Prepared in cooperation with the Bureau of Ocean Energy Management

2014 Seafloor Sediment Analysis and Mapping - Southern Maine

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Maine Coastal Program, January 2016

Disclaimer

For an overview of the Maine Coastal Mapping Initiative (MCMI) information products, including maps, data, imagery, and reports visit http://www.maine.gov/dacf/mcp/planning/mcmi/index.htm.

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ABSTRACT

One goal of the Maine Coastal Program's cooperative agreement with the Bureau of Ocean Energy was to characterize offshore sediment deposits in order to identify potential sand resources that may be used for beach nourishment in the event of an erosional storm. In 2014, the Maine Coastal Mapping Initiative collected 28 sediment samples in the federal portion of the focus area located offshore of Kennebunkport in Southern Maine, though 49 additional samples were collected nearer to shore. Samples were processed to determine the relative concentrations of gravel, sand, and mud (Folk 1954), and the sand fraction was further analyzed to determine the degree of sorting and the distribution of grain sizes within the fraction (Wentworth 1922). Additionally, sediment color (Munsell, 1923) was also determined to further explore the potential compatibility of nourishing existing beaches with sediment dredged from offshore deposits. Although sand was more abundant closer to shore, 16 out of the 28 samples collected in federal waters contained >50% sand (mean sand composition of all samples = 46.3% ± 22. 4%). Prior to sediment dredging for beach nourishment purposes, more extensive coring and/or sub-bottom profiling would need to be conducted to estimate the volumes of these sediment deposits. In addition, these data are a critical component of benthic habitat classification and modeling performed by MCMI (see Ozmon, 2016). Overall, these data have a variety of applications and are an invaluable resource to public and private agencies who wish to more effectively manage and understand coastal and marine resources.

Introduction

Sustainable management and extraction of Maine's coastal and marine resources are necessary to ensure effective coastal resiliency and conservation efforts. The collection and analysis of geophysical and seafloor sediment data allow state and federal agencies to proactively identify the resources available to enhance resiliency, improve management of resources within their jurisdiction, and develop a more comprehensive understanding of potential resources. A key component of coastal resiliency and conservation efforts is access to quality nearshore and offshore sand and gravel resources. However, quantitative assessments for many of these resources have been conducted in mostly state waters (e.g. Kelley et al., 1997a, b). Recently, the Bureau of Ocean Energy Management (BOEM) has recognized the need to identify additional outer continental shelf (OCS) sand resources for beach nourishment and coastal restoration projects because sand resources in state waters are either diminishing or are of poor quality, or otherwise unavailable (U.S. Department of the Interior, 2014). The goals of this investigation are to describe and characterize marine sediment samples in the coverage area approximately 3-8 nm offshore of Kennebunkport, ME, to enable benthic habitat classification via the federally-approved Coastal and Marine Ecological Classification Standard (CMECS; FGDC, 2012), identify potential sediment resources for beach nourishment as outlined by BOEM, and investigate the relationship between sediment grain size and multibeam backscatter intensity to refine interpretations of seafloor sediment distribution across mapped areas.

Objectives

- Identify and map seafloor sand resources in the North Atlantic OCS focus areas established in the Maine Coastal Program's (MCP) cooperative agreement with BOEM
- Investigate the relationship between sediment grain size and multibeam backscatter intensity to map seafloor sediment types
- Characterize sediment grain size distributions and sorting to support benthic habitat classification

Focus Area

The 2014 focus area was chosen outside of Wells Embayment, where fluvial sand deposits from the discharge of the Little, Mousam, and Kennebunk Rivers were expected to have occurred due to the glacial history of the area (Figure 1). Kelley et al. (1987) documented sand deposits in the region nearshore and observed gravel bands in between the sandy and rocky zones. Existing literature also indicates that mixed gravel and sand substrates are common in Maine's coastal regions where water depth does not exceed 50 m (Kelley et al. 1987).

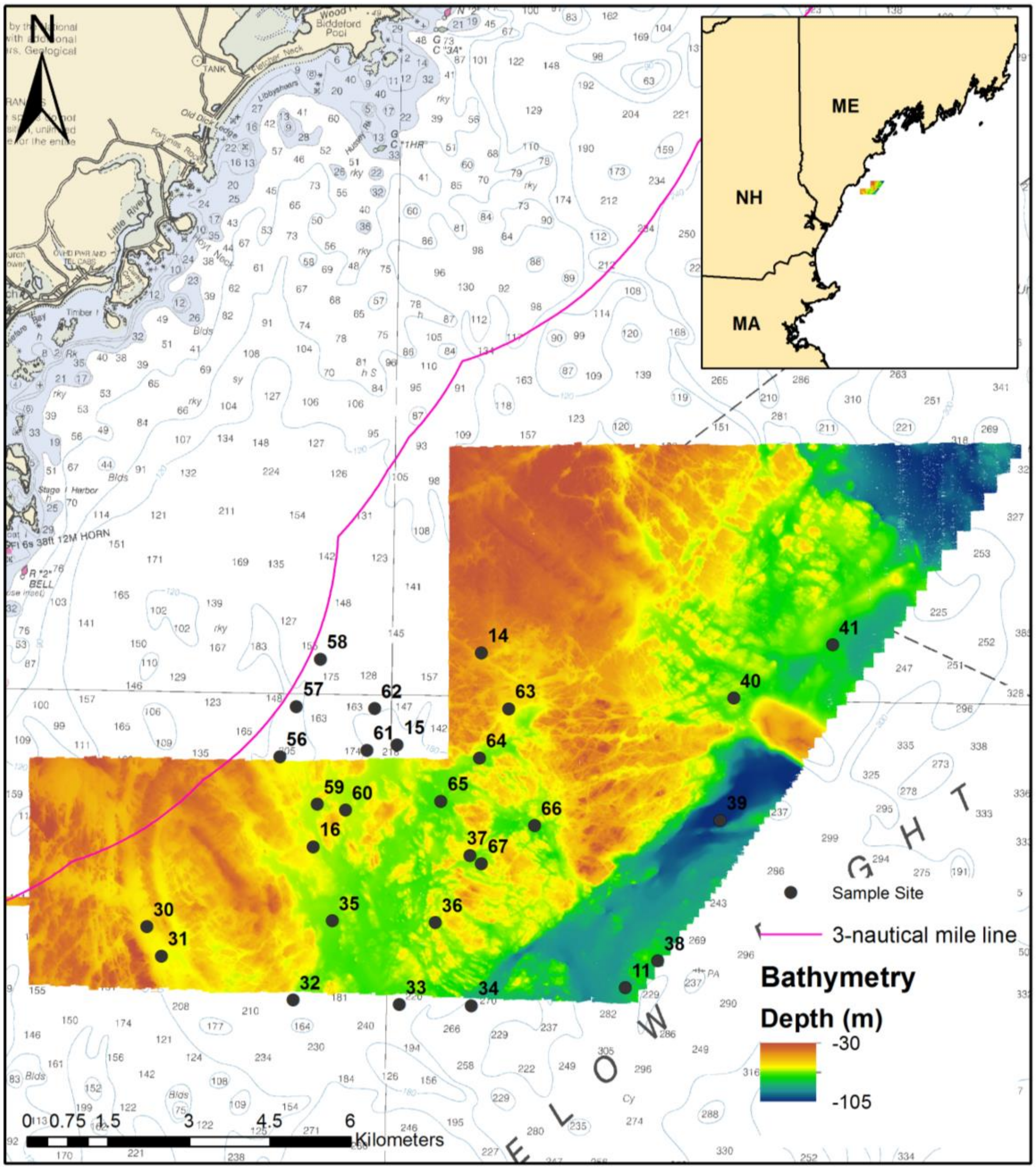

Figure 1. MCMI 2014 survey area bathymetry and grab sample sites (black circles with sample ID number) relative to 3-nautical mile line (state-federal jurisdiction boundary).

Methods

In the BOEM focus area, grab sample locations were selected in areas where preliminary analyses of multibeam echosounder (MBES) backscatter intensity data suggested the presence of a predominantly sandy and/or gravelly seafloor. Although a variety of environmental, geometric, and other external factors must be considered when interpreting backscatter data, the signal has been shown to directly relate to unconsolidated sediment grain size and seafloor roughness (Lurton and Lamarche, 2015), which makes this technique desirable for the purposes of this investigation. In addition to interpretations of MBES backscatter and depth data, the decisions to sample in areas immediately adjacent to the coverage area were influenced by a review of navigational chart bathymetry and existing literature that pertained to the seafloor geology (e.g. Barnhardt et al., 1997; 1998; and Kelley et al., 1997; 1998) of the focus area.

The bottom sampler used was a clamshell style 9 x 9” Ponar grab sampler. Immediately upon retrieval, the sediment surface was partitioned into two subsamples; a minimum of 1000 cm^3 was set aside for grain-size analysis and the remainder was sieved for infaunal analysis (for details, see Ozmon, 2015). Sediment subsamples were then bagged, labeled, and stored in coolers before and during transport to the sedimentology laboratory at the University of Maine (UMaine).

At each location where the sampler returned empty after three attempts a hard substrate (e.g. bedrock, boulders, etc.) was inferred. The x and y coordinates (WGS84, UTM Zone 19N meters; GPS horizontal accuracy at surface ±3 m) of each attempt were logged to account for vessel drift in between sampling attempts. Coordinates were not recorded until the sampler reached bottom and when the wench tether was visually confirmed to have a vertical/near-vertical orientation relative to a flat sea surface. The depth for each location was determined in real time using a hull-mounted single-beam fathometer and was not referenced to a specific vertical datum (e.g. MLLW). Thus, the vertical uncertainty associated with depths recorded for each site may be as much as the typical tidal range in the focus area (approximately 3 m).

Sediment samples were analyzed using standard laboratory techniques for the textural analyses. Sieve methods were used to determine the proportion of gravel-, sand-, and mud-sized particles to classify the overall sample using Folk classification scheme (Folk 1954; Figure 2 and Table 1). Grain-size statistical parameters were calculated by graphical and moment methods for the sand-sized portion of samples that contained greater than 20% sand-sized particles (Wentworth, 1922). This process was automated for samples processed at UMaine using a Rapid Sediment Analyzer settling tube. The remainder of each bulk sample was preserved for archiving at MCP in Augusta, ME.

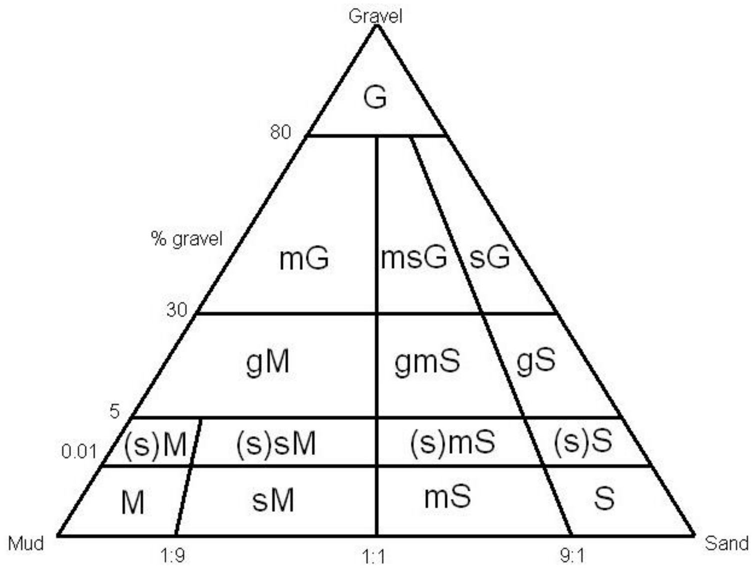

Figure 2. Sediment classification ternary diagram. Uppercase letters indicate predominant size component (m, = mud, s = sand, g = gravel, (s) = slightly gravelly). From Folk, 1954.

Table 1. Ternary diagram from Figure 3 modified from Folk (1954) to include classification R (rock or boulders) in table format.

Folk Code	Description	% gravel	Sand:Mud
R	Rock or Boulders	-	-
G	Gravel	80-100	-
sG	Sandy gravel	30-80	> 9:1
msG	Muddy sandy gravel	30-80	1:1 – 9:1
mG	Muddy gravel	30-80	< 1:1
gS	Gravelly sand	5-30	> 9:1
gmS	Gravelly muddy sand	5-30	1:1 – 9:1
gM	Gravelly mud	5-30	< 1:1
(s)S	Slightly gravelly sand	0.01-5	> 9:1
(s)mS	Slightly gravelly muddy sand	0.01-5	1:1 – 9:1
(s)sM	Slightly gravelly sandy mud	0.01-5	1:9 – 1:1
(s)M	Slightly gravelly mud	0.01-5	< 1:9
S	Sand	0-0.01	> 9:1
mS	Muddy Sand	0-0.01	1:1 – 9:1
sM	Sandy Mud	0-0.01	1:9 – 1:1
M	Mud	0-0.01	< 1:9

Results

Between May and November 2014, a total of 28 samples were collected in federal waters within and adjacent to the approximately 40 mi^2 (107 km^2) survey area. Table 2 contains a summary of sample depth and grain size analyses.

Table 2. Summary of sediment sample depth and grain size analyses.

Sample ID	Depth[1] (m)	Gravel (%)	Sand (%)	Mud (%)	S:M	Folk (1954)	Sand-sized Fraction Wentworth (1922)
K0011	87.2	52.43	7.01	40.56	0.17	mG	med. sand, poorly sorted
K0014	54.0	58.53	29.59	11.88	2.49	sG	coarse sand, well sorted
K0015	68.4	0.24	67.60	32.16	2.10	mS	fine sand mod. well sorted
K0016	65.6	0.92	55.88	43.20	1.29	mS	fine sand, mod. well sorted
K0030	61.0	6.20	62.36	31.44	1.98	mS	med. sand, mod. sorted
K0031	60.8	1.26	56.74	42.00	1.35	mS	fine sand, mod. well sorted
K0032	71.5	0.53	60.14	39.33	1.53	mS	fine sand, mod. sorted
K0033	74.0	8.13	64.80	27.07	2.39	mS	med. sand poorly sorted
K0034	85.5	3.28	35.71	61.01	0.59	sM	fine sand, mod. sorted
K0035	72.9	0.53	67.93	31.54	2.15	mS	fine sand, poorly sorted
K0036	70.0	90.36	0.42	9.22	0.05	G	-
K0037	71.0	45.96	36.70	17.35	2.12	msG	coarse sand, mod. sorted
K0038	82.0	55.45	11.80	32.75	0.36	mG	med. sand, poorly sorted
K0039	102.0	0.50	28.71	70.79	0.41	sM	fine sand, poorly sorted
K0040	73.0	28.72	44.28	27.00	1.64	gmS	med. sand, mod. sorted
K0041	77.3	2.75	61.84	35.42	1.75	mS	fine sand, mod. sorted
K0056	64.5	0.81	63.15	36.04	1.75	mS	fine sand, mod. sorted
K0057	62.8	33.51	40.79	25.70	1.59	gmS	coarse sand, mod. sorted
K0058	55.2	47.60	32.38	20.02	1.62	msG	coarse sand, mod. sorted
K0059	66.5	8.06	50.84	41.10	1.24	mS	med. sand, poorly sorted
K0060	66.0	6.96	73.59	19.45	3.78	mS	fine sand, mod. sorted
K0061	65.4	4.13	59.95	35.92	1.67	mS	med. sand poorly sorted
K0062	57.8	16.75	45.50	37.75	1.21	gmS	coarse sand, mod. sorted
K0063	60.8	4.92	73.24	21.84	3.35	mS	med. sand, mod. well sorted
K0064	70.4	39.44	32.05	28.52	1.12	msG	fine sand, mod. well sorted
K0065	72.7	4.31	56.85	38.84	1.46	mS	fine sand, mod. sorted
K0066	74.4	10.93	56.93	32.15	1.77	gmS	med. sand, mod. sorted
K0067	71.5	5.23	69.27	25.50	2.72	mS	med. sand, mod. sorted

[1]Depth measurements were recorded in real time and may differ from multibeam bathymetry data by ± 3m (i.e. the expected tidal range within the coverage area).

Appendix A contains additional data such as coordinates and Munsell colors for each sample. Table 3 illustrates the distribution of samples based on 10-m depth intervals. All samples were collected at depths ranging from 54 to 102 m but were mostly concentrated between 60 to 80 m. No samples were collected at depths less than 50 m or greater than 102 m, which generally reflects the lack of extensive unconsolidated substrate at depths less than 50 m, the general absence of depths less than 50 m in the survey area, and the scarcity of predominantly sandy material at depths greater than 80 m in federal waters within the survey area. A total of 16 samples were predominantly (>50% by weight) sand, 4 predominantly gravel, and 2 predominantly mud. The six remaining samples contained a mixture of all three size-fractions that were < 50% by weight.

Table 4 contains a summary of the distribution among samples based on grain-size analyses using the Folk (1954) classification system modified to include rocky/bouldery (R) substrates as well as unknown substrates. The backscatter map in Figure 3 illustrates the results shown in Table 4, where samples are colored based on Folk (1954) classification and the darkest shades of gray generally represent fine-grained, muddy sediments (e.g. mostly silt and clay), lighter shades represent progressively coarser material (e.g. sand and gravel); the lightest shades (e.g. white) represent bare rock. Although these conventions are useful for gross interpretations of sediment composition/distribution, there are many variables that can affect the backscatter intensity for a given substrate (e.g. beam angle incidence, slope, roughness, water content, biota, variations within water column, etc.; Lurton and Lamarche, 2015).

Table 3. Summary of sample depth distribution.

Depth (m)	**Number of Samples**
<50	0
50-59.99	3
60-69.99	10
70-79.99	11
80-89.99	3
>90	1

The sand-sized fraction of these samples were most frequently composed of fine or medium sand (graphic mean) and were commonly moderately or poorly sorted (Table 5; Appendix B). One sample, K0036 contained much less than the required 20%% sand-sized material and thus was not assigned a Wentworth classification (Appendix B).

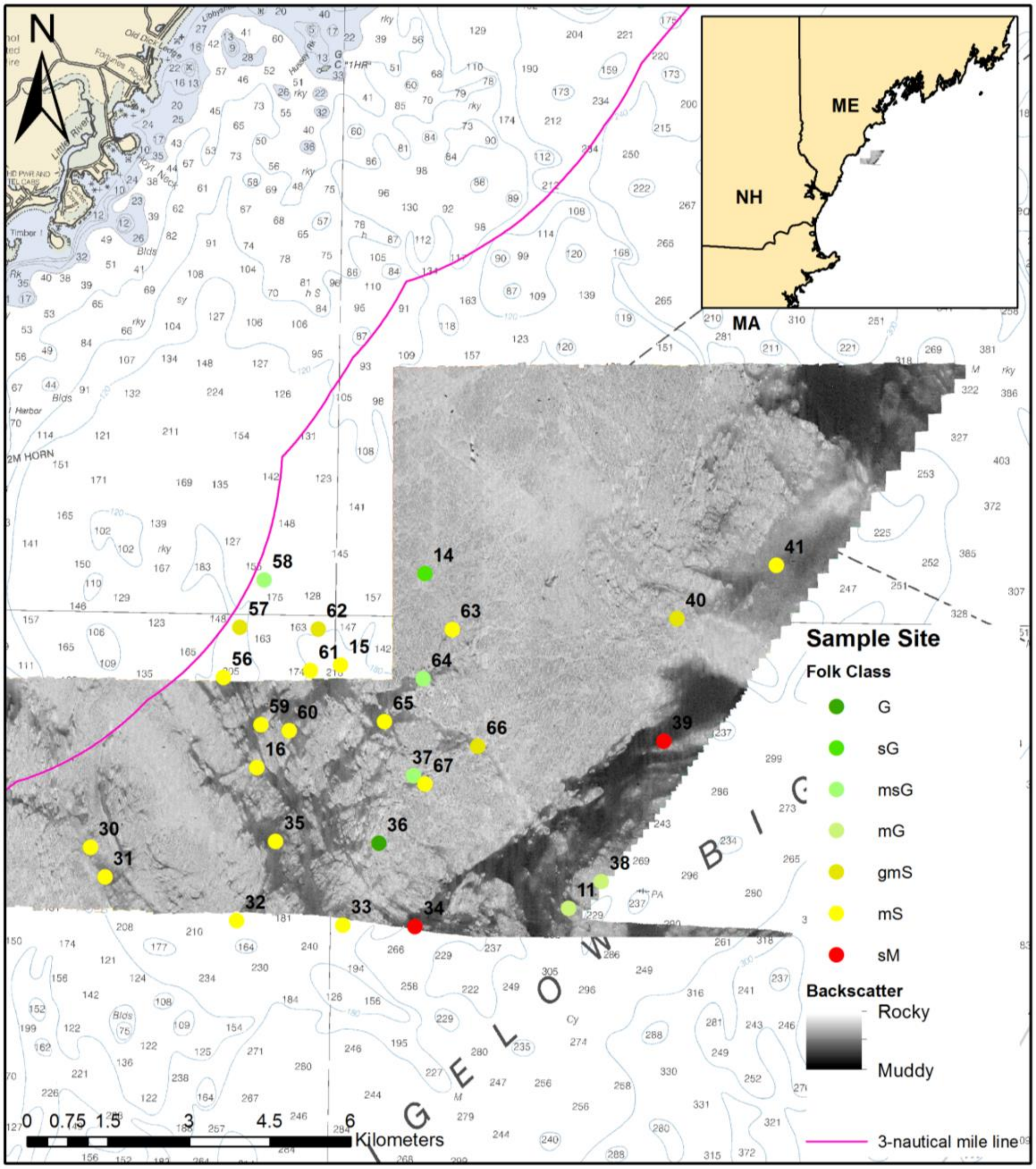

Figure 3. Sample sites colored (circles) based on Folk (1954) classification overlain with backscatter intensity, where darker colors indicate the presence of softer sediments, such as mud or clay, and lighter colors indicate the presence of harder substrates, such as bedrock or boulders.

Table 4. Summary of sample distribution based on modified Folk (1954).

Folk Code ID	**Folk Class.**	**# of Samples**
1	R	0
2	G	1
3	sG	1
4	msG	3
5	mG	2
6	gS	0
7	gmS	4
8	gM	0
9	(s)S	0
10	(s)mS	0
11	(s)sM	0
12	(s)M	0
13	S	0
14	mS	15
15	sM	2
16	M	0
17	Unknown	0

Table 5. Summary of graphic mean and sorting for sand-sized portion of qualifying samples.

Graphic Mean Size	**# of Samples**
V. Coarse Sand	0
Coarse Sand	5
Med. Sand	11
Fine Sand	11
V. Fine Sand	0
Sorting (graphic std. dev.)	**# of Samples**
V. Well Sorted	0
Well Sorted	3
Mod. Well Sorted	3
Mod. Sorted	14
Poorly Sorted	7

Discussion

The distribution of sediment types was consistent with existing interpretations of seafloor morphology within and adjacent to the focus area (e.g. Barnhardt et al., 1997; 1998 and Kelley, et al., 1997a, b). The majority of seafloor within the survey area consisted of rocky outcrops at less than 60 m depth (Fig. 4). The occurrences of sandy surficial deposits at depths less than 60 m were limited to discontinuous, shallow valleys in the highly-fractured bedrock. Although numerous, these deposits were spatially discontinuous and presumably thin. Limited grain-size data (e.g. K0014) also suggest that the cleanest (e.g. lack of fine-grained/muddy sediment) sands and gravels within the survey area were present in this type of setting at similar depths. Laterally extensive surficial deposits of predominantly sandy and/or gravelly material within the survey area were scarce and were restricted to the most prominent valleys in between outcrops and at depths ranging from 60 - 75 m. Although the majority of samples from 60 – 75 m depth were predominantly sand (e.g. mS, gmS), a considerable proportion of mud was very common (mean % mud = 32.8). Overall, grain-size data indicate that predominantly fine (e.g. mud) sediments are most common as depth increases beyond approximately 70 m and is a common trend observed along the coast of Maine (e.g. Kelley et al., 1997; Barnhardt et al., 1998).

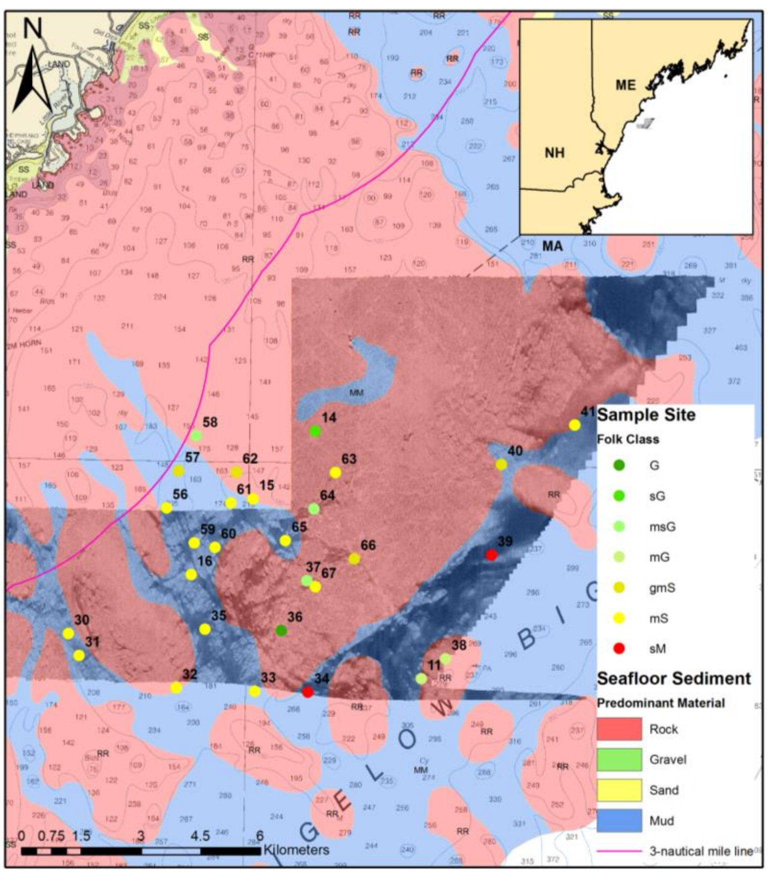

Figure 4. Generalized seafloor sediment map from Barnhardt et al. (1996) showing interpreted extent of seafloor substrates (Barnhardt et al., 1998) and sample site Folk (1954) classification.

BOEM was most interested in sand deposits at depths < 30 m for this investigation. Although the data collected by MCMI suggest that these deposits are mostly absent in the focus area, the sampling and survey data collected in deeper waters allow the characterization of sediment and geographic extent of the unconsolidated sediment in federal waters. In addition, the data collected by MCMI can serve as a resource to refine existing seafloor sediment and bathymetric maps of the region. Once final bathymetry and backscatter data products are generated, MCMI plans to perform in-depth spatial assessments of potential sand deposits at pre-defined depth intervals (e.g. 5 m, 10 m) in federal water within the 2014 coverage area.

Conclusions

During the 2014 survey season, MCMI collected a total of 28 bottom samples within the 40 mi^2 survey area. Analyses of grain-size, bathymetry, and backscatter data suggest that laterally extensive surficial deposits of predominantly sandy and/or gravelly material within the survey area were scarce and were restricted to the most prominent valleys in between outcrops and at depths ranging from 60 - 75 m. The occurrences of sandy surficial deposits at depths less than 60 m were limited to discontinuous, shallow valleys in the highly-fractured bedrock. Although numerous, these deposits were spatially discontinuous and presumably thin. Overall, data collected by MCMI indicate very low sand and gravel resource potential using traditional methods in the survey area offshore of Southern Maine.

In addition, these data are a critical component of benthic habitat classification and modeling performed by MCMI (see Ozmon, 2016). Overall, these data have a variety of applications and are an invaluable resource to public and private agencies who wish to more effectively manage and understand coastal and marine resources.

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Appendix A – Sample Site Coordinates and Munsell Colors

Sample ID	Northing (m)	Easting (m)	Munsell Color (Wet)
K0011	4793249	396247	2.5Y 4/2, dark grayish brown
K0014	4799476	393576	5Y 4/2, olive gray
K0015	4797768	392012	5Y 4/2, olive gray
K0016	4795869	390453	5Y 4/2, olive gray
K0030	4794383	387360	5Y 4/2, olive gray
K0031	4793836	387631	5Y 4/3, olive
K0032	4793022	390078	5Y 4/3, olive
K0033	4792935	392049	5Y 5/3, olive
K0034	4792914	393393	5Y 4/3, olive
K0035	4794495	390803	5Y 4/3, olive
K0036	4794461	392722	gravel
K0037	4795710	393364	5Y 4/3, olive
K0038	4793749	396850	5Y 4/4, olive
K0039	4796360	398011	5Y 4/4, olive
K0040	4798634	398262	5Y 4/4, olive
K0041	4799625	400101	5Y 4/3, olive
K0056	4797547	389835	5Y 4/3, olive
K0057	4798476	390142	5Y 4/4, olive
K0058	4799357	390586	5Y 4/1, dark gray
K0059	4796662	390527	5Y 4/4, olive
K0060	4796550	391052	5Y 4/2, olive gray
K0061	4797666	391451	5Y 4/3, olive
K0062	4798441	391593	5Y 4/3, olive
K0063	4798433	394083	5Y 4/4, olive
K0064	4797521	393541	5Y 4/3, olive
K0065	4796718	392826	5Y 4/3, olive
K0066	4796265	394562	5Y 4/2, olive gray
K0067	4795558	393578	5Y 4/3, olive

Coordinates are listed in projected coordinate systems WGS 84 UTM Zone 19N (meters).

Appendix B – Rapid Sediment Analyzer Raw Data

(See PDF attached)