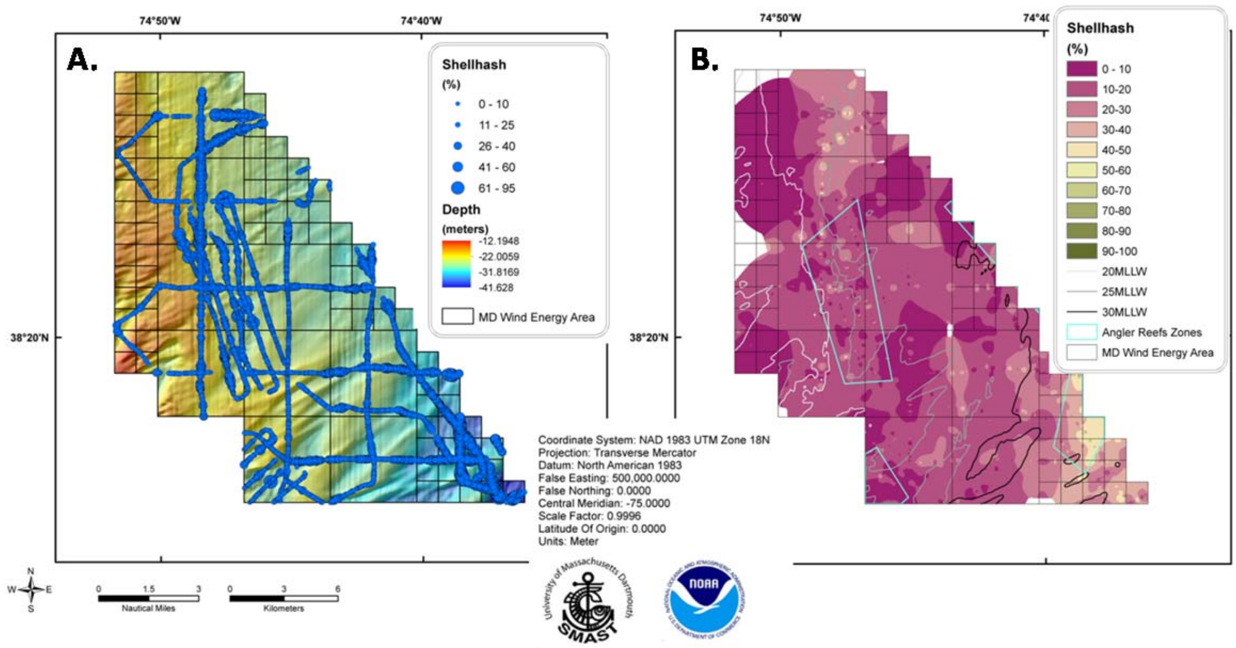


Figure 2-19. HabCam surficial shell hash coverage: A. Graduated circles represent the percentage of shell hash substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. B. Interpolated prediction of surficial sediment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

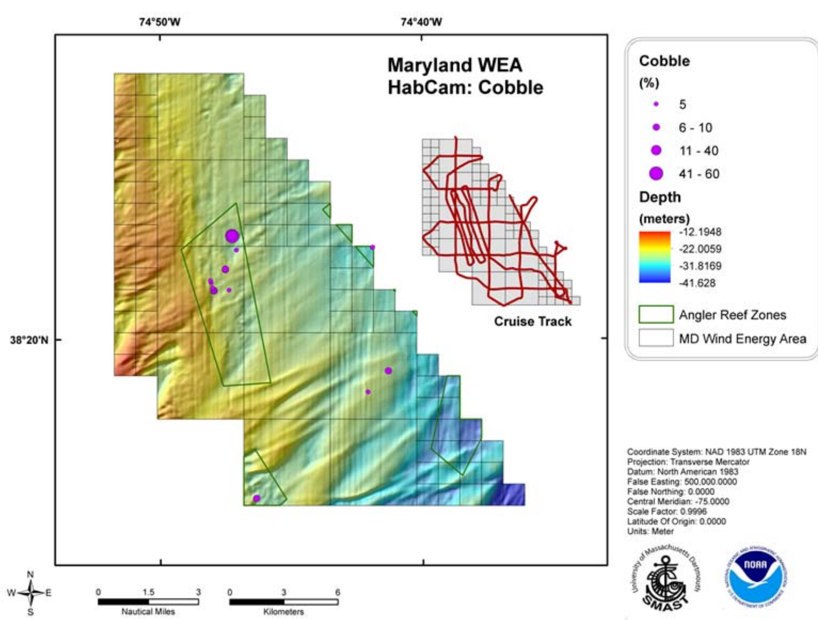


Figure 2-20. HabCam surficial cobble coverage: Graduated circles represent the percentage of cobble substrate recorded at each annotated HabCam image. Approximately every 50th photo was annotated, equivalent to approx. 30 m distance between photos. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins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

2.3.2.3 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.

2.3.2.4 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.

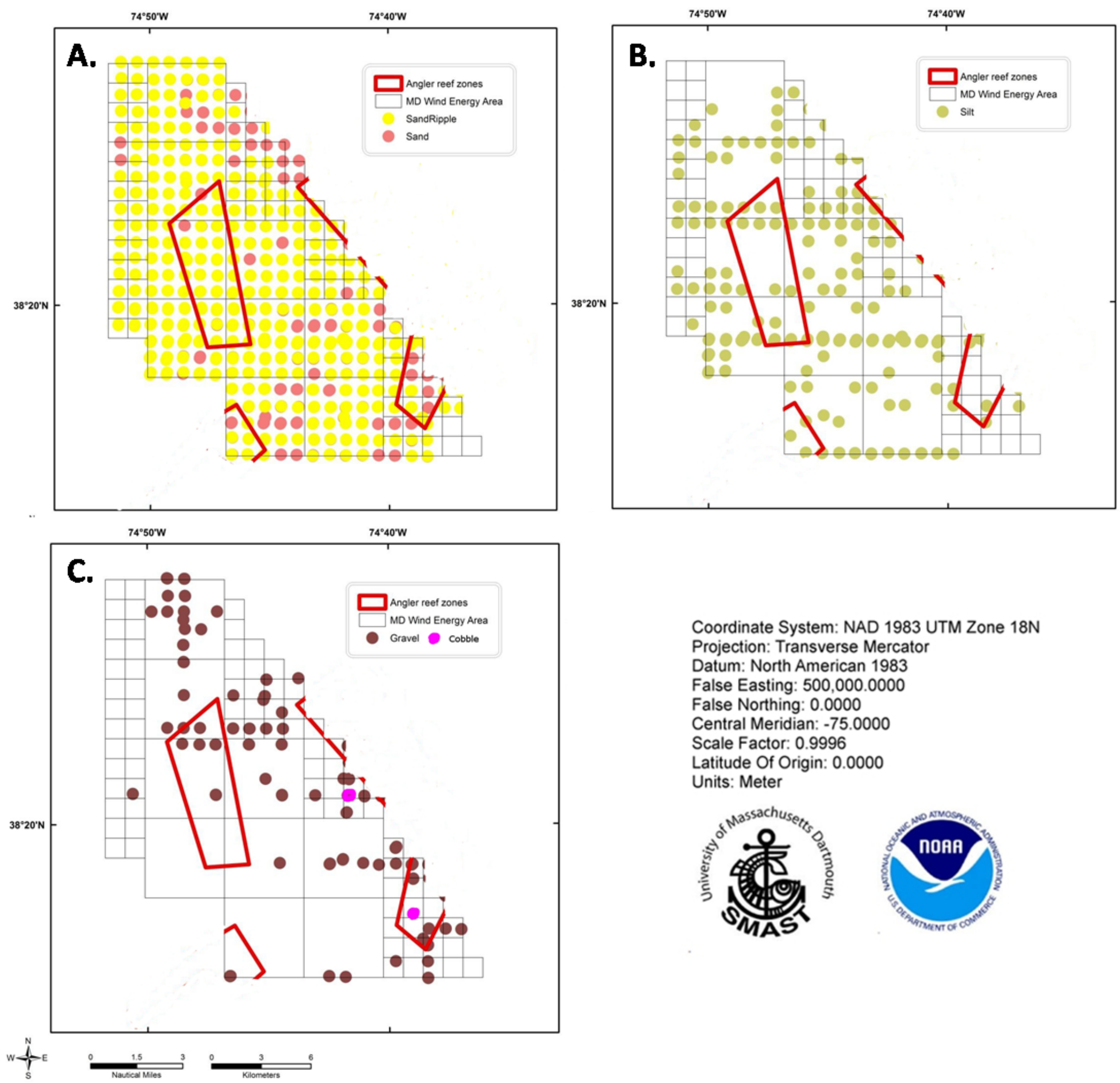


Figure 2-21. UMASS SMAST surficial sediments (presence-absence) observations: A. Sand and Sand Ripples, B. Silt, C. Gravel and Cobble. Source data: (NOAA 2013b, BOEM 2013, CB&I 2014, Hawkins 2013), Appendix 1.

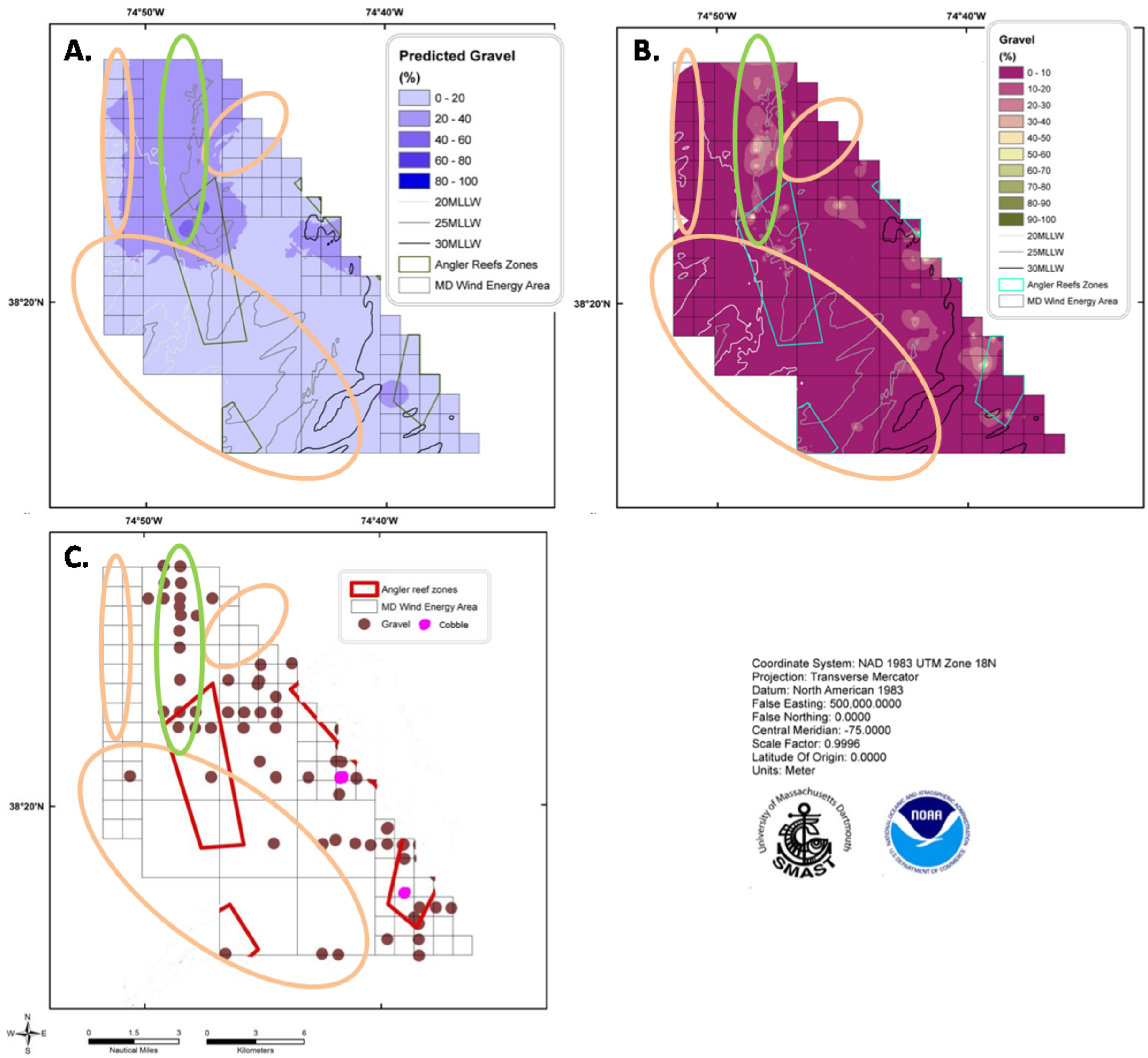


Figure 2-22. Comparison of gravel cover patterns: A. Prediction from interpolation of grab sample grain size analysis (Fig. 2-14 A), B. Prediction from interpolation of HabCam photographic annotation (Fig. 2-18 B), C. Observed presence/absence pattern from UMASS SMAST photographic annotation (Fig. 2-21 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 1.

2.3.3 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 an6 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

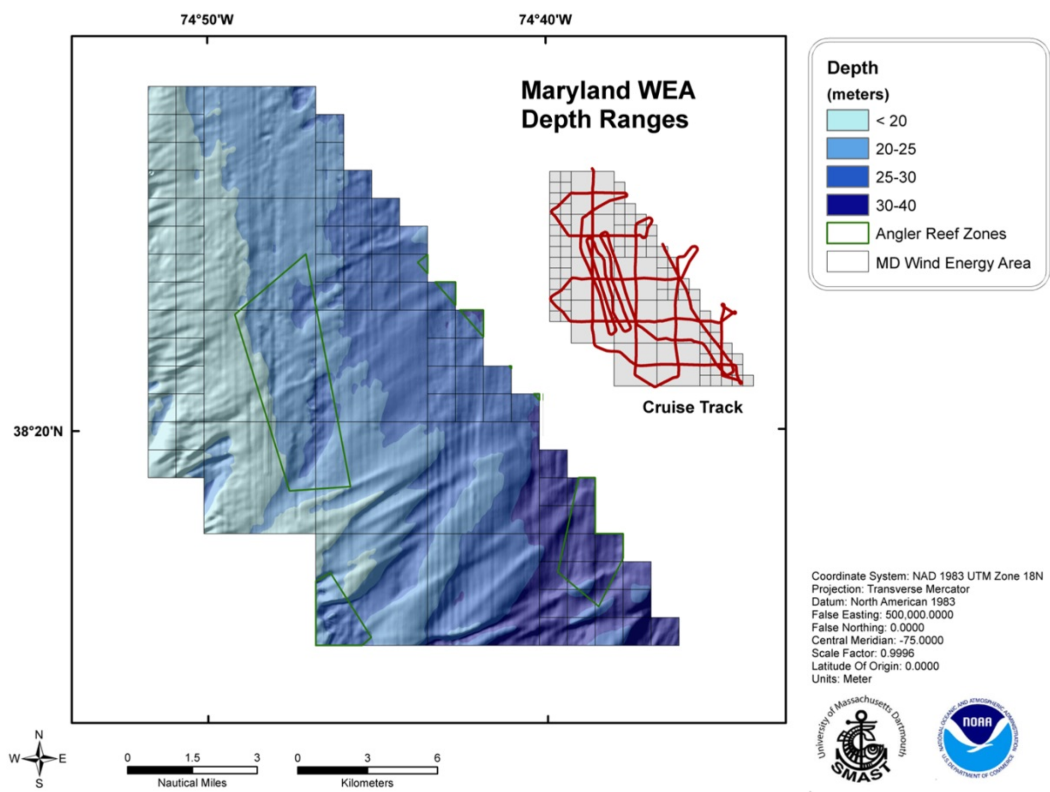


Figure 2-23. Bathymetric zones corresponding to depth ranges in Table 2-6 in the MD WEA. Data horizontal resolution is 2 m. Source data: (Hawkins 2013, BOEM 2013, CB&I 2014).

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.

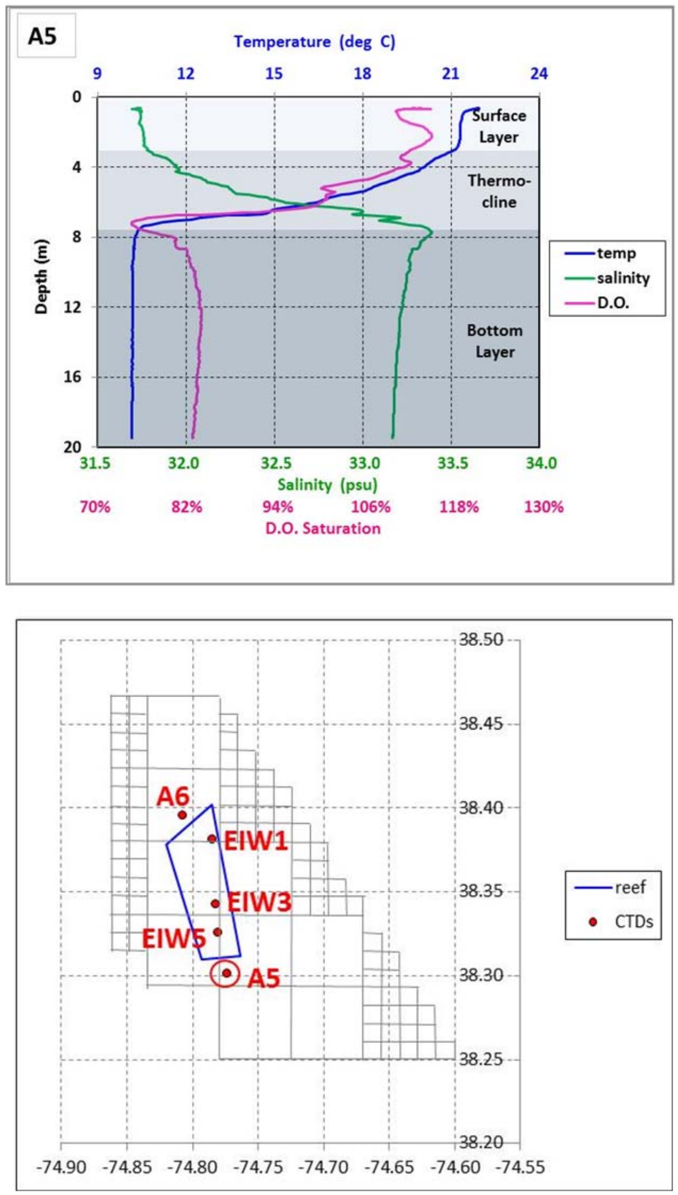


Figure 2-24. Vertical CTD casts in the MD WEA made aboard R/V *Resolute*: A. Plot of CTD parameters at Station A5; Blue line is temperature (values on blue scale); green line is salinity (values on green scale); rose line is dissolved oxygen (D.O.: values on rose scale) B. Map of MD WEA showing positions 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.

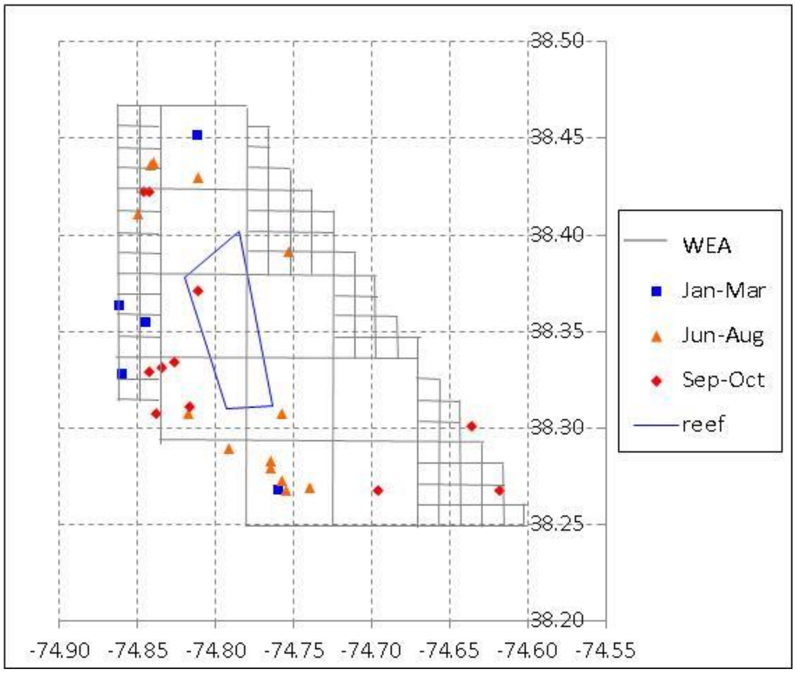


Figure 2-25. Positions of vertical CTD casts made in or near the MD WEA by NEFSC surveys in various seasons between 2003 and 2012. Data sources: (BOEM 2013, Hawkins 2013, NOAA, NEFSC 2014).

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

2.3.4 Biota

2.3.4.1 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 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.

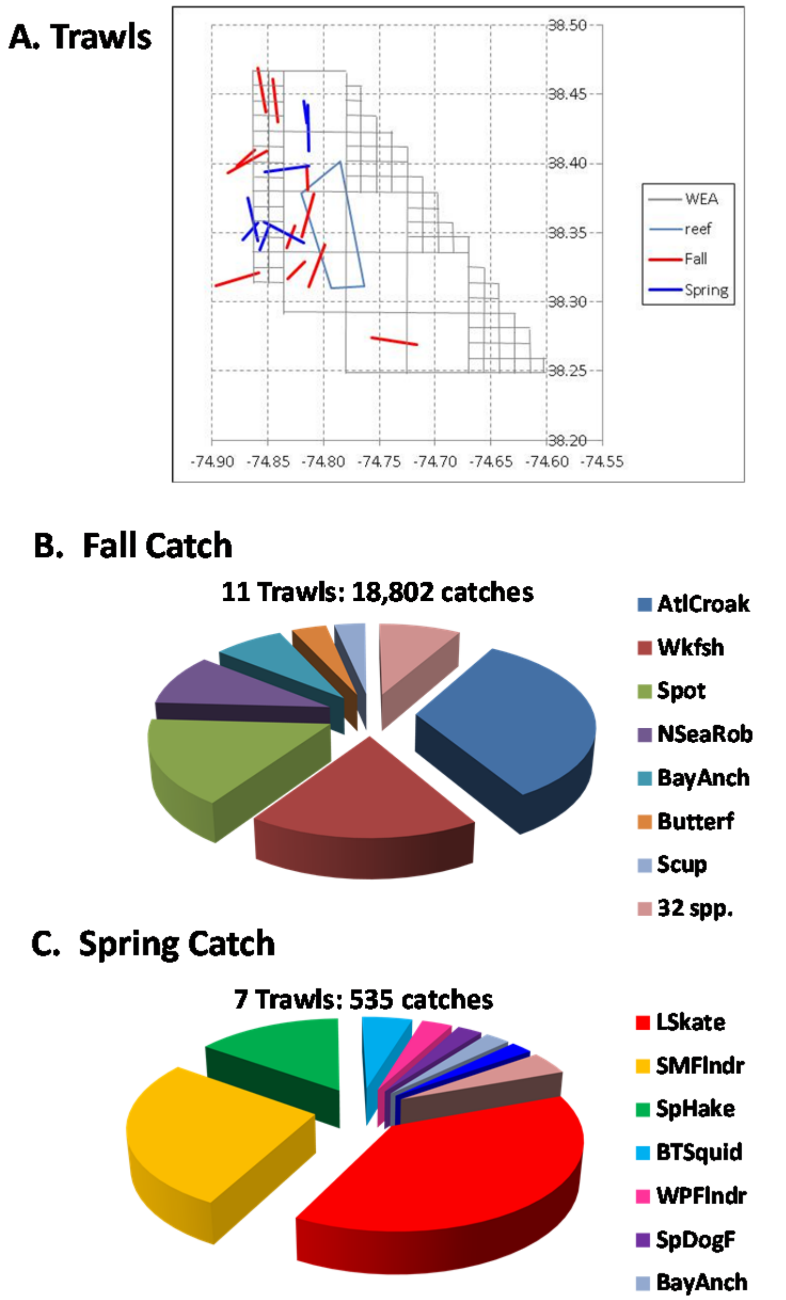
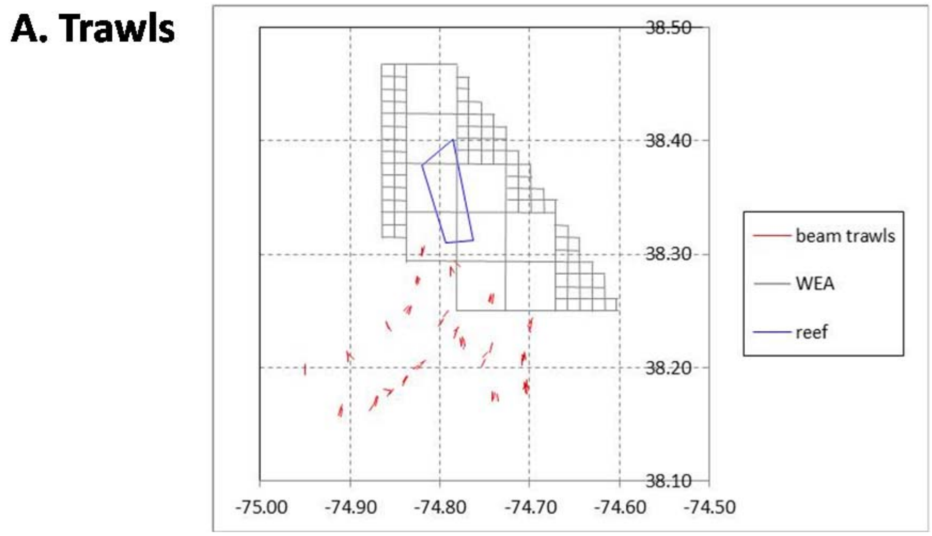


Figure 2-26. NEFSC bottom trawl surveys in the MD WEA. A. Trawl tracks impinging on the WEA, B. Summary of fall catch by percentage of individuals caught, and C. Summary of spring catch by percentage of individuals caught. Fish name abbreviations: AtlCroak – Atlantic croaker, Wkfhs – weakfish, NSeaRob – 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).



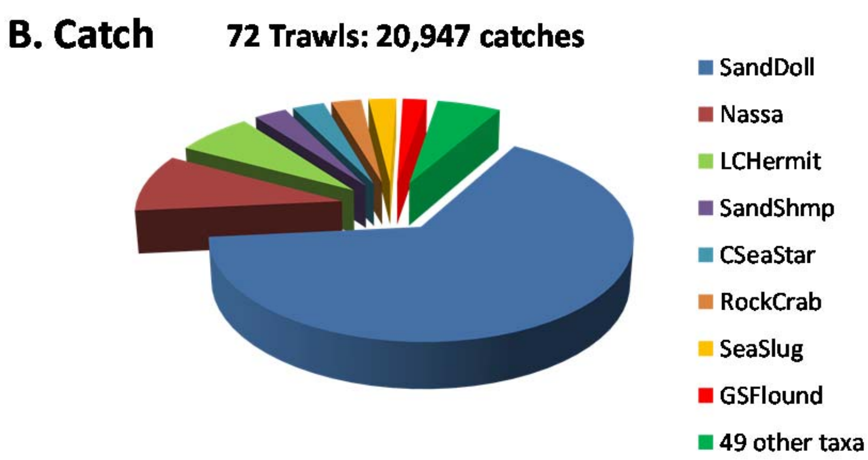


Figure 2-27. 2008 Delmarva beam trawl survey near the MD WEA: A. Trawl tracks in WEA vicinity, B. Summary of catch by percentage of individuals caught Abbreviations: SandDoll – sand dollar, Nassa - Nassa snail (dog whelk), LCHermit – long clawed hermit crab, SandShmp – sand shrimp, CSeaStar – common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

2.3.4.2 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

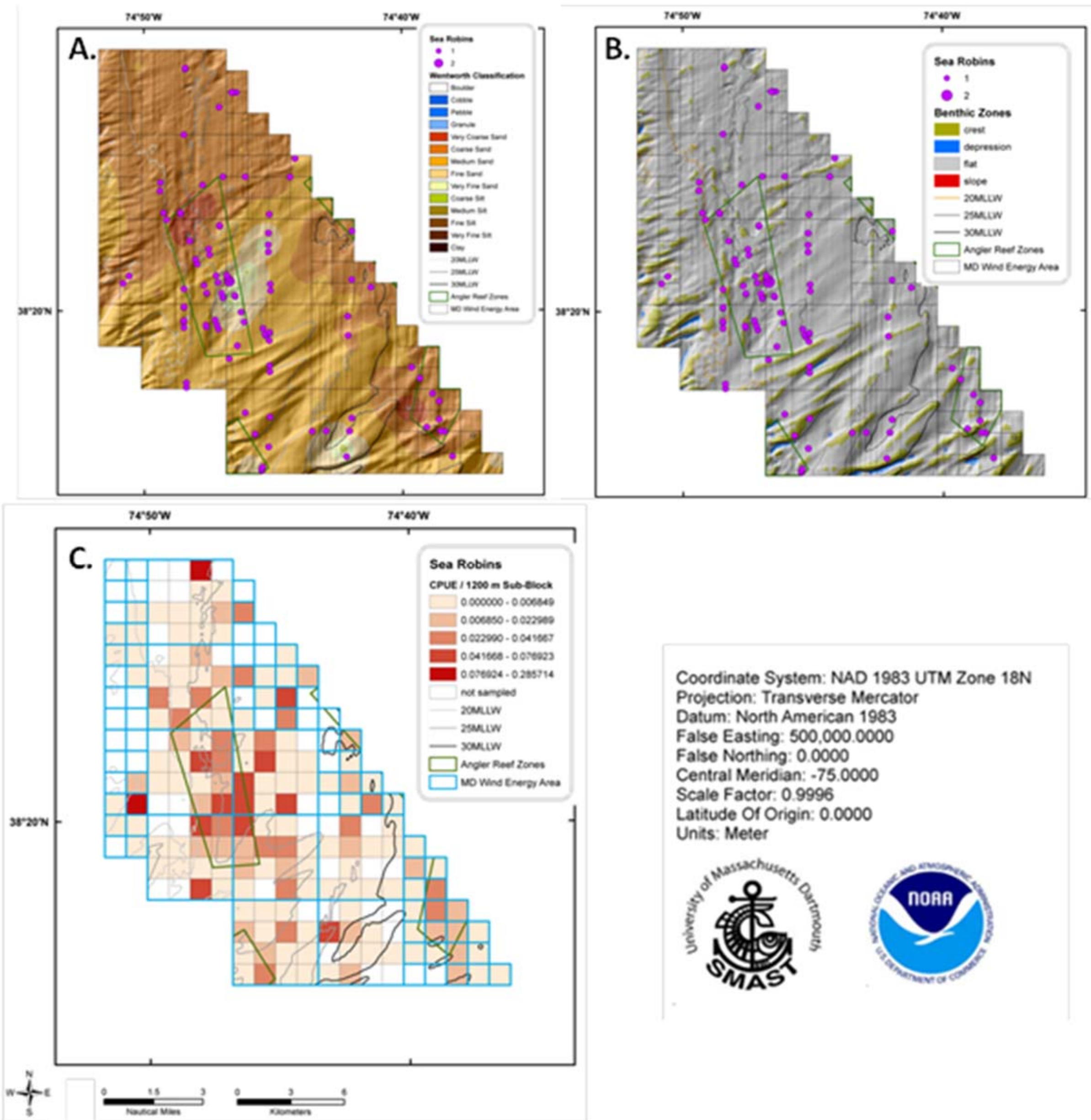


Figure 2-28. Sea robin (*Prionotus* spp.) abundance from HabCam: A total of 99 sea robins were recorded from the HabCam images in the MD WEA; A. Sea Robin counts per image overlaid on mean grain size for the MD WEA., B. Sea Robin counts per image overlaid on benthic zones for the MD WEA. C. Sea Robins 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).

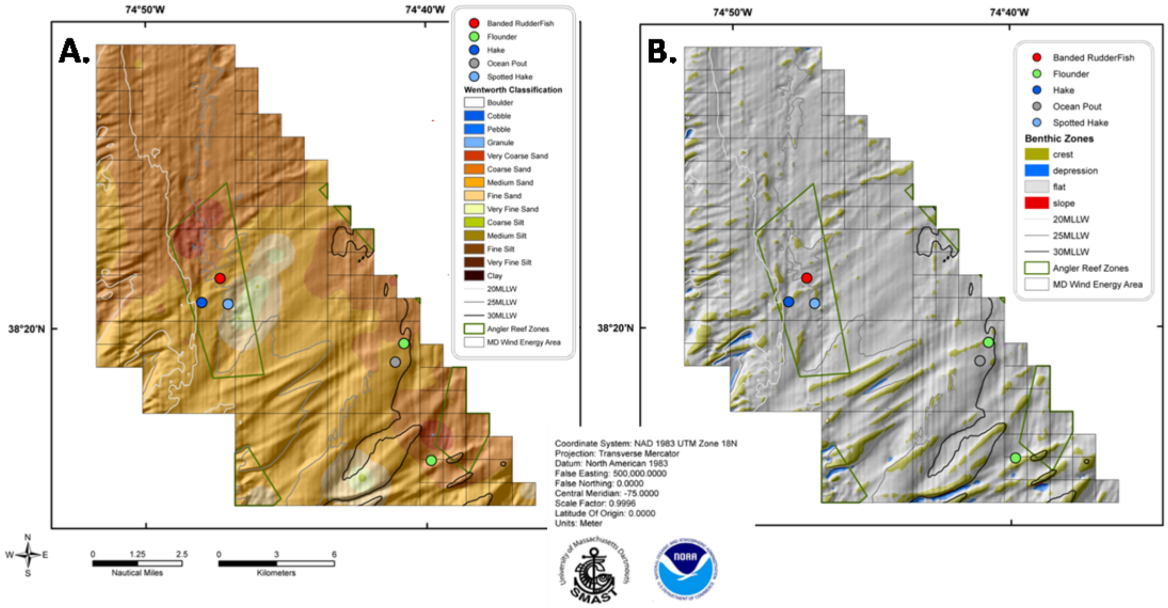


Figure 2-29. Abundance of five identified fish species from HabCam: (1) Banded rudderfish (*Seriola zonata*), (2) flounder (Pleuronectiformes), (3) unclassified hake (*Urophycis* spp.), (4) spotted hake (*Urophycis regia*), and (5) ocean pout (*Macrozoarces americanus*): A. Overlaid on mean grain size 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).

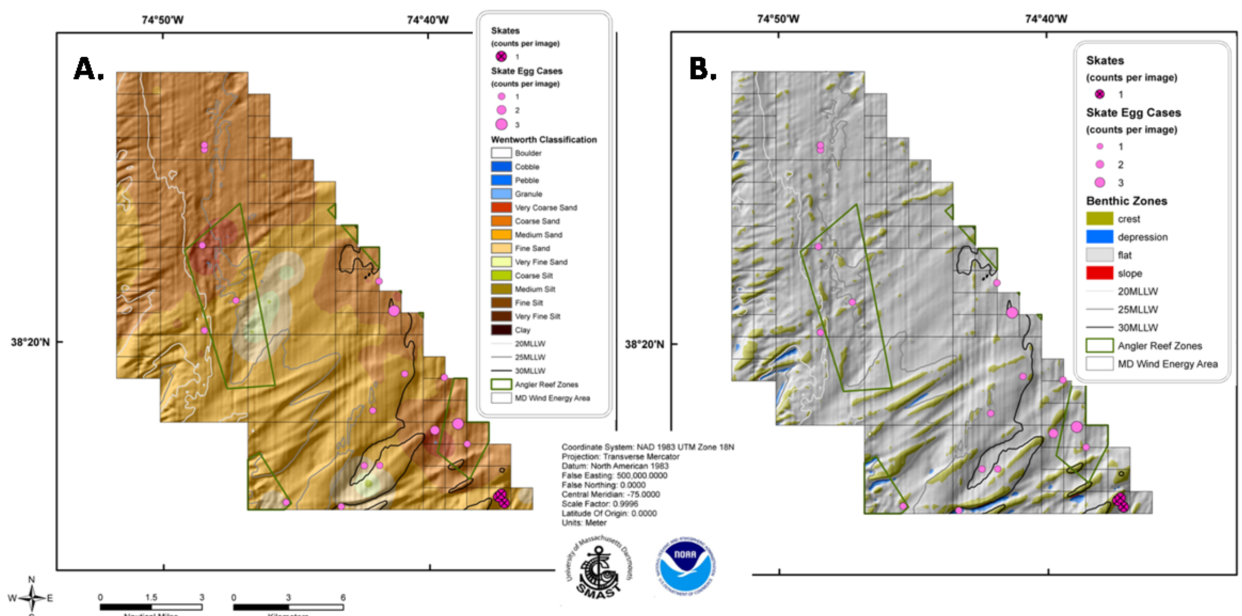


Figure 2-30. Abundance of skates (Rajidae) and egg cases from HabCam. Counts per image are overlaid on mean grain size for the MD WEA: A. Overlaid on mean grain size for the MD WEA, and B. Overlaid on benthic zones size for the MD WEA. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b, CB&I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

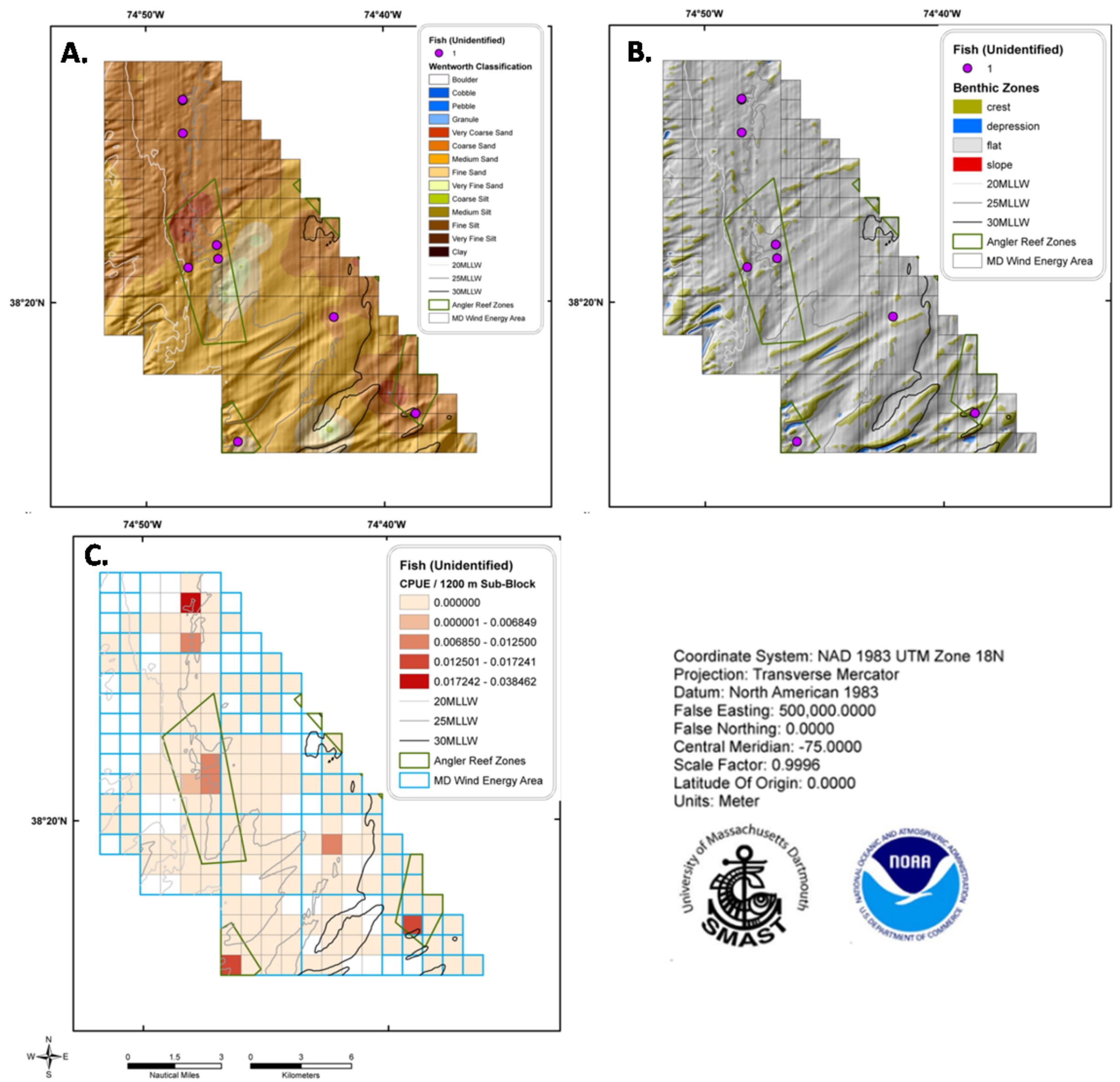


Figure 2-31. Abundance of unidentified bony fish (Osteichthyes) from HabCam: A. Counts per image overlaid on mean grain size for the MD WEA., B. Counts per image overlaid on benthic zones for the MD WEA. C. CPUE/1207 m sub-block in the MD WEA. Source data: (BOEM 2013, Hawkins 2013, NOAA 2013a, NOAA 2013b,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

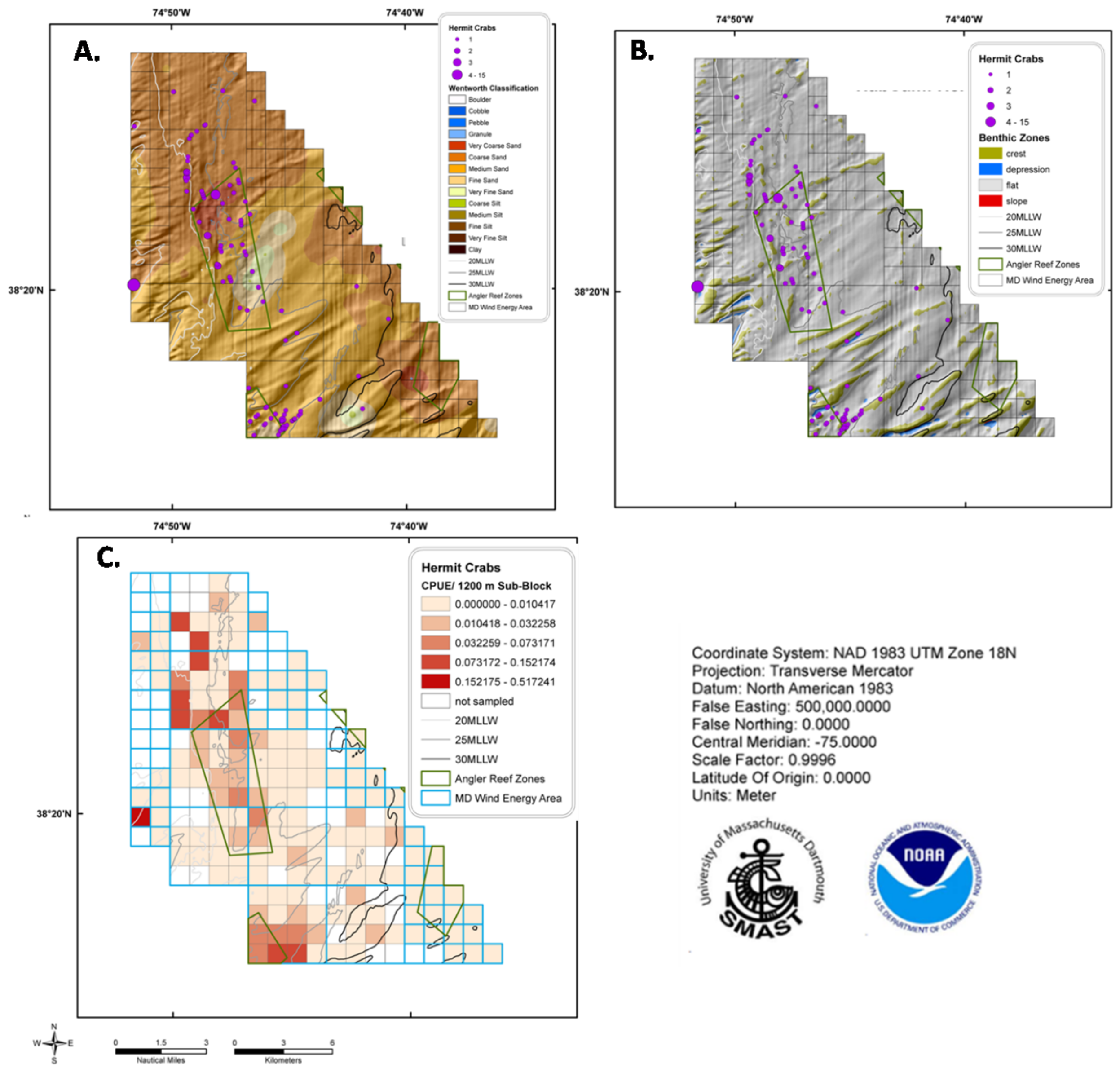


Figure 2-32. Hermit crab (*Pagurus* spp.) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. A total of 102 hermit crabs were recorded from the HabCam images. There appears to be a concentration 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).

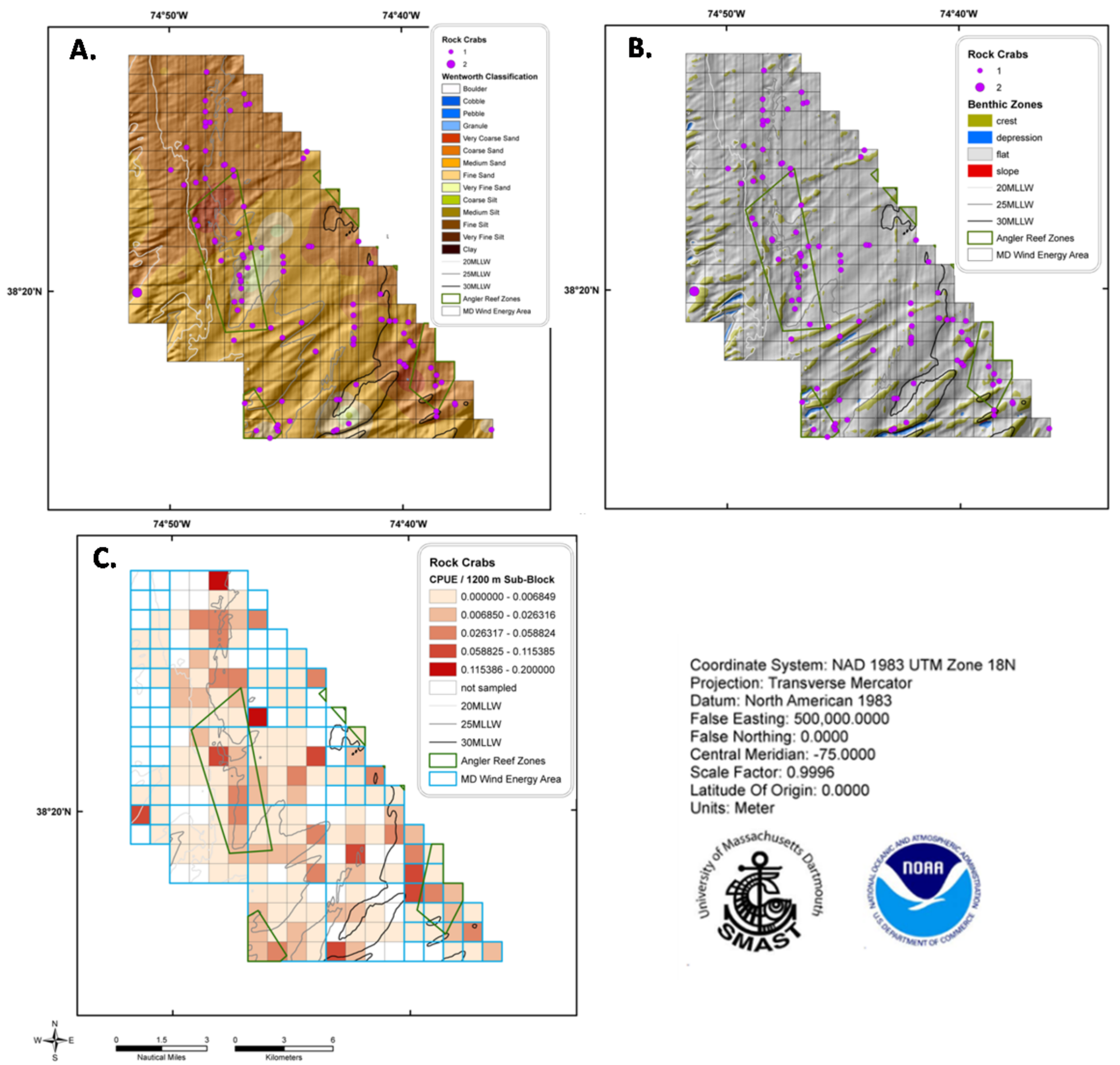


Figure 2-33. Rock Crab (*Cancer irroratus*) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

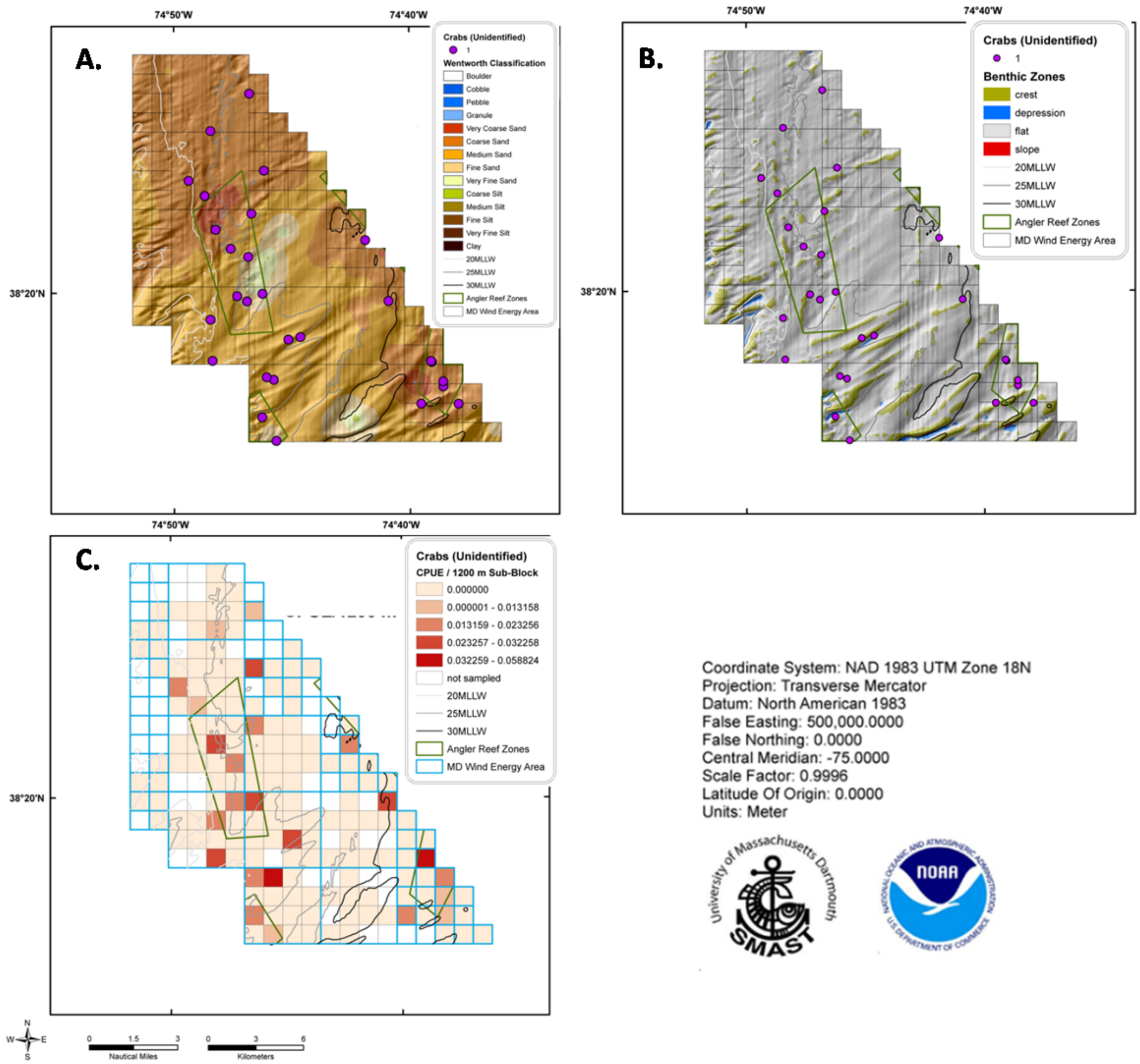


Figure 2-34. Unidentified crab (Brachyura) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

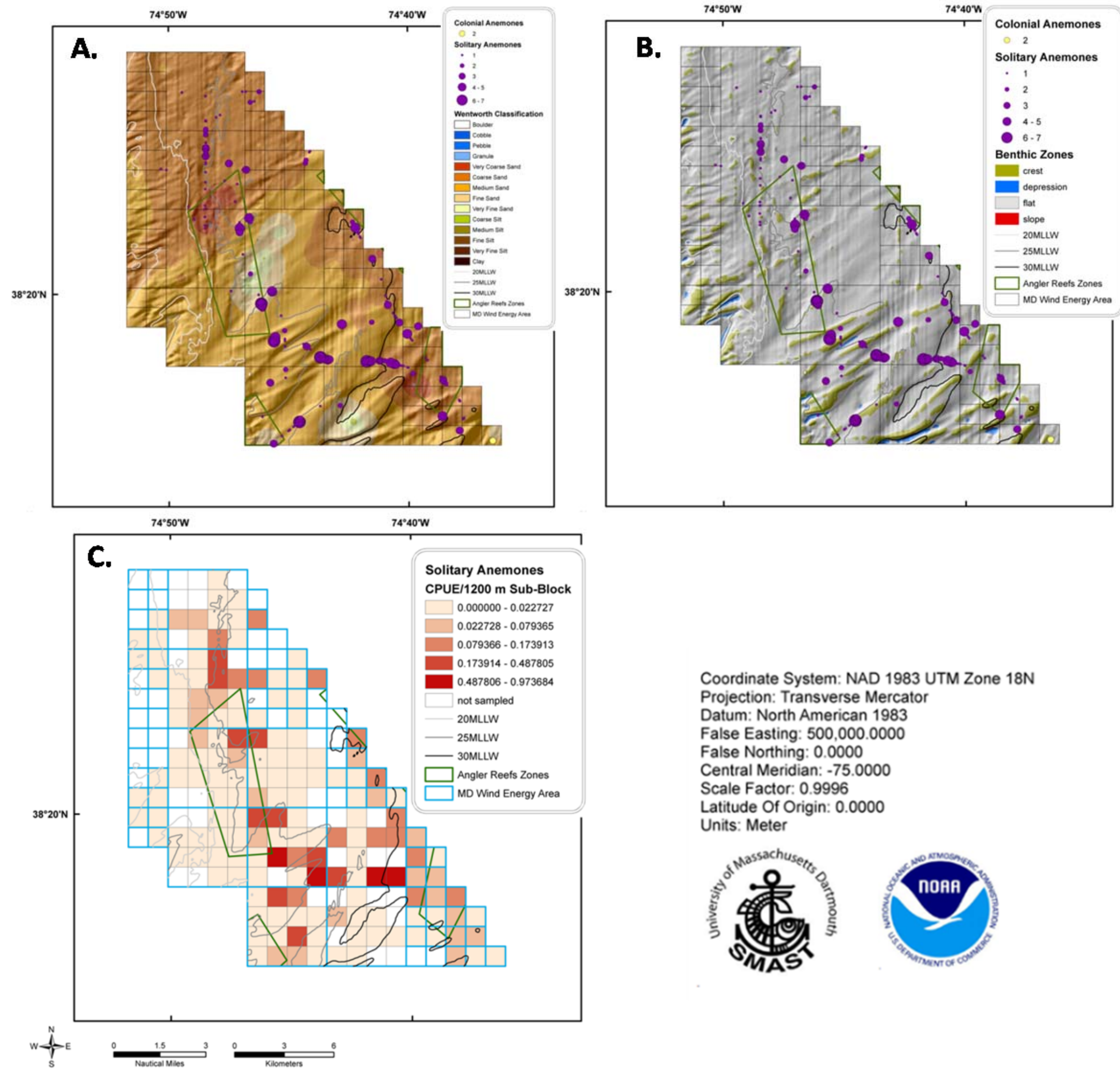


Figure 2-35. Solitary and colonial anemones abundances from HabCam: Two colonial anemones were counted (yellow dot) from the same image in the southeast corner of the MD WEA. A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block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

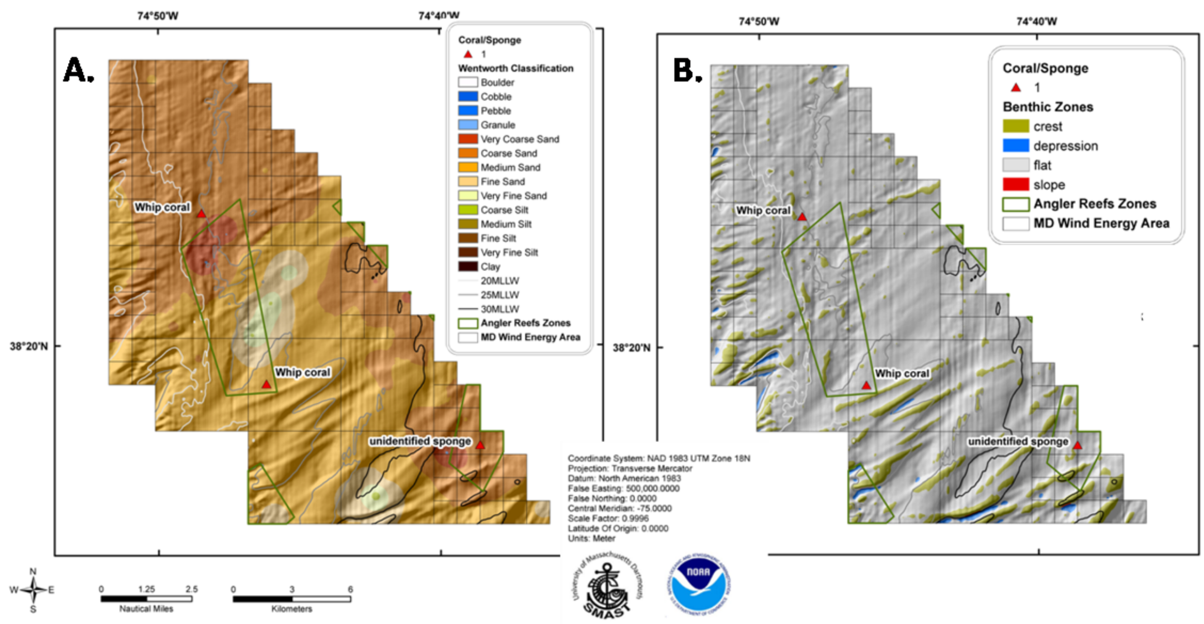


Figure 2-36. Coral and sponge abundances from HabCam: two whip corals (*Leptogorgia virgulata*) and one unidentified sponge associated with mean grain size. One of the corals and the one sponge recorded were also associated with angler reef zones. The sponge was found at a depth > 35 m. A. Overlaid on 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).

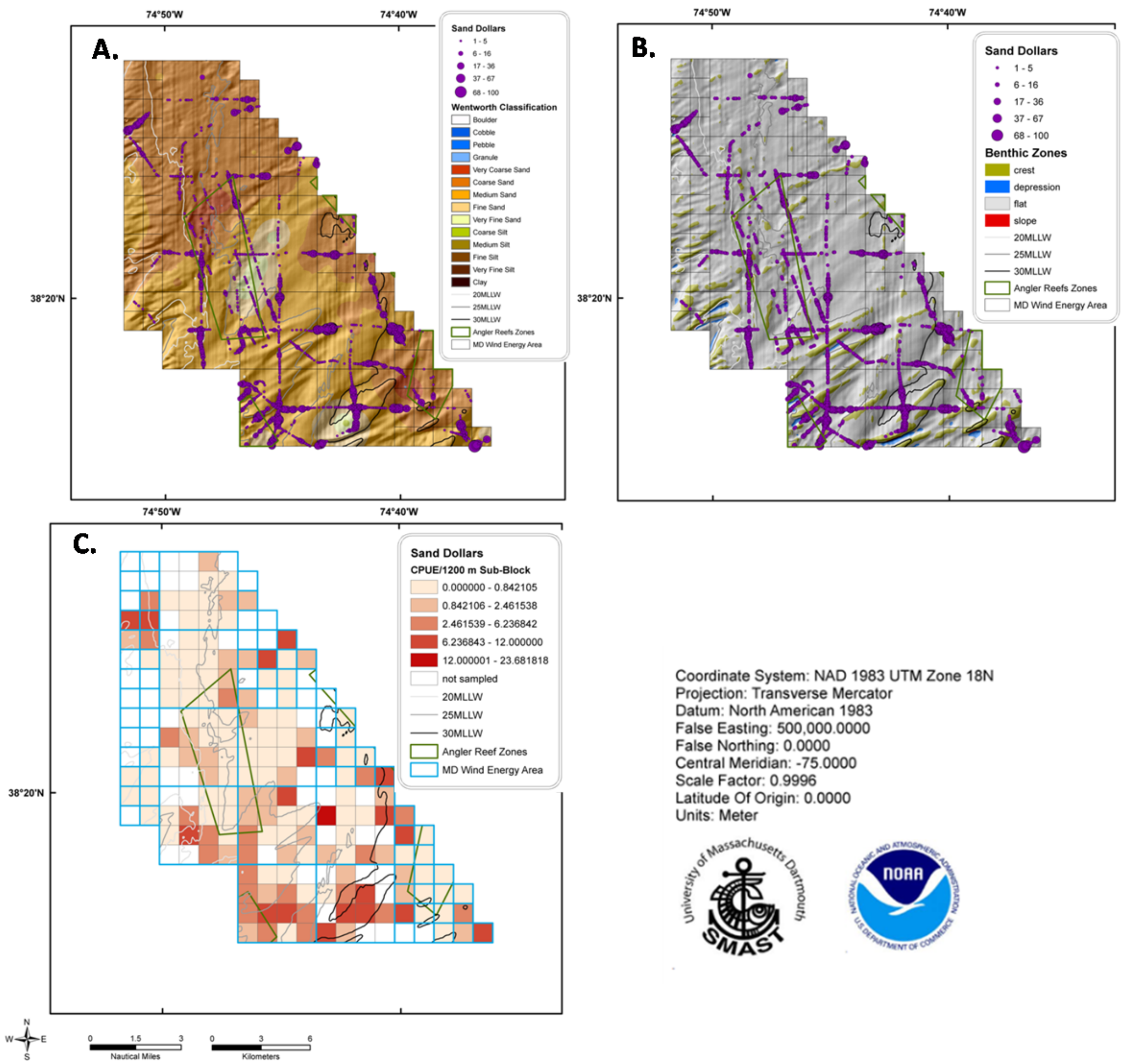


Figure 2-37. Sand dollar (*Echinarachnius parma*) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA, and C. CPUE/1207 m sub-block in the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

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.

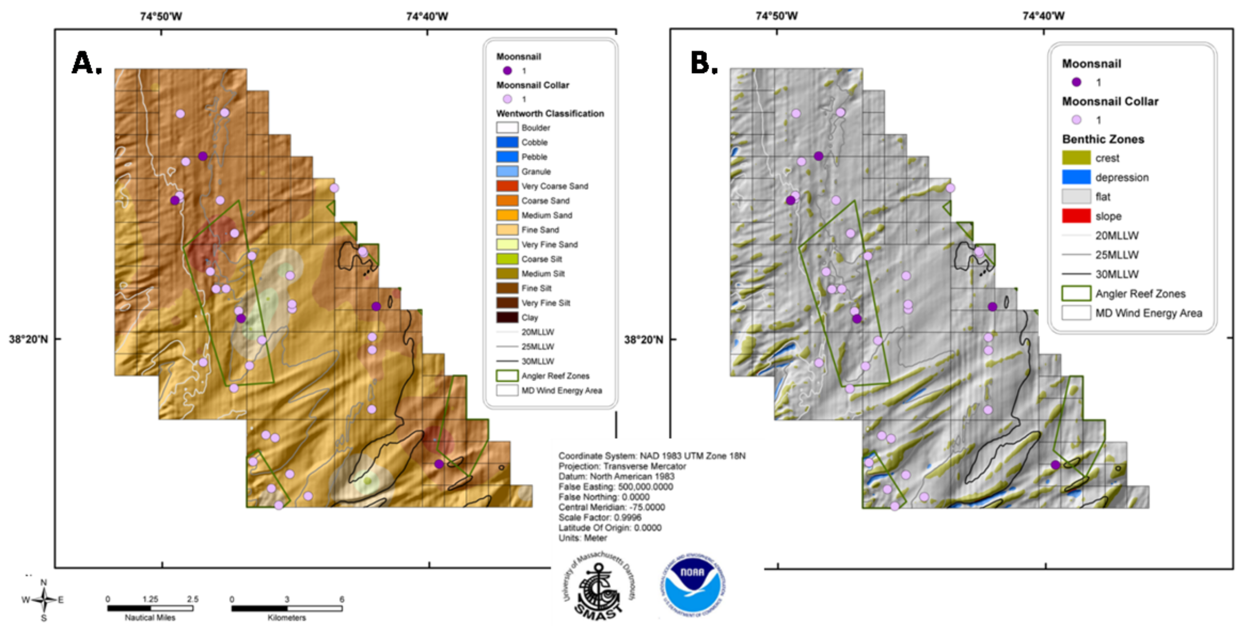


Figure 2-38. Moon snail (Naticidae) and sand collar (naticid egg cases) abundances from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

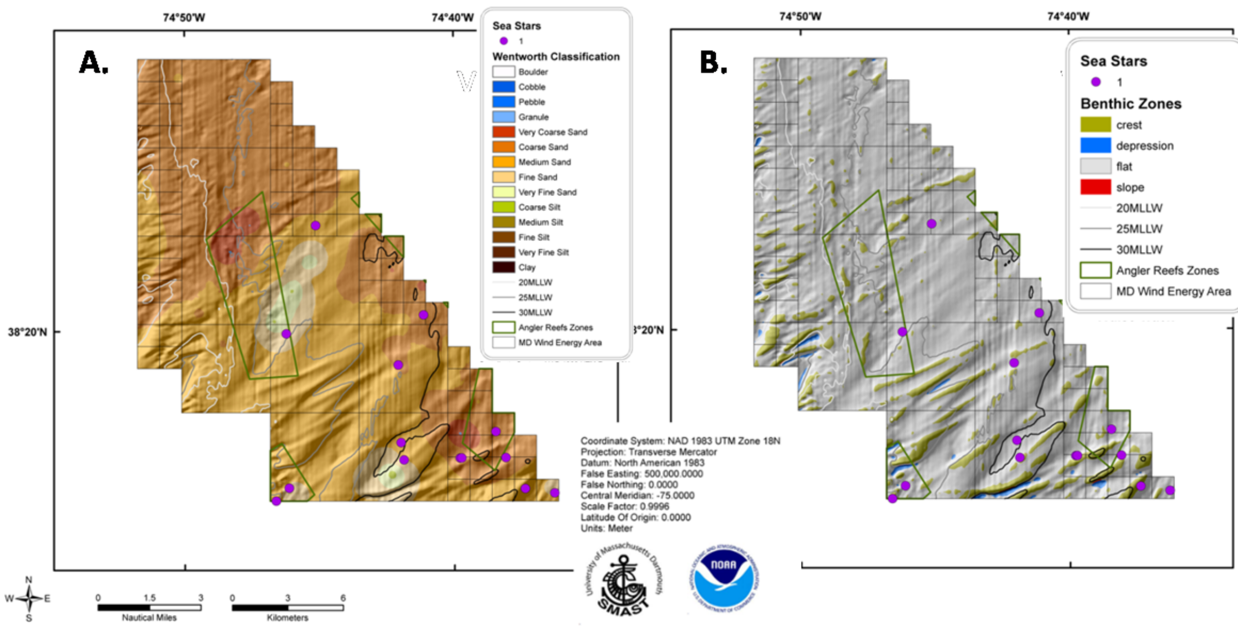


Figure 2-39. Sea star (*Asterias* sp.) abundance from HabCam: A. Overlaid on mean grain size for the MD WEA, B. Overlaid on benthic zones size for the MD WEA. Source data: (NOAA 2013b, CB&I 2014, Hawkins 2013, BOEM 2013, NOAA 2013a).

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.

2.3.4.3 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 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).

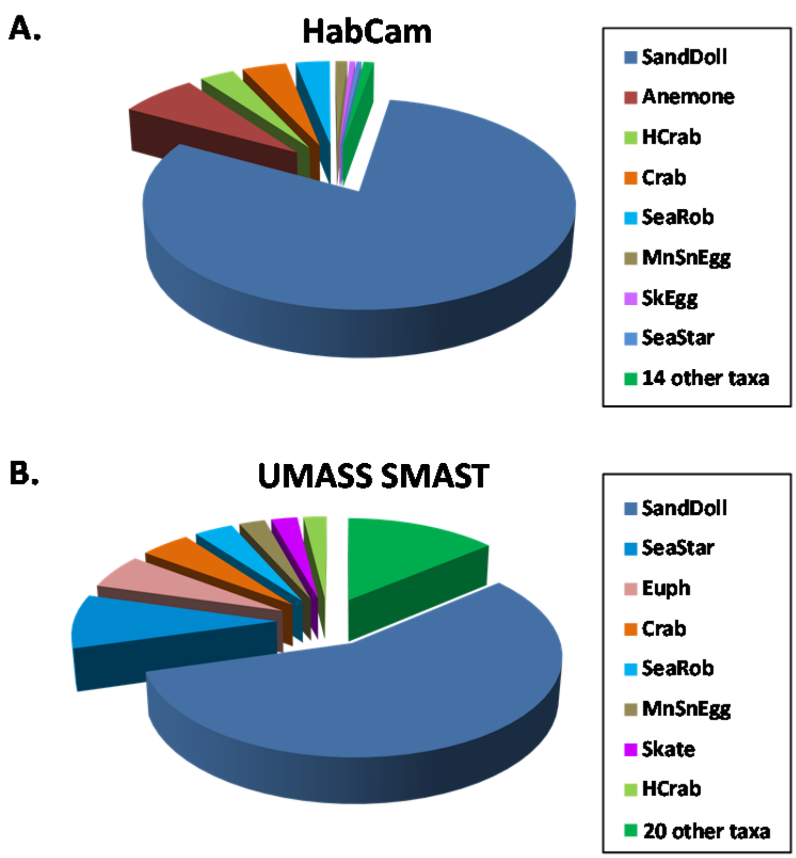


Figure 2-40. Comparison of proportions of epifauna by visual methods: A. HabCam, and B. SMAST surveys. Abbreviations: SandDoll – sand dollars, HCrab – hermit crabs, SeaRob – sea robins, MnSnEgg – moon snail egg cases, SkEgg – skate egg cases, SeaStar – sea stars, Euph – euphausiids.

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.

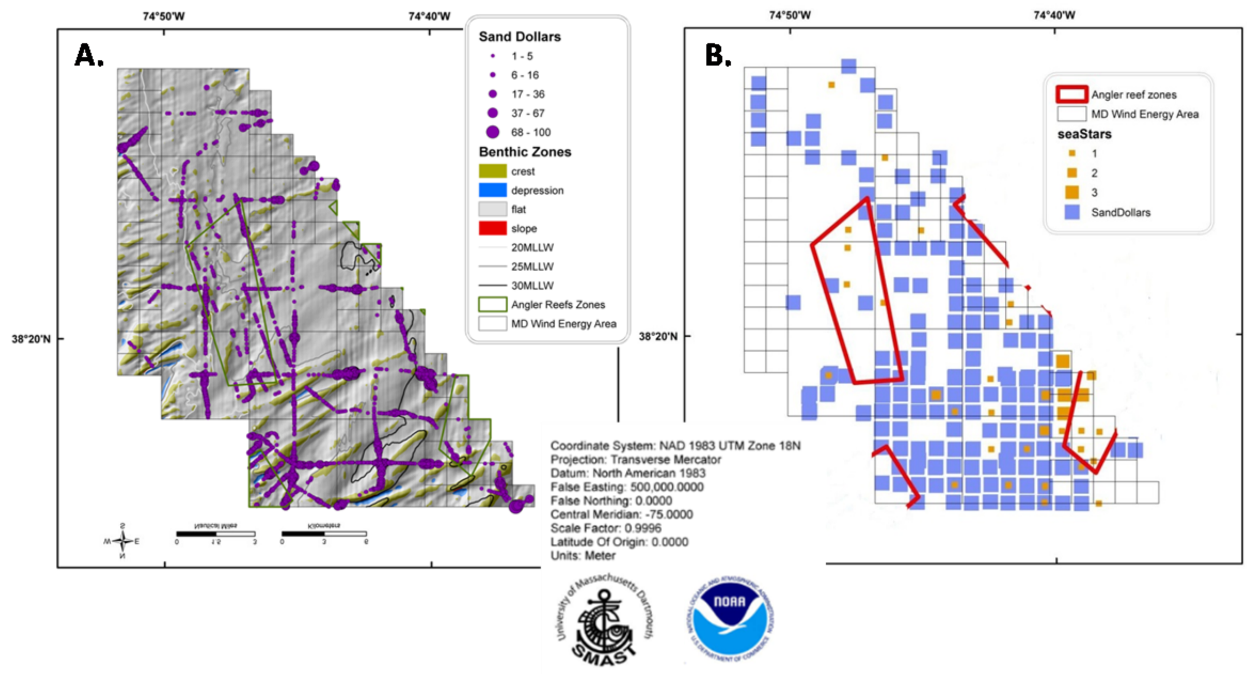


Figure 2-41. Comparative plots of sand dollar distribution in the MD WEA: based on data from A. HabCam IV (left, from Fig. 2-37 B), and from B. the UMASS-SMAST camera pyramid (Appendix X Fig. 16).

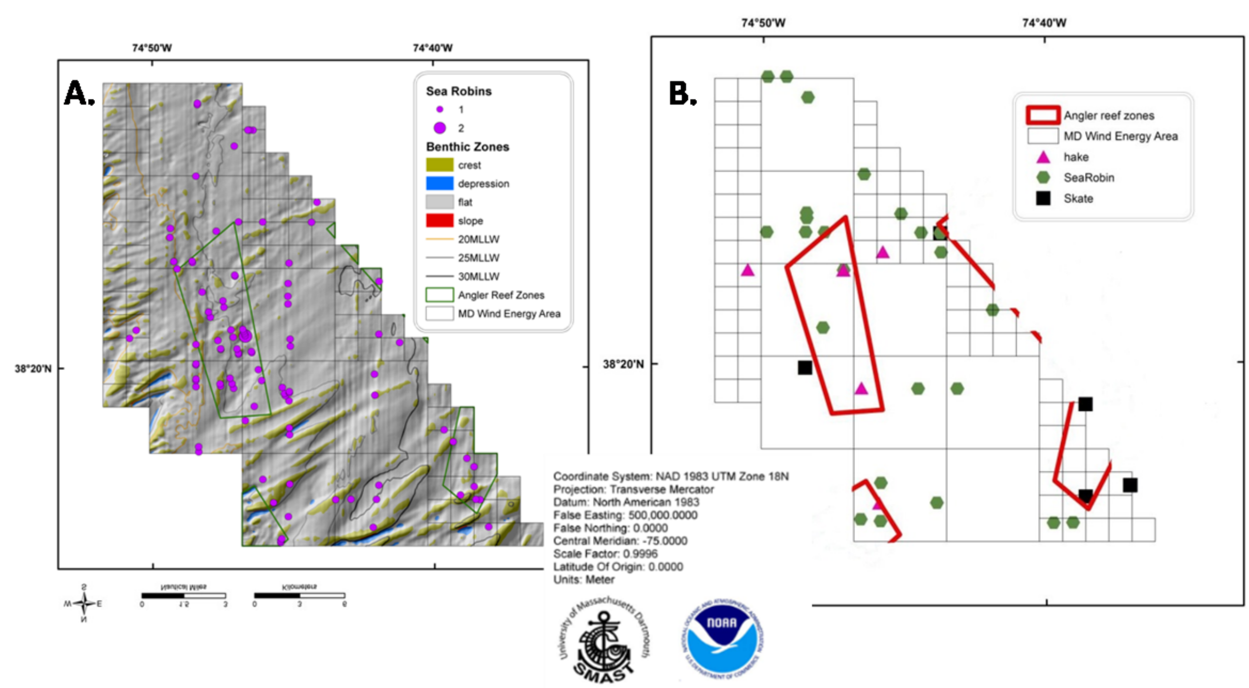


Figure 2-42. Comparative plots of sea robin distribution in the MD WEA based on data from A. HabCam IV (from Fig. 2-28 B), and from B. the UMASS-SMAST camera pyramid (Appendix 1, Fig. 27).

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.

2.3.4.4 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.

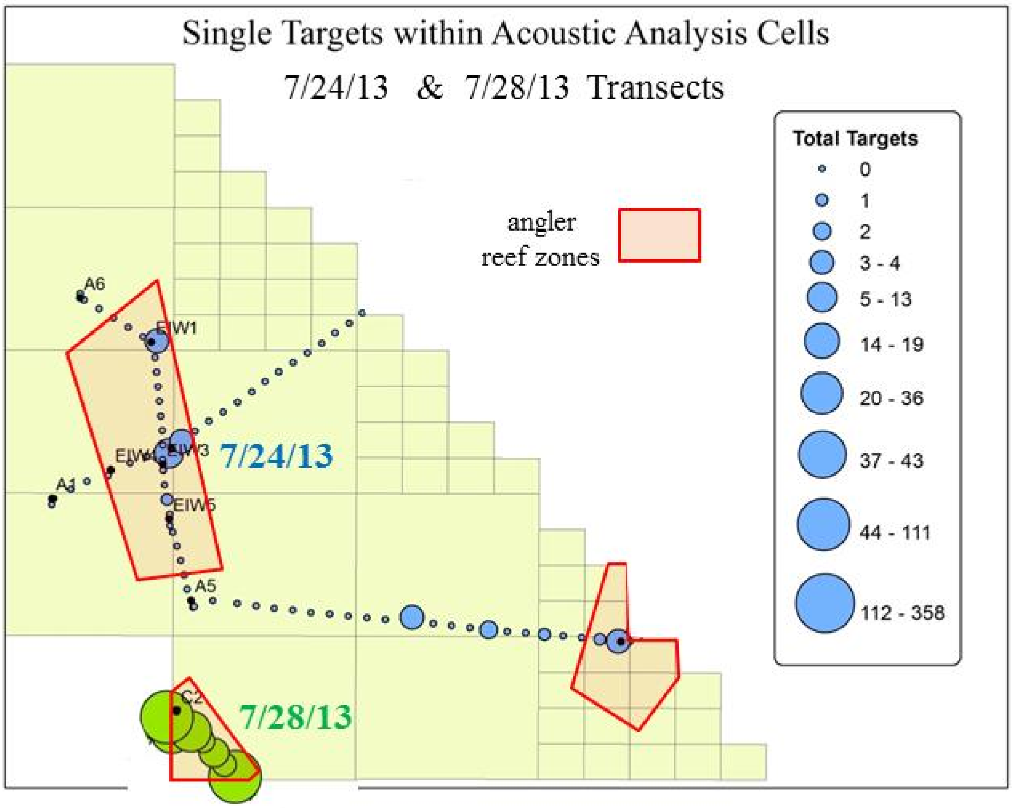


Figure 2-43. Acoustic targets detected during 7/24/13 and 7/28/13 transects on NOAA vessel *Resolute* in MD WEA. Red outlined areas show angler reef zones within the WEA. Two of these zones and the corresponding acoustic surveys also extend outside of the WEA (not shown).

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.

2.3.4.5 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 7 & 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 7 & 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 8B).

2.4 Comparison of Methods and Integration of Results

2.4.1 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

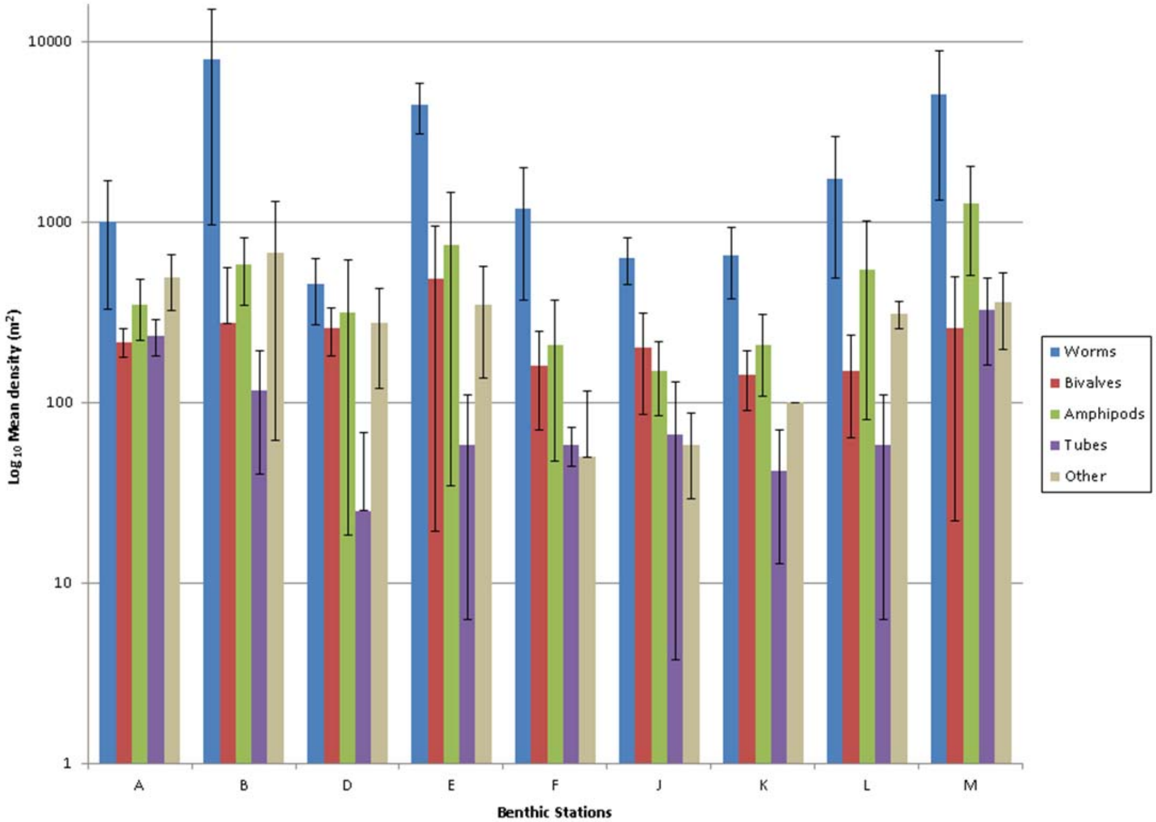


Figure 2-44. Log_{10} mean infaunal densities ± 1 standard deviation for benthic taxa. Samples were taken from nine stations aboard the NOAA ship *Gordon Gunter*, from July 4-9, 2013 in the MD WEA. Organisms were divided into five categories: worms, bivalves, amphipods, tubes, and others. Letter designations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

recorded by us. The UMASS team was better able to recognize sand ripples (Appendix 1, Figs. 4, 17) and included them in their sediment classification scheme as a result.

2.4.2 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 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 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).

2.4.3 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 4, 5). However they have some disadvantages. They are poor at catching the numerous smaller organisms

(Appendix 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 1, Table 3 and Appendix 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 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 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 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.

2.5 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 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 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 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.

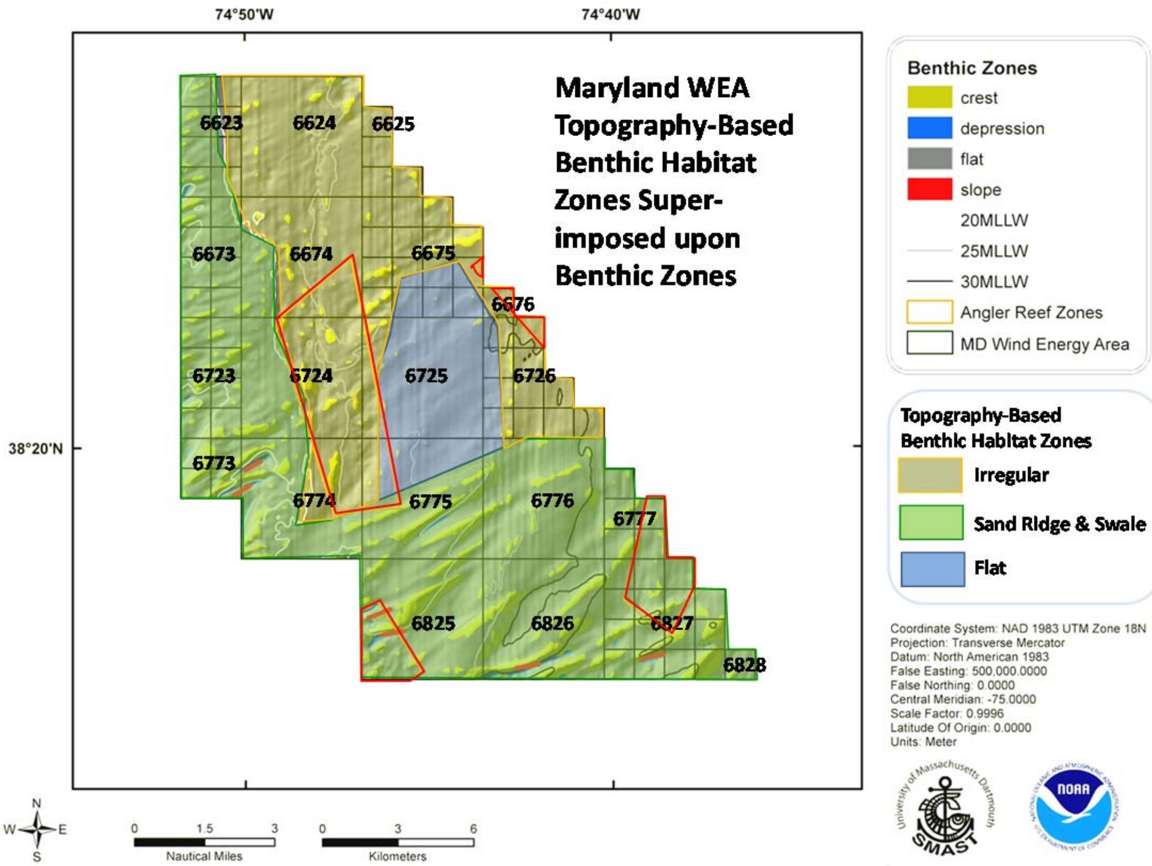


Figure 2-45. Topography-based benthic habitat zones superimposed upon benthic zones. Red lines indicate angler reef zones. Source data: (CB&I 2014, Hawkins 2013, BOEM 2013).

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 4 and 5**)**.

2.6 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:
[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.

2.7 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 4 and 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 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.

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APPENDIX 1

University of Massachusetts Dartmouth

School for Marine Science and Technology

Department of Fisheries Oceanography

SMAST video survey for a Wind Energy Area off the coast of Maryland

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APPENDIX 2

Grain size statistics for 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	Rep. No.	Lat (ddmm.mmmm)	Lon (ddmm.mmmm)	Mean D (m)	mean (phi)	std. dev.	skew-ness	Kurto-sis	gravel	sand	mud	sand in fines	Folk cat
A	1	3826.6183	7448.5102	24.6	0.644	0.723	-0.070	5.399	1.5%	98.5%	0.0%	100.0%	(g)S
A	2	3826.6642	7448.5642	24.8	0.898	0.995	-1.088	4.679	5.7%	94.3%	0.0%	100.0%	gS
A	3	3826.7182	7448.6125	24.4	0.558	0.782	-0.044	3.203	3.5%	96.5%	0.0%	100.0%	(g)S
B	1	3823.9796	7448.4171	26.9	1.691	0.666	-0.171	9.756	1.2%	98.8%	0.0%	100.0%	(g)S
B	2	3824.014	7448.4575	26.7	-0.930	1.137	1.263	2.655	57.2%	42.8%	0.0%	100.0%	sG
B	3	3824.0247	7448.5038	26.3	-0.231	0.922	0.037	3.146	15.8%	84.2%	0.0%	100.0%	gS
D	1	3818.9062	7448.4951	21.1	1.348	0.509	-0.024	8.050	0.6%	99.4%	0.0%	100.0%	(g)S
D	2	3818.9939	7448.4954	21.6	1.182	0.529	-0.016	3.699	0.0%	100.0%	0.0%	100.0%	S
D	3	3818.8755	7448.4857	21.1	1.535	0.401	-0.005	10.307	0.1%	99.9%	0.0%	100.0%	(g)S
E	1	3824.0836	7445.2224	28.9	0.054	1.117	-0.335	2.666	16.5%	83.5%	0.0%	100.0%	gS
E	2	3824.1518	7445.2171	28.1	-0.405	1.379	-0.831	1.909	34.3%	65.7%	0.0%	100.0%	sG
E	3	3824.213	7445.1726	28.9	-1.036	1.558	9.774	2.275	55.4%	44.6%	0.0%	100.0%	sG
F	1	3821.5193	7445.2124	28.5	0.337	1.134	-1.240	2.786	14.4%	85.6%	0.0%	100.0%	gS
F	2	3821.5919	7445.2342	28.4	0.606	0.855	-0.239	3.589	4.9%	95.1%	0.0%	100.0%	(g)S
F	3	3821.3871	7445.1095	28.4	0.519	0.949	-0.167	2.533	6.1%	93.9%	0.0%	100.0%	gS
J	1	3818.9648	7441.8709	27.8	0.432	1.078	-1.237	3.031	13.2%	86.8%	0.0%	100.0%	gS
J	2	3818.8665	7441.8994	27.7	0.529	0.846	-0.286	4.319	4.1%	95.9%	0.0%	100.0%	(g)S
J	3	3818.9767	7441.9245	28.0	0.488	1.051	-1.094	3.091	12.5%	87.5%	0.0%	100.0%	gS
K	1	3816.3022	7441.7899	30.8	1.030	0.815	-0.525	8.035	3.1%	96.9%	0.0%	100.0%	(g)S
K	2	3816.3575	7441.9058	31.8	1.144	0.664	-0.089	4.578	1.0%	99.0%	0.0%	100.0%	(g)S
K	3	3816.2762	7441.837	30.5	1.048	0.568	-0.008	2.920	0.1%	99.9%	0.0%	100.0%	(g)S
L	1	3818.9705	7438.6707	37.9	1.041	0.542	-0.006	3.468	0.3%	99.7%	0.0%	100.0%	(g)S
L	2	3818.8239	7438.6217	37.7	-0.977	1.395	1.776	1.576	51.9%	48.1%	0.0%	100.0%	sG
L	3	3818.8298	7438.5023	37.5	0.557	1.121	-2.683	4.540	10.3%	89.7%	0.0%	100.0%	gS
M	1	3816.2876	7438.589	33.9	0.258	0.905	-0.297	3.014	10.4%	89.6%	0.0%	100.0%	gS
M	2	3816.2417	7438.5581	34.8	-0.774	0.980	-0.031	2.521	39.5%	60.5%	0.0%	100.0%	sG
M	3	3816.3577	7438.6357	33.0	0.026	0.963	-0.347	3.108	13.8%	86.2%	0.0%	100.0%	gS

APPENDIX 3

Grain size statistics 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: Tewes 2013.

Site	N Lat (ddmm.mm mm)	W Lon (ddmm.mm mm)	mean (phi)	gravel	sand	mud	sand in fines	Folk cat
T14M	3818.8150	7400.1140	0.949	4.20%	91.28%	4.52%	95.3%	(g)S
T14S	3817.6250	7400.2130	1.083	2.00%	97.96%	0.04%	100.0%	(g)S
T29M	3818.8680	7400.5320	0.870	4.90%	92.96%	2.14%	97.7%	(g)S
T293	3820.1110	7400.5470	0.839	4.50%	92.29%	3.21%	96.6%	(g)S
T29S	3817.6110	7400.5960	1.092	1.80%	97.49%	0.71%	99.3%	(g)S
T16S	3817.6280	7400.7500	1.333	1.60%	96.66%	1.74%	98.2%	(g)S
T16E	3820.1670	7400.8060	0.963	2.10%	96.32%	1.58%	98.4%	(g)S
T16M	3818.8710	7400.8380	1.165	0.40%	99.58%	0.02%	100.0%	(g)S
T12M	3818.8310	7401.2810	1.191	1.70%	95.99%	2.31%	97.7%	(g)S
T12E	3820.2070	7401.3030	1.198	1.40%	98.58%	0.02%	100.0%	(g)S
T12S	3817.5660	7401.4100	1.388	0.50%	99.48%	0.02%	100.0%	(g)S
T15S	3820.2910	7402.2150	0.651	8.50%	91.45%	0.05%	99.9%	gS
T15E	3817.6650	7402.2150	1.388	0.30%	99.69%	0.01%	100.0%	(g)S
T15M	3819.3850	7402.3280	0.924	3.30%	95.78%	0.92%	99.0%	(g)S
T32S	3818.9520	7402.4710	1.146	1.40%	98.58%	0.02%	100.0%	(g)S
T33E	3819.6330	7402.4760	1.766	0.00%	98.84%	1.16%	98.8%	S
T33S	3817.6260	7402.6320	1.617	0.30%	99.68%	0.02%	100.0%	(g)S
T9M	3818.8300	7402.8900	1.911	0.30%	98.01%	1.69%	98.3%	(g)S
T9E	3817.5940	7402.8920	1.427	0.50%	99.46%	0.04%	100.0%	(g)S
T10S	3820.2350	7403.2940	0.711	5.80%	93.61%	0.59%	99.4%	gS
T10M	3818.9900	7403.4320	0.889	4.80%	92.28%	2.92%	96.9%	(g)S
T10E	3817.6160	7403.5860	0.837	4.90%	95.09%	0.01%	100.0%	(g)S
T32E	3820.0370	7404.3700	1.255	0.90%	99.10%	0.00%	100.0%	(g)S
T32M	3819.0580	7404.4020	1.742	0.00%	99.98%	0.02%	100.0%	S
T32S	3817.6130	7404.4790	1.311	1.00%	98.97%	0.03%	100.0%	(g)S
T11S	3820.2590	7404.6800	1.208	1.00%	98.95%	0.05%	99.9%	(g)S
T11M	3818.9460	7404.7420	1.165	1.20%	98.78%	0.02%	100.0%	(g)S
T11E	3817.6190	7404.8160	1.569	0.00%	99.97%	0.03%	100.0%	S
T7R	3819.7330	7404.9310	1.519	0.10%	99.87%	0.03%	100.0%	(g)S
T28M	3818.9270	7405.1330	1.989	0.20%	98.70%	1.10%	98.9%	(g)S
T28S	3817.6140	7405.2630	2.083	0.00%	99.98%	0.02%	100.0%	S
X1	3820.0920	7405.4570	1.690	0.02%	99.97%	0.01%	100.0%	(g)S
X2	3818.7540	7405.4680	1.816	0.00%	44.03%	55.97%	44.0%	sM
X3	3817.6990	7405.6090	2.351	0.00%	99.98%	0.02%	100.0%	S
T7	3820.1450	7405.6370	1.949	0.10%	98.81%	1.09%	98.9%	(g)S
T27E	3819.6580	7405.6980	1.548	0.30%	99.69%	0.01%	100.0%	(g)S

APPENDIX 3 (continued)

Grain size statistics from the benthic grab stations taken by Emily Tewes (UMES) during the summer of 2012. Folk category (Folk cat) abbreviations: S - sand, (g)S – slightly gravelly sand, gS – gravelly sand, sM – sandy mud. Source: Tewes 2013

Site	N Lat (ddmm.mmmm)	W Lon (ddmm.mmmm)	mean (phi)	gravel	sand	mud	sand in fines	Folk cat
BD1	3817.5910	7440.1390	1.490	0.90%	99.10%	0.00%	100.0%	(g)S
BD2	3818.8860	7440.2460	1.776	0.40%	99.56%	0.04%	100.0%	(g)S
BD3	3819.9910	7440.3140	1.265	5.70%	94.28%	0.02%	100.0%	gS
BD7	3817.9390	7440.7390	1.009	3.40%	96.54%	0.06%	99.9%	(g)S
BD5	3819.5630	7440.7990	0.306	15.10%	84.46%	0.44%	99.5%	gS
BD4	3820.0620	7441.0370	1.816	0.10%	99.87%	0.03%	100.0%	(g)S
BD6	3819.0320	7441.0410	0.773	4.80%	95.17%	0.03%	100.0%	(g)S
BD8	3817.7610	7441.0550	0.653	2.60%	97.38%	0.02%	100.0%	(g)S
T24E	3819.9420	7441.4210	-0.062	35.80%	62.45%	1.75%	97.3%	sG
T24M	3818.7930	7441.4320	0.941	4.70%	95.27%	0.03%	100.0%	(g)S
T24S	3817.5030	7441.5440	1.442	1.30%	97.53%	1.17%	98.8%	(g)S
T31M	3818.8510	7441.6790	0.452	6.80%	91.90%	1.30%	98.6%	gS
T31E	3820.0430	7441.6960	0.949	4.70%	93.79%	1.51%	98.4%	(g)S
T31S	3817.7290	7441.8070	1.102	2.80%	95.60%	1.60%	98.4%	(g)S
BD10	3819.0900	7442.0780	0.413	18.80%	81.17%	0.03%	100.0%	gS
BD11	3820.0160	7442.1050	0.269	9.80%	88.36%	1.84%	98.0%	gS
BD9	3817.7460	7442.1290	1.059	2.20%	97.78%	0.02%	100.0%	(g)S
T25E	3819.9690	7442.5390	0.776	2.40%	97.58%	0.02%	100.0%	(g)S
T25M	3818.8270	7442.5570	0.510	10.30%	87.67%	2.03%	97.7%	gS
T25S	3817.4490	7442.5820	1.056	1.50%	98.47%	0.03%	100.0%	(g)S
BD13	3819.4630	7442.6010	1.105	0.60%	96.86%	2.54%	97.4%	(g)S
BD15	3817.8840	7442.9550	-0.911	28.50%	71.50%	?	?	gS
BD14	3818.9530	7443.0060	1.626	0.20%	98.58%	1.22%	98.8%	(g)S
BD12	3820.0560	7443.0070	1.648	0.60%	97.78%	1.62%	98.4%	(g)S
T30M	3818.8940	7443.2400	1.535	0.80%	96.63%	2.57%	97.4%	(g)S
T30S	3817.6210	7443.2480	0.554	14.30%	84.58%	1.12%	98.7%	gS
T30E	3820.0680	7443.2560	0.963	5.70%	91.62%	2.68%	97.2%	gS
BD17	3818.8980	7443.5750	1.644	0.10%	99.02%	0.88%	99.1%	(g)S
BD18	3819.9990	7443.5820	1.290	0.60%	99.36%	0.04%	100.0%	(g)S
T13M	3818.6880	7443.6220	1.591	0.30%	99.67%	0.03%	100.0%	(g)S
T13S	3820.1860	7443.6350	1.362	0.40%	97.69%	1.91%	98.1%	(g)S
BD16	3817.7980	7443.6390	1.276	1.20%	98.28%	0.52%	99.5%	(g)S
T26M	3818.8560	7444.0450	1.188	0.90%	98.39%	0.71%	99.3%	(g)S
T26E	3820.0600	7444.0730	1.108	4.40%	94.58%	1.02%	98.9%	(g)S
T26S	3817.5230	7444.1140	1.336	0.40%	99.57%	0.03%	100.0%	(g)S

APPENDIX 4.

Taxonomic list of 10-year (2003-2012) NEFSC Fall bottom trawl survey catches in the MD WEA. Species are arranged by their percentage of numerical representation from the entire 10-year seasonal catch (% count). The proportion of trawls in which they occurred (% frequency) is also listed. Names in **bold type** represent demersal species associated with benthic habitats. Asterisks (*) indicate managed species in the northeast; one asterisk (*) non-federal managed, two asterisks (**) federally managed in the northeast region. Source: (NOAA, NEFSC 2014, Atlantic States Marine Fisheries Commission 2014).

Common Name	Scientific Name	% Count	% Freq
Atlantic croaker*	***Micropogon undulatus***	**29.98%**	**82%**
Weakfish*	***Cynoscion regalis***	**16.34%**	**64%**
Spot*	***Leiostomus xanthurus***	**14.75%**	**73%**
Northern sea robin	***Prionotus carolinus***	**8.89%**	**91%**
Longfin squid*	*Dorytethis peallii*	7.22%	73%
Bay anchovy	*Anchoa mitchilli*	6.61%	55%
Scup**	***Stenotomus chrysops***	**4.99%**	**82%**
Butterfish**	*Peprilus triacanthus*	3.83%	73%
Spotted hake	***Urophycis regia***	**1.53%**	**73%**
Smallmouth flounder*	***Etropus microstomus***	**1.37%**	**45%**
Striped anchovy	*Anchoa hepsetus*	1.18%	55%
Windowpane flounder**	***Scophthalmus aquosus***	**0.43%**	**82%**
Silver Anchovy	*Engraulus eurystole*	0.41%	9%
Little skate**	***Leucoraja erinacea***	**0.38%**	**73%**
Clearnose skate**	***Raja eglanteria***	**0.38%**	**73%**
Bluefish**	*Pomatomus saltatrix*	0.29%	73%
Bull nose ray	*Myliobatis freminvilli*	0.28%	64%
Smooth dogfish	*Musteleus canis*	0.21%	82%
Striped sea robin	***Prionotus evolans***	**0.19%**	**55%**
Summer flounder**	***Paralichthys dentatus***	**0.18%**	**100%**
Pinfish	*Lagodon rhomboides*	0.11%	9%
Northern puffer	*Spheroides maculatus*	0.07%	18%
Northern kingfish	***Menticirrhus saxatilis***	**0.06%**	**27%**
Black sea bass**	***Centropristis striata***	**0.06%**	**45%**
Winter skate**	***Leucoraja ocellata***	**0.06%**	**18%**
American sand lance	***Ammodytes americanus***	**0.05%**	**18%**
Southern kingfish	***Menticirrhus americanus***	**0.03%**	**18%**
Southern Rock crab	***Cancer irroratus***	**0.03%**	**36%**
Fourspot flounder	***Paralichthys oblongus***	**0.02%**	**27%**
Horseshoe crab*	***Limulus polyphemus***	**0.01%**	**22%**
Inshore lizardfish	***Synodus foetens***	**0.01%**	**18%**
Penaeid shrimp	**Penaeidae**	**0.01%**	**18%**
Striped cusk eel	***Ophidion marginatum***	**0.01%**	**9%**
Lady crab	***Ovalipes ocellatus***	**0.01%**	**9%**
Silver hake**	***Merluccius bilinearis***	**0.01%**	**9%**
Monkfish**	***Lophius americanus***	**0.01%**	**9%**
Cow nosed ray	*Rhinoptera bonasus*	0.01%	9%
Blotched cusk eel	***Ophidion grayi***	**0.01%**	**9%**
Jonah crab	***Cancer borealis***	**0.01%**	**9%**

APPENDIX 5.

Taxonomic list of 10-year (2003-2012) NEFSC Spring bottom trawl survey catches in the MD WEA. Species are arranged by their percentage of numerical representation from the entire 10-year seasonal catch (% count). Names in **bold type** represent demersal species associated with benthic habitats. Asterisks (*) indicate managed species in the northeast; one asterisk (*) non-federal managed, two asterisks (**) federally managed in the northeast region. Source: (NOAA, NEFSC 2014, Atlantic States Marine Fisheries Commission 2014).

Common Name	Scientific Name	% Count	% Freq
Little skate*	***Leucoraja erinacea***	**38.24%**	**86%**
Smallmouth flounder*	***Etropus microstomus***	**27.20%**	**43%**
Spotted hake	***Urophycis regia***	**14.73%**	**71%**
Bobtail squid	**Sepiolidae**	**5.10%**	**57%**
Windowpane flounder*	***Scophthalmus aquosus***	**3.12%**	**43%**
Spiny dogfish**	*Squalus acanthias*	2.55%	71%
Bay anchovy	*Anchoa mitchilli*	2.55%	14%
Striped bass*	*Morone saxatilis*	2.27%	43%
Winter skate*	***Leucoraja ocellata***	**1.70%**	**57%**
Penaeid shrimp	**Penaeidae**	**0.85%**	**14%**
Southern Rock crab	***Cancer irroratus***	**0.57%**	**29%**
Silver hake*	***Merluccius bilinearis***	**0.28%**	**14%**
Red hake*	***Urophycis chuss***	**0.28%**	**14%**
Summer flounder*	***Paralichthys dentatus***	**0.28%**	**14%**
Horseshoe crab*	***Limulus polyphemus***	**0.28%**	**14%**

APPENDIX 6.

Complete taxonomic list of 2008 Delmarva beam trawl survey catches near the MD WEA. Species are arranged by their percentage of numerical representation from the entire catch (% count). The proportion of trawls in which they occurred (% frequency) is also listed. Asterisks (*) indicate managed species in the northeast. The horseshoe crab was the only non-federally managed species among these. Source: (unpublished NEFSC trawl data, Atlantic States Marine Fisheries Commission, 2014).

Common Name	Scientific Name	Count percent	Catch frequency
Sand Dollar	*Echinarachnius parma*	65.20%	75.00%
Nassa snail	*Nassarius* sp.	9.39%	87.50%
Longclaw hermit crab	*Pagurus longicarpus*	6.87%	88.89%
Sand shrimp	*Crangon septemspinosa*	2.90%	69.44%
Common sea star	*Asterias* sp.	2.83%	87.50%
Rock crab	*Cancer irroratus*	2.66%	73.61%
Dwarf warty sea slug	*Pleurobranchaea tarda*	2.44%	81.94%
Gulf Stream Flounder	*Citharichthys arctifrons*	2.12%	87.50%
Acadian hermit crab	*Pagurus acadianus*	1.76%	40.28%
Northern Sea Robin	*Prionotus carolinus*	1.07%	63.89%
Flatclaw hermit crab	*Pagurus pollicarus*	0.84%	54.17%
Spotted Hake	*Urophycis regia*	0.62%	56.94%
Smooth Astarte clam	*Astarte castanea*	0.31%	25.00%
Longfin squid *	*Doryteuthis pealeii*	0.21%	23.61%
Butterfish *	*Peprilus triacanthus*	0.15%	31.94%
Sand Lance	*Ammodytes americanus*	0.09%	8.33%
Sea Scallop *	*Placopecten magellanicus*	0.09%	12.50%
Crab unclass.	Brachyura	0.06%	4.17%
Humphrey's Wentletrap	*Epitonium humphreysi*	0.05%	4.17%
Northern Moon Shell	*Euspira heros*	0.04%	5.56%
Northern dwarf tellin clam	*Tellina agilis*	0.03%	2.78%
Bobtail Squid	Sepiolidae	0.03%	8.33%
Windowpane *	*Scophthalmus aquosus*	0.02%	5.56%
Fourspot Flounder	*Paralichthys oblongus*	0.02%	5.56%
Florida lady crab	*Ovalipes floridanus*	0.02%	6.94%
Black Sea Bass *	*Centropristis striata*	0.02%	4.17%
Little Skate *	*Leucoraja erinacea*	0.02%	2.78%
Seahorse	*Hippocampus hudsonius*	0.01%	4.17%
File Yoldia clam	*Yoldia limatula*	0.01%	2.78%
Well Ribbed Dove Shell	*Anachis lafresnayi*	0.01%	2.78%

APPENDIX 6 (continued)

Complete taxonomic list of 2008 DelMarVa beam trawl survey catches near the MD WEA.

Common Name	Scientific Name	Count percent	Catch frequency
Spider crab, unclass.	*Libinia* sp.	0.01%	4.17%
Clearnose Skate	*Raja eglanteria*	0.01%	2.78%
Cusk-eel, unclass.	Ophidiidae	0.01%	2.78%
Nine-spined spider crab	Libinia marginata	0.01%	2.78%
Hermit Crab unclass.	Paguridae	0.01%	2.78%
Jackknife Clam	*Ensis directus*	0.01%	2.78%
Surf Clam *	*Spisula solidissima*	0.01%	2.78%
Red Hake *	*Urophycis chuss*	<0.01%	1.39%
Summer Flounder *	*Paralichthys dentatus*	<0.01%	1.39%
Winter Skate *	*Leucoraja ocellata*	<0.01%	1.39%
Silver Hake *	*Merluccius bilinearus*	<0.01%	1.39%
Monkfish*	*Lophius americanus*	<0.01%	1.39%
Unknown Flounder #1	Pleuronectiformes	<0.01%	1.39%
Unknown Flounder #2	Pleuronectiformes	<0.01%	1.39%
Fish unclassified	Osteichthyes	<0.01%	1.39%
Skate Egg in Case	Chondraichthyes	<0.01%	1.39%
Jonah crab	*Cancer borealis*	<0.01%	1.39%
Sea cucumber	*Pentamera pulcherrima*	<0.01%	1.39%
Shark's Eye Moon Shell	*Neverita duplicata*	<0.01%	1.39%
Purple sea urchin	*Arbacia punctulata*	<0.01%	1.39%
Mantis shrimp	*Nannosquilla grayi*	<0.01%	1.39%
Commensal crab	*Pinnixa cylindrica*	<0.01%	1.39%
American Lobster *	*Homarus americanus*	<0.01%	1.39%
Sea Cucumber unclass.	Holothuria	<0.01%	1.39%
Horseshoe Crab*	*Limulus polyphemus*	<0.01%	1.39%
Sand star	*Luidia clathrata*	<0.01%	1.39%

APPENDIX 7

Benthic infaunal summary from the nine grab sample stations taken aboard the NOAA ship *Gordon Gunter* in the MD WEA.

Sample	Est. Numbers per sq m					Grain Size
	worms	bivalves	amphipods	tubes	other	Folk cat
A1	1,625	250	425	250	675	(g)S
A2	275	225	425	275	450	gS
A3	1,125	175	200	175	350	(g)S
A mean	1008.3	216.7	350.0	233.3	491.7	
A stdev	682.5198	38.18813	129.90381	52.04165	166.4582	
B1	275	75	350	50	0	(g)S
B2	9,675	600	825	200	1,200	sG
B3	14,050	150	575	100	825	gS
B mean	8000.0	275.0	583.3	116.7	675.0	
B stdev	7038.599	283.9454	237.60962	76.37626	613.9015	
D1	300	325	75	0	325	(g)S
D2	650	175	650	75	400	S
D3	400	275	225	0	100	(g)S
D mean	450.0	258.3	316.7	25.0	275.0	
D stdev	180.2776	76.37626	298.25884	43.30127	156.1249	
E1	5,675	525	1,525	75	325	gS
E2	4,850	925	550	0	575	sG
E3	2,925	0	150	100	150	sG
E mean	4483.3	483.3	741.7	58.3	350.0	
E stdev	1411.19	463.9055	707.25408	52.04165	213.6001	
F1	325	75	25	50	0	gS
F2	1,275	150	325	75	125	(g)S
F3	1,950	250	275	50	25	gS
F mean	1183.3	158.3	208.3	58.3	50.0	
F stdev	816.369	87.79711	160.72751	14.43376	66.14378	
J1	425	100	125	0	75	gS
J2	700	175	100	125	25	(g)S
J3	775	325	225	75	75	gS
J mean	633.3	200.0	150.0	66.7	58.3	
J stdev	184.2779	114.5644	66.143783	62.91529	28.86751	

APPENDIX 8A. Taxonomic detail of benthic infaunal summary from the nine grab sample stations taken aboard the NOAA ship *Gordon Gunter* in the MD WEA: worms: polychaete annelids by family plus oligochaetes and sipunculids.

Group	Taxon	A	B	D	E	F	J	K	L	M	total	fraction	occurrence
worms	Oligochaeta	5	133	0	36	4	4	0	0	25	207	13.7%	48.1%
worms	Polygordiidae	3	49	0	69	8	2	4	8	18	161	10.7%	66.7%
worms	Syllidae	6	31	1	25	11	2	5	5	31	117	7.8%	51.9%
worms	Lumbrinereidae	0	4	1	15	13	7	1	29	29	99	6.6%	66.7%
worms	Dorvilleidae	2	59	0	7	1	3	2	2	8	84	5.6%	48.1%
worms	Paraonidae	5	24	0	13	4	1	5	2	24	78	5.2%	59.3%
worms	Cirratulidae	0	13	1	16	4	2	4	6	15	61	4.0%	55.6%
worms	Goniadidae	1	3	0	17	9	8	0	6	10	54	3.6%	55.6%
worms	Phyllodocidae	5	0	0	0	1	4	1	0	26	37	2.5%	29.6%
worms	Nemertea	3	2	0	9	2	4	4	3	6	33	2.2%	44.4%
worms	Spionidae	0	24	0	1	3	0	0	2	0	30	2.0%	29.6%
worms	Glyceridae	0	0	0	4	5	0	0	5	13	27	1.8%	29.6%
worms	Sigalionidae	4	0	1	2	1	4	1	1	4	18	1.2%	48.1%
worms	Terebellidae	0	3	0	4	1	0	0	0	8	16	1.1%	22.2%
worms	Eunicidae	0	0	0	0	0	0	0	9	5	14	0.9%	11.1%
worms	Ampharetidae	2	2	0	1	0	1	0	0	4	10	0.7%	25.9%
worms	Capitellidae	0	6	0	0	0	1	0	0	0	7	0.5%	11.1%
worms	Pilargidae	0	4	0	2	0	0	0	0	0	6	0.4%	7.4%
worms	Orbiniidae	0	2	0	1	0	0	0	2	1	6	0.4%	14.8%
worms	Maldanidae	0	0	0	0	0	0	0	4	1	5	0.3%	14.8%
worms	Onuphidae	2	3	0	0	0	0	0	0	0	5	0.3%	11.1%
worms	Opheliidae	0	3	0	0	1	0	0	0	0	4	0.3%	7.4%
worms	Nephtyidae	2	1	0	0	0	0	0	0	1	4	0.3%	14.8%
worms	Polynoidae	0	1	0	2	0	0	0	1	0	4	0.3%	14.8%
worms	Scalibregmatidae	0	1	0	2	0	0	0	0	0	3	0.2%	7.4%
worms	Oenonidae	0	0	0	0	0	0	2	0	0	2	0.1%	3.7%
worms	Nereididae	0	1	0	0	0	0	0	0	0	1	0.1%	3.7%
worms	Magelonidae	0	0	0	0	0	0	0	1	0	1	0.1%	3.7%
worms	Sipuncula	0	1	0	0	0	0	0	0	0	1	0.1%	3.7%

APPENDIX 8B. Taxonomic detail of benthic infaunal summary from the nine grab sample stations taken aboard the NOAA ship *Gordon Gunter* in the MD WEA: bivalves and amphipod crustaceans by species.

Group	Taxon	A	B	D	E	F	J	K	L	M	total	fraction	occurrence
bivalves	Bivalves unclassified	6	14	0	36	1	4	0	1	7	69	4.6%	44.4%
bivalves	*Spisula solidissima*	0	6	6	6	13	5	5	2	0	43	2.9%	59.3%
bivalves	*Astarte castanea*	0	2	6	0	1	3	2	1	6	21	1.4%	44.4%
bivalves	*Tellina tenella*	1	0	9	0	0	2	0	0	0	12	0.8%	22.2%
bivalves	*Ensis directus*	0	1	1	0	1	1	3	3	1	11	0.7%	33.3%
bivalves	*Periploma leanum*	1	0	0	0	0	2	3	0	2	8	0.5%	18.5%
bivalves	*Solamen glandula*	0	0	3	0	0	0	0	3	2	8	0.5%	22.2%
bivalves	*Nucula proxima*	0	1	0	0	0	0	1	0	1	3	0.2%	11.1%
bivalves	*Periploma fragile*	0	0	0	0	2	0	0	0	0	2	0.1%	7.4%
bivalves	*Cyclocardia borealis*	0	0	0	0	0	0	0	1	1	2	0.1%	7.4%
bivalves	*Placopecten magellanicus*	0	0	0	1	0	1	0	0	0	2	0.1%	7.4%
bivalves	*Mytilus edulis*	0	0	0	1	0	0	0	0	0	1	0.1%	3.7%
bivalves	*Arctica islandica*	0	0	0	0	0	0	0	1	0	1	0.1%	3.7%

Group	Taxon	A	B	D	E	F	J	K	L	M	total	fraction	occurrence
amphipods	*Unciola irrorata*	6	9	0	5	3	1	0	14	2	40	2.7%	44.4%
amphipods	*Protohaustorius wigleyi*	8	2	20	0	1	2	5	1	0	39	2.6%	48.1%
amphipods	*Rhepoxynius hudsoni*	0	1	6	0	0	0	1	1	0	9	0.6%	14.8%
amphipods	*Pseudunciola obliquua*	0	7	0	0	0	0	0	0	0	7	0.5%	7.4%
amphipods	*Bathyporeia quoddyensis*	0	1	2	0	0	0	3	0	0	6	0.4%	11.1%
amphipods	*Hippomedon serratus*	0	0	0	0	1	2	0	1	0	4	0.3%	14.8%
amphipods	*Byblis serrata*	0	2	0	0	0	0	0	1	0	3	0.2%	7.4%
amphipods	*Dyopedos manacantha*	0	1	0	0	1	0	0	1	0	3	0.2%	11.1%
amphipods	*Parahaustorius attenuatus*	0	0	3	0	0	0	0	0	0	3	0.2%	7.4%
amphipods	*Ameroculodes* spp. complex	0	0	0	0	0	1	1	0	1	3	0.2%	11.1%
amphipods	*Phoxocephalus holbolli*	0	2	0	0	0	0	0	1	0	3	0.2%	7.4%
amphipods	*Acanthohautorius similis*	0	1	0	0	0	0	0	0	0	1	0.1%	3.7%

APPENDIX 8C. Taxonomic detail of benthic infaunal summary from the nine grab sample stations taken aboard the NOAA ship *Gordon Gunter* in the MD WEA: other taxa (non-amphipod crustaceans, gastropod mollusks, and echinoderms by species, others by major taxon) and station totals for counts and taxa (all groups).

Group	Taxon	A	B	D	E	F	J	K	L	M	total	fraction	occurrence
other	Ascidiacea	7	2	16	2	0	1	0	0	1	29	1.9%	37.0%
other	*Tanaissus psammophilus*	5	2	0	3	7	0	2	5	1	25	1.7%	37.0%
other	*Chiridotea coeca*	0	0	0	2	2	4	1	1	0	10	0.7%	25.9%
other	*Edotia triloba*	0	6	0	0	0	0	1	3	0	10	0.7%	22.2%
other	*Pseudoleptocuma minus*	4	2	0	0	0	0	0	2	1	9	0.6%	18.5%
other	*Echinarachnius parma*	0	0	2	0	0	1	2	0	0	5	0.3%	14.8%
other	Naticidae sp. juvenile	0	0	1	0	2	1	0	0	1	5	0.3%	14.8%
other	*Cancer irroratus*	0	2	1	0	0	1	0	0	0	4	0.3%	14.8%
other	*Pagurus annulipes*	0	1	1	0	0	0	0	0	0	2	0.1%	7.4%
other	Cephalochordata	1	0	0	0	1	0	0	0	0	2	0.1%	7.4%
other	*Caecum johnsoni*	1	0	0	0	0	0	0	0	1	2	0.1%	7.4%
other	*Oxyurostylis smithi*	0	0	0	0	0	0	0	1	0	1	0.1%	3.7%
other	*Crangon septemspinosa*	0	0	0	0	0	0	1	0	0	1	0.1%	3.7%
other	*Dissodactylus mellitae*	0	0	1	0	0	0	0	0	0	1	0.1%	3.7%
other	*Politolana polita*	0	1	0	0	0	0	0	0	0	1	0.1%	3.7%
other	*Eulimastoma engonium*	0	0	0	0	0	0	0	0	1	1	0.1%	3.7%
other	*Turbonilla interrupta*	0	0	0	0	0	0	0	0	1	1	0.1%	3.7%
	TOTAL COUNTS	80	436	82	282	104	75	60	130	259	1508	100.0%	
	TOTAL TAXA	29	50	26	33	35	36	31	42	41	78		