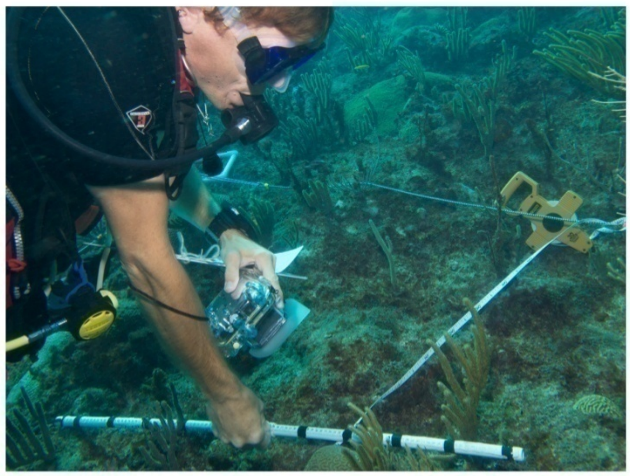
Assessment of the Community Structure, Status, Health and Resilience of Coral Reefs off St. Kitts and Nevis

June 2011



Khaled bin Sultan Living Oceans Foundation

Andrew Bruckner
Chief Scientist
and
Amanda Williams
GIS Analyst

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Khaled bin Sultan Living Oceans Foundation
8181 Professional Place
Landover, MD, 20785 USA
Philip G. Renaud, Executive Director

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SUMMARY

From June 4-12, 2011 the Khaled bin Sultan Living Oceans Foundation, in collaboration with seven divers from St. Kitts and Nevis, two researchers from Grenada, and six scientists from The Nature Conservancy, characterized the coral reefs around St. Kitts and Nevis. The team examined 25 different reef communities on the leeward and windward sides of the islands at depths of 0-25 m. Two permanent Legacy Sites were established, one at Dieppe Bay (10-12 m depth) and one north of Basseterre at the Vent (16-18 m depth). At each site, detailed assessments of the coral community structure and health, benthic assemblages, and reef fishes were conducted using a modified Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol. Habitat features and individual corals were photo-documented, and 10 m phototransects were taken at each site. The assessments included a characterization of 1) species diversity and abundance, benthic cover, size and condition of reef building corals and patterns of coral recruitment; 2) cover of six algal functional groups; 3) substrate condition; 4) benthic cover of sponges, tunicates and other sessile invertebrates; 5) prevalence and impact of nuisance species; 6) abundance of keystone motile invertebrates (sea urchins, lobster, octopus and conch); and 7) abundance and size structure of 88 species of ecologically and commercially important fishes.

Coral reefs exhibited diverse geomorphic structures. This included:
1) reefs constructed of fused elkhorn coral skeletons;
2) coral-colonized volcanic boulders that had fallen from surrounding cliffs;
3) low relief reef platforms with undercut ledges and encrusting coral communities;
4) spur and groove reef systems;
5) high relief, old growth mountainous star coral (*Montastraea faveolata*) pinnacles;
6) shelf edge reef slope communities;
7) deep water coral ridges;
8) submerged bank reefs; lobate star coral (*Montastraea annularis*) frameworks;
9) patch reefs, and
10) gorgonian and sponge dominated hardgrounds and reef slopes.

In addition to mid-depth (10-30 m) coral reef habitats, a continuous shallow water (0-10 m depth) elkhorn coral (*Acropora palmata*) framework extends over 15 km along the Atlantic coastline, from Nevis, across the Narrows, to Barkers Point off St. Kitts. *Acropora palmata* frameworks also occur on the northwestern end of St. Kitts, near Dieppe Bay.

Coral reef communities were dominated by macroalgae (35% cover) and turf algae (21%), with moderate cover of crustose coralline algae (8%) and cyanobacteria (5%). Living coral cover ranged from a low of 3% to a maximum of 16%, with most sites having 6-13% live cover. Coral communities were dominated by *Porites*, *Montastraea*, *Agaricia*, *Siderastrea* and *Diploria* (respectively) with 24 other species occurring at lower abundances. Most colonies were small (10-40 cm diameter), except for *Montastraea annularis* (complex) and *Acropora palmata*. Corals had low levels of partial tissue mortality (14%), although much higher mortality was observed in the larger, dominant frame building corals (*Montastraea annularis*, 59% and

Acropora palmata, 82%). Recent mortality was low, except in isolated colonies. Five coral diseases were observed, but these were relatively uncommon (1.2%). A mild bleaching event, affecting about 6% of all corals was documented; this was attributed to unusually warm water temperatures. Aggressive invertebrates, including sponges, tunicates, colonial anemones, gorgonians, cyanobacteria and certain macroalgae were observed on most reefs, affecting 1-5% of the remaining colonies. While numerous dead standing coral skeletons were observed (especially *A. palmata*), many of the largest frame-building corals (*M. annularis*) had small surviving tissue remnants that were beginning to resheet over the skeletons. Moderate levels of recruitment were also observed, although these were mostly brooding corals (*Agaricia* and *Porites*).

Reef fish populations were dominated by juveniles and small adults with few larger fish. A total of 10 parrotfish (0.4%) and 1 grouper (0.4%) were 40 cm or larger in length. Less than 5% of all fish were 31-40 cm in length, while 22% of the grunts and seabasses and 13% of the parrotfishes and snappers were 21-30 cm in length. Predatory food fishes were uncommon, and consisted predominantly of graysby, red hind, coneys, yellowtail snapper and mahogany snapper. While some reefs had fairly high numbers of parrotfish, these were generally juveniles and initial phase fish, with few large terminal phase males. The other important herbivorous fishes, the surgeonfishes, also generally occurred as individuals or in very small schools. Large motile invertebrates including lobster and conch were also rare.

Most reefs showed moderate levels of resilience, as demonstrated by the presence of coral recruits, tissue remnants on larger corals that were resheeting, and a high abundance of juvenile corals, as well as a low prevalence of coral diseases. The reefs have, however, been severely impacted by past disturbances and a high cover and abundance of dead coral framework and dead colonies were evident. Negative resilience indicators included: 1) high cover of macroalgae and cyanobacteria, which was greatest near the coastline especially off populated areas; 2) low abundances and small size of predatory fishes; and 3) low biomass of herbivores, including surgeonfishes, parrotfishes and *Diadema* urchins. Promising signs of recovery were apparent in many locations, but certain areas (e.g. Grid Iron) may require decades to rebound, as sources of coral recruits (*A. palmata*) and fragments are minimal.

St. Kitts and Nevis could help promote the recovery of these reefs and enhance the resilience through several key steps. These include: reduction of fishing pressure on herbivores and key predatory fishes; implementation of fishery reserves within sites that exhibit the highest resilience; addressing runoff and discharge of nutrients and sewage especially on the western, leeward sides of St. Kitts; and implementation of ecological restoration approaches emphasizing coral nurseries, removal of pest species and possible translocation of key herbivores (*Diadema*) to reef habitats, if a source population is identified. A detailed coral reef monitoring program should be implemented to assess future changes and gauge success of management interventions.

Forward

When we first began this mission in early June, several of the researchers had their first exposure to the rapid assessment protocol we were applying to assess the resilience of these reefs. They received a compressed one day training workshop with classroom lectures, demonstrations, and field practice. Over the next 10 days, they were able to practice different aspects of the survey: benthic assessments, coral surveys, and fish assessments. By the end of the mission, most members of the research team had become experts in at least one aspect of the survey protocol. The number of transects they we able to complete on a dive and the detail of information we collected greatly improved from the start to finish. The divers worked together effectively and efficiently both in water and out, and worked diligently at night to enter their data. In addition to the standard rapid assessments, we were able to establish two permanent sites, one on the north coast within a recovering *Acropora cervicornis* population, and a second on the leeward reef near Bassaterre that still contained healthy *Montastraea faveolata* and *M. franksi* populations. These stations represent the start of a permanent monitoring program that will provide key information on patterns of recovery and future changes to reef communities.

It is my hope that the information we collected is the beginning of a new generation for the conservation and management of St. Kitts and Nevis. This project was intended to be the start of a permanent monitoring effort that the local participants will spearhead. This effort can provide critical, information the government can use in marine spatial planning and zoning and the development of more sustainable fisheries measures.

The Global Reef Expedition research and educational activities represents a step forward in an ongoing collaboration between policy makers, divers and other user groups, especially the fishers. By using the information and recommendations presented here, in concert with the habitat maps created by The Nature Conservancy and the outputs of various stakeholder meetings on Marine Protected Areas and Fisheries Use Patterns, it is possible to design new conservation measures that can help the coral reefs of St. Kitts and Nevis rebound from past disturbances. Promotion of healthy reefs is an imperative step all residents and visitors must take if the reefs will remain able to support healthy fish populations. In addition to future efforts to reduce pollution and implement environmentally friendly coastal development projects, it is critical that all stakeholders promote and support sustainable fishing practices. Through a concerted effort by all, local communities will be able to continue to rely on these precious resources as a source of income and food for their families and the larger populace on St. Kitts and Nevis for today and far in to the future.

Acknowledgements

I thank each of you for your dedication to this project and your willingness to participate, even when diving conditions were far from favorable. The work was completed through a partnership with the Nature Conservancy (TNC) Caribbean Program. Phil Kramer and his team at TNC in Florida assisted in identifying possible survey locations and provided detailed habitat maps to assist in our work. Ruth Blyther, the Eastern Caribbean Country Representative, and Nancy Graff the Eastern Caribbean Project Coordinator, were instrumental in all aspects of the research preparation and coordination of the associated stakeholder events. I am grateful for the assistance, local dive knowledge and the guidance underwater we received from Auston Mcleod and Pro-Divers. Pro-Divers provided us with a reliable and safe dive platform, assistance with all of our gear, considerable local knowledge on suitable sites for our work, and the ability to access distant coral reefs off the Atlantic coast that are not normally visited by dive operators.

The research team included scientists from the Florida and USVI TNC offices along with KSLOF researchers, local divers from St. Kitts and Nevis, AGGRA experts Claire Morrall and Jerry Mitchell from Grenada, and a University of Miami scientist. We were fortunate to have participation in our dive surveys by Ross University and St. Christopher National Trust.

Special thanks to McClean Hobson for his assistance with berthing at the Cruise Ship Pier, security for the ship, crew and scientists, and help with logistical arrangements. Janice Hodge provided assistance with all outreach and media associated with this project, including organization of the opening reception, fishers event and outreach cruise, and media interviews. Finally, thanks to all the hard work of the crew and officers of the Golden Shadow – the Global Reef Expedition and this mission in St. Kitts and Nevis wouldn't be possible without all of your dedication.

This work was completed under a Memorandum of Understanding between the Khaled bin Sultan Living Oceans Foundation and the Government of St. Kitts and Nevis, including the Ministry of Agriculture, Marine Resources, and Constituency Empowerment, St. Kitts; Department of Physical Planning and Environment, St. Kitts; Maritime and Civil Aviation Affairs, St. Kitts and Nevis; Ministry of Tourism & International Transport, St. Kitts; and Department of Agriculture, Fisheries, Nevis.

I am truly grateful for the opportunity to explore the coral reefs of St. Kitts and Nevis and hope the information generated through this project will aid in future management and conservation initiatives.

Andrew Bruckner, Ph.D.
Chief Scientist, KSLOF
March 2012

Background

The Federation of St. Kitts and Nevis is a two-island nation located in the Eastern Caribbean centered on 17° 20’ N, 62° 45’ W (Fig. 1). St. Kitts is 168 square km in area, with a coastline of 167 km. Nevis, the smaller of the two islands, is 94 square km in area, with a coastline of 94 km. The total population is approximately 50,000, with 38,000 living on St Kitts (227 people/sq km) and 12,000 on Nevis (128 people/sq km). The land masses are volcanic with steep mountainous slopes. The ocean shelf is relatively small (approximately 845 square km), but it supports a number of critical habitats, with fringing reefs along much of the coastline and deeper submerged bank reef structures offshore. While these areas support many key marine species, including endangered corals and turtles, commercially important food fishes and invertebrates, and marine mammals, little was known about their status prior to these assessments.

In 2010, the government of St. Kitts and the Nature Conservancy (TNC) completed the first benthic habitat mapping project. This effort resulted in high resolution habitat maps for the shallow shelf (to about 25 m depth) containing twelve different benthic habitats (Fig. 2). These maps were used to draft a federation-wide marine zoning plan to protect coral reefs, seagrass beds, nursery grounds and other areas vital to the Federation’s marine life and economy. The draft marine zoning plan has identified several important candidate sites for protection including areas of endangered corals and large seagrass beds, most notably in the Narrows, the shallow area between the two islands. These areas serve as vital breeding grounds and nursery areas for reef fishes and queen conch (*Strombus gigas*). As of 2011, St. Kitts and Nevis had no officially declared marine protected areas. However, as part of the Convention on Biological Diversity Program of Work on Protected Areas (PoWPA) requirements, a national gap assessment was recently completed. This includes the identification of important marine areas for protection. It is the intent of the Federation to declare these areas as MPAs, as a commitment to fulfill the Caribbean Challenge, a regional initiative to protect at least 20% of coastal areas and establish effective management methods through a sustainable funding framework (Morton Anthony, 2010).

The narrow shelf surrounding the twin islands supports extensive shallow marine habitats, including sea grass beds, gorgonian hardground areas, sand and algal communities, and diverse coral reef assemblages. Coral reefs occur in windward and leeward locations, having developed on both the Atlantic and Caribbean sides. Some reefs fringe the mainland and often extend several hundred meters from the shoreline. There are several linear reefs running parallel to the coastline, 1-2 km offshore, a submerged offshore bank reef that slopes quickly into deep water, and circular patch reefs on the leeward side surrounded by sand. Due to a lack of quantitative data from most reefs in the region, the main intent of this study was to characterize these reef systems and obtain information on the population dynamics and health of the reef building corals and the status of reef fish populations. Simultaneously, data were collected on associated benthic organisms, habitat quality, threat, and patterns of recovery from past disturbances.

Methods

Site selection

A two-pronged approach was used to identify survey locations. First, The Nature Conservancy (TNC) identified 100 random locations around the island that were located in one of four habitat types: *Acropora palmata* framework, gorgonian hardgrounds, gorgonian slope and hard coral framework. These sites were provided to a local dive operator for his recommendations. Using habitat maps, he identified each of the known dive sites around the island that contain hard corals. Many of the sites identified by TNC ended up being impractical for survey as they were located in very shallow water (<2 m depth) within dead Acropora patches. Two of these were examined, but because of the lack of live coral, similarity, and difficulty accessing them due to high wave action, the remainder were not examined. Ultimately, each of the sites recommended by the dive operator were surveyed, with gaps in coverage filled in with sites identified by TNC and additional hardground areas that were identified through exploration.

Survey Approach

The resilience assessments conducted in St. Kitts and Nevis include measures of corals, fish, algae and motile invertebrates through application of attributes of the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol (Lang et al. 2010), the IUCN bleaching resilience protocol (Obura and Grimsditch 2009), and several additions. Data were collected using a combination of belt transects, point intercept methods, quadrats and photographic documentation. Five measures were recorded for corals: 1) benthic cover; 2) coral diversity and abundance (by species); 3) coral size class distributions (by species); 4) coral recruitment; and 5) coral condition including prevalence of disease, bleaching and biotic interactions Fish abundance and size structure were assessed for a select group of species. Other benthic attributes, including cover of algae and non-coral invertebrates and substrate type were also recorded. A total of 25 locations were examined, with two sites revisited on multiple dives and established as KSLOF Legacy Sites (Fig. 1).

Fish Assessments: For fish, abundance and size structure for 88 species of reef fishes are collected along 2 m X 30 m belt transects, targeting species that have a major functional role on reefs or are major fisheries targets. A T square marked in 5 cm increments was used to gauge fish size. A minimum of 6 transects was conducted by each “fish” diver per site. Other indicators recorded along belt transects include large motile invertebrates (urchins, octopus, lobster, large crabs, queen conch, sea cucumbers).

Coral Assessments: Belt transects, each 10 m long and 1 m wide, are used to assess coral species diversity, abundance and size structure. Within each belt, each coral 4 cm in diameter or larger was identified and measured (length, width and height) to the nearest 1 cm using a 1 m bar. Visual estimates of tissue loss, using a 1 m bar marked in 1 cm increments, was recorded for each colony over 4 cm in diameter. If the coral exhibited recent tissue loss, the amount of remaining tissue, the percent that recently died and the percent that died long ago were estimated for the entire colony surface. Tissue loss was categorized as recent mortality (occurring within the last 1-5 days), transitional mortality (filamentous green algae and diatom colonization, 6-30 days), and old mortality (>30 days). For each coral with partial or whole colony mortality, the cause of mortality was identified, if possible. The diagnosis included an assessment of the type of disease, the extent of bleaching, predation, competition, or overgrowth, or other cause of mortality. Each coral was first carefully examined to identify cryptic predators, such as snails (*Coralliophila abbreviata*) and fireworms (*Hermodice carunculata*). Lesions were then diagnosed into four categories: recent tissue loss, skeletal damage, color change, and unusual growth patterns (an individual colony could have multiple characteristics such as color change and recent tissue loss), and when possible, a field name was assigned. Diseases were identified according to Bruckner (2010b) and Raymundo *et al.* (2008), as yellow band disease (YBD), white plague (WP), black band disease (BBD), Caribbean ciliate infection (CCI), dark spots disease (DSD), white band disease (WBD) or unknown.

Coral Recruitment: Sampling for corals smaller than 4 cm was done using a minimum of five 0.25 m^2 quadrats per transect. Each quadrat was located at fixed, predetermined intervals (e.g. 2, 4, 6, 8, 10 m), alternating between right and left side of the transect. Recruits were identified in both point intercept surveys and belt transects. These corals were divided into recruits (0-2 cm diameter) and juveniles (2.1-3.9 cm).

Benthic cover: Cover of major functional groups (corals identified to species, sponges, other invertebrates, and six groups of algae including macroalgae, erect coralline algae, crustose coralline algae, fine turfs, turf algae with sediment and cyanobacteria) and substrate type (hardground, sand, mud, fused rubble, unstabilized rubble, recently dead coral, bleached coral, live coral) were assessed along 10 m transects using either recorded observations and/or photographic assessments.

a. Recorded observations: Point intercept method was used, whereas the organism and substrate is identified every 10 cm along a 10 m transects (total 100 points/transect), with a minimum of six transects examined per location.
b. Photographic assessment: A 10 m long transect tape was extended along depth contours at 20, 15, 10 and 5 m depth. Continuous digital still photographs were taken from of the reef substrate from a height of approximately 0.6-0.75 meters above the substrate, using a one meter bar divided into 5 cm increments placed perpendicular to the transect tape as a scale bar. Approximately 20 photographs were taken per transect to allow for overlap between adjacent images with two photo transects (each 10 m in length) per depth. Images were downloaded onto a computer, and benthic community composition, coral cover and cover of other organisms and substrate type, and the size (planar surface area) of corals were analyzed. Cover was determined by recording the benthic attribute located directly below a random points with 30-50 points per photograph, using Coral Point Count (CPCE) software developed by the National Coral Reef Institute (NCRI). This software also allows you to trace the outline of individual corals to determine their planar surface area.

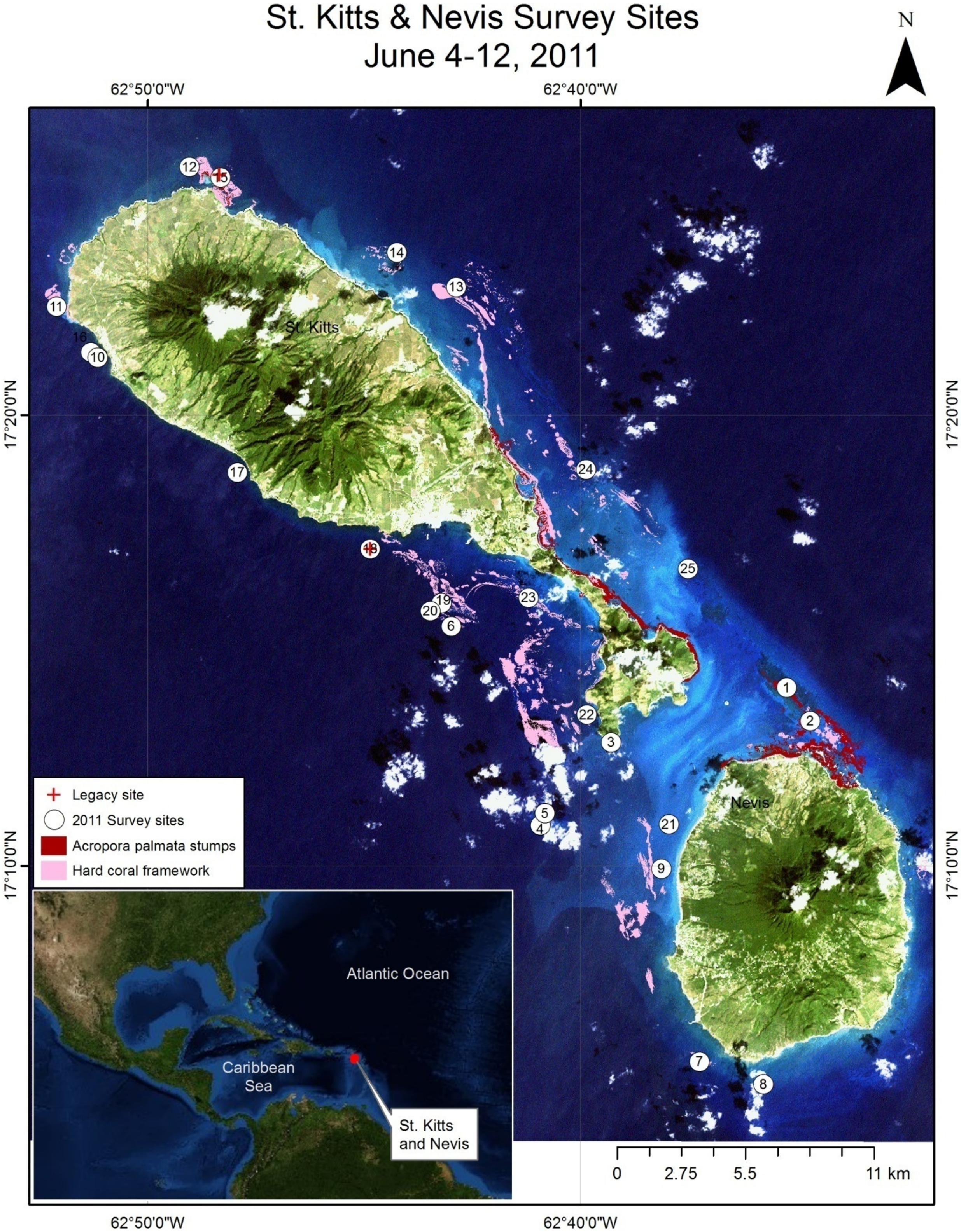


Fig. 1. Location of SCUBA assessments off St. Kitts and Nevis.

ID	Name	Date	Depth_m	Long_W	Lat_N
1	Gridiron 1	4-Jun-11	7.0	-62.587430	17.232540
2	Gridiron 2	4-Jun-11	6.5	-62.578220	17.220240
3	Nags Head	4-Jun-11	10.0	-62.654920	17.212320
4	Monkey Shoals	5-Jun-11	19.0	-62.682220	17.181560
5	Monkey Shoals, Donut	5-Jun-11	10.3	-62.680560	17.186050
6	Brimstone Shallows South	5-Jun-11	17.4	-62.716490	17.255310
7	Caverns	6-Jun-11	9.0	-62.621010	17.094060
8	Two Mill Reef	6-Jun-11	14.0	-62.596320	17.085710
9	Four Seasons Reef	6-Jun-11	12.4	-62.635580	17.165540
10	Sandy Point	7-Jun-11	15.0	-62.852790	17.354710
11	Pump Bay Reef	7-Jun-11	12.0	-62.868530	17.373520
12	Dieppe Bay	7-Jun-11	11.5	-62.817440	17.425220
13	Grange Bay	8-Jun-11	22.8	-62.714700	17.380810
14	Half Moon Bay	8-Jun-11	23.0	-62.737450	17.393510
15	Punch Bowl	8-Jun-11	6.0	-62.805480	17.421290
16	Sandy Point 2	9-Jun-11	12.0	-62.855360	17.356650
17	Paradise Reef, Old Bay Road	9-Jun-11	17.0	-62.798920	17.312240
18	The Vent	10-Jun-11	16.5	-62.747760	17.283920
19	Coconut Tree Rock	10-Jun-11	14.0	-62.720360	17.263860
20	Brimstone Shallows North	10-Jun-11	18.0	-62.724670	17.260930
21	Four Seasons Reef 2	11-Jun-11	16.2	-62.632690	17.181990
22	Turtle Bar	11-Jun-11	11.0	-62.664410	17.222580
23	Friars Bay Reef	11-Jun-11	16.0	-62.686790	17.265890
24	Half Moon Bay	12-Jun-11	11.0	-62.664710	17.313310
25	Boneyard	12-Jun-11	17.0	-62.625330	17.276590

Table 1. Locations examined off St. Kitts and Nevis. The date, depth and GPS coordinate are provided for each site.

Results

1. Habitat classes

The habitat map created for St. Kitts and Nevis identified 12 habitat classes (Fig. 2). These maps extend from the shoreline to a depth of about 25 m; they do not include the offshore bank reefs (Monkey Shoals). In total, the shallow habitats identified cover an area of 326.15 km^2. Potential coral reef habitats, represented by five potential habitat types (*Acropora palmata* stumps; hard coral framework; flat gorgonian hardground; algal reef flat; and rugose gorgonian slope) occupy 53 km^2, or roughly 16% of the shallow marine environment; the remainder consists of soft bottom habitats in seven classes (Table 2). One notable feature of the marine environment is an absence of mangrove habitats. There is one small area containing mangroves (not depicted on these maps), on the southern end of St. Kitts, but this is isolated from other marine environments.

Habitat	Area (sq km)
Acropora palmata stumps	5.74
Hard coral framework	15.78
Flat gorgonian hardground	28.55
Algal reef flat	0.61
Rugose gorgonian slope	2.56
Dense macroalgae on seagrass	27.75
Dense seagrass	31.00
Sparse seagrass	3.70
Semi-consolidated rubble	25.95
Unconsolidated sand with algae	19.30
Sand	163.56
Lagoonal muds	1.65
Total Area Mapped	326.15

Table 2. Habitat classes identified in the marine habitat maps and the areas of each habitat type in square km.

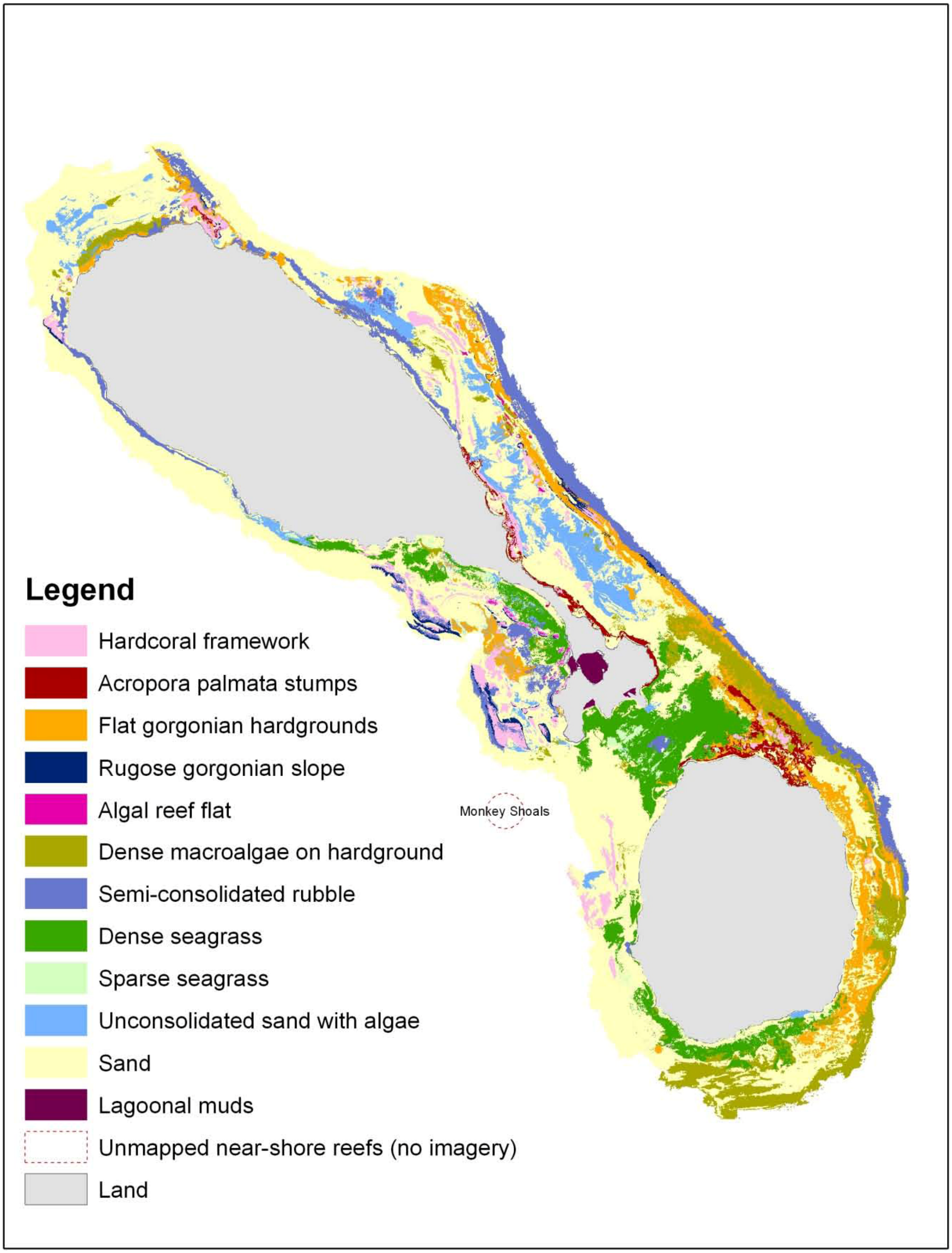


Fig. 2. Habitat map developed by TNC and NCRI.

2. Benthic communities

Using point intercept transects the percent cover of each substrate type (biotic or abiotic) was determined for the 25 locations. Benthic substrates were colonized primarily by algae and cyanobacteria (mean, all sites pooled = 69%), with more than half of this cover consisting of fleshy macroalgae (mean cover = 35%). Next most abundant algal functional group was turf algae (mean = 21%), with lower cover of crustose coralline algae (CCA, mean=7.8%) and cyanobacteria (mean=5.2%). At five sites, cyanobacterial cover exceeded 10% (Fig 4). Erect coralline algae was rare (mean=0.6%) except at site 25 (8.4%). Sites showed considerable variation in algal cover (Fig. 3).

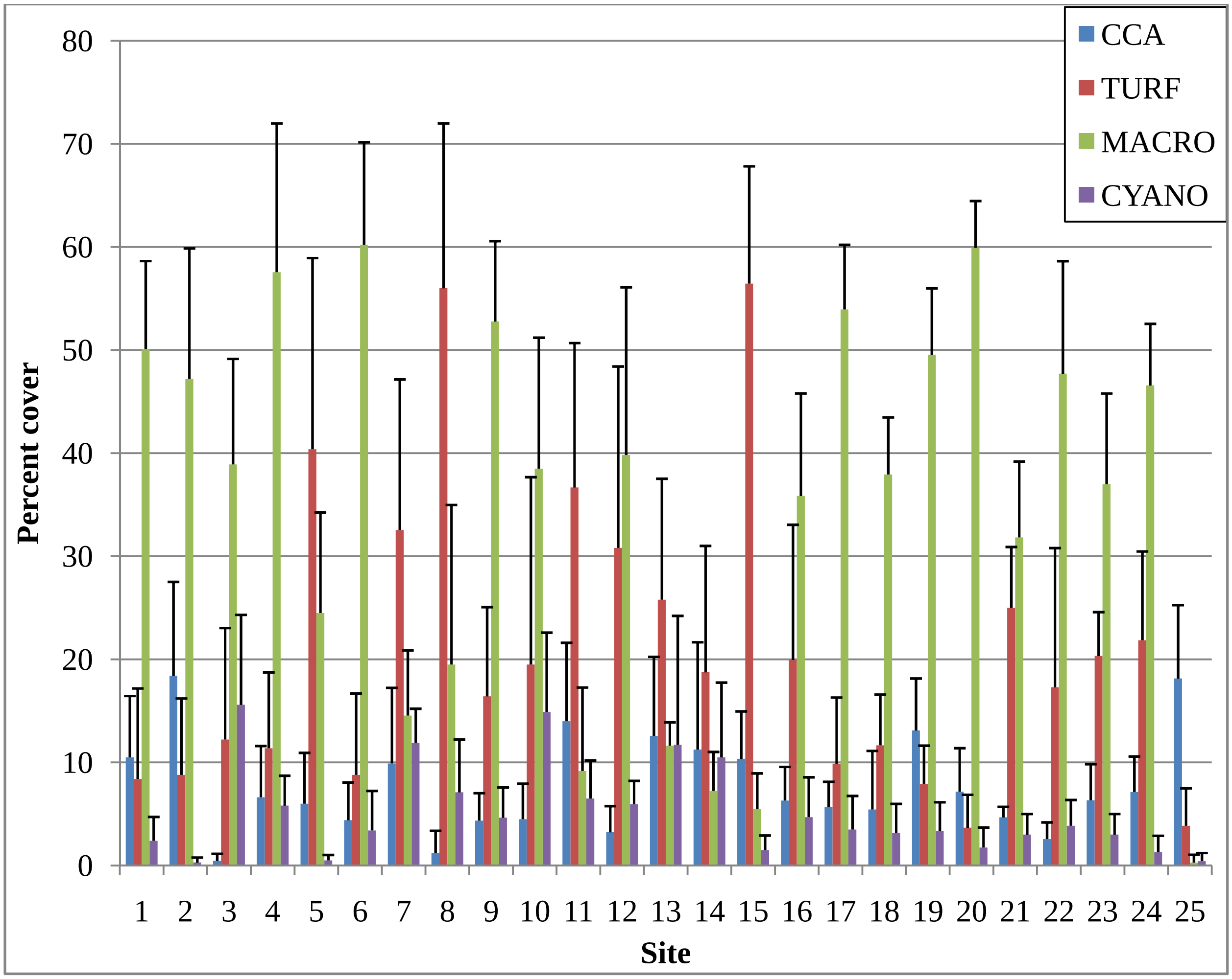


Fig. 3. Benthic cover of the major functional groups of algae including crustose coralline algae (CCA), turf algae (TURF), fleshy macroalgae (MACRO) and cyanobacteria CYANO).

Non-coral invertebrates covered about 10% of the bottom. These included aggressive invertebrates (AINV) that were observed overgrowing and killing corals as well as non-aggressive sponges, cnidarians and other taxon. In addition, 7% of the substrates were uncolonized pavement, rubble or sand (Fig. 5).

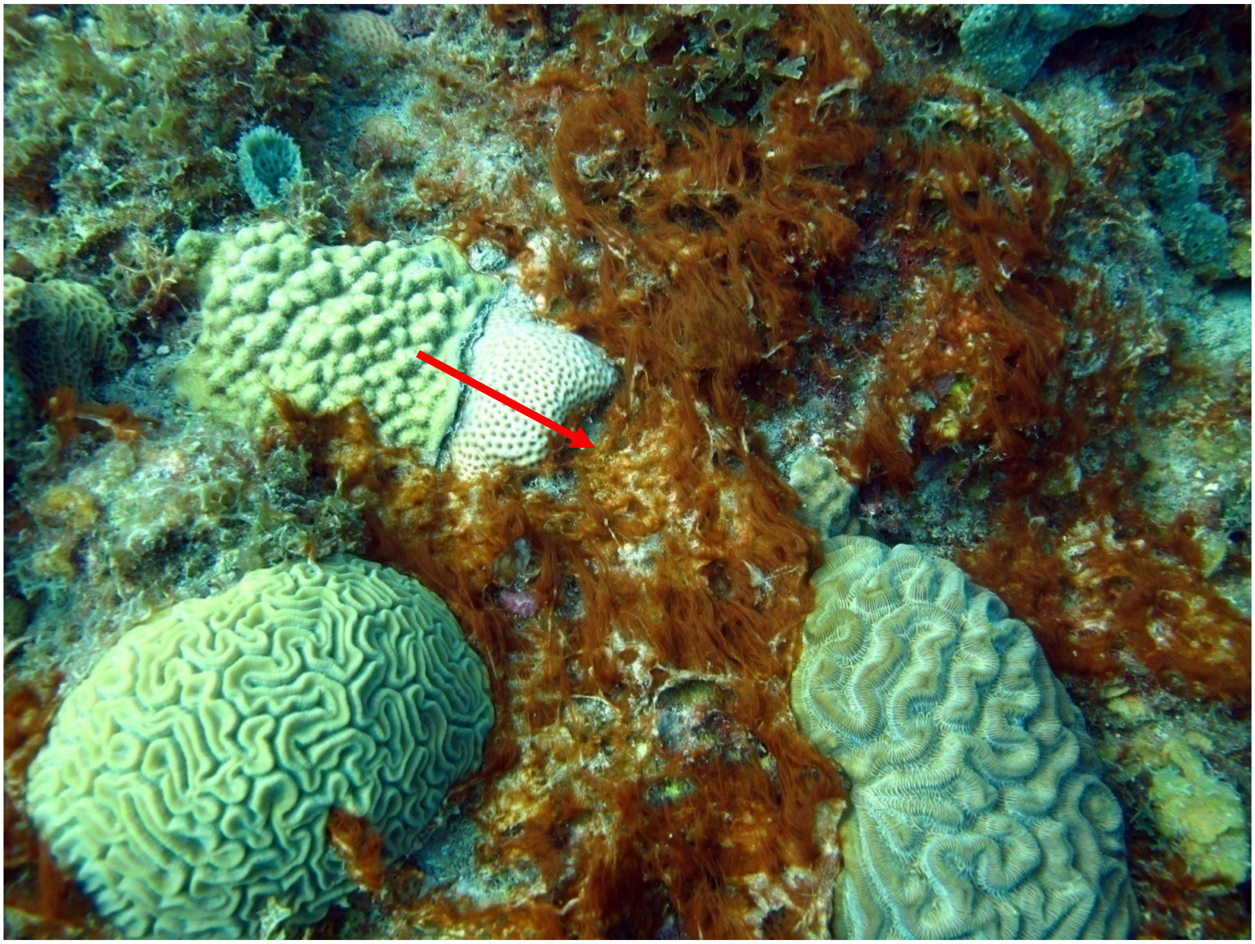


Fig. 4. Dense mats of cyanobacteria (arrow) were observed carpeting the bottom and the margins of corals at several sites, especially sites 3, 7, 10, 13 and 14.

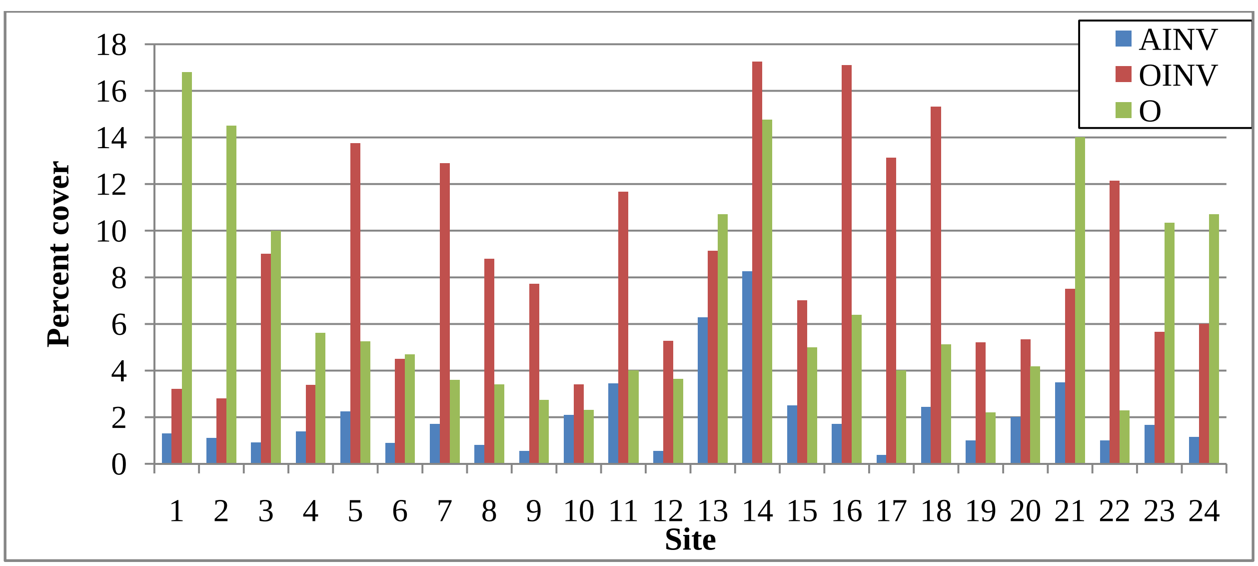


Fig. 5. Percent cover of aggressive overgrowing invertebrates (AINV), other invertebrates (OINV) and non-living substrates (O). Site 25 is not included here as this site was an outlier: 58% of the bottom consisted of uncolonized pavement.

3. Coral community structure

Diversity: Coral diversity was fairly representative of eastern Caribbean reefs, containing nearly 2/3 of all shallow reef building corals (36 species) reported from the wider Caribbean (Appendix 1). Certain corals were found on all reef types, but many species were much less common, occurring only in very specific habitats. Nearly every genus known from the region was represented. Coral taxon that were absent include *Agaricia tenuifolia* (thin lettuce leaf coral), *Mycetophyllia ferox* (rough cactus coral), *Oculina* spp. (ivory coral), *Solenastrea bournoni* (smooth star coral), *Isophyllastrea rigida* (rough star coral), and *Cladocera arbuscula*.

Fig. 6. One of the less common corals, *Mussa angulosa* (flower coral) had settled on a dead *M. faveolata* colony.

Cover: Living coral cover (all species pooled) was less than 15% in all locations except sites 18, 19, 20 and 23, and less than 10% in nine locations (36% of the sites) (Fig. 7). *Porites* spp. had the highest cover (mean=3.7%), followed by *Montastraea* (2.9%), *Siderastrea* (1.5%), *Diploria* (1.4%) and *Agaricia* (0.8%) (Fig. 8). Twelve other scleractinian coral genera and one hydrozoan coral had a mean live cover of less than 0.5% (pooled for all reefs, Fig. 9).

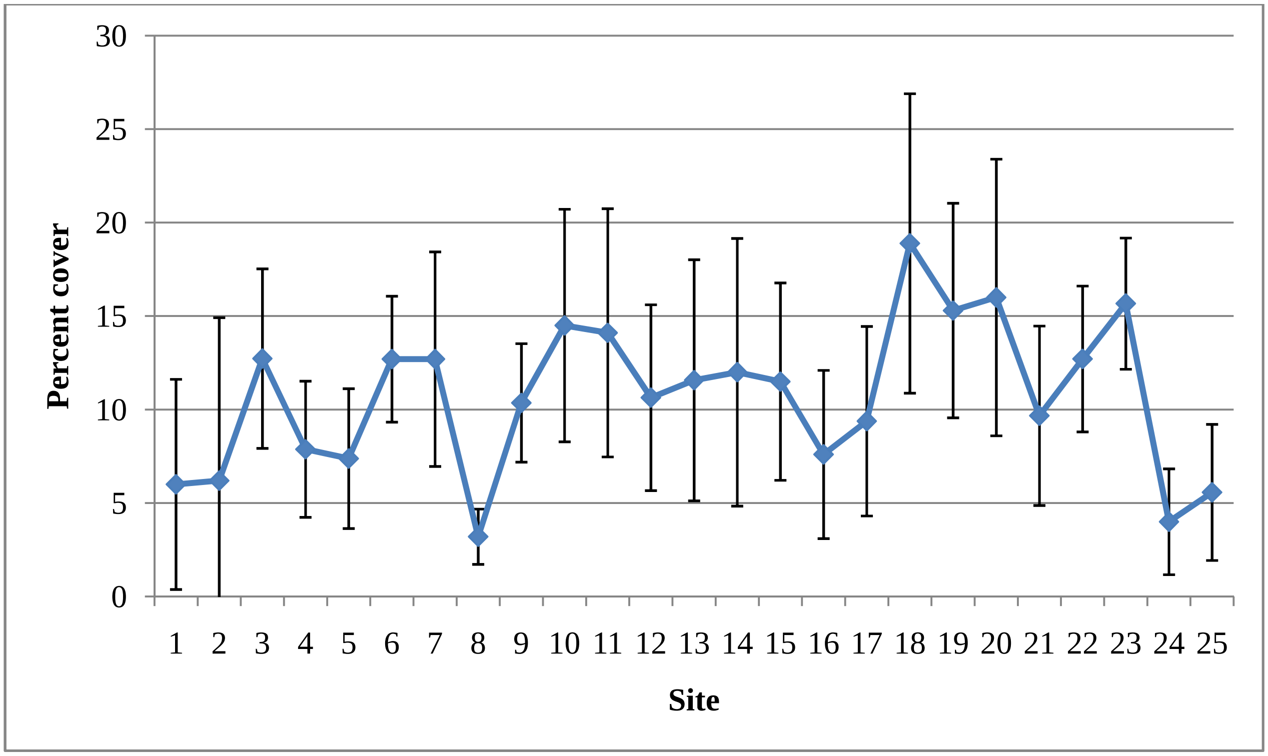


Fig. 7. Mean percent live coral cover (all species pooled) for 25 sites examined off St. Kitts and Nevis.

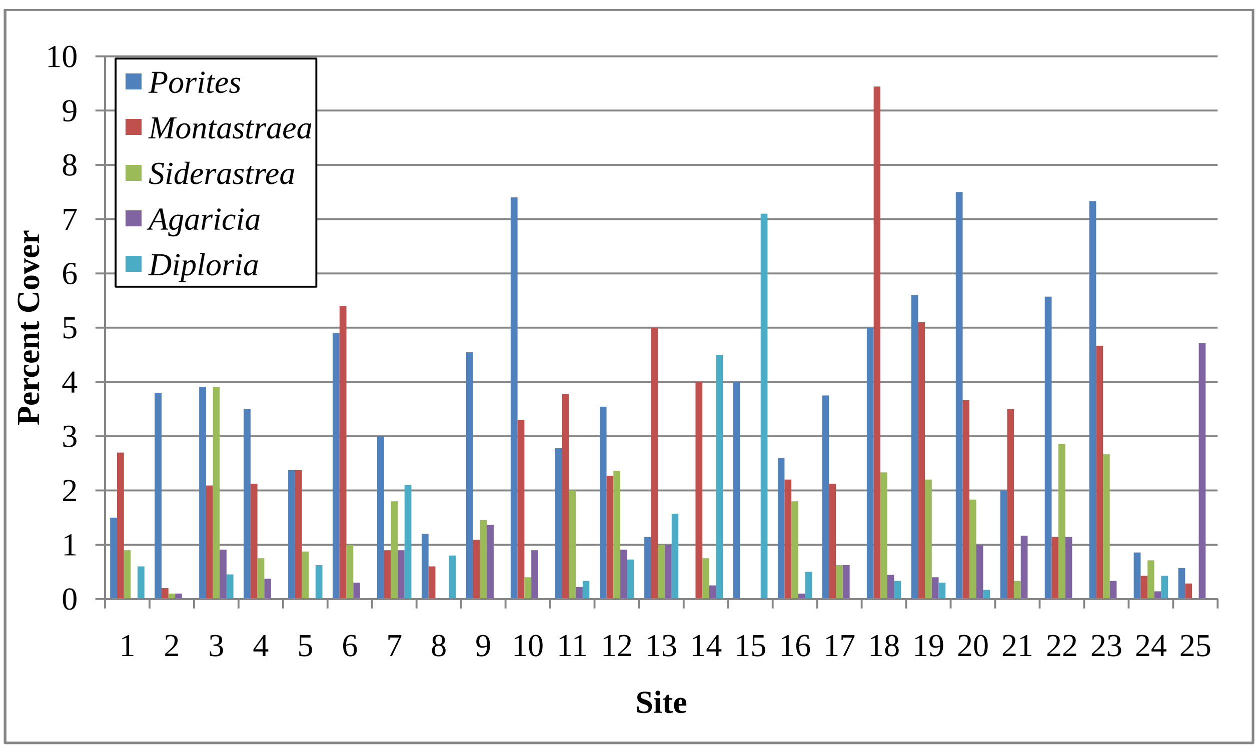


Fig. 8. Mean percent live coral cover of the five dominant Genera of scleractinian corals.

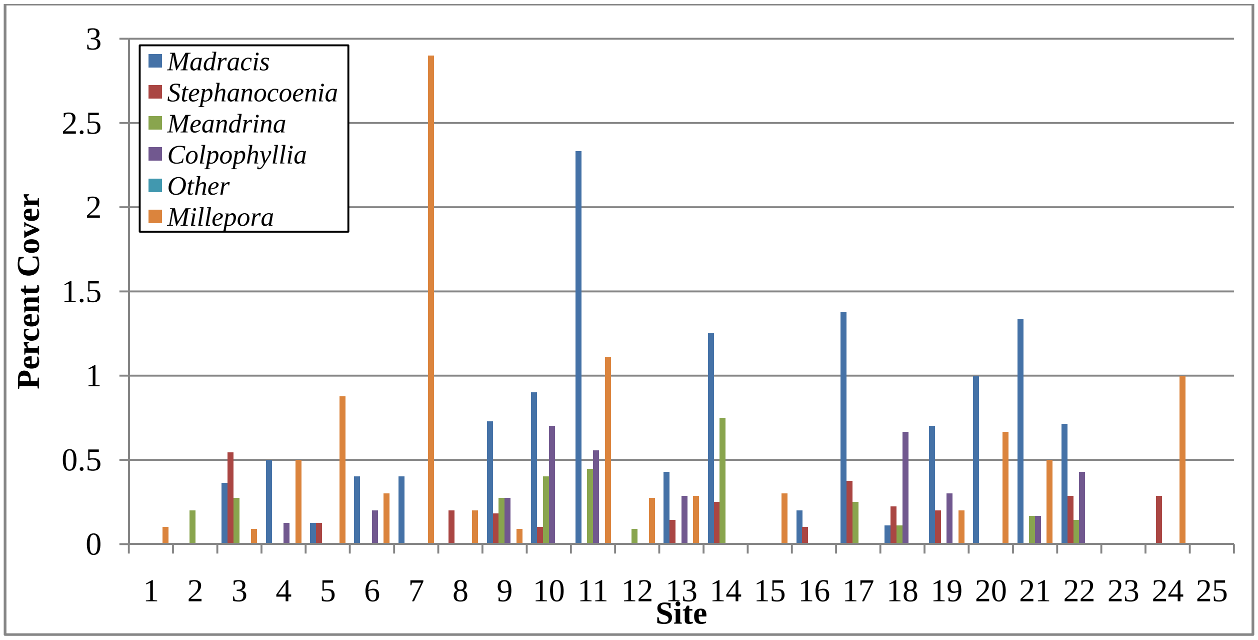


Fig. 9. Mean percent live coral cover for less common scleractinian corals and *Millepora* (fire coral). Other includes 18 species.

Abundance: Within belt transects (25 reefs; n=108), a total of 5,427 corals were assessed. Corals occurred at a mean density of 5.02 colonies/sq. meter. The most abundant coral overall was *Porites astreoides* (30% of all corals), followed by *M. annularis* complex (17.2%), *Siderastrea siderea* (13.4%), and *Agaricia* spp. (8.2%). Two other corals made up over 5% of the population (*Diploria strigosa* and *M. cavernosa*), while all other species each made up 4% or less of the total population of reef building corals. Rare species pooled under "other corals" (1% of the population overall) included the golfball coral (*Favia fragum*), spiny flower coral (*Mussa angulosa*), sinuous cactus coral (*Isophyllastrea sinuosa*), sunray lettuce coral (*Leptoseris cucullata*), pillar coral (*Dendrogyra cylindricus*), flower coral (*Manacina areolata;* Fig 10), and solitary corals (*Scolymia* spp.) (Fig. 11).

Fig. 10. *Manacina aerolata* was identified at a single site (# 21) located off Nevis.

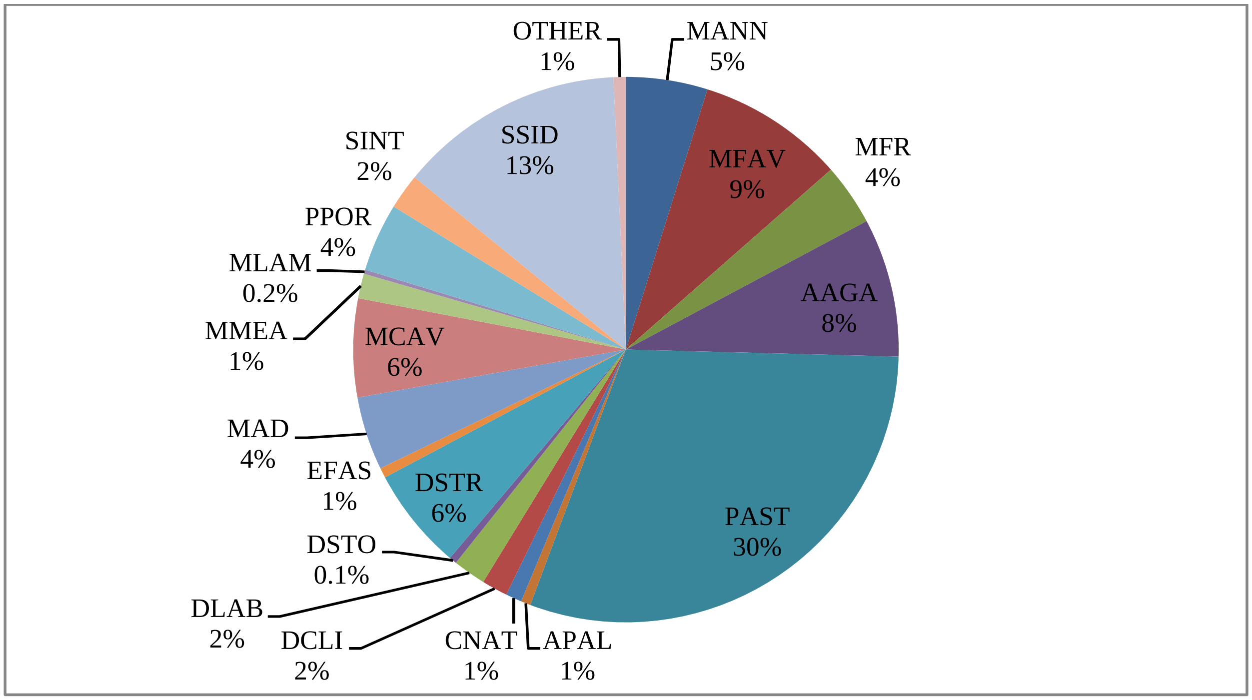


Fig. 11. Relative abundance of scleractinian coral taxon (pooled for all reefs and depths). The percent of the total population is shown for each coral taxon. PAST= *Porites astreoides*, AAGA= *Agaricia agariciies*; MFR= *Montastraea franksi*; MFAV= *M. faveolata*; MANN= *M. annularis*; SSID= *Siderastrea siderea*; SINT= *Stephanocoenia intersepta*; PPOR= *P. porites*; MLAM= *Mycetophyllia lamarcki*; MMEA= *Meandrina meandrites*; MCAV= *M. cavernosa*; MAD= *Madracis* spp.; EFAS= *Eusmilia fastigiata*; DSTR= *Diploria strigosa*; DSTO= *Dichocoenia stokessi*; DLAB= *Diploria labyrinthiformis*: DCLI- *D. clivosa*; CNAT= *Colpophyllia natans*; APAL= *Acropora palmata.*

Endangered species: While extensive *Acropora palmata* framework was present on the exposed Atlantic side, and dense stands of dead elkhorn coral colonies in growth position were observed, only isolated live colonies (<1% cover) were identified on these reefs. This included a small number of adult colonies estimated at 4-7 years in perfect condition, small tissue remnants that were resheeting over older skeletons, sexual recruits, and fragments that had fused and had new protobranches (Plate 1). Staghorn coral, *Acropora cervicornis*, was also rare, and was not identified within any belt transects. It did, however, occur on a single reef on the leeward side off Nevis (one small colony). This species did appear to be recovering near Dieppe Bay, at the northern end of St. Kitts (Punch Bowl, site 15). A small stand of *A. cervicornis* was also identified at the base of the elkhorn coral framework on the southeastern end of St. Kitts, off Mosquito Bluff (Site 25). There were 16 colonies, the largest of which was up to 80 cm in diameter; these occurred in three patches (1-2 m diameter each). Most (12) were in good shape; four colonies had multiple branches with prominent areas of white, recently denuded skeleton. Tissue loss was due to snail predation and threespot damselfish (*Stegastes planifrons*) algal lawns.

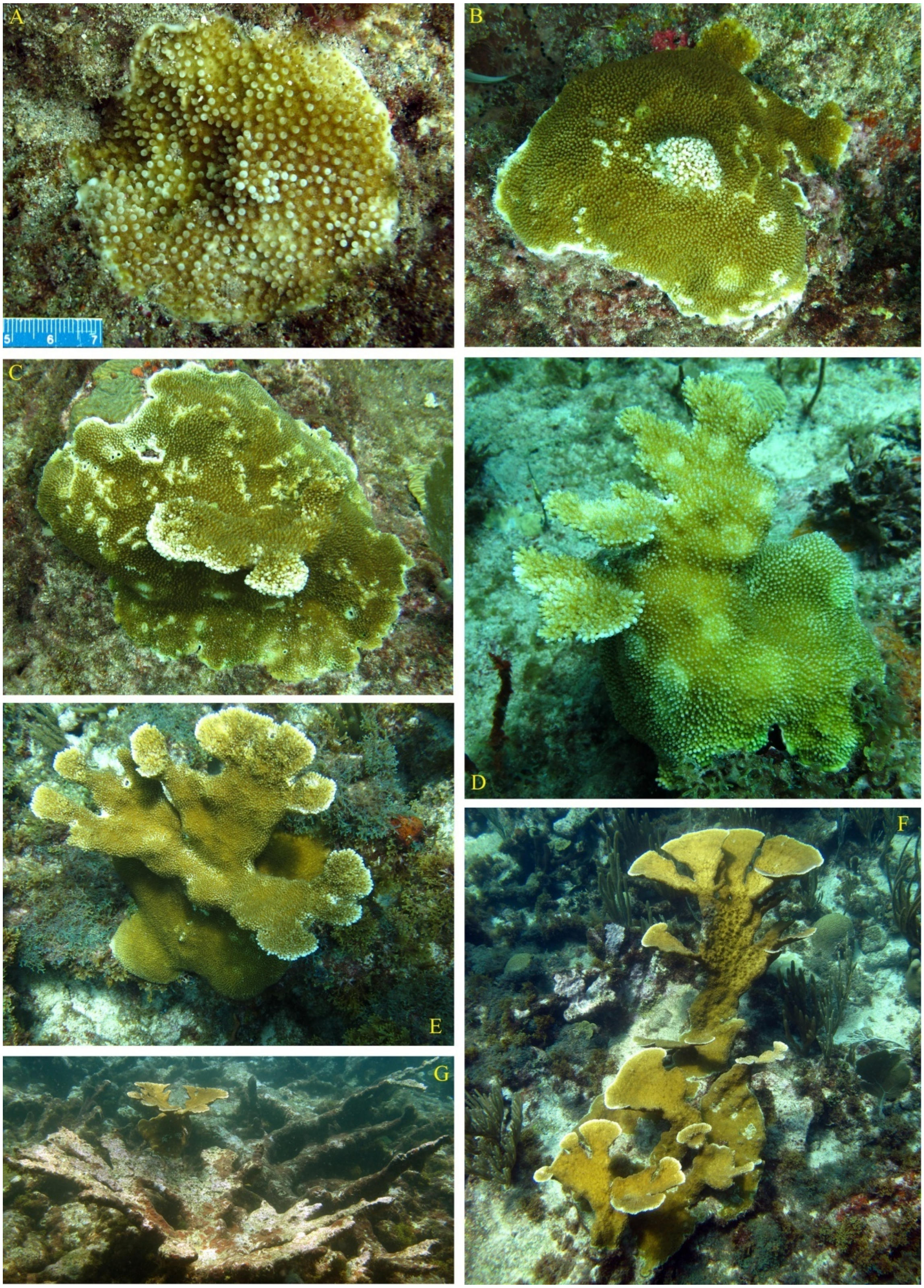


Plate 1. Recolonization the dead *A. palmata* framework at Grid Iron by *A. palmata*. A. Sexual recruit. B. Early stages of protobranch development. C. Colony with small protobranches. D and E. Young colonies with small branches. F. Regrowth of colony from branch fragment. G. Regrowth of tissue remnant on dead skeleton.

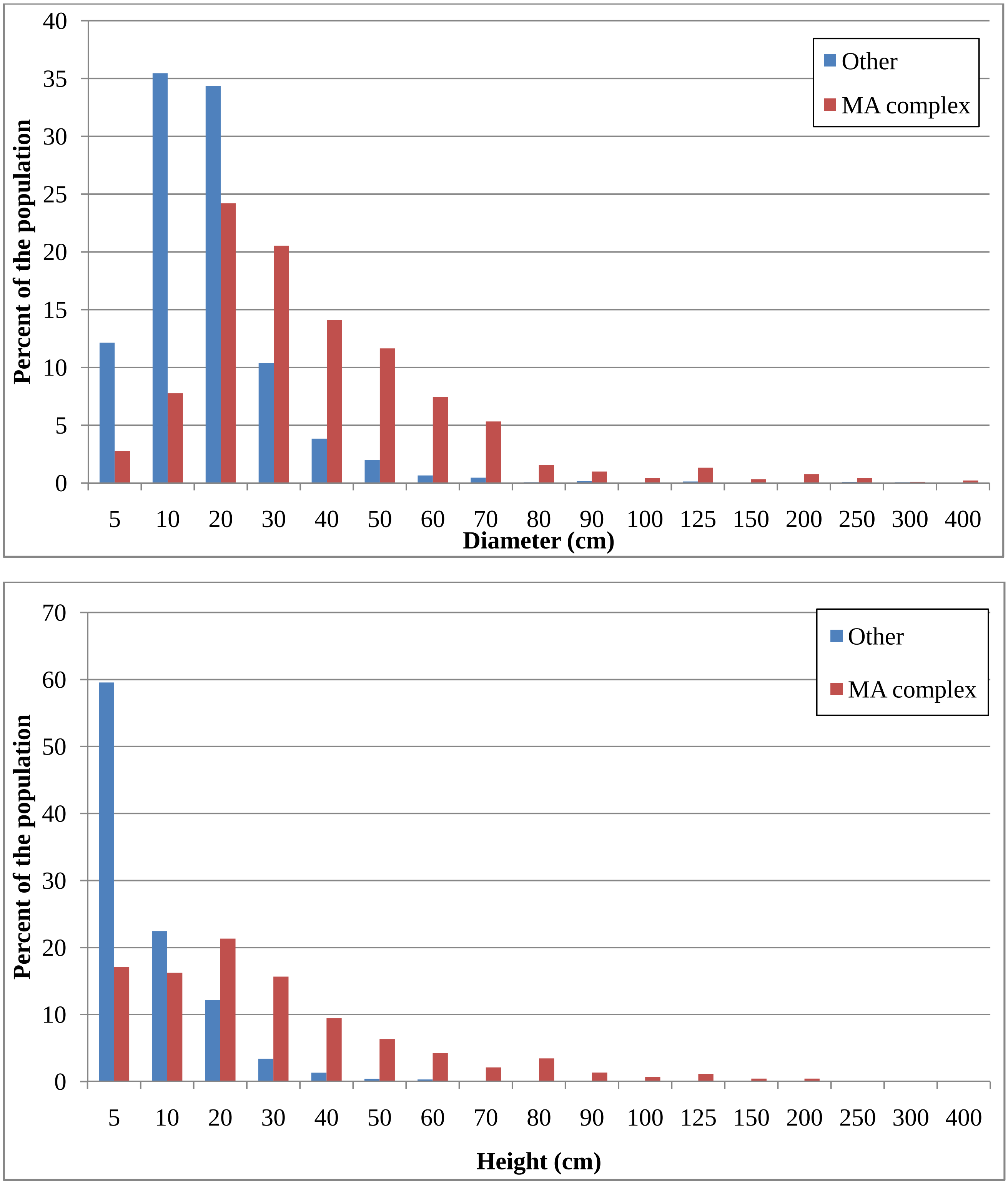


Fig. 12. Size structure of corals from 25 reefs off St. Kitts and Nevis. Corals are pooled into two groups: a) all species except *Montastraea annularis* complex (blue bars) and b) *M. annularis* complex (red bars). The maximum diameter (top) and height (bottom) is expressed as a percent of the total population for each group.

Coral size structure: The vast majority of the living corals (all species) were small to medium size (10-40 cm in diameter; <40 cm height) and colonies larger than 70 cm diameter were rare (Fig. 12). *Montastraea annularis* (complex) colonies were larger (mean diameter=35 cm, se=1.11; mean height= 27 cm, se=0.91) than all other corals (pooled species, mean diameter=15 cm, se=0.23; mean height= 7 cm, se=0.16) except *Acropora palmata* (mean = 114 cm). *Montastraea annularis* (mean diameter= 43 cm) was also larger than *M. faveolata* (mean diameter = 34 cm) and *M. franksi* (mean diameter = 33 cm). These differences are due to a larger number of colonies of *M. faveolata* in the 20-29 cm size class, more *M. franksi* in the 20-39 cm size class, and a larger number of *M. annularis* colonies in the 50-79 cm size classes (Fig. 13).

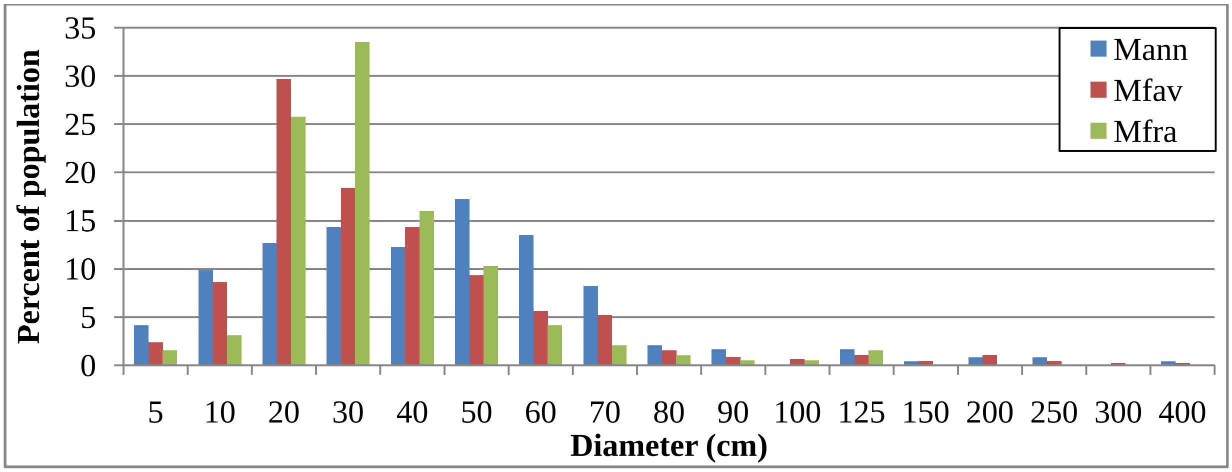


Fig. 13. Size (diameter) of *Montastraea annularis* (complex) on 25 reefs in St. Kitts and Nevis. *M. annularis* (Mann) are blue bars, *M. faveolata* are red bars and *M. franksi* are green bars.

Other species showed considerable variation in size. The smallest corals were *Agaricia* (9.7 cm) and *S intersepta* (9.9 cm), while *A. palmata* (mean=114 cm), *C. natans* (mean = 33 cm) and *M. cavernosa* (mean= 24 cm) were largest (Fig. 14).

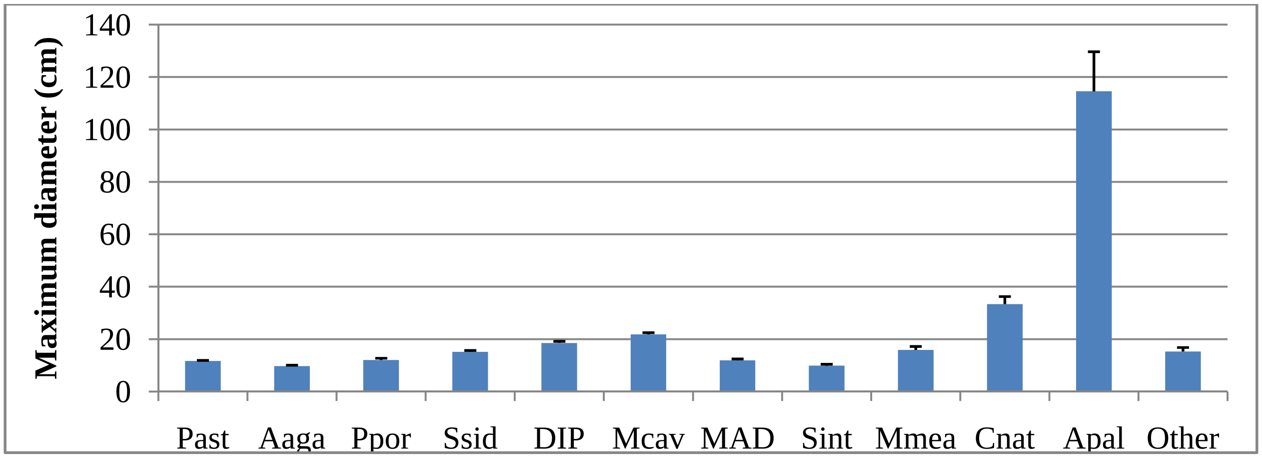


Fig. 14. Size (mean diameter, cm) of the dominant functional groups of scleractinian corals pooled from 25 locations. Corals are listed from most (left) to least abundant (right).

Coral mortality: The mean amount of partial tissue loss for pooled species (all sites are pooled) was 13.6% (recent and old mortality) with low levels of recent mortality (mean=0.7%). Significant differences in mortality were observed between sites, with the highest amount of mortality observed at site 19 (Fig. 15). A more detailed examination of partial tissue loss by taxon reveals the distinct differences among functional groups, with *Acropora palmata* (mean = 82%) and *M. annularis* colonies (mean = 59%; Fig. 16) missing the most live tissue, followed by *M. faveolata* (mean =37%), *M. franksi* (mean=24%), and *M. cavernosa* (mean= 23%). Other species were missing less than 15% of their tissue (Fig. 17).

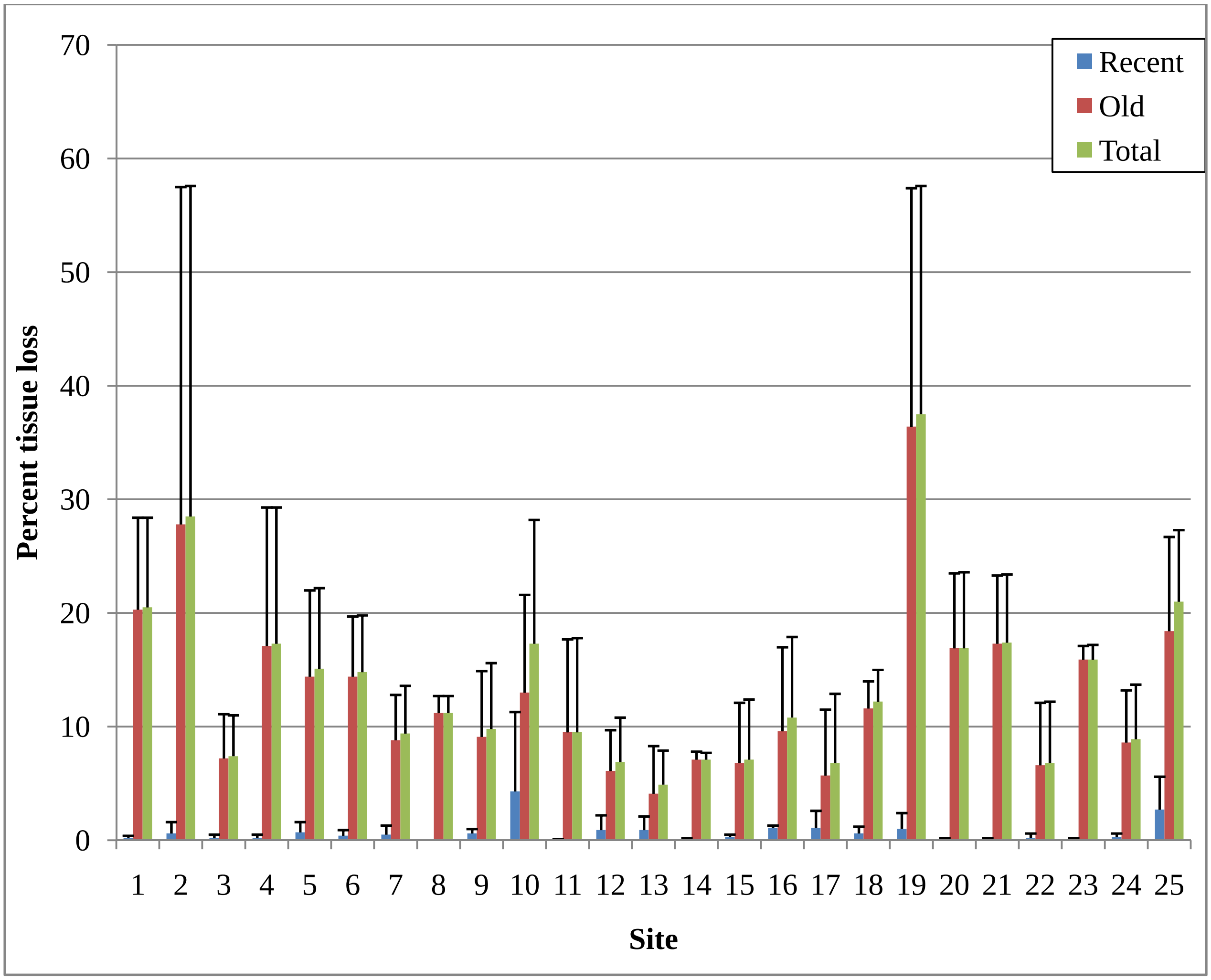


Fig. 15. Percent partial tissue loss for pooled coral species (all corals 4cm or larger) at each site. Mortality is divided into recent (blue), old (red) and total (green).

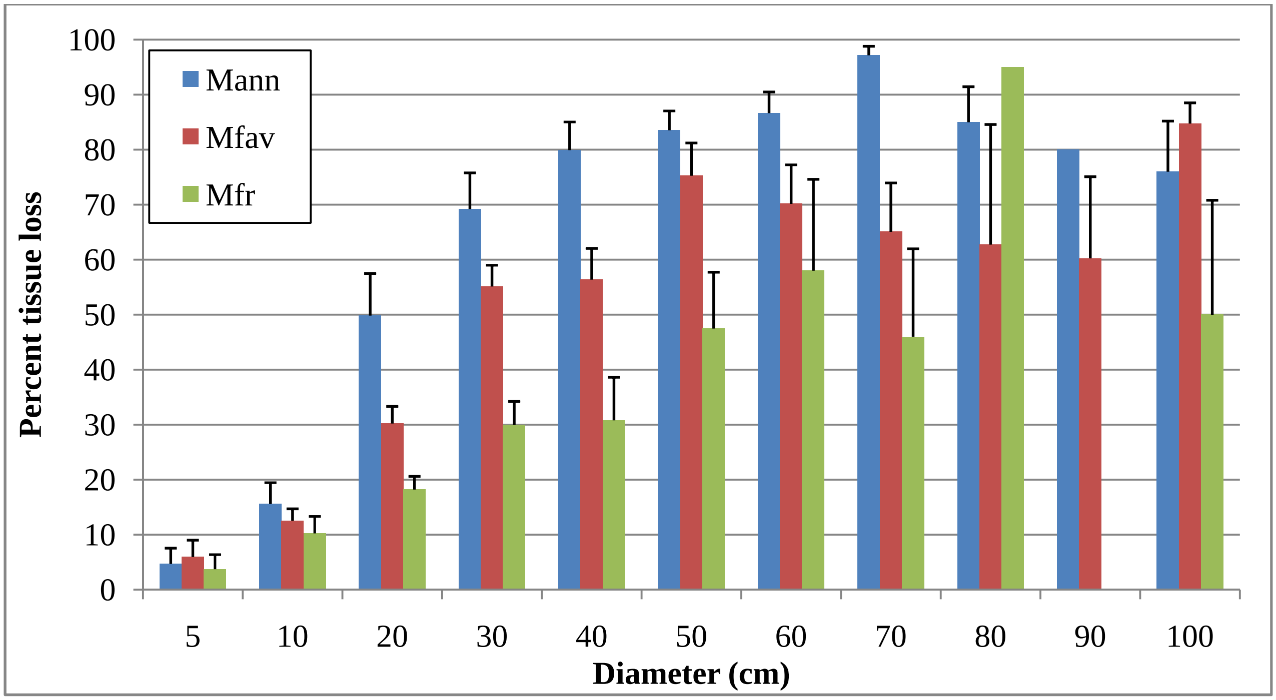


Fig. 16. Partial tissue loss in colonies of *Montastraea annularis* (complex) of different sizes. Mortality for *M. annularis* (blue), *M. faveolata* (red) and *M. franksi* (green) are shown for colonies from < 10 cm diameter (5) to colonies that are 100 cm or larger (100).

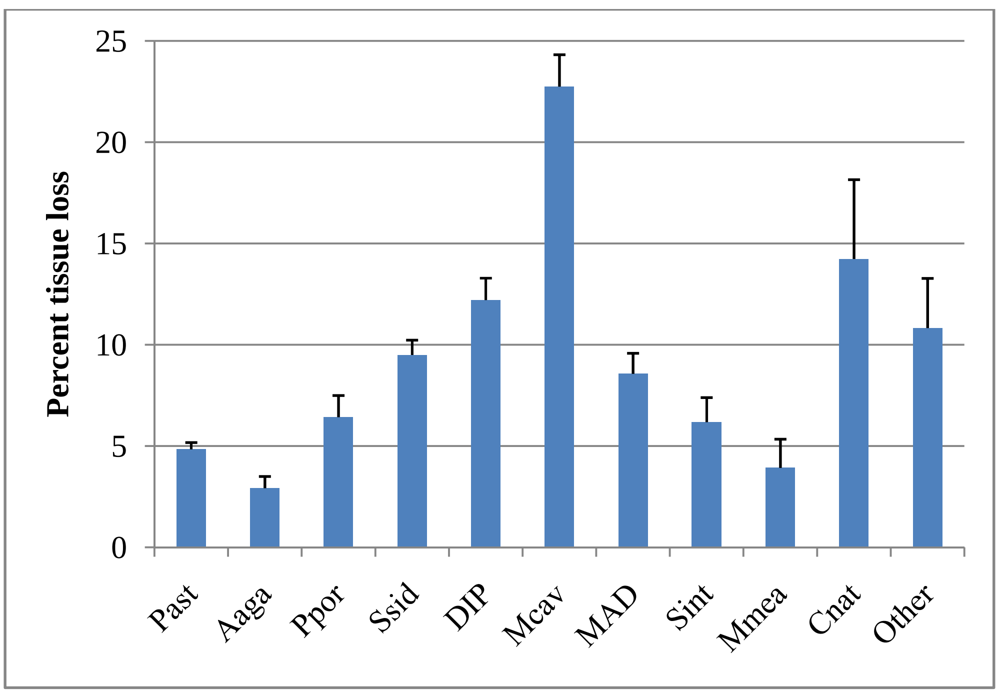


Fig. 17. Mean amount of partial tissue loss observed in the dominant functional groups of scleractinian corals, excluding *M. annularis* complex and *A. palmata*.

Coral remnants and recruits: Most locations had a high abundance of small corals, including tissue remnants and recruits. Many of the key framework builders (e.g. the larger, older star corals *Montastraea faveolata* and *M. annularis* and elkhorn corals, *A. palmata*) had died, but there were as many, if not more, large colonies of these species with living tissue remnants (e.g. 1-15 cm diameter patches of tissue on larger skeletons; Fig 18; 20; Plate 2).

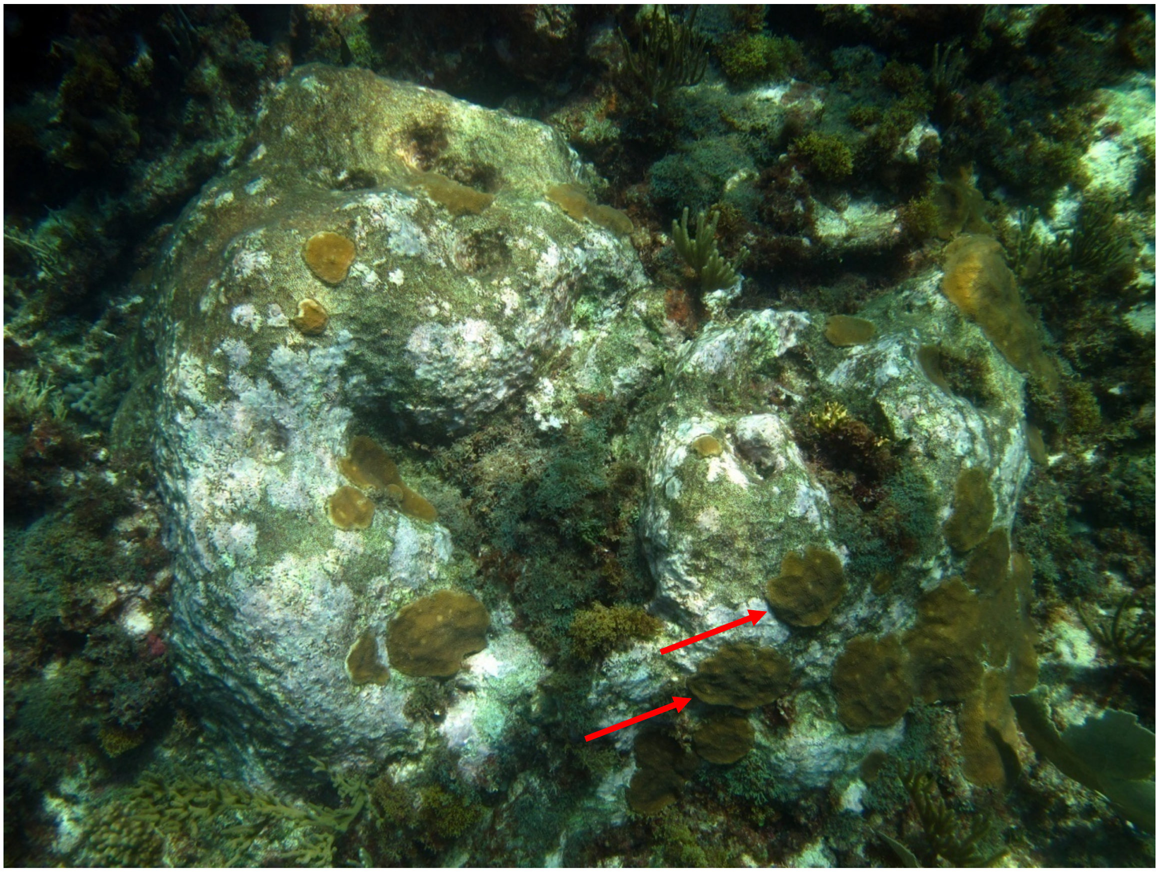


Fig. 18. Colony of *Montastraea faveolata* (mountainous star coral) that lost about 70% of its tissue. Mortality has stopped and tissue remnants are beginning to resheet, as evidenced by the upward and outward growth that is elevated off the skeleton (arrow).

Dead coral skeletons and the surrounding reef substrate supported settlement and colonization of new corals (especially mustard hill coral, *Porites astreoides*). Selected reefs had moderate levels of recruitment, dominated by *Porites* (mean=2.6 recruits/m^2), *Agaricia* (mean=2.0 recruits/m^2) and *Siderastrea* (mean=1.5 recruits/m^2), with a low abundance of recruits and juvenile (3-5 cm diameter) colonies of brain corals (*Diploria* spp., *Colpophyllia natans* and *Meandrina meandrites*), large-cupped star coral (*Montastraea cavernosa*), and flower coral (*Eusmilia fastigiata*) (Fig. 19). A large number of the recruits and juvenile corals had settled on skeletons of *A. palmata* and *M. annularis* (complex) and showed considerable growth (Fig. 21).

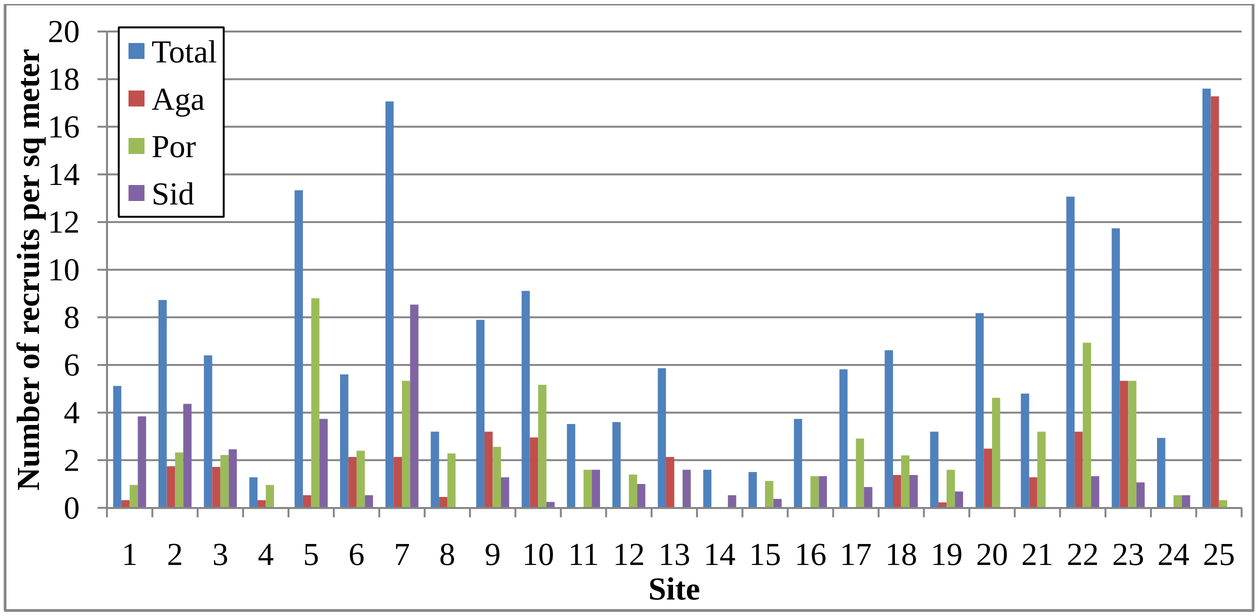


Fig. 19. Patterns of recruitment within the 25 sites. Recruits are presented as the number per sq meter for all species pooled (blue), *Agaricia* (red), *Porites* (green) and *Siderastrea* (purple).

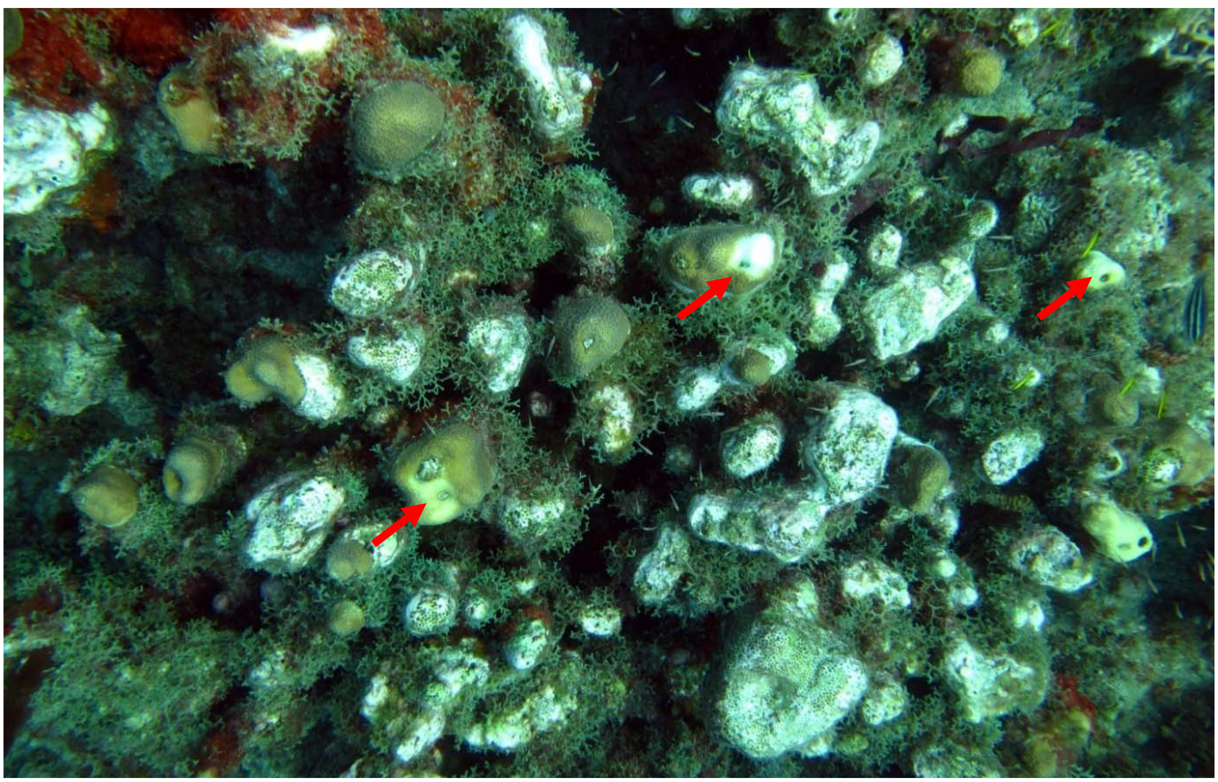
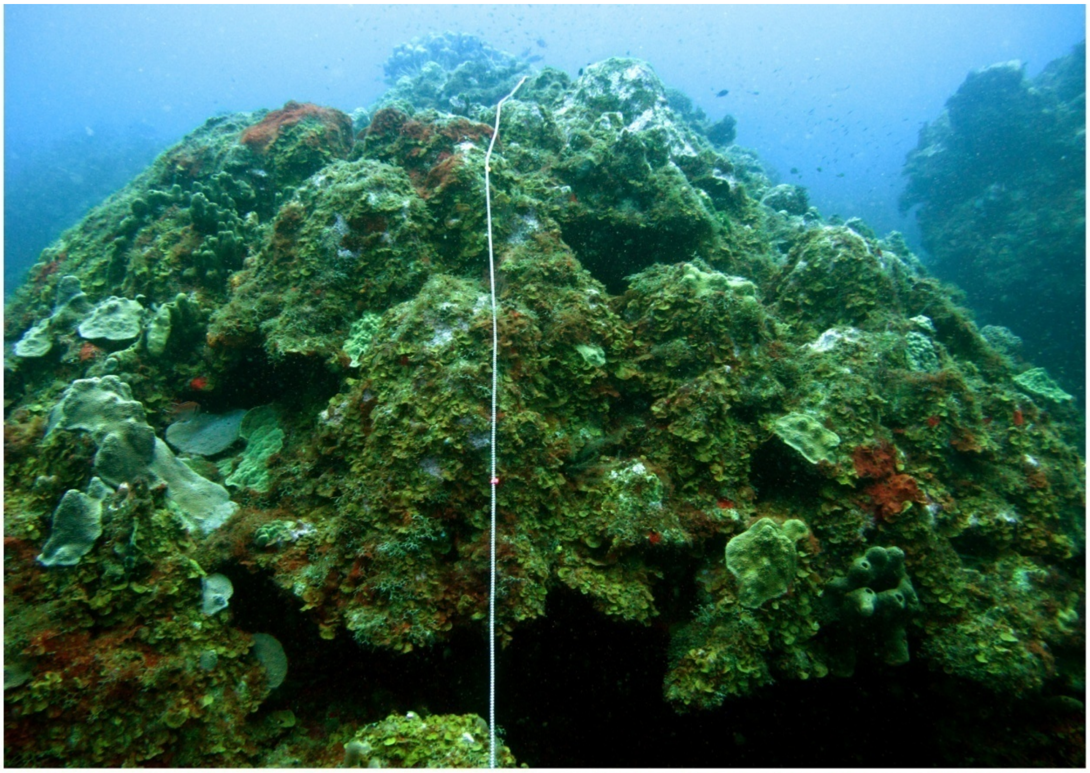


Fig. 20. Example of a lobate star coral (*Montastraea annularis*) with about 75% old mortality. A few lobes are still living, but several are partially bleached (arrows). Dead skeleton is colonized by *Dictyota* (macroalgae), crustose coralline algae and turf algae. Cyanobacterial mats are apparent in the upper right.



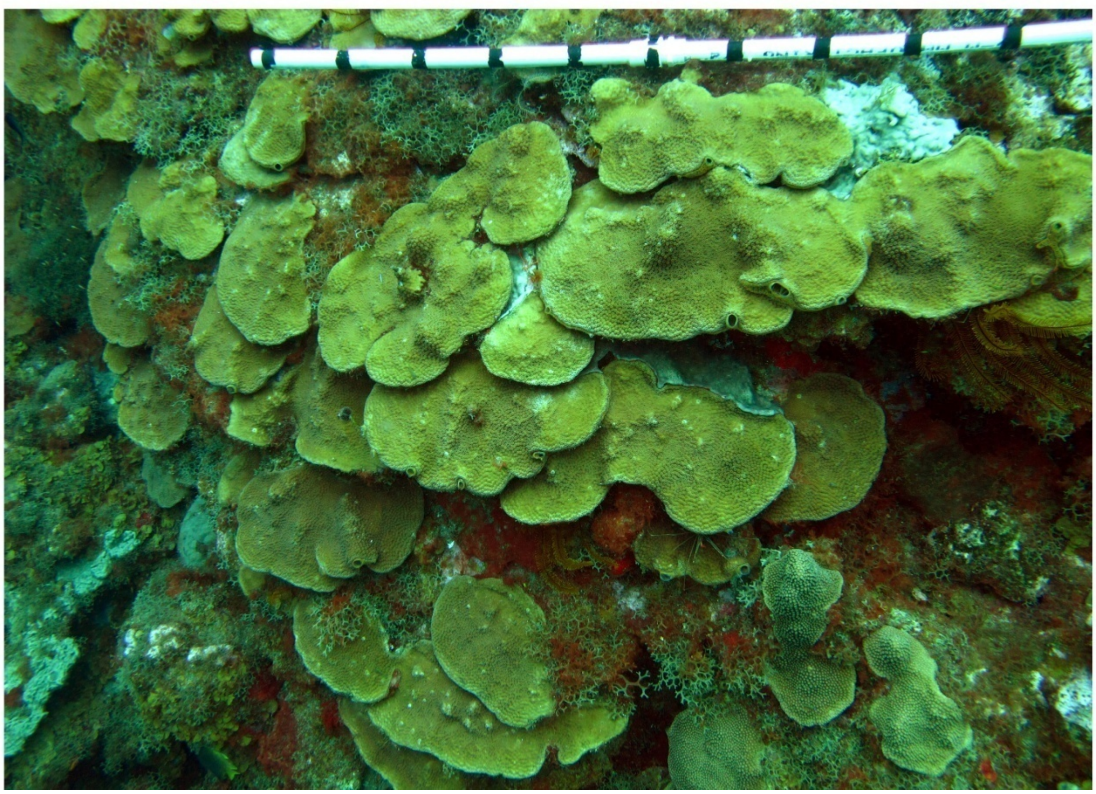


Plate 2. Site 10 was a high relief site formed by unusually large (3-5 m tall, 5-10 m wide) colonies of *M. faveolata*, most with extensive (>90%) mortality; small tissue remnants (top photo; transect line is 3 m long) and larger overlapping plates occurred on the sides (lower photo; scale bar= 1m) of some colonies.

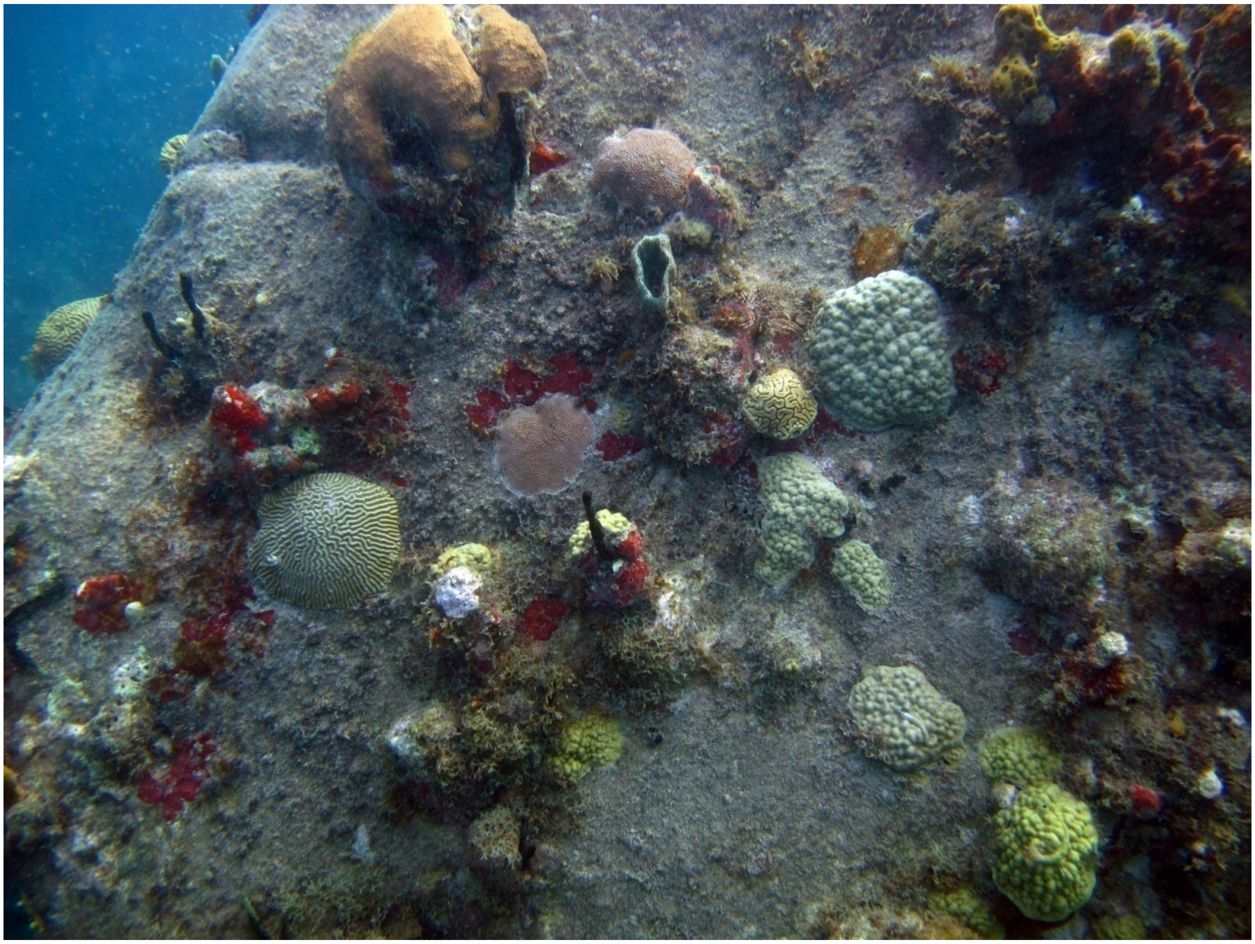


Fig. 21. Colonization of a dead *Montastraea faveolata* skeleton by other species, including *Porites astreoides, Diploria strigosa, D. labyrinthiformis, M. annularis,* and *Siderastrea siderea*.

4. Coral stressors

Corallivores: Coral eating snails (*Coralliophila abbreviata*) were identified on 40% of the reefs (n=10) at a low abundance (n=164 snails total; 19 affected corals). Affected corals had a mean of 8.8 snails/colony (sd=1.66). These were mostly small (mean size = 13 mm, sd=0.4; maximum = 44 mm), with 44% male. The largest individuals were observed on *A. cervicornis* and A. *palmata*. The size structure is shown in Fig. 23. Fireworms (*Hermodice carunculata*) were seen in low numbers, and feeding scars were noted on *A. cervicornis* and *A. palmata*.

Predation by parrotfishes (spot biting and focused biting: Fig 22) was rare, with the exception of three sites dominated by *M. annularis* and *M. faveolata* (Sites 6, 18, 19, 20). Total partial mortality attributed to fish bites was very low (<1%). A high abundance of *Stegastes planifrons* were noted at some reefs. In particular, they were abundant in reefs constructed primarily by massive boulder corals (*M. annularis* complex). Algal lawns were noted on > 1% of all corals.

Examples of corals observed with lesions caused by predators are shown in Plate 3.

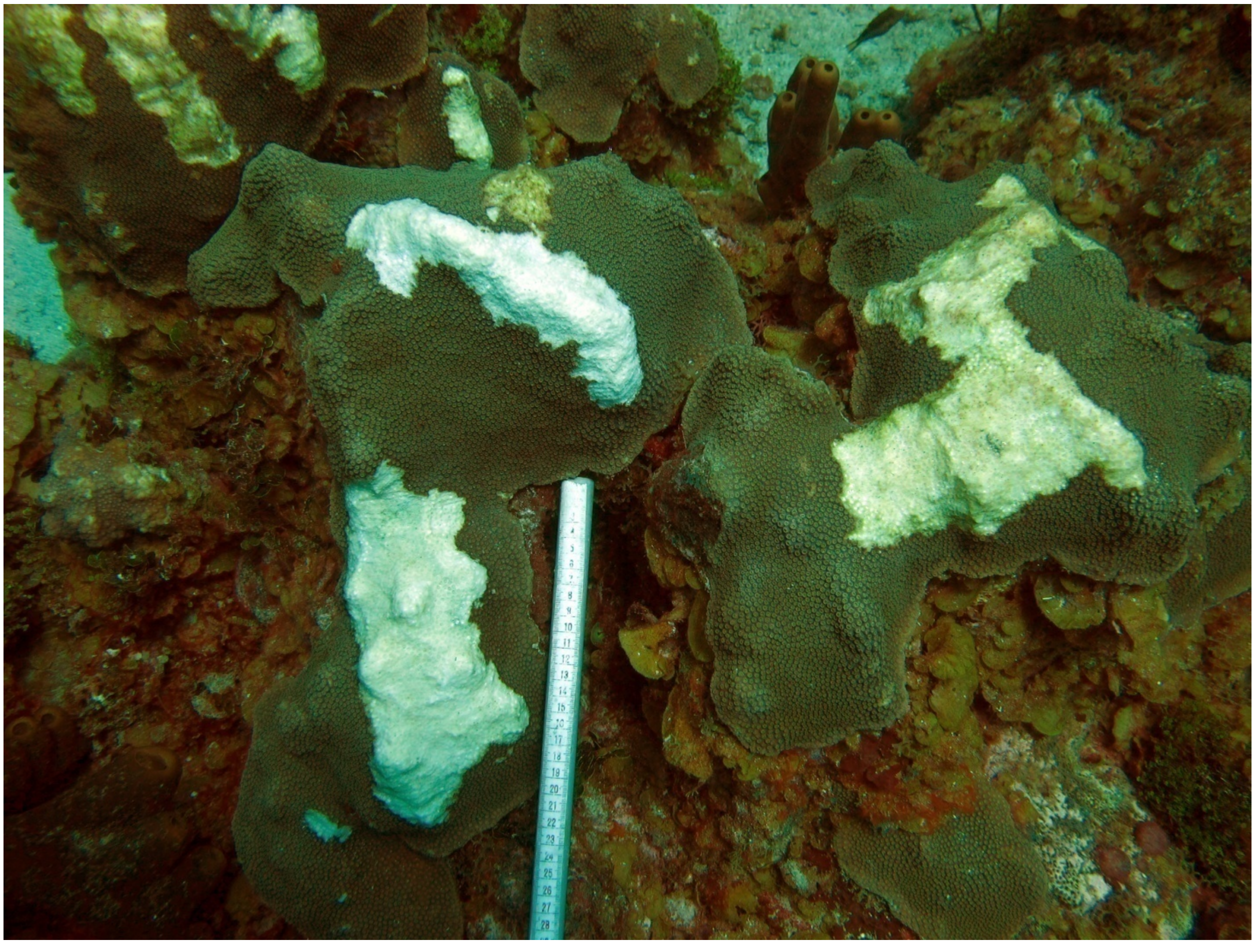


Fig. 22. Focused biting by *Sparisoma viride* on *M. faveolata*. Extensive lesions were identified on a single offshore *Montastraea* reef (site 19).

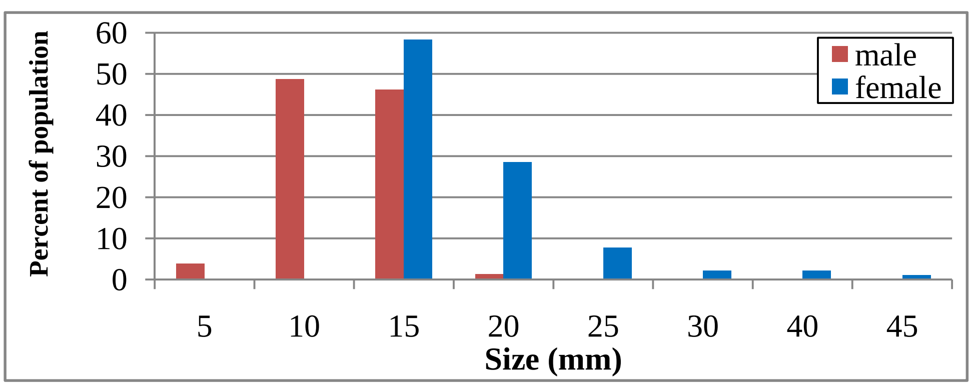


Fig. 23. Population structure of the coral eating snail (*Coralliophila abbreviata*).

Coral diseases and bleaching: Coral diseases observed in St. Kitts and Nevis included dark spots disease (DSD), yellow band disease (YBD), black band disease (BBD), white plague (WP) and white band disease (WBD) (Plate 4 and 5). In general diseases were rare; no outbreaks were observed. Dark spots disease was most common, occurring at 10 sites. White band disease was noted from a single location within *Acropora cervicornis* populations at Punch Bowl (site 15). This site also had the highest prevalence of YBD among *M. faveolata* colonies and a low prevalence of BBD affecting *Diploria strigosa* and *M. cavernosa*. YBD was also observed at 5 other sites. White plague was observed at 5 sites. The mean prevalence of all diseases (all corals and sites pooled) was 1.2% (Fig. 24). The different coral diseases observed in St. Kitts and Nevis are shown in plate 2 and 3.

A much higher proportion of colonies were showing signs of bleaching (over 6% on some reefs). While very few of these corals were bleached white, most were partially bleached or pale in color. During these surveys, waters around St. Kitts and Nevis were unusually warm for June.

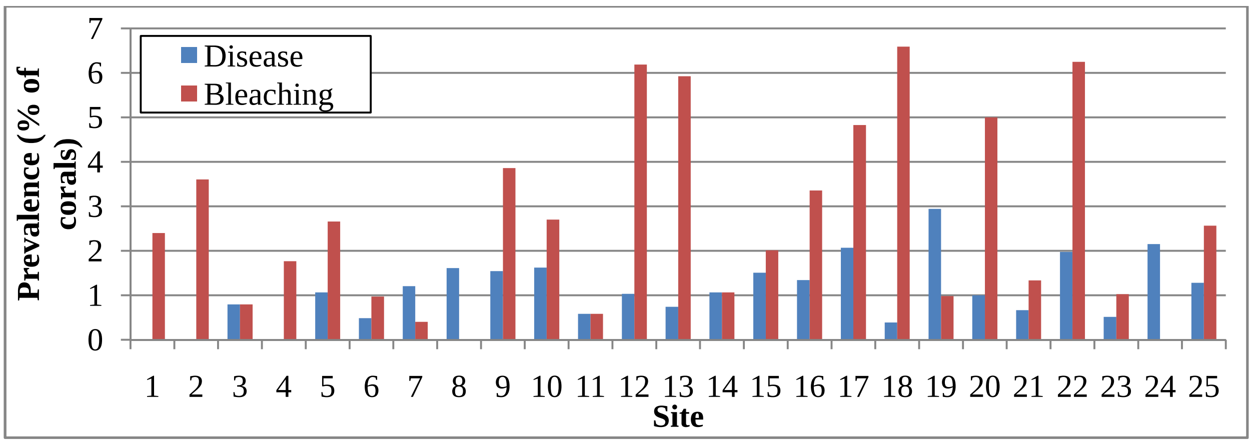


Fig. 24. Prevalence of coral diseases and bleaching by site. All diseases are pooled and prevalence is calculated as the percent of affected corals for all species 4 cm diameter or larger located within belt transects at each site.

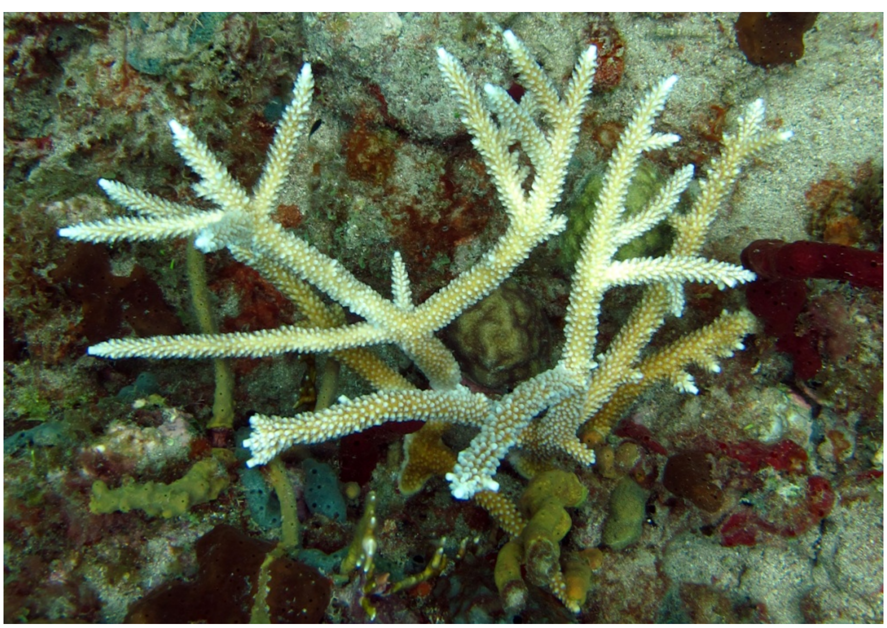


Fig. 25. Partial bleaching in *Acropora cervicornis*. The upper branches are pale, while pigmentation at the base is normal.

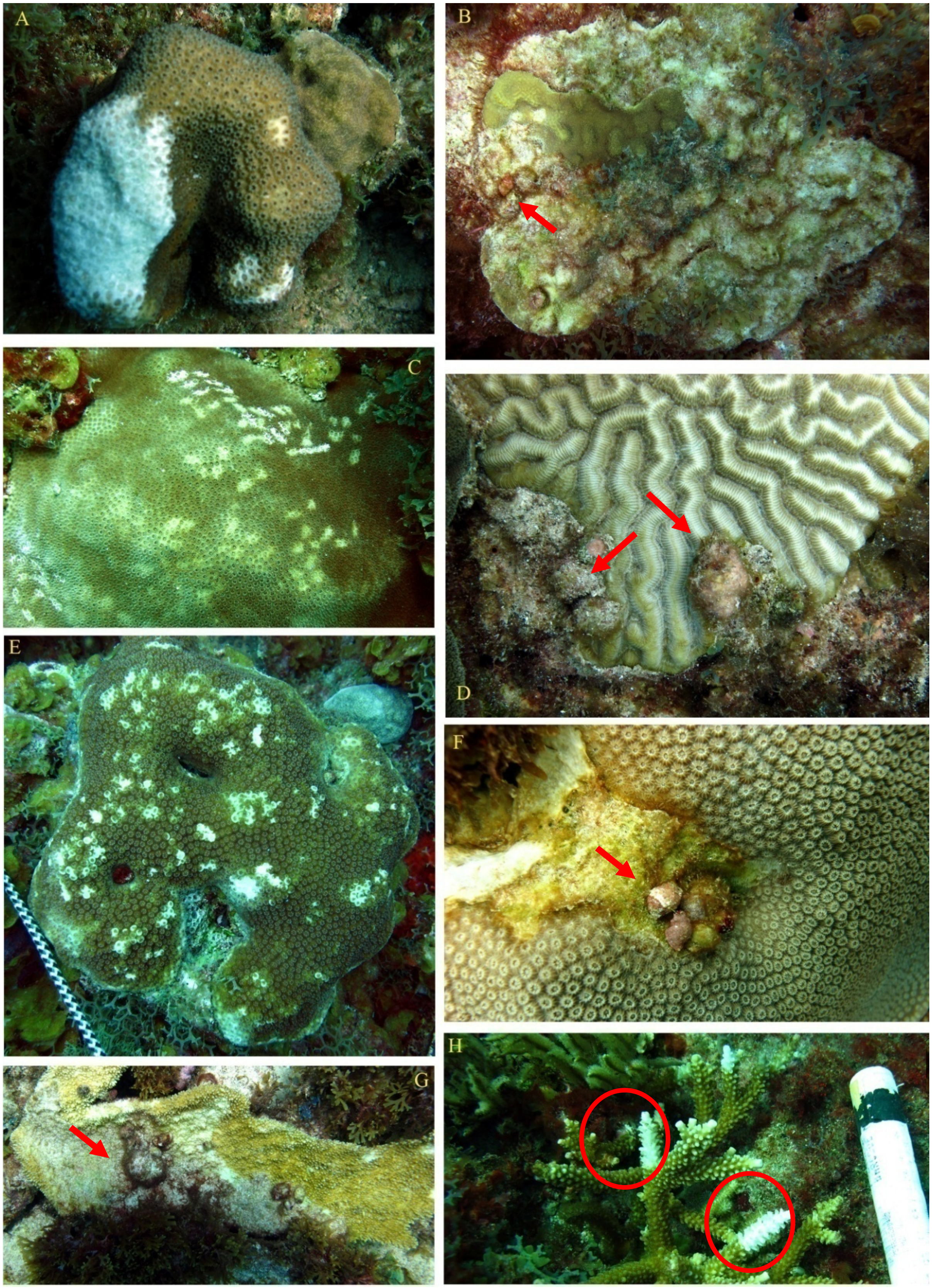


Plate 3. Signs of predation on scleractinian corals (see below for full legend).

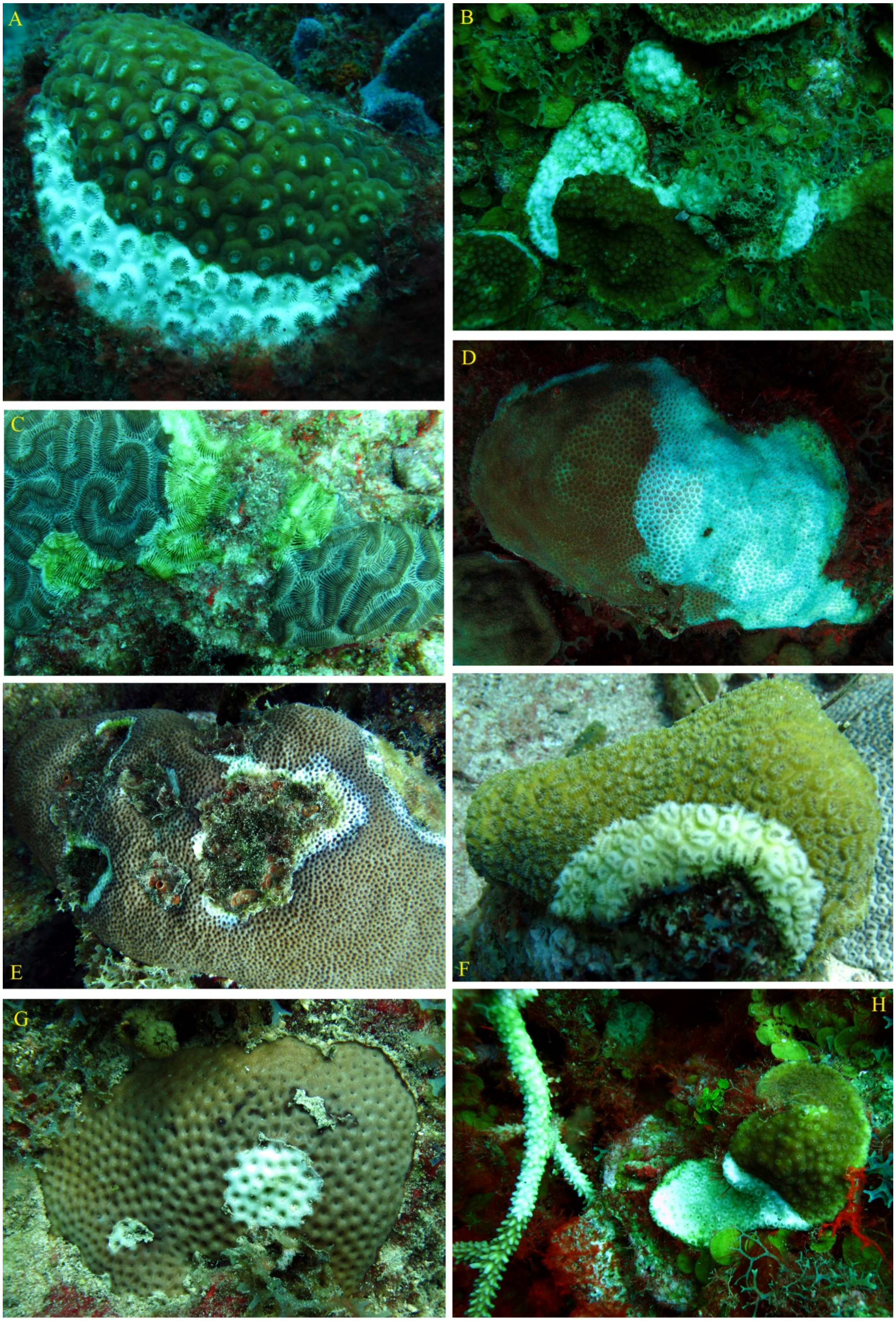


Plate 4. White syndromes on massive and branching corals.

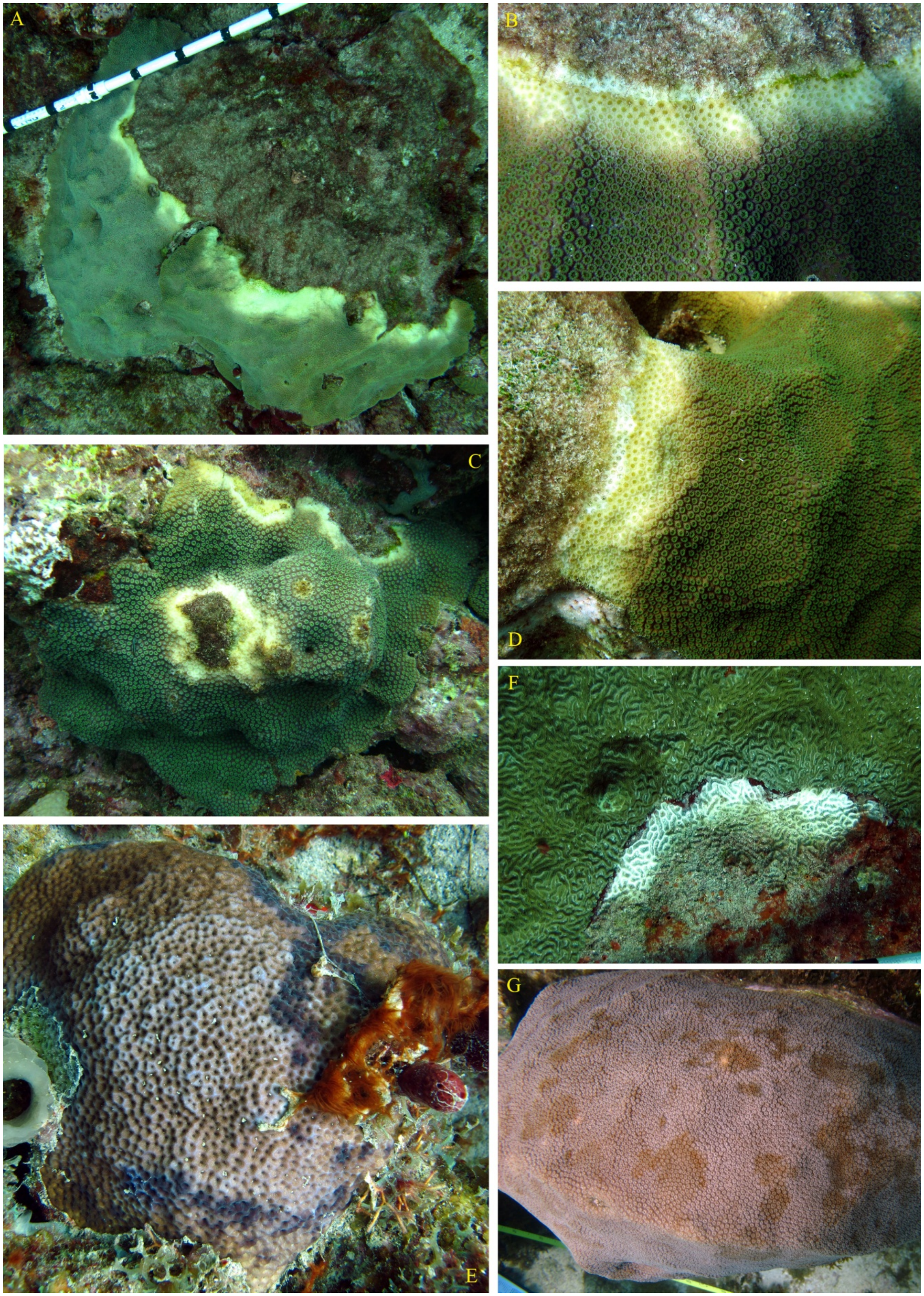


Plate 5. Various coral diseases affecting massive corals.

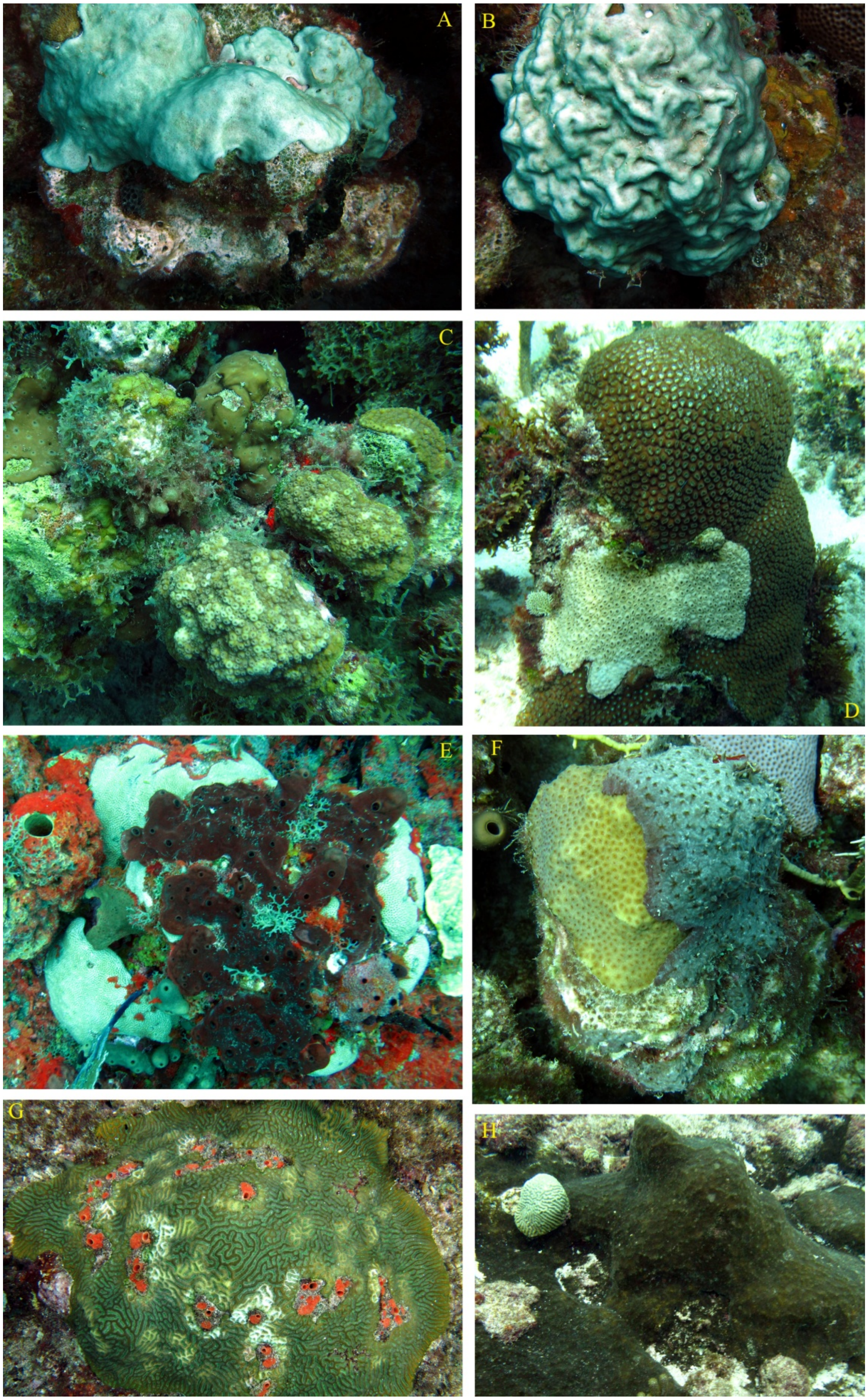


Plate 6. Examples of aggressive invertebrates that overgrow and bioerode corals.

Plate Legends

Plate 3. Signs of predation on scleractinian corals. A. Focused biting by *Sparisoma viride* on *M. annularis*. B. *Coralliophila abbreviata* snails feeding on *P. astreoides*. Approximately 60% of the colony has been consumed. C. Spot biting by parrotfish on *P. astreoides*. D. *Coralliophila abbreviata* feeding on *Diploria strigosa*. E. Spot biting on *M. annularis*. F. *Coralliophila* feeding on *M. faveolata*. G. *Coralliophila* feeding on a fragment of *A. palmata*. H. *Hermodice* fireworm scars on *A. cervicornis.*

Plate 4. White syndromes on massive and branching corals. A. White plague on *M. cavernosa*. White plague on *M. faveolata*. B. Transitional mortality on *C. natans*. A narrow band of recent mortality separates live tissue from previously denuded, algal colonized skeleton. D. Unidentified white syndrome on *Stephanocoenia intersepta*. E. White plague-like lesions on *Siderastrea siderea*. Mortality initiated in a previously killed part of the colony and is spreading outward. F. White plague on *Dichocoenia stokessi*. G. Unidentified focal lesions on Siderastrea siderea. H. White band disease -like lesion on *Acropora cervicornis*. The disease spread to the adjacent *M. faveolata* colony.

Plate 5. Various coral diseases affecting massive corals. A-D. Various cases of yellow band disease. A. Large older colony of *M. faveolata* that has lost nearly 50% of its tissue from YBD. B-C. Closeup of the typical progression of yellow band disease. Areas first affected becomes a darker color before dying. Most recently affected tissue is light to lemon yellow. Generally, recent mortality is limited to a very narrow band. D. Two lesions on a *M. faveolata* colony. The band spreads outward 1-2 cm per month. E. Dark spots disease on Siderastrea siderea. F. Black band disease *on Diploria clivosa*. G. Dark spots disease in *M. faveolata*.

Plate 6. Examples of aggressive invertebrates that overgrow and bioerode corals. A-B. *Trididemnum* tunicate overgrowing stony corals. Both corals are >95% dead. C. *Anthosigmella* sponge on *M. franksi*. D. *Palythoa* (colonial anemone) overgrowing a large cup star coral (*M. cavernosa*). E. *Ulosa funicularis* sponge growing on a bleached *S. siderea* colony. F. *Svenzea zeai* sponge overgrowing *M. annularis*. G. *Cliona delitrix (Cliona laticavicola)* boring sponge invading a *Diploria strigosa* colony. H. Mat of brown symbiotic *Cliona* spp. carpeting the reef substrate.

Other stressors affecting corals included aggressive invertebrates (plate 6). This included bioeroding (e.g. *Cliona*) and encrusting sponges (e.g. *Anthosigmella*), encrusting tunicates (*Trididemnum*), colonial anemones (*Palythoa*), gorgonians (*Erythropodium*).

Diseases were also observed on other organisms including sponges, especially colonies of *Xestospongia* (Fig. 26), and coralline algae.

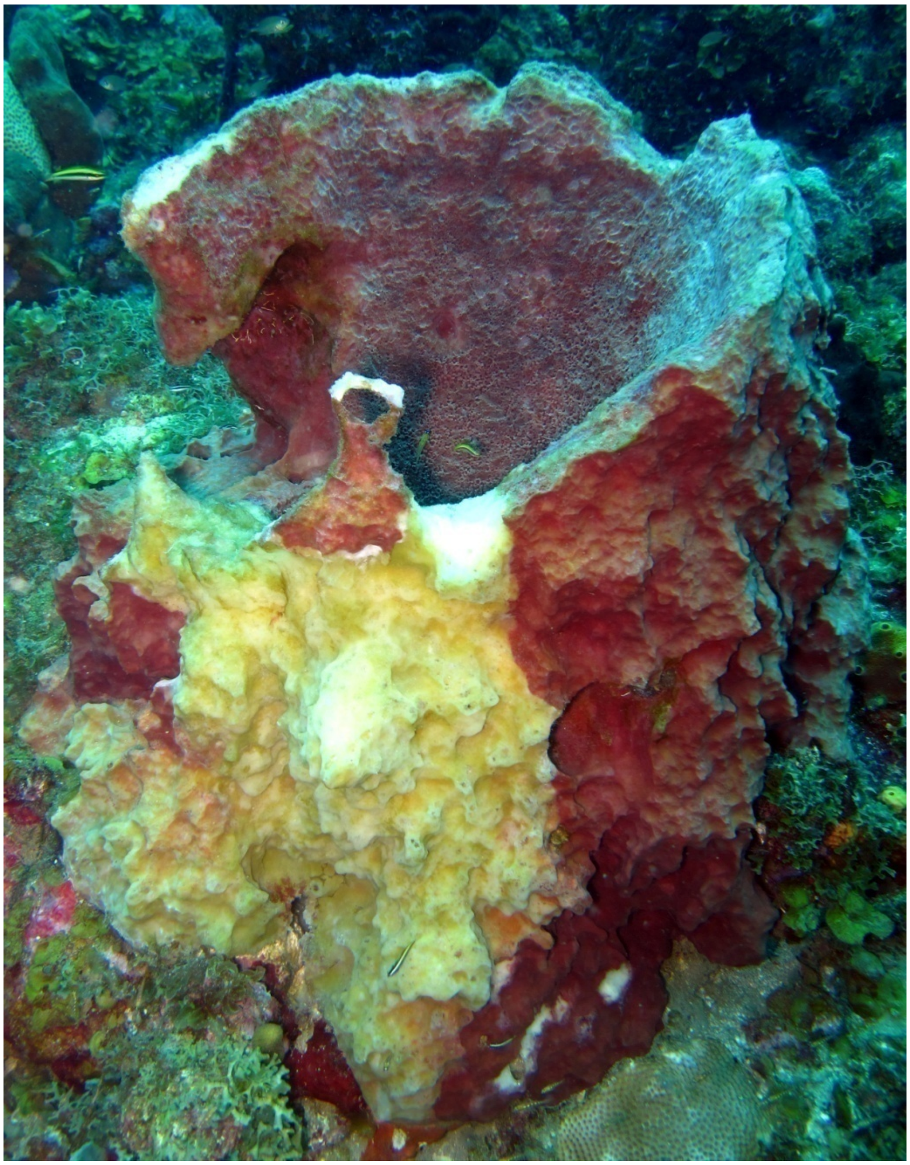


Fig. 26. Diseased *Xestospongia muta*.

5. Reef Fish

Belt transects (244 total, 30 m X 2 m) were used to assess 88 species (Appendix 1) of commercially important and ecologically relevant reef fish communities on 25 reefs in St. Kitts and Nevis. In general, reef fish communities exhibited a low diversity, abundance and density, and biomass (Fig 27; Appendix 3).

All species of snappers, groupers and other top predators were extremely rare. A single shark (nurse shark), southern stingray (n=8) and several (n=4) spotted eagle rays were observed outside of the transects. In total, 264 seabasses were observed (1.8 fish/100 m^2), predominantly consisting of coney (*Cephalopholis fulva*, 55%), graysby (*Cephalopholis cruentata*, 30%) and red hind (*Epinephelus guttatus*, 13%) and a single larger black grouper (*Mycteroperca bonaci*). Snappers (0.43 fish/100 m^2) were dominated by mahogany snapper (*Lutjanus mahogoni*, 66%) and yellowtail snapper (*Ocyurus chrysurus*, 26%). Only two barracuda and 34 bar jack (*Caranx ruber*) were recorded.

Second level predators were dominated by grunts, with the highest abundance of tomtates (*Haemulon aurolineatum*, 43%, 3.2 fish/100 m^2) and French grunts (*Haemulon flavolineatum*, 26%, 1.9 fish/100 m^2). Wrasses were also rare, with exception of the yellowhead wrasse (*Halichoeres garnoti*, 77%, 1.5 fish/100 m^2) and a low density of Spanish hogfish (*Bodianus rufus*, 16%, 0.3 fish/100 m^2).

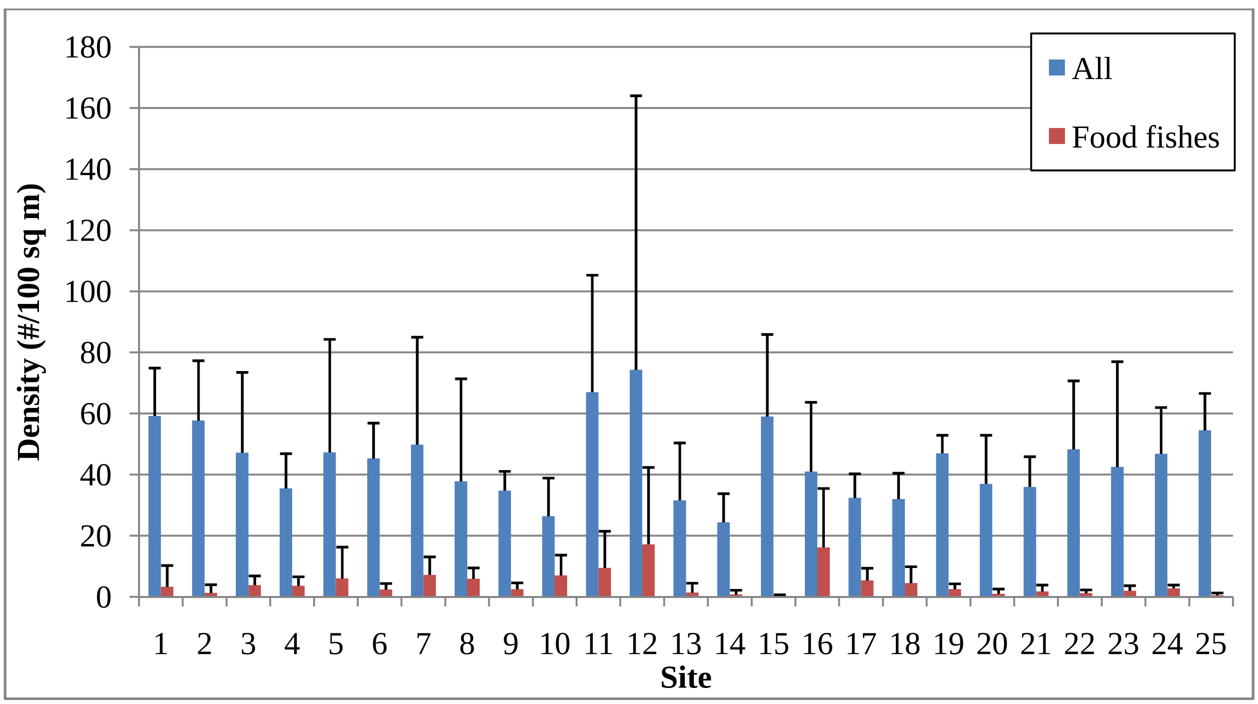


Fig. 26. Density of reef fishes (number of fish per 100 sq m) observed at each site. Blue bars represent all AGRRA species pooled and red bars are commercially valuable food fishes.

While some reefs had fairly high numbers of parrotfish, these were generally juveniles and initial phase fish, with few large terminal phase males. The other important herbivorous fishes, the surgeonfishes, also generally occurred as individuals or in very small schools (Table 3), with populations dominated by the ocean surgeonfish (*Acanthurus bahianus*, 71% of surgeonfishes, 8.8/ fish/100 m^2) and blue tang (*Acanthurus coeruleus* 28%, 3.5 fish/100 m^2), and few doctorfish (*Acanthurus chirurgus* 1%, 0.1 fish/100 m^2) (Fig. 27). The long-spined black urchin (*Diadema antillarum*) was also notably absent from most reefs.

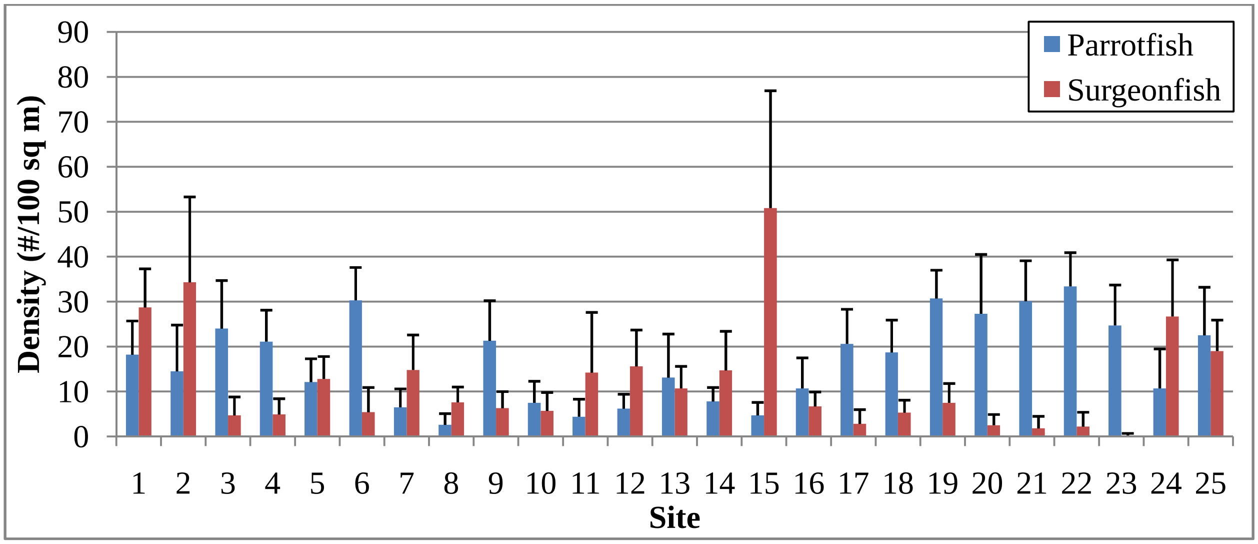


Fig. 27. Density of the two key groups of herbivorous reef fishes (# fish per 100 sq m) observed at each site. Blue bars include 10 species of parrotfishes and red bars are three species of surgeonfishes.

Species	Common name	Density	% of total
Scarus coelestinus	Midnight Parrotfish	0.0	0.2
Scarus coeruleus	Blue Parrotfish	0.0	0.0
Scarus guacamaia	Rainbow Parrotfish	0.0	0.2
Scarus iseri	Striped Parrotfish	7.2	40.9
Scarus taeniopterus	Princess Parrotfish	2.1	12.1
Scarus vetula	Queen Parrotfish	0.4	2.4
Sparisoma atomarium	Greenblotch Parrotfish	0.3	1.5
Sparisoma aurofrenatum	Redband Parrotfish	4.4	24.9
Sparisoma chrysopterum	Redtail Parrotfish	0.1	0.8
Sparisoma radians	Bucktooth Parrotfish	0.0	0.0
Sparisoma rubripinne	Yellowtail Parrotfish	0.1	0.5
Sparisoma viride	Stoplight Parrotfish	1.9	10.8

Table 3. Density (#/100m^2) of parrotfish observed on 25 reefs in St. Kitts and Nevis.

In addition to a low abundance of most reef fishes, most fish were small in size (6-20 cm total length). A total of 10 parrotfish (0.4%) and 1 grouper (0.4%) were 40 cm or larger in length. Less than 5% of all fish were 31-40 cm in length, while 22% of the grunts and seabasses and 13% of the parrotfishes and snappers were 21-30 cm in length (Fig. 28). The populations were primarily dominated by juveniles (and initial phase parrotfish) with few new recruits and few large adults and terminal phase parrotfishes. In addition, there was a total absence of snapper and seabass recruits and very few grunt recruits (8%).

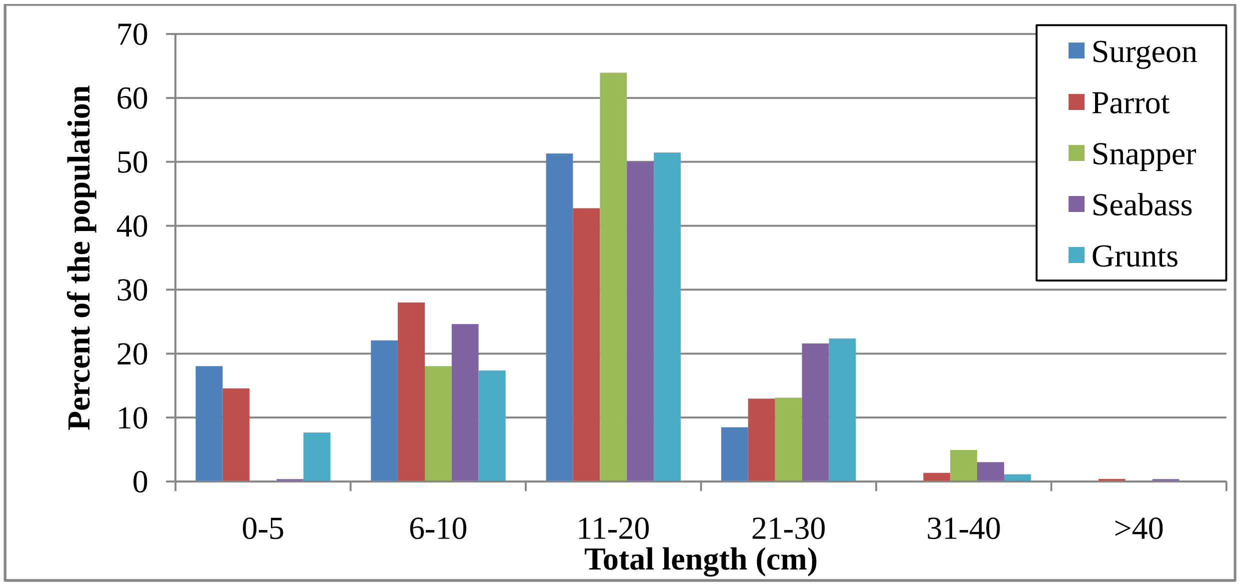


Fig. 28. Size (total length) of reef fish recorded along transects on 25 reefs in St. Kitts and Nevis.

Human Impacts: Fishing gear was noted on most reefs, including derelict traps, lost hooks and monofilament line and numerous small fishing boats were seen in each bay (Fig. 29). One derelict fishing trap, which had been on a reef for several months contained 22 fish, each fish was small (15-30 cm total length), and the catch consisted of 4 doctorfish, 1 schoolmaster snapper, 1 red hind and 15 stoplight parrotfish.

Invasive lionfish were noted in several locations, but numbers were fairly low (<2/reef).

Fig. 29. Antillean Z fish trap deployed on a reef in St. Kitts.

6. Comparisons among locations

An analysis of population trends of corals and reef fishes was undertaken to determine the factors affecting the occurrence and abundance of reef communities, and if the condition (health) varied among locations. Initial factors examined included: 1) Site variations; 2) depth; 3) windward vs. leeward reefs; and 4) reef type (e.g. *Acropora* framework vs. *Montastraea* reef).

Statistical analysis of the fish and coral transect survey data was performed using PRIMER v6 (Clarke and Gorley 2006). The fish data was examined looking at the abundance of grunts, parrotfish, seabass, snappers, surgeonfish and damselfish. The coral data was examined looking at 23 species groups. Data was square root transformed before analysis in order to prevent data skewing due to high abundances of one or two taxon. The Bray-Curtis similarity index (Bray and Curtis 1957) was used to determine similarity among sites based on abundance of fish group (functional group, family, etc.). Habitat variables (site, island grouping, exposure, depth and habitat type) were analyzed to determine which factors were responsible for differences in fish and coral composition among sites in St. Kitts and Nevis. Transects were averaged by site and analyzed again for the same habitat variables (excluding site). Variation in fish and coral composition with respect to habitat variables was tested using a 1-way Analysis of Similarity (ANOSIM) (Table 4). Non-metric multidimensional scaling (NMDS) was used to provide a visual summary of the Bray-Curtis similarity matrix. By projecting all variables onto x and y axes, an MDS plot helps illustrate which points are close to one another and which are distant. Thus the physical distance of points on the plot illustrates their relative distance in the dataset.

Table 4 – ANOSIM results for fish and coral abundance data. Analysis results based on data were transects were averaged by site are indicated by "(grouped)" label. Results in bold have MDS plots included in this report.

Data	Factor	p	R
coral	site	0.001	0.587
coral	island	0.023	0.138
coral	**exposure**	**0.001**	**0.396**
coral	**depth**	**0.001**	**0.219**
coral	**habitat**	**0.001**	**0.298**
coral (grouped)	island	0.165	0.147
coral (grouped)	**exposure**	**0.001**	**0.560**
coral (grouped)	**depth**	**0.027**	**0.235**
coral (grouped)	**habitat**	**0.001**	**0.479**
fish	site	0.001	0.491
fish	island	0.039	0.060
fish	**exposure**	**0.001**	**0.379**
fish	**depth**	**0.001**	**0.201**
fish	**habitat**	**0.001**	**0.415**
fish (grouped)	island	0.134	0.139
fish (grouped)	**exposure**	**0.001**	**0.506**
fish (grouped)	**depth**	**0.019**	**0.238**
fish (grouped)	**habitat**	**0.001**	**0.537**

The coral (Fig. 30) and fish (Fig. 31) group composition varied significantly with exposure, depth and habitat type with both transect data and averaged site data (4). While island grouping was found to be significant with the transect data, it was not significant with the averaged site data. This is mainly due to unbalanced sampling at the two islands.

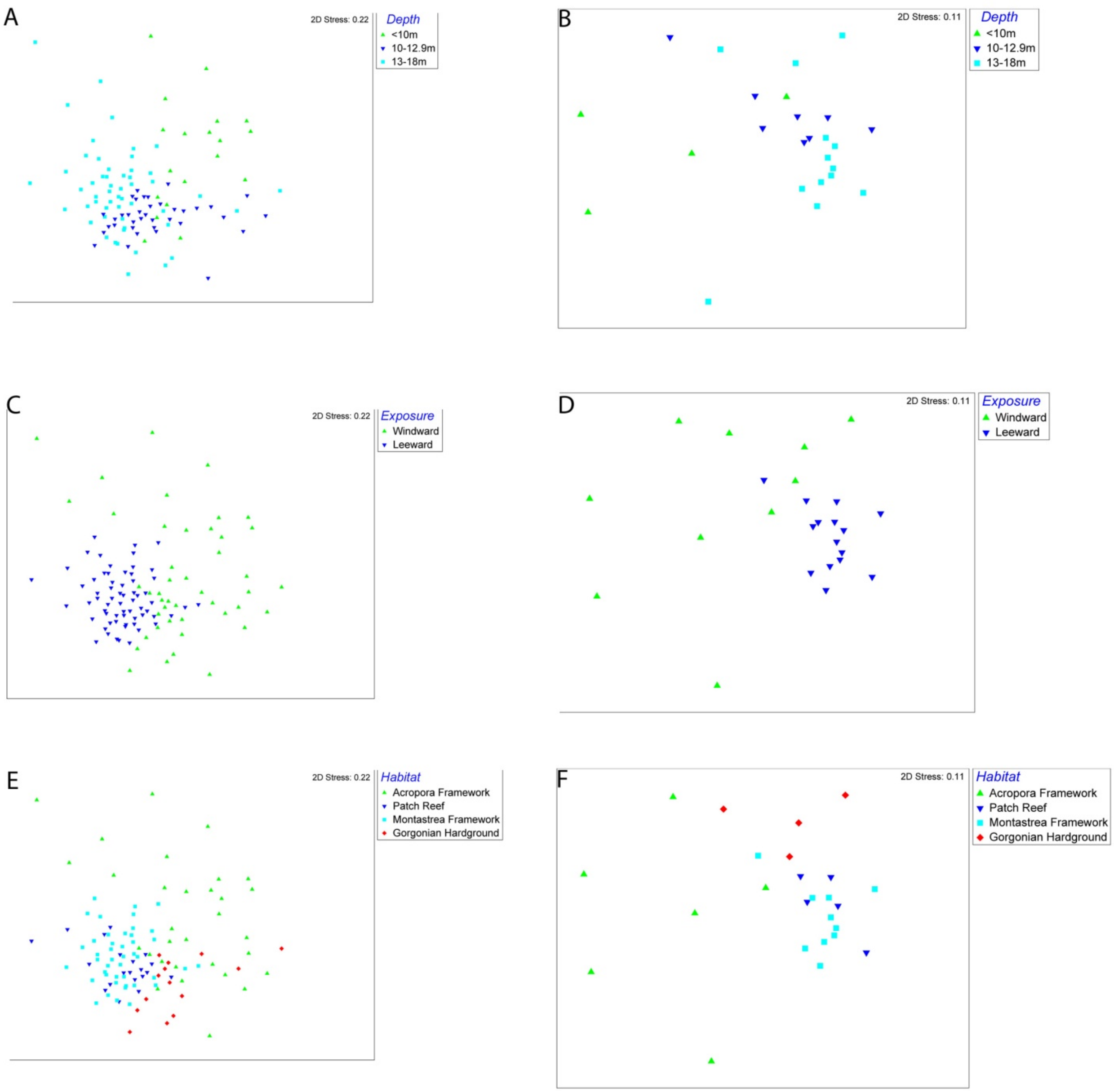


Fig. 30. Nonmetric multidimensional scaling (NMDS) of coral composition in St. Kitts and Nevis. Each dot represents a transect (left figures, A, C, E) or each dot represents a site (transects averaged) (right figures, B, D, F). Comparisons are between depths (A, B), exposure (C, D) and habitat type (E, F).

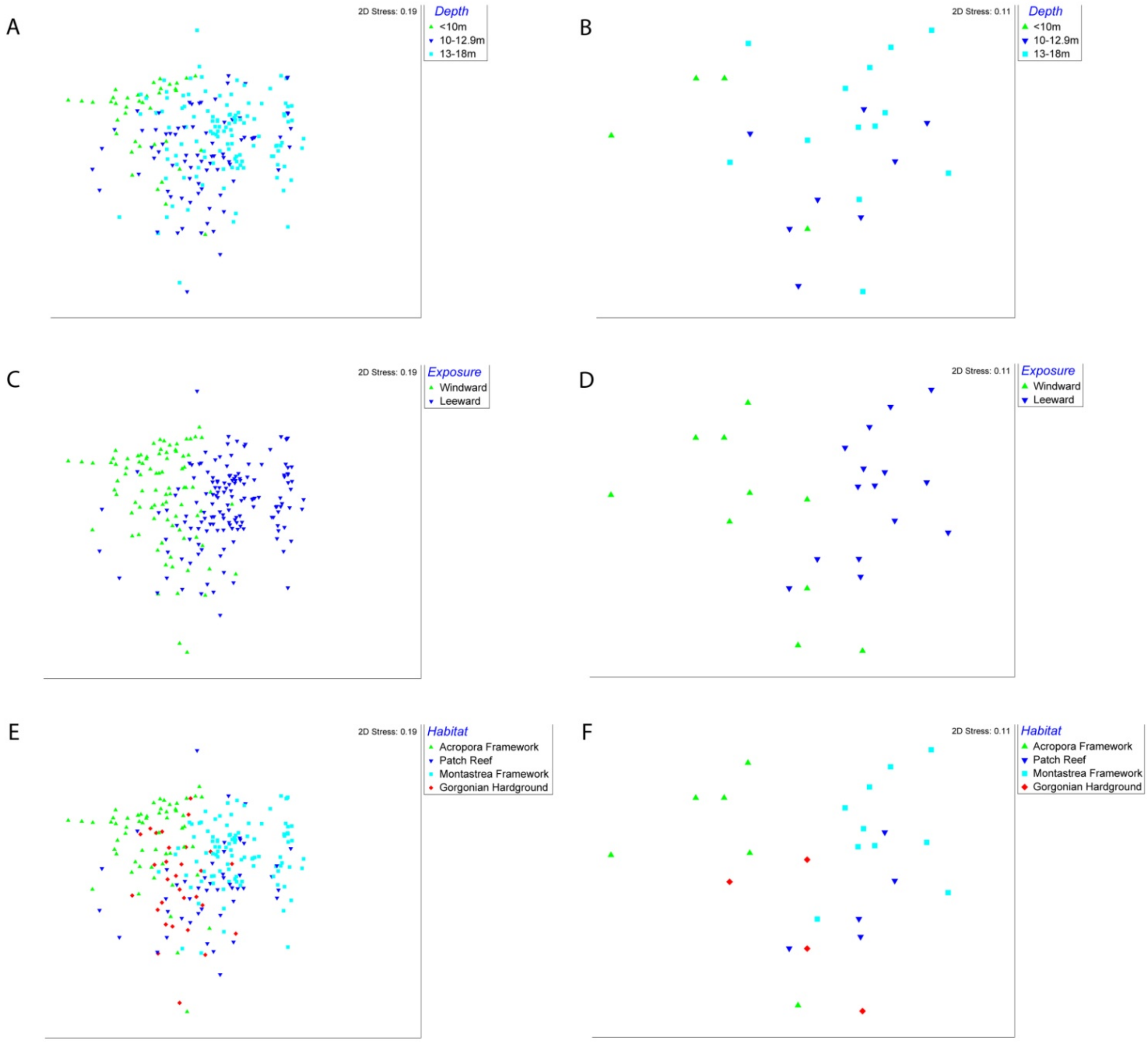


Fig. 31. Nonmetric multidimensional scaling (NMDS) of fish composition in St. Kitts and Nevis. Each dot represents a transect (left figures, A, C, E) or each dot represents a site (transects averaged) (right figures, B, D, F). Comparisons are between depths (A, B), exposure (C, D) and habitat type (E, F).

An effort was made to distinguish sites based on basic percent cover parameters using PRIMER v6 (Clarke and Gorley 2006). The average percent cover of dead coral, live coral, macroalgae, turf algae, crustose coralline algae (CCA), cyanobacteria and aggressive invertebrates was entered in for each of the 25 sites surveyed around St. Kitts and Nevis. Data was square root transformed before analysis in order to prevent data skewing due to high abundances of one or two variables. The Bray-Curtis similarity index (Bray and Curtis 1957) was used to determine similarity among sites based on the percent cover of the biologic variables. The three factors examined were distance from shore, distance from Basseterre and depth.

Factor	**p-value**	**R - value**
Distance from shore	0.035	0.225
Distance from Basseterre	0.329	0.032
Depth	0.013	0.270

Table 5. Similarity among sites for percent cover data.

While both distance from shore and depth are found to be significant factors in determining differences among the sites, the R-value for both is low (Table 5). This indicates that these two factors are either not strongly influencing these sites, or that the variables used in the analysis were too coarse.

7. Resilience assessment

A select group of biological and environmental resilience indicators were used to characterize and compare the resilience of the 25 reefs examined in this study. These include: 1) substrate quality; 2) biotic cover of algal functional groups; 3) aggressive invertebrates; 4) coral diversity and cover; 5) coral mortality; 6) recruitment; 7) relief (Fig. 32); 8) herbivore abundance. The specific parameters used included the following negative resilience indicators: cover of rubble, macroalgae, aggressive invertebrate, cyanobacteria, dead coral, and partial colony mortality. Positive resilience indicators included: relief, cover of live coral and crustose coralline algae, density of recruits, density and size of parrotfish and acanthurids. All data were ranked on a scale of 1 to 5 and a resilience index was calculated (Fig. 33; 34).

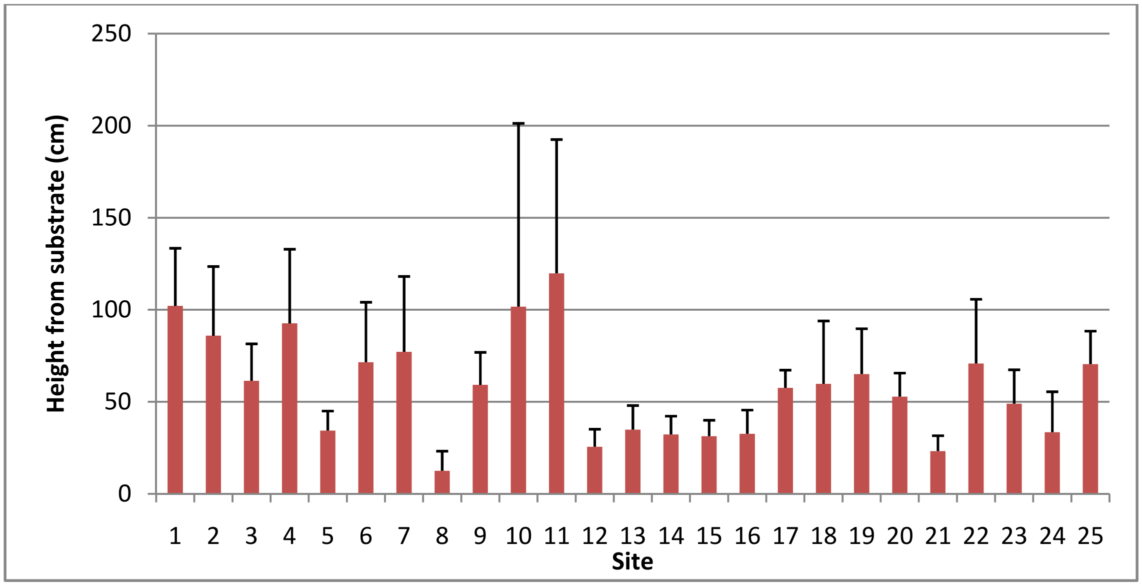


Fig. 32. Estimated relief at each site. Relief weas determined by measuring the height from the reef substrate to the top of the corals, with a minimum of 30 measures per site.

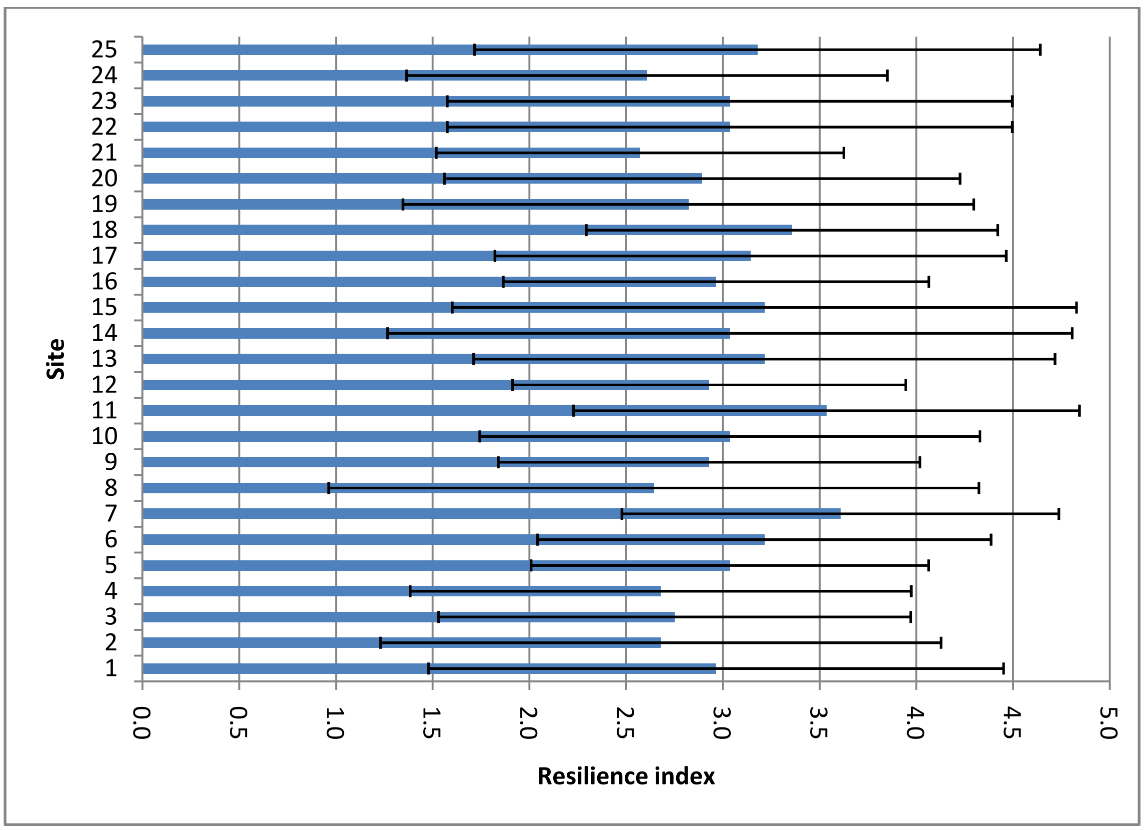


Fig. 33. Cumulative resilience index score calculated from 14 resilience indicators.

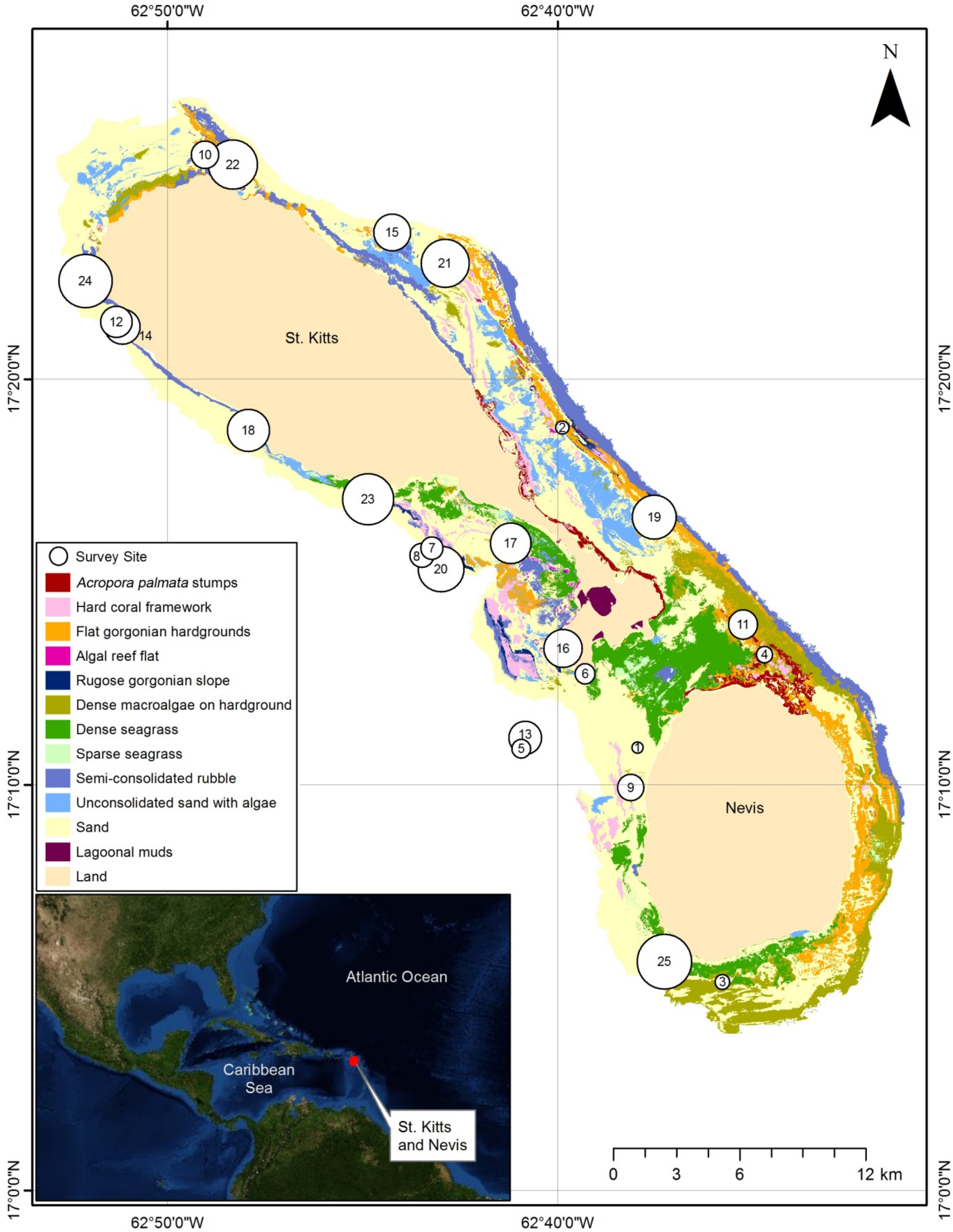


Fig. 34. Survey sites renumbered from lowest reslience (1, smallest circle) to highest resilience (25, largest circle).

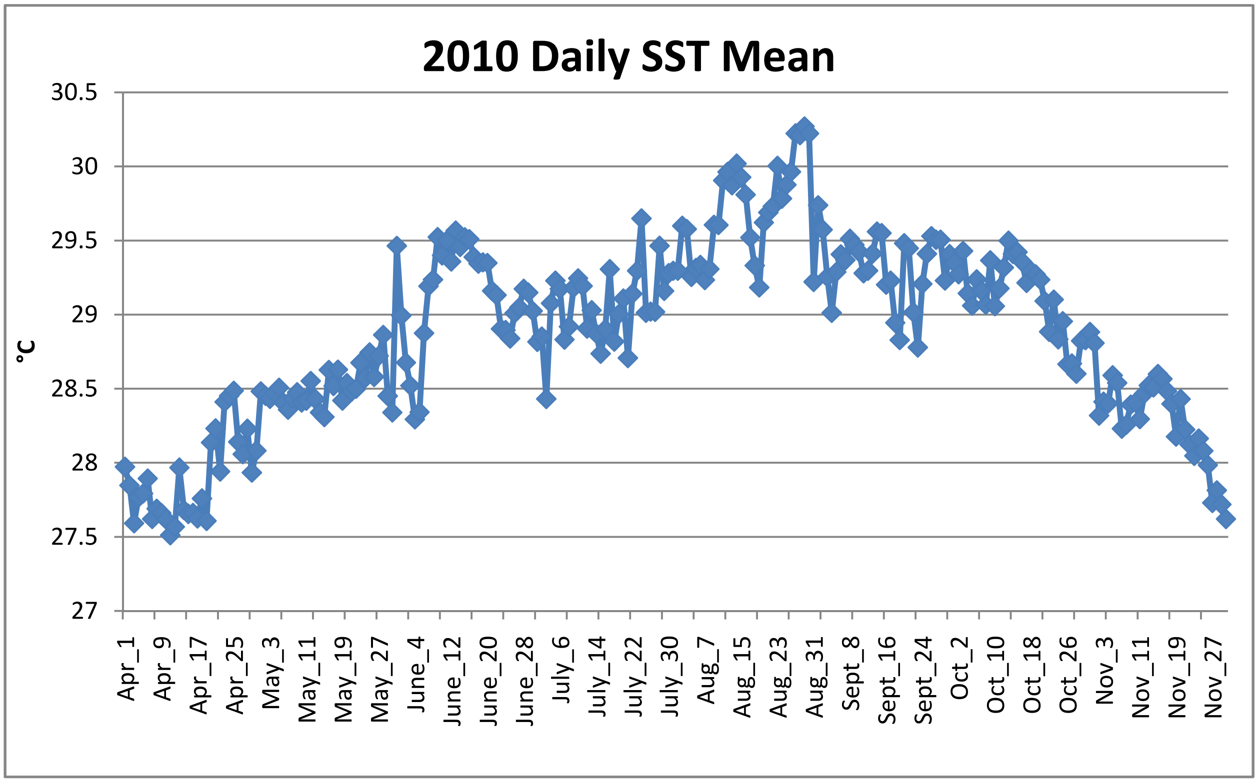
Discussion

1. General observations: St. Kitts and Nevis is surrounded by extensive coral reef habitat and contains several offshore reef communities. These included reefs with a diverse geomorphology as well as extensive hardground habitats colonized by gorgonians. Reef habitats contained numerous threatened reef-building species. Coral cover in most locations was very low and showed evidence of extensive old mortality (presence of dead coral skeletons) that occurred several decades ago (e.g. elkhorn coral skeletons in growth position) and more recently (mortality of massive corals, possibly following the 1998 and 2005 bleaching events). In contrast, recent mortality was minimal. In general, the reefs with the highest cover occurred on the leeward side of the island, including sites in close proximity to the most densely populated area. While these reefs still contained healthy populations of coral, they may be highly vulnerable to future impacts, as several indicators of resilience (high herbivory, low cover of fleshy algae, high cover of crustose coralline algae, high recruitment, good water quality) were very low.

2. Past disturbances: Evidence of several particularly severe past disturbances was visible, although most locations were showing promising signs of recovery. These reefs, like other locations in the Caribbean, were affected by severe bleaching events in 1998 and 2005, periodic damage from hurricanes, and disease outbreaks and other acute events. Nearshore reefs also appear to be subjected to chronic stressors including sedimentation from dredging and coastal development, input of nutrients and pollutants (especially on reefs adjacent to populated coastlines), and intensive fishing pressure. Characteristic signs of degradation included reefs with extensive stands of dead corals still in growth position, high abundances of fleshy macroalgae, cyanobacterial mats covering the substrate, shifts in community assemblages from coral dominated systems to encrusting sponge, tunicate and soft coral communities, low species diversity, low abundances and small sizes of reef fishes, and depleted populations of commercially important reef fishes, lobster and conch.

3. Stresses: During our reef assessments, water temperatures were extremely high. A pocket of warm water was sitting over the eastern Caribbean, causing reef temperatures to exceed 29° C and occasionally reach 30°C; 27-28° C is normal for this time of year. Interestingly, water temperatures were slightly warmer in 2010 than in 2011, but the temperature started out warmer in 2010 and increased more slowly (Fig. 35 a). In 2011, the temperature was lower at the beginning of the year, increasing by over 2° C in a period of about a week (Fig. 35 b). As a result of the sudden temperature spike, corals began to show signs of stress and large proportion of the corals had begun to bleach. There were no stark white corals, but the perimeters of the colonies and the edges of corallites were white, certain species had turned pale blue, and others were light yellow, instead of their normal dark brown or green coloration.

A.



B.

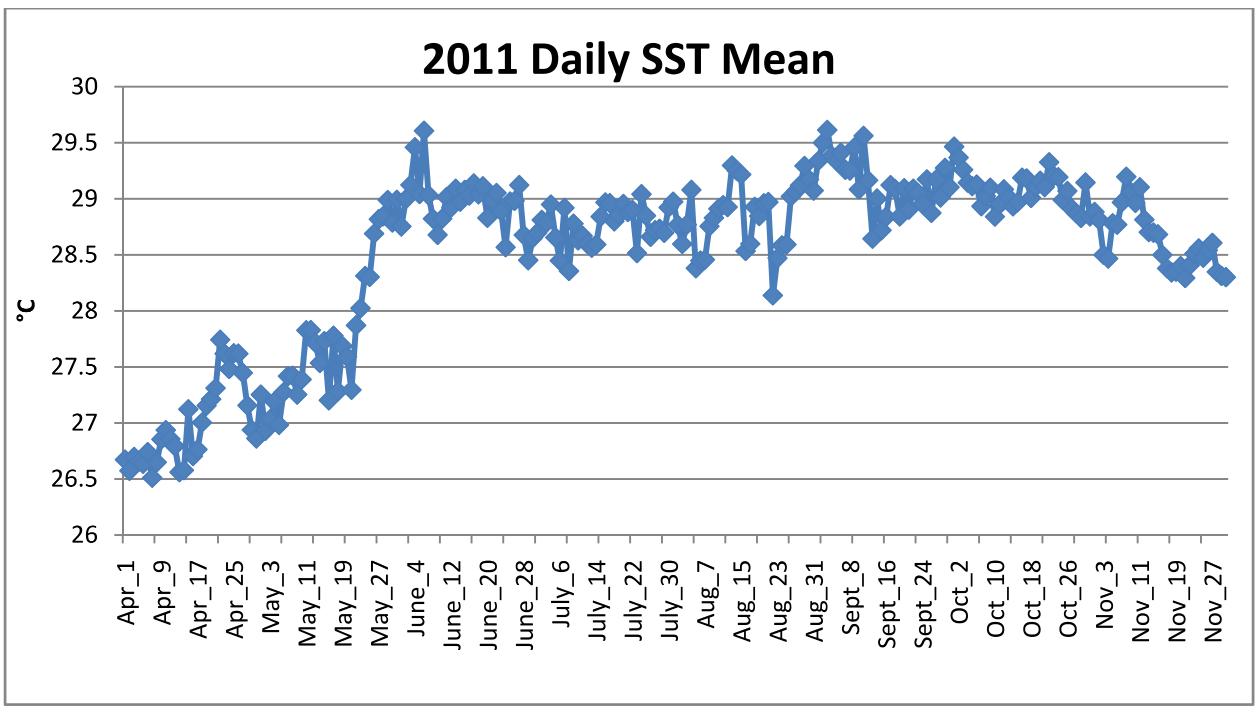


Fig. 35. Sea surface temperature (SST) data for St. Kitts and Nevis (pooled for all locations at 11 km resolution) during 2010 (top) and 2011 (bottom). Data courtesy of NOAA.

Several diseases were noted on our surveys, including black band disease, white plague, dark spots disease and yellow band disease. This time of year is usually the period when disease prevalence increases, but most cases of disease were fairly minor – colonies had small (2-5 cm) patches of white exposed skeleton. In fact, there was not a single colony seen with a severe infection of white plague, which is something that I have seen on every other reef system I have examined over the last 10 years. On certain reefs (e.g. Dieppe Bay), many of the remaining larger colonies of mountainous star corals had prominent yellow band disease lesions, but these were older infections that first appeared 1-3 years ago, as evidenced by the extensive patches of denuded skeleton (this disease kills corals at rates of 1-2 cm per month as compared to 1 cm per day for white plague).

4. Endangered species: In an area known as Grid Iron (on the Atlantic side of Nevis and St. Kitts), there is an extensive elkhorn coral framework that was predominantly dead, having lost most of the *Acropora palmata* over 30 years ago (Fig. 36). The presence of dense thickets of dead corals, still in normal upright growth position, suggests this mortality event was from white band disease (WBD) and not hurricane damage or other factors. WBD is the primary factor responsible for a mass die-off of this species throughout the wider Caribbean over a period of about a decade (1979-1990), and in most locations this species is now considered critically endangered. The presence of isolated sexual recruits, small, completely live colonies (10-30 cm diameter) with protobranches, surviving remnants on larger elkhorn coral skeletons, and surviving fragments is indicative of early stages of recovery of this species. However, several of these colonies were being impacted by predators (*Coralliophila abbreviata*, coral-eating snails) and algal lawns associated with damselfish territories.

Fig. 36. Dead elkhorn coral stand typical for the Iron Shore. This stand was located east of the Narrows in 5 m depth. Dead colonies in the distance are in growth position.

A shallow reef in the northwest corner of the island, near Dieppe Bay, was also constructed of dead standing elkhorn corals and collapsed, fused elkhorn rubble. Many of these skeletons were extensively colonized by brain corals and other species, some which were estimated at 20 years or older. There was also a high number of sexual recruits of elkhorn coral and juvenile elkhorn coral colonies in excellent health.

The closely related staghorn coral (*Acropora cervicornis*) was extremely rare throughout St. Kitts and Nevis. During the first half of the mission a single colony was identified off Nevis, and one on a deeper dive on the northern coast of St. Kitts in the Atlantic. At Dieppe reef, this coral appeared to be successfully recolonizing the reef, with an abundance of small colonies in shallow water and some medium to large (15-50 cm diameter) colonies in deeper water, all of which were in excellent condition. A legacy site was established on this reef to follow growth of these colonies, and determine if the reef develops thickets as were commonly seen 30 years ago (Fig. 31).

Fig. 37. Example of a healthy staghorn coral colony (*Acropora cervicornis*) within the Legacy Site.

5. Resilience: With exception of a few sites, most reefs exhibit a high potential to rebound from past impacts, but persistence of these reef systems hinges on the successful development and implementation of new management measures for fisheries, marine zoning, and steps to address runoff, siltation and land-based pollution. On nine reefs, the substrate quality is good – prominent encrustations of pink crustose coralline algae covering 10% or more of the bottom were found under the macroalgae. These reefs still contain a moderate amount of live coral (10-15% cover) dominated by a diverse assemblage of small corals in excellent health. There were moderate levels of recruitment of many of the important reef building corals. Reefs still a high number of small colonies of lobate and mountainous star coral, both surviving tissue remnants that were actively growing and juveniles that had colonized these reefs in the past 5-10 years. Because corals consist of colonies of animals, small patches of live tissue can continue to grow upward and outward and it may resheet over the original skeleton, if conditions are conducive to growth. Several deeper reefs were characterized by a dominance of the third species of star coral, boulder star coral (*Montastraea franksi*), and large sheets of scroll coral (*Agaricia lamarcki*), both in good condition. The presence of rare and endangered elkhorn coral and

staghorn coral on the windward Atlantic reefs, including newly settled sexual recruits, tissue remnants and fragments that were rapidly growing, and the occasional larger adult colony, provides a glimpse of the high potential for recovery of these species.

On an extensive reef track off the northwestern end of Nevis, corals were primarily small in size (3-15 cm diameter) with extensive patches of dead coral rubble between these colonies (Fig 38). This rubble had higher numbers of recruits than anywhere else we examined and more species of recruits were represented (Fig. 39). Much of the rubble was unstable, which usually is not conducive to coral settlement, yet the corals settled and were growing. Overall this site ranked lowest in terms of resilience.

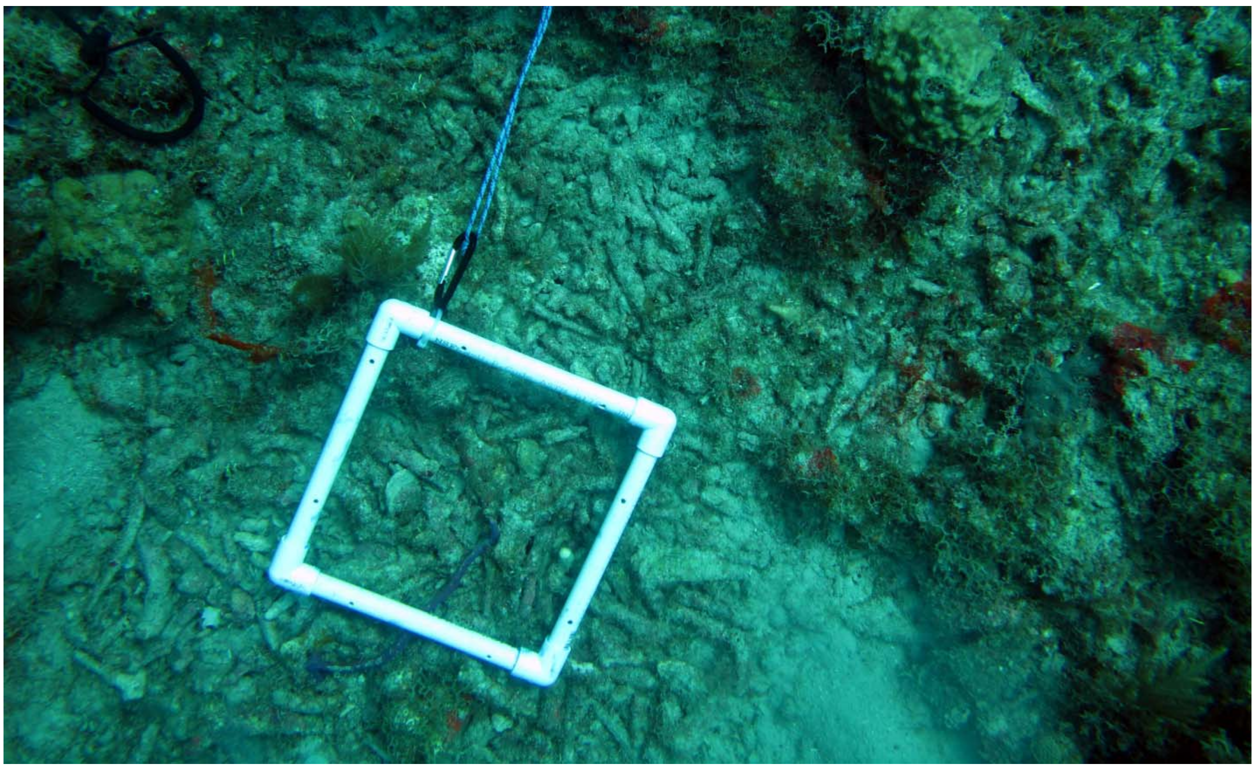


Fig. 38. Accumulations of rubble at site 21.

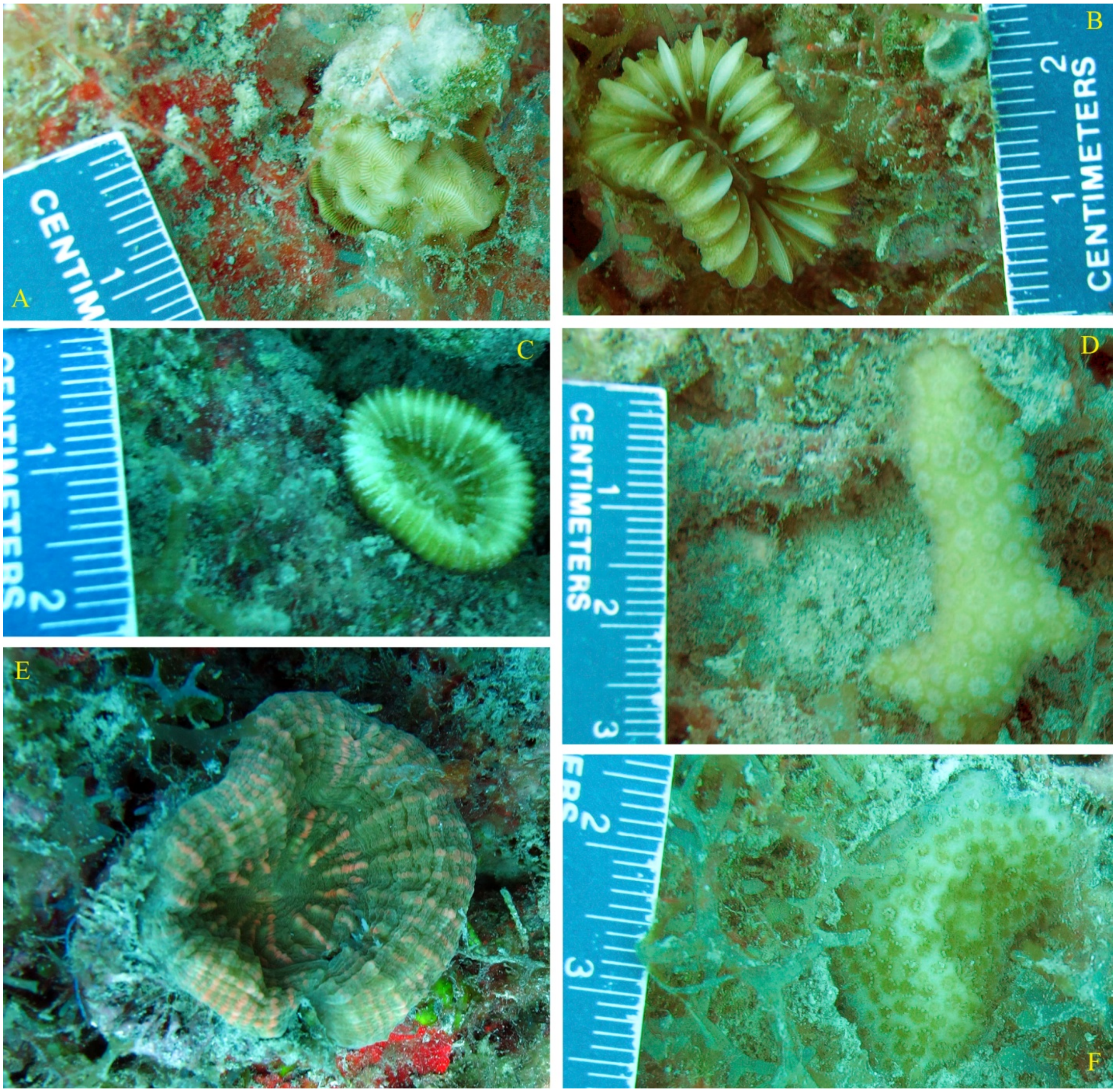


Fig. 39. Recruits observed at site 21. A. *Agaricia agaricites*; B. *Eusmilia fastigiata*; C. *Manacina aereolata*; D. *Madracis mirabilis*; E. *Mussa angulosa*; F. *Porites astreoides*.

Recommendations

Increase herbivory

Reef substrates and coral skeletons were covered by dense growth of fleshy seaweeds (macroalgae), especially on reefs located on the leeward (western) side of the island. In most locations cover exceeded 50%. A key herbivore, the long spined black sea urchin (*Diadema antillarum*) has not recovered to any significant level on any reef examined (Fig. 40). Only a few isolated sea urchins were seen. Other important herbivores, namely acanthurids (surgeonfishes) and parrotfishes, were at very low abundances and biomass. Schools of acanthurids were absent; these fish, when present occurred as single fish or in small aggregations of 5-10 fish. Parrotfish populations were dominated by juvenile and initial phase fish, with few large terminal phase fish seen. The most common fish observed in fish traps, however, were parrotfishes.

Recommendation: It is recommended that the fishing of herbivorous reef fish species on St. Kitts and Nevis coral reefs be controlled and managed to a sustainable level to enhance herbivory and control the proliferation of macroalgae. Further exploration of shallow habitats should be undertaken to determine if there are any large populations of Diadema.

Fig. 40. ***Diadema antillarum*** **were rarely observed during these assessments. A few sites had isolated individuals.**

Improve habitat quality

Reefs located close to the coastline, adjacent to developments, tended to have the lowest cover of crustose coralline algae. The reef substrates in these areas were carpeted with macroalgae. Mats of filamentous red cyanobacteria covered hard substrates, dead corals, and sediment patches and often occurred on top of the macroalgae. In places, these cyanobacteria were overgrowing living corals. Cyanobacteria was absent on offshore locations and on windward reefs. Crustose coralline algae is known to be a cue for coral larvae; larvae are unable to settle and survive in areas with dense growths of algae.

Recommendation: It is strongly recommended that St. Kitts and Nevis invest in sewage treatment facilities to improve water quality and increase the resilience of its valuable coral reefs. It is also recommended that a water quality monitoring program be established to document sources of nutrient inputs and determine the relationship of these with the condition of the substrate.

Establish coral nurseries

In several locations around the Caribbean (e.g. Florida, USVI, Bahamas, Belize, Dominican Republic), coral nurseries are being established to culture corals for transplantation to degraded reefs. The most successful and promising efforts involve the growth of elkhorn coral (*A. palmata*) and staghorn coral (*A. cervicornis*), two endangered corals that once were highly abundant. St. Kitts and Nevis have extensive elkhorn coral habitat on the windward sides of the islands. Most of these areas contain remnants of elkhorn coral forestes dense assemblages of dead skeletons in growth position. These contain isolated live colonies. Because the colonies are so rare, there is a very limited potential for successful reproduction and recolonization relies on external sources of larvae which may not exist. Staghorn coral is also extremely rare, although this coral also once was abundant in several locations as evidences by dead accumulations of branches and small surviving colonies. Rebuilding elkhorn coral populations on windward reefs is critical to health of the coral reefs, as these provide key habitat for fishery species, and these corals will help build reef strucutres and provide a barrier to storm waves, protecting vulnerable coastlines.

Recommendation: Several protected locations adjacent to coral reefs and in nearshore locations on the leeward side of the islands should be designated as coral nursery areas. Small fragments of elkhorn coral and staghorn coral should be transplanted onto artificial substrates, maintained and propagated in these locations. Once colonies reach an adequate size and abundance, they should be transplanted onto the reefs, in locations they formerly occurred.

Establish a monitoring program

Prior to the surveys conducted during this research mission, there were very few data available on the condition of coral reefs in this region, or the threats affecting their health. Scientific knowledge forms the basis for management. Without reliable information on the coral reefs of St. Kitts and Nevis, it is very difficult to understand future changes to these reefs or to determine the most appropriate strategies to enhance their conservation.

Recommendation: a coral reef monitoring program should be established to track changes that occur to the reefs, determine the impacts of future disturbances, and validate the improvements resulting from new management and conservation strategies.

Marine Zoning

The coral reefs of St. Kitts and Nevis are extremely valuable, providing critical ecosystem services, jobs, revenue through tourism, and food. In some cases these reefs may be affected by conflicting uses such as fishing and dive tourism. Human activities threaten the survival of these ecosystems, especially activities such as unsustainable fishing, use of destructive fishing gear, coastal development, and runoff. Many of these exhibit a unique structure or contain threatened corals. Detailed habitat maps have been developed for the shallow marine habitats and the spatial distribution of fishing effort has been characterized. The current study identified and examined the most valuable coral reef areas surrounding the islands.

Recommendation: a portion of all representative reef types and associated shallow habitats should be established as marine protected areas and other areas zoned for different uses to minimize human impacts and maximize benefits obtained from these resources.

Reduce unsustainable fishing

Reef fish populations throughout St. Kitts and Nevis were dominated by juveniles and small adults, and many of the key fishery species were absent or extremely rare. In addition, other species that are critical to the health of the reefs were also uncommon. The use of certain non-selective gear, such as gill nets and fish traps may be placing considerable pressure on fish populations by removing non-preferred species (e.g. butterflyfish, angelfish, doctorfish, squirrelfish, grunts, wrasses etc.) and by capturing fish at too small a size to allow them to reach reproductive maturity.

Recommendation: A review of existing fishery management strategies should be undertaken. Measures to reduce the take of juveniles and non-target species, and closed seasons during the reproductive period for economically valuable species should be considered. In particular, fishing of predatory fish species should be managed to a sustainable level to prevent increases in populations of prey fish (e.g damselfish) capable of modifying the reef habitat.

References

Bray, J. R. and J. T. Curtis. 1957. An Ordination of the Upland Forest Communities of Southern Wisconsin. Ecological Monographs 27:326-349.

Clarke, K. R. and R. N. Gorley. 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Lang, J., K.W. Marks, P. A. Kramer, P. Richards Kramer & R.N. Ginsburg. 2010. AGRRA Protocols Version 5.4. online at http://www.agrra.org/method/methodhome.html

Morton Anthony. 2010. Letter of engagement submitted to KSLOF regarding the Government of St Kitts and Nevis's interest in participation in the Caribbean *Global Reef Expedition: Science Without Borders*® program.

Obura, D.O. & G. Grimsdith. 2009. Resilience Assessment of coral reefs – Assessment protocol for coral reefs, focusing on coral bleaching and thermal stress. IUCN working group on Climate Change and Coral Reefs. IUCN, Gland, Switzerland. 70 pages.

Raymundo, L.J., C.S. Couch, A.W. Bruckner, C.D. Harvell, T.M. Work, E.Weil, C.M. Woodley, E. Jordan-Dahlgren, B.L. Willis, G.S. Aeby & Y. Sato. 2008. Coral disease handbook: Guidelines for assessment, monitoring and management. CRTR, Australia. 131 pp

Appendix I. List of participants.

Name	Affiliation
Thierry Beths	Ross University School of Veterinary Medicine
Chris Biggs	The Nature Conservancy
Jeanne Brown	The Nature Conservancy
Graeme Browne	Ministry of Sustainable Development
Andy Bruckner	Living Oceans Foundation
James Byrne	The Nature Conservancy
Nick Dupre	St. Kitts National Trust
Brooke Gintert	University of Miami/RSMAS
Daniel Green	The Nature Conservancy
Emma Grigg	Ross University School of Veterinary Medicine
Tony Hall	Ross University School of Veterinary Medicine
Jerry Mitchell	St. George's University, Grenada
Clare Morrall	St. George's University, Grenada
Jason Phillip	St. Kitts National Trust
Philip Renaud	Living Oceans Foundation
Christopher Slade	The Nature Conservancy
Amanda Williams	Living Oceans Foundation

Appendix 2. Coral species observed in St. Kitts and Nevis

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Acropora cervicornis							x						x		x					x					x
Acropora palmata	x	x													x									x	x
Agaricia agaricites	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x
Agaricia humilis	x														x										
Agaricia lamarcki			x	x		x	x		x	x	x		x					x	x	x					
Colpophyllia natans			x	x	x	x	x	x	x	x	x	x	x	x				x	x	x	x	x	x	x	x
Dendrogyra cylindrus	x	x	x	x	x	x	x	x			x					x		x		x		x	x	x	x
Dichocoenia stokesii					x		x	x	x	x	x	x	x	x								x			
Diploria clivosa	x	x	x												x									x	x
D. labyrinthiformis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Diploria strigosa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Eusmilia fastigiata			x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		
Favia fragum			x		x		x																		
Isophyllastrea rigida																									
Isophyllia sinuosa			x									x				x									x
Leptoseris cucullata										x												x			
Madracis decactis	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		x
Madracis mirabilis			x				x		x	x		x									x				
Manicina areolata																					x				
Meandrina meandrites			x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Millepora alcicornis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Millepora complanata	x	x	x				x				x	x			x										x
Montastraea annularis	x	x	x	x	x	x	x		x	x	x	x				x	x	x	x	x	x	x	x		x
M. cavernosa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Montastraea faveolata	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Montastraea franksi			x	x	x	x	x		x	x		x	x	x		x	x	x	x	x	x	x	x		
Mussa angulosa			x			x	x			x	x	x									x	x	x		
Mycetophyllia aliciae			x			x	x			x															
M. lamarckiana	x		x	x	x	x	x		x	x	x			x		x	x	x	x	x	x	x	x		
Porites astreoides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Porites furcata	x											x													
Porites porites	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Scolymia cubensis						x		x	x									x							
Scolymia lacera							x										x	x							
Siderastrea radians	x	x	x		x		x	x																	
Siderastrea siderea	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
S. intersepta	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x		

Appendix 3. Abundance and density of 88 reef fish (pooled for all reefs).

Family	Common	Scientific	Number	Density
Angelfishes			38	0.26
	Cherubfish	*Centropyge argi*	0	0.00
	Blue Angelfish	*Holacanthus bermudensis*	0	0.00
	Queen Angelfish	*Holacanthus ciliaris*	1	0.01
	Rock Beauty	*Holacanthus tricolor*	23	0.16
	Gray Angelfish	*Pomacanthus arcuatus*	1	0.01
	French Angelfish	*Pomacanthus paru*	13	0.09
Barracudas			2	0.01
	Great Barracuda	*Sphyraena barracuda*	2	0.01
Boxfishes			9	0.06
	Spotted Trunkfish	*Lactophrys bicaudalis*	9	0.06
Butterflyfishes			118	0.82
	Foureye Butterflyfish	*Chaetodon capistratus*	82	0.57
	Spotfin Butterflyfish	*Chaetodon ocellatus*	2	0.01
	Reef Butterflyfish	*Chaetodon sedentarius*	0	0.00
	Banded Butterflyfish	*Chaetodon striatus*	29	0.20
	Longsnout Butterflyfish	*Prognathodes aculeatus*	5	0.03
Chubs			137	0.95
	Chub	*Kyphosus spp.*	137	0.95
Damselfishes			175	1.22
	Yellowtail Damselfish	*Microspathodon chrysurus*	175	1.22
Filefishes			14	0.10
	Scrawled Filefish	*Aluterus scriptus*	0	0.00
	Whitespotted Filefish	*Cantherhines macrocerus*	2	0.01
	Orangespotted Filefish	*Cantherhines pullus*	12	0.08
	Slender Filefish	*Monacanthus tuckeri*		0.00
Grunts			1059	7.38
	Black Margate	*Anisotremus surinamensis*	0	0.00
	Porkfish	*Anisotremus virginicus*	0	0.00
	Juvenile Grunt	*Haemulon / Anisotremus*	81	0.56
	White Margate	*Haemulon album*	0	0.00
	Tomtate	*Haemulon aurolineatum*	452	3.15
	Caesar Grunt	*Haemulon carbonarium*	105	0.73
	Smallmouth Grunt	*Haemulon chrysargyreum*	135	0.94
	French Grunt	*Haemulon flavolineatum*	279	1.94
	Cottonwick	*Haemulon melanurum*	1	0.01
	Sailors Choice	*Haemulon parra*	0	0.00
	White Grunt	*Haemulon plumierii*	6	0.04
	Bluestriped Grunt	*Haemulon sciurus*		0.00
Jacks			45	0.31
	Bar Jack	*Caranx ruber*	45	0.31
	Permit	*Trichonotus falcatus*	0	0.00
Morays				0.00
	Green Moray	*Gymnothorax funebris*	0	0.00
	Goldentail Moray	*Gymnothorax miliaris*	0	0.00
	Spotted Moray	*Gymnothorax moringa*	0	0.00
Parrotfishes			2539	17.69
	Bluelip Parrotfish	*Cryptotomus roseus*	0	0.00
	Juvenile Parrotfish	*Scarus / Sparisoma*	144	1.00
	Midnight Parrotfish	*Scarus coelestinus*	5	0.03
	Blue Parrotfish	*Scarus coeruleus*	1	0.01
	Rainbow Parrotfish	*Scarus guacamaia*	6	0.04
	Striped Parrotfish	*Scarus iseri*	1039	7.24
	Princess Parrotfish	*Scarus taeniopterus*	306	2.13
	Queen Parrotfish	*Scarus vetula*	60	0.42
	Greenblotch Parrotfish	*Sparisoma atomarium*	38	0.26
	Redband Parrotfish	*Sparisoma aurofrenatum*	633	4.41
	Redtail Parrotfish	*Sparisoma chrysopterum*	21	0.15
	Bucktooth Parrotfish	*Sparisoma radians*	0	0.00
	Yellowtail Parrotfish	*Sparisoma rubripinne*	12	0.08
	Stoplight Parrotfish	*Sparisoma viride*	274	1.91

Family	Common	Scientific	Number	Density
Porcupinefishes			5	0.03
	Ballonfish	*Diodon holocanthus*	4	0.03
	Porcupinefish	*Diodon hystrix*	1	0.01
Porgies			3	0.02
	Jolthead Porgy	*Calamus bajonado*	0	0.00
	Saucereye Porgy	*Calamus calamus*	2	0.01
	Sheepshead Porgy	*Calamus penna*	0	0.00
	Pluma Porgy	*Calamus pennatula*	1	0.01
Pufferfishes			2	0.01
	Bandtail Pufferfish	*Sphoeroides spengleri*	2	0.01
Scorpionfishes			1	0.01
	Lionfish	*Pterois spp.*	1	0.01
Seabasses			264	1.84
	Graysby	*Cephalopholis cruentata*	78	0.54
	Coney	*Cephalopholis fulva*	145	1.01
	Rock Hind	*Epinephelus adscensionis*	6	0.04
	Red Hind	*Epinephelus guttatus*	34	0.24
	Nassau Grouper	*Epinephelus striatus*	0	0.00
	Black Grouper	*Mycteroperca bonaci*	1	0.01
	Yellowmouth Grouper	*Mycteroperca interstitialis*	0	0.00
	Tiger Grouper	*Mycteroperca tigris*	0	0.00
	Yellowfin Grouper	*Mycteroperca venenosa*	0	0.00
Snappers			61	0.43
	Mutton Snapper	*Lutjanus analis*	0	0.00
	Schoolmaster	*Lutjanus apodus*	4	0.03
	Cubera Snapper	*Lutjanus cyanopterus*	0	0.00
	Gray Snapper	*Lutjanus griseus*	0	0.00
	Dog Snapper	*Lutjanus jocu*	0	0.00
	Mahogany Snapper	*Lutjanus mahogoni*	40	0.28
	Lane Snapper	*Lutjanus synagris*	1	0.01
	Yellowtail Snapper	*Ocyurus chrysurus*	16	0.11
Surgeonfishes			1789	12.46
	Ocean Surgeonfish	*Acanthurus bahianus*	1275	8.88
	Doctorfish	*Acanthurus chirurgus*	16	0.11
	Blue Tang	*Acanthurus coeruleus*	498	3.47
Triggerfishes			55	0.38
	Queen Triggerfish	*Balistes vetula*	0	0.00
	Ocean Triggerfish	*Canthidermis sufflamen*	0	0.00
	Black Durgon	*Melichthys niger*	55	0.38
	Sargassum Triggerfish	*Xanthichthys ringens*	0	0.00
Wrasses			280	1.95
	Spanish Hogfish	*Bodianus rufus*	46	0.32
	Slippery Dick	*Halichoeres bivitattus*	18	0.13
	Yellowhead Wrasse	*Halichoeres garnoti*	215	1.50
	Puddingwife	*Halichoeres radiatus*	1	0.01
	Hogfish	*Lachnolaimus maximus*	0	0.00

Appendix 4. Coral datasheet

Surveyor:	Site Name:		Reef Type:	Reef Zone:
Date:	Day #: Site #:	Latitude:	Subzone/Habitat	
Start Time:	Bottom Temp.: °C/ °F	Longitude:		
Start Depth: ft/ m		Site Comments:		
End Depth: ft/ m		Transect Comments:		
All ≥ 4 cm Corals				

Species Code	# Isolates	Maximum (cm)			% Bleach (P, BL)	% Partial Mortality			Disease	Predation overgrowth	Comments
		Length	Width	Height		New	Trans	Old			

Appendix 5. Benthic datasheet

Surveyor:			Site:			Date:		Time:		Temperature:		°C/ °F
Compass Bearing:			Start Depth:	ft/	m	End Depth:	ft/	m			Quadrats	
Transect #:	0 m	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m	9 m	#	≤ 2 cm Coral Recruits
0 cm											1	
10 cm												
20 cm											2	
30 cm												
40 cm											3	
50 cm												
60 cm											4	
70 cm												
80 cm											5	
90 cm												
Compass Bearing:			Start Depth:	ft/	m	End Depth:	ft/	m			Quadrats	
Transect #:	0 m	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m	9 m	#	≤ 2 cm Coral Recruits
0 cm											1	
10 cm												
20 cm											2	
30 cm												
40 cm											3	
50 cm												
60 cm											4	
70 cm												
80 cm											5	
90 cm												
Compass Bearing:			Start Depth:	ft/	m	End Depth:	ft/	m			Quadrats	
Transect #:	0 m	1 m	2 m	3 m	4 m	5 m	6 m	7 m	8 m	9 m	#	≤ 2 cm Coral Recruits
0 cm											1	
10 cm												
20 cm											2	
30 cm												
40 cm											3	
50 cm												
60 cm											4	
70 cm												
80 cm											5	
90 cm												

Substrate codes

DC = dead coral
RDC = recently dead coral
BL = fully bleached
HG = hardground
R = rubble
S = sand
C = live coral
I = invert

Coral codes

use first letter of genus
and three letters of species

Condition

ID disease, predation, bleaching, other compromising feature

Algae codes

m = macroalgae
t = turf
cca=crustose coralline
e = erect coralline
cy = cyanobacteria
TS = turf + sed.

Special algae

Dic = dictyota
Lob = lobophora
Mic = microdictyon
Hal = halimeda
Peys = Peyssonellia

Invert

Gorg = seafan
Octo = soft coral
Anem = anemone
Paly = palythoa
Tun = tunicate
SP = sponge
RSP = rope sponge
TSP = tube sponge
BSP = barrel sponge
ESP = encrusting sponge

AINV = aggressive invert

Nuisance species

Eryth = Erythropodium
Paly = Palythoa
Clidel = Cliona delitrix
Clio = Cliona (brown)
Tridi = Trididemnum
Chon=Chondrilla sponge

Appendix 6. Fish datasheet

Surveyor:	Date:		Site Name:		AGRRA Code:	
Day #: Site #:	Latitude:		Longitude:		Bottom Temp.:	°C / °F
Transect #:	Start Time:		Start Depth:	ft / m		
Site Comments:			Transect Comments:			
Group	0-5 cm	6-10 cm	11-20 cm	21-30 cm	31-40 cm	> 40 cm
Family Angelfish						
Butterflyfish						
Grunt						
Parrotfish						
Grouper/Hind						
Snapper						
Surgeonfish						
Triggerfish						
Chub						
Moray						
Species Hogfish						
Puddingwife						
Slippery Dick						
Spanish Hogfish						
Yellowhead Wrasse						
Orangespotted Filefish						
Scrawled Filefish						
Whitespotted Filefish						
Jolthead Porgy						
Pluma						
Saucereye Porgy						
Sheepshead Porgy						
Balloonfish						
Porcupinefish						
Bar Jack						
Permit						
Bandtail Pufferfish						
Great Barracuda						
Spotted Trunkfish						
Yellowtail Damselfish						
Lionfish						

Surveyor:	Date:		Site Name:		AGRRA Code:	
Day #: Site #:	Latitude:		Longitude:		Bottom Temp.:	°C / °F
Transect #:	Start Time:		Start Depth:	ft / m		
Site Comments:			Transect Comments:			
Group	0-5 cm	6-10 cm	11-20 cm	21-30 cm	31-40 cm	> 40 cm
Family Angelfish						
Butterflyfish						
Grunt						
Parrotfish						
Grouper/Hind						
Snapper						
Surgeonfish						
Triggerfish						
Chub						
Moray						
Species Hogfish						
Puddingwife						
Slippery Dick						
Spanish Hogfish						
Yellowhead Wrasse						
Orangespotted Filefish						
Scrawled Filefish						
Whitespotted Filefish						
Jolthead Porgy						
Pluma						
Saucereye Porgy						
Sheepshead Porgy						
Balloonfish						
Porcupinefish						
Bar Jack						
Permit						
Bandtail Pufferfish						
Great Barracuda						
Spotted Trunkfish						
Yellowtail Damselfish						
Lionfish						