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Sampling methods for Acropora corals, other benthic coral reef organisms, and marine debris in the Florida Keys: Field protocol manual for 2011-2012 assessments

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Field Protocol Manual for 2011-2012 Assessments




December 2011

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UNCW

NOAA CORAL REEF CONSERVATION PROGRAM

Florida Keys National Marine Sanctuary

Sampling Methods for *Acropora* Corals, Other Benthic Coral Reef Organisms, and Marine Debris in the Florida Keys

Field Protocol Manual for 2011-2012 Assessments

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Cover photo. Examples of benthic coral reef organisms and underwater survey methods used during 2011 in the upper Florida Keys National Marine Sanctuary. Upper left: *Acropora palmata* at Elbow Reef, Florida Keys; Upper right: Marine debris surveys; Lower left: Coral abundance, size, and condition surveys; Lower right: *A. cervicornis* colony measurements.

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Overview

The 2011-2012 sampling of *Acropora c*orals, other coral reef benthic invertebrates, and marine debris in the Florida Keys National Marine Sanctuary (FKNMS) is being undertaken as a spatially intensive effort to provide updated population distribution and abundance information. The particular focus of surveys in the Florida Keys, as well as in the U.S. Caribbean (Puerto Rico and the U.S.V.I.), concerns the habitat distribution, colony density, size, condition, and population abundance of *Acropora* corals. Surveys in the Florida Keys also include assessments of urchins, mollusks, anemones, corallimorpharians, and marine debris. These additional assessments are relatively fast and easy to perform. Annual surveys for *Acropora* corals began in 2006 in the Florida Keys in response to their listing on the Federal Endangered Species List, as well as the paucity of large-scale information on habitat distribution, abundance, and condition in the Florida Keys. Periodic surveys for *Acropora* corals as part of our long-term monitoring and assessment program date back to 1999. The purpose of this field protocol manual is to outline the *Acropora* sampling procedures used in the Florida Keys and to standardize survey methods for the Florida and U.S. Caribbean regional population assessments planned for 2012. A previous draft of this manual was prepared for Florida Keys National Marine Sanctuary personnel in June 2011 to help guide the field sampling in 2011.

The Florida Keys surveys during May-September 2011 were conducted from the southern boundary of Biscayne National Park to the Alligator Reef area offshore of Islamorada. These surveys are an outgrowth of previous efforts conducted by our program to quantify the abundance and condition of coral reef benthic organisms throughout the FKNMS, including the Tortugas region (Miller et al. 2002, see http://people.uncw.edu/millers), with a particular focus on comparisons of organism distribution, abundance, size, and condition related to the FKNMS no-take zones implemented in 1997. The goal of the 2012 field effort is to expand the geographic scope of these surveys to include Biscayne National Park and a large portion of the FKNMS from northern Key Largo to Key West, which encompasses most of the geographic distribution and hence populations of the two *Acropora* species (*A. cervicornis* and *A. palmata*). Previous benthic survey efforts by our program in the FKNMS, excluding the Tortugas region, consisted of:

- 80 sites sampled Keys-wide in 1999;
- 45 sites in the lower Keys region in 2000;
- 108 sites Keys-wide in 2001, 195 sites Keys-wide in 2005;
- 107 sites in the upper Keys region in 2006;
- 235 sites Keys-wide in 2007;
- 145 sites Keys-wide in 2008;
- 160 sites Keys-wide in 2009;

- 120 sites sampled in the upper Keys in 2010; and
- 280 sites sampled in the upper Keys in 2011.

Three hundred sites were targeted for the 2011 surveys; ultimately, we were able to sample 280 sites in the upper Florida Keys region during May-September 2011. Data obtained from earlier efforts, together with existing habitat mapping information for the FKNMS, were used to guide the sampling of benthic coral reef organisms and marine debris in 2011. In a similar manner, we will use existing data and habitat maps in the U.S. Virgin Islands and Puerto Rico to help guide their sampling in 2012.

The overall goals of the 2011 sampling effort were to:

- Continue the temporal data sets on the abundance and size of *Acropora* corals, urchins, anemones and corallimorpharians, and mollusks, as well as the frequency, density, amount, and impacts of entangled marine debris throughout the upper Florida Keys and a portion of the middle Keys region.
- Use the 2011 surveys as a guide for the 2012 Keys-wide effort to optimize sampling of *Acropora* corals in terms of the number of sites, effort expended per site, and the allocation of sites among habitat types, along-shelf position (regional location), and management zones (i.e. FKNMS no-take zones).

The 2011 surveys provided the opportunity to conduct detailed population assessments of several groups of benthic invertebrates dating back to 1999. The sampling effort in 2011 provided information on the:

- Depth range and physical structure (maximum vertical relief) of survey sites;
- Density, size class, and condition (percent live tissue, disease, bleaching, predation) of all scleractinian corals greater than 4 cm in maximum diameter;
- Distribution, density, size, and condition of *Acropora* corals, including counts, measurements, and assessments of condition (e.g. bleaching, disease, and predation) at the skeletal and physiological levels of a colony;
- Density and size (test diameter) of sea urchins, representing an ongoing effort to monitor recovery of the historically abundant long-spined sea urchin *Diadema antillarum*;
- Density of sea anemones and corallimorpharians;
- Density and total/shell length of mollusks such as sea slugs, nudibranchs, and select gastropods (*Coralliophila* spp., *Leucozonia nassa*, and *Thais deltoidea*), including queen conch (*Strombus gigas*); and

- Density, amount (length and weight) of marine debris, especially lost fishing gear (angling gear and trap debris), and the number of sessile benthic invertebrates exhibiting tissue abrasion from debris entanglement.

I. Sampling Design

The sampling design for assessing benthic coral reef organisms and marine debris in the Florida Keys during 2011 consisted of a target sampling effort of 300 sites, from northern Key Largo near the boundary between the FKNMS and Biscayne National Park to the Alligator Reef area. The sampling design for 2012 will ideally include most of the Florida Keys archipelago, excluding the Marquesas and Tortugas regions, from northern Biscayne National Park to Key West. The sampling incorporates three factors or levels in a two-stage stratification design: habitat type (includes cross-shelf location and depth), geographic region (along-shelf position), and management zone (i.e. areas inside and outside FKNMS no-take zones). The habitat strata selected for the 2011 sampling incorporated most of the hard-bottom and coral reef habitat types from the island platform (e.g. inshore patch reefs such as Tavernier Rocks) inshore of Hawk Channel to ~15 m depth along the offshore reef tract. Based upon previous surveys and existing knowledge of the distribution of *Acropora* corals, the 2011 (and 2012) efforts did not (and will not) include nearshore hard-bottom, hard-bottom/seagrass matrix habitats, or deeper (> 15 m) fore-reef areas. The following hard-bottom and coral reef habitats were sampled in 2011, with examples shown in Figures I-1 and I-2 below:

- Inshore patch reefs along the island platforms, inshore of Hawk Channel (e.g. Cheeca Rocks and Tavernier Rocks);
- Mid-channel patch reefs from the shoreward to seaward edge of Hawk Channel;
- Offshore patch reefs seaward of Hawk Channel;
- Shallow (< 6 m), low-relief hard-bottom;
- Back-reef rubble;
- High-relief spur and groove; and
- Deeper fore-reef habitats (6-15 m) encompassing continuous, low-relief hard-bottom, patchy hard-bottom, and low-relief spur and groove.

In addition to habitat type, sites are further categorized by geographic region, or along-shelf position (e.g. upper, middle, and lower Keys). During 2011, only two regions in the Florida Keys were surveyed:

- The upper Keys region from the southern BNP boundary down to Davis Reef (Tavernier Creek) and
- A portion of the middle Keys region from Crocker Reef to Alligator Reef.

Management zone is a third factor in the stratification design and consists of randomly selected sites located inside and outside of FKNMS no-take zones designated as Sanctuary Preservation Areas (SPAs), Ecological Reserves (ERs), and Research Only Areas (ROs). The sampling design also incorporates areas inside and outside of John Pennekamp Coral Reef State Park (designated in 1960), where spearfishing, lobster/crab trap fishing, and marine life collection are prohibited, as well as the Key Largo Sanctuary Management Area, which encompasses the boundaries of what was the Key Largo National Marine Sanctuary (designated in 1975). The following Sanctuary no-take zones were sampled in 2011, arranged from northeast to southwest, while the 2012 surveys will ideally include all 23 no-take zones from Key Largo to Key West (see Figure I-3):

- Carysfort/South Carysfort SPA: offshore patch reefs, back-reef rubble, high-relief spur and groove, and deeper fore-reef habitats;
- The Elbow: back-reef rubble, high-relief spur and groove, and deeper fore-reef habitats;
- Dry Rocks SPA: offshore patch reefs and high-relief spur and groove;
- Grecian Rocks SPA: high-relief spur and groove and deeper fore-reef habitats;
- French Reef SPA: back-reef rubble and high-relief spur and groove;
- Molasses Reef SPA: back-reef rubble, high-relief spur and groove, and deeper fore-reef habitats;
- Conch Reef SPA: shallow hard-bottom and deeper fore-reef habitats;
- Conch Reef RO: deeper fore-reef habitats;
- Davis Reef SPA: shallow hard-bottom and deeper fore-reef habitats;
- Hen and Chickens SPA: mid-channel patch reefs;
- Cheeca Rocks SPA: inshore patch reefs; and
- Alligator Reef SPA: shallow hard-bottom and deeper fore-reef habitats.

Sites are selected for sampling using a habitat map of the Florida Keys and a grid system constructed in a geographic information system (GIS). Grid cells 200-m x 200-m (40,000 m^2) in dimension are used to randomly select sites from the combination of habitat type, geographic region, and management zone factors (Figure I-4). Benthic habitat types are designated using regional benthic habitat maps provided by NOAA and Florida's Fish And Wildlife Research Institute. The habitat classification scheme accounts for features that correlate with benthic faunal distributions, including cross-shelf position, topographic complexity, and the proportion of sand interspersed among hard-bottom structures. A geographic regional stratification variable is used to account for oceanographic and geological features in the Florida Keys that influence the distribution and community composition of hard-bottom and reef habitats. Geographic regions are defined as follows: upper Florida Keys (BNP boundary south to Davis Reef), middle Florida Keys (Crocker Reef southwest to Moser Channel), and lower Florida Keys (Big Pine Shoal west to Satan Shoal). FKNMS no-take zones are incorporated as a third stratification variable that delineates areas open and closed to consumptive activities. Within each no-take zone, a minimum of two replicate sites are sampled in a given habitat type.

A two-stage sampling design following Cochran (1977) and adapted by Smith et al. (2011) is used to control for spatial variation in population metrics at scales smaller than the grid cell minimum mapping unit. Using this design, the 200-m by 200-m grid cells containing targeted coral reef and hard-bottom habitats are designated as primary sample units (Figure I-4). The second-stage sample unit is defined as a belt transect of fixed area (15-m x 1-m in dimension) within each primary sample unit. The size of an individual primary sampling unit allows divers to swim to the location of any given second-stage sampling unit from a moored or anchored vessel. The power of the stratified random sampling approach is essentially two-fold: 1) the habitats comprising the most area are initially allocated more sites than those with less area (i.e., a proportional design); and 2) habitats exhibiting more variability with respect to particular metrics (e.g. coral density) are allocated more sites than those with less variability. The ultimate power of this approach is derived more from the number of sites sampled rather than the effort expended per site.

Figure I-1. Examples of patch reef and shallow hard-bottom habitats in the Florida Keys.

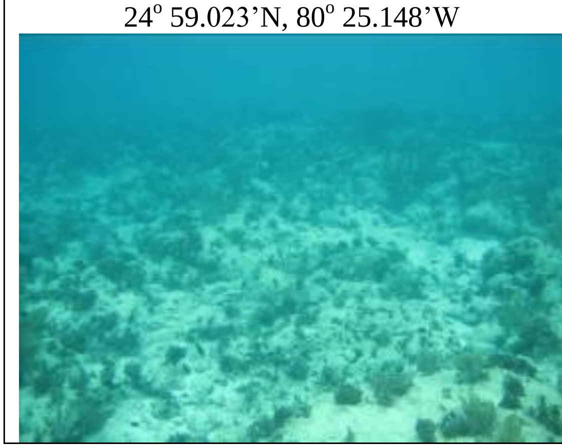
Inshore patch reef
Tavernier Rocks, 2.4-4.6 m
24° 56.594’N, 80° 33.376’W

Offshore patch reef
West of Elbow Reef, 4.3-6.1 m
25° 09.213’N, 80° 16.074’W

Mid-channel patch reef
West of Turtle Rocks, 2.1-3.7 m
25° 17.210’N, 80° 13.425’W

Offshore patch reef
Inshore of Conch Reef, 3.7-6.1 m
24° 57.363’N, 80° 29.576’W

Low-relief hard-bottom
Little Pickles Reef, 4.3-5.5 m
24° 59.023’N, 80° 25.148’W



Low-relief hard-bottom
Crocker Reef, 3.4-4.3 m
24° 54.518’N, 80° 31.631’W

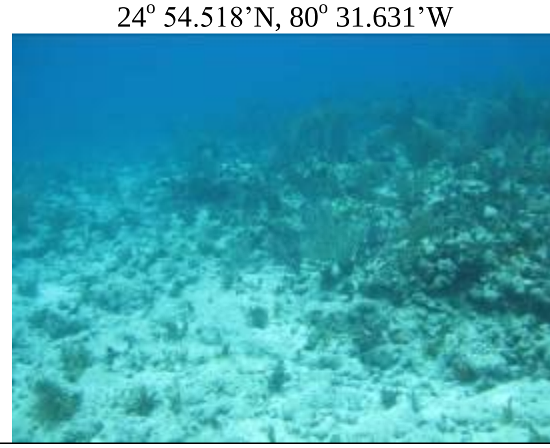


Figure I-2. Examples of high-relief spur and groove and deeper fore-reef habitats in the Florida Keys.

High-relief spur and groove
South Carysfort Reef, 1.5-5.2 m
25° 12.566'N, 80° 13.102'W

High-relief spur and groove
Sand Island, 3.0-5.2 m
25° 01.089'N, 80° 22.099'W

Low-relief hard-bottom
Little Conch Reef, 8.8-10.1 m
24° 56.428'N, 80° 28.515'W

Low-relief spur and groove
Conch Reef, 13.4-14.3 m
24° 57.156'N, 80° 27.133'W

Patchy hard-bottom
East of Dry Rocks, 6.4-7.9 m
25° 07.719'N, 80° 17.641'W

Low-relief spur and groove
Pickles Reef, 8.5-9.4 m
24° 59.031'N, 80° 24.968'W

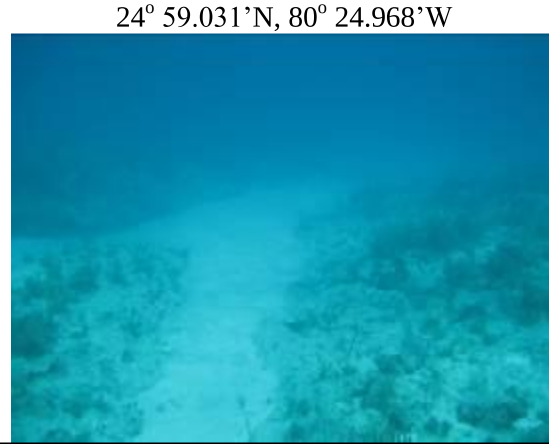


Figure I-3. The Florida Keys National Marine Sanctuary study area and additional management units in the larger south Florida ecosystem.

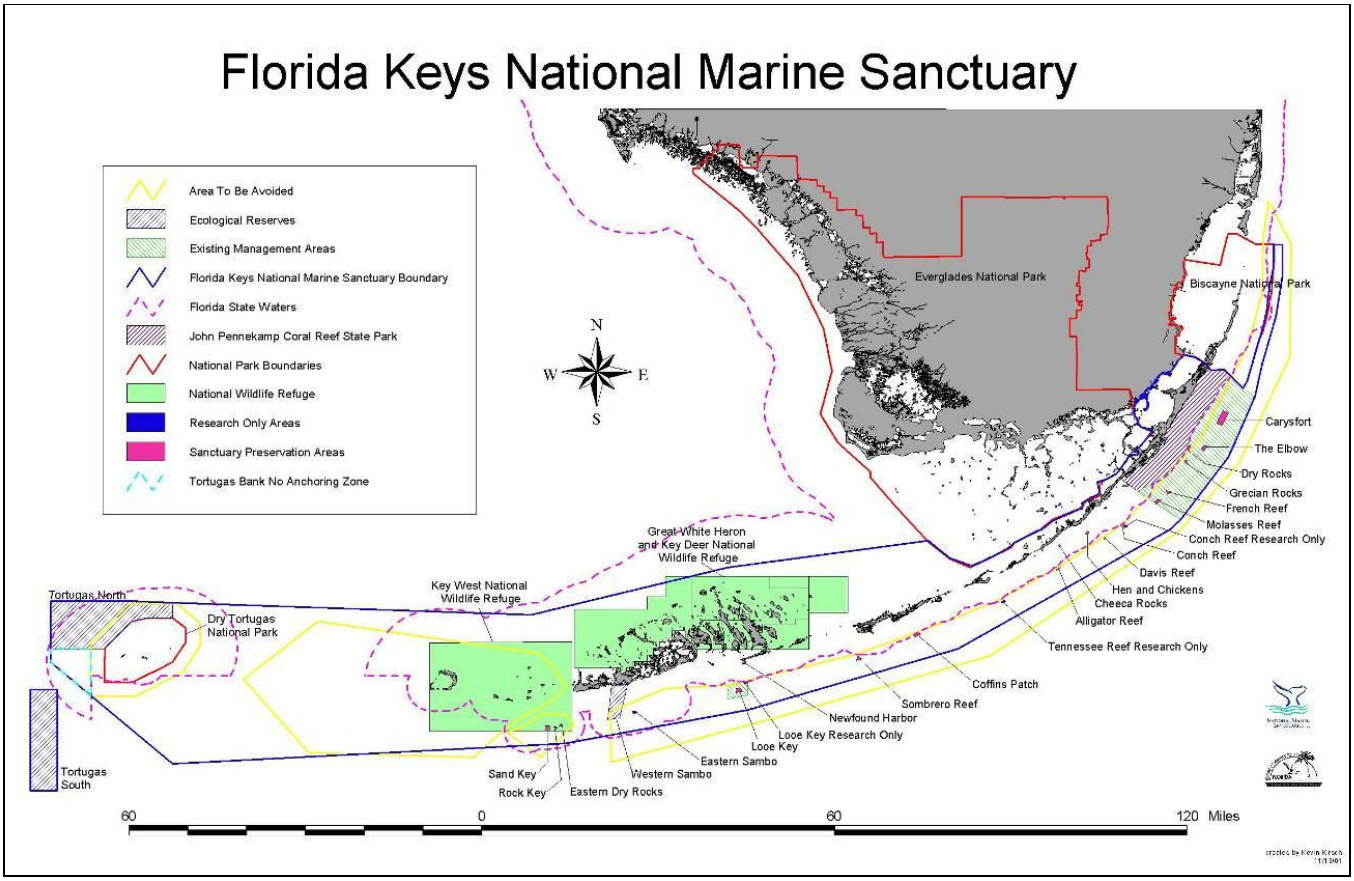
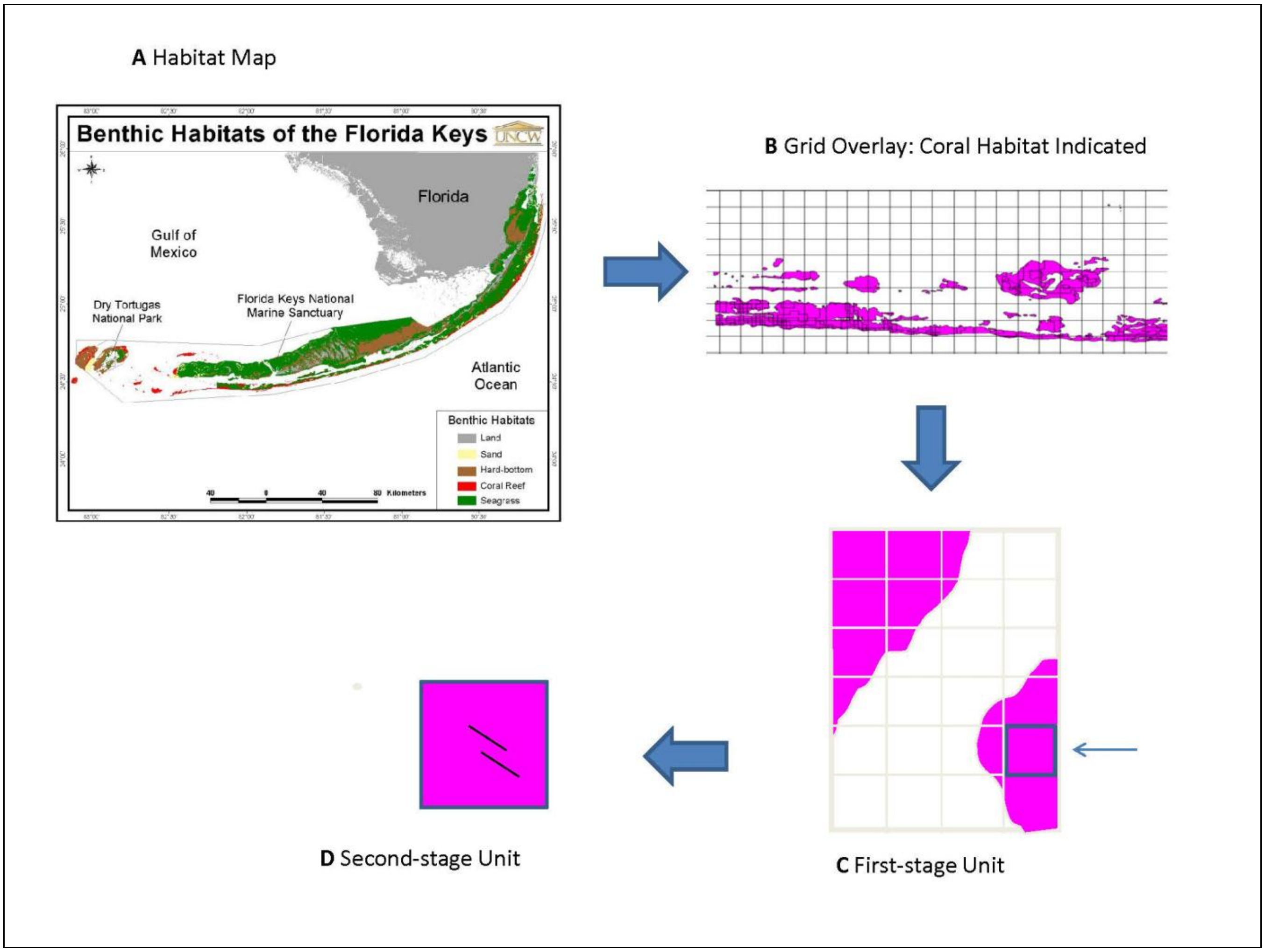


Figure I-4. The two-stage stratification designed for the Florida Keys: (A) incorporates habitat type (cross-shelf position and depth), geographic region (along-shelf position), and management zone, utilizing a grid of 200-m x 200-m cells overlain onto existing habitat and bathymetry maps. (B) The example below shows an example of the two-stage stratification approach, where first- or primary-stage units shown as squares with a targeted habitat type are randomly selected based upon the three stratification variables. (C) An enlarged view of the sample grid with the arrow indicating a 200-m x 200-m cell containing a targeted benthic habitat type. (D) An enlarged view of one sample cell where second-stage units (transects) are deployed at random GPS points within a particular cell. Note that in 2011 we deployed two 15-m transects in each cell (site) surveyed.



III. Field Protocols

A. Site Demarcation and Initial Transect Deployment

The sample effort for 2011 targeted 300 sites, with an additional 156 alternate sites, from the southern boundary of Biscayne National Park to Alligator Reef offshore of Islamorada. Sites are randomly selected from the total domain of 200-m x 200-m cells overlaying the Florida Keys habitat map, constrained proportionally by habitat type, geographic region, and management zone factors. Ultimately, we surveyed 280 sites (Figure A-1) during May-September 2011 during 29 days of field operations. Randomly generated waypoints are located in the center of each 200-m x 200-m cell selected for sampling. Details regarding the sample design are found in Smith et al. (2011). Upon arrival at the waypoint, if the intended habitat is not immediately found, an area up to 100-m radially out from the waypoint is searched. If the appropriate habitat type is still not found, a note is made and the closest alternate site should be sampled instead.

Once on-site, a diver-flag with a GPS receiver attached to a buoy is deployed to mark the site. We presently use a Garmin® global positioning system receiver (model GPS76) to determine the position at each site. Upon water entry, the survey team of two to four divers proceeds to the dive flag, descends to the bottom, and haphazardly lays out two 15-m transect tapes approximately 5 to 10-m apart. Because of dive-safety considerations, transect tapes should not be located more than 15-m apart (50 feet). A 1-m wide belt centered on each 15-m long transect tape (15 m^2) is surveyed for most of the benthic variables described below (see Figure A-2), for a total of 30 m^2 surveyed per site. Exceptions to this pattern are the coral density/size/condition surveys for all non-*Acropora* corals, which are surveyed in 10-m x 1-m (10 m^2) belt transects, and marine debris, which is surveyed in 15-m x 2-m belt transect (30 m^2). At all sites sampled during 2011, 15-m^2 belt transect areas were surveyed for:

- Minimum and maximum depth;
- Maximum vertical relief of the substratum such as ledges, spur edges, crevices, coral heads, and sponges such as *Xestospongia muta*;
- Number of colonies, skeletal unit size, live tissue surface area, and condition (bleaching, disease, predation, overgrowth) of *Acropora* corals;
- Numbers and test sizes (diameter) of sea urchins (echinoids);
- Numbers of anemones and corallimorpharians; and
- Numbers and total lengths or shell lengths of nudibranchs, the lettuce sea slug (*Elysia crispata*), and the gastropods *Coralliophila* (all species), *Leucozonia nassa*, *Thais deltoidea*, and *Strombus gigas*.

Smaller transect areas (10-m x 1-m) were surveyed for the numbers of colonies, sizes (binned by size class), and condition of all other scleractinian corals greater than 4 cm in maximum diameter. Finally, 15-m x 2-m belt transect areas were surveyed for the density of marine debris, the length of all angling gear and lobster/crab trap rope recovered, the numbers of benthic organisms exhibiting abrasion stress (partial mortality due to tissue loss), and the wet weight of all debris collected per transect. Data are collected using pencils and pre-printed slates that facilitate efficient recording. At the end of the day, slates are photocopied for archival purposes, data are transferred to pre-printed sheets and checked for errors related to coding or counts, and then entered into spreadsheets using portable computers. Copies of information printed on the slates and an equipment list for the field are included in the Appendix.

Figure A-1. Sampling locations for *Acropora* corals, other benthic coral reef organisms, and marine debris in the upper Florida Keys National Marine Sanctuary during May-September 2011. Two-hundred and eighty (280) sites were surveyed for coral density, size, and condition, including *Acropora* corals, as well as urchins, anemones, corallimorpharians, mollusks, and marine debris from the southern boundary of Biscayne National Park to Alligator Reef.

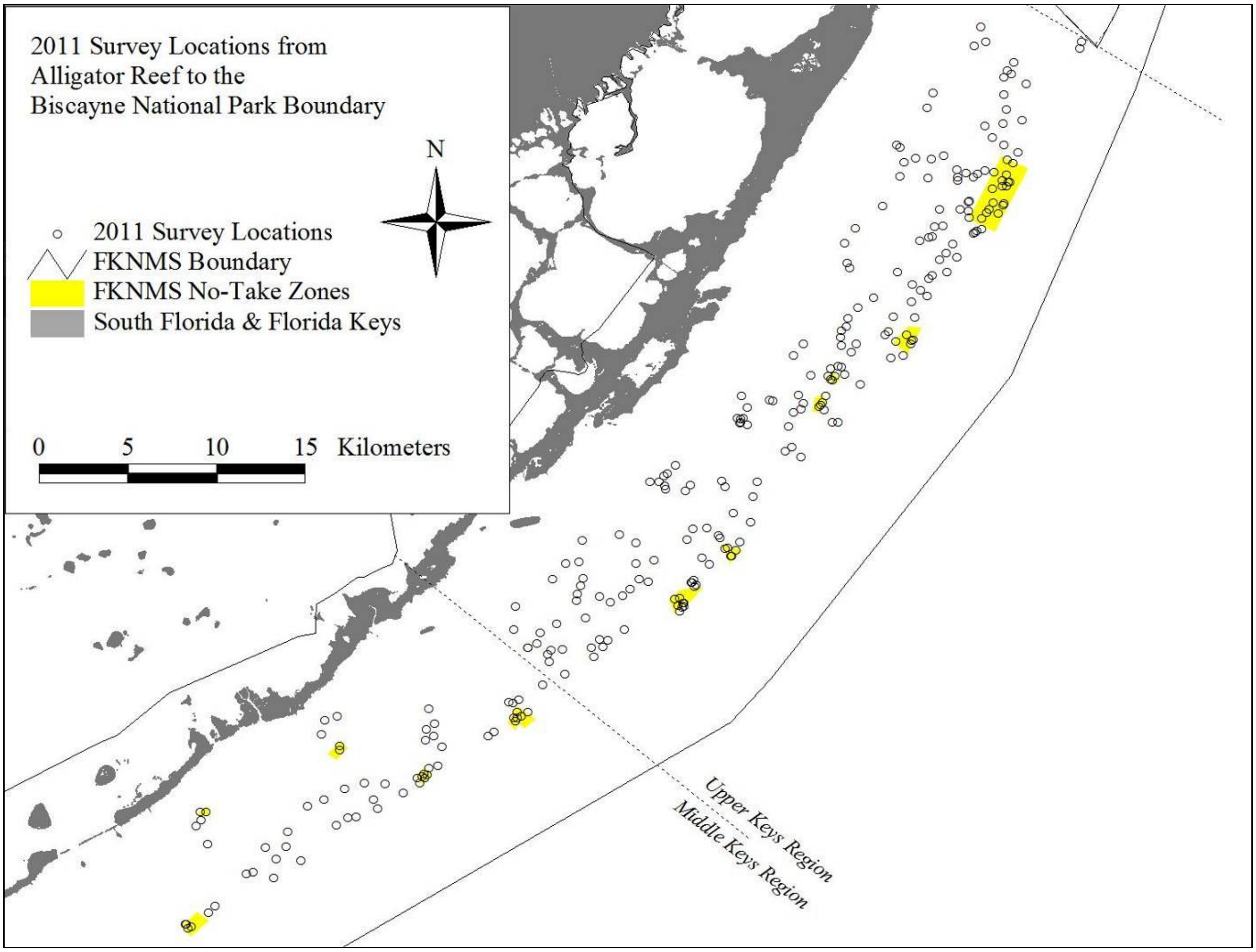


Figure A-2. Images that illustrate underwater methods of data collection.

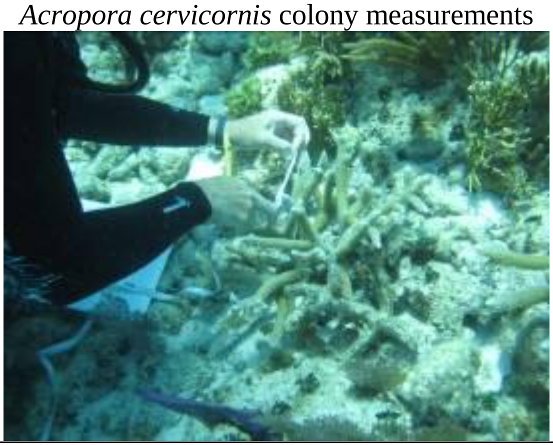
Underwater slate for data collection

Marine debris retrieval

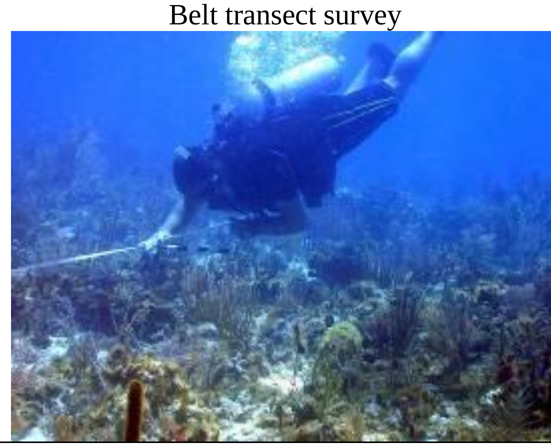
Using the 0.5-m scale bar

Transect deployment

Acropora cervicornis colony measurements



Belt transect survey



B. Physical Data

In addition to GPS recordings of site location and general site description notes, additional physical data consist of measurements of minimum and maximum depth along sampled transects, as well as maximum vertical relief. These data are collected on both 1-m by 15-m belt transects at each site. The diver swims along the transect and notes the minimum and maximum depths of the transect using a depth gauge. The maximum vertical relief of hard substrate features (including ledges, spur edges, crevices, coral heads, and structural sponges (but excluding gorgonians and *Millepora alcicornis*) encountered within the 15-m x 1-m belt transect is recorded to the nearest cm. We use a 50- or 100-cm scale bar to estimate the greatest vertical relief features encountered within the belt transect boundaries. The surveyor also notes the identity of the maximum vertical relief feature. These data are used to summarize the depth range and average depth surveyed for each site, as well as the maximum and the average maximum vertical relief of the transects surveyed.

C. *Acropora* Corals

To document the current population status of *Acropora* corals, we assessed the spatial distribution, colony abundance, size, and condition of these two species in the upper Florida Keys during 2006, 2010, and 2011, as well as Keys-wide in 2007-09. These efforts contribute to a temporal record dating back to 1999 on the abundance, size, and condition of *Acropora* corals. Using a stratified random sampling design, the goals of the 2011 surveys were to continue this temporal record in the upper and a portion of the middle Florida Keys, but also to prepare for a Keys-wide assessment in 2012. The data will be used to construct population abundance estimates by size class and by habitat to provide comparisons to similar data collected in the Florida Keys during 2006-2011.

The field methodology for assessing *Acropora* corals consists of the following:

- Once replicate 15-m transects are deployed at a particular site, *Acropora* corals are sampled for presence-absence, colony numbers, colony sizes, and condition by species. *Acropora* corals are identified to species. If the F_1 hybrid, *A. prolifera* is encountered, it is noted and sampled too.
- An area 0.5 m out on each transect side (a 15-m x 1-m or 15-m^2 belt transect) is searched for *Acropora* corals.
- *Acropora* colonies are assessed at both the skeletal unit and physiological unit levels, as described below, for numbers, size, and condition.

There are currently six levels of measurement we consider when *Acropora* corals are encountered. First, if *Acropora* corals are present, but are not encountered within transect boundaries, a note is made of their presence at the site. The second level of measurement consists of presence-absence recordings within transect boundaries. These data provide an estimate of transect frequency of occurrence; in other words, the percentage of transect stations where either species was encountered. We have found that even this semi-quantitative metric provides a clear picture of differences in habitat distribution in the Florida Keys.

The third and fourth levels of measurement (see Table C-1) for *Acropora* corals involve recording the size and condition of each colony (skeletal unit and physiologic unit) within the 15 m^2 belt transects. A skeletal unit is defined as a continuous skeleton, regardless of whether or not the colony is partitioned into several individual patches of continuous live tissue (Figure C-3). Physiologic units are defined as individual patches of continuous live tissue that are contained within a skeletal unit. Of course, it can be very challenging in some cases to determine what constitutes the original skeletal unit; for example, if a much older skeleton has been recently colonized by one or more new colonies. New colonies can generally be identified by regular tissue boundaries, polyps and/or color different from other pieces of contiguous tissue. The tissue boundaries of physiologic units most often display evidence of recent or long-term tissue mortality. We purposely avoid ramet and genet terminology because it is impossible to know for sure, unless genetic analyses are conducted. In the past, we have sampled for genetic work (Hemond and Vollmer 2010). Distinguishing physiologic units within skeletal units provides a useful measure of colony fragmentation, especially when associated with predation, bleaching, or disease. However, it is problematic and time consuming to count and measure physiologic units on large skeletal units. In the Florida Keys, we have conducted these measurements because densities are low and most colonies we encounter are small.

The third level of measurement focuses on the skeletal unit. First, the skeletal unit's size is determined by measuring the maximum branching diameter, secondary branching diameter (perpendicular to the maximum diameter), and maximum height to the nearest centimeter. Care should be taken to identify, as best as possible, the former extent of the skeletal unit in cases where tissue mortality has occurred. The skeletal unit observations are useful because they provide some measure of a colony's history. Next, the skeletal unit should be assessed for percent live tissue or dead skeleton (no live tissue) using categories of 10% (e.g. completely alive, 0-10% dead, 10-20% dead, etc.). The recorder should note whether or not the dead colony areas appear to be recent or not. Recently dead areas are defined as any non-living part of the coral in which the corallite structures are white and either still intact or covered by a layer of fine mud and/or silt. In contrast, long-dead areas are generally defined as any non-living parts of the coral in which the corallite structures are either gone or covered over by organisms that are not easily removed. When recently dead areas of a colony are present, a cause of the mortality is noted if possible (e.g. disease, predation, breakage, or overgrowth). Finally, the condition of the skeletal unit is noted; the current notable conditions include, but are not limited to:

- Presence of disease (white band, white pox);
- Evidence of predation (damselfishes, snails, fireworms);
- Evidence of bleaching (pale, partially bleached, bleached);
- Overgrowth causing tissue loss by algae, *Palythoa*, gorgonians, sponges, and other corals; and
- Colony damage due to obvious physical impacts from breakage (i.e. storm events), abrasion, and burial.

The fourth level of measurement focuses on the physiologic units contained within the skeletal unit. The size, percent dead tissue, and condition are assessed for each individual physiologic unit using the same procedures described above for skeletal units. If a skeletal unit has not suffered partial mortality (or the living portion of the skeletal unit is a single patch of live tissue), the same size, percent dead tissue, and conditions should be noted for the physiological colony as for the skeletal unit. It is common to have multiple physiologic units per skeletal unit.

The fifth level of measurement consists solely of meticulous measurements of all live tissue (e.g. individual branches, patches, and bases) to accurately estimate the surface area of live tissue within each colony, and include the number and length of individual branches, sizes and numbers of individual living patches, and size of bases, where colonies attach to the bottom. For example, if an *Acropora cervicornis* colony is encountered and consists of two patches of live tissue on one larger skeletal unit, the following measurements would be made:

- Level three – one skeletal unit assessment of colony size , percent dead tissue, and colony condition;
- Level four – two physiologic unit assessments of colony size , percent dead tissue, and colony condition;
- Level five – two physiologic unit assessments surface area based on all live tissue (e.g. individual branches, patches, and bases).

These precision measurements are extremely time consuming, and may be omitted if surface area is not of primary importance to the investigation.

The sixth level of measurement transitions from population metrics to more of a mapping effort. Terminology transitions too, from skeletal and physiologic units to clumps, thickets and stands, based on the areal extant of the coral (Table C-1). For example, *Acropora palmata* is still abundant at a few locations in the Florida Keys (see Grecian Rocks, lower left image, in Figure C-2). At these locations, it is simply impossible to identify individual colonies and even if one could, it would not be practical to measure all of them individually. The same can be said for *A. cervicornis* (Figure C-1). Accordingly, new terminology is required to guide sampling. Methods for the sixth level of sampling focus on size measurements of the clumps, thickets, and stands, including perimeter, maximum diameter, secondary diameter, and height. Tapes are used at the smaller ranges of these categories, while enhanced GPS (e.g. accuracy to less than 3 meters, while typical differential GPS has 3-5 m accuracy) can be used for larger thickets and stands by measuring perimeters, if available. The perimeters may be recorded by divers swimming with the GPS or by a crew using a vessel, depending on the distance (height is still measured by tape). Decisions about using tape or GPS are based on feasibility to measure a thicket or stand in a timely and safe manner, and availability of enhanced GPS or standard dGPS, relative to the size of the clumps, thickets, or stands.

Clearly, clumps, thickets, and stands fall outside traditional population metrics. However, in the case of *Acropora cervicornis* and *A. palmata*, when such features are encountered using a two-stage stratified random design, they are a useful metric to help evaluate the status of the species. Results provide an estimate of the number of these larger features by habitat type, geographic region, and management zone. Further, when GPS is used to measure such features their locations are also determined, which could be useful in a repeated designs study. Repeated measures designs, while not part of the current study, could have significant management relevance in the Florida Keys, where the location of the last remaining *A. palmata* thickets and stands are known. If recovery occurs, it will likely be from: the expansion of existing *Acropora* clumps, thickets, and stands; recruitment; growth and expansion of existing small colonies; or a combination of all these elements. Recruitment and growth and expansion of existing colonies are population metrics specifically measured as part of our sampling program. The larger clumps, thickets, and stands are also picked up in the existing sample design, but because they are rare, variance remains large.

A potential seventh level of measurement deals with sub-sampling of clumps, thickets, and stands. The metrics in level seven are similar to measurements in previous levels, and include condition (disease, predation, bleaching, overgrowth, and breakage), percent live versus dead, physiologic number and sizes, and branch numbers and sizes (for percent cover calculations). It is possible that percent cover might be a relevant metric, in cases where clearly defined patches exist, but are either not continuous or include other features (e.g. large head or mounding corals, sand patches). Which of these metrics are sampled will depend on questions being asked and time available to sample. Such sampling needs to be balanced against the larger program goal of trying to sample more sites, rather than intensely sampling a few sites. We do not have extensive experience sampling larger clumps, thickets, and stands, as these are relatively rare in the Florida Keys. A detailed manual for demographic sampling of *A. palmata* (Williams et al. 2026), to document the status and trends of individual colonies, includes colony measurements that are similar to ours, but breaks down at higher densities when identifying individual colonies becomes difficult. At a minimum, presence and absence of diseases, predation, and bleaching is a reasonable first approach, and is what we intend to include as a part of future sampling, along with an estimate of percent living tissue versus dead skeleton. Finer-scale measurements to obtain variance estimates using quadrats or point-intercept techniques can be considered as well. However, these finer-scale measurements fall outside the realm of our program goal, which is to estimate the population sizes of these two coral species.

Because disease, disease-like conditions, and predation on *Acropora* corals can be confusing, descriptions below provide some clarification, along with Figure C-4. White band disease is characterized by complete coral tissue degradation of Caribbean *Acropora* corals. The disease exhibits a sharp demarcation between apparently healthy coral tissue and exposed coral skeleton. These signs are identical to plague, except that white band is specific to *Acropora* corals; in addition, plague has not been found on these species. Tissue loss usually proceeds from the base of the colony branch to the tip, although it can begin in the middle of a branch in *A. cervicornis*. There are two etiologies of white band disease: type I and type II. In type I, tissue destruction is associated with the moving front of the band. In type II, there is at times a bleached zone between the area of tissue degradation and the moving front. If the bleached zone is not present, type I is visually indistinguishable from type II. The only way to distinguish the two types is to observe the band progression over time.

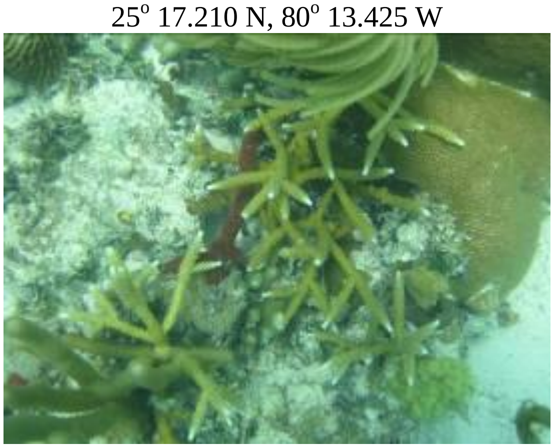
White pox is characterized by coral tissue degradation that occurs in association with circular lesions on the Caribbean scleractinian coral *Acropora palmata*. Rapid loss of tissue progresses along a distinct line, or with small remnants of tissue sometimes present near the margin of, irregularly shaped patches anywhere on the upper or lower surfaces of *Acropora palmata* branches. The average rate of tissue loss is 2.5 cm^2/day, although rates up to 10.5 cm^2/day can occur.

Figure C-1. Examples of *Acropora cervicornis* in hard-bottom and coral reef habitats of the Florida Keys.

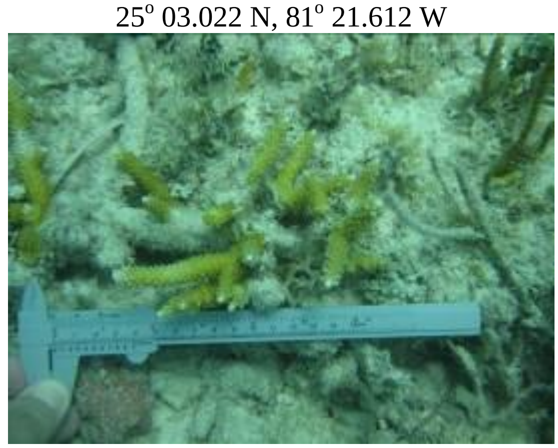
Mid-channel patch reef, 3.0-4.0 m
West of Conch Reef
24^{o} 57.529 N, 80^{o} 29.427 W

Mid-channel patch reef, 1.5-3.0 m
Basin Hill Shoals
25^{o} 13.250 N, 80^{o} 15.618 W

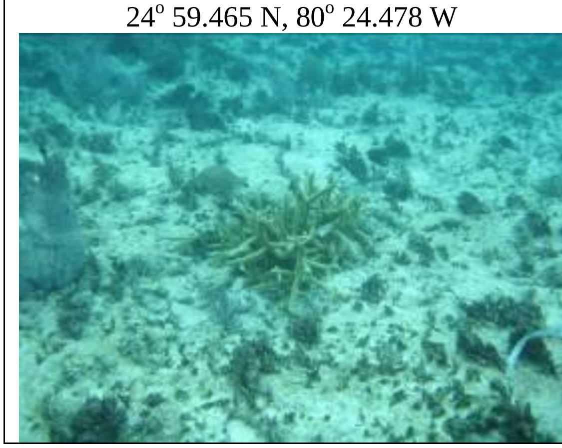
Mid-channel patch reef, 2.1-3.7 m
West of Turtle Rocks
25^{o} 17.210 N, 80^{o} 13.425 W



Offshore patch reef, 4.3-4.9 m
White Bank (NW of French Reef)
25^{o} 03.022 N, 81^{o} 21.612 W



High-relief spur and groove, 3.7-4.6 m
NE Pickles Reef
24^{o} 59.465 N, 80^{o} 24.478 W



Low-relief hard-bottom, 4.6-6.1 m
Conch Reef C2
24^{o} 57.292 N, 80^{o} 27.504 W

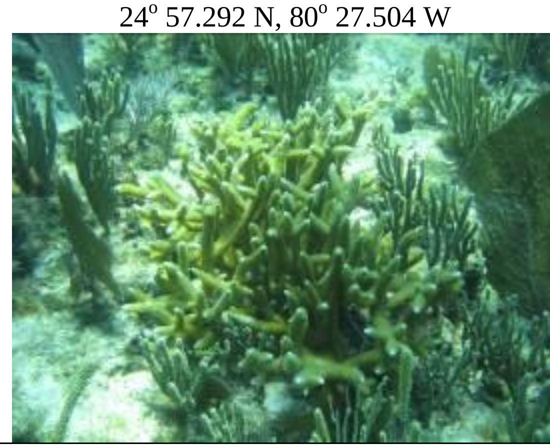
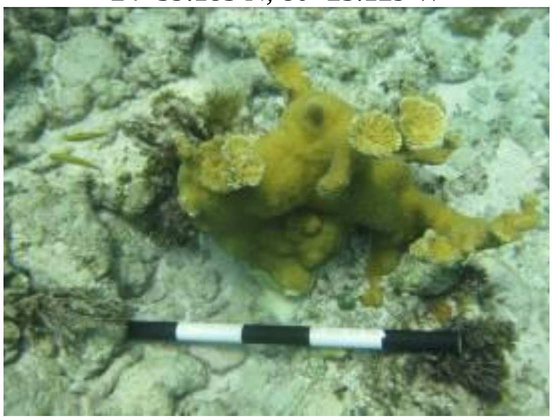


Figure C-2. Examples of *Acropora palmata* in hard-bottom and coral reef habitats of the Florida Keys.

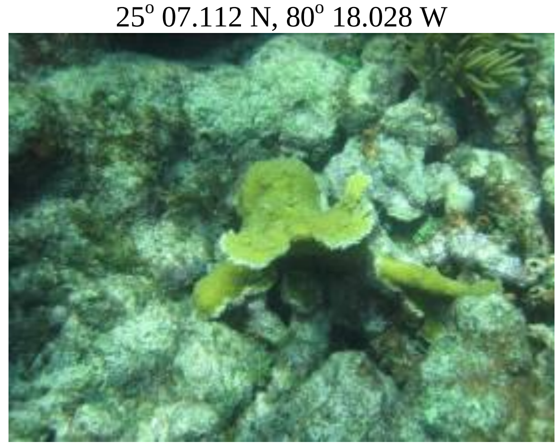
Back reef rubble, 2.4-2.7 m
Pickles Reef
24^{o} 59.185 N, 80^{o} 25.129 W



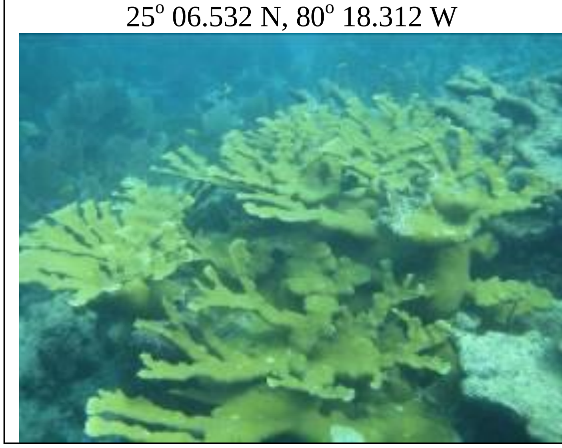
High-relief spur and groove, 2.4-5.5 m
Carysfort Reef C5
25^{o} 13.332 N, 80^{o} 12.603 W

High-relief spur and groove, 3.0-5.2 m
Sand Island
25^{o} 01.089 N, 80^{o} 22.099 W

High-relief spur and groove, 2.7-5.2 m
Little Grecian Rocks
25^{o} 07.112 N, 80^{o} 18.028 W



High-relief spur and groove, 2.7-4.6 m
Grecian Rocks SPA
25^{o} 06.532 N, 80^{o} 18.312 W



High-relief spur and groove, 5.2-7.9 m
Elbow Reef SPA
25^{o} 08.752 N, 80^{o} 15.421 W

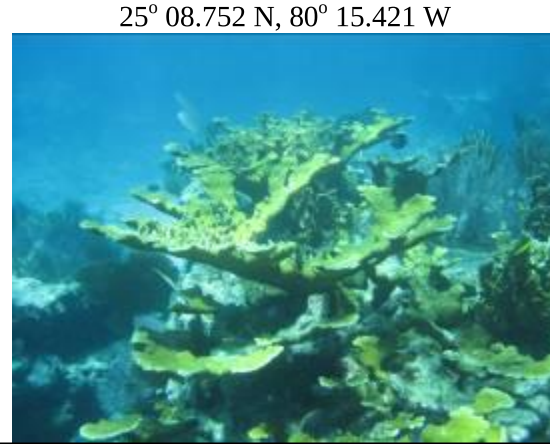


Figure C-3. Examples of a skeletal unit versus a physiologic unit in *Acropora cervicornis*. Note branch in black box separated from larger colony by dead branch area, indicated by arrow.

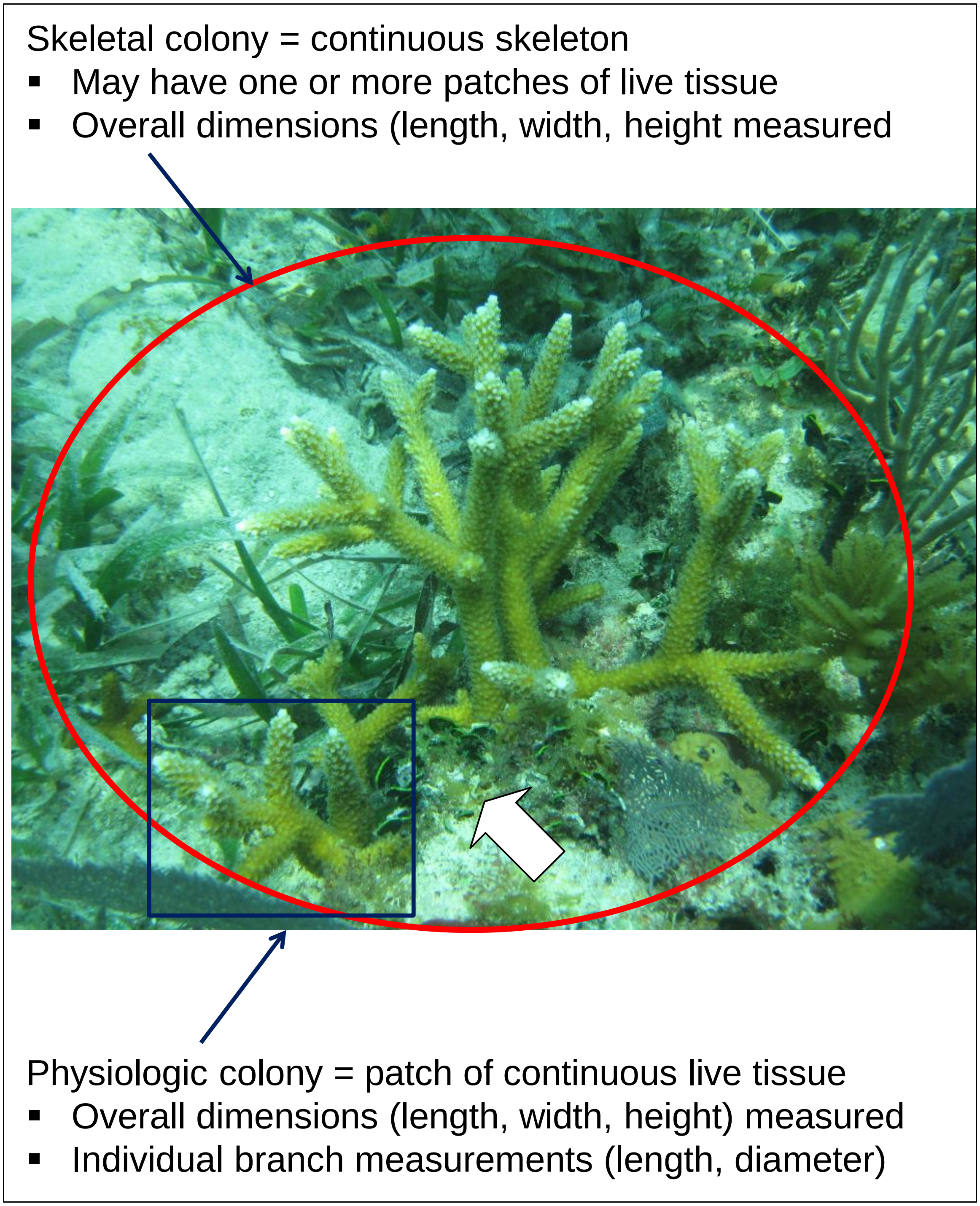
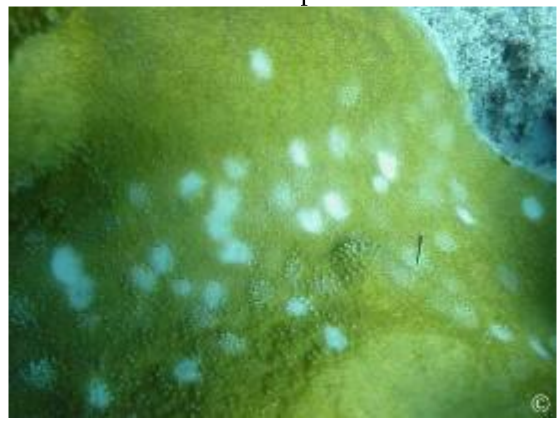


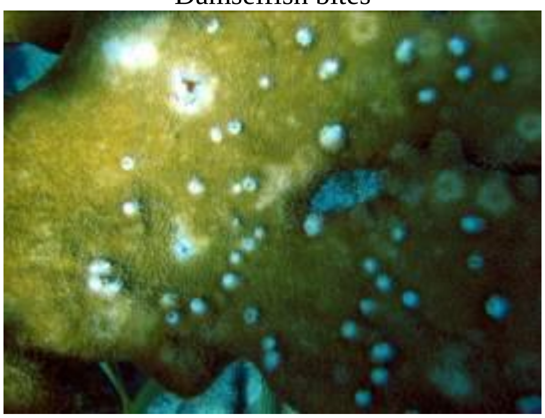
Figure C-4. Disease, disease-like conditions, and predation of *Acropora* corals.

White band type II in *Acropora*

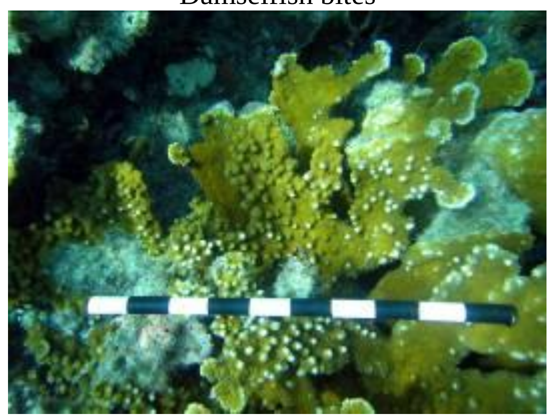
White pox



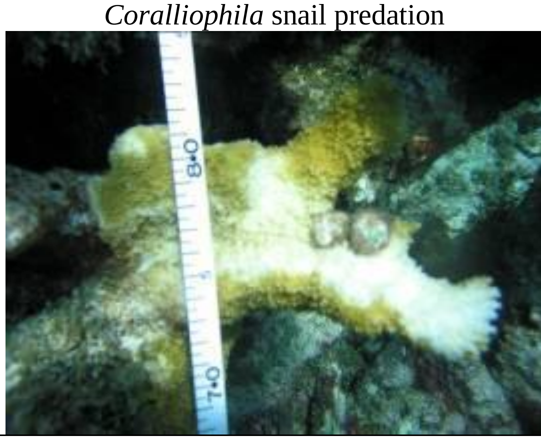
Damselfish bites



Damselfish bites



Coralliophila snail predation



Possible snail predation or white pox

Table C-1. *Acropora* population metrics for Level 3, 4, 6, and 7. Levels 1 and 2 deal with presence-absence at the site and transect levels, respectively. Level 5 measurements include branch and patch sizes and numbers for colony surface area estimates. Level 7 metrics might also include cover, branch density and branch diameter. Clumps, thickets, and stands are arbitrary terms that we are evaluating for longer-term usage, and could change before the 2012 field season. Acrv = *A. cervicornis*, Apal = *A. palmata*.

Unit Size	**Size Parameters Level 3-4**					**Condition Measurements Levels 3-4**		
	Maximum Diameter	Second Diameter	Height	Perimeter		Patches/ Skeletal Colony	Percent Living and dead	Disease, bleaching, predation, overgrowth
Small						**Level 6**		
Acrv < 25 cm	Tape/Ruler	Tape/Ruler	Tape/Ruler	x		Count or	Visual or	Visual or
Apal < 1 m						Measure	Measure	Measure
Medium								
Acrv 25-100 cm	Tape/Ruler	Tape/Ruler	Tape/Ruler	x		Count or	Visual or	Visual or
Apal 1-3 M						Measure	Measure	Measure
Clump	**Size Parameters Level 6**					**Condition Measurements (Level 7)**		
Acrv 1-5 m	Tape	Tape	Tape	Tape		Sub Sample	Sub Sample	Sub Sample
Apal 3-10 m								
Thicket								
Acrv 5-30 m	Tape/GPS	Tape/GPS	Tape	Tape/GPS		Sub Sample	Sub Sample	Sub Sample
Apal 10-30 m								
Stand								
Acrv >30 m	Tape/GPS	Tape/GPS	Tape	Tape/GPS		Sub Sample	Sub Sample	Sub Sample
Apal >30 m								

D. Anemones and Corallimorpharians

Quantitative surveys of other benthic cnidarians in the Florida Keys during 2011 were conducted at 280 sites in the middle and upper Florida Keys, with a Keys-wide effort planned for 2012. These surveys target anemones (O. Actiniaria) and corallimorpharians (O. Corallimorpharia) known to occur in the Florida Keys, with a particular focus on the larger and conspicuous or field-identifiable members of both orders. Similar surveys were conducted in the study area during 1999-2001 (211 sites), 2005 (195 sites), 2008 (145 sites), 2009 (160 sites), and 2010 (120 sites), as well as in the Dry Tortugas region during 2000, 2006, and 2008. Because some species of anemones and corallimorpharians are collected for the marine aquarium trade, these surveys are designed to quantify differences in distribution, density, and abundance among habitats and management zones in the Florida Keys.

Since 1999, we have encountered five conspicuous anemone species, all of which tend to have solitary and larger polyps compared to other cnidarians: the giant Caribbean or pink-tipped anemone *Condylactis gigantea* in the Family Actiniidae, the ringed or corkscrew anemone *Bartholomea annulata* in the Family Aiptasiidae, the speckled anemone *Epicystes* (=*Phymanthus*) *crucifera* in the Family Phymanthidae, *Bunodosoma granulifera* (first record since study inception), and *Lebrunia danae*. Two other anemones, the knobby anemone (*Heteractis lucida*) and the sun anemone *Stichodactyla* (=*Stoichactis*) *helianthus*, are rarely encountered, but are still searched for during the benthic surveys. Tube-dwelling anemones and very cryptic species (e.g. *L. coralligens*) are not included in these surveys. Figure D-1 shows six of the seven anemone species (*S. helianthus* not shown) that are targeted in belt transect surveys. Three corallimorpharians are also included for sampling: *Discosoma* (=*Paradiscosoma*) *carlgreni* and *D. sanctithomae* in the Family Actinodiscidae and *Ricordea florida* in the Family Corallimorpharidae (Figure D-2). Corallimorpharians, sometimes called false corals, differ from anemones in the arrangement of the tentacles, and may be solitary, but are typically found in clusters.

Anemones and corallimorpharians are surveyed in two 15-m x 1-m belt transect surveys per visited site. The procedures for sampling are as follows:

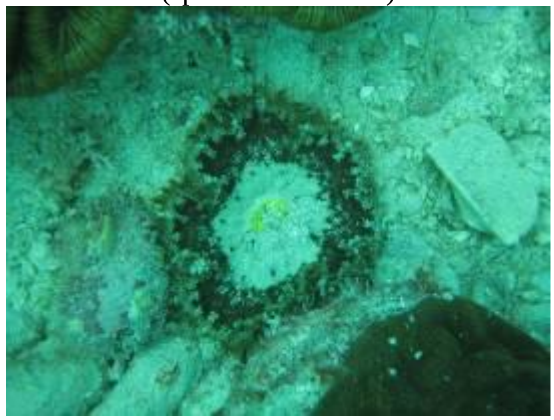
- Once transects are deployed, start at one end of the transect tape and search 0.5 m out from the left transect side using the 0.5-m scale bar. At the end of the 15-m transect, turn around and search the other side of the transect tape (similar to the belt transect surveys for physical data, urchins, mollusks, and *Acropora* corals).
- Any anemones or corallimorpharians that are encountered within the 0.5-m belt area on each side of the transect are identified and counted.
- Data recorded on the slate includes the abbreviation for the species and the number of individuals encountered.

- The abbreviations used for these organisms are as follows and consist of a four-letter code with the first letter of the genus and generally the next three letters of the scientific name:
    - *Bartholomea annulata* = BANN
    - *Bunodosoma granulifera* = BGRA
    - *Condylactis gigantea* = CGIG
    - *Epicystes crucifera* = ECRU
    - *Lebrunia danae* = LDAN
    - *Stichodactyla helianthus* = SHEL
    - *Discosoma carlgreni* = DCAR
    - *D. sanctithomae* = DSAN
    - *Ricordea florida* = RFLO

Figure D-1. Anemones (Cnidaria, Anthozoa) surveyed for presence-absence, density, and habitat distribution in the Florida Keys. Not pictured is *Stichodactyla helianthus* (sun anemone), which is rarely encountered.

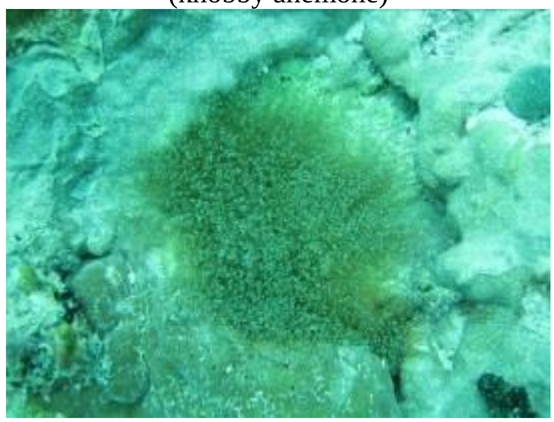
Bartholomea annulata
(corkscrew anemone)

Epicystes crucifera
(speckled anemone)



Bunodosoma granulifera

Heteractis lucida
(knobby anemone)



Condylactis gigantea
(giant pink-tipped anemone)

Lebrunia danae

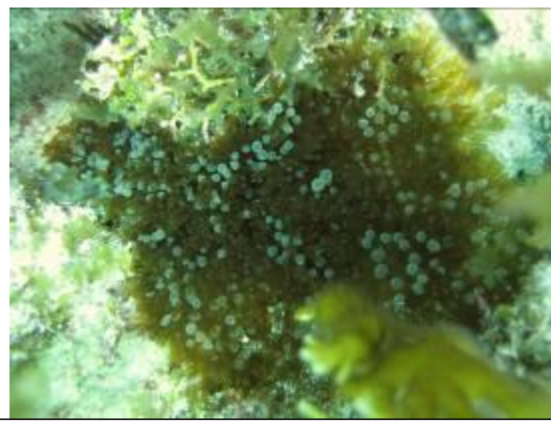
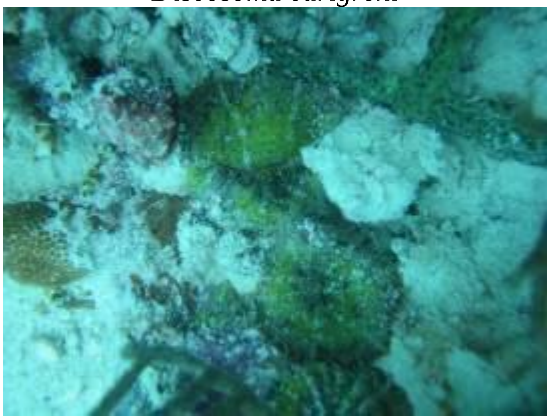


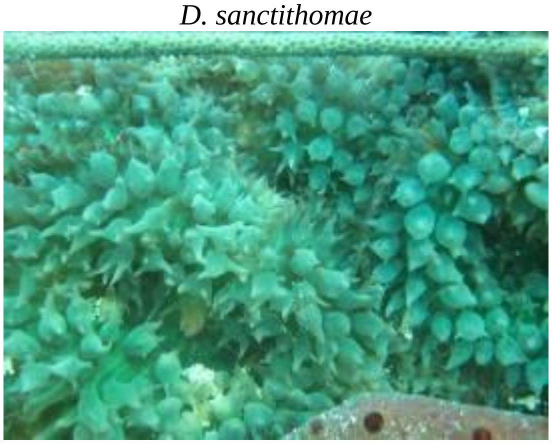
Figure D-2. Corallimorpharians (Cnidaria, Anthozoa, Corallimorpharia) surveyed for presence-absence, density and habitat distribution.

Discosoma carlgreni

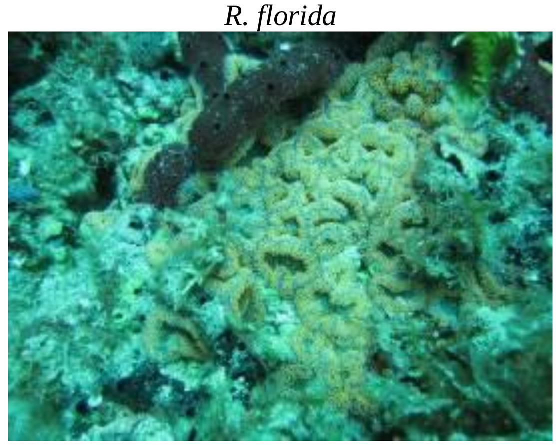


Ricordea florida

D. sanctithomae



R. florida



D. sanctithomae

R. florida

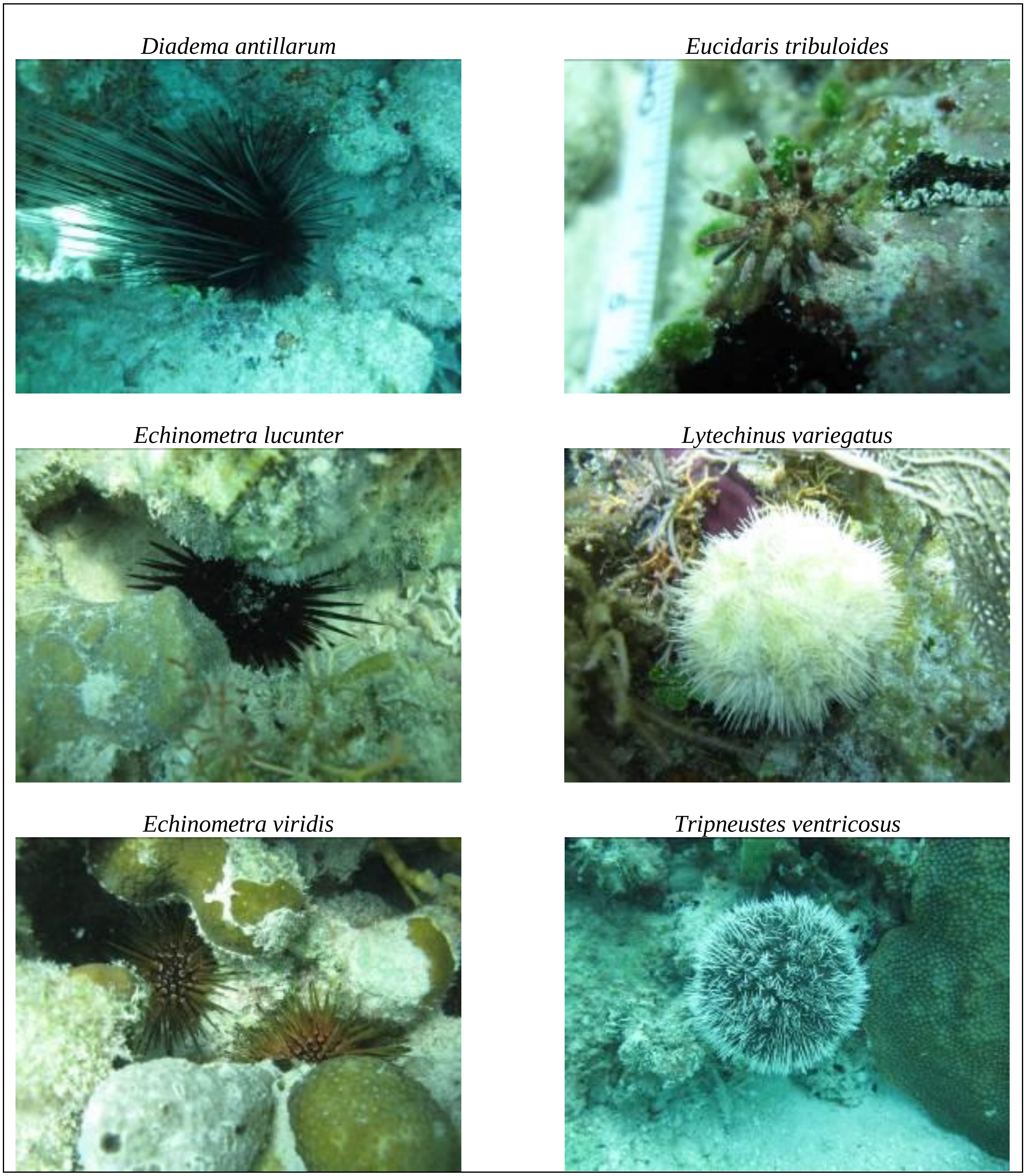
E. Urchins

Beginning in 1999, we have conducted large-scale surveys of urchin abundance and size in a diversity of habitats across the south Florida shelf encompassing now over 1,100 sites. We recently described the population status of *Diadema antillarum* based upon surveys of 235 sites along ~200 km of the Florida reef tract during 2007. Additional surveys were conducted Keys-wide in 2008 (145 sites), 2009 (160 sites), and 2010 (120 sites). Urchin surveys include all echinoids encountered, in addition to *D. antillarum*, and to our knowledge, these efforts represent the only large-scale, repeated, surveys for urchins being conducted in the Florida Keys.

Quantitative surveys in the upper and a portion of the middle Florida Keys during May-September 2011 targeted echinoids known to occur coral reef and hard-bottom habitats throughout the Florida Keys; thus, our surveys do not include sand dollars and sea biscuits, which tend to occur in soft-sediment habitats and not in reef environments. The accompanying figure shows each of the six echinoids commonly encountered (Figure E-1). Urchins are surveyed in two 15-m x 1-m belt transect surveys per site. The procedures for sampling are as follows:

- Once transects are deployed, start at one end of the transect tape and search 0.5 m out from the left transect side using the 0.5-m scale bar. At the end of the 15-m transect, turn around and search the other side of the transect tape (similar to the belt transect surveys for physical data, cnidarians, mollusks, and *Acropora* corals).
- Any urchins that are encountered within the 0.5-m belt area on each transect side are counted and measured for test diameter (not including the spines) to the nearest mm (0.1 cm) using plastic calipers or a ruler.
- Data recorded on the slate includes the abbreviation for the species and the test sizes of the of individuals encountered for each species.
- The abbreviations used for these organisms are as follows and consist of a four-letter code with the first letter of the genus and generally the next three letters of the scientific name:
    - *Arbacia punctulata* = APUN
    - *Diadema antillarum* = DANT
    - *Echinometra lucunter* = ELUC
    - *Echinometra viridis* = EVIR
    - *Eucidaris tribuloides* = ETRI
    - *Lytechinus variegatus* = LVAR
    - *Tripneustes ventricosus* = TVEN

Figure E-1. Urchin (echinoid) species surveyed for habitat distribution, density, and size (test diameter) in the Florida Keys. Not shown is *Arbacia punctulata*.



F. Mollusks

The Florida Keys marine ecosystem supports a diverse fauna of mollusks belonging to several orders. Opisthobranch mollusks, for example, are represented by at least 30 species of sea slugs (Sacoglossa) and 23 species of nudibranchs (Nudibranchia), including at least three endemic species. Data on the status and trends of mollusk populations and habitat utilization patterns in the Florida Keys are generally limited, with the exception of queen conch (*Strombus gigas*). Since 2001, we have conducted intermittent surveys of various gastropod mollusk species in conjunction with assessments of other benthic coral reef organisms (Figure F-1). In 2007, 2010, and most recently in 2011, we surveyed *Coralliophila* snail predation on *Acropora* corals and quantified the density two other Neogastropoda species (*Leucozonia nassa* and *Thais deltoidea*) that were particularly abundant on high-relief spur and groove reefs. During 2001 and 2008-2009, we surveyed *Cyphoma* abundance, size, and gorgonian host occupation patterns.

During 2011, replicate 15-m x 1-m belt transects per site were surveyed for the following sacoglossan, nudibranch, and Neogastropoda mollusks:

- The lettuce sea slug, *Elysia* (*Tridachia*) *crispata*, Class Gastropoda, Subclass Opisthobranchia, Order Sacoglossa, Family Elysiidae;
- All nudibranchs encountered, including *Hypselodoris edenticulata* (Florida regal sea goddess), *H. bayeri* (black-spotted sea goddess), *Chromodoris kempfi* (purple-crowned sea goddess), *C. nyalya* (red-line blue sea goddess), and *Glossodoris sedna* (red-tipped sea goddess) of the Class Gastropoda, Subclass Opisthobranchia, Order Nudibranchia; and
- The Neogastropoda mollusks *Thais deltoidea* (Lamarck) of the Family Thaididae, *Coralliophila* sp. of the Family Coralliophilidae, *Leucozonia nassa* (Gmelin) of the Family Fasciolariidae, and the queen conch (*Strombus gigas*) of the Family Strombidae.

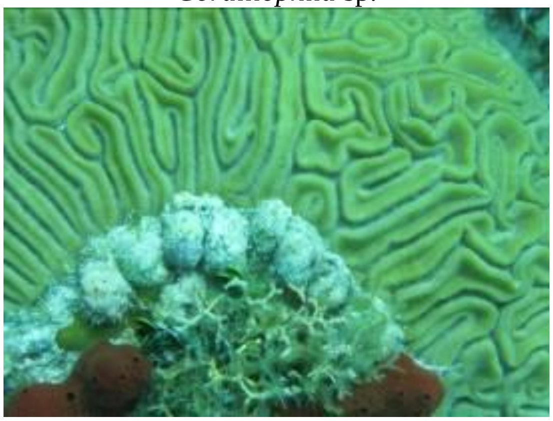
Of the targeted species, members of the genera *Chromodoris* and *Hypselodoris* are generally very rare. However, all of the targeted mollusks encountered are quantified to determine transect frequency of occurrence, density, shell or total length, and substratum occupancy patterns. An accompanying figure (Figure F-1) shows the more common mollusks that are included in the belt transect surveys. Mollusks are surveyed in two 15-m x 1-m belt transect surveys per visited site. The procedures for sampling mollusks are as follows:

- Once transects are deployed, start at one end of the transect tape and search 0.5 m out from the left transect side using the 0.5-m scale bar. At the end of the 15-m transect, turn around and search the other side of the transect tape (similar to the belt transect surveys for physical data, cnidarians, urchins, and *Acropora* corals).

- Any of the targeted mollusk species that are encountered within the 0.5-m belt area on each transect side are counted and measured for total or shell length. The type of substratum the mollusk is found occupying, such as coral (indicate species) or algae (indicate by functional group) should also be noted.
- For queen conch, shell lip thickness is measured with plastic calipers, in addition to total shell length.
- Data recorded on the slate includes the abbreviation for the species, the shell or total length of each individual, and the substratum type where the mollusk was found (e.g. algal turf, crustose coralline algae, and coral species).
- The abbreviations used for these organisms are as follows and consist of a four-letter code with the first letter of the genus and generally the next three letters of the scientific name:
    - *Chromodoris kempfi* = CKEM
    - *Chromodoris nyalya* = CNAY
    - *Flabellina* sp. = FLAB
    - *Glossodoris sedna* = GSED
    - *Hypselodoris bayeri* = HBAY
    - *Hypselodoris edenticulata* = HEDE
    - *Hypselodoris olgae* = HOLG
    - *Hypselodoris picta* = HPIC
    - *Elysia (Tridachia) crispata* = TCRI
    - *Coralliophila* sp. = CABB
    - *Leucozonia nassa* = LNAS
    - *Thais deltoidea* = TDEL
    - *Strombus gigas* = SGIG (surveyed for shell lip thickness and total shell length)

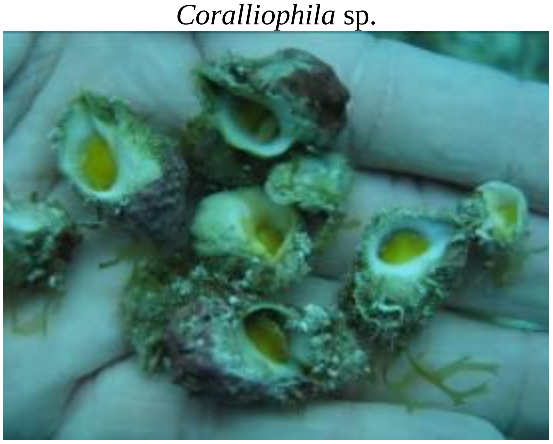
Figure F-1. Selected mollusks (sacoglossans, nudibranchs, gastropods) surveyed for habitat distribution, density, and size in the Florida Keys. Not pictured are certain nudibranchs of the genera *Hypselodoris* and *Chromodoris* that are infrequently encountered, as well queen conch (*Strombus gigas*).

Coralliophila sp.



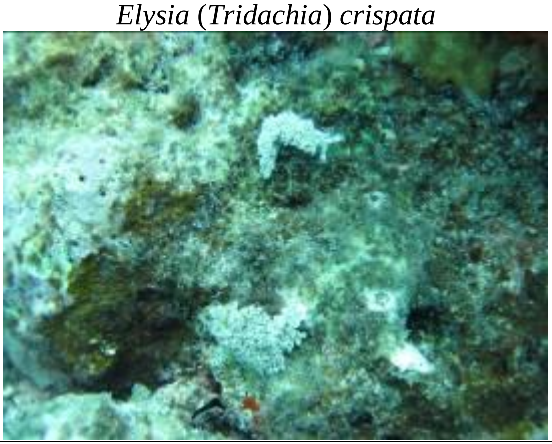
Thais deltoidea

Coralliophila sp.



Leucozonia nassa

Elysia (*Tridachia*) *crispata*



Glossodoris sedna

G. Marine Debris

Baseline data on marine debris and the biological impacts to coral reef benthic organisms were collected by our program during 2000, 2001, and 2008 (Chiappone et al. 2002c, 2004, 2005). Earlier surveys consisted of quantitative surveys of debris at 45 sites in the lower Keys from inshore to offshore during 2000, followed by surveys of 63 platform margin sites Keys-wide in 2001. These initial efforts addressed several questions pertaining to marine debris and its impacts to benthic organisms. First, what is the spatial extent and frequency of remnant fishing gear at multiple spatial scales in the Florida Keys? Second, what factors, such as habitat type (depth) or management regime (closed or open to fishing) affect the spatial variability of marine debris occurrence? Third, what are the biological impacts of marine debris, especially from remnant commercial and recreational fishing gear, on reef biota such as hard corals and sponges? As a follow-up to these initial surveys, a major effort was expended during 2008 to document the different debris types, length (where applicable), weight, and impacts to benthic coral reef organisms (e.g. abrasion damage) at 145 sites partitioned by habitat type, regional sector, and management zone from northern Key Largo to SW of Key West. To our knowledge, these data represent the most comprehensive site-level assessment of marine debris and its corresponding impacts in the Florida Keys. These data demonstrate the ubiquitous and damaging characteristics of marine debris, particularly derelict fishing gear, even within "protected" no-fishing zones in the Sanctuary. In 2010, we were able to incorporate marine debris surveys in our upper Keys sampling design to document the frequency of occurrence and biological impacts of marine debris encountered in the course of belt transect surveys for other benthic variables. During 2011, these surveys were continued at 280 sites in the upper Keys and included measurements of debris length and debris collection per transect for weight determinations.

Marine debris is surveyed along both 15-m transects, but an area 1-m out from each transect side is searched instead of 0.5 m, thus yielding a total belt transect area of 30 m^2. Along each belt transect, any marine debris encountered is identified, counted, measured (if applicable), and collected (Figures G-1 and G-2). The number of organisms impacted by marine debris is also noted, where a marine debris impact is considered where an item is causing abrasion damage to *Millepora* and scleractinian corals, gorgonians, sponges, and the colonial zoanthid *Palythoa*. For entangled hook-and-line angling gear, measurements of total length of monofilament, wire leaders, wire, and hooks are made either underwater or on-board the research vessel. For trap gear, total length of trap rope is measured, not including plastic pot openings, plastic trap grating, wooden slats, and cement used to weight the traps. For each transect, all marine debris encountered is recovered from the bottom and placed into labeled mesh gear bags to determine total wet weight per transect once on-board the research vessel. A digital 50-pound scale is used (we use the Rapala® model RSDS-50) to obtain the wet weight of marine debris collected along each transect. Debris items are also categorized according to whether it was biologically fouled or not. In cases where the entangled debris is either too large or too difficult to remove due to incorporation into the substrate, the debris may be left behind, but a note is made of its occurrence, size, and any abrasion damage to benthic organisms. In addition, intact lobster/crab traps, whether buoyed or not, are not disturbed.

Of the debris entangled on the seabed, we divide entangled items into three major categories: angling gear, lobster/crab trap gear, and other debris. Angling gear consists of monofilament with or without lead sinkers and hooks, wire leader (including piano wire), lead sinkers, and fishing rods with or without intact reels. Lobster/crab trap gear can include: intact traps, rope with or without attached buoys, wooden slats, plastic trap grating, plastic pot openings (trap throats), and cement. Other debris encompasses everything else that is not angling or trap gear related, including metals, glass, and plastics.

The procedures for sampling marine debris are as follows:

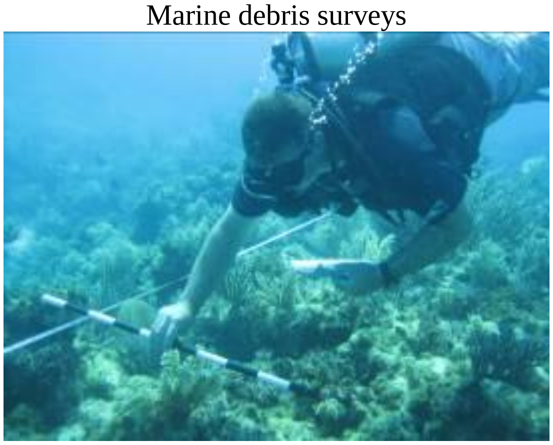
- Once transects are deployed, start at one end of the transect tape and search 0.5 m out from the left transect side using the 1-m scale bar. At the end of the 15-m transect, turn around and search the other side of the transect tape (similar to the belt transect surveys for physical data, cnidarians, urchins, mollusks, and *Acropora* corals). Note that a wider search area is used for marine debris compared to all of the other benthic variables.
- If debris is encountered within the belt transect boundaries, the item is identified, recorded as fouled or clean, measured for total length to the nearest cm (only angling gear and trap rope).
- The observer should note if the debris item is in contact with any benthic coral reef invertebrates and count and identify the organisms impacted by tissue/skeletal abrasion.
- For each transect, all debris encountered is placed into a collection bag and brought back on-board for the determination of wet weight. Note that debris weight for each transect includes all debris items encountered along a transect.
- Data recorded on the slate include the debris type, length (if applicable), whether the item is fouled or not, the number of individuals or colonies of each type of organism exhibiting abrasion damage, and the wet weight for all items encountered along the transect.

Figure G-1. Surveys of marine debris consist of 1-m search areas out on each side of a 15-m transect. Any debris encountered on a transect is identified, measured (applicable to angling gear such as monofilament line and lobster/crab trap gear such as trap rope) and collected for weighing. If the debris consists of angling gear or trap rope, each individual item is measured to the nearest cm, either while underwater or once back on the boat. Any milleporid hydrocoral, scleractinian coral, gorgonian, sponge, or colonial zoanthid (*Palythoa*) in contact with debris and exhibiting tissue/skeletal abrasion is noted.

Marine debris surveys

Trap rope abrasion

Marine debris surveys



Trap rope entanglement

Marine debris surveys

Trap grating

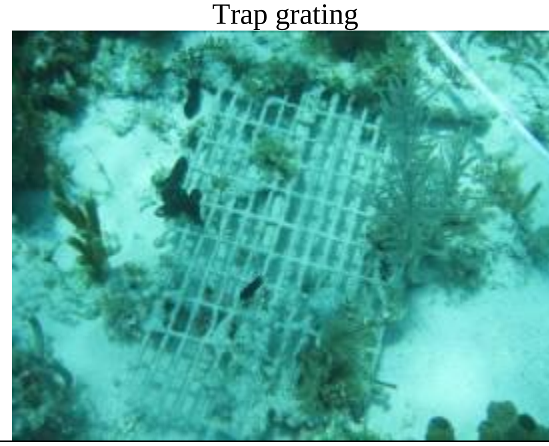


Figure G-2. Examples of marine debris commonly encountered on the seabed in the Florida Keys.

Monofilament

Trap rope debris

Trap rope debris

Trap rope debris

Intact lobster trap

Trap grating

References

Acropora Biological Review Team (2005) Atlantic *Acropora* Status Review Document. Report to National Marine Fisheries Service, Southeast Regional Office, 152 p

Aronson RB, Precht WF (2001) White-band disease and the changing face of Caribbean coral reefs. Hydrobiologia 460:25-38

Ault JS, Bohnsack JA, Meester GA (1998) A retrospective (1979-1996) multispecies assessment of coral reef fish stocks in the Florida Keys. Fish Bull 96:395-414

Ault JS, Diaz GA, Smith SG, Luo J, Serafy JE (1999) An efficient sampling survey design to estimate pink shrimp population abundance in Biscayne Bay, Florida. N Amer J Fish Mgmt 19:696-712

Auster PJ, Langton RW (1999) The effects of fishing on fish habitat. In Fish habitat: essential fish habitat and rehabilitation, ed. L. Benaka, pp. 150-187. AFS Symposium 22, Bethesda

Bauer JC (1976) Growth, aggregation, and maturation in the echinoid, *Diadema antillarum*. Bull Mar Sci 26:273-277

Bauer JC (1980) Observations on geographical variations in population density of the echinoid *Diadema antillarum* within the western north Atlantic. Bull Mar Sci 30:509-515

Benaka, L. R. (1999) Fish habitat: Essential fish habitat and rehabilitation. AFS Symposium 22, Bethesda, MD

Bohnsack JA, Harper DE, McClellan DB (1994) Fisheries trends from Monroe County, Florida. Bull Mar Sci 54:982-1018

Bohnsack JA (1997) Consensus development and the use of marine reserves in the Florida Keys, U.S.A. Proc Eighth Intl Coral Reef Symp 2:1927-1930

Bohnsack JA, Ault JS (1996) Management strategies to conserve marine biodiversity. Oceanography 9:73-82

Bohnsack JA, Harper DE, McClellan DB (1994) Fisheries trends from Monroe County, Florida. Bull Mar Sci 54:982-1018

Bruckner AW (2002) Proceedings of the Caribbean *Acropora* workshop: Potential application of the U.S. Endangered Species Act as a conservation strategy. NOAA Tech Mem NMFS-OPR-24, Silver Spring, MD, 199 p

Bursey CR, Guanciale JM (1977) Feeding behavior of the sea anemone *Condylactis gigantea*. Comp. Biochem Physiol 57A:115-117

Bursey CR, Harmer JA (1979) Induced changes in the osmotic concentration of the coelenteron fluid in the sea anemone *Condylactis gigantea*. Comp. Biochem Physiol 64A:73-76

Cairns S, Calder DR, Brinckmann-Voss A, Castro CB, Pugh PR, Cutress CE, Jaap WC, Fautin DG, Larson RJ, Harbison GR, Arai MN, Opresko DM (1991) Common and scientific names of aquatic invertebrates from the United States and Canada: Cnidaria and Ctenophora. Amer Fish Soc Publ 22, Bethesda, 75 p

Carpenter RC (1988) Mass mortality of a Caribbean sea urchin: Immediate effects on community metabolism and other herbivores. Proc Natl Acad Sci USA 85:511-515

Carpenter RC, Edmunds PJ (2006) Local and regional scale recovery of *Diadema* promotes recruitment of scleractinian corals. Ecol Lett 9:271-280

Chadwick NE (1991) Spatial distribution and the effects of competition on some temperate Scleractinia and Corallimorpharia. Mar Ecol Prog Ser 70:39-48

Chiappone M, Dienes H, Swanson DW, Miller SL (2003) Density and gorgonian host-occupation patterns by flamingo tongue snails (*Cyphoma gibbosum*) in the Florida Keys. Carib J Sci 39:116-127

Chiappone M, Dienes H, Swanson DW, Miller SL (2005) Impacts of lost fishing gear on coral reef sessile invertebrates in the Florida Keys National Marine Sanctuary. Biol Conserv 121:221-230

Chiappone M, Miller SL, Swanson DW, Ault JS, Smith SG (2001) Comparatively high densities of the long-spined sea urchin in the Dry Tortugas, Florida. Coral Reefs 20:137-138

Chiappone M, Rutten LM, Swanson DW, Miller SL (2009) Population status of the urchin *Diadema antillarum* in the Florida Keys 25 years after the Caribbean mass mortality. Proceedings of the 11th International Coral Reef Symposium, pp. 706-710

Chiappone M, Sullivan KM (1997) Rapid assessment of reefs in the Florida Keys: Results from a synoptic survey. Proc 8th Int Coral Reef Symp 2:1509-1514
Chiappone M, Swanson DW, Miller SL (2002a) Density, spatial distribution and size structure of sea urchins in coral reef and hard-bottom habitats of the Florida Keys. Mar Ecol Prog Ser 235:117-126
Chiappone M, Swanson DW, Miller SL, Dienes H (2004) Spatial distribution of lost fishing gear on fished and protected offshore reefs in the Florida Keys National Marine Sanctuary. Carib J Sci 40:312-326
Chiappone M, Swanson DW, Miller SL, Smith SG (2002b) Large-scale surveys on the Florida Reef Tract indicate poor recovery of the long-spined sea urchin *Diadema antillarum*. Coral Reefs 21:155-159
Chiappone M, White A, Swanson DW, Miller SL (2002c) Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. Mar Pollut Bull 44:597-604
Clark KB (1994) Ascoglossan (=Sacoglossa) molluscs in the Florida Keys: Rare marine invertebrates at special risk. Bull Mar Sci 54:900-916
Clark KB (1978), Busacca M (1978) Feeding specificity and chloroplast retention in four tropical Ascoglossa, with a discussion of the extent of chloroplast symbiosis and the evolution of the order. J Moll Stud 44:272-282
Clark KB, DeFreese DB (1987) Population ecology of Caribbean Ascoglossa (Mollusca: Opisthobranchia): A study of specialized algal herbivores. Amer Malac Bull 5:259-280
Cochran WG (1977) Sampling techniques, 3rd ed. Wiley, NY
Colin PL (1978) Caribbean reef invertebrates and plants. TFH Publications, Neptune City, 512 p
Colin PL, Heiser JB (1973) Associations of two species of cardinalfishes (Apogonidae: Pisces) with sea anemones in the West Indies. Bull Mar Sci 23:521-524
Davis GE (1977) Effects of recreational harvest on a spiny lobster, *Panulirus argus*, population. Bull Mar Sci 27:223-236
Dayton PK, Thrush SF, Agardy MT, Hofman RJ (1995) Environmental effects of marine fishing. Aquat Conserv Mar Freshw Ecosys 5:205-232
Debrot AO, Naglekerken I (2006) Recovery of the long-spined sea urchin *Diadema antillarum* in Curacao (Netherlands Antilles) linked to lagoonal and wave sheltered shallow rocky habitats. Bull Mar Sci 79:415-424
DeMaria K (1996) Changes in the Florida Keys marine ecosystem based upon interviews with experienced residents. The Nature Conservancy, Key West and Center for Marine Conservation, Washington DC, 134 p
DeVantier LM, De'ath G, Turak E, Done TJ, Fabricius KE (2006) Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef. Coral Reefs 25:329-340
Done TJ (1999) Coral community adaptability to environmental change at the scales of regions, reefs and reef zones. Amer Zool 39:66-79
Dunn DF (1981) The clownfish sea anemones: Stichodactylidae (Coelenterata: Actiniaria) and other sea anemones symbiotic with pomacentrid fishes. Trans Amer Phil Soc 71:1-115
Dustan P, Halas JC (1987) Changes in the reef-coral community of Carysfort Reef, Key Largo, Florida: 1974 to 1982. Coral Reefs 6:91-106
Edmunds PJ, Bruno JF (1996) The importance of sampling scale in ecology: Kilometer-wide variation in coral reef communities. Mar Ecol Prog Ser 143:165-171
Edmunds PJ, Carpenter RC (2001) Recovery of *Diadema antillarum* reduces macroalgal cover and increases abundance of juvenile corals on a Caribbean reef. Proc Natl Acad Sci USA 98:5067-5071
Elliot J, Cook CB (1989) Diel variation in prey capture behavior by the corallimorpharian Discosoma sanctithomae: Mechanical and chemical activation of feeding. Biol Bull 176:218-228
Fautin DG (1988) Anthozoan dominated benthic environments. Proc Sixth Intl Coral Reef Symp 3:231-236
Fautin DG, Lowenstein JM (1992) Phylogenetic relationships among scleractinians, actinians, and corallimorpharians (Coelenterata: Anthozoa). Proc Seventh Intl Coral Reef Symp 2:665-670
Fishelson L (1970) Littoral fauna of the Red Sea: the population of non-scleractinian anthozoans of shallow waters of the Red Sea (Eilat). Mar Biol 6:106-116
FMRI (Florida Marine Research Institute) (1998) Benthic habitats of the Florida Keys. FMRI Tech Rep TR-4. FDEP, St. Petersburg, 53 p

Forcucci D (1994) Population density, recruitment and 1991 mortality event of *Diadema antillarum* in the Florida Keys. Bull Mar Sci 54:917-928

Francis L (1973) Intraspecific aggression and its effect on the distribution of *Anthopleura elegantissima* and some related sea anemones. Biol Bull 144:73-92

FWCC (Florida Fish and Wildlife Conservation Commission) (2000) Fishing lines. Division of Marine Fisheries, Tallahassee, 8 p

FWCC (Florida Fish and Wildlife Conservation Commission) (2001) Commercial marine life (tropical ornamental) harvest for Monroe County, 1997-99. Florida Marine Research Institute, St. Petersburg

Gardner TA, Cote IM, Gill JA, Grant A, Watkinson AR (2003) Long-term region-wide declines in Caribbean corals. Science 301:948-960

Gladfelter WB (1982) White-band disease in *Acropora palmata*: implications for the structure and growth of shallow reefs. Bull Mar Sci 32:639-643

Hamner WM, Dunn DF (1980) Tropical Corallimorpharia (Coelenterata: Anthozoa): feeding by envelopment. Micronesica 16:37-41

Hanlon RT, Kaufman L (1976) Associations of seven West Indian reef fishes with sea anemones. Bull Mar Sci 26:225-232

Hartog JC den (1977) The marginal tentacles of *Rhodactis sanctithomae* (Corallimorpharia) and the sweeper tentacles of *Montastrea cavernosa* (Scleractinia): their cnidom and possible function. Proc Third Intl Coral Reef Symp 1:463-469

Hartog JC den (1980) Caribbean shallow-water Corallimorpharia. Zool Ver 176:1-83

Hatcher RG, Johannes RE, Robertson AI (1989) Review of research relevant to the conservation of shallow water tropical marine ecosystems. Oceanogr Mar Biol Ann Rev 27:337-414

Hemond EM, Vollmer SV (2010) Genetic diversity and connectivity in the threatened staghorn coral (*Acropora cervicornis*) in Florida. PloS One 5(1): e8652. doi:10.1371/journal.pone.0008652

Herrnkind W, Stanton G, Conklin E (1976) Initial characterization of the commensal complex associated with the anemone, *Lebrunia danae*, at Grand Bahama. Bull Mar Sci 26:65-71

Hughes TP, Baird AH, Dinsdale EA, Moltschaniwskyj NA, Pratchett MS, Tanner JE, Willis BL (1999) Patterns of recruitment and abundance of corals along the Great Barrier Reef. Nature 397:59-63

Humann P (1992) Reef creature identification. New World Publ., Orlando, 320 p

Jaap WC (1984) The ecology of the south Florida coral reefs: A community profile. US Fish Wildl Serv, Washington DC

Jaap WC, Halas JC, Muller RG (1988) Community dynamics of stony corals (Scleractinia and Milleporina) at Key Largo National Marine Sanctuary, Key Largo, Florida during 1981-1986. Proc 6th Int Coral Reef Symp 2:237-243

Jackson JBC (1997) Reefs since Columbus. Coral Reefs 16:S23-S32

Jennings S, Lock JM (1996) Population and ecosystem effects of reef fishing. In Reef fisheries, eds. N.V.C. Polunin and C.M. Roberts, pp. 193-218. Chapman and Hall, NY

Jennings S, Polunin NVC (1996) Impacts of fishing on tropical reef ecosystems. Ambio 25:44-49

Jennison BL (1981) Reproduction in three species of sea anemones from Key West, Florida. Can J Zool 59:1708-1719

Jones GP, Syms C (1998) Disturbance, habitat structure and the ecology of fishes on coral reefs. Austral J Ecol 23:287-297

Kaplan EH (1988) A field guide to southeastern and Caribbean seashores. Houghton Mifflin, Boston, 425 p

Kier PM, Grant RE (1965) Echinoid distribution and habits, Key Largo Coral Reef Preserve, Florida. Smithsonian Misc Coll 149:1-68

Lazar KE, Vaughan D, Grober-Dunsmore R, Bonito V (2005) Relatively low densities of *Diadema antillarum* on the Florida reef tract do not indicate population recovery. Proc Gulf Caribb Fish Inst 56:837-838

Lee TN, Clarke ME, Williams E, Szmant AF, Berger T (1994) Evolution of the Tortugas Gyre and its influence on recruitment in the Florida Keys. Bull Mar Sci 54: 621-646

Lessios HA (1988) Mass mortality of *Diadema antillarum* in the Caribbean: What have we learned? Annu Rev Ecol Syst 19:371-393

Lessios HA (2005) *Diadema antillarum* populations in Panama twenty years following mass mortality. Coral Reefs 24:125-127

Levy JM, Chiappone M, Sullivan KM (1996) Invertebrate infauna and epifauna of the Florida Keys and Florida Bay. Volume 5: Site characterization for the Florida Keys National Marine Sanctuary. The Preserver, Zenda, 166 p

Lidz BH (2006) Pleistocene corals of the Florida Keys: Architects of imposing reefs-Why? J Coast Res 22:750-759

Lidz BH, Reich CG, Shinn EA (2003) Regional Quanternary submarine geomorphology in the Florida Keys. Geol Soc Amer Bull 115:845-866

Limbaugh C, Pederson H, Chace FA (1961) Shrimps that clean fishes. Bull Mar Sci Gulf Carib 11:237-257

Lizama J, Blanquet RS (1975) Predation of sea anemones by the amphinomid polychaete, *Hermodice carunculata*. Bull Mar Sci 25:442-443

Mac Nally R, Fleishman E (2004) A successful predictive model of species richness based on indicator species. Conserv Biol 18(3): 646-654

Macia S, Robinson MP, Nalevanko A (2007) Experimental dispersal of recovering *Diadema antillarum* increases grazing intensity and reduces macroalgal abundance on a coral reef. Mar Ecol Prog Ser 348:173-182

Mahnken C (1972) Observations on cleaner shrimps of the Genus *Periclemenes*. Bull Nat Hist Mus Los Angeles County 14:71-83

Marszalek DS, Babashoff G, Noel MR, Worley DR (1977) Reef distribution in south Florida. Proc 3rd Int Coral Reef Symp 2:223-229

Mayor PA, Rogers CD, Hillis-Starr ZM (2006) Distribution and abundance of elkhorn coral, *Acropora palmata*, and prevalence of white-band disease at Buck Island Reef National Monument, St. Croix, US Virgin Islands. Coral Reefs 25:239-242

Miller MW, Bourque AS, Bohnsack JA (2002) An analysis of the loss of acroporid corals at Looe Key, Florida, USA: 1983-2000. Coral Reefs 21:179-182

Miller MW, Kramer KL, Williams S, Johnston L, Szmant AM (In press) Assessment of current rates of *Diadema antillarum* larval settlement. Coral Reefs

Miller RG (1981) Simultaneous statistical inference. Springer-Verlag, NY

Miller SL, Chiappone M, Rutten LM (2007) 2007 Quick look report: Large-scale assessment of *Acropora* corals, coral species richness, urchins and *Coralliophila* snails in the Florida Keys National Marine Sanctuary and Biscayne National Park. CMS, UNCW-Wilmington, Key Largo, FL, 147 p

Miller SL, Chiappone M, Rutten LM, Swanson DW (2009) Population status of *Acropora* corals in the Florida Keys. Proceedings of the 11th International Coral Reef Symposium, pp. 775-779

Miller SL, Swanson DW, Chiappone M (2002) Multiple spatial scale assessment of coral reef and hard-bottom community structure in the Florida Keys National Marine Sanctuary. Proc 9th Int Coral Reef Symp 1:69-77

Murdoch TJT, Aronson RB (1999) Scale-dependent spatial variability of coral assemblages along the Florida Reef Tract. Coral Reefs 18:341-351

Myhre S, Acevedo-Gutierrez A (2007) Recovery of sea urchin *Diadema antillarum* populations is correlated to increased coral and reduced macroalgal cover. Mar Ecol Prog Ser 329:205-210

NOAA (National Oceanic and Atmospheric Administration) (1996) Final management plan/environmental impact statement. Volume II: Development of the management plan: environmental impact statement. NOS/SRD, Silver Spring, 245 p

Pandolfi JM (2002) Coral community dynamics at multiple scales. Coral Reefs 21:13-23

Pandolfi JM, Bradbury RH, Sala E, Hughes TP, Bjorndal KA, Cooke RG, McArdle D, McClenachan L, Newman MJH, Paredes G, Warner RR, Jackson JBC (2003) Global trajectories of the long-term decline of coral reef ecosystems. Science 301: 955-958

Paulay G (1997) Diversity and distribution of reef organisms. in Birkeland C (ed), Life and death of coral reefs. Chapman & Hall, NY, pp 298-353

Pitts PA (1994) An investigation of near-bottom flow patterns along and across Hawk Channel, Florida Keys. Bull Mar Sci 54:610-620

Porter JW, Meier OW (1992) Quantification of loss and change in Floridian reef coral populations. Am Zool 32:625-640

Precht WF, Miller SL (2007) Ecological shifts along the Florida Reef Tract: The past is the key to the future. Ch. 9 in Geological Approaches to Coral Reef Ecology. Aronson RB (ed), Springer, NY, pp 237-312

Robbin DM (1981) Subaerial $CaCO_3$ crust: A tool for timing reef initiation and defining sea level changes. Proc Fourth Intl Coral Reef Symp 1:575-579

Roberts CM (1995) Effects of fishing on the ecosystem structure of coral reefs. Conserv Biol 9:988-995

Rutten LM, Chiappone M, Swanson DW, Miller SL (In press) Stony coral species diversity and cover in the Florida Keys using design-based sampling. Proc 11th Intl Coral Reef Symp

Saila SB, Kocic VLJ, McManus JW (1993) Modeling the effects of destructive fishing practices on tropical coral reefs. Mar Ecol Prog Ser 94:51-60

Sebens KP (1982) Intertidal distribution of zoanthids on the Caribbean coast of Panama: Effects of predation and dessication. Bull Mar Sci 32:316-335

Sefton N, Webster SK (1986) Caribbean reef invertebrates. Sea Challengers, Monterey, 112 p

Shick JM (1991) A functional biology of sea anemones. Chapman and Hall, New York, 395 p

Shinn EA, Hudson JH, Halley RB, Lidz B (1977) Topographic control and accumulation rate of some Holocene coral reefs: South Florida and Dry Tortugas. Proc Third Intl Coral Reef Symp 2:1-7

Shinn EA, Hudson JH, Robbin DM, Lidz B (1981) Spurs and grooves revisited: construction versus erosion Looe Key Reef, Florida. Proc Fourth Intl Coral Reef Symp 1:475-483

Shinn EA, Lidz BH, Kindinger JL, Hudson JH, Halley RB (1989) Reefs of Florida and the Dry Tortugas. U.S. Geological Survey, St. Petersburg, 53 p

Smith NP (1994) Long-term Gulf-to-Atlantic transport through tidal channels in the Florida Keys. Bull Mar Sci 54:602-609

Smith SG, Swanson DW, Chiappone M, Miller SL, Ault JS. 2011. Probability sampling of stony coral populations in the Florida Keys. Environ Monit Assess 183:121-138.

Smith WL (1973) Record of a fish associated with a Caribbean sea anemone. Copeia 1973:597-598

Smith SG, Swanson DE, Chiappone M, Miller SL, Ault JS (2011) Probability sampling of stony coral populations in the Florida Keys. Environmental Monitoring and Assessment 183: 121-138

Somerfield PJ, Jaap WC, Clarke KR, Callahan M, Hackett K, Porter J, Lybolt M, Tsokos C, Yanev G (2008) Changes in coral reef communities among the Florida Keys, 1996-2003. Coral Reefs DOI 10.1007/s00338-008-0390-7

Tilmant JT (1989) A history and an overview of recent trends in the fisheries of Florida Bay. Bull Mar Sci 44: 3-22.

Van-Praët M (1985) Nutrition of sea anemones. Adv Mar Biol 22:65-99

Voss GL (1976) Seashore life of Florida and the Caribbean. Banyan Books, Miami, 199 p

Voss GL, Bayer FM, Robins CR, Gomon M, LaRoe ET (1969) The marine ecology of the Biscayne National Monument. University of Miami, Miami, 169 p

Voss GL, Voss NA (1955) An ecological survey of Soldier Key, Biscayne Bay, Florida. Bull Mar Sci 5:203-229

Watling L, Norse EA (1998) Disturbance of the seabed by mobile fishing gear: A comparison to forest clearcutting. Conserv Biol 12:1180-1197

Wheaton JL, Jaap WC (1988) Corals and other prominent benthic Cnidaria of Looe Key National Marine Sanctuary. Fla Mar Res Publ 43:1-25

Weil E, Torres JL, Ashton M (2005) Population characteristics of the sea urchin *Diadema antillarum* in La Parguera, Puerto Rico, 17 years after the mass mortality event. Rev Biol Trop 53:219-231

Williams DE, Miller MW, Kramer KL (2008) Recruitment failure in Florida Keys *Acropora palmata*, a threatened Caribbean coral. Coral Reefs 27:697-705

Williams DE, Miller MW, Kramer KL (2006). Demographic monitoring protocols for threatened Caribbean spp. Corals. NOAA Technical Memorandum NMFS-SEFSC-543. 112 pp.

Zubillaga AL, Marquez LM, Croquer A, Bastidas C (2008) Ecological and genetic data indicate recovery of the endangered coral *Acropora palmata* in Los Roques, southern Caribbean. Coral Reefs 27:63-72

Appendix

Appendix 1. Example data slates used for benthic surveys in the Florida Keys.

Appendix 1A. Dive log data slate used to record the dive #, site #, time up and down, maximum depth (z), bottom time, tank pressure at the beginning and end of the dive, and water temperature.

Date : ______________ **Sampling Location:** ____________________________________ **Scanned:** _____ **Entered:** _______

Diver : ______________

Dive	Site	Time ↓	Time ↑	Z	BT	PSI ↓	PSI ↑	Temp

Diver : ______________

Dive	Site	Time ↓	Time ↑	Z	BT	PSI ↓	PSI ↑	Temp

Diver : ______________

Dive	Site	Time ↓	Time ↑	Z	BT	PSI ↓	PSI ↑	Temp

Diver : ______________

Dive	Site	Time ↓	Time ↑	Z	BT	PSI ↓	PSI ↑	Temp

Appendix 1B. Example data slate used to record the site #, habitat, station or transect #, along with physical and biological variables. MinZ = minimum transect depth, measured in feet using a digital depth gauge. MaxZ = maximum transect depth. MVR-ID = maximum vertical relief measured along a transect, along with the identification of the relief feature. Under the ACRV and APAL columns, a "+" indicates a species is present within a belt transect boundary. ANEM = anemones, which are identified and counted. CMOR = corallimorpharians, which are identified and counted. Targeted mollusks are identified, measured for total or shell length to the nearest 0.1 cm, along with the substratum type occupied (e.g. algal turf, coralline algae, coral) when encountered. Urchins are identified and measured for test diameter to the nearest 0.1 cm.

Date : 8/27/2011 Observer: MC Station Size: 1m x 15 m Scanned: ✓ Entered: ✓

Site	Habitat	Station	MinZ	MaxZ	MVR-ID	ACRV	APAL	ANEM	CMOR	Mollusks	Urchins
257	MPR	1	12	17	60 Dead Coral	Ø	Ø	Bann 1	Ø	Ø	Evir 2.1, 1.8
		2	13	16	90 Dead Coral	1	Ø	Ø	Ø	Tdel 3.7	Ø
258	OPR	1	10	15	138 Mfav	2	1	Bann 1	Ø	Ø	Evir 2.8 Dant 6.0
		2	11	14	85 Ssid	3	Ø	Bann 11	Ø	Ø	Etri 3.1
259	LRHB	1	13	14	16 Acrv	1	Ø	Bann 1111	Rflo 28	Ø	Etri 2.5, 2.1 Dant 1.3
		2	13	14	24 Sbou	Ø	Ø	Ø	Ø	Ø	Ø

Appendix 1C. Example data slate used to record information on the size and condition of all colonies, both at the skeletal and physiologic levels, of *Acropora* corals. Skeletal-level measurements include overall colony dimensions (length, width, and height), along with visual assessments of live tissue vs. dead skeleton and condition (bleaching, disease, predation, and overgrowth). Physiologic colony-level measurements include overall dimensions, condition notes, as well as individual branch (branch length and diameter or width) and basal measurements.

Date: 8/27/2011 **Observer:** LMR **Data:** acropora **Station Size:** 1m x 15 m **Scanned:** ✓ **Entered:** ✓

(257)	-1	Ø Acropora	(258)	-1	2 Acrv 1Apal	(258)	-2	3 acrv Ø Apal	(259)	-1	1 acrv Ø Apal
(257)	-2	1 Acrv Ø Apal		Col①	acrv B 67 32 18		Col①	acrv B 12 9 5		Col①	acrv 17 6 3
	Col①	acrv B 27 15 11			90 LD 5Rd ukm			Ø dead			90 Ld Ø Rd
		75 LD 1Rd Sog		Sub1	acrv B 10 6 4		Sub1	acrv B 12 9 5			Loose
	Sub1	acrv B 20 10 6			Ø Dead			Ø dead		Sub1	acrv 6 4 2
		Ø Dead			C 2x 4,5,4,2,1			e 4x2, 3x2			Ø dead
		e 5x3, 2x2			C 1.5x 6, 2,3,1,1			C 3x 2,1,1,3,2			Loose
		C 4x 6,4,2,3			C 1x 2,4,2,2			C 2x 2,2,5,3			C 1x 6,2,2
		C 3x 2,4,2,2			C 0.5x 1,2,1,1,2			C 1.5x 3,2,2			C 0.5x 2,1
		C 2x 7,8,10		Sub2	acrv C 1 1 6			C 1x 2,2,1,3,4,2	(259)	-2	Ø acropora
		C 1x 4,3,3,3,2			Ø dead		Col②	acrv B 11 4 3			
		C 1x 7,1,1,2,3			C 1x 6			Ø dead			
	Sub2	acrv B 6 3 2		Sub3	acrv e 3 2 0		Sub1	acrv B 9 2 2			
		15 Ld 5Rd Sog			Ø dead			Ø dead			
		C 2x 4,3			e 3x2			C 2x 6,2			
		C 1x 2,1,1		Col②	acrv B 9 6 3			C 1x 4,2,1,1			
					50 LD 5 RD			C 0.5x 1,1,1			
					gf(cora 1.6, 1.3)		Sub2	acrv B 3 2 2			
				Sub1	acrv B 9 4 2			C 1x 3,1			
					Ø LD 10Rd			C 0.5x 2,2,1			
					gf(cora 1.6, 1.3)		Col③	acrv B 5 4 3			
					C 2x 4,5,3,2			Ø Dead			
					C 1.5x 3,2,2			e 2x2			
					C 1.0x 2,2,2,1,1			C 1x 3,2,4			
				Sub2	acrv e 2 1 0			C 0.5x 2,2,1			
					Ø dead						
					e 2x1						
				Col①	Apal B 225 170 165						
					95 LD 1 Rd						
					Dams, wbd,						
					gf(cora 2.3, 1.7)						
				Sub1	Apal B 25 18 13						
					Ø LD 25 Rd						
					wbd, gf(cora 2.3, 1.7)						
					m 5 4 2						
					e 15 x 10, 12x4						
					C 6x7						
					Bp 7 7 2, 13 6 2						
					Bp 5 4 1, 3 2 1						

Appendix 1D. Example data slate used to record information on the number, size (binned by max. diameter size classes), and condition of all scleractinian corals greater than 4 cm in maximum diameter. For each belt transect, all scleractinian corals > 4 cm encountered are identified, counted, binned into size class intervals (e.g. 4-10 cm, 10-15 cm, etc.), and noted for condition (bleaching, disease, overgrowth, and predation).

Date: 8/27/2011 **Observer:** LMR **Data:** Stony Coral **Station Size:** 1m x 10 m **Scanned:** ✓ **Entered:** ✓

(257)-1	(257)-2	(258)-1	(258)-2	(259)-1	(259)-2				
past 3A	ssid 3Cp	Ssid 8B pb	Dcyl 13D BBd	ssid 2B	ssid 2F				
Ssid 1A	1B pb	2A	acrv 2A	2C	ppor 1Ap				
mcav 7D	acrv 3D Sog	3C fb	2B	2Cp	1D break				
ppor 3Cp	Srad 1Ap	apal 23F p	1A p	mcav 1B	2Cp				
1Cp	1Ap	(dams, wbd	past 1A	smic 1B	Smic 2C abra				
1Ap	1Ap	gf cora 2.3 1.7)	7C	ssid 1A	(trap rope)				
mann 13C	1Ap	past 1A	ssid 2B	Srad 1Ap	mcav 2B				
mfav 9F	Scol ØA	1B	4A	1Ap	Ssid 3A				
Dlab 4C gf	mann 8B	2A	7D p	ppor 1A	2D				
(cora 3.2, 1.7,	Smic 2A dk	2A	7C pb	pdiv 2B fb	1A pb				
2.0, 2.3)	ppor 1B fb	aagr 1Ap	2A p	acrv 1F Loose	7B mott				
past 2A	1C fb	1Ap	8D clio	Srad 1Ap	2D ukd				
ssid 3B	2F	ffra ØA	mfav 4A		Srad 1Ap				
3B	mcav 6Bp	ØAp	ssid 2A		1Bp				
4A	ssid 8B clio	past 6B	mfav 1F Loose						
mcav 2B	ppor 1B Sog	Acrv 1C gf	Dcyl 9B ukm						
2F	1F Sog	(cora 1.6, 1.3)	mcav 2D gb						
Ssid 2D	mfav 6B ukm	Acrv 7F ukm	(cora 2.0)						
ppor 1A	aagr 2B	pdiv 2C	ffra ØA						
Srad 1Ap	3A	3D	aagr 2B						
1Ap	ssid 7D Sog	1B	2A dkp						
mcav 2B	mann 7C	mcav 2D	2C gb						
Ssid 4A	3B gb		(cora 1.7)						
4B mott	(cora 3.2)								
mfav 8C ukm	mcav 3B								
6B ukm									

Appendix 1E. Example data slate used to record marine debris observations. Information collected includes the site #, habitat type, station # (transect #), the type of debris, length (cm, if applicable), the identification off benthic invertebrates experiencing abrasion damage, and the total wet weight of all debris items. For each debris item, the surveyor also notes whether the debris is fouled or clean. All debris items per transect are placed in a mesh bag and brought back to the surface to determine total weight.

Date: 8/27/2011 Observer: MC Station Size: 2m x 15 m Scanned: ✓ Entered: ✓

Site	Habitat	Station	Debris ID	Length	Impacts	Weight
257	MPR	1	wire leader	112	SSid-1	54 oz
			wire leader	95	—	
			monofilament	245	—	
			metal grating	—	—	
		2	wire leader	80	—	28 oz
			trap cement	—	— (heavy)	
			wire leader	88	—	
			monofilament	174	pame-1 pdiv-1	
			plastic bag	—	—	
			glass bottle	—	—	
258	OPR	1	Trap rope	982	mcav-1	55 oz
		2	monofilament	60	—	1 oz
			wire leader	14	—	
259	LRHB	1	trap rope	163	pfle-1, pdic-1	46 oz
		2	trap wood	—	—	37 oz
			metal ring	—	—	
			trap wood	—	—	

Appendix 2. Equipment and supply list for benthic surveys in the Florida Keys.

<u>Dive Flag/GPS Buoy</u>:
Slic Pro-Bullet dive flag buoy (with extra1 lb. weight)
Mesh bag (with wire handle and extra 3 lb. weight)
Polypropylene line (3/8” diameter, 50’ length)
Garmin GPSmap 76
Aquapak waterprooof bag

<u>Sampling Gear</u>:
Two Keson fiberglass tapes (30m length)
Six PVC scale bars (modular 50cm lengths)
Assorted PVC slates (8 ½” x 11”, printed templates)
Pencils (usually Papermate Sharpwriter 0.7mm)
Measuring tools (rulers, calipers, and tapes)
Two mesh bags for (debris collection)
CanonSD1200IS Digital Elph Camera
Canon WP-DC29 Waterproof Case