DEVELOPMENT OF BENTHIC AND FISH MONITORING PROTOCOLS FOR THE ATLANTIC/ CARIBBEAN BIOLOGICAL TEAM: NATIONAL CORAL REEF MONITORING PROGRAM

SUBMITTED TO CORAL REEF CONSERVATION PROGRAM

BY

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1. Overview

1.1. Historical context

NOAA's Coral Reef Conservation Program is developing a national monitoring plan for all coral reefs under the US jurisdiction – including Pacific, Atlantic, Gulf and Caribbean. This National Coral Reef Monitoring Plan (NCRMP) builds upon a decade of work supported by CRCP and will focus on four monitoring themes: benthic community condition, fish community structure, climate, and socioeconomic condition.

The Coral Program assembled a Working Group (WG) of scientists and managers with expertise on coral reef ecosystems from nine different offices or science centers across four NOAA line offices from the U.S. Pacific and Atlantic/Caribbean regions. The charge to the WG was to:

- develop unified monitoring questions and goals
- develop a long-term monitoring plan within a constrained budget of ~$4.5 million per year
- identify core indicators within four general themes: coral/benthos, fish, climate, and people
- develop monitoring approaches consistent within jurisdictions and comparable across regions
- develop an approach for a national-level status and trends assessment report

The WG convened nine workshops during 2010-2013 to develop and refine the approaches detailed in the overarching National Plan (CRCP, 2014). In general, the target domain for *NCRMP* is reef habitats shallower than 30 m within the NOAA Coral Program geographic priority areas. The WG has adopted the general principle of geographically comprehensive monitoring, *i.e.*, that the broad goal is spreading sampling effort widely across the reefs within each jurisdiction, rather than focusing effort at "representative" stations, given concerns that identifying such stations is an inherently subjective and unreliable process.

National monitoring of fish and benthos is divided between NMFS Pacific Islands Fishery Science Center Coral Reef Ecosystem Division (CRED) and an Atlantic/Caribbean (Atl/Car) biological monitoring group, co-led by NOS National Centers for Coastal Ocean Science (NCCOS) and NMFS Southeast Fisheries Science Center (SEFSC). This document focuses on the Atlantic/ Caribbean geographies of NCRMP. Monitoring of fish and coral/benthos are to have equal weighting in relation to survey design and survey allocation. Fish monitoring will follow extant jurisdictional monitoring programs, although techniques differ (point count method in the Florida Keys and Dry Tortugas and belt transect in Puerto Rico, US Virgin Islands and Flower Garden Banks). Benthic monitoring will consist of a technique to assess percent cover of biotic and abiotic elements and a technique to quantify density and size frequency distribution of stony corals.

The Atlantic/ Caribbean working group consisting of NCRMP partner scientists from NOAA, the National Park Service (NPS), the Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and Nova Southeastern University (NOVA) held two workshops to provide guidance on the techniques needed to accomplish NCRMP goals and objectives. The working group concluded that NCRMP benthic metrics should at a minimum include techniques to estimate benthic cover and coral size/abundance. For benthic cover, the group strongly preferred in situ Line Point Intercept (LPI) transects, compared to photographs. LPI requires additional time in the water and does not provide permanent visual observations (digital images) for later analysis of emergent questions; however it does provide greater resolution of difficult-to-distinguish categories (*e.g.* algal turfs) and avoids significant post-processing time, making results available more rapidly. Size/abundance data are derived from 10 x 1m belt transects, producing data on colony size, colony density, and population size structure, as well as additional information on coral community composition. LPI transects are conducted in concert with each fish transect. Coral community structure is surveyed on a subset of fish sites, based on statistical allocation formulas.

1.2. Approach and implementation

A benthic working group of NCRMP partners was formed in 2013 to draft field protocols based on the recommendations to NCRMP from the benthic workshop (June 5-6, 2012). Early draft protocols were field-tested at Broad Key in April, 2013. At this time, extensive discussions were held to improve and increase the efficiency of the approach. Additionally, methods and allocations were based on single stage survey designs; these are utilized in Puerto Rico, USVI, and Flower Garden Banks National Marine Sanctuary (FGBNMS). Survey methods in Florida and the Dry Tortugas have historically used a two stage sampling design.

All protocols were implemented in 2013 field sampling for the USVI (July) and FGBNMS (Sept). It is anticipated that few changes will be made for the implementation in Puerto Rico in 2014.

2. Benthic Protocols

2.1. Coral demographics protocol overview

Coral demographics protocols were developed to provide coral species-specific data at a more detailed level than percent cover. This protocol details data collection for colony size, density, and population size structure. It addresses four Tier 1 metrics and two Tier 3 metrics (Table 1). Other NCRMP indicator metrics were not included due to capacity limitations or restriction of the sampling design. Coral disease is considered a Tier 1 metric (NCRMP, 2014); however it was decided to omit from data collection for two reasons: 1) the temporal scale of sampling (bi-annual) is considered not sufficient to produce meaningful data, and 2) concerns about potential

inconsistencies in field identification of all coral diseases by field personnel. Specifics of the coral demographics protocol are based closely on other existing monitoring programs in the Atlantic/Caribbean region, including Atlantic and Gulf Rapid Reef Assessment (AGRRA; Caribbean-wide), Florida Reef Resiliency Program (FRRP; Florida), SCREAM (Sanctuaries Coral Reef Ecosystem Assessment and Monitoring, Florida), and USVI Territorial Coral Reef Monitoring Program (TCRMP; USVI*)*. Transect dimension is 10 x 1 m which is consistent with existing monitoring programs and is sufficient to complete at depths between 2-30 m.

2.2. LPI protocol overview

The Line Point-Intercept (LPI) method was chosen to provide a measure of percent cover of biotic and abiotic components of the benthos in a stratified random sampling design in hard bottom and coral reef habitats. The method is designed to provide resolution of benthic cover estimates for ecologically important groups (*e.g.* macroalgae, turf algae, crustose coralline algae, corals, sponges, sand/sediment, etc.). LPI surveys are concurrent with fish surveys. The WG recommended that point-based methods are the preferred approach to derive estimates of percent benthic cover. LPI has several advantages over other point type techniques (such as photoquadrats) that require significant effort to post-process data after sample collection. In the protocol described here, divers record both abiotic and biotic features with each observation. The protocol collects information for four Tier 1 metrics and one Tier 3 metric (Table 1). The LPI method is implemented along a 20m transect. In USVI, FGBNMS and Puerto Rico, this is the same transect (less 5m) used for the fish survey. In Florida, methodologies for co-location of LPI transect and RVC Cylinder are in development. Observations are taken every 20 cm, or 5 per meter, for a total of 100 observations. Percent cover is calculated by the number of observations of a specific biological group divided by the total number of observations for all groups.

3. Metrics

Indicator metrics, as identified in the NOAA Coral Reef Conservation Program National Coral Reef Monitoring Plan (Draft 11/13), are addressed within these protocols as described in detail below. Metrics that are not addressed by the protocols were excluded due to limitations for field effort (*e.g.* recruitment, reproduction, microbial communities, metabolic performance) or the sampling frequency. Non-indigenous species, including lionfish, will be noted if encountered on fish surveys.

Table 1. NCRMP Indicator metrics as addressed in current (2013) Atl/ Car NCRMP benthic and fish protocols. 2013 benthic protocols were developed for percent cover (LPI) and coral demographics. A dash (-) means the metric is not currently addressed in the protocols.

NCRMP Indicator	Benthos/coral metric	Current NCRMP protocols
Tier 1 Indicators - Critical	Abundance and size structure	Coral demographic/Fish
	Coral condition (*e.g.* bleaching)	Coral demographic (limited)
	Percent cover of benthic organisms/substrate	LPI
	Rugosity	Fish
	Benthic/Fish species richness/diversity	Coral demographic/Fish/LPI
	Key benthic/coral/fish species	Coral demographic/Fish/LPI
Tier 2 – Important	Growth rate	-
	Bioerosion rate	-
Tier 3 - Informative	Reproduction	Fish
	Recruitment	Fish
	Mortality	Coral demographic
	Metabolic performance	-
	Microbial communities	-
	Non-indigenous species	Fish
	Protected species	Coral demographic/Fish/LPI (coral, lobster, conch)

3.1. Coral abundance and size structure

Coral abundance and size structure are the minimum metrics necessary to describe status and trends in coral population dynamics. The Atl/Car coral demographic protocols address this metric where all corals >4cm are identified to species and measured for size within a 10x 1m transect. Size measurements are included as length, width, and height, consistent with AGRRA, SCREAM and FRRP methodologies. Enumeration of gorgonian size/abundance and juvenile corals were recommended by the 2012 working group; however, due to field logistics constraints, these were not included in the 2013 benthic protocols.

3.2. Coral condition

The 2013 coral demographics protocols draft addresses coral condition in two ways: estimation of coral bleaching and of mortality. See 3.7 below for additional information on mortality. The benthic working group did not initially include metrics for coral condition due to the 1) uncertainties inherent in field identification of disease and bleaching, 2) the bi-annual sampling plan, and 3) the intent that intensive, event-based local sampling would occur via complementary monitoring programs within each jurisdiction. At the Broad Key training workshop, bleaching condition was added to the protocols to serve as an early warning system if needed. Bleaching is noted if present, and described as total colony bleaching or partial bleaching.

3.3. Percent cover of benthic organisms/ substrate

The 2013 line point intercept protocols draft includes nineteen taxonomic groupings (including bare substrate) that are typical reef or hardbottom constituents to quantify percent cover at all NCRMP survey sites. Groups include: scleractinian corals to species, turf algae (clumped or not), macroalgae (including three major genera -*Dictyota, Halimeda, Lobophora*, other fleshy and other calcareous), calcifying red algae (crustose coralline algae, *Peysonnellia*), gorgonians (upright and encrusting), sponges (*Cliona* and all others) cyanobacteria, *Millepora*, *Palythoa*, seagrass, bare and other. These groupings comprise the majority of benthic taxa found on hardbottom and reef habitats throughout the Atlantic and Caribbean basins. Divers record observations of these groups every 20 cm along a 20m transect. Observations are grouped by substrate type: hardbottom, soft or rubble. Percent cover is calculated as the number of observations for all groupings divided by the total number of observations.

3.4. Rugosity

Complexity measurements provide information on the topographic complexity (substratum rugosity) of survey locations where reef fish, line point-intercept, and demographic surveys are conducted. In many cases, the benthic complexity is an important indicator of benthic and fish communities.

Characterization of topographic complexity along the fish transect (FGBNMS, Puerto Rico, USVI) or RVC cylinder (FL) consists of three separate elements:

- Minimum and maximum depth along each 25m transect (or 15m diameter RVC cylinder);
- Amplitude of substratum relief, recorded as the maximum vertical relief in a 25m x 4m belt transect or a 15m diameter RVC cylinder; and
- An estimate of the relative proportion of different relief categories for the sample unit using six categories ranging from < 0.2 m to > 2 m.

3.5. Benthic/coral diversity

Percent cover of coral species will be calculated using the LPI data. All coral observations will be recorded to the lowest possible taxa (species preferred). Frequency of occurrence and species richness may also be evaluated using this method.

Within the coral demographics transect, corals measuring >4cm are identified to species, counted, and dimensions are measured. Although juvenile corals (<4 cm) are not enumerated in the current survey design, unique juveniles species (those not present on transect in size classes >4cm) are identified on the datasheet. The objective is to ensure diversity addresses all coral species within the demographics transect. This methodology is consistent with CREMP.

3.6. Key species

Key species include the subcategories of protected species, lobster, urchins, and conch. Abundance and size structure of ESA coral species are quantified within the demographic survey area (10x1 m). The presence or absence of currently listed and candidate ESA corals are also specifically noted on the 25X2 m LPI belt transect after the LPI survey has been completed.

3.7. Mortality

Estimation of coral mortality includes both old mortality, and recent mortality, each measured separately. Old mortality is an estimate of the percentage of old dead, tissue-free skeleton on the overall coral colony. This methodology is consistent with AGRRA, FRRP, and SCREAM. Recent mortality is an estimate of the percentage of exposed white bare skeleton on the overall coral colony. This methodology is consistent with AGRRA, FRRP, SCREAM, and TCRMP.

4.0 Fish

NCRMP fish surveys will gather data on the number and size of reef fishes within sample units at the lowest feasible taxonomic resolution (typically species level). This abundance data can be converted to a range of diversity indicators, including richness per sample unit, as well as calculated diversity and evenness measures. Similarly, assuming the dimensions of survey units are known, information on size and numbers allows for the calculation of density and biomass per taxon or functional group, with biomass estimated using species-specific length-to-weight conversion parameters available from a range of published and web-based sources, *e.g.*, FishBase 2000; Kulbicki *et al.* 2005.

NCRMP fish protocol for the USVI, Puerto Rico (Menza et al., 2006) and Flower Garden Banks National Marine Sanctuary (Caldow et al., 2009) will follow techniques previously established by the Biogeography Branch with some slight adjustments. In summary: a 25x4 m belt transect will be used to assess fish communities. Fish are identified to species or lowest possible taxon, and sizes estimated (fork length) within 5 cm size bins (0-5, 5-10, etc). Fishes over 35 cm are recorded as actual size.

4.1 Metrics

Tier 1 fish indicators include abundance and size structure. These can be grouped taxonomically by family, by trophic/functional group, or managed species. Fish species/family/trophic group biomass may also be a useful metric. Fish species richness will provide a measure of diversity within various strata in a given jurisdiction. Key species may be jurisdictionally specific and are recorded as species observed on transect. Key species may include all managed grouper, snapper and parrotfish species. Lionfish are common across the jurisdictions and their occurrence/density information may be useful for local managers/researchers.

4.2 Size estimate changes

For select managed species, groupers (Serranidae) and snappers (Lutjanidae), we improved the resolution of size estimates to include exact fork length measurement for up to 10 individuals and, if N>10, mean size was recorded for the additional individuals.

4.3 Additional fish diver tasks

In section 3.4 we define an NCRMP biological metric for rugosity or topographic complexity. The purpose of this metric is to provide information on the topographic complexity of locations where fish and benthic surveys are conducted. In order to balance in-water tasks, the fish diver will conduct the topographic complexity assessment upon conclusion of the fish survey. Once the fish survey is done and starting at meter 24, the diver will measure the highest hardbottom feature in all 24 2x2 m grids (right and left sides of transect tape) back to the start of the transect. The fish diver will also record a minimum and maximum depth along the entire transect as well

as the maximum vertical hardbottom relief area along the entire transect. Relief frequency data will be used to develop an index that will be used to characterize habitat types and correlate with fish communities.

5.0 Contributors

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Appendices

A: LPI protocol

B: Coral demographics protocol

C: Fish/topographic complexity protocol

Line Point-Intercept (LPI) Survey Protocol for the Atlantic/Caribbean

National Coral Reef Monitoring Program (NCRMP)
Coral Reef Conservation Program (CRCP), National Oceanic and Atmospheric Administration
Updated 05 Aug 2013

Introduction

NCRMP is a broad spatial snapshot for reef condition (*i.e.* fish species composition/density/size, benthic cover, and coral density/size/condition) to provide context for local-scale studies of tropical reef ecosystems. Data collection will occur at stratified random sites where the sampling domain for each region (*e.g.* Puerto Rico, USVI, Flower Garden Banks and Florida) is partitioned by habitat type and depth, sub-regional location (*e.g.* along-shelf position) and management zone. NCRMP is intended to supplement local monitoring efforts by providing large-scale data on reef fishes and the benthos.

The LPI sampling is designed to provide resolution of benthic cover estimates for ecologically important cover types/groups (*e.g.* macroalgae, turf algae, crustose coralline algae, corals, sponges, sand/sediment, etc.). More detailed information on scleractinian corals, specifically density, size, and condition (percent mortality and bleaching) measurements, is being collected via the NCRMP Coral Demographics sampling.

Goal of LPI Surveys

The goal of these surveys is to provide a measure of percent cover of biotic and abiotic components of the benthos, using the Line Point-Intercept (LPI) method in a stratified random sampling design in hard bottom and coral reef habitats in the U.S. Atlantic and Caribbean. Surveys are concurrent with and along the same transect as fish surveys.

Likely task allocation scenarios

- 1 LPI diver:
    - LPI diver collects LPI data and completes key species survey.
    - No demographic data are collected during this survey.

- 1 LPI diver + 1 Demographics diver:
    - Upon completion of the LPI transect, the LPI diver will coordinate with the coral demographic diver and assist with completing the demographic transect (if LPI benthic ID skills allow), if bottom time and/or bottom complexity dictate.
    - It is a higher priority for the demographic transect to be completed than for the LPI diver to complete the key species survey (*i.e.* macro-invertebrate [spiny

lobster, queen conch, *Diadema* urchin] counts and coral ESA presence-absence). However, every effort should be made, in cases where LPI and coral demographic surveys are concurrently conducted at a site, to complete both surveys completely.

Line Point-Intercept (LPI) Transect Information

1. Line Point-Intercept (LPI) transects will be surveyed at all fish survey sites: 25m transect (PR, USVI, FGBNMS) or 15m diameter (RVC) cylinder (FL) (Appendix I).

    a. Where fish transects (not RVC cylinders) are used, the LPI diver (and Demographic diver, if present) will use the same transect as the fish diver (Appendix I).

        i. Benthic divers will follow along behind the fish diver at a distance to avoid influencing swimming behavior of fishes (*i.e.* the LPI diver should start when the fish diver is near the 5m mark, then the Demographic diver will start).
        ii. The fish diver will tie off start of transect tape and continue to keep the transect tape relatively taut throughout survey.
        iii. The fish diver may use weights to secure the transect tape along the bottom.
        iv. The fish diver should avoid wrapping the tape around substrate or biotic object, as this will distort sampling distances and locations for the benthic diver.
        v. At Fish + LPI + Demographic sites, LPI diver may assist demo diver to finish demo transect within depth/time limits of dive. Demographic data completion has higher priority than key species (macro-invertebrates and ESA-proposed corals species) data collection, but if possible, key species surveys should be completed at all LPI sites.

            1) If LPI diver assists Demographic diver in survey completion, LPI diver starts her/his survey at 10 m and works until s/he finishes a complete meter and meets Demographic diver. LPI and Demographic divers will coordinate to avoid duplicating counts.
            2) To ensure that all space is surveyed, there should be no surveys of partial meters.

    b. Where RVC fish cylinders are used (*e.g.* Florida), the LPI diver will establish the transect using a random compass heading and in close proximity (*i.e.* safe diver distance) to the fish surveyor.

        i. Details are in development and will be added to this protocol when they are complete.

2. Locating the sample site(s) and survey area(s).
   Divers are deployed together and maintain contact with each other throughout the entire census.

   a. Prior to entering the water, one of the benthic divers obtains a random compass heading for the transect and records the compass bearing (0-360^{o}) on the datasheet.

   b. Navigate to previously selected sites using a handheld GPS unit.

   c. Where appropriate, the boat can drop a weighted float that will mark the start of the transect.

      i. Dropping a float with soft weight in the St. John VINP and VICR is acceptable.

   d. Divers will descend as rapidly but safely as possible to maintain relative proximity to the centroid position.

   e. The only instance where the transect should deviate from the designated path is to stay above 99 ft.

   f. Do not alter the predetermined course if the centroid is not on hardbottom or the bearing does not cover hardbottom.

      i. If it becomes apparent that no hardbottom is in the vision of the dive team (*i.e.*, continuous sand, seagrass or limited visibility), then the dive will be terminated and an alternate site selected.
      ii. If hardbottom is observed in the vicinity of the site, then the dive continues as planned- starting on the centroid, or close approximation, and on the predetermined random bearing.
      iii. On-site, do not avoid structural features within a habitat such as a sand patch or an anchor as these are "real" features of the habitats.

3. The LPI diver is responsible for collecting the following information:

   a. LPI data: 100 points, at 20cm intervals, starting at the 20cm mark and ending at the 20m mark along the transect tape.

   b. Macro-invertebrate counts (spiny lobster, queen conch, *Diadema* urchins) in a 25m x 2m belt transect area AFTER completing the LPI survey, concurrently when the LPI diver is swimming from meter marker 25 (*i.e.*, the end of the transect tape) to meter marker 0 (*i.e.*, the beginning of the transect tape).

c. Presence-absence of nine (9) ESA candidate scleractinian coral species in a 25m x 2m belt transect area AFTER completing the LPI survey and concurrently with the macro-invertebrate (*i.e.* lobster, conch, urchin) counts.

d. Underwater photographs of the general survey area, including the transect seascape, as well as interesting features and species identification questions.

4. LPI transects will start at 20cm from the beginning (marker 0) of the transect tape and continue to the 20m marker. Sand patches and other non-hard-bottom features will not be skipped, and 100 points (one point every 20 cm) will be collected along the 20m section of the transect.

    a. Note that the 20m LPI transect survey length is less than the 25m fish belt transect length (Appendix I).

    b. One hundred data (100) points for benthic cover will be collected along the 20m transect length, with data collected at 20cm intervals. The estimated average time for completion is 15-20 min (5-7 points scored per minute).

        i. The LPI diver will frequently check the number of marks while collecting data; for example, at every meter marker, there should be multiples of five points accounted for on the data sheet. If there are an incorrect number of data points at any meter, the LPI diver will try to correct the count while still on the transect.
        ii. At the end of the LPI survey, if there are <100 or >100 data points, effort is made by LPI diver to correct the count while still on the transect. If 100 points ±5 (95 to 105 points) are collected, data are acceptable and may be entered into database.
        iii. Come back to the boat with 100, or do not come back. ☺ Disclaimer: This statement is not endorsed by the NOAA Dive Program.

Field Equipment

1. LPI and Demo datasheets, clipboard, pencil (and spare pencil)
2. Instrument to aid in locating exact point under transect tape (*e.g.*, PVC stick, ruler)
3. Slide marker to keep point location along transect (optional, *e.g.*, clothes pin)
4. Camera (battery, housing)
5. 50cm or 1m PVC stick or other rigid measuring device for key species surveys to accurately determine a 1m linear distance out from the transect tape

Notes for field equipment for fish divers:

1. Each fish diver may need a few weights (ankle, soft) to periodically place along the 25m transect tape to hold it down to the substrate.
2. Each fish diver must securely tie off the beginning and end of the 25m transect tape.

Line Point-Intercept Survey Protocols

1. Complete datasheet header (Figure 1).
    a. Fill in all categories legibly
    b. Circle habitat type observed at diver scale (not mapped category)

LPI Diver		Fish Diver		Demo Diver	
Site ID		Date		Time	
Habitat type	Bedrock Linear Patch Pavement Scattered Coral/Rock				

Figure 1. NCRMP LPI datasheet header.

Photographs of the site

2. While the LPI diver waits for the fish surveyor to proceed down the transect (giving at least a 5m head-start), the LPI diver should take underwater photographs of the general survey area, including the specific transect survey area for general site characterization, as well as of other divers conducting surveys, along with unique features, and for species identification purposes.

    a. Prior to taking any photographs of the site, one photograph should be taken of the slate to include the site name and date.

    b. Photographs should be oriented just left, forward, and just right of transect.

    c. Photographs may also be taken of anything unusual (*e.g.* rare fish, bleached or rare corals) and for species identification clarification.

    d. The process for downloading and storing site photographs is detailed in a separate document titled “Photo Documentation Manual”.

Line Point Intercept Point Identification

3. At 20cm intervals along the transect tape, identify and categorize the substratum type according to protocol/available data sheet options (Figure 2, Appendix II). Identify each point for the substrate type and the biotic organism (if any).

    a. Abiotic/substratum categories include hard (*i.e.*, hard-bottom or reef), soft (*i.e.*, sand or mud), and rubble (Figure 2, Appendix II).

    b. Biotic categories include coral to species, bare, algal turf, etc., as shown in Figure 2 and Appendix II.

    c. Example #1: if a point falls on bare sand, one mark is recorded in the "Soft" column along the "Bare" row.

    d. Example #2: if a point falls on turf algae growing on hard-bottom with no sand trapped in the turf filaments, one mark is recorded in the "Hard-bottom" column along the "TURF-no sediment" row.

4. Exercise caution when identifying a particular point to evaluate. The most objective way to score a point along the transect is to use a straight edge (*e.g.*, pencil) and vertically orientate it downward toward the substratum. Bias, subjectivity and "artificial selection" of favored substrates (*e.g.*, corals) should be avoided. However, the point should be identified quickly – no 'dithering'.

5. Record the first abiotic/biotic bottom type encountered.
    a. Gorgonian branches are not valid points, but gorgonian holdfasts are valid points. In other words, canopy cover by "soft" branching organisms such as gorgonians, branching *Millepora*, and sponges is not scored unless the point intercepts a holdfast/attachment point. The approach for assessing benthic cover is not considering "canopy" cover above the actual substratum.
        i. When a point falls on encrusting *Millepora* growing on a gorgonian, it is scored as gorgonian ONLY IF the point falls on the holdfast of the gorgonian. The vertical, flexible "fan" area of the sea fan is not a valid point.
        ii. This same point is scored as *Millepora* when the point falls on the attachment point of an encrusting or branching *Millepora* colony.

    b. Branching corals (*e.g. Acropora* spp.) are valid points.

    c. Algae (*e.g. Sargassum*, *Dictyota*) are valid points.
        i. Example #1: a patch of *Dictyota* macroalgae growing on and covering CCA would be scored as *Dictyota.*
        ii. Example #2: If a branching *Sargassum* plant were intersected by the transect, only the holdfast should be scored if the transect tape intersects the algal holdfast.

Categories: one tick every 20cm	Hardbottom	Soft	Rubble
Coral (to Genus)			
Bare			
TURF-no sediment			
TURF w/sediment			
MACRO-Dictyota			
MACRO-Halimeda			
MACRO-Lobophora			
MACRO-other fleshy			
MACRO-other calcareous			
CCA			
Peysonnellia			
GORG upright			
GORG encrusting			
SPONGE other			
SPONGE Cliona spp			
CYANOBACT/DIATOM			
Millepora			
PALYTHOA			
SEAGRASS			
Other			

Figure 2. Abiotic and biotic section of LPI datasheet.

AFTER completing the LPI survey, the LPI diver may assist the coral demographic diver in completing the demographic transect within depth/time limits of the dive and if LPI diver benthic ID skills allow. If there is no need to assist the demographic diver, the LPI diver will conduct the Macro-invertebrates counts and the Endangered Species Act proposed coral species presence/absence survey in a 25m x 2m belt transect (25m in length, 1m on each transect side).

Assisting with the Demographics Surveys

6. If LPI and Demographic surveys are being conducted at a site, LPI diver should bring a Demo datasheet with him/her to facilitate assisting Demo diver in data collection.
7. If LPI diver assists Demographic diver in survey completion, LPI diver starts her/his survey at 10 m and works until s/he finishes a complete meter and meets Demographic diver. LPI and Demographic divers will coordinate to avoid duplicating counts.
8. To ensure that all space is surveyed, there should be no surveys of partial meters.
9. LPI diver needs to be familiar with Coral Demographics Survey Protocol.

Macro-invertebrates counts

10. All Caribbean spiny lobster (*Panulirus argus* and *P. guttatus*), queen conch (*Strombus gigas*), and long-spined sea urchins (*Diadema antillarum*) are counted within the 25m x 2m belt transect (Figure 3).
    a. This survey area lies within the 25m x 4m fish belt transect area and is defined as the full length of the transect (*i.e.* 25m length) with a width of one meter on each side of the transect tape (Appendix I). This is also the same transect area that is surveyed for the ESA proposed coral species presence-absence.
    b. A 25m x 2m belt transect area provides density estimates of numbers of organisms of each species per 50 m^2, while ensuring that all area is thoroughly surveyed.
    c. If no search occurs, denote this with an "X" in the Count column. ***This is critical to record at those sites where, due to logistics, the macro-invertebrate counts could not be completed, which is entirely different from a survey where no organisms were encountered.***

Macroinvertebrates on 25x2 transect	
Count	
Lobster	
Conch	
Diadema	

Figure 3. Macro-invertebrate section on LPI datasheet.

Endangered Species Act proposed coral species presence-absence

11. Presence-absence within the 25m x 2m belt transect of all nine (9) Atlantic/Caribbean coral species proposed to be ESA-listed will be recorded at each site (Figure 4).
    a. This transect lies within the 25m x 4m fish belt transect and is defined as the full length of the transect (*i.e.*, 25m length) with a width of one meter on each side of the transect tape (Appendix I). This is the same belt transect area that is surveyed for numbers of spiny lobster, queen conch, and *Diadema* urchins as described above.
    b. Atlantic/Caribbean ESA-proposed scleractinian coral species are *Acropora palmata*, *A. cervicornis*, *Agaricia lamarcki*, *Dendrogyra cylindrus*, *Dichocoenia stokesi*, *Montastraea annularis*, *M. faveolata*, *M. franksi*, and *Mycetophyllia ferox*.
    c. Photograph any colonies that are of uncertain identity and verify.
    d. Presence is denoted by a "1" (one).
    e. Absence is denoted by a "0" (zero).
    f. If no search occurs, denote this with an "X" on the data sheet. ***This is critical to record at those sites where, due to logistics, the ESA-proposed or listed coral presence-absence surveys could not be completed, which is entirely different from a survey where species were absent (not encountered) within the 25m x 2m belt transect survey area.***

Presence(1)/Absence(0) on 25x2 transect	
A. palmata	
A.cervicornis	
D. cylindrus	
M. ferox	
A. lamarcki	
M. annularis	
M. franksi	
M. faveolata	
D. stokesii	

Figure 4. LPI datasheet section naming ESA-listed and proposed coral species.

Data Entry into Database

Data should be entered into the database (see example in Figure 5) as soon as possible, preferably the same day.

- More detailed data entry information will be provided on site.

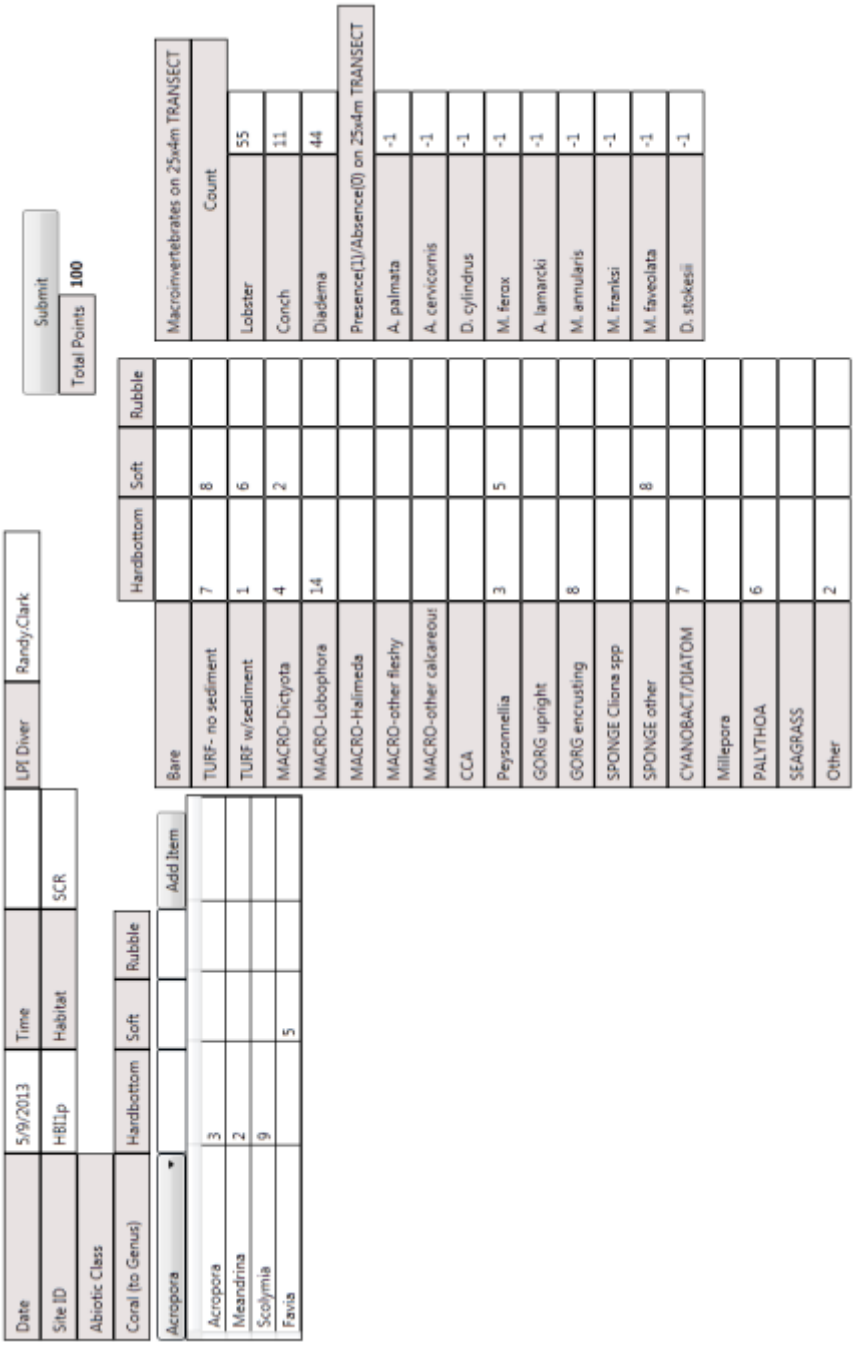
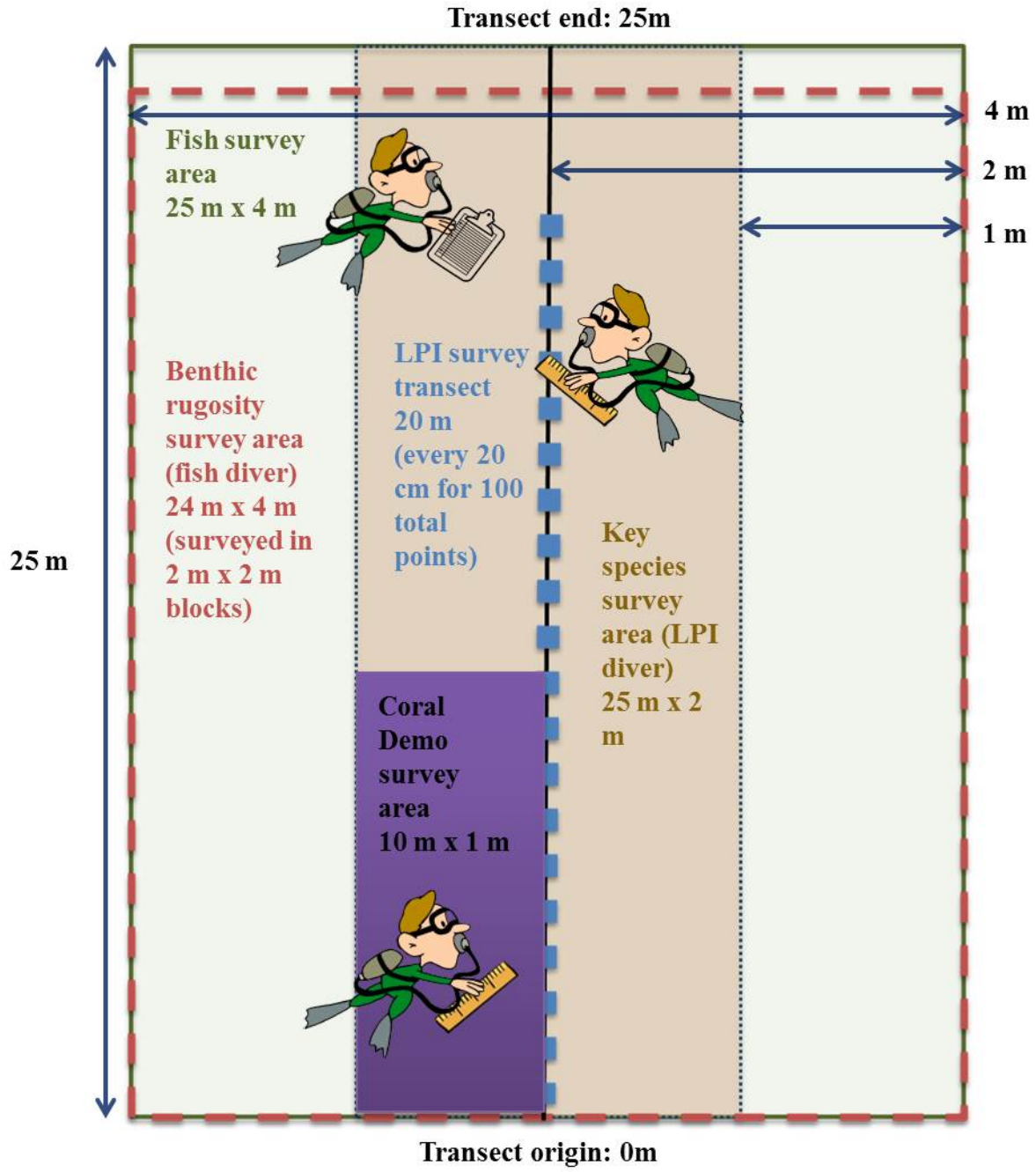


Figure 5. LPI data with example of data entry.

Appendix I.

Diagram of all surveys

Size of each survey area is also indicated. Fish, LPI and Coral Demographics will be surveyed as the divers move out away from the transect origin. Other invertebrates (*e.g.* spiny lobster, queen conch, *Diadema* urchins) and topographic complexity will be surveyed as the divers return to the transect origin.



Appendix II.

Categories and definitions

1. Corals: scleractinian corals to species
2. Bare Substratum (hard-bottom, rubble, or sand)
    a. Hard-bottom = uncolonized, with or without dusting/ veneer of sand < 2.5 cm (1 inch) deep
    b. Soft = bare sand, depth of ≥ 2.5 cm (1 inch)

    c. Rubble = uncolonized; > 2.5 cm grain size (see Wentworth Scale), larger than sand, moveable, up to cobbles and boulders (25+ cm) that are moveable.
3. Turf Algae – visible algal tufts or filaments on the substratum
    a. No sediment – only algal filaments with no trapped sediment
    b. With sediment – algal filaments with trapped sediment that has a cushiony texture
4. Macroalgae
    a. Dictyota
    b. Halimeda
    c. Lobophora
    d. Other fleshy, non-calcareous forms such as *Laurencia*, *Padina*, and *Sargassum*
    e. Other calcareous forms - *e.g. Penicillus* and *Udotea*, branching red algae such as *Galaxaura*, *Amphiroa*, and *Jania*
5. CCA – crustose coralline algae, exclusive of *Peysonnellia* species
6. *Peysonnellia*
7. Gorgonians
    a. Upright - basal attachment only. Do not record branch canopy cover.
    b. Encrusting – includes *Briareum asbestinum* and *Erythropodium caribaeorum*
8. Sponges
    a. *Cliona* spp. - In the Atlantic, the following species could be encountered: *aprica, caribbea, delitrix*, and *langae*
    b. Other - including and combining upright and encrusting morphotypes. Similar to branching gorgonians, branch sponge canopy cover is not recorded.
9. Cyanobacteria/Diatoms
10. *Millepora* - milleporid hydrocorals
11. *Palythoa* - colonial zoanthids, including both *P. caribeorum* and *P. mammilosa*
12. Seagrasses – all species combined
13. Other - include hydroids, anemones, corallimorpharians, zoanthids other than *Palythoa*, bryozoans, and tunicates

Appendix III. Examples of benthic categories for LPI surveys.

1. Scleractinian Corals (to species)

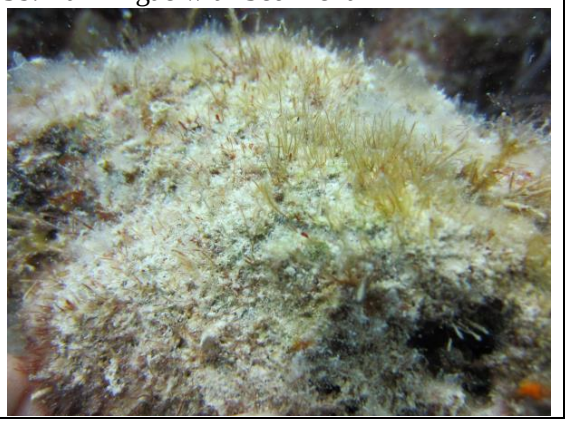
2a. Bare Hard-bottom

2b. Bare Soft (Uncolonized sand)

2c. Bare Rubble

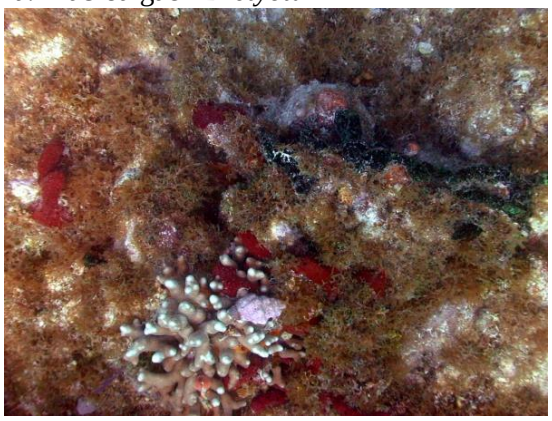
3a. Turf Algae (no sediment)

3b. Turf Algae with Sediment

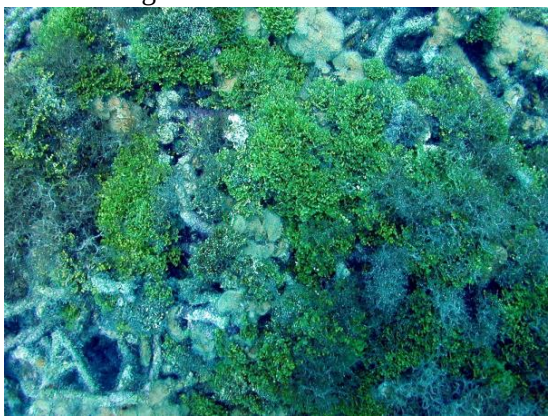


Appendix III. continued

4a. Macroalgae - *Dictyota*

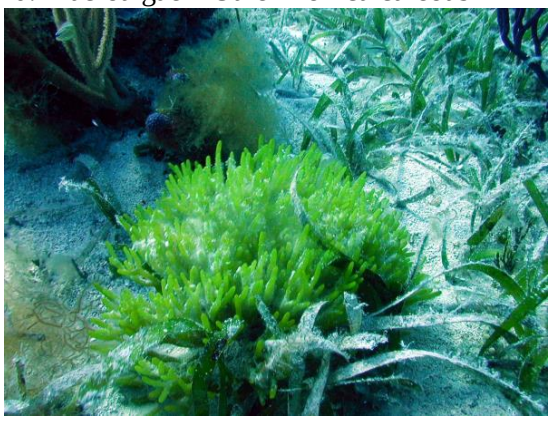


4b. Macroalgae - *Halimeda*



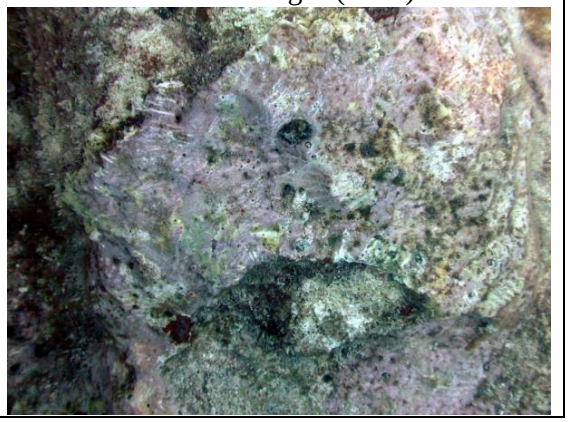
4c. Macroalgae - *Lobophora*

4d. Macroalgae – Other Non-calcareous



4e. Macroalgae – Other Calcareous

5. Crustose Coralline Algae (CCA)



Appendix III. continued

6. *Peysonnelia*

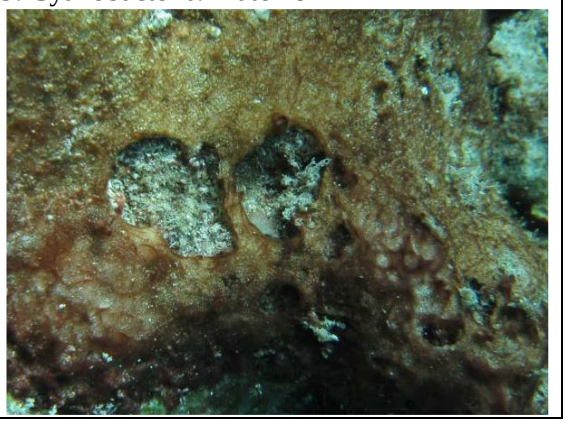
7a. Gorgonian - Upright

7b. Gorgonian - Encrusting

8a. Sponges – *Cliona* spp.

8b. Sponges - Other

9. Cyanobacteria/Diatoms



Appendix III. continued

10. Milleporid Hydrocorals (*Millepora*)

11. Palythoa (colonial zoanthid)

12. Seagrass

13. Other (anemones)

13. Other (corallimorpharians)

13. Other (zoanthids)

Coral Demographics Survey Protocol for the Atlantic/Caribbean

National Coral Reef Monitoring Program (NCRMP)
Coral Reef Conservation Program (CRCP), National Oceanic and Atmospheric Administration
Updated 26 June 2013

Introduction

NCRMP is a broad-spatial snapshot for reef condition (*i.e.* fish species composition/density/size, benthic cover, and coral density/size/condition) to provide context for local-scale studies of tropical reef ecosystems. Data collection will occur at stratified random sites where the sampling domain for each region (*e.g.* Puerto Rico, USVI, Flower Garden Banks and Florida) is partitioned by habitat type and depth, sub-regional location (*e.g.* along-shelf position) and management zone. NCRMP is intended to supplement local monitoring efforts by providing large-scale data on reef fishes and the benthos.

This coral demographics protocol was devised to provide additional, species-specific insight (and 'signal magnitude') for corals than is provided by percent cover. Specifics of the protocol are based closely on other long-established monitoring programs in the Atlantic region, including AGRRA (Caribbean-wide), SCREAM (Florida), and FRRP (Florida). However, the sampling resolution may not capture the population structure of rare or uncommon corals, including currently-listed or candidate ESA species.

Precise designations of coral condition (*e.g.* specific disease types, minor bleaching/paling conditions) are NOT included due to the low temporal resolution of the NCRMP sampling (biennial and potentially not seasonally consistent) and the wide array of surveyors involved, which is why the survey protocol is designed to capture the least ambiguous colony conditions likely to be encountered, specifically recent mortality (*i.e.* dead white skeleton) and bright-white bleaching on a partial or an entire coral colony.

Goal of Coral Demographics Surveys

The goal of the coral demographic surveys is to collect and report information on species composition, density, size, abundance, and specific parameters of condition (% live vs. dead and bleaching) of non-juvenile scleractinian corals (> 4 cm maximum diameter), and of overall species diversity (all corals) using 10m x 1m belt transects in a stratified random sampling design in hard-bottom and coral reef habitats in the U.S. Atlantic and Caribbean.

Likely task allocation scenarios

- 1 Demographic diver:
    - Demographic diver collects all coral demographic data in a single 10m x 1m belt transect area per site.

- 1 Demographic + 1 LPI diver:
    - When the LPI diver completes the LPI transect, s/he will coordinate with the coral demographic diver to assist with completing the demographic transect (if LPI benthic ID skills allow).
    - It is a higher priority for the demographic transect to be completed than for the LPI diver to complete the key species survey (*i.e.* macro-invertebrate [spiny lobster, queen conch, *Diadema* urchin] counts and coral ESA presence-absence). However, every effort should be made, in cases where LPI and coral demographic surveys are concurrently conducted at a site, to complete both surveys completely.

- 2 Demographic divers:

    - The 10m x 1m belt transect area should be subdivided, with the two divers starting at opposite ends of the transect tape.
    - This is preferable at deeper sites with shorter bottom time.
    - At sites where only coral demographic surveys are conducted, randomized grid cells (*e.g.* 50m x 50m in the USVI and Puerto Rico, 250m x 250m in the Florida Keys) will be selected and GPS waypoints generated for the center (centroid) of the grid cell. The survey team will navigate on the boat to the GPS waypoint, deploy a surface buoy or dive flag to mark the site, descend to the marker buoy, and then, using a random compass heading, deploy a 10m transect tape.

Coral Demographic Transect Information

1. Coral demographic transects will usually occur at a subset of the fish/LPI sample sites (Appendix I), as the demographic surveys will usually take longer to complete, particularly within dense coral habitats.

    a. Where fish transects (not RVC cylinders) are used, the LPI and Demographic divers may use the same transect as the fish diver (Appendix I).
        - Benthic divers will follow along behind the fish diver at a distance to avoid influencing swimming behavior of fishes (*i.e.* the LPI diver should start when the fish diver is near the 5m mark, then the Demographic diver will start).
        - The fish diver will tie off start of transect tape and continue to keep the transect tape relatively taut throughout survey.
        - The fish diver may use weights to secure the transect tape along the bottom.

- If the fish diver wraps the tape around substrate or biotic object, s/he will minimize the amount of tape that is actually wrapped so that the LPI diver can track distances between points.
- At Fish + LPI + Demographic sites, LPI diver may assist demo diver to finish demo transect within depth/time limits of dive. Demographic data completion has higher priority than key species (macro-invertebrates and ESA-proposed corals species) data collection, but if possible, key species surveys should be completed at all LPI sites.
    1. If LPI diver assists Demographic diver in survey completion, LPI diver starts her/his survey at 10 m and works until s/he finishes a complete meter and meets Demographic diver. LPI and Demographic divers will coordinate to avoid duplicating counts.
    2. To ensure that all space is surveyed, there should be no surveys of partial meters.

b. Where RVC fish cylinders are used (*e.g.* Florida), the LPI and Demographic divers will establish the transect using a random compass heading and in close proximity (*i.e.* safe diver distance) to the fish surveyor.
    - Details are in development and will be added to this protocol when they are complete.

c. Where the coral demographic surveys occur independently of fish/LPI surveys, they may not use the exact same transect location or bearing, but will represent the same grid space (*e.g.* 50m x 50m map grid cell in the USVI and Puerto Rico, 250m x 250m map grid cell in the Florida Keys).

2. Demographics transect area will be 10m long by 1m wide (Figure 1, Appendix I).
    a. This is less than the size of the LPI and fish transects.

    b. Demographics transects will begin at/near the 0meter marker on the transect.

    c. The transect tape should be secured so that it moves as little as possible.

    d. The transect line will be surveyed along the **left** edge of the transect area starting at meter marker zero (0) and proceeding to meter marker 10. This means the area of the transect is to the left side of the tape.
        - Do not split the transect area ½ on either side of the tape.

    e. This transect area is consistent with existing demographic monitoring programs including AGRRA, CREMP, SCREAM, and FRRP.

3. Every possible effort will be made to complete the entire 10m x 1m belt transect.
    a. If the whole belt transect area cannot be completed:
        - Finish at a whole meter and note the meters of completion on the datasheet.

- (optional, and ONLY if this can be accomplished immediately) Mark the transect and survey the end-points carefully, and send another team to complete the remaining transect area using the original datasheets.
- Data may be discarded, or may be retained for density, size, condition for that site, but not used for species richness or any sort of species/area, or any sort of stratum-level analyses.

4. When a coral demographic transect is split between two demographic surveyors:

    a. A transect will only be split by opposite ends (horizontally). Surveyors will work opposite ends (0m and 10m marks, respectively), and will converge somewhere between meter markers 0 and 10. They will coordinate to avoid duplicating counts upon convergence.

    b. A transect will NOT be split width-wise (vertically) between surveyors. This minimizes the potential for double-counting colonies.

    c. One diver will be the demographic "lead" diver and will be responsible for all the data entry for both divers; i.e, the lead demographic diver will enter all the data in one survey in the offline database module.

5. Bottom time may be highly variable between sites, depending on the density of corals at a site and the number of coral demographic surveyors.

Field equipment

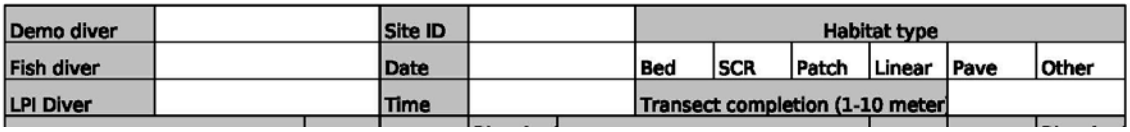
1. Demographics datasheet, clipboard, pencil (& backup pencil)
2. Transect tape
3. Small rigid measuring instrument, marked in cm.
    - Because the transect tape will be more or less taut across the substratum, the coral demographic surveyor will either need a ruler or scale bar to measure colony dimensions.
4. Measuring instrument, marked in cm increments for measuring coral colony dimensions AND/OR for measuring 1m out from the transect tape.
    - *e.g.* 0.5 or 1m PVC marked measurements or with measuring tape securely attached.
5. Camera (battery, housing)
6. Optional: CREMP 4cm measuring tool
7. Optional: ankle weights or some other means of weighing down the transect tape.

Notes for field equipment for fish divers:

1. Each fish diver may potentially need a few weights (ankle, soft) to periodically place along the 25m transect tape to hold it down to the substrate.
2. Each fish diver must securely tie off the beginning and end of the 25m transect tape.

Coral demographic survey protocols

1. Complete datasheet header (Figure 1) before beginning survey.



Demo diver		Site ID		Habitat type					
Fish diver		Date		Bed	SCR	Patch	Linear	Pave	Other
LPI Diver		Time		Transect completion (1-10 meter					

Figure 1. NCRMP demographic datasheet header.

Photographs of the site

1. If the Demographic diver is working a transect independently of the LPI/Fish diver, s/he should take photos of the site. Otherwise, the LPI diver will take photos of the site.

    a. Prior to taking any photographs of the site, one photograph should be taken of the slate to include the site name and date.

    b. Photographs should be oriented just left, forward, and just right of transect.

    c. Photographs may also be taken of anything unusual (*e.g.* rare fish, bleached or rare corals) and for species identification clarification.

    d. The process for downloading and storing site photographs is detailed in a separate document titled “Photo Documentation Manual”.

Species/colony identification

2. Each individual scleractinian coral colony ***with all or any part of the living colony or skeletal unit within the transect area*** will be identified (Figure 2).

    a. Record each individual on datasheet (Figure 3).

    b. Thickets/clumps. If the skeletal unit is connected, identify as one individual. If not, then they are considered multiple individuals (Appendix II).
        i. Species such as *Acropora cervicornis*, *A. palmata*, *Eusmilia fastigiata, Porites porites*, *Madracis* spp. or *M. annularis* may have large colony areas by these criteria.

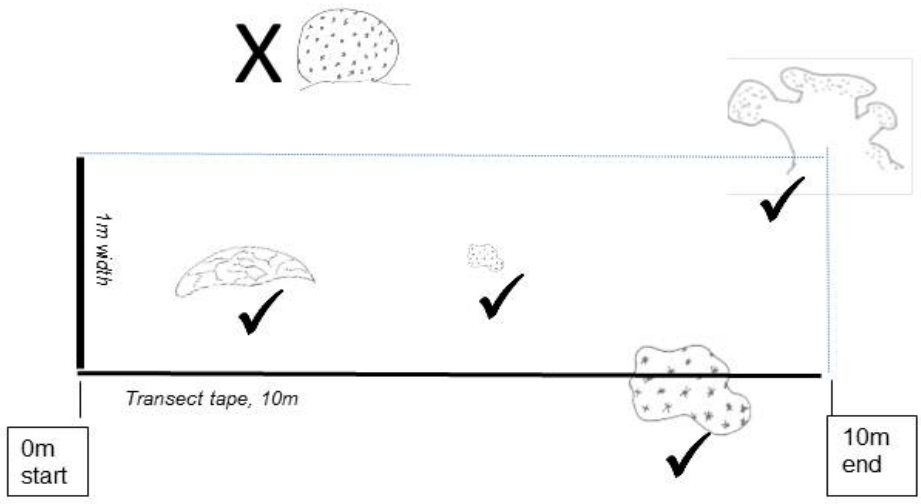


Figure 2. Schematic of example 10m x 1m transect area.
Corals with all or part of colony within transect area are included (✓).
Corals outside of the transect area are not included (X).

A. All visible corals of any size will be identified to the species level (Figure 3).

   a. If species-level identification is not possible, take photo for later analysis.

   b. ID *Montastraea* spp. to species; do NOT lump as species complex if possible (*i.e.* identify as *annularis*, *faveolata*, or *franksi*).

NCRMP Coral Demo

Demo diver		Site ID	
Fish diver		Date	
LPI Diver		Time	

Coral Dimensions				Old mort. (%)	Recent mort. (%)	Bleached-Total, Partial, None (T, P, N)	Disease-Present (P), Absent (A)
Coral ID	Max Diam (cm)	Perp Diam (cm)	Height (cm)				

Figure 3. Datasheet section showing coral identification, dimension, and condition headers and data entry.

B. When a scleractinian colony **smaller than 4 cm maximum dimension** (< 4cm) of a species that is not present as a larger, measured colony is encountered in the transect area (Figure 2):
   a. Identify the coral to lowest possible taxonomic resolution (Figure 3).

   b. Then draw a line through the rest of the column, and continue to the next coral.

c. Data will be used for species richness calculations only, not density, so any juveniles of a species only need to be recorded once per transect, regardless of the number of times encountered.

- This methodology is consistent with CREMP. This allows an estimate of richness concurrent with the coral demographic surveys, which are biased due to the > 4cm cut-off, but the present funding of NCRMP does not allow time for juvenile coral surveys.

C. When a scleractinian colony **with a maximum skeletal dimension of greater than 4 cm** (>4 cm) is encountered in the transect area, continue with ALL of the following measurements.

Coral colony size measurements

Measure entire coral (skeleton + live tissue) on a planar dimension to three (3) exact dimensions (cm).

- Measurements should be made to the nearest centimeter (cm).
- Do not bin, estimate, or aggregate measurements. For example, measurements of length, width, and height of a colony might be 5cm x 3cm x 2cm, respectively.

1. Measure the **maximum diameter** (cm) of identifiable skeletal unit.
   (Figures 4, 5, Appendix II)
   - location where diameter of skeletal unit is widest
   - make sure to measure skeletal unit, not just live tissue

2. Measure the **perpendicular diameter** of skeletal unit (Figure 4).
   - perpendicular to maximum diameter

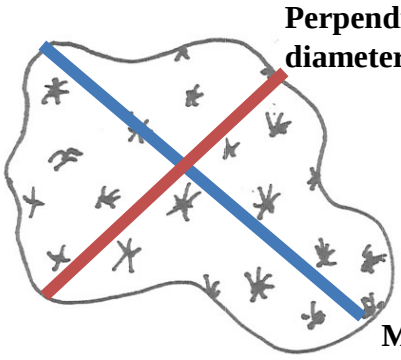


Figure 4. Example of measurements of perpendicular diameter and maximum diameter.

3. Measure the **height** (cm) of the skeletal unit (Figure 5).
   - Height is measured from the base of the skeletal unit perpendicular to plane of growth.
     - If the colony is growing on a slope, measure perpendicular to the slope
   - Measure linearly
     (*i.e.* do not drape tape across the colony)
     - If the colony has an encrusting morphology, the height of the colony should still be measured to the nearest 0.5cm.

- This methodology is consistent with AGRRA, SCREAM, and FRRP methodologies.

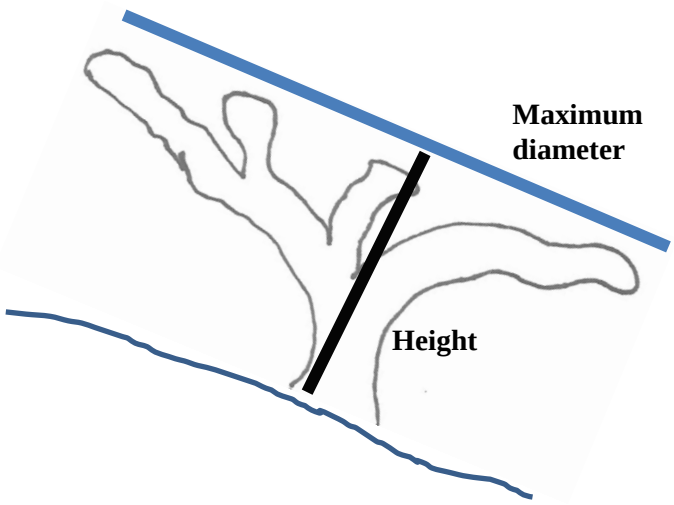


Figure 5. Height and width measurements perpendicular to plane of growth. Colony is shown on a sloped reef.

Coral condition measurements

4. **Old mortality** (%)

   a. Estimate the percent dead skeletal cover (partial mortality estimate for each colony) based on skeletal structure. Skeletal structure = (old or recent) mortality + live tissue (Figure 6).

      - Consider where tissue is supposed to be on the colony, depending on species and morphology (not on columnar colonies such as *Eusmilia fastigiata* and *Montastraea annularis*)

      - This methodology is consistent with AGRRA, SCREAM, and FRRP

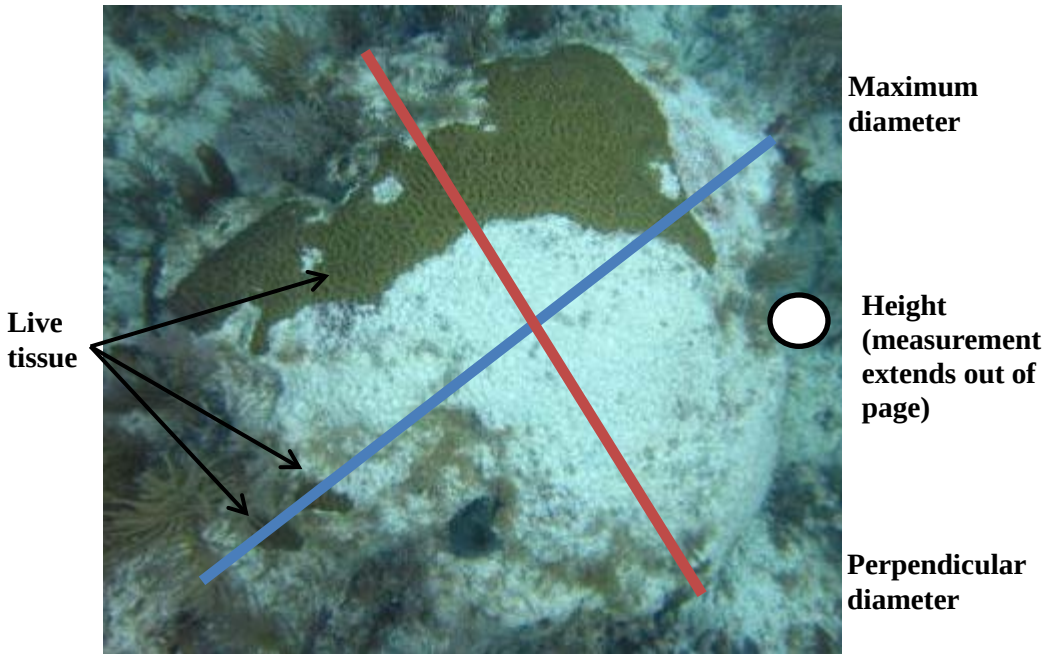


Figure 6. (example) Entire skeletal unit is measured for dimensions (max diameter, perpendicular diameter, height). Estimate % old mortality (~70%).

5. **Recent Mortality (%)**

   a. Estimate the recent mortality as a percentage of the total colony size (**NOT** as a percentage of total mortality).

      - For example, a theoretical colony with an encrusting morphology with dimensions of 10cm x 10cm with one-quarter of the colony recently dead would be scored as 25% recent mortality.

   o Recent mortality is defined as **exposed white bare skeleton** un-colonized by algae or other organisms. Examine carefully to be sure that bleached tissue is not present.

- This methodology is consistent with AGRRA, TCRMP, FRRP, and SCREAM

6. **Bleaching** (**T/P/N**)

   a. Note if any coral bleaching is present or absent

   o **T =** Total bleaching: **bright-white** bleaching over the entire colony[1]

[1] NOTE: *Siderastrea siderea* and *S. radians* may appear bright blue rather than white when bleached.

- Bleaching is defined as bright white tissue.
- Other conditions such as various shades of paling or disease are *not* included.

- **P** = Partially bleached: **bright-white** bleaching over a part of the colony

- **N** = No bleaching: no bleaching present.
  - Use this code to indicate **no bleaching**. If a colony is exhibiting any apparent "discoloration" of tissue, unless it is partially or completely white, this condition should be scored as "No bleaching".
  - Do not leave this item blank.

Figure 7. Partially bleached *Montastraea* coral colony. Because pigment is still visible around the lower right and upper left margins of the colony, this bleaching condition would be scored as *partially bleached*.

Notes

a. Notes may be added into the bottom of the datasheet.

   - Notes can be used to indicate any field observation that may be important, such as presence of an ecological incident (*e.g.* disease).

   - Notes are for reference only and do NOT get included in the database.

Data Entry into Database

a. Enter data into the database (see example in Figure 8) as soon as possible, preferably the same day as underwater data collection.

   - More detailed data entry information will be provided on site.

Figure 8. Coral demographic database with data entry example. Each coral colony is entered sequentially. Note the check box for juvenile corals (< 4 cm max. diameter). In this example, AGAHUM is a juvenile, while the MONFAV colony is not.

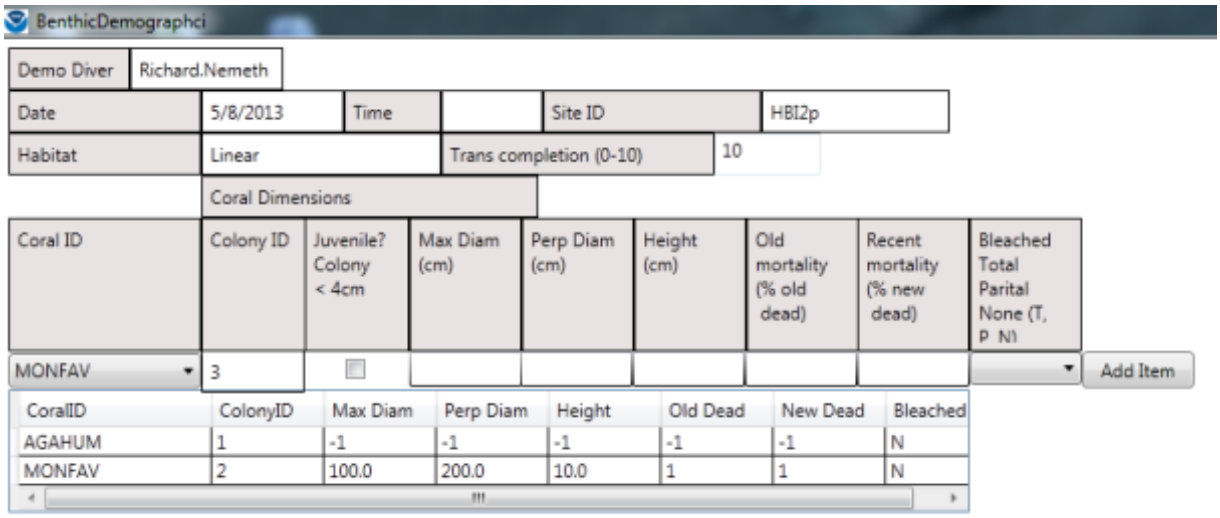


Figure 9. Coral demographic database with a second data entry example. Each coral colony is entered sequentially. Note the check box for juvenile corals (< 4 cm max. diameter). In this example, the entries indicate partially bleached colonies and disease was present.

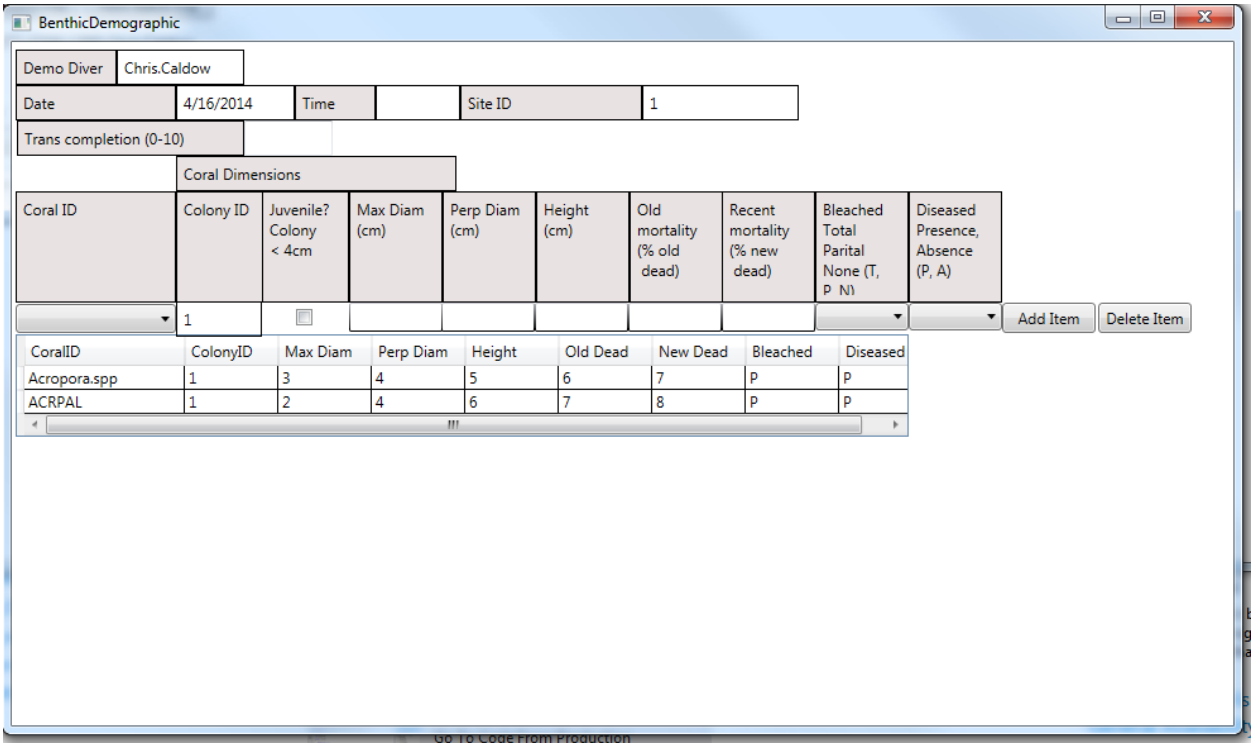
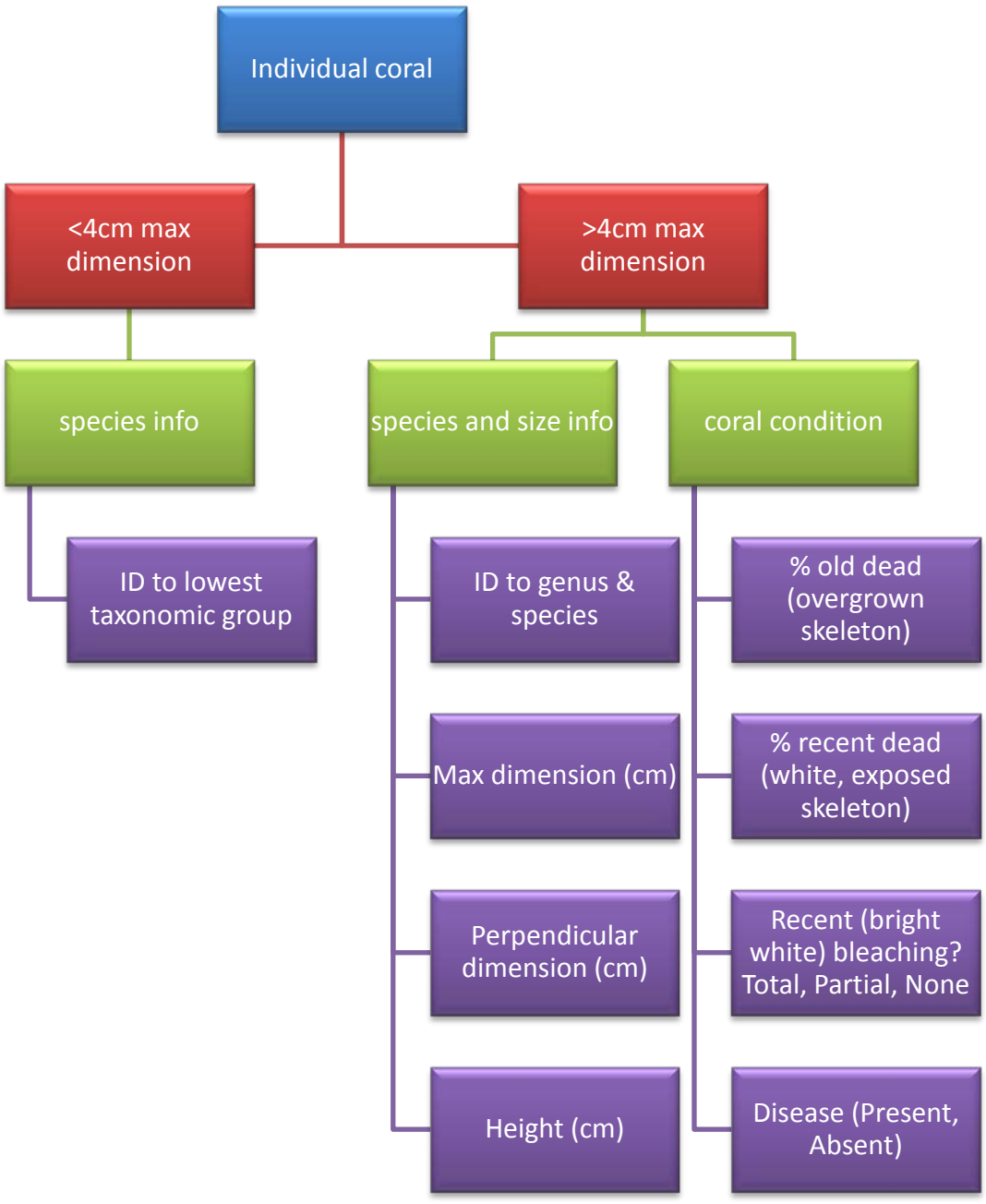
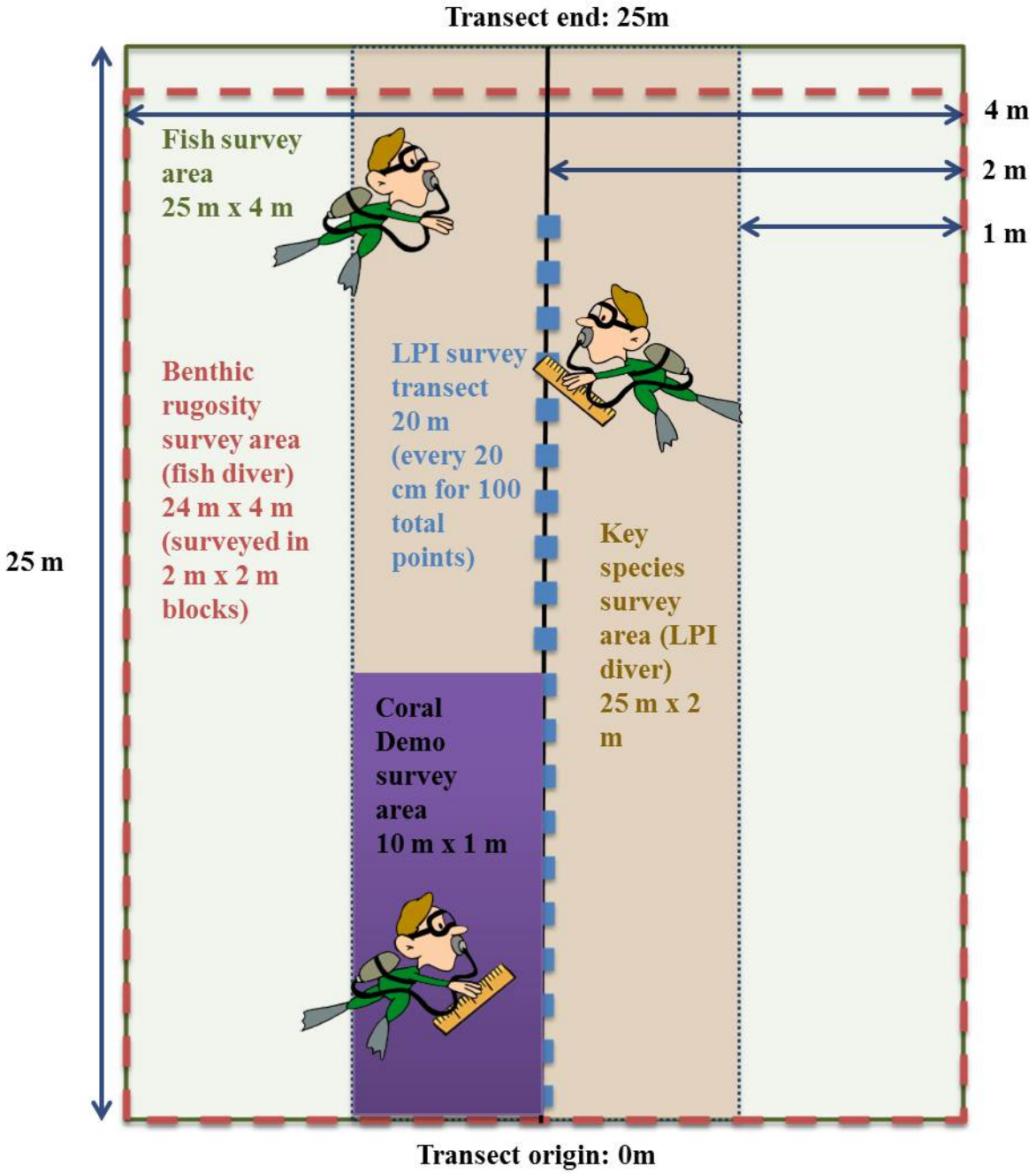


Figure 10. Summary of NCRMP coral demographic sampling.



Appendix I.

Diagram of all surveys. Size of each respective survey area is also indicated. Fish, LPI, and Coral Demographics will be surveyed as the divers move out away from the transect origin. Other invertebrates (e.g. spiny lobster, queen conch, *Diadema* urchins) and topographic complexity will be surveyed as the divers return to the transect origin.



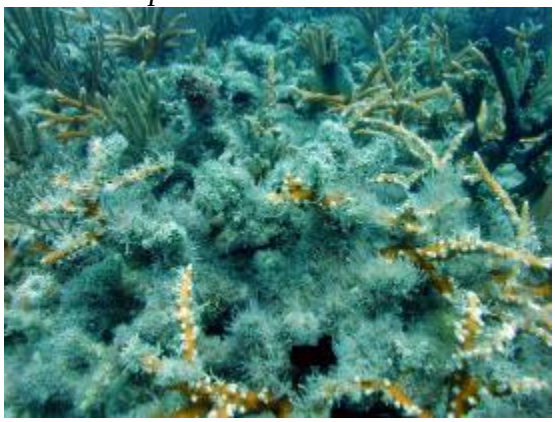
Appendix II.

Categories and definitions (see figures on following page)

- **Skeletal unit:** A coral colony is identified as a 'skeletal unit', which could contain one or more live patches of tissue.

- **Individual:** Thickets/clumps of corals, *e.g.* thickets of branching scleractinian coral species such as *Acropora*, *Madracis*, and *Porites* that are connected by skeletal units (or indistinguishable) are counted and measured as a single individual (see example images on next page (*protocol source*: AGRRA).

Small *Acropora cervicornis* thicket

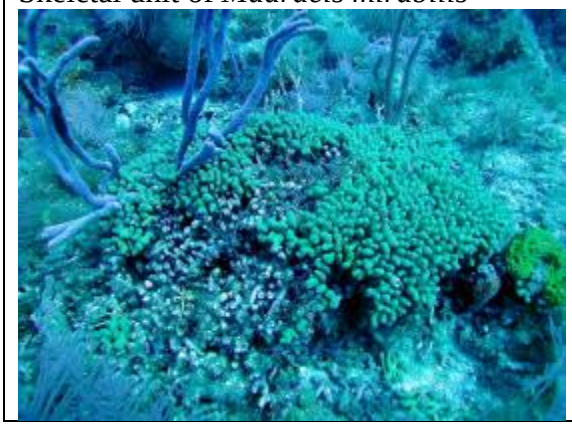


Small *Acropora palmata* thicket

Skeletal unit of *Eusmilia fastigiata*

Skeletal unit of *Montastraea annularis*

Skeletal unit of *Madracis mirabilis*



Skeletal unit of *Porites porites porites*

Belt Transect Fish Survey Protocol for Atlantic/ Caribbean

National Coral Reef Monitoring Program
Coral Reef Conservation Program, National Oceanic and Atmospheric Administration
Updated: 26 June 2013

Belt Transect Fish Census
Once in the field, the boat captain navigates to previously selected sites using a handheld GPS unit. On-site, divers are deployed and maintain contact with each other throughout the entire census. One diver is responsible for collecting data on the fish communities utilizing the belt-transect visual census technique over an area of $100m^2$ (25m length X 4m width). The belt-transect diver obtains a random compass heading for the transect prior to entering the water and records the compass bearing (0-360°) on the data sheet. Where appropriate, the boat can drop a weighted float that will mark the start of the transect. The boat can drop the divers near the float and the team descends down the float line. Dropping a float in the VINP and VICR is not an option so divers are dropped as close to the GPS position as possible. The divers will descend as rapidly, yet safely, as possible to maintain relative proximity to the centroid position. If it becomes apparent that no hardbottom is in the vision of the dive team (i.e., continuous sand or seagrass or limited visibility), then the dive will be terminated and an alternate selected. If hardbottom is observed in the vicinity of the site, then the dive continues as planned- starting on the centroid, or close approximation, and on the predetermined random bearing. Do not alter the predetermined course if the centroid is not on hardbottom or the bearing does not cover hardbottom.

Visibility at each site must be sufficient to allow for identification of fish at a minimum of 2m away. Once reasonable visibility is ascertained, the diver attaches a tape measure to the substrate and allows it to roll out for 25m while s/he collects data.

Although the habitat should not be altered in any manner by lifting or moving structure, the observer should record fish seen in holes, under ledges and in the water column. To identify, enumerate, or locate new individuals, divers may move off the centerline of the transect as long as s/he stays within the 4m transect width and does not look back along area already covered. The diver is allowed to look forward toward the end of the transect for the distance remaining (i.e. if the diver is at meter 15, s/he can look 10 meters distant, but if s/he is at meter 23, s/he can only look 2 meters ahead).

On-site, no attempt to avoid structural features within a habitat such as a sand patch or an anchor should be made as these features affect fish communities and are "real" features of the habitats. The only instance where the transect should deviate from the designated path is to stay above 99 ft.

The transect should take 15 minutes regardless of habitat type or number of animals present. This allows more mobile animals the opportunity to swim through the transect and standardizes the samples collected to allow for comparisons.

Data are collected on the following:

1. Logistic information - diver name, dive buddy, station, transect bearing, date, time of survey.

2. Taxa presence - as the tape roles out at a relatively constant speed, the diver records all fish species to the lowest taxonomic level possible that come within 2m of either side of the transect. To decrease the total time spent writing, four letter codes are used that consist of the first two letters of the genus name followed by the first two letters of the species name. In the rare case that two species have the same four-letter code, letters are added to the species name until a difference occurs. If the fish can only be identified to the family or genus level, then this is all that is recorded. If the fish cannot be identified to the family level, then no entry is necessary.

3. As the fish diver proceeds down the transect, they need to attach an ankle weight to the tape so the tape is relatively immovable for the LPI diver. The tape could also be tied around a hard feature but with minimal tape usage as the LPI diver is making measurements every 20cm.

4. Abundance & size - the number of individuals per species is tallied in 5cm size class increments up to 35cm using visual estimation of **fork length** (Figure 1). If an individual is greater than 35cm, then an estimate of the **actual fork length** is recorded. Actual size (cm FL) is recorded for certain managed species. These include:

Cephalopholis cruentata	graysby
Cephalopholis fulva	coney
Dermatolepis inermis	marbled grouper
Epinephelus adscensionis	rock hind
Epinephelus guttatus	red hind
Epinephelus morio	red grouper
Epinephelus striatus	nassau grouper
Lutjanus analis	mutton snapper
Lutjanus apodus	schoolmaster
Lutjanus buccanella	blackfin snapper
Lutjanus cyanopterus	cubera snapper
Lutjanus griseus	gray snapper
Lutjanus jocu	dog snapper
Lutjanus mahogoni	mahogany snapper
Lutjanus synagris	lane snapper
Mycteroperca bonaci	black grouper
Mycteroperca interstitialis	yellowmouth grouper
Mycteroperca tigris	tiger grouper
Mycteroperca venenosa	yellowfin grouper
Mycteroperca phenax	scamp
Ocyurus chrysurus	yellowtail snapper
Lachnolaimus maximus	hogfish

5. When Fish diver has completed the fish survey and is at m 25, s/he begins the swim back to m 0 while conducting the Topographic Complexity Survey (Appendix 1).

6. Photos - individuals too difficult to identify or unique in some manner may be photographed for later clarification.

7. At end of survey, when divers are on boat, the LPI diver reviews fish datasheet for completeness and legibility. LPI diver checks, at a minimum, the following:
    a. Legibility of all logistic information
    b. Legibility of all species codes, bin size class marks and size numbers
    c. Legibility of all rugosity measure numbers

8. When LPI diver has certified Fish datasheet has met this quick qa/qc check, LPI diver initials sheet in “check by diver” box.

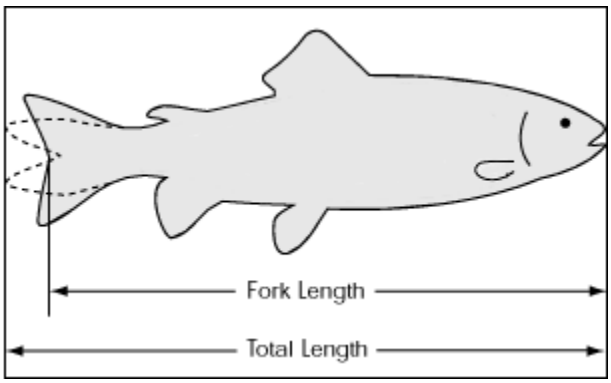


Figure 1: Fork length measurement compared with total length measurement. Fork length is recorded.

Appendix 1:

Topographic Complexity Survey Protocol for the Atlantic/ Caribbean

Introduction

NCRMP is a broad spatial snapshot for reef condition (*i.e.* fish species composition/density/size, benthic cover, and coral density/size/condition) to provide context for local-scale studies of tropical reef ecosystems. Data collection will occur at stratified random sites where the sampling domain for each region (*e.g.* Puerto Rico, USVI, Flower Garden Banks and Florida) is partitioned by habitat type and depth, sub-regional location (*e.g.* along-shelf position) and management zone. NCRMP is intended to supplement local monitoring efforts by providing large-scale data on reef fishes and the benthos.

The following protocol pertains to NCRMP topographic complexity surveys conducted in conjunction with reef fish surveys using a 25-m x 4-m belt transects, as well as RVC fish counts (roving visual counts). The purpose of this survey is to provide information on the topographic complexity (substratum rugosity) of survey locations where reef fish surveys and line point-intercept surveys are conducted. The data collection procedure described below captures basic information on the depth range, vertical relief, and surface topography.

Characterization of topographic complexity along a 25-m fish transect or 15-m diameter RVC cylinder consists of three separate elements:

- Minimum and maximum depth along each 25-m transect (or 15-m diameter RVC cylinder);
- Amplitude of substratum relief, recorded as the maximum vertical relief in a 25-m x 4-m belt transect or a 15-m diameter RVC cylinder; and
- An estimate of the relative proportion of different relief categories for the sample unit (i.e., 100-m^2 belt transect or 176-m^2 RVC cylinder), using six different categories ranging from < 0.2 m to > 2 m.

Minimum/maximum depth and maximum vertical relief measurements are made within the 25-m x 4-m portion of the transect (or 15-m diameter RVC cylinder). In locations where 25-m x 4-m belt transects are used, 24 relief frequency measurements occur along **BOTH** transect sides (starting at meter 24 and 2-m out on each transect side).

Step 1 (slope). **Substratum slope**: using a digital depth gauge, record the maximum and minimum depth encountered within the 25-m x 4-m belt transect or 15-m diameter RVC cylinder. This information provides the depth range of the sample unit, as well as the potential variability of the substratum in certain habitats such as spur and groove.

Step 2 (amplitude). **Maximum vertical relief**: using a digital depth gauge or a 0.5- or 1-m measuring device, record the maximum vertical relief present in the 25-m x 4-m belt

transect area or 15-m diameter RVC cylinder. This is accomplished by measuring the height of the most structurally complex feature in the sample unit, whether a coral head, barrel sponge, side of a coralline spur, or other topographic feature. Note that gorgonians, branching sponges, and branching *Millepora alcicornis* colonies are NOT included in this measurement.

Step 3 (frequency). **Surface area topography (relief frequency)**: An estimate of the surface topography of the sample unit (i.e., 25-m x 4-m fish belt transect or 15-m diameter RVC cylinder) can be accomplished in many ways. In locations where a 25-m x 4-m belt transect is used to sample fishes, the entire transect cannot be easily viewed all at once. Therefore, one approach is to subdivide the 100-m^2 area into smaller subplots (e.g. 2-m x 2-m areas, n=24 per sample unit in this example), with each subplot scored for the highest hard-bottom relief feature (Figure 1). Each 2-m x 2-m sub-plot is scored for vertical relief using one of the following six categories: < 0.2 m, 0.2-<0.5 m, 0.5-<1.0 m, 1.0-<1.5 m, 1.5-<2 m and 2+ m. Looking within each individual sub-plot, measure the highest relief feature (not including "soft complexity" features such as branching gorgonians, sponges, and fire corals) and place a mark in the appropriate relief category on the datasheet. In cases where RVC cylinders are sampled, either subdivide the 176-m^2 area into smaller subunits or estimate the relative area of the entire sampling unit represented by the six relief categories shown below.

Example data along a 25-m x 4-m belt transect, subdivided into 2-m x 2-m subplots (for ease of sampling):

(24 marks recorded on the underwater datasheet)

Category	Frequency (number of 2-m x 2-m units)
< 0.2 m	5
0.2-<0.5 m	6
0.5-<1.0 m	10
1.0-<1.5 m	2
1.5-<2.0m	2
2 m+	0

In this example, an estimated 20% of the sample unit had < 0.2 m of relief, 24% had 0.2-0.5 m of relief, and so on.

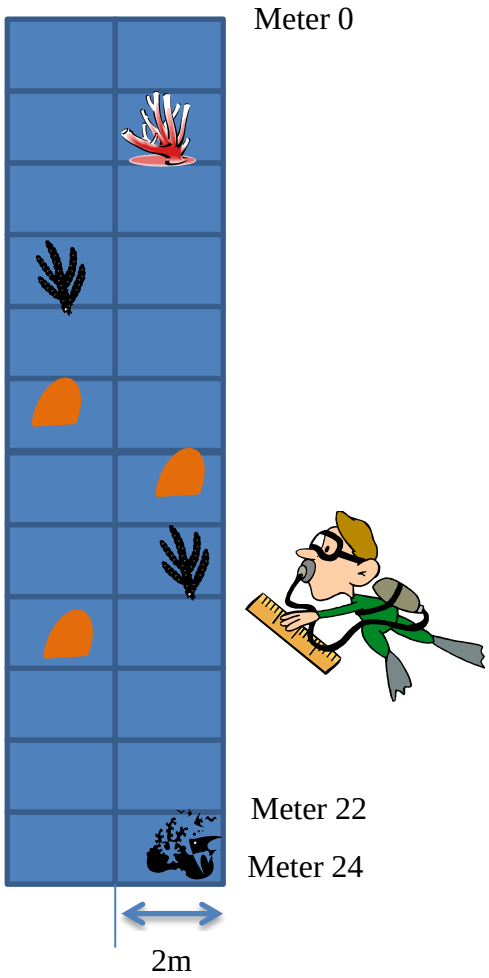


Figure 1. Example of the 2-m x 2-m grids for measuring topographic complexity along a 25-m x 4-m belt transect survey area for reef fishes in the U.S. Virgin Islands, Flower Garden Banks and Puerto Rico. In Florida, within the RVC cylinder dimensions (15-m diameter), the maximum and minimum depth, as well as the relative coverage of the six different relief categories, are visually estimated for the ~177 m^2 survey area.