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ASSESSMENT OF DREDGED MATERIAL CREATED HABITAT IN THE SOUTH ATLANTIC BIGHT – FERNANDINA BEACH OCEAN DREDGED MATERIAL DISPOSAL SITE (ODMDS)

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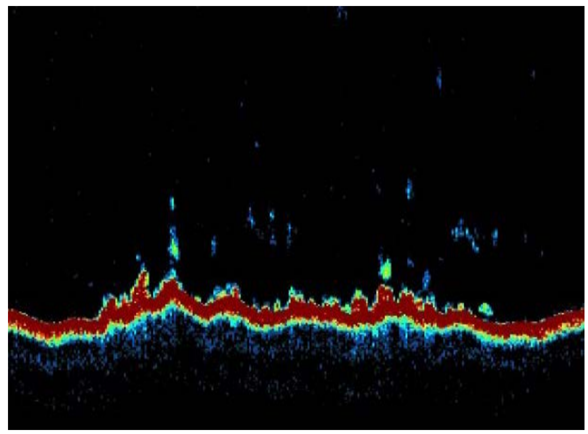

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EXECUTIVE SUMMARY

The National Centers for Coastal Ocean Science (NCCOS) collaborated with EPA Region 4 Water Protection Division of Coastal and Marine Resources and Wetland Enforcement Section to assess Ocean Dredge Material Dump Sites (ODMDS) as essential fish habitat off the coast of Fernandina Beach, FL. The objectives of this project were to: (1) establish common monitoring protocols for assessing benthic biological habitats and fish communities comparable to surveys previously conducted in the southeast region; and (2) evaluate fishery acoustic surveys and metrics of remotely sensed fish density as measures of the habitat value and beneficial use of rocky dredge material disposed at the Fernandina Beach ODMDS.

NCCOS and EPA scientists conducted the research from the NOAA Ship *Nancy Foster* in 2016 surveying the Fernandina ODMDS with multibeam sonar, in-water diver surveys, and fishery echosounder surveys. Dive teams conducted biological and topographical assessments of the benthic and fish communities on sites identified on the bathymetry maps, focusing on man-made rocky features and natural ledges. The mission was heavily impacted by multiple tropical storm systems, which caused low visibility. For this reason, in-water fish data is not presented in this report.

The updated bathymetry maps of the entire ODMDS clearly delineated dump sites, natural rock features and surrounding sand, revealing the mosaic of seafloor habitat types in the area. Complexity data derived from bathymetry were used in concert with the topography and rugosity information collected at depth. Although dump sites and natural ledges seemed very different at depth, complexity metrics were not significantly different. This was an unbalanced study, however, with 21 ODMDS sites and 14 Natural ledges (three of which were in a site northeast of the ODMDS).

Sponges, tunicates, octocorals, and hard corals dominated the benthic community of all sites, although, benthic cover of each organism differed by habitat type. Dump sites hosted greater numbers of tunicates, octocorals, and *Oculina sp*. which contributed to the greater frequency of taller biota at these locations. The sponge was the dominant invertebrate on Natural ledges lending to the lower average biotic height of those sites. The differences in depth and nature of abiotic structure along with the turbid water are the most probable forcing factors determining the composition of the benthic communities in each habitat type.

The use of fishery acoustic surveys overcame some of the limitations of low visibility experienced during dive surveys. Fish densities surveyed at night were much higher in the eastern portion of the survey area in a region where rocky ledges and outcrops were mixed with sand compared to the area around the disposal material. Acoustic densities assessed during the day around the dive stations were highly variable, with generally higher densities associated with the natural ledge features. Though sample sizes of high rugosity disposal material were low, it appears that high-relief, high-rugosity disposal materials influences the habitat use by fish with higher densities of fish, and especially fish schools likely made up of small-bodied fish that would be important prey for larger predatory fishes. This initial finding suggests taller disposal sites may provide relatively higher habitat value to fishes than low relief disposal sites.

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1. INTRODUCTION

1.1. Background

The US EPA Ocean Dumping Program is charged with managing ocean dumping of dredge materials and monitoring the condition and status of offshore dump sites designated for the disposal of dredged material from the maintenance and expansion of ports along the US Atlantic Coast. These dumped materials can sometimes provide benefits in the form of created habitats such as rocky reefs. The National Dredging Team (EPA, USACE, Maritime Administration, NOAA's NOS, NOAA's NMFS, FWS, USCG) developed a list of recommendations in 2003 for improving dredged material management. Recommended action number 6 is to encourage research and development on beneficial uses of dredged material, including habitat creation and restoration, and make available information on beneficial use demonstration projects. Better understanding the value of the habitat through proper assessment and the critical factors in the design of the habitat will improve our ability to design future placement and disposal strategies for dredged material that maximize the value of the created habitat.

EPA Region 4 has identified a number of projects in the Southeastern U.S. where habitat has been created from dredged material disposal. One of those is the rocky habitat unintentionally created in the western portion of the Fernandina Beach Ocean Dredged Material Disposal Site (ODMDS) offshore northeastern Florida (Figure 1-1). The Fernandina ODMDS was designated in 1987. The site is approximately 2 nmi^2 area centered on 30° 32'N by 81° 18' W. The site is about 7 miles offshore of Fernandina Beach, FL. Approximately 20 million cubic yards of dredged material has been disposed at the Fernandina Beach ODMDS. Most of the material is maintenance material from the Kings Bay Entrance Channel which averages 626,000 cubic yards of silty dredged material per year. Over 1.2 million cubic yards of dredged material was disposed in the southern portion of the ODMDS between 2011 and 2012 from deepening of Naval Station Mayport. Material was a combination of silts, clay, sand, and shell. During a September 2010 public meeting on ocean disposal, EPA learned that there are significant coral and live bottom habitats located within the Fernandina Beach ODMDS that are frequented by recreational divers and fishermen. Upon review of the site designation administrative record, it was discovered that contrary to current regional policy, no site clearing (sidescan/video) was conducted at the site prior to designation and thus EPA and the USACE were unaware of live bottom habitat located within the site. Furthermore, initial sidescan imagery and followed by high-resolution multibeam echosounder surveys, linear ridges of large rubble were located in the western area of the ODMDS, and a natural rocky ledge was evident in the eastern region of the ODMDS (US EPA 2013).

EPA has conducted some preliminary acoustic and diver rapid assessments of the Fernandina Beach ODMDS habitat as part of its routine ODMDS monitoring (US EPA 2014). Results from those initial surveys indicated high abundance of fish and live bottom habitat at the monitoring sites including the disposed rubble and natural rocky ledge.

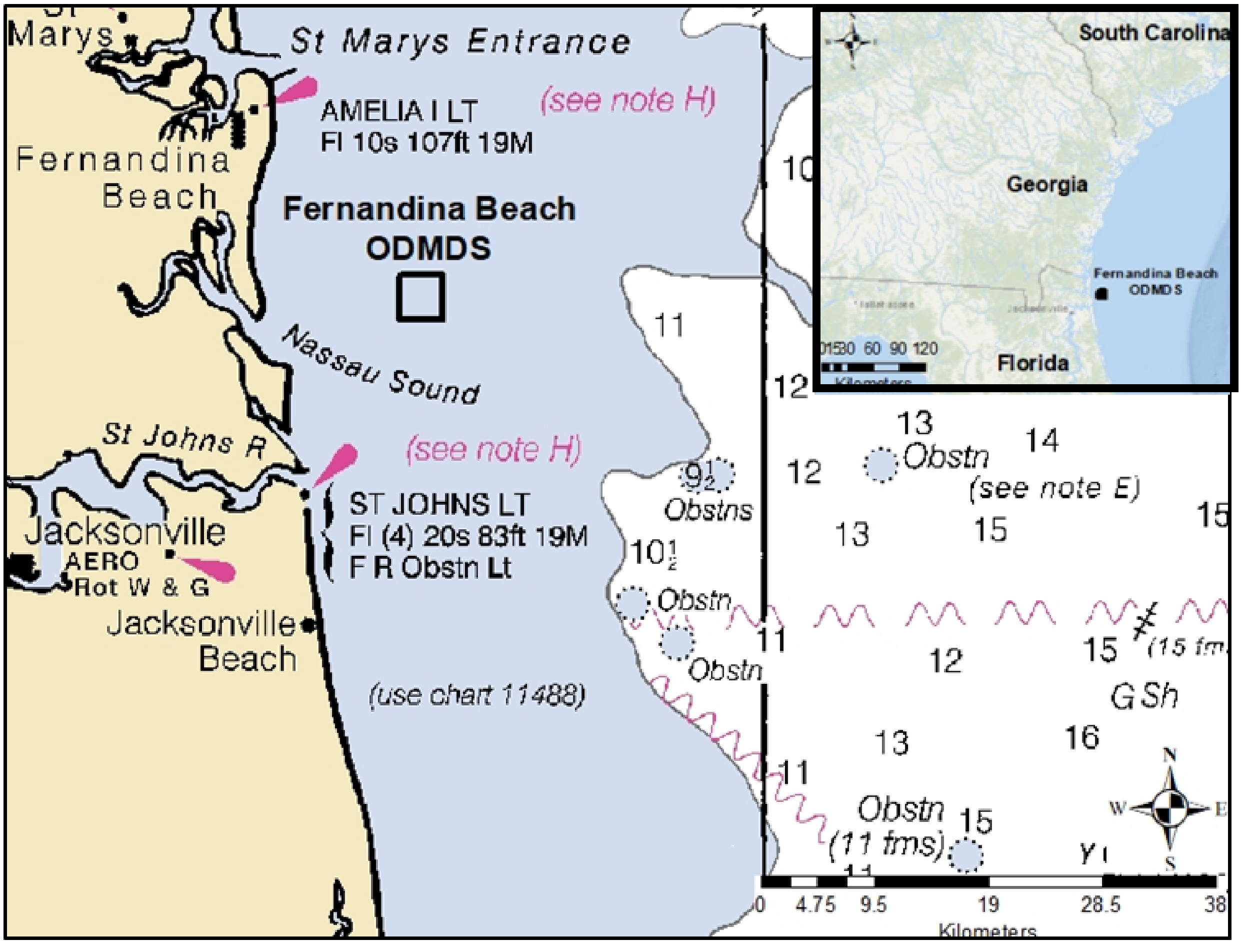

Figure 1-1. Location of Fernandina Beach ODMDS offshore Fernandina Beach and Jacksonville, Florida.

Physical structure of habitats can influence the colonization of benthic invertebrates as well as the composition and residency of fish communities. Vertical relief, or the elevation of the structure relative to the surrounding substrate, and complexity or rugosity of the structure are two of the most often reported factors that influence abundance, diversity and size of benthic invertebrates and fishes (Costa et al. 2014 and references therein). High relief and rugosity provide refuge for small prey fishes, and shelter from current and tides for weak swimming invertebrates. The interplay of physical structure and biological cover remain at the center of habitat value and functional ecology. Several methods are available to assess structural complexity. First, chain rugosity measures the ratio of path over a surface to the straight-line distance between two points (McCormick 1994). More recently, underwater digital sensors that measure water depth are used to measure fine scale changes in relief and complexity (Dustan et al. 2014). Remote sensing of the surface of the seafloor using multibeam sonar can provide an additional measure of seafloor complexity over a range of spatial scales.

Diver visual surveys provide the highest level of detail for characterizing the composition and abundance of benthic invertebrates, plants and fish communities. Data describing all three communities (fish, invertebrate, and plant) is collected along the same band transect providing evidence for direct associations between fish species and benthic habitat and physical structure. Detection of fishes and identification of habitat species by divers is highly dependent upon water clarity, light and behavioral avoidance by fish species. These limitations can be overcome by fishery acoustics to augment characterization of the fish community. The method relies upon the transmission of high-frequency sound pulses that reflect off the seafloor and fish in the water column. Fishery acoustics is relatively new in ecological assessments of rocky and coral reefs (Costa et al, 2014, Campanella and Taylor 2016). The magnitude of the reflection from fish is generally proportional to the size of fish; however, fish species cannot be identified without visual verification. Other advantages to fishery acoustics is that the method is not restricted to daylight hours and much larger areas can be covered in a short time. Acoustics are not affected by low light or visibility, making day and night surveys possible. By using scientifically calibrated split-beam echosounders (SBES) on research vessels, surveys can cover large areas relatively quickly providing estimates of relative densities over 100s of square kilometers in a day.

1.2. Objectives

The objectives of this project were two-fold:

- Establish common monitoring protocols for assessing benthic biological habitats and fish communities using methods comparable to surveys previously conducted in the southeast region rocky reef and artificial reef visual surveys.
- Evaluate fishery acoustic surveys and metrics of remotely sensed fish density as measures of the habitat value and beneficial use of rocky dredge material disposed at the Fernandina Beach ODMDS

To accomplish these objectives NOAA's National Centers for Coastal Ocean Science collaborated with EPA Region 4 Water Protection Division Coastal and Marine Resources and Wetland Enforcement Section to conduct a research cruise and ecological assessment of the Fernandina Beach ODMDS.

2. METHODS

The Fernandina ODMDS was surveyed using three methods during September 2016 as part of the research cruise NF-16-07 – Habitat Mapping Southeast on board the NOAA Ship Nancy Foster. The mission was conducted over two cruise legs: Leg II 1-5 September, Leg IV 21-27 September, 2016. Hydrographic multibeam surveys were used to map the region and characterize the seafloor complexity and identify locations for dive surveys. In-water diver surveys were used to (1) conduct benthic biological assessments of the habitats, focusing exclusively on disposed material hardbottom and natural hardbottom habitats, and (2) characterize fish communities inhabiting the hardbottom habitats. Fishery acoustic surveys were used to remotely assess distribution of fish densities relative to the disposed and natural hardbottom habitats in the ODMDS.

Figure 2-1. NOAA Ship Nancy Foster (R-352). Photo courtesy NOAA Office of Marine and Aviation Operations.

2.1. Seafloor Mapping and Site Selection

Previous research cruises conducted by the EPA Region 4 Water Protection Division Coastal and Ocean Protection Section provided high-resolution seafloor bathymetry layers covering 30% of the ODMDS. In September 2016, the remaining portion of the ODMDS and including a buffer outside the managed area was surveyed using multibeam echosounders (MBES). System components and parameters for the MBES on the NOAA Ship Nancy Foster are presented in Table 2-1. Data acquisition and processing was managed by the ship's survey technicians. High resolution bathymetry layers (1 m x 1 m grid cells) were plotted in ArcGIS to visually examine the complexity of the seafloor and identify features resembling the rock rubble dredge material disposal. The shapes of the features were extended teardrops, mostly surrounded by sand, and easily identified in the multibeam surfaces. A natural ledge feature was also identified from the multibeam data. Dive biological assessment stations were located on disposal material features (21 stations) and on the natural rocky ledges (13 stations). Stations were spaced so that a 50 m transect following the rocky feature would be at least 100 m from any other transect at a neighboring station (Figure 2-2).

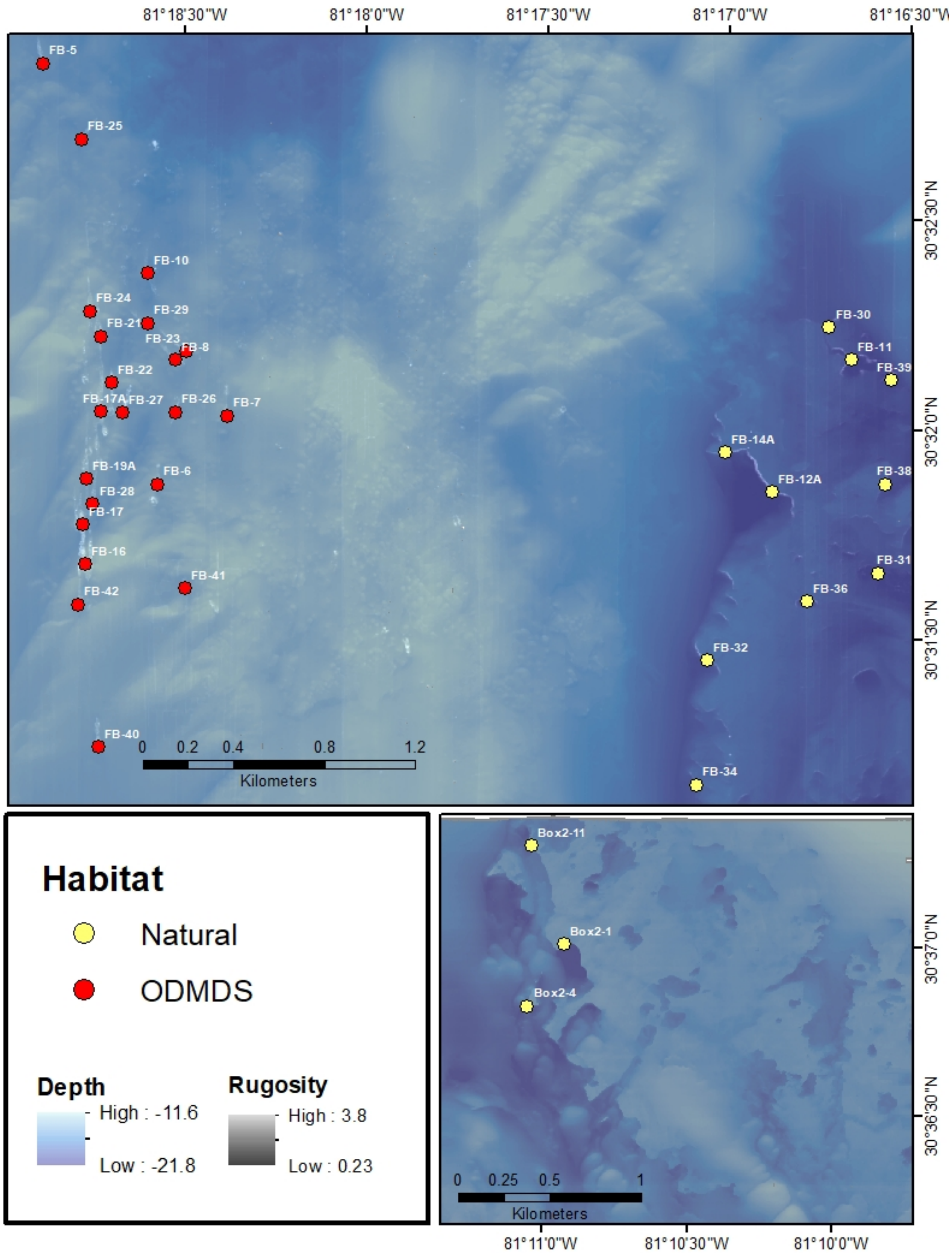

Figure 2-2. Study sites inside and outside the designated dumpsite. Bathymetry is shaded blue with 30% transparency over rugosity presented as gray scale to highlight high-relief features in white such as ledges and dredge material. Red dot sites are ODMDS dredge material, yellow dots are on natural ledges mixed hardbottom. The top panel is the ODMDS boundary. The lower panel is the natural ledge sampled north of the ODMDS.

Table 2-1. Equipment used for multibeam echosounder surveys on the NOAA Ship Nancy Foster.

Hardware	Manufacturer	Model	Description
Primary multibeam echosounder	Reson	7125 SV2	400 kHz echosounder with 512 beams, collecting across 60 degrees port and starboard
Sound speed at surface	Seabird	SBE 45	Sound velocity at surface using thermosalinograph for ships computing system
Sound speed profiler	Oceanscience	UnderwayCTD	Sound velocity profiles taken at approximately 4 hour intervals during surveys

Seafloor complexity was analyzed quantitatively to delineate disposal and natural hardbottom habitats from surrounding unconsolidated sediments. A 0.5-m resolution base bathymetry surface was used to derive surfaces that characterize the shape and complexity of the seafloor. Slope, rugosity, standard deviation of depth, mean depth and slope of slope were calculated for each 0.5 by 0.5 m cell by analyzing the surrounding 3 x 3 cells using the Spatial Analyst tools in ArcGIS (v. 10.4, ESRI). The resulting surface shows the complexity of the seafloor at the same 0.5 m resolution. Rugosity provided the strongest "signature" of hardbottom habitats, confirmed by the shape of features, especially the teardrop ridge shape of the disposal materials and the natural rocky ledges.

Seafloor complexity surfaces were used to predict four different habitat types throughout the ODMDS and surrounding area. The rugosity surface was reclassified as a binary layer splitting original values at 0.25, a threshold that indicated a break in the surface from the rocky disposal material and surrounding smoother sand surface. The hardbottom sites from these two classes are identified as ledges and dump sites. The slope surface was reclassified using three slope values using the following ranges: < 0.627, 0.627 – 1.569, and >1.569. These slope values conformed to visual interpretation or three habitat types: dredge material, ledge, and mixed hardbottom. Manual editing and reviewing was necessary to remove artifacts in the data from ship motion. The reclassified rasters contained four new habitat classes – disposal site, ledge, mixed hardbottom and sand. Pavement, or very low relief hardbottom with attached biological organisms, was also reported by divers, but could not be differentiated using multibeam surfaces and is therefore combined in the mixed hardbottom class.

2.2. Benthic Habitat Assessment

The benthic habitats found in the ODMDS and natural ledge sites are comprised mostly of filter feeders such as intricate tunicates, gorgonians, sponges, and scleractinian corals in the genus *Oculina*. All of the ODMDS habitats have large rocks and clumped sediments as the base material for the benthic invertebrates to grow on. These unique habitats are challenging to quantify with one type of sampling. A combination of Line Point Intercept, Invertebrate Demographic, Rugosity, and *in-situ* Topographic sampling provided a more complete description of each site. Benthic and fish community data was collected using the same transect tape, which was laid out by the fish diver.

To measure percent cover of biotic and abiotic components of the benthos we used a Line Point Intercept (LPI) method. At the bottom, the LPI diver took a picture in each cardinal direction for a landscape perspective of each site before following along the 50 m long transect tape laid out by the fish count. Starting at 0.5 m, LPI divers recorded the top layer of primary biota and the abiotic substrate type below each point every half meter to 50 m for a total of 100 points. Biotic categories included hard coral species, gorgonians, sponges, zoanthids, tunicates, hydroids, algae, and anemones. Abiotic categories were Hardbottom, Softbottom, and Rubble. (See Appendix B for a complete list of categories and data sheets.) LPI divers also designated the observed habitat type at each site as Ledge, Pavement, Mixed Hardbottom/Sand, Rubble, or Unconsolidated/Soft Sediment. Pavement was a class not easily discernable in the multibeam surfaces, but noted by divers during visual habitat assessments.

To provide more detailed and species-specific information on invertebrate populations, we modified the coral demographic protocols from the National Coral Reef Monitoring Program (NCRMP; Roberson et al. 2014). A benthic diver collected invertebrate demographics data after the fish and LPI diver began their surveys. The demographic survey started at 0 m and measured the maximum diameter and height in cm, percent mortality, and bleaching status of hard corals, sponges, and octocorals on the left side of the transect tape for 10 m x 1 m box. If there was no hardbottom habitat at 0 m, then the demo diver began the transect at the meter mark at which hardbottom habitat began and proceeded for 10 meters documenting start and end meter mark on the datasheet.

Small-scale rugosity measurements, or contour, were determined using an Onset HOBO U20 Titanium Water Level Logger (U20-001-02-Ti) containing a pressure-transducer that records fine-scale variation in depth, from which bottom elevations were inferred. As per methods in Dustan et al. (2013), a single diver swam along the transect, which was laid out by the fish diver, with the logger suspended from a line and positioned as close to the substrate as possible. The logger was moved approximately 10 cm per second over the length of each 50 m transect. The logger was raised 1 m above and rapidly lowered back down to the substrate surface in a spike motion five times at the start and end of each transect and three times every 5 m between these endpoints. Because the logger recorded continuously during each dive, these spikes were used to identify the transects within the data stream and calibrate the distance surveyed. The data from each sensor was downloaded and the sensor reset after each morning and afternoon dive operation. During post-dive processing, the distance calibration spikes were removed from each file using Microsoft Excel, and the raw pressure recorded by the pressure-transducer was converted from units of psi to m of water depth, assuming an atmospheric pressure of 1 atmosphere. The transect length was scaled to 50 m based on sampling rate. Large-scale rugosity measurements were derived for areas surrounding the transects from multibeam bathymetry data collected over the site, see sections 2.1 and 3.1.

Topographic complexity was measured at each site by structural surveys conducted along the same transect tape used for fish, LPI, and demographic sampling. The fish diver collected the topographic data either after the outbound conspicuous fish survey during the inbound cryptic fish survey or after both fish surveys on the return swim to retrieve the transect tape. The priority of this survey was to collect maximum abiotic and biotic structural height within each 2 m x 1 m wide block on the left side for the entire 50 m transect. The diver entered 0 cm if the habitat had no abiotic structure within a block. The biotic measurements focused on organisms that create vertical structure: octocoral, sponge, coral, macroalgae, and bare. The diver also recorded a quick visual estimate of percent area encrusted by biotic organisms for each 2 m x 1 m block as an expansion of percent cover for invertebrate community.

2.3. Statistical Analysis of Benthic Assessments

Parametric and non-parametric tests were conducted in R (npmc package, Helms & Munzel 2005, R Development Core Team, 2013). A t-test was used to compare differences in biota percent coverage collected by LPI methods in variables that approximated normal distributions and displayed equal variance. Mann Whitney U tests were used on variables that failed either normal distribution or equal variance requirements of the t-test.

To document how structural complexity affects fish community metrics, such as composition and diversity, the contour of each reef was measured using the Water Level Logger. For each transect, the contour of the hardbottom reef was visualized by plotting transect distance against water depth. The vertical relief of each transect was calculated as the difference between the minimum and maximum depth along the transect. Digital reef rugosity (DRR) (Dustan et al. 2013) was represented by the standard deviation of depths along each transect. An alternative measure of rugosity was calculated as the ratio of the actual surface contour distance to the linear transect distance as:

$$C = D / L$$

where C = rugosity, L = linear distance of transect (m), and D = distance of transect following the natural surface contour (m) (Risk 1972, McCormick 1994). The distance of the natural surface contour (D) was calculated as the sum of the hypotenuses between every two successive depth measurements recorded by the water level logger. To visualize the distribution of complexity values across reefs, Gaussian based kernel density (Sheather and Jones 1991) was estimated using the 'stats' package (R Development Core Team 2014).

The spatial variability of each transect was visualized with variograms. Variograms are a spatial analysis technique that decomposes the spatial variability in a transect among distance classes (Legendre and Fortin 1989, Legendre and Legendre 2012). The distance classes corresponded to every measurement of depth (m) separated by 10 cm through the entire transect distance (e.g, 10 cm, 20 cm, 30 cm… 280 cm, 290 cm, 300 cm). The variance attributed to each of these distance classes is called the semivariance. The semivariance was calculated as:

$$W(d)$$

$$\gamma(d) = 1 / (2N(d)) \, \Sigma \, (y_i - y_i{+}d)^2$$

where γ(d) is the semivariance at distance class d, N(d) is the number of pairs for separation of distance class d, yi is the depth at location i and yi+d is the depth at location i plus the distance class value d, and W(d) is the final location of the transect that corresponds to distance class d (Isaaks and Srivastava 1989, Legendre and Legendre 2012). The semivariance was plotted against distance classes up to 15 m (half the transect length). This ensured that we plotted the spatially structured component of each transect. The resulting variograms depict the spatial scale over which the complexity of each reef varied.

2.4. Fish Community Assessment

Fish communities were surveyed in a narrow depth range, 47-75 feet of sea water (fsw), using two types of underwater visual census band transects referred to in this document as conspicuous and cryptic fish surveys as documented in Whitfield et al. (2014). Focusing on highly mobile and conspicuous fish, divers identified fish of all sizes to lowest possible taxonomic level within a 50 m x 10 m (500 m^2) transect. The width of the transect depended on visibility and was documented on the data sheet per standard protocol. Most transects were 1-4 meters wide due to reduced visibility. Fish were sized using Total Length (TL) in 10 cm categories up to 90 cm. Actual length was used for fish greater than 90 cm. Divers also noted height of the conspicuous fish over the bottom to link the diver data in with acoustic sampling conducted from the vessel. Conspicuous surveys were conducted at all 52 of the natural and artificial hardbottom sites.

To census smaller benthic-oriented (cryptic) fish, divers documented small-bodied (2-20 cm TL) cryptic and juvenile fish to species over 25 m x 2 m (50 m^2) along the same transect on the return swim from the conspicuous survey. Fish were sized in smaller bins for this survey type up to 20 cm TL. Divers also documented certain macroinvertebrates (sea urchins, spiny and slipper lobsters) on a gross scale (single, few, or many) as well as actual numbers of threatened and endangered species (sea turtles, marine mammals). The use of band transects ensured comparability with some of the fish community metrics sampled by Whitfield et al. (2014). Due to time constraints at depth, cryptic surveys were conducted at 47 of the 52 sites.

2.5. Fishery Acoustic Assessment

A splitbeam echosounder (SBES) detects fish and other objects in the water column by propagating rapid pulses of high-frequency sound and recording the reflection or echo from objects (or the seafloor) with densities that differ from the surrounding water. The fish swim bladder, an organ that many fish use to regulate buoyancy, reflects the majority of the sound transmitted by the SBES transducer. The intensity of the reflected sound (target strength) is proportional to the size of the swim bladder, which results in an echo positively correlated to fish size. When fish are in close proximity, such as in schools or aggregations, it is not possible to discern individual fish and characterize individual target strength. In this case, the total intensity of the reflected sound from the school provides an index of the density of the school.

The SBES system used was a Simrad EK60 splitbeam echosounder operated at three frequencies, 38, 120 and 200 kHz. Three transducers were mounted into the hull of the ship and referenced to a common point to provide precise offsets relative to ship's navigation, multibeam echosounders and other data acquisition systems. Each transducer has a nominal beam geometry of 7° and results in a swath or footprint that is about 12% of range from the transducer face (or water depth), or about 3 m swath at the seafloor in 25 m water depth. The pulse transmission (ping) characteristics, data acquisition and data viewing were controlled from a workstation operating Simrad ER60 software (Simrad Fisheries, version 2.4.3) and connected by local area network to three General Purpose Transceivers (GPTs). The ping timing was triggered by and synchronized to the Reson 7125 MBES. Each ping is co-registered with the ship's time server, navigation and motion system including time in GMT, latitude and longitude, pitch, roll, and heave. Output power, pulse length, and other ping transmission properties are provided in Table 2-6. Data files are logged in 100 MB file segments and stored on the ship server for archiving and analysis.

Table 2-2. Acquisition parameters for the Simrad EK60 SBES on the NOAA Ship Nancy Foster used to map fish density distributions in the ODMDS.

Parameter	Echosounder Frequency		
	38 kHz	120 kHz	200 kHz
Transducer depth (m)	3.43	3.43	3.43
Transmit power (dB-W)	1000	220	100
Pulse length (µs)	256	128	128
Absorption (dB-km)	6.4	47.0	88.0
Sound velocity (nominal, m s^{-1})	1540	1540	1540
Calibration gain (dB)	22.6	20.14	20.3

Prior to the research cruise, the system was calibrated using a standard target - 38.1 mm diameter tungsten carbide (WC) sphere hung below the transducer. This target has a known theoretical acoustic target strength based on the composition sphere diameter and environmental conditions. The LOBE program in ER60 software (Simrad Fisheries, v. 2.4.3) was used to acquire position and target strength for the sphere. The calibration sphere was systematically moved through the beam from forward to aft and port to starboard. The LOBE program calculates the system receiver gain to bring the observed target strength in concordance with the theoretical target strength for the sphere. The process was repeated for each operating frequency.

The SBES surveys were designed in two ways. First, SBES data were collected simultaneously with the MBES survey during the September 2016 cruise. These surveys spanned late-afternoon to early mornings outside diver operations. Line plans were devised to complete the MBES coverage of the ODMDS, with parallel lines spaced about 60-80 meters that ensured >100% ensonification of the seafloor. The second survey design for SBES was conducted over selected dive stations to provide a contemporary and daytime acoustic assessment over disposed and natural hardbottom to complement the diver visual assessments. Sites were selected opportunistically based on the daily dive operations. The sites were surveyed in the morning closest in time to the first dive station, during mid-day when possible, and in the afternoon at the conclusion of dive operations for the day. About five parallel lines were spaced about 25-30 m apart and about 1 km in length (not including turns). In some cases, when dive stations were in close proximity, the survey lines were oriented or lengthened to span more than one station.

The SBES data were processed using Echoview software (version 7.4 and 8.0, Echoview Pty Ltd, Hobart, Tasmania). The data were heave corrected to remove vertical motion caused by swell and waves. The seafloor was delineated and data were cleaned to remove interference and surface air bubbles from ship's wake prior to processing the water column data for fishes. Faint echoes that were likely plankton and other non-fish targets were excluded using a threshold of -55 dB. The remaining echoes were used in a single target detection algorithm to isolate fish greater than about 6 cm in length. The speed of the vessel and rate of ping transmissions resulted in multiple and sequential targets from individual fish. The split-beam transducer detects the range and horizontal position of the target within the beam at each ping using a phase-differential array. A fish tracking algorithm was used to accumulate sequential echoes from single fish targets. The single targets representing individual fish were stored in a database with a geographic position determined by the ship's GPS and corrected for relative position of fish within the acoustic beam, depth below the sea surface, and a mean target strength (TS, in dB). The TS in dB is a log-scale measure of the acoustic backscattering strength. Fish size (total length) in centimeters was derived from the acoustic target strength using a generalized acoustic size to fish length relationship,

$$TL = 10^{(TS+64.0035)/19.2}$$

where TS is target strength measured in dB, TL is calculated length in cm (Love 1977). The equation fits closely with observation of reef fish of the same taxonomy that were observed during diver surveys for this project and published elsewhere (Johnston et al. 2006).

Individual fish targets were counted and binned into 100-m intervals along survey transects. The density calculation accounted for the increasing detection of individual fish as the acoustic beam footprint increases by depth, standardizing the beam width to a 1-m swath using the following equation:

$$Cw = 2 \times range \times \tan(0.5BA)$$

where Cw is the weighted count of an individual fish accounting for detection in an increasing beam swath with increasing range, and the tangent of the half beam angle (BA = 7°). Weighted counts are summed for each 100 m interval producing a density with the units fish 100 m^{-2}.

When fish are aggregated in schools (e.g., less than about 20 cm vertical spacing), individual targets cannot be discerned or enumerated. The acoustic backscatter of the school is the sum of the backscatter from the individuals. Fish schools were delineated using a detection algorithm that isolates the acoustic backscatter in the school from the background noise. Polygons were drawn around the shape of the school and the total acoustic backscatter intensity was calculated, a procedure known as echo-integration. To calculate fish density in schools, the total acoustic backscatter intensity must be scaled to the size of the average fish in the school. Some schools included discernable tracks from individual fish on the outer margin of the schools or an average fish size for the survey. The total acoustic backscatter is divided by the average backscatter of an individual fish, creating a density that has units of fish m^{-2}, which is then multiplied by 100 to achieve similar magnitude of values as in the density estimates of area swept for individual fish (fish 100 m^{-2}). Acoustic fish density layers are created for each survey as point shapefiles in a GIS with the centroid of the interval used as the geographic position for densities of individual fish and the centroid of the fish school.

The SBES fish density shapefiles were divided into size categories that represent small prey species, conspicuous fishes, and large fishery-important species. Small fish, less than 11 cm, likely represent smaller reef species and smaller planktivorous fish species. This size group differs from the visual fish assessment in that it will not include all cryptic fish that were hidden within the structured habitat and not detected by the SBES. Medium fish, between 11 cm and 29 cm, include juvenile or small adults of targeted fishery species. Large fish, greater than 29 cm, include larger economically valuable fish within the grouper/snapper complex and other pelagic predators. Densities were plotted using symbols proportional to the magnitude of fish density (fish 100 m^{-2}) with zero densities excluded. Fish densities within a 50 m buffer of hardbottom habitat stations were averaged and summarized for each dive stations and compared between (1) disposed hard material, or (2) natural hardbottom. Linear models were used to evaluate correlative relationships between measures of density and the descriptors of seafloor complexity.

3. RESULTS

3.1. Bathymetry and Seafloor Complexity in the ODMDS

About 20% of the ODMDS was mapped during a cruise conducted independently by the EPA in 2015. The area covered confirmed the location of many of the dredge material disposal points (Figure 3-1). During the 15 additional days of operations in 2016, we were able to complete the survey of the ODMDS management area, and extend coverage following natural bathymetric features such as ledges and submerged river channels outside of the ODMDS boundary (Figure 3-1).

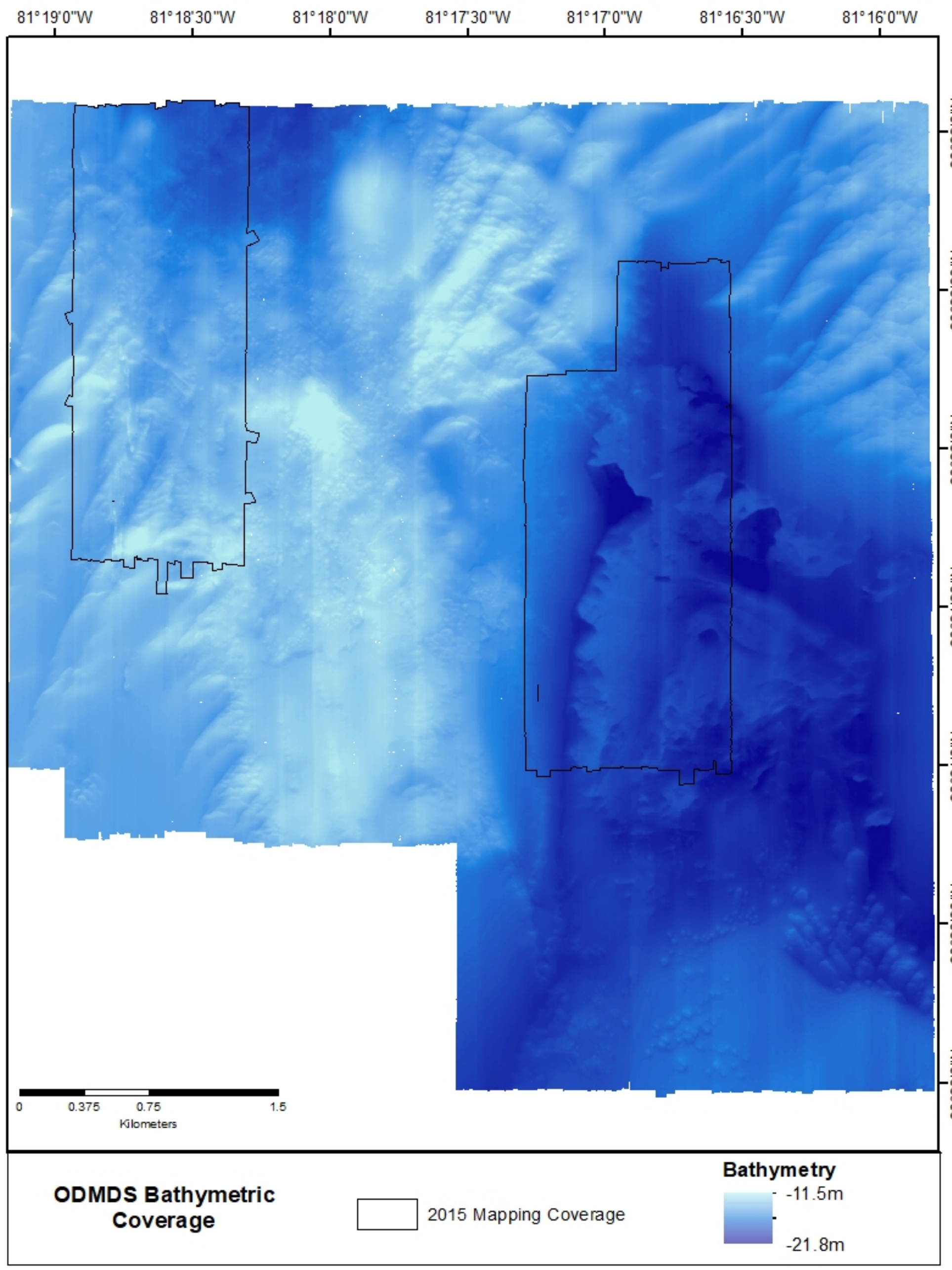

Figure 3-1. Bathymetric surface of Fernandina Beach ODMDS merged from surveys conducted during 2015 (outlined by polygons) and 2016 (this project).

Derivatives of the bathymetric surface such as rugosity and slope provided indicators of rocky material that was differentiated from the surrounding unconsolidated sediments (Figure 3-2). Using threshold values of 0.25 rugosity units, the dredge material was easily delineated (Figure 3-3). The maps show likely hardbottom habitats within the ODMDS, but have not been validated due to limited visual verification as a result of poor visibility during the in-water assessments.

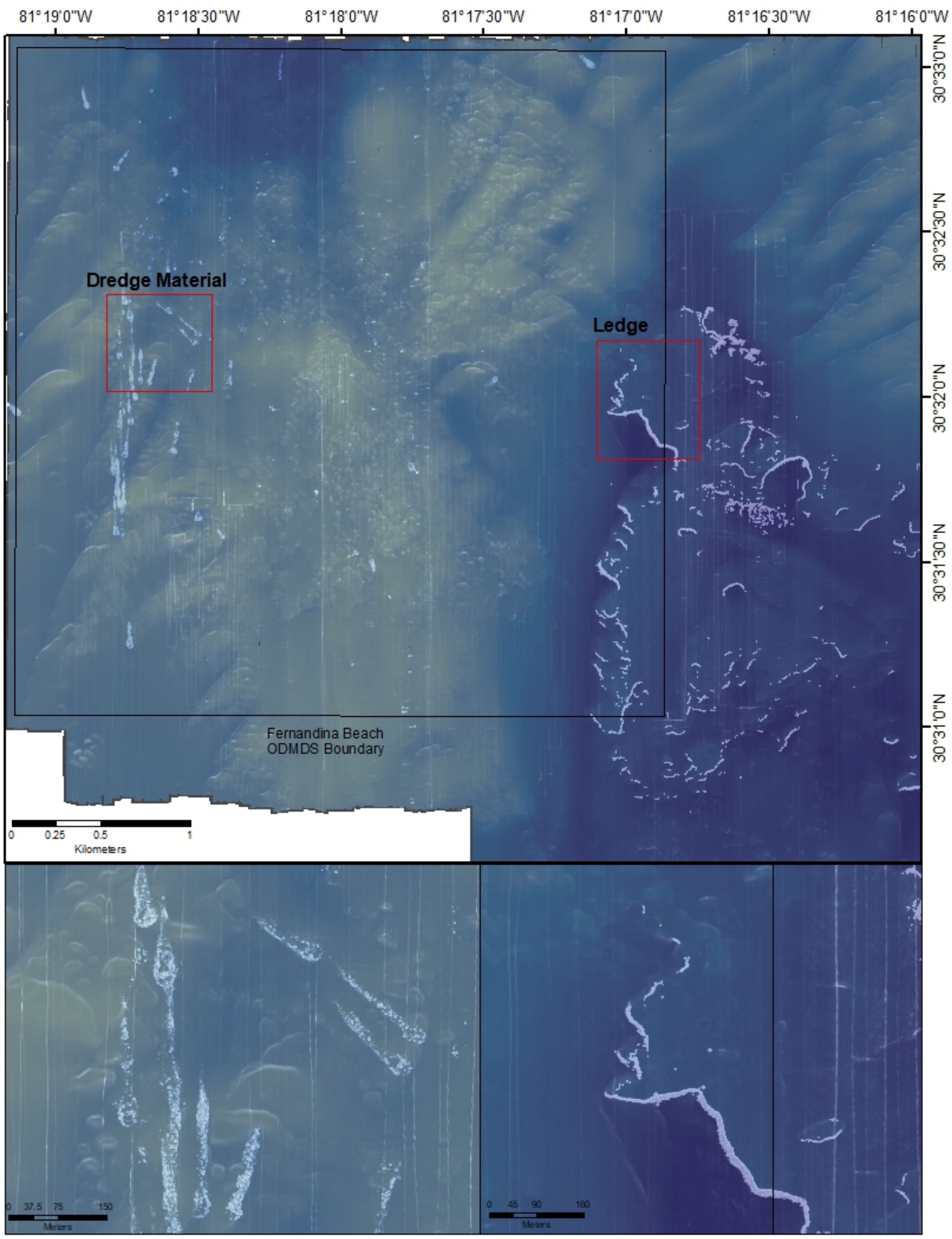

Figure 3-2. Compiled surface of bathymetry and surface rugosity metric to highlight disposal material and natural rocky reefs. Bathymetry scale is the same as Figure 3-1 with transparency set to 50% for bathymetry. Rugosity is scaled dark (low rugosity) to white (high rugosity).

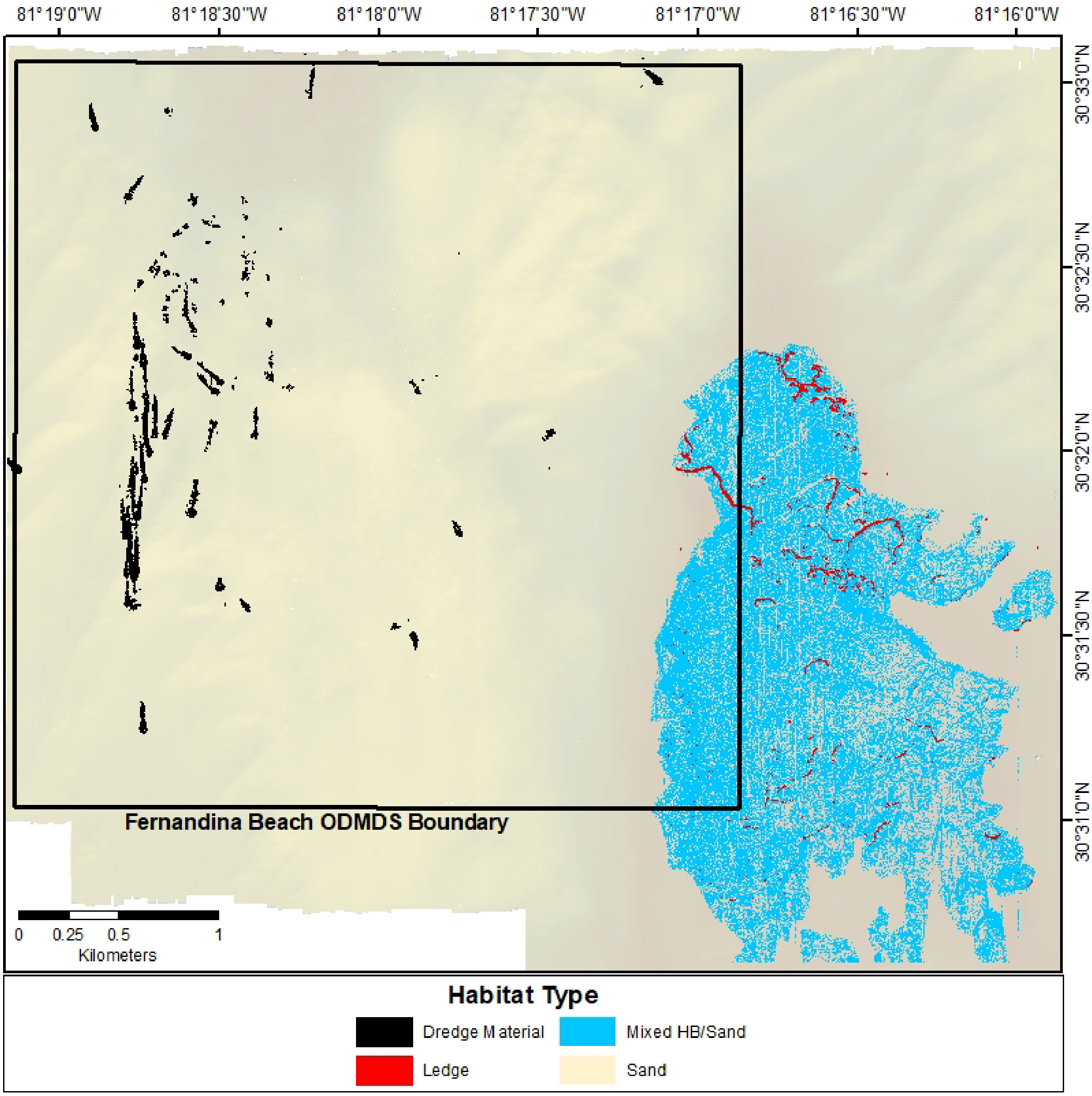

Figure 3-3. Delineated rock disposal material features (black), and likely ledge features (red) among mixed hardbottom (blue)) and unconsolidated sand (tan) detected from multibeam bathymetry and seafloor surface complexity metrics.

3.2. Habitat Assessment

The habitat assessment took place over two research cruises in 2016, September 1 – September 8 and September 21 - 28, during which a combined 262 dives were conducted to survey 21 western disposal sites, 11 eastern ledge sites (Figure 2-2), and 3 natural hardbottom sites located approximately three nm northeast of the ODMDS boundary (Table 3-1). Over 5300 m^2 of habitat was surveyed for benthic cover, invertebrate demographics, in situ topography and rugosity, as well as fish abundance and presence. Divers measured 1645 invertebrates for height, diameter, and bleached status. Multiple storm systems moved through the Fernandina Beach area before, during, and after both cruises significantly reducing the water clarity for all of the sites particularly during the last cruise. As a result, not all sites have complete data collections. Low visibility resulted in either cancellation of dives while at depth or shortening of the length of the transect to maintain safe dive buddy communication. Line Point Intercept surveys were completed for 35 sites, Invertebrate Demographics for 34 sites, Topographic surveys for 34 sites, in situ Rugosity for 28 sites, and Percent Encrusting for 27 sites.

Overall percent live cover did not vary significantly between the natural ledges and ODMDS sites, although the physical appearance was quite different – rocky jetty-like features vs. continuous natural ledges with undercuts (Figure 3-4).

Table 3-1. Summary table of in- water data collected at each site. An 'X' denotes data collected at that site. Almost all in water fish sampling was hampered by very low visibility. Divers completed transects but the data is not representative of the fish community present at most sites.

Site	Latitude	Longitude	Region	LPI	ID	Topography	% Encrust	Fish Census	Rugosity
FB-8	30.53608	-81.3087	ODMDS	X	X	X	X	X	X
FB-7	30.53385	-81.3064	ODMDS	X		X	X	X	X
FB-6	30.53113	-81.3096	ODMDS	X	X	X	X	X	
FB-5	30.54783	-81.3148	ODMDS	X	X	X		X	X
FB-42	30.52633	-81.3132	ODMDS	X	X	X		X	X
FB-41	30.52698	-81.3083	ODMDS	X	X	X		X	
FB-40	30.52068	-81.3122	ODMDS	X	X	X	X		X
FB-39	30.53534	-81.2759	Ledge	X	X	X	X	X	
FB-38	30.5312	-81.2762	Ledge	X	X	X	X	X	X
FB-36	30.52654	-81.2797	Ledge	X	X	X	X	X	
FB-34	30.51924	-81.2848	Ledge	X	X	X	X	X	
FB-32	30.52417	-81.2843	Ledge	X	X	X	X	X	X
FB-31	30.52767	-81.2765	Ledge	X	X	X	X	X	X
FB-30	30.53742	-81.2787	Ledge	X	X	X	X	X	X
FB-29	30.53753	-81.31	ODMDS	X	X	X	X	X	X
FB-28	30.53033	-81.3125	ODMDS	X	X	X	X	X	X
FB-27	30.53395	-81.3112	ODMDS	X	X	X	X	X	X
FB-26	30.534	-81.3087	ODMDS	X	X	X	X	X	X
FB-25	30.54483	-81.3131	ODMDS	X	X	X	X	X	X
FB-24	30.538	-81.3127	ODMDS	X	X	X		X	X
FB-23	30.53642	-81.3083	ODMDS	X	X	X	X	X	X
FB-22	30.53517	-81.3117	ODMDS	X	X	X		X	X
FB-21	30.537	-81.3122	ODMDS	X	X	X	X	X	X
FB-19A	30.53133	-81.3128	ODMDS	X	X	X		X	
FB-17A	30.534	-81.3122	ODMDS	X	X	X	X	X	X
FB-17	30.52953	-81.313	ODMDS	X	X	X	X	X	X
FB-16	30.52793	-81.3129	ODMDS	X	X	X	X	X	X
FB-14A	30.53247	-81.2835	Ledge	X	X	X		X	X
FB-13A	30.52767	-81.2838	Ledge	X	X		X	X	
FB-12A	30.53087	-81.2813	Ledge	X	X	X	X	X	X
FB-11	30.53615	-81.2777	Ledge	X	X	X	X	X	X
FB-10	30.5395	-81.31	ODMDS	X	X	X	X	X	X
Box2-4	30.61373	-81.1841	Box2	X	X	X	X		X
Box2-11	30.62173	-81.1839	Box2	X	X	X	X	X	X
Box2-1	30.6168	-81.182	Box2	X	X	X		X	X

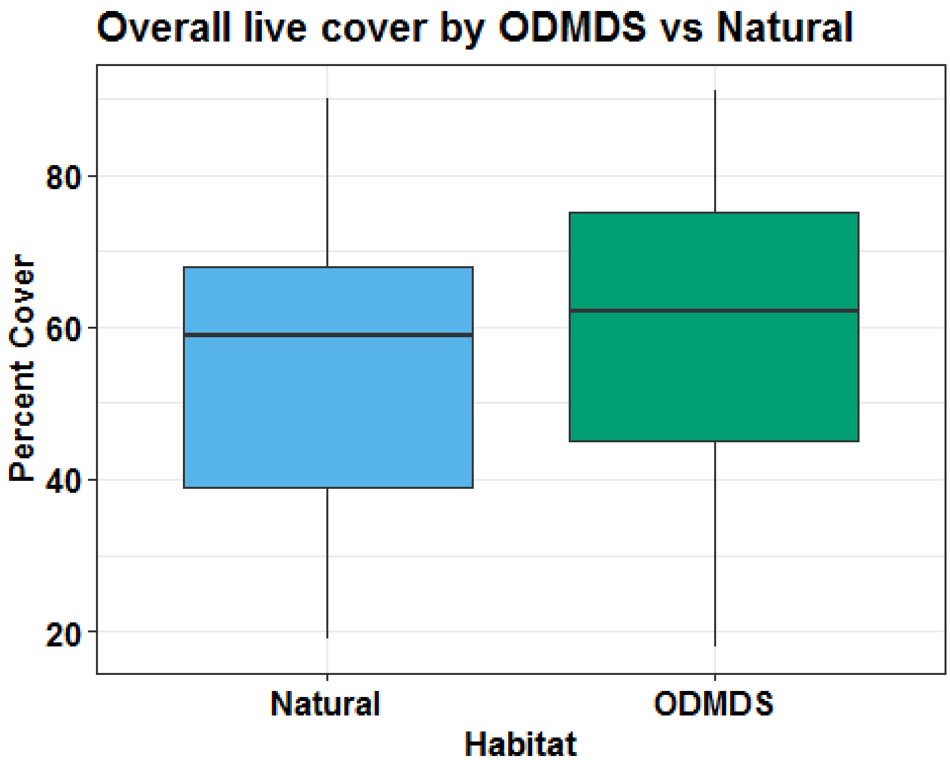

Figure 3-4. Overall live cover – Natural (14) 55.45% (±6.02) vs. ODMDS (21) 57.21% (±4.63). See Table 3-2 for statistical comparison.

Over natural rocky habitats, sponge (20.62%), tunicate (13.37%), coral (7.41%) and hydroid (7.35%), dominated percent cover, comprising over 48% of live cover. Disposal site habitat percent cover was dominated by tunicate (18.69%), coral (12.71%), sponges (10.98%), and octocorals (9.54%) with just under 52% of live cover attributed to those four biota (Table 3-2, Figure 3-5, 3-6, & 3-7). Pairwise differences of biota between the two habitat types indicated sponges make up more of the biological community over natural habitats, whereas tunicates contribute to more coverage over disposal sites (Table 3-2). Though lower in cover, octocorals were significantly higher on disposal sites than natural sites. Hydroids were more prevalent on natural features. Algal components were not prevalent on either habitat type. Natural sites hosted 5.8% macroalgal cover with very little turf and dumpsites had the opposite with 5.2% turf cover and extremely low macroalgal cover.

EPA R4 conducted a habitat assessment at the Fernandina Beach ODMDS in August 2013 (US EPA 2014). Although conditions and techniques were different, the results were similar. Divers collected data along a 25 meter transect. Results from that survey indicate 49% live cover on the ODMDS stations and 45% live cover on natural stations. However, hydroids and macroalgae were not included in the assessment.

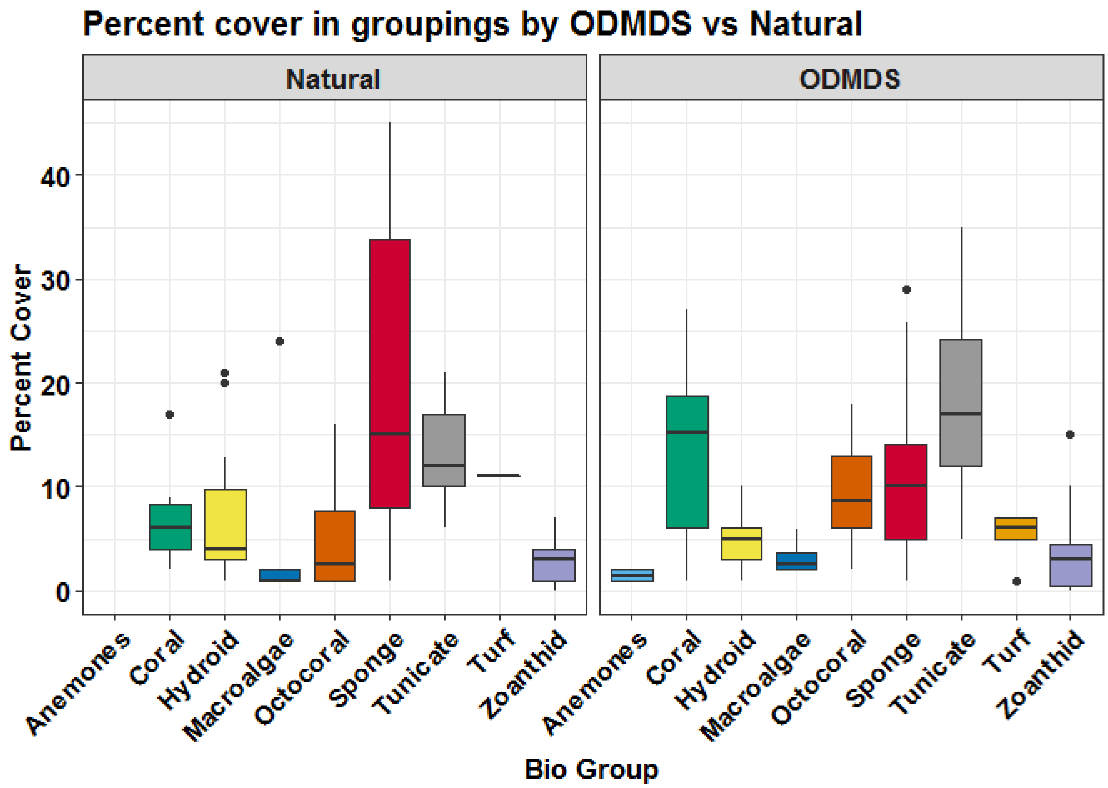

Figure 3-5. Percent cover of Biotic group by Habitat type averaged over natural (14) versus disposal sites (21).

*Table 3-2. Statistical analysis results comparing mean percent cover (SE) of biota categories between habitat types: Natural (14) and ODMDS (21). The P value is the result of either a Mann Whitney test designated by a U statistic, or if the data was normally distributed with equal variance, then a two-tailed t-test was conducted and a t statistic with accompanying degrees of freedom were reported [t (df)]. P values with an * designate a significant difference between habitat types with omega = 0.05. Anemone percent cover was also collected but only recorded at four ODMDS sites.*

Biota % Cover	Natural	ODMDS	P value	U or T Stat	Normality
Live Cover	55.45 (6.02)	57.217 (4.63)	0.815	t = -0.235 (33)	Yes
Coral	7.41 (1.43)	12.71 (1.81)	0.113	U = 99.5	Yes
Hydroid	7.35 (1.74)	4.46 (0.70)	0.016*	U = 75.5	No
Macroalgae	5.80 (4.55)	3.26 (0.93)	0.430	U = 128.5	No
Octocoral	5.58 (1.73)	9.54 (1.05)	0.015*	U = 74.5	No
Sponge	20.62 (3.96)	10.98 (1.79)	0.043*	U = 86.5	Yes
Tunicate	13.37 (1.48)	18.69 (1.82)	0.023*	t = -2.388 (33)	Yes
Turf	0.78 (NA)	5.20 (1.11)	0.270	U = 125	No
Zoanthid	3.00 (1.22)	3.61 (1.09)	0.161	U = 109	No

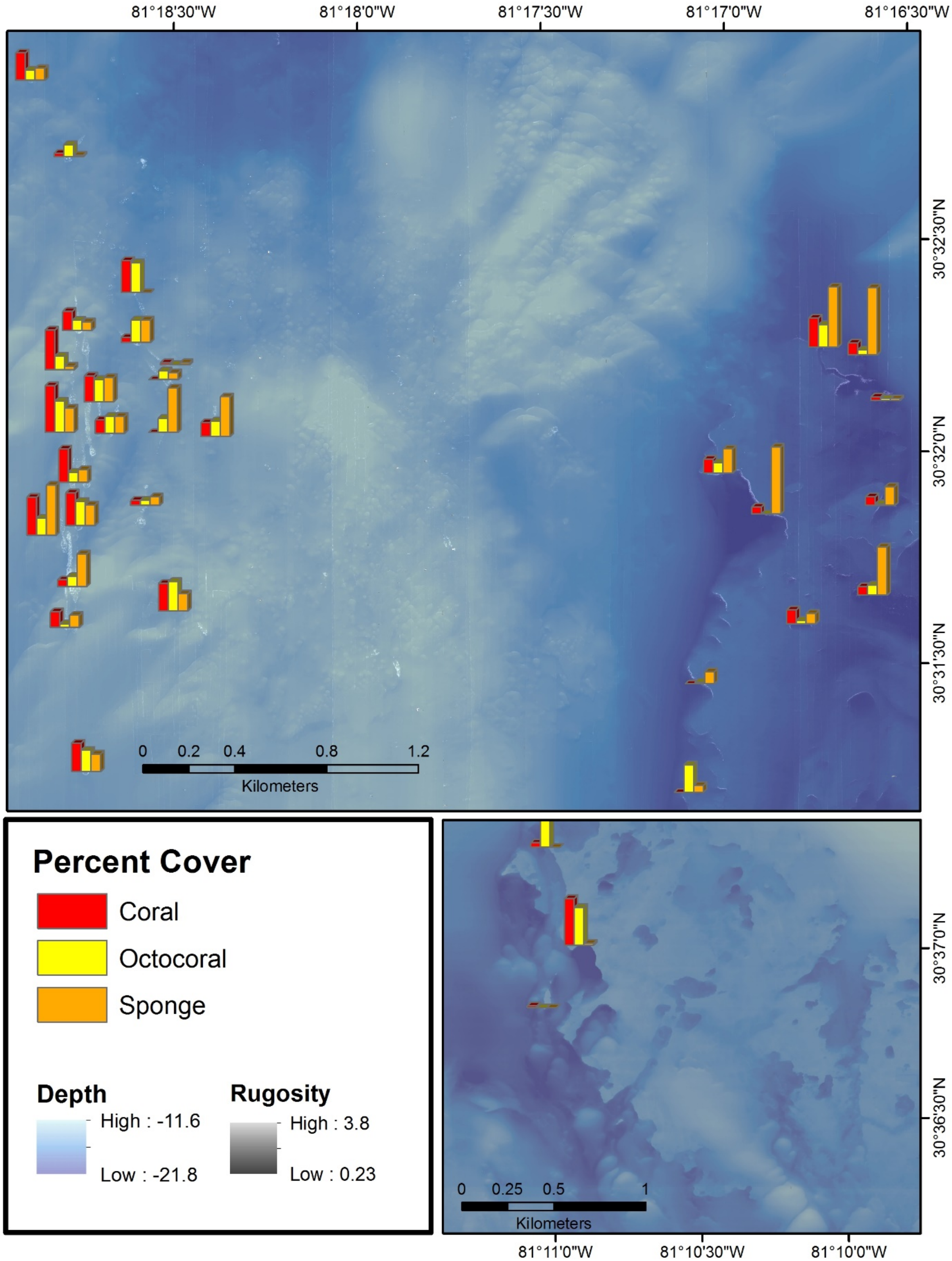

Figure 3-6. Percent cover by station of corals, octocorals, and sponges. The top panel is the ODMDS boundary with dumpsites on the left and natural ledge sites on the right. The lower panel is the natural ledge sampled Northwest of the ODMDS.

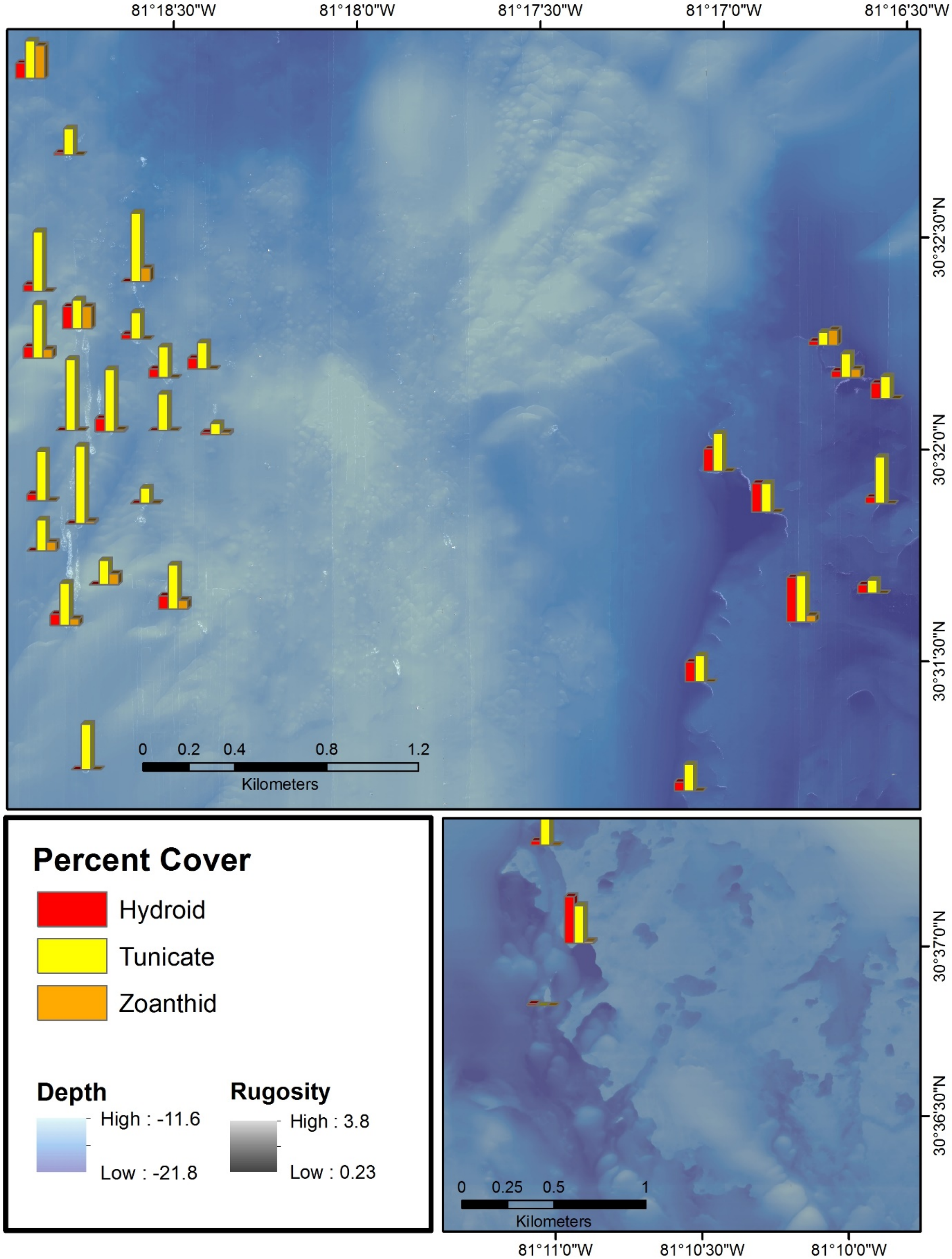

Figure 3-7. Percent cover by station of hydroids, tunicates, and zoanthids. The top panel is the ODMDS boundary with dumpsites on the left and natural ledge sites on the right. The lower panel is the natural ledge sampled Northwest of the ODMDS.

Analysis of demographic data also showed no difference between organism density at the disposal sites and natural rocky habitats (Figure 3-8). Differences between densities of biotic categories mirrors percent cover from the LPI. Sponges were higher density on natural sites, octocorals were more abundant on disposal sites (Figure 3-9). The tallest organisms measured on both habitat types were octocorals. Marginally taller octocorals were encountered on disposal sites (Figure 3-10). Sponges provided the second tallest structure for biological organisms.

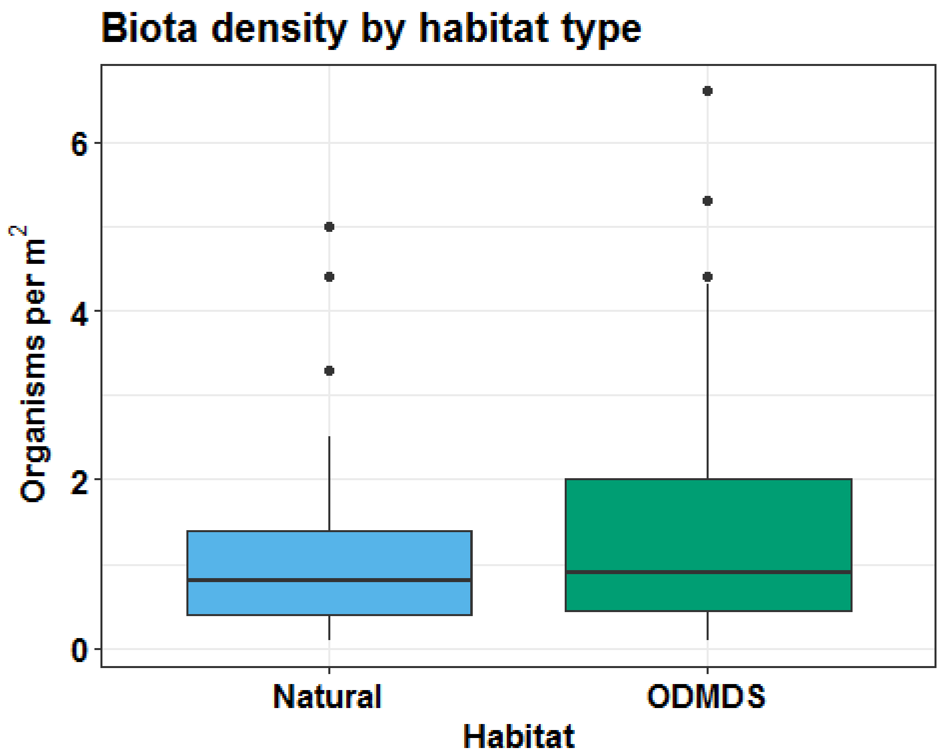

Figure 3-8. Biota density by habitat type: natural (14) and ODMDS (20).

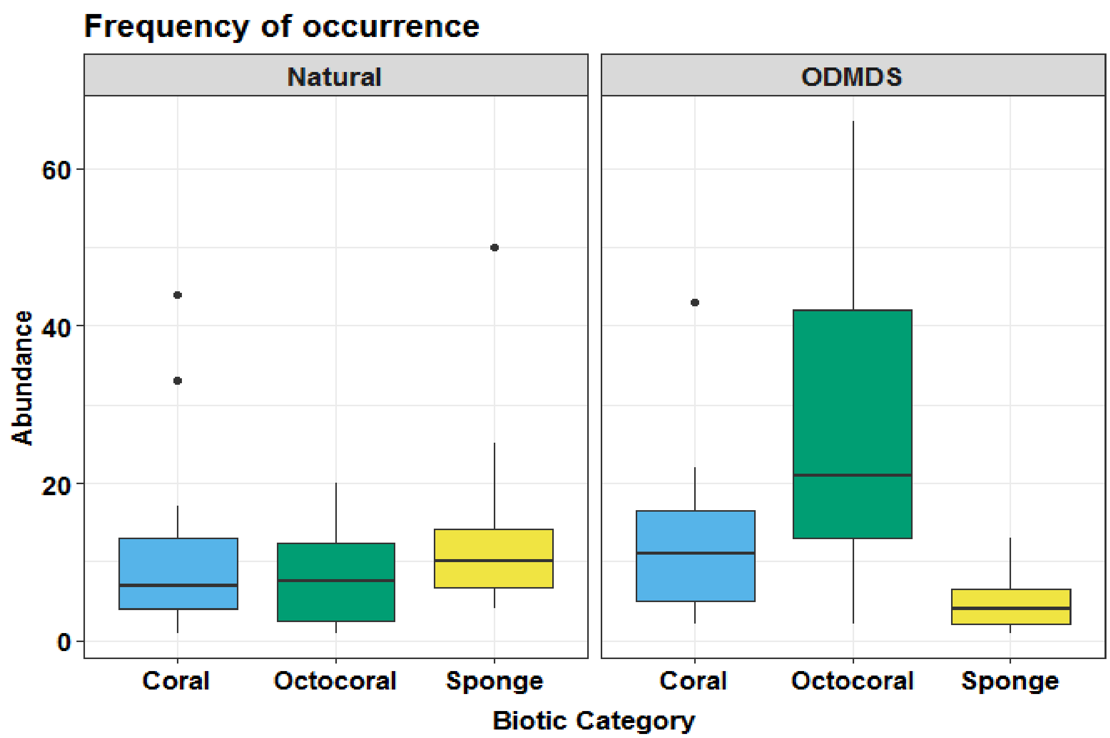

Figure 3-9. Abundance by biotic category for Natural (13) and ODMDS (21) sites

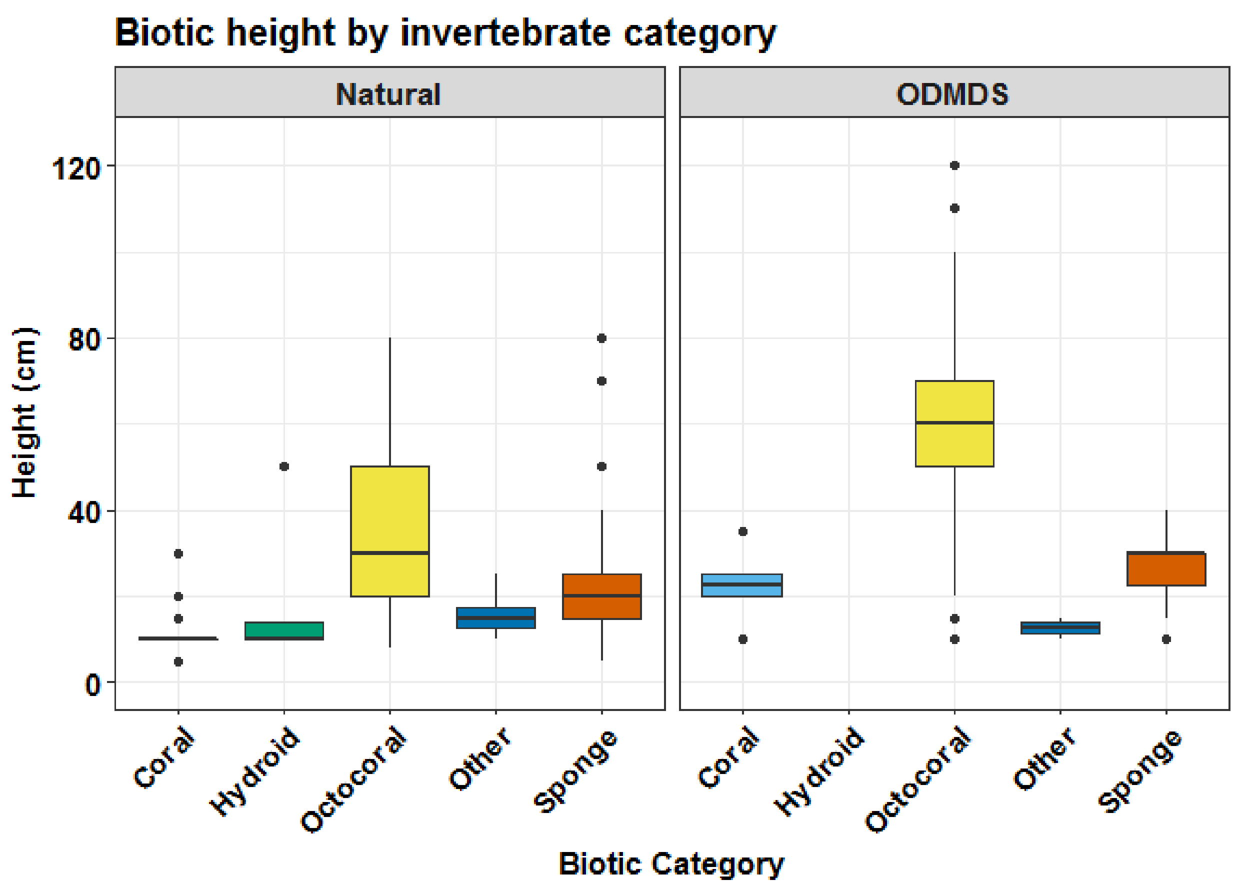

Figure 3-10. Biotic height by category presented as box-whisker plots, outliers are shows as individual dots.

Within the ODMDS, disposal and natural sites had similar height, relief and rugosity measurement ranges (Figure 3-11, Table 3-3). This is possibly due to the difference in sample size between the two habitat types (21 ODMDS sites vs. 13 Natural sites). Even though natural sites had more measurements of heights <100 cm, there were more ODMDS sites overall making the mean height differences insignificant. Natural ledges are located in significantly greater depths (62 - 72 fsw) than the dump sites (42 – 58 fsw).

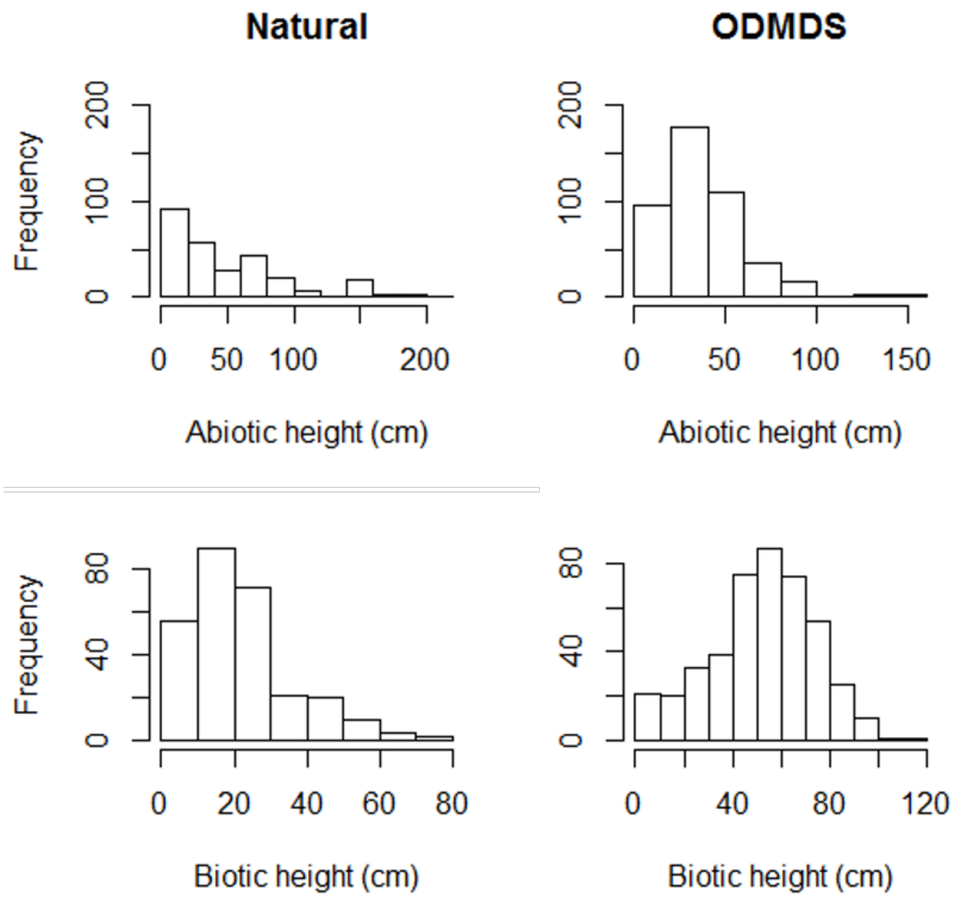

Figure 3-11. Frequency histogram of abiotic and biotic heights (cm) measured in situ by habitat type.

Table 3-3. Structure of the habitat was measured and calculated at different scales. For each site (N = 35) rugosity was derived from the multibeam bathymetry. Maximum depth, minimum depth, average depth, relief (difference between max and min), Digital Reef Rugosity (DRR) and Chain value were all calculated from data collected in situ by the HOBO pressure sensor at depth. Abiotic height was collected in situ at 34 sites. T- tests were conducted unless data did not pass equal variance or normal distribution approximation when we used Mann Whitney U tests.

Factor	Natural	ODMDS	P	U or t stat	Normality
MB rugosity	0.252579	0.251716	0.649	U = 133	Yes
Max depth	72.46	58.29	<0.001*	t = 15.6 (26)	Yes
Min depth	62.63	42.63	<0.001*	t = 14.62 (26)	Yes
Avg depth	67.69042	50.88131	<0.001*	t = 14.36 (26)	Yes
Relief	4.25544	4.165467	0.81	t = 0.243 (26)	Yes
DRR	0.284309	0.288834	0.581	U = 78	No
Chain	3.809406	3.789955	0.792	U = 84	No
Abiotic Height	31.400	39.127	0.887	U=132	No

The physical structure of natural features were higher than disposal sites with a caveat that two sites with extreme measures of relief were located outside the ODMDS area designated Box 2 (Fig 3-12, Fig 3-13). It is also worth noting that these two natural ledge sites are limestone outcroppings while ledge features inside the ODMDS are a combination of exposed limestone and ancient worm reef.

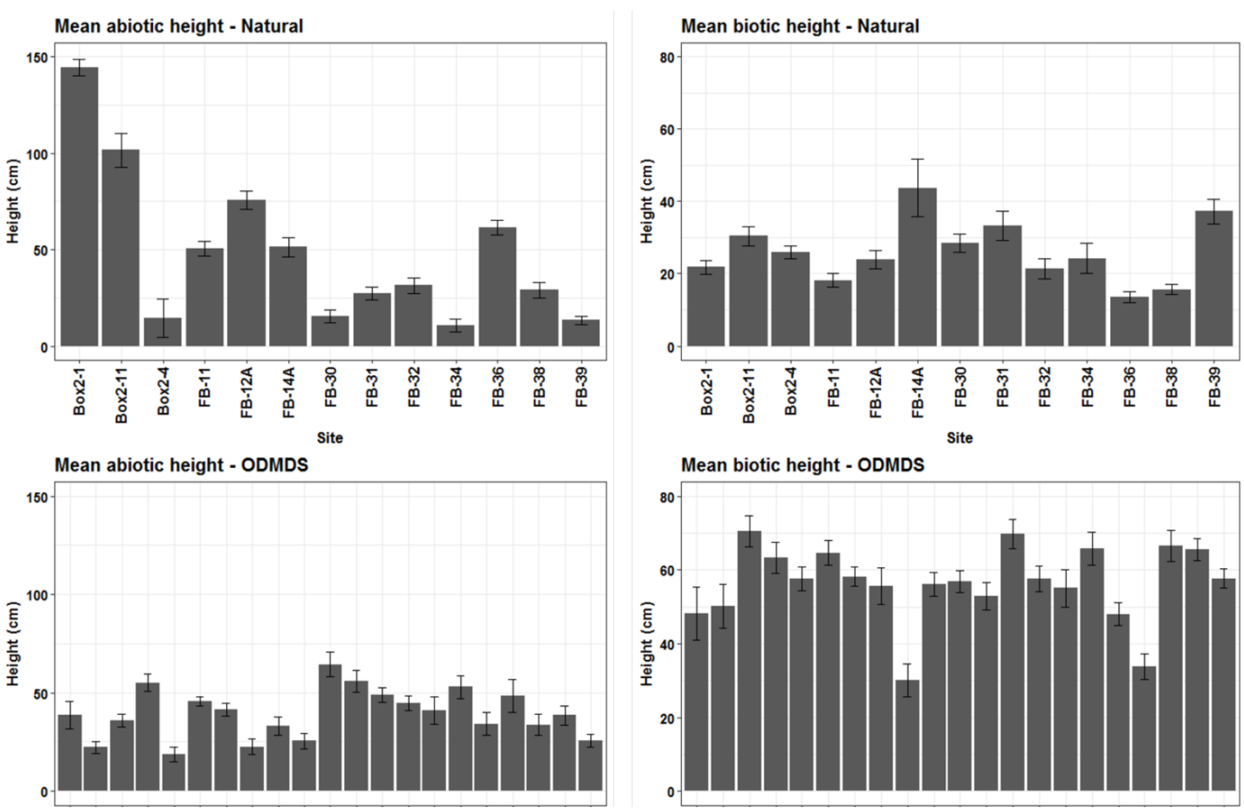

Figure 3-12. Biotic and abiotic height by site for natural and disposal sites presented as mean +standard error.

Site Site

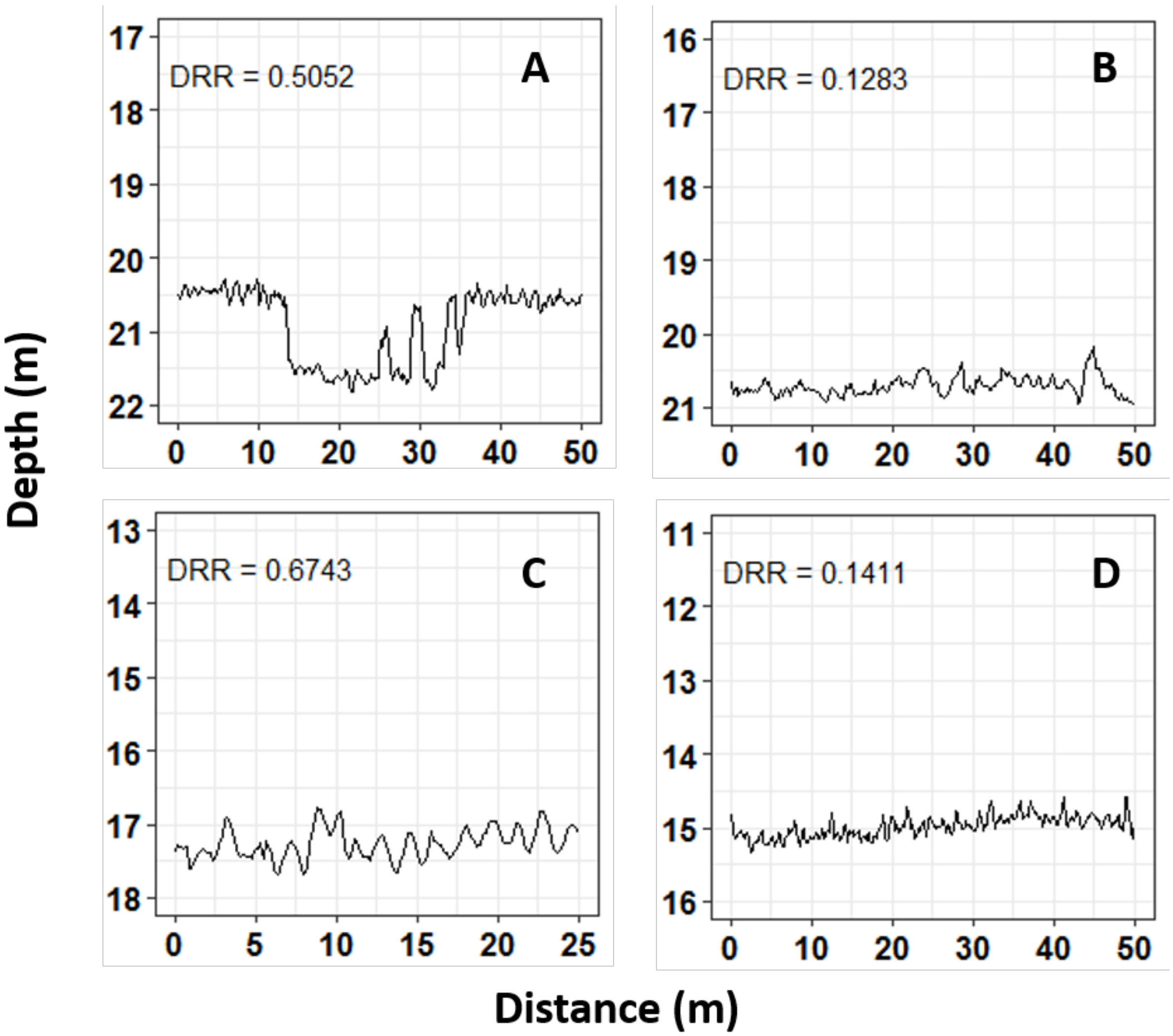

Figure 3-13. Hobo sensor derived depth profiles of four example sites used to derive digital reef rugosity, (A) natural ledge high relief (Box2-04), (B) natural ledge low relief (FB-38), (C) ODMDS site high relief (FB-25), (D) ODMDS low relief (FB-23).

Percent encrusting data was collected during the topography survey. Due to low visibility and limited time at depth, 27 out of 35 sites were sampled. Data ranged from 0-100 percent encrusting (Fig. 3-14). Small-scale site descriptions are achievable combining LPI data with percent encrusting estimates.

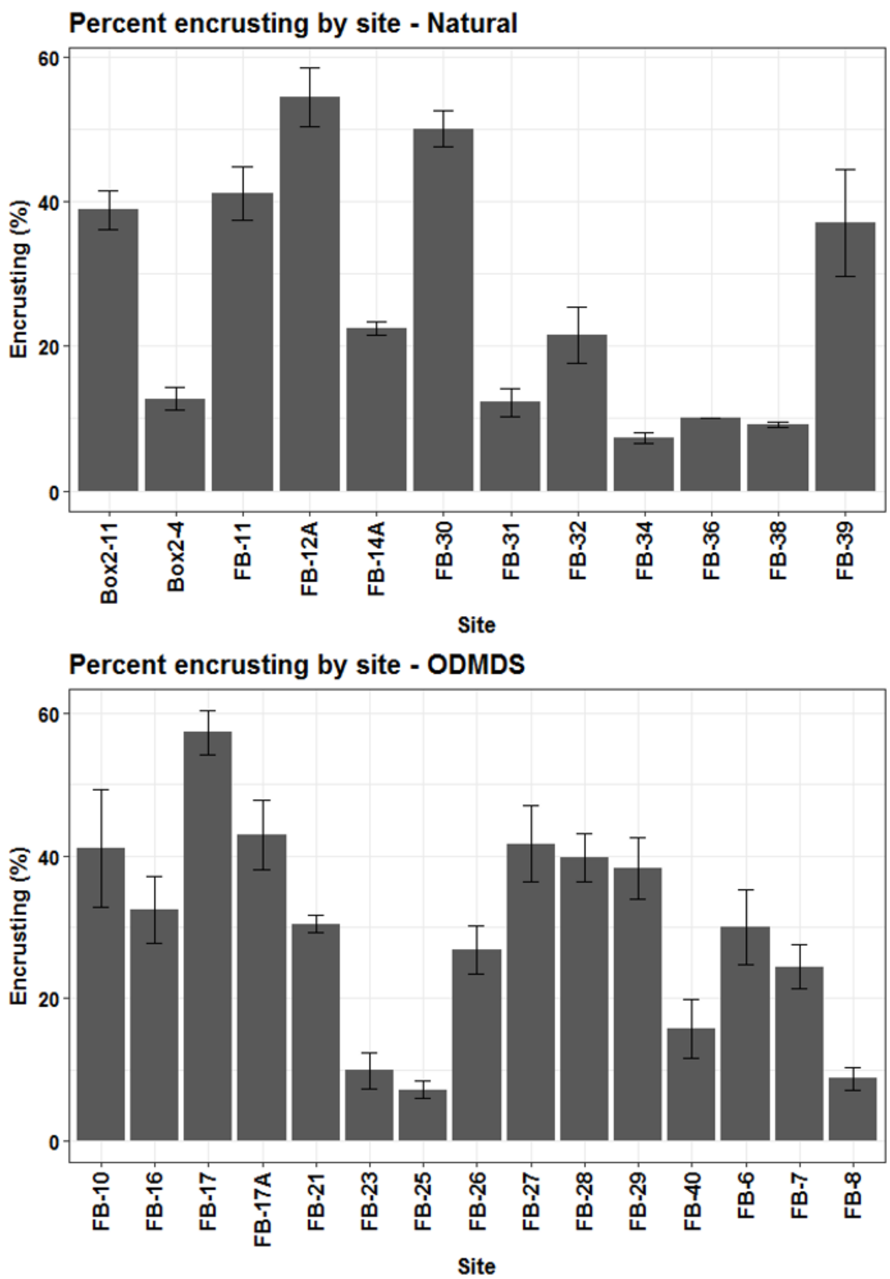

Figure 3-14. Percent encrusting by site and habitat type.

3.3. Fish Community Assessment

Due to poor weather and visibility, fish data were not consistently recorded at several sites and so were not analyzed and will not be reported here.

3.4. Fishery Acoustic Assessments

Fishery acoustic surveys were conducted during two operations. The night multibeam operations, which did not cover the entire ODMDS management area (Figure 3-15), allowed for mapping of parts of the ODMDS that mostly included unconsolidated sand and some natural colonized rock habitats. These night surveys display distribution of fishes that show how unconsolidated habitats may be used by fishes for foraging at night. The portions of the ODMDS area that were surveyed with multibeam in 2015 did not include fishery acoustic surveys and were not resurveyed in 2016. This leaves a gap in night fish distributions over the majority of the disposal materials and the prominent ledge feature to the east (Figure 3-15). The night surveys show significantly higher densities of medium and small fish in the east and southeast area of the survey in close proximity to the natural ledge and mixed hardbottom features. Fish densities over the ODMDS disposal sites were lower and more sparsely distributed.

Fishery acoustic surveys conducted during the day and coordinated with diver assessments provided a coincident image of fish density distributions. Surveys were conducted over 21 diver stations over dredge material disposal points and five natural rocky reef stations (Figure 3-16). Overall density varied considerably across sites.   Individual fish and small fish school were observed over the range of hardbottom habitats (Figure 3-16).

The dredge material disposal points were lower relief and more isolated than the contiguous rocky ledges and low-relief rocky habitats. Restricting analysis of fish density associated with the disposal and natural rocky habitats indicated relatively lower fish density associated with the disposed materials, but a difference that was not statistically significant (Figure 3-18).

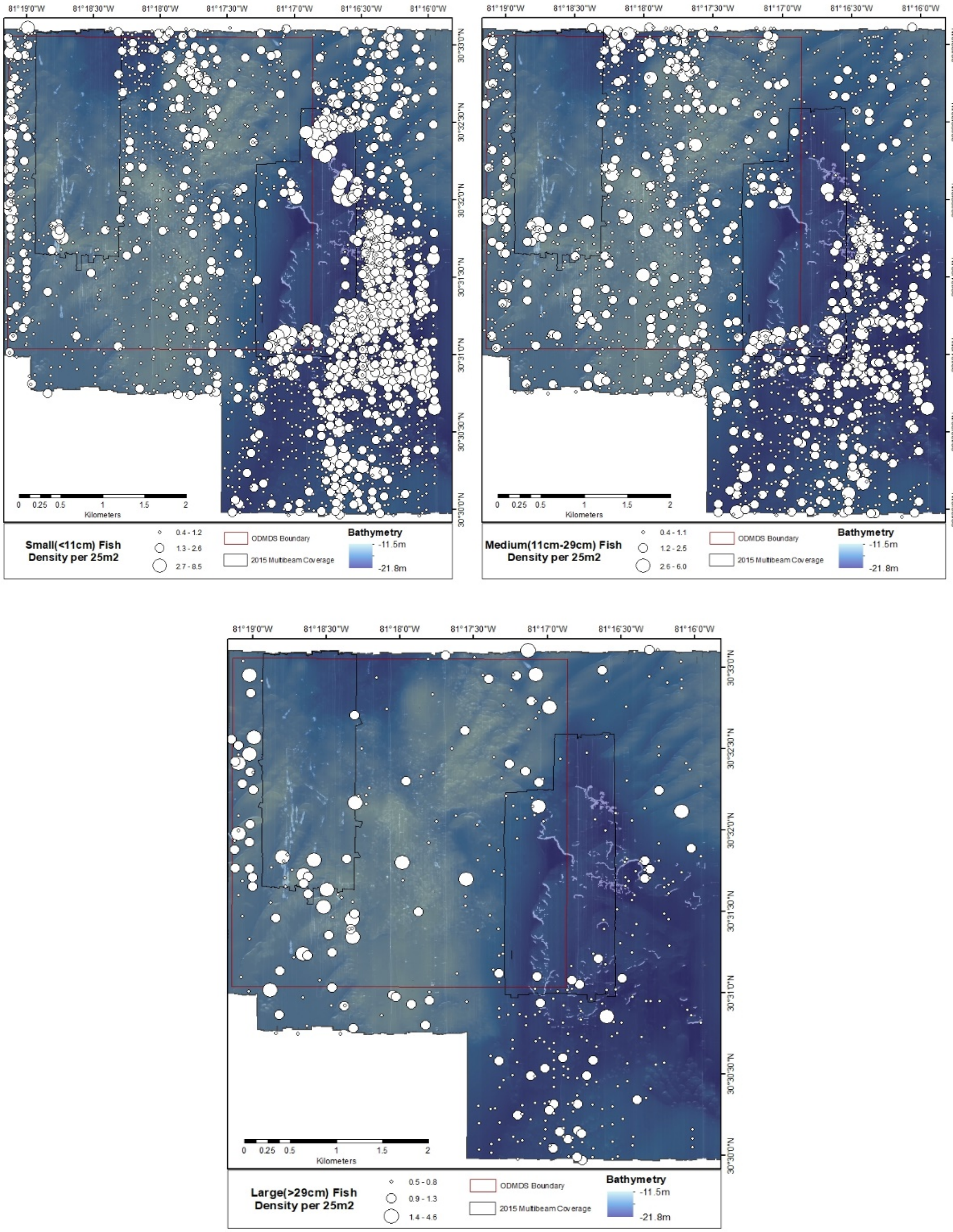

Figure 3-15. Night time acoustic densities for three size (a) small fish less than 12 cm, (b) medium fish between 12 and 29 cm, and (c) large fish >29 cm. Symbols are proportional to densities in each panel legend. Where no fish were encountered, zero density is represented by blank space. Fish schools were not visible during night surveys (schools tend to dissipate at night). Gaps in coverage identified by dark polygons are in areas surveyed using multibeam in 2015 but not resurveyed using fishery acoustic methods.

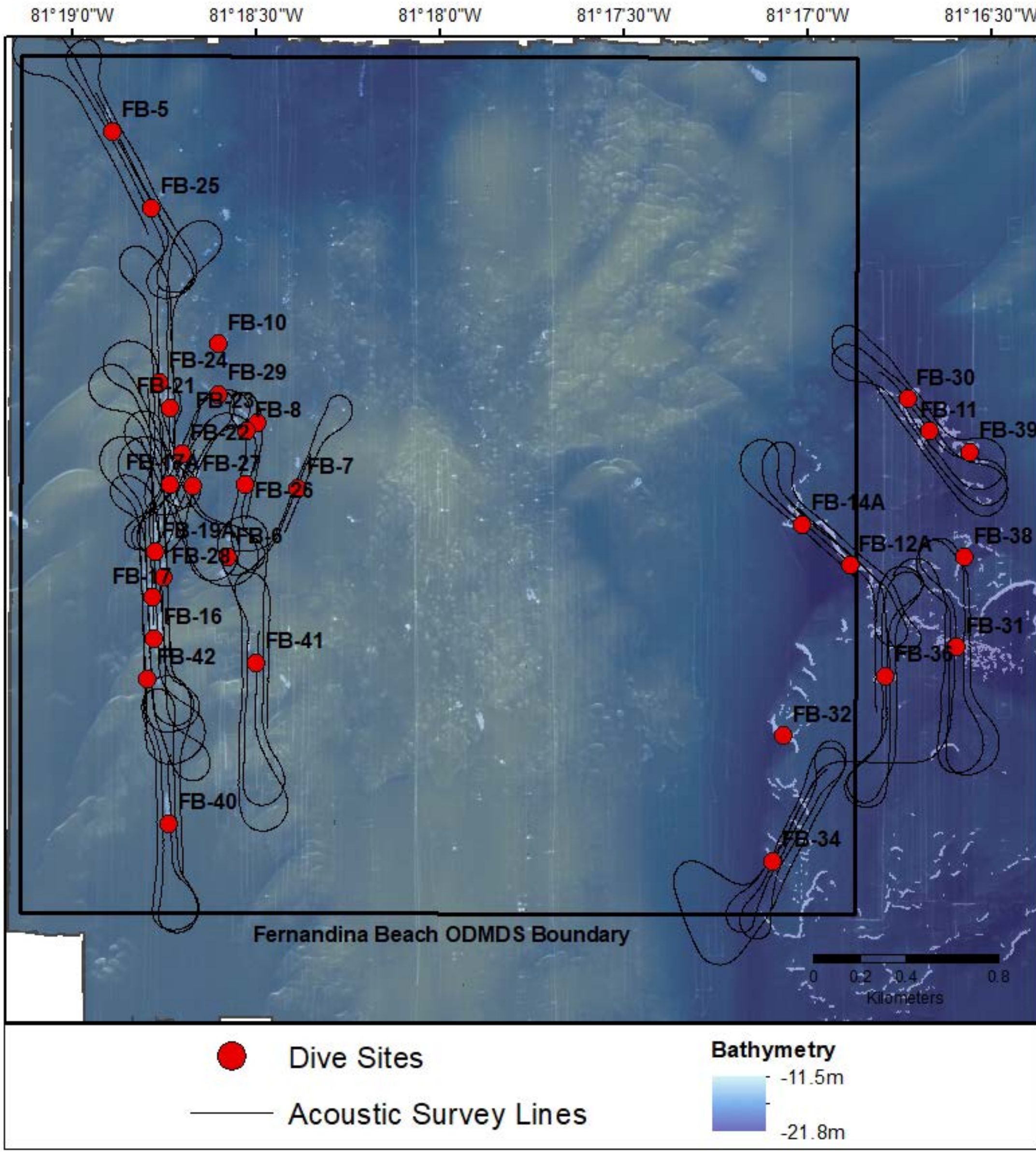

Figure 3-16. Overview of fishery acoustic tracklines conducted during daytime and paired with diver visual observations at dive stations (red circles).

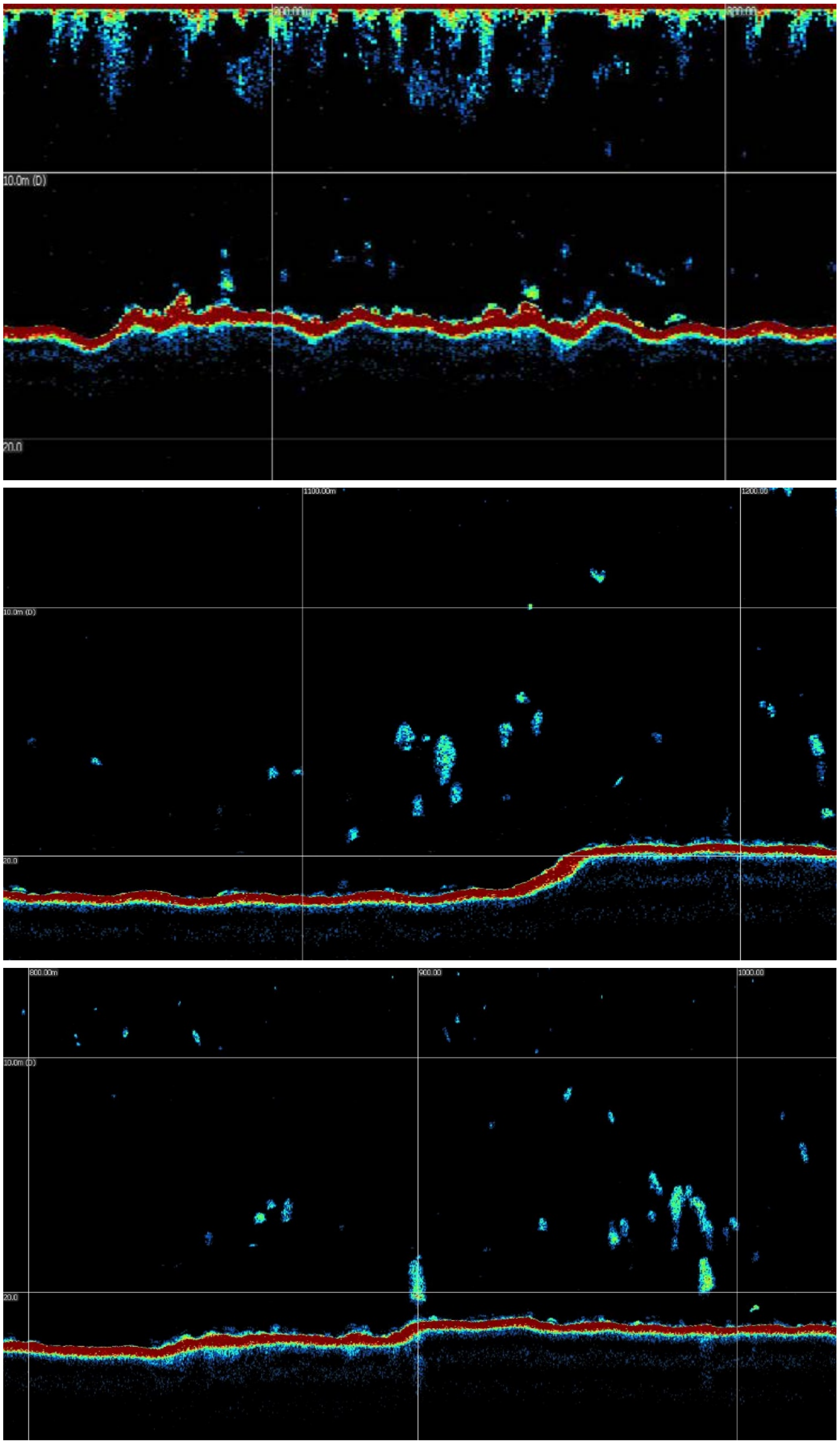

Figure 3-17. Example echograms showing segments of the water column including small to large individual fish (blue to light green traces) and fish schools (blue-green blobs) over three hardbottom seafloor features (thick red line): (TOP) rocky disposal material, (MIDDLE) ledge, and (BOTTOM) mixed hardbottom/sand. Surface bubbles in green to red are visible in top panel. Depth scale is shown to left and distance along transect shown at top.

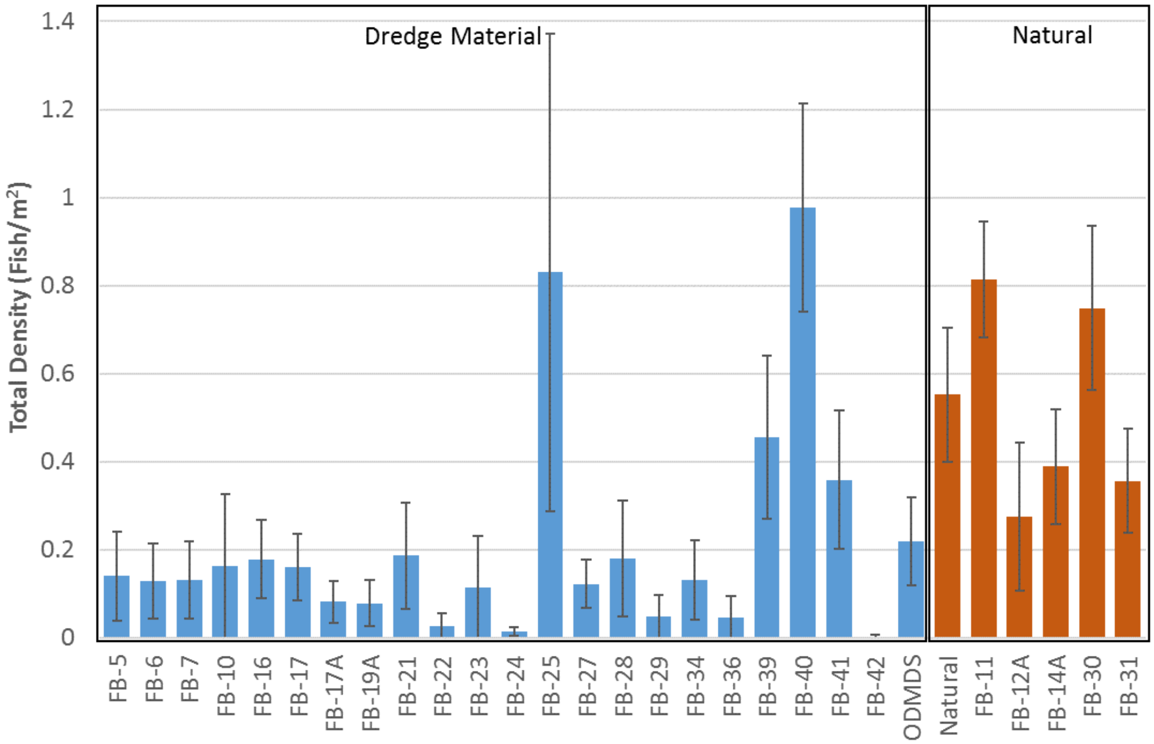

Figure 3-18. Mean (and standard error) acoustic densities for all fish size classes within 50m radius buffer of each dive site grouped by dredge material and natural (ledge features). Overall averages for each habitat type are labeled as ODMDS and Natural.

Acoustic densities on natural ledges were significantly higher than on disposal sites (p=0.001), although some disposal sites had comparable densities. The high variation in density was most often related to the presence of fish schools, which were sparse but relatively high density during the day. Figures 3-17 to 3-19 show distribution of fish density for all size classes including fish schools and acoustic densities for specific size classes are presented in Appendix. There were significant statistical relationships between physical descriptors of the seafloor (e.g., digital reef rugosity (DRR), and relief) and any measure of fish density (Table 3-4). Densities for separate size classes of fish were not related to rugosity nor relief, but were most often higher over natural hardbottom than over the disposal sites. Fish schools were higher in number and density over habitats that had higher relief and digital reef rugosity, but were unrelated to habitat type. Total density was higher in more rugose habitats, such as FB-25 and FB-40. Due to poor visibility, rugosity measures were not recorded on FB-39 and FB-41 where relatively higher acoustic densities were observed.

Although not directly comparable, diver-collected fish densities on the transects were considerably higher during the 2013 EPA Survey (US EPA 2014), with a mean of 2.47 fish/m^2 at the ODMDS sites and 2.52 fish m^2 on the natural ledge sites, but also indicated slightly higher fish densities on the natural ledge sites. The differences in densities between the two studies are due to differences in technique and the probability that very high numbers of cryptic species on the bottom during the 2013 survey that may not have been detected with the SBES during this survey.

Table 3-4. Summary linear model statistics (p-values) for effects of habitat type (ODMDS or natural), digital reef rugosity (DRR) and relief on fish size class. P-values from linear models are provided when <0.05. ns indicates factor was not significant (p>0.05).

Size Class	Habitat	DRR	Relief
Large	0.002	ns	ns
Medium	0.000003	ns	ns
Small	0.000002	ns	ns
School	ns	0.001	0.02
Total	0.001	0.006	ns

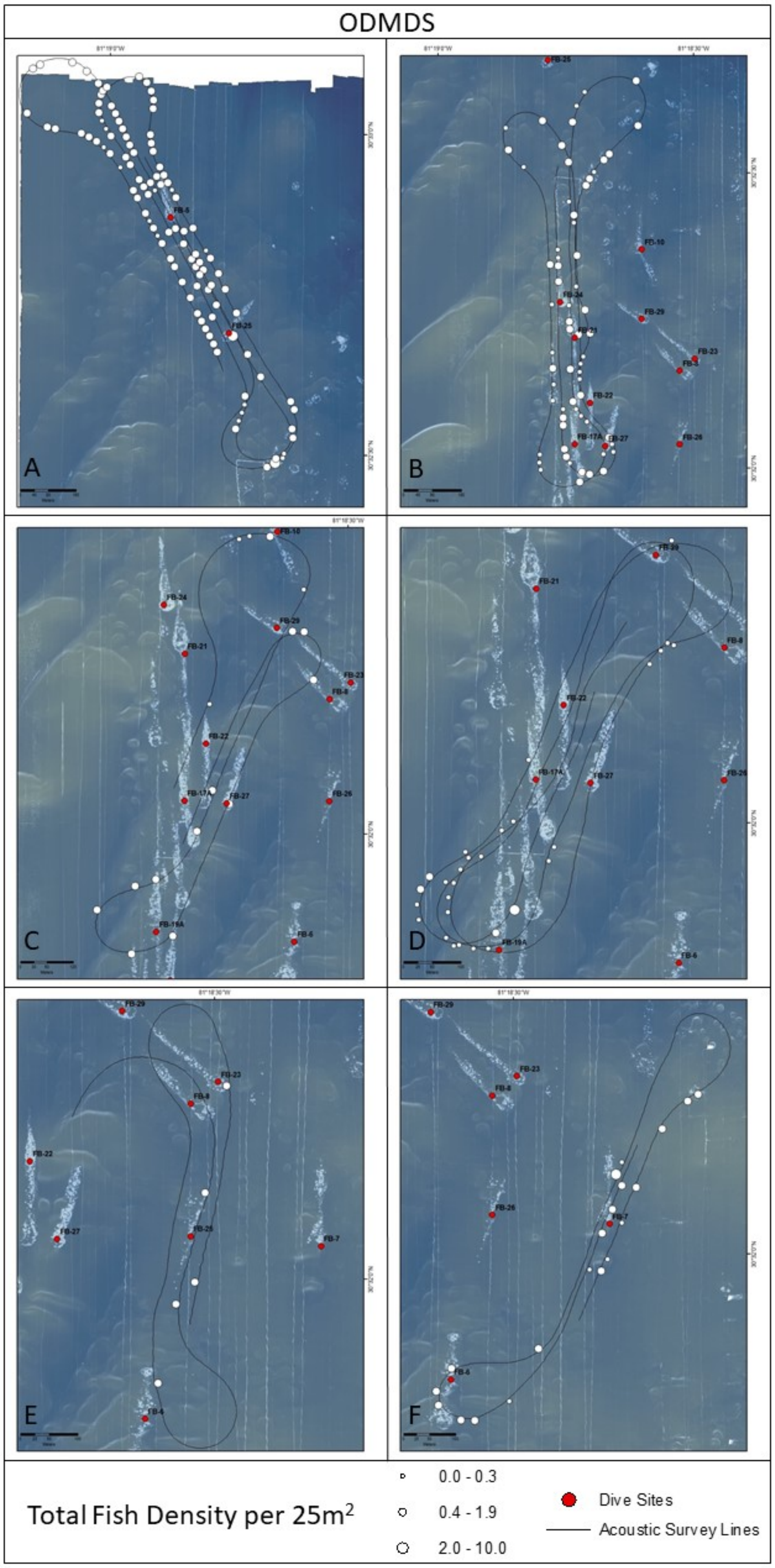

Figure 3-19. Daytime densities of all fish sizes over each dive station over a subset of disposal sites. Tracklines are shown to indicate total coverage. In some cases, a survey was used to cover more than one dive site.

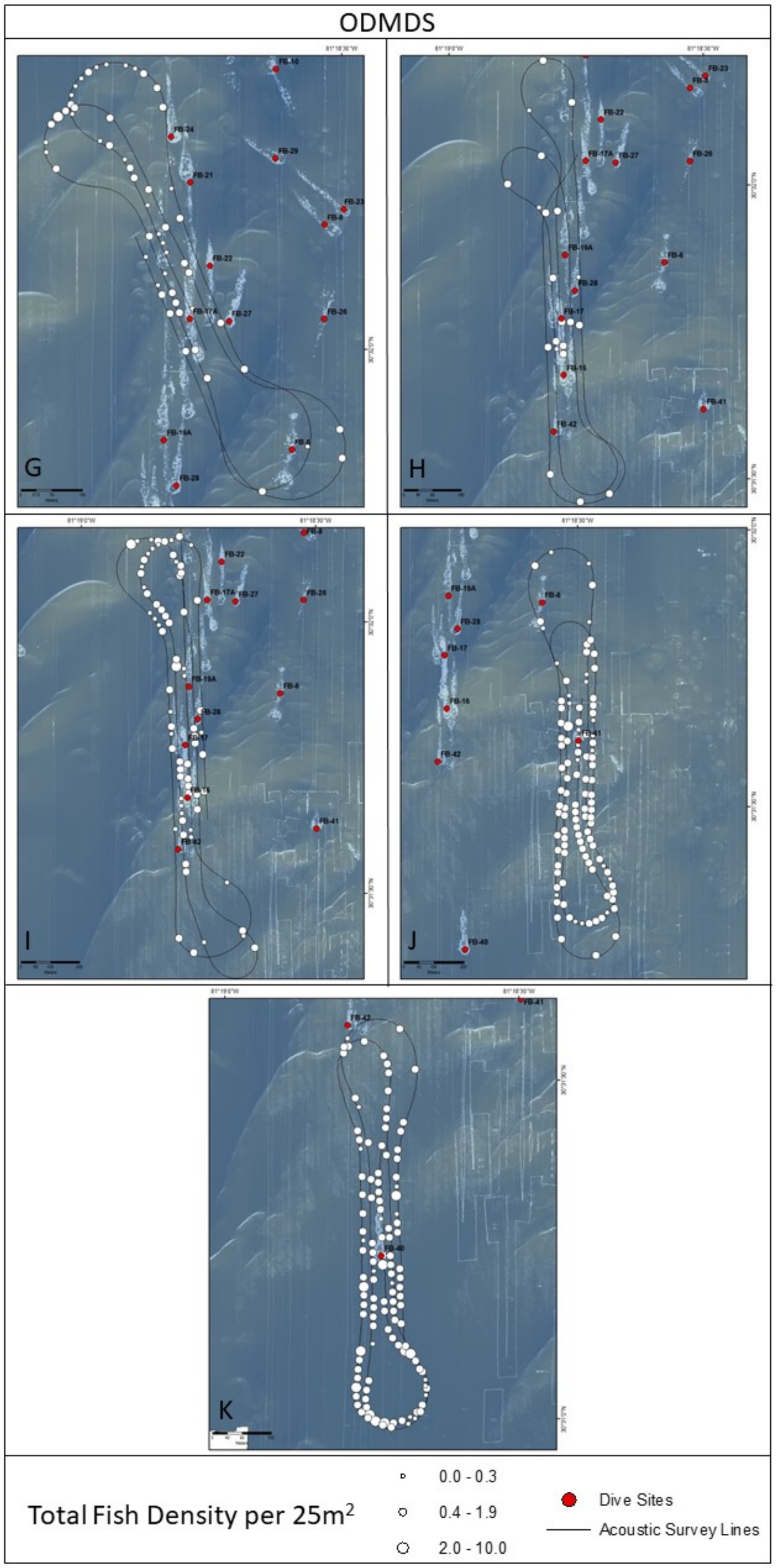

Figure 3-20. Remaining disposal site daytime acoustic surveys. Symbology as in Figure 3-19.

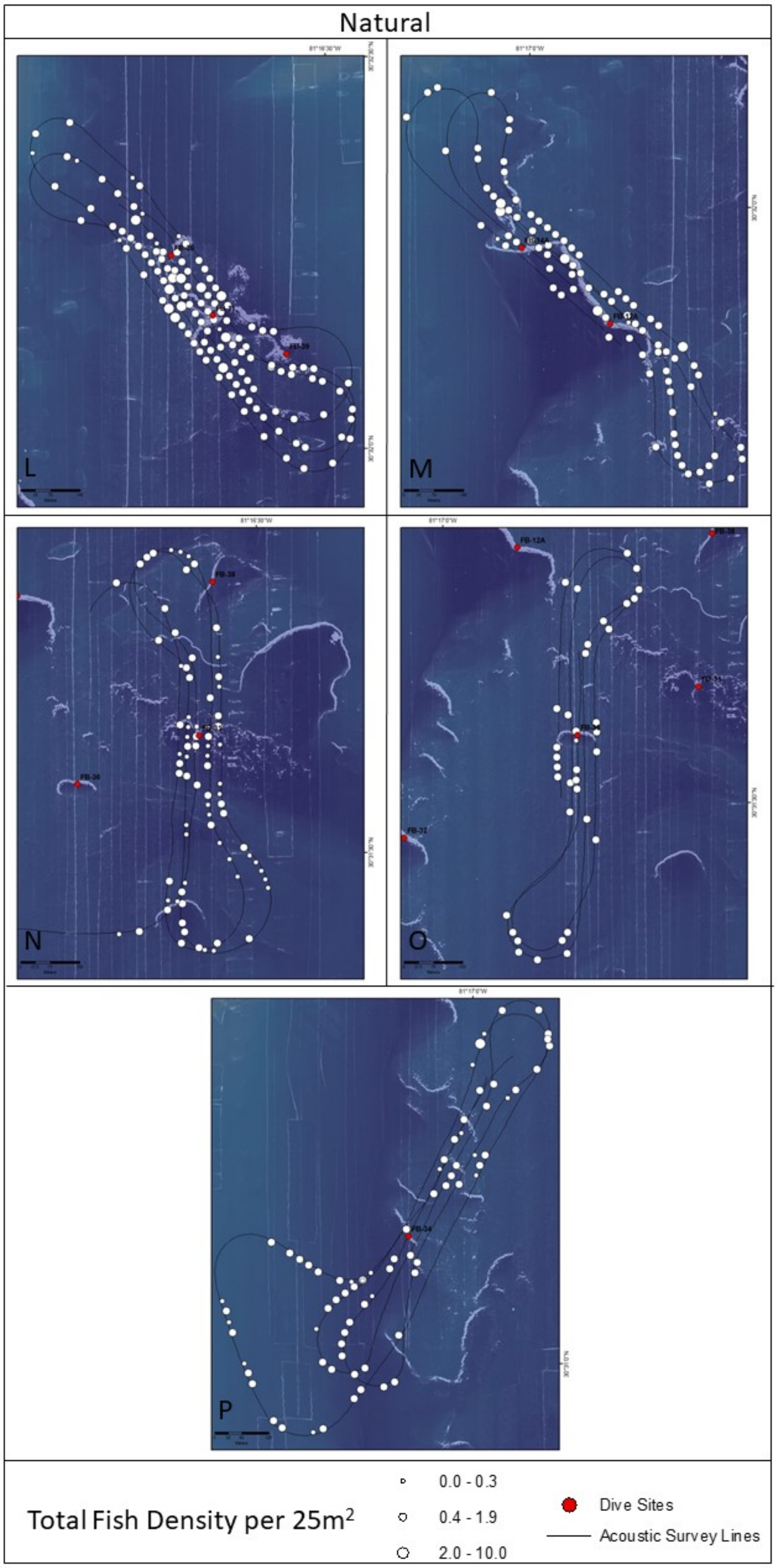

Figure 3-21. Daytime acoustic surveys over natural ledge and mixed hardbottom areas in the eastern region of the ODMDS. Symbology as in Figure 3-19

4. CONCLUSIONS

The new multibeam base map clearly showed the disposal materials in the ODMDS, making delineation and site selection easy. The base maps also provided evidence for many ledge and mixed rocky outcrop features within and directly adjacent to the ODMDS boundary. The relatively close proximity of the natural and artificial reef features raises interesting questions on connectivity across the habitat mosaic and benthic organism substrate preference between the two types of features.

Sponges, tunicates, octocorals, and hard corals dominated the benthic community of all sites, although, benthic cover of each organism differed by habitat type. The same nutrient-rich waters with lower light penetration that characterize the nearshore reef systems of the Southeast Atlantic influence all of the sites. Sediment-shifting events, common in this region, can also influence community structure (Figurski et al 2016). The nature of the structures themselves determines the organismal make-up of each habitat type.

The dump sites resemble underwater jetties of strips of large boulders, sediments, and rocks allowing greater surface area on to which certain organisms can adhere. What is missing from these jetty strips, are large areas of flat surface needed by vase sponges and other invertebrates with larger base structures in order to grow into the water column. Conversely, the base structures of tunicates, octocorals, and Oculina spp. can attach and thrive on smaller areas of hardbottom. Therefore, the higher frequency of octocorals at dump sites is most likely the driving force of greater numbers of taller organisms seen in the results. There is little flat surface on the dump sites for organisms such as sponges that require large base structure. Tunicates are able to persist and thrive on uneven hard structures of all kinds, including rubble. Sponges, on the other hand, tend to require a stable base to maintain stability to expand into the water column. Octocorals and *Oculina spp.* can also thrive with small areas of hard bottom to attach. This higher frequency of octocorals is most likely the driving force of greater numbers of taller organisms at the disposal sites.

Natural ledges are mostly narrow strips of hard bottom with flat pavement-like surfaces that are constrained by the drop off and the sand veneer that often covers the pavement bordering most natural ledges in the Southeast. This habitat is ideal for sponges, octocorals, hydroids, and tunicates, but is limited to the surface area provided by the top of the exposed limestone ledge. There are few complexities to ledges limiting hardbottom available for colonization. The natural ledges were also 14 – 20 fsw deeper than the disposal sites. It is probable that the added depth compounded the lack of light penetration making growth challenging for octocorals that depend on some nutrients from photosynthetic symbiont algae. Sponges, however, thrive in such low light, nutrient-rich habitats and this what we found. The minimal presence of macroalgae found at either habitat type is indicative of the low light conditions. The differences in depth and nature of abiotic structure along with the turbid water are the most probable forcing factors determining the composition of the benthic communities in each habitat type.

This study represents the first comprehensive survey of dredge disposal areas using fishery acoustics as a metric of fish habitat use and potential habitat value. The use of fishery acoustic surveys overcame some of the limitations of low visibility that was experienced during attempted dive surveys. Proximity to the coastline and relatively shallow depths resulted in heavy particulates in the water following strong coastal storms in the region just prior to our surveys. The acoustic surveys covered broader areas and included the unconsolidated sand that makes up the majority of the seafloor in the ODMDS.

Recognizing there were gaps in survey coverage, fish densities surveyed at night were much higher in the eastern portion of the survey area in a region where rocky ledges and outcrops were mixed with sand compared to the area around the disposal material. Acoustic densities assessed during the day around the dive stations were highly variable, with generally higher densities associated with the natural hardbottom ledge features. A few notable examples were a collection of high relief disposal sites that held high densities of primarily schooling fishes. Though sample sizes of high rugosity disposal material were low, it appears that high-relief, high-rugosity disposal materials influences the habitat use by fish with higher densities of fish, and especially fish schools likely made up of small-bodied fish that would be important prey for larger predatory fishes. This initial finding suggests taller disposal sites may provide higher value to fishes.

A limitation of the fishery acoustic approach is the inability to detect fish that are in crevices or very close proximity to the seafloor (within about 20-50 cm) due to an effect called the "acoustic deadzone". This occurs when the returning pulse from the fish is occluded by the larger reflection from the hard seafloor and the zone is thicker with a more rugose seafloor. Fish detection may have been more challenging in the higher relief and rugosity of the natural ledge features than the dump sites but density assessed during the day around dive stations, although variable, was higher over the natural hard bottom ledges.

5. DATA MANAGEMENT

Field data sheets were maintained and controlled according to SESD SOP (USEPA, 2007d) for the duration of the field survey. Following completion of the field surveys, the data sheets were maintained by the Principal Investigators. Upon completion of the final report, the data sheets and associated project records were stored in the SESD Records Center and NCCOS. All data generated for this field investigation, whether hand-recorded or recorded and stored in an electronic data logger, were recorded, stored and managed according to SESD SOP (USEPA 2007e). Data entered onto the data sheets was transcribed into an MS Access Database each day during the survey and were QA/QC'd for accuracy by the person that entered the data and verified by the person that collected the data. Both parties verified that the data was entered correctly. Fishery acoustic data was stored on hard drives and duplicated on data servers on board the ship. NOAA NCCOS was responsible for ensuring all requirements of data management and archiving are met (NCCOS Data Management Policy *In Review*).

6. QUALITY ASSURANCE/QUALITY CONTROL

Quality control procedures were used in the field to ensure that reliable data are obtained. This was a limited scope field investigation for which advanced detailed sample plan and design criteria are not necessary. Diver datasheets were reviewed (e.g. during surface interval) for completeness and legibility by another diver. After the datasheet was reviewed, the reviewer initials the "checked by diver" box on the datasheet. Data entered onto the data sheets was transcribed into an MS Access Database each day during the survey and QA/QC was performed for accuracy by the person that entered the data and verified by the person that collected the data. Both parties verified that the data was entered correctly. Data entry accuracy was verified by the person that conducted the underwater survey.

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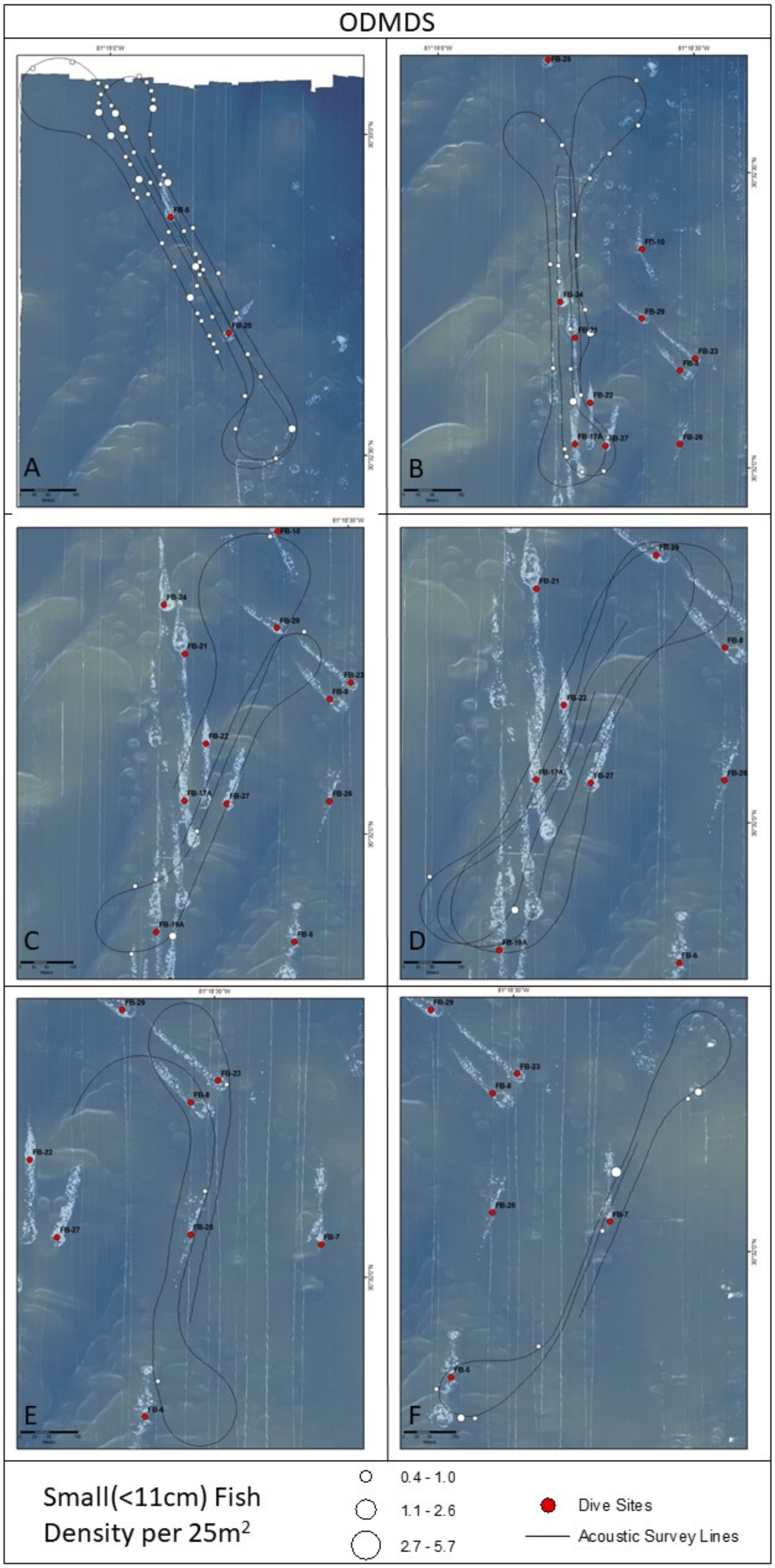
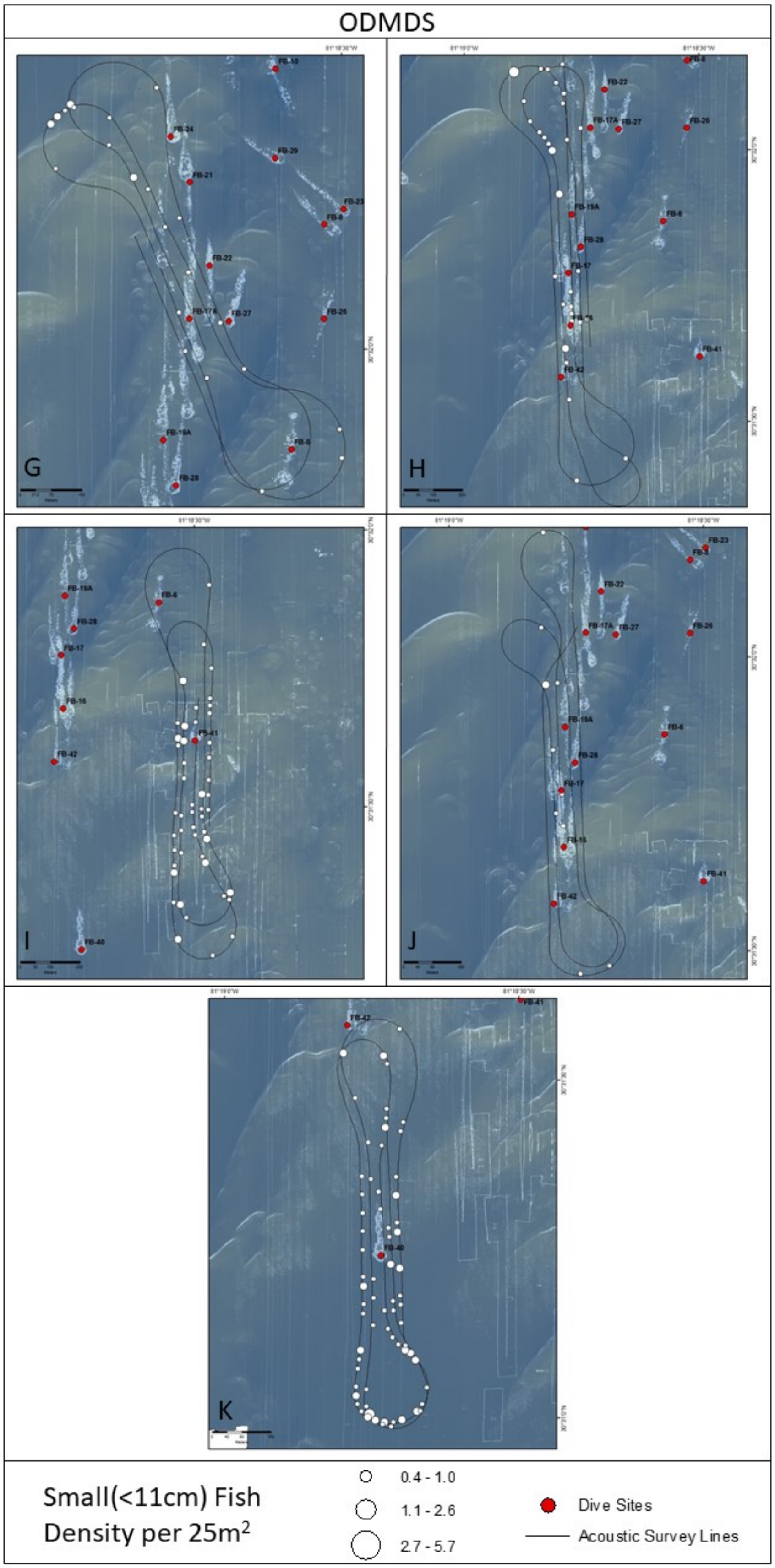
8. APPENDICES

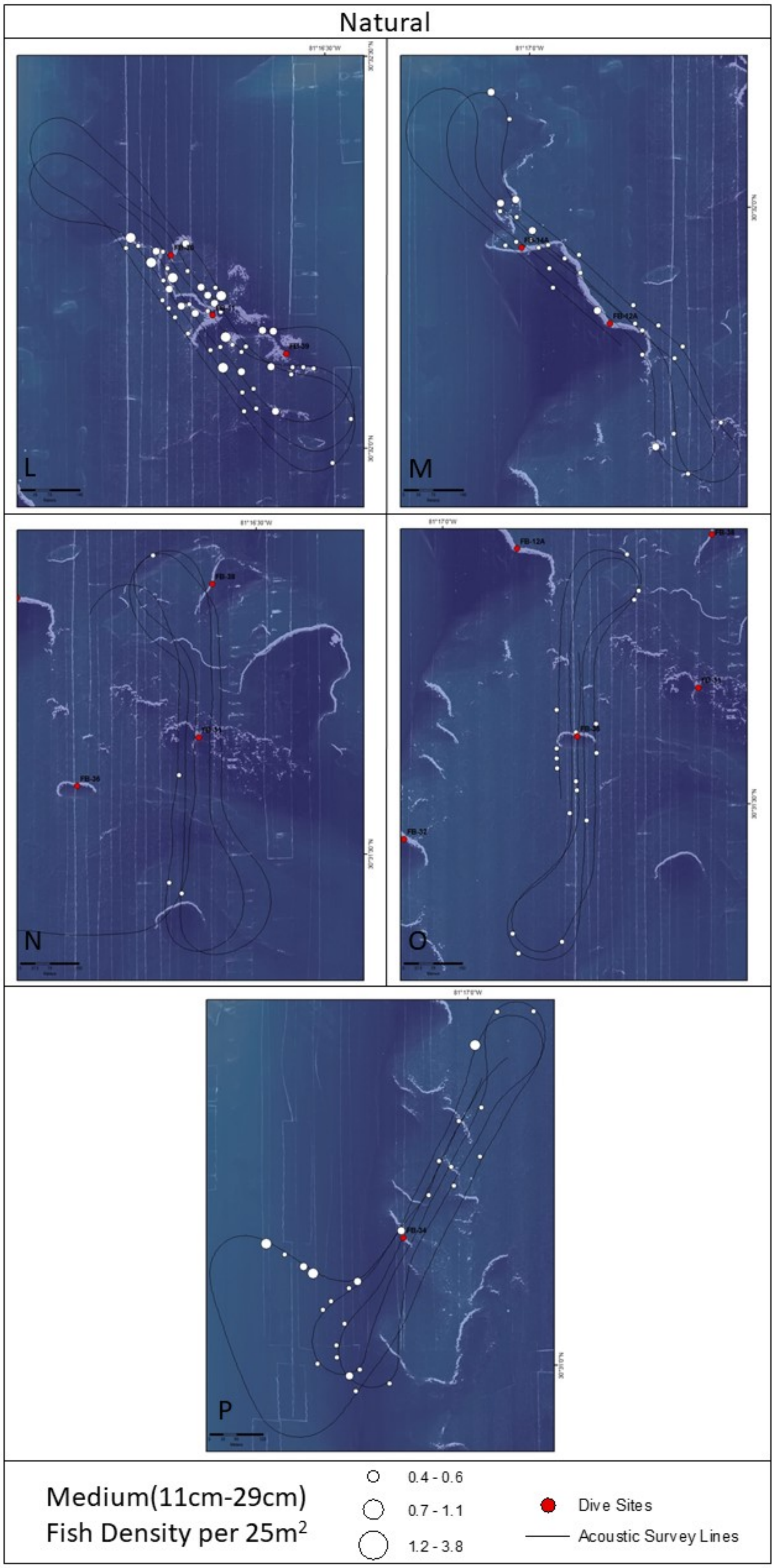
Appendix A

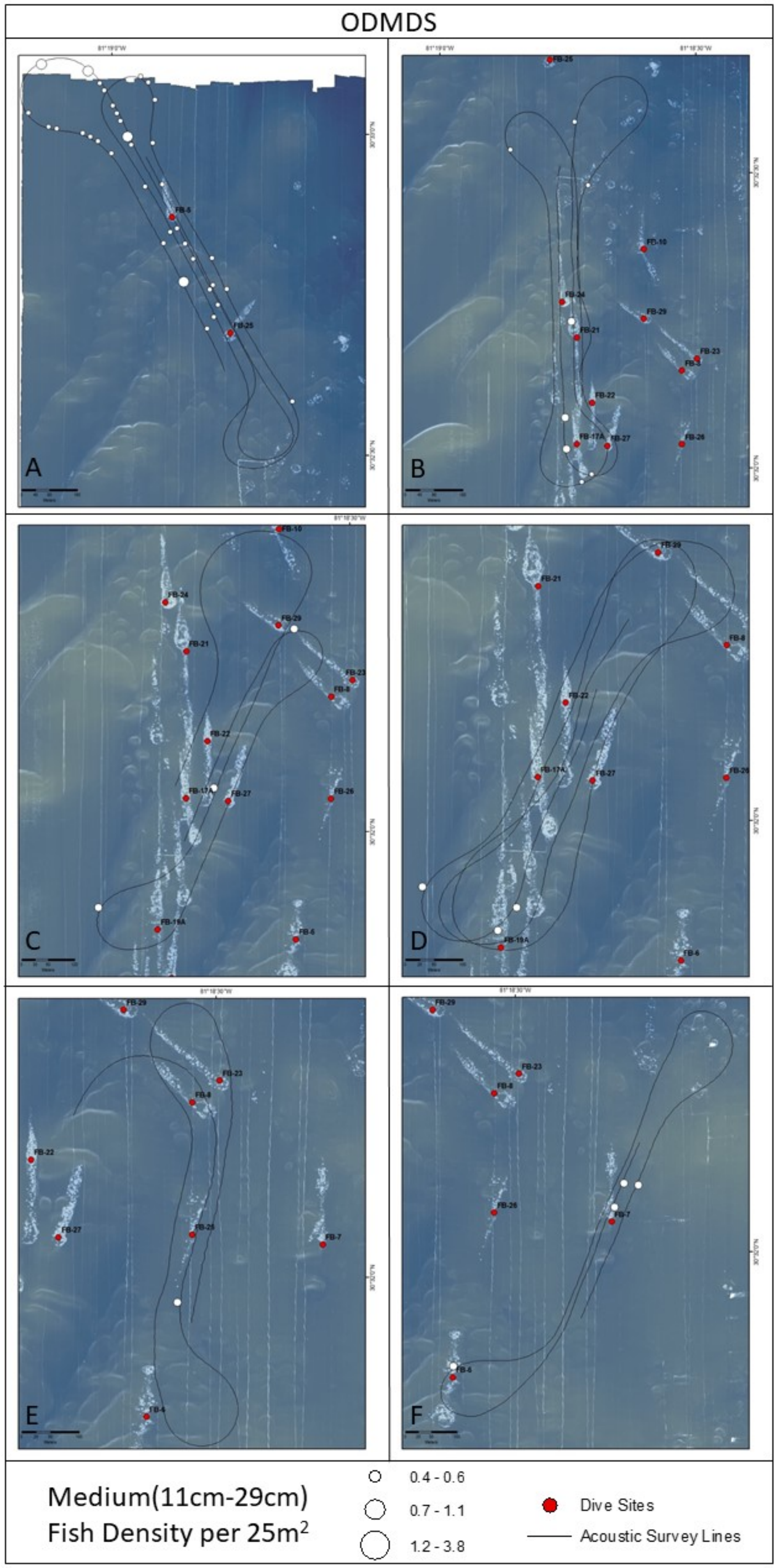
Fishery Acoustic Density Maps by Size Class

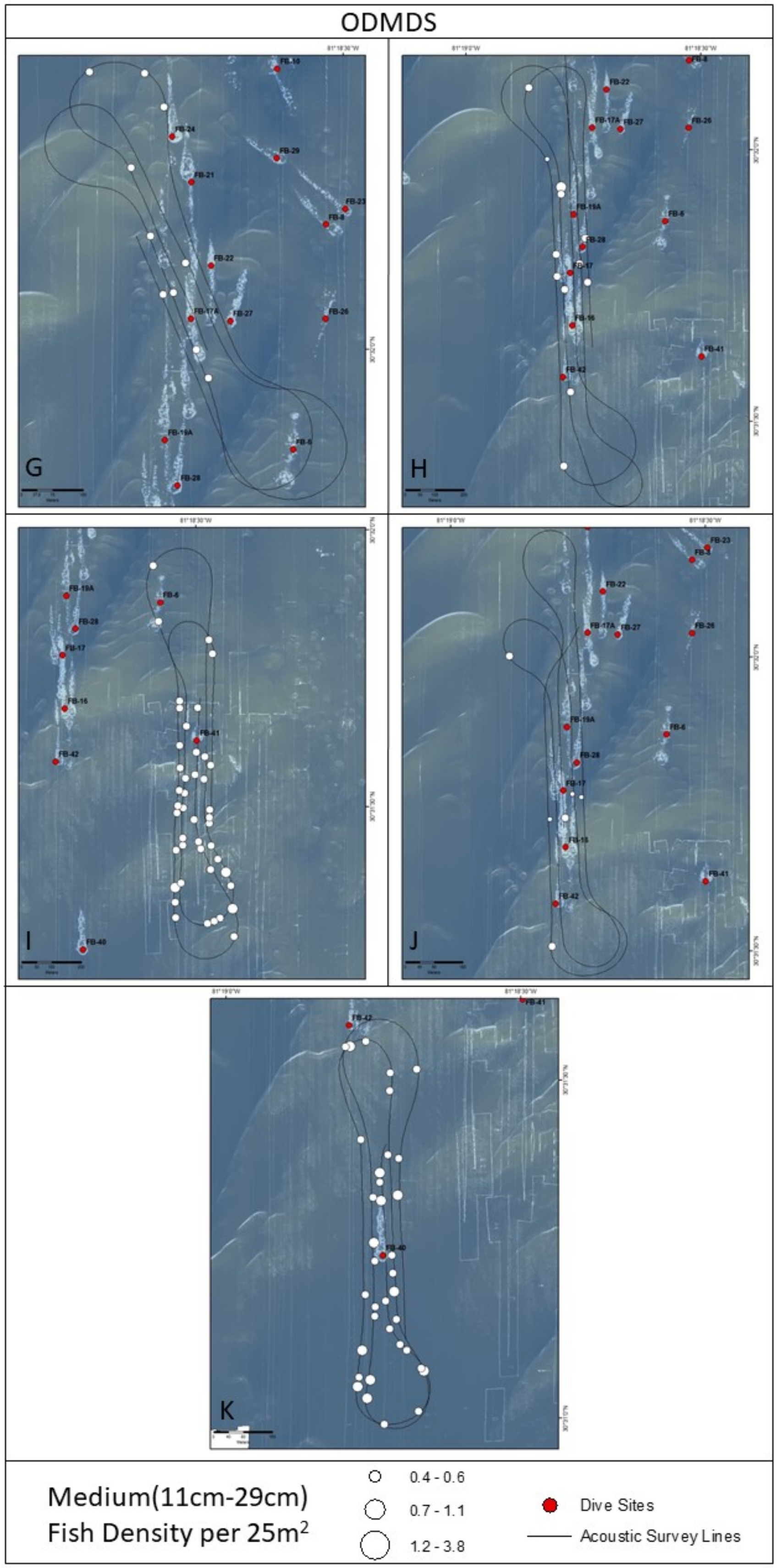
The following maps show acoustic densities for each size class: small (fish estimated length less than 12 cm), medium (estimated length between 12 and 29 cm) and large (estimated length greater than 29 cm). Dive stations are labeled. Each survey traversed one or more stations using three to five parallel transects. Symbols on each map represent density of fish for each size class. Tracklines are shown to indicate total coverage. In some cases, a survey was used to cover more than one dive site.

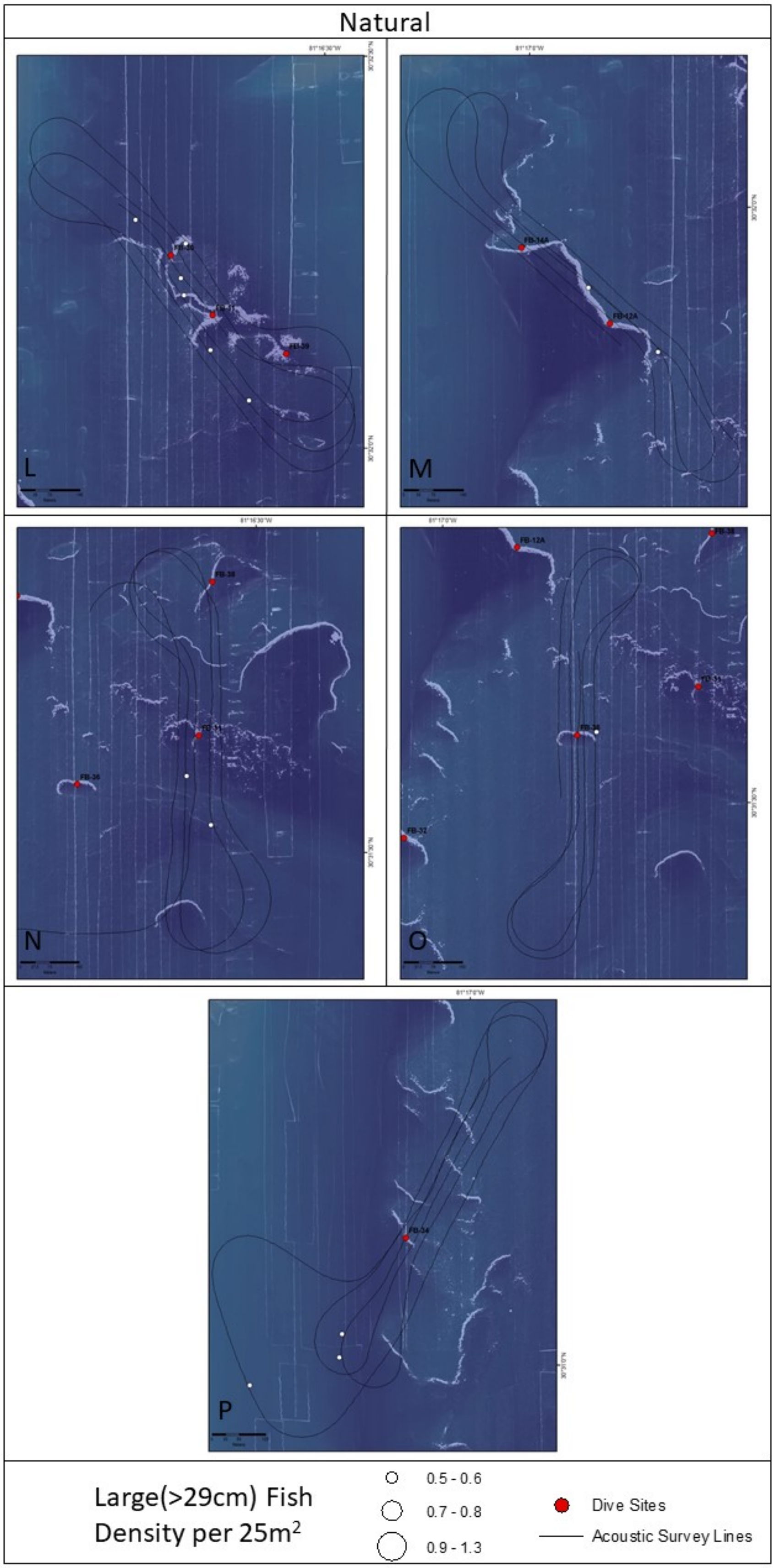

ODMDS
A
B
C
D
E
F
Small(<11cm) Fish
Density per 25m2
0.4 - 1.0
1.1 - 2.6
2.7 - 5.7
Dive Sites
Acoustic Survey Lines

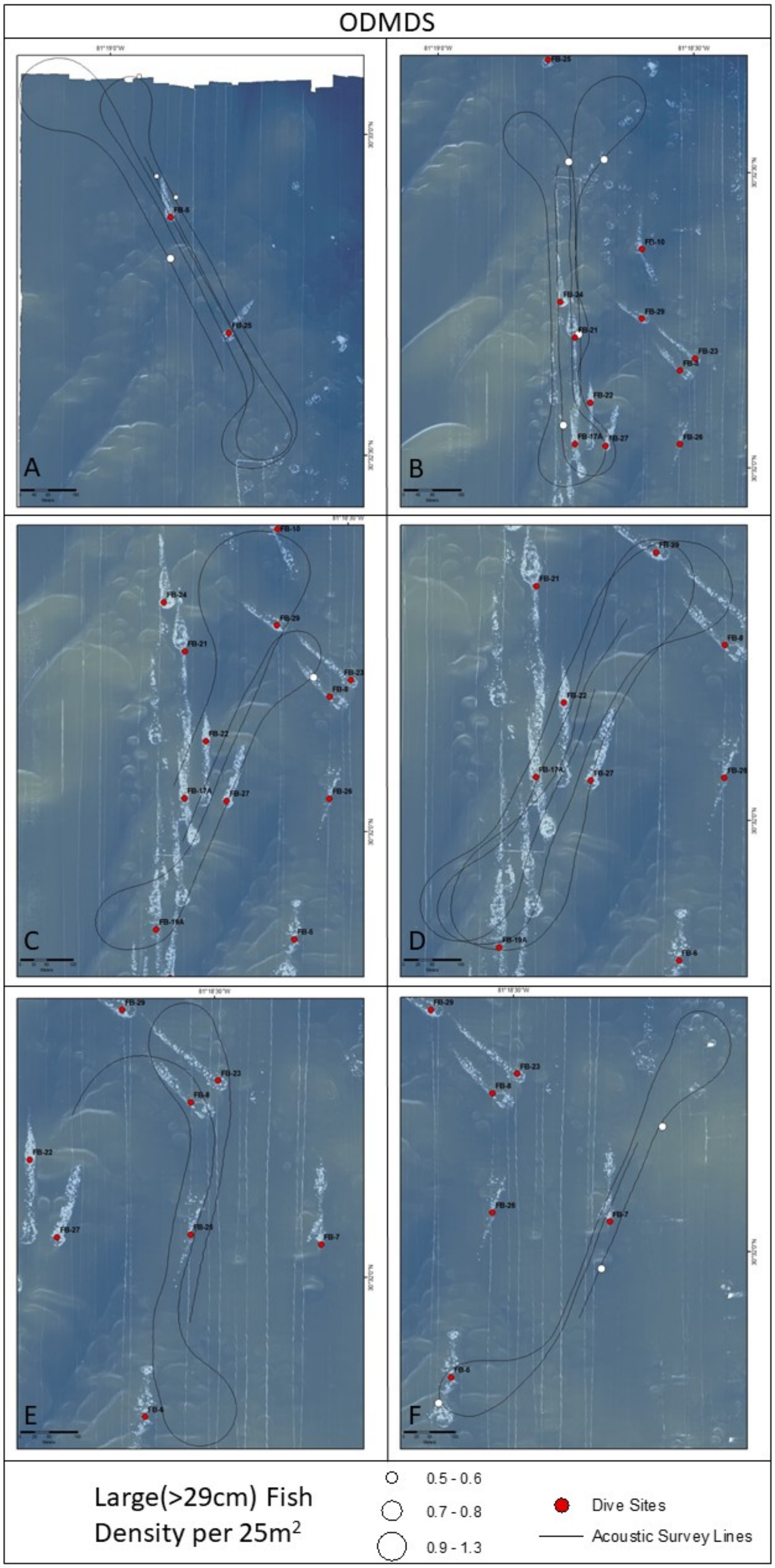

ODMDS
G
H
I
J
K
Small(<11cm) Fish Density per 25m²
0.4 - 1.0
1.1 - 2.6
2.7 - 5.7
Dive Sites
Acoustic Survey Lines

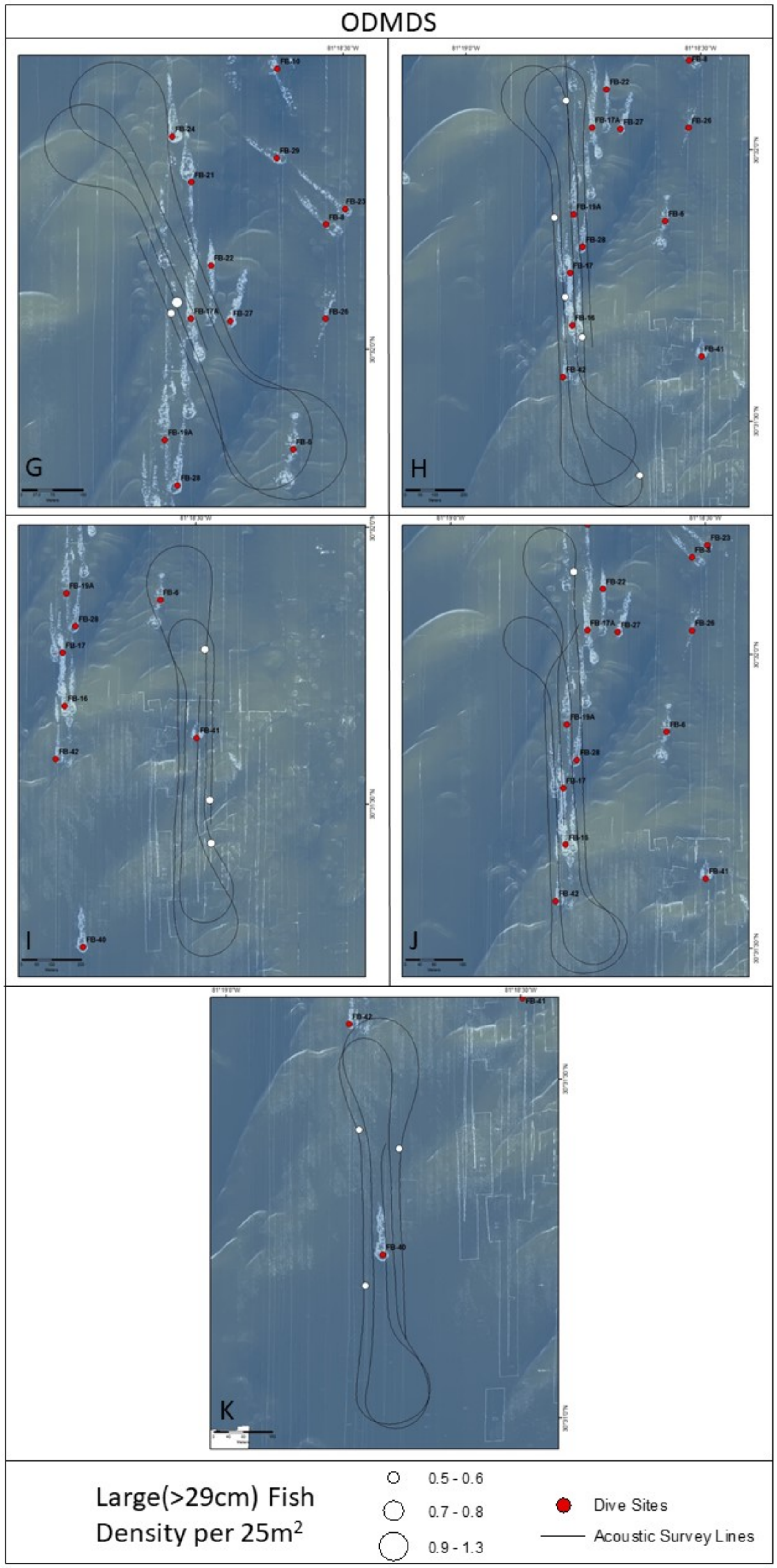

Natural
L
M
N
O
P
Medium(11cm-29cm)
Fish Density per 25m2
0.4 - 0.6
0.7 - 1.1
1.2 - 3.8
Dive Sites
Acoustic Survey Lines

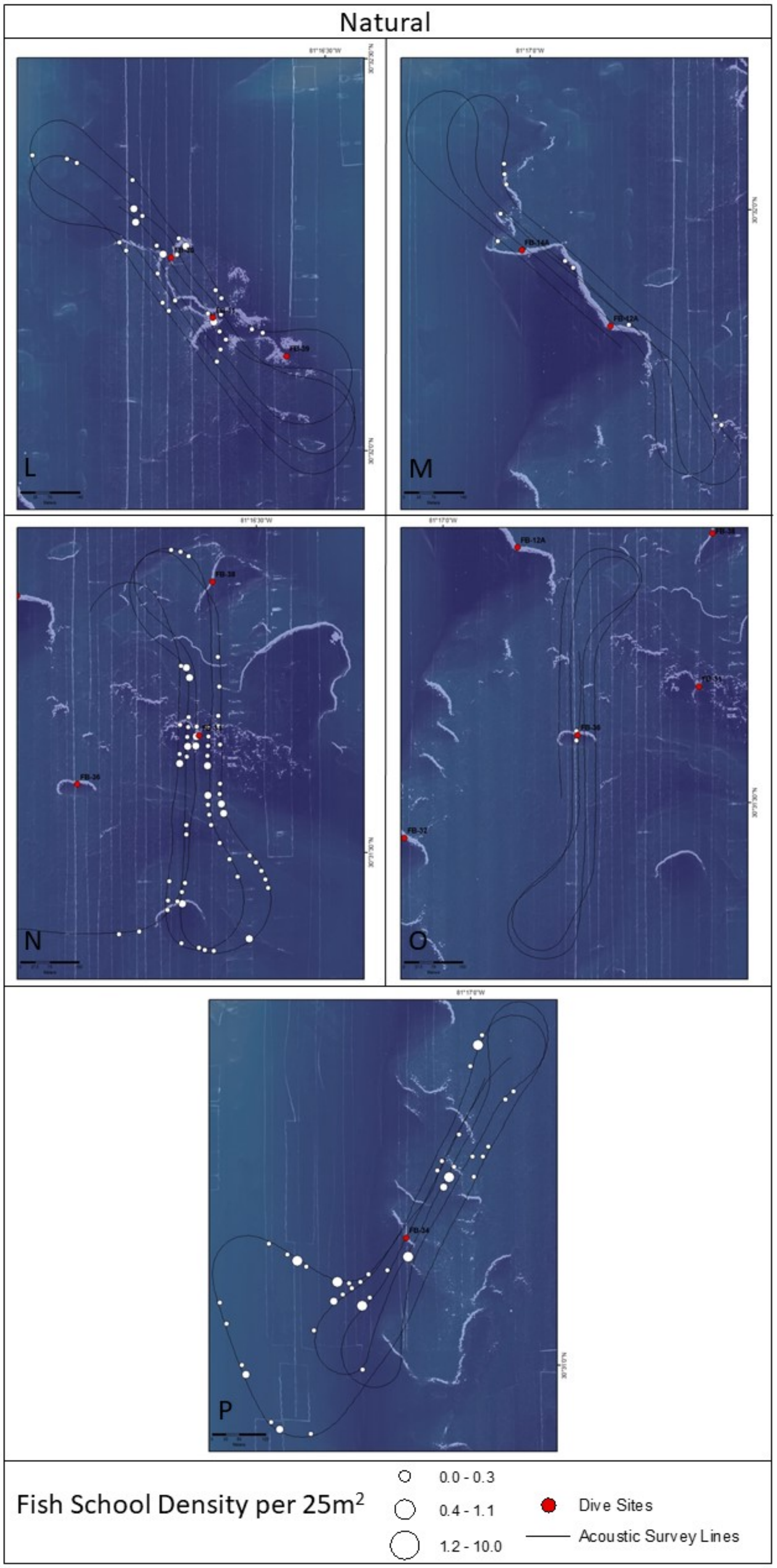

ODMDS
A
B
C
D
E
F
Medium(11cm-29cm)
Fish Density per 25m2
0.4 - 0.6
0.7 - 1.1
1.2 - 3.8
Dive Sites
Acoustic Survey Lines

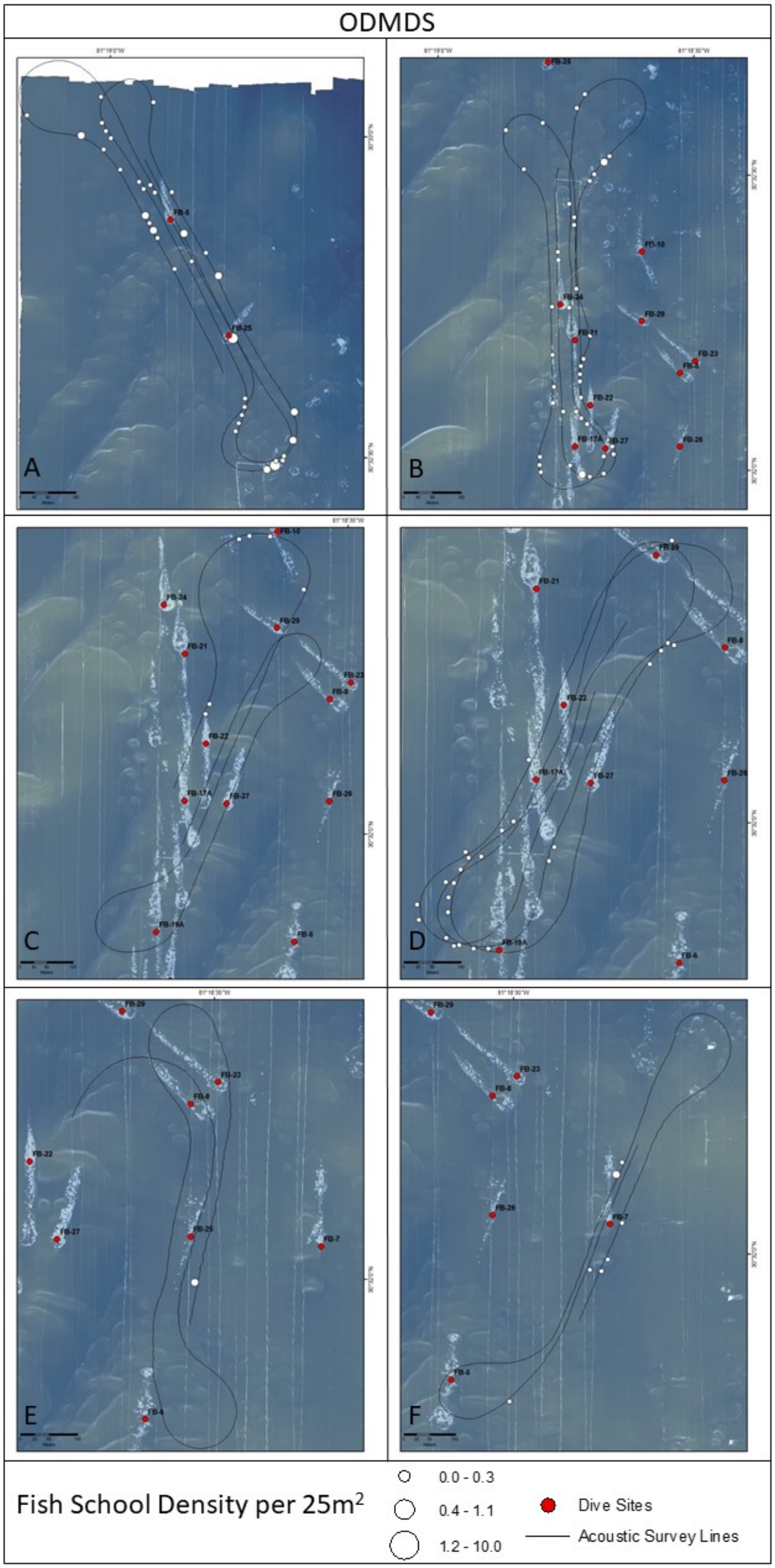

ODMDS
G
H
I
J
K
Medium(11cm-29cm)
Fish Density per 25m2
0.4 - 0.6
0.7 - 1.1
1.2 - 3.8
Dive Sites
Acoustic Survey Lines

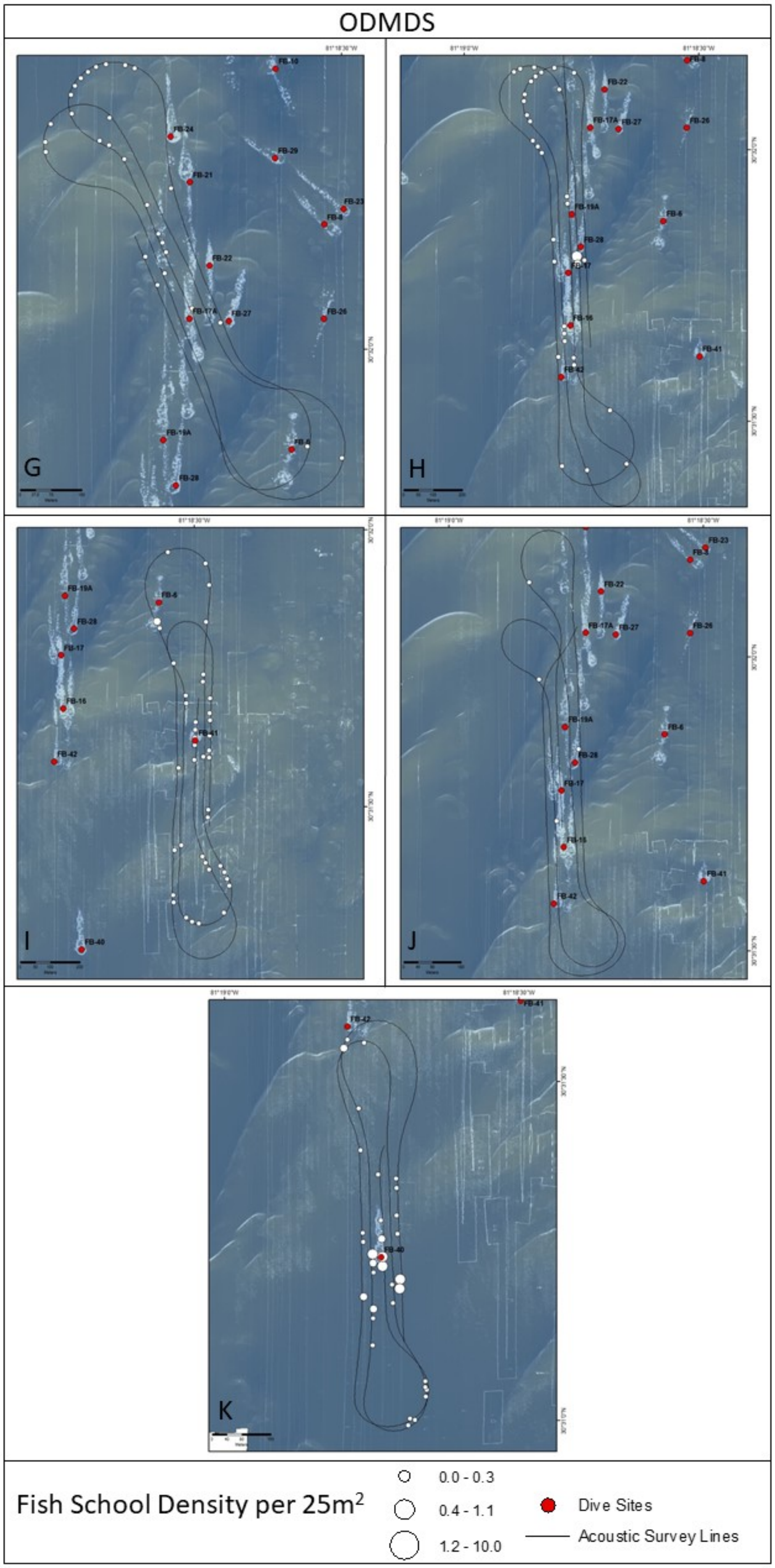

Natural
L
M
N
O
P
Large(>29cm) Fish
Density per 25m2
0.5 - 0.6
0.7 - 0.8
0.9 - 1.3
Dive Sites
Acoustic Survey Lines


ODMDS
A
B
C
D
E
F
Large(>29cm) Fish Density per 25m2
0.5 - 0.6
0.7 - 0.8
0.9 - 1.3
Dive Sites
Acoustic Survey Lines


ODMDS
G
H
I
J
K
Large(>29cm) Fish Density per 25m2
0.5 - 0.6
0.7 - 0.8
0.9 - 1.3
Dive Sites
Acoustic Survey Lines


Natural
L
M
N
O
P
Fish School Density per 25m²
0.0 - 0.3
0.4 - 1.1
1.2 - 10.0
Dive Sites
Acoustic Survey Lines


ODMDS
A
B
C
D
E
F
FB-5
FB-25
FB-10
FB-34
FB-29
FB-21
FB-23
FB-8
FB-22
FB-17A
FB-27
FB-26
FB-19A
FB-6
FB-7
Fish School Density per 25m²
0.0 - 0.3
0.4 - 1.1
1.2 - 10.0
Dive Sites
Acoustic Survey Lines


ODMDS
G
H
I
J
K
Fish School Density per 25m2
0.0 - 0.3
0.4 - 1.1
1.2 - 10.0
Dive Sites
Acoustic Survey Lines

Appendix B

Survey Protocols

EPA Line Point Intercept (LPI) Survey Protocol

Goal

Data collected by LPI surveys are intended to provide a measure of percent cover of biotic and abiotic components of the benthos. Surveys are concurrent with and along the same transect as fish surveys

Likely task allocation scenario

1 fish diver + LPI diver + Demo diver

- Fish diver completes conspicuous fish surveys on outbound transect (50 x 10m) and prey fish surveys on return transect (25 x 2m).
- LPI diver completes LPI tasks (biota identification 100 points) on outbound transect and rugosity survey on return transect using the HOBO water level sensor.
- Demo diver conducts coral demographics survey on outbound transect (10m x 1 m on left); then returns to 0 m and takes topography measurements along the 50m outbound transect while also surveying macroinvertebrates; then the demo diver reels up the tape.

LPI Transect Methods

LPI transects will be surveyed at all fish survey sites along the same transect (50m transect).

1. Site selection, navigation, and deployment

   a. **Headers on all datasheets are filled out prior to entering water** – site number, date, time, buddy. Fill in all categories legibly (except habitat type)

LPI Diver		**Site ID**		**Rugosity**	**Spike 5 times to begin/end**
Fish Diver		**Date**		**Start time**	
DEMO Diver		**Time**		**End time**	

Figure 1 LPI datasheet header.

   b. **test camera & strobes by taking a picture of the datasheet** – make sure site name is in picture.

   c. Small boats will navigate to the selected site using a handheld GPS unit. When the coordinate has been reached, confirm depth with coxswain then deploy a weighted float to mark the start of the transect.

   d. Divers will descend following the weighted line as rapidly and safely as possible, maintaining good buddy contact. If the site exceeds the maximum allowable depth (either by diver table limits or cruise limit (130')) the dive is aborted and a new site is selected.

   e. Fish and Benthic dives are intended to quantify communities in hardbottom areas. Where no hardbottom is visible divers are instructed to take a 360-degree short video and two or three close up photos representative of sediment type, abort the dive and select a new site.

2. LPI In water methods

   a. LPI diver will follow behind fish diver at a reasonable distance to minimize buddy separation yet avoid influencing swimming behavior of fishes.

   b. Fish surveyor will anchor the transect tape at 0m and at a minimum of two additional places along the transect to secure the tape along the bottom; ensuring data are collected along the same path as the fish data collection and minimizing transect billowing in current. Transect tape will NOT be wrapped around abiotic or biotic objects, as this distorts sampling distances.

   c. While waiting for fish diver **–4 photos capturing 360 landscape of the site and one looking down the transect.** That is 6 pictures total: datasheet, landscape (4), and down transect.

   d. **LPI divers record the following at 100 points (every 50cm) along the transect. Starting at 0.5 m ending at 50 m.**

      i. Identify **top layer** of primary biota and substrate type below point record mark in appropriate biota row in the corresponding abiotic column (E.g. sponge upright on hardbottom).

         1. abiotic categories are: hard (rock, reef, hard bottom), soft/sand (sand or mud), and rubble (unconsolidated rocks fist size or smaller; see appendix II for complete definitions).

            a. Hardbottom with a veneer of sand (< 0.5cm) is recorded as hard bottom. Where sand depth exceeds 0.5cm, record abiotic habitat as sand.

         2. biotic categories are: bare, macroalgae (red, green, brown), coral, and other inverts.

      ii. Exercise caution when identifying a particular point to evaluate. The most objective way to score a point along the transect is to use a straight edge (e.g., pencil) and vertically orientate it downward toward the substratum. Bias, subjectivity and "artificial selection" of favored substrates (e.g., non-bare) should be avoided. However, the point should be identified quickly.

      iii. Sand patches are not skipped. If substrate is bare – without any small organism, even if unidentifiable, record a tick mark in the appropriate abiotic/bare area of the datasheet (see Fig 2).

      iv. The initial biotic organism encountered is what is recorded.

         1. Octocorals

            a. Some are highly branched and/or fan like. Octocoral is recorded when any part of the organism is the first item encountered below the point. You do NOT need to hit the holdfast to score octocoral.

2. Sponges:

   a. Occasionally sponges encrusted with other organisms (e.g. zoanthids, algae) are encountered. In this scenario, the primary organism attached to the benthos is scored – sponge. For branching sponges, if a branch is encountered by the point, sponge is recorded, you do NOT need to hit the holdfast to score sponge in this scenario.

3. Branching corals (e.g. *Oculina*)

   a. most ODMDS corals are small, solitary cups or small heads. Some habitats have larger heads of branching *Oculina*. If your point is on the branches of this coral colony, *Oculina* is scored.

4. Encrusting organisms (turf algae, sponge, tunicates, soft coral, bryozoan, *Millepora*/fire coral) - are valid points. Anytime this is the first organism encountered – score as appropriate.

5. Algae are valid points.

   a. Depending on the season, many species can be tall and act as a canopy to other encrusting organisms. If this canopy is the first biota encountered at the target point – record the appropriate algae category. The target point does NOT have to be at the holdfast of the algae to be recorded.

v. double check that the proper number of points were collected. You should have 100 points EVERY time. If you shortened the transect short due to time or other limitations – write down the distance where you stopped sampling.- you should have the appropriate # of points for the distance traveled.

vi. At the end of the dive circle the appropriate habitat type category: Ledge, Pavement, Mixed Hardbottom/Sand, Rubble, Unconsolidated (Sand/Soft) (sidebar of datasheet).

Observed Habitat Type (circle)
Ledge Pavement
Mixed HB/Sand
Rubble Unconsolidated

3. At the end of the transect, the LPI diver will write down the start time of the rugosity survey:

LPI Diver		Site ID		Rugosity	Spike 5 times to begin/end
Fish Diver		Date		Start time	
DEMO Diver		Time		End time	

4. **Rugosity:** The LPI diver spikes the sensor 5 times, then lowers the sensor to just above the substrate. The diver then swims at a steady yet slower pace of 10 cm/second paying close attention to raising the lowering the sensor with the topography of the transect. Only change the height of the sensor for changes in the actual substrate/bottom, not the biotic cover.
   a. The LPI diver will spike the sensor once every 5 meters.
   b. The survey is meant to follow the transect as these measurements are directly relatable to the fish and benthic data collected on this site.
5. Take stock of the Demo diver – where are they in their duties?
   a. Communicate with the demo diver underwater (using datasheet) if they need you to do the macroinvertebrate survey or reel in the tape.
6. LPI out of water
   a. Between dives or as soon as possible after your dive, exchange LPI datasheets with another diver to ensure data consistency and continuity between divers. Any problems encountered should be documented thoroughly on the datasheet.

Appendix 1 – LPI Categories & Definitions

1. Abiotic categories & Bare substrate
   a. hardbottom – rock. Bare hardbottom is uncolonized rock, without or with (<2.5 cm or 1") a dusting of sand.
   b. soft/sand = sand or mud. Bare sand is selected when uncolonized sand exceeds 2.5 cm depth (1")
   c. Rubble – moveable rock (larger than sand) up to fist size that are moveable.

Invertebrate Demographics Survey Protocol

This invertebrate demographics protocol is based on the NCRMP coral demographics survey to provide more detailed and species-specific insight ('signal magnitude') for invertebrate populations than is provided by percent cover.

Goal of Coral Demographics Surveys

The goal of the invertebrate demographic survey is to collect and report information on species composition, density, size, abundance, and specific parameters of condition (% live vs. dead, bleaching) and of overall species diversity using 10m x 1m belt transects in a stratified random sampling design in hardbottom and coral reef habitats.

Likely task allocation scenario

1 fish diver + LPI diver + Demo diver

- Fish diver completes conspicuous fish surveys on outbound transect (50 x 10m) and prey fish surveys on return transect (25 x 2m).
- LPI diver completes LPI tasks (biota identification of 100 points) on outbound transect and rugosity survey on return transect using the HOBO water level sensor.
- Demo diver conducts coral demographics survey on outbound transect (10m x 1 m on left); then returns to 0 m and takes topography measurements along the 50m outbound transect while also surveying macroinvertebrates; then the demo diver reels up the tape.

Coral Demographic Transect Information

Establishing the transect

1. The Demographic and LPI divers will use the same transect as the Fish diver.
    a. Benthic divers follow behind the Fish diver at a distance to avoid influencing swimming behavior of fishes (*i.e.*, the LPI diver starts when the Fish diver is near the 5m mark, or as visibility allows, then the Demographic diver starts).

    b. The Fish diver secures the start of transect tape and continues to keep the transect tape relatively taut throughout survey, using weights clipped to the transect tape along the bottom so that it moves as little as possible.

    c. The Fish diver will avoid wrapping the tape around substrate or biotic objects, as this will distort sampling distances and locations for the benthic diver.

    d. At Fish + LPI + Demographic sites, LPI diver may assist the Demographic diver to finish the coral demographic survey within depth/time limits of dive.

i. If LPI diver assists Demographic diver in survey completion, LPI diver begins his/her demographic survey at the tenth meter of the survey and works until s/he finishes a complete meter and meets Demographic diver. LPI and Demographic divers will coordinate to avoid duplicating counts.

ii. To ensure that all space is surveyed, there will be no surveys of partial meters.

e. Bottom time may be highly variable between sites, depending on the density of corals and the number of Demographic surveyors.

IMPORTANT: A new datasheet is to be used for each demographic survey, one survey per sheet (*i.e.,* do not record data for survey Y on the back of survey X's datasheet).

2. Demographic survey area is 10m long by 1m wide.

a. The demographic survey is conducted along the **LEFT** edge of the transect line.

b. Every effort will be made to complete the entire 10m x 1m belt transect.

i. If the whole belt transect area cannot be completed, finish at a whole meter and note the meters of completion on the datasheet.

c. The survey starts at meter marker zero (0) and proceeds to meter marker 10, unless the starting point (0m) is not on hardbottom. If the 0m on the transect tape is not on hardbottom, see **DECISION RULE** below.

DECISION RULE (Figure 2):

- If the beginning of the survey (tape=0m) is located on softbottom (sand, mud, seagrass), the coral survey will start at the first encounter with hardbottom on the **LEFT** side of the tape. Round down to the nearest whole meter to start the survey.
  - The first encounter is determined when hardbottom is present within the 1m width survey area. Hardbottom does not have to be present directly under the tape for it to be considered present in the survey area.
  - For example, if the 0m point on the survey tape is in sand and the reef/hardbottom starts at 6.3m, the coral survey starting point should move to 6m and continue to the 16m mark for a total of 10m.

CAUTION: If the coral survey starting point is moved from 0, this may impact bottom times. Be extremely cautious of your dive time and air supply!

- If no hardbottom exists between 0 and 10m, the demographic survey should be terminated and an alternate selected.

- Regardless of where survey starts, always record survey start and end locations on the datasheet (Figure 1).

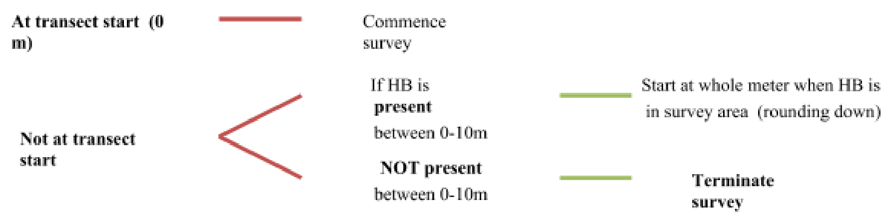


Figure 2. Decision rule for coral demographic survey.

3. When a coral demographic survey area is split between two Demographic surveyors:
    a. A transect will only be split by opposite ends (horizontally). Surveyors will work opposite ends (meter marker 0 and meter marker 10, respectively), and will coordinate to avoid duplicating counts upon convergence.
        i. A transect will not be split width-wise (vertically) between surveyors. This minimizes the potential for double-counting colonies.
    b. Both divers will record their own start and end positions on data sheet (Figure 1).
    c. One diver will be the Demographic "lead" diver and will be responsible for all the demographic data entry for both divers (the lead Demographic diver will enter all the demographic data in one survey into the offline database module).
        i. On each datasheet used for the survey, the "lead" Demographic diver will enumerate and record the total number of datasheets for the survey (Figure 3).
    d. The name of the second Demographic diver will be recorded on ALL datasheets associated with that dive site.

Field equipment

- Demographics datasheet, clipboard, pencil, spare pencil
    - One survey per datasheet
- Small rigid measuring instrument, marked in cm (*e.g.,* "Flexiruler")
- Measuring instrument, marked in cm increments, used for measuring coral colony

dimensions AND/OR for measuring 1m out from the transect tape (*e.g.*, 0.5 or 1m PVC, marked in units or with measuring tape securely attached)

- Camera, battery, housing (optional)

Coral demographic survey protocols

1. *Logistics and station information* – Names of all divers, station, date, time of survey and diver checks (Figure 3).

ODMDS Invertebrate Demographics			Demo Diver		
Site ID			Fish Diver		
Date			LPI Diver		
Begin transect		Habitat Type			
End transect		Ledge	MHB/S	Pavement	Unconsolidated / Other

Figure 3. NCRMP coral demographic datasheet header with logistic and station information.

Species/colony identification – These are the invertebrates that will be measured if the base of the invertebrate is within the 10 x 1 m box: *Oculina varicosa*, Oculina spp, coral spp, vase sponge, mounding sponge, branching octocoral, upright octocoral (whip).

a. Record each individual on datasheet.

b. Thickets/clumps. If the skeletal unit is connected, identify as one individual. If not, then record them as multiple individuals.

c. Take photographs of anything unknown.

Figure 4. Schematic of example 10m x 1m transect area. Corals with all or part of colony (excluding branches) within transect area are included (✓). Corals entirely outside of the transect area are not included (X).

Invertebrate	Max Diam (cm)	Height (cm)	% Mortality	Bleached Total Partial None (T,P,N)

Figure 5. Datasheet section showing invertebrate identification, dimensions, condition categories and data entry.

4. *Invertebrate size measurements* - Measure entire invertebrate (skeleton + live tissue) on a planar dimension (2D) to two (2) exact dimensions (cm).
   - Measurements made to the nearest whole centimeter (cm).
   - Do not bin, estimate, or aggregate measurements. For example, measurements of length, width, and height of a colony might be 5cm x 3cm, respectively.

   a. Maximum diameter Length – Measure the - maximum diameter (cm) of identifiable skeletal unit.

      i. Measure location where diameter of skeletal unit is widest

      ii. Measure skeletal unit, not just the live tissue

   b. Height – Measure the **height** (cm) of the skeletal unit.

      i. Height is measured from the base of the skeletal unit perpendicular to plane of growth.

1. If colony is growing on a slope, measure perpendicular to the slope
2. Measure linearly (*i.e.*, do not drape tape across the colony)
3. If the colony has an encrusting morphology, the minimum height of the colony should be reported as 1.0cm.

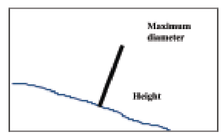


Figure 7. Height and width measurements perpendicular to plane of growth. Colony is shown on a sloped reef.

5. *Invertebrate condition measurements* – For each measured coral, the total colony area is assessed for mortality and bleaching.
   - Estimate the percent dead skeletal cover (partial mortality estimate for each colony) based on skeletal structure. Skeletal structure = (old or recent) mortality + live tissue. Assess the entire colony, including underneath sides of branching corals.
   - Consider how species and morphology influence normal tissue location (*e.g.*, not on columnar colonies such as *Eusmilia fastigiata* and *Orbicella annularis*).
6. Mortality – Estimates of mortality are collected, if applicable (Figure 8). Only include invertebrates that have living tissue present, *i.e.*, total mortality (% old + % recent) is less than 100. **If total mortality is 100%, do not record the colony**.

   - NOTE: The diseased area of coral colonies SHOULD NOT be recorded as partial mortality, unless the diseased area HAS NO LIVING TISSUE [i.e. the coral skeleton (calyx) structure IS CLEARLY VISIBLE in the diseased area].

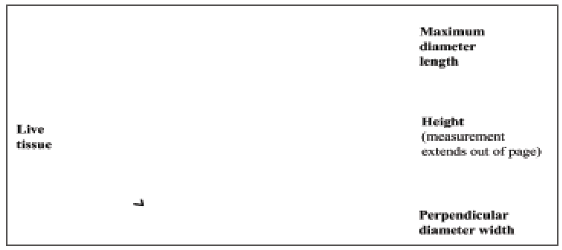


Figure 8. Entire skeletal unit is measured for dimensions [maximum diameter (blue), perpendicular diameter (red) and height (circle).] Estimate % old mortality (~70%).

a. <u>Bleaching (T/P/N)</u> – Note if any coral bleaching is present or absent (Figure 9).

   i. **Total bleaching (T)**: **bright-white** bleaching over the entire colony[1]

      1. Bleaching is defined as bright white tissue.

      2. Other conditions such as various shades of paling or disease are *not* included.

   ii. **Partial bleaching (P)**: **bright-white** bleaching over a part of the colony

   iii. **No bleaching (N)**: no bleaching present. Use this code to indicate **no bleaching**. Do not leave this item blank.

      1. If a colony is exhibiting any apparent "discoloration" of tissue, unless it is partially or completely white, this condition should be scored as "No bleaching".

Figure 9. Partially bleached *Orbicella* coral colony. Because pigment is still visible around the lower right and upper left margins of the colony, this bleaching condition is scored as *partially bleached*.

7. *Photographs* – The Demographic diver may choose to take additional photos of anything unusual (*e.g.*, rare fish, bleached or rare corals), for species identification purposes, unique site features, and other divers. If the Demographic diver does take photographs, the following should be done:
    a. Station Documentation
        i. One photograph is taken of the site name and date on the datasheet prior to taking any photographs of the site.

Data sheet review

At end of survey, when divers are on boat, the dive team exchanges datasheets for review by checking for completeness and legibility. A diver cannot review his/her own datasheet. After the datasheet has been reviewed, the reviewer initials the "checked by diver" box (Figure 1).

1. *Fish datasheet* – Review includes, at a minimum, verifying the following:
    a. Completeness and legibility of all logistics information; including random heading(s) and reason for change is circled, if applicable.
    b. Completeness and legibility of all species codes, bin size class marks and size numbers (for select species and individuals >35cm).
    c. Completeness and legibility of all Topographic Complexity records.
        i. Stratum slope – Minimum and maximum depth (recorded in ft).

ii. Maximum vertical relief (recorded in cm)

iii. Surface area topography – 24 total tick marks.

2. *LPI datasheet* – Review includes, at a minimum, verifying the following:
    a. Completeness and legibility of all logistics information.
    b. Confirmation of observed habitat type with dive team and is circled.
    c. Completeness and legibility of macroinvertebrate records. NOTE: All boxes are to be filled out. If this component was not conducted, "X" through section is required.
3. *Coral Demographic datasheet* –Review includes, at a minimum, verifying the following:
    d. Completeness and legibility of all logistics information; including identification of second Demographic surveyor (if applicable).
    e. Completeness and legibility of transect start and end locations (integer).
    f. Completeness and legibility of percent hardbottom of survey component.
    g. Annotation in "Notes" section reporting the presence of multiple datasheets utilized for data collection (if applicable).

EPA Topographic Complexity Survey Protocol

Goal

Structural surveys are intended to provide information on topographic complexity at each site where fish and line point intercept (LPI) surveys are conducted. Surveys are concurrent with and along the same transect as fish surveys.

Likely task allocation scenario

1 fish diver + LPI diver + Demo diver

- Fish diver completes conspicuous fish surveys on outbound transect (50 x 10m) and prey fish surveys on return transect (25 x 2m).
- LPI diver completes LPI tasks (biota identification 100 points) on outbound transect and rugosity survey on return transect using the HOBO water level sensor.
- Demo diver conducts coral demographics survey on outbound transect (10m x 1 m on left); then returns to 0 m and takes topography measurements along the 50m outbound transect while also surveying macroinvertebrates; then the demo diver reels up the tape.

Topographic Complexity (TOPO) Transect Methods

TOPO transects will be surveyed at all fish survey sites along the same transect (50m transect).

ODMDS Topographic Datasheet		Topo Diver	
Site ID		Fish Diver	
Date		LPI Diver	
Min Depth		Measure tallest abiotic and biotic item in each 2 m L x 1m W box on the LEFT side of the transect	
Max Depth			
	Abiotic	Biotic	

Figure 1 TOPO datasheet header – should be completed by diver prior to entering water.

a. Small boats will navigate to the selected site using a handheld GPS unit. When the coordinate has been reached, confirm depth with coxswain then deploy a weighted float to mark the start of the transect.

b. Divers will descend following the weighted line as rapidly and safely as possible, maintaining good buddy contact. If the site exceeds the maximum allowable depth (either by diver table limits or cruise limit (130’) the dive is aborted and a new site is selected.

c. These dives are intended to quantify communities in hardbottom areas. Where no hardbottom is visible divers are instructed to take a 360-degree short video and two or three close up photos representative of sediment type, abort the dive and select a new site.

2. TOPO In water methods

a. Demo surveys will be conducted on out bound transect. TOPO surveys will be conducted on the Outbound beginning at 0m.

b. The TOPO/Demo diver collects the following height measurements in every 2m L x 1m wide block.

    i. The priority of this survey is to collect maximum structural height. Within each 2m long x 1m wide block of the transect, record the maximum abiotic (hardbottom) and biotic relief in the appropriate cell of the datasheet to the nearest 5 cm (record actual measurements if taken).

        1. biota (e.g. sponge) growing on the hard substrate should not be included in the hardbottom measurement. The height recorded here is of the hardbottom only.

        2. if there is no hardbottom within the 2 x 1m area – record a 0 (zero) for that row on the datasheet.

    ii. within each 2 x 1m box also, record the height of the maximum biotic component (to the nearest 5cm) within that 2 x 1m block and record it in the appropriate cell of the datasheet, thus recording two heights and one check mark within each 2 x 1m block (biotic, hardbottom, & undercut). NOTE: you do not need to record the maximum height of each biotic component listed on the datasheet – unless this diver has an inordinate amount of bottom time and can collect such data without buddy separation or bottom time violation.

        1. for biotic height measurements, height is measured by extending the organism vertically and recording max. height. Do NOT record vertical height of organism bent in the current.

c. record % encrusted - The percent encrusting determination is intended to be a quick visual assessment to capture the other biotic elements, primarily sponges, tunicates and zoanthids that will not be measured or counted as part of the Demographic or Topographic complexity data sheets. Data will be used to compare against LPI and Demo data. It is determined by estimating the total percent of the abiotic 2x1m plot covered by biotic components. The 2x1m assessment areas of the topographic data sheet lends itself to this determination since the diver should be able to quickly (30 seconds or less) make a determination of the percent coverage for each frame. Nearly all surface area of rock/rubble reefs at the Fernandina ODMDS are covered by these organisms with pockets of sand or bare areas in between. Encrusting doesn't mean "flat". Some of the sponges or tunicates can be quite large.

    i. This is a general estimate based upon the diver's best judgement and the diver should not allow this determination to extend their bottom time.

d. **Minimum site depth and Maximum site depth** – record these to the nearest foot (using dive computer). The difference in these two measures provides the depth range of the site and substratum slope.

3. Macroinvertebrate count: 1-20 = Few, 21-100 = Many, 101+ = Abundant
    a. Purple Urchins – record general abundance (few, many, abundant) or actual count. Whichever time permits. Species differentiation is not necessary.

    b. Spiny or Slipper Lobster - record general abundance (few, many, abundant) or actual count. Whichever time permits.

    c. Seastar - record general abundance (few, many, abundant) or actual count. Whichever time permits.

4. TOPO out of water methods

    a. Between dives or as soon as possible after your dive, exchange datasheets with another diver to ensure data consistency and continuity between divers. Any problems encountered should be documented thoroughly on the datasheet.
    b. Data entry into database should be done as soon as possible.

ODMDS Topographic Datasheet		Topo Diver					
Site ID		Fish Diver					
Date		LPI Diver					
Min Depth		Measure tallest abiotic and biotic item in each 2 m L x 1m W box on the LEFT side of the transect					
Max Depth							
	Abiotic	Biotic					
Distance	Hardbottom	Octocoral	Sponge	Coral	Macroalgae	Bare	% Encrusted
0-02							
02-04							
04-06							
06-08							
08-10							
10-12							
12-14							
14-16							
16-18							

Figure 2. TOPO datasheet – record max. hardbottom height (cm), biota height (cm), and % encrusting every 2 x 1m.

PERCENT ENCRUSTING PROTOCOL

The percent encrusting determination is intended to be a quick visual assessment to capture the other biotic elements, primarily sponges, tunicates and zoanthids that will not be measured or counted as part of the Demographic or Topographic complexity data sheets. Data will be used to compare against LPI and Demo data. It is determined by estimating the total percent of the abiotic 2x1m plot covered by biotic components. The 2x1m assessment areas of the topographic data sheet lends itself to this determination since the diver should be able to quickly (30 seconds or less) make a determination of the percent coverage for each frame. Nearly all surface area of rock/rubble reefs at the Fernandina ODMDS are covered by these organisms with pockets of sand or bare areas in between. Encrusting doesn't mean "flat". Some of the sponges or tunicates can be quite large.

This is a general estimate based upon the diver's best judgement and the diver should not allow this determination to extend their bottom time.

EPA FISH SURVEYS

Goal

Data collected by fish surveyors provide a comprehensive measure of fish species diversity, abundance, length frequency, and biomass at a site. Surveys are concurrent with and along the same transect as LPI surveys.

Likely task allocation scenario

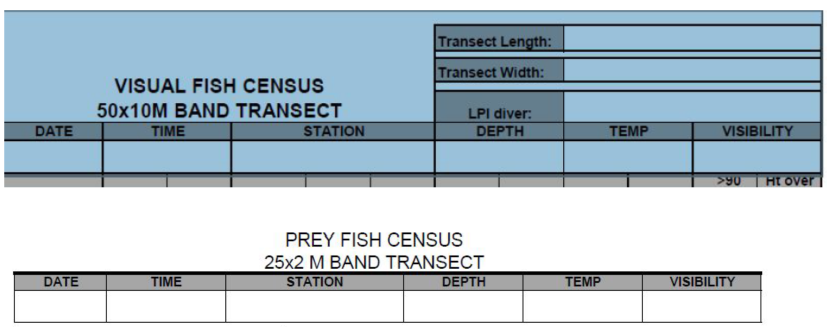
1 fish diver + LPI diver + Demo diver

- Fish diver completes conspicuous fish surveys on outbound transect (50 x 10m) and prey fish surveys on return transect (25 x 2m).
- LPI diver completes LPI tasks (biota identification 100 points) on outbound transect and rugosity survey on return transect using the HOBO water level sensor.
- Demo diver conducts coral demographics survey on outbound transect (10m x 1 m on left); then returns to 0 m and takes topography measurements along the 50m outbound transect while also surveying macroinvertebrates; then the demo diver reels up the tape.

Fish Transect Methods

1. Site selection, navigation, and deployment

    a. **Headers on all datasheets are filled out prior to entering water** – site number, date, time, buddy.



VISUAL FISH CENSUS
50x10M BAND TRANSECT

Transect Length:	
Transect Width:	
LPI diver:	

DATE	TIME	STATION	DEPTH	TEMP	VISIBILITY

PREY FISH CENSUS
25x2 M BAND TRANSECT

DATE	TIME	STATION	DEPTH	TEMP	VISIBILITY

Figure 1 Conspicuous (top) and prey (bottom) fish datasheet headers are filled out prior to entering the water.

   b. Small boats will navigate to the selected site using a handheld GPS unit. When the coordinate has been reached, confirm depth with coxswain then deploy a weighted float to mark the start of the transect.

   c. Divers will descend following the weighted line as rapidly and safely as possible, maintaining good buddy contact. If the site exceeds the maximum allowable depth (either by diver table limits or cruise limit (130')) the dive is aborted and a new site is selected.

d. Fish and Benthic dives are intended to quantify communities in hardbottom areas. Where no hardbottom is visible divers are instructed to abort the dive and select a new site.

2. Fish In water methods

   a. On the bottom, the fish diver will choose a bearing that maximizes contact with the habitat and record that bearing before beginning the transect.

   b. LPI and all other divers will follow behind fish surveyor at a reasonable distance to minimize buddy separation and avoid influencing swimming behavior of fishes.

   c. Fish surveyor will anchor the transect tape at 0m and at a minimum of two additional places along the transect to secure the tape along the bottom; ensuring LPI data are collected along the same path as the fish data collection and minimizing transect billowing current. The transect tape will NOT be wrapped around abiotic or biotic objects, as this distorts sampling distances.

   d. **Conspicuous surveys are conducted on outbound transect.** These surveys target larger bodied, highly-mobile, fish of all sizes. Record the following for this survey:

      i. Conspicuous transect area is **50 x 10m (5 m to each side of the transect**). If visibility does not allow 10m width, adjust width according to viz but document width used.

      ii. Likewise, if transect is shortened due to time limits, record length of transect completed. Documenting area deviations from the 50 x 10m protocol is critical to maintain data consistency.

      iii. For this survey, larger, more mobile species are counted first (e.g. groupers) and smaller, more site attached species (e.g. grunts) are counted second (this stratification method is described in more detail in Samoilys & Carlos, 2000; Sanderson & Solonsky, 1986).

      iv. There is no time limit for this survey, however 15min is suggested. Faster surveys are more likely to miss fish (especially cryptic ones) and longer times may overextend bottom time.

      v. Maintain buddy contact. It is the fish surveyor's responsibility to set the pace for the dive, don't leave your buddy in the dust. Discuss as a team how to maintain contact (set times, sound, distance on meter tape, etc…).

      vi. For each fish encountered,

         1. identify to species (or finest level possible), recording the first two letters of the genus and first two of species (e.g. MYMI = *Mycteroperca microlepis*) OR common name (e.g. Gag) in the code field of the datasheet (Fig 2). Whichever is faster, you can always look up the sci. code on the boat.

a. If you are unsure of species identification, take a picture/GoPro video, ask LPI diver to photograph the fish for you, or sketch a picture of the fish. Fish ID guides will be provided to assist in identification back on the boat.

2. enumerate the fish & estimate size based on categories on datasheet (Fig 2). Fish length estimates are based on **fish total length.**

   a. Record actual length for fish larger than 90cm TL (to nearest cm) in the >90cm column (Fig 2).

   b. Calibrate length estimates. Use meter tapes, data sheet, clip boards, or other means as a point of reference to periodically calibrate length estimates. Practicing length estimation on non-mobile objects, such as rocks, invertebrates can improve your ability to quickly & accurately estimate fish lengths. Remember, fish (among other things) appear larger underwater….so calibrate regularly. ☺

   c. Record noteworthy species (# & TL) observed off transect. Such as larger grouper or snapper. Be sure to note that it was an off transect observation.

   d. Record number of Endangered/Threatened species anywhere at site (within limit of visibility). These include: manatee, turtles, and whales.

3. Record visibility estimate. Using the transect tape and an underwater feature, record horizontal visibility on the bottom.

4. Identify height over bottom for each fish species. Record average/typical position in the water column for each species encountered using the following categories: 0 (0-1); 1 (1-3); 3 (>3)

CODE	1-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	>90 estim. L	Ht over btm (m)

Figure 2. Conspicuous fish datasheet. Fish species is recorded in the code field and enumerated in appropriate total length columns. Actual TL is recorded for fish >90cm TL.

Figure 3. An example of fish fork length compared to total length (TL). TL (in cm) is recorded in these surveys.

e. **Prey fish surveys are conducted on return transect.** These surveys target smaller (< 20cm) fish that are typically site attached and cryptic, thus harder to see during the conspicuous surveys.

   i. The area of this survey **is 25m x 2m (1m each side of the transect)**. Because this is a shorter survey it can be conducted anywhere along the transect. Discuss with dive buddies where the best point is to conduct this survey – although it may ultimately depend on habitat configuration, as **hardbottom is our target** in these surveys.

   ii. All fish encountered <20 cm TL are identified to species, enumerated, and sized as described above and recorded on prey fish datasheet.

   iii. make note of species of interest and ESA species (# & TL) observed off transect as time permits (see 2 above for description).

   iv. There is no specified time limit for this survey however experience has identified 5 - 7 min as adequate.

3. Fish surveys - out of water methods

   a. Between dives or as soon as possible after your dive, exchange datasheets with another diver to ensure data consistency and continuity between divers. Any problems encountered should be documented thoroughly on the datasheet.

Appendix C

Field Data Sheets

EPA Line Point-Intercept Datasheet

FB ODMDS 2016

LPI Diver		**Site ID**		**Rugosity**	**Spike 5 times to begin/end**
Fish Diver		**Date**		**Start time**	
DEMO Diver		**Time**		**End time**	

Substrate: H - Hardbottom S - Soft R - Rubble

6 pictures = clipboard, N, S, E, W, transect

Meter	Cover	Sub	Meter	Cover	Sub	Meter	Cover	Sub	Meter	Cover	Sub
0.5			13			25.5			38		
1.0			13.5			26			38.5		
1.5			14			26.5			39		
2.0			14.5			27			39.5		
2.5			15			27.5			40		
3.0			15.5			28			40.5		
3.5			16			28.5			41		
4.0			16.5			29			41.5		
4.5			17			29.5			42		
5.0			17.5			30			42.5		
5.5			18			30.5			43		
6.0			18.5			31			43.5		
6.5			19			31.5			44		
7.0			19.5			32			44.5		
7.5			20			32.5			45		
8.0			20.5			33			45.5		
8.5			21			33.5			46		
9.0			21.5			34			46.5		
9.5			22			34.5			47		
10			22.5			35			47.5		
10.5			23			35.5			48		
11			23.5			36			48.5		
11.5			24			36.5			49		
12			24.5			37			49.5		
12.5			25			37.5			50		

Heading	
Original	
Alternate	

Observed Habitat Type

(circle)

Ledge Pavement

Mixed HB/Sand

Rubble

Unconsolidated

Macroinvertebrate Counts

50 x 1 m

Purple Urchins	
Lobster	
Seastars	
Other	

Categories:
1-20 = Few (F)
21-100 = Many (M)
> 100 = Abundant (A)

Notes

6 pictures = clipboard, N, S, E, W, transect

100 points LPI

Rugosity: **Note begin time**
Spike 5 times begin/end
Spike 3 times every 5 meters
Note end time

Benthos	**Code**	**H**	**S**	**R**
Bare	Bare			
Oculina varicosa	Ovar			
Oculina sp.	Osp			
Phyllangia americana	Pam			
Hard coral	Hcor			
Gorg - branch	Gbr			
Gorg - whip/single	Gwh			
Gorg - encrust	Gen			
Sponge - vase	Sva			
Sponge - encrust	Sen			
Sponge - branching	Sbr			
Zoanthid/Palythoa	Zoa/Paly			
Tunicate	Tun			
Hydroids	Hyd			
Macro Algae	Malg			
Turf Algae	Talg			
Anemone	Anem			

ODMDS Live Bottom Demographics			Demo Diver	
Site ID		Transect: 10 m L x 1 m W	Fish Diver	
Date			LPI Diver	
Begin transect		Habitat Type		
End transect		Ledge MHB/S	Pavement Unconsolidated	Rubble

Organism	Max Diam (cm)	Height (cm)	% Mortality	Bleached Total Partial None (T,P,N)	Invertebrate	Max Diam (cm)	Height (cm)	% Mortality	Bleached Total Partial None (T,P,N)

Organisms to measure	Hard Corals	Sponge			Octocoral	
	Oculina varicosa, Oculina spp, coral spp	Vase	Branched	Mound	Branch	Whip
Codes	Ocu var, Ocu spp, cor spp	Spo vas	Spo Bra	Spo mou	Oct br	Oct wh

ODMDS Topographic Datasheet		Topo Diver	
Site ID		Fish Diver	
Date		LPI Diver	
Min Depth		Measure tallest abiotic and biotic item in each 2 m L x 1m W box on the LEFT side of the transect	
Max Depth			

	Abiotic	Biotic					
Distance	Hardbottom	Octocoral	Sponge	Coral	Macroalgae	Bare	% Encrusted
0-02							
02-04							
04-06							
06-08							
08-10							
10-12							
12-14							
14-16							
16-18							
18-20							
20-22							
22-24							
24-26							
26-28							
28-30							
30-32							
32-34							
34-36							
36-38							
38-40							
40-42							
42-44							
44-46							
46-48							
48-50							

Macroinvertebrate Counts 50m L x 1m W Left	Few 1- 20	Many 21-100	Abundant >100
Purple Urchin			
Spiny/Slipper Lobster			
Seastar			
Other			

Notes

CONSPICUOUS FISH CENSUS 50x10M BAND TRANSECT	Note transect length for conspicuous and prey transects	
	Transect LxW	
	LPI Diver	
Fish Diver	Demo Diver	

DATE	TIME	STATION	DEPTH	Heading	VISIBILITY

CODE	1-10	10-20	20-30	30-40	40-50	>50 cm	Ht over bottom (0, 1-3, >3)
Tomtate							
Black Sea Bass							
Gag							
Sheepshead							
Grunt sp							
Gray Triggerfish							
Spottail Pinfish							

CRYPTIC FISH CENSUS

25 x 2 M BAND TRANSECT

DATE	DIVER	STATION	DEPTH	TIME	Visibility

CODE	<2	2-5	5-7	7-10	10-15	15-20	> 20
Belted Sandfish							
Slippery Dick							
Cubbyu							
Pinfish							
Cocoa Damselfish							
Highhat							
Spottail Pinfish							
W. Soapfish							
Blenny sp							
Oyster Toadfish							

END OF REPORT

U.S. Environmental Protection Agency
Scott Pruitt, Administrator

Region 4
Onis "Trey" Glenn, III, Regional Administrator

Water Protection Division
Mary Walker, Director

U.S. Department of Commerce
Wilbur Ross, Secretary

National Oceanic and Atmospheric Administration
Dr. Benjamin Friedman, Acting Under Secretary for Oceans and Atmosphere

National Ocean Service
Dr. Russell Callender, Assistant Administrator for Ocean Service and Coastal Zone Management

The National Centers for Coastal Ocean Science
Dr. Steven Thur, Acting Director

The National Centers for Coastal Ocean Science provides research, scientific information and tools to help balance the nation's ecological, social and economic goals. Our partnerships with local and national coastal managers are essential in providing science and services to benefit communities around the nation. http://coastalscience.noaa.gov