Sediment and Benthic Fauna Characterization at Four Maine Beaches and the Jackknife Ledge Dredge Disposal Site, 2016-2020

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Prepared in with support of National Oceanic and Atmospheric Administration, Office of Coastal Management, Project of Special Merit Award NA17NOS4190170

Maine Coastal Mapping Initiative, December 2020

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Acknowledgements

The Maine Coastal Mapping Initiative would like to acknowledge the efforts of the University of Maine sediment laboratory personnel, Hodgdon Vessel Services, and Maine Geological Survey in the data collection and sediment analysis presented in this report. Funding for this study was provided by provided by the National Oceanic and Atmospheric Administration Office of Coastal Management (award number NA17NOS4190170).

Suggested citation:

Enterline, C, T. Trott, B, Kraun. 2020. Sediment and Benthic Fauna Characterization at Four Maine Beaches and the Jackknife Ledge Dredge Disposal Site, 2016-2019. Maine Coastal Program, Maine Department of Marine Resources, W. Boothbay Harbor, ME. 29 p.

ABSTRACT

The collection and analysis of seafloor habitat data allows state and federal agencies the information needed to responsibly manage nearshore coastal activities such as dredging, nourishment, and sand disposal. Recent efforts in Maine have identified that understanding sediment transport and the management of beach sediment and nourishment materials is vital to creating better municipal and regional beach management plans, as well as informing dredging and sand disposal. We determined differences among biological communities among nearshore sites, determined sediment grain size based on surface grab samples and backscatter assessment, and assessed differences in grain size and biological community composition at one dredge disposal site pre- and post-disposal and compare these characteristics to a proposed new disposal site. Surficial sediment from grab samples showed evidence of recent nourishment at many of the sampling sites. When combined with repeated efforts to collect backscatter, repeated sampling has the capability of demonstrating the broad surficial sediment changes following sand nourishment/disposal activities. We found that benthic species assemblages were representative of sandy bottom benthos, although there were some differences among sites and following sand disposal, likely due to differences among sediment type, specifically the amount of gravel. Although direct comparisons are not possible because of the sampling methodology, pre- and post-disposal similarities of species assemblages were found differ significantly. We also found that among the beaches sampled, Wells Beach was distinct based on its species assemblage and the presence of a rare species that is sensitive to disturbance. While further sampling should be performed at these sites to determine the effects of pre- and post-management activities and impacts over time, this additional benthic habitat data when combined with bathymetric change data collected during the same time period provides coastal managers a more comprehensive understanding about how nearshore sand placement impacts these areas.

Background and Purpose

The collection and analysis of seafloor habitat data allows state and federal agencies the information needed to responsibly manage nearshore coastal activities such as dredging, nourishment, and sand disposal. Recent efforts in Maine have identified that understanding sediment transport and the management of beach sediment and nourishment materials is vital to creating better municipal and regional beach management plans, as well as informing dredging and sand disposal. In 2006, a legislatively-approved Beaches Stakeholder Group prepared a report which proposed creation of an integrated beach management plan (Beach Stakeholder Group, 2006). This plan called for a better understanding about sediment management and the role beach nourishment might play in maintaining resiliency of Maine's coastal communities. In response, the Maine Geological Survey, with support from the Maine Coastal Program, are working to develop recommendations and prioritizations for beach management including nourishment schedules and monitoring.

Maine's experience with beach nourishment has generally been limited to the nearshore disposal of dredged materials as part of federal dredging of navigation channels by the US Army Corps of Engineers. Recent projects have occurred in nearshore waters off Wells, Old Orchard Beach, Saco, Scarborough, and Phippsburg. As part of a larger project to collect high-resolution topographic-bathymetric data over time to determine sand movement patterns at these sites, we collected additional information about benthic habitat and biological communities to develop a more thorough assessment of geologic resources and the biologic communities among them. By developing a more comprehensive understanding of the benthic habitat and the changes that occur after human interventions like sand nourishment and dredge disposal, managers can better understand the impacts and use the information to inform future actions.

This report provides a summary and analysis of the data collected during seafloor sampling efforts conducted by the Maine Coastal Program during 2016-2020 in support of efforts to better understand nearshore sand movement and dredge disposal effects at four Maine beaches and a nearshore disposal site (Figure 1). The objectives of this investigation were to (1) perform benthic habitat classification using the Coastal and Marine Ecological Classification Standard (CMECS; FGDC, 2012) and statistical analyses to determine differences among biological communities among four beaches (2) determine nearshore sediment grain size based on surface grab samples and backscatter assessment to develop a "baseline conditions" assessment at four beaches; and (3) assess differences in grain size and biological community composition at one dredge disposal site pre- and post-disposal and compare these characteristics to a proposed new disposal site. This additional benthic habitat data when combined with bathymetric change data collected during the same time period will provide coastal managers a more comprehensive understanding about how nearshore sand placement impacts these areas.

Focus Areas and Previous Work

Together the beaches at Wells, Old Orchard Beach, Saco, Scarborough, and Phippsburg (Figure 1) comprise about 40% of the area of all of Maine's beaches. In 1998, the Southern Maine Beach Stakeholder Group released a series of recommendations that included developing and maintaining information on beach erosion and beach nourishment, and developing local and regional management plans. These plans have helped inform onshore and nearshore sand nourishment placement and timing at Wells, Saco and Scarborough, which each received nourishment sand one or more times during 2015-2020 (Table 1).

To track changes in beach elevation over time and following onshore and nearshore sand placements, the Maine Geological Survey, Maine Sea Grant, and University of Maine Cooperative Extension established the State of Maine Beach Profiling Project (Maine SeaGrant 1999), to measure beach profiles at selected beaches in southern. These data have been used to qualitatively evaluate how sediment has moved after storms and after nourishment projects (Slovinsky and Dickson, 2007-2015). Additionally, the Maine Geological Survey has collected annual alongshore RTK-GPS terrestrial surveys of the seaward extent of dominant vegetation at each of this project's focus area beaches. These data have been used to supplement volunteer work, and have been used by local, regional, state, and federal managers to help inform decision-making associated with dune and beach management.

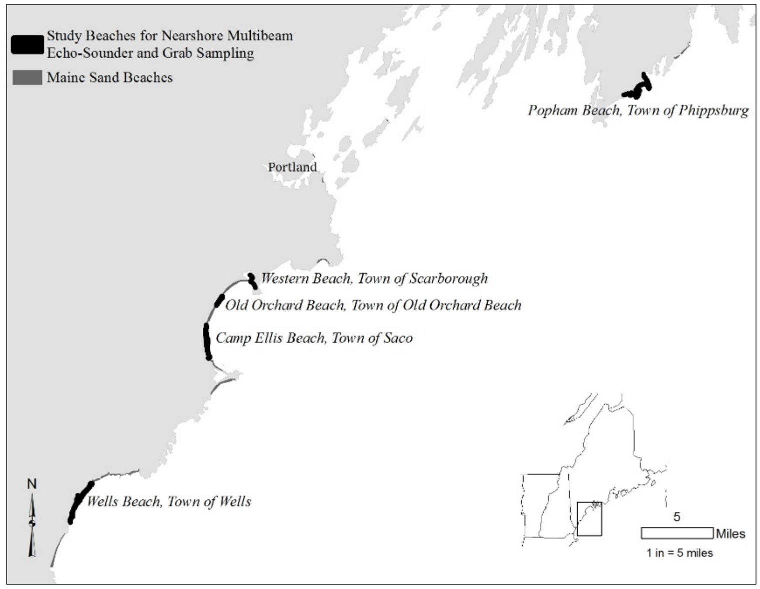

Figure 1. Multibeam echo-sounder collected bathymetry and backscatter, and grab samples collected water quality, surface sediment, and benthic fauna information at four Maine beaches and a dredge disposal site during the study period 2016-2020

At the Jackknife Ledge disposal area off Phippsburg, sand from dredging operations within the Kennebec River has been placed many times since the area was formally identified as a disposal area in 1998, chosen under the assumption that nearshore circulation would move this sand onshore at Popham Beach. However, bathymetry surveys in 2016 found that 19,500 cubic yards that had been placed at the site in 2011 had barely shifted from the original disposal cone (Dobbs 2016). With this new information the Maine Geological Survey recommended further characterization of the seafloor sediment and habitat at the existing disposal site preceding and following another disposal scheduled to occur in 2017, as well as characterization of potential new disposal sites to the west of Jackkinfe Ledge, again with the intent of placing disposal sand close enough to Popham Beach to allow for nearshore and onshore movement.

While recent efforts to collect bathymetric information at these sites, including water-penetrating LiDAR has been collected at some of these sites (USACE 2014, 2018), there has been no effort to characterize benthic habitat and the sediment changes following sand placement

Table 1. Recent onshore and nearshore sand placement and volumes at four Maine study beaches and a dredge disposal area from 2015-2020.

Site and Town	Disposal Month - Year	Volume (yd^3)	Placement
Wells Beach, Wells	June - 2018	30,000	Nearshore
Wells Beach, Wells	July - 2020	20,000	Nearshore
Camp Ellis Beach, Saco	March - 2019	62,000	Onshore
Western Beach, Scarborough	April - 2015	166,325	Onshore
Jackknife Ledge Disposal Area, Phippsburg	April - 2017	14,186	Nearshore

over time in these nearshore areas. The additional seafloor sediment and biological community characterizations performed in 2016-2020 will supplement these existing data resources and newly collected nearshore bathymetry to provide baseline characterizations of the benthic habitat for consideration in future nearshore nourishment decisions.

Methods

Field methods used during this investigation consisted of collecting high-resolution bathymetry and backscatter data using a multi-beam echosounder (MBES) and bottom sampling. MBES data were acquired aboard the R/V Amy Gale with a Kongsberg EM2040c set to a survey frequency of 300 kHz and high-density beam forming with 400 beams per ping. Parallel lines with consistent spacing (based on depth) were run at 6 - 6.5 knots throughout the survey area. Data acquisition was performed using the Quality Positioning Services (QPS) Quality Integrated Navigation System (QINSy) acquisition software (Table 2). The modules within QINSy integrated all systems and were used for real-time navigation, survey line planning, data time tagging, data logging, and visualization. Bathymetric data were processed using Qimera and time-series backscatter data were processed using QPS' Fledermaus Geocoder Tool software. Because data were acquired over multiple years, no single software version was used for the acquisition and processing software; in each year the most recent software versions were used.

Grab sample locations were selected in areas where preliminary analyses using the multibeam backscatter intensity data to target a range of intensity values that would suggest differences in sediment type. The bottom sampler was a single platform rig outfitted with a clamshell style Ponar grab sampler, GoPro Hero 3+ digital video camera inside a Group B Inc. dive housing, Keldan underwater dive light, dive lasers spaced at 10 cm for scale, and a Xylem Exo 1 to collect water column data (salinity, temperature, pH, dissolved oxygen, and chlorophyll concentrations; Figure 2). The 23 x 23 cm Ponar grab was capable of collecting a maximum volume of 8.2 liters of unconsolidated sediment per sampling attempt. Coordinates (WGS84, UTM Zone 19N meters; GPS horizontal accuracy at surface ±3 m) were recorded when the sampler reached bottom and when the wench tether was visually confirmed to have a

Table 2. Multibeam echo-sounder data were acquired and sediment grab samples, benthic fauna, and water column and seafloor water chemistry and video were taken at four beaches and the Jackknife Ledge area at multiple dates during the spring and fall from 2016-2020.

Site	Multibeam Echo-Sounder Data Acquisition Dates	Grab Sampling Dates
Wells Beach	Aug 2018, June 2019, Sept 2019, June 2020, August 2020	Sept. 10, 2019
Camp Ellis Beach, Saco	May 2019, Sept-Oct 2019, May 2020	Oct. 15, 2019
Old Orchard Beach	June 2019, Oct 2019, Oct 2020	Oct. 15, 2019
Western Beach, Scarborough	Aug 2018, June 2019, Oct 2019, June 2020, Oct 2020	Oct. 15, 2019
Jackkinfe Ledge – Current Disposal Area	July 2016, Nov 2017, May 2020	Sept. 20, 2016, May 11, 2017, Oct. 3, 2017
Jackkinfe Ledge – Potential New Disposal Areas	Oct 2017, Oct 2018, May 2019, Oct 2019, May 2020	Sept. 20, 2016, May 11, 2017, Nov. 20, 2019

vertical/near-vertical orientation relative to a flat sea surface. True depth (referenced to MLLW in meters) at each sample site was extracted from the final bathymetric surface (4-m grid) and was included with the data in this report. At each location where the sampler returned empty after three attempts, a hard substrate (e.g. bedrock, boulders, etc.) was inferred and confirmed later with video footage captured during each sampling attempt. Immediately upon retrieval, the sediment surface was photographed and partitioned into two subsamples; a minimum of 1000 cm^3 was set aside for grain-size analysis and the remainder was processed to collect infauna samples (see Ozmon, 2017). Sub-samples were divided so each contained portions of the entire depth of the original grab sample.

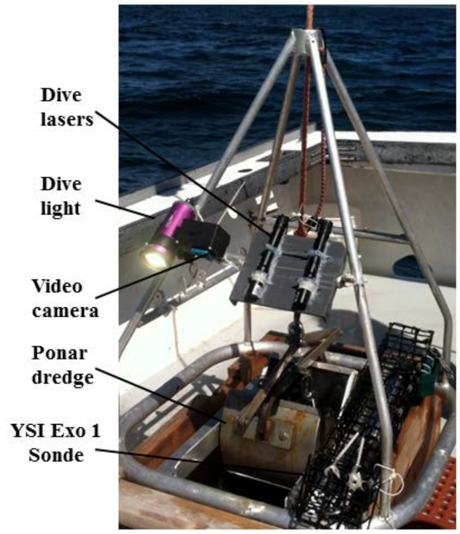

Figure 2. A grab sampling platform was used that collected various samples using a Ponar grab sampler (23 cm^2), GoPro Hero 3+ with dive housing and light, scale lasers, and Xylem Exo 1.

Sediment subsamples were bagged, labeled, transported in coolers, and held in refrigerators until being processed at the sedimentology laboratory at the University of Maine. Sediment samples were analyzed using standard laboratory techniques for the textural analyses of marine sediments (Poppe et al., 2005) by the sedimentology laboratory. The proportion of gravel-, sand-, silt-, and clay-sized particles were used to classify the overall sample using Folk (1974). Samples were also categorized by geologic substrate group and subgroup (Figure 4), as defined by the Coastal and Marine Ecological Classification Standard (FGDC, 2012). The Wentworth (1922) grain-size scale for major textural splits, and in instances where the silt/clay ratio could not be determined accurately (e.g. mud-sized (silt + clay) portion was less than 5% of total weight) total mud was divided evenly between silt (phi size 4 - 8) and clay (phi size 8 - 12) fractions.

Sediment grain size analyses were compared with MBES backscatter and bathymetry to develop geologic descriptions of each study area. Benthic fauna assemblages were compared among the sites and study years based on species richness and the Shannon and Simpson Index of Diversity using analysis of similarities (ANOSIM) and similarity percentages breakdown (SIMPER). Non-metric multi-dimensional scaling (nMDS) plots were also used to compare pre- and post-disposal samples collected at Jackknife Ledge, and species assemblages among the four southern beaches. The relationship of sediment grain size and species assemblages at the four southern beaches was compared using the the Spearman rank correlation (BIOENV Global Test). All analyses were performed in PRIMER (v.7).

Results

Bathymetry and backscatter collected at the five study sites informed the collection of 39 grab samples taken at these sites during 2016-2020, 17 in nearshore areas off the Southern Maine beaches, and 22 at the Jackknife Ledge dredge disposal area, current and proposed. Unconsolidated sediment samples were retrieved from 37 sites and rocky substrates were observed at 2 sites, both on the current Jackknife Ledge disposal area. Table 3 (at end of report) contains a summary of sample location, water depth, sediment penetration depth, and textural properties.

Sediment Characterizations

The seafloor in the coverage areas is characterized by distinct zones of high and low backscatter intensity that reflect differences in seafloor substrate (Figures 4 and 5). In general, coarse sand and/or gravel are represented by high backscatter intensity (light grey/white areas) and muddy material is represented by the lowest backscatter intensity (darkest tones). Rocky areas contain irregular, heterogeneous patches of high and low intensity. 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). Limited sampling at each grain size class found a general pattern of decreasing backscatter intensity with grain size (Figure 3). As expected, the highest standard deviations are observed within variably surfaced, heterogeneous textural classes. Although all textural classes are not represented and sample sizes within each class are small, the positive correlation between increasing grain size and higher intensity backscatter may be used as a basis when using backscatter to infer gross scale distribution of unconsolidated substrates. Seafloor characterizations varied among the four southern beaches and the Jackknife Ledge areas based on bathymetry, backscatter, and surficial grain size from grab samples. Each site is described below in further detail.

Wells Beach, Town of Wells

From 2018 to 2020, MCMI performed mapping along an approximately 1 nautical mile section of Wells Beach, Maine, beginning at the Wells Harbor jetties and collecting data in a SE direction along the shore at navigable depths. Approximately identical bounds were mapped once in the spring and fall of each year from 2018 to 2020 for a total of 5 datasets. Depths (referenced to NAVD88) in the area ranged from 16.13 feet (4.92 meters) to 34.84 feet (10.62 meters). The seafloor in this area is generally flat, deepening in the seaward direction with a few submerged rocks to the southwest. Bathymetric highs are located at the edge of the jetties at the Harbor entrance and at the southwestern corner of the mapped area, where the USACE has used as a dredge disposal site. Four seafloor sediment samples were collected in fall 2019 (Figure 4A). The sediments consist of moderately well-sorted very fine to slightly gravelly sand with trace shell hash.

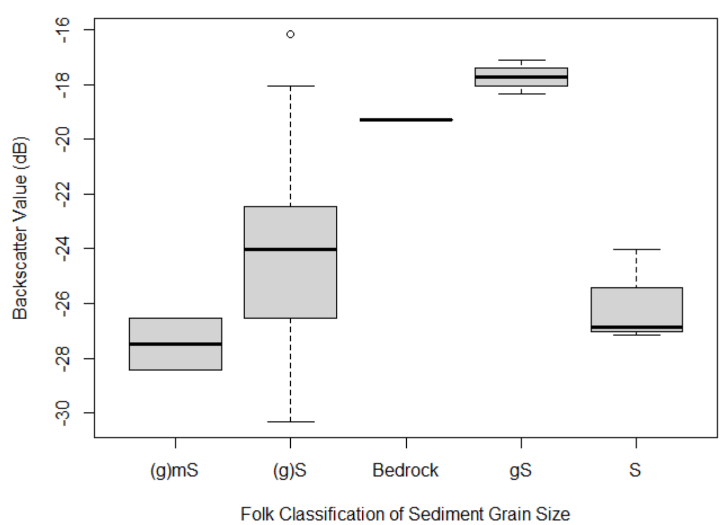

Figure 3. Backscatter intensity (dB) was found to generally correlate with surficial grain size, as defined using the Folk classification scheme, among the 39 sample sites.

Camp Ellis Beach, Town of Saco

In 2019 and 2020, MCMI performed mapping off Saco Beach and Ferry Beach, Maine from the Goosefare Brook entrance in the north to Ram Island near the Saco jetties in the south. Approximately identical bounds were mapped

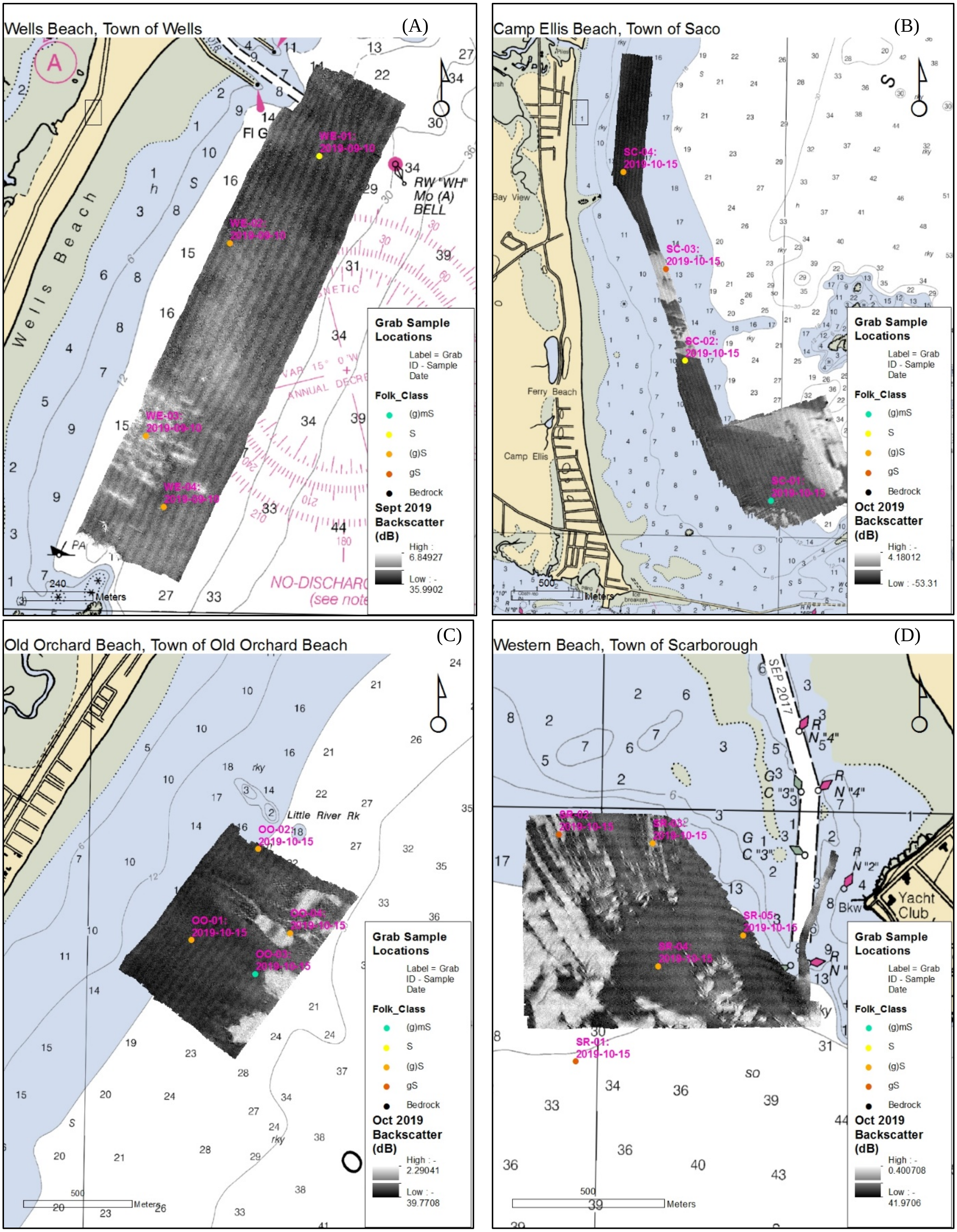

Figure 4. Grab samples collecting water chemistry, surficial sediment, and benthic fauna were collected at four Southern Maine beaches in 2019, shown here with grain size classification and backscatter intensity (dB).

twice in 2019 (spring and fall) and once in the spring of 2020 for a total of 3 datasets. Depths (referenced to NAVD88) in the area ranged from 15.39 feet (4.69 meters) to 44.19 feet (13.47 meters). The seafloor in this area is generally flat, deepening in the seaward direction with large rippled scour depressions pinching out in the landward direction are present west and southwest of Eagle Island. Four seafloor sediment samples were collected in fall 2019 (Figure 4B). The sediments in this area are slightly more heterogenous than the other beach study areas, with grain sizes ranging from very fine sand, slightly gravelly fine-medium muddy sand, and gravelly coarse sand. The sample with the coarser grain sizes was sampled from the northernmost RSD that was mapped.

Old Orchard Beach, Town of Old Orchard Beach

MBES data was collected at the proposed USACE nearshore disposal site off Old Orchard Beach, Maine in 2019 and 2020. Approximately identical bounds were mapped twice in 2019 (spring and fall) and once in the spring of 2020 for a total of 3 datasets. Depths (referenced to NAVD88) in the area ranged from 19.69 feet (6.00 meters) to 36.05 feet (10.99 meters). The seafloor in this area is generally flat, deepening in the seaward direction with large RSDs along the southeastern edge. Four seafloor sediment samples were collected in fall 2019 (Figure 4C). The sediments consist of moderately well-sorted slightly gravelly fine-medium sand with trace shell hash. One sample has a higher content (approximately 10%) of mud-sized grains than the other 3 samples. No samples were collected in the rippled scour depressions.

Western Beach, Town of Scarborough

From 2018 to 2020, MCMI performed mapping in the coastal area of Scarborough, Maine. The survey area was located south of Pine Point Beach and due west of the southern tip of Prouts Neck. Approximately identical bounds were mapped once in the spring and fall of each year from 2018 to 2020 for a total of 5 datasets. Depths (referenced to NAVD88) in the area ranged from 10.58 feet (3.22 meters) to 38.53 feet (11.74 meters). The seafloor in this area is more heterogeneous than the other nearshore beach study sites. The eastern edge of the data coverage area, closest to land, is smooth and gently sloping in the landward direction. The rest of the area mapped consists of many amorphous rippled scour depressions cutting into the otherwise relatively smooth seafloor. Five seafloor sediment samples were collected in fall 2019 (Figure 4D). The sediments collected consist of slightly gravelly fine-medium sand to gravelly medium-coarse sand. The samples with the coarser grain sizes were sampled from rippled scour depressions.

Jackknife Ledge Current and Potential Disposal Areas

The Jackknife Ledge dredge disposal site (as marked on NOAA chart 13295) was mapped by MCMI in 2016 and 2017. Depths (referenced to mean lower low water) in and around the disposal site ranged from 14.57 feet (4.44 meters) to 73.95 feet (22.54 meters). The seafloor here is generally flat with elongate SW-NE trending bedrock outcrops in the northwest portion of the mapped area. A large (approximately 0.23 nautical miles in diameter) loosely circular mound is centered slightly west of the marked disposal site boundary. This is most likely the result of the past dredge spoil dumping. Sediments collected within 11 grab samples consist of fine to coarse sand with occasional shell hash found (Figure 5B). The samples containing more coarse sands were found in those taken from the dredge spoil mound mentioned above and one in a rippled scour depression.

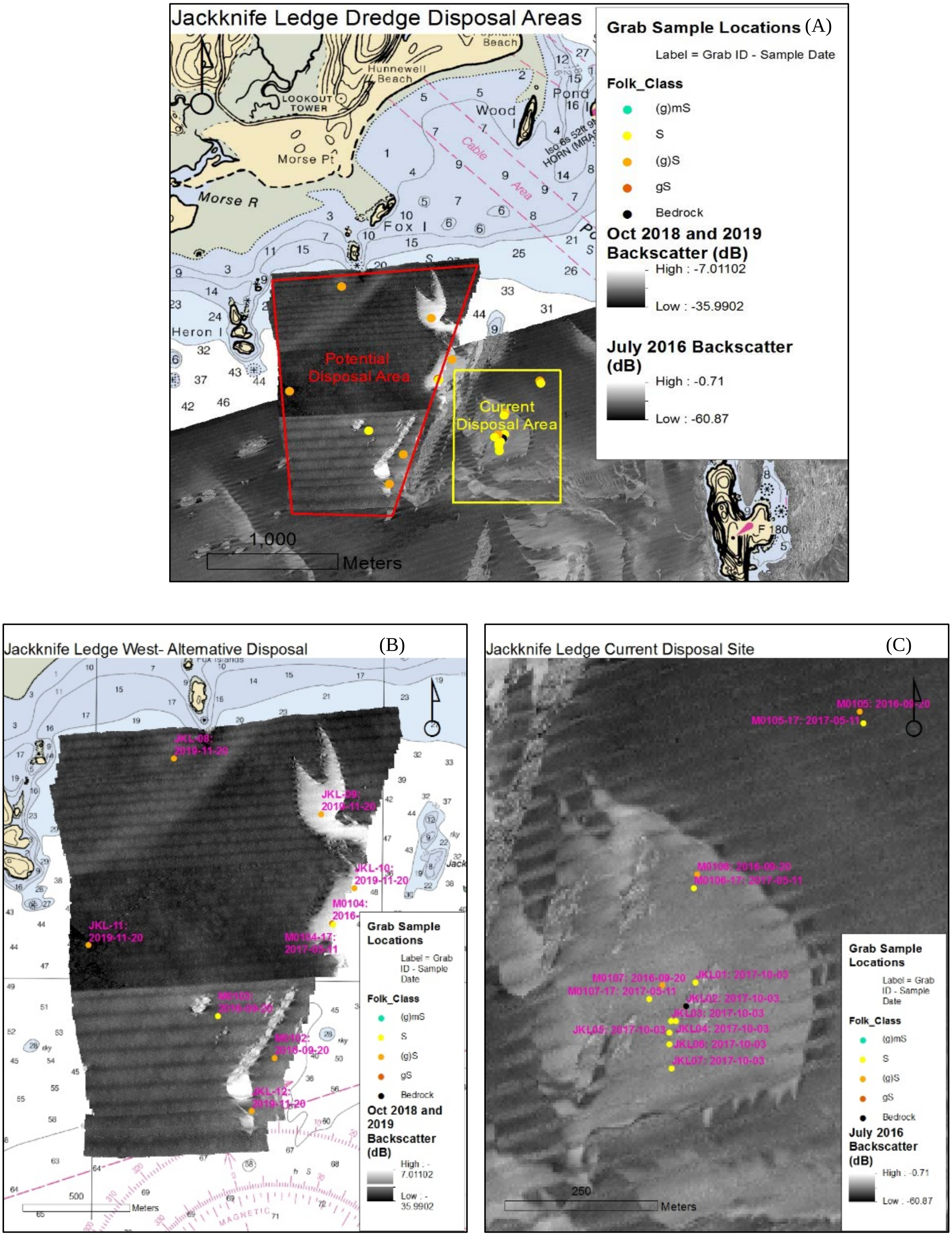

Figure 5. Grab samples collecting water chemistry, surficial sediment, and benthic fauna were collected at the current and potential Jackknife Ledge disposal areas, shown here with grain size classification and backscatter intensity (dB).

The area immediately west of the current Jackknife Ledge disposal site was mapped as a possible alternative to the current disposal site (Figure 5C). Depths in the area mapped from 2018-2019 ranged from 10.99 feet (3.35 meters) to 69.48 feet (21.18 meters). The seafloor in this area mostly flat and homogenous, with scattered ledges in the northernmost and southeastern portions of the area. Rippled scour depressions are abundant along the eastern edge of the mapped area. Sediments collected within 5 grab samples consisted of slightly gravelly sand with some shell hash intermixed in all areas mapped except for sediments sampled from rippled scour depressions. Sorting was generally good. Within the rippled scour depressions, sediment collected consist of coarse to very coarse sand with some larger (greater than 100 mm in diameter) shells and shell fragments intermixed.

Benthic Fauna Characterization

General Description of Benthic Species Assemblages

Species assemblages among study locations were representative sandy bottom benthic fauna and contain tube-building and errant worms, clams, isopods, and amphipods listed in decreasing abundance (Figures 6 and 7). Predatory snails, sand dollars, ribbon worms, peanut worms and acorn worms were present as minor components. Species richness among study locations was consistent with this abundance-based generalized faunal description, with differences among proportions of taxonomic groups resulting from few individuals of many species, for example crustaceans. There were some notable exceptions: at Wells Beach, crustaceans dominated both species richness and abundance; at Jackknife Ledge, there were more species of predatory snails and in greater abundance than found among all beach locations. Species diversity measured by the Shannon and Simpson Index of Diversity was largely the same among Jackknife Ledge and beach subtidal species assemblages (Table 4). This trend and the roughly comparable evenness values hold despite differences in the number of grab samples taken among these two areas. The consistency among locations when compared with these metrics underscores the value of describing species assemblages in terms of richness and abundance for their finer information.

Table 4. Descriptive summary of survey results and diversity of benthic species assemblages sampled with a standard 8.1L ponar grab. Metrics for each location are from pooled samples. Location abbreviations: JKL, Jack Knife Ledge; WE, Wells Beach; OO, Old Orchard Beach; SC, Saco Beach; SR, Scarborough Beach. Numbers refer to the year of sampling: 17, 2017; 19, 2019.

Location-Month-Year	KL-9-16	JKL-5-17	JKL-10-17	JKL-11-19	OO-10-19	SC-10-19	WE-9-19	SR-10-19
No. Samples	6	4	6	5	4	4	4	4
Number of Individuals	214	135	87	25	123	67	44	37
Range in Abundance/Sample	1–27	1 – 27	1 – 6	1 – 5	1 – 32	1 – 11	1 – 7	1 – 9
Mean SD Among Samples	3.44	6.22	2.14	0.71	5.57	1.36	1.47	0.94
Number of Species (S)	30	23	14	10	14	18	16	14
Margalef Richness (d)	5.40	4.48	2.91	2.80	2.70	4.04	3.96	3.60
Pielou's Evenness	0.79	0.72	0.83	0.97	0.77	0.82	0.84	0.88
Shannon (H')	2.68	2.25	2.20	2.24	2.04	2.38	2.33	2.32
Simpson Index of Diversity (1-D)	0.90	0.79	0.86	0.86	0.83	0.87	0.86	0.87

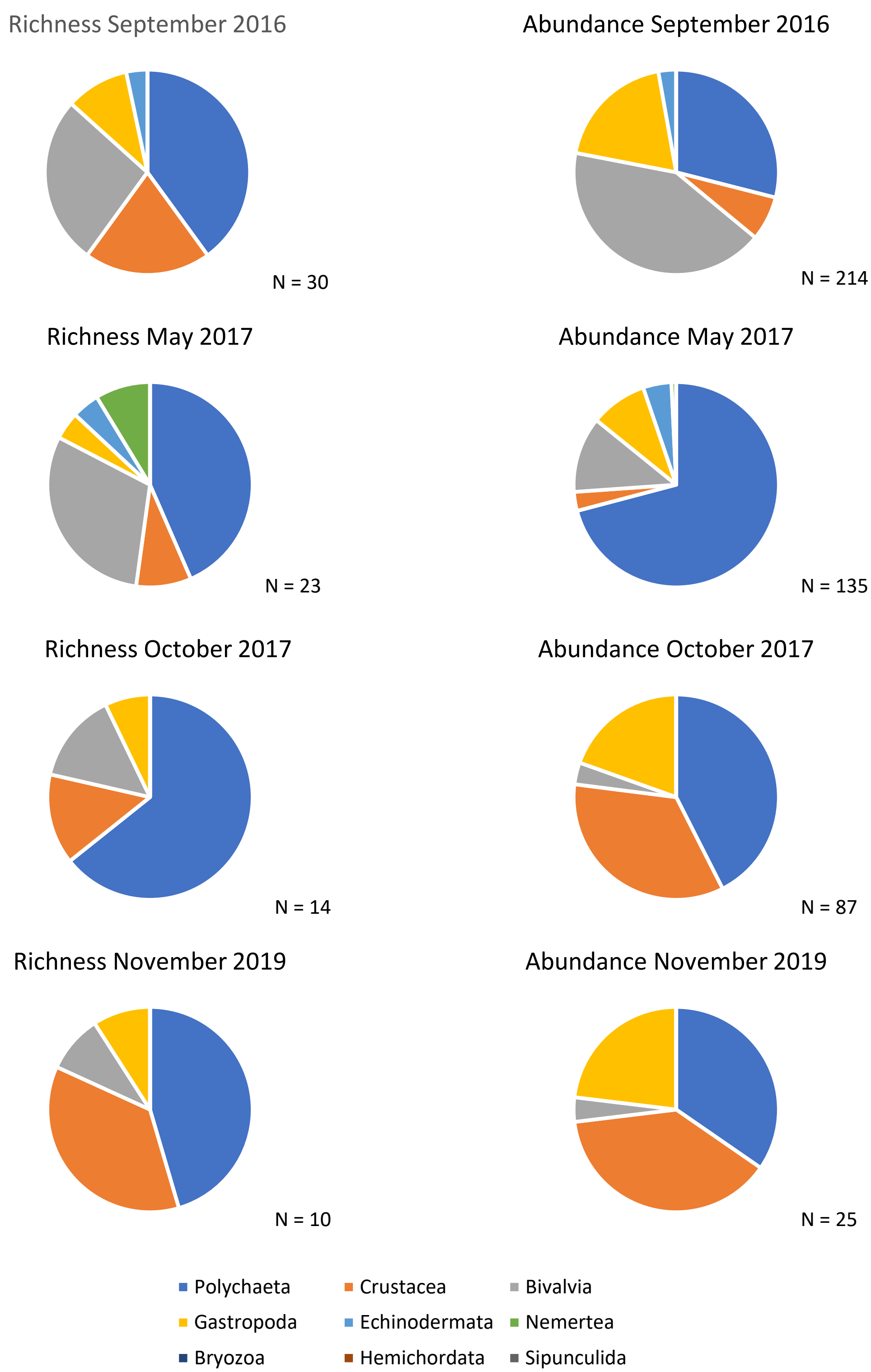

Figure 6. Percentage composition of Jack Knife Ledge species assemblages represented as species richness and abundance, based on the number (N) of taxa and number of individuals, respectively.

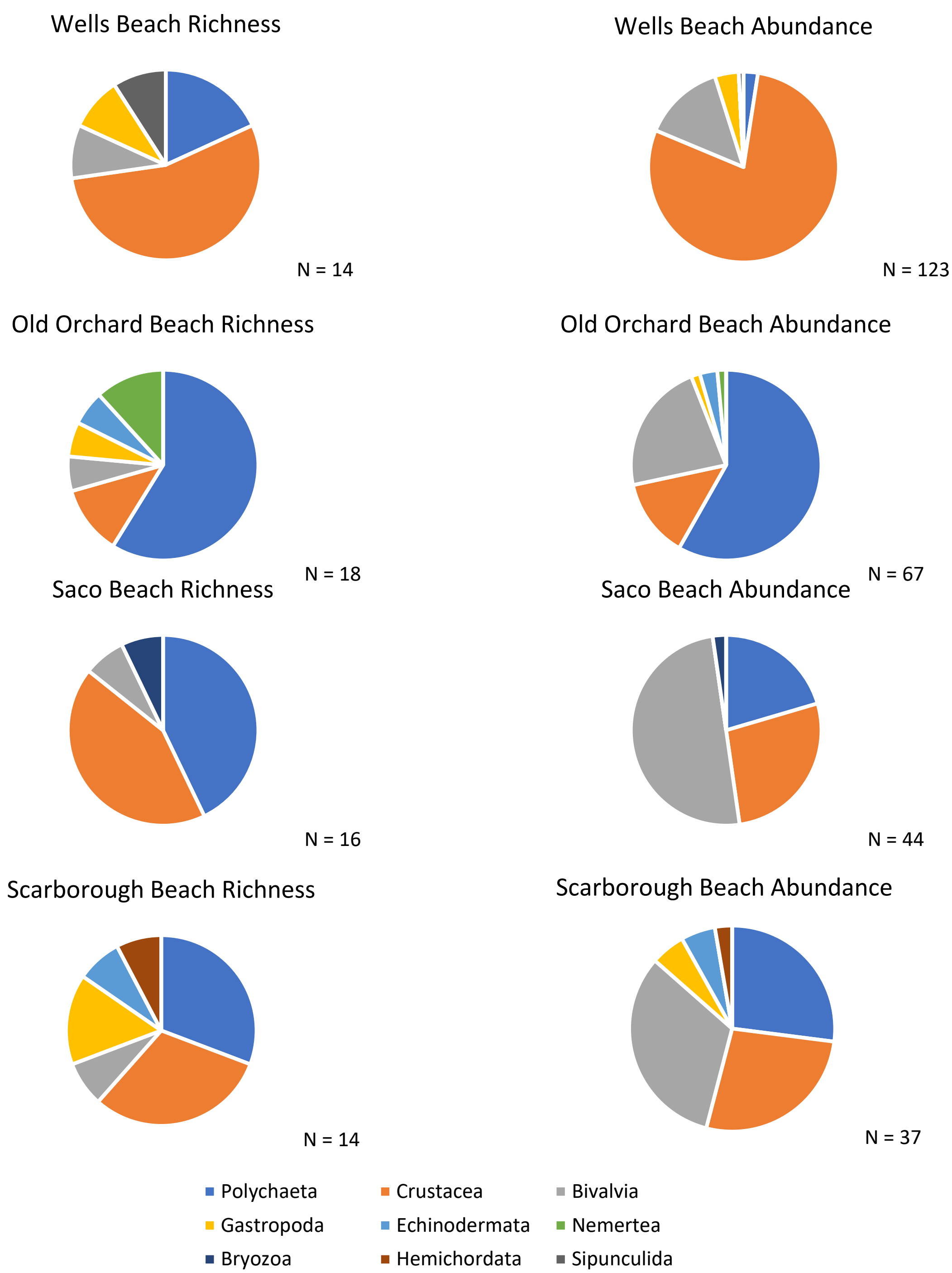

Figure 7. Percentage composition of beaches species assemblages represented as species richness and abundance, based on the number (N) of taxa and number of individuals, respectively.

Southern Maine Beaches

Most beaches were sampled in 2019 at varying times following disposal of sand either onshore or nearshore (Table 1). Evaluation of the benthic community before and after these events was not possible because there are no pre-disposal samples.

Benthic species assemblages from the same beach were more alike than those from different beaches and group accordingly in an nMDS plot, except for Scarborough Beach (Figure 8A). Overall, this relationship was statistically significant (ANOSIM Global R = 0.194, P<0.006). Pairwise tests showed that the Wells Beach species assemblage significantly differed from those of Old Orchard (R=0.74, P<0.03) and Saco Beach (R=0.74, P<0.03), and nearly so for Scarborough Beach (R = 0.198, P<0.057). Old Orchard, Saco, and Scarborough beaches were not significantly different from each other. Further analyses using nested ANOSIM tested to investigate whether the clustering of same beach samples could be explained by bottom depth, bottom temperature, and sediment type, i.e., Folk Classifications, were not statistically significant. These physical

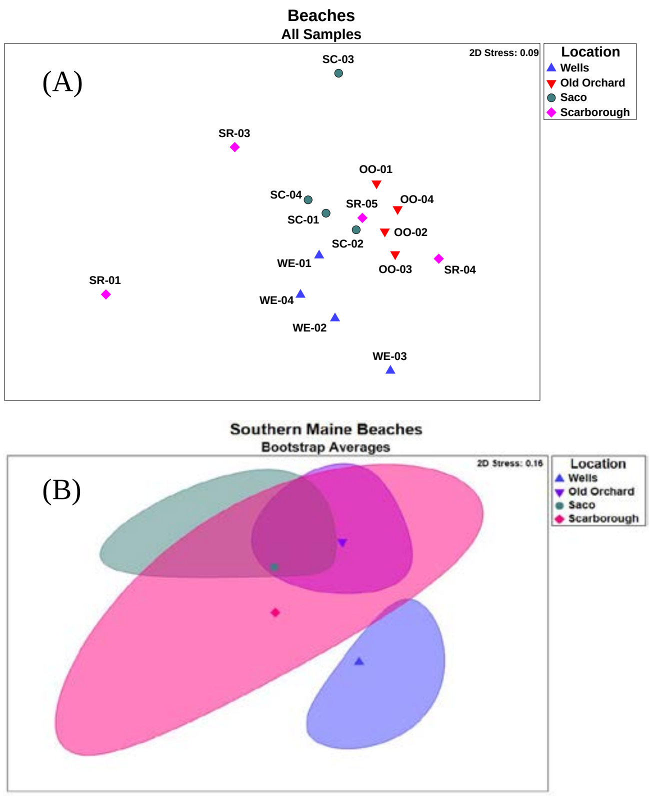

Figure 8. Non-parametric multivariate analysis two dimensional MDS plots of square root transformed benthic fauna abundance. (A) All samples. (B) Bootstrap average regions drawn to envelope 95% of bootstrap averages with their group average depicted by symbols.

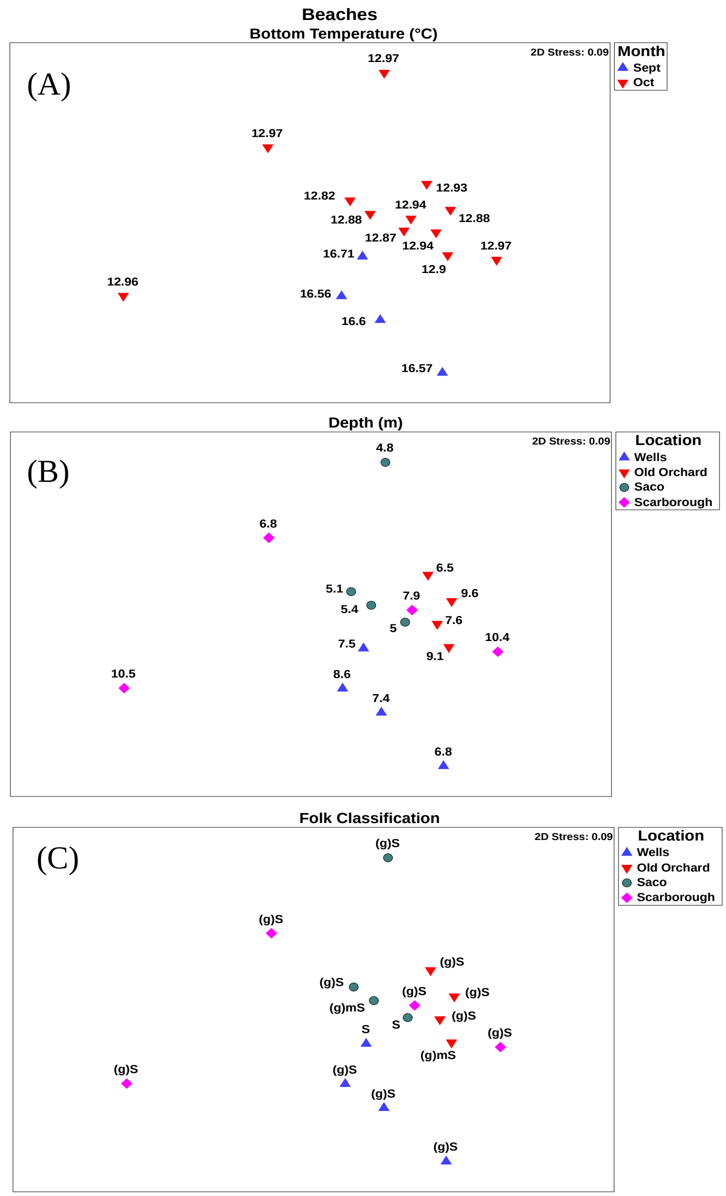

Figure 9. Abiotic measures associated with nonparametric multidimensional scaling of faunal assemblages from southern Maine beaches. A, Bottom temperatures. B, Depths. C, sediment Folk classifications. Symbols in A correspond to locations in B and C.

measures associated with Bray-Curtis similarities among benthic assemblages from each beach are shown in nMDS plots (Figure 9).

Wells Beach species assemblages were distinct for containing mostly crustaceans, a position held by polychaetes at the other beaches (Figure 7). These crustaceans were species of amphipods and isopods which prefer sandy habitats. Folk classifications were too coarse for distinguishing such habitat preferences and lead to nonsignificant associations. Instead, percentages of sand, gravel and mud had the finer resolution for characterizing differences among beaches (Figure 10B). Comparisons of these sediment types and all combinations of them with beaches species assemblages showed that the combination of sand and gravel best explained the grouping of similarities when displayed on an nMDS plot (Figure 8A). A two-way test of sediment percentages and species assemblage similarities within the levels of location using Spearman rank correlation was statistically significant (BIOENV Global Test $\rho = 0.476$, $P<0.05$), with the combination of sand and gravel having the largest correlation among the three types or possible combinations of sediments. To generalize with caution, the kinds of species found among beaches was related to the amount of sand and gravel present, and not mud, sand, or gravel alone or combinations of mud with sand or gravel or a combination of all three types.

Wells Beach was distinguished from the other beaches by the types of species found there. Nonparametric multidimensional analysis of bootstrap averages of species abundances among the four beaches clearly distinguished Wells Beach from the others (Figure 8B). Furthermore, the unique dominance of crustaceans there was made more unusual by the presence of the amphipod *Americhelidium americanum* (Bousfield, 1973). This species is rare (Bousfield 1973) and classified as sensitive to disturbance (Borja et al. 2000). Based on information gathered at the time of the discovery of this species, reproductive females bearing eggs are present from May through September. Reproduction in crustaceans is influenced by sea water temperatures, so the reproductive life cycle of *A. americanum* could differ from that which was observed when it was described nearly 50 years ago (Bousfield 1973). Its rareness, sensitivity to disturbance, and uncertainties about the life cycle/reproduction of this uncommon species should be considered during plans for sand disposal at Wells Beach.

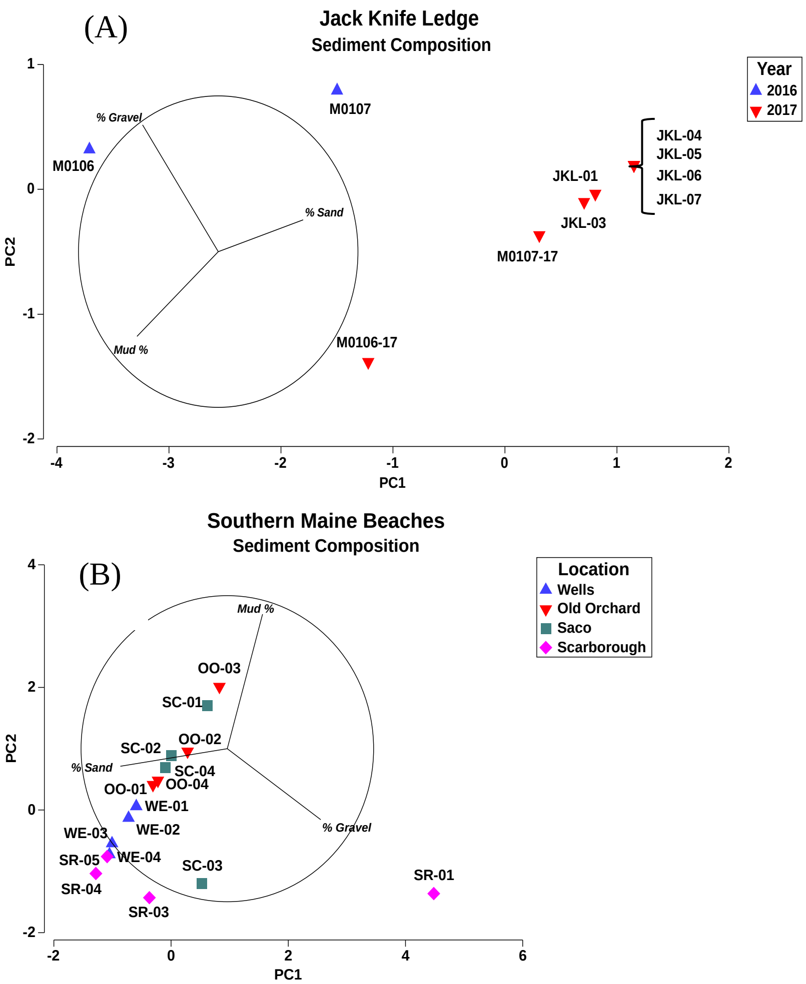

Figure 10. Principal component analysis of sediment composition at A, Jack Knife Ledge; B, southern Maine beaches.

Jackknife Ledge

Jackknife Ledge is a designated disposal area, and benthic sampling followed a schedule designed to monitor, in a loose sense, the response of the benthic community. Since the timeline of benthic sampling will be referred to in the following paragraphs, the schedule is detailed next for context. Jackknife Ledge was sampled over the course of four years: once during 2016, twice in 2017, once in 2019, and never in 2018. In general, samples were taken from within the disposal area and to the west of it, with one location sampled east of the area. The timing of sampling during 2016 and 2017 provides a snapshot of before and after dredge disposal from 21 to 26 April 2017. In 2016, two locations were sampled on the disposal site, each resampled in 2017, and four additional locations were sampled, three west and one east of that area. Sampling in May 2017 included resampling of the two before-mentioned 2016 locations along two others that resampled one west and one east 2016 location. Later that year, during October 2017, Jackknife Ledge was sampled at six new locations all within the disposal area and no resampling took place. Sampling during 2019 focused on locations outside of the disposal area at spatially widely separated locations west of it.

The pattern of similarities among benthic assemblages paralleled the yearly sampling schedule and placement of sample locations. Samples from 2016 and 2017 group by year, while 2019 samples were dissimilar and did not cluster (Figure 11A). These differences in similarity among years and areas sampled were statistically significant as shown by a nested analysis of similarity test with areas nested within years (ANOSIM Global R = 0751, P<0.007). That test also shows that comparisons within years or within areas were not significantly different. In conclusion, the combination of year and area sampled is important for understanding the pattern of similarity among Jackknife Ledge benthic assemblages.

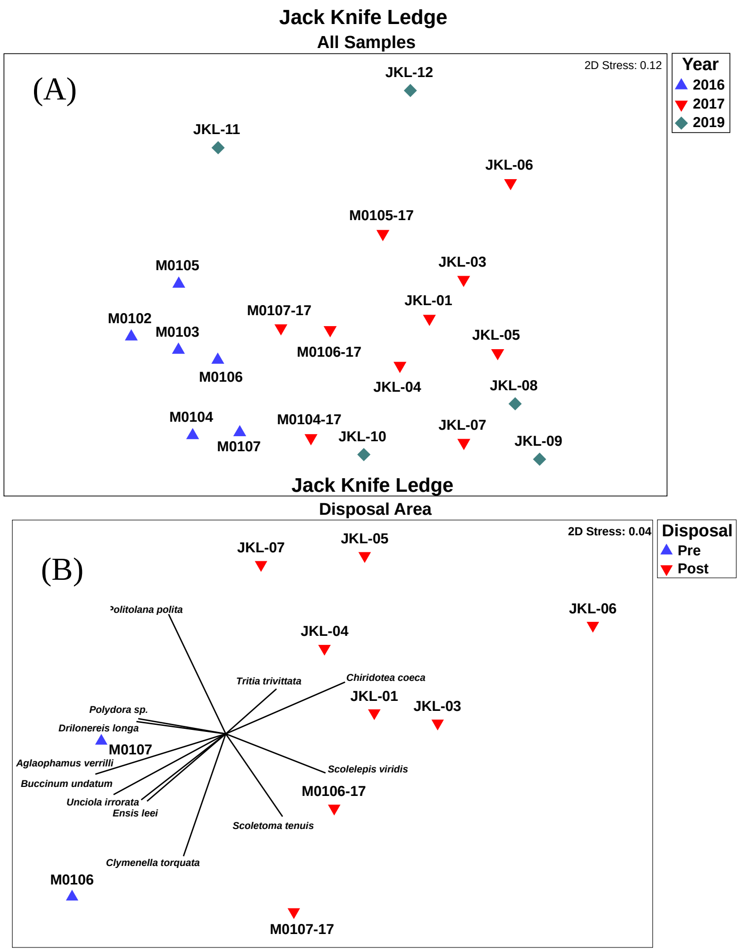

Figure 11. Non-parametric multivariate analysis two dimensional nMDS plots of square root transformed benthic fauna abundance. Each symbol represents a single sample. A. All samples. B. Samples from the disposal area taken pre- and post-disposal. Only M0107, M0107-17 and M0106 and M0106-17 were repeated samples. Species contributing most to pre- and post-disposal dissimilarity are shown with vector lengths representing the strength of contribution determined by Pearson Correlation.

The timing of sampling during 2016 and 2017 provided a snapshot of before and after dredge disposal from 21 to 26 April 2017. Benthic assemblages were directly comparable pre- and post-disposal at only two locations. A total of four samples severely restricts statistical analyses, and while hierarchal cluster analysis separates samples according to pre and post-disposal (Figure 12), the sample size was below the limit for detecting statistical significance and results in an ANOSIM Global R = 1, P = 0.33 and a non-significant SIMPER test. Consequently, to increase sample size for contrasts, benthic assemblage similarities were compared pre- and post-disposal in 2016 and 2017, respectively, among all samples taken from the disposal area, ignoring samples from locations east and west of it. The resulting analyses showed that benthic assemblages sampled pre- and post-disposal were dissimilar and form two separate groups in two-dimensional nMDS plots (Figure 11B). The difference was statistically significant (ANOSIM Global R = 0.56, P<0.002) as were comparisons of sample similarities among months (ANOSIM Global R = 0.66, P<0.002). Sediments changed in composition following disposal with the two resampled locations becoming mostly sand as were the 2017 samples (Figure 10A). It followed that species assemblages pre- and post-deposition differed significantly based on Folk classifications (ANOSIM Global R = 0.56, P<0.002). Similar statistical comparisons with bottom temperature and depth were not significant. Bottom temperatures, depths, and Folk Classifications associated with Bray-Curtis similarities among benthic assemblages from the Jackknife Ledge disposal area are shown in nMDS plots (Figure 12).

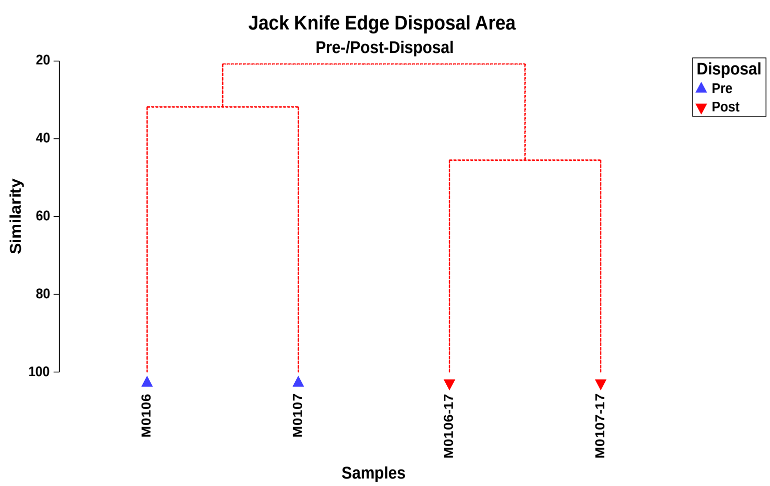

Figure 12. Hierarchal cluster analysis using group average of pre- and post-disposal species assemblages. Both MO106 and MO107 are in the disposal area and sampled in 2016, then resampled in 2017. They represent the only such case in this study. Red dashed lines connect samples that are not statistically significant from each other (SIMPER Test, P>0.05).

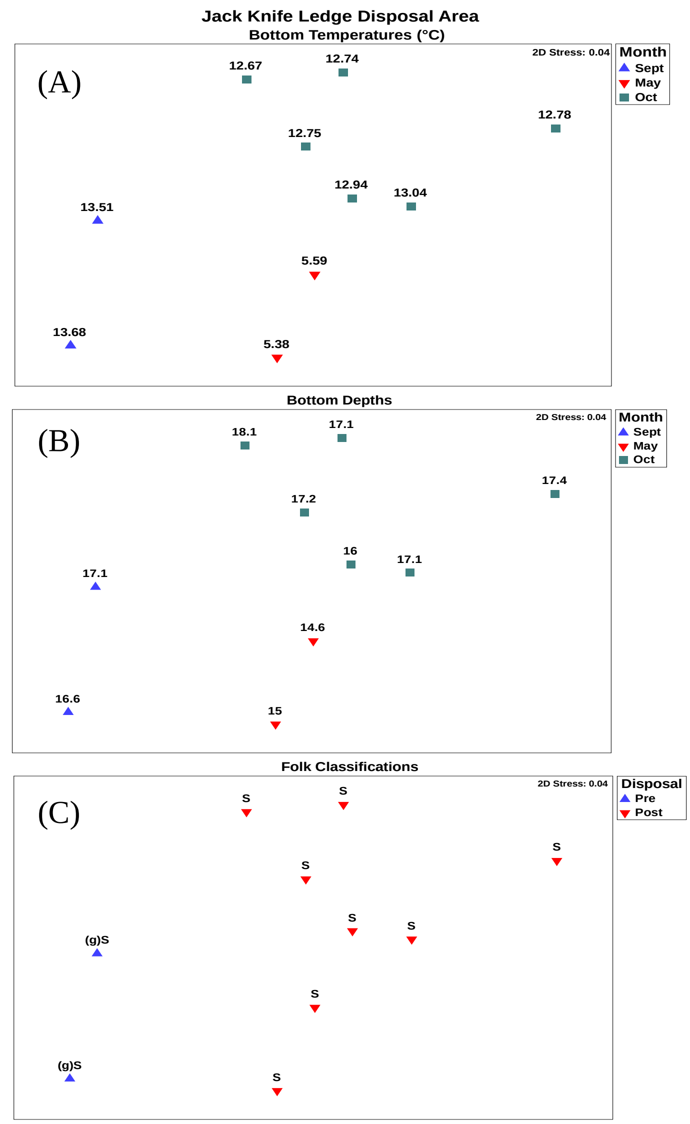

Figure 12. Non-parametric multivariate analysis two dimensional nMDS plots of square root transformed benthic fauna abundance plotted with: A, bottom temperatures; B, bottom depths; and C, sediment Folk classifications.

There were 12 discriminating species contributing to 70% to the dissimilarity between pre- and post-disposal species assemblages (Table 5). Trends in changes among these species were: the increase in small predatory snails (*Tritia trivittatus*) replacing larger ones (*Buccinum undatum*), fewer tube building worms (*Clymenella torquata* and *Polydora sp.*), the disappearance of errant polychaetes and razor clams, and more scavenging isopods (*Politolana polita* and *Chirodotea coeca*). These relationships were visualized by superimposing the Pearson correlations for each of these species with pre- and post-disposal assemblages on an nMDS plot, with vector length indicating the degree of correlation and direction corresponding with pre- and post-disposal samples (Figure 11B).

In summary, statistically significant distinctions among similarities of benthic species assemblages at Jackknife Ledge were related to when samples are taken (year/month). Temporal changes in assemblages were also related to disposal, with the caveat that too few samples were taken pre- and post-disposal to permit resampling and direct comparisons. In this regard, the location of sampling stations influenced the degree that similarities among benthic assemblages differed. This fact was most evident among the spatially disparate 2019 samples and their corresponding large species dissimilarities. These limitations along with the unbalanced sampling design of this study suggest that caution be used in interpreting disposal effects.

Table 5. Species contributing to 70% of the dissimilarity between pre-and post-disposal sample locations in the disposal area. The average dissimilarity of pre- and post-disposal species assemblages was 89.16%.

Species	Group	Group Pre Mean Abundance	Group Post Mean Abundance	Mean Dissimilarity	Contribution %	Cumulative %
Buccinum undatum	Predatory Snails	9	0	9.5	10.66	10.66
Clymenella torquata	Large Tube-building Worms	8	5	8.65	9.7	20.36
Tritia trivittata	Predatory Snails	0	6	6.31	7.08	27.45
Politolana polita	Scavenging Isopods	3	4	5.25	5.89	33.34
Aglaophamus verrilli	Errant Worms	4	0	4.85	5.44	38.78
Scoletoma tenuis	Errant Worms	0	5	4.54	5.09	43.88
Drilonereis longa	Errant Worms	4	0	4.38	4.91	48.79
Polydora sp.	Small Tube-building Worms	4	0	4.38	4.91	53.7
Scolelepis viridis	Errant Worms	0	4	4.3	4.83	58.53
Chiridotea coeca	Scavenging Isopods	0	3	4.25	4.77	63.29
Ensis leei	Razor Clams	3	0	3.29	3.69	66.98
Unciola irrorata	Mobile Surface Amphipods	3	0	3.29	3.69	70.67

Discussion and Recommendations

In support of efforts to better understand nearshore sand movement and dredge disposal effects, the Maine Coastal Program collected high-resolution bathymetry and backscatter and grab samples for water chemistry, surficial sediment, and fauna characterizations at four Maine beaches in Wells, Saco, Old Orchard Beach, and Scarborough, and a nearshore disposal site at Jackknife Ledge. This information provides a basis for understanding how recent sand disposals may have impacted the benthic habitat at these sites, how the sediment and benthic fauna assemblages differ or are consistent among the sites, and to provide a baseline characterization for further study of these sites over time following recent nourishment. This information could potentially be used as baseline information for near-future (before 2022) nourishment, however beyond that horizon additional surveys should be performed to describe pre-nourishment conditions.

Bathymetry and backscatter collected by multibeam echo-sounder (MBES) surveys was used to describe the submerged geological formations, sediment characterizations, and change in bathymetry and sediment over time due to natural processes and nourishment/disposal activities. We found that sediment characterizations derived from grain size (Folk 1974) from surficial sediment samples showed a general pattern of decreasing backscatter intensity with grain size as expected (Lurton and Lamarche, 2015). The backscatter and bathymetry were then used to describe general characterizations of sediment and formations at each site, such as rippled scour formations. Changes in elevation following seasonal current patterns and nourishment/disposal activities is described in associated reports of this work (MGS and MCP 2020a, MGS and MCP 2020b).

Surficial sediment from grab samples at Wells and Saco showed evidence of recent nourishment at many of the sampling sites, being comprised of mostly sand, with samples away from the nourishment areas and at the other beach sites being comprised of gravel and sand mixtures, with some having higher proportions of mud. Because sampling at the four southern beaches was only performed in 2019, these samples cannot be used to determine with confidence the post- impacts of nourishment activities, however future efforts could be made to sample these sites over time to determine the length of impact and provide a baseline before future nourishment activities. At Jackknife Ledge, limited sampling was performed at the same locations pre- and post- sand disposal. The change in composition at these sites from sand and gravel mixtures to primarily sand with traces of mud shows a change following disposal. When combined with repeated efforts to collect backscatter, this repeated sampling thus has the capability of demonstrating the broad surficial sediment changes following sand nourishment/disposal activities.

Benthic fauna characterizations should be used to inform activities that will alter or impact the benthic environment. Sampling at Jackknife Ledge and the four southern Maine beaches found that species assemblages were representative of sandy bottom benthos, although there were some differences among sites and following sand disposal at Jackknife Ledge, likely due to differences among sediment type, specifically the amount of gravel. Although direct comparisons were not possible because of the sampling methodology, pre- and post-disposal similarities of species assemblages were found differ significantly at Jackknife Ledge. We also found that among the beaches sampled, Wells Beach was distinct based on its species assemblage and the presence of a rare species that is sensitive to disturbance.

The abundance and types of species found undoubtedly was influenced by seasonality and water temperature with sampling performed during the months of May and September through November. Bottom water temperatures ranged from 5.38°C in May 2017 to 13.68°C in September 2016 at Jackknife Ledge. While the number of species and individuals were about the same per sample, the kinds of species were not. These sampling months were the pre- and post-disposal sequence samples intended for comparison. This inconsistency among months of sampling leads to a second reason that a cautionary approach is required when interpreting the results of statistical analyses.

The results and analyses presented in this report are limited primarily by small sample size. Benthic organisms at Jackknife Ledge and the surveyed beaches had low density and were widely dispersed, features that can be inferred by the range in abundance per sample. This situation was highlighted by two cases in which grabs successfully sampled sediment but contained no organisms. Surficial sediment characterizations were likely influenced at some sites by recent nourishment/disposal activities that impacted only a portion of the study area. Other constraints related to low sample number were the absence or limited number of pre-disposal samples. No pre-disposal grab samples were made at any beaches surveyed. At Jackknife Ledge, there were only two pre-disposal grab samples that were positioned where dredge disposals were released so that direct comparisons could be made by resampling post-disposal. This situation limited statistical analyses to ones that require caution for interpreting their results.

Future sampling programs require schedules that are consistent among months and number of samples. The distribution and abundance of organisms in the target area need to be considered when estimating the number of samples needed to achieve the goals of a study. Some stations need to be located outside the area of concern to compare pre- and post-disposal changes to those within the target area. Depending on the goals of future studies, increasing the number of grab samples, performing sampling during a consistent month, achieving a consistent range among depths sampled, and sampling pre- and post-disposal would allow more robust analysis of the impact of nearshore management activities.

Through this study, we determined differences among biological communities among nearshore sites, determined sediment grain size based on surface grab samples and backscatter assessment, and assessed differences in grain size and biological community composition at one dredge disposal site pre- and post-disposal and compare these characteristics to a proposed new disposal site. While further sampling should be performed at these sites to determine the effects of pre- and post-management activities and impacts over time, this additional benthic habitat data when combined with bathymetric change data collected during the same time period provides coastal managers a more comprehensive understanding about how nearshore sand placement impacts these areas.

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Table 3. Grab sample data from locations at four Maine beaches and the Jackknife Ledge current and proposed alternative disposal site.

	Sample Information					Seafloor Water Chemistry					Sediment Data						Benthic Fauna		
Site	Grab Sample ID	Sample Date	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Seafloor Depth (m)	Floor Salinity (PSU)	Floor Temp (oC)	Floor pH	Floor DO (mg/L)	Floor Chlorophyll (μg/L)	CMECS Substrate SubGroup	Folk Classification	Backscatter value (dB)	% Gravel	% Sand	Mud %	Phylum	Family	Species and CMECS Biotic Groups
Jackknife Ledge (Potential Alternative Disposal Area)	M0102	9/20/2016	43.713467	-69.789450	19.5	32.3	13.6	8.0	7.7	1.97	5	Slightly Gravelly Sand	(g)S	1.07%	91.15%	7.78%	Annelida	Cirratulidae	Small Surface-Burrowing Fauna: *Chaetozone setosa*
																		Glyceridae	Larger Deep-Burrowing Fauna: *Glycera dibranchiata*
																		Goniadidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Maldanidae	Larger Deep-Burrowing Fauna: *Drilonereis longa*
																		Oenonidae	Larger Deep-Burrowing Fauna: *Phylo ornatus*
																		Orbiniidae	Small Surface-Burrowing Fauna: *Pholoe minuta*
																		Pholoidae	Larger Deep-Burrowing Fauna: *Goniada maculata*
																	Arthropoda	Unciolidae	Small Surface-Burrowing Fauna: *Unciola irrorata*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Arcticidae	Clam Bed: *Arctica islandica*
																		Buccinidae	Mobile Mollusks on Soft Sediments: *Buccinum undatum*
																		Cardiidae	Clam Bed: *Parvicardium pinnulatum*
																		Nuculidae	Clam Bed: *Ennucula tenuis, Nucula proxima*
																		Tellinidae	Clam Bed: *Ameritella agilis*
																		Thraciidae	Clam Bed: *Thracia myopsis*
																		Veneridae	Clam Bed: *Gemma gemma*
Jackknife Ledge (Potential Alternative Disposal Area)	M0103	9/20/2016	43.715183	-69.792733	17.9	32.2	14.2	7.9	7.7	3.26	4	Fine Sand	S	0.00%	97.65%	2.35%	Annelida	Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																	Arthropoda	Unciolidae	Small Surface-Burrowing Fauna: *Unciola irrorata*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Arcticidae	Clam Bed: *Arctica islandica*
																		Buccinidae	Mobile Mollusks on Soft Sediments: *Buccinum undatum*
																		Nuculidae	Clam Bed: *Ennucula tenuis, Nucula proxima*
																		Tellinidae	Clam Bed: *Ameritella agilis*
																		Thraciidae	Clam Bed: *Thracia myopsis*
Jackknife Ledge (Potential Alternative Disposal Area)	M0104	9/20/2016	43.719067	-69.786183	16.7	32.2	13.9	7.9	7.7	2.88	Gravelly Sand	gS	-18.35	12.97%	86.23%	0.81%	Annelida	Ampharetidae	Larger Tube-Building Fauna: *Ampharete arctica*
																		Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Oenonidae	Larger Deep-Burrowing Fauna: *Drilonereis longa*
																	Mollusca	Buccinidae	Mobile Mollusks on Soft Sediments: *Buccinum undatum*
Jackknife Ledge (Potential Alternative Disposal Area)	M0104-17	5/11/2017	43.719017	-69.786117	15.3	31.2	5.6	7.9	10.3	1.58	Coarse Sand	S	-	0.00%	99.06%	0.94%	Annelida	Lumbrineridae	Larger Deep-Burrowing Fauna: *Scoletoma tenuis*
																		Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Polynoidae	Small Surface-Burrowing Fauna: *Enipo gracilis*
																	Mollusca	Tellinidae	Clam Bed: *Ameritella tenella*
Jackknife Ledge (East of Current Disposal Area)	M0105	9/20/2016	43.718983	-69.776533	14.3	32.3	13.5	7.9	7.4	3.22	Slightly Gravelly Sand	(g)S	-30.32	0.07%	98.22%	1.71%	Annelida	Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Oenonidae	Larger Deep-Burrowing Fauna: *Drilonereis longa*
																		Pholoidae	Small Surface-Burrowing Fauna: *Pholoe minuta*
																		Scalibregmatidae	Small Surface-Burrowing Fauna: *Scalibregma inflatum*
																		Spionidae	Small Tube-Building Fauna: *Polydora* sp.
																	Arthropoda	Bodotriidae	Small Surface-Burrowing Fauna: *Pseudoleptocuma minus*
																		Chaetiliidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea tuftsii*
																		Idoteidae	Mobile Crustaceans on Hard or Mixed Substrates: *Edotia triloba*
																		Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Arcticidae	Clam Bed: *Arctica islandica*
																		Buccinidae	Mobile Mollusks on Soft Sediments: *Buccinum undatum*
																		Nuculidae	Clam Bed: *Ennucula tenuis*
																		Tellinidae	Clam Bed: *Ameritella agilis*
																		Thraciidae	Clam Bed: *Thracia myopsis*

	Sample Information					Seafloor Water Chemistry					Sediment Data						Benthic Fauna		
Site	**Grab Sample ID**	**Sample Date**	**Latitude (Decimal Degrees)**	**Longitude (Decimal Degrees)**	**Seafloor Depth (m)**	**Floor Salinity (PSU)**	**Floor Temp (oC)**	**Floor pH**	**Floor DO (mg/L)**	**Floor Chlorophyll (µg/L)**	**CMECS Substrate SubGroup**	**Folk Classification**	**Backscatter value (dB)**	**% Gravel**	**% Sand**	**Mud %**	**Phylum**	**Family**	**Species and CMECS Biotic Groups**
Jackknife Ledge (East of Current Disposal Area)	M0105-17	5/11/2017	43.718817	-69.776450	13.1	31.2	5.7	7.9	10.4	1.19	Fine Sand	S	-	0.00%	95.55%	4.45%	Annelida	Cirratulidae	Small Surface-Burrowing Fauna: *Chaetozone setosa*
																		Maldanidae	Larger Tube-Building Fauna: *Nicomache (Loxochona) quadrispinata*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys picta*
																		Polynoidae	Small Surface-Burrowing Fauna: *Enipo gracilis*
																		Spionidae	Small Surface-Burrowing Fauna: *Scolelepis viridis*
																	Arthropoda	Idoteidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea coeca*
																		Phoxocephalidae	Mobile Crustaceans on Hard or Mixed Substrates: *Rhepoxynius epistomus*
																	Echinodermata	Echinarachnidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Cardiidae	Clam Bed: *Parvicardium pinnulatum*
																		Mactridae	Clam Bed: *Mactromeris polynyma*
																		Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Nuculidae	Clam Bed: *Ennucula delphinodonta, Nucula crenulata*
																		Tellinidae	Clam Bed: *Ameritella agilis*
																		Lineidae	Small Surface-Burrowing Fauna: *Micrura sp., Micrura affinis*
Jackknife Ledge (Current Disposal Area)	M0106	9/20/2016	43.716600	-69.779800	16.6	32.4	13.7	8.0	8.5	2.39	Slightly Gravelly Sand	(g)S	-24.65	1.11%	95.67%	3.22%	Annelida	Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Nephtyidae	Larger Deep-Burrowing Fauna: *Aglaophamus verrilli*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Unciolidae	Small Surface-Burrowing Fauna: *Unciola irrorata*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Buccinidae	Mobile Mollusks on Soft Sediments: *Buccinum undatum*
																		Naticidae	Clam Bed: *Euspira heros*
																		Pharidae	Clam Bed: *Ensis leei*
																		Tellinidae	Clam Bed: *Ameritella agilis*
Jackknife Ledge (Current Disposal Area)	M0106-17	5/11/2017	43.716400	-69.779867	14.6	31.2	5.6	8.0	10.4	1.54	Medium Sand	S	-	0.00%	97.39%	2.61%	Annelida	Lumbrineridae	Larger Deep-Burrowing Fauna: *Scoletoma tenuis*
																		Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys picta*
																		Spionidae	Small Surface-Burrowing Fauna: *Scolelepis viridis*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Tellinidae	Clam Bed: *Ameritella agilis, Ameritella versicolor*
Jackknife Ledge (Current Disposal Area)	M0107	9/20/2016	43.714983	-69.780483	17.1	32.6	13.5	8.0	8.3	1.12	Slightly Gravelly Sand	(g)S	-22.13	0.78%	97.80%	1.42%	Annelida	Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Nephtyidae	Larger Deep-Burrowing Fauna: *Aglaophamus verrilli*
																		Oenonidae	Larger Deep-Burrowing Fauna: *Drilonereis longa*
																		Spionidae	Small Tube-Building Fauna: *Polydora*
																	Arthropoda	Bodotriidae	Small Surface-Burrowing Fauna: *Pseudoleptocuma minus*
																		Chaetiliidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea tuftsii*
																		Cirolanidae	Mobile Crustaceans on Hard or Mixed Substrates: *Politolana polita*
																	Mollusca	Buccinidae	Mobile Mollusks on Soft Sediments: *Buccinum undatum*
Jackknife Ledge (Current Disposal Area)	M0107-17	5/11/2017	43.714783	-69.780750	15.0	31.3	5.4	8.0	10.3	1.11	Coarse Sand	S	-	0.00%	99.07%	0.93%	Annelida	Lumbrineridae	Larger Deep-Burrowing Fauna: *Scoletoma tenuis*
																		Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata, Praxillella praetermissa*
																		Orbiniidae	Small Surface-Burrowing Fauna: *Leitoscoloplos robustus*
																		Spionidae	Small Tube-Building Fauna: *Laonice cirrata*
																	Mollusca	Tellinidae	Clam Bed: *Ameritella agilis*

Site	Grab Sample ID	Sample Date	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Seafloor Depth (m)	Floor Salinity (PSU)	Floor Temp (oC)	Floor pH	Floor DO (mg/L)	Floor Chlorophyll (µg/L)	CMECS Substrate SubGroup	Folk Classification	Backscatter value (dB)	% Gravel	% Sand	Mud %	Phylum	Family	Species and CMECS Biotic Groups
Sample Information						**Seafloor Water Chemistry**					**Sediment Data**						**Benthic Fauna**		
Jackknife Ledge (Current Disposal Area)	JKL01	10/3/2017	43.715033	-69.779817	16.0	32.3	12.9	7.8	8.3	2.50	Medium Sand	S	-	0.00%	99.62%	0.38%	Annelida	Lumbrineridae	Larger Deep-Burrowing Fauna: *Scoletoma fragilis, Scoletoma tenuis*
																		Spionidae	Small Surface-Burrowing Fauna: *Scolelepis viridis*
																	Arthropoda	Cirolanidae	Mobile Crustaceans on Hard or Mixed Substrates: *Politolana polita*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Jackknife Ledge (Current Disposal Area)	JKL02	10/3/2017	43.714683	-69.780000	15.6	32.2	13.2	7.9	8.5	3.92	Bedrock/rocky		-				No organisms in sample		
Jackknife Ledge (Current Disposal Area)	JKL03	10/3/2017	43.714467	-69.780300	17.1	32.2	13.0	7.9	8.5	3.18	Medium Sand	S	-	0.00%	99.51%	0.49%	Annelida	Lumbrineridae	Larger Deep-Burrowing Fauna: *Scoletoma tenuis*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys picta*
																		Spionidae	Small Surface-Burrowing Fauna: *Scolelepis viridis*
																	Arthropoda	Idoteidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea coeca*
																	Mollusca	Mytilidae	Clam Bed: *Mytilus edulis*
																		Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Jackknife Ledge (Current Disposal Area)	JKL04	10/3/2017	43.714467	-69.780200	17.2	32.4	12.8	7.9	8.3	2.09	Bedrock/rocky	S	-	0.00%	100.00%	0.00%	Annelida	Lumbrineridae	Larger Deep-Burrowing Fauna: *Scoletoma tenuis*
																		Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Spionidae	Small Tube-Building Fauna: *Laonice cirrata, Scolelepis (Scolelepis) squamata*
																	Arthropoda	Cirolanidae	Mobile Crustaceans on Hard or Mixed Substrates: *Politolana polita*
																		Idoteidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea coeca*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Jackknife Ledge (Current Disposal Area)	JKL05	10/3/2017	43.714300	-69.780333	17.1	32.3	12.7	7.9	8.6	2.14	Medium Sand	S	-	0.00%	100.00%	0.00%	Annelida	Nereididae	Larger Deep-Burrowing Fauna: *Nereis zonata* ; Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																		Spionidae	Small Tube-Building Fauna: *Scolelepis (Scolelepis) squamata*
																	Arthropoda	Cirolanidae	Mobile Crustaceans on Hard or Mixed Substrates: *Politolana polita*
																		Idoteidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea coeca*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Tellinidae	Clam Bed: *Ameritella tenella*
Jackknife Ledge (Current Disposal Area)	JKL06	10/3/2017	43.714133	-69.780333	17.4	32.3	12.8	7.9	8.6	2.22	Medium Sand	S	-	0.00%	100.00%	0.00%	Annelida	Spionidae	Small Surface-Burrowing Fauna: *Scolelepis viridis*
																	Arthropoda	Idoteidae	Mobile Mollusks on Hard or Mixed Substrates: *Chiridotea coeca*
Jackknife Ledge (Current Disposal Area)	JKL07	10/3/2017	43.713783	-69.780283	18.1	32.3	12.7	8.0	8.5	2.32	Medium Sand	S	-	0.00%	100.00%	0.00%	Annelida	Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx* ; Small Tube-Building Fauna: *Scolelepis (Scolelepis) squamata*
																	Arthropoda	Cirolanidae	Mobile Mollusks on Hard or Mixed Substrates: *Politolana polita*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Jackknife Ledge (Proposed Alternative Disposal Area)	JKL-08	11/20/2019	43.725850	-69.795450	8.0	32.5	9.8	7.7	8.2	1.99	Medium Sand	S	-23.39	0.28%	99.12%	0.60%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Jackknife Ledge (Proposed Alternative Disposal Area)	JKL-09	11/20/2019	43.723583	-69.786867	13.0	N/A	N/A	N/A	N/A	N/A	Coarse Sand	S	-16.15	0.58%	96.85%	2.58%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Jackknife Ledge (Proposed Alternative Disposal Area)	JKL-10	11/20/2019	43.720533	-69.784900	15.2	N/A	N/A	N/A	N/A	N/A	Slightly Gravelly Sand	(g)S	-	1.20%	97.94%	0.86%	Annelida	Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys incisa*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*

	Sample Information					Seafloor Water Chemistry					Sediment Data						Benthic Fauna		
Site	Grab Sample ID	Sample Date	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Seafloor Depth (m)	Floor Salinity (PSU)	Floor Temp (oC)	Floor pH	Floor DO (mg/L)	Floor Chlorophyll (µg/L)	CMECS Substrate SubGroup	Folk Classification	Backscatter value (dB)	% Gravel	% Sand	Mud %	Phylum	Family	Species and CMECS Biotic Groups
Jackknife Ledge (Proposed Alternative Disposal Area)	JKL-11	11/20/2019	43.718067	-69.800283	15.6	N/A	N/A	N/A	N/A	N/A	Fine Sand	S	-27.49	0.04%	96.32%	3.64%	Annelida	Orbiniidae	Small Surface-Burrowing Fauna: *Leitoscoloplos robustus*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																	Arthropoda	Chaetiliidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea tuftsii*
																		Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																		Unciolidae	Mobile Crustaceans on Hard or Mixed Substrates: *Unciola dissimilis*
																	Mollusca	Tellinidae	Clam Bed: *Ameritella agilis*
Jackknife Ledge (Proposed Alternative Disposal Area)	JKL-12	11/20/2019	43.711250	-69.790733	20.9	33.0	9.8	7.8	7.8	2.91	Fine Sand	S	-23.39	0.17%	94.76%	5.07%	Annelida	Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																		Spionidae	Small Surface-Burrowing Fauna: *Scolelepis viridis*
Old Orchard Beach	OO-01	10/15/2019	43.515517	-70.360750	6.5	32.0	12.9	7.8	7.9	5.28	Fine Sand	S	-27.17	0.10%	95.45%	4.46%	Annelida	Cirratulidae	Small Surface-Burrowing Fauna: *Chaetozone setosa*
																		Lumbrineridae	Small Surface-Burrowing Fauna: *Scoletoma fragilis*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
Old Orchard Beach	OO-02	10/15/2019	43.519333	-70.357033	7.6	32.0	12.9	7.9	7.9	3.64	Fine Sand	S	-26.54	0.72%	95.67%	3.60%	Annelida	Cirratulidae	Small Surface-Burrowing Fauna: *Chaetozone setosa*
																		Lineidae	Small Surface-Burrowing Fauna: *Micrura affinis*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Orbiniidae	Larger Deep-Burrowing Fauna: *Phylo ornatus*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Tellinidae	Clam Bed: *Ameritella agilis*
Old Orchard Beach	OO-03	10/15/2019	43.514150	-70.357067	9.1	31.1	12.9	7.8	7.6	7.76	Fine Sand	S	-28.43	0.01%	95.59%	4.41%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Phyllodocidae	Small Surface-Burrowing Fauna: *Eteone longa*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Mollusca	Tellinidae	Clam Bed: *Ameritella agilis*
Old Orchard Beach	OO-04	10/15/2019	43.515867	-70.355117	9.6	32.1	12.9	7.9	8.0	2.02	Fine Sand	S	-23.71	0.20%	95.86%	3.94%	Annelida	Cirratulidae	Small Surface-Burrowing Fauna: *Chaetozone setosa*
																		Maldanidae	Larger Tube-Building Fauna: *Clymenella torquata*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Orbiniidae	Small Surface-Burrowing Fauna: *Leitoscoloplos fragilis*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Tellinidae	Clam Bed: *Ameritella agilis*

	Sample Information					Seafloor Water Chemistry					Sediment Data						Benthic Fauna		
Site	Grab Sample ID	Sample Date	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Seafloor Depth (m)	Floor Salinity (PSU)	Floor Temp (oC)	Floor pH	Floor DO (mg/L)	Floor Chlorophyll (µg/L)	CMECS Substrate SubGroup	Folk Classification	Backscatter value (dB)	% Gravel	% Sand	Mud %	Phylum	Family	Species and CMECS Biotic Groups
Saco Beach	SC-01	10/15/2019	43.468917	-70.367417	5.4	31.8	12.9	7.7	8.1	2.05	Fine Sand	S	-26.54	0.08%	99.45%	0.47%	Annelida	Glyceridae	Larger Tube-Building Fauna: *Glycera capitata*
																		Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																	Arthropoda	Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Tellinidae	Clam Bed: *Ameritella agilis*
Saco Beach	SC-02	10/15/2019	43.477500	-70.375100	5.0	32.1	12.9	7.8	7.6	3.28	Very Fine Sand	S	-26.86	0.00%	95.18%	4.82%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																		Unciolidae	Mobile Crustaceans on Hard or Mixed Substrates: *Unciola dissimilis*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Tellinidae	Clam Bed: *Ameritella agilis*
Saco Beach	SC-03	10/15/2019	43.483167	-70.376867	4.8	32.1	12.9	7.9	7.9	7.88	Gravelly Sand	gS	-17.09	6.51%	91.83%	1.66%	Annelida	Lumbrineridae	Small Surface-Burrowing Fauna: *Scoletoma tenuis*
																		Orbiniidae	Small Surface-Burrowing Fauna: *Leitoscoloplos fragilis*
																	Arthropoda	Chaetiliidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea coeca*
																		Cirolanidae	Mobile Crustaceans on Hard or Mixed Substrates: *Politolana concharum*
																		Gammaridae	Mobile Crustaceans on Hard or Mixed Substrates: *Gammarus oceanicus*
																	Bryozoa	Bugulidae	Attached Bryozoans: *Bicellariella ciliata*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Mytilidae	Clam Bed: *Mytilus edulis*
Saco Beach	SC-04	10/15/2019	43.489117	-70.380717	5.1	32.0	12.8	7.8	7.8	7.29	Fine Sand	S	-30.32	0.13%	94.47%	5.40%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Orbiniidae	Small Surface-Burrowing Fauna: *Scoloplos sp.*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Tellinidae	Clam Bed: *Ameritella agilis*
Scarborough Beach	SR-01	10/15/2019	43.526000	-70.334183	10.5	31.2	13.0	7.9	8.1	2.13	Gravelly Sand	gS	-	19.50%	72.94%	7.56%	Arthropoda	Idoteidae	Mobile Crustaceans on Hard or Mixed Substrates: *Idotea balthica*
																	Mollusca	Littorinidae	Diverse Soft Sediment Epifauna: *Lacuna vincta*
Scarborough Beach	SR-02	10/15/2019	43.532583	-70.335017	7.5	32.2	13.0	7.9	7.9	2.32	Gravelly Sand	gS	-17.72	7.22%	96.58%	0.00%	No organisms in sample		
Scarborough Beach	SR-03	10/15/2019	43.532367	-70.331200	6.8	32.2	13.0	7.9	8.3	0.76	Slightly Gravelly Sand	(g)S	-18.04	4.17%	95.61%	0.22%	Annelida	Oenonidae	Larger Deep-Burrowing Fauna: *Arabella iricolor*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
Scarborough Beach	SR-04	10/15/2019	43.528800	-70.330917	10.4	32.2	13.0	7.9	8.2	0.94	Fine Sand	S	-24.65	0.34%	99.42%	0.24%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Haustoriidae	Mobile Crustaceans on Hard or Mixed Substrates: *Protohaustorius wigleyi*
																	Echinodermata	Echinarachniidae	Sand Dollar Bed: *Echinarachnius parma*
Scarborough Beach	SR-05	10/15/2019	43.529733	-70.327483	7.9	32.2	12.9	7.9	8.2	0.63	Fine Sand	S	-22.45	0.31%	98.21%	1.48%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																		Orbiniidae	Small Surface-Burrowing Fauna: *Leitoscoloplos robustus*
																		Spionidae	Small Surface-Burrowing Fauna: *Spiophanes bombyx*
																	Arthropoda	Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Hemichordata	Harrimaniidae	Small Surface-Burrowing Fauna: *Saccoglossus kowalevskii*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Tellinidae	Clam Bed: *Ameritella agilis*

	Sample Information					Seafloor Water Chemistry					Sediment Data						Benthic Fauna		
Site	Grab Sample ID	Sample Date	Latitude (Decimal Degrees)	Longitude (Decimal Degrees)	Seafloor Depth (m)	Floor Salinity (PSU)	Floor Temp (oC)	Floor pH	Floor DO (mg/L)	Floor Chlorophyll (µg/L)	CMECS Substrate SubGroup	Folk Classification	Backscatter value (dB)	% Gravel	% Sand	Mud %	Phylum	Family	Species and CMECS Biotic Groups
Wells Beach	WE-01	9/10/2019	43.314067	-70.551017	7.5	31.3	16.7	7.9	8.8	8.19	Very Fine Sand	S	-27.17	0.00%	96.83%	3.17%	Annelida	Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																	Arthropoda	Chaetiliidae	Mobile Crustaceans on Hard or Mixed Substrates: *Chiridotea coeca*
																		Haustoriidae	Mobile Crustaceans on Hard or Mixed Substrates: *Protohaustorius wigleyi*
																		Phoxocephalidae	Mobile Crustaceans on Hard or Mixed Substrates: *Rhepoxynius epistomus*
																		Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Tellinidae	Clam Bed: *Ameritella agilis*
Wells Beach	WE-02	9/10/2019	43.311350	-70.554700	7.4	31.3	16.6	8.0	8.2	7.69	Fine Sand	S	-25.28	0.02%	97.45%	2.53%	Annelida	Flabelligeridae	Small Surface-Burrowing Fauna: *Pherusa aspera*
																		Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																	Arthropoda	Haustoriidae	Mobile Crustaceans on Hard or Mixed Substrates: *Haustorius canadensis*
																		Oedicerotidae	Mobile Crustaceans on Hard or Mixed Substrates: *Americhelidium americanum*
																		Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
																		Tellinidae	Clam Bed: *Ameritella agilis*
																	Sipunculida	Golfingiidae	Small Surface-Burrowing Fauna: *Phascolopsis gouldii*
Wells Beach	WE-03	9/10/2019	43.305400	-70.558083	6.8	31.4	16.6	8.0	8.4	18.68	Medium Sand	S	-18.67	0.08%	96.20%	3.72%	Annelida	Nephtyidae	Small Surface-Burrowing Fauna: *Nephtys bucera*
																	Arthropoda	Haustoriidae	Mobile Crustaceans on Hard or Mixed Substrates: *Haustorius canadensis, Protohaustorius wigleyi*
																		Unciolidae	Mobile Crustaceans on Hard or Mixed Substrates: *Pseudunciola obliquua*
																	Mollusca	Nassariidae	Mobile Mollusks on Hard or Mixed Substrates: *Tritia trivittata*
Wells Beach	WE-04	9/10/2019	43.303233	-70.557267	8.6	31.4	16.6	8.0	8.3	14.98	Fine Sand	S	-23.39	0.36%	98.76%	0.89%	Annelida	Sigalionidae	Small Surface-Burrowing Fauna: *Sthenelais limicola*
																	Arthropoda	Haustoriidae	Mobile Crustaceans on Hard or Mixed Substrates: *Haustorius canadensis, Protohaustorius wigleyi*
																		Phoxocephalidae	Mobile Crustaceans on Hard or Mixed Substrates: *Rhepoxynius epistomus*
																		Tryphosidae	Mobile Crustaceans on Hard or Mixed Substrates: *Wecomedon nobilis*
																		Unciolidae	Mobile Crustaceans on Hard or Mixed Substrates: *Pseudunciola obliquua*
																	Mollusca	Mactridae	Clam Bed: *Mactromeris polynyma*
																		Tellinidae	Clam Bed: *Ameritella agilis*