Standard Operation Procedures For Nearshore Hardbottom Monitoring Of Beach Nourishment Projects

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Preface

This document is a “Standard Operating Procedure” of nearshore hardbottom monitoring. It is designed to assist those applying for Joint Coastal Permits for beach nourishment projects that have nearshore hardbottom with the potential of being impacted by the project. This document can assist these applicants by providing Department-approved methodologies to monitor these nearshore hardbottoms, allowing applicants to spend less time and money developing monitoring protocols in the application phase. This document was developed by DEP staff in conjunction with monitoring crews who have conducted the majority of the nearshore hardbottom monitoring for nourishment projects in the state of Florida. The monitoring protocols that have been commonly adopted in Joint Coastal Permits were discussed with the monitoring firms, and the most effective methodologies used to identify project-related impacts on nearshore hardbottom have been incorporated into this document.

This document is for guidance purposes only and is not currently adopted by Rule or Statute, although many of the monitoring protocols discussed in the document have been required in permits and / or monitoring plans in order to provide reasonable assurance of predicted impacts. The purpose of this document is to provide guidance to applicants on hardbottom monitoring protocols that have been approved and permitted in nearshore beach projects. Thus, if planning a project where nearshore hardbottom is present and monitoring will be required to provide reasonable assurance of predicted impacts, an applicant can use these methods and protocols to make the permitting process more efficient, predictable and consistent.

This document will continue to be refined as needed and as any better methodologies are developed and utilized successfully to monitor nearshore hardbottom for potential impacts from nourishment projects. The most current version will remain available on the Department website, and can be requested at any time.

The use of any brand names in this document does not constitute an endorsement by the Florida Department of Environmental Protection.

Content

INTRODUCTION

Many valuable ecological functions are provided by areas of hardbottom and their associated communities. Hardbottom itself is an attachment and shelter resource, providing habitat critical for the recruitment/settlement, growth, and reproduction of numerous organisms. In this capacity, hardbottom habitat serves as a nursery, spawning, and foraging area for ecologically and economically valuable species. In general, hardbottom communities contain moderate to relatively high diversities of algae, invertebrates, and fishes. Various hardbottom habitat types often provide distinct ecological functions, as the types of benthic communities present on hardbottom are generally determined by the characteristics of the hardbottom habitat (*e.g.*, its distance from shore, water depth, physical relief, and exposure). Organisms associated with hardbottom habitats in turn provide further ecological services, as they contribute to local food webs (intercommunity nutrient exchange), help maintain water clarity, provide shelter and recruitment surfaces, and act as a source of larval supply.

Biological monitoring of nearshore hardbottom for restoration and nourishment projects is necessary to document potential adverse impacts due to beach restoration and nourishment activities. As such, the goal of biological monitoring is to evaluate the condition and function of hardbottom resources over time. Compared to physical monitoring (*i.e.*, beach profiles), biological monitoring is a more precise and practical method of determining impacts; though both types of monitoring are reviewed by the Department and used in the determination of project-related impacts to resources. While hardbottom monitoring conditions have been incorporated into Joint Coastal Permits (**JCP**), and further details are often included in approved hardbottom monitoring plans, these plans and methods have often differed between projects and among monitoring firms. Thus, a need for standardized monitoring designs and procedures for restoration and nourishment projects exists, including details regarding data collection, analysis, quality assurance/quality control (**QA/QC**), reporting, and filing.

Repeated cycles of nourishment and monitoring conducted for numerous projects have provided insight into efficient and effective methods for the collection and interpretation of biological data. The purpose of this document is to standardize operating procedures for biological monitoring of hardbottom resources to improve consistency of methods among monitoring firms and projects, and to expedite the Department's review of biological monitoring plans and reports. As part of this effort, the Department of Environmental Protection (**DEP**) has implemented methods for more consistent review of monitoring data, including the development of a geographic information systems (**GIS**) **-** based hardbottom geodatabase, a defined monitoring review procedure and feedback loop between the Department and permittee, and a uniform filing system for consistent submittal of monitoring data by firms participating in monitoring. This filing system uses standardized units, nomenclature, and file formats. In this text, "Department" refers to compliance officers as well as the resource staff in the Beaches, Inlets, and Ports program (**BIP)**. All correspondence (*e.g.*, emails) should be addressed to BIP resource staff (**BMES@dep.state.fl.us**), while formal correspondence should <u>also</u> be addressed to JCP Compliance (**JCPCompliance@dep.state.fl.us**).

Units of Measure: The metric system, the standard system of units used in scientific endeavors, should be used for recording and reporting measurements made during the course of hardbottom habitat biological monitoring (*e.g.*, in the initial habitat characterization and also in pre- and post- construction surveys). Thus, depth and length should be reported in meters (m), sediment accumulation in centimeters (cm), and areas in meters squared (m^2). For the Uniform Mitigation Assessment Method (**UMAM**), larger areas may be converted and reported as acres. Density should be reported as individuals per meters squared (N/m^2). The cover of functional groups within sampling areas (quadrats) should be measured and reported as percent (%) cover. Tapes or lines marked in meters should be used during surveys. Tapes or lines currently marked in feet may continue to be used, though they should be phased out over time and replaced with tapes or lines marked in meters. As most SCUBA depth gauges in the United States are graded in feet, water depth measurements should be re-calculated to meters. Note that citations from engineering reports that use cubic yards and cubic yards per foot are acceptable and need not be converted to metric units in biological monitoring reports.

A. Hardbottom definitions and classifications system

A glossary of terms can be found at the end of this document (Appendix A). The Glossary is limited to terms that are used in biological monitoring plans and reports. Any additional terms should be obtained in published glossaries; clarification of terms used may also be requested from BIP resource staff.

Hardbottom provides substrate for attached and motile benthic species, such as algae, sponges, corals, and sea urchins, *etc*. Benthic communities formed by these species provide shelter and food sources for fish, marine turtles, and countless other marine organisms. The composition of each community varies based on factors that are used to characterize hardbottom, such as relief, water depth, and the persistence of substratum exposure.

A uniform hardbottom community classification system is necessary to identify each type of hardbottom habitat, so that a consistent and repeatable method for collecting, interpreting, and evaluating hardbottom data can be established for all projects that have monitoring programs. In this manner, hardbottom habitats can be identified and tracked over time, and changes in these habitats can be objectively documented according to the defined classification parameters. The following section provides definitions for the classification parameters of hardbottom as well as the types of impacts that may occur to hardbottom habitats as a result of beach management activities.

1. Classification of nearshore hardbottom habitat types

Hardbottom habitats can be characterized using a classification system based on four features of the underwater landscape: 1) position of hardbottom (its distance from the shoreline and the predicted equilibrium toe-of-fill [**ETOF**], the water depth); 2) physical features of hardbottom (*e.g.*, hardbottom relief, substratum type, and sediment cover); 3) duration of hardbottom exposure; and 4) ecological function of hardbottom benthic communities. Each of these features is described in greater detail below.

a. Position of hardbottom: distance from predicted ETOF and water depth

The distance from the predicted ETOF to the hardbottom edge (according to the design of the project) should be taken into account when evaluating potential effects of beach nourishment; for example, distance can be classified as short if < 50 m; intermediate if 50 –100 m; or far if > 100 m. The closer hardbottom is to the predicted ETOF of the project, the greater the potential for impacts from nourishment, especially for low relief hardbottom. The gradient of impacts should be considered in the monitoring plan, such that areas more likely to be impacted by the nourishment are monitored to a greater degree (more thoroughly) than areas less likely to be impacted.

i. Nearshore hardbottom

Hardbottom ranging from the shore to a depth of -4 m[1], typically exposed as a 200-400 meter wide strip. Nearshore hardbottom can be divided into 3 zones: a) supralittoral (zone slightly above the tidal line); b) littoral (intertidal area between high spring tide and low spring tide marks); and c) upper sublittoral (from the low spring tide mark to a depth of -4 meters). Daily changes in water temperature, salinity, turbidity, and surf conditions are typical of nearshore hardbottom areas, and are driven by waves, longshore and cross-shore currents, and tides. Tidal influenced emersion is typical of intertidal areas, while both inter- and sub- tidal nearshore hardbottom are subject to scouring by suspended and mobilized sediments driven by waves and currents. Typical nearshore hardbottom communities are adapted to these conditions, though that does not mean they are highly persistent. Frequent burial by sediments of low relief nearshore hardbottom means these areas are generally ephemeral. However, cycles of disturbance (burial and exposure) provide recruitment opportunities, and benthic organisms typically re-colonization newly exposed substratum rapidly.

ii. Intermediate hardbottom

Hardbottom in water depths ranging from -4 m to -8 m. Compared to nearshore hardbottom, intermediate hardbottom communities generally experience less stress from sediment scour and accumulation due to lower wave energy and cross-shore transport of sediment from the beach by currents. Intermediate hardbottom is typically more persistent, and its benthic communities are generally more diverse and stable than those in nearshore

[1]Depth boundaries reported here for nearshore as well as intermediate and offshore hardbottom are to some extent artificial boundaries that, nevertheless, afford some measureable stratification of a highly variable environmental and biological continuum.

areas. As in other hardbottom areas, hardbottom relief greatly influences community diversity and stability in intermediate hardbottom areas.

iii. Offshore hardbottom

Hardbottom in water depths deeper than -8 meters to -12 m. Offshore hardbottom tends to be the most persistent of the types described here. As a result, benthic communities in offshore areas tend to be more stable and thus contain older and larger organisms than in nearshore and intermediate hardbottom areas. As a stressor, cross-shore sediment transport from the beach plays less of a role in offshore hardbottom areas. This is due both to distance of offshore areas from the beach, and also to the presence of negative relief features, like troughs and pits, which trap sediment moving in the cross-shore direction.

b. Physical features of hardbottom: relief, substrate type, and sediment cover

i. Relief

Relief is measured as the height of positive relief features relative to adjacent negative relief features. Measurements are usually made within a distance of less than 10 m. The following three categories should be used to describe relief in nearshore hardbottom areas.

(1) *Low relief hardbottom*

Less than 0.3 m relief; hardbottom typical as low ledges and flat areas; small relief features include pits and mounds.

(2) *Medium relief hardbottom*

0.3 to 1.0 m relief; may be ledges, scarps, or mounds, shallow pits, and troughs or furrows.

(3) *High relief hardbottom*

Greater than 1.0 m relief; typical high relief features include higher ledges, knolls, hillocks, and ridges, while negative relief features include deeper pits, troughs, and furrows/grooves.

ii. Substratum type

The type of substrata comprising a site is an important feature of the physical hardbottom environment; as such, substratum type should also be used to classify hardbottom habitats. Six main types of marine hard substrata are generally encountered in Florida, and more than one type may be found at a given site. It is important to distinguish among: 1) worm rock (live or dead), 2) Anastasia formation limestone (lithified Coquina shells); 3) reef-rock (limestone composed of coral skeletons and lithified coral rubble); 4) sandstone of different origins (*e.g.*, lithified carbonate sand [oolite], dune sandstone [eolianite = aeolianite], and beach rock); and 5) anthropogenic material, like concrete. All rock types in Florida (excluding anthropogenic material) are limestones of different sorts or lithified mixes of carbonate sand/gravel and terrigenous non-carbonate sediments.

The sixth substratum category, a special type of hardbottom habitat, is rubble. Rubble consists of loose debris of sizes larger than coarse gravel [> 32 mm], but smaller than boulders [< 256 mm]). The origin of rubble can be either natural (*e.g.*, physical erosion of rocks, bioerosion of rocks, physical and biological destruction of corals, formation of rhodolithes, *etc.*) or anthropogenic (*e.g.*, dredging of rocks and spoiling in adjacent areas). Rubble size and wave energy directly influence rubble stability, which in turn influences ecological succession, and thus, the types of communities that form in rubble fields and their persistence. The crevices and interstitial spaces that typically exist within rubble filled areas offer numerous opportunities for the recruitment of sessile organisms and also serve to provide shelter for juvenile motile species. Thus, rubble fields function as recruitment and nursery habitat for a variety of species. Areas of rubble should therefore be considered as a resources from the standpoint of potential impacts from beach nourishment.

iii. Sediment distribution

The distribution of sediment within hardbottom areas, its presence over hardbottom as burial, partial burial, or dusting of benthos, is another important characteristic of hardbottom habitats. Both the distribution of sediment as well as the time periods over which particular distributions of sediment persist should be used to classify hardbottom habitats.

c. Persistence/Exposure of hardbottom

Hardbottom exposure varies due to site-specific conditions, and greatly influences the composition of hardbottom communities. Evaluating the duration of hardbottom exposure is, therefore, of fundamental importance to classifying hardbottom habitat types. Physical hardbottom characteristics (*e.g.*, ratio of sediment to hardbottom, hardbottom relief) as well as the structure and composition of biological assemblages can aid in the evaluation of hardbottom exposure. Both persistent and ephemeral hardbottom types may exist within a project area.

i. Persistent hardbottom

Persistent hardbottom habitats are consistently exposed and generally visible in aerial photographs and/or verified by *in situ* field surveys. Burial by sediments can occur within these habitats, but the time period over which hardbottom substrata are exposed is of sufficient duration to allow for benthic succession to form well developed communities. Due to the presence of relatively stable environmental conditions, persistent hardbottom habitats generally exhibit communities with lower rates of turnover and sessile benthic populations with older age classes. For example, most macroalgae in persistent hardbottom areas are perennial species, and some fishes reside in these areas through their entire life cycles. Transient larval and juvenile stages of species can be found year-round, though peaks in their abundance generally correspond to species-specific periods of larval production and recruitment.

ii. Ephemeral hardbottom

Ephemeral hardbottom habitats are disturbance-mediated non-equilibrium systems, and benthic community structure tends to be driven by dynamic physical conditions associated with wave activity, sediment scour, and sediment accumulation. *R-selected* species are typical of such habitats, as high rates of larval production lend themselves to rapid colonization of newly exposed substrata. For example, communities in ephemeral hardbottom habitats are typically composed of fast-growing macroalgal species (*e.g.*, *Chaetomorpha* spp. and *Ceramium* spp.), filamentous turf, *Padina* spp., *Gracilaria* spp., opportunistic green and brown sheet form algae (*e.g.*, *Ulva* spp. and *Dictyota* spp.), and other early succession species with short life cycles. Benthic forms typical for more persistent communities can be present in ephemeral hardbottom areas, though normally only as recruits and juveniles. The diversity and identity of algae as well as the presence or lack thereof of sessile invertebrates can be useful indicators of the frequency with which a hardbottom areas is disturbed by sediment accumulation and scour.

2. Definitions of hardbottom impacts

The terms used to describe the types of impacts that nourishment projects can have on monitored hardbottom habitats are defined below:

a. Direct impacts

Direct impacts to hardbottom are those that occur from burial by sediments derived from beach nourishment and restoration projects. A seaward shift in the position of the hardbottom edge is a manifestation of a direct impact. Burial of hardbottom results in a complete (or nearly complete) loss of hardbottom habitat and their associated communities. The duration over which the sediment-dominated habitat persists will depend on the physical conditions of the habitat (*e.g.*, wave energy, strength of the long-shore and cross-shore currents, *etc.*), and also on the frequency with which nourishment is conducted and additional sediment is introduced into the system. In addition to outright mortality and loss of future recruitment of benthic organisms, direct impacts result in lost habitat for motile species such as turtles and fishes.

Burial of hardbottom by project sediment within a project's permitted fill template or predicted ETOF is considered a permitted direct impact, since the burial of this hardbottom is typically offset by mitigation requirements established during the permitting phase of the project. Burial of hardbottom outside the established fill template or predicted ETOF, by the equilibration of fill further than predicted (beyond the permitted fill template or predicted ETOF), is considered to be an unpermitted direct impact.

b. Secondary/Indirect impacts

Secondary impacts (often used interchangeably with "indirect impacts") to hardbottom are those that occur outside of a project's permitted fill template or predicted ETOF (*i.e.*, are not due to the position of the equilibrated toe-of-fill), from increased post-construction cross-shore and/or downdrift sediment transport of material (fill) used to nourish the beach. The increased sediment load in the nearshore area can lead to increased turbidity and potentially scour and also to sediment movement over the hardbottom, which can result in the accumulation of sediments over the hardbottom as discontinuous thin layers or as deeper patches.

With respect to monitoring, a substantial increase in the proportion of sand relative to hardbottom and/or average sediment depth seaward of the predicted ETOF would indicate such secondary impacts. Secondary impacts may also be expressed through the degradation of the previously existing hardbottom community (*e.g.*, loss of species and cover), or through by noticeable shifts in community structure (*e.g.*, a macroalgae community is replaced with a turf algae community).

c. Permitted impacts

Permitted impacts are those expected to occur during or after project construction (*i.e.*, predicted or expected impacts). These impacts have been authorized to occur, typically with offsetting mitigation required. Permitted impacts consist of direct impacts (burial of hardbottom by project sediment) that occur within the permitted fill template or predicted ETOF.

d. Unpermitted Impacts

Unpermitted impacts to resources are those that occur as a result of a project that are not expected, predicted, or authorized in the permit. The extent, nature (direct vs. secondary impacts), and duration of these impacts are recorded through the biological monitoring program.

e. Permanent impacts

Permanent impacts to resources are those impacts attributed to a project which are enduring or lasting in nature. In nourishment and/or restoration projects, hardbottom impacts from beach fill are typically considered to be permanent if they: a) occur within/shoreward of the predicted ETOF; or b) occur outside/seaward of the predicted ETOF and have not recovered by the end of the monitoring period, which is typically three years after construction. While hardbottom shoreward of the project's ETOF may become exposed or remain partially exposed between nourishments, this hardbottom tends to be buried again during each subsequent nourishment. As such, impacts to these resources are typically authorized as permanent impacts and fully mitigated for as part of a nourishment project.

f. Temporary impacts

Hardbottom impacts are considered to be temporary if they have abated and receded by the end of the monitoring period, typically three years after construction. Depending on the type of impact (*e.g.*, burial or community degradation), abatement or recession of temporary impacts would be indicated by total re-exposure of buried hardbottom or by total biological community recovery in the area of impact.

B. Hardbottom monitoring preliminaries: requirements, initial habitat characterization and mapping, and permanent transect establishment

Regulatory monitoring plans shall provide reasonable assurance under State regulatory requirements (Chapter 161 and part IV of 373, F.S.) that approved projects will have no impacts beyond those permitted and offset with mitigation (*i.e.*, unpermitted impacts to nearshore hardbottom and their associated benthic communities). This section provides an overview of the pre-project recommended qualifications / specifications of the monitoring crew and their equipment, initial habitat characterization and map creation, and the establishment of the monitoring grid (*i.e.*, permanent transect and quadrat locations, *etc.*). The recommendation set forth in this section are intended to ensure that best standards and practices are met, that habitats are properly characterized such that UMAM may be used if needed, and that an effective survey grid for biological monitoring is established in the project area.

1. Qualifications/specifications of monitoring staff and equipment

a. Monitoring staff qualifications

Biological monitoring shall be conducted by staff that have previous experience with monitoring nearshore hardbottom communities and scientific knowledge of marine benthic ecosystems, local flora and fauna, including algae, octocorals, scleractinian corals, sponges, echinoderms, *etc.*. Written agency approval of biological monitoring personnel prior to proceeding with the yearly monitoring is typically included as a specific condition in JCP permits. The monitoring firm will provide names and resumes for the proposed monitoring crew to JCP Compliance and BIP resource staff for review and approval. Resumes provided should include details of previous hardbottom monitoring conducted for beach nourishment projects and/or other relevant experience. Each year, and prior to the start of the field season (*i.e.*, commencement of project monitoring), new crew member or subcontractor names and resumes shall be provided to DEP staff for approval. If a new crew member does not have previous experience with nearshore hardbottom community monitoring, then it is the responsibility of the monitoring crew/firm to provide new crew member with appropriate pre-season training.

Monitoring surveys should be conducted using SCUBA, unless the depth of water is more conducive to the use of snorkel gear. In either case, monitoring firm crew/staff shall conduct their work according to the dive safety program of the contracted firm.

b. Quality assurance / quality control (QA/QC) of monitoring personnel

To ensure consistency, all in-water crew members should participate in cross training with one another to verify correct species identification practices and survey methods using standard QA/QC procedures at the beginning of each monitoring season. For each crew member, QA/QC results should reflect consistency of greater than or equal to 90% for species identification. Any individual scoring under this minimum should receive training and should not participate in monitoring until they meet the minimum requirement of 90%. QA/QC cross training results should be provided to DEP staff upon request. After completion of annual project monitoring, a summary of the QA/QC procedures used to check the accuracy of the field data entered into Excel spreadsheets (raw data submittal) shall be submitted to DEP along with raw field survey data.

c. Vessel positioning system specifications

The navigation and positioning system (Global Positioning System [**GPS**]) employed on the vessel should have the capability of at least 1 meter positional accuracy which can be attained by using Differential GPS (DGPS) or Real-Time Kinematic (RTK) systems. GPS receivers should have 12 or more channels, as this improves the accuracy of the location information. The GPS system must communicate with the navigation software in real-time.

Navigational control should be maintained on a PC compatible hardware system (or equivalent) running a Hydrographic Data Collection and Processing (HYPACK) program (or equivalent software) that provides state-of-the-art navigation and hydrographic surveying and post processing capabilities. Information provided from the GPS system must allow the navigation/hydrographic software to display the vessels location in reference to pre-planned lines, targets, or GIS loaded information in real time. All survey data recorded should be backed up regularly to guard against loss. Raw data shall be provided to the Department upon request, in a Microsoft Excel spreadsheet.

d. Diver positioning system specifications

When the exact position of a swimming diver needs to be recorded, such as during the nearshore hardbottom edge survey described below, the following are recommended for the positioning system. The diver should tow a buoy with a DGPS antenna mounted on it, attached by a cable to the positioning system. The buoy should be on the shortest possible tether, such that it is directly over the diver. An option for a positioning system is a Trimble AgGPS with Pro Beacon (though an equivalent system may be used) interfaced with the HYPACK Hydrographic Data Collection and Processing Program with correction from a U.S. Coast Guard Navigational Beacon. The locator, which automatically acquires and simultaneously tracks GPS satellites, should precisely measure code phase and Doppler phase shifts, and compute time, latitude, longitude, height, and velocity once per second. The positioning data should be tracked using the HYPACK program (or equivalent). Data should be backed up regularly to guard against loss.

2. Habitat characterization and mapping prior to project construction

Habitat characterization and mapping prior to submission of the application is required for all projects containing hardbottom resources, including new permits or major modifications to existing permits, and particularly for projects in areas where mapping has not been done before, or where previous mapping efforts did not include the entire project area. Exceptions, at the discretion of the Department, can be made for projects that have recently been monitored. In addition to later aiding in the development of the biological monitoring plan, and the establishment of the permanent monitoring grid, initial hardbottom characterization and mapping is crucial to the permitting process as it provides information on the type(s) of habitat(s) within the project area necessary for UMAM analysis (if required), pursuant to Rule 62-345.400, F.A.C.

Habitat characterization and mapping provides information on the hardbottom habitat(s) in the project area necessary to determine if the entire project will be evaluated in UMAM as one assessment area or as multiple, different assessment areas. According to Rule 62-345.200 (1), F.A.C., an assessment area is all or part of a site that is sufficiently homogeneous in character such that impact can be assessed as a single unit. Thus, information obtained during the initial habitat survey and mapping enables the Department to determine whether resources are heterogeneous enough to warrant separating the site into more than one assessment area.

Hardbottom characterization and mapping goals:

- Delineate boundaries between distinct hardbottom habitat types to determine the number of assessment areas within the project area, Rule 62-345.200 (1), F.A.C.
- Determine the acreage of each assessment area, Rule 62-345.400 (3), F.A.C.
- Classify community type(s) present in each assessment area, Rule 62-345.400 (5), F.A.C.
- Evaluate uniqueness of flora and fauna in each assessment area, Rule 62-345.400 (6), F.A.C.
- Provide information needed to accurately characterize the ecological values and functions provided by each assessment area, including but not limited to the provision of substrate and the potential for wildlife use, Rule 62-345.400 (7, 8, and 10).

To meet these goals, hardbottom habitats within the project area shall be quantitatively and qualitatively characterized prior to submission of the application. Habitat characterization should usually take place the summer prior to the submittal of the application. The Department recommends performing the quantitative and qualitative pre-construction characterization according to the methodology described below (Sections B.2.a-c) and the classification system detailed above (Section A.1). According to the Department's recommended methodology and classification system, characterization and delineation of hardbottom types should be based on differences in landscape features (*e.g.*, relief, sediment cover, and benthic communities) at a scale of 10's of meters. The information/data needed to properly characterize and map hardbottom habitat within the project area are collected and developed through desktop work as well as *in situ* reconnaissance surveys. Generating a preliminary habitat map of the project area is the first step in the recommended process. The preliminary map should then be verified, corrected, and added to according to the results of the *in situ* reconnaissance survey. This work will culminate in a habitat characterization statement and a hardbottom characterization map.

a. The preliminary habitat map

Information available on the condition and distribution of hardbottom resources shall be used to qualitatively characterize the assessment areas, pursuant to Rule 62-345.400, F.A.C. This information typically includes all available data, including historical and current aerial photographs, previous biological monitoring data, physical data, bathymetric information (*e.g.*, LIDAR), and any other applicable information for the project area. The qualitative characterization work will include the following three tasks: 1) estimating the distribution of hardbottom;

2) estimating the persistence of hardbottom; and 3) estimating the position of hardbottom (distance from shore and the predicted ETOF to the hardbottom edge, also the depth of water), within the project area. Other location and landscape features should also be evaluated; for instance, proximity to major channels, inlets, outfalls, and any other major man-made structures (including artificial reefs) and natural resources (*e.g.*, mangroves and seagrass beds). The preliminary habitat map of potential hardbottom as well as any existing *in situ* data for the project area should be used by the monitoring crew to prepare for the *in situ* reconnaissance survey conducted prior to submission of the application. The information below details each of the three recommended desktop tasks and the information that should be used to create the preliminary habitat map.

i. Hardbottom distribution

The existing and historical distribution of hardbottom (nearshore, intermediate, and offshore) within the project area and under the influence of the project (typically 600 m updrift, 1 km downdrift, and 300 m seaward of the predicted ETOF) should be determined.

ii. Distribution of hardbottom categorized by persistence of exposure

Based on the review and comparisons of historical and current hardbottom coverage, hardbottom areas within the project area should be assigned to one of the following four categories of hardbottom persistence (see "types" below). Each type should be delineated and identified on the preliminary habitat map.

1. Persistent hardbottom that is currently exposed
2. Ephemeral hardbottom that is currently exposed
3. Ephemeral hardbottom that is currently not exposed but that has the potential to be re-exposed (based on historical evidence of exposure)
4. Ephemeral hardbottom that is currently not exposed and has a low potential of being re-exposed (based on historical evidence of exposure)

iii. Hardbottom position

The distance from both the shore and the predicted ETOF to the landward hardbottom edge should be estimated based on the design of the project and on the current and historical distribution of hardbottom. The depth of water over hardbottom areas should also be estimated.

b. In situ project area reconnaissance survey

An *in situ* reconnaissance survey shall be used to delineate the hardbottom edge, and to gather information/data on the physical and biological features of the hardbottom in the project area, all of which are required to complete UMAM, pursuant to Rule 62-345.400, F.A.C. The survey should also be used to verify and correct, as needed, the preliminary habitat map. Towed video surveys are not sufficient for any of the tasks mentioned above, and should not be substituted for *in situ* reconnaissance survey work. The preliminary map (desktop-created) of all potential hardbottom locations should be used by the monitoring crew to plan the *in situ* reconnaissance survey; for example, to determine the number, length, and configuration of temporary transects that shall be used to rapidly survey the area during the characterization stage.

i. Verification of the preliminary hardbottom map

As part of the *in situ* reconnaissance survey, monitoring crews should verify the distribution and persistence categorization of all potential hardbottom within the project area and under the influence of the project, as shown in the preliminary map. Divers should use a diver positioning system while doing so, and particular attention should be paid to transitions between different hardbottom areas. Physical and biological features of the hardbottom that are also assessed and measured during the reconnaissance survey (see section B.2.b.iii below) can assist in verifying the persistence of hardbottom exposure as delineated in the preliminary hardbottom map. For example, sediment depth measurements along with sediment cover and biotic assemblage observations can provide additional information that can be used to verify persistence of hardbottom exposure in an area. Seismo-acoustic surveys may also be used, but not in lieu of in water surveys.

ii. Hardbottom edge delineation

The full, project area extent of the nearshore hardbottom edge (the visible border between the sand and hardbottom) shall be delineated during the *in situ* reconnaissance survey. If sand cover over hardbottom is intermittent, and benthic components are observed protruding through the sediment, then the emergent epifaunal edge (defined as the landward most edge of the area where benthic components are protruding) should be delineated in these areas. Even if a hardbottom edge is visible, the shoreward most limit of the epifaunal edge (if present) should be mapped as the hardbottom edge. The distribution of hardbottom will influence the way in which the edge is mapped; for instance: 1) when hardbottom is distributed as narrow strips (width less than 30 m), both the offshore and landward edges should be mapped; and 2) when hardbottom occurs in patches, the entirety of each patch should be outlined. Discussing possible techniques/methods with BIP resource staff is recommended prior to mapping the hardbottom edge in complex situations.

The hardbottom edge shall be mapped by a diver swimming with a positioning system (as described in section B.1.d). The diver should swim at a speed conducive to maintaining the buoy on as short a tether as possible, in order to accurately map the edge with minimal influence from waves, currents, and wind. As the hardbottom edge is mapped, its relief characteristics should be recorded. It is recommended that the relief characteristics of the hardbottom edge be recorded as: low (> 0.3 m), medium (0.3 m – 1 m), or high (> 1 m]) relief. Results from this mapping should also be used to verify the distance from both the shore and the predicted ETOF (according to the design of the project) to the hardbottom edge.

iii. In situ survey of physical and biological hardbottom features

The aim of this *in situ* survey is to gather information (observations and measurements) about the physical (*e.g.*, relief, substratum type, and sediment cover) and biological (*e.g.*, composition and distribution of communities) features of the project area. Differences in landscape features (physical and biological) at a scale of 10's of meters should be used to classify hardbottom types for the overall characterization and mapping of the project area (refer to classification section).

Temporary transects should be used to survey the project area. The number and lengths of transects should be great enough to ensure the project area is adequately characterized at a scale of 10's of meters. A fishbone style temporary transect grid, consisting of parallel transects arranged along (and perpendicular to) a central transect line (Figure 1 below) is a useful configuration for such surveys. Other temporary transect grid-

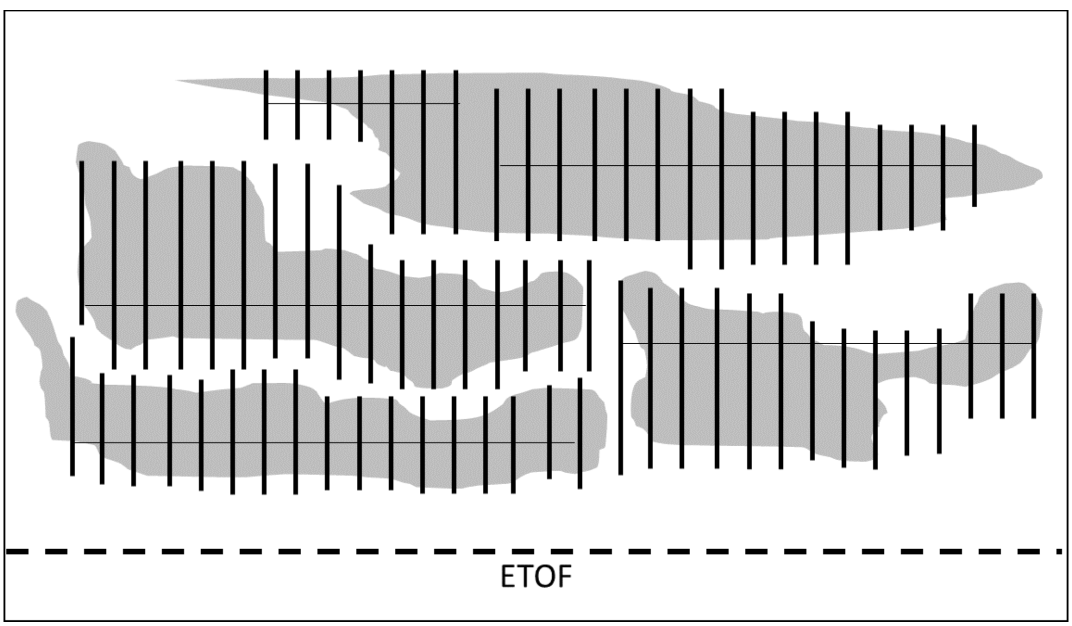

Figure 1. Fishbone style temporary transect configuration for an *in situ* reconnaissance survey. The white background represents sediment, grey shapes

represent hardbottom, solid black lines represent transect lines, and the dashed black line represents the predicted ETOF. The distance between parallel transects is 10 m.

configurations (*e.g.*, zig zag, concentric circles, *etc.*) may also be used, so long as hardbottom within the project area can be adequately characterized at the specified scale.

(1) *Physical hardbottom features*

Three physical features should be identified and mapped: relief, substratum type, and sediment within hardbottom areas.

(a) *Relief*

Relief is measured as the height of positive relief features relative to adjacent negative relief features (see section A.1.b.i). For the purposes of characterizing hardbottom habitats, the Department recommends measuring relief at three different scales:

<u>Small scale</u> relief should be assessed quantitatively over single meters at a minimum, and at a distance of less than 5 m at a maximum, by taking water depth readings at upper and lower points of relief features using a depth gauge. Small scale relief should be expressed using the following three categories of relief: <u>Low relief</u> (less than 0.3 m), <u>Medium relief</u> (0.3 to 1.0 m), and <u>High relief</u> (greater than 1.0 m) (see section A.1.b.i for definitions). During surveys divers should measure *small scale* relief (multiple measurements per area), and in particular note areas that share the same sort of relief features and areas where relief types change.

<u>Intermediate scale</u> relief should be assessed over distances of 10's to 100's of meters. Intermediate scale relief should be assessed and expressed qualitatively, by describing the uniformity of small scale relief features (*i.e.*, the distribution of areas sharing similar degrees of small scale relief).

<u>Large scale</u> relief should be assessed over distances of 100's to 1000's of meters. Large scale relief is best assessed and expressed qualitatively, by describing the uniformity of intermediate scale relief features (*i.e.*, the distribution of areas sharing similar degrees of intermediate scale relief). In some instances, large scale relief may be further described by indicating the presence of specific

relief features, like ridges formed by a second reef laying seaward of nearshore hardbottom.

(b) *Substratum type*

Six main types of marine hard substratum are generally encountered in Florida, and more than one type may be found at a given site. Divers should record the types of hard substratum present with the project area and delineate their distributions. Divers shall distinguish worm rock (alive or dead) from other substrata, and should also distinguish among Anastasia limestone, reef-rock, sand-stone, rubble, and anthropogenic material (see section A.1.b.ii for a description of each substratum type).

(c) *Sediment within hardbottom areas*

Information on the distribution of sediment patches within areas of exposed hardbottom aids in the characterization of the project area and in the classification of different habitats. Sediment within hardbottom areas, such as patches of buried or dusted hardbottom should be evaluated: a reasonable number of sediment thickness measurements should be taken and the general location of the findings recorded. The general location, size, and depth of larger sediment patches should also be recorded and the general character of the sediment in each patch should be noted (coarse vs. fine).

(2) *Biological hardbottom features*

Information on the flora and fauna and the communities they comprise should be collected. Observations, counts, and measurements should be detailed enough to adequately characterize and classify the biological features of the hardbottom and to roughly delineate their distributions within the project area.

(a) *Community information*

Divers shall collect and record information (based on observations and counts) on species richness, the abundance and diversity of functional groups, and the presence of dominant species or groups. These data will be used to classify hardbottom within the project area by their community type. Dominant organisms are typically used to identify types of communities (*e.g.*, turf algae community; mixed turf and fleshy algae community; mixed fleshy algae, scleractinian/octo coral, and sponge community). Information on the richness and diversity of functional groups shall be used to further describe (in the characterization report and hardbottom habitat characterization map) and subdivide community types within the project area. For each community type, the distribution shall be delineated and the acreage calculated.

Several measurements of the size of organisms in groups of interest (*e.g.*, scleractinians and octocorals, sponges) should be made. Measurements should provide information on the average size of organisms as well as the size of the largest individuals/colonies within the assessment area. The presence and rough size of recruits should also be noted. These data provide a reasonable approximation of the age of a community, and therefore can be used to assist in verifying the distribution of hardbottom types based on their persistence of exposure.

(b) *Indicator species*

The presence of species, or groups of species that tend to indicate general environmental conditions should be recorded. For example, the absence of species or groups that are more vulnerable to sediment (*e.g.*, macroalgae and octocorals) in an area where species or groups that are more tolerant of sediment (*e.g.,* turf algae) are present wound tend to indicate the area is prone to sediment stress. In a similar way, the presence of abundant cyanobacteria in an area would tend to indicate high nutrient levels.

(c) *Listed species*

The presence and general abundance of any listed or invasive species observed within the project area during reconnaissance shall be recorded. The general location/distribution of sessile listed/invasive species shall also be recorded. All listed/invasive organisms shall be identified to species level (or to lowest taxonomic level possible).

c. Hardbottom characterization map and report

Findings from the desktop analysis and the *in situ* survey of physical and biological hardbottom features shall be provided to the Department in a habitat characterization report and as a habitat characterization map. The characterization report and map will be used to complete UMAM (pursuant to 62-345.400, F.A.C.) and to develop the monitoring methodology (*e.g.*, number and position of permanent transects and sampling stations) that will be used for subsequent surveys, including pre-construction and post-construction hardbottom monitoring.

i. Habitat characterization map

The habitat characterization map will be based on the preliminary desktop work and the *in situ* reconnaissance survey and should be supplied to DEP as a collection of shapefiles (preferably as an ESRI file geodatabase). The following GIS data should be provided:

1. Polygons representing the distribution of hardbottom types that differ in their persistence of exposure should be provided for the entire project area (see sections B.2.a.i, B.2.a.ii, and B.2.b.i). Data should have attributes indicating each of the different hardbottom persistence types present.

2. Lines or polygons representing the *in situ* mapped hardbottom edge. This may be a single line representing the nearshore edge, two lines representing the nearshore and offshore edges, or polygons representing hardbottom patches, depending on the distribution of hardbottom (see section B.2.b.ii). These data should have attributes indicating which portion of each line or polygon represents hardbottom, emergent epifauna, or sand.

3. Lines or polygons representing *in situ* measured hardbottom edge relief. These data should have attributes indicating hardbottom relief as Low (less than 0.3 m), Medium (0.3 to 1.0 m), or High (greater than 1.0 m) (see section B.2.b.ii).

4. Polygons representing physical relief within the project area at the intermediate scale (10's to 100's of meters) (see section B.2.b.iii.(1).(a)). Physical relief data should have attributes indicating Low (less than 0.3 m), Medium (0.3 to 1.0 m), and High (greater than 1.0 m) relief.

5. Polygons representing substratum type within the project area (see section B.2.b.iii.(1).(b)). Substratum data should have attributes indicating worm rock (alive or dead), Anastasia limestone, reef-rock, sand-stone, rubble, and anthropogenic material (see section A.1.b.ii for a description of each type).

6. Polygons representing the distribution of different community types within the project area. Community data should have attributes indicating each different community type, as determined by the dominate biotic features of the surveyed assemblages (see sections B.2.b.iii.(2).(a) and (b)).

7. Polygons representing the distribution of all sessile listed species within the project area (see sections 2.b.iii.(2).(c)). Data should have attributes indicating the distribution of each listed species.

ii. Habitat characterization report

A detailed description (characterization) of the project area shall be submitted to the Department. The characterization report shall be based on data gathered during the *in situ* reconnaissance survey, data presented in the habitat characterization map, and knowledge of the project area and the surrounding landscape. The Department recommends the document consist of two main sections: I) methods, and then II) results. The Departments recommended format and the information required to run UMAM, if necessary, are described below.

The methods section should provide a detailed description of the methods used to produce the preliminary habitat map (desktop work) and to conduct the *in situ* reconnaissance surveys. The results section should provide a comprehensive description of hardbottom habitats and communities within the project area as well as additional information required to complete UMAM.

The results section should consist of three main subsections, one for each UMAM indicator: *(1)* Hardbottom habitat/community types (their classification and distribution); *(2)* Location and landscape support; and *(3)* Water environment. Each UMAM indicator subsection (1-3 above) should contain two parts: *(a)* a description for the indicator; and *(b)* a final brief evaluation for the indicator. Details for each UMAM indicator are provided below.

(1) *Hardbottom habitat/community types*

(a) *Description*

The distribution and quality of habitats and communities within the project area reflect a balance of water temperature, salinity, nutrients, water quality, and the presence of nearby productive hardbottom, mangrove and seagrass communities. All of these communities are susceptible to human disturbance through direct physical damage, such as dredging, filling, or boating impacts, and to indirect damage via changes in water quality, currents, and sedimentation.

The hardbottom habitat/community description shall include classification of different hardbottom habitat/community types. These hardbottom habitat/community types shall be classified by both their habitat characteristics (*e.g.*, position with respect to the shore and the predicted ETOF, duration of hardbottom exposure, and their physical features like relief, substratum type, water depth, and sediment cover) and by their biological features (*e.g.*, species richness, organismal abundance, diversity of functional groups; and presence of dominant, indicator, listed, and invasive species).

The following attributes are identified in Rule 62-345.500(6)(c), F.A.C. to evaluate the "Community Structure" category. These attributes should be taken into account when writing the hardbottom habitat/community description. For some attributes, information may need to be provided in addition to the description of hardbottom habitat/community types.

<u>Attributes:</u>

- Species number and diversity of benthic organisms:
  The appropriateness, number, and diversity of benthic organisms should be evaluated.
- Listed, non-native or inappropriate species:
  Species should be identified and their abundances and distributions should be evaluated.
- Regeneration, recruitment and age distribution:
  Natural regeneration and recruitment should be noted, as well as evidence of appropriate age distribution (based on organism size).
- Condition of appropriate species:
  The health and biomass of appropriate species should be evaluated.
- Structural features:
  Whether the structural features in the project area are appropriate for the system or whether there is evidence of physical impact should be evaluated.
- Topographic features such as relief, stability, and interstitial spaces (hardbottom and reef communities):
  The appropriateness and condition of topographic features such as relief, stability, and interstitial spaces for hardbottom and reef communities should be evaluated.
- Spawning or nesting habitats:
  The condition and number of spawning and nesting habitats such as rocky or sandy bottoms should be assessed.

(b) *Final Evaluation*

For each community type, provide a final brief evaluation of whether or not the benthic community is indicative of conditions that provide optimal support for all of the functions typical of the assessment area and provide optimal benefit to marine organisms. If the benthic communities do not fully support the functions identified and do not fully provide benefits to marine organisms, then this information should be briefly described.

(2) *Location and landscape support*

(a) *Description*

The value of functions provided by the hardbottom within the project area to marine organisms are influenced by the location of the landscape and its relationship with surrounding areas. If surrounding habitats are unavailable, poorly connected, or degraded, then the value of functions provided by the hardbottom area to marine organisms is reduced. The availability, connectivity, and quality of offsite habitats, and offsite land/water uses which might adversely impact marine organisms utilizing these habitats are factors to be considered in characterizing the hardbottom habitat.

The following attributes are identified in Rule 62-345.500(6)(a), FAC to evaluate the "Location and Landscape Support" category. These attributes should be taken into account when writing the location and landscape support description. Specifically, provide a brief description of each of the following attributes:

<u>Attributes</u>:

Proximity of hardbottom within the project area to:

- Other natural communities, such as hardbottom, mangroves, and seagrass)
- Sources of larvae from benthic communities similar to the project site
- Mitigation areas (artificial hardbottom such as limestone reefs)
- Inlets or other significant relief features (*e.g.*, sand bars)
- Groins or other structures that may alter coastal processes
- Channels or areas of chronic (*e.g.*, maintenance) dredging
- Acute or chronic sources of turbidity
- Outfalls or other known sources of pollutants

(b) *Final Evaluation*

Provide a final brief evaluation of whether or not the hardbottom area within the project area is ideally located such that the surrounding landscape provides opportunity for the hardbottom area to perform beneficial functions at an optimal level. If the location of the hardbottom area limits its opportunity to perform beneficial functions, thereby reducing its optimal ecological value, then this information should be briefly described.

(3) *Water environment*

(a) *Description*

Water depth, wave dynamics and currents, water clarity and quality, as well as water use (*e.g.*, recreational or industrial activities) may facilitate or preclude the water environment's ability to perform certain functions and may benefit or adversely impact its capacity to support certain organisms. If the water environment is degraded, then the value of functions provided by the hardbottom area to marine organisms is reduced. Accordingly, these aspects of the water environment are factors to be considered in characterizing the hardbottom habitat within the project area.

The following attributes are identified in Rule 62-345.500(6)(b), FAC to evaluate the "Water Environment" category. These attributes should be taken into account when writing the water environment description. Specifically, brief descriptions for each of the following with respect to the project area shall be provided.

<u>Attributes:</u>

- Existing water quality data
- Water depth, wave dynamics/energy, currents and light penetration
- Use by species with specific hydrological requirements
- Biological indicators – presence of species or groups tolerant of or susceptible to water quality degradation/flow alteration

(b) *Final Evaluation*

Provide a final brief evaluation of whether or not the hydrology, water quality, and hydrodynamics support functions and provide benefits to marine organisms at optimal capacity for the assessment area. If the water environment in the hardbottom area exhibits reduced support functions, thereby limiting benefits to marine organisms, then this information should be briefly described.

3. Establishment of permanent transects (and offshore stations)

Following identification of potential hardbottom (section B.2.a above) and creation of the habitat characterization map (see section B.2.c.i above for details), locations of permanent sampling transects will be finalized. Transects are intended to be positioned to ensure that the variability in the hardbottom habitat is captured by their permanent locations, and so that areas between transects can be evaluated by the interpolation of data between adjacent transects. Transect are to be permanent once established to ensure repeatability among surveys.

Strategically plotted permanent transects will be used to document changes over time in hardbottom communities and habitats under the influence of the project (*i.e.*, adjacent to the fill template and usually 600 m updrift and 1000 m downdrift). For the purposes of detecting hardbottom impacts associated with beach nourishment, the zone of interest generally extends seaward from the predicted ETOF out to 300 m. The standard length of monitoring transects is therefore between 150 m and 200 m (project dependent), though the actual permanent lengths of transects will vary depending on the width (distance in cross-shore direction) and the configuration of exposed hardbottom during the pre-construction survey. The following two paragraphs and Figure 2 provide examples of how the width and the configuration of hardbottom influence the length and density of transects. Transects should start at the nearshore hardbottom edge and extend seaward. In cases where the predicted ETOF crosses hardbottom, transects should start at the predicted ETOF and extend seaward; in all other cases, transects should start at the nearshore hardbottom edge. During the pre-construction (baseline) survey, the entire standard length (*e.g.*, 150 m or 200 m; project specific) of each transect should be surveyed to determine the positions of the nearshore and offshore hardbottom edges. These positions establish the permanent length of each transect; once established, these transect lengths should be monitored in full in all subsequent surveys.

Hardbottom width during the baseline survey will influence the permanent length of monitoring transects. For example, if the width of the hardbottom area is less than the standard transect length, then the width of the hardbottom will define the length of the transect (Figure 2A, middle transect). However, if the width of the hardbottom is greater than the standard transect length, then all associated monitoring will terminate at the seaward end of the standard transect line (*e.g.*, at meter 150) (Figure 2A, left hand transect). In this case, the 150 m long transect line defines the extent of monitoring. If the nearshore hardbottom edge is located more than 150 m from the predicted ETOF, then the length of the transect may be reduced to 100 m (or less, depending on the width of the hardbottom), but all transects used to monitor this hardbottom area should start at the nearshore hardbottom edge (see Figure 2A, right hand transect).

The configuration hardbottom during the pre-construction survey will also influence the length of permanent transect lines. In cases where the hardbottom is fragmented by broad shore parallel areas of sand, each transect should end at the seaward hardbottom edge, or at the end of the standard transect length (*e.g.*, 200 m in this case), whichever is shorter (Figure 2B, middle and left hand transects, respectively). These broad sand areas will be captured during the survey using the line-intercept method (see section C.3.b.i.(1) below), and they should be recorded and reported as sand patches/troughs. When exposed hardbottom in the monitoring area exists as very narrow strips of hardbottom (the width of the majority of hardbottom strips are less than 50 m in the cross-shore direction), then shorter transects should be used (*i.e.*, the width of hardbottom determines the transect length). However, in such a situation, a greater number of transects should also be used (*i.e.*, multiple short transects per narrow strip of hardbottom) to better characterize the monitoring area (Figure 2B, right hand transects).

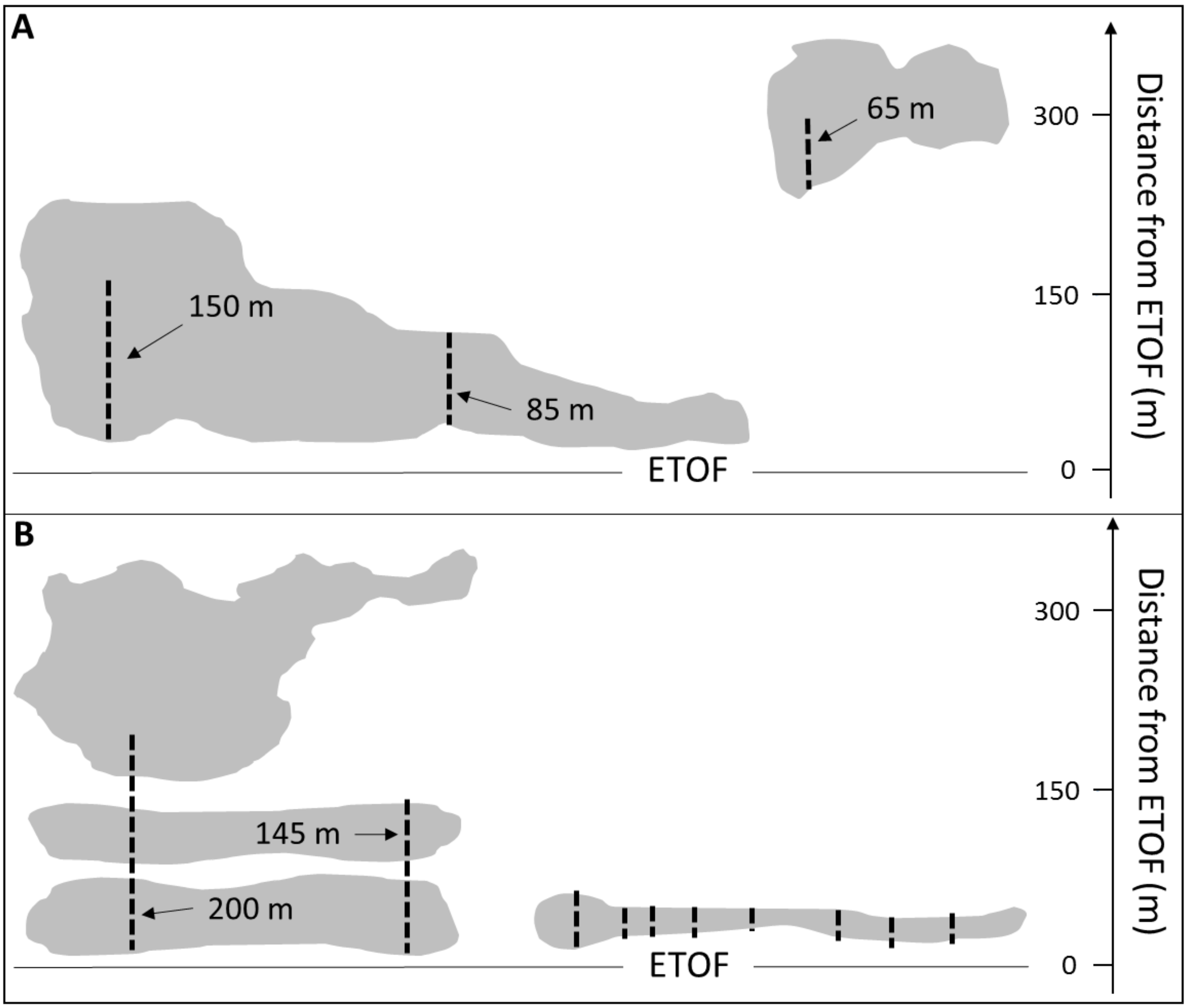

Figure 2. Depictions of transect lengths and densities by hardbottom width (cross-shore direction), location, and configuration. **A**. Transect line lengths (m) for nearshore wide and narrow hardbottom areas. Transect line length for an area of hardbottom farther offshore is also

provided. **B**. Transect line lengths for hardbottom fragmented by broad shore parallel areas of sand. The density of short transect lines for an area of hardbottom represented by a narrow strip is also provided. For A and B, hardbottom is represented by filled grey shapes and transects are represented by dashed black lines. Transect lines lengths are provided with arrows indicating the transect to which they are paired. In each figure, the position of the predicted ETOF relative to the hardbottom is provided (see inset label and the scale on the vertical axis indicating distance (m) from the predicted ETOF).

In certain projects, "offshore" areas (hardbottom in water depths of 8 to 12 m) and "borrow" areas may also be included in monitoring requirements. Offshore areas should be monitored using offshore "stations" made up of several permanent sampling quadrats, or small transect / quadrat sampling stations. Borrow areas should be monitored using the same protocols as those described for the project area (habitat monitoring). For both offshore and borrow areas, specific monitoring protocols will be designed in consultation with DEP personnel.

C. Annual hardbottom monitoring standard operating procedures

The standard operating procedures described herein provide consistent and repeatable annual monitoring methods to document sediment dynamics and changes in hardbottom communities. Their use ensures that annual monitoring tasks will be performed consistently among projects over time. The aim of these tasks is to measure and document any unpermitted direct and/or secondary (indirect) impacts occurring from the spread of project sand (further than predicted) and increased sediment accumulation in the monitoring area.

Five biological monitoring surveys, each conducted in the summer time, are typically required in Joint Coastal Permits for nourishment projects (see surveys below). The Department may agree to monitoring outside of the summer season, but all monitoring surveys would still need to be conducted in the same season to ensure comparability among surveys. The following surveys are typical for monitoring conducted under Joint Coastal Permits:

- A *pre-construction survey* conducted the summer prior to construction; this survey serves as the baseline survey for all subsequent monitoring.
- An *initial post-construction survey* shortly after project completion (preferably within 6 months).
- *Annual post-construction surveys* conducted for 3-5 years; these survey are used to verify whether unpermitted impacts to nearshore hardbottom resources have occurred as a result of the project.

All post-construction surveys are intended to be conducted in the summer, as close to the date of the baseline survey as possible. If applicable, surveys should also be conducted as close to the date of the summer aerial photo as possible, preferably within 20 days.

The following three *in situ* survey components are typically required by Joint Coastal Permits and are intended to be conducted during each monitoring event (includes pre- and post- construction monitoring): 1) ground-truthing of hardbottom to verify areas defined in aerial photographs (and/or side-scan or multi-beam sonar; this requirement is project specific); 2) hardbottom edge delineation; and 3) shore perpendicular transect surveys (and offshore stations/borrow areas, if required). These *in situ* surveys are used to document the nearshore boundary between sand and exposed hardbottom, the physical relief, sediment cover and depth, species and functional group dominance and abundance, and size structure of organisms in the monitoring area. Monitoring methods for each of the *in situ* surveys are described in detail below, and data analysis and reporting procedures are provided in section D.

1. Aerial photograph verification: ground-truthing of hardbottom distribution

Diver verification of hardbottom areas identified in aerial photographs (and/or side-scan or multi-beam sonar) is project specific, and may be required by the Permit/Monitoring Plan in addition to the hardbottom edge survey. This survey should be comprehensive enough to verify edges of patchy hardbottom, and should focus on delineating and verifying hardbottom borders. Bounce dives are not sufficient for this task, and should not be used to verify presence / absence of a particular patches of hardbottom. Specifications and technical details for Physical Monitoring (including aerial photography for environmental assessment) are provided in the DEP document "Monitoring Standards for Beach Erosion Control Projects" (dated May 2014) which may found on the DEP website at the following location: http://www.dep.state.fl.us/beaches/publications/tech-rpt.htm#RegionalMonitoringPlan .

2. Hardbottom edge survey

Delineation of the nearshore hardbottom edge provides information on hardbottom exposure within the project area and allows determination of any direct impacts due to hardbottom burial by project fill. The nearshore hardbottom edge is defined as the visible boundary between the sand and the hardbottom. If sand cover over the hardbottom is intermittent, and benthic components are observed protruding through the sediment, then this edge, known as the emergent epifaunal edge, should serve as the hardbottom edge in these locations. In such a situation, the hardbottom edge should be delineated as the edge of the area where benthic components are protruding from the sediment. Even if a hardbottom edge is visible, the area where benthic components are protruding from the sediment should be used as the hardbottom edge.

Joint Coastal Permits typically require the entire length of the hardbottom edge in the area under the potential influence of the project to be mapped by a diver swimming with a positioning system, as described in section B.1.d. Bounce dives should <u>not</u> be used to delineate the hardbottom edge. The Department may agree to changes in this methodology if sufficient justification is provided (submit requests to BIP resource staff). During edge delineation, the diver should swim at a speed conducive for maintaining the buoy on as short a tether as possible, in order to accurately map the hardbottom edge, with minimal influence from waves, current, and wind. As the hardbottom edge is mapped, the relief characteristics of the edge should be recorded according to project-specific classification of the relief (*e.g.*, low, medium, high relief). Gaps/breaks in the hardbottom edge produced by areas of deep sediment greater than 1 m across should be noted during the edge survey.

Hardbottom edge delineation should use GIS-based desktop analysis of aerial photographs as described above, and *in situ* mapping should be compared and contrasted with aerial photographs. Hardbottom edge *in situ* mapping should be conducted as close as possible to the aerial photography survey in order to have a comparison of two different methods of hardbottom edge delineation. See section D.2 for reporting of raw data following surveys.

The hardbottom edge survey will aid in the determination of direct impacts from nourishment projects; for example, a seaward shift in the hardbottom edge indicates a loss of hardbottom, whereas a landward shift in the edge indicates a gain in hardbottom. The permanence of any direct impacts will be evaluated by examining the position of the hardbottom edge in subsequent surveys.

3. Transect survey methodology

During each annual monitoring event, each permanent, shore-perpendicular transect is surveyed according to the methods described in this section. Along each transect, the following are taken/conducted pursuant to permit requirements: a video survey, interval sediment depth measurements, line-intercept measurements, and quadrat sampling.

a. Transect set up

Prior to data collection during each monitoring event, divers will set up permanent transect lines by extending taught measurement tapes or weighted lines with clear meter marks along their entire length. Meter marks on transects should be able to be recognized and used by surveyors in the field, and visible in all video collected. The beginning and end of each transect should be secured by a permanent stainless-steel pin[2]. Two (2) or three (3) additional smaller pins or nails should be used to mark the beginning and end of each transect in case the initial pin is lost. Stainless steel pins or nails should also mark the corners of each quadrat. Any other method that would aid in the establishment of permanent marker may also be used (*e.g.*, small pyramids created by cementing small boulders together or small cinderblocks cemented to the benthos). GPS-coordinates and water depth measurements (using calibrated diver's depth gauge) are to be recorded at least every 50 m along each transect to allow transect positions to be restored if pins are

[2] Note: Several smaller pins should also be installed along each transect (*e.g.*, a nail at each 5th meter mark) to better guide the permanent transect and increase the repeatability of the survey, as well as to guide the placement of quadrats [see next section].

lost. Annual maintenance of pins/nails used to mark positions is highly recommended. If the exact location of a permanent sampling station (quadrat/transect) cannot be relocated due to lost markers, the monitoring report should describe the methods used to re-establish the sampling station (quadrat/transect) (see section D.3).

b. Transect sampling

To minimize sediment disturbance, interval sediment depth measurements and line-intercept measurements should be the first data collected following transect set up. Video data and benthic quadrat surveys may then occur in any order. Transect sampling includes all data collections listed below, unless transects are specified to be "sediment only". The applicant's agent may be required by the permit to establish "sediment only" transects in situations where logistical constraints prohibit the collection of all data (*e.g.*, BEAMR) along all transects; for instance, in circumstances that require more accurate/detailed data on sedimentation and sediment dynamics, or for projects where a greater number of transects are needed to characterize the habitat due to the high heterogeneity of the hardbottom or the large size of the project area. Sediment only transects are intended to be established in the same fashion as full-protocol transects; however, only interval sediment depth and line-intercept measurements are to be taken along their lengths. See section D.2 for reporting of raw data following surveys.

i. Sediment: interval depth measurements and line-intercept surveys

Sediment depth measurements via the interval sediment depth method and sediment patch size/position measurements via the line-intercept method will be conducted along each transect to track changes in sediment cover (over time and space) on the hardbottom within the project area. These surveys should be conducted first during each monitoring event, after transects are set up, in order to measure undisturbed sediments.

(1) *Interval sediment depth measurements*

Sediment depth is to be measured every meter along the entire length of each permanent transect, inclusive of sand patches. For each measurement, a stainless-steel ruler, graduated in centimeters (0 to 30 cm), should be pressed through the sediment until the ruler reaches the surface of hard substrate or is totally immersed in sand. Sediment depth should be measured and recorded to the nearest centimeter; rounding should be used to achieve this (*e.g.*, sediment thickness less than 0.5 cm should be recorded as "0", while thickness greater than 0.5 cm, but equal or less than 1 cm, should be recorded as "1 cm", *etc.*). Measurements greater than 30 cm should be recorded as "> 30 cm".

All depth measurements should be recorded in a table printed on waterproof paper, labeled in 1 m increments; the transect number should also be reported for each of these tables. Measurement sheets should be checked for accuracy and completeness immediately after each dive and sheets should be scanned or photographed, preferably the day of the survey.

(2) *Line-intercept surveys of sand patches*

Line-intercept surveys are used to document areas of uninterrupted sand (patches and troughs) greater than 0.5 m in length along the transect line that lack protruding hardbottom benthic components. The landward and seaward edge of each sand patch/trough should be recorded during the line-intercept survey by reference to meter marks along the transect.

ii. Digital video and photo documentation of transects

Digital video transect surveys serve as archival data sets for resolution of unclear quadrat and sediment survey data. As mentioned above, a line or tape should be extended along the entire length of each transect prior to the video for accurate video reference. During the survey the videographer will swim at a rate no faster than five (5) meters per minute, and will hold the camera at a height of 40 cm above the hardbottom. A convergent laser guidance system should be used to help maintain the height of the camera.

A standard underwater display should be videotaped at the beginning and end of each transect and integrated directly onto the digital video record. The standard display should report the following:

- Standard JCP permit number (*e.g.*, 0163435-001)
- DEP monument number (*e.g.*, R-103.5);
- Transect number as 4 digits based on monument number (*e.g.*, 1035)
- Survey date (*e.g.*, 06/25/2013);
- Water depth in meters for both the start (meter 0) and end (final meter) of the transect (*e.g.*, start depth = 2m, end depth = 4.5m);
- Any pertinent notes.

Additionally, a 360^{o} panoramic view should be recorded both at the start and end of each transect from an elevation of about 1 m above the benthos at an angle of about 30^{o} to the horizon. GPS navigational coordinates (Florida State Plane Coordinate System, East Zone NAD 83) of the video transect locations are to be overlaid on recent aerial photographs and included in the project monitoring reports.

In addition to video, representative digital photographs of quadrats or organisms/conditions of importance may also be required by permit condition or included in the monitoring plan or may be provided by the monitoring firm as supporting information. Please limit possible confusion by sorting and clearly labeling photographs (folders and subfolders) when submitting them to the Department. See section D.2 for video and photo reporting guidelines.

iii. Quadrat data collection

Joint Coastal Permits typically require benthic communities and their habitats to be characterized quantitatively using the quadrat method, which includes sampling habitat and assemblages within permanently positioned quadrats along each transect[3]. The intent of this protocol is to ensure that the same quadrats (same location and size) are sampled in each annual survey in order to document changes in communities over time.

Quadrats 1.0 m^2 (preferred) or 0.5 m^2 (minimum) in size typically are used to sample the hardbottom community along each transect. The same sized quadrats should be used throughout the entire project area and in each monitoring event; once a quadrat size is selected for a particular project, it should not be changed. Quadrats smaller than 0.5 m^2 should not be used. A sampling area of at least 10 m^2 per 150 m long transect[4] is typical of monitoring conducted for Joint Coastal Permits. Quadrats should be distributed along each transect such that at least 2.5 m^2 of area is sampled in the following zones (enough area to characterize each zone): 0-30 m; 30-60 m; 60-100 m; 100-150 m (or up to 200 m if longer). The number of quadrats established should be weighted such that there is greater sampling towards the nearshore region of each transect.

In order to facilitate repeated sampling of the same quadrats in successive surveys: the northeast corner of each quadrat should align with a particular meter mark on the transect, a pin (or nail or eye-bolt) should be installed to mark the location of each quadrat, and an additional pin/marker should also be installed at the northwest corner of each quadrat. During the pre-construction survey, the permanent positions of all quadrats should be established such that areas covered by sand are avoided *(i.e.*, quadrat placement during establishment shall be biased to include hardbottom).

If in any subsequent survey a quadrat is found to have been completely buried by sand, its position should not be changed (*i.e.*, permanent quadrats

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[3] Note: Benthic quadrat survey methods are subject to revision and development of finer details.

[4] Note: Statistical analysis of data collected during the Habitat Mapping will assist in the estimation of the sampling area for each particular community type. This requirement can be changed to the larger or smaller sampling size per transect. A power-analysis should be conducted before and after the monitoring to aid in determining the monitoring requirement and the interpretation of results.

should at all times remain in their initial [baseline] positions). Quadrats buried by sand are also not to be replaced with new quadrats. Buried quadrats should be recorded as having 100% sand cover (functional group "Sediment" in the BEAMR survey; cover recorded as 100%). The depth of sediment in such quadrats should still be measured and reported (as described in section C.3.b.iii.(1).(a) below).

The quadrat sampling protocol described below is similar to that used in the Benthic Ecological Assessment for Marginal Reefs (BEAMR) (Lybolt and Baron, 2006). Datasheets for quadrat surveys have a standardized layout similar to that used for BEAMR (Figure 3), to simplify data collection and entry for reporting and statistical treatment (see section D.2 for quadrat survey reporting requirements). The data sheet presented in Figure 3 is a rudimentary example; it should be modified to include the information detailed in section C.3.b.iii.(1) prior to use.

Project Name	**Site Name / Transect Name**
Date	**Data Collector**

Quad Label: **Sample Name or #**		List macroalgae Genus % List every coral colony ~and coral condition(s)	% cover or max size (cm)
Max Relief (cm)			
Max Sediment Depth (cm)			
Sessile Benthos…	**% Cover**		
Sediment- (circle all: sand shell mud)			
Macroalgae- Fleshy+Calcareous			
Turf- algae+cyanobacteria (circle all: g r b)			
Encrusting Red Algae			
Sponge			
Hydroid			
Octocoral			
Stony Coral			
Tunicate			
Bare Hard Substrate			
other-…			

Total Must = 100%

Standard Abbreviations: and abbreviation formats	Macroalgae: Pool to Genus = Genu or Genus: Avra, Bryopsis, Bryothamnion, Caul, Codi, Dasya, Dasycladus, Grac, Hali, Hypn, Sarg…
	Octocoral: Genus of each colony = Genu: Gorg, Lept, Plex… except Pseudopterogorgia=Pspt, Plexaurella=Plla, Pseudoplexaura=Pspl
	Stony Coral: Genus species of each colony = G spe: A cer, A aga, C nat, M ann, M cav, P ame, O dif, S rad, S sid, S bou, S hya, S int..
	Coral condition: W=white disease(s), O=other disease(s), B=bleaching, Coral Stress Index # 0 1 2 3
	Other- includes: Anemone, Wormrock, Annelid (excluding wormrock), Barnacle, Bivalve, Bryozoan, *Millepora* sp., Seagrass, Zoanthid.

Figure 3. Rudimentary example of standard BEAMR sheet for data entry (from Baron and Lybolt, 2006). This sheet should be modified to include the information detailed in section C.3.b.iii.(1) below to reflect the new standard operating procedures.

(1) *Quadrat sampling*

Quadrat sampling includes the following measurements, each of which is described in detail below:

- Hardbottom relief measurements (both small and intermediate scales);
- Species documentation (includes percent cover estimates [if > 1%] of biological functional groups such as algae, cyanobacteria, and benthic sessile invertebrates; it also includes specific size measurements of octocorals and scleractinian corals);
- Percent cover of abiotic elements (*e.g.*, sediment, rubble, etc.); and
- Sediment depth measurements.

Small scale hardbottom relief should be measured within each quadrat in terms of the difference in elevation (vertical height) between the lowest and highest points using a ruler; relief should be reported in cm. Intermediate scale relief should be determined by measuring the amplitude of relief within a 5 m radius of each quadrat.

The *in situ* quadrat sampling method is limited to organisms that can be visually recorded and identified in the field. Visual estimates of cover (percent) should be based on a planar view, and all sessile organisms and abiotic elements should be pooled to 21 major functional groups, which consist of: sediments[5], bare hard substratum, rubble, macroalgae[6], turf algae[7], encrusting red coralline algae[8], cyanobacteria[9] (blue-green algae), sponges, scleractinian corals, octocorals, anemones, zoanthids, hydroids, hydrocorals (*e.g.*, *Millepora* sp.), sessile worms (not including *Phragmatopoma* spp.), wormrock, bivalves, barnacles, bryozoans, echinoderms, and tunicates. Each functional group should be given a percent cover value (0-100%, with a minimum of 1%). If cover is less than 1%, then only the functional group or species should be listed. The total cover of all functional groups should sum to 100%.

(a) *Substratum*

Percent cover of sediment, bare substratum, and rubble in each quadrat should be estimated and recorded. Sediments include sand,

[5] Note: Sediments characterized by circling the descriptor on the sheet, or by including a short additional characterization (*e.g.*, rubble, or circled descriptor sand and then + shell hash, *etc.*).
[6] Note: Macroalgae include fleshy macroalgae and geniculate calcareous algae, (*e.g.*, *Halimeda*); record non-geniculate calcareous branching red algae separately.
[7] Note: Turf algae include all algae with thallium less than 10 mm that form dense cover.
[8] Note: Encrusting red coralline (calcareous) algae are to be recorded separately from non-calcareous encrusting and calcareous branching and geniculate algae.
[9] Only Cyanobacteria covering hardbottom or organisms are to be included in percent cover estimates. Cyanobacteria covering sediments should be noted, but not recorded in estimates of cover.

shell hash, and mud (any loose particulate). Additionally, three (3) sediment depth measurements should be taken haphazardly within each quadrat. The mean and standard deviation of these sediment depth measurements should be reported for each quadrat.

(b) *Macroalgae*

See the glossary in Appendix A for a list of groups included within "Macroalgae". The percent cover of macroalgae should be reported as total cover, and further as cover of Chlorophyta, Rhodophyta, and Phaeophyta. The percent cover of all dominant macroalgae (those species/genera with greater than 5% cover) in each quadrat should also be reported. All other macroalgae (those with less than 5% cover per genus) should only be listed, and should be identified to at least the genus level.

(c) *Turf algae, Encrusting red coralline algae, Cyanobacteria, and Seagrass*

Total percent cover should be estimated and reported separately for each of the specified groups. The percent cover of encrusting red coralline algae should be reported separately from the cover of macroalgae. Only Cyanobacteria covering hardbottom or benthic organisms should be included in quadrat percent cover estimates. Cyanobacteria over sand (most often as mats) are to be noted and assessed, but these data are not to be included in the quadrat percent cover estimates; doing so would obscure the percent cover value of the sediment category.

(d) *Sponges*

The total percent cover of all sponges should be estimated and reported. Further, the identities of known common sponge species/genera should be listed (*e.g.*, *Pione lampa*, *Cliona deletrix*, *C. varians*, *Cinachyrella apion*, *C. alloclada, Phorbas amaranthus*, *Desmapsamma anchorata, etc.*).

(e) *Octocorals and Scleractinian corals*

Total percent cover should be estimated and reported separately for each of these groups. Size measurements should also be made and reported for each of these groups. The maximum dimension of each octocoral and scleractinian coral should be measured to the nearest centimeter. The smallest size recorded should be one (1) cm; for colonies less than one (1) centimeter in size (height or width), the measurement recorded should be < 1 cm. Octocorals should be identified to at least the genus level, and scleractinian corals to the species level. Abnormal conditions exhibited by each colony should also be recorded and reported (*e.g.*, bleaching, disease, predation, *etc.*).

(f) *Anemones, Zoanthids, Hydroids, Hydrocorals, Sessile worms (not including Phragmatopoma spp.), Wormrock, Bivalves, Barnacles, Bryozoans, Echinoderms, and Tunicates*

Total percent cover should be estimated and reported separately for each of these groups.

D. Reporting Protocol

1. Notification of commencement, progress, and completion of work

The commencement dates of surveys should be reported to the Department compliance officer and to BIP resource staff using the following email addresses: JCPCompliance@dep.state.fl.us and BMES@dep.state.fl.us. Notification of commencement should be provided **7 days** prior to the start of monitoring and also the **day that work begins**. Monitoring agents should report progress to the DEP JCP compliance officer and BIP resource staff via **weekly** emails during the monitoring period. Once work has been **completed**, the monitoring agent should notify JCP compliance / BIP resource staff no later than the following business day.

2. Monitoring data submissions

Joint Coast Permits typically require submittal of all raw data within **45 days** of completing annual monitoring[10].The monitoring agent should provide raw data to the Department in electronic format, preferably on a single portable hard drive. All data should be provided in a standardized format, as specified below. Data submitted in the Excel workbook (transect monitoring data) should have been checked against field datasheets to ensure accuracy and should be corrected by the monitoring agent prior to the 45 day deadline. Data provided to the Department consists of the following, each of which are described below: aerial photographs, video and photographs; hardbottom edge survey data; raw transect survey data, and field datasheets.

[10] State and federal monitoring required by permit is eligible for reimbursement pursuant to program statute and rule. In order to comply with Florida Auditor General report 2014-064 regarding conflicts of interest and to be consistent with s. 287.057(17)(a)(1), Florida Statutes, all monitoring data and statistical analysis must be provided directly and concurrently from the monitor to the DEPARTMENT/LOCAL SPONSOR/permittee/consultant.

a. Aerial photographs

Aerial photographs should be georeferenced and provided in tiff (tagged image file format). The projected coordinate system and datum used to georeference the images should also be provided.

b. Video and photographs

Video and photographs should appear in separate subfolders on the hard drive, and each folder should contain separate (named) subfolders for each transect (and quadrat, if applicable to photographs).

c. Hardbottom edge survey data

Hardbottom edge data should be supplied to DEP as a collection of shapefiles (preferably as an ESRI file geodatabase). GIS data should be provided as lines or polygons representing the *in situ* mapped hardbottom edge for the current survey. The edge may be a single line representing the nearshore edge, two lines representing the nearshore and offshore edges, or polygons representing hardbottom patches, depending on the distribution of hardbottom in the project area (project specific). Hardbottom edge data should have attributes that indicate the portion of each line or polygon that represents hardbottom or emergent epifauna. If sand patches greater than 0.5 m in length are crossed during the edge survey, these portions of lines/polygons should, as attributes, be indicated as sand. Hardbottom edge data should also have attributes that indicate the relief along the edge, and portions of lines/polygons should be indicated as Low (less than 0.3 m), Medium (0.3 to 1.0 m), or High (greater than 1.0 m) relief. Lines/polygons representing the baseline *in situ* mapped hardbottom edge, and a line(s) representing the predicted (permitted) ETOF should also be provided with each collection of shapefiles submitted to DEP for each post-construction monitoring event.

A separate collection of shapefiles (preferably as an ESRI file geodatabase) should be provided for any *in situ* artificial reef mapping conducted. Similar attributes as in the hardbottom monitoring should be provided with these data.

d. Transect survey data

Interval sediment depth measurements, line-intercept data, and BEAMR quadrat cover (physical and biological) data should be supplied in Excel format to the Department. A separate Excel workbook should be supplied for artificial reef monitoring transect data.

In addition to the raw data files, an Excel geodatabase workbook (in DEP recommended format) for hardbottom transect data should also be provided for submission to the DEP geodatabase. A blank template as well as a filled-in example of the Department recommended format for the geodatabase workbook may be requested from BIP resource staff by email (BMES@dep.state.fl.us). No geodatabase file is required for artificial reef monitoring data.

Each Excel workbook submitted to DEP should be identified by a descriptive name so as to easily differentiate data (*i.e.*, Hardbottom vs. Artificial reef).

e. Field datasheets and survey logs

Copies (photographs or scans) of field datasheets should be submitted in pdf format.

3. Annual biological monitoring report submission

Joint Coast Permits typically require submittal of an annual monitoring report to the Department within **90 days** of completing annual monitoring. The information in each monitoring report should be presented in a standard format (*e.g.*, the order/organization of survey results, the names of sections/chapters, *etc.*) as described in the following sections (Department recommended report format). Along with the monitoring report, the data analyzed to produce the report should be submitted to DEP. This submission should include tables used in the analysis of data and to construct figures, as well all tables and figures provided in the report (in Excel format). The data table entered into PRIMER (statistical program) and the PRIMER analysis file should also be submitted.

Monitoring reports are intended to be cumulative, thus data (in the form of summary tables and figures) from all previous monitoring efforts should be provided in each report, in an updated fashion. For example, a figure (or separate figures for each transect) depicting sediment depths within quadrats by transect for the year 1 post-construction report should include data from: the baseline survey, the initial post-construction survey, and the current (Year 1 post-construction) survey. However, not all data sets will be analyzed and compared statistically. Temporal comparisons by way of univariate and multivariate tests should be confined to data collected during the most recent monitoring event (current survey) and the baseline survey; thus, statistical tests will not be used to compare results between different post-construction monitoring events.

The annual monitoring report should clearly describe methods and any deviations from the monitoring plan/conditions of permit or the SOP. It should also provide results in an easy to interpret manner. Conclusions regarding the results of each survey or the performance of the project are not required to be submitted in the report, but a discussion / interpretation section may be provided as an appendix to the report if desired. Any noteworthy explanatory observations and other ancillary information should also be provided in an Appendix.

a. Report title formatting

The title of each report should follow a format similar to the one below, where the survey period (*i.e.*, pre-construction, initial post-construction, year 1 post-construction, *etc.*), the project name and permit number, the county in which the project is taking place, and the date of the survey are given. An example is provided below; information specified in brackets [*italicized text*] is intended to be filled in with project specific details.

> "[*Survey Period*] Biological Hardbottom Monitoring Report for the [*Project Name*] (Permit No: *[###### - ### -* JC]) in [*County Name*] County, [*Calendar Year for Survey*]"

Example:

> Year 1 Post-construction Biological Hardbottom Monitoring Report for the Acme Beach Nourishment Project (Permit No: 123456 - 001 - JC) in Acme County, 2015"

b. Format of Section 1: Background information and results summary

This section of the report should provide project related information, such as a description of the project (*e.g.*, density of fill), its location (referencing R-monuments), and a historical account of projects at or including the project area (*i.e.*, previous nourishment dates, cubic volume of fill placed, DEP monument markers between which fill was placed, *etc.*). A general description of the hardbottom resources (*e.g.*, average relief and distance of hardbottom to the predicted ETOF) monitored should also be provided. A brief summary of monitoring results (without discussion or interpretation), which includes monitoring dates and main results (*e.g.*, changes in sediment depth, direct cover, and major functional groups) should conclude this section.

c. Format of Section 2: Methods

This section of the report should describe the monitoring procedures employed. If SOP methodologies are followed in full, the description should simply cite the Standard Operating Procedures document. Any specific requirements specified by the Permit and/or the Biological Monitoring Plan should be described in full. A detailed description of all statistical analyses performed (*e.g.*, models run, factors, factor levels and interactions included in models, post-hoc tests and any correction factors used, data transformations and their justification, *etc.*), and the methods by which model assumptions were validated (*e.g.*, visually through graphical analysis of the residuals) should also be provided. A post hoc power analysis should be run for all univariate (hypothesis) tests. See section D4 below for a description of the types of analyses to be performed.

d. Format of section 3: Results

The report shall concisely and objectively present results from: A) all survey periods to date; and B) comparison of the current survey to the baseline survey (see subsections A and B below). Results should be presented in an orderly and logical sequence using both text, tables, and figures. Results should not contain descriptions of methods and should be presented without interpretation or discussion.

Descriptive statistics as well as summaries of statistical analyses (univariate and multivariate tests) shall appear in either the text, typically parenthetically (*e.g.*, 14.3 +/- 4.5 cm (mean +/- SD); paired t-test: df = 11, t = 4.58, p = 0.035), or in relevant tables and figures. Means should be accompanied by their standard deviations in text and tables, and by their standard errors in figures. If using pie charts (not recommended), numerical values for each slice of the pie should be provided. The results section includes two separate subsections, presented below. See section D4 for information pertaining to descriptive statistics, statistical tests, and analyses for each type of survey data collected during annual monitoring.

i. Subsection A – all surveys

Results from all survey periods to date (as descriptive statistics in tables and figures).

ii. Subsection B – current vs. baseline survey

Results from the comparison (statistical analyses and descriptive statistics) of the current survey to the baseline survey.

e. Literature cited and appendices

All literature cited in the monitoring report should be provided in a "Literature Cited" section, presented as an alphabetized list by the first author's last name. Copies of literature cited in the report should be made available as pdf documents to the Department upon request. Supplementary material (explanatory or statistical) should also be provided as an appendix to the report.

4. Data and their analysis

A number of different types of data will be collected during each monitoring event. The types of data, the specific temporal and spatial comparisons, and the types of analyses that generally are to be used are presented below. All tables either presented in the report, used to produce figures for the report, or to input data into statistical packages, as well as results of statistical tests, shall be provided to DEP in electronic format (excel files) along with the biological monitoring report.

a. Data

Data to be analyzed for each monitoring report include: aerial photographs of hardbottom (ground-truthing of hardbottom), hardbottom edge surveys (*in situ* delineation), hardbottom exposure (via sediment patch dynamics based on line-intercept data), sediment depth data (from interval depth measurements and quadrat specific depth measurements), benthic community/functional group composition (quadrat BEAMR data), and coral count and size data.

b. Temporal comparisons

The only temporal comparison to be made via statistical tests (univariate and multivariate) is between the current survey and the baseline survey. Such a comparison represents repeated measures and, depending on the statistical test, these data are to be analyzed accordingly (*e.g.*, paired T-test, repeated measures ANOVA/ANCOVA, linear mixed-effects models, MANOVA, *etc.*). Multivariate analysis by way of PRIMER does not require such repeated measures tests, due to the non-parametric permutation based nature of its routines. Comparison among all monitoring events should solely be through descriptive/summary statistics, presented in graphical or tabular form in the report.

c. Types of analyses

i. Descriptive statistics

Unlike inferential statistics (hypothesis tests [see univariate and multivariate tests below]), descriptive statistics aim to provide simple quantitative summaries of a sample (*i.e.*, they describe the main features of a collection of information). Such summaries may be either quantitative (*i.e.*, summary statistics) or visual (*i.e.*, straightforward graphs). These statistics generally include measurements of central tendency (*e.g.*, mean, median, and mode) and dispersion (*e.g.*, variance and/or standard deviation). Numerical descriptors like mean and standard deviation are good for summarizing continuous data (like the density [N/m^2] of a particular species), while frequency and percentage are more useful in terms of describing categorical data.

When presented, a measurement of central tendency should be paired with its associated measurement of dispersion (*e.g.*, a mean and its standard deviation). The standard error of the mean (measurement of variability in a sample mean) is typically provided along with the mean when presented in graphical form; in all other cases (*e.g.*, text and tables), the standard deviation should be provided along with the mean. Confidence intervals (*e.g.*, 95%) are typically provided when presenting median values.

One of the most useful and effective statistical calculations is the estimation of percentage change. For example, in the assessment of change in percent cover, size class distribution, and sediment depth over time. The following example provides the formula for calculating percent change over time for sediment depth: %Change = ((Depth F – Depth I)/Depth I))*100; where Depth F is the final sediment depth (depth during the most recent monitoring event), and Depth I is the initial sediment depth (depth during the baseline survey). Changes expressed as percentages provide useful summaries for changes occurring in hardbottom communities as a result of beach nourishment. Percent change may be presented in tabular and/or graphical form, and can be used as the dependent variable in analyses of sediment depth, sand patch size, percent cover, *etc.*

ii. Univariate tests

These consist of both parametric and non-parametric hypothesis tests. While the results of such tests are useful in determining whether impacts from nourishment have occurred, the statistical significance of change in the absolute value of a parameter or in percentage does not necessarily reflect a critical, biologically meaningful threshold. Thus, while tests can indicate significant differences, differences that are not significant can still be meaningful. Several useful univariate tests are provided below.

(1) *T-test*

Simple hypothesis test that operates on the mean. One-sample, Two-sample, and Paired tests are possible; Homoscedastic (equal variance) and Heteroscedastic (unequal variance) tests are also available. Programs should provide a p-value to compare to a pre-determined alpha (usually 0.05). While inappropriate for other, more complex statistical tests, Microsoft Excel may be used to run T-tests.

(2) *ANOVA*

More advanced hypothesis test that also operates on means. In the event assumptions of general linear models are not met, non-parametric ANOVA, generalized linear, or mixed-effects models may be used to account for the nature of the data. Analysis of covariance (ANCOVA may also be useful. Repeated measures (*i.e.*, violation assumption of independence) must be handled appropriately.

iii. Multivariate tests

These statistics encompass the simultaneous observation and analysis of more than one outcome/dependent variable. Multivariate analysis of variance (MANOVA) models may be used, though analysis via PRIMER routines is more common. Various PRIMER routines are described in 1-6 below. MANOVA and PERMANOVA are suggested for complex multivariate hypothesis tests.

(1) *Similarity matrix*

The original data matrix should include data from the current survey as well as from the baseline survey. Bray-Curtis similarity should be used to produce the resemblance matrix. In order to even out the influence of dominant and rare species, data should be square root, fourth root, or log (x+1) transformed prior to producing the resemblance matrix.

(2) *Cluster analysis with Similarity Profile (SIMPROF) Test*

Based on simple agglomerative hierarchal clustering, creates a dendrogram from a similarity matrix. *Group average linking* should be used. Similarity profile analysis (SIMPROF) should be used in conjunction with cluster analysis (tree production). The pi statistic and the results of the associated hypothesis test should be presented in the results section of the monitoring report.

(3) *nMDS ordination*

A technique for mapping samples in a low dimensional space (typically 2-D) such that the distance between samples approximately reflects (to one degree or another) similarity in community structure. Model checking should include interpreting the resultant Shepard Diagrams (smooth increasing curves are best) and Stresses (2-D and 3-D), which provide information on the distortion between the ranked dissimilarities and corresponding distances in the plot. Stress scores are to be reported; as a rule of thumb, a score of: < 0.05 suggests excellent representation; < 0.1 suggests a good fit; < 0.2 suggests the pattern is still useful, but should not be completely trusted; and > 0.3 suggests the pattern is little better than random points.

(4) *Analysis of Similarity (ANOSIM)*

Compares the variation in species abundance and composition among sampling units in terms of grouping factors (or experimental treatment levels). The histogram, R-statistic, and p-values provided as outputs should be reported.

(5) *Similarity of Percentage (SIMPER)*

Used to determine the role of individual taxa in contributing to the separation (dissimilarity) between two groups of samples (*e.g*., Artificial vs. Natural, Baseline vs. Year 1 post-construction).

(6) *Second Stage Analysis (2STAGE)*

Provides a succinct summary in a 2-d picture of the relationship between the multivariate sample patterns under various choices.

d. Specific analyses for survey data

i. Aerial photographs of hardbottom

These should be reviewed to verify the distribution and acreage of hardbottom in the current post-construction survey relative to the baseline survey.

ii. Hardbottom edge surveys

The current post-construction survey hardbottom edge (lines/polygons) should be compared to baseline hardbottom edge and both seaward and landward shifts in the position of the edge should be evaluated. A qualitative description of changes in the position of the nearshore hardbottom edge should be included in the annual monitoring report.

iii. Line-intercept data

Sand patch and hardbottom positions and lengths along each transect should be provided in a table and also displayed graphically in a horizontal bar graph for each transect (see Figure 4 below). The figure is intended to be cumulative in order to compare among years to assess sedimentation dynamics and changes resulting from the project; thus, successive monitoring events will generate additional bar graphs for each transect (as in Figure 4).

Along with the size and position of sediment patches, these data also provide information on the total length and also ratio of sand to hardbottom along each transect. The ratio for sediment to hardbottom should be expressed as a percent: the percentage of each transect line that is comprised of sediment and hardbottom, respectively. This percentage is derived by dividing the total length of sediment and hardbottom, respectively, by the permanent length of the transect line established during the baseline survey.

For line-intercept data the following comparisons shall be made and presented in each monitoring report:

Monitoring data for all years:

The mean percentage of hardbottom (calculated across all transects) within the project area should be presented by survey (as in Figure 5). The percent of hardbottom along each transect should be presented by survey for each transect (as in Figure 6).

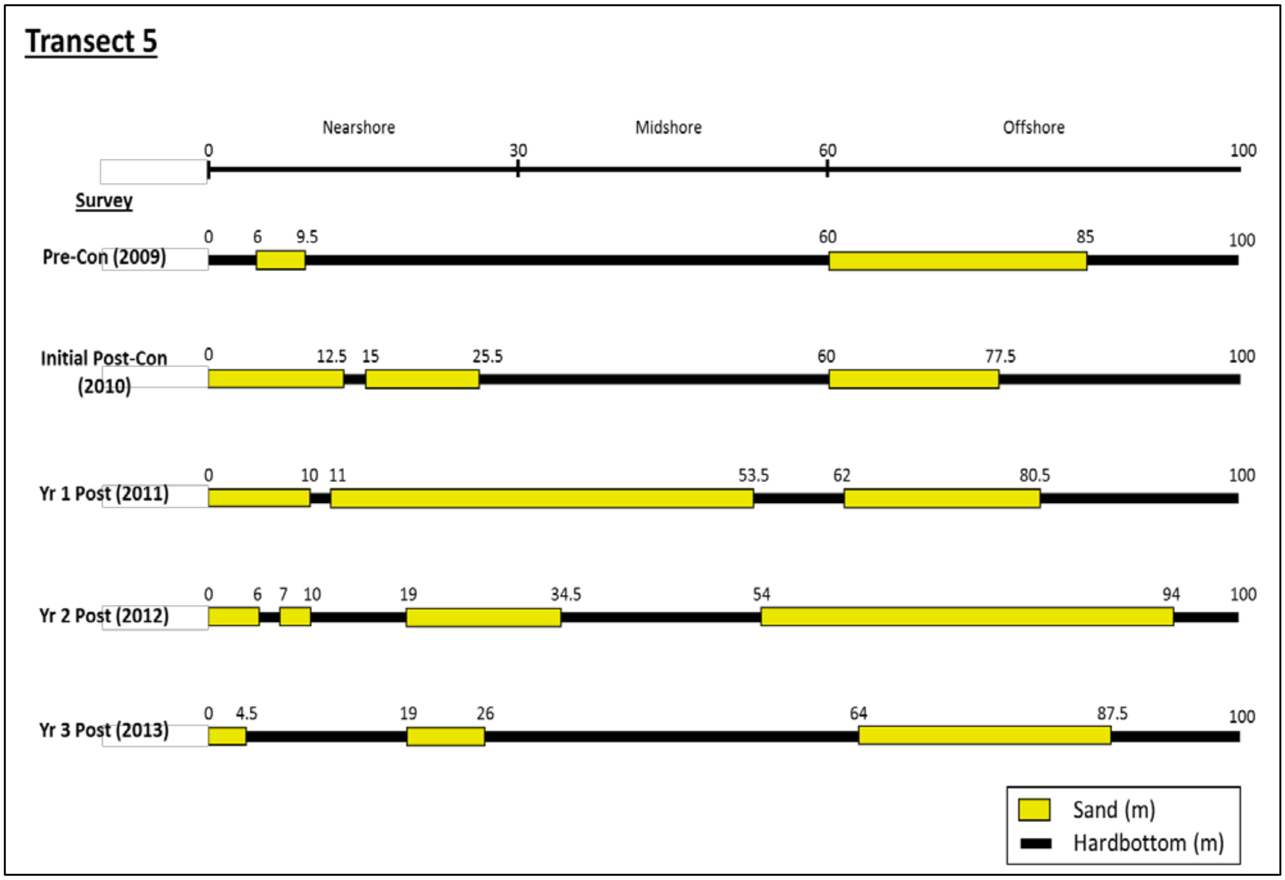


Figure 4. Examples of line-intercept plots depicting sand patch locations along a single transect for multiple surveys. The figure references a 100 m long transect line; the start and end position of each sand patch are identified. “Pre-con” survey equals baseline survey.

Baseline vs. current survey data:

The change (raw and percent) between the baseline and the current survey in the percent of hardbottom along each transect should be presented in the report for each transect (as in Figure 7, Left and Right). A univariate test (Paired T-test for two samples) should be used to statistically compare the percent of hardbottom within the project area between the baseline and the most recent (current) survey. Since this test is conducted at the project area level, the percent of hardbottom along each transect at these two time points will be included in the dataset. The first sample should contain values for each transect from the baseline survey and the second sample should contain values for each transect from the current survey. Results of the test should be reported.

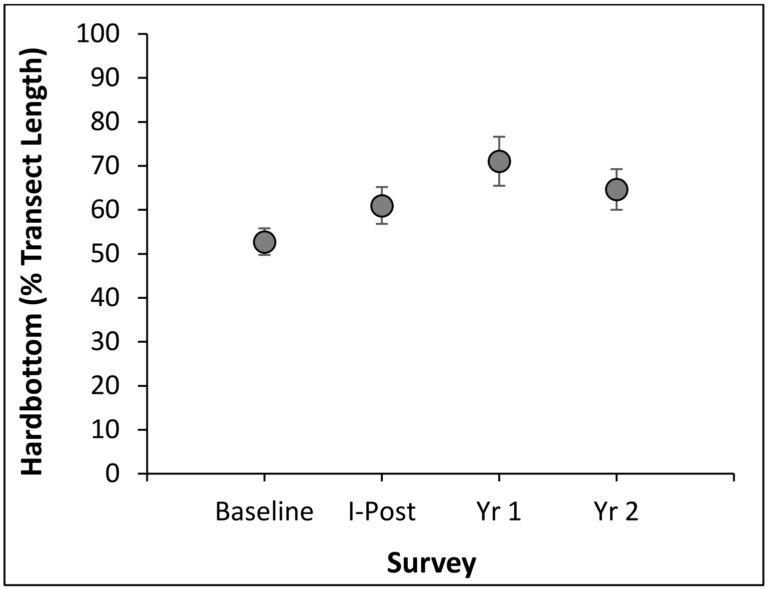


Figure 5. Example of a scatter plot for mean percent hardbottom in the entire project area by survey. Bars are SE. Means are calculated from transect level data for each survey.

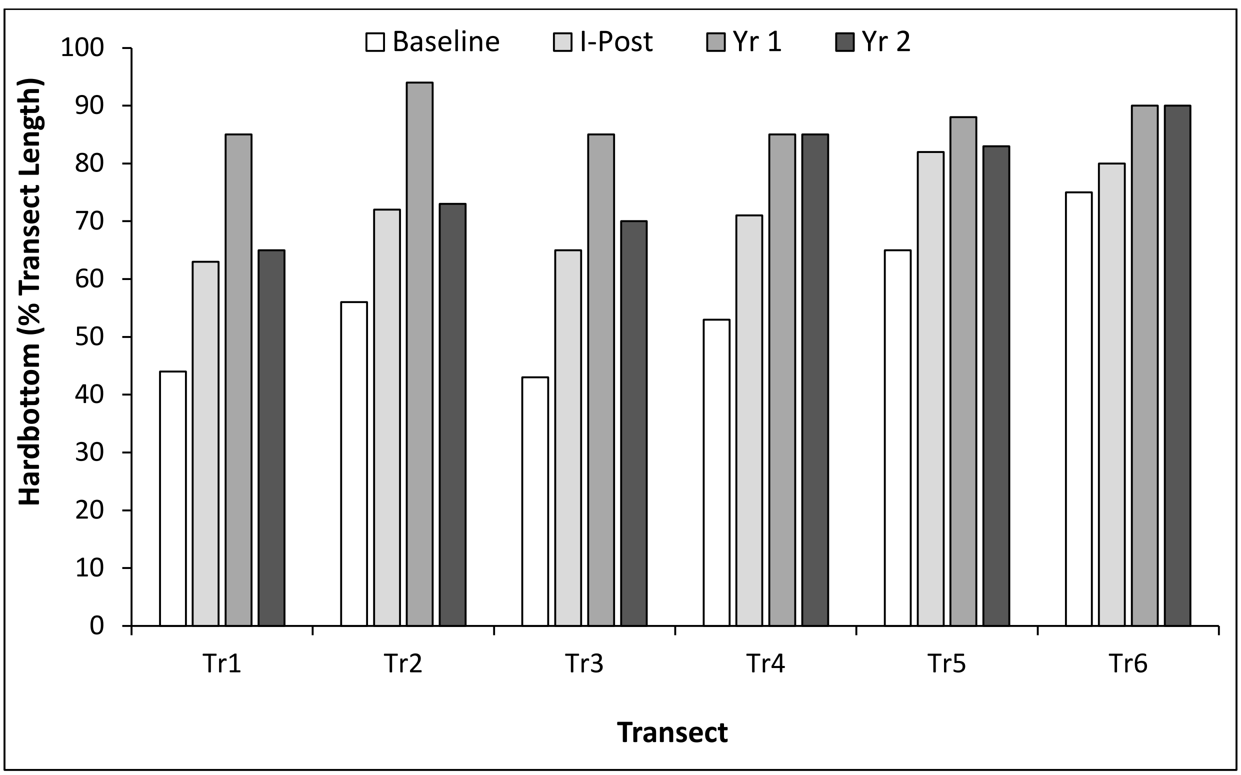


Figure 6. Example of a bar plot for the percent of hardbottom along transects by survey. I-Post, Yr 1, and Yr 2 in the inset legend refer to the initial, year 1, and year 2 post-construction surveys, respectively.

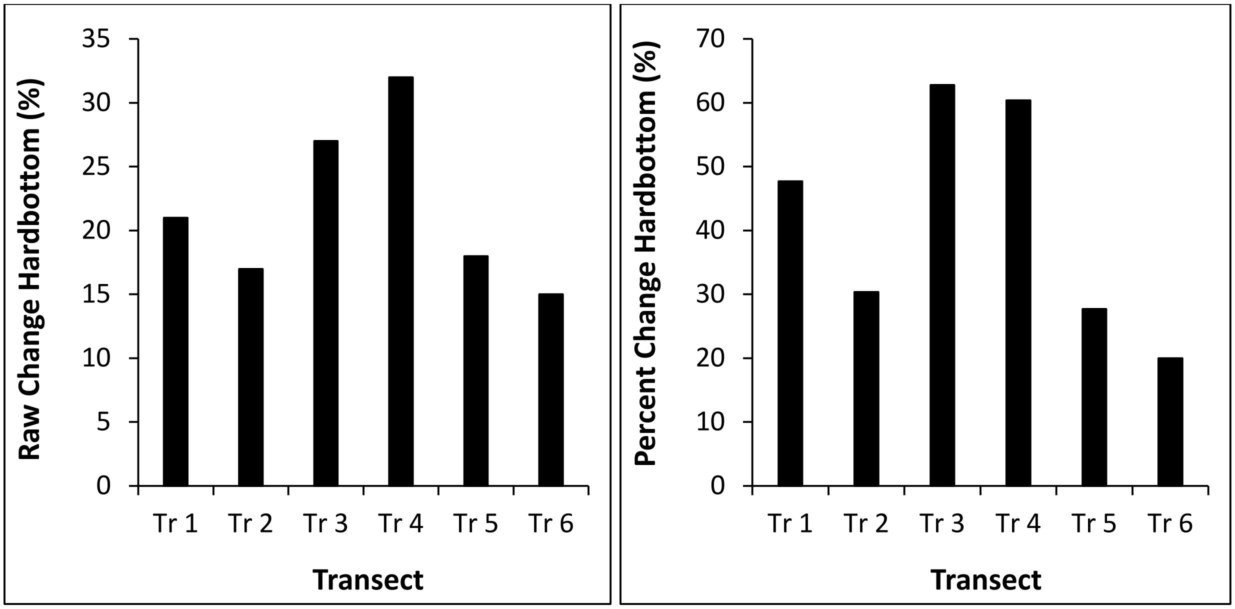


Figure 7. Examples of bar plots reporting changes in the percent of hardbottom along each transect between the baseline and the current monitoring survey**. Left.** Raw change in percent hardbottom. **Right.** Percent change in percent hardbottom.

iv. Sediment depth

Two different sets of sediment depth measurements are collected during each monitoring survey: 1) interval depth measurements along each transect; and 2) depth measurements within each quadrat. These two data sets will be handled separately, and each should be analyzed and presented in the report in the following ways:

(1) *Interval sediment depth measurements*

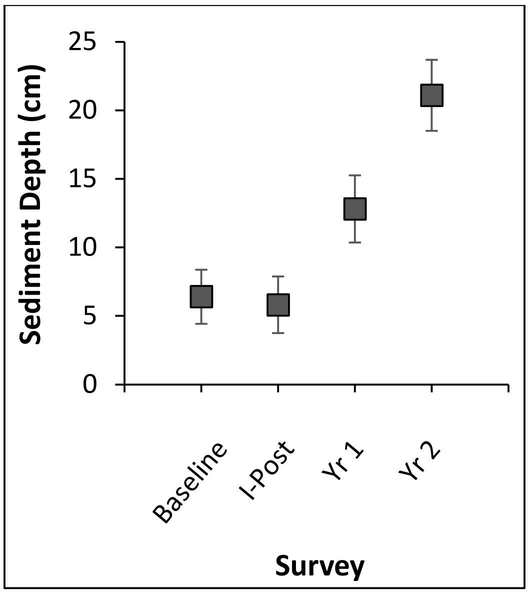
These measurements should be summarized (means with error information) for the entire project area, by transect, and per transect by zone within transect (see below). Transect zones represent sections of transects with similar distances from the predicted ETOF; specific zones will be determined on a project-by-project basis. Three zones (nearshore, midshore, and offshore) will typically be employed, with the first zone encompassing the first 30 – 50 meters along each transect.

<u>Monitoring data for all years:</u>

Summary statistics for interval sediment depth measurements should be calculated and provided by survey for: the entire project area (as in Figure 8, Left); zones within the entire project area (as in Figure 8, Right); all transects (as in Figure 9); and by zone for each transect (as in Figure 10, Left and Right).

Baseline vs. current survey data:

Change (raw and percent) in mean sediment depth between the baseline and current survey should be calculated and presented by transect (as in Figure 7, Left and Right). A univariate test (*e.g.*, repeated measures ANOVA) should be used to statistically compare sediment depth over time. Fixed main effects in the full model should include transect and survey as well as their interaction. Zone may be included as fixed or random effect, depending on the model. It is suggested that separate repeated measures tests (Paired-t tests, one-way ANOVA's) be used to investigate a significant interaction between transect and survey. Results of analyses should be presented in text or in a table.



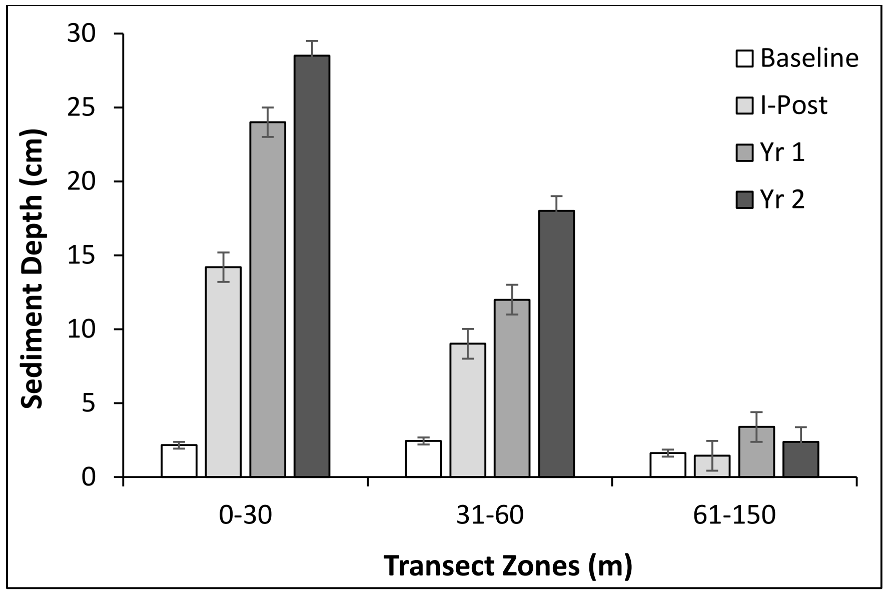


Figure 8. Examples of figures reporting mean interval sediment depth by survey. **Left.** Scatter plot for mean sediment depth for the entire project area. **Right.** Bar plot for mean depth by zone for the entire project area; zones are ordered from left to right: Nearshore, Midshore, and Offshore. All bars are SE.

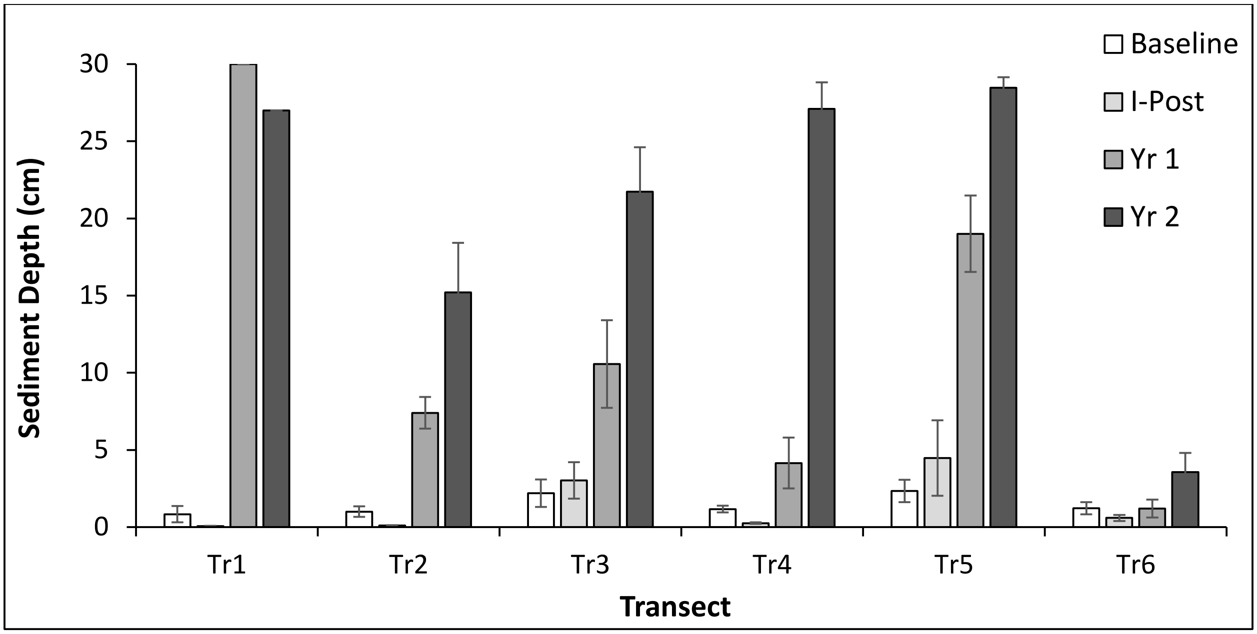


Figure 9. Examples of a bar plot reporting mean interval sediment depth by survey for each transect. Bars are SE.

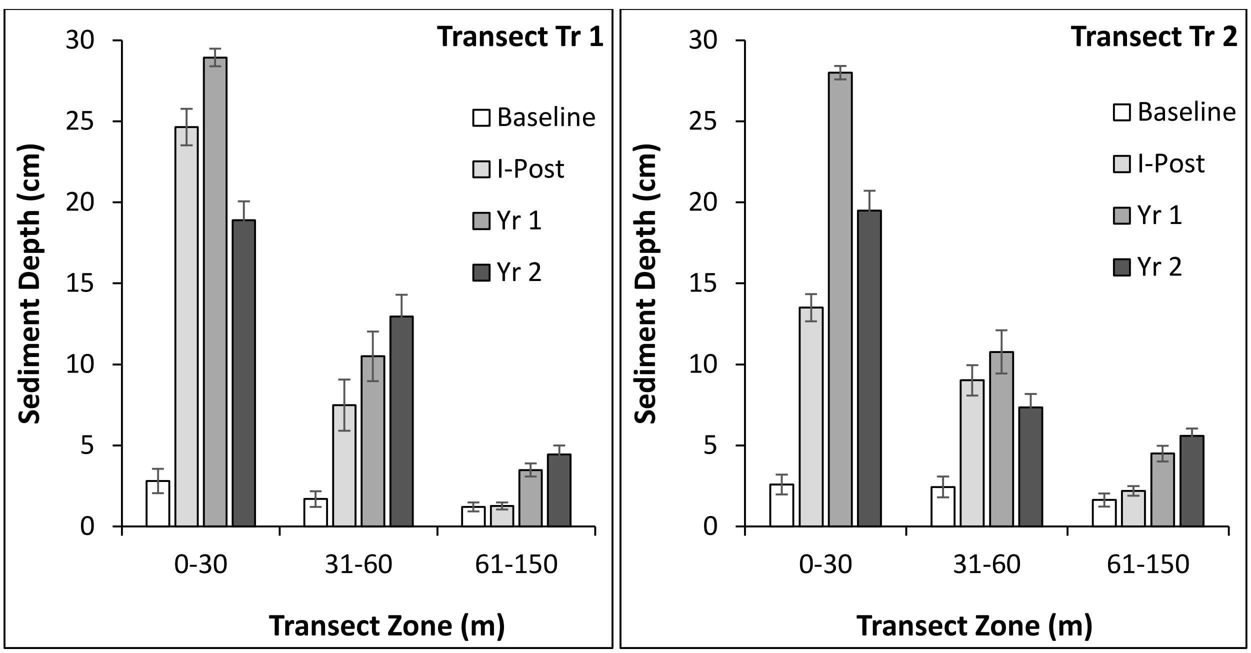


Figure 10. Examples of bar plots reporting mean sediment depth by transect zone over time independently for each of two transects. **Left.** Transect Tr 1. **Right.** Transect Tr 2. Zones are ordered from left to right: Nearshore, Midshore, and Offshore. Bars are SE.

(2) Sediment depth within quadrats

Three measurements of sediment depth should be collected from each quadrat. The mean of these three measurements will serve as the sediment depth for each respective quadrat, and from here on this metric will be referred to as quadrat sediment depth. As with interval sediment depth measurements, three zones (nearshore, midshore, and offshore) will typically be employed in the analysis of these data. Quadrat sediment depth measurements should be analyzed and presented in the report in the following ways:

<u>Monitoring data for all years:</u>

Summary statistics for quadrat sediment depth should be calculated and presented by survey for: the entire project area (as in Figure 8, Left); zones within the entire project area (as in Figure 8, Right); all transect (as in Figure 9); and by zone for each transect (as in Figure 10).

<u>Baseline vs. current survey data:</u>

Changes (raw and percent) in quadrat sediment depth between the baseline and the current survey should be calculated and presented by transect in the report (as in Figure 7, Left and Right). A univariate test (*e.g.*, repeated measures ANOVA) should be used to statistically compare sediment depth by transect over time. Fixed main effects in the full model should include transect and survey as well as their interaction, and quadrat should be included as a nested random effect (nested within transect). It is suggested that separate one-way repeated measures ANOVA's be used to investigate a significant interaction between transect and survey. Results of analyses should be presented in text or in tabular form.

v. Relief within quadrats

Within quadrat relief data should be analyzed and presented in the report in the following ways:

<u>Monitoring data for all years:</u>

Summary statistics for hardbottom relief should be calculated and provided for: the entire project area (as in Figure 8, Left); zones within the entire project area (as in Figure 8, Right); all transects (as in Figure 9), and by zone for each transect (as in Figure 10).

Baseline vs. current survey data:

Change (raw and percent) in relief within quadrats between the baseline and current survey should be calculated and presented by transect in the report (as in Figure 7, Left and Right). A univariate test (*e.g.*, repeated measures ANOVA) should be used to statistically compare relief by transect over time. For example, fixed main effects in the full model should include transect and survey as well as their interaction, and quadrat should be included as a nested random effect (nested within transect). Sediment depth may be used as a covariate, depending on the model. It is suggested that separate one-way repeated measures ANOVA's be used to investigate a significant interaction between transect and survey. Results of analyses should be presented in tabular form, and may also be referred to in text, within parentheses.

vi. Within quadrat coral counts and size measurements

Size specific measurements should be made on all corals (octocorals and scleractinians) within each quadrat (see section C.3.b.iii.(1).(e) for details). Data sets for coral counts and size will be handled separately, and data should be analyzed and presented in the report in the following ways:

(1) *Coral count data*

Monitoring data for all years:

The number of corals (abundance) within the project area should be provided in tabular form by group, and also by genus (octocorals) and species (scleractinian corals) within group (see example format in Table 1 below). Coral abundance within each zone along each transect should also be provided in tabular form by group and by genus (octocorals) and species (scleractinian corals) within group (see example format in Table 2 below).

Baseline vs. current survey data:

Change in coral abundance between the baseline and current survey should be calculated and presented for each group (as in Figure 11). Figures for percent change may also be provided. Change in coral abundance between the baseline and current survey should also be presented for each genus (octocoral) and species (scleractinian) within each group for the entire project area (as in Figure 12, Left and Right). Figures for percent change may also be provided.

Table 1. Example of the tabular format used to report coral abundance by survey for the entire project area. Data should be provided for groups and subgroups (genus/species) within groups.

Group	Genus/Species	Abundance			
		Pre-Con (n)	I-Post Con (n)	Year 1 (n)	Year 2 (n)
Octocoral	A				
	B				
	C				
	D				
	E				
	F				
	Sum				
Scleractinian	Gg				
	Hh				
	Ii				
	Jj				
	Kk				
	Ll				
	Sum				

Table 2. Example of the tabular format used to report coral abundance by survey per zone for a single transect. Data should be provided for groups and subgroups (genus/species) within groups for nearshore (NS), midshore (MS), and offshore (OS) zones, respectively.

Group	Genus / Species	Abundance											
		Pre-Con			I-Post			Year 1			Year 2		
		NS (n)	MS (n)	OS (n)	NS (n)	MS (n)	OS (n)	NS (n)	MS (n)	OS (n)	NS (n)	MS (n)	OS (n)
Octocoral	A												
	B												
	C												
	D												
	E												
	F												
	Sum												
Scleractinian	Gg												
	Hh												
	Ii												
	Jj												
	Kk												
	Ll												
	Sum												

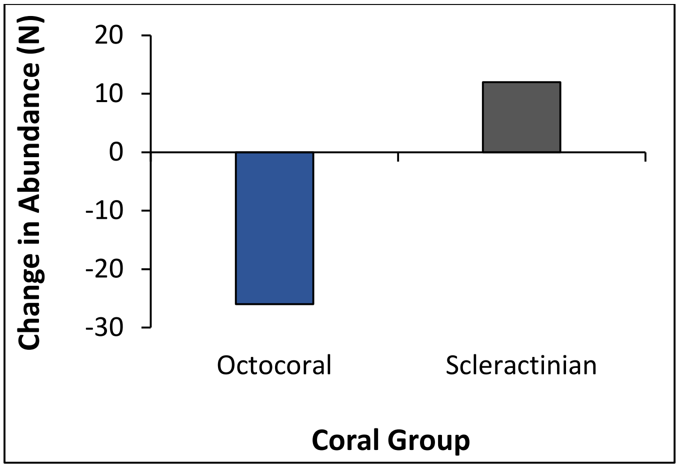


Figure 11. Example of a bar plot presenting change in coral group abundance within the entire project area between the baseline and the current survey.

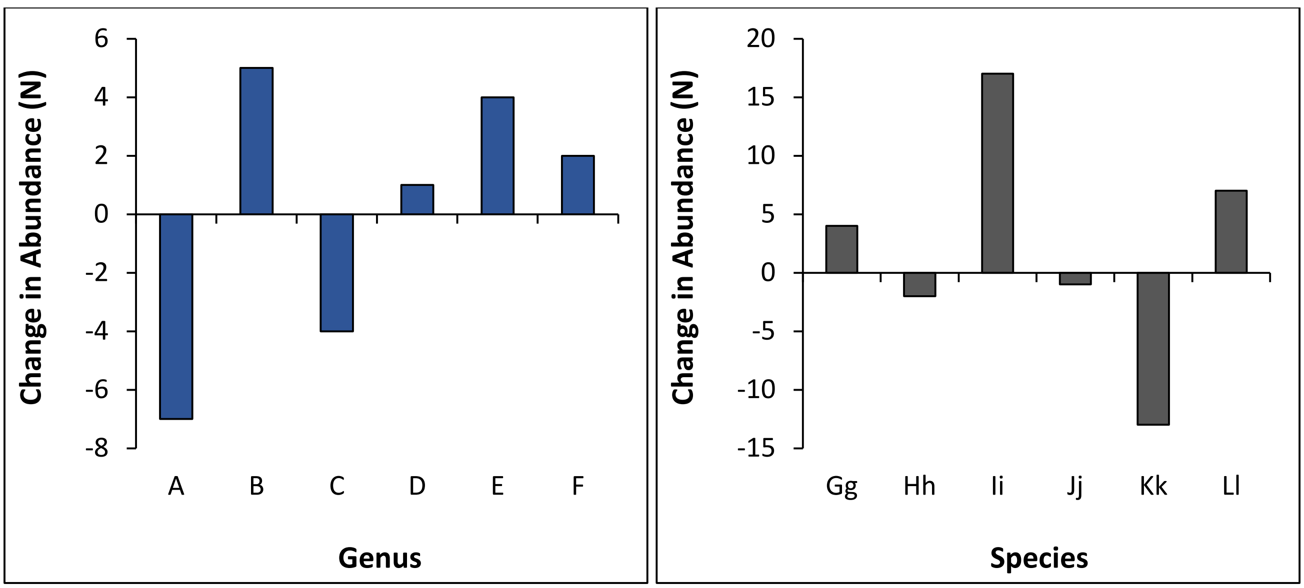


Figure 12. Examples of bar plots reporting change in coral subgroup abundance within the entire project area between the baseline and the current survey. **Left.** Octocorals, by genus. **Right.** Scleractinians, by species.

(2) Coral size data

Monitoring data for all years:

Size data are often skewed, which means the distribution of these data are poorly described by the mean. Summary information for size data should therefore be reported using box-and-whisker plots, which graphically depict data through quartiles. The lower and upper bounds of the box indicate the first and third quartiles (50% of the data reside between these bounds) while the middle band of the box indicates the second quartile, which is the median of the distribution. The whiskers on either side of the box indicate variability outside the upper and lower quartiles. Outliers are indicated by individual points (stars in the Figures 13-15 below).

Summary statistics for coral size should be calculated and provided by survey for: the entire project area by group (as in Figure 13); and the entire project area by genus (octocorals) and species (scleractinian corals) within group (as in Figures 14 and 15). Summary statistics for coral size should also be presented by survey for: each transect by group; and each transect by genus (octocorals) and species (scleractinian corals) within group. Figures presenting transect level summary statistics should be similar to Figures 13-15 below, but at the transect level.

Baseline vs. current survey data:

Histograms (size-frequency distributions) should be constructed for each octocoral genus and scleractinian species using project level (entire area) data from the baseline and current survey, respectively (as in Figure 16). The distribution for the current survey should be qualitatively compared to the baseline distribution in each histograms (*i.e.*, within each genus and each species). Figures (histograms) and results of qualitative comparisons should be provided in the report for each genus and each species.

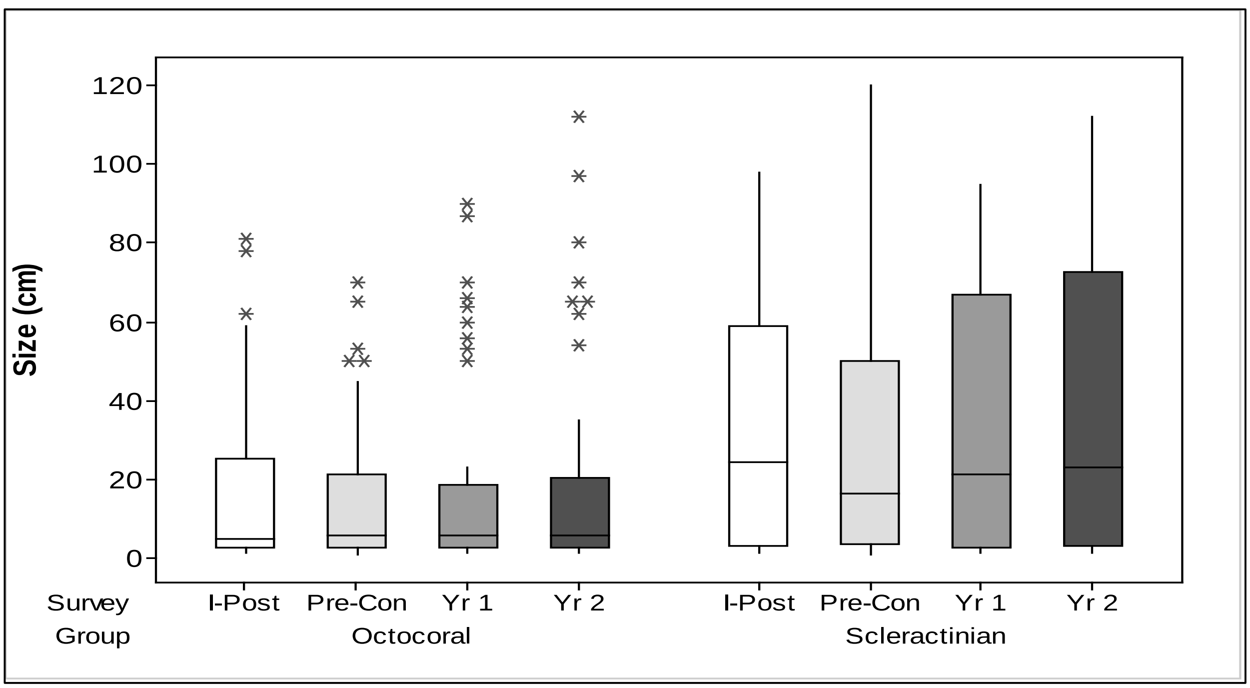


Figure 13. Examples of box-and-whisker plots reporting coral size within the project area by survey for each group.

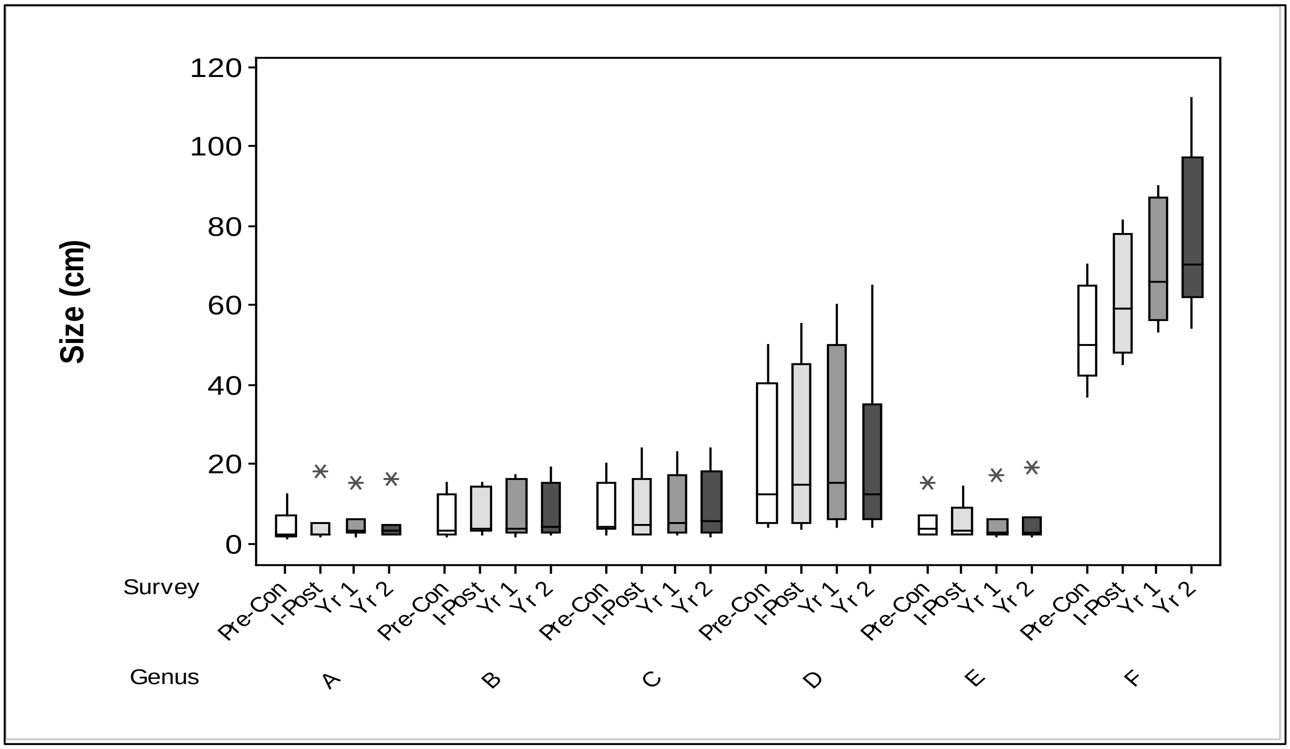


Figure 14. Examples of box-and-whisker plots reporting Octocoral size within the project area by survey for each genus.

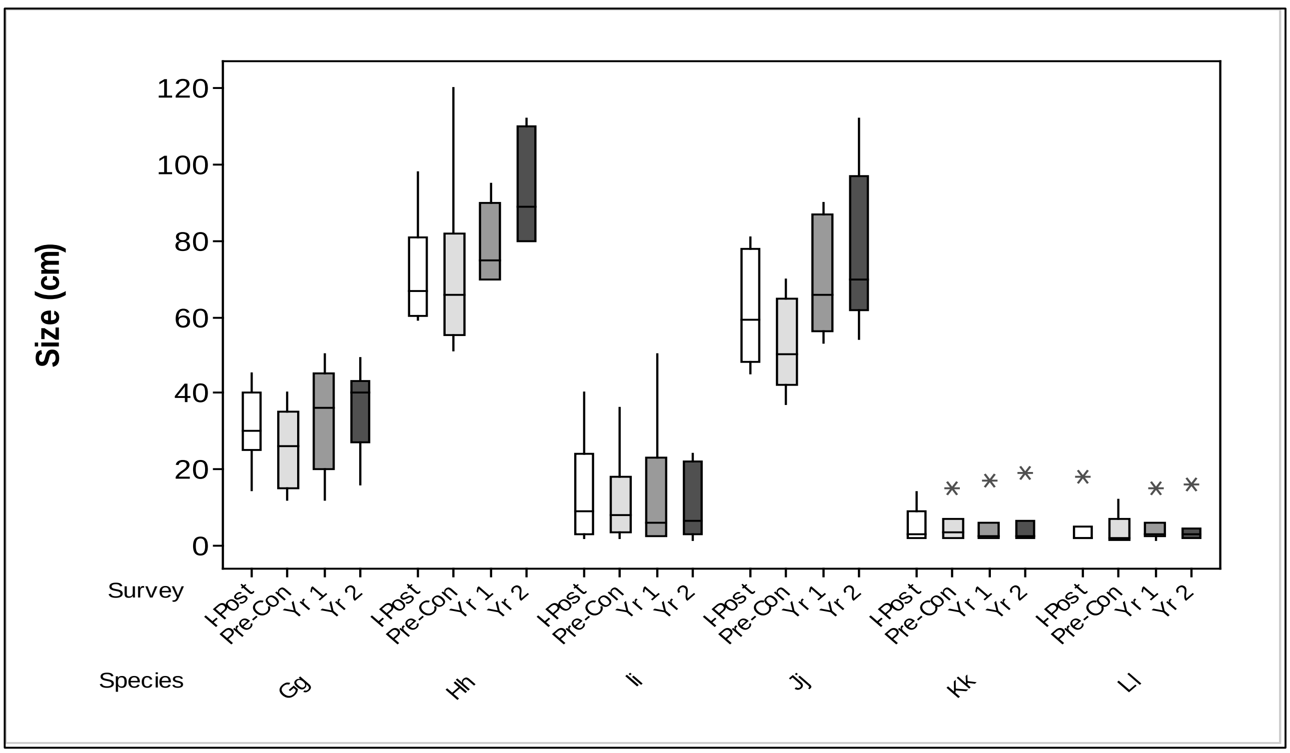


Figure 15. Examples of box-and-whisker plots reporting Scleractinian size within the project area by survey for each species.

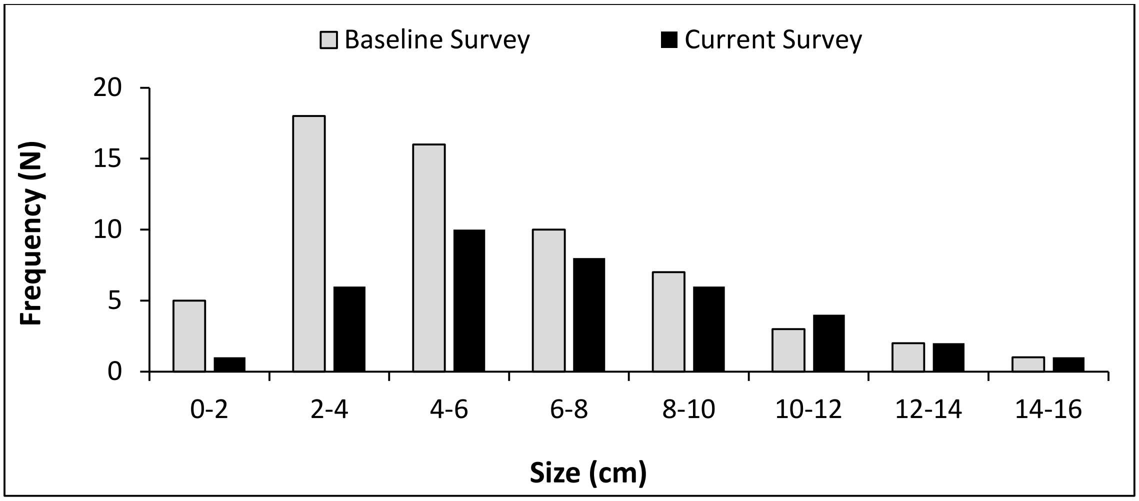


Figure 16. Example histogram presenting baseline and current survey size-frequency distributions for a scleractinian coral species.

vii. Benthic community and substratum composition (BEAMR) data

(1) *Sediment cover*

Sediment includes sand, shell hash, and mud (any loose particulate), but does not include coral rubble. These groups should be summed to the single category “sediment”. Within quadrat sediment cover (%) data should be analyzed and presented in the report in the following ways:

<u>Monitoring data for all years:</u>

Summary statistics for sediment cover (%) within quadrats should be calculated and provided by survey for: the entire project area (as in Figure 8, Left); zones within the project area (as in Figure 8, Right), all transects (as in Figure 9), and zones within each transect (as in Figure 10).

<u>Baseline vs. current survey data:</u>

Change (raw and percent) in sediment cover within quadrats between the baseline and the current survey should be calculated and presented by transect (as in Figure 7, Left and Right). A univariate test (*e.g.*, repeated measures ANOVA) should be used to statistically compare sediment cover by transect over time. Fixed main effects in the full model should include transect and survey as well as their interaction, and quadrat should be included as a nested random effect (nested within transect). It is suggested that separate one-way repeated measures ANOVA’s be used to investigate a significant interaction between transect and survey. Results of analyses should be presented in text or in tabular form.

(2) *Functional groups*

Analysis of functional group cover data should include summaries (as figures or tables) for groups and subgroups as well as multivariate analysis of the full functional group dataset (lowest taxonomic level for macroalgae, octocorals, and scleractinian corals).

Monitoring data for all years:

Analysis should consist of summaries for groups and subgroups. Summaries for the mean percent cover of eight (8) major functional groups within the entire project area should be calculated and presented by survey (*e.g.*, as in Figure 17 below); each column for each survey should sum to 100%. The eight (8) major functional groups reported should be: Sediment, Bare hardbottom, Rubble, Cyanobacteria, Macroalgae (summation of all algal groups save turf and encrusting red), Turf algae, Encrusting red algae, and Invertebrates (summation of all invertebrate groups).

In addition to this, mean percent cover within the project area of: a) major algal groups (Chlorophyta, Phaeophyta, Rhodophyta, Turf algae, and Encrusting Red Algae) plus Cyanobacteria (as in Figure 18); and b) major invertebrate functional groups (as in Figure 19), should be calculated and presented by survey in the report, respectively .The eight (8) major invertebrate functional groups reported should be: Sponges, Scleractinian corals, Octocorals, Hydroids, Wormrock, Tunicates, and Other. Unless contributing substantial to community composition, “Other” should be a summation of the following invertebrate functional groups: Anemones, Zoanthids, Hydrocorals, Sessile worms (not including Phragmatopoma spp.), Bivalves, Barnacles, and Echinoderms.

Finally, the mean percent cover of 16 functional groups should be calculated and presented by transect over time (as in Figure 20); each column for each survey should sum to 100%. The 16 functional groups reported should be: Sediment, Bare hardbottom, Rubble, Macroalgae, Turf algae, Encrusting red algae, Cyanobacteria, Sponges, Scleractinian corals, Octocorals, Hydroids, Wormrock, Bryozoans, Tunicates, and Other. Unless contributing substantial to community composition, “Other” should be a summation of the following functional groups: Anemones, Zoanthids, Hydrocorals, Sessile worms (not including Phragmatopoma spp.), Bivalves, Barnacles, and Echinoderms.

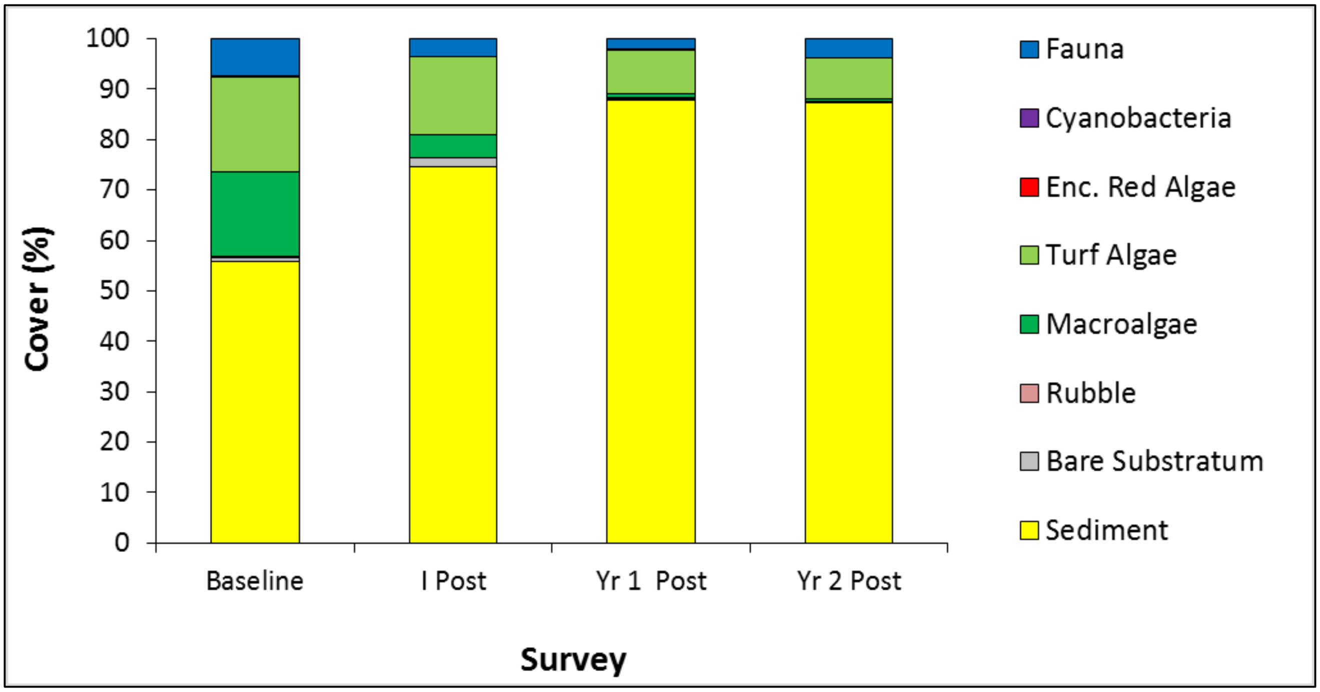


Figure 17. Example of a stacked bar plot reporting mean percent cover of functional groups within the project area over time (by survey). Error bars are purposefully not included in this plot.

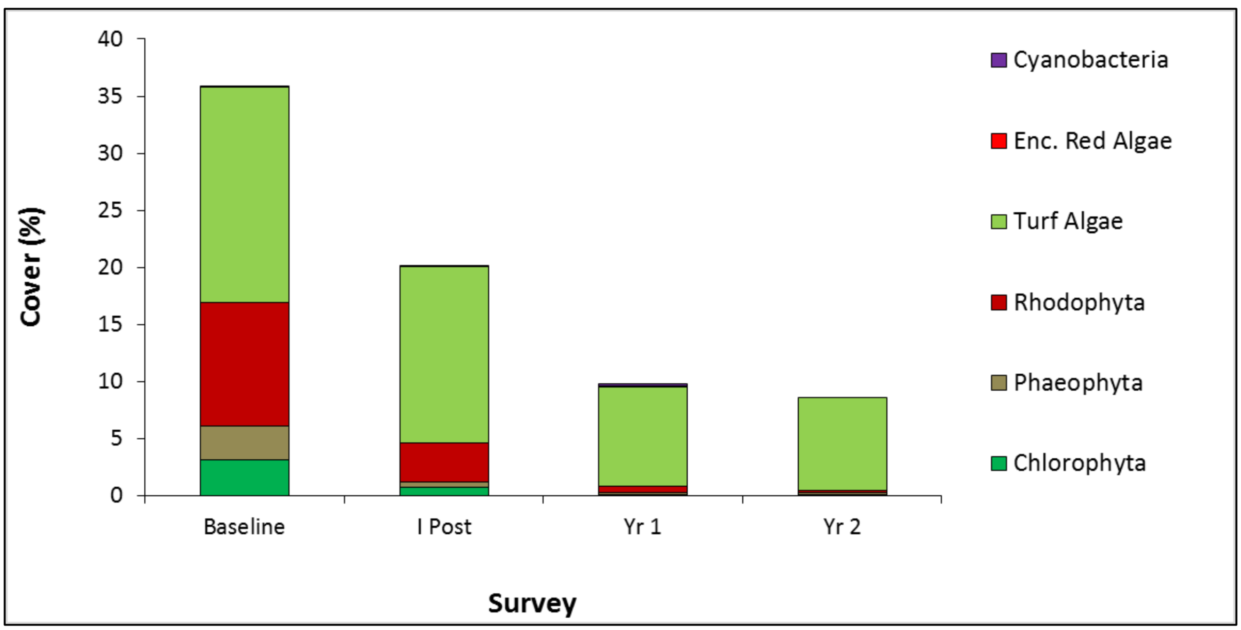


Figure 19. Example of a stacked bar plot reporting mean percent cover of algal functional groups plus cyanobacteria within the project area over time (per survey). Error bars are purposefully not included.

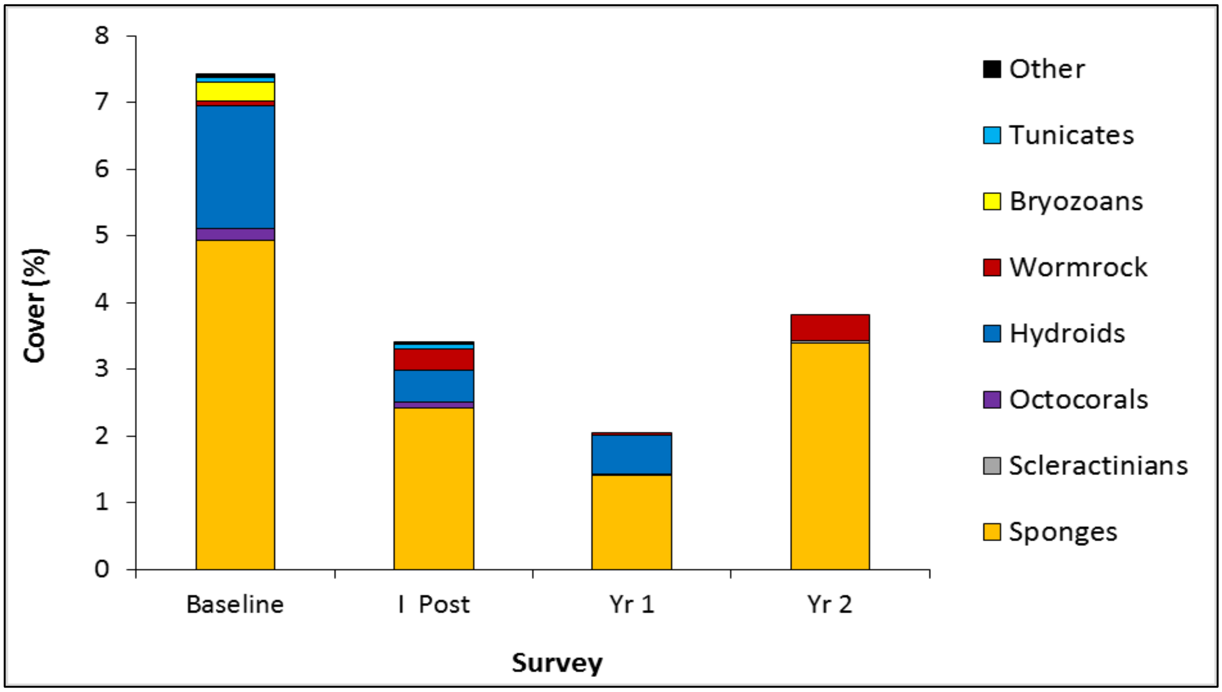


Figure 19. Example of a stacked bar plot reporting mean percent cover of invertebrate functional groups within the project area over time (per survey).

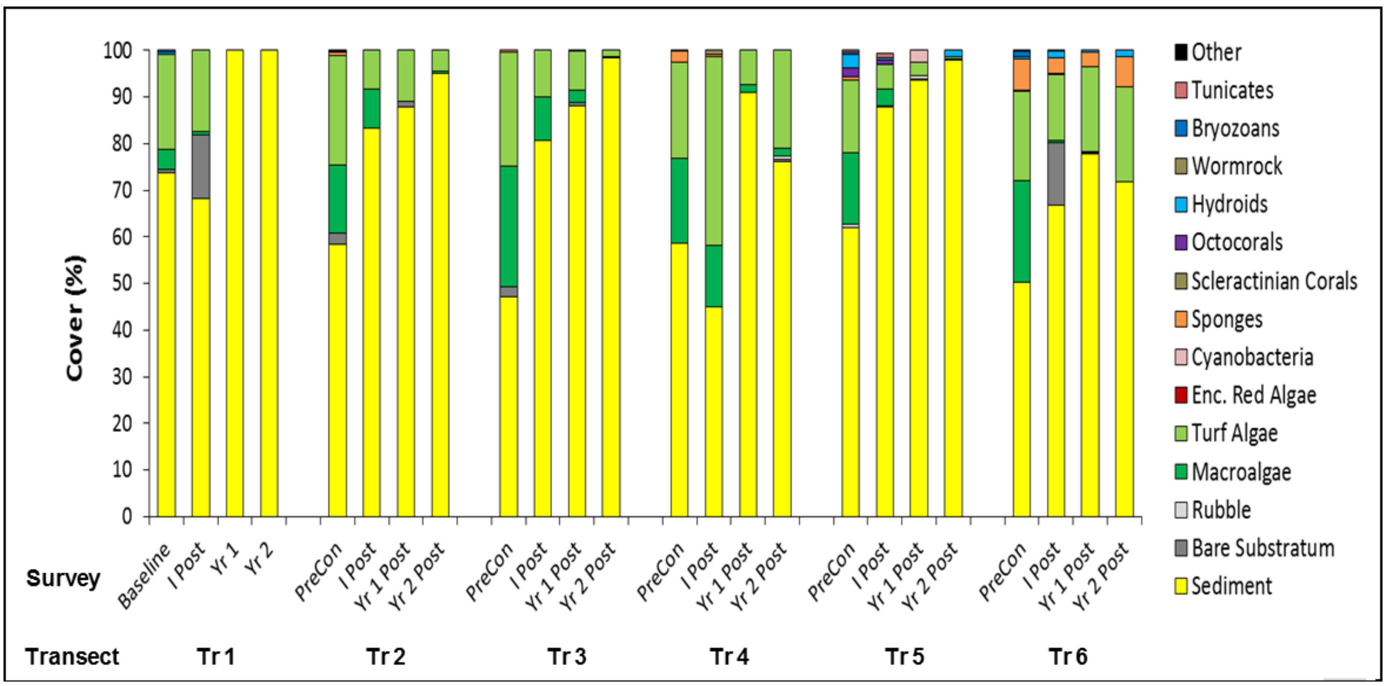


Figure 20. Example of a stacked bar plot reporting mean percent cover of functional groups over time by transect. The functional group "other" is comprised of anemones, zoanthids, hydroids, hydrocorals, sessile worms, bivalves, barnacles, bryozoans, and echinoderms.

Baseline vs. current survey data:

Summary statistics

Change (raw) in the mean cover (%) of eight (8) major functional groups and 18 subgroups should be calculated and presented in tabular form (as in the example format presented in Table 3 below). The seven (7) major functional groups should consist of: Sediment, Bare hardbottom, Rubble, Macroalgae, Turf algae, Encrusting red algae, Cyanobacteria, and Invertebrates. Macroalgal subgroups should consist of: Chlorophyta, Phaeophyta, Rhodophyta, and Encrusting red algae. Invertebrate subgroups should consist of: Sponges, Scleractinian corals, Octocorals, Anemones, Zoanthids, Hydrocorals, Sessile worms, Wormrock, Bivalves, Barnacles, Bryozoans, Echinoderms, and Tunicates.

Multivariate analysis

Non-parametric multivariate analyses (preferably using PRIMER) should be conducted to determine whether functional groups (BEAMR data) differ between the pre-construction and current post-construction survey. The full biological dataset collected during BEAMR quadrat surveys (down to lowest taxonomic level) should be used in the analysis. Figures (*e.g.*, CLUSTER and nMDS plots) and results of permutation tests (*e.g.*, R and p from one-way ANOSIM) should be presented.

Table 3. Example of the tabular format used to report per transect raw change in the cover (%) of major functional groups and subgroups between the baseline and the current survey.

Group	Subgroup	Change in Cover					
		Tr 1 (%)	Tr 2 (%)	Tr 3 (%)	Tr 4 (%)	Tr 5 (%)	Tr 6 (%)
Sediment							
Bare Substratum							
Rubble							
Macroalgae							
	Chlorophyta						
	Phaeophyta						
	Rhodophyta						
Enc. Red Algae							
Turf algae							
Cyanobacteria							
Invertebrates							
	Sponges						
	Scleractinians						
	Octocorals						
	Anemones						
	Zoanthids						
	Hydroids						
	Hydrocorals						
	Sessile Worms						
	Wormrock						
	Bivalve						
	Barnacle						
	Bryozoans						
	Echinoderms						
	Tunicates						

LITERATURE CONSULTED

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DEP "Monitoring Standards for Beach Erosion Control Projects" (dated May 2014) which may found on the DEP website at this location: http://www.dep.state.fl.us/beaches/publications/tech-rpt.htm#RegionalMonitoringPlan . See page 25 of the document for Aerial Photography specifications.

Erftmeijer, P.L.A., Riegl, B., Hoeksema, B.W., and Todd, P.A. (2012) Environmental impacts of dredging and other sediment disturbances on corals: a review. Marine Pollution Bulletin. 64: 1737-1765.

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APPENDICES

Appendix A: Glossary of Terms

The following summarizes and defines some terms that are commonly used in monitoring plans and reports under DEP-managed projects, as well as in other documents related to ecological issues with nourishment projects. If a word used to define is *italicized*, then the word is also defined in this glossary. This glossary will continue to be updated as the Standard Operating Procedures document is refined.

A

Abrasion
The act or process of damaging or wearing away something by rubbing, grinding, or scraping.

Active profile
Portion of the profile characterized by sediment movement from a nourishment project, as equilibrium is achieved.

Assemblage
A group of organisms defined according to phylogenetic, ecological, or other study-dependent criteria

Attrition
The act or process of wearing down by friction – abrasion, impacts and grinding together of clasts in motion, resulting in smaller and more-rounded particles. The term attrition is more applicable to mobile particles per se (*i.e.*, collisions between particles and the resulting physical effects)

Algae
A diverse group of aquatic autotrophic eukaryotes lacking vascular tissue. DEP standard operating procedures for hardbottom monitoring categorizes algae into three major groups: *Macroalgae, Turf algae,* and *Blue-green algae (cyanobacteria). Encrusting (crustose) coralline red algae* are a separate subgroup of macroalgae.

B

Bar (sand bar, longshore bar)
A subtidal sedimentary ridge normally positioned approximately in parallel to the shoreline, offshore of the beach. Bars consist of sediments similar to those in the beach; there can be more than one longshore bar. Bars form continuous or compartmented linear, sinuous, or crescent patterns in plan view, often producing periodic or rhythmic relief features along the shore. Normally the shoreward slope is steeper than the seaward slope.

Beach

An accretional relief feature built by breaking waves at the shoreline. Although other definitions exist, the term *Beach* is defined here as the part of the landform located in between the low tide mark and the upper reach of storm waves (*i.e.*, zone of unconsolidated material that extends landward from the mean low-water line to the location of marked change in material or physiographic form, or to the line of vegetation).

Beach nourishment

The maintenance of a restored beach by the replacement of sand (161.021, F.S.), usually to compensate for beach *erosion* and the recession of the shoreline. DEP does not recommend using the term "re-nourishment"; instead, the very first nourishment at a site should be called *beach restoration,* and all following nourishment events should be referred to as *nourishments*.

Beach restoration

Placement of sand on an eroded beach in order to create a recreational area and provide storm protection for upland properties. 161.021, F.S.

Blue-green algae (*Cyanophyceae, cyanobacteria)*

Prokaryotic photosynthetic microorganisms that are more closely related to bacteria than to higher (eukaryotic) algae. Monitoring surveys of benthic communities primarily deal with two growth forms: mats (like *Schizothrix* spp.) and filamentous forms (like *Lyngbya* spp.) overgrowing erected organisms (octocorals, corals, sponges). However, short erect wick-like bundles (like *Symploca* spp.) or compact cotton'puff-like buttons (like *Schizotrix* and *Spirocoleus* spp.) may also be encountered.

Borrow area

The location where sand is mined for *beach nourishment*. Very different relief features can be used as sand sources for nourishment: sand is mined on dry land for onshore borrow areas (also referred to as an upland sand source or a sand mine); sand for offshore borrow areas can come from large sand waves (*e.g.,* in the Gulf side of Florida shelf), tidal deltas (*ebb delta* or *flood delta*), or from troughs in between ridges in southeast Florida (*e.g.*, in between Outer/3rd and Middle/2nd reefs).

C

Calcareous algae

Algae that secrete calcium carbonate - $CaCO_3$. Represented in Rhodophyta (the largest group), Chlorophyta, and less so in Phaeophyta (*Padina* is the only brown algae that secretes $CaCO_3$). Cyanophyta (cyanobacteria) are also capable of calcification.

Climax Species

Species typically found in a hardbottom assemblage that has reached an equilibrium or steady state. Typically seen in more persistent hardbottom communities.

Community

In ecology, a community is defined as an assemblage or association of populations of two or more different species occupying the same geographical area. In the case of nearshore hardbottom, the community consists of all hardbottom dwelling benthic organisms including flora and fauna (both motile and sedentary). A community does not include the non-living parts of an ecosystem (substrata, sediments, water).

Coral

The term “coral” sometimes has broad interpretation, including all Anthozoa and some other groups of sedentary Cnidarians with calcareous, horny, or soft skeletons. In the case of beach nourishment monitoring, “Coral” refers to species of the phylum Cnidaria found in state waters including:

1. Class Anthozoa, including the subclass Octocorallia, commonly known as gorgonians, soft corals, and telestaceans; and
2. Orders Scleractinia, commonly known as stony corals; Stolonifera, including, among others, the organisms commonly known as organ-pipe corals; Antipatharia, commonly known as black corals; and Hydrozoa, including the family Millaporidae and family Stylasteridae, commonly known as hydrocoral. 403.93345, F.S.

For the purposes of biological monitoring, specific types of corals shall be described as follows: scleractinian corals; octocorals; hydrocorals.

Coral reef

An erosion resistant marine ridge or mound consisting predominately of compacted coral together with algal material and biochemically deposited magnesium and calcium carbonates. Secondary depositional processes play an important role in reef framework development, and loose material (rubble and sand) generated and deposited by storm waves is often lithified and incorporated into the matrix of the reef frame. In addition to hermatypic corals, numerous organisms contribute to coral reef formation and growth (*e.g.*, hydrocorals, calcareous algae, and sponges). Here, coral reefs are viewed as relief features that may vary greatly in scale, from a few meters across and in amplitude of relief to several kilometers long and hundreds of meters in vertical dimension.

Cross-shore sediment transport

A wave and / or tide-generated movement of shallow-water coastal sediments toward or away from the shoreline.

Cuspate
Shoreline form of involving sharp seaward-pointing cusps (normally at regular intervals) between which the shoreline follows a smooth arc.

D

Depth of closure
Point at which sediment from the beach no longer moves offshore due to wave activity. Typically this is also the seaward limit of profiles, due to a transition between active and inactive zones of cross-shore sediment transport.

Density of beach fill
The volume of sand per unit of shoreline (units: m^3/m; $yards^3$/foot).

Diversity
The proportional abundances of species in a given area. Note that species "Richness" is the number of species in a given area.

E

Ebb delta = *Ebb shoal*
Relief feature formed by sediment deposition via tidal currents directly seaward of an inlet. Often has fan-like (delta) plan form, although other shapes are possible. See also *Flood delta*.

Ecological functions
Substantive ecological processes that occur within a community or ecosystem. These functions include, but are not limited to, providing cover and refuge; breeding, nesting, denning, and nursery areas; corridors for wildlife movement; food chain support; and natural water storage, natural flow attenuation, and water quality improvement, which enhances fish, wildlife, and listed species utilization. 373.403, F.S.

Ecological value
The value of functions (see *Ecological functions*) performed by uplands, wetlands, and other surface waters relative to the abundance, diversity, and habitats of fish, wildlife, and listed species.

Encrusting (crustose) coralline red algae
Red nongeniculate algae belonging to the division Rhodophyta which form crusts ranging from a few millimeters to several centimeters in thickness. Crusts may be thin and leafy to thick and strongly adherent. Some crusts may be marked by knobby protuberances ranging from millimeters to several centimeters in height. May occur on any hard substrata (*e.g.*, rock,

coral skeletons, and shells), and as epiphytes on other organisms. Some are free living as rhodoliths (round, free living specimens).

Erosion

The wearing away of land or the removal of consolidated or unconsolidated material from the coastal system by wind or wave action, storm surge, tidal or littoral currents or surface water runoff. Erosion includes:

(a) Landward horizontal movement of the mean high-water line or beach profile.

(b) The vertical lowering or volumetric loss of sediment from the beach and dune or the offshore profile. (62B-41, F.A.C.)

Erosion hot spot

Shoreline segment characterized by erosion rates that are significantly greater than adjacent shoreline segments.

Escarpment

A steep slope or long cliff along a beach that occurs from faulting and resulting erosion, which separates two relatively level areas of differing elevations.

Equilibrium toe-of-fill *(ETOF)*

A line determined by the estimated distance over which nourishment fill will spread (equilibrate its cross-shore profile) under average wave conditions and with respect to specific grain size of sediments used in *beach nourishment*. The estimated ETOF is usually predicted pre-project using "average conditions", which often relates to storm frequency (*e.g.*, such storm happens on average once in 25 years).

F

Flood delta = flood shoal

Relief feature that forms in a lagoon behind a barrier island directly landward from an inlet as a result of sediment deposition by tidal currents. See also *Ebb delta*.

Functional groups

Biotic and abiotic components of an ecosystem specifically selected as survey components for the purposes of monitoring. Biotic components include taxonomic (scleractinian corals, octocorals, sponges, *etc.*) and non-taxonomic (macroalgae, turf algae, *etc.*) groups of benthic organisms used in the accepted monitoring protocol. Abiotic components include substrata (sediments, rubble, and bare hardbottom).

Furrow
A channel-like relief feature which crosses hardbottom perpendicular to the shoreline. Often ends with a delta composed of sand at the seaward opening of the channel, and indicates transport from the beach seaward.

G

Geomorphology
The study of relief features and their origins.

H

Habitat
The non-living part of a landscape and ecosystem, characterized by relief, substrata, water with all dissolved and suspended material, air, and respectively the dynamics of all these components. Use of the term "habitat" as a synonym for "ecosystem" or "community" is inappropriate.

Hardbottom
Rocky substratum, normally immobile, that functions as an attachment surface (substratum suitable for recruitment) for benthic flora and sedentary fauna. Loose debris of sizes larger than gravel, shells, *etc.* can still serve as hard substratum for attachment by flora and fauna and should therefore be classified as hardbottom. However, a single shell or rock with algae growing on it in a sand dominated area would not change the classification of the surrounding landscape from sand to hardbottom. If a rubble field serves as hard substratum (*i.e.*, it hosts macroalgae and sedentary fauna typical for hardbottom while still consisting of lose debris that may occasionally become mobile under increased water motion associated with storms), it shall be classified separately as "lose rocks" or "rubble field". In such a case, it is necessary to evaluate the range and average size of debris and their distribution (scattered or joined to a pavement, *etc.*); this is critical for understanding the stability of such substrata.

I

J

K

L

Ledge

Many dictionaries define a ledge as an underwater ridge, especially of rocks beneath the sea and near the shore. In nearshore projects, ledges are often underwater step-like relief features, with a cliff from 0.1 m to 3m high, stretched nearly shore parallel, and with an upper surface more or less flat and dipping seaward with a low gradient. The extension of ledges alongshore is variable, from a few to hundreds of meters.

Littoral

The term “littoral” has different uses in biology and engineering. The biological definition of “littoral” is synonymous with “intertidal” (an indefinite zone extending seaward from the shoreline to just beyond the breaker zone). See *sublittoral* and *supralittoral* for specific littoral zones.

Littoral transport (drift)

Movement of non-cohesive sediments, (i.e., sand) along the foreshore and shore face via the action of breaking waves and longshore currents. Littoral transport is also called longshore transport or littoral drift. In engineering the term “littoral” refers to a much broader zone than in biology, which may, or may not include the intertidal zone. For Biological Monitoring Plans, Reports, and other documents it is recommended that the terms “longshore sediment transport” and “cross-shore sediment transport” be used instead of the term “littoral drift (transport)”.

Long-shore sediment transport

A wave- and/or tide-generated movement of shallow-water coastal sediments parallel to the shoreline

M

Macroalgae

A collective term used for marine alga that are attached to the benthos and generally visible to the naked eye. For the purpose of monitoring, Macroalgae is defined as algae whose fronds are greater than 15 mm, alternative to turf algae, growing as separate plants (not as a “turf”). Further, three distinct subgroups are recognized, these being: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae).

N

Net sediment transport

The difference between the sediment transport magnitude in the dominant direction and the transport magnitude in the secondary direction. Sediment transport is usually considered to be positive to the right as an observer looks seaward. The net sediment transport can be positive, negative, or zero.

O

P

Profile

A cross-section taken perpendicular to a given beach contour; the profile may include the face of a dune or sea wall, extend over the backshore, across the foreshore, and seaward underwater into the nearshore zone.

Q

R

r-selected species (r-strategists)

Species whose populations are governed by their biotic potential (maximum reproductive capacity, **r)**, as opposed to K-selected species, which are governed by the availability of resources (i.e. populations of K-selected species fluctuate at or near their carrying capacity). The production of numerous small offspring followed by exponential population growth is the defining characteristic of r-selected species. They require short gestation periods, mature quickly (and thus require little or no parental care), and possess short life spans. Unlike K-selected species, members of this group are capable of reproduction at a relatively young age; however, many offspring die before they reach reproductive age.

Reef

"Reefs" mean:

1. Limestone structures composed wholly or partially of living corals, their skeletal remains, or both, and hosting other coral, associated benthic invertebrates, and plants; or
2. Hard-bottom communities, also known as live bottom habitat or colonized pavement, characterized by the presence of coral and associated reef organisms or worm reefs created by the *Phragmatopoma* spp. (403.93345, F.S.)

Rugosity

A coefficient characterizing relief: the ratio of the distance following the relief to the direct distance (straight line). For example, if the distance from the beginning of a transect to the end of a transect measured by a chain laid down on the ground is 22 m, and the distance measured by a stretched tape is 20 m, then R would be: R = 22:20 = 1.1.

S

Sand bypassing
The mechanical or natural movement of sand from one beach adjacent to an inlet or from within an inlet system, to another beach adjacent to the same inlet. (62B-41.002, F.A.C.)

Sand patch
An area of sand greater than 0.5 m in length (as measured under the transect line) that is greater than 1 cm in depth lacking hardbottom benthic components protruding through the sediment.

Scour
Erosion caused by waves and currents or by the interaction of waves and currents with man-made structures or natural features. (62B-41.002, F.A.C.)

Sediments
A solid fragmental material that originates from weathering of rocks and is transported or deposited by air, water, or ice, or that accumulates by other natural agents, such as chemical precipitation from solution or secretion by organisms (biological origin), and that forms in layers on the Earth's crust or surface at ordinary temperatures in a loose, unconsolidated form (for example, sand, gravel, silt, mud).

Sedimentation
The process of sediment particles settling out of the water column, where particles were suspended, and accumulation on the sea floor.

Sediment transport
Movement of sediments by wave energy and currents.

Sediment budget
The mass balance between inputs and outputs of sediment within a defined coastal environment.

Shell hash
Crushed and often attrited (*see Attrition*) shell material. May also be termed *shell detritus.*

Shoreface
The narrow zone seaward from the low tide shoreline permanently covered by water, over which the beach sands and gravels actively oscillate with changing wave conditions.

Shoreline
The intersection of a specified plane of water with the shore or beach. (62B-41.002, F.A.C.)

Sublittoral
The environment beyond the intertidal mark; usually as a shelf immediately below the intertidal zone.

Supralittoral
Spray or splash zone – zone where water reaches areas of dry beach or rock either with spray of braking waves, or with wave and wind set-up.

T

Turf algae
An assemblage of short (<10 mm in height) algae growing in clusters or brush-like mats. These microalgal species have a high diversity. Turf algae are capable of trapping sediments and prevent settlement of larvae of benthic fauna like scleractinian corals, octocorals, and sponges. Turf algae and associated sediments are also able to kill corals by gradual encroachment.

Turbidity
the cloudiness or haziness of a fluid caused by individual particles (total suspended or dissolved solids) that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.

Trench
A long narrow submarine depression with relatively steep sides.

Trough
A long and broad submarine depression with gently sloping sides.

U

V

W

X

Y

Z