Distribution, Abundance, and Condition of *Acropora* Corals, Other Benthic Coral Reef Organisms, and Marine Debris in Biscayne National Park and the Florida Keys National Marine Sanctuary

2012 Quick Look and Data Summary Report




June 2013

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NOAA CORAL REEF CONSERVATION PROGRAM

NCRI NATIONAL CORAL REEF INSTITUTE

NOVA SOUTHEASTERN UNIVERSITY

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Cover photo: Examples of methods and benthic coral reef organisms sampled in the Florida Keys during May-November 2012. Upper left: elkhorn coral (*Acropora palmata*) at Grecian Rocks, Florida, Upper right: giant pink-tipped anemone (*Condylactis gigantea*), Lower left: staghorn coral (*Acropora cervicornis*), Lower right: belt transect survey.

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2012 Executive Summary

During 73 days of fieldwork from May 7 to November 18, 2012, scientists from the Oceanographic Center at Nova Southeastern University (NSU-OSC), with collaborators from the Florida Keys National Marine Sanctuary (FKNMS), National Park Service-Biscayne National Park (NPS-BNP), and the Florida Fish and Wildlife Research Institute (FWC-FWRI), surveyed the density, size, and condition of *Acropora* corals, other benthic coral reef organisms, including urchins, anemones, corallimorpharians, and mollusks, as well as marine debris abundance and impacts to the benthos at 600 sites in BNP and the FKNMS from northern Key Largo to southwest of Key West near the Marquesas Keys (Figure 1). The Florida Keys field surveys were part of a larger effort to assess the distribution, density, size, condition, and population size of *Acropora* corals in U.S. territorial waters, including Puerto Rico and the U.S. Virgin Islands. In the Florida Keys, benthic surveys using replicate 15-m transects were conducted using a two-stage stratified design (Smith et al. 2011) that partitioned the sampling domain by habitat type (cross-shelf location and depth), geographic region, and management zone. Funding was provided by NOAA's Coral Reef Conservation Program and The Department of Commerce's 1535 Endangered Species Act Projects. Logistical support in the Florida Keys was provided by a number of institutional partners, including NOAA/FKNMS, NPS-BNP, FWC-FWRI, the Keys Marine Lab of the University of South Florida-Florida Institute of Oceanography (USF-FIO), Aquarius Reef Base – University of North Carolina-Wilmington, and Quiescence Diving Services. To support work with our expanding partner groups in the U.S. Virgin Islands and Puerto Rico, a Field Protocol Manual was produced in 2011 and updated in 2012 to help guide assessments of *Acropora* population habitat distribution, density, size, and condition.

Ten coral reef and hard-bottom habitat types were sampled in the Florida Keys from inshore of Hawk Channel to the deeper fore-reef, from 0.9 m to 18 m depth. The habitats sampled included inshore patch reefs, mid-channel patch reefs, offshore patch reefs, reef rubble, shallow (< 6 m) hard-bottom, inner line reef tract spur and groove, platform margin high-relief spur and groove, and the deeper fore-reef (6-15 m depth) encompassing continuous, low-relief hard-bottom, patchy hard-bottom, and low-relief spur and groove habitats. Sites were further partitioned by geographic region (Biscayne, upper Keys, middle Keys, and lower Keys), and management zone, which included sites within Biscayne National Park, as well as areas inside and outside of Sanctuary no-take zones designated as Sanctuary Preservation Areas, Research Only Areas, and Ecological Reserves. All 23 of the FKNMS no-take zones, exclusive of the Tortugas region (i.e., Tortugas North and South), were included in the 2012 sampling. For the 600 Florida Keys sites sampled, latitude/longitude points were randomly generated in a geographic information system

(GIS) incorporating available benthic habitat and bathymetry data for the sampling domain. At each site, two 15-m transects were used to inventory benthic coral reef organisms and marine debris, with data collected on: depth and topographic complexity; *Acropora* coral density, size, and condition; urchin density and size; anemone and corallimorpharian density; density and size of mollusks; and marine debris type, density, length, weight, and impacts to sponges and benthic cnidarians. At a subset of the 600 sites (n=202) density, size and condition of all scleractinian coral colonies (> 4 cm max. diameter) by species were also measured along two 10-m transects. This report summarizes results and provides descriptive data by habitat type and management zone for the benthic variables measured during 2012. The report is divided by section for each of the major categories of variables measured and includes data tables, data maps, and underwater images. The data collection effort by the Florida Keys survey team required 1,304 SCUBA dives and ~550 hours of underwater bottom time.

Population assessments of *Acropora* corals conducted in 2012 represent a continuation of our surveys that have focused on the habitat distribution, density, size, condition, and population size estimates of these two species conducted since 2006 when both species were formally listed as Threatened under the U.S. Endangered Species Act. In addition, we have conducted population assessments of all coral species, including *Acropora* spp., Keys-wide in 1999-2001, 2005, 2009, and most recently in 2012, as well as in the Dry Tortugas region during 1999-2000, 2006, and 2008. In the Florida Keys, both species continue to show characteristic distribution patterns, with staghorn coral (*A. cervicornis*) more frequently encountered, in greater densities (up to 1.17 colonies per m^2) on inner line reef tract, shallow (< 6 m) hard-bottom, and mid-channel and offshore patch reef habitats. Sparsely distributed staghorn corals were also found on deeper (6-15 m) hard-bottom. The largest staghorn coral colony encountered was 144 cm in maximum skeletal dimension, but approximately 85% of the sampled colonies were < 50 cm in maximum diameter. We estimate that approximately 73% of the staghorn corals in the Florida Keys between northern Biscayne National Park and Western Dry Rocks (~8.5 million skeletal colonies) occur on mid-channel and offshore patch reefs, with another 17% distributed mostly on shallow (< 6 m) hard-bottom habitat. Historically, staghorn coral occurred on some deeper fore-reef areas (especially low-relief spur and groove) in larger thickets of interlocking colonies, but no such thickets have been encountered during the past 25 years. In contrast to the pattern evident for *A. palmata*, it is estimated that most (~98%) of the staghorn corals present in the Florida Keys occur outside of FKNMS no-take zones. Approximately 17% of the physiologic staghorn coral colonies (i.e. live tissue patches) were categorized as either pale or partially pale, but no partially bleached or completely bleached colonies were encountered. Colonies frequently contained multiple patches of live tissue along with dead branches or partially dead branches.

Predation by *Coralliophila* snails (1.3%) and damselfishes (1.8%) was apparent and occurred in similar frequencies to previous years. No disease-like symptoms were encountered on the colonies assessed.

Relative to its congener, elkhorn coral (*Acropora palmata*) exhibits a narrower habitat distribution, with a few reefs supporting larger aggregations. The size range of skeletal colonies (n = 42) ranged from 5 cm to 278 cm, with an average of 57 ± 10 cm. Among the habitat types sampled, elkhorn corals were found mostly on inner line reef tract and shallow spur and groove sites, but also a few offshore patch reefs. In previous years, we encountered a few isolated colonies on offshore patch reefs, back-reef rubble, and shallow hard-bottom, but most colonies are presently confined to shallow fore-reef areas in the Florida Keys. Elkhorn corals were most common and characterized by larger colony sizes on several high-relief spur and groove reefs, especially within FKNMS no-take zones such as South Carysfort Reef, Elbow Reef, Grecian Rocks, and French Reef; a similar pattern was also evident for colony size. Several shallow spur and groove reefs continue to support reasonably large thickets, with most patches approximately 15-20 m in diameter. Reefs where stands (not just isolated colonies) of elkhorn coral occur in the Florida Keys include (from north to south): South Carysfort Reef, Elbow Reef, Horseshoe Reef, Grecian Rocks, French Reef, Sand Island, Molasses Reef, Sombrero Reef, and Looe Key. We estimate that more than 90% of the existing elkhorn corals (~361,000 total) between northern BNP and Western Dry Rocks occur in these high-density thickets. In contrast to the size structure of staghorn corals, there is a greater range in size and a greater abundance of larger (> 1 m diameter) elkhorn corals. Approximately 61% of the elkhorn coral colonies encountered during 2012 were < 50 cm in maximum diameter, but ~12% are larger than 1-m in maximum diameter. Most (87%) of the elkhorn coral colonies in the FKNMS occur within Sanctuary no-take zones. No disease-like symptoms or overgrowth by other organisms that was causing tissue loss were documented. Of the physiologic colonies (i.e., live tissue patches) assessed, approximately 38% were pale or partially pale, while about 2% were partially bleached. Predation by *Coralliophila* snails and damselfishes was apparent on 6.9% of live tissue patches (i.e., physiologic colonies), represented by *Coralliophila* snails (1.7%) and damselfishes (5.2%). No disease-like symptoms were encountered on the colonies assessed.

Surveys for all scleractinian coral species were conducted at 202 of the 600 sites, along replicate 10-m x 1-m belt transects. Surveys included the number, size (max. diameter), and condition (percent live tissue, bleaching, disease, overgrowth, and predation) of all corals by species. These data were used to compute abundance estimates, prevalence of different conditions, and population size structures. A total of 18,979 corals representing 39 species were identified, counted, measured, and assessed for condition. Ten species accounted for approximately 92% of all of the corals encountered, with *Siderastrea siderea*, *Porites*

astreoides, *Agaricia agaricites*, *Stephanocoenia michelinii*, and *P. porites porites* the most abundant. Coral species can be broadly grouped into those that are ubiquitous and abundant in most of the habitats surveyed, those that are less abundant overall, but common in certain habitats (e.g. *Montastraea faveolata*), and rarer species (e.g. *Mussa angulosa*). Prevalence of different adverse conditions such as disease and bleaching was generally low, with prevalence estimates of 1.1% and 1.4%, respectively. Active overgrowth of corals by other organisms (8.1% of all colonies), along with various levels of bleaching were the most common conditions noted. Many of the most common corals exhibited differences in frequency of occurrence and density among the ten coral reef and hard-bottom habitats surveyed. Mid-channel (average of 9.1 colonies per m^2) and offshore patch reefs (average of 6.5 colonies per m^2) continue to harbor relatively high densities of many species, especially the larger reef framework species. Comparisons between FKNMS no-take zones and reference areas indicated generally greater densities in FKNMS no-take zones for patch reef habitats, but lower in no-take zones for many other habitat types such as inner line reef tract and deeper fore-reef areas. For the habitats and depth range sampled in 2012, we estimate that there are approximately 2.7 billion (± 0.2 billion) scleractinian corals > 4 cm in max. diameter from northern Biscayne National Park to the western Dry Rocks area. Approximately 85% of all stony corals are 20 cm or smaller in maximum diameter and < 1 % are larger than 100 cm in size, mostly represented by large-sized species such as *Colpophyllia natans*, *Diploria* spp., *Montastraea* spp., and *S. siderea*. Because of the relatively small area of FKNMS no-take zones from Key Largo to Key West (5.81% of the total habitats sampled), approximately 3.9% of all scleractinian corals occur within no-take zones.

Seven echinoid (urchin) species were surveyed for site presence, transect frequency of occurrence, density, and size during 2012. A total of 4,972 individuals were counted and measured for test diameter (TD). Similar to previous years, most (~90%) urchins sampled were either *Echinometra viridis*, which was particularly abundant on many mid-channel and offshore patch reefs, or *Eucidaris tribuloides*, which was most abundant in reef rubble and high-relief spur and groove reefs. Densities of the long-spined sea urchin (*Diadema antillarum*) are still relatively low by historical (pre-1983) standards; the maximum site-level density recorded during 2010 was only 0.267 individuals per m^2. However, two temporal trends are apparent relative to similar surveys dating back to 1999. First, densities of *D. antillarum* have slowly increased since 1999, with the greatest densities of larger (> 5 cm TD) individuals found on mid-channel and offshore patch reefs, along with recently settled recruits in reef rubble habitats. Second, there has been a notable increase in the average and maximum sizes of individuals encountered over the past 10 years. In 2012, individuals as large as 10.2 cm TD were recorded, which we never encountered in the Florida Keys prior to 2005. The average size of *D. antillarum* up until 2005 was < 3.0 cm TD, while 2012

yielded an average size of 6.5 cm TD (257 individuals). At sites where small (3-5 individuals) aggregations of urchins were found, there were clear and obvious grazing impacts to the substratum. Assuming these trends continue, and as more space becomes cleared of algae, it will be important to monitor potential changes to the benthos, for example, recruitment of corals and other invertebrates. Measuring smaller corals (< 4 cm diameter) is time consuming and requires relatively strong taxonomic skills. We have measured these smaller corals in the past and have good baselines for future comparisons, but did not include the work in 2012. For most of the species encountered, including *D. antillarum*, urchins tended to be more frequently encountered and occurred in greater densities at reference sites compared to FKNMS no-take zones. Whether this result is due to greater urchin predation inside the no-take zones compared to reference areas, better recruitment outside the zones, or other reasons, is unknown.

Five anemone and three corallimorpharian species were encountered during 2012. *Bunodosoma granulifera* and the sun anemone (*Stichodactyla helianthus*) were searched for, but not found. A total of 1,095 anemones were counted, mostly represented by *Bartholomea annulata* (69%) and *Lebrunia danae* (19%). Anemones generally showed similar spatial patterns in abundance among habitats in 2012 compared to previous survey years dating back to 1999, with *B. annulata* exhibiting the broadest habitat distribution and greatest frequency of occurrence and abundance. A total of 6,971 corallimorpharians were counted, of which 76.8% were *Ricordea florida*, followed by *Discosoma sanctithomae* (23.1%) and *D. carlgreni* (0.2%). Similar to previous years, corallimorpharians were most abundant on mid-channel and offshore patch reefs, especially in the lower Keys, with mean densities as high as 10.8 individuals per m^2.

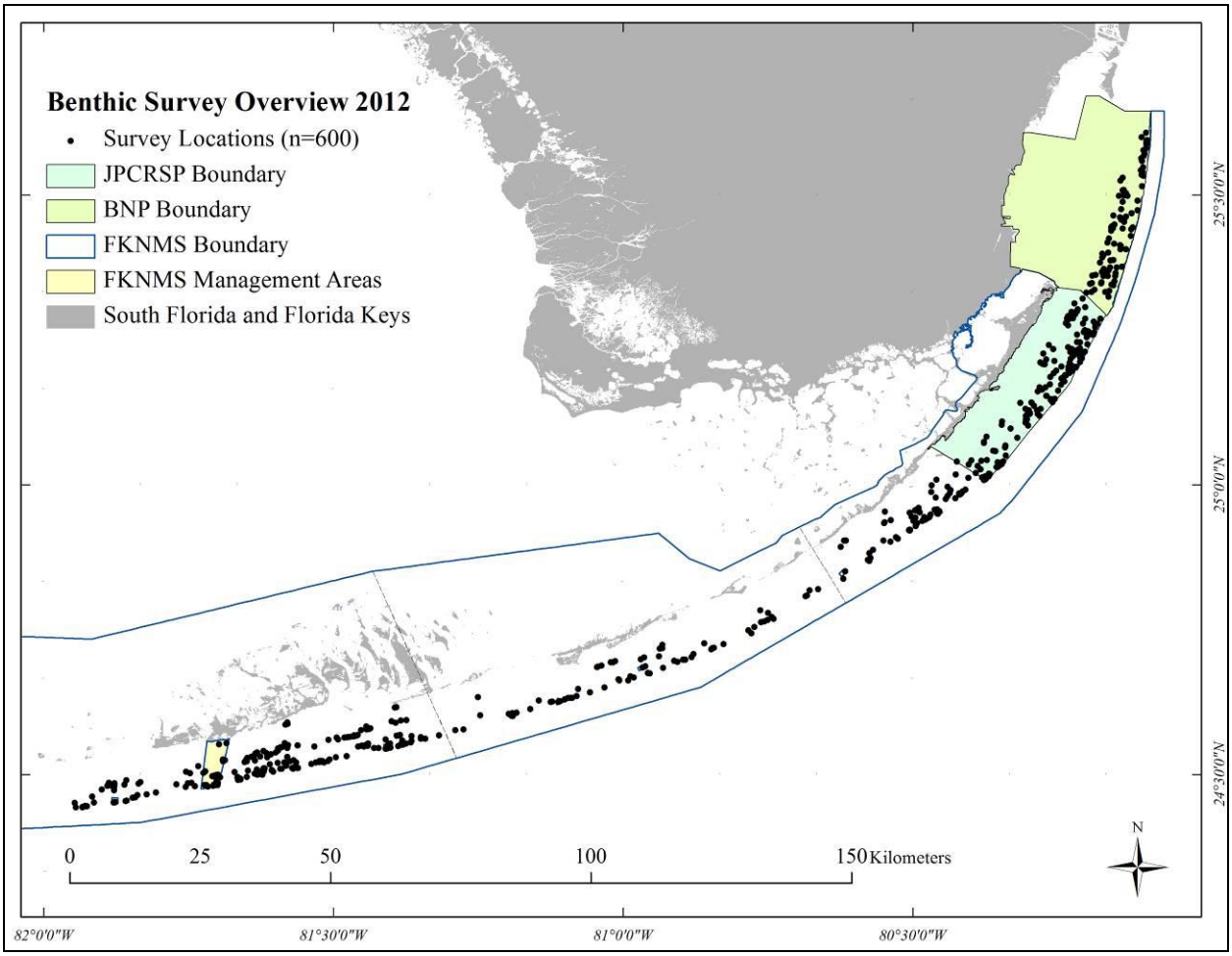
Surveys of the abundance, size, and substratum occupancy patterns of mollusks continued during 2012. All nudibranchs encountered, the sacoglossan *Elysia* (*Tridachia*) *crispata* (lettuce sea slug), and four gastropod species (*Coralliophila* sp., *Leucozonia nassa*, *Thais deltoidea*, and *Strombus gigas*) were enumerated and measured for shell length; in addition, the substratum occupied by a mollusk at the time of the survey was also noted. Only two nudibranch species were encountered: *Chromodoris* (*Mexichromis*) *nyalya* (19 individuals) and *Glossodoris sedna* (3). All but four of the 40 individuals of the lettuce sea slug (*E. crispata*) were encountered on algal turf in shallow, high-relief spur and groove reef habitats. Of the gastropods inventoried, the deltoid rock snail (*T. deltoidea*), an important micro-herbivore of turf algae, as well as a potential predator of other invertebrates, including *Coralliophila* snails, was the second most abundant (525 individuals), with most individuals occurring on high-relief spur and groove reefs. Approximately 96% of the individuals encountered were found either occupying algal turf or

crustose coralline algae. Of the 971 corallivorous snails (*Coralliophila* sp.) recorded, 98% were found on live coral tissue. A total of 19 different scleractinian coral taxa were found with corallivorous snails. Comparison to similar surveys dating back to 2007 suggests that *Coralliophila* snail abundance is increasing and that a greater diversity of coral species is experiencing snail predation. Particularly noteworthy was the diversity of coral species (19 species) encountered during 2012 with active snail predation.

Surveys of marine debris, including lost hook-and-line and lobster and crab trap fishing gear, carried out in 2011 represent a continuation of similar efforts conducted in the Florida Keys in 2000, 2001, 2008, and 2010. Data collected in 2012 included the type and frequency (density) of debris, the length of angling gear and lobster/crab trap rope, the total wet weight of debris recovered, as well as the frequency of benthic coral reef organisms impacted by tissue abrasion from debris entanglement. A total of 1,058 debris items were encountered from the 600 sites. Marine debris was found at about 64% of the sites and in all habitats, including all 23 no-take zones. Nearly 46% of the debris encountered consisted of lost hook-and-line fishing gear such as monofilament line, wire leaders, and lead sinkers. The remaining debris consisted of lobster and crab trap gear (41%) and other items such as glass, metals, and plastics (13%). Just over 0.62 km of angling gear, mostly represented by monofilament and fishing wire, was recovered, along with 2.69 km of lobster/crab trap rope, and ~450 kg of debris (approximately 989 pounds) was recovered from the seabed. A total of 531 sessile invertebrates represented by milleporid hydrocorals (72 colonies), scleractinian corals (114 colonies), gorgonians (243 colonies), sponges (98 individuals), and *Palythoa* (4 individuals) were recorded with abrasions from entanglement with marine debris, usually fishing gear.

Impacts to the benthos from the January 2010 cold-front event continue to be apparent in particular patch reef areas of the Florida Keys. Large numbers of patch reefs in the Cannon Patch/Higdons Reef area, Mosquito Bank, Tavernier Rocks, Cheeca Rocks, south of Duck Key, and Newfound Harbor appear to have suffered the most mortality, especially larger *Montastraea* colonies, as well as gorgonians, as evidenced by the larger numbers of dead, upright gorgonian skeletons. However, areas further offshore of inshore patch reef and shallow bank areas appeared to have suffered little damage from the January 2010 event. Finally, we witnessed more lionfish in 2012 than ever before, as evidenced by greater site prevalence and more individuals (usually 3-6 in a 100-m^2 area) compared to 2010-11. Lionfish were particularly common in habitats such as patch reefs with large coral heads or overhangs.

Figure ES-1. Sampling locations for *Acropora* corals, other benthic coral reef organisms, and marine debris in Biscayne National Park (BNP), the Florida Keys National Marine Sanctuary, and John Pennekamp Coral Reef State Park (JPCRSP) during May-November 2012. A total of 600 sites were surveyed for *Acropora* coral density, size, and condition, as well as urchins, anemones, corallimorpharians, mollusks, and marine debris from north of Fowey Rocks in BNP to the Western Dry Rocks area, southwest of Key West.



I. Introduction

Like many coral reef ecosystems, the Florida Keys have exhibited significant change in recent decades, including the loss of coral cover due to disease, as well as cold-fronts and hyperthermal events that cause coral bleaching (Jaap 1984; Aronson and Precht 2001; Chiappone et al. 2002; Lirman et al. 2011). In addition, a considerable array of phenomena affect Florida Keys reefs, such as continental influence (Biscayne Bay and Florida Bay exchange) and destructive tropical storms (Precht and Miller 2007). These stressors make it challenging to discern the degree to which human activities have affected ecological integrity relative to natural system variability (Somerfield et al. 2008).

While understanding the causes of coral reef decline is a fundamental pursuit among coral reef ecologists, our sampling program was designed specifically to document the status and trends of no-take management zones throughout the Florida Keys National Marine Sanctuary (FKNMS). To evaluate potential changes in no-take management zones, it is necessary to also document changes caused by natural system variability, such as mortality events caused by disease or bleaching, coral recruitment events (especially related to *Acropora* corals), or recovery of the previously abundant sea urchin, *Diadema antillarum*. By broadly sampling populations among multiple habitat types across the south Florida shelf, inside and outside of the no-take management zones, and throughout the Florida Keys from south of Miami to the Dry Tortugas, over a 13-year period, we have documented the distribution, abundance, and changes over time of coral reef organisms and communities in the region. Our data and results are unprecedented in spatial coverage and establish a baseline from which future comparisons can be made, related to further decline, recovery, or stasis. It is important to note that our program began in the late 1990s, long after major declines had already occurred in the region, specifically the loss of *D. antillarum* and *Acropora* corals.

In 2012, during 73 days of fieldwork from May 7-November 18, we sampled 600 sites stratified by cross-shelf habitat type, along-shelf position, and management zone from the northern boundary of Biscayne National Park to southwest of Key West encompassing Biscayne National Park and the Florida Keys National Marine Sanctuary. Surveys of *Acropora* corals included assessments of colony density at two different levels (skeletal colonies and physiologic colonies), as well as colony size, and condition. Physiologic colonies reflect patches of living tissue, often multiple in number, that are found on what are typically considered individual colonies (i.e. skeletal colonies), amidst partially or totally dead branches or groups of branches. Surveys of all other scleractinian corals included measurements of colony density, size class, estimates of percent live tissue vs. dead skeleton, and condition assessments of bleaching

disease, predation, and overgrowth. Other benthic coral reef organisms were surveyed for numbers and sizes, including urchins, anemones, corallimorpharians, and mollusks. Marine debris surveys continued in 2012 and consisted of measurements of the number, length, and weight of debris, as well as counts of benthic invertebrates exhibiting abrasion stress from debris entanglement. Our program team was joined by scientists from Grays Reef National Marine Sanctuary, the FKNMS, the Florida Fish and Wildlife Research Institute, the National Park Service-BNP, and Nova Southeastern University. Over 1,000 SCUBA dives and ~550 hours of underwater bottom time were needed to complete the surveys. Funding was provided by NOAA's Coral Reef Conservation Program and the Department of Commerce's 1535 Endangered Species Act Projects. Boat and diving support were provided by NOAA's Aquarius Reef Base Program, the upper and lower Keys offices of the FKNMS, FWRI, and the NPS.

The 2012 surveys add to a growing temporal base of observations made by our program since 1998 (Chiappone et al. 2002a, b; Miller et al. 2002). Previous surveys aided in optimizing a sampling plan for obtaining estimates of abundance and size of benthic coral reef organisms, with a particular focus on *Acropora* corals (see previous Quick Look reports at http://people.uncw.edu/millers), which is part of a Florida and U.S. Caribbean effort to determine the population status of these species. In the Florida Keys, our sampling program is specifically designed to help resource managers evaluate the performance of smaller protected areas (no-take zones) relative to other factors that influence the larger ecosystem. This report is divided into several sections to summarize the observations and data collected for each of the major classes of variables measured during 2012. Accompanying summary tables, underwater images, and maps are included to illustrate some of the spatial patterns observed for the variables measured along the Florida Keys from south of Miami to southwest of Key West.

II. Study Area and Survey Methods

Florida Keys Study Area and Sampling Objectives

The Florida Keys comprise an archipelago of limestone islands spanning more than 360 km from south of Miami to the Dry Tortugas. With the exception of isolated banks in the Flower Gardens area in the northwestern Gulf of Mexico, the Florida Keys ecosystem represents the only region of extensive coral reef development in the continental U.S. (Jaap 1984). The islands are part of the larger south Florida shelf, a submerged Pleistocene platform 6-35 km wide and generally < 12 m deep (Lidz et al. 2003). The primary influences on the distribution and development of Florida Keys reefs are paleotopography and fluctuating sea level (Shinn et al. 1989; Lidz et al. 2003). Bedrock throughout south Florida is Pleistocene limestone, either exposed on the seafloor or lying underneath Holocene reefs and sands (Shinn et al. 1989). Proceeding seaward from the shorelines of the Pleistocene islands, a nearshore rock ledge extends ~2.5 km from the shoreline, with the seabed consisting of hard-bottom, seagrass, and isolated inshore patch reefs (FMRI 1998). Seaward of the island platform is Hawk Channel, a broad trough-like depression dominated by mostly non-coralline, non-oolitic grainstone, dotted with several thousand patch reefs whose distribution is affected by the number and width of tidal passes connecting Florida Bay and the Atlantic Ocean (Marszalek et al. 1977; Shinn et al. 1989). Bands of rock ridges exist further offshore along the outer shelf and on the upper slope from 30-40 m depth before the shelf tapers off into the Straits of Florida. The semi-continuous offshore reef tract is emergent in places, in which Holocene reefs sit atop a ridge of Pleistocene corals (~86-78 ka), forming a shelf-margin ledge (Lidz et al. 2003), with a series of outlier reefs seaward of this main reef tract at 30-40 m depth (Lidz 2006). Like inner shelf margin patch reefs, the distribution and coverage of platform margin reefs reflects exchange processes between Florida Bay and the Atlantic Ocean (Marszalek et al. 1977; Shinn et al. 1989), the size and orientation of the Pleistocene islands, and the proximity of the Florida Current to the platform margin (Pitts 1994; Smith 1994).

The 2012 sampling of *Acropora* corals, other benthic coral reef organisms, and marine debris in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) was undertaken as a spatially intensive effort to document the population status of staghorn and elkhorn corals. The 2012 surveys conducted from May 5 to November 18 were an outgrowth of previous efforts conducted by our program dating back to 1998 to quantify the abundance and condition of coral reef benthos throughout the FKNMS, including the Tortugas region (Miller et al. 2002). Previous surveys 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 Keyswide in 2001, 195 sites Keys-wide in 2005, 107 sites in the upper Keys region in 2006, 235 sites Keyswide in 2007, 145 sites Keyswide in 2008, 160 sites Keyswide in 2009, 120 sites in the upper Keys region in 2010, and 280 sites in the upper Keys region in 2011. Data obtained from these earlier efforts, together with existing habitat mapping information for the FKNMS, were used to guide the sampling of *Acropora* corals, other benthic coral reef organisms, and marine debris in 2012. The overall goals of the 2012 sampling effort were two-fold:

- To collect information on the habitat distribution, colony abundance, size, and condition of *Acropora* corals, to derive population abundance estimates by habitat and management zone for BNP and the FKNMS from south of Miami to southwest of Key West; and
- To continue the temporal data sets on the abundance and size of non-*Acropora* corals, urchins, anemones, corallimorpharians, and mollusks, as well as the density, length, weight, and impacts of marine debris to benthic coral reef organisms Keys-wide.

Specific data sets collected during 2012 included:

- Depth and physical structure (maximum vertical relief) of survey sites;
- Distribution, density, size, and condition (bleaching, disease, overgrowth, and predation) of *Acropora* coral colonies;
- Density, size class, percent live tissue vs. dead skeleton, and condition of non-*Acropora* corals at a subset (n=202) of all sites;
- 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, as well as density and size of mollusks such as sea slugs, nudibranchs, and other gastropods (*Coralliophila* sp., *Leucozonia nassa*, *Strombus gigas*, and *Thais deltoidea*); and
- Density, length, weight, and impacts of entangled marine debris, representing a continuation of efforts carried out in 2000-01, 2008, and 2010-11.

Survey Design and Field Methods

The sampling design for assessing *Acropora* corals, other benthic coral reef organisms, and marine debris encompassed 600 sites visited during May-November 2012. Sites were distributed from the northern boundary of Biscayne National Park (BNP) to west of Key West near the Marquesas Keys (Figure 2-1).

The sampling design included ten habitat types (Table 2-1), as well as all 23 no-take zones designated as Sanctuary Preservation Areas (SPA) or Research Only Areas (RO) between northern Key Largo and southwest of Key West.

The habitat strata sampled during 2012 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 reef tract. However, the 2012 effort did not include nearshore hard-bottom, hard-bottom/seagrass matrix habitats, or deeper (> 15 m) fore reef areas, as these areas do not appear to support significant *Acropora* populations based upon previous surveys. The habitats sampled during 2012 were inshore patch reefs, mid-channel patch reefs, offshore patch reefs, reef rubble, shallow (< 6 m) hard-bottom, inner line reef tract spur and groove from Grecian Rocks northward to Turtle Reef, shallow (< 10 m) high-relief spur and groove along the platform margin, and deeper fore-reef habitats from 6-15 m depth. Deeper fore-reef habitats encompassed continuous, low-relief hard-bottom, patchy hard-bottom, and low-relief spur and groove. Table 2-2 lists the sites by benthic habitat type and management zone, along with summaries of transect depth sampled and maximum vertical relief. Sites were further categorized by along-shelf position and management zone (i.e. inside and outside of FKNMS no-take zones). Figures 2-2 to 2-8 show the spatial distribution of sampling locations by habitat type for the 600 sites, along with the boundaries of existing management areas, including no-take zones in the FKNMS. Figures 2-9 to 2-12 illustrate examples of each of the hard-bottom and coral reef habitat types sampled during 2012.

A geographic information system (GIS) containing digital layers for benthic habitat (FMRI 2000), bathymetry, and management zone boundaries (e.g. FKNMS no-take zones) was used to facilitate delineation of the sampling survey domain, strata, and sample units (Figure 2-13). Existing resolution of benthic habitats is such that the survey domain was divided into a grid of individual cells 200-m by 200-m (40,000 m^2) in area that serve as primary sampling units. A two-stage sampling scheme we adapted (Smith et al 2011) following Cochran (1977) was employed to control for spatial variation in population metrics at scales smaller than the grid cell minimum mapping unit. Grid cells containing targeted reef and hard-bottom habitats were designated as primary sample units. A second-stage sample unit was defined as a belt transect of fixed area (15-m x 1-m in dimension) within a primary sample unit. The size of an individual primary sampling unit allowed divers to swim to the location of any given second-stage sampling unit from a moored or anchored vessel.

To control for spatial variation in the benthic variables assessed, the Florida Keys survey domain was partitioned into strata based upon: 1) habitat type and depth, 2) geographic region (along-shelf position), and 3) management zones comprising Biscayne National Park (BNP), areas outside of Sanctuary no-take zones, and Sanctuary no-take zones. Grid cells (sites) 200-m x 200-m in dimension were randomly select sites from the combination of habitat type, regional sector, and management zone. Habitats were designated using regional benthic habitat maps (FMRI 2000). The habitat classification scheme accounted for features that correlate with benthic fauna distributions, including cross-shelf position, topographic complexity, and the proportion of sand interspersed among hard-bottom structures. A geographic regional stratification variable was used to account for oceanographic and geological features in the Florida Keys that may influence the distribution and community composition of hard-bottom and reef habitats (Marszalek et al. 1977; Shinn et al. 1989). Regional sectors were defined as: Biscayne (southern BNP boundary to Miami), upper Florida Keys (BNP boundary south to Alligator Light), middle Florida Keys (Alligator Light southwest to Bahia Honda), and lower Florida Keys (Bahia Honda 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. 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.

The underwater surveys consisted first of going to randomly selected, pre-determined coordinates with a differential global positioning system. A Garmin® global positioning system receiver (model GPS76) was used to determine the position at each site. The original sampling list encompassed 660 sampling locations, with an additional 300 alternate sites. If the original waypoint was not the intended habitat type, based on visual assessment by a snorkeler or boat observers, the closest alternate site was sampled instead. Once on-site, a two- or three-person diver team deployed two transect tapes 15-m in length, marked in 1-m increments, along the bottom. A 1-m wide belt centered on each 15-m long transect tape was surveyed at each site for most (i.e., except for non-*Acropora* corals and marine debris) of the benthic variables described below, with a total of 60-m^2 surveyed (Figure 2-10). At all 600 sites sampled during 2012, two replicate 15-m^2 belt transect areas per site were surveyed for:

- Minimum and maximum depth;

- Maximum vertical relief of the substratum such as ledges, spur edges, crevices, coral heads, and sponges;
- Number of colonies, skeletal unit size, live tissue surface area, and condition (bleaching, disease, predation, overgrowth) of *Acropora* corals;
- Numbers and test diameters of all sea urchins (echinoids);
- Numbers of anemones and corallimorpharians;
- Numbers and total lengths/shell lengths of nudibranchs, the lettuce sea slug (*Elysia crispata*), and the gastropods *Coralliophila* sp., *Leucozonia nassa*, and *Thais deltoidea*; and
- The frequency of marine debris and the numbers of benthic organisms exhibiting abrasion stress (partial mortality due to tissue loss).

Smaller belt transect areas (10-m x 1-m) were surveyed for the numbers of colonies, sizes (binned by size class), percent live tissue vs. dead skeleton, and condition of all other scleractinian corals greater than 4 cm in maximum diameter at 202 (34%) of the 600 sites. 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 encountered, the numbers of benthic organisms exhibiting abrasion stress (partial mortality due to tissue loss), and the wet weight of all debris collected per transect. All data were collected underwater using pencils, rulers, and pre-printed slates that facilitate efficient recording (Figure 2-14). At the end of the day, GPS and site images were downloaded, while slates were scanned for archival purposes and then data were entered into an Access database.

For the *Acropora* (n=600 sites) coral surveys, replicate 15-m x 1-m belt transects were sampled per site. *Acropora* coral colonies (skeletal and physiologic colonies) were measured for maximum and minimum diameter, as well as height, and assessed for condition (e.g. mortality, bleaching, disease, predation, overgrowth). All colonies located within the belt transect were included in the survey, even if a portion of the colony extended outside of the boundaries of the belt transect. Individual colonies were identified as continuous skeletal units, regardless of whether the skeletal unit contained multiple patches of separate live tissue. Only colonies containing live tissue were included in the survey. Smaller belt transect areas (10-m x 1-m) were surveyed for all non-*Acropora* coral colonies at a subset (n=202) of the 600 sites. Each colony greater than 4 cm in maximum diameter was identified, measured and binned by size class (see below), and assessed for condition (e.g. mortality, bleaching, disease, predation, overgrowth). The sizes and conditions of colonies were recorded using the following codes:

Code	Max Diameter (cm)	Code	Disease Condition	Code	Overgrowth Condition
0	0 to 4 cm	NODZ	No disease	NOG	No overgrowth
1	4 to 10 cm	BBDZ	Black band	AOG	Algae
2	10 to 20 cm	RBDZ	Red band	BOG	Bryozoans
3	20 to 30 cm	WBDZ	White band	COG	Corals
4	30 to 40 cm	YBDZ	Yellow band	GOG	Gorgonians
5	40 to 50 cm	WPII	White plague type 2	MOG	*Millepora*
6	50 to 60 cm	WPOX	White pox	POG	*Palythoa*
7	60 to 70 cm	DKSP	Dark spot	SOG	Sponges
8	70 to 80 cm	NECR	Necrosis	TOG	Tunicates
9	80 to 90 cm	UNKD	Unknown	ZOG	Zoanthids
↓	↓			UOG	Unknown

Code	Mortality Condition	Code	Bleaching Condition	Code	Other Condition
A	0-20% dead	NOBL	No bleaching	NOTH	No other mortality
B	20-40% dead	PPAL	Partly pale	ABRA	Abrasion
C	40-60% dead	PALE	Pale	CLIO	*Cliona* spp.
D	60-80% dead	PBLC	Partly bleached	DAMS	Damselfish
F	80-100% dead	BLCH	Bleached	FISH	Fish bites/scrapes
		MOTT	Mottled	GAST	Gastropod feeding
				UNKM	Unknown

Non-*Acropora* coral sizes were recorded using 10-cm incremental classes, to facilitate rapid assessment. Size class 0 was used to record the maximum diameter of species that have a small maximum size, such as *Favia fragum* and *Scolymia* spp., which would otherwise be excluded due to the overall adult (non-juvenile) size class lower-limit of 4 cm. There is no upper limit imposed on the maximum diameter size classes. Mortality was recorded using 20% incremental classes and included visual estimates of recent and long-term tissue death. Any colonies with lighter tissue coloration than normal were assessed for bleaching. Partially pale and pale colonies were not included in the bleaching data analyses, although their condition was recorded. Mottling, or small patterns of light and dark discolorations often found on colonies of *Siderastrea siderea*, was also recorded, but not included in the bleaching data analyses. Only disease conditions that were actively causing tissue death or lesions on a colony were recorded. If a colony showed signs of a disease that could not be clearly identified, the condition was recorded as unknown disease. If a colony contained patches of necrotic issue with no identifiable cause, it was recorded as necrosis. Dark-spot condition/syndrome was recorded as a disease, even though it does not typically result in lesions or rapid tissue death. Overgrowth of coral tissue by another organism (e.g. algae, sponges, gorgonians, *Palythoa*, and other corals) was noted only if overgrowth by the organism was clearly causing tissue death or lesions. Overgrowth of organisms onto dead portions of a colony was not recorded, nor was overgrowth or shading of live tissue with no resulting lesions or tissue death.

Physical impacts, such a sediment scour, contact with other organisms, and fishing gear damage (e.g. trap rope abrasion) were recorded as abrasion. The presence of boring sponges such as *Cliona delitrix* was recorded if a sponge was actively causing tissue death lesions, but was not recorded if a sponge was only visible on dead portions of a colony. The presence of damselfish nests or gardens was recorded whenever they were found adjacent to, or surrounded by, live tissue. Likewise, fish bites/scrapes were only recorded if they were found on live tissue. Whenever gastropods were observed on a coral colony, the identity and total length of each individual was noted, regardless of whether the gastropods were actively feeding on live coral tissue. However, only gastropods actively feeding on live coral tissue were recorded as a mortality condition. Apparent gastropod feeding scars with no gastropods present was recorded as unknown mortality. Any tissue death that could not be attributed to disease, abrasion, boring sponges, or predation was also recorded as unknown mortality.

Statistical analyses using the two-stage sampling design are based upon Cochran (1977) and Smith et al. (2011). Density and abundance calculations were based upon the number of organisms or marine debris items recorded within the belt transect stations (i.e. within each of the 15-m x 1-m, 10-m x 1-m, or 15-m x 2-m belt transects). First, density (no. of individuals or colonies or debris items per unit area, m^2) was calculated for each station. Next, mean density and variance were calculated for each site, using the densities of the two stations. The mean site-level densities and variances were then used to calculate mean stratum-level (habitat, management zones, and habitat by management zone) densities and variances. Finally, stratum-level and domain abundance estimates were calculated based upon the stratum-level densities and variances, as well as the proportional areas of each stratum within the domain (Smith et al. 2011).

Statistical comparisons of stratum-level mean colony densities and abundances were made among habitat types, between protected zones and reference areas, and among habitat types within protected zones and references areas. Statistical comparisons of means were conducted by calculating confidence intervals (CI) based on the equation CI = mean $\pm$ t[α, df] *standard error, with standard errors estimated by the two-stage, stratified design (Cochran 1977; Smith et al. 2011). Confidence intervals were adjusted for multiple comparisons using the Bonferroni procedure (Miller 1981). While this adjustment made for relatively conservative statistical testing, it reduced the probability of spurious significant pair-wise comparisons. The experiment-wise error rate was held at $\alpha = 0.05$ and the comparison-wise error rate was adjusted based on the number of multiple comparisons (comparison-wise error rate = α /c, where c = k (k-1)/2). For example, if an alpha-level of 0.05 was used to test for differences in mean coral densities

among six habitat types (k = 6), then the alpha level was adjusted by dividing 0.05 by 15 to yield an adjusted alpha of 0.0033.

Training and Partnerships

The 2012 field effort was part of a larger regional effort to provide information on the habitat distribution, density, size, condition, and population estimates of *Acropora* corals in U.S. territorial waters, including southern Florida, the U.S. Virgin Islands, and Puerto Rico. A Field Protocol Manual was drafted in June 2011 to assist with training for benthic surveys. An updated version of the Field Protocol Manual was completed in December 2011 and was provided to colleagues in the U.S. Virgin Islands and Puerto Rico, in addition to on-site training in both locations during February 2012 and training in the Florida Keys during May and June 2012. The Florida Keys surveys were a collaborative effort involving several agencies and institutions, including the participation of scientists from Grays Reef National Marine Sanctuary, the Florida Keys National Marine Sanctuary, Biscayne National Park, the Florida Fish and Wildlife Research Institute, and the National Coral Reef Institute at the Oceanographic Center of Nova Southeastern University.

Logistics Summary

Seventy-three (73) field days were required to sample 600 sites among ten habitat types (0.9-18 m depth) from northern Biscayne National Park to southwest of Key West. Boat support was provided the Key Largo and Key West offices of the FKNMS, BNP, FWRI, and Quiescence Diving Services on Key Largo. All underwater surveys were conducted using SCUBA. Not including SCUBA dives made by BNP-NPS personnel, a total of 1,304 dives were completed by the remaining participants during 73 days of fieldwork, in which divers logged a combined total of ~550 hours of underwater bottom time (Table 2-3). The depth of SCUBA dives ranged from 6 feet to 58 feet. The sampling effort depended upon 6 to 8 hours in the water daily by a two- or three-person benthic team to complete an average of eight (8) sites per day. Typically 30-40 minutes per site were needed to sample the targeted benthic variables.

Figure 2-1. Sampling locations for *Acropora* corals, other benthic coral reef organisms, and marine debris in the Florida Keys from south of Miami to southwest of Key West surveyed during May-November 2012. BNP: Biscayne National Park, FKNMS: Florida Keys National Marine Sanctuary, JPCRSP: John Pennekamp Coral Reef State Park.

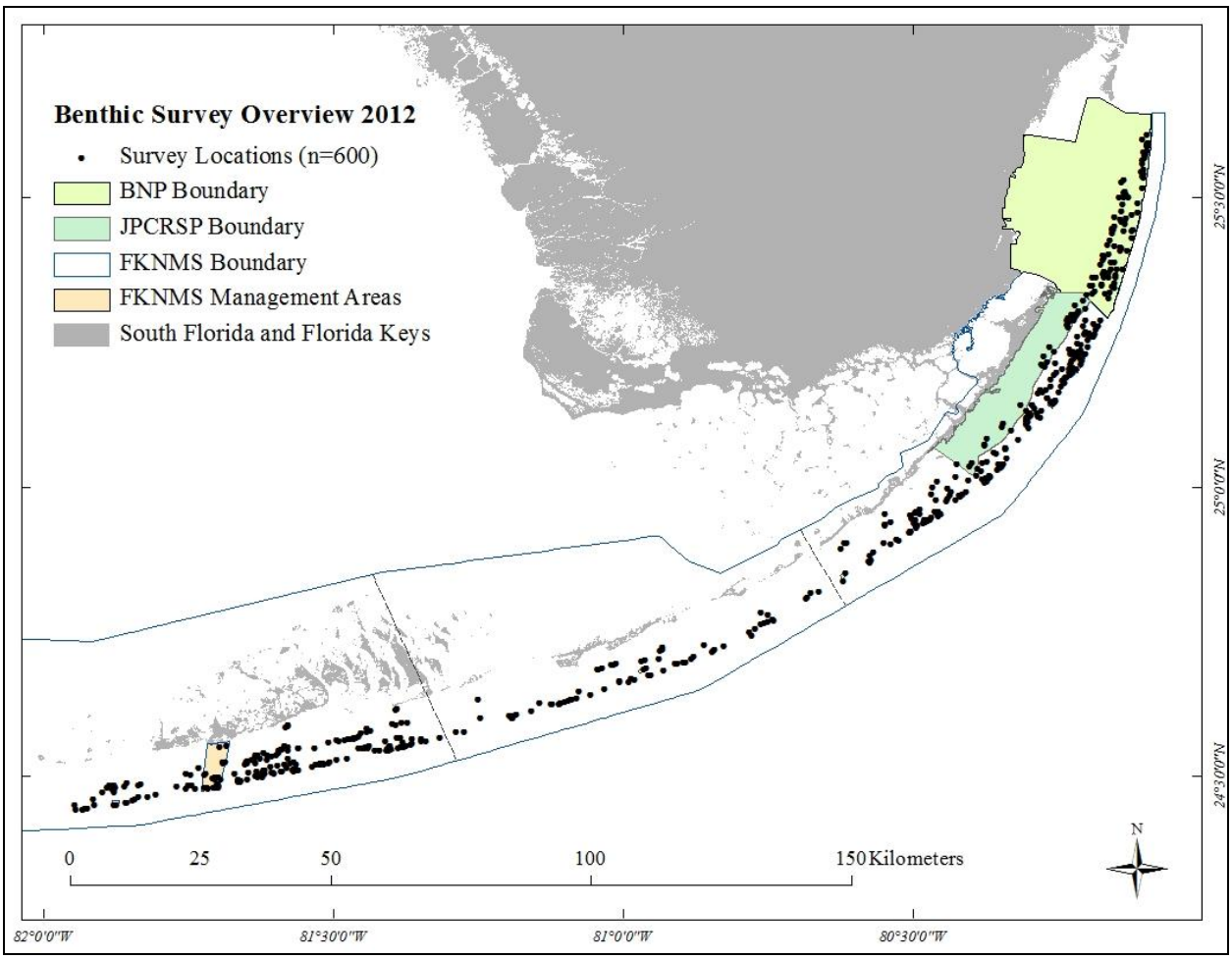


Figure 2-2. Sampling locations by benthic habitat type in Biscayne National Park (BNP) during May-November 2012.

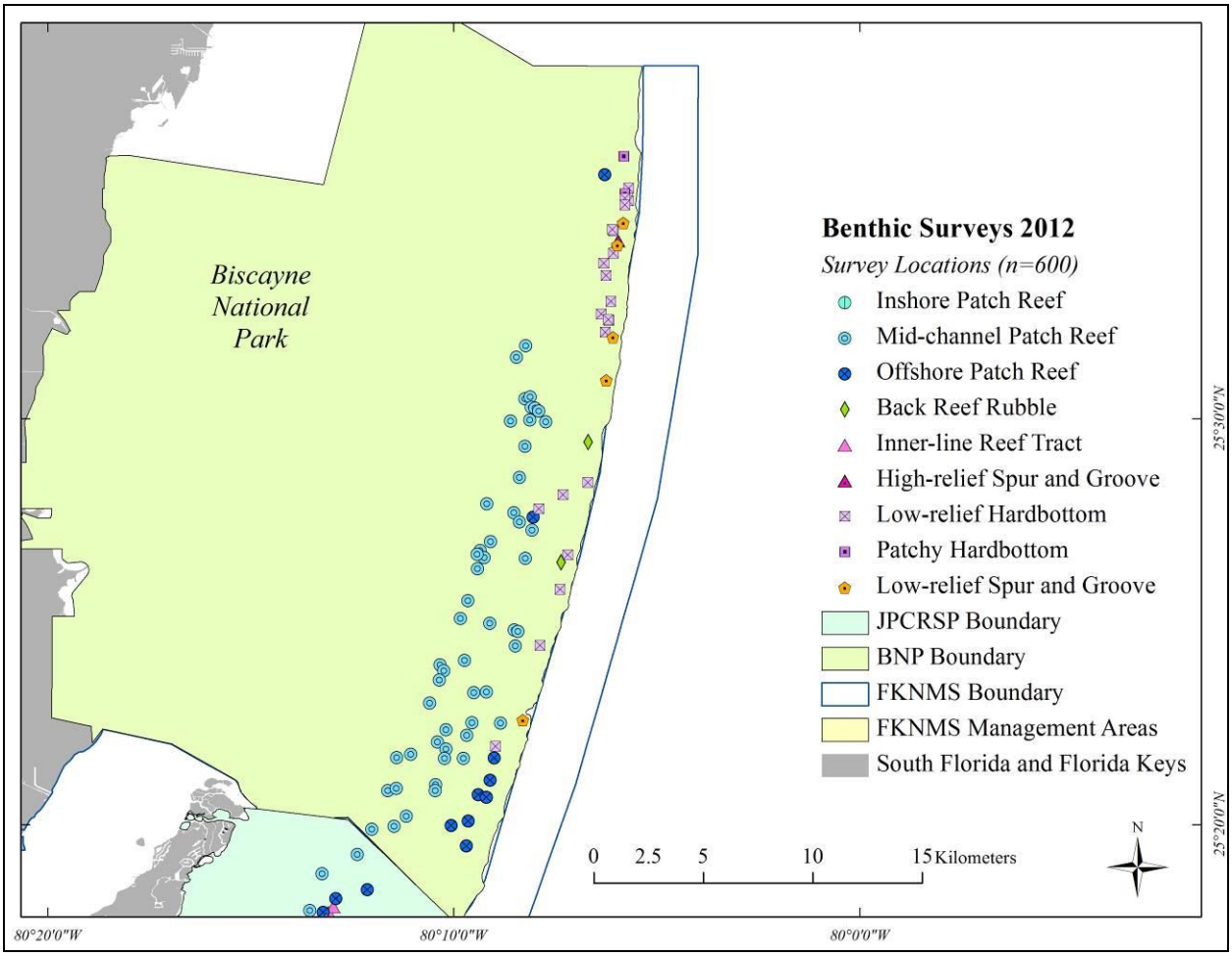


Figure 2-3. Sampling locations by benthic habitat type in John Pennekamp Coral Reef State Park (JPCRSP) and the upper Florida Keys National Marine Sanctuary between the southern Biscayne National Park (BNP) boundary and Molasses Reef during May-November 2012.

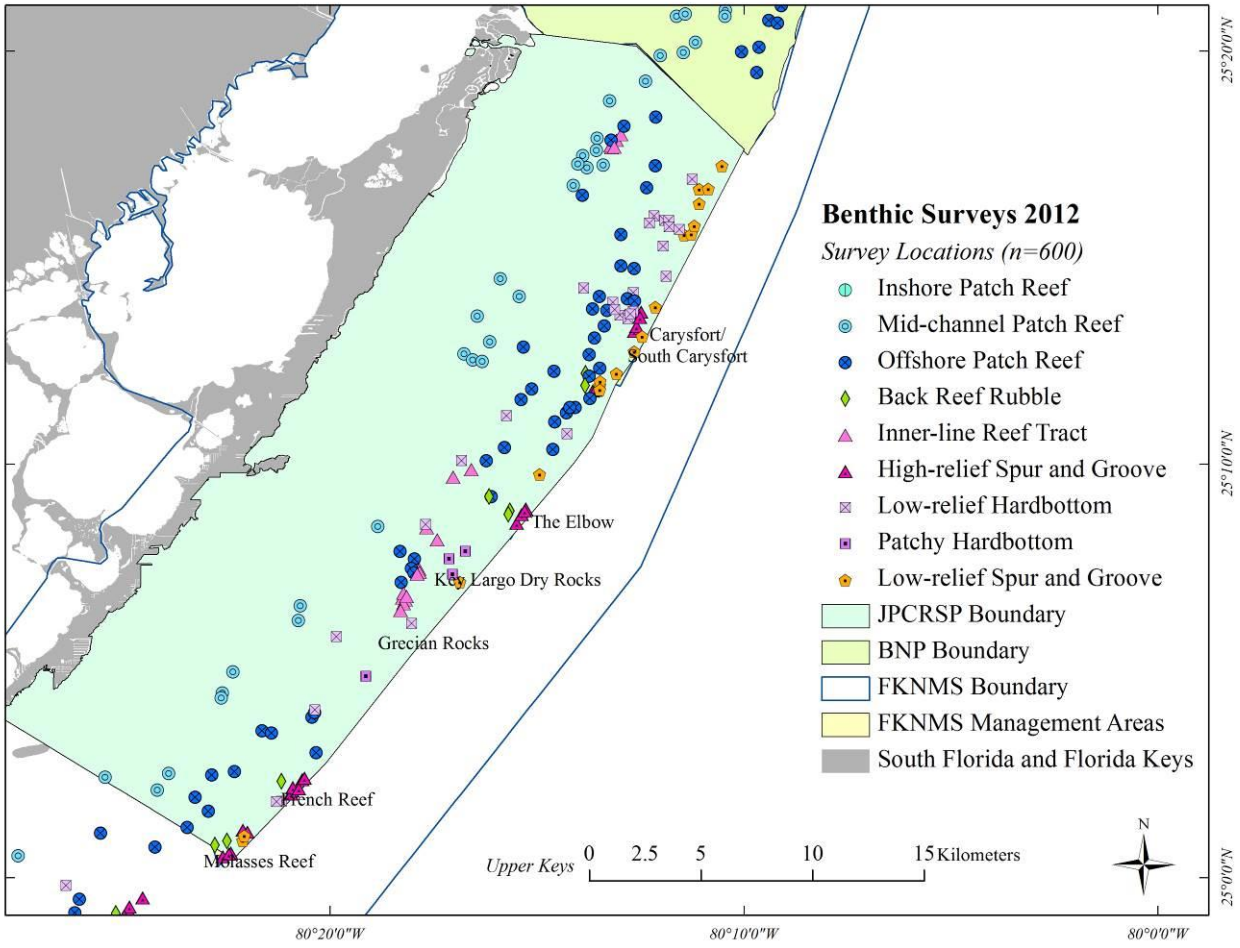


Figure 2-4. Sampling locations by benthic habitat type in the upper Florida Keys National Marine Sanctuary from Molasses Reef to Alligator Reef during May-November 2012.

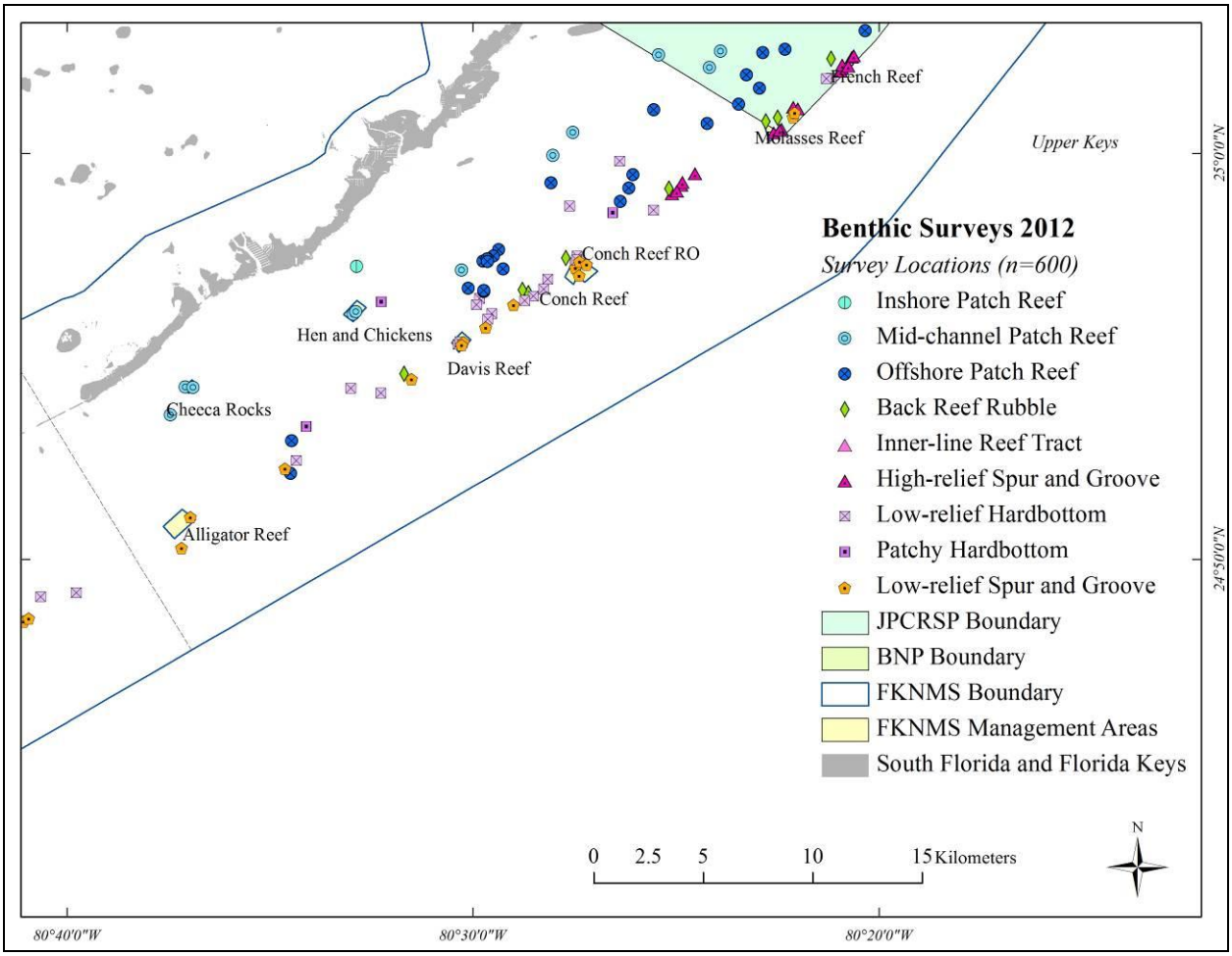


Figure 2-5. Sampling locations by benthic habitat type in the middle Florida Keys National Marine Sanctuary from Alligator Reef to Coffins Patch during May-November 2012.

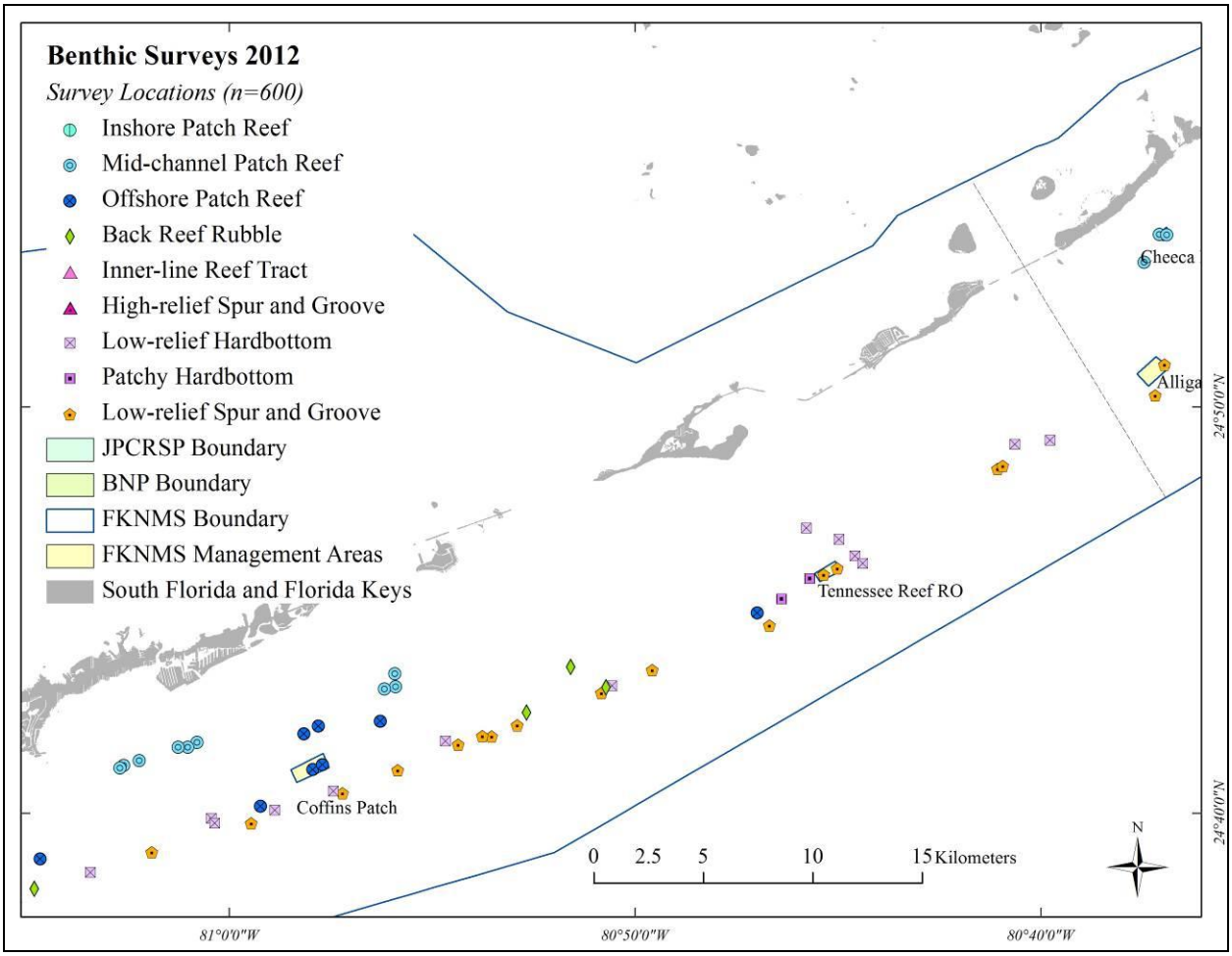


Figure 2-6. Sampling locations by benthic habitat type in the middle Florida Keys National Marine Sanctuary from Coffins Patch to Newfound Harbor during May-November 2012.

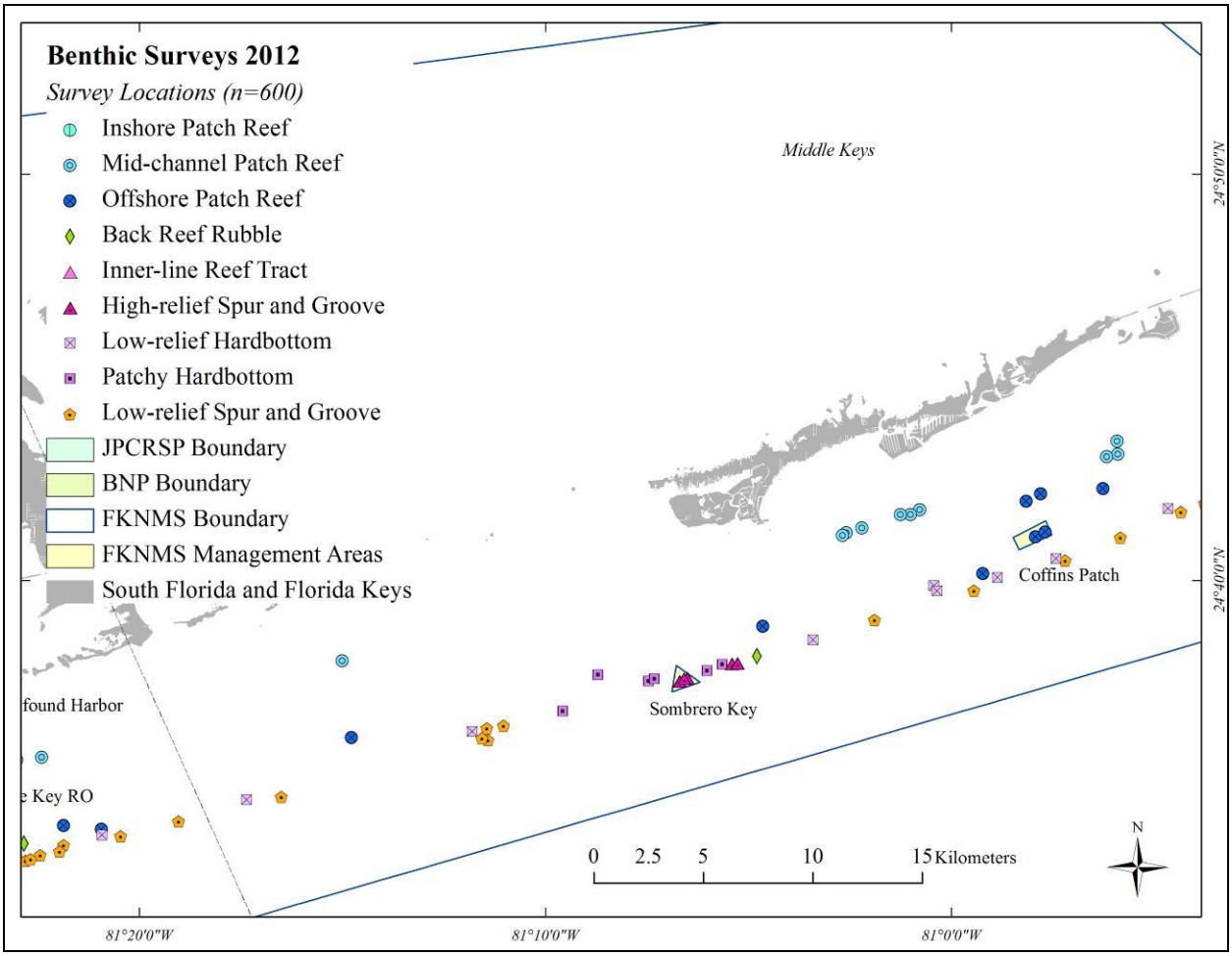


Figure 2-7. Sampling locations by benthic habitat type in the lower Florida Keys National Marine Sanctuary from Newfound Harbor to Western Sambo Ecological Reserve during May-November 2012.

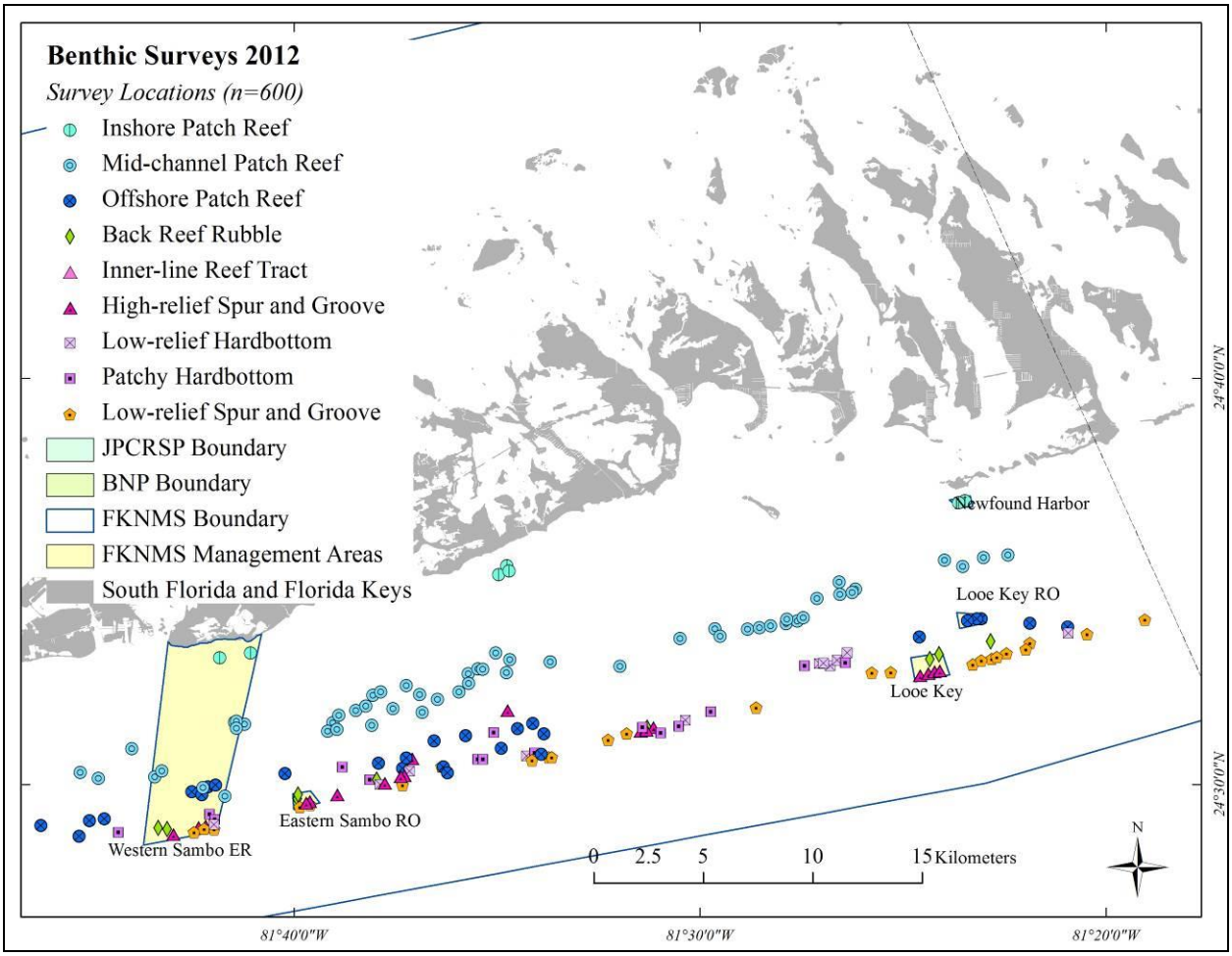


Figure 2-8. Sampling locations by benthic habitat type in the lower Florida Keys National Marine Sanctuary from Western Sambo Ecological Reserve to Western Dry Rocks during May-November 2012.

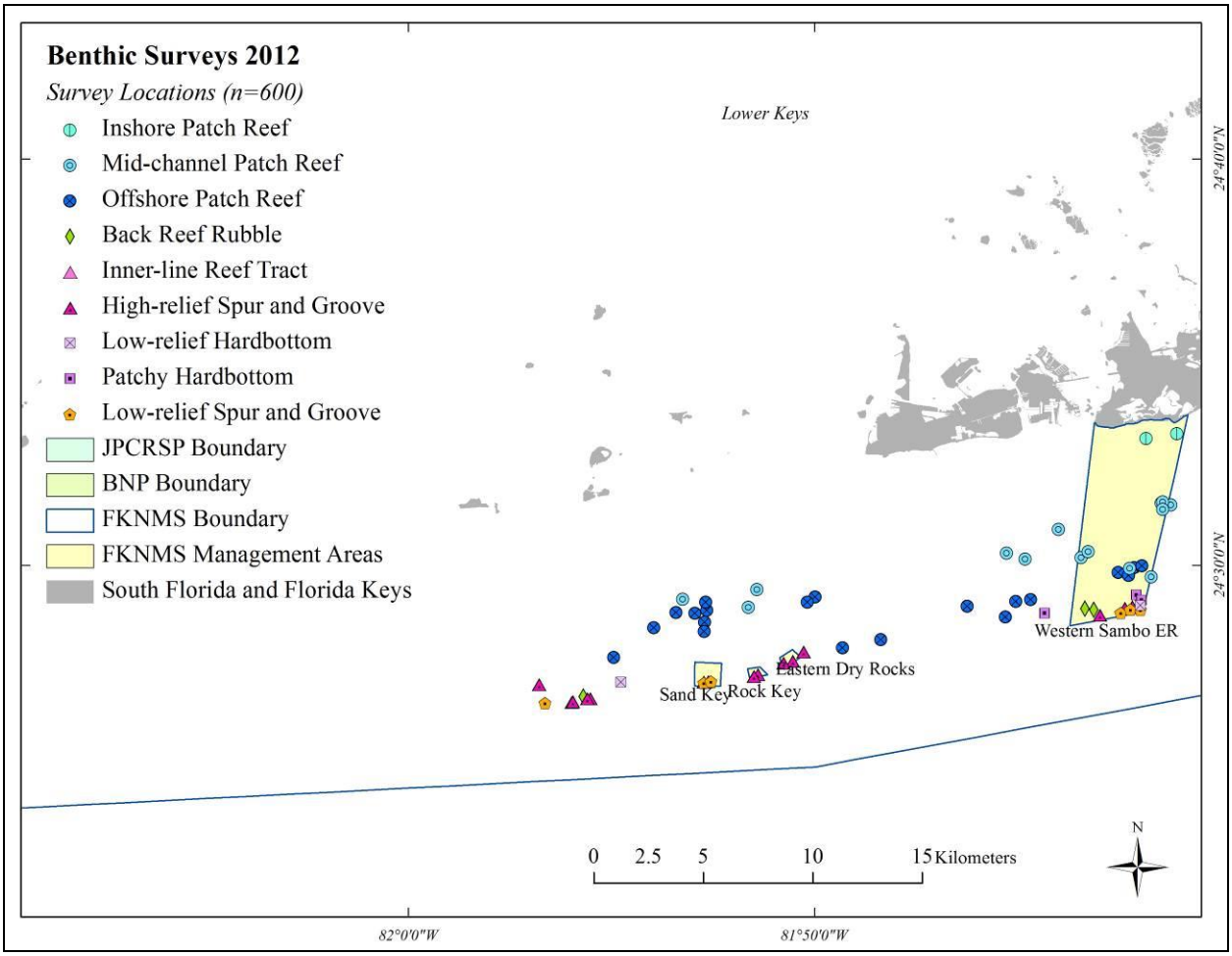


Figure 2-9. Examples of inshore, mid-channel and offshore patch reefs sampled in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Inshore patch reef
Cheeca Rocks SPA, 2.4-3.7 m
24° 54.252'N, 80° 36.896'W

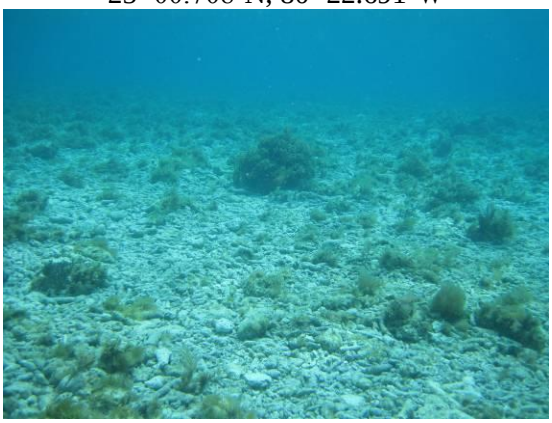
Mid-channel patch reef
Basin Hill Shoals, 2.4-4.3 m
25° 14.412'N, 80° 15.868'W

Offshore patch reef
West of South Carysfort Reef, 1.5-2.7 m
25° 12.752'N, 80° 13.797'W

Offshore patch reef
Watsons Reef area, 11.0-12.2 m
25° 10.067'N, 80° 15.239'W

Figure 2-10. Examples of reef rubble and shallow (< 6 m) low-relief hard-bottom sites sampled in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Reef rubble
Molasses Reef SPA, 1.5-3.0 m
25° 00.708'N, 80° 22.691'W



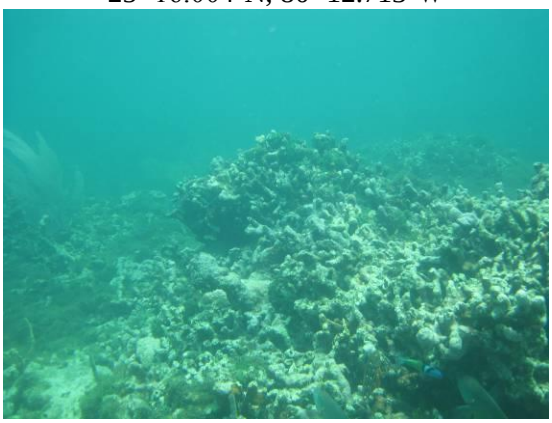
Reef rubble
Pickles Reef, 2.7-3.4 m
24° 59.480'N, 80° 24.978'W

Low-relief hard-bottom
Carysfort Reef SPA, 3.0-3.7 m
25° 13.399'N, 80° 12.772'W

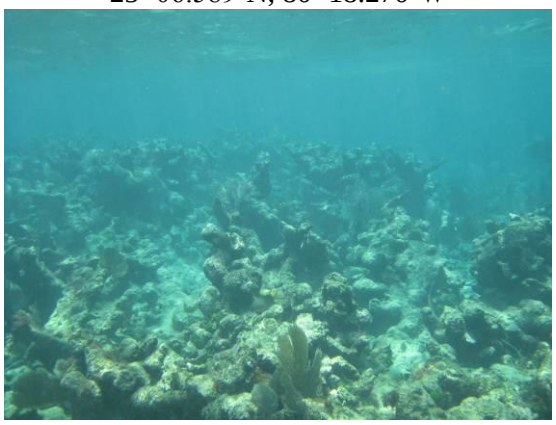
Low-relief hard-bottom
North of Watsons Reef, 4.0-5.5 m
25° 11.468'N, 80° 14.254'W

Figure 2-11. Examples of inner line reef tract and platform margin high-relief spur and groove reefs sampled in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Inner line reef tract spur and groove
Turtle Rocks, 3.7-4.3 m
25° 16.004'N, 80° 12.713'W



Inner line reef tract spur and groove
Grecian Rocks SPA, 1.8-3.7 m
25° 06.589'N, 80° 18.270'W



Platform margin high-relief spur and groove
French Reef SPA, 4.9-8.5 m
25° 02.026'N, 80° 20.960'W

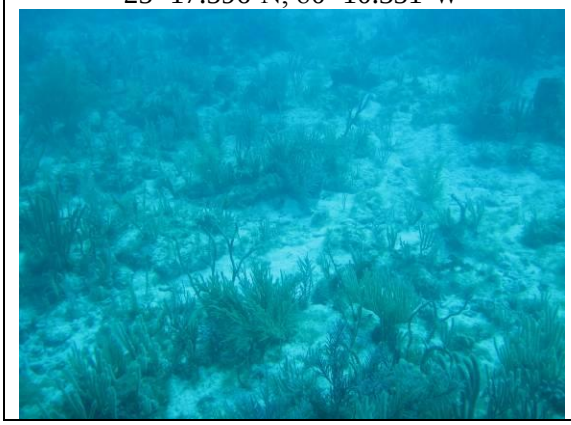
Platform margin high-relief spur and groove
Elbow Reef SPA, 2.1-5.5 m
25° 08.572'N, 80° 15.475'W

Figure 2-12. Examples of deeper (6-15 m) fore-reef habitats sampled in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Low-relief hard-bottom
Whistle Buoy, 6.7-8.5 m
25° 17.411'N, 80° 10.412'W

Low-relief spur and groove
SW of Davis Reef, 10.7-11.3 m
24° 55.148'N, 80° 30.428'W

Patchy hard-bottom
Whistle Buoy, 10.4-11.3 m
25° 17.596'N, 80° 10.351'W



Low-relief spur and groove
Molasses Reef SPA, 12.2-13.4 m
25° 00.482'N, 80° 22.423'W

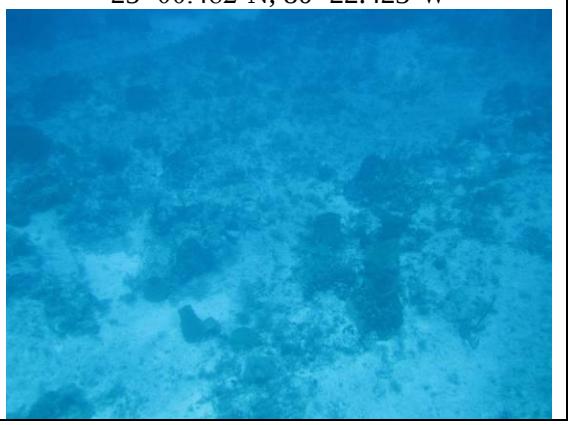


Figure 2-13. The two-stage stratification design for Florida Keys benthic survey during 2012: (A) incorporates habitat type (cross-shelf position and depth), geographic region (along-shelf position), and management zone, utilizing a grid of 200-m x 200-m cells overlain onto existing habitat and bathymetry 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 (15-m transects) are deployed at random GPS points within a particular cell or site.

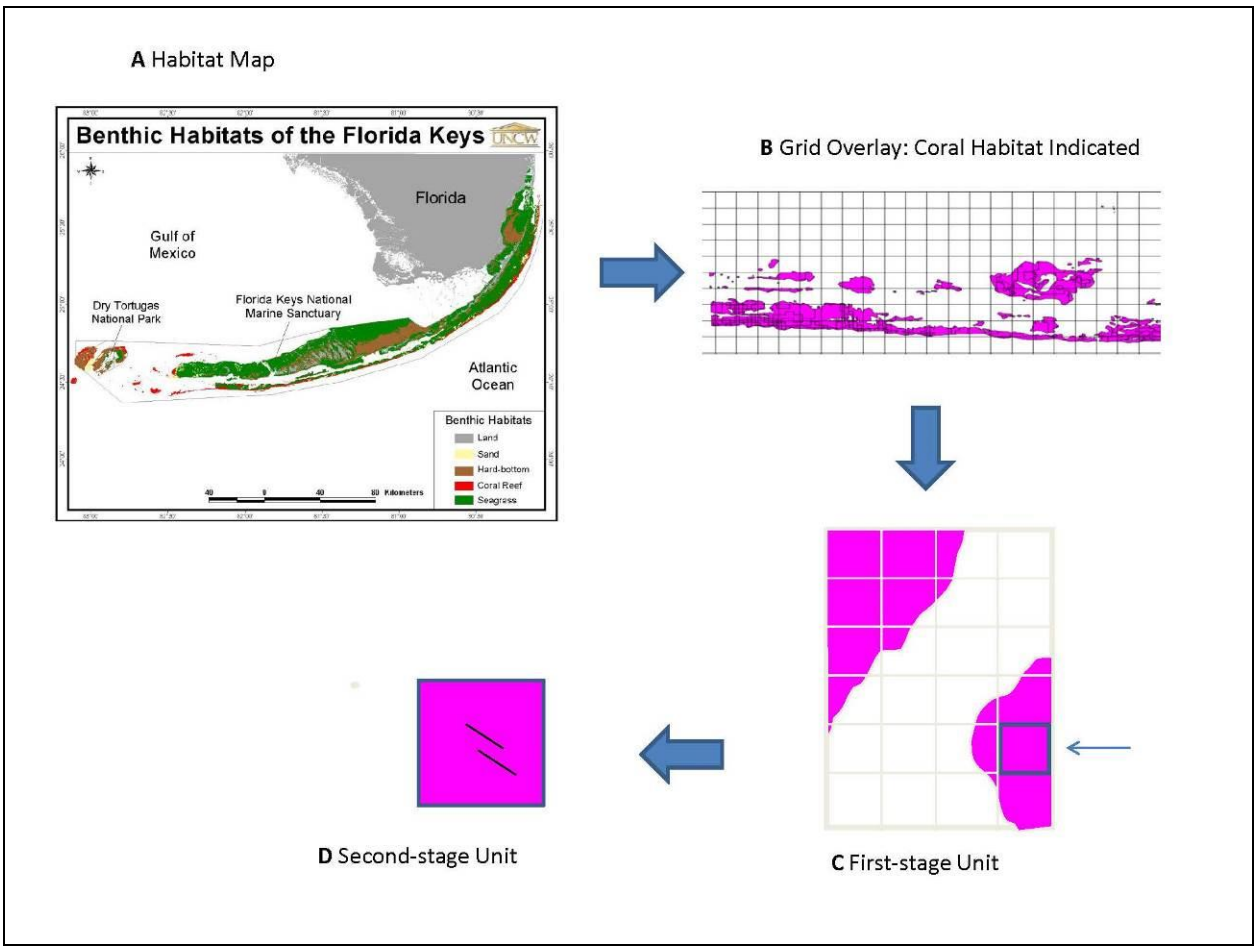


Figure 2-14. Examples of benthic survey methods used by this program to sample *Acropora* corals, other benthic coral reef organisms, and marine debris.

Underwater slate for data collection

Marine debris retrieval

Using the 0.5-m scale bar

Transect deployment

Acropora cervicornis colony measurements

Belt transect survey

Table 2-1. Sampling effort for *Acropora* corals, other benthic coral reef organisms, and marine debris in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) during May-November 2012. At each site, two replicate 15-m x 1-m transects were surveyed per site for all variables, except for non-*Acropora* corals (two 10-m x 1-m belt transect areas) and marine debris (two 15-m x 2-m belt transect areas). FKNMS no-take zones are Ecological Reserves, Sanctuary Preservation Areas, and Research Only Areas. Available sites (n_h) are the number of 200-m x 200-m grid cells containing a particular habitat type from Biscayne National Park through the lower Florida Keys to 15-m depth, based upon existing habitat and bathymetry maps (FRMI 2000). ns: not sampled.

Habitat type/region/protection	No. sites	Depth range (m)	Available sites (n_h) (%)	% of Effort	No. transects (area, m^2)
Inshore patch reefs					
BNP	2	4.6-6.7	166 (1.44)	0.33	4 (60)
FKNMS reference areas	4	0.9-7.3	221 (1.91)	0.67	8 (120)
FKNMS no-take zones	4	1.2-3.2	30 (0.26)	0.67	8 (120)
Total	10	0.9-7.3	417 (3.61)	1.67	20 (300)
Mid-channel patch reefs					
BNP	50	1.8-10.1	1,369 (11.85)	8.33	100 (1,500)
FKNMS reference areas	90	1.2-9.4	1,711 (14.81)	15.00	180 (2,700)
FKNMS no-take zones	11	3.0-9.4	59 (0.51)	1.83	22 (330)
Total	151	1.2-10.1	3,139 (27.17)	25.17	302 (4,530)
Offshore patch reefs					
BNP	9	4.9-11.9	144 (1.25)	1.50	18 (270)
FKNMS reference areas	98	1.5-13.4	1,604 (13.88)	16.33	196 (2,940)
FKNMS no-take zones	15	3.0-9.4	90 (0.78)	2.50	30 (4500
Total	122	1.5-13.4	1,838 (15.91)	20.33	244 (3,660)
Reef rubble (< 15 m)					
BNP	2	2.7-4.0	80 (0.69)	0.33	4 (60)
FKNMS reference areas	16	3.4-7.9	255 (2.21)	2.67	32 (480)
FKNMS no-take zones	11	1.5-7.0	57 (0.49)	1.833	22 (330)
Total	29	1.5-7.9	392 (3.39)	4.83	58 (870)
Inner line reef tract					
BNP	0		0 (0)	0	0 (0)
FKNMS reference areas	9	1.8-5.8	77 (0.67)	1.50	18 (270)
FKNMS no-take zones	9	1.5-7.3	20 (0.17)	1.50	18 (270)
Total	18	1.5-7.3	97 (0.84)	3.00	36 (5400
High-relief spur and groove (< 15 m)					
BNP	1	6.1-8.5	33 (0.29)	0.17	2 (30)
FKNMS reference areas	28	1.8-10.7	86 (0.74)	4.67	56 (840)
FKNMS no-take zones	33	1.8-14.9	153 (1.32)	5.50	66 (990)
Total	62	1.8-14.9	272 (2.35)	10.33	124 (1,860)
Shallow (< 6 m) hard-bottom					
BNP	16	2.4-6.7	171 (1.48)	2.67	32 (480)
FKNMS reference areas	20	1.5-6.4	814 (7.05)	3.33	40 (600)
FKNMS no-take zones	4	4.3-5.8	58 (0.50)	0.67	8 (120)
Total	40	1.5-8.2	1,043 (9.03)	6.67	80 (1,200)
Low-relief hard-bottom (6-15 m)					
BNP	6	5.8-9.1	209 (1.81)	1.00	12 (180)
FKNMS reference areas	42	5.8-12.2	1,619 (14.01)	7.00	84 (1,260)
FKNMS no-take zones	6	6.1-9.4	79 (0.68)	1.00	12 (180)
Total	54	5.8-12.2	1,907 (16.51)	9.00	108 (1,620)

Table 2.1 continued

Habitat type/region/protection	No. sites	Depth range (m)	Available sites (n_h) (%)	% of Effort	No. transects (area, m^2)
Patchy hard-bottom (6-15 m)					
BNP	2	4.3-7.9	150 (1.30)	0.33	4 (60)
FKNMS reference areas	28	5.8-12.5	266 (2.30)	4.67	56 (840)
FKNMS no-take zones	2	6.4-7.6	14 (0.12)	0.33	4 (60)
Total	32	4.3-12.5	430 (3.72)	5.33	64 (960)
Low-relief spur and groove (6-15 m)					
BNP	5	6.1-13.4	254 (2.20)	0.83	10 (150)
FKNMS reference areas	54	6.7-14.6	1,653 (14.31)	9.00	108 (1,620)
FKNMS no-take zones	23	6.7-18.0	111 (0.96)	3.83	46 (690)
Total	82	6.1-18.0	2,018 (17.47)	13.67	164 (2,460)
All habitat types					
BNP	93	4.6-6.7	2,576 (22.30)	15.50	372 (5,580)
FKNMS reference areas	389	0.9-7.3	8,306 (71.89)	64.83	1,556 (23,340)
FKNMS no-take zones	118	1.2-3.2	671 (5.81)	19.67	472 (7,080)
Total	600	0.9-18.0	11,553 (100)	100	1,200 (18,000)

Table 2-2. Physical data summary for sampling locations in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) during May-November 2012. Sites are arranged from NE to SW by habitat type and management zone. Asterisked sites (**) are Sanctuary no-take zones (ERs, SPAs or ROs). Mean ± 1 SE transect depth, maximum vertical relief, and mean maximum vertical relief are based upon two 15-m x 1-m transects surveyed per site.

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
Inshore Patch Reefs					
Biscayne National Park (BNP)					
West of Triumph Reef (C10)	25˚ 29.925'	80˚ 08.581'	5.6 ± 0.3	100	74 ± 26
East of Elliot Key (C9)	25˚ 26.663'	80˚ 09.417'	5.4 ± 0.5	140	115 ± 25
BNP Total (2)			5.5 ± 0.1	120 ± 20	95 ± 21
FKNMS Reference Areas					
Tavernier Rocks (C8)	24˚ 57.225'	80˚ 32.857'	4.3 ± 1.2	260	235 ± 25
Saddlebunch Keys (C3)	24˚ 35.388'	81˚ 34.753'	2.1 ± 0.6	185	178 ± 8
Saddlebunch Keys (C4)	24˚ 35.258'	81˚ 34.699'	2.5 ± 0.6	160	155 ± 5
Saddlebunch Keys (C2)	24˚ 35.169'	81˚ 34.953'	2.7 ± 0.4	140	125 ± 15
FKNMS Reference Area Total (4)			2.9 ± 0.5	186 ± 26	173 ± 23
FKNMS No-take Zones					
Newfound Harbor SPA (C136)**	24˚ 36.985'	81˚ 23.465'	2.1 ± 0.4	150	145 ± 5
Newfound Harbor SPA (C137)**	24˚ 36.941'	81˚ 23.618'	2.2 ± 0.2	115	108 ± 8
Western Sambo ER (C139)**	24˚ 33.241'	81˚ 41.069'	2.3 ± 0.6	180	175 ± 5
Western Sambo ER (C138)**	24˚ 33.122'	81˚ 41.826'	2.7 ± 0.4	160	155 ± 5
FKNMS No-take Zone Total (4)			2.3 ± 0.1	151 ± 14	146 ± 14
Inshore Patch Reef Total (10)			**3.2 ± 0.4**	**159 ± 14**	**146 ± 14**
Mid-channel Patch Reefs					
Biscayne National Park (BNP)					
Bowles Bank (A117)	25˚ 31.793'	80˚ 08.219'	7.0 ± 0.4	70	63 ± 8
Northern BNP (A113)	25˚ 31.514'	80˚ 08.448'	5.9 ± 0.3	110	105 ± 5
Northern BNP (A121)	25˚ 30.533'	80˚ 08.115'	5.9 ± 0.3	50	50 ± 0
Northern BNP (A118)	25˚ 30.490'	80˚ 08.235'	5.5 ± 0.4	130	106 ± 24
West of Triumph Reef (A124)	25˚ 30.277'	80˚ 07.986'	8.1 ± 0.6	130	120 ± 10
SE of Sands Cut (Marker 13) (A122)	25˚ 30.271'	80˚ 08.092'	7.7 ± 0.3	90	73 ± 18
West of Triumph Reef (A126)	25˚ 30.163'	80˚ 07.879'	8.3 ± 0.5	155	123 ± 33
West of Triumph Reef (A123)	25˚ 29.977'	80˚ 08.124'	5.5 ± 0.2	150	95 ± 55
West of Triumph Reef (A127)	25˚ 29.909'	80˚ 07.725'	7.9 ± 0.4	80	80 ± 0
Inshore of Triumph Reef (A119)	25˚ 29.308'	80˚ 08.242'	6.2 ± 0.6	180	135 ± 45
Central BNP (A114)	25˚ 28.552'	80˚ 08.377'	5.9 ± 1.1	120	120 ± 0
Central BNP (A104)	25˚ 27.902'	80˚ 09.178'	6.3 ± 0.6	140	135 ± 5
Central BNP (A111)	25˚ 27.684'	80˚ 08.517'	4.6 ± 0.5	190	118 ± 73
Central BNP (C27)	25˚ 27.458'	80˚ 08.376'	7.2 ± 0.8	150	115 ± 35
East of Elliot Key (A125)	25˚ 27.251'	80˚ 08.067'	6.8 ± 0.4	100	90 ± 10
East of Elliot Key (A107)	25˚ 26.968'	80˚ 09.091'	3.4 ± 0.3	95	70 ± 25
East of Elliot Key (A103)	25˚ 26.755'	80˚ 09.344'	5.0 ± 0.5	100	85 ± 15
East of Elliot Key (A105)	25˚ 26.575'	80˚ 09.245'	3.7 ± 0.4	50	50 ± 0
West of Long Reef (A120)	25˚ 26.557'	80˚ 08.233'	4.3 ± 0.4	90	80 ± 10
East of Elliot Key (A100)	25˚ 26.307'	80˚ 09.405'	4.0 ± 0.6	100	85 ± 15
South-central BNP (S67)	25˚ 25.520'	80˚ 09.650'	3.1 ± 0.3	45	42 ± 4
East of Elliot Key (A96)	25˚ 25.082'	80˚ 09.825'	4.4 ± 0.6	105	95 ± 10
South-central BNP (A108)	25˚ 24.956'	80˚ 09.104'	2.4 ± 0.2	90	68 ± 23
South-central BNP (A112)	25˚ 24.800'	80˚ 08.507'	7.3 ± 0.5	90	85 ± 5
South-central BNP (A115)	25˚ 24.756'	80˚ 08.412'	7.8 ± 0.6	135	115 ± 20
Inshore of Long Reef (A116)	25˚ 24.400'	80˚ 08.478'	8.4 ± 0.5	130	112 ± 19
South-central BNP (A97)	25˚ 24.048'	80˚ 09.726'	3.2 ± 0.4	75	63 ± 13
South-central BNP (A87)	25˚ 23.938'	80˚ 10.328'	3.7 ± 0.6	100	90 ± 10
South-central BNP (A88)	25˚ 23.792'	80˚ 10.243'	3.5 ± 0.4	70	58 ± 13
South-central BNP (A89)	25˚ 23.558'	80˚ 10.348'	3.7 ± 0.5	120	95 ± 25
Southern BNP (A106)	25˚ 23.267'	80˚ 09.189'	7.1 ± 0.8	200	180 ± 20

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
Southern BNP (A101)	25˚ 23.250'	80˚ 09.500'	5.8 ± 0.8	80	68 ± 13
Southern BNP (A86)	25˚ 22.992'	80˚ 10.583'	4.9 ± 0.6	70	63 ± 8
Southern BNP (A102)	25˚ 22.514'	80˚ 09.545'	5.5 ± 0.6	130	73 ± 58
Pacific Light (A109)	25˚ 22.505'	80˚ 08.844'	9.3 ± 0.4	90	90 ± 0
Southern BNP (A93)	25˚ 22.336'	80˚ 10.189'	3.3 ± 0.3	78	62 ± 17
Southern BNP (A99)	25˚ 22.197'	80˚ 09.678'	3.8 ± 0.5	120	90 ± 30
Southern BNP (A90)	25˚ 22.032'	80˚ 10.392'	3.7 ± 0.3	60	50 ± 10
Southern BNP (A94)	25˚ 21.860'	80˚ 10.182'	6.8 ± 0.9	140	120 ± 20
Southern BNP (A85)	25˚ 21.731'	80˚ 11.054'	3.0 ± 0.3	50	45 ± 5
Southern BNP (A82)	25˚ 21.650'	80˚ 11.400'	3.9 ± 0.3	45	38 ± 8
Southern BNP (A98)	25˚ 21.638'	80˚ 09.760'	8.8 ± 0.3	80	63 ± 18
Southern BNP (A95)	25˚ 21.638'	80˚ 10.221'	4.6 ± 0.9	80	66 ± 14
Southern BNP (A91)	25˚ 20.981'	80˚ 10.440'	6.0 ± 0.8	70	65 ± 5
Southern BNP (C25)	25˚ 20.896'	80˚ 11.412'	4.3 ± 0.4	70	59 ± 11
Southern BNP (A92)	25˚ 20.842'	80˚ 10.448'	8.2 ± 0.2	70	57 ± 14
Southern BNP (A80)	25˚ 20.835'	80˚ 11.620'	2.9 ± 0.2	44	42 ± 2
Southern BNP (A84)	25˚ 20.206'	80˚ 11.165'	5.0 ± 0.6	185	158 ± 28
Southern BNP (A83)	25˚ 19.958'	80˚ 11.460'	6.7 ± 0.4	95	93 ± 3
Southern BNP (A79)	25˚ 19.890'	80˚ 12.014'	4.0 ± 0.2	80	78 ± 3
BNP Total (50)			5.5 ± 0.3	102 ± 6	85 ± 4
FKNMS Reference Areas					
Turtle Harbor (A77)	25˚ 19.268'	80˚ 12.371'	4.3 ± 0.3	70	65 ± 5
Turtle Harbor (A76)	25˚ 18.794'	80˚ 13.239'	6.9 ± 0.3	90	70 ± 20
Turtle Harbor (A73)	25˚ 17.888'	80˚ 13.543'	2.6 ± 0.1	20	18 ± 3
Turtle Harbor (A74)	25˚ 17.591'	80˚ 13.563'	2.8 ± 0.1	55	53 ± 3
Turtle Harbor (A70)	25˚ 17.464'	80˚ 13.891'	2.1 ± 0.1	25	25 ± 0
Turtle Harbor (C24)	25˚ 17.264'	80˚ 14.009'	3.4 ± 0.2	15	15 ± 0
Turtle Harbor (A75)	25˚ 17.237'	80˚ 13.397'	2.7 ± 0.1	40	35 ± 5
Turtle Harbor (A72)	25˚ 17.178'	80˚ 13.788'	2.1 ± 0.1	70	55 ± 15
Turtle Harbor (A69)	25˚ 16.745'	80˚ 14.114'	2.4 ± 0.4	140	140 ± 0
Basin Hill Shoals (A68)	25˚ 14.490'	80˚ 15.878'	2.4 ± 0.4	140	135 ± 5
Basin Hill Shoals (C23)	25˚ 14.061'	80˚ 15.420'	2.7 ± 0.6	120	103 ± 18
Basin Hill Shoals (A65)	25˚ 13.585'	80˚ 16.439'	2.7 ± 0.5	135	133 ± 3
Basin Hill Shoals (A67)	25˚ 12.962'	80˚ 16.137'	3.3 ± 0.5	95	83 ± 13
Basin Hill Shoals (A63)	25˚ 12.666'	80˚ 16.755'	3.7 ± 0.4	120	110 ± 10
Basin Hill Shoals (A64)	25˚ 12.520'	80˚ 16.548'	3.7 ± 0.5	100	85 ± 15
Basin Hill Shoals (A66)	25˚ 12.491'	80˚ 16.317'	4.4 ± 0.3	80	65 ± 15
West of Elbow Reef (A62)	25˚ 08.490'	80˚ 18.837'	2.7 ± 0.2	60	60 ± 0
SW of Cannon Patch Reef (A60)	25˚ 06.578'	80˚ 20.712'	4.3 ± 0.3	80	80 ± 0
SW of Cannon Patch Reef (A61)	25˚ 06.222'	80˚ 20.760'	3.1 ± 0.3	65	50 ± 15
Mosquito Bank (A59)	25˚ 04.973'	80˚ 22.338'	4.0 ± 0.3	70	60 ± 10
Mosquito Bank (A57)	25˚ 04.461'	80˚ 22.593'	3.8 ± 0.4	100	98 ± 3
Mosquito Bank (A58)	25˚ 04.345'	80˚ 22.619'	3.3 ± 0.2	100	90 ± 10
Mosquito Bank (A56)	25˚ 02.523'	80˚ 23.895'	3.0 ± 0.2	115	113 ± 3
Mosquito Bank (A55)	25˚ 02.428'	80˚ 25.425'	3.1 ± 0.3	75	70 ± 5
Mosquito Bank (C22)	25˚ 02.118'	80˚ 24.166'	3.2 ± 0.2	100	61 ± 39
Marker 39 (S43)	25˚ 00.522'	80˚ 27.533'	3.0 ± 0.2	65	65 ± 0
Triangles area (A54)	24˚ 59.951'	80˚ 28.028'	4.7 ± 0.2	100	80 ± 20
West of Conch Reef (A53)	24˚ 57.127'	80˚ 30.274'	5.3 ± 0.1	30	27 ± 4
South of Cheeca Rocks (C18)	24˚ 53.563'	80˚ 37.450'	5.6 ± 0.3	105	98 ± 8
East Turtle Shoal (C17)	24˚ 43.430'	80˚ 55.915'	6.5 ± 0.8	105	98 ± 8
East Turtle Shoal (A52)	24˚ 43.109'	80˚ 55.893'	5.9 ± 0.6	90	79 ± 11
East Turtle Shoal (C16)	24˚ 43.053'	80˚ 56.170'	6.5 ± 0.6	150	115 ± 35
NW of Coffins Patch SPA (A51)	24˚ 41.738'	81˚ 00.777'	6.8 ± 0.4	140	133 ± 8
East of Marker 48 (S432)	24˚ 41.622'	81˚ 01.005'	5.9 ± 0.2	125	90 ± 35
Marker 48 Marathon (S433)	24˚ 41.622'	81˚ 01.248'	4.1 ± 1.3	50	45 ± 5
West of Marker 48 (S434)	24˚ 41.296'	81˚ 02.205'	6.8 ± 0.9	190	160 ±30
West of Marker 48 (S435)	24˚ 41.179'	81˚ 02.588'	5.9 ± 0.5	150	110 ± 40
West of Marker 48 (S436)	24˚ 41.113'	81˚ 02.680'	5.5 ± 0.7	220	170 ± 50

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
Offshore of Bahia Honda (S35)	24˚ 38.019'	81˚ 15.002'	8.8 ± 0.3	80	65 ± 15
North of Looe Key RO (A50)	24˚ 35.649'	81˚ 22.407'	6.2 ± 0.1	155	113 ± 43
North of Looe Key RO (A49)	24˚ 35.588'	81˚ 23.014'	7.9 ± 0.3	85	61 ± 24
North of Looe Key RO (A48)	24˚ 35.369'	81˚ 23.522'	7.6 ± 0.3	75	58 ± 18
North of Looe Key RO (A47)	24˚ 35.523'	81˚ 23.970'	7.9 ± 0.2	130	103 ± 28
SW of Newfound Harbor (A45)	24˚ 34.806'	81˚ 26.158'	6.9 ± 0.4	170	118 ± 53
SW of Newfound Harbor (A46)	24˚ 34.731'	81˚ 26.249'	8.2 ± 0.1	50	50 ± 0
NE of American Shoal (A44)	24˚ 34.678'	81˚ 26.543'	5.6 ± 0.5	135	93 ± 43
SW of Newfound Harbor (A43)	24˚ 34.979'	81˚ 26.561'	7.2 ± 0.5	90	75 ± 15
SW of Newfound Harbor (A42)	24˚ 34.582'	81˚ 27.117'	8.1 ± 0.2	55	40 ± 15
NE of American Shoal (A41)	24˚ 34.106'	81˚ 27.450'	8.7 ± 0.2	55	53 ± 3
NE of American Shoal (A40)	24˚ 34.027'	81˚ 27.598'	7.5 ± 0.6	160	150 ±10
NE of American Shoal (C14)	24˚ 34.071'	81˚ 27.852'	5.3 ± 0.2	50	45 ± 5
NE of American Shoal (A39)	24˚ 33.959'	81˚ 27.870'	5.3 ± 0.2	65	55 ± 10
NE of American Shoal (A38)	24˚ 33.904'	81˚ 28.254'	6.4 ± 0.1	40	38 ± 3
NE of American Shoal (A37)	24˚ 33.863'	81˚ 28.527'	6.9 ± 0.2	90	85 ± 5
NE of American Shoal (A36)	24˚ 33.823'	81˚ 28.825'	7.5 ± 0.2	65	63 ± 3
NE of American Shoal (A35)	24˚ 33.652'	81˚ 29.499'	6.8 ± 0.3	120	100 ± 20
North of American Shoal (A34)	24˚ 33.833'	81˚ 29.625'	8.0 ± 0.1	50	48 ± 3
North of American Shoal (S32)	24˚ 33.598'	81˚ 30.481'	6.0 ± 0.1	35	28 ± 8
North of American Shoal (A33)	24˚ 32.913'	81˚ 31.968'	5.4 ± 0.1	45	38 ± 8
West Washerwoman Shoal (A31)	24˚ 33.019'	81˚ 33.686'	6.5 ± 0.1	30	25 ± 5
North of American Shoal (A32)	24˚ 33.019'	81˚ 33.686'	5.9 ± 0.2	100	85 ± 15
W. Washerwoman (A29)	24˚ 33.071'	81˚ 34.680'	5.8 ± 0.6	180	123 ± 58
W. Washerwoman (A300)	24˚ 32.755'	81˚ 34.759'	7.2 ± 0.3	80	58 ± 23
W. Washerwoman (A28)	24˚ 33.236'	81˚ 35.025'	4.6 ± 0.3	70	55 ± 15
W. Washerwoman (A27)	24˚ 32.832'	81˚ 35.346'	2.0 ± 0.2	45	43 ± 3
North of Maryland Shoal (A26)	24˚ 32.843'	81˚ 35.462'	3.0 ± 0.1	80	60 ± 20
North of Maryland Shoal (A25)	24˚ 32.487'	81˚ 35.695'	5.2 ± 0.3	130	85 ± 45
North of Maryland Shoal (A24)	24˚ 32.729'	81˚ 35.699'	2.8 ± 0.3	150	105 ± 45
North of Maryland Shoal (A23)	24˚ 32.280'	81˚ 35.927'	4.7 ± 0.2	80	70 ± 10
North of Pelican Shoal (C12)	24˚ 32.094'	81˚ 36.463'	5.0 ± 0.1	60	53 ± 8
North of Pelican Shoal (A22)	24˚ 31.777'	81˚ 36.838'	7.1 ± 0.5	130	110 ± 20
North of Pelican Shoal (A21)	24˚ 32.214'	81˚ 36.897'	5.5 ± 0.4	170	125 ± 45
North of Pelican Shoal (A20)	24˚ 32.438'	81˚ 37.228'	5.0 ± 0.3	155	118 ± 38
North of Eastern Sambo (S21)	24˚ 31.867'	81˚ 37.555'	6.3 ± 0.4	90	65 ± 25
North of Pelican Shoal (A19)	24˚ 32.278'	81˚ 37.859'	4.0 ± 0.2	45	40 ± 5
North of Pelican Shoal (A18)	24˚ 32.198'	81˚ 38.047'	4.4 ± 0.2	30	28 ± 3
North of Pelican Shoal (A17)	24˚ 31.457'	81˚ 38.082'	5.5 ± 0.5	60	53 ± 8
North of Pelican Shoal (A16)	24˚ 31.934'	81˚ 38.227'	2.8 ± 0.1	45	43 ± 3
North of Eastern Sambo (A15)	24˚ 31.819'	81˚ 38.470'	3.7 ± 0.1	90	73 ± 18
North of Eastern Sambo (A13)	24˚ 31.702'	81˚ 38.889'	5.5 ± 0.4	60	53 ± 8
North of Eastern Sambo (A12)	24˚ 31.355'	81˚ 38.937'	3.5 ± 0.3	45	43 ± 3
North of Eastern Sambo (A10)	24˚ 31.520'	81˚ 39.036'	5.2 ± 0.3	80	63 ± 18
North of Eastern Sambo (A11)	24˚ 31.310'	81˚ 39.164'	5.9 ± 0.6	180	163 ± 18
East of Western Sambo ER (A9)	24˚ 31.481'	81˚ 41.216'	5.9 ± 0.5	90	85 ± 5
West of Western Sambo ER (A8)	24˚ 30.883'	81˚ 43.986'	5.9 ± 0.2	50	48 ± 3
West of Western Sambo ER (C11)	24˚ 30.152'	81˚ 44.810'	6.6 ± 0.3	70	53 ± 18
West of Western Sambo ER (A7)	24˚ 30.299'	81˚ 45.261'	6.7 ± 0.9	130	115 ± 15
Middle Ground (A6)	24˚ 29.404'	81˚ 51.416'	7.7 ± 0.6	130	98 ± 33
Middle Ground (A5)	24˚ 28.963'	81˚ 51.618'	6.3 ± 0.4	50	45 ± 5
Middle Ground (A4)	24˚ 29.163'	81˚ 53.244'	4.7 ± 0.1	50	40 ± 10
FKNMS Reference Area Total (90)			5.2 ± 0.2	91 ± 5	76 ± 4
FKNMS No-take Zones					
Hen and Chickens (C145)**	24˚ 56.102'	80˚ 32.879'	6.9 ± 0.4	120	115 ± 5
Hen and Chickens (C144)**	24˚ 56.040'	80˚ 32.943'	5.7 ± 0.9	240	240 ± 0
Cheeca Rocks (C146)**	24˚ 54.250'	80˚ 37.078'	4.8 ± 0.3	125	113 ± 13
Cheeca Rocks (C147)**	24˚ 54.240'	80˚ 36.892'	4.2 ± 0.5	130	108 ± 23
Western Sambo ER (C142)**	24˚ 31.559'	81˚ 41.415'	5.1 ± 0.3	70	53 ± 18

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
Western Sambo ER (C143)**	24˚ 31.379'	81˚ 41.415'	6.7 ± 0.7	80	75 ± 5
Western Sambo ER (A410)**	24˚ 31.529'	81˚ 41.457'	5.3 ± 0.3	85	68 ± 18
Western Sambo ER (C141)**	24˚ 29.712'	81˚ 41.699'	6.9 ± 0.8	80	78 ± 3
Western Sambo ER (C168)**	24˚ 29.924'	81˚ 42.232'	7.1 ± 0.3	70	65 ± 5
Western Sambo ER (C140)**	24˚ 30.335'	81˚ 43.249'	7.3 ± 0.5	90	60 ± 30
Western Sambo ER (A409)**	24˚ 30.187'	81˚ 43.425'	8.7 ± 0.3	45	43 ± 3
FKNMS No-take Zone Total (11)			6.2 ± 0.4	103 ± 16	92 ± 17
Mid-channel Patch Reef Total (151)			**5.3 ± 0.1**	**95 ± 4**	**80 ± 3**
Offshore Patch Reefs					
Biscayne National Park (BNP)					
North of Fowey Rocks (C131)	25˚ 36.003'	80˚ 06.275'	5.6 ± 0.3	75	53 ± 23
Central BNP (A209)	25˚ 27.569'	80˚ 08.039'	5.9 ± 0.3	75	63 ± 13
Southern BNP (A207)	25˚ 21.644'	80˚ 09.002'	9.5 ± 0.4	65	58 ± 8
Southern BNP (A208)	25˚ 21.099'	80˚ 09.095'	7.6 ± 0.6	125	100 ±25
Southern BNP (A204)	25˚ 20.738'	80˚ 09.389'	6.2 ± 0.4	120	110 ± 10
Southern BNP (C55)	25˚ 20.674'	80˚ 09.186'	8.3 ± 0.3	70	68 ± 3
Southern BNP (A203)	25˚ 20.088'	80˚ 09.633'	7.7 ± 0.3	125	95 ± 30
Southern BNP (A201)	25˚ 19.977'	80˚ 10.053'	10.4 ± 0.3	60	60 ± 0
Southern BNP (A202)	25˚ 19.478'	80˚ 09.687'	11.6 ± 0.1	49	40 ± 10
BNP Total (9)			8.1 ± 0.7	85 ± 10	72 ± 8
FKNMS Reference Areas					
North of Turtle Reef (A78)	25˚ 18.399'	80˚ 12.120'	5.5 ± 0.6	140	93 ± 48
Turtle Rocks (C53)	25˚ 18.180'	80˚ 12.895'	4.7 ± 0.2	60	58 ± 3
Turtle Rocks (C134)	25˚ 17.844'	80˚ 13.206'	3.7 ± 0.5	160	155 ± 5
Turtle Harbor (A200)	25˚ 17.222'	80˚ 12.132'	8.1 ± 0.2	100	73 ± 28
Turtle Harbor (A308)	25˚ 16.690'	80˚ 12.340'	7.5 ± 0.3	70	60 ± 10
Turtle Harbor (A71)	25˚ 16.510'	80˚ 13.893'	3.2 ± 0.1	80	65 ± 15
North of Carysfort Reef (A337)	25˚ 15.554'	80˚ 12.966'	3.8 ± 0.2	70	50 ± 20
North of Carysfort Reef (A338)	25˚ 14.802'	80˚ 12.966'	5.0 ± 0.4	80	80 ± 0
North of Carysfort Reef (A198)	25˚ 14.734'	80˚ 12.648'	7.5 ± 0.5	90	85 ± 5
West of Carysfort Reef (A334)	25˚ 14.063'	80˚ 13.485'	4.6 ± 0.5	105	98 ± 8
West of Carysfort Reef (C96)	25˚ 13.757'	80˚ 13.654'	3.0 ± 0.6	85	70 ± 15
West of Carysfort Reef (A335)	25˚ 13.724'	80˚ 13.306'	4.2 ± 0.3	90	70 ± 20
West of Carysfort Light (A336)	25˚ 13.344'	80˚ 13.371'	4.4 ± 0.3	50	45 ± 5
West of S. Carysfort Reef (A333)	25˚ 13.056'	80˚ 13.607'	3.7 ± 0.5	160	140 ± 20
Basin Hill Shoals (A187)	25˚ 12.837'	80˚ 15.318'	2.1 ± 0.2	60	40 ± 20
West of S. Carysfort Reef (A195)	25˚ 12.648'	80˚ 13.732'	2.9 ± 0.4	55	48 ± 8
West of S. Carysfort Reef (A190)	25˚ 12.253'	80˚ 14.579'	3.8 ± 0.4	85	73 ± 13
SW of S. Carysfort Reef (C38)	25˚ 12.132'	80˚ 13.727'	7.4 ± 0.4	65	53 ± 13
SW of S. Carysfort Reef (A330)	25˚ 11.819'	80˚ 15.110'	4.3 ± 0.2	55	43 ± 13
Watsons Reef (A332)	25˚ 11.596'	80˚ 13.713'	4.8 ± 0.4	40	35 ± 5
SW of S. Carysfort Reef (C51)	25˚ 11.561'	80˚ 15.379'	4.7 ± 0.1	45	43 ± 3
Watsons Reef (C52)	25˚ 11.376'	80˚ 14.196'	4.6 ± 0.5	80	70 ± 10
Watsons Reef (A193)	25˚ 11.374'	80˚ 14.068'	5.5 ± 0.5	130	78 ± 53
Watsons Reef (A191)	25˚ 11.249'	80˚ 14.282'	6.6 ± 0.6	95	78 ± 18
Watsons Reef (A188)	25˚ 11.025'	80˚ 14.563'	9.1 ± 0.3	80	58 ± 23
Watsons Reef (A185)	25˚ 10.405'	80˚ 15.776'	3.9 ± 0.4	100	95 ± 5
Watsons Reef (A189)	25˚ 10.362'	80˚ 14.613'	12.6 ± 0.5	50	43 ± 8
NW of Elbow Reef (A183)	25˚ 10.087'	80˚ 16.216'	4.6 ± 0.6	300	255 ±45
NW of Elbow Reef (A184)	25˚ 09.218'	80˚ 16.098'	4.6 ± 0.1	45	43 ± 3
NW of Key Largo Dry Rocks (A180)	25˚ 07.887'	80˚ 18.299'	3.4 ± 0.1	80	75 ± 5
North of Dry Rocks (A182)	25˚ 07.709'	80˚ 17.955'	5.6 ± 0.2	120	90 ± 30
North of Grecian Rocks (A181)	25˚ 07.139'	80˚ 18.272'	5.3 ± 0.4	130	90 ± 40
White Bank (A319)	25˚ 03.987'	80˚ 20.365'	4.7 ± 0.1	70	68 ± 3
White Bank (A318)	25˚ 03.878'	80˚ 20.427'	5.5 ± 0.1	90	75 ± 15
White Bank (A178)	25˚ 03.547'	80˚ 21.632'	3.8 ± 0.2	60	55 ± 5
White Bank (A179)	25˚ 03.494'	80˚ 21.406'	5.0 ± 0.3	80	65 ± 15
White Bank (A320)	25˚ 03.025'	80˚ 20.330'	5.0 ± 0.4	90	80 ± 10

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
White Bank Dry Rocks (A177)	25˚ 02.568'	80˚ 22.301'	3.8 ± 0.2	80	63 ± 18
White Bank (A174)	25˚ 02.481'	80˚ 22.855'	2.5 ± 0.1	30	30 ± 0
White Bank (A172)	25˚ 01.939'	80˚ 23.258'	2.8 ± 0.1	25	24 ± 2
White Bank (A175)	25˚ 01.606'	80˚ 22.933'	6.4 ± 0.2	68	57 ± 12
White Bank (A173)	25˚ 01.211'	80˚ 23.445'	7.5 ± 0.3	110	73 ± 38
Inshore of Molasses Reef (A170)	25˚ 01.072'	80˚ 25.537'	3.0 ± 0.2	50	38 ± 13
White Bank (A171)	25˚ 00.738'	80˚ 24.226'	5.6 ± 0.3	68	49 ± 19
Inshore of Pickles Reef (C50)	24˚ 59.476'	80˚ 26.052'	6.8 ± 0.2	75	70 ± 5
Triangles area (A165)	24˚ 59.274'	80˚ 28.072'	3.6 ± 0.2	90	68 ± 23
Inshore of Pickles Reef (A169)	24˚ 59.148'	80˚ 26.155'	7.9 ± 0.1	55	53 ± 3
Inshore of Pickles Reef (A168)	24˚ 58.824'	80˚ 26.366'	9.4 ± 0.2	52	44 ± 9
West of Conch Reef (A162)	24˚ 57.631'	80˚ 29.357'	5.4 ± 0.2	80	73 ± 8
West of Conch Reef (A163)	24˚ 57.477'	80˚ 29.484'	5.5 ± 0.4	140	115 ±25
West of Conch Reef (C48)	24˚ 57.404'	80˚ 29.647'	5.1 ± 0.2	75	75 ± 0
West of Conch Reef (A161)	24˚ 57.347'	80˚ 29.745'	5.0 ± 0.2	50	50 ± 0
West of Conch Reef (C49)	24˚ 57.336'	80˚ 29.629'	6.6 ± 0.2	60	55 ± 5
West of Conch Reef (A297)	24˚ 57.156'	80˚ 29.254'	6.9 ± 0.3	85	65 ± 20
West of Conch Reef (A159)	24˚ 57.127'	80˚ 30.274'	5.0 ± 0.3	70	55 ± 15
West of Conch Reef (A160)	24˚ 56.678'	80˚ 30.107'	6.6 ± 0.1	35	34 ± 2
West of Conch Reef (C90)	24˚ 56.627'	80˚ 29.726'	8.5 ± 0.4	110	90 ± 20
West of Conch Reef (A289)	24˚ 56.595'	80˚ 29.726'	7.5 ± 0.6	150	125 ± 25
SW of Crocker Reef (A158)	24˚ 52.928'	80˚ 34.459'	10.1 ± 0.3	60	55 ± 5
NE of Alligator Reef (A156)	24˚ 52.121'	80˚ 34.489'	10.1 ± 0.1	45	43 ± 3
Tennessee Reef (A155)	24˚ 44.928'	80˚ 46.987'	7.1 ± 0.1	50	50 ± 0
East of Coffins Patch SPA (A151)	24˚ 42.264'	80˚ 56.263'	6.4 ± 0.4	120	98 ± 23
West Turtle Shoal (A150)	24˚ 42.139'	80˚ 57.794'	4.1 ± 0.2	50	45 ± 5
Marker 47 (A149)	24˚ 41.949'	80˚ 58.153'	5.0 ± 0.4	95	73 ± 23
SW of Coffins Patch SPA (A267)	24˚ 40.167'	80˚ 59.221'	7.8 ± 0.3	90	83 ± 8
NE of Delta Shoal (S437)	24˚ 38.869'	81˚ 04.642'	5.7 ± 0.1	50	45 ± 5
Offshore of Bahia Honda (S189)	24˚ 36.136'	81˚ 14.773'	9.0 ± 0.1	50	45 ± 5
West of Marker 22 (C30)	24˚ 33.875'	81˚ 20.935'	7.4 ± 0.1	60	50 ± 10
North of Looe Key SPA (A147)	24˚ 33.630'	81˚ 24.588'	6.1 ± 0.2	100	80 ± 20
North of Maryland Shoal (C45)	24˚ 31.245'	81˚ 33.842'	8.9 ± 0.1	55	48 ± 8
Maryland Shoal (S154)	24˚ 30.748'	81˚ 33.899'	5.5 ± 0.3	50	40 ± 10
North of Maryland Shoal (A240)	24˚ 31.506'	81˚ 34.109'	8.2 ± 0.2	85	85 ± 0
North of Maryland Shoal (A2580	24˚ 31.374'	81˚ 34.482'	6.1 ± 0.9	100	85 ± 15
West of Maryland Shoal (A239)	24˚ 30.893'	81˚ 34.885'	9.1 ± 0.3	85	83 ± 3
North of Marker 26 (A236)	24˚ 31.204'	81˚ 35.763'	6.2 ± 0.4	100	90 ± 10
West of Marker 26 (A144)	24˚ 30.287'	81˚ 36.210'	6.7 ± 0.1	50	43 ± 8
West of Marker 26 (A143)	24˚ 30.432'	81˚ 36.315'	8.8 ± 0.1	65	58 ± 8
North of Marker 26 (C44)	24˚ 31.072'	81˚ 36.540'	7.5 ± 0.8	140	125 ±15
NE of Pelican Shoal (A255)	24˚ 30.653'	81˚ 37.225'	6.3 ± 0.4	60	55 ± 5
West of Marker 26 (A141)	24˚ 30.396'	81˚ 37.319'	10.5 ± 0.2	70	70 ± 0
Inshore of Pelican Shoal (A140)	24˚ 30.527'	81˚ 37.915'	4.3 ± 0.3	80	53 ± 28
North of Middle Sambo (C43)	24˚ 30.267'	81˚ 40.219'	4.6 ± 0.1	61	49 ± 13
Stock Island Channel (A233)	24˚ 29.152'	81˚ 44.667'	9.2 ± 0.2	100	84 ± 16
Stock Island Channel (A231)	24˚ 29.108'	81˚ 45.032'	8.5 ± 0.2	100	85 ± 15
Stock Island Channel (A230)	24˚ 28.725'	81˚ 45.286'	9.9 ± 0.2	80	75 ± 5
Stock Island Channel (A139)	24˚ 28.992'	81˚ 46.231'	6.2 ± 0.2	55	48 ± 8
Key West Ship Channel (A138)	24˚ 28.163'	81˚ 48.358'	6.9 ± 0.1	35	30 ± 5
West of Ship Channel (A137)	24˚ 27.962'	81˚ 49.304'	6.5 ± 0.3	80	75 ± 5
North of E. Dry Rocks (A135)	24˚ 29.220'	81˚ 49.981'	8.4 ± 0.3	140	105 ±35
North of E. Dry Rocks (A136)	24˚ 29.086'	81˚ 50.165'	7.2 ± 0.4	130	125 ± 5
Middle Ground (A131)	24˚ 28.893'	81˚ 52.649'	5.2 ± 0.3	80	60 ± 20
Middle Ground (A134)	24˚ 29.091'	81˚ 52.672'	6.6 ± 0.5	120	110 ± 10
Middle Ground (A132)	24˚ 28.601'	81˚ 52.699'	5.6 ± 0.4	120	113 ± 8
Middle Ground (A133)	24˚ 28.366'	81˚ 52.712'	6.0 ± 0.7	130	95 ± 35
Middle Ground (A130)	24˚ 28.819'	81˚ 52.938'	4.6 ± 0.1	90	60 ± 30
Middle Ground (A129)	24˚ 28.837'	81˚ 53.405'	3.0 ± 0.2	40	35 ± 5

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
Middle Ground (C42)	24˚ 28.460'	81˚ 53.948'	7.5 ± 0.7	190	190 ± 0
Middle Ground (A128)	24˚ 27.729'	81˚ 54.943'	8.8 ± 0.2	70	70 ± 0
FKNMS Reference Area Total (98)			6.0 ± 0.2	84 ± 4	71 ± 3
FKNMS No-take Zones					
Carysfort Reef SPA (C160)**	25˚ 14.001'	80˚ 12.809'	8.2 ± 0.7	150	130 ± 20
Carysfort Reef SPA (C197)**	25˚ 13.947'	80˚ 12.640'	7.1 ± 0.2	75	70 ± 5
Carysfort Reef SPA (A415)**	25˚ 12.325'	80˚ 13.479'	3.7 ± 0.4	70	48 ± 23
Dry Rocks SPA (C161)**	25˚ 07.480'	80˚ 18.026'	4.6 ± 0.2	60	55 ± 5
Dry Rocks SPA (C162)**	25˚ 07.366'	80˚ 17.959'	5.7 ± 0.2	60	53 ± 8
Coffins Patch SPA (C193)**	24˚ 41.191'	80˚ 57.688'	5.7 ± 0.2	75	53 ± 23
Coffins Patch SPA (C192)**	24˚ 41.074'	80˚ 57.929'	4.1 ± 0.4	50	40 ± 10
Looe Key RO (A411)**	24˚ 33.969'	81˚ 21.869'	6.9 ± 0.2	100	98 ± 3
Looe Key RO (A412)**	24˚ 34.081'	81˚ 23.061'	7.2 ± 0.2	80	65 ± 15
Looe Key RO (C157)**	24˚ 34.077'	81˚ 23.173'	6.8 ± 0.3	140	105 ± 35
Looe Key RO (S337)**	24˚ 34.032'	81˚ 23.404'	7.0 ± 0.2	95	83 ± 13
Western Sambo ER (S342)**	24˚ 29.983'	81˚ 41.927'	8.0 ± 0.5	135	110 ± 25
Western Sambo ER (C158)**	24˚ 29.936'	81˚ 42.120'	6.9 ± 0.3	80	73 ± 8
Western Sambo ER (C159)**	24˚ 29.751'	81˚ 42.260'	6.9 ± 0.3	80	70 ± 10
Western Sambo ER (A413)**	24˚ 29.817'	81˚ 42.510'	5.3 ± 0.1	65	48 ± 18
FKNMS No-take Zone Total (15)			6.3 ± 0.4	88 ± 8	73 ± 7
Offshore Patch Reef Total (122)			**6.2 ± 0.2**	**85 ± 3**	**72 ± 3**
Reef Rubble (< 15 m)					
Biscayne National Park (BNP)					
North of Triumph Reef (C41)	25˚ 29.415'	80˚ 06.687'	3.4 ± 0.3	25	23 ± 3
Long Reef (C40)	25˚ 26.462'	80˚ 07.356'	2.9 ± 0.1	20	20 ± 0
BNP Total (2)			3.1 ± 0.2	23 ± 3	21 ± 1
FKNMS Reference Areas					
SW of S. Carysfort Reef (A331)	25˚ 12.200'	80˚ 13.824'	6.9 ± 0.1	55	48 ± 8
SW of S. Carysfort Reef (C39)	25˚ 11.914'	80˚ 13.822'	6.9 ± 0.1	25	20 ± 5
West of Elbow Reef (C37)	25˚ 09.218'	80˚ 16.158'	6.6 ± 0.3	35	33 ± 3
Pickles Reef (C36)	24˚ 59.130'	80˚ 25.168'	5.3 ± 0.2	50	39 ± 11
Conch Reef (C35)	24˚ 57.422'	80˚ 27.702'	3.7 ± 0.1	20	19 ± 1
Little Conch Reef (C91)	24˚ 56.640'	80˚ 28.779'	4.9 ± 0.1	25	23 ± 3
Little Conch Reef (A298)	24˚ 56.551'	80˚ 28.630'	5.5 ± 0.1	25	23 ± 3
Crocker Reef (C34)	24˚ 54.573'	80˚ 31.689'	5.9 ± 0.1	22	21 ± 1
South of Duck Key (C33)	24˚ 43.595'	80˚ 51.580'	5.0 ± 0.1	30	28 ± 3
South of Duck Key (C109)	24˚ 43.091'	80˚ 50.715'	7.8 ± 0.1	28	27 ± 1
South of Duck Key (S270)	24˚ 42.474'	80˚ 52.668'	7.0 ± 0.1	42	41 ± 1
East of Delta Shoal (C32)	24˚ 38.133'	81˚ 04.792'	5.6 ± 0.2	30	27 ± 4
South of Looe Key RO (C29)	24˚ 33.517'	81˚ 22.839'	5.6 ± 0.1	30	28 ± 3
American Shoal (A213)	24˚ 31.392'	81˚ 31.295'	4.9 ± 0.2	55	38 ± 18
Pelican Shoal (A253)	24˚ 30.110'	81˚ 37.962'	4.0 ± 0.2	25	23 ± 3
Western Dry Rocks (C58)	24˚ 26.758'	81˚ 55.688'	3.9 ± 0.3	50	50 ± 0
FKNMS Reference Area Total (16)			5.6 ± 0.3	34 ± 3	30 ± 3
FKNMS No-take Zones					
Elbow Reef SPA (C215)	25˚ 08.867'	80˚ 15.655'	4.1 ± 0.1	25	18 ± 8
Elbow Reef SPA (C216)	25˚ 08.785'	80˚ 15.687'	3.7 ± 0.3	20	15 ± 5
French Reef SPA (C154)	25˚ 02.329'	80˚ 21.173'	4.4 ± 0.1	15	14 ± 2
Molasses Reef (C155)	25˚ 00.879'	80˚ 22.485'	4.3 ± 0.2	20	18 ± 3
Molasses Reef (S334)	25˚ 00.780'	80˚ 22.780'	4.5 ± 0.1	21	18 ± 3
Looe Key SPA (C149)	24˚ 33.198'	81˚ 24.111'	4.7 ± 0.2	23	22 ± 2
Looe Key SPA (C148)	24˚ 33.079'	81˚ 24.337'	3.2 ± 0.1	18	17 ± 2
Eastern Sambo RO (S329)	24˚ 29.745'	81˚ 39.899'	2.4 ± 0.1	20	18 ± 2
Eastern Sambo RO (C150)	24˚ 29.646'	81˚ 39.913'	2.1 ± 0.2	40	35 ± 5
Western Sambo ER (C151)	24˚ 28.895'	81˚ 43.119'	1.8 ± 0.1	50	48 ± 3
Western Sambo ER (S390)	24˚ 28.926'	81˚ 43.339'	6.6 ± 0.2	65	55 ± 10
FKNMS No-take Zone Total (11)			3.8 ± 0.4	29 ± 5	25 ± 4
Reef Rubble Total (29)			**4.7 ± 0.3**	**31 ± 3**	**28 ± 2**

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
Inner Line Reef Tract (< 6 m)					
Biscayne National Park (BNP)					
BNP Total (0)					
FKNMS Reference Areas					
Turtle Rocks (A408)	25˚ 17.982'	80˚ 12.966'	4.1 ± 0.3	50	45 ± 5
Turtle Rocks (A407)	25˚ 17.842'	80˚ 13.078'	3.5 ± 0.4	70	68 ± 3
Turtle Rocks (C133)	25˚ 17.709'	80˚ 13.210'	2.9 ± 0.4	135	128 ± 8
Turtle Rocks (C135)	25˚ 17.679'	80˚ 13.133'	5.0 ± 0.5	170	135 ± 35
Turtle Rocks (A406)	25˚ 17.660'	80˚ 13.197'	3.7 ± 0.5	110	100 ± 10
NW of Elbow Reef (A405)	25˚ 09.870'	80˚ 16.581'	3.3 ± 0.5	85	58 ± 28
NW of Elbow Reef (A404)	25˚ 09.694'	80˚ 17.022'	3.7 ± 0.3	100	85 ± 15
West of Elbow Reef (A402)	25˚ 08.467'	80˚ 17.662'	4.6 ± 0.4	130	130 ± 0
North-North Dry Rocks (A403)	25˚ 08.176'	80˚ 17.402'	4.6 ± 0.6	310	240 ± 70
FKNMS Reference Area Total (9)			3.9 ± 0.2	129 ± 26	110 ± 20
FKNMS No-take Zones					
Dry Rocks SPA (A436)	25˚ 07.458'	80˚ 17.840'	3.3 ± 0.6	260	145 ± 115
Dry Rocks SPA (C217)	25˚ 07.390'	80˚ 17.835'	4.3 ± 0.9	180	140 ± 40
Dry Rocks SPA (C218)	25˚ 07.340'	80˚ 17.892'	4.0 ± 0.5	270	218 ± 53
Grecian Rocks SPA (C219)	25˚ 06.885'	80˚ 18.219'	3.4 ± 0.3	90	85 ± 5
Grecian Rocks SPA (C220)	25˚ 06.803'	80˚ 18.147'	6.2 ± 0.5	80	80 ± 0
Grecian Rocks SPA (A437)	25˚ 06.767'	80˚ 18.246'	2.2 ± 0.4	50	45 ± 5
Grecian Rocks SPA (A439)	25˚ 06.719'	80˚ 18.177'	4.1 ± 1.1	260	155 ±105
Grecian Rocks SPA (A440)	25˚ 06.626'	80˚ 18.221'	3.5 ± 0.4	100	88 ± 13
Grecian Rocks SPA (C163)	25˚ 06.465'	80˚ 18.291'	6.6 ± 0.3	70	65 ± 5
FKNMS No-take Zone Total (9)			4.2 ± 0.5	151 ± 31	113 ± 18
Inner Line Reef Tract Total (18)			**4.0 ± 0.3**	**140 ± 20**	**112 ± 13**
High-relief Spur and Groove (< 15 m)					
Biscayne National Park (BNP)					
Brewster Reef (A225)	25˚ 34.377'	80˚ 05.948'	6.9 ± 0.5	190	170 ± 20
BNP Total (1)			6.9	190	170
FKNMS Reference Areas					
South of S. Carysfort Reef (A222)	25˚ 11.791'	80˚ 13.582'	7.8 ± 0.5	180	133 ± 48
South of S. Carysfort Reef (A221)	25˚ 11.776'	80˚ 13.655'	6.7 ± 0.6	175	160 ± 15
North of French Reef (C75)	25˚ 02.413'	80˚ 20.613'	8.8 ± 0.4	90	80 ± 10
North of French Reef (A220)	25˚ 02.370'	80˚ 20.665'	8.1 ± 0.5	70	60 ± 10
Sand Island (A218)	25˚ 01.145'	80˚ 22.105'	4.2 ± 0.3	100	95 ± 5
Sand Island (C186)	25˚ 01.101'	80˚ 21.994'	7.5 ± 0.4	90	80 ± 10
Pickles Reef (A217)	24˚ 59.509'	80˚ 24.522'	8.2 ± 0.5	150	113 ± 38
Pickles Reef (C72)	24˚ 59.297'	80˚ 24.839'	4.8 ± 0.2	60	45 ± 15
Pickles Reef (C71)	24˚ 59.224'	80˚ 24.867'	6.3 ± 0.6	170	138 ± 33
Pickles Reef (C73)	24˚ 59.073'	80˚ 24.971'	7.8 ± 0.6	90	85 ± 5
Pickles Reef (A216)	24˚ 59.014'	80˚ 25.091'	5.6 ± 0.3	60	53 ± 8
Delta Shoal (C69)	24˚ 37.959'	81˚ 05.265'	4.6 ± 0.2	45	43 ± 2
Delta Shoal (C68)	24˚ 37.950'	81˚ 05.401'	3.9 ± 0.4	115	113 ±3
American Shoal (A215)	24˚ 31.400'	81˚ 31.143'	4.4 ± 0.4	160	155 ± 5
American Shoal (C67)	24˚ 31.335'	81˚ 31.312'	5.9 ± 0.7	190	165 ± 25
American Shoal (A214)	24˚ 31.314'	81˚ 31.449'	6.1 ± 0.6	120	78 ± 43
Maryland Shoal (S151)	24˚ 31.826'	81˚ 34.736'	3.7 ± 0.7	110	93 ± 18
NE of Pelican Shoal (A235)	24˚ 30.633'	81˚ 37.081'	6.0 ± 0.4	130	98 ± 33
East of Pelican Shoal (C61)	24˚ 30.223'	81˚ 37.275'	5.0 ± 0.3	100	80 ± 20
East of Pelican Shoal (C63)	24˚ 30.194'	81˚ 37.369'	3.7 ± 0.7	150	140 ± 10
Pelican Shoal (C62)	24˚ 30.028'	81˚ 37.762'	3.7 ± 0.4	165	143 ± 23
No Name Reef (A210)	24˚ 29.744'	81˚ 38.927'	4.1 ± 0.9	190	133 ± 58
East of E. Dry Rocks (C60)	24˚ 27.869'	81˚ 50.257'	4.0 ± 0.4	85	70 ± 15
Western Dry Rocks (C28)	24˚ 26.718'	81˚ 55.512'	5.3 ± 0.7	180	118 ± 63
Western Dry Rocks (C59)	24˚ 26.712'	81˚ 55.592'	3.0 ± 0.6	70	64 ± 7
West of W. Dry Rocks (C57)	24˚ 26.640'	81˚ 55.945'	5.6 ± 0.2	60	50 ± 10
West of W. Dry Rocks (A358)	24˚ 26.620'	81˚ 55.972'	7.8 ± 0.3	60	48 ± 13

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
West of W. Dry Rocks (C56)	24˚ 27.063'	81˚ 56.777'	10.1 ± 0.4	110	95 ± 15
FKNMS Reference Area Total (28)			5.8 ± 0.4	117 ± 9	97 ± 7
FKNMS No-take Zones					
Carysfort Reef SPA (C180)**	25˚ 13.681'	80˚ 12.479'	3.0 ± 0.4	100	80 ± 20
Carysfort Reef SPA (C181)**	25˚ 13.557'	80˚ 12.512'	3.7 ± 0.6	185	183 ± 3
Carysfort Reef SPA (A424)**	25˚ 13.339'	80˚ 12.586'	5.4 ± 0.6	200	173 ± 28
Carysfort Reef SPA (A423)**	25˚ 13.219'	80˚ 12.649'	3.7 ± 0.6	190	190 ± 0
Elbow Reef SPA (C182)**	25˚ 08.920'	80˚ 15.266'	9.2 ± 0.6	150	145 ± 5
Elbow Reef SPA (C183)**	25˚ 08.876'	80˚ 15.296'	8.4 ± 0.5	180	170 ± 10
Elbow Reef SPA (A426)**	25˚ 08.786'	80˚ 15.369'	6.2 ± 0.7	240	180 ± 60
Elbow Reef SPA (A425)**	25˚ 08.580'	80˚ 15.483'	3.8 ± 0.3	250	168 ± 83
French Reef SPA (C184)**	25˚ 02.183'	80˚ 20.899'	5.1 ± 0.4	150	125 ± 25
French Reef SPA (C185)**	25˚ 02.156'	80˚ 20.751'	13.8 ± 0.5	110	108 ± 3
French Reef SPA (A427)**	25˚ 02.096'	80˚ 20.903'	7.8 ± 0.7	180	155 ± 25
French Reef SPA (A428)**	25˚ 02.026'	80˚ 20.932'	10.4 ± 0.7	180	138 ± 43
Molasses Reef (A429)**	25˚ 00.603'	80˚ 22.395'	8.9 ± 0.7	245	198 ± 48
Molasses Reef (S383)**	25˚ 00.570'	80˚ 22.438'	7.9 ± 0.5	155	143 ± 13
Molasses Reef (S382)**	25˚ 00.509'	80˚ 22.584'	7.8 ± 0.8	230	180 ± 50
Sombrero Key SPA (A421)**	24˚ 37.593'	81˚ 06.497'	5.2 ± 0.5	190	190 ± 0
Sombrero Key SPA (C177)**	24˚ 37.581'	81˚ 06.581'	4.0 ± 0.6	210	205 ± 5
Sombrero Key SPA (C176)**	24˚ 37.520'	81˚ 06.692'	5.9 ± 0.8	160	143 ± 18
Looe Key SPA (C165)**	24˚ 32.801'	81˚ 24.090'	5.9 ± 0.6	170	155 ± 15
Looe Key SPA (C164)**	24˚ 32.778'	81˚ 24.220'	4.9 ± 0.7	140	135 ± 5
Looe Key SPA (A418)**	24˚ 32.731'	81˚ 24.376'	5.6 ± 0.5	200	183 ± 18
Looe Key SPA (A417)**	24˚ 32.685'	81˚ 24.574'	5.9 ± 0.5	220	210 ± 10
Eastern Sambo RO (C166)**	24˚ 29.583'	81˚ 39.607'	3.6 ± 0.4	100	81 ± 19
Eastern Sambo RO (S355)**	24˚ 29.551'	81˚ 39.697'	3.2 ± 0.4	100	85 ± 15
Western Sambo ER (C169)**	24˚ 28.984'	81˚ 42.169'	5.0 ± 0.2	75	73 ± 3
Western Sambo ER (A420)**	24˚ 28.940'	81˚ 42.348'	2.7 ± 0.2	60	53 ± 8
Western Sambo ER (S358)**	24˚ 28.774'	81˚ 42.963'	5.4 ± 0.8	120	110 ± 10
Eastern Dry Rocks SPA (C170)**	24˚ 27.641'	81˚ 50.524'	4.5 ± 0.6	120	110 ± 10
Eastern Dry Rocks SPA (C171)**	24˚ 27.590'	81˚ 50.756'	3.7 ± 0.6	175	143 ± 33
Rock Key SPA (C172)**	24˚ 27.304'	81˚ 51.388'	3.4 ± 0.5	100	75 ± 25
Rock Key SPA (C173)**	24˚ 27.267'	81˚ 51.488'	3.3 ± 0.5	50	50 ± 0
Sand Key SPA (C175)**	24˚ 27.133'	81˚ 52.605'	3.7 ± 0.6	100	100 ± 0
Sand Key SPA (C174)**	24˚ 27.125'	81˚ 52.719'	3.1 ± 0.7	100	85 ± 15
FKNMS No-take Zone Total (33)			5.6 ± 0.4	156 ± 10	137 ± 8
Spur and Groove Total (62)			**5.7 ± 0.3**	**139 ± 7**	**120 ± 6**
Low-relief Hard-bottom (< 6 m)					
Biscayne National Park (BNP)					
Fowey Rocks (A226)	25˚ 35.509'	80˚ 05.714'	5.3 ± 0.2	50	48 ± 3
Fowey Rocks (C79)	25˚ 35.420'	80˚ 05.780'	3.2 ± 0.1	55	53 ± 3
Fowey Rocks (A227)	25˚ 35.359'	80˚ 05.695'	5.9 ± 0.3	50	40 ± 10
Fowey Rocks (C80)	25˚ 35.261'	80˚ 05.783'	2.7 ± 0.1	42	34 ± 9
Brewster Reef (A356)	25˚ 34.656'	80˚ 06.094'	5.3 ± 0.2	85	70 ± 15
Brewster Reef area (A357)	25˚ 34.067'	80˚ 06.060'	4.7 ± 0.2	30	30 ± 0
Brewster Reef area (C99)	25˚ 33.821'	80˚ 06.305'	4.1 ± 0.2	70	55 ± 15
Star Reef (A354)	25˚ 32.882'	80˚ 06.125'	4.0 ± 0.2	45	35 ± 10
Star Reef (A352)	25˚ 32.575'	80˚ 06.365'	5.9 ± 0.1	40	33 ± 8
Ledberry Reef area (S239)	25˚ 32.433'	80˚ 06.190'	4.9 ± 0.6	75	65 ± 10
Star Reef (A341)	25˚ 32.419'	80˚ 06.174'	4.7 ± 0.5	35	34 ± 2
Star Reef (A355)	25˚ 32.121'	80˚ 06.265'	3.8 ± 0.2	40	38 ± 3
Triumph Reef (A350)	25˚ 28.425'	80˚ 06.695'	5.5 ± 0.4	32	29 ± 4
Long Reef (A349)	25˚ 26.639'	80˚ 07.187'	4.3 ± 0.2	30	30 ± 0
Long Reef (A348)	25˚ 25.793'	80˚ 07.381'	5.3 ± 0.1	25	25 ± 0
Inshore of Long Reef (A347)	25˚ 24.410'	80˚ 07.874'	5.3 ± 0.2	60	49 ± 11
BNP Total (16)			4.7 ± 0.2	48 ± 4	42 ± 3
FKNMS Reference Areas					
West of Carysfort Reef (A194)	25˚ 14.258'	80˚ 13.868'	2.1 ± 0.2	55	50 ± 5

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
West of Carysfort Reef (A197)	25˚ 13.912'	80˚ 13.164'	3.7 ± 0.2	70	58 ± 13
Watsons Reef (A329)	25˚ 11.173'	80˚ 15.732'	3.7 ± 0.2	60	45 ± 15
NW of Elbow Reef (A325)	25˚ 10.083'	80˚ 16.823'	3.1 ± 0.2	50	48 ± 3
West of Elbow Reef (C132)	25˚ 08.542'	80˚ 17.686'	5.5 ± 0.1	65	60 ± 5
SW of Grecian Rocks (A323)	25˚ 05.824'	80˚ 19.841'	5.6 ± 0.1	30	29 ± 1
White Bank (A321)	25˚ 04.050'	80˚ 20.363'	4.3 ± 0.1	30	28 ± 3
Inshore of Pickles Reef (A316)	24˚ 59.804'	80˚ 26.382'	4.8 ± 0.2	50	40 ± 10
West of Pickles Reef (A315)	24˚ 58.703'	80˚ 27.614'	4.0 ± 0.1	40	33 ± 8
Little Conch Reef (C92)	24˚ 56.373'	80˚ 28.723'	5.6 ± 0.1	48	47 ± 2
North of Tennessee Reef RO (A280)	24˚ 47.016'	80˚ 45.774'	4.4 ± 0.1	45	38 ± 8
North of Tennessee Reef RO (A282)	24˚ 46.740'	80˚ 44.969'	5.7 ± 0.1	50	40 ± 10
South of Conch Reef (A279)	24˚ 43.130'	80˚ 50.564'	5.8 ± 0.2	40	33 ± 8
Marker 20 (A276)	24˚ 40.534'	80˚ 57.425'	5.1 ± 0.3	25	24 ± 2
SW of Coffins Patch SPA (A380)	24˚ 40.068'	80˚ 58.868'	5.7 ± 0.2	50	43 ± 8
SW of Coffins Patch SPA (A274)	24˚ 39.871'	81˚ 00.430'	5.8 ± 0.1	40	38 ± 3
West of Marker 22 (C31)	24˚ 33.725'	81˚ 20.924'	5.9 ± 0.3	30	25 ± 5
Offshore of Maryland Shoal (A211)	24˚ 30.696'	81˚ 34.271'	5.1 ± 0.2	35	28 ± 8
Inshore of Pelican Shoal (A257)	24˚ 30.327'	81˚ 37.159'	4.0 ± 0.1	45	45 ± 0
Pelican Shoal (A254)	24˚ 29.995'	81˚ 37.872'	5.8 ± 0.1	30	30 ± 0
FKNMS Reference Area Total (20)			4.8 ± 0.2	44 ± 3	39 ± 2
FKNMS No-take Zones					
Carysfort Reef SPA (C198)**	25˚ 13.691'	80˚ 12.669'	5.5 ± 0.1	35	35 ± 0
Carysfort Reef SPA (C199)**	25˚ 13.625'	80˚ 12.744'	5.2 ± 0.2	60	50 ± 10
Carysfort Reef SPA (A433)**	25˚ 13.520'	80˚ 12.798'	4.4 ± 0.1	45	38 ± 8
Western Sambo ER (C203)**	24˚ 29.008'	81˚ 41.970'	5.3 ± 0.1	40	38 ± 3
FKNMS No-take Zone Total (4)			5.1 ± 0.2	45 ± 5	40 ± 3
Shallow Hard-bottom Total (40)			**4.8 ± 0.2**	**46 ± 2**	**40 ± 2**
Low-relief Hard-bottom (6-15 m)					
Biscayne National Park (BNP)					
Fowey Rocks (A401)	25˚ 35.669'	80˚ 05.688'	8.6 ± 0.3	43	42 ± 2
Brewster Reef (A342)	25˚ 35.509'	80˚ 05.714'	6.2 ± 0.3	130	105 ± 25
Ledberry Reef area (A353)	25˚ 35.420'	80˚ 05.780'	6.9 ± 0.2	75	73 ± 3
Inshore of Triumph Reef (A340)	25˚ 28.122'	80˚ 07.308'	7.3 ± 0.3	70	55 ± 15
Inshore of Triumph Reef (A346)	25˚ 35.359'	80˚ 05.695'	6.6 ± 0.4	35	33 ± 3
SW of Pacific Reef (A339)	25˚ 35.261'	80˚ 05.783'	7.9 ± 0.3	30	25 ± 5
BNP Total (6)			7.3 ± 0.4	64 ± 15	55 ± 12
FKNMS Reference Areas					
Turtle Harbor (A314)	25˚ 16.895'	80˚ 11.247'	11.7 ± 0.1	50	50 ± 0
Turtle Harbor (A309)	25˚ 16.003'	80˚ 12.168'	11.1 ± 0.4	100	65 ± 35
North of Carysfort Reef (A311)	25˚ 15.897'	80˚ 11.912'	11.0 ± 0.2	65	50 ± 15
North of Carysfort Reef (A312)	25˚ 15.895'	80˚ 11.810'	10.5 ± 0.3	65	55 ± 10
North of Carysfort Reef (C93)	25˚ 15.833'	80˚ 12.283'	10.9 ± 0.2	50	48 ± 3
North of Carysfort Reef (A313)	25˚ 15.737'	80˚ 11.802'	9.7 ± 0.2	62	51 ± 11
Turtle Harbor (S285)	25˚ 15.672'	80˚ 11.557'	9.2 ± 0.1	80	63 ± 18
North of Carysfort Reef (C94)	25˚ 15.270'	80˚ 11.950'	8.3 ± 0.2	50	49 ± 1
North of Carysfort Reef (C115)	25˚ 14.539'	80˚ 11.880'	8.3 ± 0.2	40	35 ± 5
North of Carysfort Reef (A307)	25˚ 14.146'	80˚ 12.670'	8.8 ± 0.1	40	38 ± 3
Watsons Reef (C129)	25˚ 10.731'	80˚ 14.268'	12.0 ± 0.2	25	20 ± 5
South of Grecian Rocks (A303)	25˚ 06.144'	80˚ 18.028'	8.1 ± 0.1	35	35 ± 0
SW of French Reef (A219)	25˚ 01.843'	80˚ 21.171'	8.9 ± 0.4	50	48 ± 3
SW of French Reef (C74)	25˚ 01.831'	80˚ 21.287'	10.8 ± 0.6	65	58 ± 8
Little Pickles Reef (A317)	24˚ 58.602'	80˚ 25.550'	7.6 ± 0.3	70	58 ± 12
Conch Reef (A301)	24˚ 57.471'	80˚ 27.435'	6.9 ± 0.3	75	68 ± 8
SW of Conch Reef (A300)	24˚ 56.903'	80˚ 28.151'	9.2 ± 0.2	50	46 ± 4
Little Conch Reef (A390)	24˚ 56.653'	80˚ 28.252'	6.6 ± 0.2	50	48 ± 3
Little Conch Reef (C113)	24˚ 56.483'	80˚ 28.506'	6.8 ± 0.2	35	28 ± 8
West of Little Conch Reef (A288)	24˚ 56.422'	80˚ 29.837'	7.3 ± 0.2	40	32 ± 8
West of Little Conch Reef (A295)	24˚ 56.269'	80˚ 29.912'	7.2 ± 0.2	75	68 ± 8
NE of Davis Reef (A290)	24˚ 56.047'	80˚ 29.536'	8.5 ± 0.2	46	46 ± 1

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
NE of Davis Reef (A296)	24˚ 55.913'	80˚ 29.633'	7.8 ± 0.4	50	42 ± 8
Crocker Reef (A286)	24˚ 54.217'	80˚ 33.003'	8.4 ± 0.1	18	15 ± 3
Crocker Reef (C89)	24˚ 54.100'	80˚ 32.269'	11.4 ± 0.1	65	53 ± 13
NE of Alligator Reef (A285)	24˚ 52.435'	80˚ 34.352'	8.5 ± 0.2	35	33 ± 3
SW of Alligator Reef (A284)	24˚ 49.183'	80˚ 39.771'	10.7 ± 0.1	40	38 ± 3
SW of Alligator Reef (S201)	24˚ 49.081'	80˚ 40.646'	8.1 ± 0.1	14	12 ± 2
East of Tennessee Reef RO (A273)	24˚ 46.329'	80˚ 44.579'	6.6 ± 0.2	48	39 ± 9
East of Tennessee Reef RO (A388)	24˚ 46.142'	80˚ 44.393'	9.5 ± 0.3	70	50 ± 20
South of Duck Key (A269)	24˚ 41.768'	80˚ 54.666'	8.4 ± 0.2	50	30 ± 20
SW of Coffins Patch SPA (A275)	24˚ 39.745'	81˚ 00.354'	6.5 ± 0.1	45	33 ± 13
East of Delta Shoal (C106)	24˚ 38.532'	81˚ 03.408'	6.3 ± 0.2	30	25 ± 5
South of Moser Channel (S264)	24˚ 36.277'	81˚ 11.802'	8.2 ± 0.1	18	17 ± 2
East of Marker 22 (A1480	24˚ 34.595'	81˚ 17.357'	8.5 ± 0.1	30	25 ± 5
West of Looe Key (A263)	24˚ 33.234'	81˚ 26.370'	6.3 ± 0.1	40	32 ± 9
West of Looe Key (A244)	24˚ 33.056'	81˚ 26.622'	7.2 ± 0.1	72	49 ± 24
West of Looe Key (A243)	24˚ 32.920'	81˚ 26.792'	6.2 ± 0.1	21	16 ± 6
West of Looe Key (A262)	24˚ 32.979'	81˚ 26.961'	6.8 ± 0.1	40	28 ± 13
West of Looe Key (A261)	24˚ 32.972'	81˚ 27.060'	6.9 ± 0.1	32	31 ± 2
East of American Shoal (A361)	24˚ 31.572'	81˚ 30.359'	8.3 ± 0.4	60	40 ± 20
NE of W. Dry Rocks (A229)	24˚ 27.117'	81˚ 54.763'	8.6 ± 0.1	45	40 ± 5
FKNMS Reference Area Total (42)			8.5 ± 0.3	49 ± 3	40 ± 2
FKNMS No-take Zones					
Carysfort Reef (C196)**	25˚ 13.742'	80˚ 13.118'	6.4 ± 0.1	50	50 ± 0
Carysfort Reef (A432) **	25˚ 13.691'	80˚ 12.669'	6.8 ± 0.2	40	40 ± 0
Conch Reef SPA (S396) **	25˚ 13.625'	80˚ 12.744'	7.2 ± 0.3	110	93 ± 18
Conch Reef SPA (C194) **	25˚ 13.602'	80˚ 12.995'	7.4 ± 0.5	90	68 ± 23
Davis Reef SPA (C195) **	25˚ 13.520'	80˚ 12.798'	7.5 ± 0.4	65	55 ± 10
Davis Reef SPA (A422) **	24˚ 57.373'	80˚ 27.444'	9.0 ± 0.2	40	38 ± 3
FKNMS No-take Zone Total (6)			7.4 ± 0.4	66 ± 12	57 ± 8
Deeper Hard-bottom Total (54)			**8.3 ± 0.2**	**52 ± 3**	**44 ± 3**
Patchy Hard-bottom (6-15 m)					
Biscayne National Park (BNP)					
North of Fowey Rocks (A399)	25˚ 36.455'	80˚ 05.806'	7.5 ± 0.2	80	78 ± 3
Fowey Rocks (C121)	25˚ 35.533'	80˚ 05.778'	5.6 ± 0.5	100	80 ± 20
BNP Total (2)			6.6 ± 1.0	90 ± 10	79 ± 1
FKNMS Reference Areas					
SW of Elbow Reef (A306)	25˚ 07.887'	80˚ 16.731'	8.3 ± 0.1	55	40 ± 15
East of Dry Rocks (A304)	25˚ 07.707'	80˚ 17.121'	9.2 ± 0.1	60	53 ± 8
East of Key Largo Dry Rocks (C128)	25˚ 07.331'	80˚ 17.039'	8.7 ± 0.1	40	37 ± 4
South of Grecian Rocks (A324)	25˚ 04.868'	80˚ 19.137'	8.7 ± 0.1	32	31 ± 1
SW of Pickles Reef (A302)	24˚ 58.535'	80˚ 26.558'	8.2 ± 0.1	50	45 ± 5
Crocker Reef (C127)	24˚ 56.346'	80˚ 32.258'	9.8 ± 0.3	75	63 ± 13
SW of Crocker Reef (S116)	24˚ 53.272'	80˚ 34.010'	10.0 ± 0.2	52	51 ± 1
West of Tennessee Reef RO (C88)	24˚ 45.775'	80˚ 45.697'	8.1 ± 0.1	35	28 ± 8
Tennessee Reef (A387)	24˚ 45.270'	80˚ 46.394'	7.8 ± 0.1	25	23 ± 3
Delta Shoal (C124)	24˚ 37.930'	81˚ 05.651'	6.1 ± 0.1	22	21 ± 1
East of Sombrero Reef (A377)	24˚ 37.773'	81˚ 06.020'	8.2 ± 0.1	40	38 ± 3
West of Sombrero Reef (S193)	24˚ 37.677'	81˚ 08.711'	6.2 ± 0.1	25	25 ± 0
West of Sombrero Reef (A266)	24˚ 37.572'	81˚ 07.321'	8.4 ± 0.2	55	48 ± 8
West of Sombrero Reef (A265)	24˚ 37.524'	81˚ 07.465'	8.8 ± 0.1	24	17 ± 7
South of Moser Channel (A376)	24˚ 36.776'	81˚ 09.575'	9.5 ± 0.1	50	37 ± 14
West of Looe Key (A245)	24˚ 32.992'	81˚ 26.414'	8.1 ± 0.1	50	40 ± 10
West of Looe Key (A241)	24˚ 32.922'	81˚ 27.428'	7.1 ± 0.1	45	45 ± 0
East of American Shoal (C81)	24˚ 31.784'	81˚ 29.732'	6.8 ± 0.1	30	30 ± 1
American Shoal (A362)	24˚ 31.426'	81˚ 30.519'	11.1 ± 0.2	75	63 ± 13
American Shoal (C123)	24˚ 31.264'	81˚ 30.965'	12.0 ± 0.2	60	48 ± 13
American Shoal (C84)	24˚ 31.403'	81˚ 31.412'	6.0 ± 0.1	50	43 ± 8
Offshore of Maryland Shoal (A259)	24˚ 30.770'	81˚ 34.072'	6.6 ± 0.2	40	38 ± 3
North of Maryland Shoal (C83)	24˚ 31.276'	81˚ 35.079'	6.9 ± 0.1	70	60 ± 10

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
West of Maryland Shoal (A238)	24˚ 30.620'	81˚ 35.348'	7.5 ± 0.2	35	33 ± 3
North of Marker 26 (A237)	24˚ 30.620'	81˚ 35.476'	7.2 ± 0.1	40	40 ± 0
Pelican Shoal (A251)	24˚ 30.112'	81˚ 38.133'	6.8 ± 0.1	55	43 ± 13
North of No Name Reef (A234)	24˚ 30.421'	81˚ 38.811'	7.1 ± 0.1	46	38 ± 8
Stock Island Channel (A232)	24˚ 28.812'	81˚ 44.327'	10.4 ± 0.1	35	33 ± 3
FKNMS Reference Area Total (28)			8.2 ± 0.3	45 ± 3	39 ± 2
FKNMS No-take Zones					
Western Sambo ER (C191)**	24˚ 29.133'	81˚ 41.949'	6.9 ± 0.2	70	60 ± 10
Western Sambo ER (C190)**	24˚ 29.264'	81˚ 42.077'	7.3 ± 0.2	60	55 ± 5
FKNMS No-take Zone Total (2)			7.1 ± 0.2	65 ± 5	58 ± 3
Patchy Hard-bottom Total (32)			**8.0 ± 0.3**	**49 ± 3**	**43 ± 3**
Low-relief Spur and Groove (6-15 m)					
Biscayne National Park (BNP)					
South of Fowey Rocks (A400)	25˚ 34.823'	80˚ 05.814'	6.4 ± 0.2	80	65 ± 15
Brewster Reef (C120)	25˚ 34.268'	80˚ 05.960'	7.0 ± 0.4	150	133 ± 18
Star Reef (A398)	25˚ 32.006'	80˚ 06.078'	11.4 ± 0.4	50	45 ± 5
South of Star Reef (C118)	25˚ 30.941'	80˚ 06.237'	13.0 ± 0.1	35	28 ± 8
Pacific Light (A397)	25˚ 22.574'	80˚ 08.294'	7.1 ± 0.1	24	22 ± 2
BNP Total (5)			9.0 ± 1.3	68 ± 23	58 ± 20
FKNMS Reference Areas					
Turtle Harbor (A396)	25˚ 17.219'	80˚ 10.521'	8.7 ± 0.2	48	39 ± 9
Turtle Harbor (A395)	25˚ 16.664'	80˚ 10.856'	11.4 ± 0.3	50	48 ± 3
Turtle Harbor (A394)	25˚ 16.657'	80˚ 11.071'	11.4 ± 0.3	80	63 ± 18
Turtle Harbor (C117)	25˚ 16.305'	80˚ 11.076'	10.8 ± 0.3	85	65 ± 20
North of Carysfort Reef (C116)	25˚ 15.772'	80˚ 11.196'	9.0 ± 0.2	65	48 ± 18
North of Carysfort Reef (A393)	25˚ 15.564'	80˚ 11.264'	10.0 ± 0.2	50	43 ± 8
North of Carysfort Reef (A392)	25˚ 15.549'	80˚ 11.438'	10.2 ± 0.2	40	38 ± 3
South of S. Carysfort Reef (C76)	25˚ 11.991'	80˚ 13.471'	7.6 ± 0.4	80	64 ± 16
South of S. Carysfort Reef (A223)	25˚ 11.904'	80˚ 13.469'	8.5 ± 0.5	60	55 ± 5
South of S. Carysfort Reef (C77)	25˚ 11.803'	80˚ 13.483'	11.0 ± 0.4	85	73 ± 13
NE of Elbow Reef (C114)	25˚ 09.759'	80˚ 14.926'	13.9 ± 0.4	90	70 ± 20
East of Dry Rocks (A391)	25˚ 07.149'	80˚ 16.855'	11.0 ± 0.3	48	42 ± 7
Little Conch Reef (C112)	24˚ 56.268'	80˚ 28.993'	9.1 ± 0.5	190	123 ± 68
NE of Davis Reef (C111)	24˚ 55.715'	80˚ 29.675'	11.4 ± 0.3	60	50 ± 10
Crocker Reef (C389)	24˚ 54.443'	80˚ 31.510'	12.2 ± 0.3	45	40 ± 5
NE of Alligator Reef (C110)	24˚ 52.243'	80˚ 34.618'	13.3 ± 0.1	32	29 ± 4
SW of Alligator Reef (C70)	24˚ 48.548'	80˚ 40.932'	8.3 ± 0.2	70	70 ± 0
SW of Alligator Reef (C126)	24˚ 48.475'	80˚ 41.064'	8.8 ± 0.1	30	23 ± 8
Tennessee Reef (A386)	24˚ 44.618'	80˚ 46.680'	10.8 ± 0.2	55	43 ± 13
Tennessee Reef (A385)	24˚ 43.525'	80˚ 49.572'	10.4 ± 0.2	38	37 ± 2
South of Conch Reef (A384)	24˚ 42.959'	80˚ 50.823'	10.6 ± 0.3	100	80 ± 20
South of Duck Key (A383)	24˚ 42.158'	80˚ 52.895'	10.2 ± 0.2	70	50 ± 20
South of Duck Key (C108)	24˚ 41.893'	80˚ 53.755'	9.5 ± 0.2	80	65 ± 15
South of Duck Key (C107)	24˚ 41.888'	80˚ 53.523'	10.7 ± 0.3	50	43 ± 8
South of Duck Key (A382)	24˚ 41.687'	80˚ 54.345'	9.4 ± 0.3	60	50 ± 10
East of Coffins Patch SPA (A381)	24˚ 41.057'	80˚ 55.834'	7.8 ± 0.3	75	70 ± 5
Marker 20 (A268)	24˚ 40.492'	80˚ 57.199'	11.2 ± 0.3	70	50 ± 20
SW of Coffins Patch SPA (A379)	24˚ 39.751'	80˚ 59.443'	9.8 ± 0.3	70	50 ± 20
East of Delta Shoal (A378)	24˚ 39.032'	81˚ 01.894'	8.4 ± 0.1	35	30 ± 5
South of Moser Channel (A375)	24˚ 36.424'	81˚ 11.026'	8.8 ± 0.2	32	31 ± 1
South of Moser Channel (A373)	24˚ 36.361'	81˚ 11.442'	8.5 ± 0.3	60	53 ± 8
South of Moser Channel (S265)	24˚ 36.111'	81˚ 11.556'	10.1 ± 0.1	50	33 ± 18
South of Moser Channel (A374)	24˚ 36.066'	81˚ 11.411'	11.7 ± 0.2	80	70 ± 10
East of Marker 22 (A372)	24˚ 34.666'	81˚ 16.504'	12.7 ± 0.1	70	55 ± 15
East of Marker 22 (A372)	24˚ 34.063'	81˚ 19.036'	12.4 ± 0.1	40	35 ± 5
West of Marker 22 (A372)	24˚ 33.702'	81˚ 20.458'	9.8 ± 0.0	40	33 ± 8
SW of Looe Key RO (A368)	24˚ 33.485'	81˚ 21.869'	7.2 ± 0.1	50	38 ± 13
South of Looe Key RO (A369)	24˚ 33.328'	81˚ 21.966'	9.8 ± 0.1	50	43 ± 8
South of Looe Key RO (A367)	24˚ 33.231'	81˚ 22.445'	8.7 ± 0.1	60	58 ± 3

Site number/site location (no. sites)	Latitude (N)	Longitude (W)	Mean depth (m)	Max. vertical relief (cm)	Mean max. vertical relief (cm)
South of Looe Key RO (C105)	24˚ 33.133'	81˚ 22.682'	10.0 ± 0.2	70	50 ± 20
South of Looe Key RO (A366)	24˚ 33.095'	81˚ 22.809'	10.7 ± 0.1	75	65 ± 10
South of Looe Key RO (C104)	24˚ 33.506'	81˚ 23.066'	9.8 ± 0.1	35	28 ± 8
South of Looe Key RO (A365)	24˚ 32.957'	81˚ 23.274'	11.9 ± 0.1	40	40 ± 0
West of Looe Key (A364)	24˚ 32.760'	81˚ 25.293'	9.8 ± 0.2	60	55 ± 5
West of Looe Key (A363)	24˚ 32.752'	81˚ 25.763'	10.7 ± 0.2	92	91 ± 1
East of American Shoal (C103)	24˚ 31.894'	81˚ 28.613'	10.6 ± 0.2	80	73 ± 8
West of American Shoal (C102)	24˚ 31.259'	81˚ 31.798'	10.3 ± 0.2	80	65 ± 15
West of American Shoal (A360)	24˚ 31.099'	81˚ 32.257'	8.9 ± 0.3	125	90 ± 35
SE of Maryland Shoal (C66)	24˚ 30.673'	81˚ 33.647'	11.3 ± 0.3	125	93 ± 33
SE of Maryland Shoal (C65)	24˚ 30.674'	81˚ 33.722'	10.2 ± 0.2	50	50 ± 0
Offshore of Maryland Shoal (S153)	24˚ 30.595'	81˚ 34.126'	7.5 ± 0.4	95	63 ± 33
W. of Marker 26 (A142)	24˚ 30.439'	81˚ 36.360'	11.3 ± 0.1	50	43 ± 8
W. of Marker 26 (A359)	24˚ 29.988'	81˚ 37.319'	10.5 ± 0.2	115	103 ±13
West of W. Dry Rocks (C101)	24˚ 26.608'	81˚ 56.634'	10.6 ± 0.2	40	33 ± 8
FKNMS Reference Area Total (54)			10.2 ± 0.2	66 ± 4	54 ± 3
FKNMS No-take Zones					
Carysfort Reef (C212)**	25˚ 13.802'	80˚ 12.135'	10.5 ± 0.2	70	60 ± 10
SE of Carysfort Light (C210) **	25˚ 13.087'	80˚ 12.453'	10.5 ± 0.3	50	48 ± 3
East of S. Carysfort Reef (C211) **	25˚ 12.724'	80˚ 12.644'	10.1 ± 0.2	38	35 ± 3
SE of S. Carysfort Reef (C209) **	25˚ 12.194'	80˚ 13.078'	12.0 ± 0.2	70	55 ± 15
Molasses Reef (C187) **	25˚ 01.008'	80˚ 22.069'	10.3 ± 0.3	50	45 ± 5
Molasses Reef (A430) **	25˚ 00.890'	80˚ 22.101'	10.1 ± 0.4	65	55 ± 10
Conch Reef SPA (S415) **	24˚ 57.337'	80˚ 27.368'	12.0 ± 0.2	60	54 ± 6
Conch Reef RO (S438) **	24˚ 57.180'	80˚ 27.471'	17.1 ± 0.3	60	60 ± 0
Conch Reef SPA (C207) **	24˚ 57.263'	80˚ 27.195'	10.5 ± 0.3	110	88 ± 23
Conch Reef RO (S439) **	24˚ 56.989'	80˚ 27.375'	14.8 ± 0.3	75	68 ± 8
Davis Reef SPA (C208) **	24˚ 55.353'	80˚ 30.229'	11.3 ± 0.2	50	48 ± 3
Davis Reef SPA (S416) **	24˚ 55.280'	80˚ 30.269'	12.8 ± 0.2	49	46 ± 4
Alligator Reef SPA (C179) **	24˚ 51.045'	80˚ 36.953'	7.2 ± 0.2	40	30 ± 10
Alligator Reef SPA (C178) **	24˚ 50.283'	80˚ 37.175'	9.8 ± 0.1	35	35 ± 0
Tennessee Reef RO (C205) **	24˚ 46.027'	80˚ 45.010'	9.4 ± 0.2	50	40 ± 10
Tennessee Reef RO (S414) **	24˚ 45.872'	80˚ 45.344'	8.5 ± 0.3	26	25 ± 2
Eastern Sambo RO (A431) **	24˚ 29.500'	81˚ 39.591'	8.9 ± 0.3	70	63 ± 8
Eastern Sambo RO (C188) **	24˚ 29.443'	81˚ 39.851'	8.4 ± 0.3	80	65 ± 15
Western Sambo ER (C201) **	24˚ 28.901'	81˚ 41.962'	11.2 ± 0.4	90	78 ± 13
Western Sambo ER (C202) **	24˚ 28.907'	81˚ 42.209'	7.8 ± 0.2	25	25 ± 0
Western Sambo ER (C200) **	24˚ 28.827'	81˚ 42.450'	10.1 ± 0.2	60	50 ± 10
Sand Key SPA (S412) **	24˚ 27.135'	81˚ 52.543'	8.5 ± 0.5	80	65 ± 15
Sand Key SPA (C204) **	24˚ 27.097'	81˚ 52.718'	8.0 ± 0.4	125	90 ± 35
FKNMS No-take Zone Total (23)			10.4 ± 0.5	62 ± 5	53 ± 4
Low-relief Spur & Groove Total (82)			**10.2 ± 0.2**	**65 ± 3**	**54 ± 2**

Table 2-3. SCUBA diving effort for benthic coral reef surveys in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS) during May-November 2012.

Scientific Diver	Affiliation*	No. of dives	Depth range (ft.)	Bottom time (hrs.)
Cody Bliss	NCRI-NSU	19	17-44	7.48
Mark Chiappone	NCRI-NSU	527	7-57	219.57
Thor Dunmire	NOAA-FKNMS	18	17-44	6.43
Paola Espitia	NCRI-NSU	53	6-48	22.68
Sarah Fangman	NOAA-GRNMS	49	9-30	24.30
Dana Fisco	NCRI-NSU	19	13-58	8.62
Jessica Joyner	NOAA-FKNMS	32	6-40	12.12
Kevin Macaulay	FWCC-FWRI	27	12-40	8.37
Karen Neely	FWCC-FWRI	42	9-42	17.23
Linh Nguyen	NOAA-FKNMS	3	20-31	1.87
Ian Rodericks	NCRI-NSU	23	13-46	10.18
Leanne Rutten	NCRI-NSU	510	7-48	217.38
Total all divers‡		1,304	7-58	549.80

‡Data do not include National Park Service divers with Biscayne National Park.

*Affiliations: NCRI/NSU = Nova Southeastern University Oceanographic Center, NOAA = National Oceanic and Atmospheric Administration, FKNMS = Florida Keys National Marine Sanctuary, GRNMS = Grays Reef National Marine Sanctuary, FWCC-FWRI = Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute (Marathon Lab).

III. Distribution and Abundance of *Acropora* Corals

Background

The declines in abundance of two of the principal Caribbean reef-building corals, staghorn coral (*Acropora cervicornis*) and elkhorn coral (*A. palmata*), are often-cited examples of the changes that have occurred on wider Caribbean reefs, including the Florida Keys, during the past several decades (Bruckner 2002; Gardner et al. 2003). The causes of these declines, which began in the late 1970s, include regional phenomena such as coral bleaching and diseases, especially white band disease (Gladfelter 1982; Aronson and Precht 2001), as well as more localized effects from tropical storms, cold fronts, and predation by corallivorous snails, fireworms, and damselfishes (Miller et al. 2002). Both corals were under consideration for addition to the U.S. Endangered Species List (ESA) in the early 1990s and were formally listed as "threatened" under the ESA in 2006, based upon range-wide population declines and lack of recovery (*Acropora* Biological Review Team 2005). Most recently, both *Acropora* species were under consideration for re-classification from "threatened" to "endangered" (Brainard et al. 2011).

Populations of both *Acropora* species remain well-below historical levels in the wider Caribbean, including the Florida Keys (Dustan and Halas 1987; Porter and Meier 1992). Moreover, localized and regional stressors remain a threat and may inhibit population recovery (*Acropora* Biological Review Team 2005; Brainard et al. 2011). Monitoring by our program addresses both the potential for further population decline, as well as the potential for recovery, should it occur. We specifically collect data on habitat distribution, colony size, and density, in order to calculate abundance estimates for both species. Using a stratified random sampling design, the goals of the 2012 surveys were to continue our long-term monitoring throughout the Florida Keys from northern Biscayne National Park (BNP) to the Western dry Rocks area southwest of Key West. The 2012 data were used to update population abundance estimates by habitat, management zone, and size class, the results of which, including time-series for both species, were published in response to NOAA's consideration for re-classifying both *Acropora* species under the ESA (Miller et al. 2013).

Acropora Survey Methods

An updated version of our field protocol manual was completed in December 2011 and provides further details on our benthic survey methods, including *Acropora* corals (Miller et al 2011). Briefly, the field methodology for assessing *Acropora* corals during 2012 consisted of the following:

- Two replicate 15-m x 1-m (15-m^2) belts transects were surveyed per site for *Acropora* corals, which were sampled for presence-absence, transect frequency of occurrence, colony numbers, colony sizes, and condition by species.
- *Acropora* colonies were assessed at both the skeletal unit and physiologic unit levels, as described below, for numbers, sizes, and condition.

Each *Acropora* colony that was encountered was assessed in two ways: 1) dimensions (maximum branch diameter, secondary branch diameter, and maximum height), percent live tissue vs. dead skeleton, and condition of "skeletal" colonies, defined as continuous skeleton, regardless of whether or not the colony was partitioned into several individual patches of continuous live tissue; and 2) overall dimensions (maximum branch diameter, secondary branch diameter, and maximum height) and condition of "physiologic" colonies, defined as individual patches of continuous live tissue that are contained within a skeletal unit. For example, if an *Acropora cervicornis* colony was encountered and consisted of two patches of live tissue on one larger skeletal unit, the following measurements were made:

- One skeletal unit assessment of colony size , percent dead tissue, and colony condition; and
- Two physiologic unit assessments of overall colony size, percent dead tissue, and colony condition.

The summary data reported below emphasize density and abundance estimates of skeletal colonies by habitat and management zone. The reason we take both skeletal and physiologic measurements is because they provide an estimate of population condition, related potentially to fragmentation and the relative proportion of ramets and genets.

Each coral colony encountered within transects was also assessed for condition. Any colonies with lighter tissue coloration than normal were assessed for bleaching. Partially pale and pale colonies were not included in the bleaching data analyses, although their condition was recorded. Only disease conditions that were actively causing tissue death or lesions on a colony were recorded. If a colony showed signs of a disease that could not be clearly identified, the condition was recorded as unknown disease. If a colony contained patches of necrotic issue with no identifiable cause, it was recorded as necrosis. Overgrowth of *Acropora* coral tissue by another organism (e.g. algae, sponges, gorgonians, *Palythoa*, and other corals) was noted only if overgrowth by the organism was clearly causing lesions or tissue death. Overgrowth of

organisms onto dead portions of a colony was not recorded, nor was overgrowth or shading of live tissue with no resulting lesions or tissue death.

Physical impacts, such a sediment scour, contact with other organisms, and fishing gear damage (e.g. trap rope abrasion) were recorded as abrasion. The presence of boring sponges such as *Cliona delitrix* was recorded if a sponge was actively causing *Acropora* tissue death lesions, but was not recorded if a sponge was only visible on dead portions of a colony. The presence of damselfish nests or gardens was recorded whenever they were found adjacent to, or surrounded by, live tissue. Likewise, fish bites/scrapes were only recorded if they were found on live tissue. Whenever gastropods such as *Coralliophila* were observed on an *Acropora* colony, the identity and total length of each individual was noted, regardless of whether the gastropods were actively feeding on live coral tissue. However, only gastropods actively feeding on live coral tissue were recorded as a mortality condition. Apparent gastropod feeding scars with no gastropods present was recorded as unknown mortality. Any tissue death that could not be attributed to disease, abrasion, boring sponges, or predation was also recorded as unknown mortality.

Statistical analyses

A two-stage sampling design following Cochran (1977) and Smith et al. (2011) was employed. Using this two-stage design, 200-m by 200-m grid cells on bathymetry and benthic habitat maps of the Florida Keys are used to help allocate targeted coral reef and hard-bottom habitats. Grid cells are designated as primary sample units (sites), while second-stage sample units (stations) for *Acropora* corals are defined as 15-m x 1-m belt transects; two stations were sampled (i.e., 30 m^2) at each site. *Acropora* coral colony density and abundance calculations were based upon the number of corals recorded within the stations (i.e. within each of the 15-m x 1-m belt transects). First, *Acropora* coral densities (no. colonies per m^2) were calculated for each station. Next, mean *Acropora* coral densities and variances were calculated for each site, using the *Acropora* coral densities for each species from the two stations. The mean site-level coral densities and variances were then used to calculate mean stratum-level (habitat, management zones, and habitat by management zone) coral densities and variances. Finally, stratum-level and domain abundance estimates were calculated based upon the stratum-level *Acropora* coral densities and variances, as well as the proportional areas of each stratum within the domain (Smith et al. 2011).

2012 *Acropora* Survey Results

Staghorn coral (*Acropora cervicornis*)

A total of 600 sites (1,200 belt transects 15-m x 1-m in dimension) were surveyed for *Acropora* corals during 2012. Staghorn coral (*A. cervicornis*) (Figure 3-1) was encountered at 18.7% of all sites and 9.1% of all sampled belt transects. Staghorn coral was found in seven of the ten sampled hard-bottom and coral reef habitat types (Table 3-1). Figures 3-2 to 3-8 show the spatial distribution of presence-absence and colony densities (skeletal colonies) for the Florida Keys study area. Evident from the spatial distribution of colonies are the relatively greater densities on patch reef, inner line reef tract (e.g. Turtle Rocks area), and shallow (< 6 m) hard-bottom habitats. Site presence, transect frequency, and mean densities were greatest on inner line reef tract, shallow hard-bottom, offshore patch reef, and mid-channel patch reef habitats (Table 3-1). The average size of skeletal colonies was also similar (30-37 cm max. diameter) among these habitats, as well as the average percent mortality of skeletal colonies (Table 3-1). Historically, staghorn coral occurred on some deeper fore-reef areas (especially low-relief spur and groove) in larger fingers of interlocking colonies, but no such thickets have been encountered during the past decade. In fact, surveys of 82 low-relief spur and groove sites during 2012 from south of Fowey Rocks in BNP to Sand Key offshore of Key West yielded only two (2) skeletal colonies of *A. cervicornis*. Comparisons of staghorn coral densities between FKNMS no-take zones and reference areas are summarized for skeletal colonies in Table 3-1 and were generally greater outside of FKNMS no-take zones. This could be due to an area effect, in that the FKNMS no-take zones represent a relatively small (< 2%) area of available habitat from northern BNP to Key West.

Staghorn coral colonies were measured at the both skeletal (continuous skeleton) and physiologic levels (live tissue patches). Examples of live tissue patches include branches separated from the larger colony by dead tissue, or patches surrounded by dead tissue that could represent either remnant survival or recruitment of a new colony (genet) onto previously dead skeleton. A total of 352 skeletal colonies and 938 physiologic colonies were counted, measured, and assessed for condition; these values indicate that, on average, a given staghorn skeletal colony consisted of two or three physiologic fragments or patches of contiguous tissue. Figure 3.9 shows the overall size distribution of *Acropora cervicornis* skeletal and physiologic colonies measured during 2012. The mean size (maximum diameter) of skeletal colonies was 27.7 cm and ranged from 1 to 144 cm, while the mean physiologic colony size was 12.7 cm and ranged from 1 to 144 cm. A noteworthy result is that 85% of the sampled staghorn corals were < 50 cm in maximum diameter and only about 4% of the skeletal colonies were larger than 70 cm. At the level of physiologic colonies (i.e., live tissue patches), 99% of the sampled staghorn corals were < 50 cm in maximum diameter (Figure 3-9).

Population abundance estimates (total numbers of colonies) of *Acropora cervicornis* were computed for skeletal colonies by habitat type and management zone (Table 3-2). These estimates take into consideration the density of colonies and the areas of the habitat types and management zones sampled. Population abundance estimates (± 95% confidence intervals) for skeletal colonies by habitat type indicate that there are ~8.5 million ± 6.6 million skeletal colonies from northern BNP to the Western Dry Rocks area for the habitats and depth range (< 15 m) sampled. The high degree of variability in these estimates reflects the patchy distribution of staghorn coral (Figures 3-2 to 3-8). In stark contrast to the pattern evident for *Acropora palmata* (see below), 98% of the staghorn corals present in the Florida Keys occur outside of Sanctuary no-take zones (ERs, SPAs, and ROs). In addition, about 73% are found on mid-channel and offshore patch reefs and another 17% on shallow hard-bottom (Table 3-2).

Elkhorn coral (*Acropora palmata*)

Elkhorn coral (*A. palmata*) (Figure 3-10) was encountered at 2.8% of all sites and 0.9% of all sampled belt transects. Similar to previous years, elkhorn coral was only found on high-relief spur and groove, to a lesser extent on inner line reef tract, and on one offshore patch reef (Table 3-3). In previous years, we have encountered a few isolated colonies on back-reef rubble and shallow hard-bottom. Figures 3-11 to 3-17 illustrate the spatial distribution of presence-absence and skeletal colony densities for the Florida Keys study area. Evident from the spatial distribution of elkhorn coral is the importance of the shallow platform margin, as well as the concentration of colonies in several FKNMS no-take zones. In the high-relief spur and groove habitat, elkhorn coral was present at 19% of all sites and 7% of all transects (Table 3-3). Several shallow spur and groove reefs continue to support thickets of elkhorn corals, with most patches approximately 15-m to 20-m in diameter. The following reef areas, listed from north to south, are known locations where stands (not just isolated colonies) of elkhorn coral are found in the Florida Keys:

- South Carysfort Reef,
- Elbow Reef,
- Horseshoe Reef,
- Grecian Rocks,
- French Reef,
- Sand Island,
- Molasses Reef,
- Sombrero Reef, and
- Looe Key.

Comparisons of elkhorn coral distribution and density between FKNMS no-take zones and reference areas for the high-relief spur and groove indicate that no-take zones encompass most of the remaining high-density areas of elkhorn coral.

Elkhorn coral colonies were measured at the both skeletal (continuous skeleton) and physiologic levels (live tissue patches). A total of 42 skeletal colonies and 139 physiologic colonies were counted, measured, and assessed for condition. Like staghorn coral, these values indicate that, on average, a given elkhorn skeletal colony consisted of three physiologic colonies or patches of contiguous tissue. Mean density (no. per m^2), average size, and average percent mortality of elkhorn corals at the skeletal level is shown in Table 3-3. The 42 skeletal colonies ranged in maximum diameter from 5 to 278 cm and averaged (± 1 SE) 57 ± 10 cm (Figure 3-18). The size distribution of skeletal colonies reflected a mixture of various size classes, including both small (< 20 cm) and larger colonies (> 90 cm). Approximately 61% of the sampled skeletal colonies were less than 50 cm in maximum diameter. However, approximately 12% were larger than 90 cm. The size distribution of elkhorn coral physiologic colonies based upon live tissue surface area also illustrated a large range of colony sizes (Figure 3-19). The 139 physiologic colonies ranged in maximum diameter from 2 to 190 cm and averaged 27 ± 3 cm.

Calculating population abundance estimates (total numbers of colonies) for *Acropora palmata* presents several challenges: 1) the species has a limited distribution, with nearly 90% of the population present in the high-relief spur and groove habitat and specifically within Sanctuary no-take zones with this habitat type; 2) within these spur and groove habitats in the no-take zones, when the species is present, it is primarily found at the shallower end of the depth range for the habitat type; and 3) when present, it often grows in relatively well-defined thickets or stands in sufficient abundance that it is difficult to identify individual colonies. Therefore, extrapolating density measurements to obtain population estimates is not straight forward and results typically include large variance terms. An additional element that impacts population estimates for a species with patchy distribution, such as *A. palmata*, is the random assignment of primary sample units. For example, within the 600 sites we randomly sampled in 2012 were eight sites considered to be "hotspots" for *A. palmata*, or "remnant" patches of high density. Population abundance estimates by habitat and management zone from the 2012 surveys reflect this sampling challenge (Table 3-4). A noteworthy result is that, relative to staghorn corals, there are two orders of magnitude fewer elkhorn corals in the Florida Keys. Of the estimate population numbers, about 56% are within FKNMS no-take zones. In addition, the majority are found on *Acropora* reefs along the inner reef line (i.e.,

between Grecian Rocks and Turtle Rocks) and the outer platform margin (i.e. between Fowey Rocks and Western Dry Rocks).

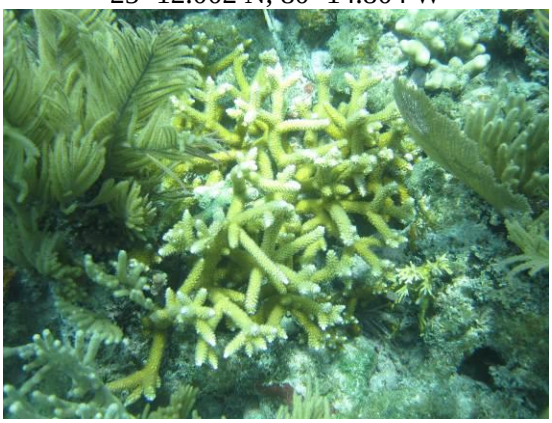
Discussion

Results from the 2012 sampling effort add to a growing spatial and temporal data set on the status and trends in Florida Keys *Acropora palmata* and *A. cervicornis* populations. Our earlier Keys-wide sampling in previous years was not optimized for *Acropora* corals, but was instead optimized for a few of the most abundant species (e.g. *Montastraea cavernosa*, *Porites astreoides*, and *Siderastrea siderea*, see Smith et al. 2011). However, the benthic data still provide important opportunities to compare populations across multiple habitat types, including managed areas in the FKNMS. What is apparent from the *Acropora* surveys is that the distribution and abundance patterns of these two species are significantly different. Most of the high-relief spur and groove reefs in the Florida Keys were sampled during 2012 and the results for elkhorn coral indicate that significant stands remain at only a handful of sites. We are aware of several significant stands of *A. palmata* in BNP, but these were not encountered in the course of our randomized surveys. Although many of the reefs with existing *A. palmata* are already within existing FKNMS no-take zones, predation by snails and damselfishes is still prevalent. In contrast, the distribution pattern of *A. cervicornis* reflects the importance of patch reefs and shallow hard-bottom to the possible recovery and maintenance of this species. The absence of staghorn corals in fore-reef habitats, where they were previously abundant, suggests that recovery has not begun. Still, it is reasonable to suggest that for staghorn corals the remaining population appears relatively stable, at least for the last ten years (Miller et al. 2013). The large number of small colonies compared to large colonies and the absence of these corals in fore-reef habitats is a concern. Further, their abundance on patch reefs, with over 5000 in the Florida Keys, is both good news and bad news. The good news is that patch reefs are abundant. The bad news is that many of them are located close to shore and are susceptible to stress caused by cold-water, such as the January 2010 event. The situation for elkhorn coral is more problematic, since population numbers are much smaller and aggregations are confined mostly to one habitat type. Finally, the mismatch between the distribution and abundance of staghorn corals and the location of no-take-zones in the Florida Keys is noteworthy. Whether or not no-take-zones might provide meaningful protection to *A. cervicornis* is uncertain, and remains a major topic of ongoing research and management interest.

Figure 3-1. Examples of staghorn corals (*Acropora cervicornis*) observed in hard-bottom and coral reef habitats in the Florida Keys during May-November 2012.

Mid-channel patch reef, 3.0-4.3 m
Turtle Rocks
25° 17.477 N, 80° 13.624 W

Offshore patch reef, 2.7-3.4 m
North of Watsons Reef
25° 12.002 N, 80° 14.804 W



Offshore patch reef, 9.8-10.4 m
Watsons Reef
25° 09.727 N, 80° 15.512 W

Inner line reef tract, 3.4-5.8 m
Turtle Reef
25° 17.603 N, 80° 13.258 W

Inner line reef tract, 4.6-6.1 m
North of Horseshoe Reef
25° 08.648 N, 80° 17.657 W

Low-relief hard-bottom, 1.8-2.4 m
Conch Reef
24° 57.663 N, 80° 27.420 W

Figure 3-2. Densities (no. skeletal colonies per m^2) of staghorn corals (*Acropora cervicornis*) in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

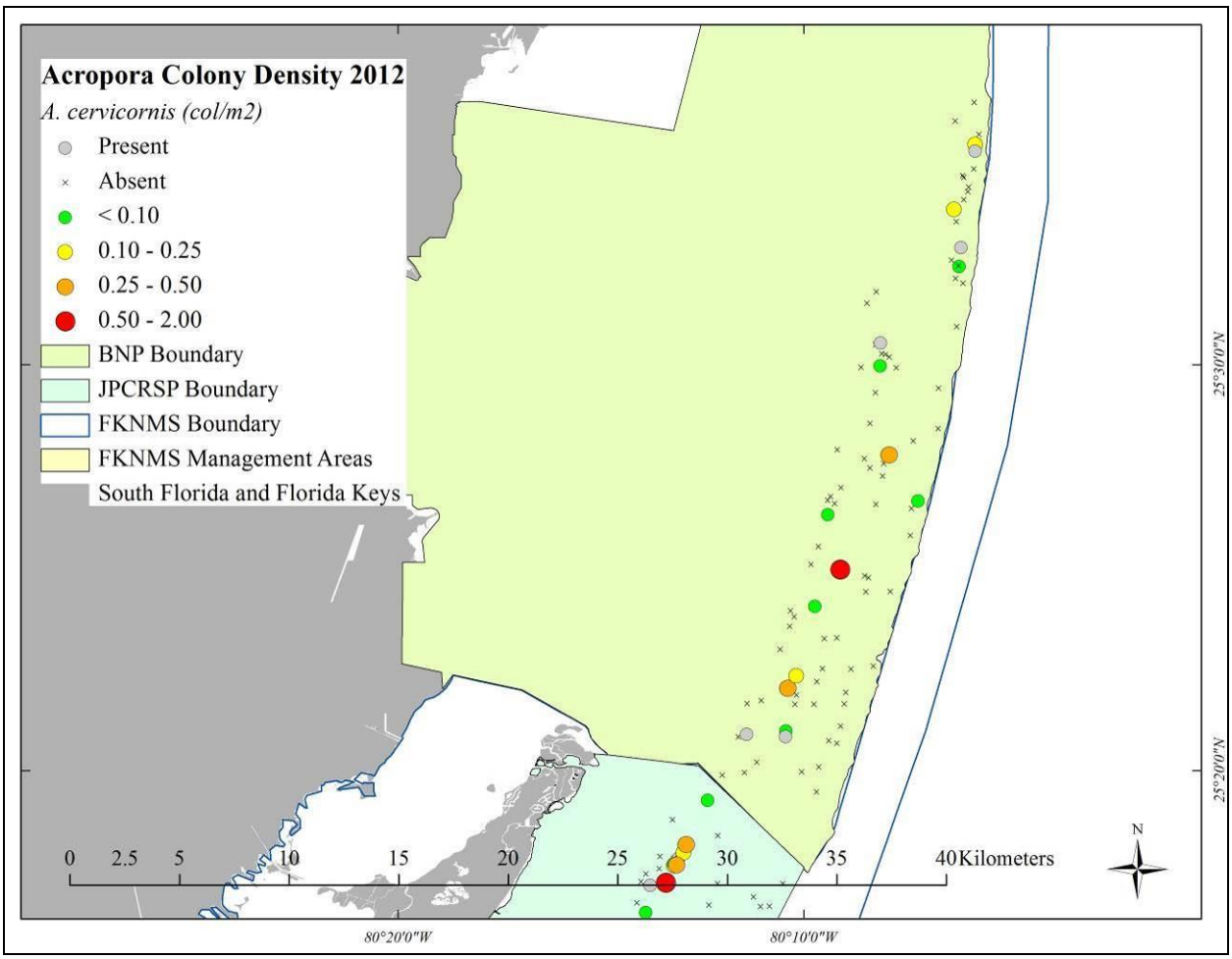


Figure 3-3. Densities (no. skeletal colonies per m^2) of all staghorn corals (*Acropora cervicornis*) in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

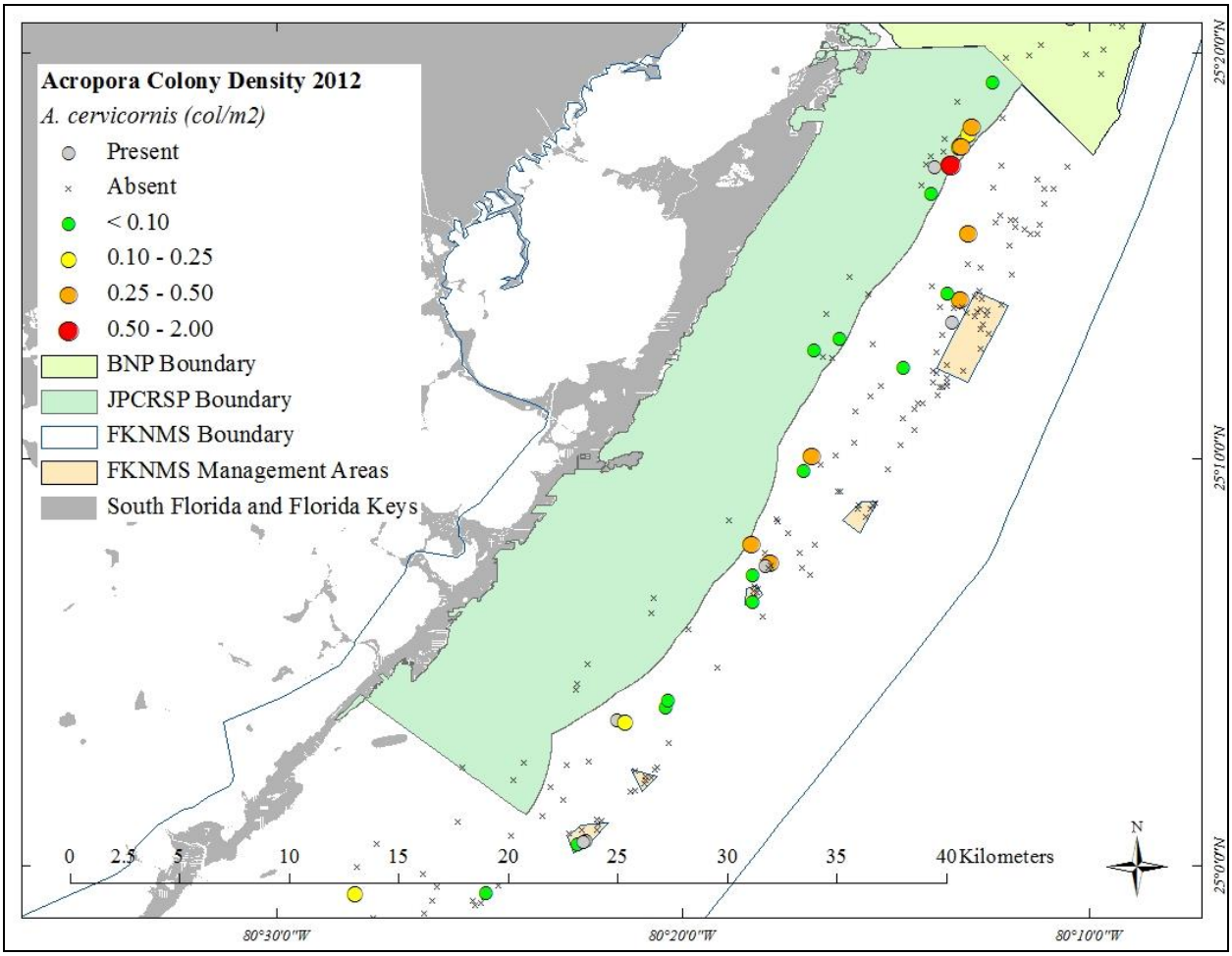


Figure 3-4. Densities (no. skeletal colonies per m^2) of staghorn corals (*Acropora cervicornis*) in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

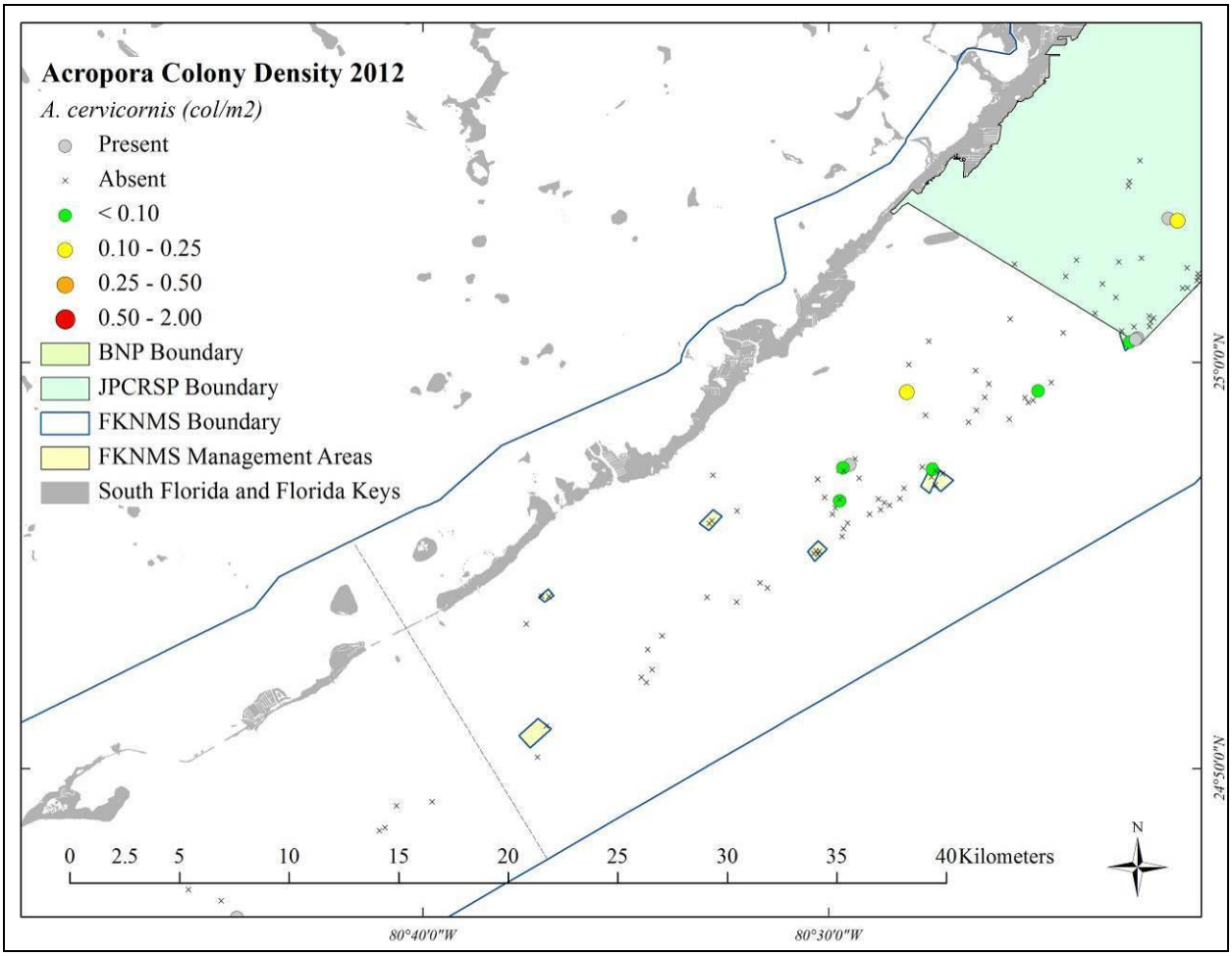


Figure 3-5. Densities (no. skeletal colonies per m^2) of staghorn corals (*Acropora cervicornis*) in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

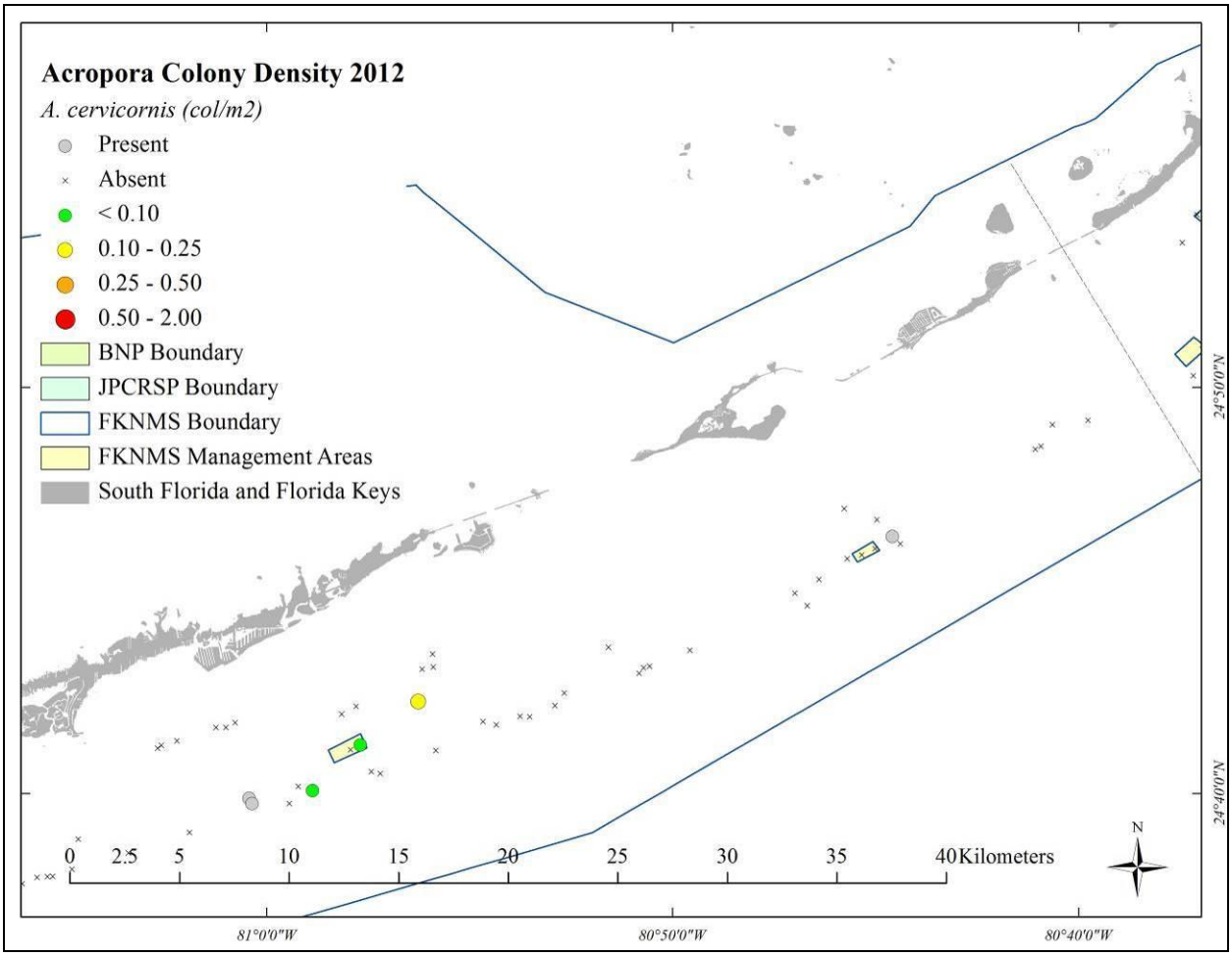


Figure 3-6. Densities (no. skeletal colonies per m^2) of staghorn corals (*Acropora cervicornis*) in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

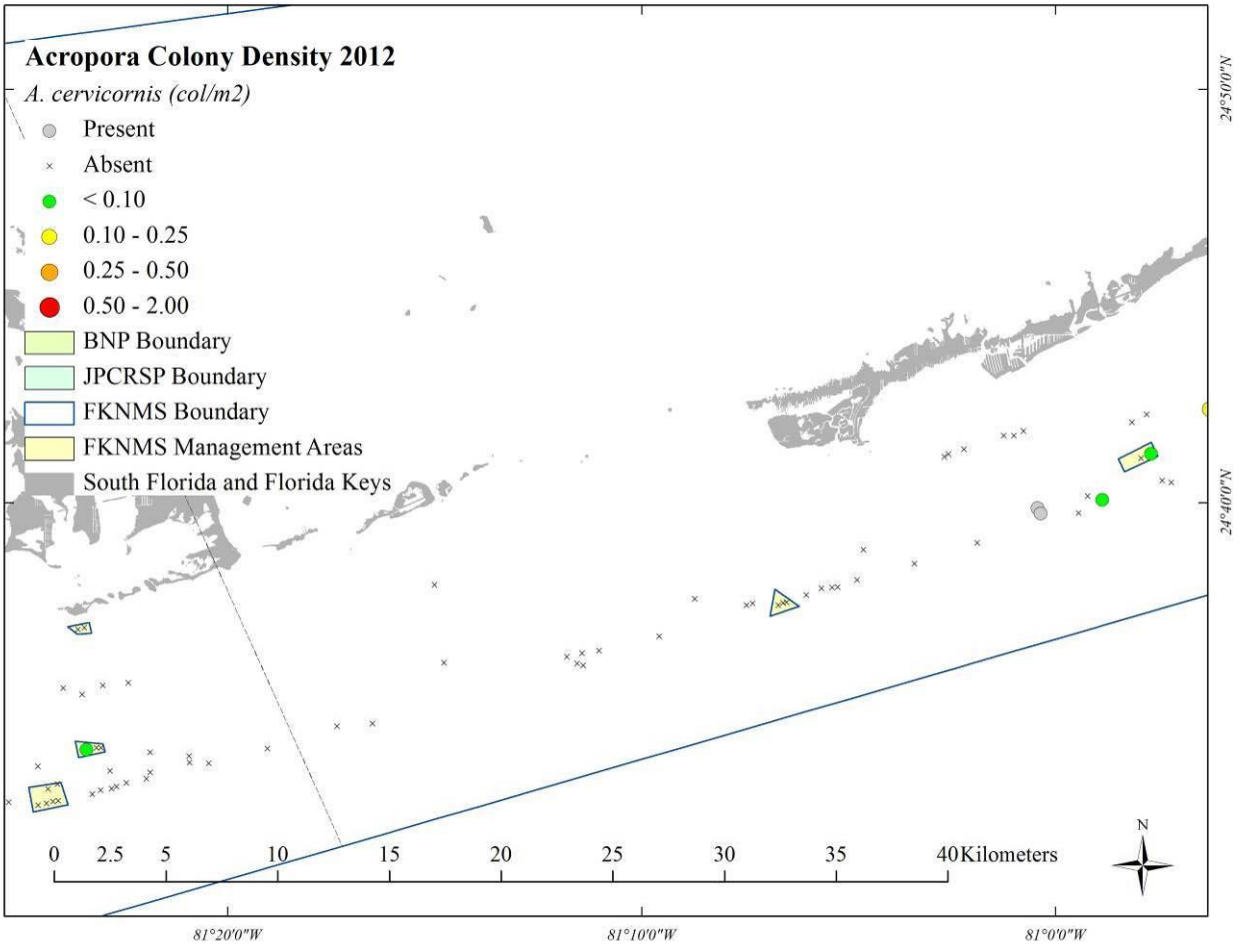


Figure 3-7. Densities (no. skeletal colonies per m^2) of staghorn corals (*Acropora cervicornis*) in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

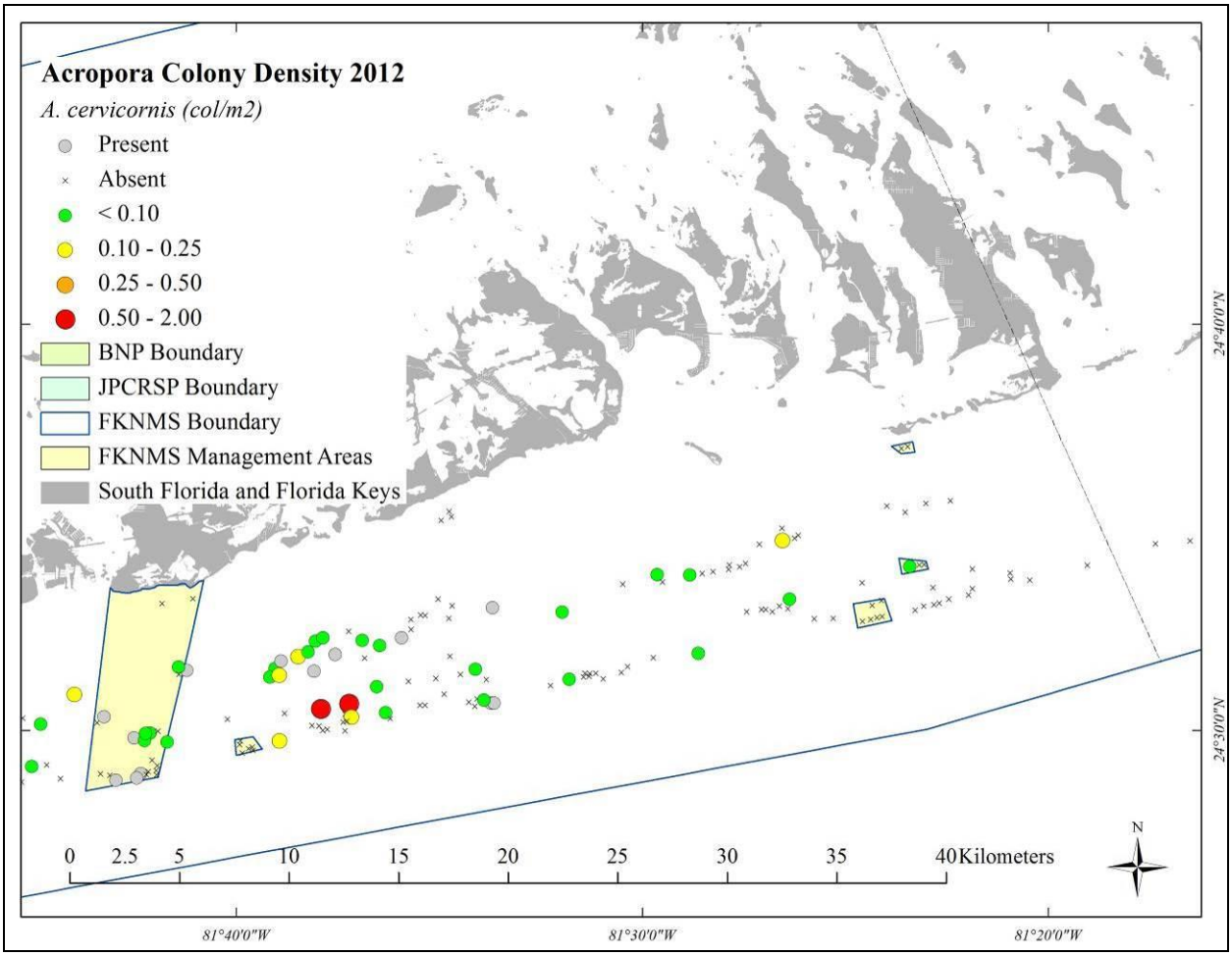


Figure 3-8. Densities (no. skeletal colonies per m^2) of staghorn corals (*Acropora cervicornis*) in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

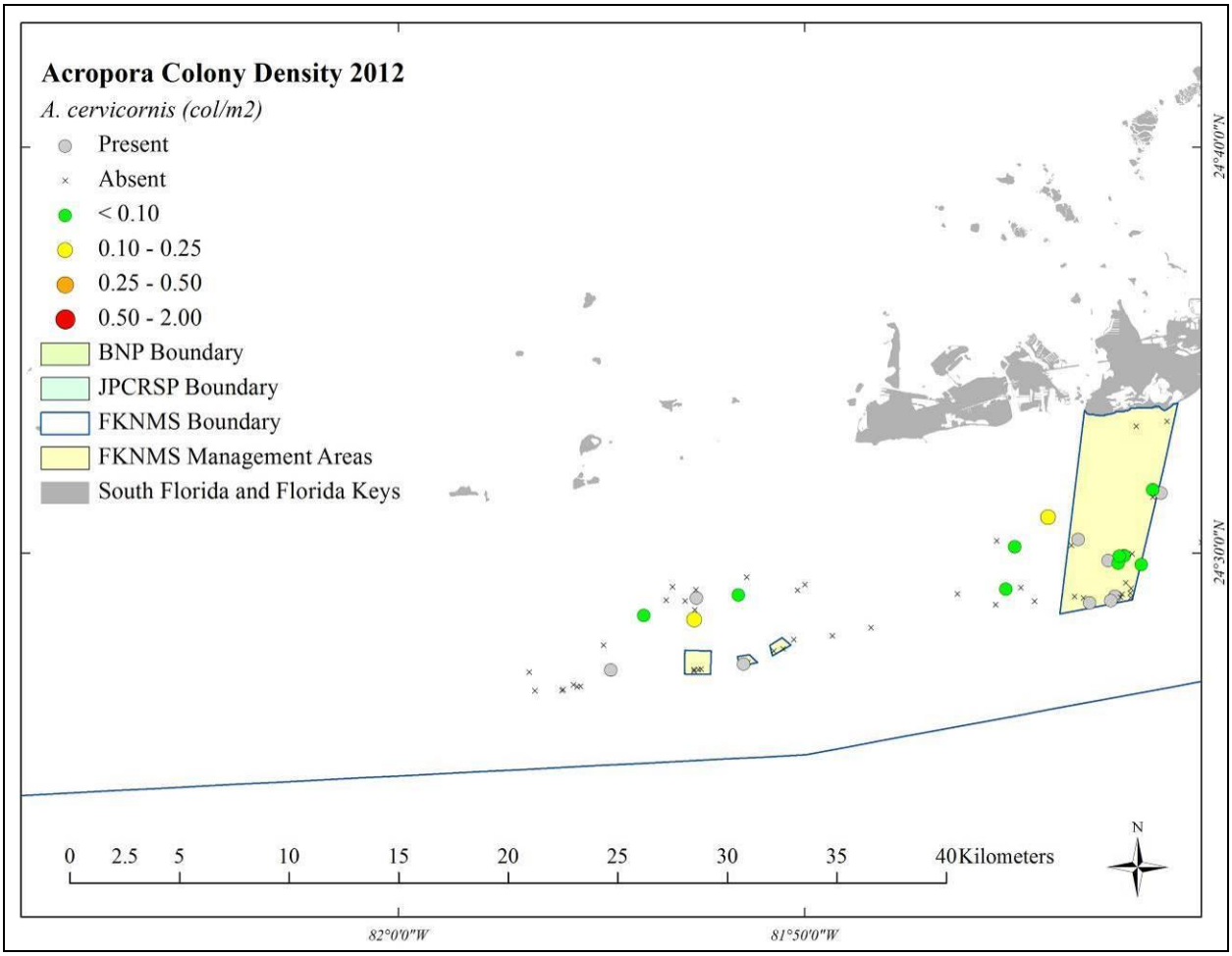


Figure 3-9. Size distribution of staghorn corals (*Acropora cervicornis*) by maximum diameter of skeletal colonies (top) and physiologic colonies (bottom) in Biscayne National Park and the Florida Keys National Marine Sanctuary, as determined from two replicate belt transect surveys (15-m x 1-m) per site at 600 sites during May-November 2012. A physiologic colony was defined as a patch of contiguous live tissue, while a skeletal colony was defined as contiguous skeleton that may have contained one or more physiologic colonies. N = number of skeletal and physiologic colonies measured.

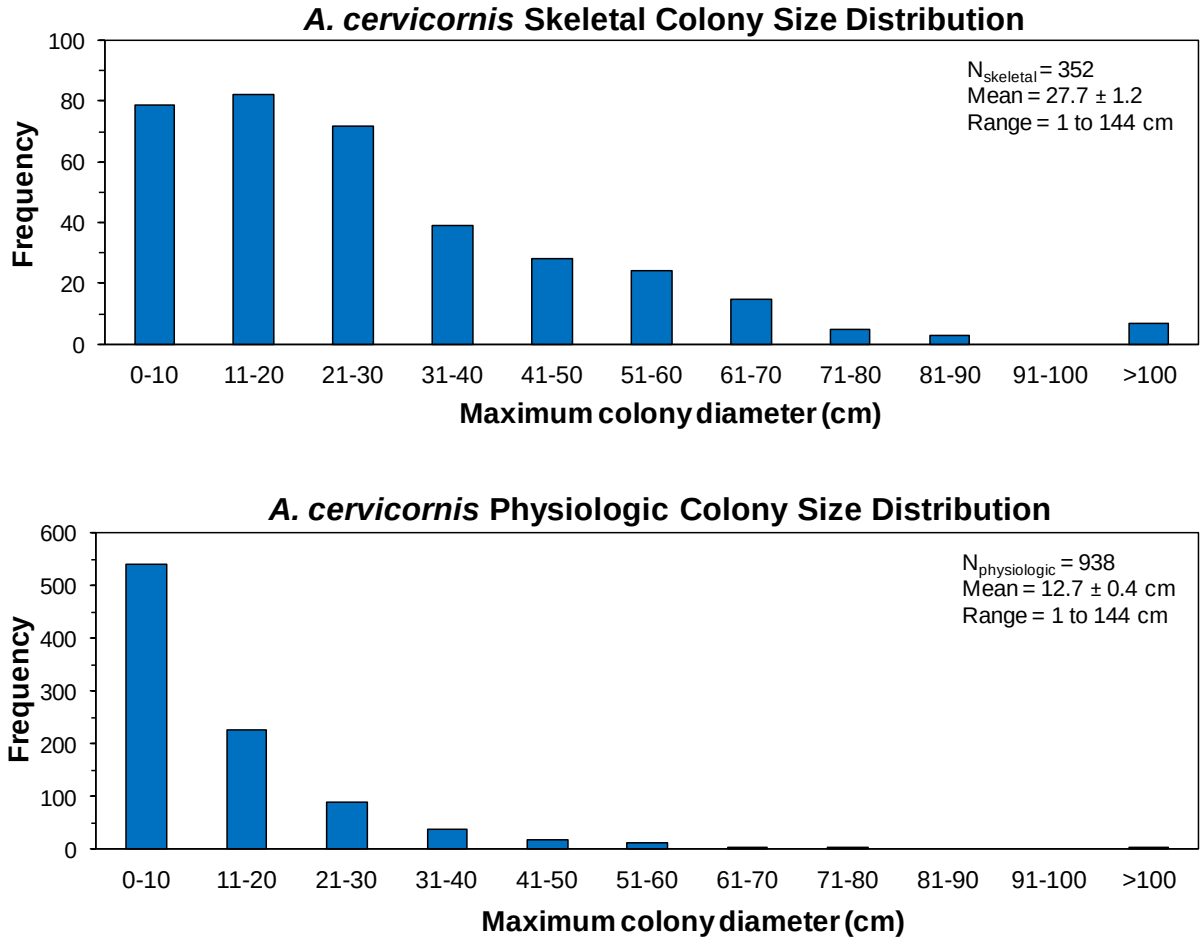


Figure 3-10. Examples of elkhorn corals (*Acropora palmata*) observed in hard-bottom and coral reef habitats in the Florida Keys during May-November 2012.

High-relief spur and groove, 1.2-3.0 m
South Carysfort Reef
25° 12.517 N, 80° 13.158 W

High-relief spur and groove, 3.4-6.1 m
Elbow Reef
25° 08.544 N, 80° 15.540 W

High-relief spur and groove, 5.2-7.0 m
Molasses Reef
25° 00.591 N, 80° 22.426 W

High-relief spur and groove, 3.0-4.9 m
Sand Island
25° 01.804 N, 80° 22.097 W

High-relief spur and groove, 4.9-8.5 m
French Reef
25° 02.026 N, 80° 20.960 W

High-relief spur and groove, 1.8-4.0 m
Grecian Rocks
25° 06.536 N, 80° 18.312 W

Figure 3-11. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

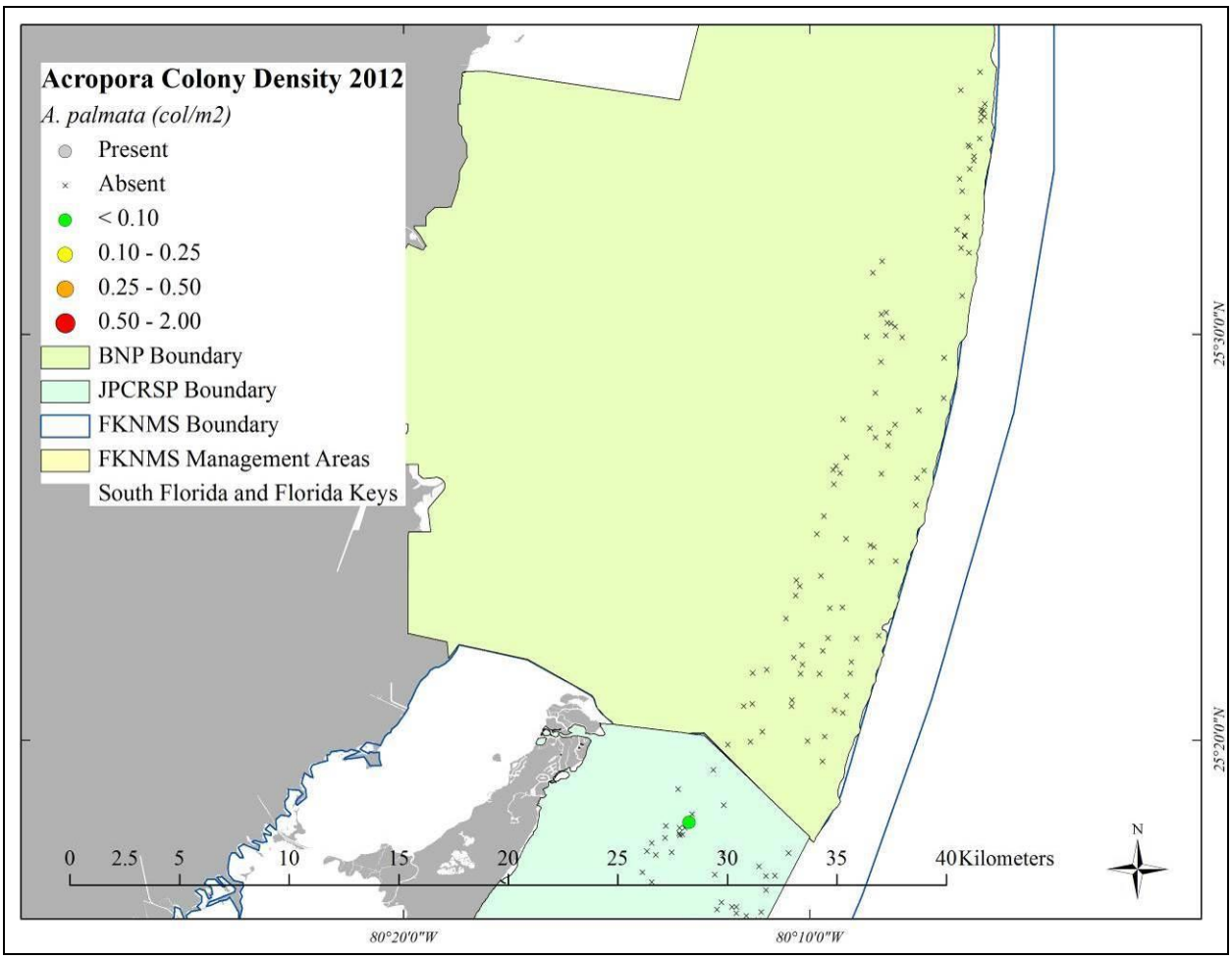


Figure 3-12. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

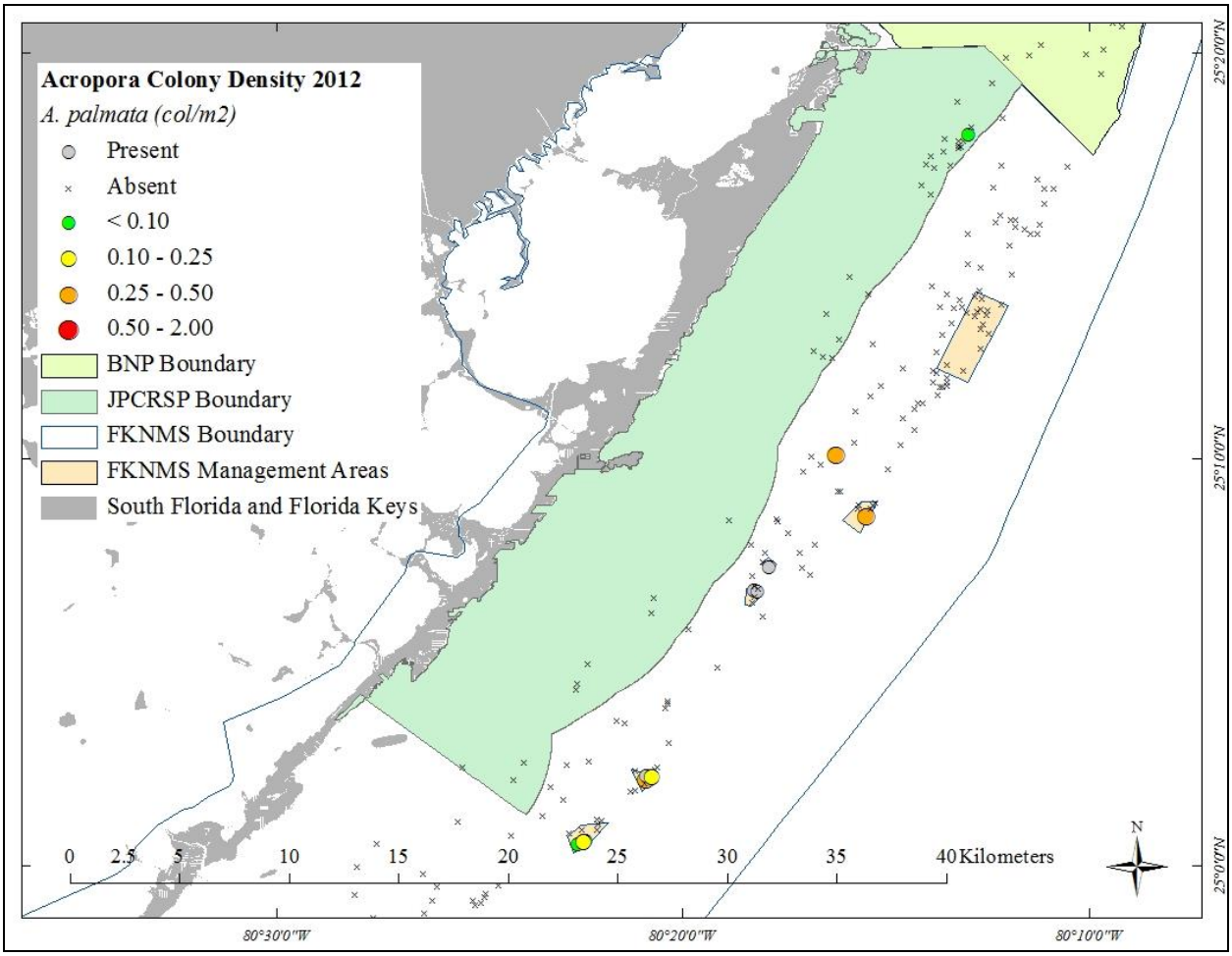


Figure 3-13. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

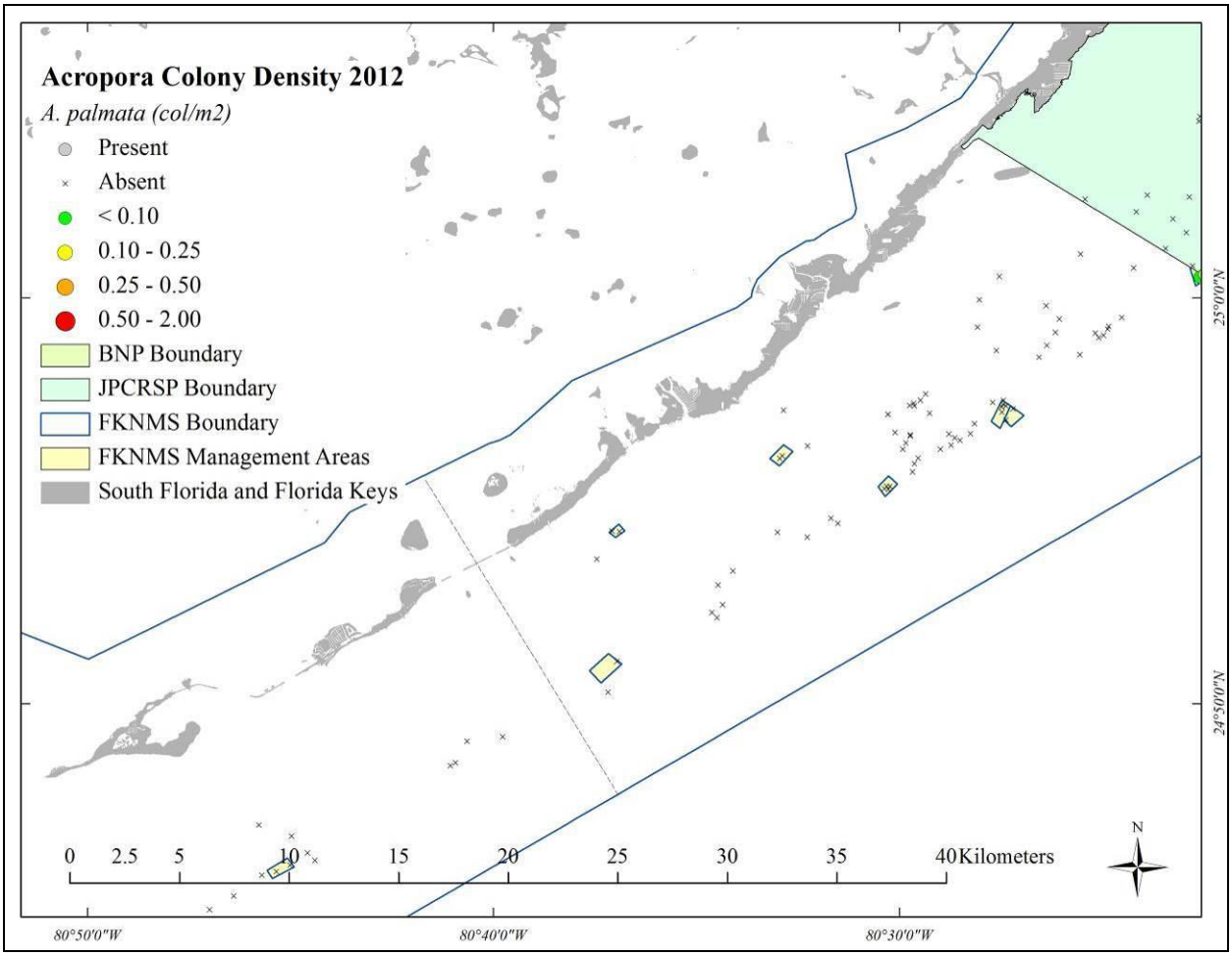


Figure 3-14. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

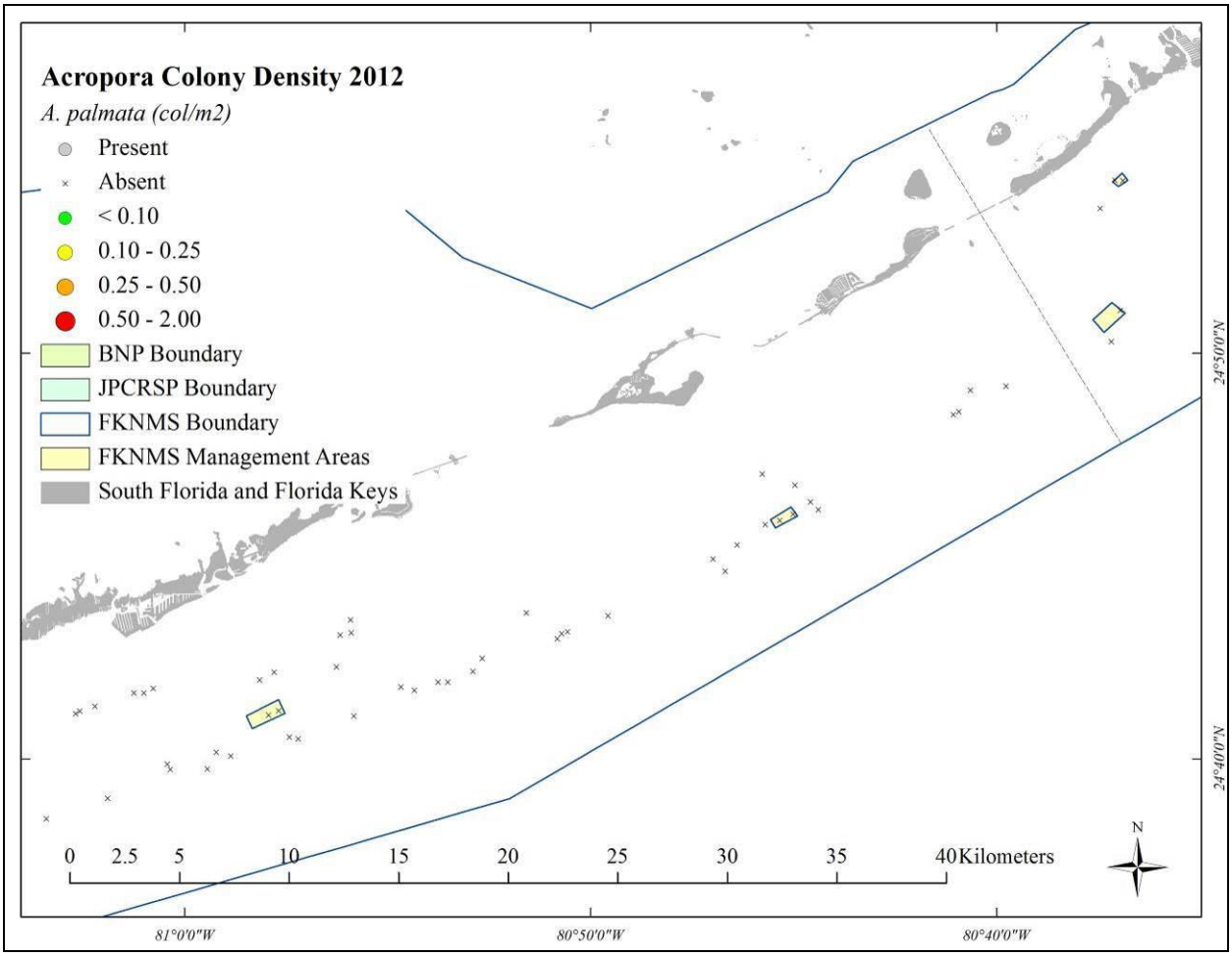


Figure 3-15. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

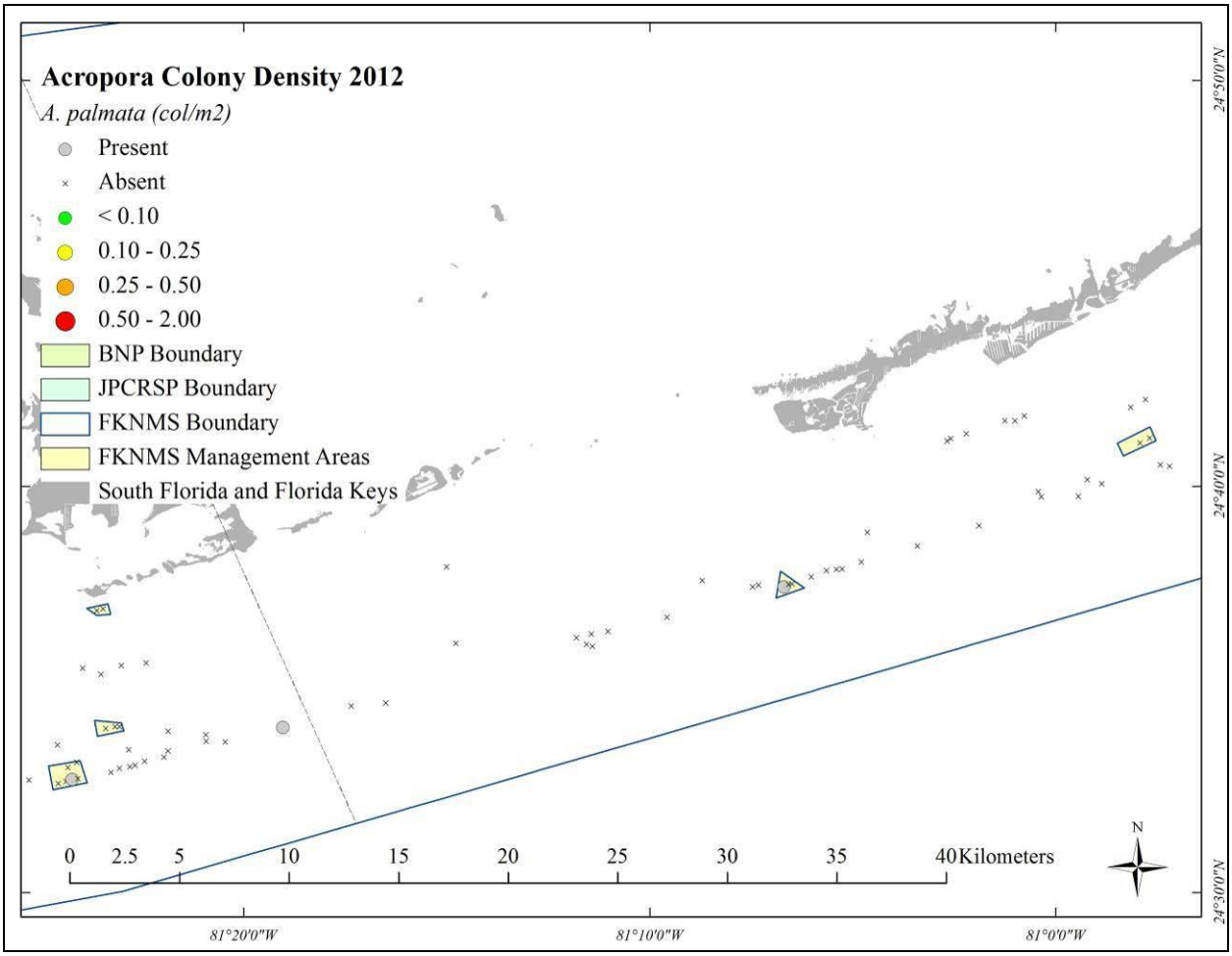


Figure 3-16. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

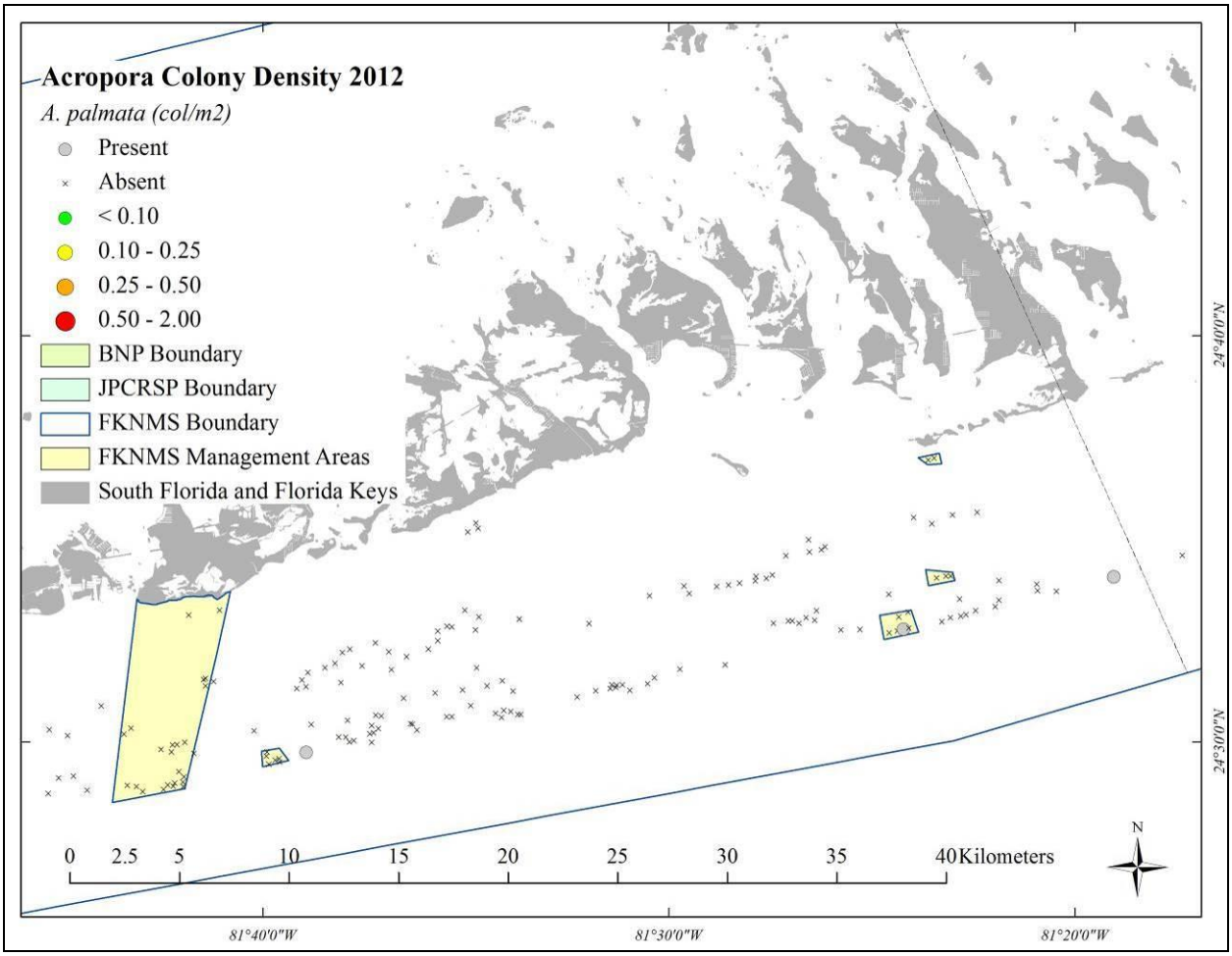


Figure 3-17. Densities (no. skeletal colonies per m^2) of elkhorn corals (*Acropora palmata*) in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary. Present: present at site, but not encountered within two replicate 15-m x 1-m belt transects at a site.

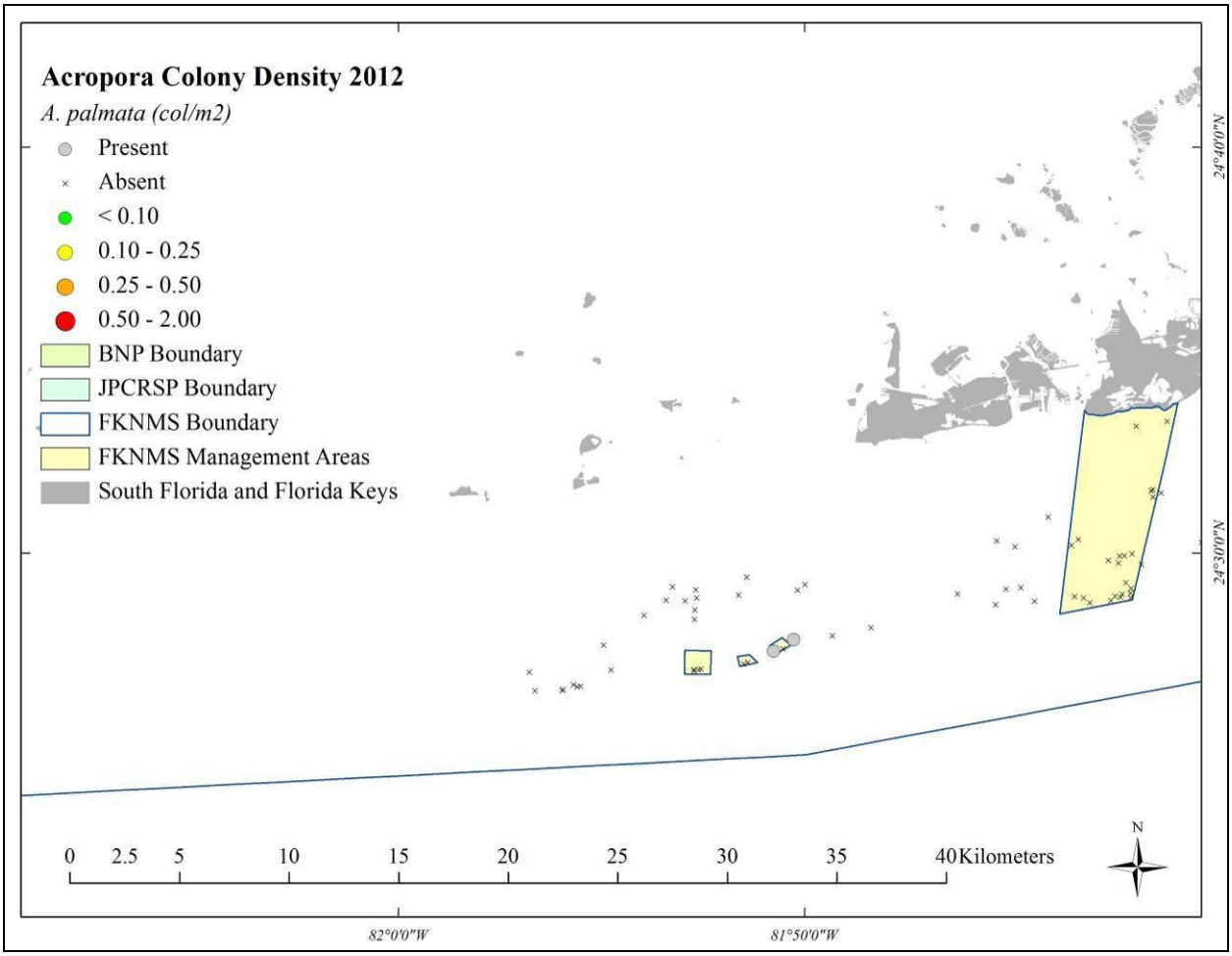


Figure 3-18. Size distribution of elkhorn corals (*Acropora palmata*) by maximum diameter of skeletal colonies (top) and physiologic colonies (bottom) in Biscayne National Park and the Florida Keys National Marine Sanctuary, as determined from two replicate belt transect surveys (15-m x 1-m) per site at 600 sites during May-November 2012. A physiologic colony was defined as a patch of contiguous live tissue, while a skeletal colony was defined as contiguous skeleton that may have contained one or more physiologic colonies. N = number of skeletal and physiologic colonies measured.

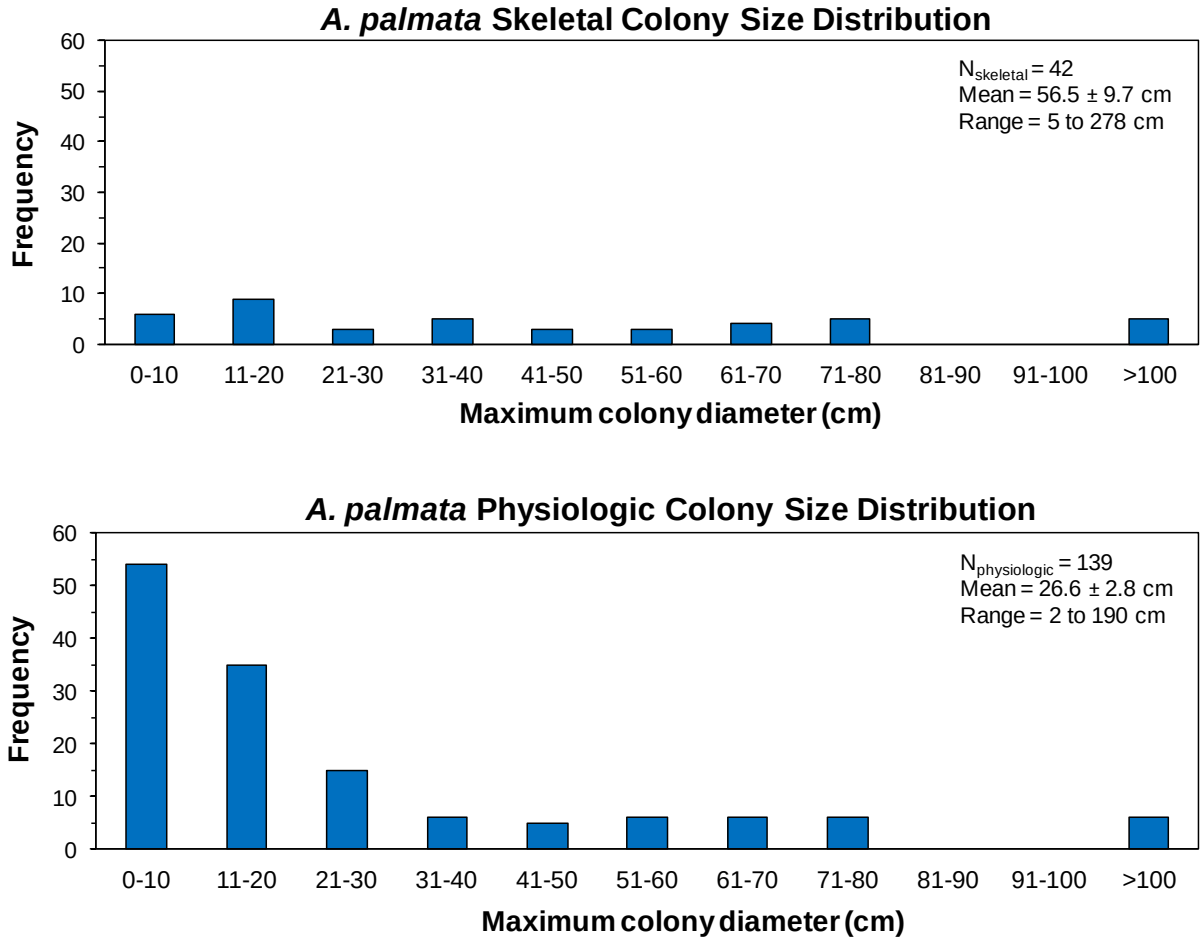


Table 3-1. Staghorn coral (*Acropora cervicornis*) mean (± 1 SE) site presence, transect frequency, density (no. skeletal colonies per m^2), size (maximum diameter), and percent (%) mortality (proportion of skeletal colony without live tissue) by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from surveys of two replicate 15-m x 1-m belt transect surveys per site at 600 sites during May-November 2012. Habitat types are arranged from inshore to offshore and FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Numbers of colonies measured is shown in parentheses for mean size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Colony density (no. per m^2)	Mean size (cm)	Mortality (%)
Inshore patch reefs					
Biscayne National Park (0)					
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		
Mid-channel patch reefs					
Biscayne National Park (52)	19.2 ± 5.5	8.7 ± 3.2	0.042 ± 0.024	41.1 ± 2.9	14 ± 2
FKNMS Reference Areas (90)	30.0 ± 4.9	14.4 ± 3.1	0.022 ± 0.007	37.0 ± 1.7	31 ± 3
FKNMS No-take Zones (11)	36.4 ± 15.2	13.6 ± 7.2	0.018 ± 0.011	24.3	28
Habitat Total (153)	26.8 ± 3.6	12.4 ± 2.2	0.029 ± 0.009	36.7 ± 1.3	26 ± 2
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (98)	27.6 ± 4.5	15.3 ± 3.1	0.038 ± 0.013	36.1 ± 2.1	33 ± 3
FKNMS No-take Zones (15)	40.0 ± 13.1	16.7 ± 7.6	0.013 ± 0.007	41.1 ± 5.3	23 ± 5
Habitat Total (122)	27.0 ± 4.0	14.3 ± 2.6	0.033 ± 0.010	36.8 ± 1.9	32 ± 2
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0		
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	66.7 ± 16.7	38.9 ± 13.5	0.089 ± 0.039	34.2 ± 5.8	6 ± 2
FKNMS No-take Zones (9)	22.2 ± 14.7	22.2 ± 10.9	0.044 ± 0.028	41.6 ± 3.0	5 ± 0
Habitat Total (18)	44.4 ± 12.1	30.6 ± 9.3	0.067 ± 0.025	36.3 ± 3.5	6 ± 1
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		
FKNMS Reference Areas (28)	7.1 ± 5.0	3.6 ± 2.5	0.010 ± 0.007	19.2	33
FKNMS No-take Zones (33)	15.2 ± 6.3	1.5 ± 1.5	0.001 ± 0.001	18.0	0
Habitat Total (62)	11.3 ± 4.1	2.4 ± 1.4	0.005 ± 0.003	18.8	22
Shallow (< 6 m) hard-bottom					
Biscayne National Park (17)	37.5 ± 12.5	17.6 ± 8.2	0.020 ± 0.010	18.6 ± 1.1	43 ± 10
FKNMS Reference Areas (23)	30.0 ± 10.5	17.4 ± 6.7	0.051 ± 0.027	38.7 ± 4.6	27 ± 3
FKNMS No-take Zones (5)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (45)	30.0 ± 7.3	15.6 ± 4.7	0.033 ± 0.014	30.7 ± 2.9	33 ± 4
Deeper (6-15 m) hard-bottom					
Biscayne National Park (5)	16.7 ± 16.7	10.0 ± 10.0	0.060 ± 0.060	16.6	26
FKNMS Reference Areas (39)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (5)	16.7 ± 16.7	10.0 ± 10.0	0.007 ± 0.007	7.0	20
Habitat Total (49)	11.1 ± 4.3	2.0 ± 1.4	0.006 ± 0.006	11.8	23

Table 3.1 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Colony density (no. per m^2)	Mean size (cm)	Mortality (%)
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (54)	7.4 ± 3.6	1.9 ± 1.3	0.001 ± 0.001	53.0	8
FKNMS No-take Zones (23)	4.3 ± 4.3	0 ± 0	0 ± 0		
Habitat Total (82)	6.1 ± 2.7	1.2 ± 0.9	0.001 ± 0.001	53.0	8

Table 3-2. Staghorn coral (*Acropora cervicornis*) population abundance estimates by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) as determined from belt transect surveys at 600 sites during May-November 2012. Low-relief hard-bottom (6-15 m) includes continuous and patchy hard-bottom, while FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Available sites (n_h) are the number of 200-m x 200-m grid cells containing a particular habitat type from northern BNP to Western Dry Rocks to 15-m depth, based upon existing habitat and bathymetry maps (e.g. FRMI 2000).

Habitat/management zone (sites sampled)	**Available sites (n_h) (% of domain)**		**No. per m^2 (mean ± 1 SE)**	**Colony abundance**	**95% CI**
Inshore patch reefs					
BNP and FKNMS reference areas (4)	387	(3.30)	0 ± 0	0	0
FKNMS no-take zones (4)	30	(0.26)	0 ± 0	0	0
Total (8)	417	(3.56)	0 ± 0	0	0
Mid-channel patch reefs					
BNP and FKNMS reference areas (142)	3,080	(26.26)	0.029 ± 0.010	3,615,475	2,379,317
FKNMS no-take zones (11)	59	(0.50)	0.018 ± 0.011	42,914	51,971
Total (153)	3,139	(26.77)	0.029 ± 0.009	3,658,390	2,431,288
Offshore patch reefs					
BNP and FKNMS reference areas (107)	1,748	(14.91)	0.035 ± 0.012	2,461,666	1,594,218
FKNMS no-take zones (15)	90	(0.77)	0.013 ± 0.007	48,006	49,735
Total (122)	1,838	(15.67)	0.033 ± 0.010	2,509,672	1,643,953
Reef rubble (< 15 m)					
BNP and FKNMS reference areas (18)	300	(2.56)	0 ± 0	0	0
FKNMS no-take zones (11)	57	(0.49)	0 ± 0	0	0
Total (29)	357	(3.04)	0 ± 0	0	0
Inner line reef tract					
BNP and FKNMS reference areas (9)	78	(0.67)	0.089 ± 0.039	277,368	253,727
FKNMS no-take zones (9)	20	(0.17)	0.044 ± 0.028	35,560	46,890
Total (18)	98	(0.84)	0.067 ± 0.025	312,928	300,618
High-relief spur and groove (< 15 m)					
BNP and FKNMS reference areas (29)	119	(1.01)	0.009 ± 0.007	43,776	68,730
FKNMS no-take zones (33)	153	(1.30)	0.001 ± 0.001	6,183	12,346
Total (62)	272	(2.32)	0.005 ± 0.003	49,958	81,077
Shallow (< 6 m) hard-bottom					
BNP and FKNMS reference areas (36)	985	(8.40)	0.038 ± 0.016	1,477,685	1,260,253
FKNMS no-take zones (4)	58	(0.49)	0 ± 0	0	0
Total (40)	1,043	(8.89)	0.033 ± 0.014	1,477,685	1,260,253
Low-relief hard-bottom (6-15 m)					
BNP and FKNMS reference areas (78)	2,307	(19.67)	0.004 ± 0.004	374,155	739,408
FKNMS no-take zones (8)	96	(0.82)	0.005 ± 0.005	18,288	39,508
Total (86)	2,403	(20.49)	0.004 ± 0.004	392,443	778,916
Low-relief spur and groove (6-15 m)					
BNP and FKNMS reference areas (59)	2,039	(17.39)	0.001 ± 0.001	92,170	127,987
FKNMS no-take zones (23)	121	(1.03)	0 ± 0	0	0
Total (82)	2,160	(18.42)	0.001 ± 0.001	92,170	127,987
All habitat types					
BNP and FKNMS reference areas (59)	11,043	(94.17)	0.023 ± 0.004	8,342,294	6,423,640
FKNMS no-take zones (23)	684	(5.83)	0.007 ± 0.003	150,951	200,451
Total (82)	11,727	(100.00)	0.020 ± 0.004	8,493,245	6,624,091

Table 3-3. Elkhorn coral (*Acropora palmata*) mean (± 1 SE) site presence, transect frequency, density (no. skeletal colonies per m^2), size (maximum diameter), and percent (%) mortality (proportion of skeletal colony without live tissue) by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from surveys of two replicate 15-m x 1-m belt transect surveys per site at 600 sites during May-November 2012. Habitat types are arranged from inshore to offshore and FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Numbers of colonies measured is shown in parentheses for mean size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Colony density (no. per m^2)	Mean size (cm)	Mortality (%)
Inshore patch reefs					
Biscayne National Park (0)					
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		
Mid-channel patch reefs					
Biscayne National Park (52)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (90)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (153)	0 ± 0	0 ± 0	0 ± 0		
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (98)	1.0 ± 1.0	1.0 ± 1.0	0.003 ± 0.003	25.8	0
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (122)	0.8 ± 0.8	0.8 ± 0.8	0.002 ± 0.002	25.8	0
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0		
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	35.0	40
FKNMS No-take Zones (9)	33.3 ± 16.7	0 ± 0	0 ± 0		
Habitat Total (18)	22.2 ± 10.1	2.8 ± 2.8	0.002 ± 0.002	35.0	40
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		
FKNMS Reference Areas (28)	7.1 ± 5.0	0 ± 0	0 ± 0		
FKNMS No-take Zones (33)	30.3 ± 8.1	13.6 ± 5.0	0.033 ± 0.014	57.1 ± 5.3	25 ± 4
Habitat Total (62)	19.4 ± 5.1	7.3 ± 2.7	0.018 ± 0.007	57.1 ± 3.8	25 ± 3
Shallow (< 6 m) hard-bottom					
Biscayne National Park (17)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (23)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (5)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (45)	0 ± 0	0 ± 0	0 ± 0		
Deeper (6-15 m) hard-bottom					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (39)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (5)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (49)	0 ± 0	0 ± 0	0 ± 0		

Table 3.1 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Colony density (no. per m^2)	Mean size (cm)	Live tissue (%)
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		

Table 3-4. Elkhorn coral (*Acropora palmata*) population abundance estimates by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) as determined from belt transect surveys at 600 sites during May-November 2012. Low-relief hard-bottom (6-15 m) includes continuous and patchy hard-bottom, while FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Available sites (n_h) are the number of 200-m x 200-m grid cells containing a particular habitat type from northern BNP to Western Dry Rocks to 15-m depth, based upon existing habitat and bathymetry maps (e.g. FRMI 2000).

Habitat/management zone (sites sampled)	**Available sites (n_h) (% of domain)**		**No. per m^2 (mean ± 1 SE)**	**Colony abundance**	**95% CI**
Inshore patch reefs					
BNP and FKNMS reference areas (4)	387	(3.30)	0 ± 0	0	0
FKNMS no-take zones (4)	30	(0.26)	0 ± 0	0	0
Total (8)	417	(3.56)	0 ± 0	0	0
Mid-channel patch reefs					
BNP and FKNMS reference areas (142)	3,080	(26.26)	0 ± 0	0	0
FKNMS no-take zones (11)	59	(0.50)	0 ± 0	0	0
Total (153)	3,139	(26.77)	0 ± 0	0	0
Offshore patch reefs					
BNP and FKNMS reference areas (107)	1,748	(14.91)	0.002 ± 0.002	174,277	338,893
FKNMS no-take zones (15)	90	(0.77)	0 ± 0	0	0
Total (122)	1,838	(15.67)	0.002 ± 0.002	174,277	338,893
Reef rubble (< 15 m)					
BNP and FKNMS reference areas (18)	300	(2.56)	0 ± 0	0	0
FKNMS no-take zones (11)	57	(0.49)	0 ± 0	0	0
Total (29)	357	(3.04)	0 ± 0	0	0
Inner line reef tract					
BNP and FKNMS reference areas (9)	78	(0.67)	0.004 ± 0.004	11,557	24,382
FKNMS no-take zones (9)	20	(0.17)	0 ± 0	0	0
Total (18)	98	(0.84)	0.002 ± 0.002	11,557	24,382
High-relief spur and groove (< 15 m)					
BNP and FKNMS reference areas (29)	119	(1.01)	0 ± 0	0	0
FKNMS no-take zones (33)	153	(1.30)	0.033 ± 0.014	204,026	166,536
Total (62)	272	(2.32)	0.018 ± 0.007	204,026	166,536
Shallow (< 6 m) hard-bottom					
BNP and FKNMS reference areas (36)	985	(8.40)	0 ± 0	0	0
FKNMS no-take zones (4)	58	(0.49)	0 ± 0	0	0
Total (40)	1,043	(8.89)	0 ± 0	0	0
Low-relief hard-bottom (6-15 m)					
BNP and FKNMS reference areas (78)	2,307	(19.67)	0 ± 0	0	0
FKNMS no-take zones (8)	96	(0.82)	0 ± 0	0	0
Total (86)	2,403	(20.49)	0 ± 0	0	0
Low-relief spur and groove (6-15 m)					
BNP and FKNMS reference areas (59)	2,039	(17.39)	0 ± 0	0	0
FKNMS no-take zones (23)	121	(1.03)	0 ± 0	0	0
Total (82)	2,160	(18.42)	0 ± 0	0	0
All habitat types					
BNP and FKNMS reference areas (59)	11,043	(94.17)	0.001 ± 0.001	185,834	363,275
FKNMS no-take zones (23)	684	(5.83)	0.009 ± 0.004	204,026	166,536
Total (82)	11,727	(100.00)	0.002 ± 0.001	361,036	486,744

IV. Abundance, Size, and Condition of Scleractinian Corals

Background

Benthic coral cover is a metric commonly used to measure the status and trends of coral reefs (e.g. see Gardner et al. 2003). However, cover is not a population metric, but is instead an emergent property that integrates density (number of organisms per unit area) and the sizes of organisms. While cover provides important information at the community level (we have measured cover in the past), it does not address significant process-based features of populations and communities. For example, similar coral cover estimates might be obtained from a reef with a few large corals or from one with many small colonies. The fates of these two reefs, so characterized, are likely to have quite different trajectories. Thus, as part of our long-term monitoring in the Florida Keys, we use a stratified sampling design to assess coral density, size (max. diameter), and condition to determine patterns in distribution and abundance (see Smith et al. 2011 and Swanson 2011). Using these data, we then derive population abundance estimates structured by species and size based upon: habitat type (cross-shelf position and depth), geographic region (along-shelf position), and management zone, such as inside and outside of FKNMS no-take zones. The 2012 surveys for scleractinian corals were similar to the 1999-2001, 2005, and 2009 and 2011 efforts, in which scleractinian corals were surveyed Keys-wide at a subset (202) of total sites (600) surveyed during May-November. Assessments of coral condition included percent live tissue vs. dead skeleton, bleaching, disease, predation, overgrowth, and presence of clionid sponges. Figure 4-1 illustrates representative examples of some of the larger coral species surveyed, although the summary data provided herein include all 39 coral taxa encountered. In addition, these data, particularly for nine Atlantic coral species proposed for listing or reclassification under the under the U.S. Endangered Species Act (ESA) (see Brainard et al. 2011 and Risenhoover 2012) are timely and were incorporated in a recent report to NOAA on the population status and trends of the ESA-candidate species (Miller et al. 2013).

Field Sampling Methods and Data Analysis

Field methodology

Field sampling protocols were adapted from Aronson et al. (1994) and the Atlantic and Gulf Rapid Reef Assessment program (Kramer and Lang 2003) to measure population-level metrics of scleractinian corals. At a subset (n=202 sites) of the 600 sites visited during 2012, two replicate 10-m x 1-m belt transects were surveyed for all scleractinian (Cnidaria, Anthozoa, Scleractinia) coral species. While our primary

goal in 2012 was directed at sampling *Acropora* populations, we determined that with a relatively small amount of additional effort we could sample all scleractinians at a subset of the 600 sites we visited. This allowed us to update our long-term sampling program and to contribute results to the ESA review process for the nine candidate species under consideration for listing or re-classification under the U.S. Endangered Species Act (Brainard et al. 2011). Each colony greater than 4 cm in maximum diameter was identified, measured, and assessed for condition (e.g. mortality, bleaching, disease, predation, overgrowth). For previous sample intervals we also measured coral recruitment, but this is a relatively time intensive effort, and because the 2012 field effort was focused on *Acropora* corals, we did not sample juvenile corals to maximize the number of sites visited. All scleractinian colonies located within the belt transects were included in the survey, even if a portion of the colony extended outside of the boundaries of the belt transect. Individual colonies were identified as continuous skeletal units, regardless of whether the skeletal unit contained multiple patches of separate live tissue. Only colonies containing live tissue were included in the survey. The size and condition of the colonies were recorded on PVC slates using the following codes:

Code	Max Diameter (cm)	Code	Disease Condition	Code	Overgrowth Condition
0	0 to 4 cm	NODZ	No disease	NOG	No overgrowth
1	4 to 10 cm	BBDZ	Black band	AOG	Algae
2	10 to 20 cm	RBDZ	Red band	BOG	Bryozoans
3	20 to 30 cm	WBDZ	White band	COG	Corals
4	30 to 40 cm	YBDZ	Yellow band	GOG	Gorgonians
5	40 to 50 cm	WPII	White plague type 2	MOG	*Millepora*
6	50 to 60 cm	WPOX	White pox	POG	*Palythoa*
7	60 to 70 cm	DKSP	Dark spot	SOG	Sponges
8	70 to 80 cm	NECR	Necrosis	TOG	Tunicates
9	80 to 90 cm	UNKD	Unknown	ZOG	Zoanthids
↓	↓			UOG	Unknown

Code	Mortality Condition	Code	Bleaching Condition	Code	Other Condition
A	0-20% dead	NOBL	No bleaching	NOTH	No other mortality
B	20-40% dead	PPAL	Partly pale	ABRA	Abrasion
C	40-60% dead	PALE	Pale	CLIO	*Cliona* spp.
D	60-80% dead	PBLC	Partly bleached	DAMS	Damselfish
F	80-100% dead	BLCH	Bleached	FISH	Fish bites/scrapes
		MOTT	Mottled	GAST	Gastropod feeding
				UNKM	Unknown

To facilitate rapid assessment of corals, colony size was recorded using 10-cm incremental classes and reported herein using four size classes: 4-20, 20-60, 60-100, and > 100 cm maximum diameter. Size class 0 was used to record the maximum diameter of species that have a small maximum size, such as *Favia*

fragum and *Scolymia* spp., which would otherwise be excluded due to the overall adult (non-juvenile) size class lower-limit of 4 cm. There is no upper limit imposed on the maximum diameter size classes. Mortality was recorded using 20% incremental classes and included visual estimates of recent (i.e., corallites visible and white, not bleached tissue) and long-term tissue death.

Each coral colony encountered within transects was also assessed for condition. Any colonies with lighter tissue coloration than normal were assessed for bleaching. Partially pale and pale colonies were not included in the bleaching data analyses, although their condition was recorded. Mottling, or small patterns of light and dark discolorations often found on colonies of *Siderastrea siderea*, was also recorded, but not included in the bleaching data analyses. Only disease conditions that were actively causing tissue death or lesions on a colony were recorded. If a colony showed signs of a disease that could not be clearly identified, the condition was recorded as unknown disease. If a colony contained patches of necrotic issue with no identifiable cause, it was recorded as necrosis. Dark-spot condition/syndrome was recorded as a disease, even though it does not typically result in lesions or rapid tissue death. Overgrowth of coral tissue by another organism (e.g. algae, sponges, gorgonians, *Palythoa*, and other corals) was noted only if overgrowth by the organism was clearly causing lesions or tissue death. Overgrowth of organisms onto dead portions of a colony was not recorded, nor was overgrowth or shading of live tissue with no resulting lesions or tissue death.

Physical impacts, such a sediment scour, contact with other organisms, and fishing gear damage (e.g. trap rope abrasion) were recorded as abrasion. The presence of boring sponges such as *Cliona delitrix* was recorded if a sponge was actively causing tissue death lesions, but was not recorded if a sponge was only visible on dead portions of a colony. The presence of damselfish nests or gardens was recorded whenever they were found adjacent to, or surrounded by, live tissue. Likewise, fish bites/scrapes were only recorded if they were found on live tissue. Whenever gastropods such as *Coralliophila* were observed on a coral colony, the identity and total length of each individual was noted, regardless of whether the gastropods were actively feeding on live coral tissue. However, only gastropods actively feeding on live coral tissue were recorded as a mortality condition. Apparent gastropod feeding scars with no gastropods present was recorded as unknown mortality. Any tissue death that could not be attributed to disease, abrasion, boring sponges, or predation was also recorded as unknown mortality.

Statistical analyses

A two-stage sampling design following Cochran (1977) and Smith et al. (2011) was employed. Using this two-stage design, 200-m by 200-m grid cells on bathymetry and benthic habitat maps of the Florida Keys are used to help allocate targeted coral reef and hard-bottom habitats. Grid cells are designated as primary sample units (sites), while second-stage sample units (stations) are defined as 10-m x 1-m belt transects; two stations were sampled at each site. Coral density and abundance calculations were based upon the number of corals recorded within the stations (i.e. within each of the 10-m x 1-m belt transects). First, coral density (no. colonies per m^2) was calculated for each station. Next, mean coral density and variance were calculated for each site, using the coral densities of the two stations. The mean site-level coral densities and variances were then used to calculate mean stratum-level (habitat, management zones, and habitat by management zone) coral densities and variances. Finally, stratum-level and domain abundance estimates were calculated based upon the stratum-level coral densities and variances, as well as the proportional areas of each stratum within the domain (Smith et al. 2011).

Statistical comparisons of stratum-level mean colony densities and abundances were made among habitat types, between protected zones and reference areas, and among habitat types within protected zones and references areas. Statistical comparisons of means were conducted by calculating confidence intervals (CI) based on the equation CI = mean ± t[α, df] *standard error, with standard errors estimated by the two-stage, stratified design (Cochran 1977; Smith et al. 2011). Confidence intervals were adjusted for multiple comparisons using the Bonferroni procedure (Miller 1981). While this adjustment made for relatively conservative statistical testing, it reduced the probability of spurious significant pair-wise comparisons. The experiment-wise error rate was held at $\alpha = 0.05$ and the comparison-wise error rate was adjusted based on the number of multiple comparisons (comparison-wise error rate = α /c, where c = k (k-1)/2). For example, if an alpha-level of 0.05 was used to test for differences in mean coral densities among six habitat types (k = 6), then the alpha level was adjusted by dividing 0.05 by 15 to yield an adjusted alpha of 0.0033.

2012 Survey Results

We are primarily interested in describing the distribution and abundance of coral reef organisms in the Florida Keys, with management zones embedded in our stratified sample design that includes habitat types and geographic (i.e. along shelf) regions. The results discussed below are divided into two main sections to address: 1) sampling effort, colony density, and colony abundance estimates by habitat and management zone (e.g. Sanctuary no-fishing zones) in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) from the northern BNP boundary southwestward to the

Western Dry Rocks area, and 2) colony sizes and Keys-wide estimates of abundance and condition assessments of bleaching, disease, overgrowth, boring, and predation.

1. Sampling effort, density, and abundance

Table 4-1 summarizes the sampling effort for scleractinian corals at the 202 Florida Keys sites surveyed during May-November 2012 by habitat type and management zone. A total of 404 belt transects (10-m x 1-m) encompassing 4,040 m^2 of hard-bottom and coral reef habitat was surveyed scleractinian corals. Also provided in Table 4-1 are the total areas of the habitats surveyed, which are important data for two reasons. First, the 2012 benthic sampling was optimized for *Acropora* corals (see Section 3), whose distribution patterns, especially *A. palmata*, are different than the more abundant coral species in the Florida Keys. Secondly, the abundance estimates presented herein reflect density and habitat areas, so a given habitat with a lower density of an organism, but comprising a larger area, might yield a greater total number of individuals than a higher density, smaller habitat area. It is also worth noting the relatively small amount of area of the sampling domain (i.e., from northern BNP to the Western Dry Rocks area) that is contained within the FKNMS zones (~5.81% of the total area for the ten habitats sampled), dramatically affects abundance estimates.

There is a pool of approximately 51 common reef-associated coral taxa (species, forms, and subspecies) that occur in the wider Caribbean and most also occur in the Florida. The more cryptic, solitary ahermatypic species such as *Colangia* spp. and *Phylangia americana* are generally not encountered. During 2012, we recorded 39 taxa, including the three subspecies of *Porites porites*, and a few (n=35) colonies of *Agaricia*, *Mycetophyllia*, and *Scolymia* that were not identified to species. A total of 18,979 corals were counted among these taxa (Table 4-1). Note that more species were encountered in reference areas compared to no-take zones for some of the habitat types, which reflects the fewer number of sites allocated to the no-take zones, but also because we did not optimize transect number or length for species richness in the no-take zones.

Figure 4-2 shows the rank-order abundance of all scleractinian corals surveyed for all 202 sites surveyed for corals in 2012. Five species combined represented about 80% of all corals surveyed: *Siderastrea siderea* (5,279 colonies, 27.8%), *Porites astreoides* (4,777 colonies, 25.2%), *Agaricia agaricites* (1,939 colonies, 10.2%), *Stephanocoenia michelini* (1,853 colonies, 9.8%) and *P. porites porites* (1,322 colonies, 7.0%). Three of these five species are brooders, while the remaining two are broadcast spawning corals. An additional seven coral species were relatively uncommon (1.2-3.5% of all corals), while the remaining

27 taxa were rare (< 1% of all corals surveyed), mostly represented by either larger, broadcast spawning corals (e.g. *Diploria labyrinthiformis*), or small, understory species that were probably never historically abundant (e.g. *Mussa angulosa*).

Mean density and total colony abundance estimates for all species combined by habitat and management zone are summarized in Table 4-2, while the spatial patterns in total coral density across the Florida Keys are illustrated in Figures 4-3 to 4-9. Similar to previous years, mid-channel (9.1 colonies per m^2) and offshore patch reefs (6.5 per m^2) yielded the greatest average coral densities, followed by shallow *Acropora palmata* reefs represented by inner line reef tract (e.g. sites like Dry Rocks and Grecian Rocks) and platform margin, high-relief spur and groove sites (Table 4-2). Because various types of patch reefs in the Florida Keys harbor the greatest coral densities and comprise relatively large habitat areas (39% of the sampling domain in 2012), it is therefore not surprising that the total coral abundance estimates for these habitats are also high. In fact, of the estimated 2.8 billion corals presented in the 2012 sampling domain, approximately 59% occur on inshore, mid-channel, and offshore patch reefs. Evident from the density distribution maps are the relatively high total densities of corals in the patch reef environment encompassing inshore, mid-channel, and offshore patch reef sites, especially in the lower Keys region.

Patterns in total coral density among FKNMS no-take zones, Sanctuary reference areas, and Biscayne National Park (BNP) show greater densities in no-take zones for mid-channel and offshore patch reefs, as well as high-relief spur and groove. Greater density values were recorded in reference areas in BNP and Sanctuary inner line reef tract and deeper fore reef habitats, such as low-relief spur and groove. It is important to note that the no-take zones were initially established to address the need to manage multiple user groups in areas that were considered among the best for coral cover and diversity, and also for fishing. Thus, differences between no-take zones and reference sites reflect this initial site-selection bias. The no-take zones, while designed to protect habitat, were generally not considered large enough to achieve improved benthic condition based on no-take protection. Indeed, the relationship between no-take protection and changes to the benthos remains an active area of research. Thus, results from 2012 are best interpreted relative to results from our sampling in 1999-2001, 2005, and 2009 (Swanson 2011).

2. Colony size and Keys-wide estimates of abundance and condition

Table 4-3 summarizes the size distribution and relative abundance of four colony size (i.e., maximum diameter) classes for all coral taxa encountered in all habitats. Nearly 85% of the 18,979 corals surveyed were 4-20 cm in maximum diameter. Of course, this overall value represents many coral species that

differ in maximum colony size attainable. So, for example, it is not surprising that most lettuce corals (*Agaricia agaricites*), golf-ball corals (*Favia fragum*), and lesser starlet corals (*Siderastrea radians*) were mostly comprised of smaller colonies. For many, but not all of the massive and previously abundant branching coral species, smaller skeletal colony sizes currently predominate. For example, none of the staghorn coral (*Acropora cervicornis*) colonies encountered were larger than 60 cm in maximum diameter (Table 4-3). However, many large colonies (> 100 cm) were also encountered for species such as *Colpophyllia natans*, *Montastraea annularis*, *M. cavernosa*, *M. faveolata*, and *Siderastrea siderea*. Overall, the largest corals represented about 1% of all corals sampled during 2012.

Condition metrics for all coral species encountered in the Florida Keys are summarized in Table 4-4, including bleaching, disease, *Cliona* sponge boring, *Coralliophila* snail grazing, and active overgrowth. The numbers presented in Table 4-4 reflect colony abundance and prevalence of different conditions; therefore, these estimates take into account both density and habitat area (see Table 1). Overall, about 12% of all corals in the Florida Keys were experiencing bleaching, disease, clionid sponge boring, snail grazing, or overgrowth by other organisms, with active overgrowth (8.1%) and bleaching (1.4%) the most prevalent. Although slightly pale, partly pale, and mottled conditions were noted whenever these conditions were observed, only partly bleached or fully bleached colonies were included in the bleaching condition analyses. Active bleaching was particularly prevalent on *Agaricia fragilis* (32.8%), *Montastraea franksi* (35.9%), and *Oculina diffusa* (11.3%), although these species were rarely observed. The remainder of the coral species, including the top-ten most abundant corals, which comprise over 90% of the coral populations of the Florida Keys for the coral reef and hard-bottom habitats surveyed, were characterized by bleaching prevalence rates less than 5%.

Disease prevalence was relatively low (1.1% of all corals), but low prevalence numbers can have dramatic impacts on populations, depending on incidence and mortality rates. Few data are available on disease incidence and mortality for corals, but disease has obviously and dramatically affected some coral species (e.g. white-band disease in *Acropora palmata* and *A. cervicornis*). For the top five most abundant species, active disease prevalence was low for *Siderastrea siderea* (< 0.1%), *Porites astreoides* (< 0.1%), *Agaricia agaricites* (1.0%), and *P. porites porites* (none found), but relatively high in *Stephanocoenia michelini* (5.6%) due to dark-spot syndrome. It is important to note that although there was one observation of black-band disease on a *M. cavernosa* colony, the remaining 171 of the 172 disease observations were dark-spot syndrome. Dark-spot syndrome was observed in nine coral species, dominated by *S. michelini* (102 affected colonies) and *S. siderea* (49 affected colonies). Clionid sponges

were relatively common on massive reef-building species such as *Colpophyllia natans* (2%), *M. faveolata* (3.5%), and *Solenastrea bournoni* (2.3%).

Active *Coralliophila* snail grazing, while affecting < 1% of all of the sampled corals, was notably prevalent on *Diploria labyrinthiformis* (20.8%) and *D. strigosa* (12.0%). Some species, such as *Montastraea f*ranksi were rarely observed, but characterized by a very high prevalence (60.6%) of active snail predation. In the case of *M. franksi*, four out of six colonies sampled had active *Coralliophila* grazing. Some of the most abundant species, such as *Agaricites agaricites*, were characterized by low prevalence of *Coralliophila* grazing (3.3%), although 51 *A. agaricites* colonies with a total of 66 snails were observed. Of the 39 coral taxa observed during the 2012 Florida Keys sampling event, 19 different species were showing signs of active snail feeding.

Overgrowth, the most common cause of tissue lesions and recent mortality, affects 8.1% of the current coral populations in the Florida Keys. Overgrowth was ubiquitous throughout the study area, found in every region and habitat type. Mortality resulting from sponge overgrowth was observed twice as often the next most frequent cause of mortality by overgrowth, which was algal overgrowth. The encrusting gorgonians (*Briareum asbestinum* and *Erythropodium caribaeorum*), the colonial zoanthid *Palythoa caribeaorum*, and fire corals (*Millepora* spp.) were responsible for the vast majority of the remaining overgrowth observations, although a few instances of overgrowth by other corals, zoanthids other than *Palythoa*, and tunicates were also observed.

Discussion

Coral density, size, and condition surveys conducted in the Florida Keys during 2012 provide a snapshot of the status of coral assemblages over a large section of the Florida Reef Tract. Most of the reef-building (hermatypic) and reef-associated coral species known to occur in the Florida Keys were encountered during the 2012 surveys. Ten of 39 species accounted for 92% of all sampled corals, represented by branching *Porites*, four species that broadcast spawn, and six species that brood larvae. Other species were somewhat common and usually abundant in particular habitats, while others were rare. Prevalence of adverse colony conditions such as bleaching, disease, predation, and overgrowth were relatively low (< 2%) for most species. Abundance estimates indicate a very large number of corals in the Florida Keys (> 2 billion), despite the fact that we did not sample the deeper fore-reef beyond 15-m depth in 2012, which supports a high-diversity, high-density coral assemblage along most of the reef tract between Miami and the Dry Tortugas.

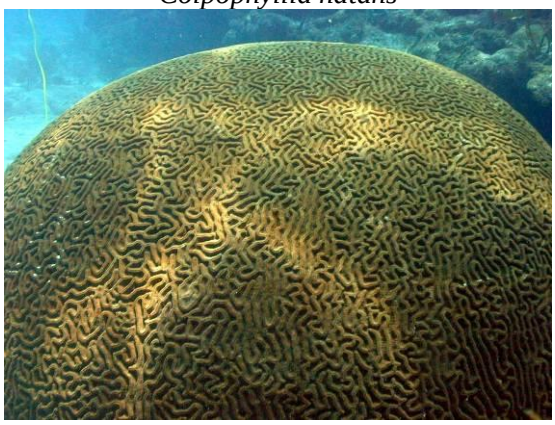
Distribution, density, and abundance patterns for many corals illustrate the importance of the patch reef environment, a pattern our program and others continue to document. For the massive framework-building species, patch reefs support greater numbers of species, colony densities, and because of the presence of several thousand patch reefs, the greatest proportion of total colonies for the habitats surveyed in 2012. Most corals in the patch reef environment fall outside of existing FKNMS no-take zones.

The high-relief spur and groove habitat, noted for the historically high abundances of *Acropora* corals, especially elkhorn coral, are dominated by a coral assemblage consisting of smaller, brooding species such as *Agaricia agaricites* and *Porites astreoides*. Thickets of elkhorn coral only persist at a few reefs in the Florida Keys. The lack of larger, hermatypic (reef-building) coral species at many spur and grooves has implications for the long-term persistence of this habitat in lieu of physical weathering, bioerosion, and rising sea level.

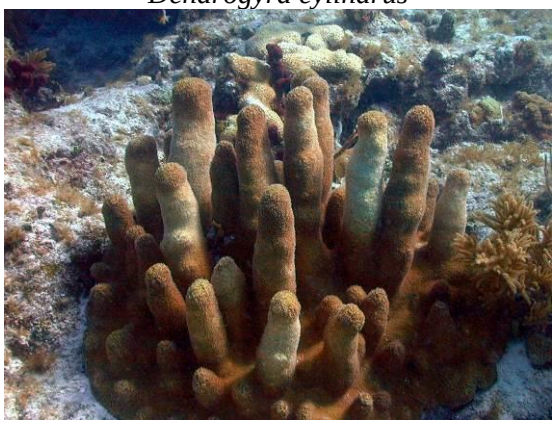
Finally, future work might consider optimizing sampling for density of coral species, such as the large head corals, to determine the potential impact of snail grazing, disease, bleaching, overgrowth, and *Cliona* sponge boring. Increased temporal sampling will also be needed to move from prevalence estimates, to include incidence and mortality rates.

Figure 4-1. Examples of larger scleractinian corals surveyed for distribution, density, size, and condition in the Florida Keys during 2012.

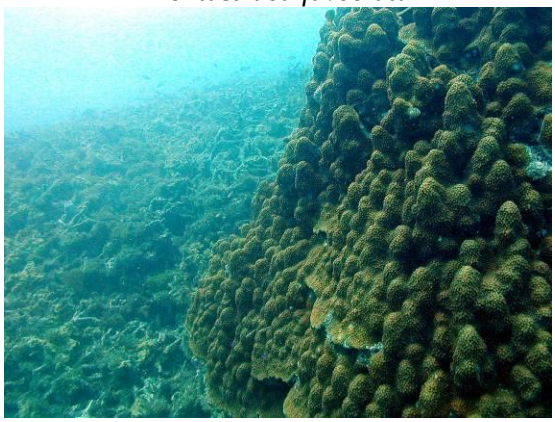
Colpophyllia natans



Dendrogyra cylindrus



Montastraea faveolata



Porites porites porites

Siderastrea siderea

Solanastrea bournoni

Figure 4-2. Rank-order abundance of scleractinian coral species (> 4 cm max. diameter) surveyed at 202 sites in the Florida Keys during May-November 2012. Data include colony counts from all sites and habitats combined. A total of 18,979 colonies among 39 coral taxa were recorded.

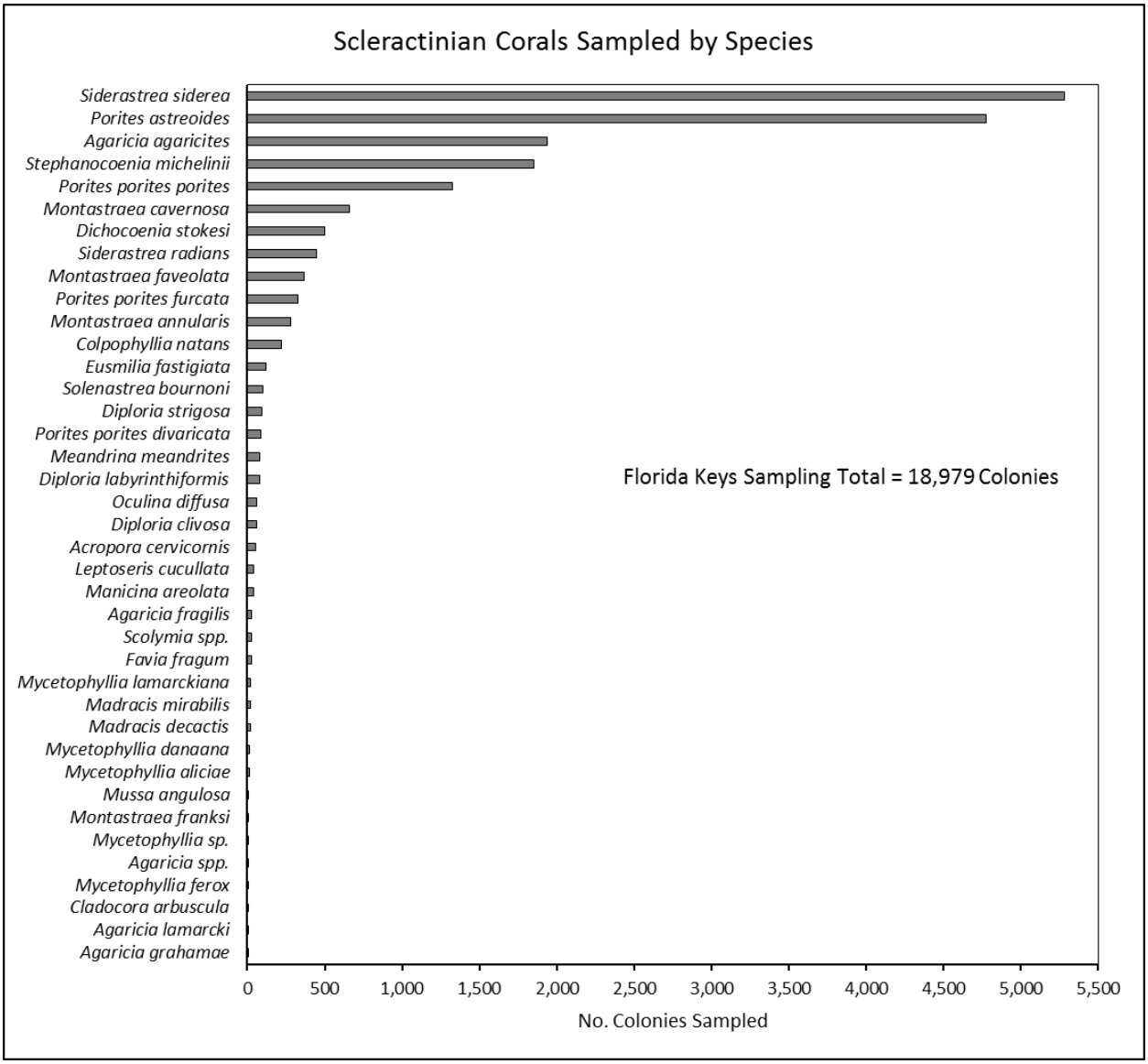


Figure 4-3. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

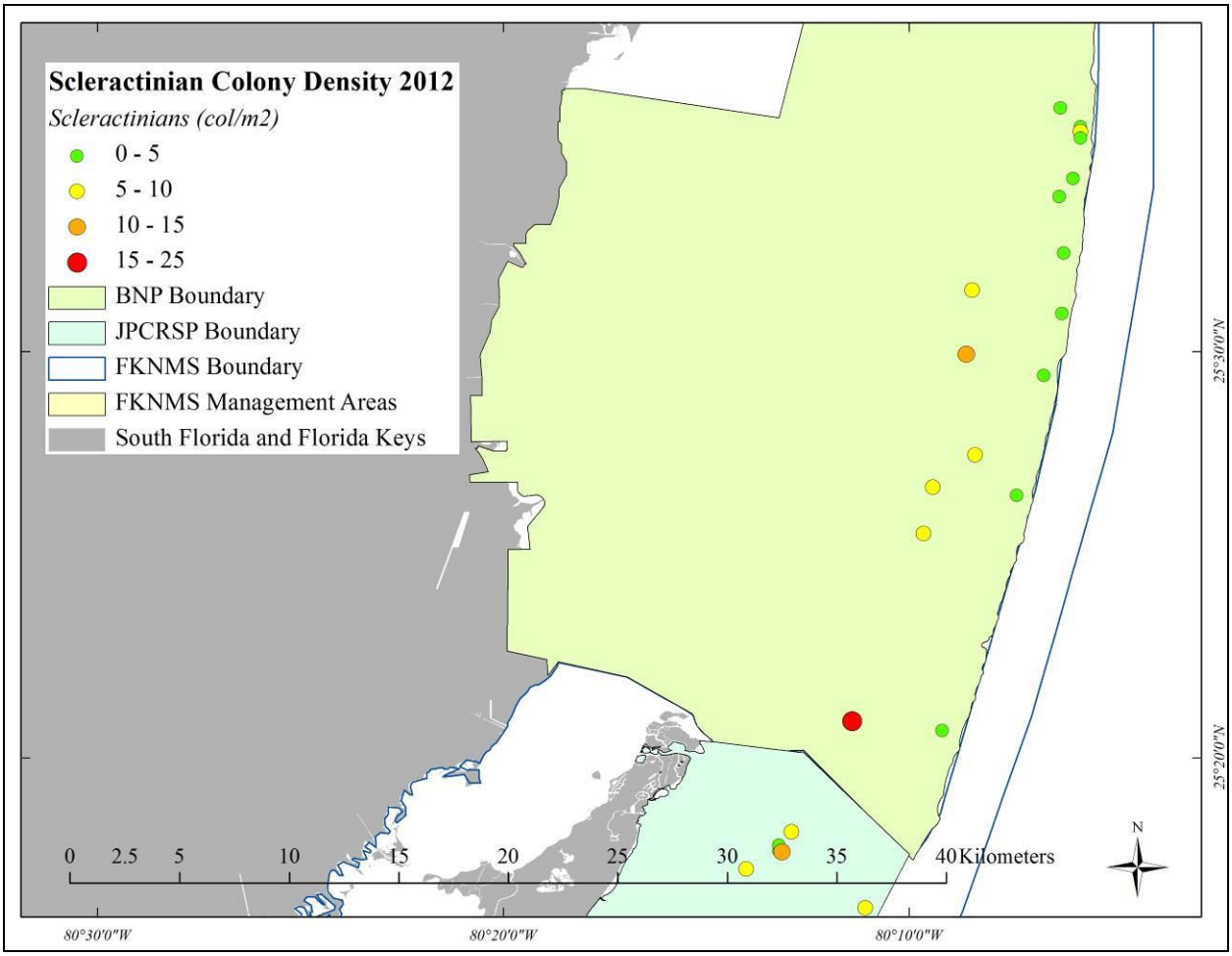


Figure 4-4. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

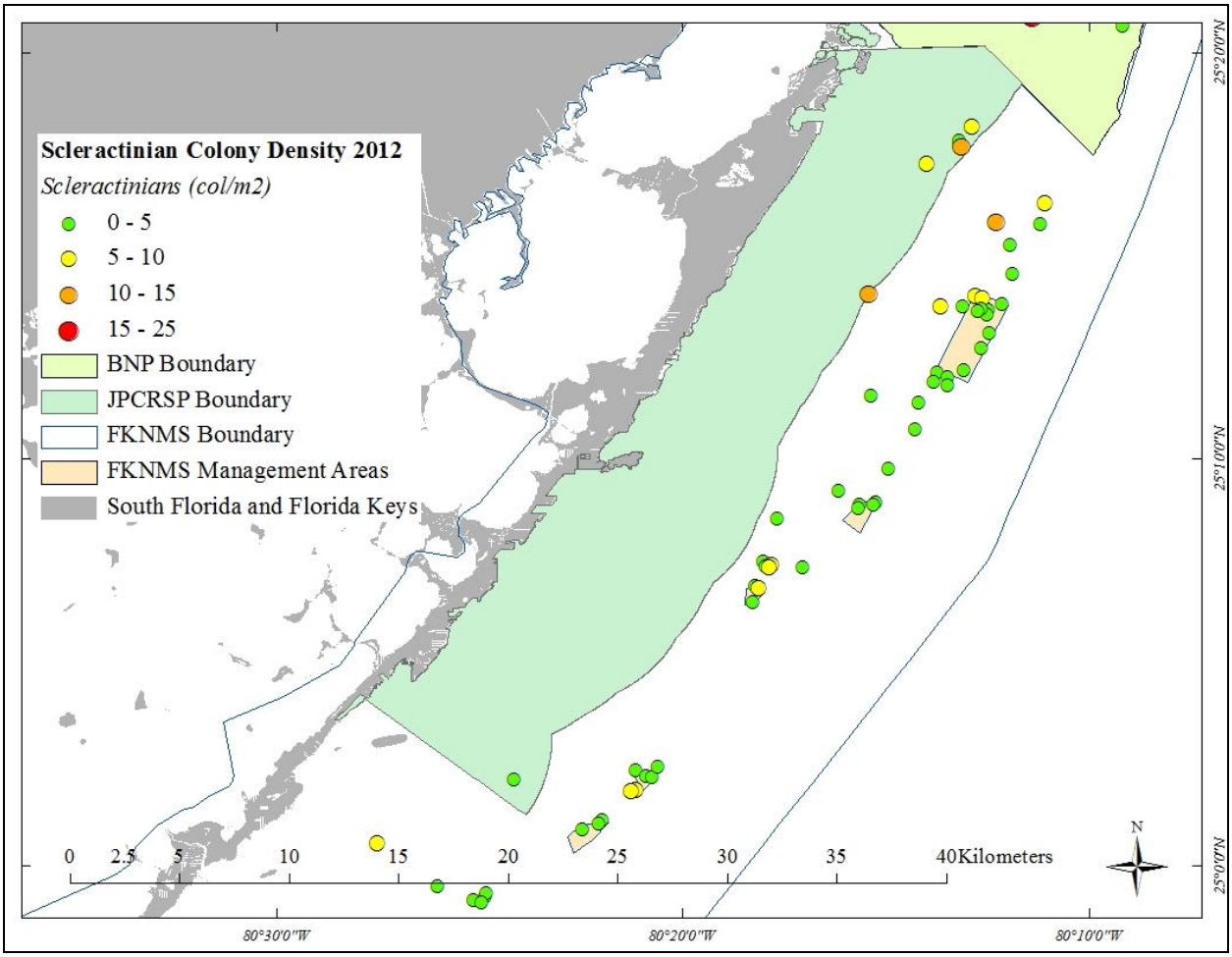


Figure 4-5. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

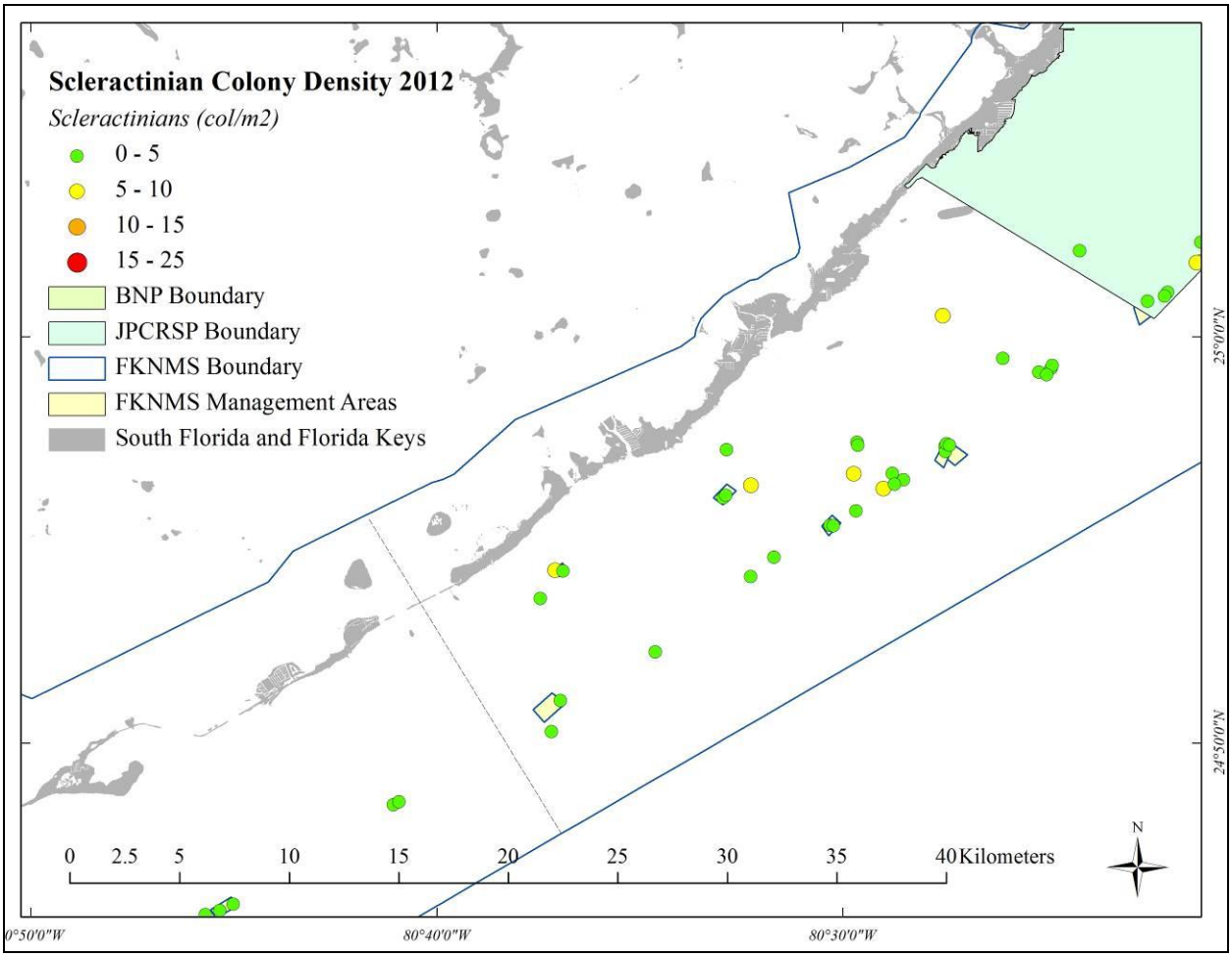


Figure 4-6. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

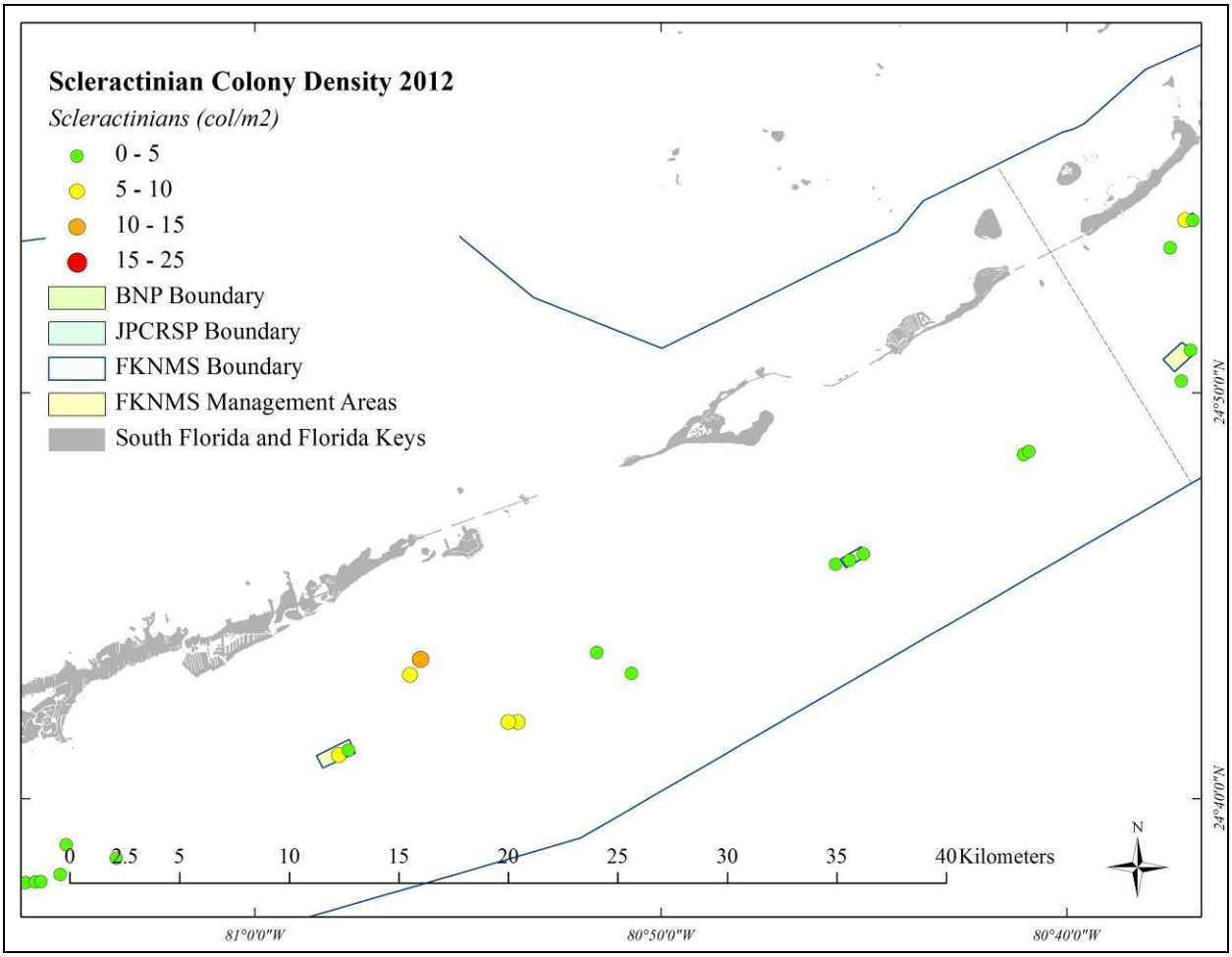


Figure 4-7. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

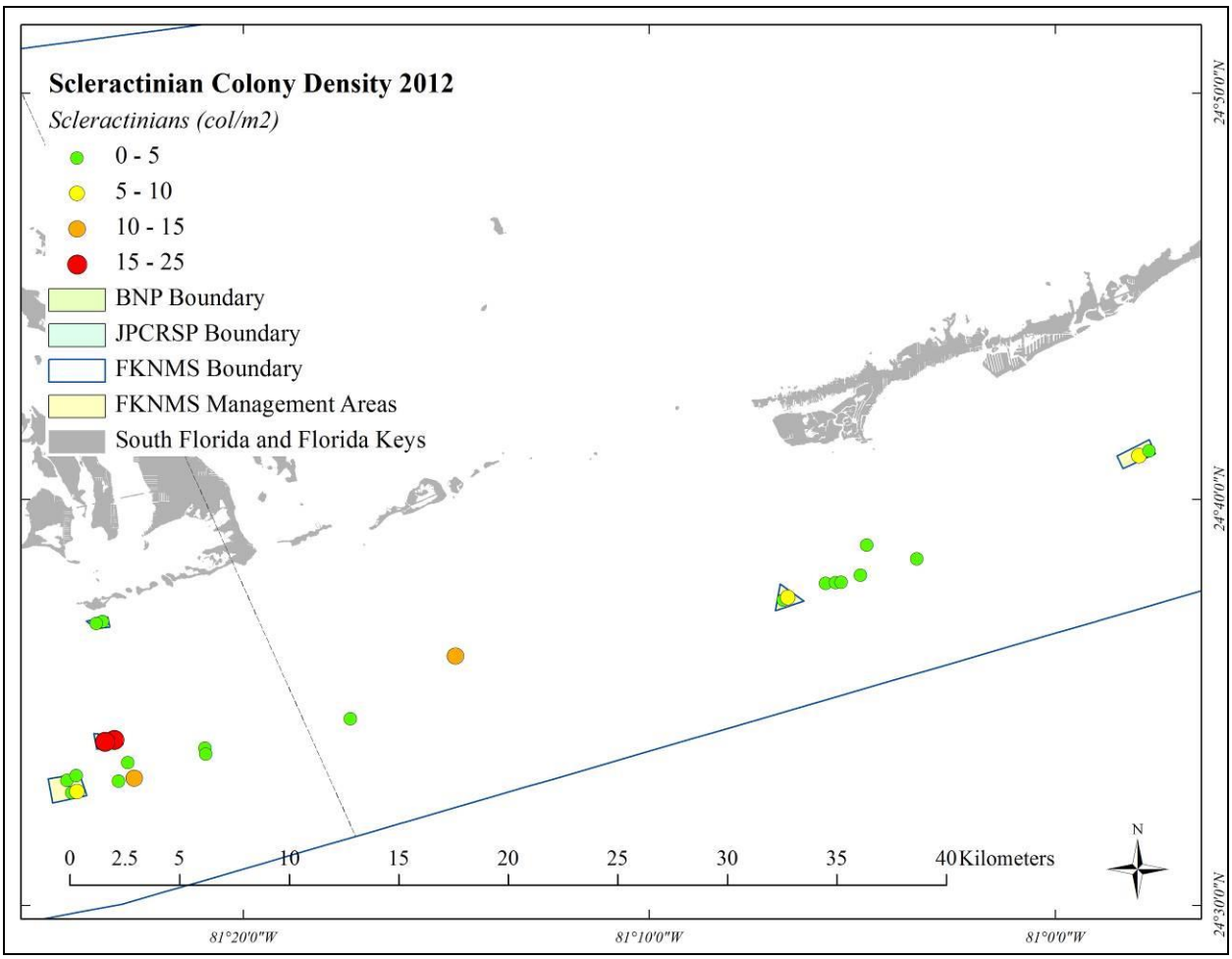


Figure 4-8. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

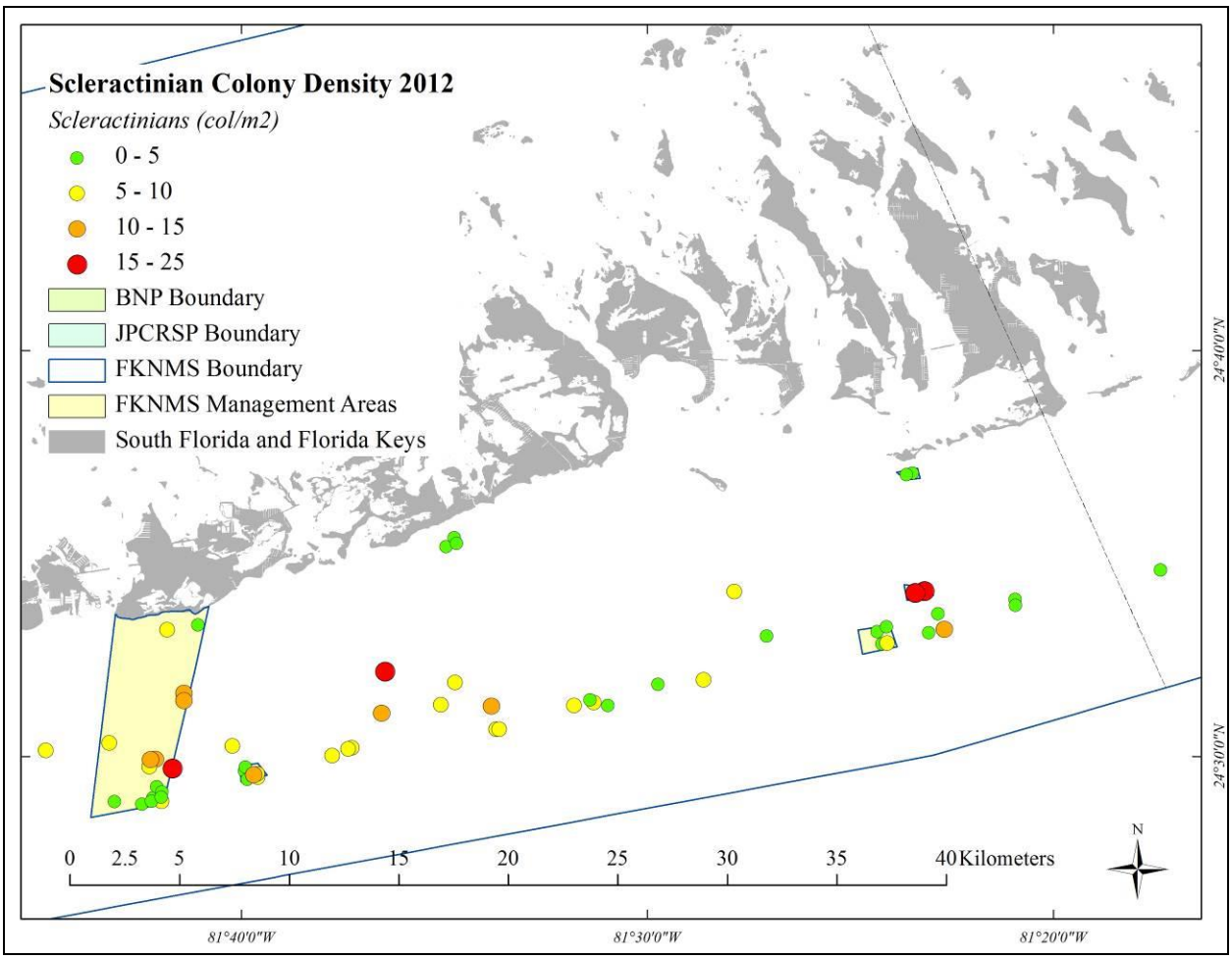


Figure 4-9. Spatial distribution of total scleractinian coral density (no. colonies per m^2) in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

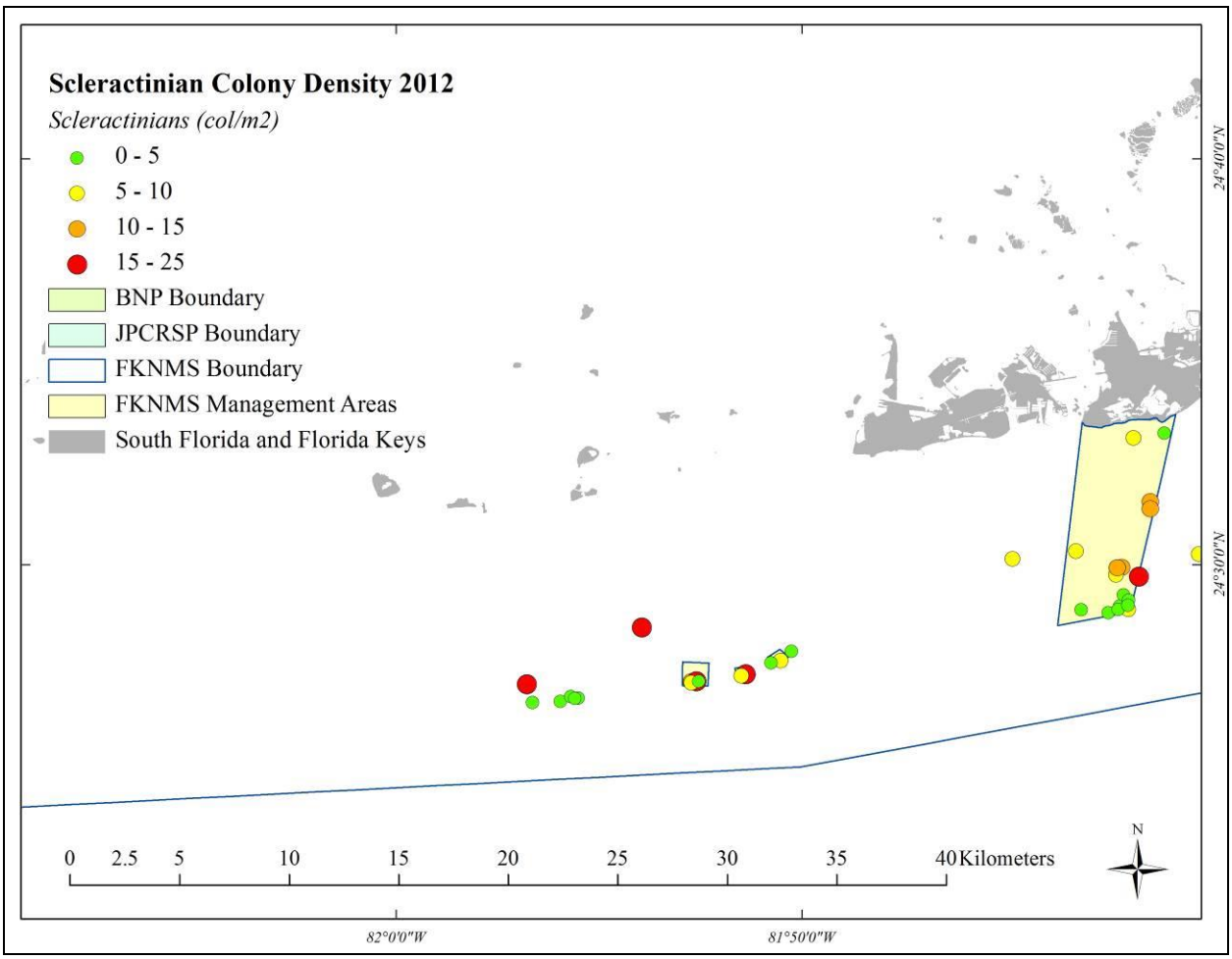


Table 4-1. Sampling effort for scleractinian corals by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) during May-November 2012. At each site, two replicate 10-m x 1-m belt transects were surveyed for coral colony numbers, sizes, and condition. FKNMS no-take zones are Ecological Reserves, Sanctuary Preservation Areas, and Research Only Areas. Available sites (n_h) are the number of 200-m x 200-m grid cells containing a particular habitat type from Biscayne National Park to the Western Dry Rocks area to 15-m depth, based upon existing habitat and bathymetry maps (e.g. FRMI 2000).

Habitat type/region/protection	Available sites (n_h) (%)	No. sites (area, m^2)	% of Effort	No. species	No. colonies
Inshore patch reefs					
BNP	166 (1.44)	0 (0)	0	0	0
FKNMS reference areas	221 (1.91)	4 (80)	1.98	14	271
FKNMS no-take zones	30 (0.26)	4 (80)	1.98	13	248
Total	417 (3.61)	8 (160)	3.96	15	519
Mid-channel patch reefs					
BNP	1,369 (11.85)	6 (120)	2.97	25	1,053
FKNMS reference areas	1,711 (14.81)	10 (200)	4.95	27	1,788
FKNMS no-take zones	59 (0.51)	9 (180)	4.46	27	1,692
Total	3,139 (27.17)	25 (500)	12.38	31	4,533
Offshore patch reefs					
BNP	144 (1.25)	2 (40)	0.99	13	84
FKNMS reference areas	1,604 (13.88)	17 (340)	8.42	29	1,961
FKNMS no-take zones	90 (0.78)	10 (200)	4.95	28	1,709
Total	1,838 (15.91)	29 (580)	14.36	31	3,754
Reef rubble (< 15 m)					
BNP	80 (0.69)	2 (40)	0.99	5	44
FKNMS reference areas	255 (2.21)	10 (200)	4.95	12	120
FKNMS no-take zones	57 (0.49)	9 (180)	4.46	4	20
Total	392 (3.39)	21 (420)	10.40	12	184
Inner line reef tract					
BNP	0 (0)	0 (0)	0	0	0
FKNMS reference areas	77 (0.67)	2 (40)	0.99	14	306
FKNMS no-take zones	20 (0.17)	5 (100)	2.48	20	527
Total	97 (0.84)	7 (140)	3.47	21	833
High-relief spur and groove (< 15 m)					
BNP	33 (0.29)	0 (0)	0	0	0
FKNMS reference areas	86 (0.74)	17 (340)	8.42	29	1,566
FKNMS no-take zones	153 (1.32)	19 (380)	9.41	26	2,424
Total	272 (2.35)	36 (720)	17.82	32	3,990
Shallow (< 6 m) hard-bottom					
BNP	171 (1.48)	4 (80)	1.98	14	237
FKNMS reference areas	814 (7.05)	4 (80)	1.98	11	168
FKNMS no-take zones	58 (0.50)	4 (80)	1.98	14	210
Total	1,043 (9.03)	12 (240)	5.94	18	615
Low-relief hard-bottom (6-15 m)					
BNP	209 (1.81)	0 (0)	0	0	0
FKNMS reference areas	1,619 (14.01)	10 (200)	4.95	24	797
FKNMS no-take zones	79 (0.68)	3 (60)	1.49	12	87
Total	1,907 (16.51)	13 (260)	6.44	24	884

Table 4.1 continued

Habitat type/region/protection	Available sites (n_h) (%)	No. sites (area, m^2)	% of Effort	No. species	No. colonies
Patchy hard-bottom (6-15 m)					
BNP	150 (1.30)	2 (40)	0.99	14	56
FKNMS reference areas	266 (2.30)	8 (160)	3.96	17	362
FKNMS no-take zones	14 (0.12)	2 (40)	0.99	11	111
Total	430 (3.72)	12 (240)	5.94	22	529
Low-relief spur and groove (6-15 m)					
BNP	254 (2.20)	1 (20)	0.50	15	112
FKNMS reference areas	1,653 (14.31)	19 (380)	9.41	30	1,743
FKNMS no-take zones	111 (0.96)	19 (380)	9.41	27	1,283
Total	2,018 (17.47)	39 (780)	19.32	32	3,138
All habitat types					
BNP	2,576 (22.30)	17 (340)	8.42	27	1,586
FKNMS reference areas	8,306 (71.89)	101 (2,020)	50.00	39	9,082
FKNMS no-take zones	671 (5.81)	84 (1,680)	41.58	36	8,311
Total	11,553 (100)	202 (4,040)	100.00	39	18,979

Table 4-2. Mean skeletal colony densities (no. per m^2) and colony abundance estimates of scleractinian corals (> 4 cm max. diameter) by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS) to the Western Dry Rocks area, as determined from surveys of two replicate 10-m x 1-m belt transects per site at 202 sites during May-November 2012. Habitat types are arranged from inshore to offshore and FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. SE = standard error, 95% CI = 95% confidence interval.

Habitat/management zone (no. sites)	Mean density (no. per m^2)	Std. Error (density)	Abundance (total colonies)	95% CI (total colonies)
Inshore patch reefs				
Biscayne National Park (0)				
FKNMS Reference Areas (4)	3.3875	0.6607	52,438,500	24,185,140
FKNMS No-take Zones (4)	3.1000	0.7158	3,720,000	2,031,040
Habitat Total (8)	3.2438	0.4615	54,105,750	16,407,793
Mid-channel patch reefs				
Biscayne National Park (6)	8.7750	1.6049	480,519,000	193,433,670
FKNMS Reference Areas (10)	8.9400	1.1100	1,101,408,000	286,218,820
FKNMS No-take Zones (9)	9.4000	1.7393	22,184,000	8,660,202
Habitat Total (25)	9.0660	0.8589	1,138,326,960	216,730,773
Offshore patch reefs				
Biscayne National Park (2)	2.1000	0.4974	12,096,000	9,118,215
FKNMS Reference Areas (17)	5.7676	1.2748	403,273,882	181,347,783
FKNMS No-take Zones (10)	8.5450	1.8614	30,762,000	14,025,355
Habitat Total (29)	6.4724	1.0365	475,851,862	152,598,358
Reef Rubble (< 15 m)				
Biscayne National Park (2)	1.1000	0.3483	3,520,000	3,547,465
FKNMS Reference Areas (10)	0.6050	0.1058	7,308,400	2,673,766
FKNMS No-take Zones (9)	0.1556	0.0330	404,444	180,803
Habitat Total (21)	0.4595	0.0856	6,745,810	2,536,305
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (2)	7.6500	4.7890	23,868,000	47,551,583
FKNMS No-take Zones (5)	5.2700	0.4969	4,216,000	899,175
Habitat Total (7)	5.9500	1.1570	23,324,000	9,798,555
High-relief spur and groove				
Biscayne National Park (0)				
FKNMS Reference Areas (17)	4.6059	1.1213	21,924,000	10,858,735
FKNMS No-take Zones (19)	6.3789	1.1172	39,039,158	13,854,229
Habitat Total (36)	5.5417	0.7937	60,293,333	17,219,423
Shallow (< 6 m) hard-bottom				
Biscayne National Park (4)	2.9625	1.2789	20,263,500	20,684,566
FKNMS Reference Areas (4)	2.1000	0.5111	82,740,000	47,620,252
FKNMS No-take Zones (4)	2.6250	0.6040	6,090,000	3,313,342
Habitat Total (12)	2.5625	0.4690	106,907,500	40,473,483
Deeper (6-15 m) hard-bottom				
Biscayne National Park (0)				
FKNMS Reference Areas (10)	3.9850	1.1289	291,383,200	172,774,109
FKNMS No-take Zones (3)	1.4500	0.4686	4,582,000	3,806,476
Habitat Total (13)	3.4000	0.9152	259,352,000	143,772,055

Table 4.2 continued

Habitat/management zone (no. sites)	Mean density (no. per m^2)	SE	Abundance (total colonies)	95% CI (total colonies)
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	2.8000		24,640,000	0
FKNMS Reference Areas (8)	2.2625	0.8339	52,128,000	40,950,684
FKNMS No-take Zones (2)	2.7750	0.0833	2,109,000	201,488
Habitat Total (12)	2.4045	0.5983	57,228,182	29,611,114
Low-relief spur and groove (6-15 m)				
Biscayne National Park (1)	2.8000	1.5475	67,984,000	477,423,546
FKNMS Reference Areas (19)	4.5868	0.5506	704,355,474	171,318,337
FKNMS No-take Zones (19)	3.3763	0.3421	30,927,053	6,350,075
Habitat Total (39)	3.9225	0.3274	638,269,200	106,027,108

Table 4-3. Size distribution and relative abundance (%) of scleractinian corals counted and measured in the Florida Keys during May-November 2012. All skeletal colonies > 4 cm in maximum diameter were surveyed in two replicate 10-m x 1-m belt transects per site at 202 sites from northern BNP to SW of Key West. For each species, the numbers in parentheses represent the proportion (%) of colonies in a particular size class. For example, 1,902 colonies or 98.09% of the 1,939 lettuce corals (*Agaricia agaricites*) (10.22% of all corals) sampled were 4-20 cm in maximum diameter.

Coral species	**Size class (maximum colony diameter, cm)**				
	4-20 cm	**20-60 cm**	**60-100 cm**	**>100 cm**	**Total**
*Acropora cervicornis**	24 (45.28)	29 (54.72)	0 (0.00)	0 (0.00)	53 (0.28)
Agaricia agaricites	1,902 (98.09)	36 (1.86)	1 (0.05)	0 (0.00)	1,939 (10.22)
A. fragilis	30 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	30 (0.16)
A. grahamae	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.01)
*A. lamarcki**	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.01)
Agaricia spp.	3 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.02)
Cladocora arbuscula	1 (100)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.01)
Colpophyllia natans	43 (19.63)	119 (54.34)	35 (15.98)	22 (10.05)	219 (1.15)
*Dichocoenia stokesi**	470 (93.81)	30 (5.99)	1 (0.20)	0 (0.00)	501 (2.64)
Diploria clivosa	39 (6.290)	18 (29.03)	3 (4.84)	2 (3.23)	62 (0.33)
D. labyrinthiformis	48 (60.76)	28 (35.44)	2 (2.53)	1 (1.27)	79 (0.42)
D. strigosa	50 (54.95)	34 (37.36)	5 (5.49)	2 (2.20)	91 (0.48)
Eusmilia fastigiata	113 (93.39)	8 (6.61)	0 (0.00)	0 (0.00)	121 (0.64)
Favia fragum	24 (100)	0 (0.00)	0 (0.00)	0 (0.00)	24 (0.13)
Leptoseris cucullata	41 (97.62)	1 (2.38)	0 (0.00)	0 (0.00)	42 (0.22)
M. decactis	14 (73.68)	5 (26.32)	0 (0.00)	0 (0.00)	19 (0.10)
M. mirabilis	17 (89.47)	2 (10.53)	0 (0.00)	0 (0.00)	19 (0.10)
Manicina areolata	40 (100)	0 (0.00)	0 (0.00)	0 (0.00)	40 (0.21)
Meandrina meandrites	46 (57.50)	31 (38.75)	2 (2.50)	1 (1.25)	80 (0.42)
*Montastraea annularis**	38 (13.72)	131 (47.29)	67 (24.19)	41 (14.80)	277 (1.46)
M. cavernosa	370 (55.89)	206 (31.12)	61 (9.21)	25 (3.78)	662 (3.49)
*M. faveolata**	66 (18.08)	152 (41.64)	70 (19.18)	77 (21.10)	365 (1.92)
*M. franksi**	1 (16.67)	4 (66.67)	1 (16.67)	0 (0.00)	6 (0.03)
Mussa angulosa	6 (75.00)	2 (25.00)	0 (0.00)	0 (0.00)	8 (0.04)
Mycetophyllia aliciae	7 (53.85)	6 (46.15)	0 (0.00)	0 (0.00)	13 (0.07)
M. danaana	15 (93.75)	1 (6.25)	0 (0.00)	0 (0.00)	16 (0.08)
*M. ferox**	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.01)
M. lamarckiana	19 (90.48)	2 (9.52)	0 (0.00)	0 (0.00)	21 (0.11)
Mycetophyllia sp.	3 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.02)
Oculina diffusa	55 (88.71)	7 (11.29)	0 (0.00)	0 (0.00)	62 (0.33)
Porites astreoides	4,356 (91.19)	417 (8.73)	4 (0.08)	0 (0.00)	4,777 (25.17)
P. porites divaricata	71 (79.78)	18 (20.22)	0 (0.00)	0 (0.00)	89 (0.47)
P. porites furcata	298 (91.41)	27 (8.28)	0 (0.00)	1 (0.31)	326 (1.72)
P. porites porites	1,228 (92.89)	89 (6.73)	2 (0.15)	3 (0.23)	1,322 (6.97)
Scolymia spp.	29 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	29 (0.15)
Siderastrea radians	441 (99.55)	2 (0.45)	0 (0.00)	0 (0.00)	443 (2.33)
S. siderea	4,422 (83.77)	801 (15.17)	46 (0.87)	10 (0.19)	5,279 (27.81)
Solenastrea bournoni	75 (73.53)	27 (26.47)	0 (0.00)	0 (0.00)	102 (0.54)
Stephanocoenia michelini	1,689 (91.15)	162 (8.74)	2 (0.11)	0 (0.00)	1,853 (9.76)
Total (39)	16,097 (84.81)	2,395 (12.62)	302 (1.59)	185 (0.97)	18,979 (100)

Table 4-4. Scleractinian coral abundance estimates (no. colonies) and prevalence (%) of colony conditions in the Florida Keys, as determined from two replicate 10-m x 1-m belt transects surveyed per site at 202 sites from northern BNP to SW of Key West during May-November 2012.

Coral Species	Total abundance (± 1 SE)	Active bleaching	Active disease	*Cliona* sponges	Snail grazing	Active overgrowth
*Acropora cervicornis**	9,493,705 ± 4,229,709	0 (0%)	0 (0%)	0 (0%)	182,000 (1.92%)	1,068,533 (11.26%)
Agaricia agaricites	239,920,883 ± 31,638,069	3,644,767 (1.52%)	2,426,433 (1.01%)	41,455 (0.02%)	7,936,847 (3.31%)	7,376,298 (3.07%)
A. fragilis	2,933,171 ± 997,035	963,238 (32.84%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
A. grahamae	9,800 ± 9,799	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
*A. lamarcki**	210,400 ± 210,400	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Agaricia spp.	466,300 ± 450,153	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Cladocora arbuscula	282,400 ± 282,400	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Colpophyllia natans	24,236,937 ± 3,022,033	1,045,200 (4.31%)	15,200 (0.06%)	484,400 (2.00%)	918,571 (3.79%)	1,940,600 (8.01%)
*Dichocoenia stokesi**	88,437,289 ± 7,509,880	1,252,500 (1.42%)	333,771 (0.38%)	314,614 (0.36%)	1,007,030 (1.14%)	2,319,341 (2.62%)
Diploria clivosa	11,897,744 ± 5,815,279	0 (0%)	0 (0%)	0 (0%)	63,164 (0.53%)	677,233 (5.69%)
D. labyrinthiformis	11,453,792 ± 2,579,596	0 (0%)	0 (0%)	0 (0%)	2,381,260 (20.79%)	624,000 (5.45%)
D. strigosa	10,888,017 ± 1,963,082	76,000 (0.70%)	0 (0%)	0 (0%)	1,301,610 (11.95%)	30,400 (0.28%)
Eusmilia fastigiata	17,659,864 ± 4,753,989	25,400 (0.14%)	0 (0%)	0 (0%)	10,364 (0.06%)	715,371 (4.05%)
Favia fragum	882,796 ± 384,436	20,164 (2.28%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Leptoseris cucullata	5,768,464 ± 1,603,206	0 (0%)	0 (0%)	0 (0%)	318,571 (5.52%)	9,800 (0.17%)
Madracis decactis	3,369,911 ± 1,175,579	0 (0%)	0 (0%)	0 (0%)	0 (0%)	644,000 (19.11%)
M. mirabilis	266,109 ± 127,343	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Manicina areolata	4,696,421 ± 1,626,202	0 (0%)	0 (0%)	0 (0%)	0 (0%)	450,000 (9.58%)
Meandrina meandrites	11,029,198 ± 2,030,738	0 (0%)	0 (0%)	0 (0%)	25,400 (0.23%)	55,067 (0.50%)
*Montastraea annularis**	24,066,400 ± 10,093,667	760,000 (3.16%)	0 (0%)	0 (0%)	804,740 (3.34%)	2,023,500 (8.41%)
M. cavernosa	98,881,536 ± 13,784,904	183,200 (0.19%)	10,000 (0.01%)	420,800 (0.43%)	571,000 (0.58%)	5,105,168 (5.16%)
*M. faveolata**	50,016,890 ± 9,783,192	152,000 (0.30%)	0 (0%)	1,753,077 (3.50%)	905,300 (1.81%)	3,549,014 (7.10%)
*M. franksi**	586,414 ± 382,900	210,400 (35.88%)	0 (0%)	0 (0%)	355,443 (60.61%)	0 (0%)
Mussa angulosa	1,169,533 ± 592,434	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Mycetophyllia aliciae	1,552,747 ± 761,148	0 (0%)	0 (0%)	0 (0%)	0 (0%)	15,200 (0.98%)
M. danaana	2,009,964 ± 1,692,114	0 (0%)	0 (0%)	0 (0%)	0 (0%)	15,200 (0.76%)
*M. ferox**	7,000 ± 6,999	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
M. lamarckiana	3,251,650 ± 1,151,992	0 (0%)	0 (0%)	0 (0%)	6,500 (0.20%)	465,600 (14.32%)
Mycetophyllia sp.	513,321 ± 367,000	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Oculina diffusa	6,484,733 ± 1,694,889	731,200 (11.28%)	15,200 (0.23%)	0 (0%)	0 (0%)	1,204,800 (18.58%)
Porites astreoides	487,742,017 ± 53,159,260	4,226,670 (0.87%)	10,364 (< 0.01%)	4,848,984 (0.99%)	376,764 (0.08%)	31,068,529 (6.37%)
P. porites divaricata	20,745,531 ± 9,082,697	0 (0%)	0 (0%)	0 (0%)	0 (0%)	4,102,821 (19.78%)
P. porites furcata	75,804,410 ± 26,232,654	304,250 (0.40%)	0 (0%)	0 (0%)	0 (0%)	6,903,067 (9.11%)
P. porites porites	233,141,904 ± 43,126,721	1,646,467 (0.71%)	0 (0%)	653,688 (0.28%)	329,650 (0.14%)	22,655,569 (9.72%)
Scolymia spp.	4,986,602 ± 1,520,120	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Siderastrea radians	69,380,511 ± 12,824,604	3,255,543 (4.69%)	20,727 (0.03%)	0 (0%)	0 (0%)	587,271 (0.85%)
S. siderea	854,739,462 ± 58,621,445	15,407,114 (1.80%)	9,369,666 (1.10%)	10,975,790 (1.28%)	492,800 (0.06%)	94,299,915 (11.03%)
Solenastrea bournoni	20,184,571 ± 3,522,992	471,533 (2.34%)	210,400 (1.04%)	456,333 (2.26%)	774,905 (3.84%)	1,899,333 (9.41%)
Stephanocoenia michelini	318,361,111 ± 49,762,341	3,386,850 (1.06%)	17,969,783 (5.64%)	2,597,838 (0.82%)	0 (0%)	29,517,989 (9.27%)
All coral species	2,717,529,508 ± 172,453,106	37,762,496 (1.39%)	30,381,545 (1.12%)	22,567,551 (0.83%)	18,761,918 (0.69%)	219,323,621 (8.07%)

V. Urchin Abundance and Size

Background

The 1983-84 Caribbean-wide mass mortality of the long-spined sea urchin *Diadema antillarum* represents one of the more spatially expansive and prolonged disturbances to coral reef ecosystems in the region (Carpenter 1988; Lessios 1988, 2005). Prior to the mass mortality event, *D. antillarum* attained high (>20 per m^2) densities on many Caribbean reefs (Lessios 1988). After the disease epidemic, caused by a still unknown water-borne pathogen, abundances declined by several orders of magnitude and have largely remained in this state for over 25 years (Lessios 2005; Weil et al. 2005; Debrot and Nagelkerken 2006), though recovery appears to be happening at some locations (Carpenter and Edmunds 2006; Idjadi et al. 2010). Together with physical impacts from storms, coral disease outbreaks, and severe bleaching episodes (Gardner et al. 2003), the reduction in urchin densities changed coral-algal dominance patterns (Carpenter 1988; Lessios 1988; Gardner e al. 2003).

In the Florida Keys, the few historical data available prior to 1983-84 indicate that *D. antillarum* densities were lower (up to 4 to 5 per m^2) (Kier and Grant 1965; Bauer 1976, 1980) than values reported for some Caribbean reefs such as Jamaica and the U.S. Virgin Islands. Historical densities of upwards of even a few individuals per m^2, however, are still one to two orders of magnitude greater than current densities in the Florida Keys. A general trend of greater algal cover was reported after the urchin mortality at several Florida Keys offshore reefs in the late 1980s and early 1990s (Jaap et al. 1988; Porter and Meier 1992). However, identifying clear relationships between urchin grazing and algae – and ultimately coral recovery – remains problematic for at least three reasons. First, few, if any, specifically designed before-and-after studies were conducted in the Florida Keys related to urchin decline. Second, the regional die-off of *Acropora* corals from white-band disease began during the late 1970s into the 1980s, prior to the *Diadema* disease epidemic, which opened up large amounts of dead coral substrate for algal colonization. Third, populations of herbivorous fish in the Florida Keys are in relatively good condition compared to many Caribbean locations, potentially confounding the story. In contrast to the rest of the Caribbean, a second disease event, similar to the 1983-84 mortality event, occurred seven years later in the Florida Keys. After initially modest recovery to 0.30-0.58 individuals per m^2, the second mass mortality once again depressed *D. antillarum* densities to < 0.01 individuals per m^2 in patch reef and shallow (< 7 m) fore-reef habitats (Forcucci 1994). With the exception of a few shallow-water areas in the Dry Tortugas (Chiappone et al. 2001), large-scale surveys of urchin densities conducted by our program during 1999-

2001 confirmed the continued pattern of poor recovery (Chiappone et al. 2002a, b), although we are beginning to see evidence of population recovery, especially with respect to size (Chiappone et al. 2013).

While several investigators have reported limited or moderate recovery populations for some Caribbean reef areas (Lessios 2005; Carpenter and Edmunds 2006; Debrot and Nagelkerken 2006; Idjadi et al. 2010), recovery in the Florida Keys appears to be occurring slower (Chiappone et al. 2002a, 2013; Lazar et al. 2005). Still, from 2005 to 2012, we have documented increases in the frequency of occurrence, density, and the sizes of *D. antillarum* from surveys of hundreds of sites in the Florida Keys. While some researchers suggest that population recovery will help to promote coral recruitment and a return to pre-mortality baseline reef conditions (Carpenter and Edmunds 2006; Macia et al. 2007; Myhre and Acevedo-Gutierrez 2007), many of the proximal causes of coral decline, such as disease and bleaching remain, which may counteract any positive influences of increased urchin grazing. Despite these uncertainties, and because of these uncertainties, there is keen interest in the spatial and temporal patterns of *D. antillarum* recovery in the Florida Keys. Coral recruitment data are also needed, which we have collected in the past, but were not collected during 2012. In addition, the slow and incomplete recovery of this urchin raises the question of what factors currently limit population recovery (Miller et al. 2010).

Beginning in 1999, we have conducted periodic, large-scale surveys of urchin density, abundance and size structure in a diversity of habitats across the south Florida shelf encompassing hundreds of sites (Chiappone et al. 2001, 2002a, b, 2009). Most recently, we described trends in population density and size structure of *Diadema antillarum* based upon data collected during 1999-2011 along ~200 km of the Florida reef tract (Chiappone et al. 2013). Below is a summary of the 2012 survey results for echinoids encountered at the 600 Florida Keys sites in terms of: site presence, which is the percentage or proportion of sites where a species was encountered within one or both sampled belt transects; transect frequency of occurrence, which is the proportion of transects where a species was present; density reported as numbers of individuals per m^2; and test sizes (individual test diameter, TD in cm). To our knowledge, this effort represents the only large-scale, repeated, and long-term surveys for urchins inhabiting hard-bottom and coral reef habitats in the Florida Keys ecosystem.

2012 Survey Results

During May-November 2012, a total of 600 sites were sampled for urchins (echinoids), by surveying two (2) replicate 15-m x 1-m belt transects per site for numbers and sizes (test diameter), yielding a total survey area of 18,000 m^2 of benthic habitat in the Florida Keys from northern Biscayne National Park

(BNP) to southwest of Key West. Seven (7) echinoid species were searched for and all but one was encountered during 2012: *Arbacia punctulata* (not encountered), *Diadema antillarum*, *Echinometra lucunter*, *E. viridis*, *Eucidaris tribuloides*, *Lytechinus variegatus*, and *Tripneustes ventricosus* (Figure 5-1). Tables 5-1 to 5-6 summarize mean site presence, transect frequency of occurrence, densities, and size (test diameter) for the six species encountered by habitat type and management zone. A total of 4,972 urchins were identified, counted, and measured, listed alphabetically as follows with total numbers counted and relative abundance (% of all echinoids) for the 600 sites:

- *Arbacia punctulata* (no individuals encountered during 2012),
- *Diadema antillarum* (257 individuals, 5.2% of all echinoids counted),
- *Echinometra lucunter* (185 individuals, 3.7%),
- *E. viridis* (3,578 individuals, 72%),
- *Eucidaris tribuloides* (921 individuals, 18.5%),
- *Lytechinus variegatus* (3 individuals, 0.1%), and
- *Tripneustes ventricosus* (28 individuals, 0.6%).

Echinoids were encountered at 376 of the 600 sites (63%) surveyed. Figures 5-2 to 5-8 show the spatial distribution of total urchin densities from northern BNP to Key West. Although echinoids are broadly distributed among hard-bottom and coral reef habitats in the Florida Keys, relatively dense concentrations are most common in the patch reef environment. Specific examples of this pattern include high densities of echinoids on several patch reefs in southern Biscayne National Park (Figure 5-2), offshore of Key Largo (Figure 5-3), and in the lower Keys, especially east of Western Sambo Ecological Reserve (Figure 5-7), as well as north of Sand Key in the Middle Ground area (Figure 5-8). This pattern largely reflects the relatively high densities (> 1 individual per m^2) of *Echinometra viridis* (see below). In addition, reef rubble continues to be an important recruitment habitat for many of the urchins in the Florida Keys.

Arbacia punctulata (Lamarck)

Since 1999, we have only encountered two individuals of *Arbacia punctulata* (Figure 5-1), which is normally associated with seagrass and other soft-sediment habitats. A total of two individuals were recorded within belt transect surveys during 2011, but none were found during 2012.

Diadema antillarum (Philippi)

A total of 247 *Diadema antillarum* were recorded (5.2% of all urchins), distributed among 143 of the 600 sites (24%) and within 14% of the sampled belt transects. Individuals were distributed among all ten of the habitats sampled, though at different densities and sizes (Table 5-1). The maximum site-level density of 0.267 individuals per m^2 was recorded from a high-relief spur and groove site at Maryland Shoal in the lower Florida Keys. Since 2001, we continue to document an increase in the number of sites where *D. antillarum* is present and a trend towards larger test sizes, especially on patch reefs. In addition, back-reef rubble areas continue to support recently settled juveniles (< 2 cm TD). Figures 5-9 to 5-15 illustrate the spatial distribution of *D. antillarum* densities throughout the Florida Keys study area and illustrate two spatial patterns: 1) generally greater densities in BNP, the upper Keys, and the lower Keys compared to the middle Keys; and 2) greater densities on patch reef and inner line reef tract habitats inshore of the main reef tract. Site presence, transect frequency, mean density (no. individuals per m^2), and average size were greatest on offshore patch reefs, followed by inner line reef tract and mid-channel patch reef habitats (Table 5-1). Similar to other echinoids, site presence, transect frequency, and density, but not necessarily average size, tended to be greater in reference areas compared to FKNMS no-take zones, especially for patch reefs. Test sizes ranged from 0.4 cm to 10.2 cm and averaged 6.5 cm. An encouraging sign in the *D. antillarum* population is the presence of both recently settled recruits, as well as individuals that have survived beyond 1-2 years of age, a pattern not evident in the Florida Keys until about 2006.

Echinometra lucunter (Linnaeus)

Two species of *Echinometra* were recorded during 2012. *E. lucunter* was the lesser abundant of the two species (185 individuals) and was encountered in only five of the ten habitats (Table 5-3). Inshore and mid-channel patch reefs yielded the greatest site presence, transect frequency, and mean density values. The greatest site-level density of 3.6 individuals per m^2 was recorded from a mid-channel patch reef site in the West Washerwoman Shoal area in the lower Keys. *E. lucunter* test sizes ranged from 0.8 cm to 5.3 cm and averaged 2.9 cm. Unlike other echinoids, there were no consistent differences in *E. lucunter* site presence, transect frequency, or density between reference areas and no-take zones (Table 5-2).

Echinometra viridis Agassiz

The most abundant urchin surveyed during 2012 was *Echinometra viridis* (3,578 individuals, 72% of all urchins), which was encountered in all habitats except deeper (> 6 m) low-relief hard-bottom and low-relief spur and groove (Table 5-3). This echinoid exhibited habitat-specific patterns of distribution and abundance similar to previous years, with the greatest densities on mid-channel patch reefs, followed by

inshore and offshore patch reefs. Densities were especially high (upwards of 5.6 individual per m^2) on mid-channel patch reefs in both the upper and lower Keys. Site presence, transect frequency of occurrence, and density tended to be greater in Biscayne National Park and FKNMS reference sites compared to FKNMS no-take zones, although there appeared to be little difference in size (Table 5-3). The test diameter (TD) of the individuals encountered ranged from 0.7 cm to 5.0 cm and averaged 3.0 cm.

Eucidaris tribuloides (Lamarck)

The slate pencil urchin, *Eucidaris tribuloides*, was the second most abundant echinoid (921 individuals 19% of all urchins) recorded during 2012. Individuals were encountered at 287 of the 600 sites (48%), 34% of the sampled transects, and from all ten of the habitat types sampled (Table 5-4). Distribution and density patterns were similar to previous surveys during 1999-2011. Mid-channel and offshore patch reefs, as well as reef rubble and spur and groove habitats along the inner reef tract and outer platform margin, yielded the greatest transect frequency of occurrence and densities (Table 5-4). Densities were relatively high on various types of patch reefs, inner line reef tract, and shallow hard-bottom. For several habitats, *E. tribuloides* site presence, transect frequency, density, and size tended to be greater in BNP and FKNMS reference sites compared to FKNMS no-take zones. For the 921 individuals encountered, test diameters ranged from 1.2 cm to 4.3 and averaged 2.4 cm.

Lytechinus variegatus (Lamarck)

Lytechinus variegatus was the least abundant of the echinoids surveyed (3 individuals, 0.1% of all urchins) and was only being recorded at three of the 600 sites (0.5%) and 0.3% of the sampled belt transects. This result is not surprising, as similar to other species such as *Arbacia punctulata* and *Tripneustes ventricosus*, this urchin is most commonly associated with seagrass and other soft-sediment habitats. Except for one individual found on a patchy hard-bottom site, the remaining two individuals were recorded from mid-channel patch reefs that were adjacent to seagrass. The three individuals ranged in size (test diameter, TD) from 6.5 cm to 8.2 cm and averaged 7.6 cm TD.

Tripneustes ventricosus (Lamarck)

Tripneustes ventricosus, most common in seagrass habitats, was one of the least abundant urchins encountered, since the 2012 sampling effort did not include seagrass habitats. Twenty-eight individuals (0.6% of all urchins) were recorded from the 600 sites, with most encountered on mid-channel and offshore patch reefs (Table 5-6). *T. ventricosus* was encountered at 20 of the 600 sites (3.3%) and 1.9% of

the sampled transects. A maximum site-level density of 0.100 individuals per m^2 was recorded from an offshore patch reef site on White Bank in an area with abundant seagrass. The size range (test diameter) of the 28 individuals sampled ranged from 4.7 to 12.0 cm, with a mean (± 1 SE) size of 8.0 ± 1.8 cm.

Discussion

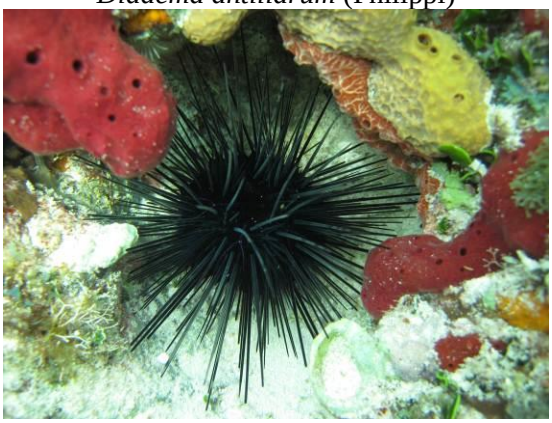
Large-scale surveys encompassing hundreds of sites in the Florida Keys since 1999 indicate that *Diadema antillarum* continues to persist at densities well below values reported before the Caribbean-wide mass mortality in 1983-84 and the Florida Keys mortality event in 1991 (Kier and Grant 1965; Bauer 1980; Forcucci 1994). Despite this pattern, the Florida Keys population continues to show signs of increasing spatial distribution and abundance, as well as an increase in mean test size, with a greater proportion of larger individuals present. In addition, the reef rubble habitat appears to continue to be an important recruitment habitat, although the fate of post-settlement individuals compared to other habitat types has not been studied. Earlier reports and recent observations indicate that other urchins show density and habitat distribution patterns similar to pre-1983 observations, indicating that other species have apparently not compensated for the loss of *D. antillarum* (Chiappone et al. 2002a). In areas with relatively high (> 0.1 individuals/m^2) and larger (> 5 cm TD) *D. antillarum*, there are obvious effects of grazing on the substratum, particularly the removal of turf and macroalgae and exposure of the substratum (Chiappone et al. 2001). This is also apparent in areas with relatively high *Echinometra* densities, despite the smaller sizes of the two congeners compared to *D. antillarum*.

The slow and prolonged recovery of *Diadema antillarum* in the Florida Keys, especially compared to reports of more rapid recovery in some Caribbean reef areas, raises several questions. Possible causes of slow recovery include poor larval survivorship, lack of adult conspecifics and hence protection from predators, absence of, or reduced recruitment habitat, and inter-specific competition. The sources of urchin larvae to the Florida Keys are not known, but may include both local and regional sources (Lee et al. 1994). Nonetheless, it is apparent that *D. antillarum* recruit to benthic habitats, especially rubble areas, but the fate of these recently settled juveniles is unknown (Chiappone et al. 2002a). A recent study of *D. antillarum* larval settlement rates indicate that low larval supply may be one factor limiting recovery (Miller et al. 2010). The predominance of relatively small test sizes from 1999-2005 indicated that recently settled individuals likely had poor survivorship into larger size classes, perhaps due to predation or physical disturbance from storms. Since 2006, however, there has been a notable shift in the size distribution towards larger individuals. Because *D. antillarum* was historically significant as a grazer, it is anticipated that continued recovery will influence patterns in reef community structure.

Figure 5-1. Urchin species surveyed for density and size (test diameter) in the Florida Keys during 2012. Not shown is *Tripneustes ventricosus* (Lamarck). Except for *Arbacia punctulata*, which is a seagrass-associated species, all other species were encountered during 2012.

Arbacia punctulata (Lamarck)

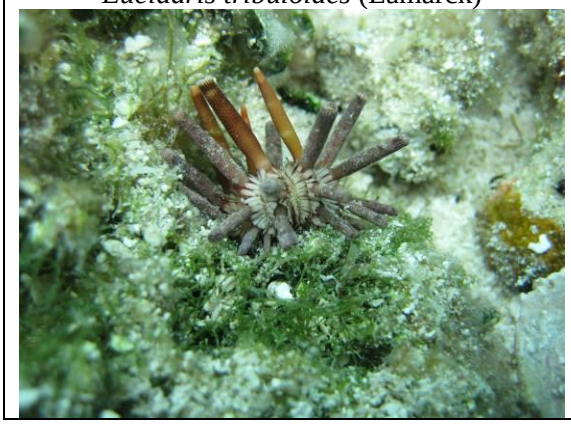
Diadema antillarum (Philippi)



Echinometra lucunter (Linnaeus)

Echinometra viridis (Agassiz)

Eucidaris tribuloides (Lamarck)



Lytechinus variegatus (Lamarck)

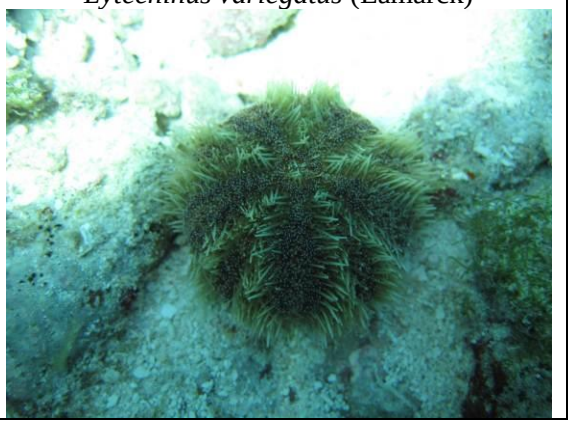


Figure 5-2. Densities (no. per m^2) of all urchin species in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

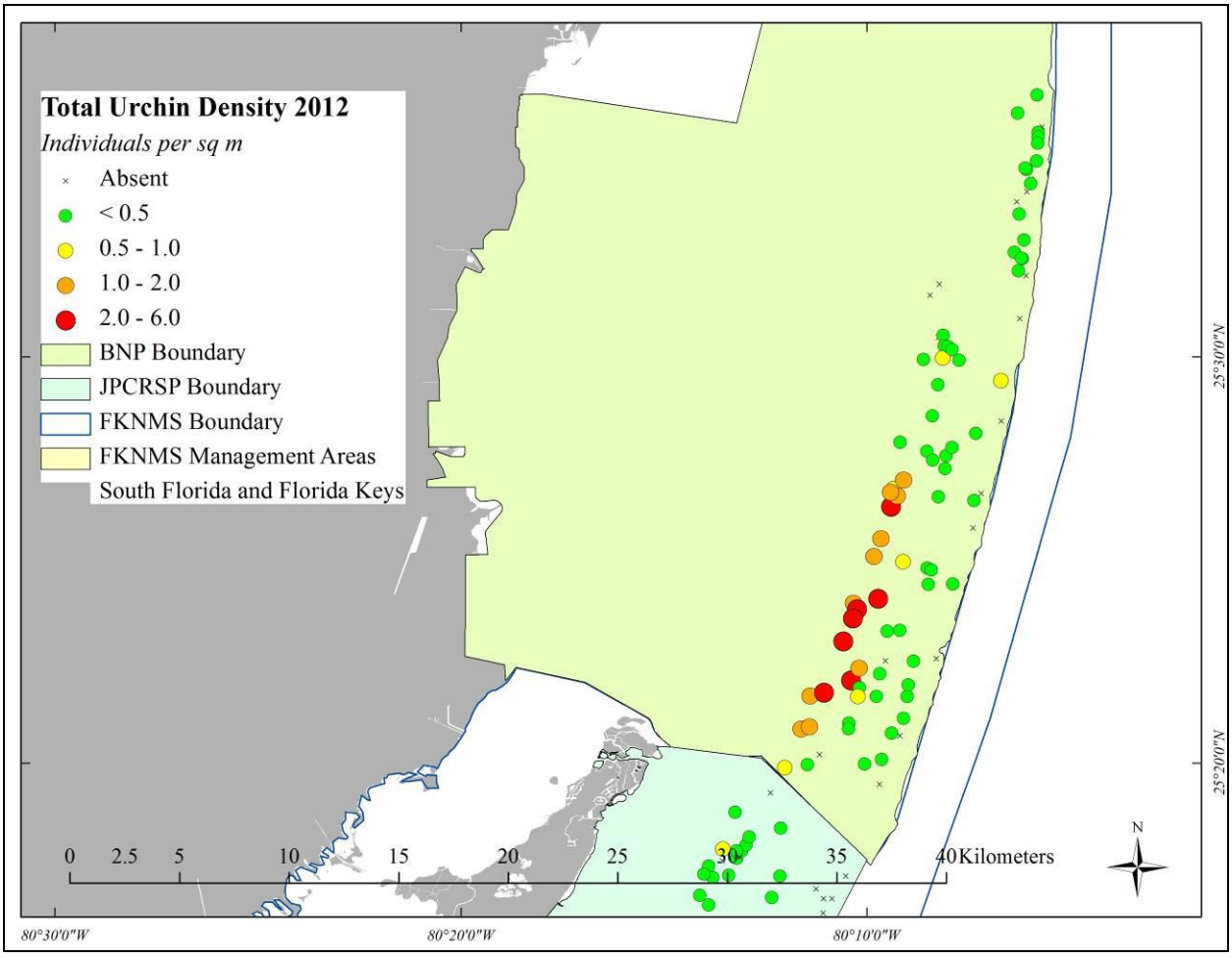


Figure 5-3. Densities (no. per m^2) of all urchin species in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

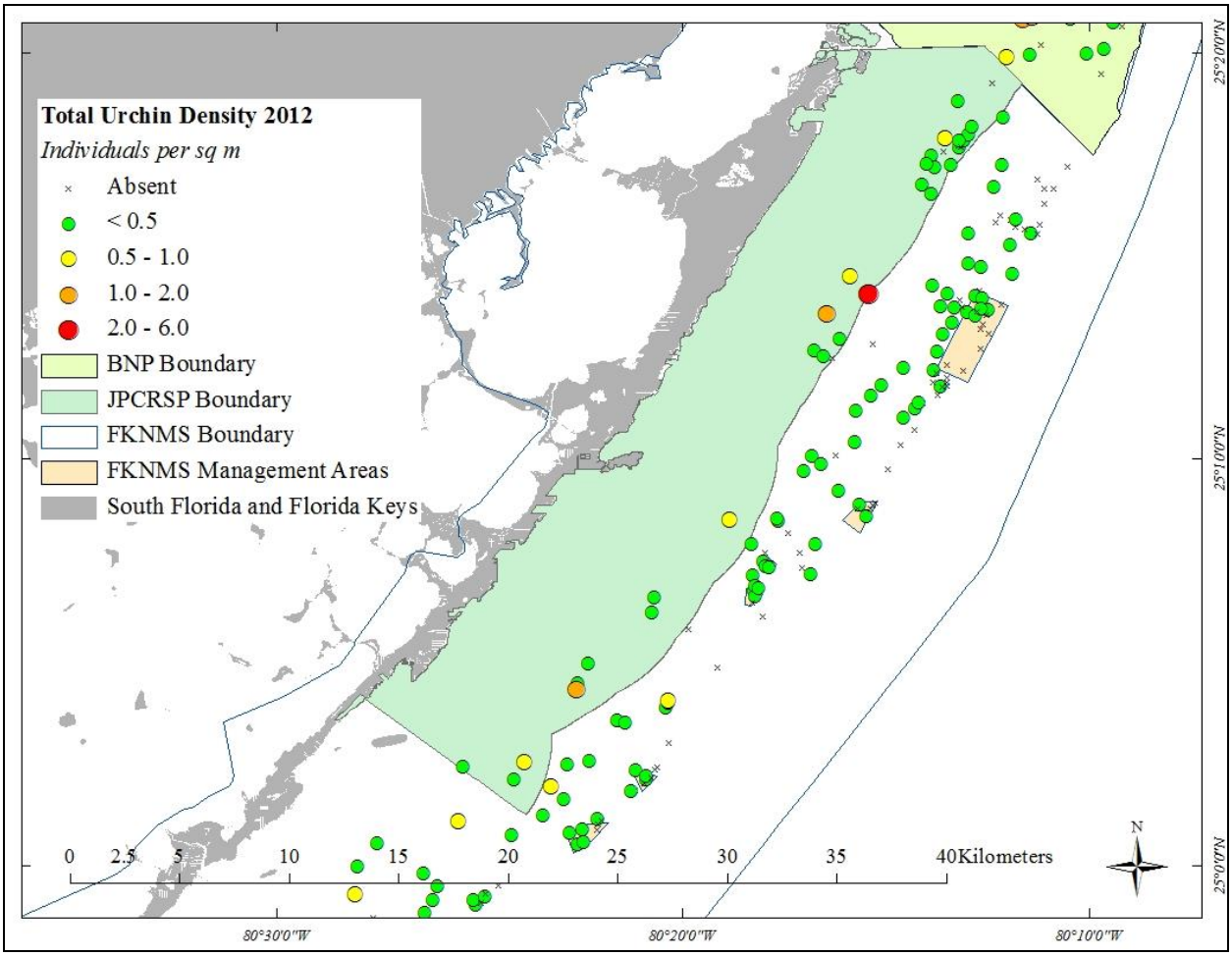


Figure 5-4. Densities (no. per m^2) of all urchin species in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

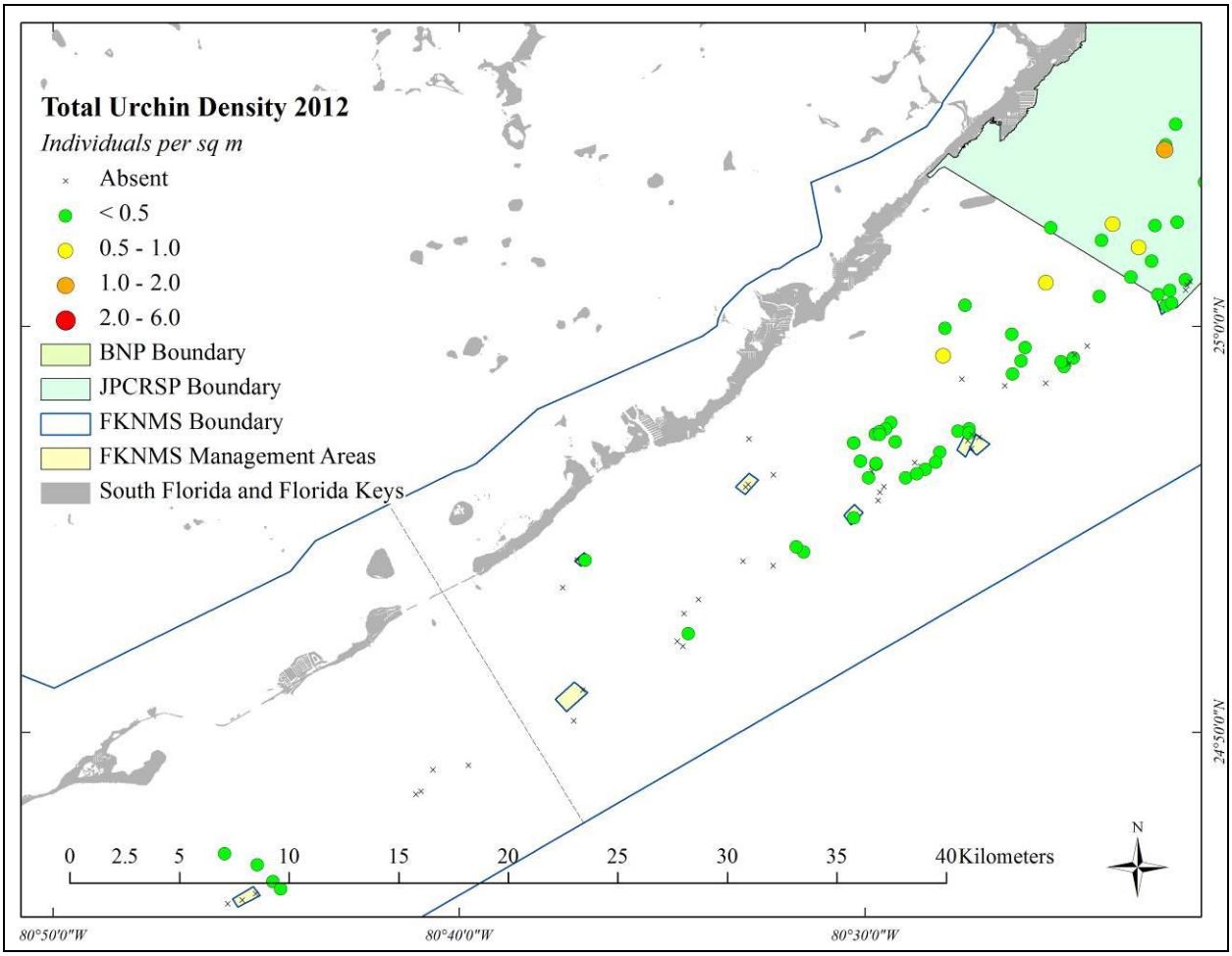


Figure 5-5. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

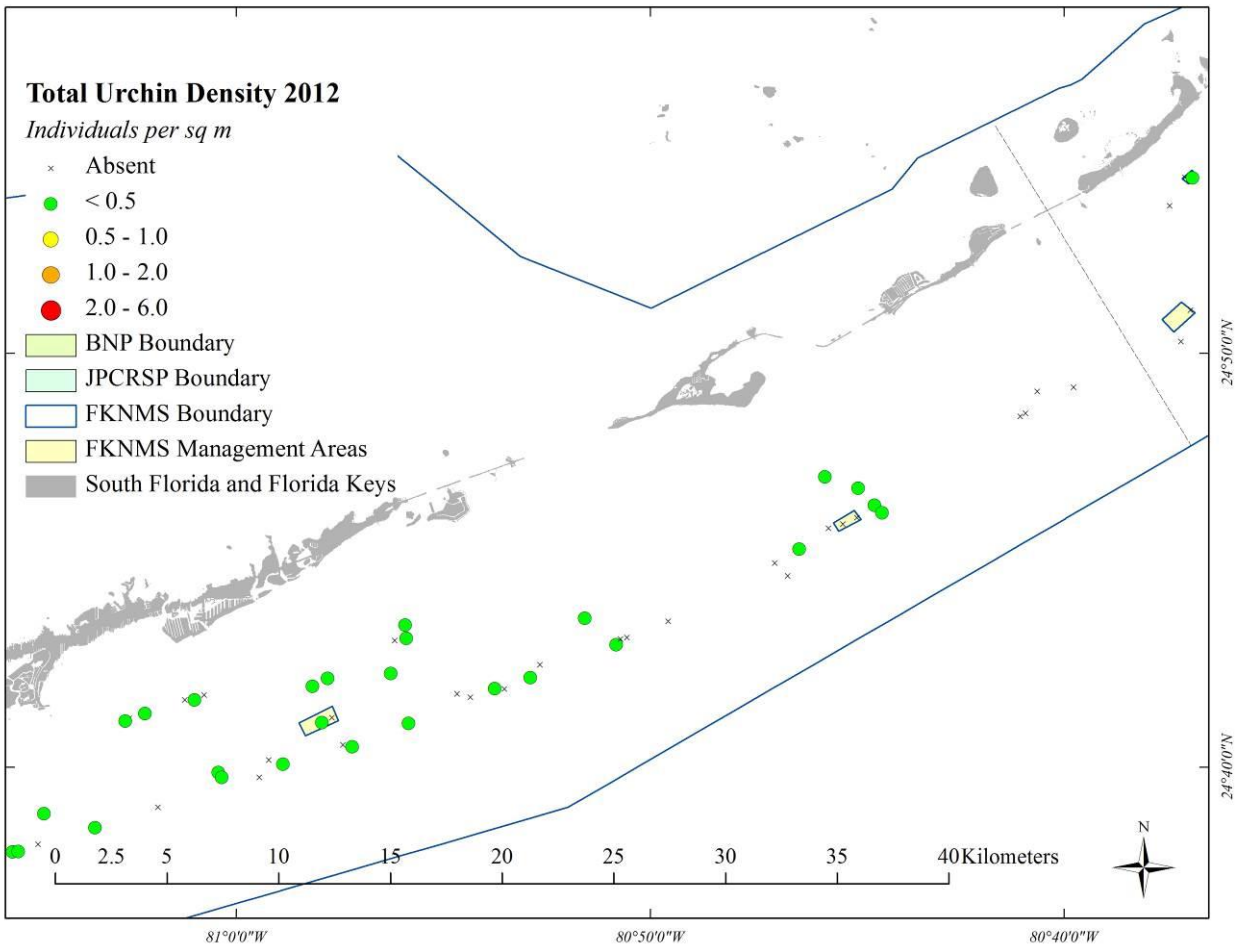


Figure 5-6. Densities (no. per m^2) of all urchin species in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

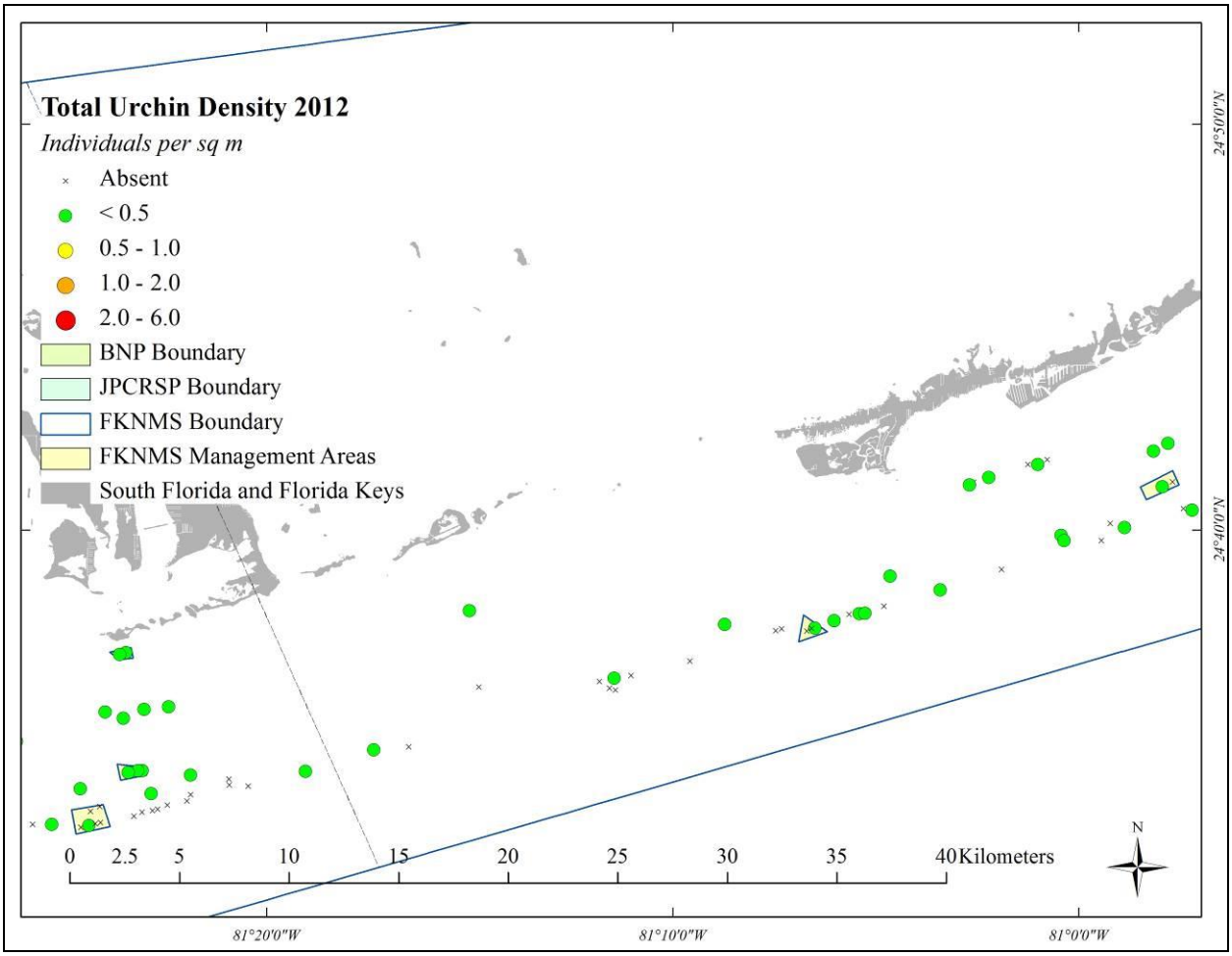


Figure 5-7. Densities (no. per m^2) of all urchin species in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

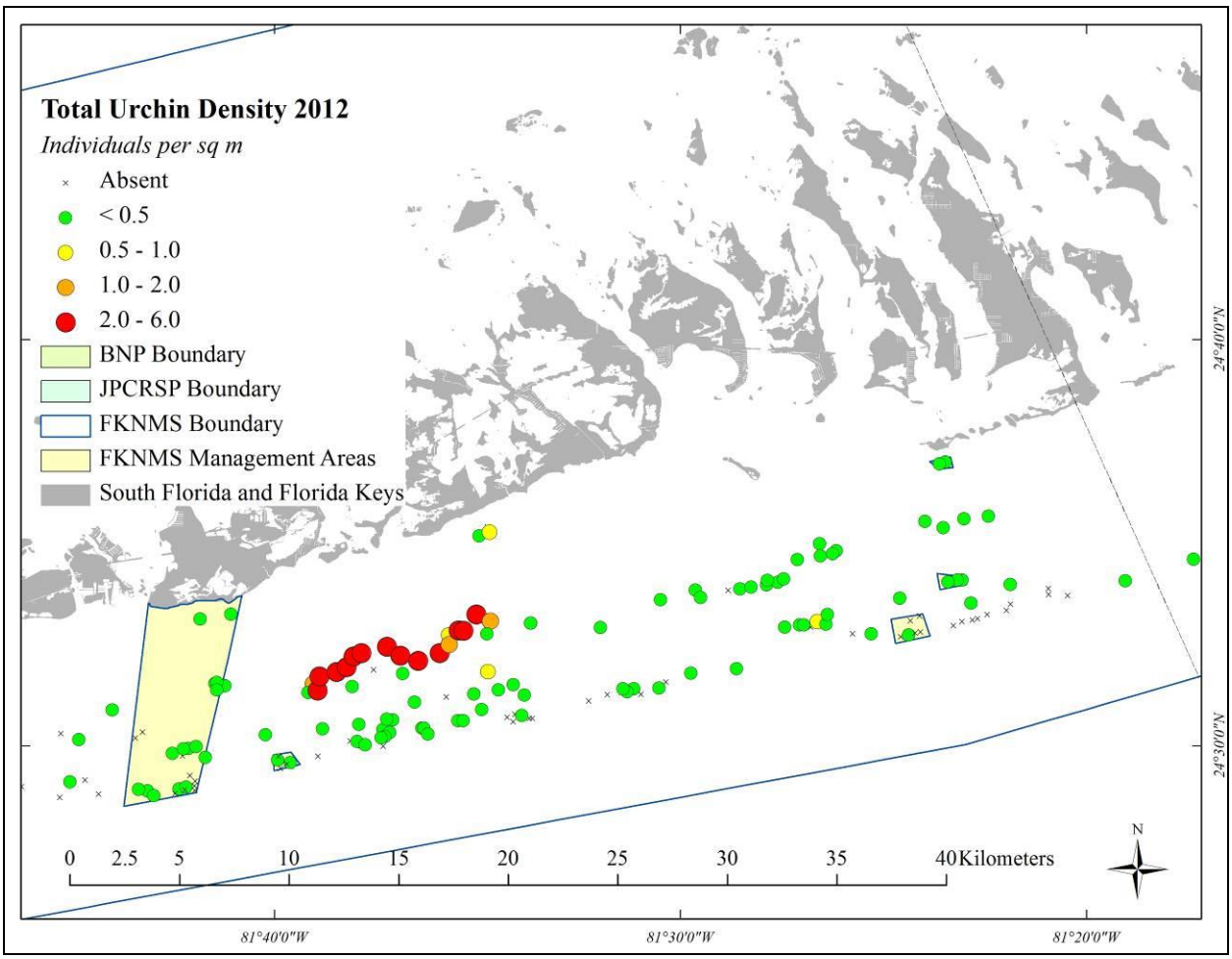


Figure 5-8. Densities (no. per m^2) of all urchin species in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

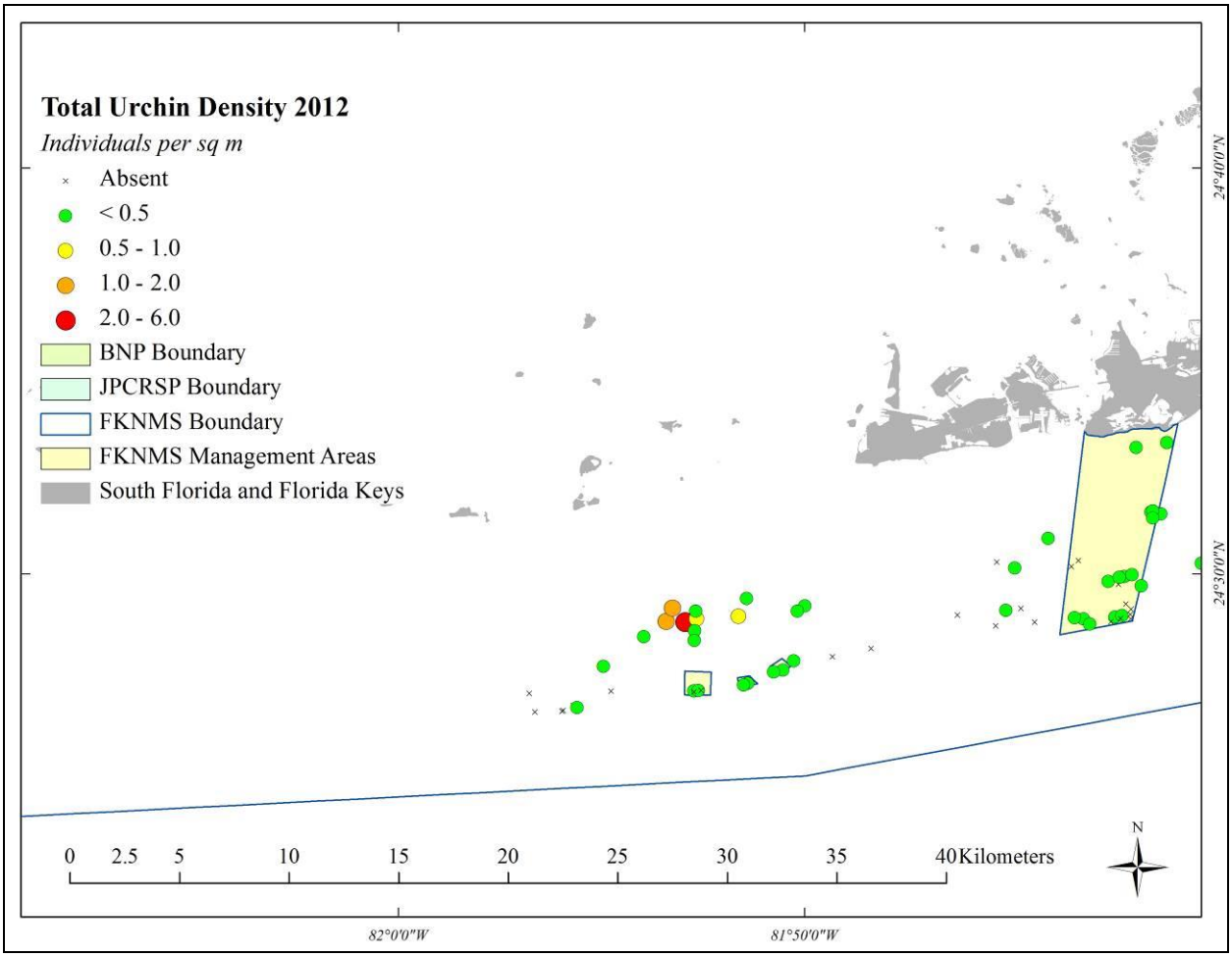


Figure 5-9. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

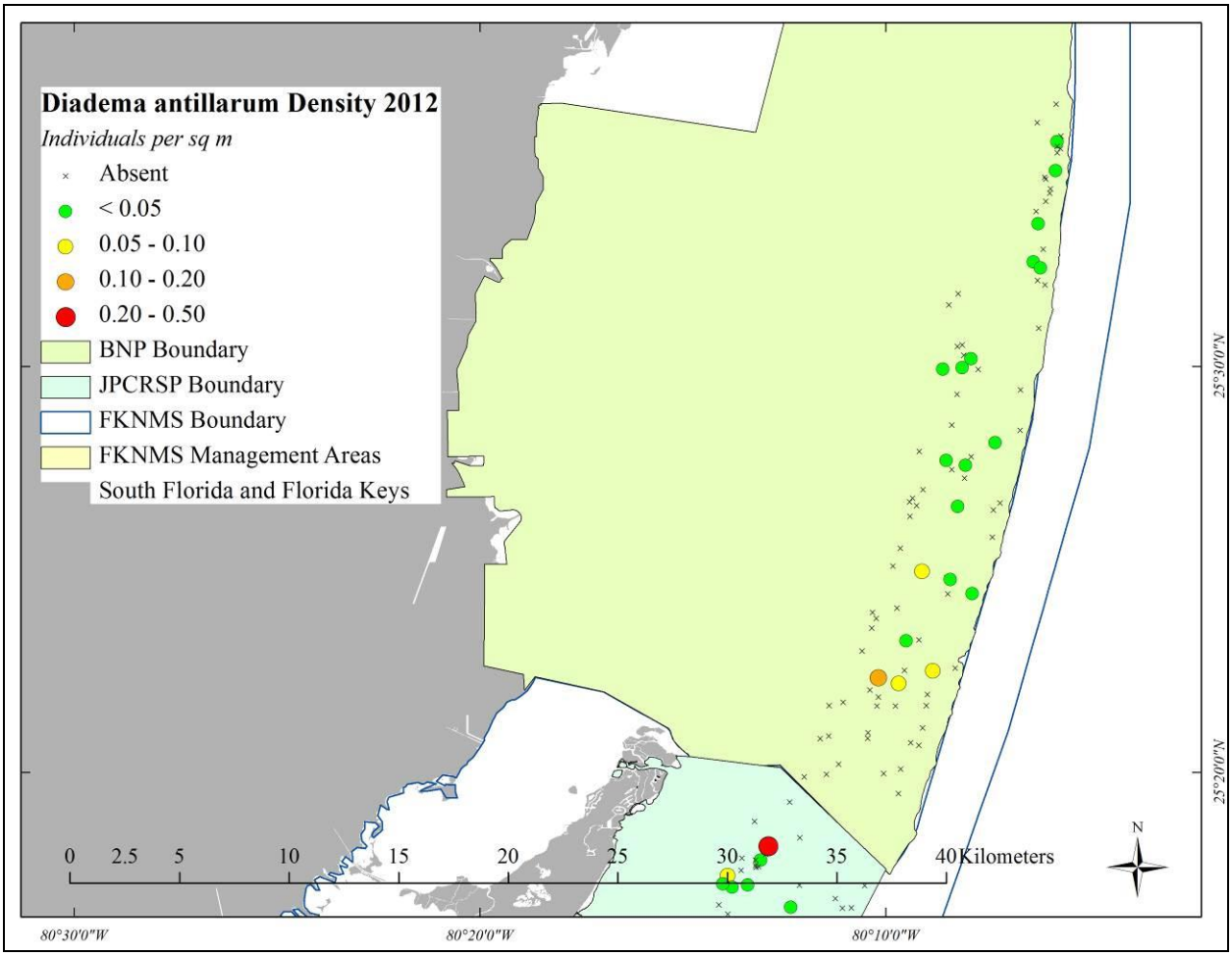


Figure 5-10. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

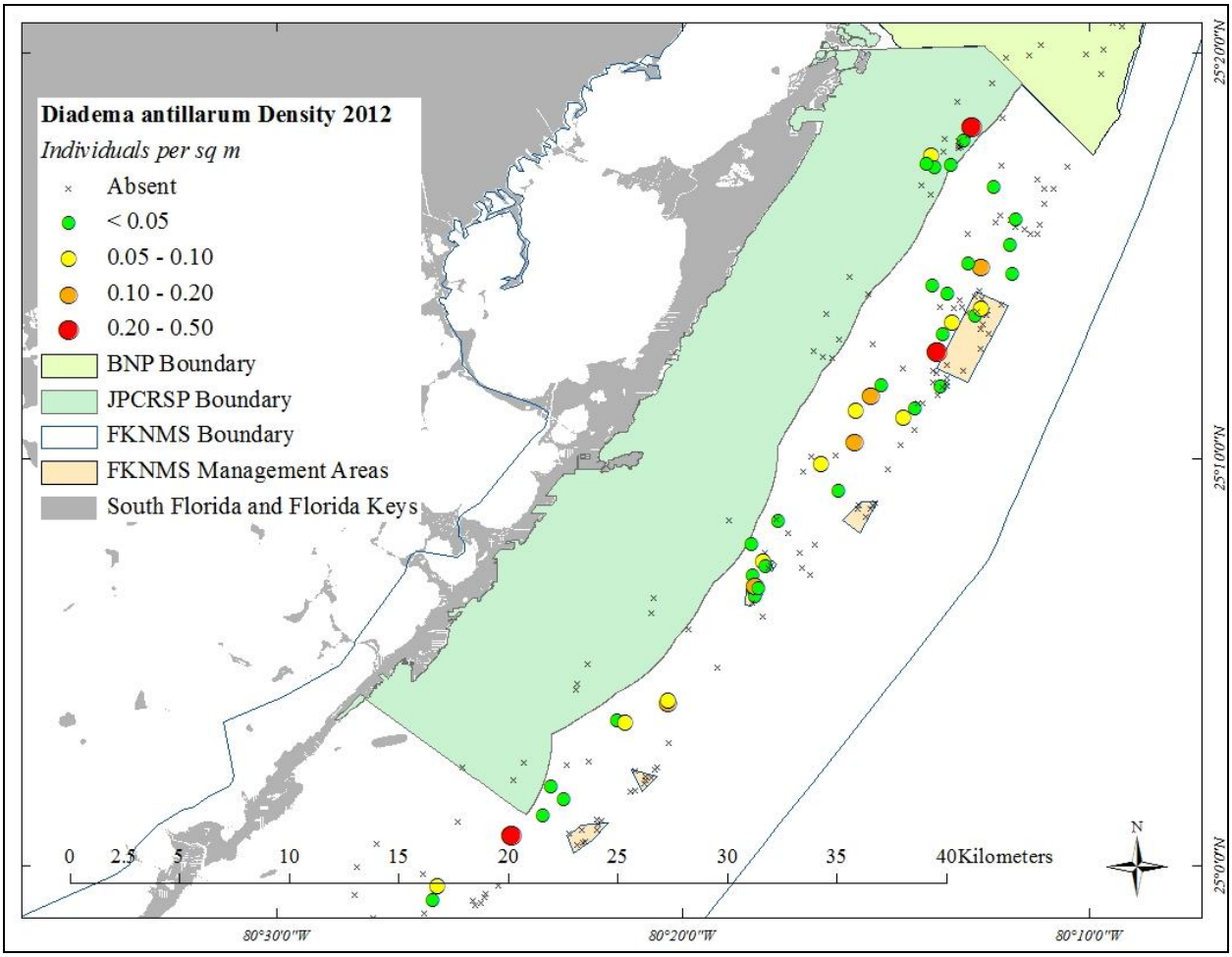


Figure 5-11. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

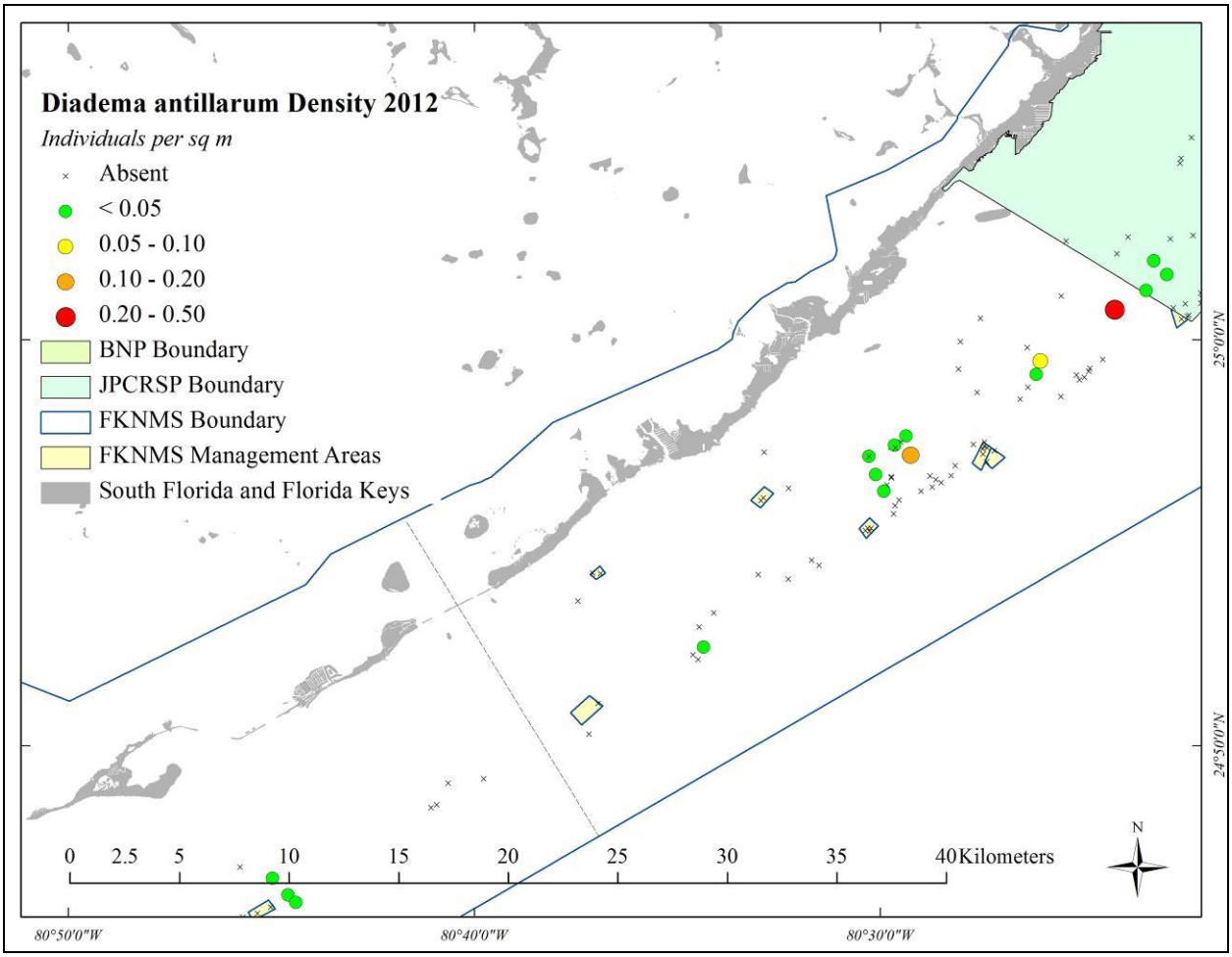


Figure 5-12. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

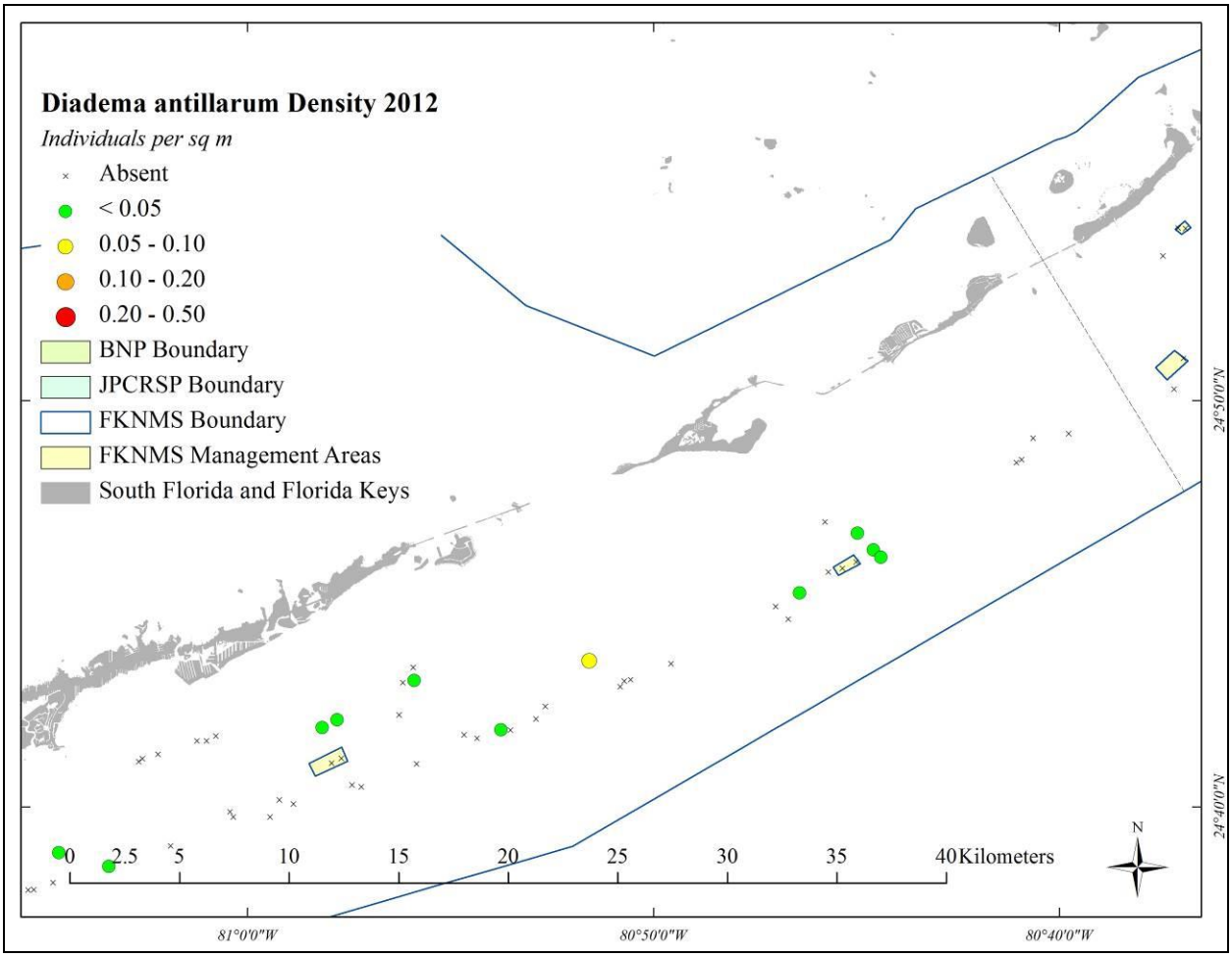


Figure 5-13. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

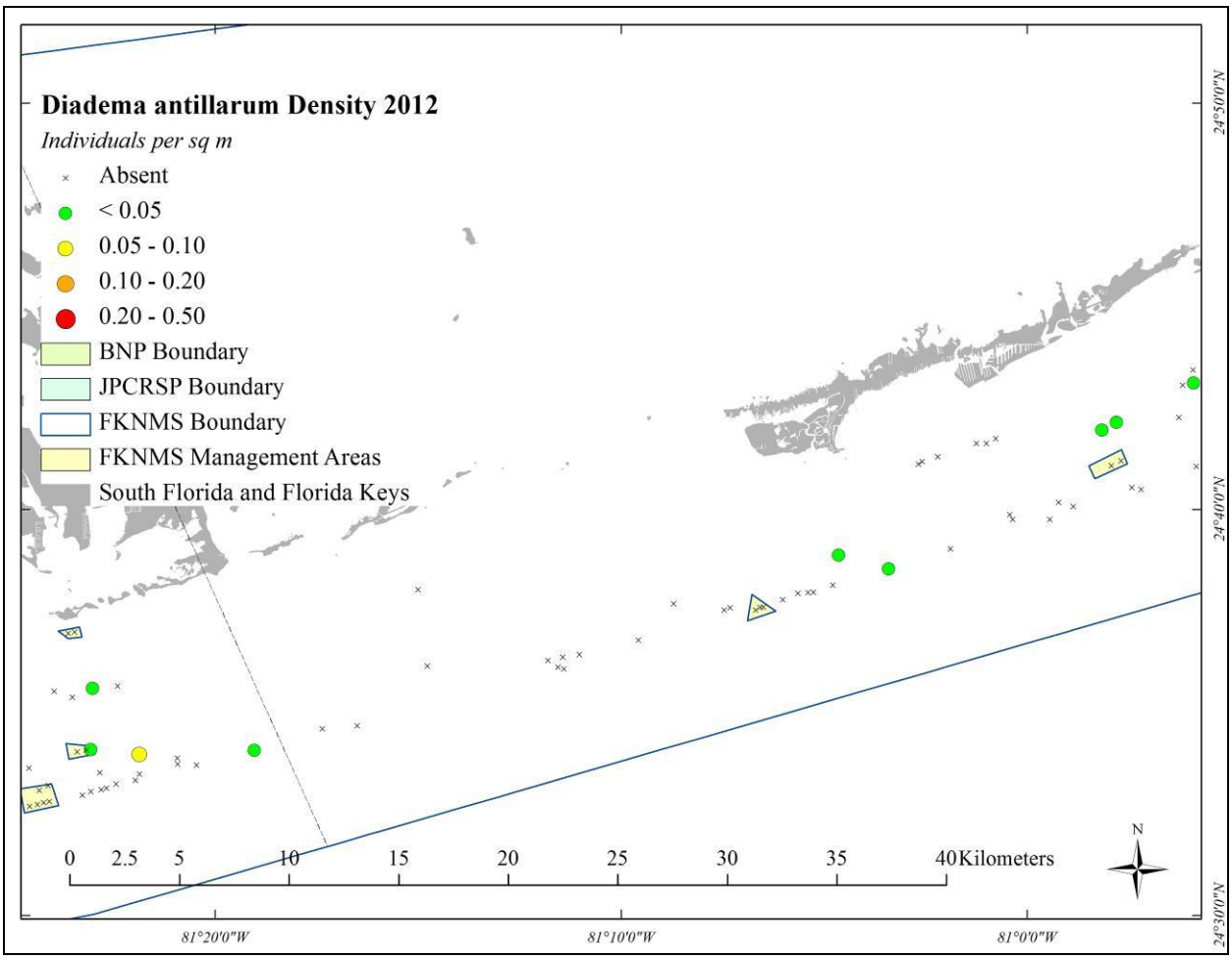


Figure 5-14. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

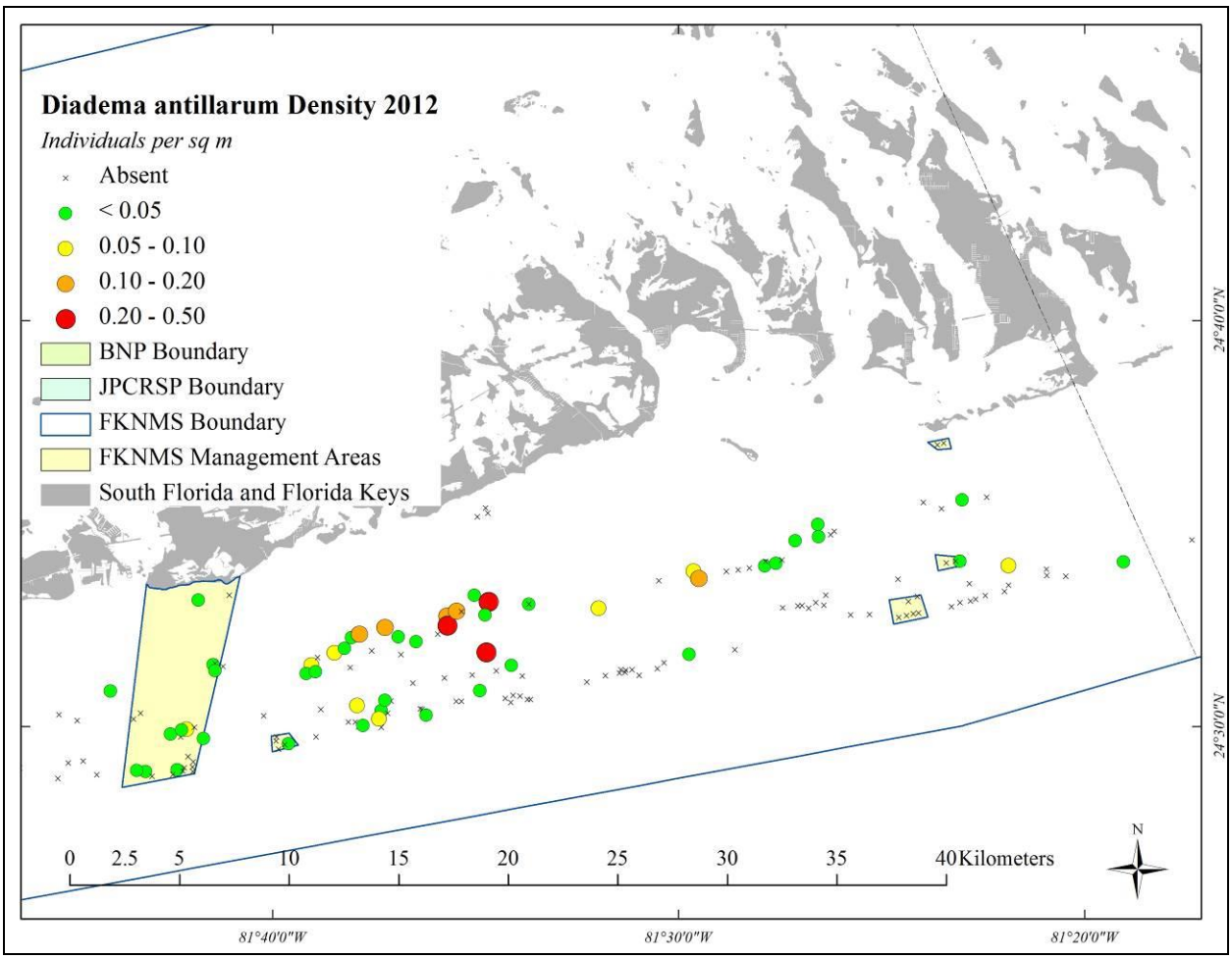


Figure 5-15. Densities (no. per m^2) of long-spined sea urchins (*Diadema antillarum*) in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

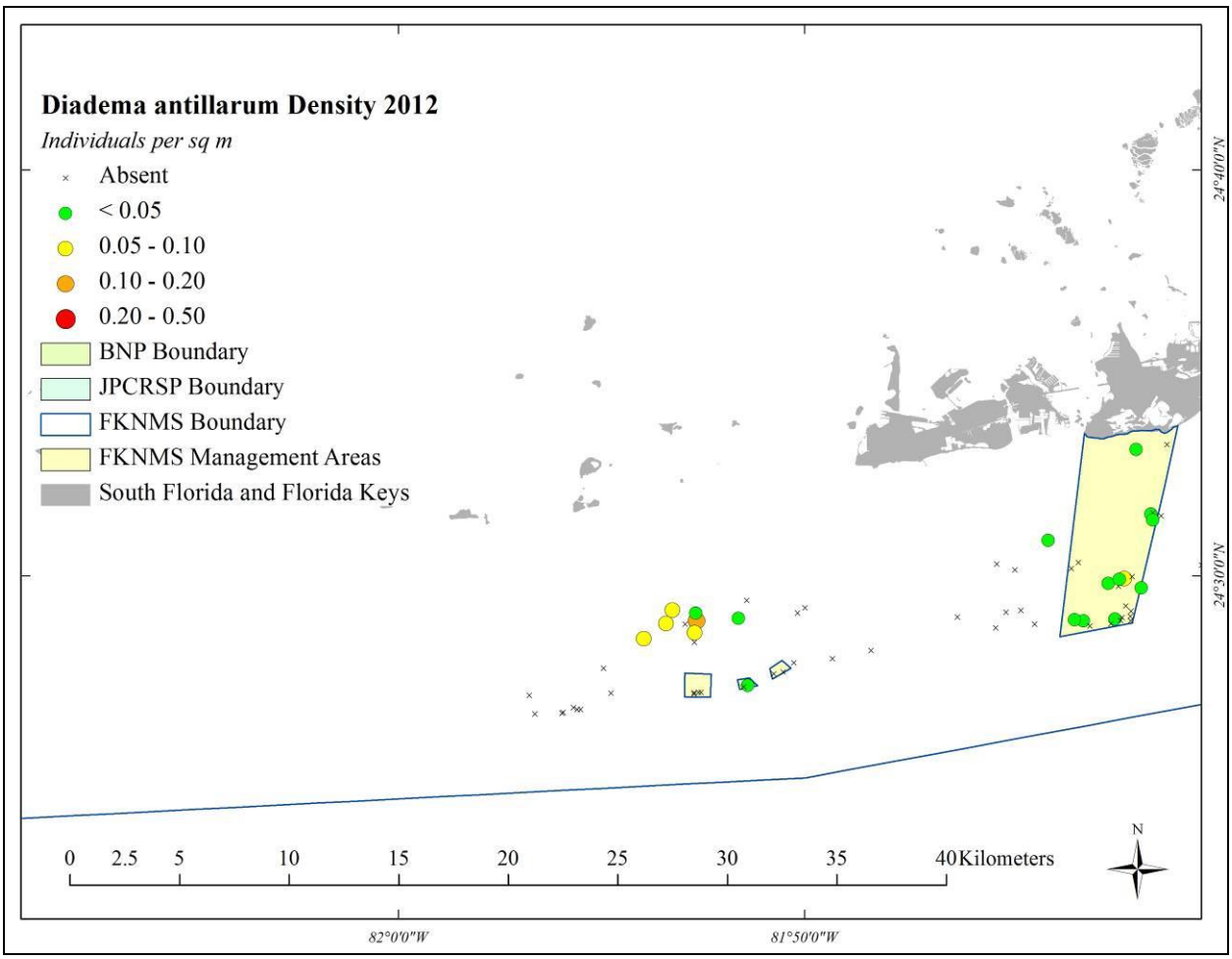


Table 5-1. Site presence, transect frequency of occurrence, density, and size (test diameter) of the long-spined sea urchin *Diadema antillarum* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for test size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	6.5	1
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	9.0	1
Habitat Total (10)	20.0 ± 13.3	10.0 ± 6.7	0.007 ± 0.004	7.8 ± 1.3	2
Mid-channel patch reefs					
Biscayne National Park (50)	20.0 ± 5.7	14.0 ± 4.3	0.013 ± 0.005	6.3 ± 1.0	19
FKNMS Reference Areas (90)	37.8 ± 5.1	21.7 ± 3.2	0.026 ± 0.005	6.5 ± 0.4	70
FKNMS No-take Zones (11)	36.4 ± 15.2	18.2 ± 7.6	0.012 ± 0.005	6.7 ± 0.9	4
Habitat Total (151)	31.8 ± 3.8	18.9 ± 2.4	0.021 ± 0.004	6.4 ± 0.3	93
Offshore patch reefs					
Biscayne National Park (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	10.0	1
FKNMS Reference Areas (98)	43.9 ± 5.0	27.0 ± 3.4	0.030 ± 0.005	6.9 ± 0.2	90
FKNMS No-take Zones (15)	40.0 ± 13.1	26.7 ± 9.6	0.022 ± 0.008	7.0 ± 0.7	10
Habitat Total (122)	41.0 ± 4.5	25.4 ± 3.0	0.027 ± 0.004	7.0 ± 0.2	101
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	12.5 ± 8.5	6.3 ± 4.3	0.006 ± 0.005	7.0 ± 0.0	3
FKNMS No-take Zones (11)	18.2 ± 12.2	9.1 ± 6.1	0.006 ± 0.004	3.0 ± 1.8	2
Habitat Total (29)	13.8 ± 6.5	6.9 ± 3.3	0.006 ± 0.003	5.0 ± 1.4	5
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	33.3 ± 16.7	22.2 ± 12.1	0.015 ± 0.008	6.8 ± 1.2	4
FKNMS No-take Zones (9)	44.4 ± 17.6	27.8 ± 12.1	0.030 ± 0.018	6.2 ± 0.8	8
Habitat Total (18)	38.9 ± 11.8	25.0 ± 8.3	0.022 ± 0.010	6.4 ± 0.6	12
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	14.3 ± 6.7	8.9 ± 4.5	0.014 ± 0.010	5.7 ± 1.5	12
FKNMS No-take Zones (33)	9.1 ± 5.1	4.5 ± 2.5	0.003 ± 0.002	1.2 ± 0.6	3
Habitat Total (62)	11.3 ± 4.1	6.5 ± 2.4	0.008 ± 0.005	3.8 ± 1.2	15
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	18.8 ± 10.1	9.4 ± 5.0	0.006 ± 0.003	4.6 ± 2.0	3
FKNMS Reference Areas (20)	20.0 ± 9.2	10.0 ± 4.6	0.012 ± 0.006	7.2 ± 0.4	7
FKNMS No-take Zones (4)	50.0 ± 28.9	25.0 ± 14.4	0.025 ± 0.016	4.9 ± 4.1	3
Habitat Total (40)	22.5 ± 6.7	11.3 ± 3.3	0.011 ± 0.004	5.8 ± 1.0	13
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	33.3 ± 21.1	16.7 ± 10.5	0.011 ± 0.007	2.8 ± 2.0	2
FKNMS Reference Areas (42)	19.0 ± 6.1	9.5 ± 3.1	0.006 ± 0.002	4.9 ± 0.9	8
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	18.5 ± 5.3	9.3 ± 2.7	0.006 ± 0.002	4.5 ± 0.8	10

Table 5.1 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	1.6	1
FKNMS Reference Areas (28)	7.1 ± 5.0	3.6 ± 2.5	0.002 ± 0.002	4.0 ± 2.1	2
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	9.4 ± 5.2	4.7 ± 2.6	0.003 ± 0.002	3.2 ± 1.5	3
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	20.0 ± 20.0	10.0 ± 10.0	0.007 ± 0.007	6.2	1
FKNMS Reference Areas (54)	3.7 ± 2.6	1.9 ± 1.3	0.001 ± 0.001	5.6 ± 2.4	2
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	3.7 ± 2.1	1.8 ± 1.0	0.001 ± 0.001	5.8 ± 1.4	3

Table 5-2. Site presence, transect frequency of occurrence, density, and size (test diameter) of the rock-boring urchin *Echinometra lucunter* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for test size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	2.8	1
FKNMS No-take Zones (4)	75.0 ± 25.0	37.5 ± 12.5	0.050 ± 0.017	2.2 ± 0.3	6
Habitat Total (10)	40.0 ± 16.3	20.0 ± 8.2	0.023 ± 0.010	2.4 ± 0.2	7
Mid-channel patch reefs					
Biscayne National Park (50)	18.0 ± 5.5	11.0 ± 3.6	0.017 ± 0.007	2.1 ± 0.2	25
FKNMS Reference Areas (90)	13.3 ± 3.6	10.0 ± 2.9	0.051 ± 0.040	2.6 ± 0.2	138
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	13.9 ± 2.8	9.6 ± 2.1	0.036 ± 0.024	2.4 ± 0.1	163
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	5.1 ± 2.2	2.6 ± 1.1	0.003 ± 0.002	2.1 ± 0.2	10
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	4.1 ± 1.8	2.0 ± 0.9	0.003 ± 0.001	2.1 ± 0.2	10
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	18.2 ± 12.2	9.1 ± 6.1	0.006 ± 0.004	1.3 ± 0.5	2
Habitat Total (29)	6.9 ± 4.8	3.4 ± 2.4	0.002 ± 0.002	1.3 ± 0.5	2
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0		0
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	2.4	1
FKNMS No-take Zones (33)	3.0 ± 3.0	1.5 ± 1.5	0.001 ± 0.001	1.7	1
Habitat Total (62)	3.2 ± 2.3	1.6 ± 1.1	0.001 ± 0.001	2.1 ± 0.4	2
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (20)	5.0 ± 5.0	2.5 ± 2.5	0.002 ± 0.002	2.2	1
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	2.5 ± 2.5	1.3 ± 1.3	0.001 ± 0.001	2.2	1
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0		0

Table 5.2 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		0
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		0

Table 5-3. Site presence, transect frequency of occurrence, density, and size (test diameter) of the green urchin *Echinometra viridis* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for test size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	50.0 ± 50.0	50.0 ± 50.0	0.867 ± 0.867	3.0	52
FKNMS Reference Areas (4)	50.0 ± 28.9	37.5 ± 23.9	0.142 ± 0.131	2.7 ± 0.6	17
FKNMS No-take Zones (4)	100.0 ± 0.0	87.5 ± 12.5	0.100 ± 0.027	2.9 ± 0.4	12
Habitat Total (10)	70.0 ± 15.3	60.0 ± 14.5	0.270 ± 0.170	2.8 ± 0.3	81
Mid-channel patch reefs					
Biscayne National Park (50)	70.0 ± 6.5	61.0 ± 6.3	0.793 ± 0.177	2.5 ± 0.1	1,190
FKNMS Reference Areas (90)	64.4 ± 5.1	56.7 ± 4.8	0.771 ± 0.154	2.8 ± 0.1	2,083
FKNMS No-take Zones (11)	18.2 ± 12.2	9.1 ± 6.1	0.006 ± 0.004	2.5 ± 0.7	2
Habitat Total (151)	62.9 ± 3.9	54.6 ± 3.7	0.723 ± 0.110	2.7 ± 0.1	3,275
Offshore patch reefs					
Biscayne National Park (9)	22.2 ± 14.7	11.1 ± 7.3	0.007 ± 0.005	2.4 ± 0.4	2
FKNMS Reference Areas (98)	28.6 ± 4.6	19.9 ± 3.5	0.070 ± 0.036	2.1 ± 0.1	207
FKNMS No-take Zones (15)	13.3 ± 9.1	6.7 ± 4.5	0.004 ± 0.003	1.3 ± 0.5	2
Habitat Total (122)	26.2 ± 4.0	17.6 ± 2.9	0.058 ± 0.029	2.1 ± 0.1	211
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	18.2 ± 12.2	9.1 ± 6.1	0.006 ± 0.004	1.0 ± 0.2	2
Habitat Total (29)	6.9 ± 4.8	3.4 ± 2.4	0.002 ± 0.002	1.0 ± 0.2	2
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	2.0	1
FKNMS No-take Zones (9)	22.2 ± 14.7	11.1 ± 7.3	0.007 ± 0.005	1.7 ± 0.8	2
Habitat Total (18)	16.7 ± 9.0	8.3 ± 4.5	0.006 ± 0.003	1.8 ± 0.4	3
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	0.9	1
FKNMS No-take Zones (33)	6.1 ± 4.2	3.0 ± 2.1	0.002 ± 0.001	1.1 ± 0.4	2
Habitat Total (62)	4.8 ± 2.7	2.4 ± 1.4	0.002 ± 0.001	1.0 ± 0.2	3
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (20)	10.0 ± 6.9	5.0 ± 3.4	0.003 ± 0.002	2.0 ± 0.0	2
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	5.0 ± 3.5	2.5 ± 1.7	0.002 ± 0.001	2.0 ± 0.0	2
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0		0

Table 5.3 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	2.2	1
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.001 ± 0.001	2.2	1
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		0

Table 5-4. Site presence, transect frequency of occurrence, density, and size (test diameter) of the slate pencil urchin *Eucidaris tribuloides* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for test size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	100.0 ± 0.0	50.0 ± 0.0	0.033 ± 0.000	2.1 ± 0.4	2
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	20.0 ± 13.3	10.0 ± 6.7	0.007 ± 0.004	2.1 ± 0.4	2
Mid-channel patch reefs					
Biscayne National Park (50)	62.0 ± 6.9	47.0 ± 6.0	0.067 ± 0.013	2.4 ± 0.1	100
FKNMS Reference Areas (90)	62.2 ± 5.1	48.3 ± 4.5	0.064 ± 0.010	2.8 ± 0.1	172
FKNMS No-take Zones (11)	27.3 ± 4.1	13.6 ± 7.0	0.009 ± 0.005	2.2 ± 0.0	3
Habitat Total (151)	59.6 ± 4.0	45.4 ± 3.4	0.061 ± 0.007	2.6 ± 0.1	275
Offshore patch reefs					
Biscayne National Park (9)	77.8 ± 14.7	50.0 ± 11.8	0.067 ± 0.028	2.4 ± 0.2	18
FKNMS Reference Areas (98)	60.2 ± 5.0	47.4 ± 4.4	0.082 ± 0.015	2.6 ± 0.1	242
FKNMS No-take Zones (15)	66.7 ± 12.6	36.7 ± 7.7	0.056 ± 0.019	2.2 ± 0.2	25
Habitat Total (122)	62.3 ± 4.4	46.3 ± 3.7	0.078 ± 0.012	2.5 ± 0.1	285
Reef Rubble (< 15 m)					
Biscayne National Park (2)	100.0 ± 0.0	75.0 ± 25.0	0.317 ± 0.283	1.6 ± 0.0	19
FKNMS Reference Areas (16)	50.0 ± 12.9	34.4 ± 9.9	0.038 ± 0.013	2.3 ± 0.3	18
FKNMS No-take Zones (11)	54.5 ± 15.7	40.9 ± 13.2	0.048 ± 0.017	1.6 ± 0.1	16
Habitat Total (29)	55.2 ± 9.4	39.7 ± 7.6	0.061 ± 0.021	1.9 ± 0.2	53
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	66.7 ± 16.7	10.7 ± 3.8	0.107 ± 0.038	2.3 ± 0.1	29
FKNMS No-take Zones (9)	44.4 ± 17.6	5.9 ± 3.4	0.059 ± 0.034	2.2 ± 0.1	16
Habitat Total (18)	55.6 ± 12.1	8.3 ± 2.5	0.083 ± 0.025	2.2 ± 0.1	45
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	50.0 ± 9.6	33.9 ± 7.3	0.067 ± 0.026	2.0 ± 0.1	56
FKNMS No-take Zones (33)	51.5 ± 8.8	30.3 ± 5.7	0.029 ± 0.007	1.8 ± 0.1	29
Habitat Total (62)	50.0 ± 6.4	31.5 ± 4.5	0.046 ± 0.012	1.9 ± 0.1	85
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	37.5 ± 12.5	28.1 ± 10.2	0.042 ± 0.025	1.9 ± 0.1	20
FKNMS Reference Areas (20)	55.0 ± 11.4	40.0 ± 9.3	0.092 ± 0.035	2.6 ± 0.2	55
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	42.5 ± 7.9	31.3 ± 6.4	0.063 ± 0.020	2.4 ± 0.2	75
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	66.7 ± 21.1	41.7 ± 15.4	0.061 ± 0.042	2.4 ± 0.4	11
FKNMS Reference Areas (42)	33.3 ± 7.4	21.4 ± 5.2	0.040 ± 0.017	2.5 ± 0.2	50
FKNMS No-take Zones (6)	33.3 ± 21.1	16.7 ± 10.5	0.011 ± 0.007	1.9 ± 0.2	2
Habitat Total (54)	37.0 ± 6.6	23.1 ± 4.5	0.039 ± 0.014	2.5 ± 0.1	63

Table 5.4 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	3.0	1
FKNMS Reference Areas (28)	35.7 ± 9.2	21.4 ± 6.0	0.027 ± 0.013	2.3 ± 0.2	23
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	34.4 ± 8.5	20.3 ± 5.4	0.025 ± 0.011	2.4 ± 0.2	24
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	20.0 ± 20.0	10.0 ± 10.0	0.007 ± 0.007	2.4	1
FKNMS Reference Areas (54)	22.2 ± 5.7	11.1 ± 2.9	0.007 ± 0.002	2.2 ± 0.2	12
FKNMS No-take Zones (23)	4.3 ± 4.3	2.2 ± 2.2	0.001 ± 0.001	2.7	1
Habitat Total (82)	17.1 ± 4.2	8.5 ± 2.1	0.006 ± 0.001	2.2 ± 0.2	14

Table 5-5. Site presence, transect frequency of occurrence, density, and size (test diameter) of the urchin *Lytechinus variegatus* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for test size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	2.0 ± 2.0	1.0 ± 1.0	0.001 ± 0.001	8.0	1
FKNMS Reference Areas (90)	1.1 ± 1.1	0.6 ± 0.6	0.0004 ± 0.0004	6.5	1
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	1.3 ± 0.9	0.7 ± 0.5	0.0004 ± 0.0003	7.3 ± 0.8	2
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	0 ± 0	0 ± 0	0 ± 0		0
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0		0
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0		0
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0		0
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	0 ± 0	0 ± 0	0 ± 0		0
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0		0

Table 5.5 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	8.2	1
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.001 ± 0.001	8.2	1
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		0

Table 5-6. Site presence, transect frequency of occurrence, density, and size (test diameter) of the urchin *Tripneustes ventricosus* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for test size.

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	14.0 ± 5.0	8.0 ± 3.0	0.006 ± 0.002	8.6 ± 0.5	9
FKNMS Reference Areas (90)	5.6 ± 2.4	3.3 ± 1.5	0.003 ± 0.001	9.6 ± 0.9	8
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	7.0	1
Habitat Total (151)	8.6 ± 2.3	5.0 ± 1.4	0.004 ± 0.001	8.9 ± 0.5	18
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	4.1 ± 2.0	2.6 ± 1.3	0.002 ± 0.001	6.8 ± 0.7	7
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	3.3 ± 1.6	2.0 ± 1.1	0.002 ± 0.001	6.8 ± 0.7	7
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0		0
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0		0
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0		0
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (20)	10.0 ± 6.9	5.0 ± 3.4	0.003 ± 0.002	7.3 ± 1.7	2
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	5.0 ± 3.5	2.5 ± 1.7	0.002 ± 0.001	7.3 ± 1.7	2
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	2.4 ± 2.4	1.2 ± 1.2	0.001 ± 0.001	6.0	1
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	1.9 ± 1.9	0.9 ± 0.9	0.001 ± 0.001	6.0	1

Table 5.6 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		0
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		0

VI. Anemone and Corallimorpharian Distribution and Abundance

Background

The Florida Keys have a long history of commercial and recreational fisheries that exploit an incredible diversity of invertebrates and fishes (Bohnsack et al. 1994). A portion of this effort is represented by commercial marine-life fisheries and aquarium hobbyists. Otherwise known as the marine ornamental fishery, aquarium fisheries from West Palm Beach to Key West target many fish, invertebrate, and algal species, in addition to sand and live rock (FWCC 2001). State and Federal waters near Key West and Marathon in the Florida Keys constitute 94% of the total fishes and invertebrates removed in southeast Florida for the marine aquarium trade. Commercial data do not include an undocumented effort from recreational fishers, nor are data available concerning species abundance patterns and population trends relative to fishing effort (NOAA 1996). The Key Largo area has been protected from marine aquarium trade species collection since 1960 in John Pennekamp Coral Reef State Park, followed by the protection in Federal waters in 1975 with the establishment of Key Largo National Marine Sanctuary (now known as the Key Largo Management Area). The Looe Key area has been protected since 1981, as well as Everglades National Park (Florida Bay), portions of the Dry Tortugas area, Biscayne National Park, and Fish and Wildlife Service management areas.

In 2012, we continued a time series dating back to 1999 that quantifies habitat-related patterns in distribution and density of selected actinian anemones (O. Actiniaria) and corallimorpharians (O. Corallimorpharia) in the Florida Keys in relation to habitat type and management zone. The paucity of basic ecological information for most Florida Keys anemone and corallimorpharian species persists, with even fewer studies reporting on the effects of populations under exploitation. Besides general Caribbean field guides (e.g. Sefton and Webster 1986; Kaplan 1988; Humann 1992) and isolated distribution studies (Voss and Voss 1955; Wheaton and Jaap 1988; reviewed in Levy et al. 1996), our program represents the only large-scale concerted effort to quantify distribution and abundance patterns for these organisms over large areas of offshore hard-bottom and coral reef habitat in the Florida Keys. The ecological importance of these organisms is best exemplified by the many anemones that form associations with several invertebrates such as cleaner shrimps (Limbaugh et al. 1961; Shick 1991) and provide refuge for smaller reef fishes (Hanlon and Kaufman 1976; Colin and Heiser 1973). Some of these associations, such as cleaning stations, provide a valuable function to reef fishes (Herrnkind et al. 1976; Sluka et al. 1999) and the large-scale removal of certain species may have important, but as of yet, undocumented effects on other biota. The results presented below from the 2012 surveys compare distribution and density patterns

by habitat and among Biscayne National Park, areas within FKNMS no-take zones established in 1997, and corresponding reference sites within the Sanctuary. During May-November 2012, a total of 600 sites were sampled by surveying two (2) replicate 15-m x 1-m belt transects per site, yielding a total survey area of 18,000 m^2 of benthic habitat in the Florida Keys from northern Biscayne National Park (BNP) to southwest of Key West. We have not sampled shallow nearshore hard-bottom, seagrass beds, tidal channels under bridges, mangrove channels, or Florida Bay, all of which may be important habitats for some species of anemones and corallimorphians.

Quantitative surveys in the Florida Keys during May-November 2012 targeted anemones (O. Actiniaria) and corallimorpharians (O. Corallimorpharia) known or suspected to occur in the Florida Keys, and focused on the larger and conspicuous or field-identifiable members of both orders. Similar surveys were conducted in 1999-2001 (211 sites), 2005 (195 sites), 2008 (145 sites), 2009 (160 sites), 2010 (120 sites), and 2011 (280 sites), as well as in the Dry Tortugas region during 2000, 2006, and 2008 (see previous Quick Look Reports at http://people.uncw.edu/millers). Five anemone species were recorded during 2012 (classification according to Cairns et al. 1991), 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, *Lebrunia danae* in the Family Aliciidae, the speckled anemone *Phymanthus* (=*Epicystis*) *crucifera* in the Family Phymanthidae, and the knobby anemone *Regactis* (=*Heteractis*) *lucida*. Although encountered in previous years, we did not record *Bunodosoma granulifera* in the Family Actiniidae or the Caribbean sun anemone *Stichodactyla* (=*Stoichactis*) *helianthus* during 2012. Corallimorpharians, sometimes called false corals, differ from anemones in the arrangement of the tentacles, and may be solitary, but are typically found in clusters. Three corallimorpharian species were encountered during 2012: *Discosoma* (=*Paradiscosoma*) *carlgreni* and *D. sanctithomae* in the Family Actinodiscidae and *Ricordea florida* in the Family Corallimorpharidae.

2012 Survey Results

Anemones

Five anemone species representing 1,095 individuals were recorded from the 600 Florida Keys sites during 2012 (Figure 6-1), represented by: *Bartholomea annulata* (757 individuals, 69% of all anemones), *Condylactis gigantea* (111 individuals, 10%), *Phymanthus* (*Epicystis*) *crucifera* (18 individuals, 2%), *Regactis* (*Heteractis*) *lucida* (2 individuals, 0.2%), and *Lebrunia danae* (207 individuals, 19%).

Bunodosoma granuliferum and *Stichodactyla helianthus* were searched for, but not encountered during 2012. Overall, 350 of the 600 sites (58%) yielded one or more anemone species from 30-m^2 search areas per site. Similar to previous years, site presence of all species combined was greatest on mid-channel (82% of sites) and offshore patch reefs (75%) and lowest in reef rubble (24%). Tables 6-1 through 6-5 contain a summary of the 2012 survey results for the five species of anemone encountered. The results include site presence (% of sites where a species was encountered within one or both belt transects), transect frequency of occurrence (proportion of transects where a species was present), density (no. of individuals per m^2), and total number of individuals found.

Bartholomea annulata (corkscrew anemone)

Similar to previous years, the corkscrew anemone (*Bartholomea annulata*) was the most abundant (757 individuals, 69% of all species) and wide-ranging anemone that was surveyed, with individuals recorded from 58% of the 600 sites and within 39% of the sampled transects. *B. annulata* was distributed among all ten of sampled hard-bottom and reef habitat types (Table 6-1). Site-level densities were as high as 0.3 individuals per m^2, with the greatest density recorded from a mid-channel patch reef inshore of Long Reef in Biscayne National Park (BNP). Site presence, transect frequency, and density were relatively similar among most of the sampled habitats, except for inshore patch reefs and reef rubble (Table 6-1). Site presence, transect frequency, and mean density on mid-channel and offshore patch reefs were greatest in BNP compared to Sanctuary no-take zones and reference areas. The summary data in Table 6-1 illustrate the broad distribution of this species across the south Florida shelf.

Condylactis gigantea (giant Caribbean anemone)

Similar to previous surveys dating back to 1999, the site presence, transect frequency, and density of the giant Caribbean anemone (*Condylactis gigantea*) were relatively low in 2012 for the hard-bottom and coral reef habitats surveyed (Table 6-2). A total of 111 individuals were found among the 600 sites, with individuals present at 14% of sites and 7.3% of the sampled transects. A maximum site-level density of 0.167 individuals per m^2 was recorded from a mid-channel patch reef inshore of Long Reef within BNP. *C. gigantea* was encountered in seven of the ten sampled habitats, and similar to previous years, site presence, transect frequency, and density were greatest on mid-channel and offshore patch reefs, followed by shallower (< 6 m) and deeper (6-15 m) hard-bottom (Table 6-2). For mid-channel patch reefs, these metrics were greater in BNP compared to Sanctuary no-take zones and reference areas.

Lebrunia danae

The branching anemone *Lebrunia danae* was the second most common (207 individuals, 19% of all anemones) of the five anemone species encountered during 2012. Similar to *B. annulata*, *L. danae* was broadly distributed (19% of sites, 11% of transects) among all ten sampled habitats (Table 6-3). Site presence and transect frequency of occurrence were greatest on inshore, mid-channel, and offshore patch reefs. Mean densities were greatest in the latter two habitats, especially mid-channel patch reefs in FKNMS no-take zones. This latter result reflected the relatively high densities of *L. danae* in the Western Sambo Ecological Reserve.

Phymanthus (*Epicystis*) *crucifera*

The speckled anemone was the second rarest anemone encountered during 2012, with only 18 individuals (2% of all anemones) found among 1.8% of sites and 1% of transects. Individuals were recorded from only three of the ten sampled habitats, two of which were mid-channel and offshore patch reef habitat types (Table 6-4). A maximum site-level density of 0.2 individuals per m^2 was recorded from a mid-channel patch reef within Western Sambo Ecological Reserve. Along with *Regactis lucida* (see below) and *Lebrunia danae* (see above), *Phymanthus crucifera* is most commonly encountered on patch reefs in the lower Florida Keys.

Regactis (*Heteractis*) *lucida*

The knobby anemone (*Regactis lucida*) was the least common (0.2% of the total) of the anemones encountered during 2012, with only two individuals found. Individuals were only recorded from two sites, both of which were in the lower Florida Keys on a mid-channel patch reef and an offshore patch reef (Table 6-5).

Corallimorpharians

A total of 6,971 corallimorpharians representing three species were recorded from the 600 Florida Keys sites during 2012: *Discosoma carlgreni* (11 individuals, 0.2%), *D. sanctithomae* (1,608 individuals, 23.1%), and *Ricordea florida* (5,352 individuals, 76.8%) (Figure 6-2). Tables 6-6 to 6-8 provide summary values for site presence (% of sites where a species was encountered within one or both transects), transect frequency of occurrence (overall proportion of transects where a species was present), density

(no. of individuals per m^2), and total number of individuals found by habitat and management zone for each of these species. Corallimorpharians were recorded from 29% of all sites surveyed and exhibit habitat distribution and density patterns similar to previous years, with patch reefs, especially in the lower Florida Keys, yielded the greatest densities.

Discosoma carlgreni

The forked-tentacle corallimorpharian, *Discosoma carlgreni*, was the rarest of the corallimorpharians encountered. Eleven total individuals were found at only four sites (< 1%) represented by just three of the ten sampled habitats (Table 6-6). The maximum site-level density was 0.167 individuals per m^2 recorded from a mid-channel patch reef in the lower Florida Keys.

Discosoma sanctithomae

The warty corallimorpharian, *Discosoma sanctithomae*, in contrast to its congener, was more broadly distributed (present in 4 of the 10 sampled habitats) and commonly encountered, especially on mid-channel and offshore patch reefs, particularly in the lower Florida Keys (Table 6-7). A total of 1,608 individuals were counted, distributed among 7.5% of all sites and 5.7% of sampled transects. The greatest overall site presence, transect frequency, and densities were recorded on mid-channel patch reefs, followed by offshore patch reefs. Of particular note were relatively dense concentrations (upwards of 6 per m^2) on mid-channel patch reefs within the Western Sambo Ecological Reserve.

Ricordea florida

The Florida corallimorpharian, *Ricordea florida*, was the most common (5,352 individuals) and widely distributed (26.7% of sites, 19.2% of transects) corallimorpharian. *R. florida* was encountered in all but one of the ten sampled habitats (Table 6-8). The greatest site-level mean density (10.8 individuals per m^2) was recorded from an offshore patch reef within the Looe Key Research Only area. Similar to previous years mean densities were greatest on mid-channel and offshore patch reefs, especially in Sanctuary reference areas and no-take zones in the lower Florida Keys.

Discussion

While numerous studies address the life history characteristics of anemones and corallimorpharians, including feeding behavior (Bursey and Guanciale 1977; Bursey and Harmer 1979; Elliot and Cook 1989), reproduction (Jennison 1981), and associations with other fauna (Limbaugh et al. 1961; Colin and Heiser 1973; Hanlon and Kaufman 1976), studies that describe or quantify habitat distribution and abundance in the Florida Keys are limited. Nine actinian species are common in the Caribbean; of these, seven are planktivores, while the two larger species (*Condylactis gigantea* and *Stichodactyla helianthus*) can eat macroscopic prey such as gastropods and echinoids (Van-Praët 1985). Several field guidebooks provide qualitative descriptions of habitat occurrence, biogeographic distribution, and taxonomic characters (Voss 1976; Kaplan 1988; Humann 1992), but with the exception of one quantitative study of benthic cnidarians at Looe Key, in which *Ricordea florida* was included (Wheaton and Jaap 1988), the data collected by our program represent the only large-scale assessments of habitat distribution and abundance of actinians and corallimorpharians on Florida Keys ocean-side habitats dating back over a decade. Levy et al. (1996) reviewed Florida Keys invertebrate inventories as of 1995 and found only three publications (e.g. Voss and Voss 1955; Voss et al. 1969) that studied abundance and habitat distribution of these organisms.

The 2012 survey results indicate that, with the exception of the corallimorpharians *Discosoma sanctithomae* and *Ricordea florida* on some mid-channel and offshore patch reefs, especially in the lower Florida Keys, mean densities of the anemones and corallimorpharians sampled were usually below one individual per 100 m^2 for the habitats sampled. Two of the five actinians and one of the three corallimorpharians species were rare and/or exhibited a very limited habitat distribution. The more commonly encountered species exhibited different density and distribution patterns. *B. annulata* was the most frequently encountered anemone and generally had similar densities among most habitats, while *Condylactis gigantea* and *Lebrunia danae* were more common on patch reefs. The most abundant corallimorpharian, *R. florida*, was most abundant on mid-channel and offshore patch reefs.

Conclusions from the 2012 surveys are confined because of poor life history knowledge and the paucity of historical abundance data for anemones and corallimorpharians. Interpretation of density patterns is further complicated because of the possibility that large numbers of these organisms are removed from the Florida Keys by commercial and private collectors, but not necessarily in the habitats that our program samples. However, surveys dating back to 1999 confirm, at least for a 12-year period, consistent patterns in habitat-based patterns of abundance. It is also possible that locations not sampled by our program, including nearshore hard-bottom and seagrass beds (ocean-side and bay-side), mangrove channels, and tidal channels into Florida Bay, comprise important habitat types for various anemones and

corallimorpharians. We did not sample any soft-sediment communities such as seagrass beds, and it is well known that some of the actinians (e.g. *Bartholomea annulata* and *Condylactis gigantea*) form relatively large aggregations in these areas. On the other hand, the present configuration of FKNMS no-take zones does not capture, perhaps, some of the higher-density areas for these organisms, especially anemones.

Certain aspects of cnidarian life history have implications for management. Recruitment of sexually produced planula into natural populations of sea anemones seems rare, and it appears that most anemones studied (see review in Shick 1991) have great longevity, low and sporadic larval recruitment, and high juvenile mortality. Asexual reproduction, especially for corallimorpharians, appears to be very important for maintenance of local aggregations if recruitment is successful (Elliot and Cook 1989), and probably explains the very high, but localized densities or clusters of *Discosoma sanctithomae* and *Ricordea florida*. Without basic information on life history, it will remain difficult to ascertain the ability of these organisms to maintain populations, especially considering the apparent level of exploitation in the Florida Keys.

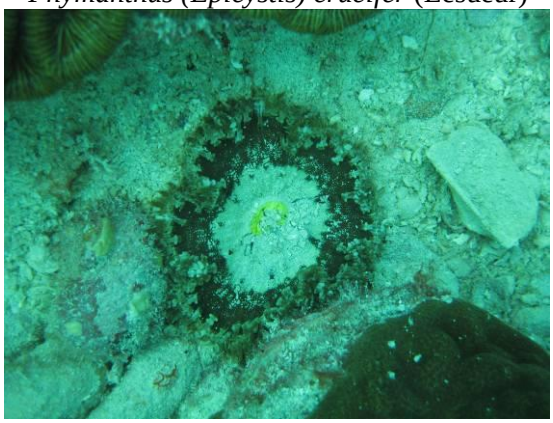
Although spatially explicit (e.g. at the scale of individual reefs) landings and fishing effort data are not available for Florida Keys anemones and corallimorpharians, the possibility that the observed density patterns are influenced by fishing should not be dismissed. For example, anecdotal observations, acquired from interviews with Florida Keys residents in 1993, indicated that *Condylactis gigantea* declined by the early 1990s, possibly due to collection, disease, or other causes (DeMaria 1996). Commercial marine life collectors and aquarium hobbyists potentially collect all of the cnidarians surveyed in this study (Bohnsack et al. 1994). Only a saltwater license is needed for recreational fishing, and a saltwater products license and commercial vessel registration is required to fish commercial quantities of unregulated species (NOAA 1996; FWCC 2000). In addition to a prohibition on collection in 23 of the no-take zones within the FKNMS (not including Tortugas North and South), fishing for these "unregulated" species is also prohibited in Biscayne National Park, John Pennekamp Coral Reef State Park/Key Largo National Marine Sanctuary (since 1960), the Florida Bay area within Everglades National Park, and Dry Tortugas National Park. Management of exploited species obviously requires information on fishing effort, population trends, and life history parameters. Density estimates for anemones and corallimorpharians provide a baseline from which to measure the effects of protection within no-fishing zones. When coupled with important and much needed information on the marine life fishery, the outputs of this sampling approach can furnish state and federal resource managers with improved guidelines on population estimates and trends relative to fishing intensity. Moreover, areas where these organisms are

protected from collecting presents an opportunity to evaluate the effects of exploitation, not only on the most economically important species, but also on a diversity of targeted, but relatively understudied taxa.

Figure 6-1. Anemones (Cnidaria, Anthozoa) surveyed for presence-absence, density, and habitat distribution in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012. *Bunodosoma granulifera* (pictured below), as well as the Caribbean sun anemone, *Stichodactyla helianthus* (Ellis) (not pictured), were not encountered during 2012.

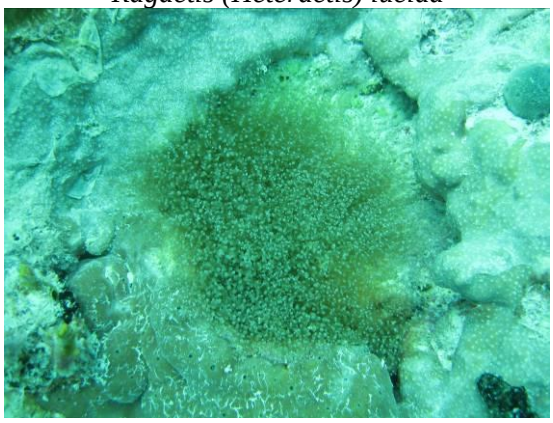
Bartholomea annulata (Lesueur)

Phymanthus (Epicystis) crucifer (Lesueur)



Bunodosoma granuliferum (Lesueur)

Ragactis (Heteractis) lucida



Condylactis gigantea (Weinland)

Lebrunia danae (D & M)

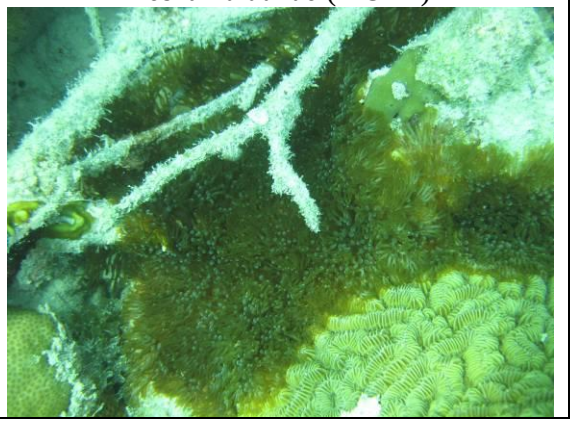
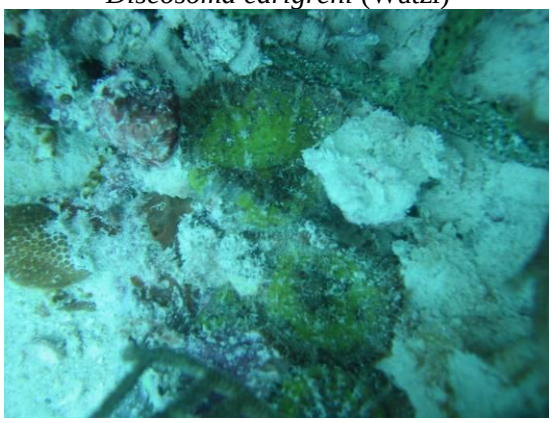


Figure 6-2. Corallimorpharians (Cnidaria, Anthozoa, Corallimorpharia) surveyed for presence-absence, density and habitat distribution in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Discosoma carlgreni (Watzl)

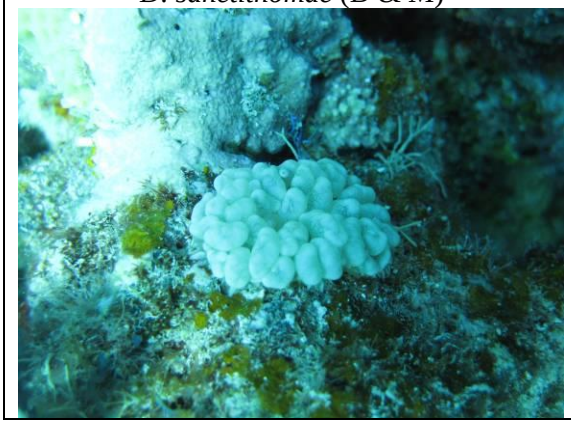


Ricordea florida (D & M)

D. sanctithomae (D & M)

R. florida (D & M)

D. sanctithomae (D & M)



R. florida (D & M)

Table 6-1. Site presence, transect frequency of occurrence, and density of the corkscrew anemone *Bartholomea annulata* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.033 ± 0.033	2
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	10.0 ± 10.0	5.0 ± 5.0	0.007 ± 0.007	2
Mid-channel patch reefs				
Biscayne National Park (50)	82.0 ± 5.5	67.0 ± 5.5	0.101 ± 0.010	152
FKNMS Reference Areas (90)	50.0 ± 5.3	33.3 ± 4.0	0.034 ± 0.005	91
FKNMS No-take Zones (11)	27.3 ± 14.1	13.6 ± 7.0	0.015 ± 0.009	5
Habitat Total (151)	58.9 ± 4.0	43.0 ± 3.3	0.055 ± 0.005	248
Offshore patch reefs				
Biscayne National Park (9)	100.0 ± 0.0	66.7 ± 8.3	0.089 ± 0.014	24
FKNMS Reference Areas (98)	59.2 ± 5.0	40.8 ± 3.9	0.040 ± 0.005	119
FKNMS No-take Zones (15)	40.0 ± 13.1	26.7 ± 9.6	0.027 ± 0.010	12
Habitat Total (122)	59.8 ± 4.5	41.0 ± 3.5	0.042 ± 0.004	155
Reef Rubble (< 15 m)				
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	1
FKNMS Reference Areas (16)	31.3 ± 12.0	18.8 ± 7.7	0.017 ± 0.007	8
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	1
Habitat Total (29)	24.1 ± 8.1	13.8 ± 4.9	0.011 ± 0.004	10
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	66.7 ± 16.7	33.3 ± 8.3	0.030 ± 0.009	8
FKNMS No-take Zones (9)	77.8 ± 14.7	44.4 ± 10.0	0.041 ± 0.009	11
Habitat Total (18)	72.2 ± 10.9	38.9 ± 6.5	0.035 ± 0.006	19
High-relief spur and groove				
Biscayne National Park (1)	100.0	50.0	0.100	3
FKNMS Reference Areas (28)	60.7 ± 9.4	33.9 ± 5.8	0.037 ± 0.009	31
FKNMS No-take Zones (33)	51.5 ± 8.8	31.8 ± 6.1	0.029 ± 0.006	29
Habitat Total (62)	56.5 ± 6.3	33.1 ± 4.1	0.034 ± 0.005	63
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	68.8 ± 12.0	53.1 ± 10.7	0.044 ± 0.011	21
FKNMS Reference Areas (20)	55.0 ± 11.4	37.5 ± 8.8	0.033 ± 0.009	20
FKNMS No-take Zones (4)	75.0 ± 25.0	50.0 ± 20.4	0.033 ± 0.014	4
Habitat Total (40)	62.5 ± 7.8	45.0 ± 6.4	0.038 ± 0.006	45
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	83.3 ± 16.7	66.7 ± 16.7	0.072 ± 0.022	13
FKNMS Reference Areas (42)	69.0 ± 7.2	45.2 ± 5.6	0.045 ± 0.007	57
FKNMS No-take Zones (6)	100.0 ± 0.0	50.0 ± 0.0	0.050 ± 0.007	9
Habitat Total (54)	74.1 ± 6.0	48.1 ± 4.8	0.049 ± 0.006	79

Table 6.1 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	100.0 ± 0.0	50.0 ± 0.0	0.050 ± 0.017	3
FKNMS Reference Areas (28)	53.6 ± 9.6	35.7 ± 7.2	0.042 ± 0.011	35
FKNMS No-take Zones (2)	50.0 ± 50.0	50.0 ± 50.0	0.050 ± 0.050	3
Habitat Total (32)	56.3 ± 8.9	37.5 ± 6.7	0.043 ± 0.010	41
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	80.0 ± 20.0	50.0 ± 15.8	0.067 ± 0.035	10
FKNMS Reference Areas (54)	53.7 ± 6.8	31.5 ± 4.4	0.031 ± 0.005	51
FKNMS No-take Zones (23)	69.6 ± 9.8	50.0 ± 8.3	0.049 ± 0.010	34
Habitat Total (82)	59.8 ± 5.4	37.8 ± 3.9	0.039 ± 0.005	95

Table 6-2. Site presence, transect frequency of occurrence, and density of the pink-tipped anemone *Condylactis gigantea* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0	0
Mid-channel patch reefs				
Biscayne National Park (50)	34.0 ± 6.8	20.0 ± 4.3	0.019 ± 0.005	28
FKNMS Reference Areas (90)	25.6 ± 4.6	12.8 ± 2.3	0.010 ± 0.002	27
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.009 ± 0.009	3
Habitat Total (151)	27.2 ± 3.6	14.6 ± 2.0	0.013 ± 0.002	58
Offshore patch reefs				
Biscayne National Park (9)	22.2 ± 14.7	11.1 ± 7.3	0.007 ± 0.005	2
FKNMS Reference Areas (98)	21.4 ± 4.2	10.7 ± 2.1	0.009 ± 0.002	26
FKNMS No-take Zones (15)	26.7 ± 11.8	13.3 ± 5.9	0.013 ± 0.006	6
Habitat Total (122)	22.1 ± 3.8	11.1 ± 1.9	0.009 ± 0.002	34
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	12.5 ± 8.5	6.3 ± 4.3	0.004 ± 0.003	2
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (29)	6.9 ± 4.8	3.4 ± 2.4	0.002 ± 0.002	2
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0	0
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0	0
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (20)	20.0 ± 9.2	10.0 ± 4.6	0.007 ± 0.003	4
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	1
Habitat Total (40)	12.5 ± 5.3	6.3 ± 2.6	0.004 ± 0.002	5
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	16.7 ± 16.7	8.3 ± 8.3	0.006 ± 0.006	1
FKNMS Reference Areas (42)	7.1 ± 4.0	4.8 ± 2.9	0.005 ± 0.003	6
FKNMS No-take Zones (6)	16.7 ± 16.7	8.3 ± 8.3	0.006 ± 0.006	1
Habitat Total (54)	9.3 ± 4.0	5.6 ± 2.5	0.005 ± 0.002	8

Table 6.2 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	1
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	1
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (32)	6.3 ± 4.3	3.1 ± 2.2	0.002 ± 0.001	2
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (54)	1.9 ± 1.9	0.9 ± 0.9	0.001 ± 0.001	1
FKNMS No-take Zones (23)	4.3 ± 4.3	2.2 ± 2.2	0.001 ± 0.001	1
Habitat Total (82)	2.4 ± 1.7	1.2 ± 0.9	0.001 ± 0.001	2

Table 6-3. Site presence, transect frequency of occurrence, and density of the anemone *Lebrunia danae* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	1
FKNMS Reference Areas (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	1
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	1
Habitat Total (10)	30.0 ± 15.3	15.0 ± 7.6	0.010 ± 0.005	3
Mid-channel patch reefs				
Biscayne National Park (50)	30.0 ± 6.5	18.0 ± 4.2	0.017 ± 0.005	26
FKNMS Reference Areas (90)	42.2 ± 5.2	25.6 ± 3.5	0.026 ± 0.004	69
FKNMS No-take Zones (11)	36.4 ± 15.2	22.7 ± 10.4	0.039 ± 0.022	13
Habitat Total (151)	37.7 ± 4.0	22.8 ± 2.6	0.024 ± 0.003	108
Offshore patch reefs				
Biscayne National Park (9)	22.2 ± 14.7	11.1 ± 7.3	0.007 ± 0.005	2
FKNMS Reference Areas (98)	25.5 ± 4.4	17.3 ± 3.3	0.021 ± 0.005	62
FKNMS No-take Zones (15)	33.3 ± 12.6	23.3 ± 9.6	0.020 ± 0.008	9
Habitat Total (122)	26.2 ± 4.0	17.6 ± 2.9	0.020 ± 0.004	73
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	1
Habitat Total (29)	3.4 ± 3.4	1.7 ± 1.7	0.001 ± 0.001	1
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	22.2 ± 14.7	11.1 ± 7.3	0.007 ± 0.005	2
FKNMS No-take Zones (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	1
Habitat Total (18)	16.7 ± 9.0	8.3 ± 4.5	0.006 ± 0.003	3
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	7.1 ± 5.0	3.6 ± 2.5	0.002 ± 0.002	2
FKNMS No-take Zones (33)	6.1 ± 4.2	3.0 ± 2.1	0.002 ± 0.001	2
Habitat Total (62)	6.5 ± 3.1	3.2 ± 1.6	0.002 ± 0.001	4
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (20)	10.0 ± 6.9	5.0 ± 3.4	0.003 ± 0.002	2
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (40)	5.0 ± 3.5	2.5 ± 1.7	0.002 ± 0.001	2
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (42)	7.1 ± 4.0	4.8 ± 2.9	0.003 ± 0.002	4
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	5.6 ± 3.1	3.7 ± 2.2	0.002 ± 0.001	4

Table 6.3 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (2)	50.0 ± 50.0	25.0 ± 25.0	0.033 ± 0.033	2
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.002 ± 0.002	2
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (54)	9.3 ± 4.0	4.6 ± 2.0	0.003 ± 0.001	5
FKNMS No-take Zones (23)	8.7 ± 6.0	4.3 ± 3.0	0.003 ± 0.002	2
Habitat Total (82)	8.5 ± 3.1	4.3 ± 1.6	0.003 ± 0.001	7

Table 6-4. Site presence, transect frequency of occurrence, and density of the anemone *Phymanthus crucifer* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0	0
Mid-channel patch reefs				
Biscayne National Park (50)	2.0 ± 2.0	1.0 ± 1.0	0.001 ± 0.001	1
FKNMS Reference Areas (90)	3.3 ± 1.9	1.7 ± 1.0	0.002 ± 0.001	5
FKNMS No-take Zones (11)	27.3 ± 14.1	18.2 ± 10.2	0.024 ± 0.018	8
Habitat Total (151)	4.6 ± 1.7	2.6 ± 1.0	0.003 ± 0.002	14
Offshore patch reefs				
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (98)	2.0 ± 1.4	1.0 ± 0.7	0.001 ± 0.000	2
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (122)	1.6 ± 1.2	0.8 ± 0.6	0.001 ± 0.000	2
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0	0
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0	0
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0	0
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	6.3 ± 6.3	3.1 ± 3.1	0.002 ± 0.002	1
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (40)	2.5 ± 2.5	1.3 ± 1.3	0.001 ± 0.001	1
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0	0

Table 6.4 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	1
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.001 ± 0.001	1
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0	0

Table 6-5. Site presence, transect frequency of occurrence, and density of the anemone *Ragactis lucida* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0	0
Mid-channel patch reefs				
Biscayne National Park (50)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (90)	1.1 ± 1.1	0.6 ± 0.6	0.0004 ± 0.0004	1
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (151)	0.7 ± 0.7	0.3 ± 0.3	0.0002 ± 0.0002	1
Offshore patch reefs				
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (98)	1.0 ± 1.0	0.5 ± 0.5	0.0003 ± 0.0003	1
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (122)	0.8 ± 0.8	0.4 ± 0.4	0.0003 ± 0.0003	1
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0	0
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0	0
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0	0
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (40)	0 ± 0	0 ± 0	0 ± 0	0
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0	0

Table 6.5 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0	0
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0	0

Table 6-6. Site presence, transect frequency of occurrence, and density of the corallimorpharian *Discosoma carlgreni* by habitat type and management zones in Biscayne National Park and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0	0
Mid-channel patch reefs				
Biscayne National Park (50)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (90)	1.1 ± 1.1	0.6 ± 0.6	0.002 ± 0.002	5
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (151)	0.7 ± 0.7	0.3 ± 0.3	0.001 ± 0.001	5
Offshore patch reefs				
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (98)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (15)	6.7 ± 6.7	3.3 ± 3.3	0.004 ± 0.004	2
Habitat Total (122)	0.8 ± 0.8	0.4 ± 0.4	0.001 ± 0.001	2
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0	0
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0	0
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0	0
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (40)	0 ± 0	0 ± 0	0 ± 0	0
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	16.7 ± 16.7	8.3 ± 8.3	0.011 ± 0.011	2
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	1.9 ± 1.9	0.9 ± 0.9	0.001 ± 0.001	2

Table 6.6 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0	0
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (23)	4.3 ± 4.3	2.2 ± 2.2	0.003 ± 0.003	2
Habitat Total (82)	1.2 ± 1.2	0.6 ± 0.6	0.001 ± 0.001	2

Table 6-7. Site presence, transect frequency of occurrence, and density of the corallimorpharian *Discosoma sanctithomae* by habitat type and management zones in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0	0
Mid-channel patch reefs				
Biscayne National Park (50)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (90)	28.9 ± 4.8	22.2 ± 4.0	0.343 ± 0.077	925
FKNMS No-take Zones (11)	45.5 ± 15.7	36.4 ± 13.6	1.021 ± 0.589	337
Habitat Total (151)	20.5 ± 3.3	15.9 ± 2.7	0.279 ± 0.065	1,262
Offshore patch reefs				
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (98)	10.2 ± 3.1	7.7 ± 2.4	0.101 ± 0.052	298
FKNMS No-take Zones (15)	13.3 ± 9.1	10.0 ± 7.2	0.098 ± 0.087	44
Habitat Total (122)	9.8 ± 2.7	7.4 ± 2.2	0.093 ± 0.043	342
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0	0
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	1
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (18)	5.6 ± 5.6	2.8 ± 2.8	0.002 ± 0.002	1
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0	0
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (40)	0 ± 0	0 ± 0	0 ± 0	0
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0	0

Table 6.7 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.004 ± 0.004	3
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.003 ± 0.003	3
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0	0

Table 6-8. Site presence, transect frequency of occurrence, and density of the corallimorpharian *Ricordea florida* by habitat type and management zones in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered in belt transect surveys.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Inshore patch reefs				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0	0
Mid-channel patch reefs				
Biscayne National Park (50)	32.0 ± 6.7	22.0 ± 5.0	0.249 ± 0.113	373
FKNMS Reference Areas (90)	41.1 ± 5.2	31.7 ± 4.4	0.934 ± 0.200	2,523
FKNMS No-take Zones (11)	45.5 ± 15.7	36.4 ± 13.6	0.697 ± 0.250	230
Habitat Total (151)	38.4 ± 4.0	28.8 ± 3.2	0.690 ± 0.128	3,126
Offshore patch reefs				
Biscayne National Park (9)	44.4 ± 17.6	38.9 ± 16.2	0.104 ± 0.053	28
FKNMS Reference Areas (98)	36.7 ± 4.9	26.0 ± 3.8	0.239 ± 0.061	703
FKNMS No-take Zones (15)	66.7 ± 12.6	53.3 ± 11.4	2.464 ± 0.932	1,109
Habitat Total (122)	41.0 ± 4.5	30.3 ± 3.6	0.503 ± 0.139	1,840
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	1
Habitat Total (29)	3.4 ± 3.4	1.7 ± 1.7	0.001 ± 0.001	1
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	66.7 ± 16.7	55.6 ± 15.5	0.348 ± 0.123	94
FKNMS No-take Zones (9)	11.1 ± 11.1	5.6 ± 5.6	0.015 ± 0.015	4
Habitat Total (18)	38.9 ± 11.8	30.6 ± 10.0	0.181 ± 0.072	98
High-relief spur and groove				
Biscayne National Park (1)	100.0	50.0	0.100	3
FKNMS Reference Areas (28)	14.3 ± 6.7	10.7 ± 5.4	0.051 ± 0.028	43
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (62)	8.1 ± 3.5	5.6 ± 2.6	0.025 ± 0.013	46
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (20)	15.0 ± 8.2	12.5 ± 7.1	0.017 ± 0.011	10
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	1
Habitat Total (40)	10.0 ± 4.8	7.5 ± 3.8	0.009 ± 0.005	11
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	50.0 ± 22.4	33.3 ± 16.7	0.111 ± 0.069	20
FKNMS Reference Areas (42)	23.8 ± 6.7	13.1 ± 3.8	0.020 ± 0.009	25
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	24.1 ± 5.9	13.9 ± 3.6	0.028 ± 0.011	45

Table 6.8 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	No. individuals
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (28)	10.7 ± 6.0	7.1 ± 4.2	0.100 ± 0.098	84
FKNMS No-take Zones (2)	50.0 ± 50.0	25.0 ± 25.0	0.083 ± 0.083	5
Habitat Total (32)	12.5 ± 5.9	7.8 ± 4.0	0.093 ± 0.085	89
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	20.0 ± 20.0	10.0 ± 10.0	0.020 ± 0.020	3
FKNMS Reference Areas (54)	18.5 ± 5.3	13.0 ± 4.0	0.030 ± 0.015	49
FKNMS No-take Zones (23)	30.4 ± 9.8	19.6 ± 6.8	0.064 ± 0.037	44
Habitat Total (82)	22.0 ± 4.6	14.6 ± 3.3	0.039 ± 0.014	96

VII. Mollusk Abundance and Size

Background

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) (Clark and DeFreese 1987; Levy et al. 1996), including several endemic species (Clark 1994). Data on the status and trends of mollusk populations and habitat utilization patterns in the Florida Keys, with the exception of queen conch (*Strombus gigas*), are generally limited and mostly qualitative in nature (Marcus 1960; Jensen and Clark 1983; Clark and DeFreese 1987). Clark (1994) noted a declining population trend for the lettuce sea slug, *Elysia* (*Tridachia*) *crispata* Mörch (see cladistic analyses in Gosliner 1995; Jensen 1996) in south Florida, based upon comparisons of occurrence and population densities between 1969-80 and 1987-93. About 50% of the nearshore populations assessed by Clark (1994) nearly two decades ago were declining due to habitat destruction, siltation, eutrophication, and over-collection.

Since 2001, we have conducted periodic surveys of various gastropod mollusk species in conjunction with surveys of other benthic coral reef organisms. For example, we encountered unusually high densities of lettuce sea slugs among 63 shallow fore reef sites during June-September 2001. While sacoglossans are not particularly rare in many shallow-water marine habitats where densities tend to be correlated with algal biomass (Clarke and DeFreese 1987), our observations offshore were considered unusual because fleshy algal cover tends to be relatively low (Chiappone et al. 1997; Miller et al. 2002). In 2007, 2009, and 2010-11, we surveyed *Coralliophila* snail predation on corals, including *Acropora* species, and also quantified the density of two other Neogastropoda species that were especially abundant on high-relief spur and groove reefs. During 2001 and 2008-2009, we surveyed *Cyphoma* abundance, size, and gorgonian host occupation patterns (Chiappone et al. 2003).

Based upon previous surveys, the following nudibranch, sacoglossan, and Neogastropoda mollusks were targeted during 2012 (Figures 7-1 and 7-2):

- The nudibranchs *Hypselodoris bayeri* (black-spotted sea goddess), *H. (edenticulata) picta* (Florida regal sea goddess), *Chromodoris (Mexichromis) kempfi* (purple-crowned sea goddess), *C. nyalya* (red-line blue sea goddess), *Glossodoris sedna* (red-tipped sea goddess) and any other

encountered nudibranchs in the Class Gastropoda, Subclass Opisthobranchia, Order Nudibranchia;

- The lettuce sea slug, *Elysia* (*Tradachia*) *crispata* (Mörch), Class Gastropoda, Subclass Opisthobranchia, Order Sacoglossa, Family Elysiidae;
- The Neogastropoda mollusks *Thais deltoidea* (Lamarck) of the Family Thaididae, *Coralliophila* sp. of the Family Coralliophilidae, *Leucozonia nassa* (Gmelin) of the Family Fasciolariidae, as well as *Strombus gigas* Linnaeus of the Family Strombidae.

Of these targeted mollusks, two nudibranch species, the lettuce sea slug, and the four gastropod mollusks were encountered during 2012. Rarer species such as *Hypselodoris bayeri* and *H. edenticulata*, *Mexichromis kempfi*, as well as *Hypselodoris olgae* Ortea and Bacallado (Figure 7-1) and an undescribed *Flabellina* species (Figure 7-2) that may be *F. verta* (Marcus) (see The Sea Slug Forum at www.seaslugforum.net/find/flabvert) were not recorded. The results below summarize site presence (% of sites where a species was encountered within one or both belt transects), transect frequency of occurrence (proportion of transects where a species was present), density (no. of individuals per m^2), size (total length or shell length in cm), and substratum occupancy patterns by habitat and management zone for the seven mollusk species recorded during 2012.

2012 Survey Results

A total of 1,200 belt transects, each 15-m x 1-m in dimension, comprising 18,000 m^2 of benthic habitat was surveyed among 600 Florida Keys sites for mollusk site presence, transect frequency, density, size (total length or shell length, depending on species), and the substratum the organism was found occupying when encountered. The 2012 surveys yielded two nudibranch species, one sacoglossan sea slug (*Elysia crispata*), and four Neogastropoda snails (*Coralliophila* sp., *Leucozonia nassa*, *Thais deltoidea*, and *Strombus gigas*). Tables 7-1 to 7-3 and 7-5 to 7-8 provide summary data by habitat and management zone for each mollusk species, as well as a summary of substratum occupancy patterns (Table 7-4) for the lettuce sea slug and three of the four gastropod mollusks.

Nudibranchs

A total of 22 nudibranchs between just two species were encountered during 2012: *Chromodoris* (*Mexichromis*) *nyalya* and *Glossodoris sedna* (Figure 7-1). As in previous years, both species were rarely encountered, which partly reflect bias in our survey methods, which are designed for larger, less cryptic

invertebrates. Nineteen (19) individuals of *C. nyalya* were encountered (Figure 7-1), distributed among just ten sites (1.7% of all sites, 0.8% of transects) comprising six of the ten sampled habitats (Table 7-1). A maximum site-level density of 0.167 individuals per m^2 was recorded from a low-relief spur and groove site near Pacific Light in BNP. The mean total length of the five individuals was 1.1 cm TL, with a size range of 0.7 to 1.7 cm. Three individuals of *Glossodoris sedna* (Figure 7-1), ranging in total length from 1.8 to 3.5 cm, were encountered at one mid-channel and one offshore patch reef within BNP, as well as a high-relief spur and groove site at Elbow Reef (Table 7-2). G. sedna was only encountered at 0.5% of all sites and 0.3% of the sampled transects.

Ascoglossan lettuce sea slugs (*Elysia crispata*) (Mörch)

A total of 40 individuals of the lettuce sea slug (*Elysia crispata*) were encountered during 2011 (Figure 7-2), with most (90%) recorded from inner line reef tract and high-relief spur and groove habitats (Table 7-3). Individuals were recorded from 15 of the 600 sites (4%) and 1.5% of the sampled transects. This distribution pattern is similar to historical surveys conducted in the Florida Keys since 2001. A maximum site-level density of 0.5 individuals per m^2 was recorded from the shallow spur and groove site at Western Dry Rocks. Total lengths of the 40 individuals measured ranged from 1.5 to 4.0 cm, with a mean size of 2.8 cm. All *E. crispata* were recorded occupying algal turf (Table 7-4).

Neogastropoda mollusks

Four Neogastropoda mollusk species were surveyed in 2012, three of which we have surveyed previously since 2007 (*Coralliophila* sp., *Leucozonia nassa*, and *Thais deltoidea*), as well as queen conch (*Strombus gigas*), which we surveyed in both 2011 and 2012 (Figure 7-2). Gastropod surveys were initiated in 2007 with the intent of documenting *Coralliophila* snail abundance and predation in conjunction with *Acropora* coral surveys. We added two additional gastropods (*L. nassa* and *T. deltoidea*) to our target list at that time, as we continue to encounter large numbers of individuals in particular habitats. We are also interested in assessing whether or not the abundance patterns of these species may be related to fishing pressure inside and outside of FKNMS no-take zones. *T. deltoidea* is a potential predator of *Coralliophila* snails (G. Delgado, FWCC/FWRI, personal communication). In addition, although scientists from FWCC/FWRI conduct focused surveys of queen conch aggregations in the Florida Keys, the data on habitat distribution, density, and size collected by our program are sent to them and provide broader-scale data from a diversity of habitats Keys wide.

A total of 971 *Coralliophila* sp. individuals (Figure 7-2) were recorded, distributed among all habitats except inshore patch reefs (Table 7-5). Individuals were encountered at 34% of all sites and 21% of sampled belt transects. We have encountered what may be different species of *Coralliophila* since 2007, but for the purposes of this report, all individuals were combined. The maximum site-level density of 1.9 individuals per m^2 was recorded from a high-relief spur and groove site a Rock Key SPA. Site presence, transect frequency, and mean density were greatest on offshore patch reef and low-relief spur and groove habitats (Table 7-5). Similar to previous years, the spatial distribution of this snail was highly aggregated in 2012. No consistent patterns in abundance or distribution were evident between no-take zones and reference areas for the majority of habitats sampled, perhaps a reflection of recruitment variability and availability of live coral. The 971 *Coralliophila* sp. enumerated and measured ranged in size (shell length) from 0.4 cm to 7.0 cm, with a mean size of 1.8 cm. Of the individuals measured, nearly 99% were found occupying coral tissue (Table 7-4). *Coralliophila* sp. exhibited a highly aggregated distribution and was almost always found as clusters of a few to tens of individuals on the edges of live coral colonies. Since 2007, we have documented an increase in the frequency of encounter and density of *Coralliophila*, as well as an increase in the number of scleractinian coral species occupied by snails and/or exhibiting obvious signs of snail predation, including *Acropora* corals. Nineteen different scleractinian species were documented with *Coralliophila* snails during 2012, with *Agaricia agaricites*, *Diploria strigosa*, *Montastraea annularis*, and *M. faveolata* the most commonly occupied (Table 7-4).

The common lesser tulip shell (*Leucozonia nassa*) (Figure 7-2) was broadly distributed among most (8 of 10) of the habitat types surveyed in 2012 and, similar to results from previous survey years, was more frequently encountered on high-relief spur and groove reefs (Table 7-6). Individuals were recorded from 52 out of 600 sites (8.7%) and 4.7% of the sampled belt transects. The maximum site-level density of 0.133 individuals per m^2 was recorded from a high-relief spur and groove site at Eastern Dry Rocks SPA. In the high-relief spur and groove habitat, both transect frequency and mean density were greater in no-take zones compared to reference areas, similar to results from 2011. Shell lengths of the 76 individuals recorded ranged from 1.9 to 6.6 cm, with a mean size of 3.4. Most (96%) of the *L. nassa* snails were found on either algal turf (82%) or crustose coralline algae (13%) (Table 7-4).

Similar to results from 2007 and 2009-11, the most abundant Neogastropoda mollusk surveyed in 2012 was the deltoid rock shell (*Thais deltoidea*) (Figure 7-2). A total of 525 individuals were found, and similar to *Leucozonia nassa*, most (86%) *T. deltoidea* were encountered on high-relief spur and groove reefs (Table 7-7). *T. deltoidea* was encountered at 87 of the 600 sites (14.5%) and 11.1% of the sampled belt transects. Site presence (79.0% ± 5.2%), transect frequency (66.9% ± 5.1%) and mean density (0.244

± 0.047) were all substantially higher in high-relief spur and groove compared to other habitats. The maximum site-level density of 1.7 individuals per m^2 was recorded from a high-relief spur and groove site at Western Dry Rocks. On high-relief spur and groove reefs, mean density was greater in FKNMS no-take zones compared to reference areas in BNP and the Sanctuary. For the 525 *T. deltoidea* individuals measured, total shell lengths ranged from 1.1 to 5.1 cm, with a mean shell length of 2.6 cm. Most of the *T. deltoidea* surveyed were either found on algal turf (91.4%) or crustose coralline algae (4.8%) (Table 7-4).

Strombus gigas Linnaeus

Surveys for queen conch (*Strombus gigas*) (Figure 7-2) were carried out in conjunction with surveys of other mollusks in the Florida Keys during 2012, particularly since a large number (29) of back-reef rubble sites were included in the survey effort, some of which are locations of extant queen conch aggregation sites in the Florida Keys (G. Delgado, FWCC/FWRI, personal communication). Data from our 2012 surveys were provided to FWCC/FWRI (R. Glazer and G. Delgado) to supplement their queen conch population surveys, as we sample a variety of hard-bottom and coral reef habitats across the south Florida shelf. Like other mollusks, queen conch were counted and measured for total shell length, as well as shell lip thickness. A total of 96 queen conch were recorded from 39 of the 600 sites (6.5%) and 4.3% of sampled belt transects. Queen conch were distributed across eight of the ten habitats, with the majority (55 of 96 individuals, 57%) encountered, not surprisingly, in the reef rubble habitat (Table 7-8). A few shallow hard-bottom and deeper fore-reef sites yielded a total of 12 individuals. The maximum site-level density of 0.633 individuals per m^2 was recorded from the back-reef rubble area within Looe Key SPA. The 96 queen conch measured ranged in total shell length (SL) from 8.0 to 27.0 cm SL, with an average of 18.1 cm SL. Of these individuals, 85 (89%) were found on algal turf, with the remainder recorded on sand. Interestingly, although queen conch have been protected from collection since 1985 in State of Florida and Federal waters, densities were greater in FKNMS no-take zones and, to a lesser, extent, FKNMS reference areas, compared to BNP (Table 7-8). The entire Florida Keys area should theoretically function as one large no-take zone for this species, thus, there should be no difference in density between Sanctuary no-take zones and reference areas, unless there are perhaps habitat differences, poaching, or some other factor(s).

Figure 7-1. Nudibranch mollusks surveyed for habitat distribution, density, and size in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Chromodoris (*Mexichromis*) *kempfi* Marcus

Hypselodoris bayeri (Marcus and Marcus)

Chromodoris nyalya Marcus and Marcus

Hypselodoris olgae Ortea and Bacallado

Glossodoris sedan (Marcus and Marcus)

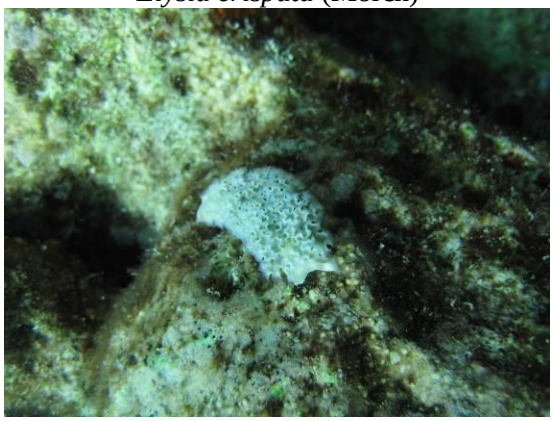
Hypselodoris picta (Schultz in Philippi)

Figure 7-2. Images of an undescribed nudibranch (*Flabellina* sp.), the sacoglossan lettuce sea slug, and gastropods surveyed for habitat distribution, density, and size in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Flabellina sp.

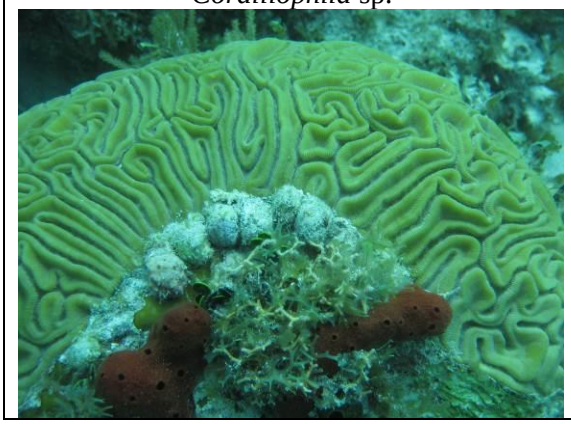
Leucozonia nassa (Gmelin)

Elysia crispata (Mörch)



Thais deltoidea (Lamarck)

Coralliophila sp.



Strombus gigas Linnaeus

Table 7-1. Summary of habitat distribution, density, and length of the nudibranch *Chromodoris nyalya* by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (90)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	0 ± 0	0 ± 0	0 ± 0		0
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	2.0 ± 1.4	1.0 ± 0.7	0.001 ± 0.001	1.1 ± 0.3	3
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	1.6 ± 1.2	0.8 ± 0.6	0.001 ± 0.001	1.1 ± 0.3	3
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0		0
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	0.9	1
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (18)	5.6 ± 5.6	2.8 ± 2.8	0.002 ± 0.002	0.9	1
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (62)	0 ± 0	0 ± 0	0 ± 0		0
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	12.5 ± 8.5	6.3 ± 4.3	0.006 ± 0.005	1.2 ± 0.0	3
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	5.0 ± 3.5	2.5 ± 1.7	0.003 ± 0.002	1.2 ± 0.0	3
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	2.4 ± 2.4	1.2 ± 1.2	0.002 ± 0.002	0.9	2
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	1.9 ± 1.9	0.9 ± 0.9	0.001 ± 0.001	0.9	2

Table 7.1 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.004 ± 0.004	1.2	3
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.003 ± 0.003	1.2	3
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	20.0 ± 20.0	10.0 ± 10.0	0.033 ± 0.033	1.2	5
FKNMS Reference Areas (54)	3.7 ± 2.6	1.9 ± 1.3	0.001 ± 0.001	1.2 ± 0.5	2
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	3.7 ± 2.1	1.8 ± 1.0	0.003 ± 0.002	1.2 ± 0.3	7

Table 7-2. Summary of habitat distribution, density, and length of the non-indigenous nudibranch *Glossodoris sedna* by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	2.0 ± 2.0	1.0 ± 1.0	0.001 ± 0.001	1.8	1
FKNMS Reference Areas (90)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	0.7 ± 0.7	0.3 ± 0.3	0.0002 ± 0.0002	1.8	1
Offshore patch reefs					
Biscayne National Park (9)	11.1 ± 11.1	5.6 ±5.6	0.004 ± 0.004	3.5	1
FKNMS Reference Areas (98)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	0.8 ± 0.8	0.4 ± 0.4	0.0003 ± 0.0003	3.5	1
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (29)	0 ± 0	0 ± 0	0 ± 0		0
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0		0
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (33)	3.0 ± 3.0	1.5 ± 1.5	0.001 ± 0.001	3.4	1
Habitat Total (62)	1.6 ± 1.6	0.8 ± 0.8	0.001 ± 0.001	3.4	1
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	0 ± 0	0 ± 0	0 ± 0		0
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0		0

Table 7.2 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		0
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		0

Table 7-3. Summary of habitat distribution, density, and shell length of the sacoglossan lettuce sea slug *Elysia* (*Tridachia*) *crispata* by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (90)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	0 ± 0	0 ± 0	0 ± 0		0
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	1.0 ± 1.0	0.5 ± 0.5	0.0003 ± 0.0003	2.7	1
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	0.8 ± 0.8	0.4 ± 0.4	0.0003 ± 0.0003	2.7	1
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	6.3 ± 6.3	3.1 ± 3.1	0.004 ± 0.004	3.1	2
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	1.5	1
Habitat Total (29)	6.9 ± 4.8	11.1 ± 11.1	0.003 ± 0.003	2.3 ± 0.8	3
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	11.1 ± 11.1	11.1 ± 11.1	0.022 ± 0.022	2.6	6
FKNMS No-take Zones (9)	33.3 ± 16.7	16.7 ± 8.3	0.022 ± 0.015	2.5 ± 0.4	6
Habitat Total (18)	22.2 ± 10.1	13.9 ± 6.8	0.022 ± 0.013	2.5 ± 0.3	12
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	10.7 ± 6.0	7.1 ± 4.2	0.021 ± 0.018	3.3 ± 0.2	18
FKNMS No-take Zones (33)	15.2 ± 6.3	9.1 ± 4.0	0.006 ± 0.003	3.0 ± 0.3	6
Habitat Total (62)	12.9 ± 4.3	8.1 ± 2.9	0.013 ± 0.008	3.1 ± 0.2	24
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	0 ± 0	0 ± 0	0 ± 0		0
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	0 ± 0	0 ± 0	0 ± 0		0

Table 7.3 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		0
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	0 ± 0	0 ± 0	0 ± 0		0

Table 7-4. Substratum occupancy patterns of lettuce sea slugs and gastropod mollusks surveyed at 600 sites in Florida Keys during May-November 2012. Data represent the number of individuals (N) and the proportion (%) of individuals found on particular substratum types.

Substratum type	***Elysia crispata***		***Coralliophila* spp.**		***Leucozonia nassa***		***Thais deltoidea***	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Scleractinian corals								
Agaricia agaricites	0	0.0	124	12.8	0	0.0	0	0.0
Acropora cervicornis	0	0.0	21	2.2	0	0.0	0	0.0
Colpophyllia natans	0	0.0	37	3.8	0	0.0	0	0.0
Dichocoenia stokesi	0	0.0	58	6.0	0	0.0	0	0.0
Diploria clivosa	0	0.0	64	6.6	0	0.0	0	0.0
D. labyrinthiformis	0	0.0	77	7.9	0	0.0	0	0.0
D. strigosa	0	0.0	149	15.3	0	0.0	0	0.0
Manicina areolata	0	0.0	1	0.1	0	0.0	0	0.0
Montastraea annularis	0	0.0	186	19.2	0	0.0	0	0.0
M. faveolata	0	0.0	129	13.3	0	0.0	0	0.0
M. franksii	0	0.0	20	2.1	0	0.0	0	0.0
M. cavernosa	0	0.0	22	2.3	0	0.0	0	0.0
Mycetophyllia aliciae	0	0.0	1	0.1	0	0.0	0	0.0
M. danaana	0	0.0	6	0.6	0	0.0	0	0.0
M. lamarckiana	0	0.0	11	1.1	0	0.0	0	0.0
Porites astreoides	0	0.0	2	0.2	0	0.0	1	0.2
P. porites	0	0.0	15	1.5	0	0.0	0	0.0
Siderastrea siderea	0	0.0	27	2.8	0	0.0	0	0.0
Solenastrea bournoni	0	0.0	10	1.0	0	0.0	0	0.0
Total coral	0	0.0	960	98.9	0	0.0	1	0.2
Algae								
Algal turf	40	100.0	2	0.2	62	81.6	480	91.4
Crustose coralline algae	0	0.0	8	0.8	10	13.2	25	4.8
Dictyota spp.	0	0.0	0	0.0	1	1.3	3	0.6
Lobophora variegata	0	0.0	0	0.0	0	0.0	1	0.2
Total algae	0	0.0	10	1.0	73	96.1	509	97.0
Other snail (same species)	0	0.0	0	0.0	0	0.0	12	2.3
Rubble (bare)	0	0.0	1	0.1	1	1.3	0	0.0
Sand (bare)	0	0.0	1	0.1	2	2.6	3	0.6
Total	40	100.0	971	100.0	76	100.0	525	100.0

Table 7-5. Summary of habitat distribution, density, and shell length of corallivorous snails (*Coralliophila* spp.) by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	34.0 ± 6.8	19.0 ± 4.0	0.066 ± 0.019	1.8 ± 0.1	99
FKNMS Reference Areas (90)	17.8 ± 4.1	9.4 ± 2.2	0.020 ± 0.006	2.0 ± 0.1	55
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	3.1	1
Habitat Total (151)	22.5 ± 3.4	12.3 ± 1.9	0.034 ± 0.008	1.9 ± 0.1	155
Offshore patch reefs					
Biscayne National Park (9)	22.2 ± 14.7	16.7 ± 11.8	0.026 ± 0.022	2.0 ± 0.2	7
FKNMS Reference Areas (98)	49.0 ± 5.1	31.1 ± 3.6	0.077 ± 0.013	1.9 ± 0.1	227
FKNMS No-take Zones (15)	46.7 ± 13.3	26.7 ± 8.3	0.064 ± 0.023	2.0 ± 0.1	29
Habitat Total (122)	46.7 ± 4.5	29.5 ± 3.2	0.072 ± 0.011	1.9 ± 0.1	263
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	25.0 ± 11.2	12.5 ± 5.6	0.019 ± 0.010	1.9 ± 0.1	9
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (29)	13.8 ± 6.5	6.9 ± 3.3	0.010 ± 0.006	1.9 ± 0.1	9
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	22.2 ± 14.7	16.7 ± 11.8	0.019 ± 0.015	2.2 ± 0.0	5
FKNMS No-take Zones (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	2.1	1
Habitat Total (18)	16.7 ± 9.0	11.1 ± 6.5	0.011 ± 0.008	2.2 ± 0.0	6
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	35.7 ± 9.2	21.4 ± 6.0	0.055 ± 0.023	1.6 ± 0.1	46
FKNMS No-take Zones (33)	33.3 ± 8.3	18.2 ± 4.8	0.110 ± 0.059	1.8 ± 0.1	109
Habitat Total (62)	33.9 ± 6.1	19.4 ± 3.7	0.083 ± 0.033	1.7 ± 0.1	155
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	56.3 ± 12.8	37.5 ± 9.7	0.092 ± 0.028	1.8 ± 0.1	44
FKNMS Reference Areas (20)	15.0 ± 8.2	10.0 ± 5.8	0.020 ± 0.015	2.0 ± 0.4	12
FKNMS No-take Zones (4)	75.0 ± 25.0	37.5 ± 12.5	0.050 ± 0.029	1.9 ± 0.2	6
Habitat Total (40)	37.5 ± 7.8	23.8 ± 5.4	0.052 ± 0.015	1.9 ± 0.1	62
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	100.0 ± 0.0	66.7 ± 10.5	0.250 ± 0.114	1.8 ± 0.1	45
FKNMS Reference Areas (42)	31.0 ± 7.2	19.0 ± 4.8	0.037 ± 0.012	1.7 ± 0.2	47
FKNMS No-take Zones (6)	50.0 ± 22.4	25.0 ± 11.2	0.028 ± 0.013	1.6 ± 0.2	5
Habitat Total (54)	40.7± 6.7	25.0 ± 4.5	0.060 ± 0.018	1.7 ± 0.1	97

Table 7.5 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	21.4 ± 7.9	12.5 ± 4.9	0.027 ± 0.011	1.7 ± 0.1	23
FKNMS No-take Zones (2)	50.0 ± 50.0	25.0 ± 25.0	0.033 ± 0.033	2.0	2
Habitat Total (32)	21.9 ± 7.4	12.5 ± 4.5	0.026 ± 0.010	1.7 ± 0.1	25
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	57.4 ± 6.8	33.3 ± 4.4	0.085 ± 0.019	1.7 ± 0.1	137
FKNMS No-take Zones (23)	52.2 ± 10.6	32.6 ± 7.4	0.090 ± 0.030	1.9 ± 0.1	62
Habitat Total (82)	52.4 ± 5.5	31.1 ± 3.6	0.081 ± 0.015	1.8 ± 0.1	199

Table 7-6. Summary of habitat distribution, density, and shell length of the lesser tulip shell *Leucozonia nassa* by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	2.0 ± 2.0	1.0 ± 1.0	0.001 ± 0.001	5.7	1
FKNMS Reference Areas (90)	5.6 ± 2.4	2.8 ± 1.2	0.002 ± 0.001	3.1 ± 0.6	5
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	4.0 ± 1.6	2.0 ± 0.8	0.001 ± 0.001	3.6 ± 0.6	6
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	5.1 ± 2.2	2.6 ± 1.1	0.002 ± 0.001	3.0 ± 0.6	5
FKNMS No-take Zones (15)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (122)	4.1 ± 1.8	2.0 ± 0.9	0.001 ± 0.001	3.0 ± 0.6	5
Reef Rubble (< 15 m)					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	4.3	1
FKNMS Reference Areas (16)	12.5 ± 8.5	6.3 ± 4.3	0.004 ± 0.003	2.4 ± 0.5	2
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.006 ± 0.006	2.7	2
Habitat Total (29)	13.8 ± 6.5	6.9 ± 3.3	0.006 ± 0.003	2.9 ± 0.5	5
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	3.1	1
FKNMS No-take Zones (9)	11.1 ± 11.1	5.6 ± 5.6	0.007 ± 0.007	2.7	2
Habitat Total (18)	11.1 ± 7.6	5.6 ± 3.8	0.006 ± 0.004	2.9 ± 0.2	3
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	35.7 ± 9.2	17.9 ± 4.6	0.021 ± 0.007	3.6 ± 0.4	18
FKNMS No-take Zones (33)	51.5 ± 8.8	30.3 ± 5.7	0.029 ± 0.006	3.3 ± 0.2	28
Habitat Total (62)	43.5 ± 6.3	24.2 ± 3.8	0.025 ± 0.004	3.4 ± 0.2	47
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	18.8 ± 10.1	12.5 ± 7.2	0.010 ± 0.006	3.5 ± 0.4	5
FKNMS Reference Areas (20)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.008 ± 0.008	2.7	1
Habitat Total (40)	10.0 ± 4.8	6.3 ± 3.2	0.005 ± 0.003	3.3 ± 0.3	6
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	2.4 ± 2.4	1.2 ± 1.2	0.001 ± 0.001	6.6	1
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	1.9 ± 1.9	0.9 ± 0.9	0.001 ± 0.001	6.6	1

Table 7.6 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	0 ± 0	0 ± 0	0 ± 0		0
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	20.0 ± 20.0	10.0 ± 10.0	0.007 ± 0.007	4.7	1
FKNMS Reference Areas (54)	3.7 ± 2.6	1.9 ± 1.3	0.001 ± 0.001	5.6 ± 0.3	2
FKNMS No-take Zones (23)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (82)	3.7 ± 2.1	1.8 ± 1.0	0.001 ± 0.001	5.3 ± 0.3	3

Table 7-7. Summary of habitat distribution, density, and shell length of the deltoid rock snail *Thais deltoidea* by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	50.0 ± 28.9	37.5 ± 23.9	0.033 ± 0.019	2.9 ± 0.5	4
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	20.0 ± 13.3	15.0 ± 10.7	0.013 ± 0.009	2.9 ± 0.5	4
Mid-channel patch reefs					
Biscayne National Park (50)	2.0 ± 2.0	1.0 ± 1.0	0.001 ± 0.001	2.2	1
FKNMS Reference Areas (90)	1.1 ± 1.1	1.1 ± 1.1	0.001 ± 0.001	2.8	2
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	1.3 ± 0.9	1.0 ± 0.7	0.001 ± 0.000	2.5 ± 0.3	3
Offshore patch reefs					
Biscayne National Park (9)	11.1 ± 11.1	5.6 ± 5.6	0.004 ± 0.004	2.1	1
FKNMS Reference Areas (98)	5.1 ± 2.2	2.6 ± 1.1	0.002 ± 0.001	3.0 ± 0.2	5
FKNMS No-take Zones (15)	6.7 ± 6.7	3.3 ± 3.3	0.002 ± 0.002	2.6	1
Habitat Total (122)	5.7 ± 2.1	2.9 ± 1.1	0.002 ± 0.001	2.8 ± 0.2	7
Reef Rubble (< 15 m)					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	2.4	1
FKNMS Reference Areas (16)	18.8 ± 10.1	15.6 ± 8.8	0.010 ± 0.006	2.6 ± 0.3	5
FKNMS No-take Zones (11)	9.1 ± 9.1	4.5 ± 4.5	0.003 ± 0.003	3.1	1
Habitat Total (29)	17.2 ± 7.1	12.1 ± 5.4	0.008 ± 0.004	2.7 ± 0.2	7
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	33.3 ± 16.7	22.2 ± 12.1	0.022 ± 0.011	2.9 ± 0.2	6
FKNMS No-take Zones (9)	44.4 ± 17.6	33.3 ± 14.4	0.044 ± 0.020	2.7 ± 0.2	12
Habitat Total (18)	38.9 ± 11.8	27.8 ± 9.2	0.033 ± 0.011	2.8 ± 0.1	18
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	64.3 ± 9.2	53.6 ± 8.5	0.158 ± 0.064	2.7 ± 0.1	133
FKNMS No-take Zones (33)	93.9 ± 4.2	80.3 ± 5.3	0.324 ± 0.067	2.6 ± 0.1	321
Habitat Total (62)	79.0 ± 5.2	66.9 ± 5.1	0.244 ± 0.047	2.7 ± 0.1	454
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	50.0 ± 12.9	34.4 ± 9.9	0.042 ± 0.016	3.1 ± 0.2	20
FKNMS Reference Areas (20)	5.0 ± 5.0	5.0 ± 5.0	0.007 ± 0.007	3.2	4
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	22.5 ± 6.7	16.3 ± 5.2	0.020 ± 0.008	3.1 ± 0.2	24
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (6)	50.0 ± 22.4	33.3 ± 16.7	0.022 ± 0.011	2.8 ± 0.2	4
Habitat Total (54)	5.6 ± 3.1	3.7 ± 2.2	0.002 ± 0.001	2.8 ± 0.2	4

Table 7.7 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	3.4	1
FKNMS Reference Areas (28)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	3.1 ± 3.1	1.6 ± 1.6	0.001 ± 0.001	3.4	1
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	1.9 ± 1.9	0.9 ± 0.9	0.001 ± 0.001	3.8	1
FKNMS No-take Zones (23)	4.3 ± 4.3	2.2 ± 2.2	0.003 ± 0.003	3.2	2
Habitat Total (82)	2.4 ± 1.7	1.2 ± 0.9	0.001 ± 0.001	3.5 ± 0.3	3

Table 7-8. Summary of habitat distribution, density, and shell length of the queen conch *Strombus gigas* by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 1-m belt transect surveys per site at 600 sites from northern BNP to southwest of Key West during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. Values represent means ± 1 SE. N = number of individuals encountered and measured for length.

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Inshore patch reefs					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (4)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (10)	0 ± 0	0 ± 0	0 ± 0		0
Mid-channel patch reefs					
Biscayne National Park (50)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (90)	4.4 ± 4.4	2.2 ± 2.2	0.001 ± 0.001	17.5 ± 2.3	4
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (151)	2.6 ± 1.3	1.3 ± 0.7	0.001 ± 0.000	17.5 ± 2.3	4
Offshore patch reefs					
Biscayne National Park (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (98)	2.0 ± 1.4	1.5 ± 1.1	0.001 ± 0.001	16.5 ± 3.5	3
FKNMS No-take Zones (15)	6.7 ± 6.7	3.3 ± 3.3	0.004 ± 0.004	25.5	2
Habitat Total (122)	2.5 ± 1.4	1.6 ± 1.0	0.001 ± 0.001	19.5 ± 3.6	5
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (16)	37.5 ± 12.5	34.4 ± 11.8	0.038 ± 0.014	20.1 ± 1.2	18
FKNMS No-take Zones (11)	36.4 ± 15.2	31.8 ± 13.9	0.112 ± 0.067	16.8 ± 2.4	37
Habitat Total (29)	34.5 ± 9.0	31.0 ± 8.4	0.063 ± 0.027	18.8 ± 1.2	55
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS No-take Zones (9)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (18)	0 ± 0	0 ± 0	0 ± 0		0
High-relief spur and groove					
Biscayne National Park (1)	0	0	0		0
FKNMS Reference Areas (28)	3.6 ± 3.6	1.8 ± 1.8	0.001 ± 0.001	21.0	1
FKNMS No-take Zones (33)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (62)	1.6 ± 1.6	0.8 ± 0.8	0.001 ± 0.001	21.0	1
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	6.3 ± 6.3	3.1 ± 3.1	0.004 ± 0.004	22.0	2
FKNMS Reference Areas (20)	10.0 ± 6.9	7.5 ± 5.5	0.005 ± 0.004	18.3 ± 0.3	3
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (40)	7.5 ± 4.2	5.0 ± 3.0	0.004 ± 0.002	19.5 ± 1.3	5
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (42)	7.1 ± 4.0	3.6 ± 2.0	0.004 ± 0.003	19.4 ± 1.4	5
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (54)	5.6 ± 3.1	2.8 ± 1.6	0.003 ± 0.002	19.4 ± 1.4	5

Table 7.8 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per m^2)	Mean size (cm)	N
Patchy hard-bottom (6-15 m)					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.017 ± 0.017	17.0	1
FKNMS Reference Areas (28)	21.4 ± 7.9	12.5 ± 4.9	0.012 ± 0.005	20.5 ± 1.2	10
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0
Habitat Total (32)	21.9 ± 7.4	12.5 ± 4.5	0.011 ± 0.005	20.0 ± 1.1	11
Low-relief spur and groove (6-15 m)					
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0
FKNMS Reference Areas (54)	11.1 ± 4.3	5.6 ± 2.2	0.004 ± 0.002	21.0 ± 1.4	7
FKNMS No-take Zones (23)	8.7 ± 6.0	6.5 ± 4.8	0.004 ± 0.003	19.0 ± 5.0	3
Habitat Total (82)	9.8 ± 3.3	5.5 ± 1.9	0.004 ± 0.001	20.5 ± 1.5	10

VIII. Marine Debris

Background

Fishing constitutes one of the most significant threats to marine biodiversity and ecosystem function, as evidenced by a significant body of historical (Dayton et al. 1995; Roberts 1995; Jennings and Polunin 1996) and more recent studies (Chuenpagdee et al. 2003; Gilardi 2005) on the numerous impacts to populations, community structure, and habitats. Besides the more obvious effects on the population structure of targeted species, fishing activities may also reduce the structural complexity of habitats or cause corresponding changes in ecological processes such as competition and predation (Russ 1991; Jones and Syms 1998; Auster and Langton 1999; Hill et al. 2003). These patterns are most obvious in areas where explosives, poisons, or other destructive fishing methods are used (Hatcher et al. 1989). However, ecological effects may occur in areas where traps, mobile fishing gear such as trawls, and potentially, even large numbers of recreational fishers operate where substantial losses of gear may occur (Hill et al. 2003; Gilardi 2005; Sheridan et al. 2005; Lewis et al. 2009).

The Florida Keys have a centuries-long history of commercial and recreational fisheries that target a great variety of fish and invertebrate species using a diversity of gear types (Bohnsack et al. 1994; Ault et al. 2005). The Florida Keys is the most important area in the State of Florida in seafood landings, dockside value, and numbers of commercial fishing vessels, especially for highly valued crustacean species, specifically pink shrimp, stone crab, and spiny lobster (Ault et al. 2005). There are also significant, but largely undocumented effects of tens of thousands of recreational fishers, who target hundreds of species using mostly hook-and-line and spear guns (Harper et al. 2000).

Baseline data on marine debris on the seabed and the impacts to coral reef benthic organisms from entanglement were collected by our program during 2000, 2001, 2008, and 2010-11 (Chiappone et al. 2002c, 2004, 2005, see previous Quick Look reports online at http://people.uncw.edu/millers). Previous surveys included 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 the impacts to benthic coral reef organisms. First, what is the spatial extent and frequency of debris at multiple spatial scales in the Florida Keys? Second, what factors, such as habitat type (depth) or management regime (areas closed or open to fishing) affect the spatial variability of marine debris? Third, what is the frequency of impacts to benthic coral reef organisms, specifically entanglement that results in tissue/skeleton abrasion? A Keys-wide effort was

expended in 2008 to document the density, length, and weight of different debris types, as well as the impacts to benthic coral reef organisms (e.g. abrasion damage) at 145 sites partitioned by cross-shelf habitat type, geographic region, and management zone from northern Key Largo to SW of Key West. These data demonstrate the ubiquitous and damaging characteristics of marine debris, particularly lost fishing gear, even within "protected" no-fishing zones in the Sanctuary. In 2010, we surveyed these marine debris metrics, but were limited to 120 sites in the upper Florida Keys. In 2011, we were limited to the upper Florida Keys, but were able to sample marine debris at 280. During May-November 2012, we added to this temporal dataset by surveying the type, density, length, weight, of marine debris, as well as the frequencies of benthic coral reef organisms exhibiting abrasion damage from entanglement at 600 sites distributed from northern Biscayne National Park (BNP) to the Western Dry Rocks area, including areas both inside and outside of no-fishing zones in the Florida Keys National Marine Sanctuary (FKNMS).

2012 Survey Results

Marine debris surveys were conducted at all 600 Florida Keys sites surveyed during May-November 2012. At each site visited, two belt transects 15-m x 2-m in dimension were used to quantify the type, transect frequency of occurrence, density, length, weight, and impacts (abrasion from entanglement) of marine debris to benthic coral reef organisms. We measured lengths of debris when applicable, specifically angling gear (e.g. monofilament, leader, and wire) and lobster/crab trap rope, as well as the combined wet weight of all debris encountered per belt transect. Figure 8-1 illustrates examples of marine debris commonly encountered. Surveys of 1,200 belt transects comprising 36,000 m^2 of hard-bottom and coral reef habitat yielded 1,044 debris items, representing 48 different items or combinations of items (Table 8-1). Of these, 15 categories (31%) were different types of hook-and-line angling gear, nine (19%) were different types of lobster/crab trap, and the remaining 24 categories (50%) were designated as "other debris". Other marine debris included a range of metal, glass, cloth, ceramic, and plastic items. Of the 1,044 total debris items counted, 469 (45% of the total) were angling gear (e.g. monofilament, wire leaders, hooks, and lead sinkers), followed by 436 trap debris items (42%), and 139 (13%) other debris items (Table 8-1).

Many of the debris items encountered during 2012 were entangled or causing damage to live tissue of benthic coral reef organisms such as stony corals, sponges, and gorgonians. A total of 531 organisms were identified as being impacted (i.e., exhibiting tissue damage from entanglement/abrasion) by marine debris, represented by *Millepora* and scleractinian corals, gorgonians, sponges, and the colonial zoanthid

Palythoa (Table 8-1). The lobster/crab trap debris encountered, especially trap rope, impacted 334 organisms (63% of all organisms), followed by lost hook-and-line gear (168 organisms, 32%), and other debris (29 impacted organisms, 5%). Similar to previous years, the data indicate that while lost hook-and-line fishing gear was the most prevalent debris category, the number of organisms entangled and damaged by lobster/crab trap debris, especially trap rope, was proportionally larger than other debris. The most frequently impacted organisms from entangled marine debris were gorgonians (46% of the total impacts) and scleractinian corals (21%), followed by sponges (18%), milleporid hydrocorals (14%), and the colonial zoanthid *Palythoa* (< 1%) (Table 8-1). The sections below summarize the distribution, density, amount (length and weight) of the three main categories of debris (e.g. lost angling gear, lobster/crab trap gear, and other), as well as total marine debris encountered at 600 sites in the Florida Keys during 2012.

Hook-and-line Angling Gear Debris

Lost angling gear was the most frequent type of marine debris encountered at the 600 survey locations in the Florida Keys in terms of the number of sites (236 sites, 39% of all sites), sampled belt transects (25%), and the number of items encountered (483 items, 46% of all debris items). Lost angling gear debris was found in all ten hard-bottom and coral reef habitats surveyed and nearly all of the 23 FKNMS no-take zones surveyed throughout the Sanctuary (Table 8-2). Figures 8-2 to 8-8 illustrate the spatial distribution and density (no. items per m^2) of angling gear debris in the Florida Keys during 2012. Site presence (% of sites where a debris item or category of debris was encountered within one or both sampled belt transects), transect frequency of occurrence (proportion of transects where a debris item or category of debris items was present), density (no. of debris items per m^2), and mean total length in meters of gear recovered per 30-m^2 transect were relatively similar among most of the sampled habitats, except for reef rubble and the deeper (6-15 m) fore reef (Table 8-2). Lost angling gear was particularly prevalent on patch reefs, even within FKNMS no-fishing zones. Similar to previous years, we continued to document lost angling gear in most of the FKNMS no-take zones. For many of the habitats surveyed, the site presence, transect frequency, and angling debris density in no-fishing zones was either similar to, or in some cases greater than in reference areas open to fishing (Table 8-2). No-take zones (arranged from NE to SW) with relatively large amounts of angling gear debris included mostly patch reef areas at Hen and Chickens SPA, Cheeca Rocks SPA, Looe Key RO, and Western Sambo ER (Figures 8-2 to 8-8).

The 483 items of lost angling gear were measured for total length to the nearest cm, when applicable. A total of 625.84 m of angling gear was retrieved from the seabed Keyswide during 2012. Although this figure may not seem significant, our total sampling effort represents < 0.1% of the total hard-bottom and

coral reef habitat from northern BNP to Western Dry Rocks (see Section 2). The lengths of angling gear debris measured (n=479 items) ranged from 0.01 to 26.60 m, with an average (± 1 SE) 1.13 ± 0.10 m. Smaller items included lead sinkers and small pieces of monofilament and fishing wire. Larger items were usually longer strands of entangled monofilament. The length distribution of angling gear indicated that about 90% of the angling gear debris was < 2.5 m (~8 feet) in length. Similar to other metrics, the average length of angling gear recovered was relatively high on patch reefs and some deeper fore-reef habitats. The average length of angling gear debris retrieved per transect tended to be greater in reference areas compared to no-take zones for many, but not all, of the habitats surveyed (Table 8-2).

Lobster/Crab Trap Debris

Lost lobster/crab trap fishing gear was the second most abundant debris type encountered in terms of the number of sites (206 sites, 34% of all sites), transect frequency (22%), and items encountered (439 items, 41% of all items) (Table 8-3). Figures 8-9 to 8-15 illustrate the spatial distribution of trap debris density (no. items per m^2) during 2012 in the Florida Keys. Of the 439 trap items recovered, approximately 45% consisted of rope (Table 8-1). Trap gear debris was encountered in all ten coral reef and hard-bottom habitats sampled (Table 8-3). Similar to angling gear debris, the site presence, transect frequency, and density of trap gear debris was substantially greater on inshore, mid-channel, and offshore patch reefs compared to other habitats. Trap debris site presence, transect frequency, and density were either similar or somewhat lower in no-take zones compared to reference sites (Table 8-3). Trap gear debris was encountered in about 50% of the 23 FKNMS no-fishing zones sampled during 2012.

Nearly 50% (196 out of 436 items) of trap debris items consisted of trap rope, either free or attached to some other trap item (Table 8-1). The 196 samples of trap rope encountered and measured totaled 2,687.59 m (> 2.5 km) in length. The lengths of trap rope encountered ranged in length from 0.30 to 150.05 m and averaged (± 1 SE) 13.44 ± 1.29 m; the average length value thus indicates that when trap rope was encountered, an average-size piece was ~44 feet in length. The length distribution of trap rope indicated that 50% of the trap rope measured was < 10 m in length, although larger pieces of rope were just as common. The average length of trap rope per 30 m^2 was greatest in high-relief spur and groove, mid-channel patch reef, and offshore patch reef habitats (Table 8-3). The former result is largely due several long sections of trap rope found at high-relief spur and groove sites west of Western Dry Rocks, as well as in the Pelican Shoal area.

Other Marine Debris

Other debris items encountered in the Florida Keys during 2012, specifically debris that was not related to hook-and-line fishing or lobster/crab trapping, were represented mostly by glass bottles, plastics, metals, as well as anchors with or without chain and rope (Table 8-1). Other debris items (n=136 items) were encountered at 103 sites (17% of all sites) and nearly 10% of the sampled belt transects, as well as all ten of the hard-bottom and coral reef habitat types sampled (Table 8-4).

Total Marine Debris

The 1,058 total marine debris items encountered represents an overall mean density of roughly three debris items per 100 m^2, a result similar to previous years. The maximum site-level mean density was 7 items per 30 m^2. Debris was encountered at 381 sites (64% of all sites) and 45% of the sampled belt transects. Figures 8-16 to 8-22 show the spatial distribution of total marine debris density (no. items per m^2) and illustrate its ubiquitous nature in the Florida Keys. Site presence, transect frequency, density, and weight relatively high in all sampled habitats, except reef rubble (Table 8-5). Although marine debris tended to be more commonly encountered in reference areas, it was rather ubiquitous in no-fishing zones as well, particularly lost fishing gear. The 1,058 debris items recovered during 2012 were collected per 30 m^2 belt transect and brought back to the surface to determine wet weight. A total of 449.512 kg (~989 pounds or 0.49 tons) of debris was retrieved from the seabed. Total wet weight collected per belt transect (i.e. per 30 m^2) was greatest on mid-channel and offshore patch reefs (Table 8-5).

Discussion

Methods of fishing can cause habitat modification or damage to benthic organisms (Russ 1991; Benaka 1999; Hill et al. 2003). While there has long been recognition of the impacts to benthic organisms from mobile fishing gear such as trawls (Watling and Norse 1998; Auster and Langton 1999; Chuenpagdee et al. 2003) and other destructive fishing practices (Saila et al. 1993; Jennings and Polunin 1996), only a handful of studies in the Florida Keys have quantified the spatial extent of marine debris, as well as the biological impacts to organisms and habitats (Chiappone et al. 2002c, 2004, 2005). Studies of lobster trap movement and large-scale studies of lobster trap abundance (Uhrin et al. 2005; Lewis et al. 2009) indicate the potential for extensive movement of deployed gear, especially during storms. Similar to debris surveys completed by our program in 2000, 2001, 2008, and 2010-11, the results from 2012 indicate the large-scale prevalence of marine debris, especially lost fishing gear, even within FKNMS no-fishing zones.

Interpretation of the data on entanglement and damage to benthic coral reef organisms from marine debris is complicated by several factors. Both the debris density and the distribution of sessile invertebrates sampled in this study are related to habitat type. It is probable that a coral-dominated reef with a given amount of hook-and-line gear will not be affected in the same way as a gorgonian-sponge dominated reef with the same density of gear. Estimates of the proportion of different taxa impacted by debris relative to total abundance estimates are also useful for placing the debris impact assessment into context. In addition, the long-term impacts to biota and the degree of recovery are unknown. For example, we do not mark and re-sample benthic organisms impacted by debris to determine whether organisms recover. We recognize that assessments would be more useful if data on the severity of each impact (e.g. amount of tissue damage) relative to the size of the organism were collected. The data presented in this report clearly indicate areas in the Florida Keys such as patch reefs where public debris collection efforts such as "reef sweeps" should be focused. Considering the intensive fishing effort and the significant increases in registered recreational boats and angler days in the Florida Keys, patterns in debris distribution and abundance, especially lost fishing gear, are not surprising. We usually found either similar or greater amounts of debris, especially lost fishing gear, in no-fishing zones compared to reference areas for many of the sampled habitats in 2012, similar to observations dating back more than a decade. Non-compliance certainly occurs in Sanctuary no-fishing zones and it is common to find "fresh" (un-fouled) hook-and-line gear in the zones. FKNMS no-take zones may attract people to fish illegally or to fish close to zone boundaries, otherwise known as "fishing the line." Storms also re-distribute debris from areas where it is initially lost into adjacent areas, including coral reefs, suggesting the need for either less mobile gear types or buffer areas to protect neighboring habitats from physical damage.

Figure 8-1. Examples of marine debris encountered in Biscayne National Park and the Florida Keys National Marine Sanctuary during May-November 2012.

Monofilament entangling staghorn coral

Trap rope abrading a coral colony

Trap rope entangling a sea fan

Trap rope entangling staghorn coral

Intact ghost trap with line attached

Trap grating and rope

Figure 8-2. Densities (no. items per m^2) of hook-and-line fishing gear debris in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

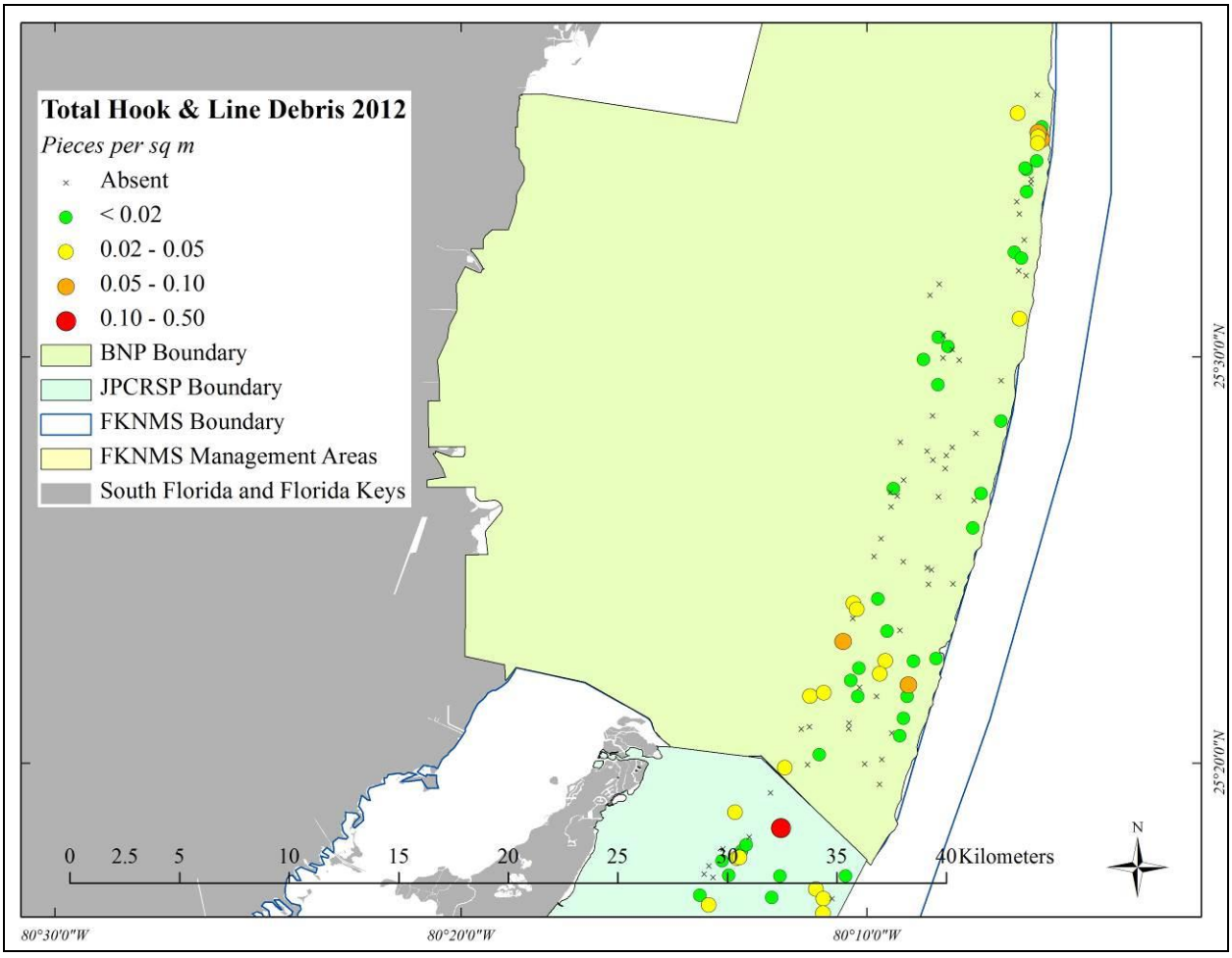


Figure 8-3. Densities (no. items per m^2) of hook-and-line fishing gear debris in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

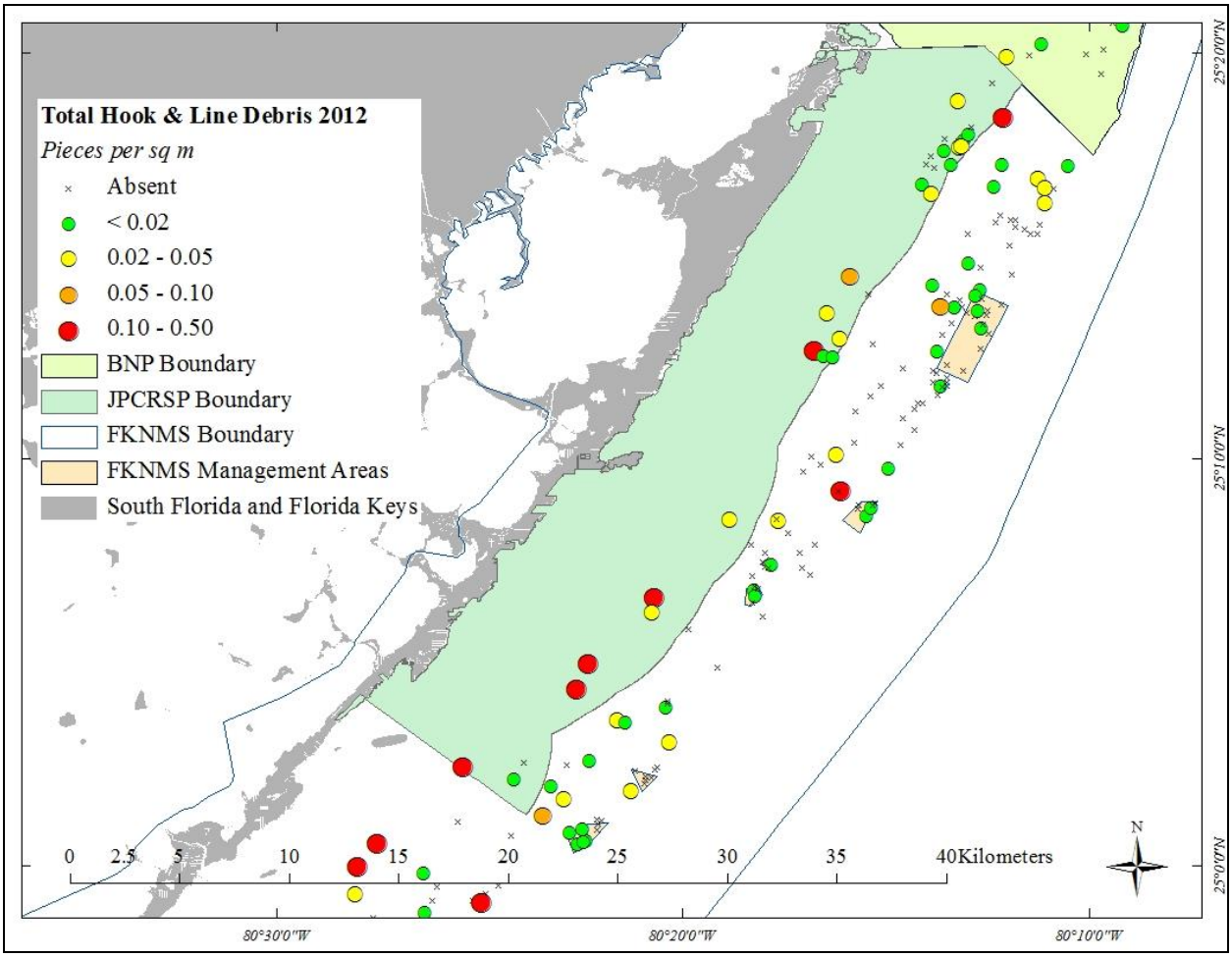


Figure 8-4. Densities (no. items per m^2) of hook-and-line fishing gear debris in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

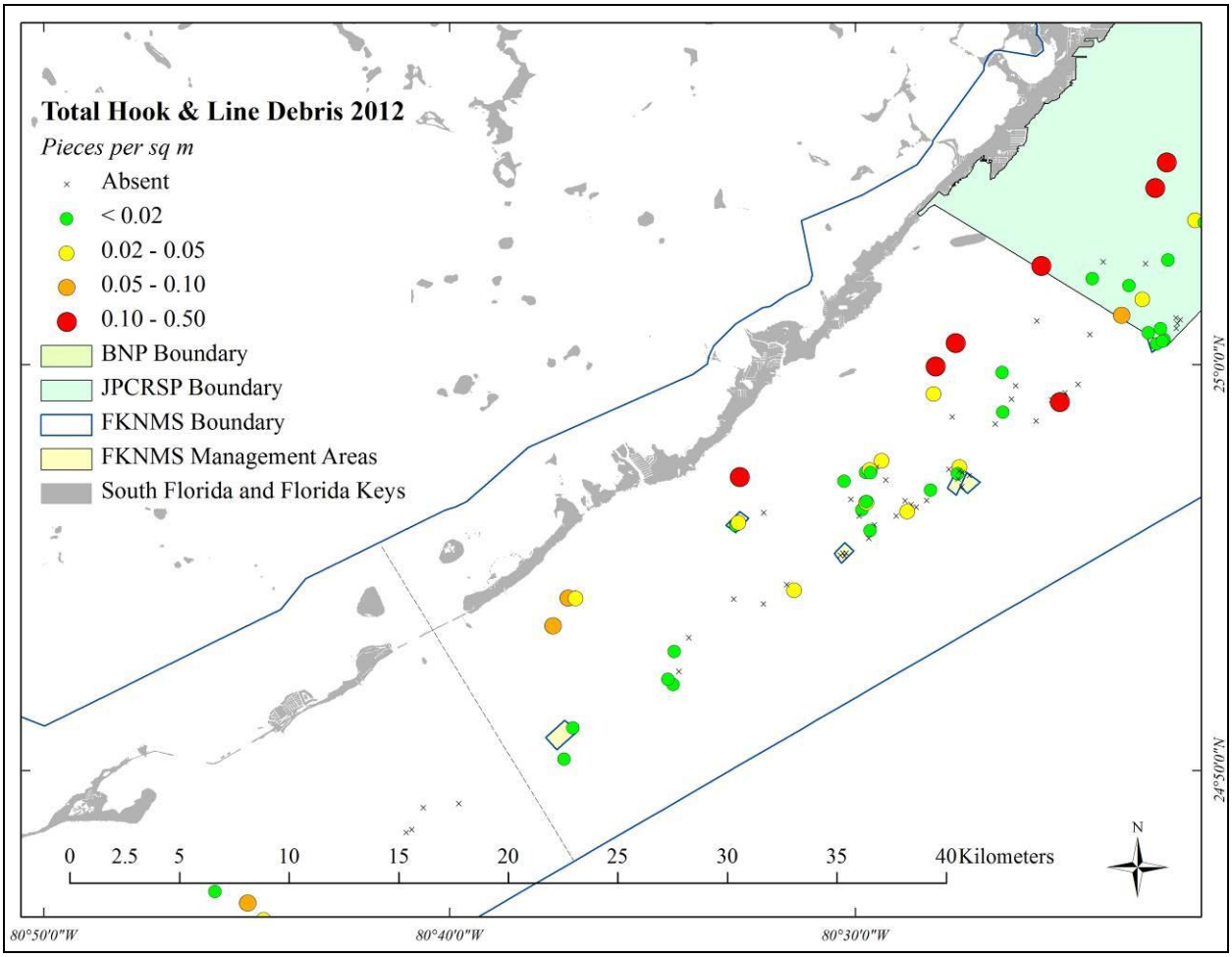


Figure 8-5. Densities (no. items per m^2) of hook-and-line fishing gear debris in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

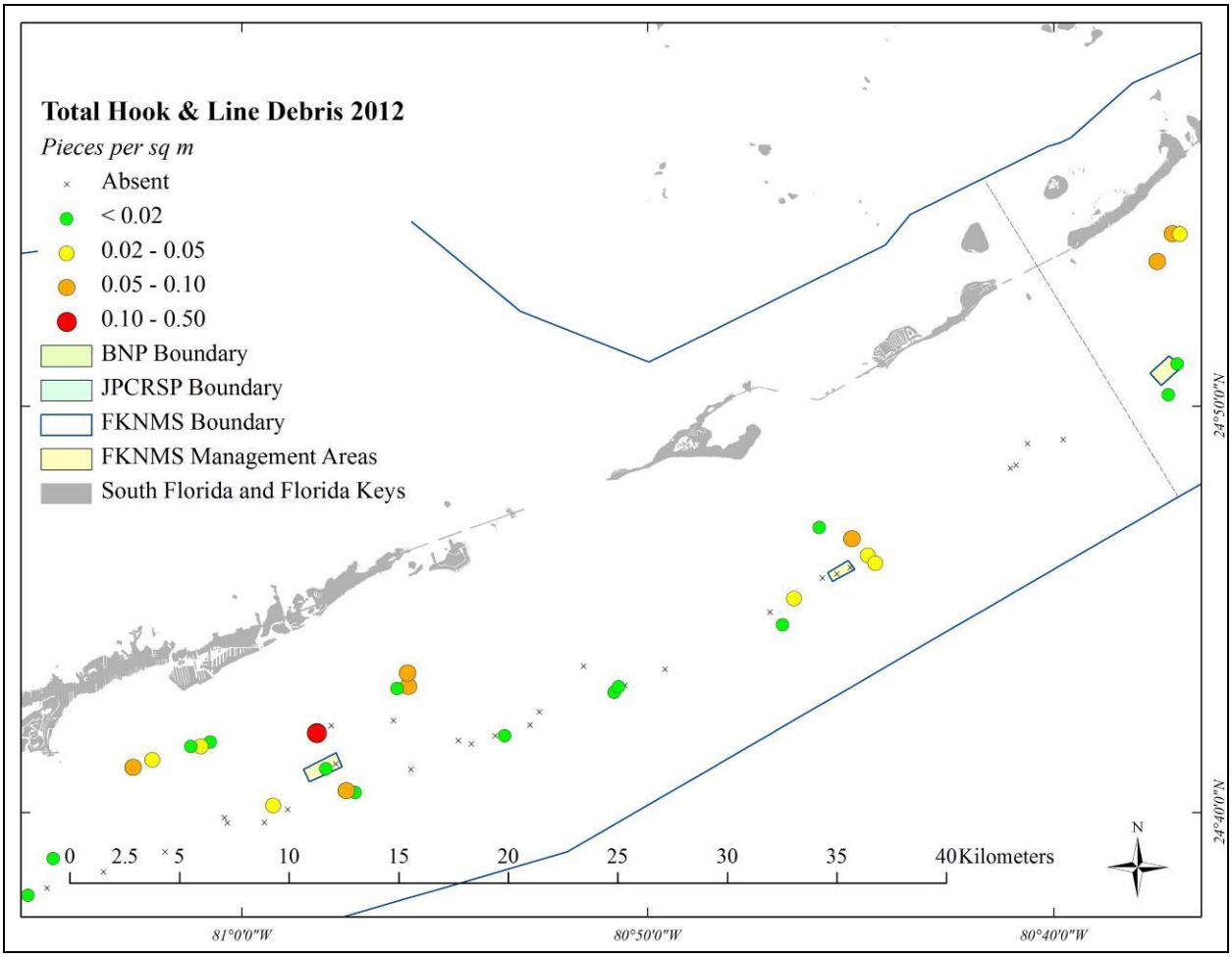


Figure 8-6. Densities (no. items per m^2) of hook-and-line fishing gear debris in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

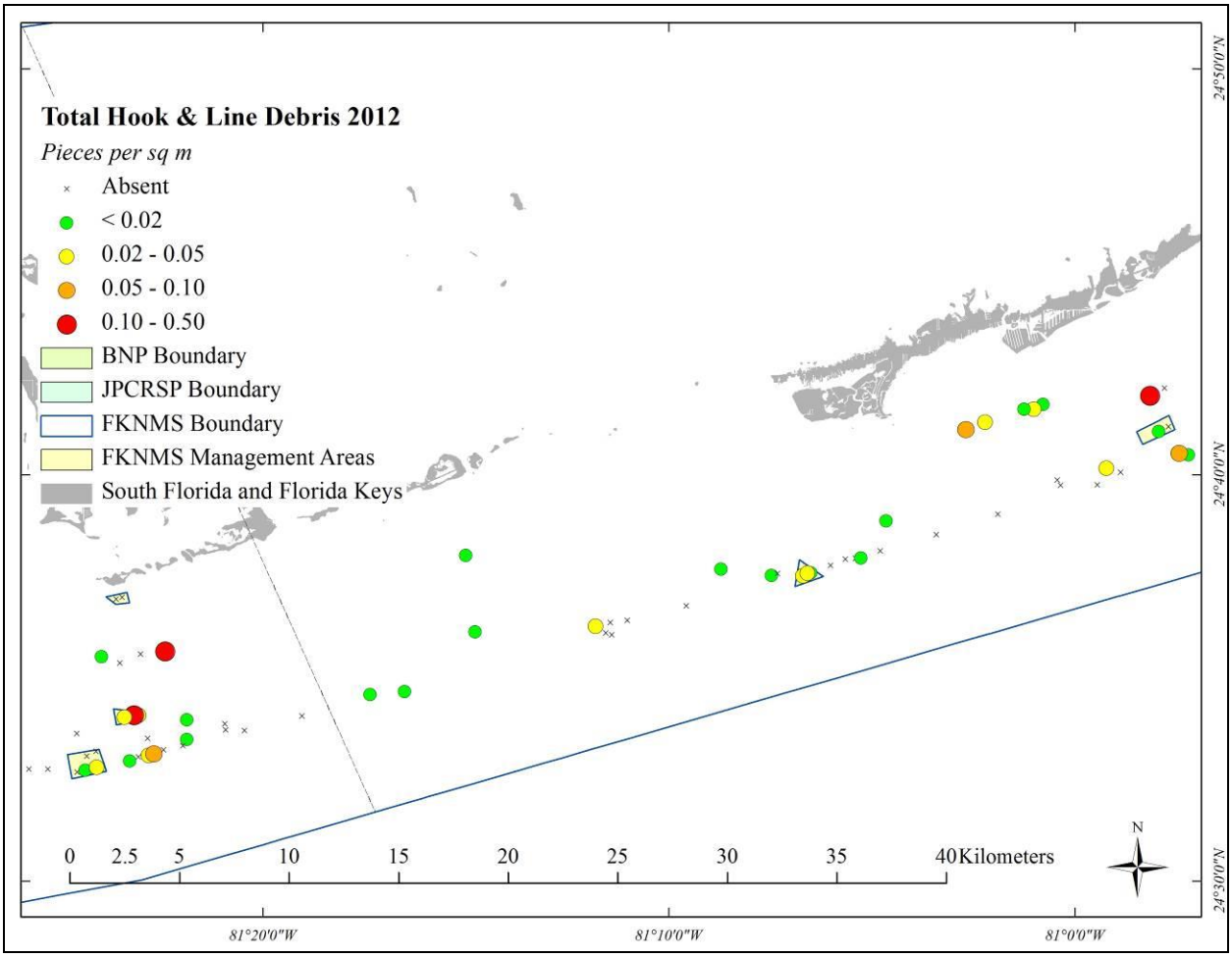


Figure 8-7. Densities (no. items per m^2) of hook-and-line fishing gear debris in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

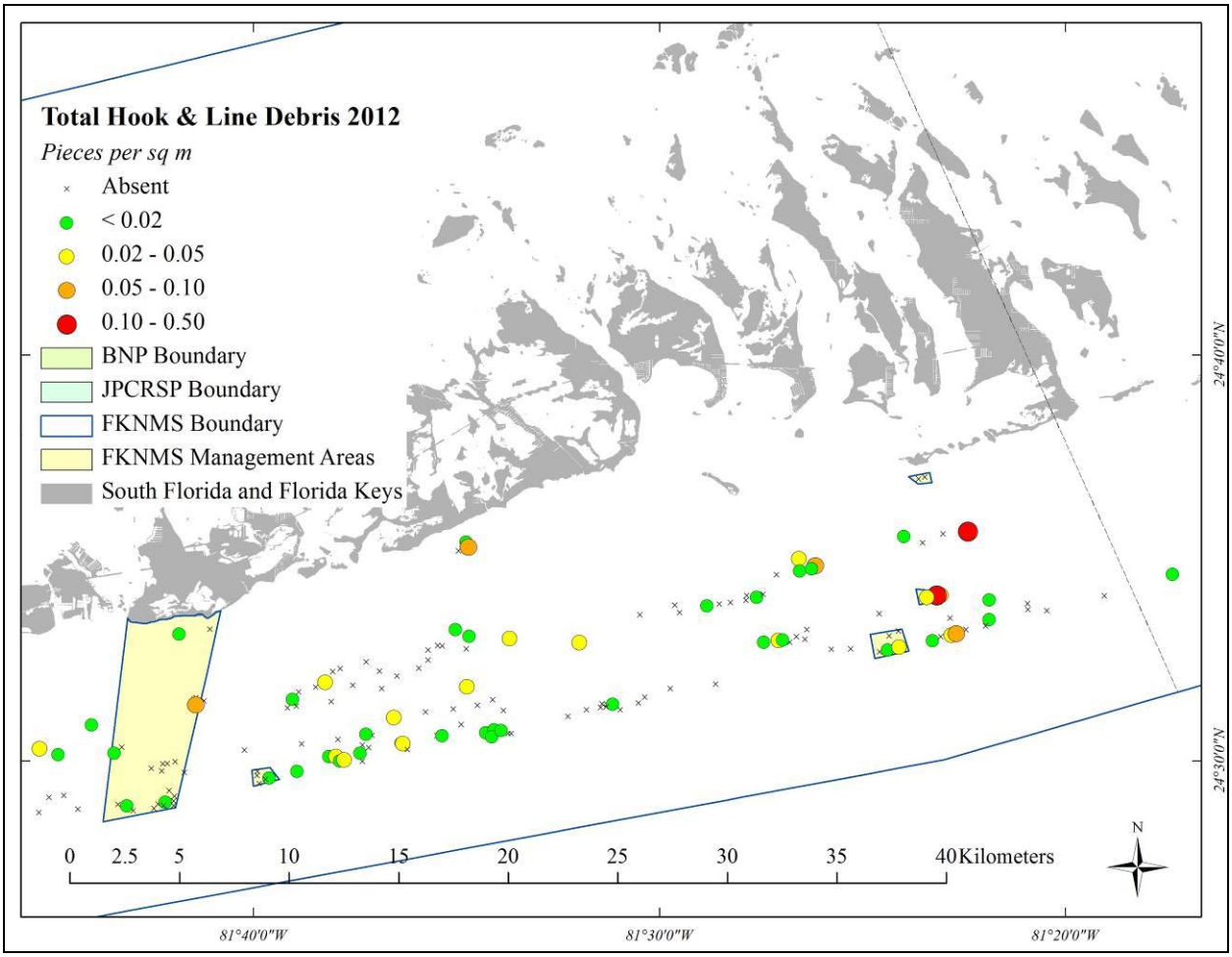


Figure 8-8. Densities (no. items per m^2) of hook-and-line fishing gear debris in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

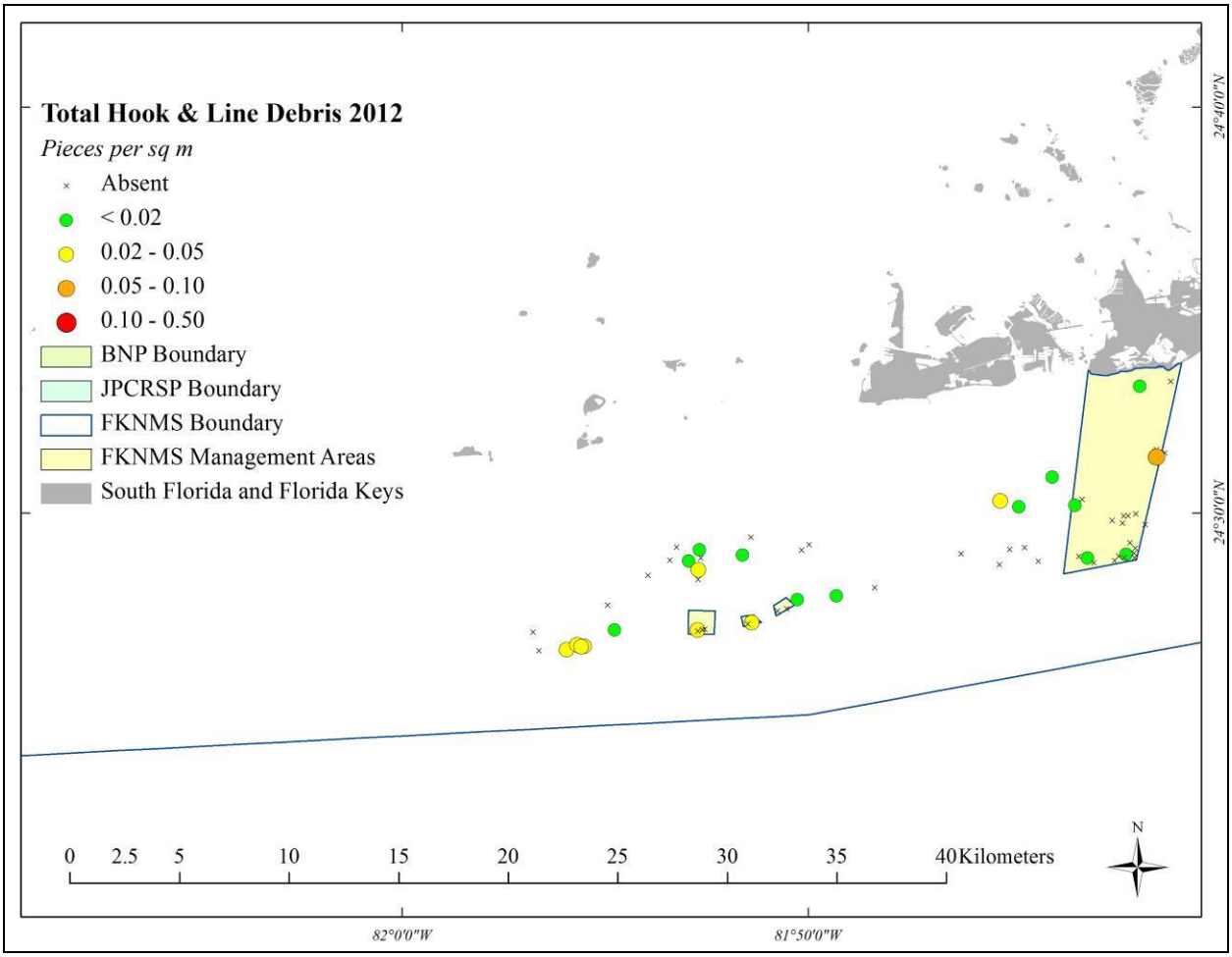


Figure 8-9. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

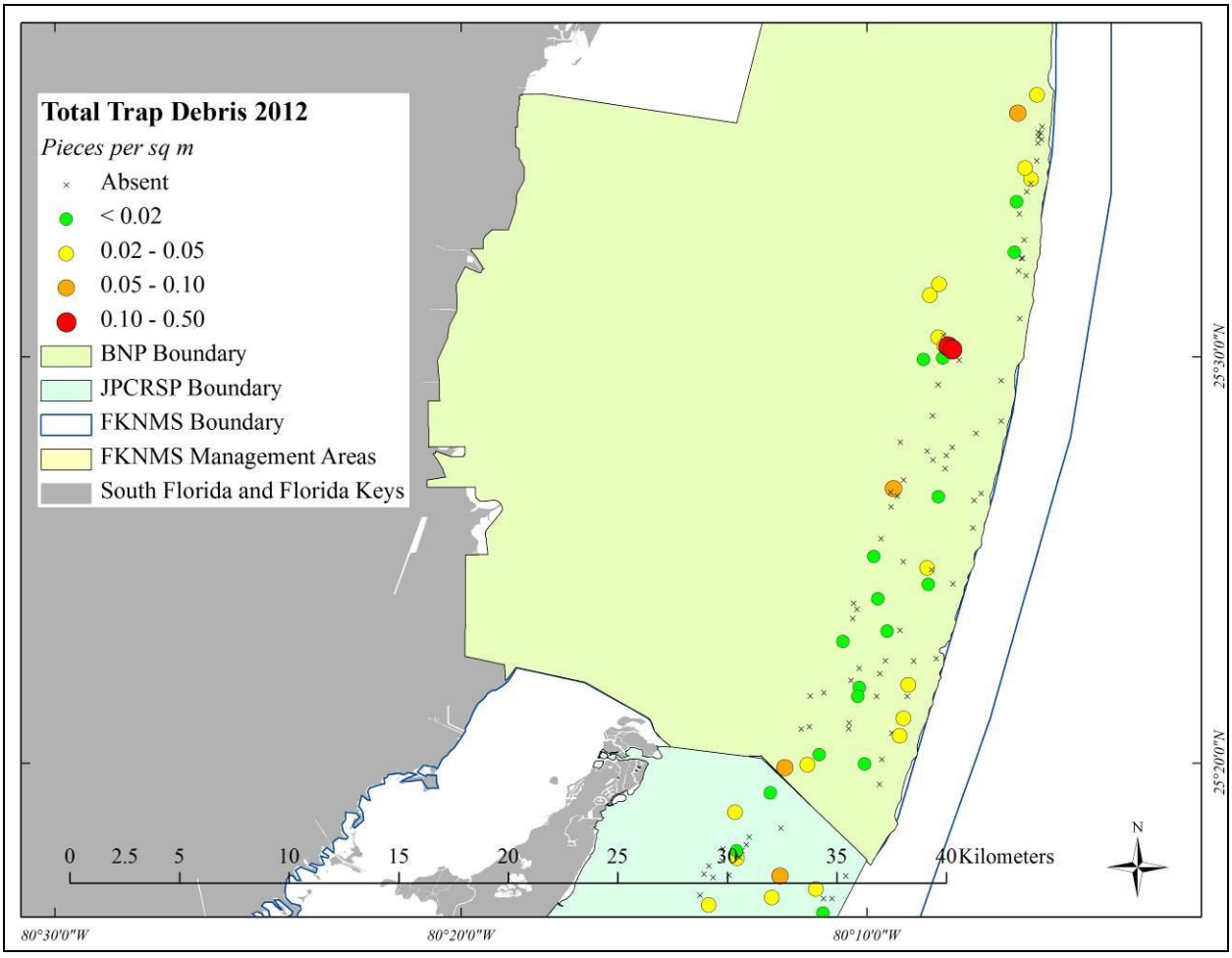


Figure 8-10. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

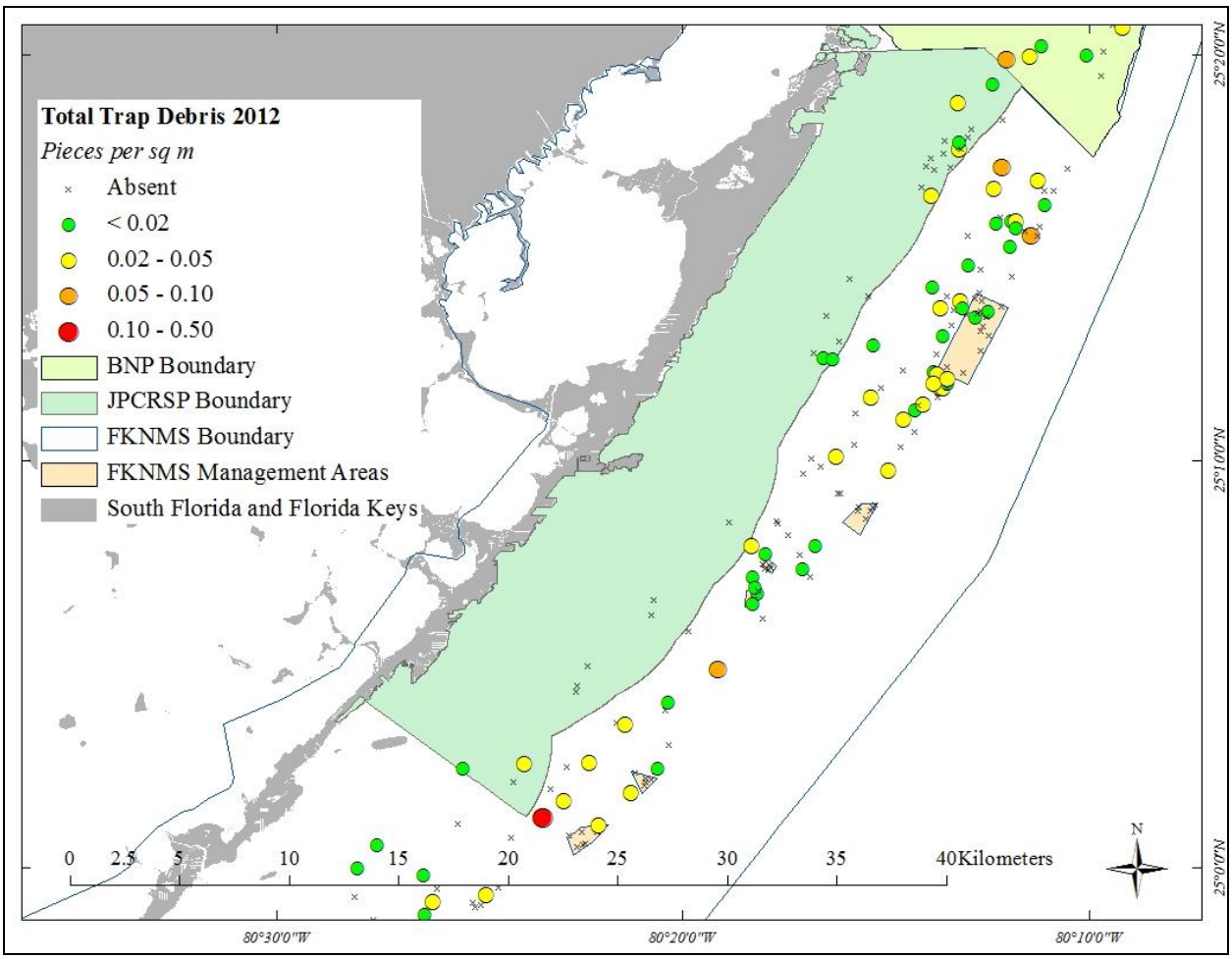


Figure 8-11. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

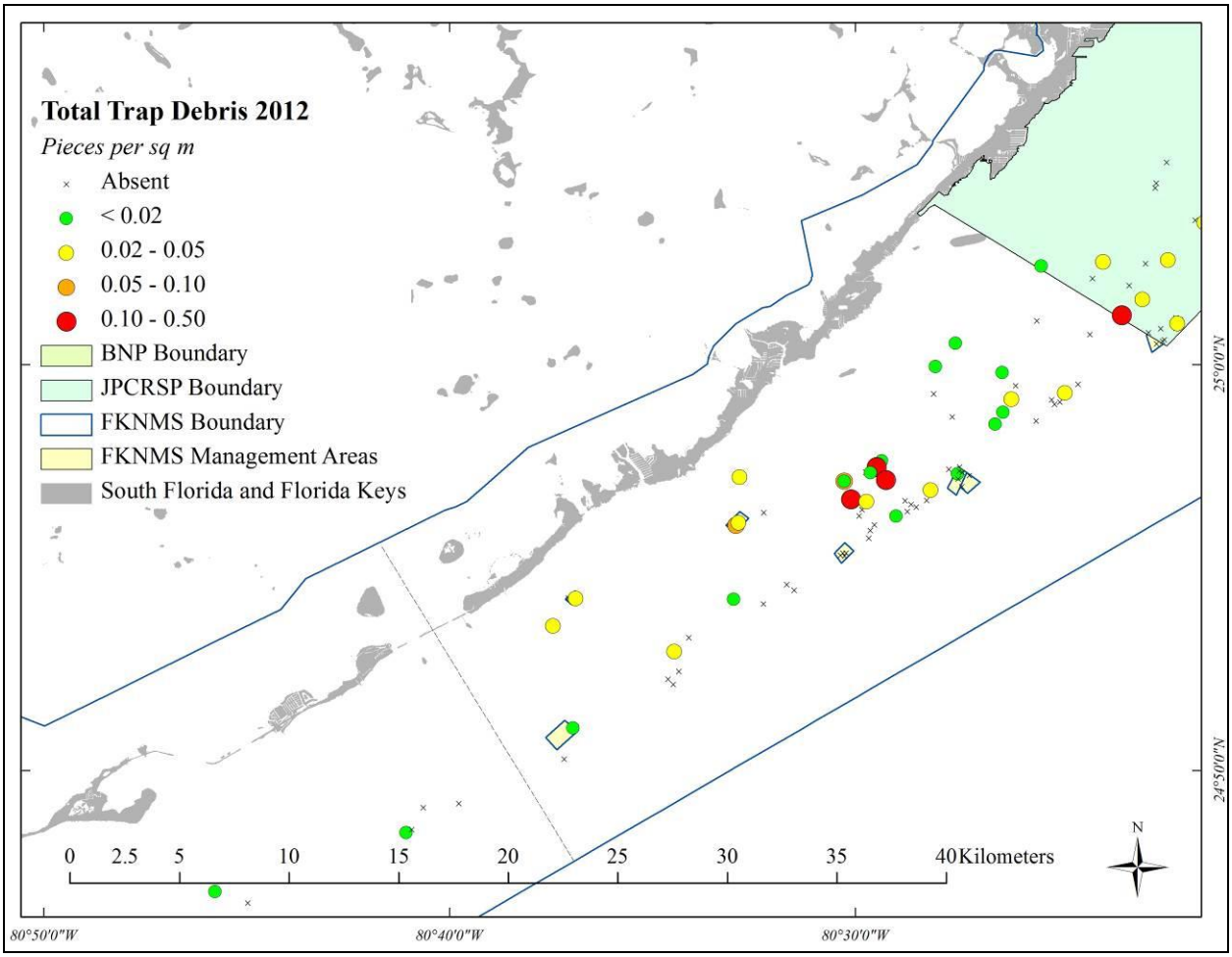


Figure 8-12. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

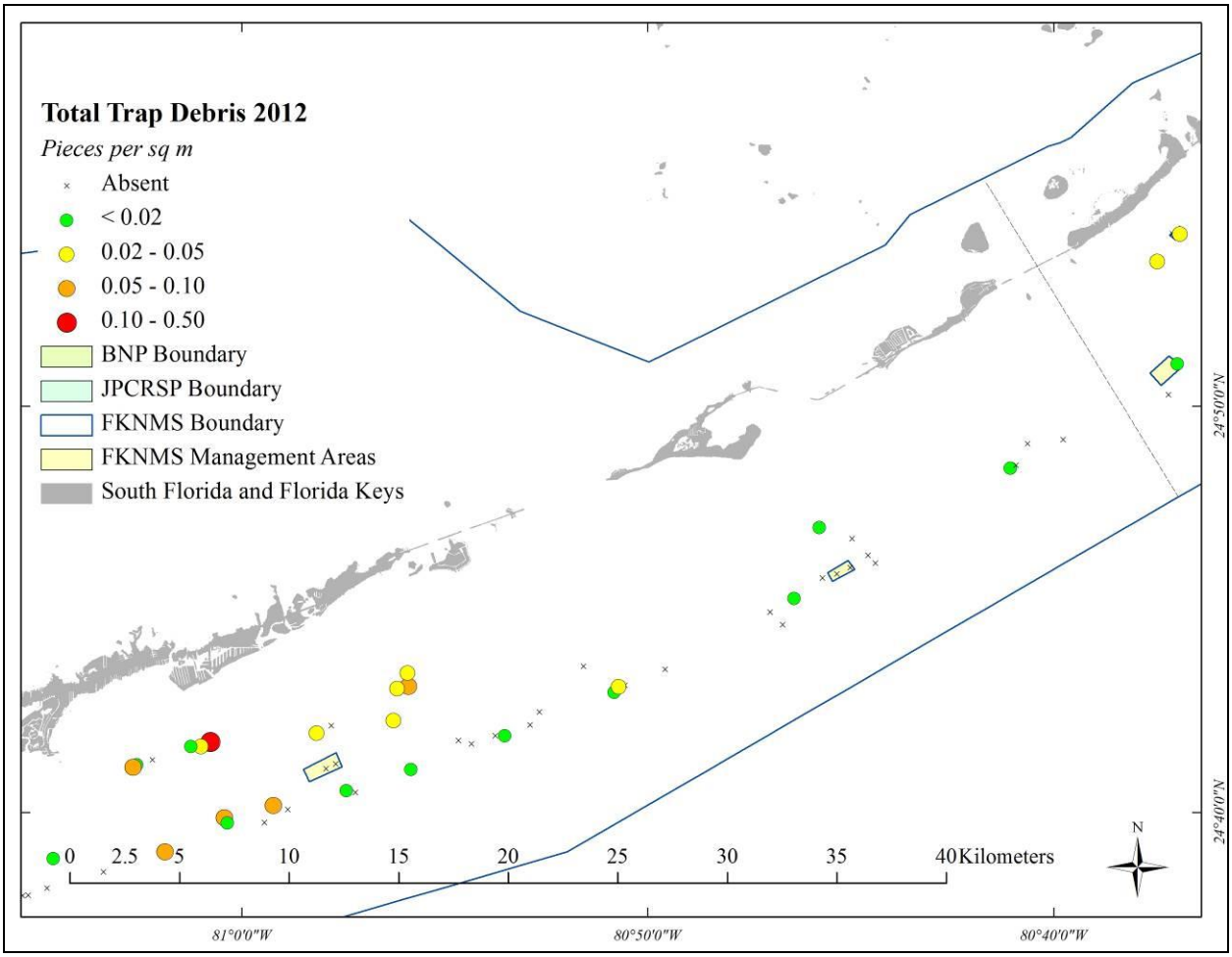


Figure 8-13. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

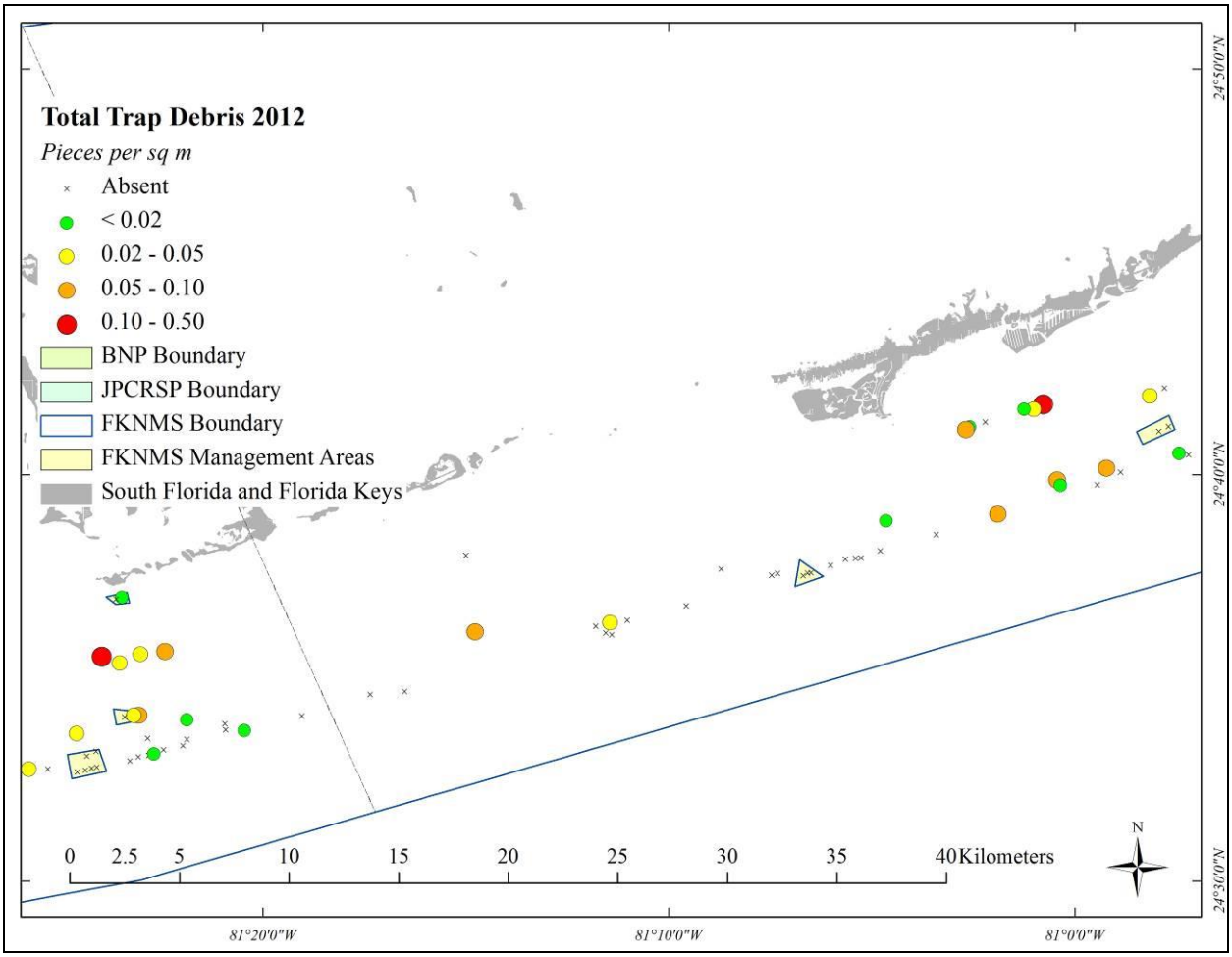


Figure 8-14. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

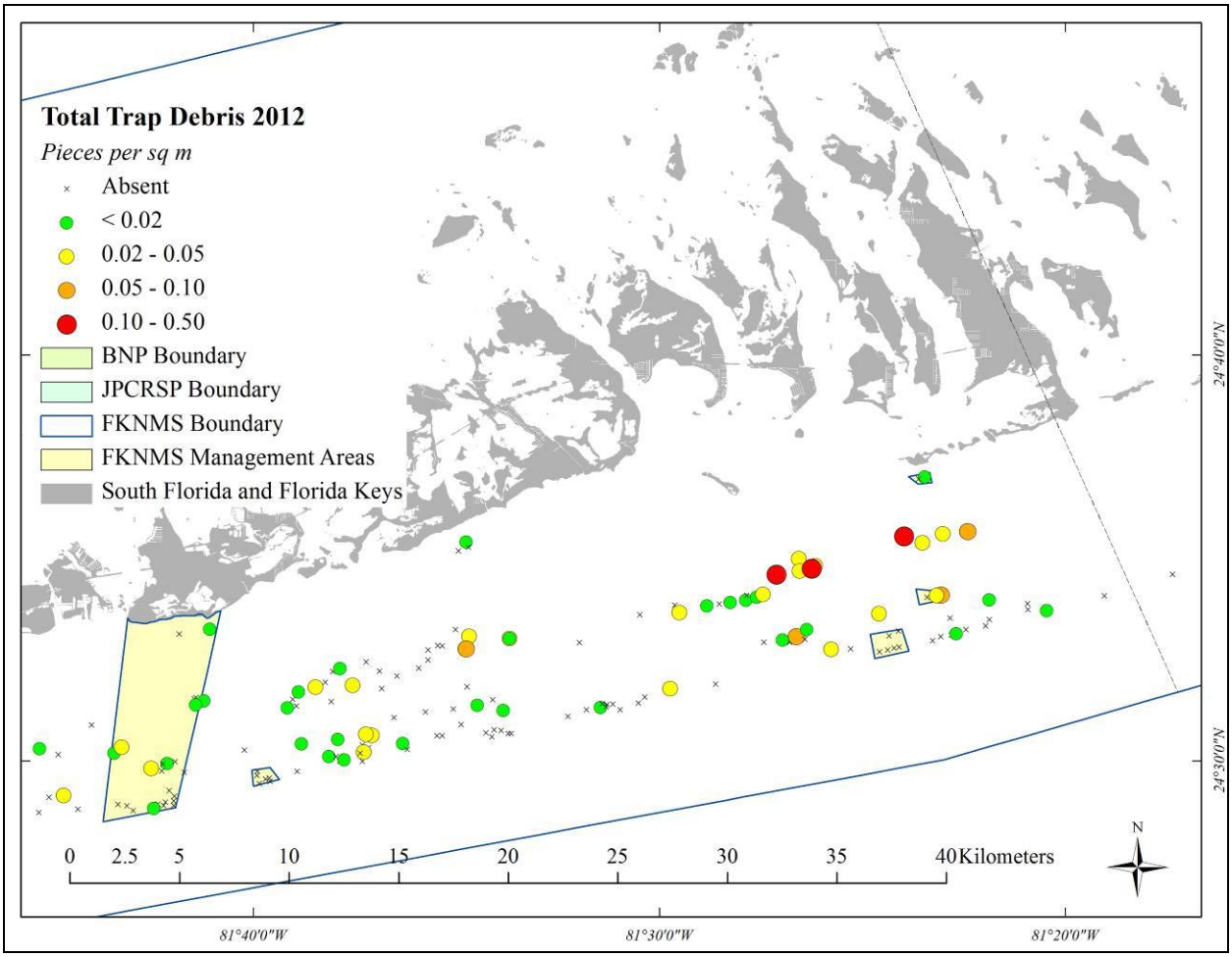


Figure 8-15. Densities (no. items per m^2) of combined lobster/crab trap fishing gear debris in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

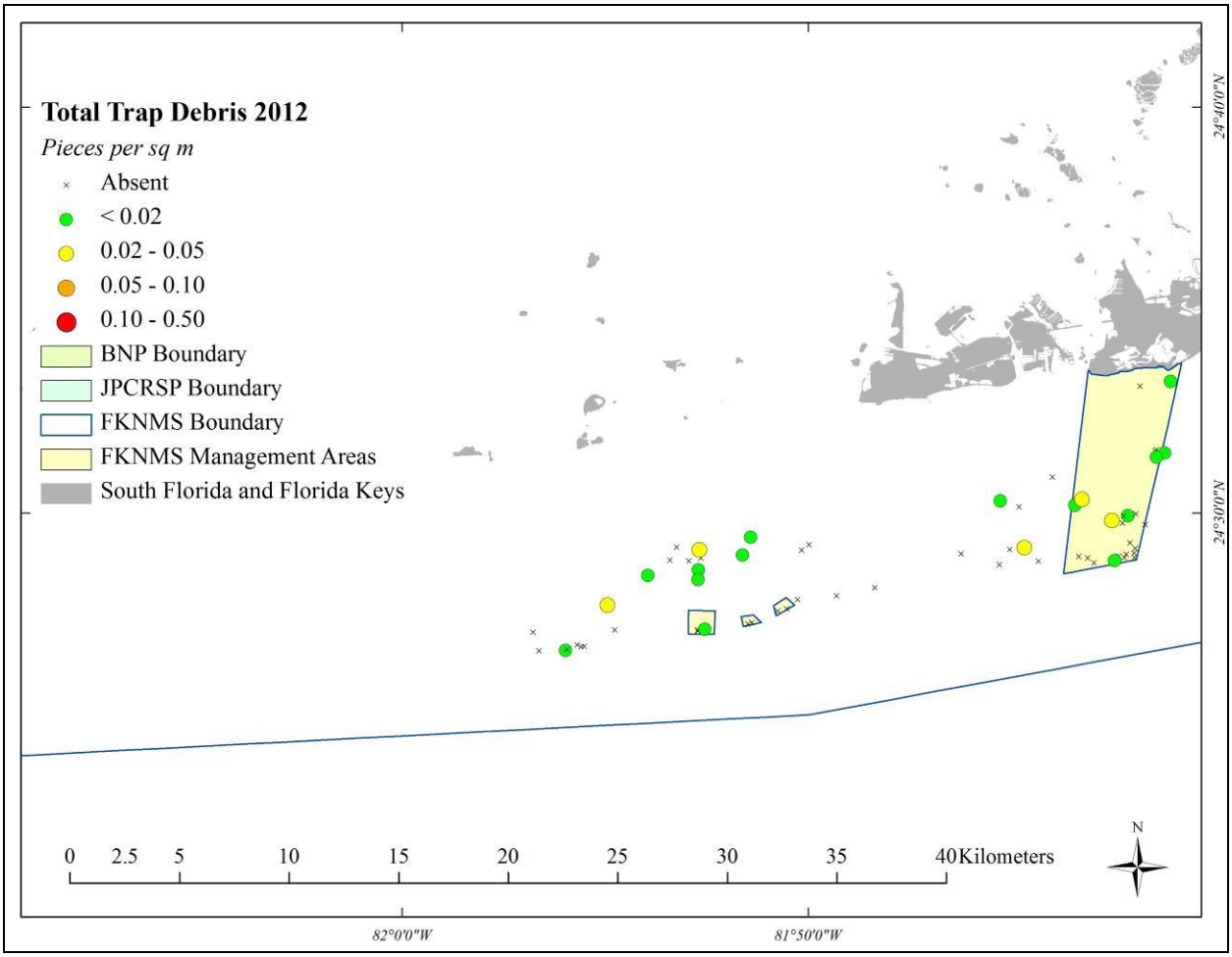


Figure 8-16. Densities (no. items per m^2) of total marine debris in Biscayne National Park surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

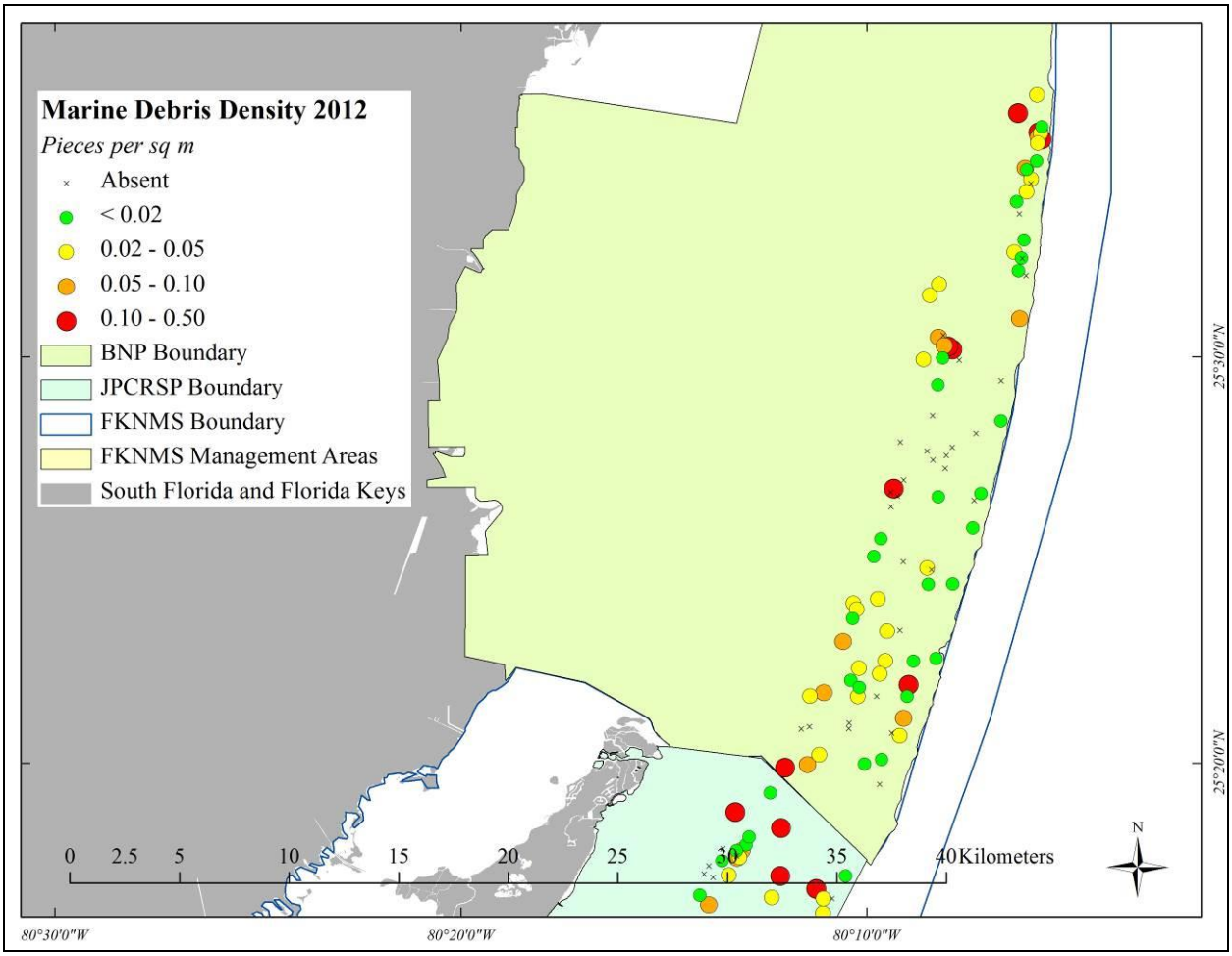


Figure 8-17. Densities (no. items per m^2) of total marine debris in the upper Florida Keys from the BNP boundary to Molasses Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

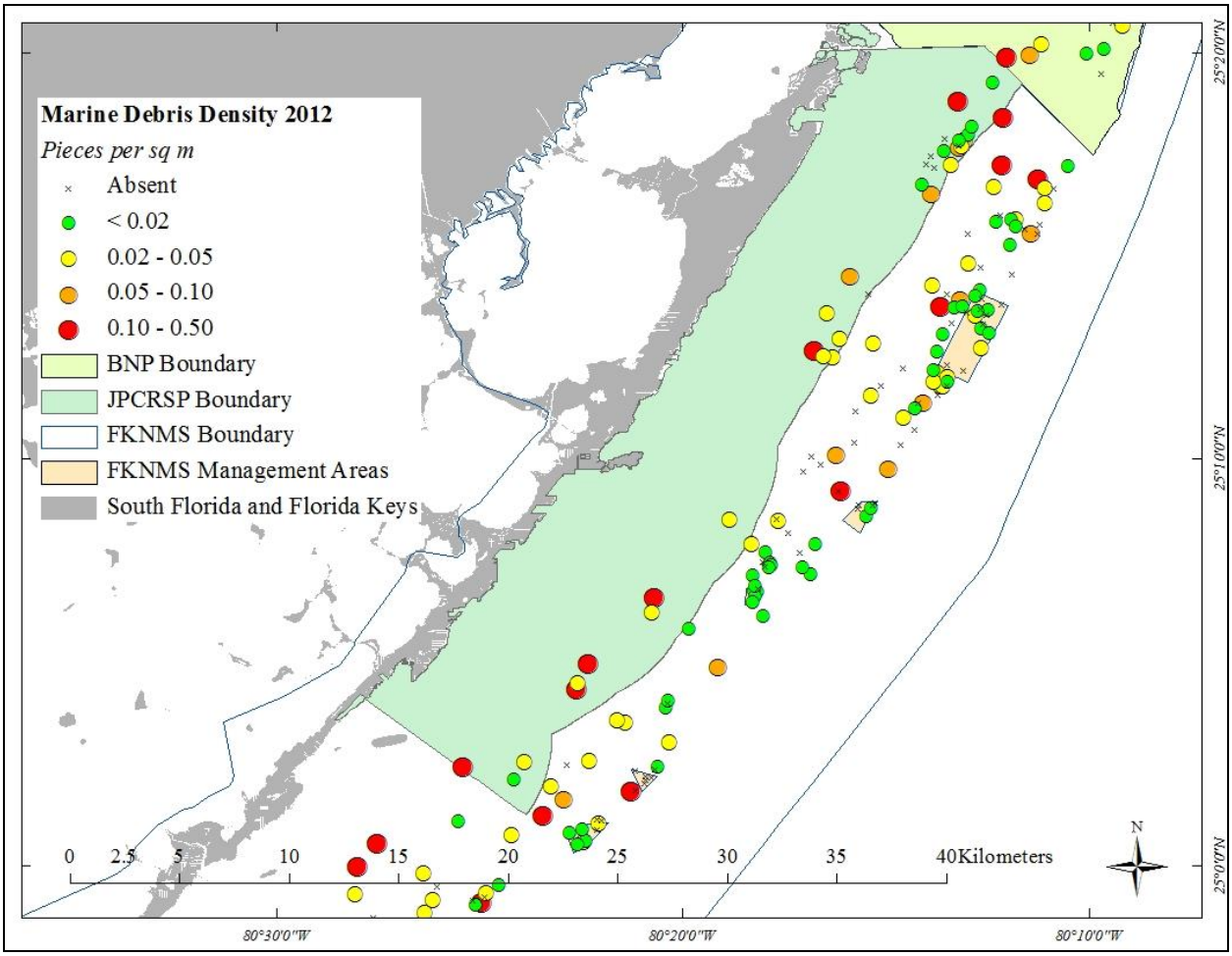


Figure 8-18. Densities (no. items per m^2) of total marine debris in the upper Florida Keys from Molasses Reef to Alligator Reef surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

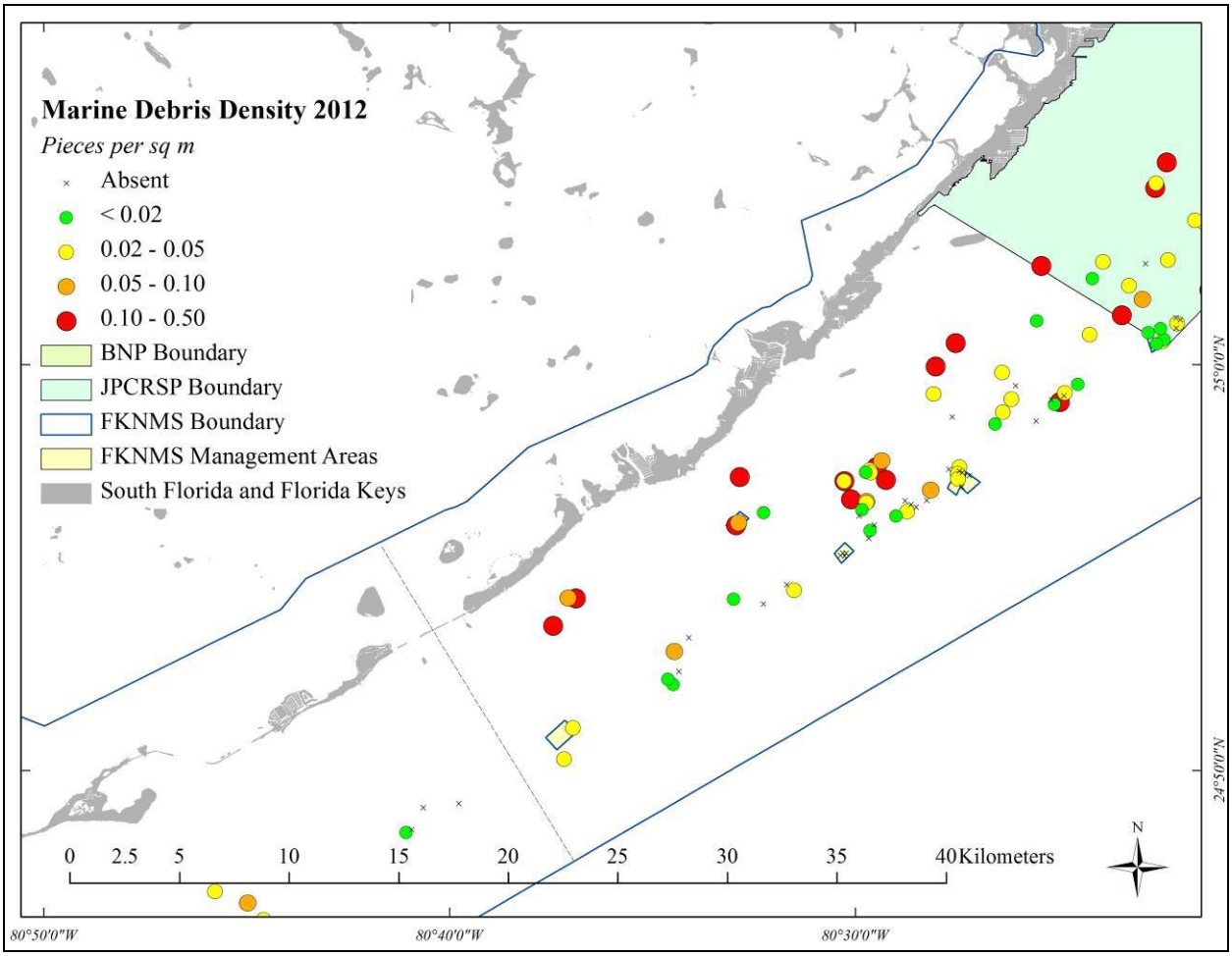


Figure 8-19. Densities (no. items per m^2) of total marine debris in the middle Florida Keys from Alligator Reef to Coffins Patch surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

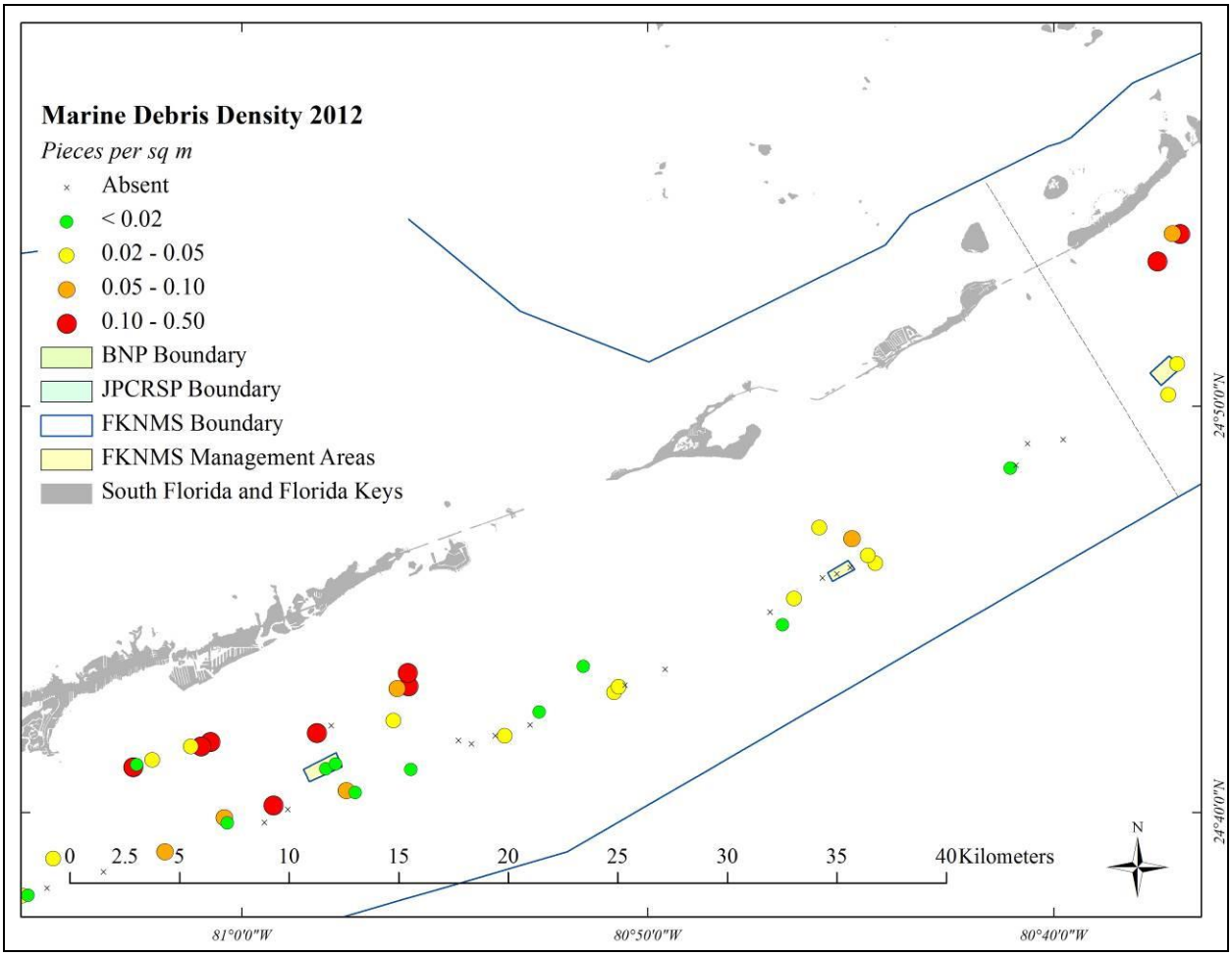


Figure 8-20. Densities (no. items per m^2) of total marine debris in the middle Florida Keys from Coffins Patch to Big Pine Key surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

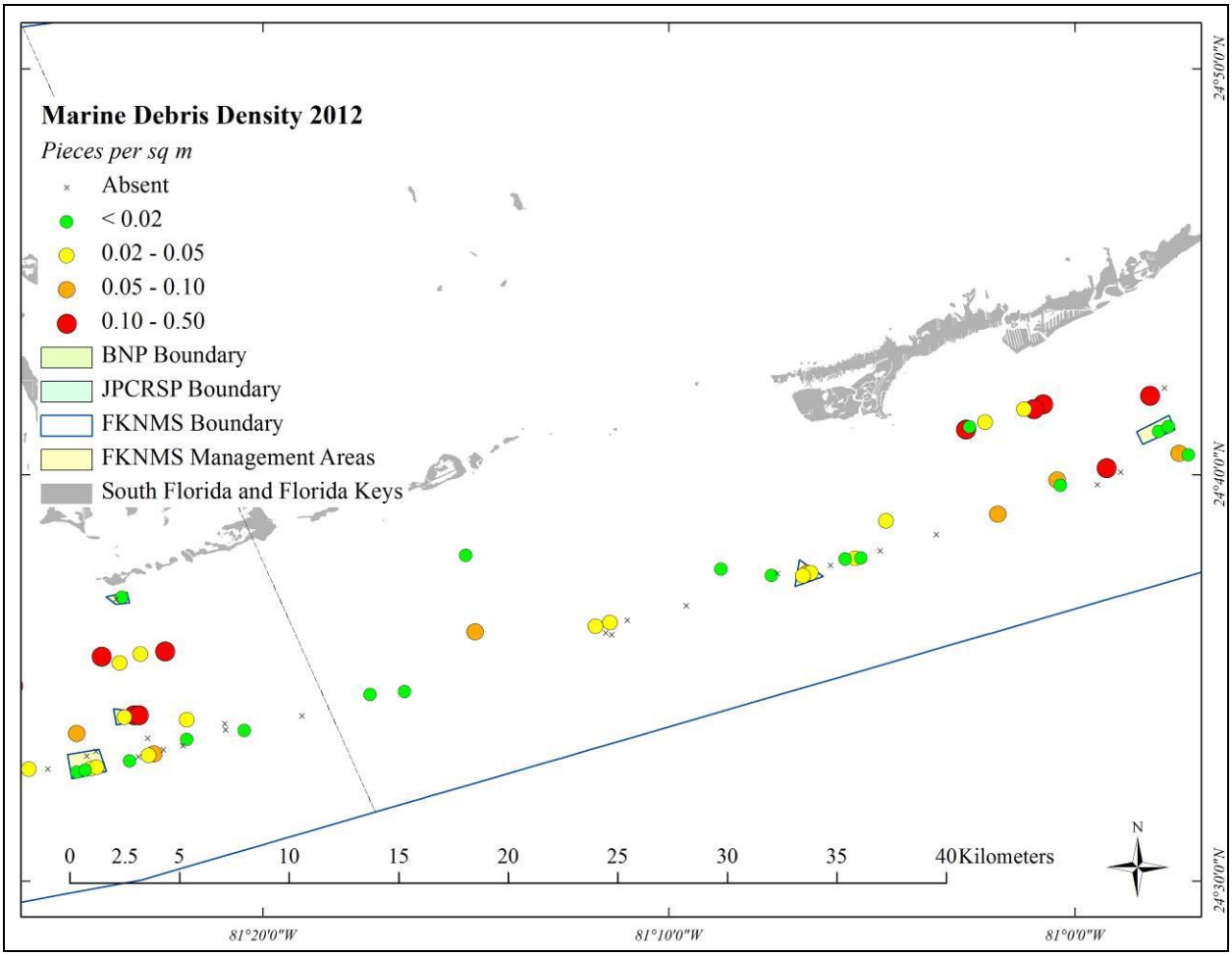


Figure 8-21. Densities (no. items per m^2) of total marine debris in the lower Florida Keys from Big Pine Key to Western Sambo Ecological Reserve surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

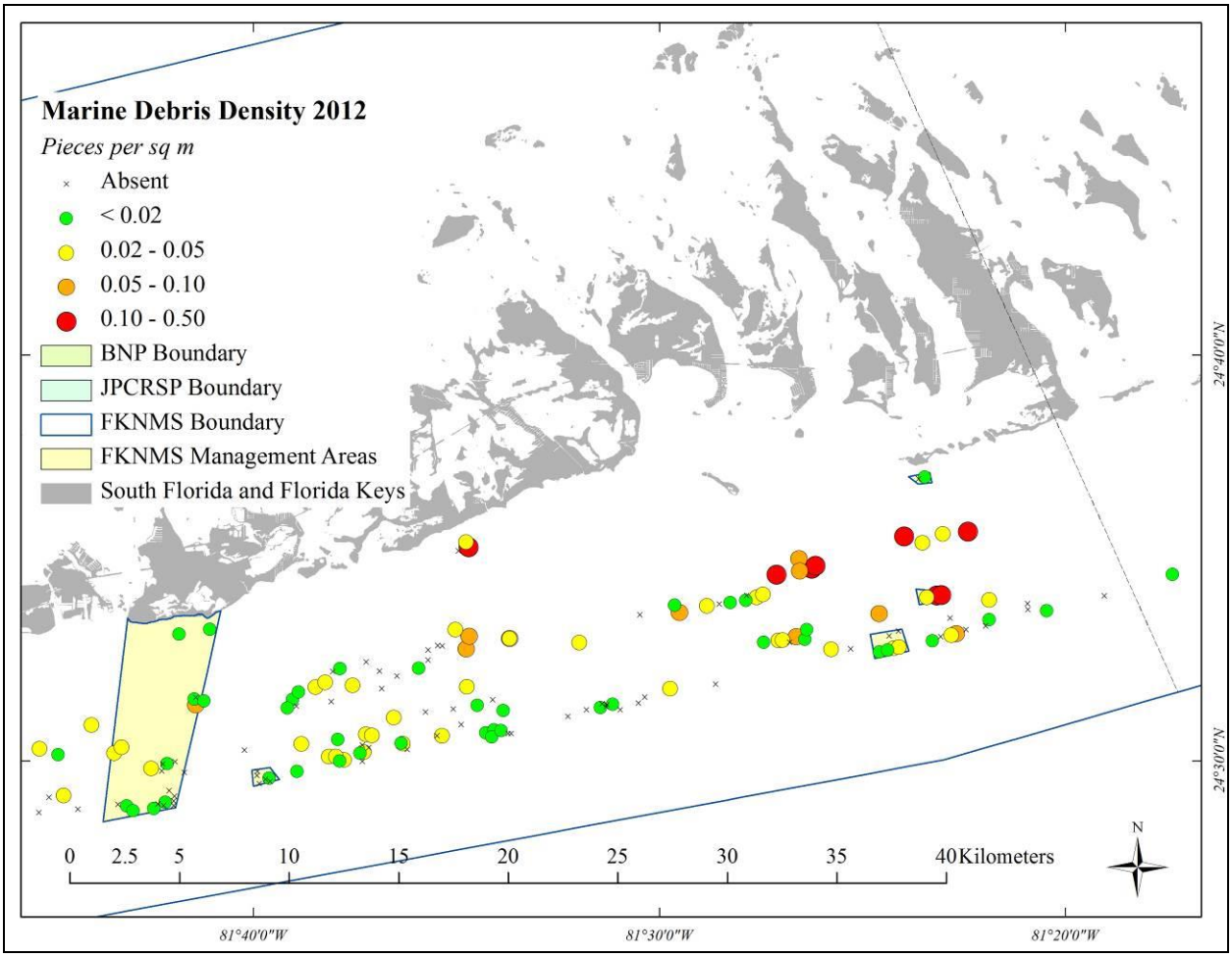


Figure 8-22. Densities (no. items per m^2) of total marine debris in the lower Florida Keys from Western Sambo Ecological Reserve to Western Dry Rocks surveyed during May-November 2012. BNP: Biscayne National Park, JPCRSP: John Pennekamp Coral Reef State Park, FKNMS: Florida Keys National Marine Sanctuary.

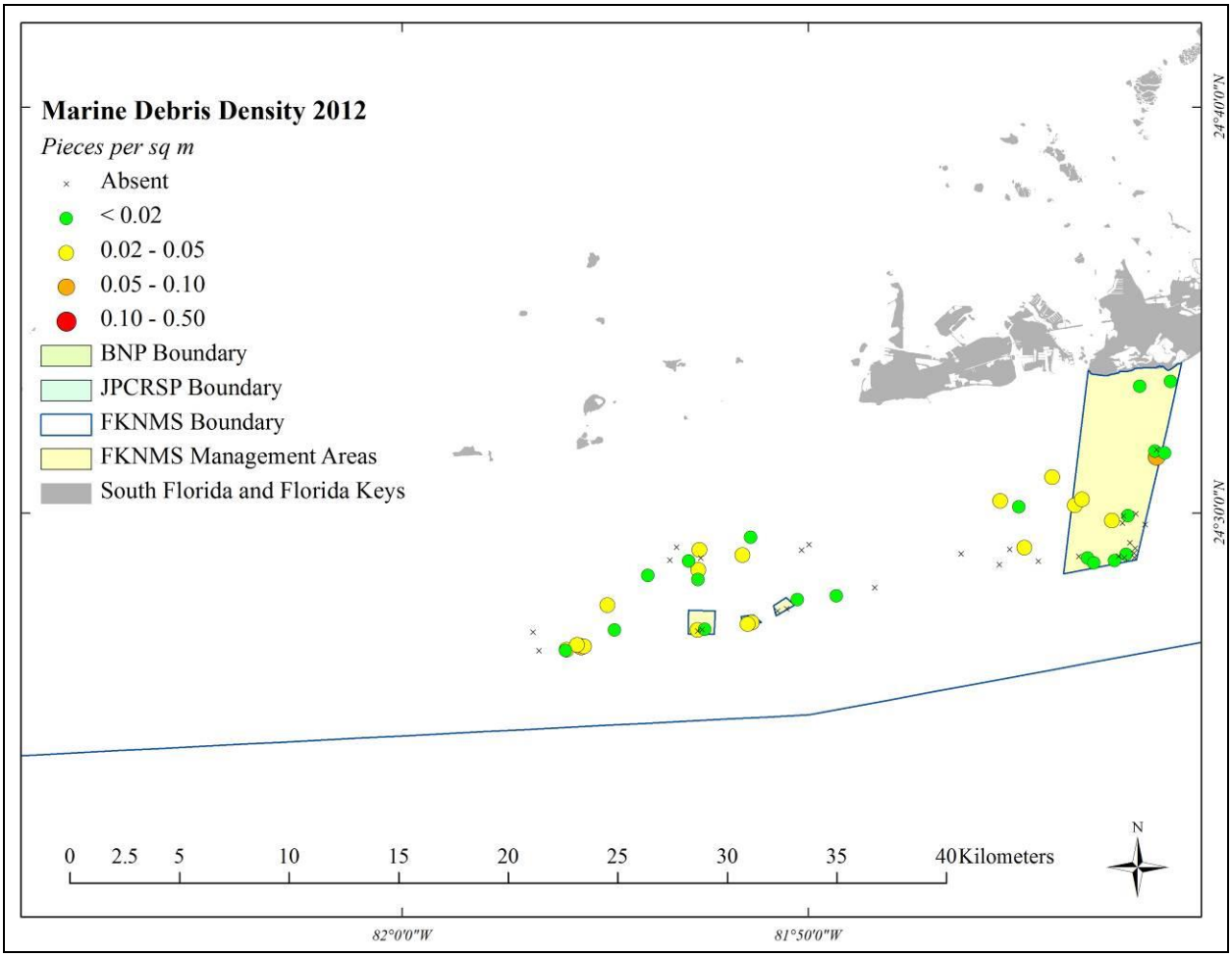


Table 8-1. Number and relative frequency (%) of marine debris items and impacts to sessile invertebrates in Biscayne National Park and the Florida Keys National Marine Sanctuary, as determined from surveys of two 15-m x 2-m belt transects per site at 600 sites (1,200 transects, 18,000 m^2) during May-November 2012. Impacted organisms were those exhibiting abrasion damage from contact or entanglement.

Debris type	**N**	**(%)**	***Millepora***		**Scleractinia**		**Gorgonians**		**Sponges**		***Palythoa***		**Total**
Angling gear debris													
Fishing rod	4	(0.4)											0
Lead sinker	25	(2.4)											0
Hook or lure	3	(0.3)											0
Monofilament	204	(19.5)	25	(34.7)	14	(12.3)	50	(20.6)	12	(12.2)	2	(50.0)	103
Monofilament+hook	21	(2.0)	2	(2.8)			8	(3.3)					10
Monofilament+hook+sinker	6	(0.6)			1	(0.9)	2	(0.8)					3
Monofilament+leader	5	(0.5)			1	(0.9)							1
Monofilament+leader+hook	4	(0.4)			4	(3.5)	2	(0.8)					6
Monofilament+leader+sinker	1	(0.1)					1	(0.4)					1
Monofilament+sinker	18	(1.7)	4	(5.6)	1	(0.9)	2	(0.8)					7
Wire/wire leader	167	(16.0)	7	(9.7)	7	(6.1)	10	(4.1)	10	(10.2)	1	(25.0)	35
Wire/wire leader+hook	4	(0.4)											0
Wire/wire hook+sinker	1	(0.1)					1	(0.4)					1
Wire/wire leader+lure	1	(0.1)											0
Wire/wire leader+sinker	5	(0.5)			1	(0.9)							1
Total angling gear debris	**469**	**(44.9)**	**38**	**(52.8)**	**29**	**(25.4)**	**76**	**(31.3)**	**22**	**(22.4)**	**3**	**(75.0)**	**168**
Lobster/crab trap debris													
Cement block	64	(6.1)											0
Plastic trap grating	17	(1.6)			1	(0.9)							1
Plastic pot opening	3	(0.3)											0
Rope	191	(18.3)	27	(37.5)	72	(63.2)	146	(60.1)	72	(73.5)	1	(25.0)	318
Rope+buoy	1	(0.1)	1	(1.4)			3	(1.2)					4
Rope+grating+wood	1	(0.1)			3	(2.6)	1	(0.4)					4
Rope+wood	3	(0.3)	1	(1.4)			1	(0.4)					2
Wood	154	(14.8)			3	(2.6)			2	(2.0)			5
Wood + pot opening	2	(0.2)											0
Total trap gear debris	**436**	**(41.8)**	**29**	**(40.3)**	**79**	**(69.3)**	**151**	**(62.1)**	**74**	**(75.5)**	**1**	**(25.0)**	**334**
Other debris													
Aluminum can or pull tab	2	(0.2)											
Anchor	2	(0.2)											
Anchor rope	7	(0.7)	3	(4.2)	1	(0.9)	2	(0.8)					6
Boat engine	1	(0.1)					1	(0.4)					1
Boat rub rail	4	(0.4)											
Bottle cap	2	(0.2)											
Brick	1	(0.1)											
Cable tie	1	(0.1)											
Coins	8	(0.8)											
Dive weight	1	(0.1)											
Fabric	1	(0.1)	1	(1.4)	1	(0.9)							2
Fiberglass	2	(0.2)							1	(1.0)			
Fishing reel handle	1	(0.1)											
Glass bottle	46	(4.4)											
Hair tie	1	(0.1)											
Lobster tickler	1	(0.1)											
Metal bracket/other metal	15	(1.4)			1	(0.9)	1	(0.4)	1	(1.0)			2
Net	4	(0.4)					1	(0.4)					1
Plastic or mesh bag	14	(1.3)	1	(1.4)			2	(0.8)					3
Plastic band/cord/cable	7	(0.7)			1	(0.9)	1	(0.4)					2
Plastic (other)	1	(0.1)											
Rope/string (non-trap)	15	(1.4)			2	(1.8)	8	(3.3)					10

Table 8.1 continued

Debris type	**N (%)**	***Millepora***	**Scleractinia**	**Gorgonians**	**Sponges**	***Palythoa***	**Total**
Snorkel keeper	1 (0.1)						
Terra-cotta tile	1 (0.1)						
Total other debris	**139 (13.3)**	**5 (6.9)**	**6 (5.3)**	**16 (6.6)**	**2 (2.0)**	**0 (0.0)**	**29**
All marine debris	**1,044 (100.0)**	**72 (100.0)**	**114 (100.0)**	**243 (100.0)**	**98 (100.0)**	**4 (100.0)**	**531**

Table 8-2. Mean (± 1 SE) site presence, transect (station) frequency, density (no. items per 30 m^2), mean length and total length (m) recovered per site (60 m^2) of combined angling gear debris by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 2-m belt transect surveys per site at 600 sites during May-November 2012. Habitat types are arranged from inshore to offshore and FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. N = number of items encountered (total length of angling gear, m).

Habitat/management zone (sites)	Site presence (%)	Station frequency (%)	Density (no. per 30 m^2)	Mean length (m)	N (length, m)
Inshore Patch Reefs					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.25 ± 0.25	1.20	1 (1.20)
FKNMS Reference Areas (4)	75.0 ± 25.0	50.0 ± 20.4	1.88 ± 1.03	0.80 ± 0.32	14 (12.45)
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.13 ± 0.13	0.01	1 (0.01)
Habitat Total (10)	50.0 ± 16.7	30.0 ± 11.1	0.85 ± 0.47	0.70 ± 0.28	16 (13.66)
Mid-channel Patch Reefs					
Biscayne National Park (50)	38.0 ± 6.9	24.0 ± 4.8	0.31 ± 0.07	0.98 ± 0.14	31 (30.49)
FKNMS Reference Areas (90)	52.2 ± 5.3	37.8 ± 4.3	0.82 ± 0.14	1.18 ± 0.12	147 (229.75)
FKNMS No-take Zones (11)	54.5 ± 15.7	36.4 ± 11.9	0.64 ± 0.23	1.10 ± 0.22	14 (17.64)
Habitat Total (151)	47.7 ± 4.1	33.1 ± 3.1	0.64 ± 0.09	1.12 ± 0.09	192 (277.88)
Offshore Patch Reefs					
Biscayne National Park (9)	44.4 ± 17.6	22.2 ± 8.8	0.28 ± 0.12	0.67 ± 0.16	5 (3.58)
FKNMS Reference Areas (98)	41.8 ± 5.0	26.0 ± 3.4	0.40 ± 0.07	1.07 ± 0.16	74 (91.58)
FKNMS No-take Zones (15)	40.0 ± 13.1	26.7 ± 9.6	0.60 ± 0.36	1.78 ± 1.02	18 (18.12)
Habitat Total (122)	41.8 ± 4.5	25.8 ± 3.0	0.41 ± 0.07	1.13 ± 0.17	97 (113.28)
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0 (0)
FKNMS Reference Areas (16)	18.8 ± 10.1	12.5 ± 7.2	0.16 ± 0.09	1.20 ± 0.26	5 (6.51)
FKNMS No-take Zones (11)	27.3 ± 14.1	13.6 ± 7.0	0.14 ± 0.07	0.52 ± 0.18	3 (1.56)
Habitat Total (29)	20.7 ± 7.7	12.1 ± 4.7	0.14 ± 0.06	0.86 ± 0.21	8 (8.07)
Inner Line Reef Tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	55.6 ± 17.6	44.4 ± 15.5	0.50 ± 0.19	1.43 ± 0.67	9 (10.60)
FKNMS No-take Zones (9)	33.3 ± 16.7	16.7 ± 8.3	0.17 ± 0.08	0.76 ± 0.12	3 (2.28)
Habitat Total (18)	44.4 ± 12.1	30.6 ± 9.2	0.33 ± 0.11	1.18 ± 0.42	12 (12.88)
High-relief Spur and Groove					
Biscayne National Park (1)	0	0	0		0 (0)
FKNMS Reference Areas (28)	42.9 ± 9.5	28.6 ± 7.0	0.43 ± 0.14	0.51 ± 0.15	24 (13.92)
FKNMS No-take Zones (33)	45.5 ± 8.8	24.2 ± 4.9	0.30 ± 0.07	0.56 ± 0.25	20 (15.69)
Habitat Total (62)	43.5 ± 6.3	25.8 ± 4.1	0.35 ± 0.07	0.54 ± 0.15	44 (29.61)
Shallow (< 6 m) Hard-bottom					
Biscayne National Park (16)	68.8 ± 12.0	46.9 ± 9.6	0.63 ± 0.17	1.05 ± 0.19	20 (24.13)
FKNMS Reference Areas (20)	40.0 ± 11.2	27.5 ± 8.5	0.40 ± 0.15	1.07 ± 0.22	16 (18.19)
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.13 ± 0.13	1.62	1 (1.62)
Habitat Total (40)	50.0 ± 8.0	33.8 ± 6.0	0.46 ± 0.10	1.09 ± 0.14	37 (43.94)
Deeper (6-15 m) Hard-bottom					
Biscayne National Park (6)	50.0 ± 22.4	33.3 ± 16.7	0.50 ± 0.32	1.73 ± 0.43	6 (10.31)
FKNMS Reference Areas (42)	33.3 ± 7.4	21.4 ± 5.2	0.26 ± 0.06	2.34 ± 0.74	22 (59.99)
FKNMS No-take Zones (6)	16.7 ± 16.7	8.3 ± 8.3	0.08 ± 0.08	0.90	1 (0.90)
Habitat Total (54)	33.3 ± 6.5	21.3 ± 4.5	0.27 ± 0.06	2.16 ± 0.58	29 (71.20)

Table 8.2 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per 30 m^2)	Mean length (m)	N	
Patchy Hard-bottom (6-15 m)						
Biscayne National Park (2)	50.0 ± 50.0	50.0 ± 50.0	1.00 ± 1.00	0.93	4	(3.70)
FKNMS Reference Areas (28)	25.0 ± 8.3	12.5 ± 4.2	0.14 ± 0.05	0.50 ± 0.14	8	(3.87)
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0	(0)
Habitat Total (32)	25.0 ± 7.8	14.1 ± 4.6	0.19 ± 0.07	0.55 ± 0.14	12	(7.57)
Low-relief spur & groove (6-15 m)						
Biscayne National Park (5)	60.0 ± 24.5	30.0 ± 12.2	0.40 ± 0.19	0.96 ± 0.54	4	(3.54)
FKNMS Reference Areas (54)	29.6 ± 6.3	17.6 ± 3.8	0.22 ± 0.05	2.15 ± 0.78	24	(42.63)
FKNMS No-take Zones (23)	8.7 ± 6.0	4.3 ± 3.0	0.04 ± 0.03	0.79 ± 0.49	2	(1.58)
Habitat Total (82)	25.6 ± 4.8	14.6 ± 2.8	0.18 ± 0.04	1.85 ± 0.61	30	(47.75)

Table 8-3. Mean (± 1 SE) site presence, transect (station) frequency, density (no. items per 30 m^2), mean length, and total length (m) recovered per site (60 m^2) of combined lobster/crab trap debris and mean length and total length (m) of trap rope recovered by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 2-m belt transect surveys per site at 600 sites during May-November 2012. Habitat types are arranged from inshore to offshore and no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. N = trap rope incidences (total length of trap rope, m).

Habitat/management zone (sites)	Site presence (%)	Station frequency (%)	Density (no. per 30 m^2)	Mean length (m)	N (length, m)
Inshore Patch Reefs					
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.25 ± 0.25		0 (0)
FKNMS Reference Areas (4)	50.0 ± 28.9	25.0 ± 14.4	0.38 ± 0.24	4.73	2 (9.45)
FKNMS No-take Zones (4)	50.0 ± 28.9	25.0 ± 14.4	0.25 ± 0.14	10.02 ± 6.98	2 (20.04)
Habitat Total (10)	50.0 ± 16.7	25.0 ± 8.3	0.30 ± 0.11	8.26 ± 4.40	4 (29.49)
Mid-channel Patch Reefs					
Biscayne National Park (50)	40.0 ± 7.0	26.0 ± 5.0	0.56 ± 0.17	17.10 ± 4.95	33 (514.04)
FKNMS Reference Areas (90)	51.1 ± 5.3	36.1 ± 4.2	0.64 ± 0.11	11.36 ± 1.14	71 (902.67)
FKNMS No-take Zones (11)	54.5 ± 15.7	36.4 ± 11.9	0.64 ± 0.24	15.09 ± 4.28	9 (136.91)
Habitat Total (151)	47.7 ± 4.1	32.8 ± 3.1	0.61 ± 0.09	13.41 ± 1.73	113 (1553.62)
Offshore Patch Reefs					
Biscayne National Park (9)	44.4 ± 17.6	27.8 ± 12.1	0.56 ± 0.26	16.84 ± 5.93	5 (92.46)
FKNMS Reference Areas (98)	48.0 ± 5.1	30.6 ± 3.6	0.57 ± 0.09	15.84 ± 4.54	49 (669.45)
FKNMS No-take Zones (15)	33.3 ± 12.6	20.0 ± 8.2	0.37 ± 0.18	9.92 ± 0.14	4 (39.68)
Habitat Total (122)	45.9 ± 4.5	29.1 ± 3.2	0.54 ± 0.08	15.64 ± 3.88	58 (801.59)
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0		0 (0)
FKNMS Reference Areas (16)	18.8 ± 10.1	12.5 ± 7.2	0.16 ± 0.09		0 (0)
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0		0 (0)
Habitat Total (29)	10.3 ± 5.8	6.9 ± 4.1	0.09 ± 0.05		0 (0)
Inner Line Reef Tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	11.1 ± 11.1	5.6 ± 5.6	0.11 ± 0.11		0 (0)
FKNMS No-take Zones (9)	33.3 ± 16.7	16.7 ± 8.3	0.17 ± 0.08	6.60 ± 1.15	3 (19.80)
Habitat Total (18)	22.2 ± 10.1	11.1 ± 5.0	0.14 ± 0.07	6.60 ± 1.55	3 (19.80)
High-relief Spur and Groove					
Biscayne National Park (1)	100.0	50.0	1.00		0 (0)
FKNMS Reference Areas (28)	32.1 ± 9.0	21.4 ± 6.5	0.27 ± 0.08	21.42 ± 5.37	6 (120.10)
FKNMS No-take Zones (33)	3.0 ± 3.0	1.5 ± 1.5	0.02 ± 0.02	15.75	1 (15.75)
Habitat Total (62)	17.7 ± 4.9	11.3 ± 3.3	0.15 ± 0.04	20.48 ± 4.49	7 (135.85)
Shallow (< 6 m) Hard-bottom					
Biscayne National Park (16)	18.8 ± 10.1	12.5 ± 7.2	0.16 ± 0.10	6.81	2 (12.62)
FKNMS Reference Areas (20)	35.0 ± 10.9	17.5 ± 5.5	0.30 ± 0.12	14.89	1 (14.89)
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.13 ± 0.13	7.88	1 (7.88)
Habitat Total (40)	27.5 ± 7.1	15.0 ± 4.1	0.23 ± 0.07	9.86 ± 2.53	4 (36.39)
Deeper (6-15 m) Hard-bottom					
Biscayne National Park (6)	16.7 ± 16.7	8.3 ± 8.3	0.17 ± 0.17		0 (0)
FKNMS Reference Areas (42)	31.0 ± 7.2	19.0 ± 4.8	0.25 ± 0.07	8.95 ± 7.15	2 (17.90)
FKNMS No-take Zones (6)	33.3 ± 21.1	16.7 ± 10.5	0.17 ± 0.11	8.30	1 (8.30)
Habitat Total (54)	29.6 ± 6.3	17.6 ± 4.0	0.23 ± 0.06	8.73 ± 4.13	3 (26.20)

Table 8.3 continued

Habitat/management zone (sites)	Site presence (%)	Transect frequency (%)	Density (no. per 30 m^2)	Mean length (m)	N	
Patchy Hard-bottom (6-15 m)						
Biscayne National Park (2)	50.0 ± 50.0	50.0 ± 50.0	0.50 ± 0.50	0	0	(0)
FKNMS Reference Areas (28)	28.6 ± 8.7	16.1 ± 5.2	0.21 ± 0.08	10.29 ± 2.07	7	(69.55)
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0		0	(0)
Habitat Total (32)	28.1 ± 8.1	17.2 ± 5.3	0.22 ± 0.08	10.29 ± 2.07	7	(69.55)
Low-relief spur & groove (6-15 m)						
Biscayne National Park (5)	0 ± 0	0 ± 0	0 ± 0		0	(0)
FKNMS Reference Areas (54)	27.8 ± 6.2	14.8 ± 3.4	0.24 ± 0.07	15.10	1	(15.10)
FKNMS No-take Zones (23)	17.4 ± 8.1	8.7 ± 4.0	0.11 ± 0.05		0	(0)
Habitat Total (82)	23.2 ± 4.7	12.2 ± 2.5	0.19 ± 0.05	15.10	1	(15.10)

Table 8-4. Mean (± 1 SE) site presence, transect (station) frequency, and density (no. items per 30 m^2) of combined "other" debris (plastics, glass, metals) by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 2-m belt transect surveys per site at 600 sites during May-November 2012. Habitat types are arranged from inshore to offshore and FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. N = number of items encountered.

Habitat/management zone (no. sites)	Site presence (%)	Station frequency (%)	Density (no. per 30 m^2)	N
Inshore patch reefs				
Biscayne National Park (2)	50.0 ± 50.0	25.0 ± 25.0	0.25 ± 0.25	1
FKNMS Reference Areas (4)	50.0 ± 28.9	37.5 ± 23.9	0.38 ± 0.24	3
FKNMS No-take Zones (4)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (10)	30.0 ± 15.3	20.0 ± 11.1	0.20 ± 0.11	4
Mid-channel patch reefs				
Biscayne National Park (50)	14.0 ± 5.0	7.0 ± 2.5	0.08 ± 0.03	8
FKNMS Reference Areas (90)	21.1 ± 4.3	11.7 ± 2.5	0.14 ± 0.03	26
FKNMS No-take Zones (11)	27.3 ± 14.1	13.6 ± 7.0	0.18 ± 0.10	4
Habitat Total (151)	19.2 ± 3.2	10.13 ± 1.8	0.13 ± 0.02	38
Offshore patch reefs				
Biscayne National Park (9)	11.1 ± 11.1	5.6 ± 5.6	0.06 ± 0.06	1
FKNMS Reference Areas (98)	16.3 ± 3.8	9.2 ± 2.2	0.11 ± 0.03	21
FKNMS No-take Zones (15)	13.3 ± 9.1	6.7 ± 4.5	0.07 ± 0.05	2
Habitat Total (122)	15.6 ± 3.3	8.6 ± 1.9	0.10 ± 0.02	24
Reef Rubble (< 15 m)				
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (16)	12.5 ± 8.5	6.3 ± 4.3	0.06 ± 0.04	2
FKNMS No-take Zones (11)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (29)	6.9 ± 4.8	3.4 ± 2.4	0.03 ± 0.02	2
Inner line reef tract (< 6 m)				
Biscayne National Park (0)				
FKNMS Reference Areas (9)	11.1 ± 11.1	11.1 ± 11.1	0.17 ± 0.17	3
FKNMS No-take Zones (9)	22.2 ± 14.7	11.1 ± 7.3	0.11 ± 0.07	2
Habitat Total (18)	16.7 ± 9.0	11.1 ± 6.5	0.14 ± 0.09	5
High-relief spur and groove				
Biscayne National Park (1)	0	0	0	0
FKNMS Reference Areas (28)	17.9 ± 7.4	10.7 ± 4.7	0.11 ± 0.05	6
FKNMS No-take Zones (33)	27.3 ± 7.9	16.7 ± 5.2	0.20 ± 0.07	13
Habitat Total (62)	22.6 ± 5.4	13.7 ± 3.5	0.15 ± 0.04	19
Shallow (< 6 m) hard-bottom				
Biscayne National Park (16)	43.8 ± 12.8	21.9 ± 6.4	0.28 ± 0.09	9
FKNMS Reference Areas (20)	20.0 ± 9.2	10.0 ± 4.6	0.10 ± 0.05	4
FKNMS No-take Zones (4)	25.0 ± 25.0	12.5 ± 12.5	0.13 ± 0.13	1
Habitat Total (40)	30.0 ± 7.3	15.0 ± 3.7	0.18 ± 0.05	14
Deeper (6-15 m) hard-bottom				
Biscayne National Park (6)	0 ± 0	0 ± 0	0 ± 0	0
FKNMS Reference Areas (42)	9.5 ± 4.6	6.0 ± 3.0	0.08 ± 0.05	7
FKNMS No-take Zones (6)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (54)	7.4 ± 3.6	4.6 ± 2.4	0.06 ± 0.04	7

Table 8.4 continued

Habitat/management zone (no. sites)	Site presence (%)	Transect frequency (%)	Density (no. per 30 m^2)	N
Patchy hard-bottom (6-15 m)				
Biscayne National Park (2)	100.0 ± 0.0	50.0 ± 0.0	0.75 ± 0.25	3
FKNMS Reference Areas (28)	17.9 ± 7.4	8.9 ± 3.7	0.09 ± 0.04	5
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0
Habitat Total (32)	21.9 ± 7.4	10.9 ± 3.7	0.13 ± 0.04	8
Low-relief spur and groove (6-15 m)				
Biscayne National Park (5)	20.0 ± 20.0	20.0 ± 20.0	0.20 ± 0.20	2
FKNMS Reference Areas (54)	7.4 ± 3.6	3.7 ± 1.8	0.04 ± 0.02	4
FKNMS No-take Zones (23)	21.7 ± 8.8	13.0 ± 5.6	0.20 ± 0.09	9
Habitat Total (82)	12.2 ± 3.6	7.3 ± 2.3	0.09 ± 0.03	15

Table 8-5. Mean (± 1 SE) site presence, transect (station) frequency, density (no. items per 30 m^2), wet weight (kg per 30 m^2), and number of items recovered of all debris categories recovered per site (60 m^2) by habitat type and management zone in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS), as determined from two replicate 15-m x 2-m belt transect surveys per site at 600 sites during May-November 2012. Habitat types are arranged from inshore to offshore and FKNMS no-take zones represent Sanctuary Preservation Areas, Ecological Reserves, and Research Only areas. N = number of items (total wet weight, kg) of all debris types encountered per site.

Habitat/management zone (no. sites)	Site presence (%)	Station frequency (%)	Density (no./30 m^2)	Wet weight (kg/30m^2)	N (kg)
Inshore patch reefs					
Biscayne National Park (2)	50.0 ± 50.0	50.0 ± 50.0	0.75 ± 0.75	0.276 ± 0.276	3 (1.106)
FKNMS Reference Areas (4)	75.0 ± 25.0	50.0 ± 20.4	2.63 ± 1.43	0.156 ± 0.128	21 (1.247)
FKNMS No-take Zones (4)	75.0 ± 25.0	37.5 ± 12.5	0.38 ± 0.13	0.203 ± 0.146	3 (1.627)
Habitat Total (10)	70.0 ± 15.3	45.0 ± 11.7	1.35 ± 0.64	0.199 ± 0.083	27 (3.980)
Mid-channel patch reefs					
Biscayne National Park (50)	64.0 ± 6.9	47.0 ± 5.8	0.96 ± 0.19	0.791 ± 0.235	96 (79.095)
FKNMS Reference Areas (90)	77.8 ± 4.4	60.0 ± 4.1	1.60 ± 0.19	0.771 ± 0.146	288 (138.714)
FKNMS No-take Zones (11)	72.7 ± 14.1	63.6 ± 13.6	1.45 ± 0.39	0.985 ± 0.487	32 (21.659)
Habitat Total (151)	72.8 ± 3.6	56.0 ± 3.3	1.38 ± 0.13	0.793 ± 0.120	416 (239.468)
Offshore patch reefs					
Biscayne National Park (9)	66.7 ± 16.7	44.4 ± 13.0	0.89 ± 0.35	0.742 ± 0.408	16 (13.353)
FKNMS Reference Areas (98)	69.4 ± 4.7	51.0 ± 4.0	1.07 ± 0.12	0.493 ± 0.082	210 (96.70)
FKNMS No-take Zones (15)	60.0 ± 13.1	36.7 ± 9.1	1.03 ± 0.48	0.297 ± 0.141	31 (8.924)
Habitat Total (122)	68.0 ± 4.2	48.8 ± 3.6	1.05 ± 0.12	0.488 ± 0.074	257 (118.977)
Reef Rubble (< 15 m)					
Biscayne National Park (2)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 (0)
FKNMS Reference Areas (16)	43.8 ± 12.8	28.1 ± 9.1	0.38 ± 0.13	0.264 ± 0.251	12 (8.448)
FKNMS No-take Zones (11)	27.3 ± 14.1	13.6 ± 7.0	0.14 ± 0.07	0.004 ± 0.002	3 (0.085)
Habitat Total (29)	34.5 ± 9.0	20.7 ± 5.8	0.26 ± 0.08	0.147 ± 0.139	15 (8.533)
Inner line reef tract (< 6 m)					
Biscayne National Park (0)					
FKNMS Reference Areas (9)	55.6 ± 17.6	50.0 ± 16.7	0.78 ± 0.29	0.031 ± 0.025	14 (0.567)
FKNMS No-take Zones (9)	88.9 ± 11.1	44.4 ± 5.6	0.44 ± 0.06	0.439 ± 0.284	8 (7.910)
Habitat Total (18)	72.2 ± 10.9	47.2 ± 8.5	0.61 ± 0.15	0.235 ± 0.147	22 (8.477)
High-relief spur and groove					
Biscayne National Park (1)	100.0	50.0	1.00	0	2 (0)
FKNMS Reference Areas (28)	78.6 ± 7.9	55.4 ± 7.0	0.79 ± 0.14	0.267 ± 0.095	44 (13.956)
FKNMS No-take Zones (33)	60.6 ± 8.6	39.4 ± 6.4	0.52 ± 0.10	0.039 ± 0.019	34 (2.580)
Habitat Total (62)	69.4 ± 5.9	46.8 ± 4.7	0.65 ± 0.08	0.141 ± 0.086	80 (16.536)
Shallow (< 6 m) hard-bottom					
Biscayne National Park (16)	93.8 ± 6.3	68.8 ± 7.7	1.06 ± 0.23	0.206 ± 0.097	34 (6.577)
FKNMS Reference Areas (20)	60.0 ± 11.2	45.0 ± 9.5	0.80 ± 0.20	0.095 ± 0.042	32 (3.799)
FKNMS No-take Zones (4)	50.0 ± 28.9	25.0 ± 14.4	0.38 ± 0.24	0.124 ± 0.119	3 (0.992)
Habitat Total (40)	72.5 ± 7.1	52.5 ± 6.2	0.86 ± 0.14	0.142 ± 0.045	69 (11.368)
Deeper (6-15 m) hard-bottom					
Biscayne National Park (6)	50.0 ± 22.4	33.3 ± 16.7	0.67 ± 0.48	0.073 ± 0.068	8 (0.879)
FKNMS Reference Areas (42)	57.1 ± 7.7	38.1 ± 5.9	0.60 ± 0.13	0.076 ± 0.028	50 (6.350)
FKNMS No-take Zones (6)	33.3 ± 21.1	16.7 ± 10.5	0.25 ± 0.17	0.021 ± 0.019	3 (0.255)
Habitat Total (54)	53.7 ± 6.8	35.2 ± 5.1	0.56 ± 0.12	0.069 ± 0.023	61 (7.484)

Table 8.5 continued

Habitat/management zone (no. sites)	Site presence (%)	Station frequency (%)	Density (no. per 30 m^2)	Wet weight (kg/30m^2)		N (kg)
Patchy hard-bottom (6-15 m)						
Biscayne National Park (2)	100.0 ± 0.0	100.0 ± 0.0	2.25 ± 0.75	0.305 ± 0.021	9	(1.219)
FKNMS Reference Areas (28)	57.1 ± 9.5	35.7 ± 6.7	0.45 ± 0.10	0.185 ± 0.069	25	(10.376)
FKNMS No-take Zones (2)	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0	(0)
Habitat Total (32)	56.3 ± 8.9	37.5 ± 6.7	0.53 ± 0.12	0.181 ± 0.061	34	(11.595)
Low-relief spur and groove (6-15 m)						
Biscayne National Park (5)	60.0 ± 24.5	40.0 ± 18.7	0.60 ± 0.37	0.377 ± 0.359	6	(3.770)
FKNMS Reference Areas (54)	51.9 ± 6.9	32.4 ± 4.8	0.51 ± 0.09	0.093 ± 0.030	55	(10.024)
FKNMS No-take Zones (23)	34.8 ± 10.2	21.7 ± 6.9	0.35 ± 0.12	0.202 ± 0.141	16	(9.299)
Habitat Total (82)	47.6 ± 5.5	29.9 ± 3.9	0.47 ± 0.07	0.141 ± 0.049	77	(23.094)

IX. Conclusions and Future Efforts

Survey results from 2012 add to a growing dataset on the distribution, abundance, size, and condition of benthic coral reef organisms in Biscayne National Park (BNP) and the Florida Keys National Marine Sanctuary (FKNMS). For many of the variables assessed, we have now developed a 13-year record dating back to 1998 to evaluate benthic community structure and change for a variety of hard-bottom and coral reef habitats in the Florida Keys, in addition to comparisons among management areas such as Sanctuary no-take zones. Our monitoring is also conducted to address the larger-scale habitat variability of coral reef and hard-bottom habitats found throughout the Florida Keys. This larger perspective allows us to interpret results from no-take-zones within the context of natural system variability and the various factors that can impact hard-bottom and coral reef communities. Benthic surveys completed in 2012 in the Florida Keys included *Acropora* corals, non-*Acropora* corals, urchins, anemones, corallimorpharians, mollusks, and marine debris. We have previously sampled the upper, middle, and lower Florida Keys three times in the last eleven years, with additional periodic efforts conducted in-between that focus regionally or on a subset of our total benthic variable list.

Despite the continual bad news typically reported in the press about the condition and fate of coral reefs, worldwide and in Florida, our results suggest that there is also good news. For example, based on our 2012 surveys:

- Staghorn corals (*Acropora cervicornis*) still occur in relatively large numbers, even though colonies are mostly small (< 1 m) and found largely in the patch reef environment. Most of the existing staghorn coral colonies in the Florida Keys are currently found outside of FKNMS no-take zones.
- Large (10-15 m diameter) thickets of elkhorn coral (*A. palmata*) continue to persist at several platform margin reefs, especially off of Key Largo such as South Carysfort, Horseshoe Reef, Grecian Rocks, French Reef, Sand Island, and Molasses Reef. Most of the remaining thickets of elkhorn coral occur within the boundaries of existing FKNMS no-take zones.
- Many other coral species continue to exist at relatively high densities and large sizes in certain habitats, especially patch reefs.
- Urchins, specifically *Diadema antillarum*, continue to show slow, but consistent increases in abundance and size. Back-reef rubble areas continue to provide an important recruitment habitat for *D. antillarum* and other echinoids, although the fate of these post-settlement juveniles has not been studied.

- While the 2010 cold-front event impacted a large number of patch reefs (Lirman et al. 2011, Colella et al. 2012), the distribution of cold water was itself patchy and many inshore and mid-channel patch reefs remain in relatively good condition.

There are also many observations and patterns that are not so encouraging:

- While staghorn corals are abundant and small (< 1 m diameter), no extensive thickets have been observed now for several years. In addition, fore-reef areas that historically supported extensive stands are largely devoid of staghorn corals.
- Elkhorn corals are extremely limited in distribution and continue to suffer tissue loss from predation. Some reef flat and reef crest areas that historically supported dense stands are devoid of this species.
- Urchin densities, specifically *Diadema antillarum*, are still, on average, at least one order of magnitude lower than reported prior to the 1983-84 mortality event.
- *Coralliophila* snails appear to be increasing in abundance and are found preying upon a greater variety of coral species than we have observed since the late 1990s.
- Marine debris, especially lost fishing gear that becomes entangled on the seabed, continues to be pervasive in many habitats, especially patch reefs, and in most of the FKNMS no-take-zones.
- Inshore and some bank/channel patch reef areas affected by the January 2010 cold-front event suffered extensive mortality of some stony coral (e.g. *Montastraea* spp.) and gorgonian species and are now largely covered with turf and drift algae. However, this pattern is not apparent on reefs further offshore.

The cumulative results of our program define baseline conditions for coral reef community structure throughout the FKNMS and Dry Tortugas, including marine protected areas. However, sampling only began in 1998 and thus represents an effort established long after major declines had already occurred throughout the system, especially related to the loss of *Acropora* corals from disease, starting in the late 1970s, the demise of the urchin *Diadema antillarum* in the early 1980s, coral bleaching, first noted as a regional phenomenon in the early 1980s and periodically since then, and various other stressors that impact this ecosystem. However, because we sample system-wide, and because we sample much more than just corals, results from our program will help us distinguish between changes that result from no-take management strategies and natural system variability.

In 2013, we are assisting with the development of survey protocols for NOAA's National Coral Reef Monitoring Program (NCRMP), including training materials, and will be participating in a two-week effort in July 2013 to help survey benthic cover, coral demographic variables (i.e. colony density, size, and condition), and fishes in the U.S. Virgin Islands, specifically St. Thomas and St. John. Through NCRMP and other funding sources, we hope to leverage available resources to help coordinate a Keys-wide sampling of reef fishes and benthic coral reef organisms in southeast Florida during 2014, including work off the coasts of Dade and Broward counties.

In 2013-2014, we will also continue to analyze data and prepare publications. Of particular note is work related to our long-term record of surveys in the FKNMS and additional multivariate work related to describe the distribution and abundance of species and habitat types throughout the region. The data set provides unmatched spatial coverage of organism habitat distribution, density, and size, as well as a means to evaluate temporal changes related to the FKNMS zoning action plan relative to larger-scale phenomena. In addition, we submitted to NOAA's Office of Protected Resources in early April 2013 an 85-page summary of the population status of nine coral species in the Florida Keys considered for listing or re-classification under the U.S. Endangered Species Act. We are also part of the Ecosystem Working Group, one of three working groups (see http://floridakeys.noaa.gov/sac/welcome.html?s=sac) of the FKNMS that is providing recommendations to the zoning action plan for the Sanctuary. The benthic data collected by our program has been instrumental in that process. We have and will continue to work closely with Ms. Nancy Diersing at the upper Keys office of the FKNMS to prepare science summaries on *Acropora* population surveys (see http://floridakeys.noaa.gov/scisummaries/elkhornstaghorn2013.pdf), marine debris (http://floridakeys.noaa.gov/scisummaries/marinedebris2013.pdf), and status and trends in *Diadema* urchins (forthcoming). Finally, we are in the process of publishing several historical overview papers on urchins, corals, and other benthic coral reef organisms in collaboration with D.L. Kissing and other researchers (e.g. K.M. Sealey, University of Miami). Below is a list of program publications to date.

Program Publications

Ault JS, Smith SG, Meester GA, Luo J, Bohnsack JA, Miller SL (2002) Baseline multispecies coral reef fish stock assessment for the Dry Tortugas. NOAA Technical Memorandum NMFS-SEFSC-487, 117 p

Ault JS, Smith SG, Meester GA, Luo J, Franklin EC, Bohnsack JA, Harper DE, McClellan DB, Miller SL, Swanson DW, Chiappone M (2002) Tortugas surveyed: Synoptic habitat and reef fish surveys

support establishment of marine reserves in the Dry Tortugas, Florida, USA. *Reef Encounter* 31: 22-23

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. *Caribbean Journal of Science* 39(1): 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. *Biological Conservation* 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, Miller SL, Swanson DW (2001) *Condylactis gigantea* – A giant comes under pressure from the aquarium trade in Florida. *Reef Encounter* 30: 29-31

Chiappone M, Rutten LM, Miller SL, Swanson DW (2007) Large-scale distributional patterns of the encrusting and excavating sponge *Cliona delitrix* Pang on Florida Keys coral substrates. In *Porifera Research - Biodiversity, Innovation, Sustainability*. Custodio MR, Lobo-Hajdu G, Hajdu E, Muricy G (eds), Museu Nacional, Rio de Janeiro, pp 255-263

Chiappone M, Rutten LM, Miller SL, Swanson DW (2013) Recent trends (1999-2011) in population density and size of the echinoid *Diadema antillarum* in the Florida Keys. *Florida Scientist* 76(1): 23-35

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, Ft. Lauderdale: 706-710*

Chiappone M, Swanson DW, Miller SL (2002) Density, spatial distribution and size structure of sea urchins in coral reef and hard-bottom habitats of the Florida Keys. *Marine Ecology Progress Series* 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. *Caribbean Journal of Science* 40: 312-326

Chiappone M, Swanson DW, Miller SL, Smith SG (2002) 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 (2002) Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. *Marine Pollution Bulletin* 44: 597-604

Eakin CM, Morgan JA, Heron SF, Smith TB, Liu G, Alvarez-Filip L, Baca B, Bartels E, bin Yusef Y, Bouchon C, Brandt M, Bruckner A, Cameron A, Chiappone M, Crabbe MJC, Day O, de la Guardia Llanso E, Díaz-Pulido G, DiResta D, Gil DL, Gilliam D, Ginsburg R, Gore S, Guzman H, Hendee J,

Hernández-Delgado E, Husain E, Jeffrey C, Jones R, Jordán Dahlgren E, Kramer P, Lang J, Lirman D, Mallela J, Manfrino C, Maréchal J, Mihaly J, Miller J, Mueller E, Muller E, Orozco C, Oxenford H, Ponce-Taylor D, Quinn N, Ritchie K, Rodriguez S, Rodríguez-Ramírez A, Romano S, Samhouri J, Sánchez Muñoz JA, Schmahl G, Shank B, Skirving W, Steiner S, Villamizar E, Walsh S, Walter C, Weil E, Williams E, Woody K (2010) Caribbean corals in hot water: Record thermal stress, bleaching, and mortality in 2005. *PLoS ONE* 5(11): e13969, doi:10.1371/journal.pone.0013969

Franklin EC, Ault JS, Smith SG, Luo J, Meester GA, Diaz GA, Chiappone M, Swanson DW, Miller SL, Bohnsack JA (2003) Benthic habitat mapping in the Tortugas region, Florida. *Marine Geodesy* 26: 19-34

Keller BD, Gleason DF, McLeod E, Woodley CM, Airame S, Causey BD, Friedlander AM, Grober-Dunsmore R, Johnson JE, Miller SL, Steneck RS (2009) Climate change, coral reef ecosystems, and management options for marine protected areas. *Environmental Management* 44: 1069-1088

Kissling DL, Precht WF, Miller SL, Chiappone M (In press) Historical reconstruction of population density and size structure of the echinoid *Diadema antillarum* Philippi on Florida Keys shallow bank reefs. Bull Mar Sci

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, Ft. Lauderdale: 775-779*

Miller SL, Chiappone M, Swanson DW, Ault JS, Smith SG, Meester GA, Luo J, Franklin EC, Bohnsack JA, Harper DE, McClellan DB (2001) An extensive deep reef terrace on the Tortugas Bank, Florida Keys National Marine Sanctuary. *Coral Reefs* 20: 299-300

Miller SL, Precht WF, Chiappone M (2004) Recognizing complexity in biological systems: Making coral reef ecology simple? A Florida case history. *Current (Journal of Marine Education)* 20: 4-11

Miller SL, Precht WF, Rutten LM, Chiappone M (2013) *Florida Keys population abundance estimates for nine coral species proposed for listing under the U.S. Endangered Species Act*. NCRI Technical Series Report, National Coral Reef Institute, Nova Southeastern University, Oceanographic Science Center, Dania Beach, FL. 85 pp

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. *Proceedings of the 9th International Coral Reef Symposium* 1: 69-77

Precht WF, Miller SL (2007) Ecological shifts along the Florida Reef Tract: The past is a key to the future. In *Geological approaches to coral reef ecology*. Aronson RB (ed), Springer, NY. Chapter 9, pp 237-312

Rutten LM, Chiappone M, Swanson DW, Miller SL (2009) Stony coral species diversity and cover in the Florida Keys using design-based sampling. *Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale: 800-804*

Swanson DW (2011) Spatial dynamics of coral populations in the Florida Keys. Open Access Dissertations, Paper 626, http://scholarlyrepository.miami.edu/oa_dissertations/626

References

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

Adams C (1992) Economic activities associated with the commercial fishing industry in Monroe County, Florida. Staff Paper SP92-27, Food and Resource Economics Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL

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, Bohnsack JA, Smith SG, Luo J (2005) Towards sustainable multispecies fisheries in the Florida, USA, coral reef ecosystem. Bull Mar Sci 76(2):595-622

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

Bak RPM, Borsboom JLA (1984) Allelopathic interaction between a reef coelenterate and benthic algae. Oecologia 63:194-198

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

Bellwood DR, Hughes TP, Folke C, Nystrom M (2004) Confronting the coral reef crisis. Nature 429:827-833

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

Brainard RE, Birkeland C, Eakin CM, McElhany P, Miller MW, Patterson M, Piniak GA (2011) Status review report of 82 candidate coral species petitioned under the U.S. Endangered Species Act. USDOC, NOAA Tech Mem NOAA-TM-NMFS-PIFSC-27, 530 p +1 Appendix 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

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. Proc 11th Intl Coral Reef Symp, Ft. Lauderdale, 706-710

Chiappone M, Sullivan KM (1997) Rapid assessment of reefs in the Florida Keys: Results from a synoptic survey. Proc 8th Intl 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

Chuenpagdee R, Morgan LE, Maxwell SM, Norse EA, Pauly D (2003) Shifting gears: addressing the collateral impacts of fishing methods in US waters. Front Ecol Envir 1(10):517–524

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

Colella MA, Ruzicka RR, Kidney JA, Morrison JM, Brinkhuis VB (2012) Cold-water event of January 2010 results in catastrophic benthic mortality on patch reefs in the Florida Keys. Coral Reefs 31:621-632

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) (2000) 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

Gilardi K (2005) Derelict gear. California Coast and Ocean 21(3):17–18

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

Harper DE, Bohnsack JA, Lockwood BR (2000) Recreational fisheries in Biscayne National Park, Florida, 1976–1991. Mar Fish Rev 62:8-26

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

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

Hill R, Sheridan P, Matthews G, Appeldoorn R (2003) The effects of trap fishing in coralline habitats: What do we know? How do we learn more? Proc Gulf Carib Fish Inst 54:1–12

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

Idjadi JA, Haring RN, Precht WF (2010) Recovery of the sea urchin *Diadema antillarum* promotes scleractinian coral growth and survivorship on shallow Jamaican reefs. Mar Ecol Prog Ser 403:91-100

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 Intl 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 Carib 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

Lewis CF, Slade SL, Maxwell KE, Matthews TR (2009) Lobster trap impact on coral reefs: Effects of wind-driven trap movement. New Zealand J Mar Fresh Res 43(1):271-282

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 Quaternary 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

Lirman D, Schopmeyer S, Manzello D, Gramer LJ, Precht WF, et al. (2011) Severe 2010 cold-water event caused unprecedented mortality to corals of the Florida Reef Tract and reversed previous survivorship patterns. PLoS ONE 6(8): e23047. doi:10.1371/journal.pone.0023047

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

Manning RB (1970) *Mithrax* (*Mithraculus*) *commensalis*, a new West Indian spider crab (Decapoda, Majidae) commensal with a sea anemone. Crustaceana 19:157-160

Mariscal RN (1970) An experimental analysis of the protection of *Amphiprion xanthurus* Cuvier and Valenciennes and some other anemone fishes from sea anemones. J Exp Mar Biol Ecol 4:134-149

Marszalek DS, Babashoff G, Noel MR, Worley DR (1977) Reef distribution in south Florida. Proc 3rd Intl 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 SM, Johnston L, Szmant AM (2010) Assessment of current rates of *Diadema antillarum* larval settlement. Coral Reefs 28: 511-515

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

Miller SL, Precht WF, Rutten LM, Chiappone M (2013) Florida Keys population abundance estimates for nine coral species proposed for listing under the U.S. Endangered Species Act. NCRI Technical Series Report, National Coral Reef Institute, Nova Southeastern University, Oceanographic Science Center, Dania Beach, FL. 85 pp

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. Proc 11th Intl Coral Reef Symp, Ft. Lauderdale: 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 Intl 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

Patten MA (2004) Correlates of species richness in North American bat families. J Biogeogr 31: 975-985

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

Pires DO, Castro CB (1997) Scleractinia and Corallimorpharia: An analysis of cnidae affinity. Proc Eighth Intl Coral Reef Symp 2:1581-1586

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

Risenhoover AD (2012) Endangered and Threatened Wildlife and Plants: Proposed Listing Determinations for 82 Reef-Building Coral Species; Proposed Reclassification of *Acropora palmata* and *A. cervicoronis*. 77 FR 73219. https://federalregister.gov/a/2012-29350

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

Russ GR (1991) Coral reef fisheries: effects and yields. In The ecology of fishes on coral reefs, ed. P.F. Sale, pp. 601-636. Academic Press, New York, USA.

Rutten LM, Chiappone M, Swanson DW, Miller SL (2009) Stony coral species diversity and cover in the Florida Keys using design-based sampling. Proc 11th Intl Coral Reef Symp, Ft. Lauderdale: 800-804

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 desiccation. Bull Mar Sci 32:316-335

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

Sheridan P, Hill R, Matthews G, Appeldoorn R, Kojis B, Matthews T (2005) Does trap fishing impact coral reef ecosystems? An update. Proc Gulf Carib Fish Inst 56:511-519.

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

Sluka R, Chiappone M, Sullivan KM, de Garine-Wichatitsky M (1999) Benthic habitat characterization and space utilization by juvenile epinepheline groups in the Exuma Cays Land and Sea Park, central Bahamas. In: Goodwin MH and Waugh GT (eds) Proc Gulf Carib Fish Inst 45:23-36

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

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

Swanson DW (2011) Spatial dynamics of coral populations in the Florida Keys. Open Access Dissertations, Paper 626, http://scholarlyrepository.miami.edu/oa_dissertations/626

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

Uhrin AV, Fonseca MS, DiDomenico GP (2005) Effects of Caribbean spiny lobster traps on seagrass beds of the Florida Keys National Marine Sanctuary: Damage assessment and evaluation of recovery. Ameri Fish Soc Symp 41:579-588

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

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