Minimum coral reef habitat mapping and biological resource survey requirements for coastal development projects in shallow coral habitats

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This document was prepared by Mark Ladd, of I.M. Systems Group Inc., for the National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service.

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TABLE OF CONTENTS

SECTION PAGE

LIST OF TABLES

1.0 INTRODUCTION

A variety of construction activities occur in or near waters of Florida that may support coral, coral reef, and live/hardbottom habitats (herein referred to as coral reef or reef; see below for definitions). Resource managers have a need for a science-based habitat mapping and biological resource survey approaches to ensure that coral reef habitats are adequately characterized prior to authorizing the modification or destruction of the habitat. The following best management practices (BMPs) have been developed for resource managers, regulatory agencies, and project applicants to address minimum data needs for shallow water coral reef habitat mapping and biological resource surveys associated with coastal development projects in Florida. The types of coastal development projects that these guidelines are appropriate for include (but are not limited to): port expansions, beach renourishment projects, dredging projects, installation of mooring buoys or anchorages, dock and jetty installations and modifications, and telecommunication cable placements. The survey approach may also be relevant for responses to unplanned impacts such as vessel groundings, anchor drags, and cable-tow drags and damages. It is important to recognize that the data collected in these surveys will be used for a functional assessment or analytical tool in order to determine appropriate compensatory mitigation. Therefore, it is essential to ensure that habitat mapping and biological resource survey protocols are designed to collect adequate information to inform the required assessments to determine mitigation before data collection begins. Draft methods should be coordinated with NMFS and other consulting agencies that have reef habitats as trust resources prior to finalization of the survey plan and commencement of fieldwork.

The following BMPs were developed through synthesis of relevant publications and reports, in addition to consultation with coral reef scientists. Note that NOAA National Marine Fisheries Service (NMFS) Protected Resources Division and other agencies may have additional survey requirements for species and critical habitats that are protected under the provisions of the Endangered Species Act.

2.0 DEFINITIONS

Coral Reef – (also referred to in this report as **Reef**) **–** Refers to coral, coral reefs, and live/hardbottom habitat as managed by the South Atlantic Fishery Management Council (SAFMC) through the Coral, Coral Reefs, and Live/Hardbottom Fishery Management Plan (FMP). The FMP manages coral species belonging to the Orders Stolonifera, Telestacea, Alcyonacea, Gorgonacea, and Pennatulacea in the Subclass Octocorallia; Orders Scleractinia and Antipatharia in the Subclass Zoantharia; and the Orders Milleporina and Stylasterina in the Class Hydrozoa. The FMP defines coral reef as hardbottoms, deep-water banks, patch reefs, and outer bank reefs. (Note: for the purposes of this report the terms “coral reef”, “reef”, and “live hardbottom” are synonymous and used interchangeably).

Shallow water – Depths ranging from 0 to 130 feet (0 to 40 meters).

3.0 HABITAT MAPPING

Habitat mapping is a critical first step in determining the distribution and location of habitats within and adjacent to a planned project site or the extent of damage to different habitats at an unplanned impact site. The distribution of habitats within a project site can, and should, guide the development of scientifically defensible survey strategies. A suite of habitat mapping methods exists that can adequately map a project area (see Table 1). The methods selected for mapping depend on multiple factors including the size, location, and scale of the project site, desired minimum mapping unit, as well as available resources and logistical limitations. It is important to recognize that the chosen habitat mapping method will influence how biological data is collected. Some acceptable habitat mapping approaches are summarized below. Alternative habitat mapping efforts should be justified and conducted with appropriate sampling design and at an appropriate scale.

Goal: Determine the size and amount of coral reef habitat that will be impacted by a planned project or event, or to determine the size and amount of coral reef habitat that was impacted by an unplanned event, as well as the characteristics of coral reef resources in the area.

3.1 Acceptable Coral Reef Habitat Mapping Methodologies

Habitat mapping should be conducted to determine the distribution and location of habitats within, and adjacent to, the proposed project area to identify coral reefs and marine resources that may be impacted, provide guidance for avoidance and minimization measures, and assist in determining appropriate compensatory mitigation. Due to the highly variable nature (e.g., size, footprint, location, etc.) of coastal development projects and uplanned impacts, there is no "one size fits all" approach for coral reef habitat mapping. Numerous methodologies exist that can adequately map coral reef habitats associated with coastal development projects. Acceptable methodologies that have been implemented in past coral reef mapping projects are listed below (see Table 1) and references listed. Often using several of the options listed can generate the best map of the area under study. The options presented have been demonstrated to provide the following data identified as the minimum reporting requirements.

3.2 Coral Reef Habitat Mapping: Minimum Reporting Requirements

- Survey dates
- Location (latitude and longitude)
- Name of person(s) or party conducting survey
- Review of previously existing data in survey area
- Coral reef habitat mapping method selection and justification (including minimum mapping unit selected)
- Coral reef habitat characterization scheme selection and justification
- Total area mapped (acres or square meters)
- Total area of proposed project (acres or square meters)
- Total area of each habitat within area mapped (acres or square meters)

- Total area of each habitat that will be impacted by project (acres or square meters)
- Site map that specifies area surveyed, delineates benthic habitats, and project footprint.
- Identification and location of nearby habitats that may provide important ecological links (e.g., seagrass beds and mangroves)
- Identification and location of known threatened or endangered species habitat

3.3 Important Benthic Habitat Mapping Considerations

Habitat Classification Schemes: Multiple habitat classification schemes have been used to map coral reef habitats in Florida. The following resources provide relevant information regarding the development and selection of broad-scale habitat classification schemes as well as more specific, regional habitat classification schemes.

- *The Coastal and Marine Ecological Classification Standard Version 4.0* (CMECES) provides guidelines for determining adequate benthic habitat mapping categories and should be consulted when determining benthic habitat classification.

- *A Classification Scheme for Mapping the Shallow-water Coral Ecosystems of Southern Florida* (NOAA 2008) provides a classification scheme for benthic habitats in southeast Florida < 30 m in depth.

- Zitello et al. (2009) provide an alternative shallow-water benthic habitat mapping scheme as well as a detailed methodology for a comprehensive mapping approach.

Minimum Mapping Unit: A minimum mapping unit (MMU) of 4,000 m^2 (1 acre) has commonly been employed for shallow water benthic habitat mapping in Florida and the Caribbean. However, the appropriate MMU should be determined on a case-by-case basis depending on the characteristics of the resources being mapped for a specific project. Pre-survey assessments to identify features that may define the MMU for a specific project may be necessary depending on the amount of information available for a proposed or impacted site. A mapping effort that requires identifying and mapping individual features such as small patch reefs (e.g., 100 m^2) must employ an MMU small enough to capture these features. For example, Zitello et al. (2009) used an MMU of 1000 m^2 (0.25 acre) to map the benthic habitats of St. John and recognized that even at this resolution they were unable to map individual features (e.g., small patch reefs) smaller than the MMU.

Ground Validation: If remote sensing is selected for delineating benthic habitat boundaries, *in situ* ground validation surveys should be required to ensure accuracy of habitat delineation and characterization. Divers should also conduct ground validation (where feasible; i.e., $\leq$ 130 feet) in areas that were difficult or impossible to characterize from remote sensing data (e.g., blurry imagery, murky water, etc.). Ground validation may be required in addition to biological resource surveys depending on the project size and accuracy of remote sensing data analysis. Depending on the project, performing additional separate accuracy assessments may be necessary to statistically verify the accuracy of a map after it is created. Such assessments should include a separate set of ground validation sites proportionally distributed throughout all habitat types.

Table 1. Acceptable coral reef habitat mapping methods.

<table>
<tr><th colspan="2">SMALL-RESOLUTION MAPPING METHODS</th></tr>
<tr><td colspan="2">Transect tapes and habitat notes</td></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>- No specialized equipment required</td><td>- Time consuming
- Requires very calm conditions
- Difficult to georeference information
- Less feasible for large projects</td></tr>
<tr><td colspan="2">Protocols, examples and references:
- Fishbone Method (Hudson & Goodwin, 2001)
- Spoke-and-wheel Method</td></tr>
<tr><td colspan="2">Surface float tow linking underwater photography with GPS coordinates
- e.g., Ozi ExplorerTM, GPS PhotolinkTM, etc.</td></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>- Georeferenced photo-documentation of area
- Good for before vs. after impact comparisons
- High accuracy and precision
- Can cover large areas relatively quickly
- Easy to post-process photos for data production
- Inexpensive</td><td>- Does not directly provide data (must be done in situ or afterwards)
- Requires large amount of digital storage space</td></tr>
<tr><td colspan="2">Protocols, examples and references:</td></tr>
<tr><td colspan="2">Underwater landscape mosaics</td></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>- Extremely accurate and high resolution complete mapping of site
- Can track changes over time at cm-scale for restoration and mitigation projects</td><td>- Small scale only (up to ~ 1,000 m2)
- Expensive
- Requires specialized equipment and personnel
- Difficult in highly complex 3-D framework and/or high gorgonian density areas</td></tr>
<tr><td colspan="2">Protocols, examples and references:
- Gleason et al., 2010
- Lirman et al., 2010
- Wild et al., 2010</td></tr>
<tr><td colspan="2">Underwater sonar positioning systems
- e.g., AquaMapTM</td></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>- Very precise (sub-meter precision)
- Quick and versatile (can create data points and area outlines)
- Quickly produces georeferenced shapefiles</td><td>- Unit expensive to purchase
- Requires trained personnel</td></tr>
<tr><td colspan="2">Protocols, examples and references:
- Miller, 2002</td></tr>
</table>

Surface towed diver with tow-board	
Pros	**Cons**
- Can map large areas (10's of km)	- Requires a large number of highly-trained personnel - Does not provide detailed information (depending on data collection pattern) - Requires specialized equipment - Requires good visibility
Protocols, examples and references: - Coral Reef Ecosystem Division Pacific Islands Science Center (PIFSC-CRED)	

LARGE-RESOLUTION MAPPING METHODS

(Some can also be applied for small-resolution mapping efforts, dependent upon selected MMU)

High resolution bathymetry (< 3m): acoustic or laser (e.g., LiDAR, multibeam sonar, etc.)	
Pros	**Cons**
- Provides topographic data (slope, aspect, volume, surface area, and elevation) - Accurate spatial and vertical resolution - Allows 3-dimensional view of the landscape	- Requires *in situ* ground truthing to determine habitats - Difficult to discriminate flat habitats (e.g., pavement vs. seagrass) - Should be supplemented by imagery when possible for habitat mapping
Protocols, examples and references: - NSUOC, 2008 - Walker et al., 2008 - Costa et al., 2009	

Aerial photography or satellite imagery Resolution depends on the method employed. The following methods listed provide the corresponding resolution (in parentheses): MERIS (200m), LandsatTM (30m), SPOT (10m), IKONOS (4m), QuickBirdTM (2.4m), Airplane-mounted photogrammetric pushbroom scanner (0.3m), Airplane-mounted frame-based photogrammetric sensor (0.3m)	
Pros	**Cons**
- Can map large areas - Visual record of habitat - High accuracy of certain habitats (e.g., sand, seagrass)	- Must be in relatively shallow water with high visibility - Difficult to ground truth features in images - Expensive if images do not already exist - No topographic information
Protocols, examples and references: - U.S. NOAA Coastal Services Center, 2001 - NSUOC, 2008 - Walker et al., 2009 - Zitello et al., 2009	

4.0 BIOLOGICAL RESOURCE SURVEYS

Once adequate habitat mapping has been conducted for a planned or unplanned coral reef impact site, the biological resources located within the area should be assessed. A variety of acceptable methods can be employed to collect the information necessary to adequately characterize the biological resources to guide avoidance, minimization, and restoration efforts. Data collection categories are broken into three ‘tiers’. Tier 1 is the absolute minimum amount of information recommended to characterize the biological resources of coral reef habitat under investigation and may not be appropriate for many projects. The final rule for the Essential Fish Habitat provisions of the Magnuson-Stevens Act (50 CFR Part 600) states that the level of detail needed for an Essential Fish Habitat assessment should be commensurate with the complexity and magnitude of the potential adverse effect of the action. Based on local characteristics, the proposed project, and the regulatory and resource trustee agencies involved, additional and more detailed surveys may be necessary to collect required data, and are discussed in the Tier 2 and Tier 3 sections of this document. Assessment of the temporal and spatial extent of direct, indirect, and cumulative impacts should be considered as part of a complete biological resource survey. Note that various regulatory authorities have their own survey protocols and minimum reporting requirements (e.g., FKNMS Benthic Survey Protocols) that should be consulted and taken into consideration when developing appropriate biological resource survey methodologies.

Goal: Characterize the reef community (or communities) that will be impacted by a proposed project, or those impacted by an unplanned event (e.g., vessel grounding), so as to provide a sufficient level of information necessary for consultation requirements and adequate avoidance and minimization efforts and determine adequate mitigation or restoration actions.

4.1 Data Collection Categories

Tier 1: The minimum amount of information necessary to adequately characterize a planned or unplanned coral reef community impact area for effectively determining avoidance, minimization, mitigation, and restoration efforts.

Tier 2: Additional survey metrics that can be added to the Tier 1 data collection protocol if required due to the magnitude and complexity of the project impacts or if time, personnel, and budget allows or if required to satisfy a state or federal requirement, in which case project planning should prepare for both levels of effort. Should not be implemented if Tier 1 assessment effort will be compromised (e.g., insufficient number of sampling sites or transects).

Tier 3: Survey metrics that can be incorporated for targeted assessments (e.g., sedimentation, nutrient enrichment, etc.). While some of these parameters are not biological measures, their demonstrated influence on coral reef biological communities warrants the collection of this data in certain circumstances.

4.2 Biological Resource Surveys: Minimum Reporting Requirements

- Survey dates
- Location (latitude and longitude)
- Name of person(s) or party conducting survey
- Review of previously existing data in survey area
- Methods selection and justification for biological resource surveys (e.g., number of surveys, locations, number of transects per site, etc.)
- Stony coral colony density
- Stony coral species richness
- Stony coral size class distribution
- Presence/absence of corals and other species listed as "Threatened" or "Endangered" under the Endangered Species Act
- Octocoral density
- Octocoral size class distribution
- Sponge density
- Sponge size class distribution
- Benthic percent cover (see Table 2)
- Topographic complexity (rugosity or complexity)

Table 2. Benthic categories for Tier 1 percent cover surveys.

	Benthic Category	**Description**	**Examples**
1	Stony Coral	All stony coral species in the Orders Scleractinia and Milleporina	*Acropora* spp, *Agaricia* spp, *Diploria* spp, *Montastrea* spp, *Porites* spp, *Siderastrea* spp,
2	Octocoral	All gorgonians (Order: Gorgonacea), telestaceans (Sub-Order: Stolonifera), and soft corals (Family: Neptheidae)	*Plexaurella nutans, Pseudopterogorgia* spp
3	Sponge	Erect and encrusting sponges	*Xestospongia muta, Clionia* spp
4	Macroalgae	All fleshy algae > 1cm	*Dictyota* spp, *Turbinaria* spp, *Lobophora* spp
5	Crustose Coralline Algae (CCA)	All encrusting CCA	*Mesophyllum* spp
6	Turf Algae	Filamentous algae < 1cm tall	*Gelidiela* spp, *Polysiphonia* spp
7	Rubble/Unconsolidated Substrate	Dead, unstable and uncolonized coral or rock rubble	
8	Pavement/Uncolonized Hardbottom		
9	Seagrass		*Syringodium* spp, *Thalassia* spp
10	Sand	Sandy bottom with no other material or organisms present	
11	Other	Unidentifiable substrate, zoanthids, anenomies, Branching CCA	*Amphiroa* spp, *Condylactis gigantea, Palythoa* spp

4.3 Important Survey Method Considerations

Sampling design: In some cases it may be desirable to stratify project areas into separate habitats if distinct reef zones exist (e.g., Middle vs. Outer Reef, fore vs. back reef). Targeted fixed sites may provide more useful information to determine temporal changes.

Sampling effort: The appropriate number of sampling locations per habitat and number of transects per sampling site depends on project size and site characteristics. A minimum of five transects per sampling site is suggested, though in many cases > 5 transects will be necessary to adequately characterize a sampling site. If previous data exists, a power analysis should be conducted to assist in determining the appropriate number of transects per habitat. If no such data exists, local state, federal, and academic coral reef experts should be consulted to determine appropriate sample size. A variety of methods exist to determine the appropriate number of sampling sites per habitat and transects per sampling sites, including: power analysis, species-area curves, performance curves, bootstrap estimates, and Pearson's product moment correlations.

Unplanned impacts: For unplanned impacts to coral reefs (e.g., vessel groundings and anchor drags) transects should be conducted in impacted and non-impacted reference areas adjacent to the impact area with similar habitat characteristics. The NOAA Damage Assessment, Remediation, and Restoration Program (DARRP) provides guidelines for planning and conducting these assessments (available at: http://www.darrp.noaa.gov/partner/coral/damage.html).

Transect location: Biological resource surveys outlined in this document should be conducted at each sampling site identified on the project impact habitat map. Benthic transects should be oriented perpendicular to the reef slope, or if there is minimal or no reef slope (i.e., similar depth contour) a random heading (0 to 360) rounded to the nearest 10 can be generated and used to determine the direction of the transects. In the case of spur-and-grove habitat, it may be appropriate to orient transects along the coral habitat 'spurs' in order to characterize the coral reef community impacted and avoid confounding the results with sand habitat (i.e., 'grooves'). Heading restrictions are appropriate to ensure transects do not overlap and are kept within the specific habitat being surveyed.

Additional organism surveys: Additional surveys for keystone organisms (e.g., *Diadema antillarum, Palythoa* spp. *Coraliophila abbreviata*, etc.) should be implemented in addition to the Tier 1 or Tier 2 surveys in regions known to contain these biotic components.

Organism counting for stony coral, octocoral, and sponge surveys: A variety of methods exist to determine which coral, sponge, octocoral, etc. colonies are counted in sampling (e.g., entire colony within belt/quadrat, any part within the belt/quadrat, ≥ 50% within the transect, etc.). Zvuloni et al. (2008) provide a review of size-frequency distribution biases that result from different counting methods with line-intercept, quadrat, and belt transect methods. Zvuloni et al. (2008) provide equations to correct for biases identified in these common sampling methods and also offer suggestions for nonbiased methodologies. The effects of sampling bias are minimized by using the same methodology within a BACI design framework. Once a method is selected it must be used in all surveys (e.g., pre- and post-project, inside/outside impact area, future monitoring, etc.) so as to produce consistent results. Methods that are known to generate size-frequency distribution biases should implement the proper mathematical corrections to accurately characterize a site (See Zvuloni et al., 2008 for details).

4.4 Tier 1: Minimum Biological Resource Surveys

A biological resource survey should characterize the reef community (or communities) that will be impacted by a proposed project, or those impacted by an unplanned event (e.g., vessel grounding), so as to provide the minimum amount of information necessary for adequate avoidance and minimization efforts and determine adequate mitigation or restoration actions.

Table 2. Summary of Tier 1 biological resource surveys data collection.

	Data Collected	Information Provided	Suggested Method(s)	Method Selection Considerations
Stony Coral Survey	- Species - Colony size (Max Diameter) – can be placed into size classes determined after data collection	- Estimates for coral colony density, species richness, and size class distribution	- Belt transects	
Octocoral Survey	- Size (Max Height) – Can be placed into size classes determined after data collection - Morphology (pre-defined categories: see Santavy et al., 2012 for details)	- Estimates for octocoral density and size class distribution	- Belt transects (combined with stony coral survey)	
Sponge Survey	- Size (Max Height) – Can be placed into size classes determined after data collection - Morphology (pre-defined categories: see Santavy et al., 2012 for details)	- Estimate for sponge density and size class distribution	- Belt transects (combined with stony coral survey)	
Benthic Percent Cover Survey	- Percent cover (using pre-defined categories; See Table 2)	- Estimate of benthic cover of project or impact site	- Video transects, photo transects, or in-situ data collection (e.g., point-intercept)	- Physical environmental characteristics (e.g., turbidity, visibility, etc.)
Rugosity Survey		- Estimate of topographic complexity of impact site	- Chain method to determine rugosity and/or complexity	- Type and size of impact - Planned vs. unplanned events

Suggested Tier 1 Biological Resource Survey Methodology

A) Belt Transects

Stony Coral Survey:

- Record all stony corals ≥ 3 cm (maximum diameter)
- Identify to species level
- Measure maximum diameter and place into size classes to be defined after data collection

Octocoral Survey:

- Record all octocorals ≥ 5 cm (maximum height)
- Measure maximum height and place into size classes to be defined after data collection
- Place into pre-defined morphology classes: planar, unbranched, branched, bushy, encrusting (See Santavy et al., 2012 for morphology class details)
- *Gorgonia* spp, *Eunicea* spp, *Plexaura* spp, *Plexaurella* spp, *Muricea* spp, and *Pterogorgia* spp have been identified as octocorals that have a strong central spine, and therefore are candid species for transplantation as part of a minimization effort. Effort should be made to identify these species in pre-construction surveys for minimization efforts.

Sponge Survey:

- Record all upright sponges (not encrusting)
- Measure maximum height and place into size classes to be defined after data collection
- Place into pre-defined morphology classes: barrel, vase, globe, tube, mound, rod (See Santavy et al., 2012 for morphology class details)

B) Video, photo, or in-situ (e.g., belt transects)
Photo transects are preferred to video transects due to the higher image resolution that they provide

Benthic Survey:

- Images (extracted from video or taken) to assess entire transect length
- Percent cover determined using Coral Point Count with Excel extensions (CPCe) software (See Kohler & Gill, 2006 for CPCe details)
    - *The appropriate number of sampling points per frame varies depending on local benthic characteristics (i.e., benthic cover). Pante & Dustan (2012) provide an excellent discussion detailing necessary steps to take in order to ensure sufficient sampling effort to quantify benthic percent cover.*

C) Chain link method

Rugosity Survey:

- Conducted at random intervals (e.g., 10m, 20m, etc.) along benthic transect to calculate Rugosity and/or Complexity:
    - Rugosity = (1/d) Complexity = 1- (d/1), where:
        1 = length of chain
        d = measured length with chain following bottom contour

*** It is not recommended to place chain transects over Acroporids, gorgonians, or other fragile benthic organisms due to a high possibility of inflicting damage. Therefore, weighted ropes or other appropriate tools should be employed to avoid these negative impacts. ***

Threatened and Endangered Species Surveys

- If any threatened or endangered species are encountered during surveys, they should be recorded and appropriate measures taken. If planned/unplanned impact sites are in known threatened or endangered species habitat, or threatened or endangered species are observed during the mapping process or biological survey process, these areas should be surveyed for the presence of threatened and endangered species. Minimum survey requirements and protocols for a variety of threatened and endangered species are provided by the NMFS Protected Resources Division and should be followed if such species are identified within a project site (e.g., Recommended Survey Protocol for *Acropora* spp. in Support of Section 7 Consultation, available at: http://sero.nmfs.noaa.gov/pr/pdf/RecommendedSurveyProtocolfor Acropora.pdf).

4.5 Tier 2: Additional Biological Resource Surveys

Table 3. Summary of Tier 2 biological resource surveys data collection.

	Data Collected	Information Provided	Suggested Method(s)	Method Selection Considerations
Stony Coral Survey	- Condition (% live/dead, disease, bleaching) - Recruitment (colonies ≤ 3cm) - Coral colony dimensions (Max Height, Width, Length)	- Estimates for coral colony mortality - Coral recruit density, survival and species richness - Coral colony surface area or 3-D area - Reproductive fitness	- Belt transects - Permanent quadrats	
Octocoral Survey	-Identification to genus level (species level if possible)	- Taxonomic richness	- Belt transects (combined with stony coral survey)	
Sponge Survey	- Identification of selected species/genera - Size measurements (Max Height, Width, Length)	- Estimates for sponge species richness, surface area or 3-D area	- Belt transects (combined with stony coral survey)	

Benthic Cover	- Refine substrate categories (as required by project)	- More detailed estimate of benthic cover of impact site	- Video transects, photo transects, or in-situ data collection (point-intercept)	
Rugosity			- Mulitbeam - Satellite imagery - Acoustic imaging	- Depends on scale
Fish Surveys	- Species - Length (cm) placed into predefined size classes	- Estimates for: fish density, species richness, size class distribution - Identify rare, threatened, or endangered organisms otherwise missed	- Belt transects Atlantic and Gulf Rapid Reef Assessment Method (See Lang et al., 2010)	

Suggested Tier 2 Biological Resource Survey Methodology

A) Belt Transects

Stony Coral Survey:

- Record all stony corals ≤ 3 cm (maximum diameter)
- Identify to species level
- Record maximum height (H), length (L), and width (W) measurements to the nearest cm for all colonies

Octocoral Survey:

- Record all octocorals ≤ 5 cm (height)
- Identify all octocorals recorded to the genus level (species level if possible)

Sponge Survey:

- Identification of selected genera or species
- Record maximum height (H), length (L), and width (W) measurements to the nearest cm for selected species

B) Video, photo, or in-situ transects

Photo transects are preferred to video transects due to the higher image resolution that they provide

Benthic Survey:

- Further refinement of benthic substrate categories if higher detail is required

Rugosity Survey:

- Use of multibeam bathymetry, satellite imagery, etc.

4.6 Tier 3: Examples of Optional Measures for Targeted Surveys

Table 4. Summary of Tier 3 options for targeted biological resource surveys.

Parameter	Data Collected	Information Provided	Suggested Method(s)
Important Species	- Size measurements	- Species density, abundance, size class distribution, etc	- Belt transects
Turbidity			- Secchi disk, nephelometer,
Sedimentation		- Sedimentation rates	- Sediment traps
Nutrient Levels	- C:N:P tissue content, δ15N, δ13C	- Nutrient levels, source of nutrients	- Macroalgae tissue nutrient content analyis, stable isotope analysis (N and C)

5.0 DATA QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

The following QA/QC procedures should be considered the minimum QA/QC for a project (largely based on those conducted by Reed et al., 2008).

All habitat identifications and transitions between habitats should be finalized by the Principal Investigator (P.I.) or trained scientists via reviews of field transcripts, videotapes, and still images.

Organism and substrate identification should be conducted by either the P.I. or trained scientists who have demonstrated expertise with coral reef biota. All questionable identifications should be reviewed by the P.I.

Individuals conducting any survey protocols should be experienced and trained in the survey methods being used.

Suggested QA/QC analyses to be completed by the P.I.:

1) CPCe Point Counts - Re-analyze at least 10% of the CPCe images at each site and compare percent cover with original results.

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