Global Reef Expedition: Pedro Bank, Jamaica

March 10-20, 2012

Final Report

Andrew W. Bruckner

Khaled bin Sultan Living Oceans Foundation

Khaled bin Sultan Living Oceans Foundation Publication # 8

Front cover: Photo by Andrew Bruckner.

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All research was performed under a permit obtained from the National Environment and Planning Agency (NEPA) (ref #18/27, 8 December, 2011). No animals or plants were collected during the research project. No animals were killed or injured during the execution of the project, and no injured or dead marine mammals or turtles were observed. No oil spills occurred from the M/Y Golden Shadow or any of the support vessels, and oil slicks were not observed. The Golden Shadow used a single anchorage during the mission located behind Southwest Cay. The Golden Shadow provided potable water to the fishers living on Middle Cay.

The information in this Final Report summarizes the outcomes of the research conducted during the March, 2012, as part of the Global Reef Expedition, to Pedro Bank Jamaica. Information presented in the report includes general methods, the activities conducted during the mission, general trends and observations, analyzed data and findings, and recommendations. The Living Oceans Foundation cannot accept any legal responsibility or liability for any errors.

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The Khaled bin Sultan Living Oceans Foundation (KSLOF) was incorporated in California as a 501(c)(3), public benefit, Private Operating Foundation in September 2000. KSLOF headquarters are in Washington DC. The Living Oceans Foundation is dedicated to the conservation and restoration of oceans of the world, and champions their preservation through research, education, and a commitment to *Science Without Borders*®. For more information, visit http://www.livingoceansfoundation.org and http://www.globalreefexpedition.com. Also on Facebook and Twitter @livingoceansfdn

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Support for the research conducted during March 2012,
as part of the Global Reef Expedition,
provided by His Royal Highness Prince Khaled bin Sultan

Philip G. Renaud, Executive Director
Andrew W. Bruckner, Chief Scientist

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EXECUTIVE SUMMARY

The Khaled bin Sultan Living Oceans Foundation (KSLOF), in partnership with The Nature Conservancy, conducted a research mission to Pedro Bank, Jamaica between March 10-20, 2012 as part of the Global Reef Expedition. The research team included scientists from KSLOF, The Nature Conservancy, the National Environment and Planning Agency of Jamaica (NEPA), Fisheries Division and Veterinary Services Division of the Ministry of Agriculture & Fisheries; the University of the West Indies, NOVA Southeastern University's National Coral Reef Institute (NCRI), the Florida Aquarium, and the Atlantic and Gulf Rapid Reef Assessment Program. The main objectives of the research were to : 1) characterize the distribution, structure and health of coral reefs; 2) evaluate the population status of reef fishes and invertebrates targeted by commercial and subsistence fisheries, including top predators, parrotfishes and surgeonfishes, lobsters and conch; 3) test the use of side scan sonar as a tool to map the distribution of shallow marine habitats; 4) obtain plankton samples to characterize the distribution, diversity and size of larval fish, conch and lobster populations; 5) conduct habitat surveys and collect oceanographic information on currents, temperature and circulation; 6) collect observational data on sea turtles, seabirds, sharks, marine mammals, and unusual floating aggregations of *Sargassum* seaweed. A primary emphasis of the work was placed on the proposed fishery reserve, with efforts to characterize coral communities and associated species and habitats within and outside the conservation zone. Other goals include: 1) the identification of other potential sites for consideration as marine protected areas; 2) characterization of the existence and condition of reefs within proposed mineral and oil exploration areas at the southwestern end of the bank; and 3) communication and outreach efforts directed towards fishing communities and government agencies, including production of media.

The research team assessed the coral reef community structure at 20 sites: 18 fore reef locations and two patch reefs. At each site, at least one 10 m X 1 m photo-transect was taken. A subset of reef fish (approx. 70 species) was quantified (abundance and biomass) within 187 belt transects (each 30 m X 2 m) with additional roving surveys to characterize the entire reef fish diversity using REEF methodology. The size and condition of approximately 3000 corals were assessed within 74 belt transects (each 10 m X 1 m). Benthic assessments using a point count method were conducted on 158 transects (each 10 m in length; 100 points). Motile invertebrates (lobster, conch, crabs, sea cucumbers and sea urchins) were counted in each location within circular plots (each 314 m^2 area). The team completed 252 dives and a total bottom time of 202 hours.

Additional data collected included 1) CTD deployments at each coral survey site to obtain salinity and temperature profiles from the surface to the bottom; 2) continuous temperature recordings at the anchorage of the Golden Shadow off southeast Cay; 3) current data, along with temperature, oxygen and turbidity using a Recording Doppler Current Profiler (RDCP) deployed at 20 m depth in Site 3; 4) side scan sonar data of each habitat class located near the fishery reserve; and 5) ichthyoplankton, phytoplankton and epiphytic algae samples. Within the proposed fishery reserve, a total of 15 sq km of backscatter data and 96 drop camera videos were acquired. In addition, 10 ichthyoplankton surveys were completed within the proposed boundaries of the fishery reserve. Two fishermen's workshops (Middle Cay, Pedro Bank and Port Antonio), an educational workshop for school children (Port Antonio); fishery assessments on Pedro Bank and on the north coast of Jamaica (St. Ann's Bay); and rapid coral assessments on the north coast (Discovery Bay, St. Ann's Bay and Port Antonio) were also undertaken.

Habitat characteristics

In the areas surveyed on Pedro Bank, coral reef, seagrass beds, rubble fields. gorgonian hardgrounds, algal soft bottom and sand flats are the primary habitats. Shallow areas surrounding the islands were predominantly rubble, algae and *Acropora palmata* framework, with some isolated patches of recovering *Acropora*. On top of the bank, sand flats, scoured hardgrounds, rubble fields with a low density of small coral heads, gorgonian/algae hardgrounds, seagrass beds and small patch reefs were identified. The best developed coral reefs were confined largely to the edge of the bank, with poor coral development within the confines of the bank, except for isolated patch reefs.

Benthic community structure

Within coral reef habitats, over 60% of the bottom was covered by algae, most of which was fleshy and erect coralline macroalgae (31%) and crustose coralline algae (18%). Live coral cover ranged from 4.9% (PB-01) to 19.2 % (PB-20) (mean at all sites = 9.5%). Mean cover of other invertebrates was 14.5%, while 12.3% of the bottom consisted of uncolonized substrate (sand, rubble or hardground); 1% was dead coral. Sites contained a total of 33 species of scleractinian corals. The most abundant corals were A*garicia*, *Siderastrea*, *Porites* and the *Montastraea annularis* complex, respectively. Most corals were small (mean diameter = 20 cm), with 30% of all colonies 21 cm or larger and 2% of the corals 100 cm or larger. The only corals with a mean diameter that exceeded 20 cm were the *M. annularis* complex, *M. cavernosa*, *Colpophyllia natans*, *Dendrogyra cylindrus*, *Acropora palmata* and *A. cervicornis*. A single taxon, *M. faveolata*, was dominated by colonies that exceeded 50 cm. All corals exhibited a very low percent partial mortality (mean = 10%) and virtually no recent or transitional mortality (<1%). The greatest amount of partial tissue loss was observed in the largest corals, including *C. natans* (20%), *M. annularis* (22%) and *M. faveolata* (27%). Coral recruits were dominated by *S. siderea* (27%), *P. astreoides* (19%), *A. agaricites* (14%), *M. cavernosa* (7%), *Favia fragum* (6.5%) and *Meandrina meandrites* (5.8%), with all species (pooled) occurring at a density of 3.3/m^2.

Reef fish communities

Reef fish populations exhibited a fairly low diversity (116 species), abundance (65 fish/100 m^2), size (mean=13 cm) and biomass (9430 grams/100 m^2). Populations were dominated by herbivores, with parrotfish occurring at the highest density (25 fish/100 m^2; most were

Sparisoma aurofrenatum, the redband parrotfish). Other abundant species were surgeonfish (11 fish/100 m^2), wrasses (9 fish/100 m^2), and grunts (6 fish/100 m^2); the density of most other functional groups was <1 fish/100 m^2. All species of fish were small; over 78% were less than 20 cm and only 3.5% were over 30 cm. Overall biomass of reef fishes was low; herbivores had the greatest biomass (5500 grams/100 m^2) followed by invertivores (2965 grams/100 m^2). Triggerfish contributed most to the biomass of invertivores, with the abundance of these species increasing with distance from the Cays. Many functional groups of fishes were rare or absent including all snappers, large serranids (populations consisted only of hinds and graysby), barracuda, morays, grunts, and angelfish. Commercially significant species showed the lowest numbers and biomass overall, emphasizing the heavy fishing pressure occurring on Pedro Bank.

Although fish populations remain healthier on Pedro Bank than that observed off mainland Jamaica, fish community structure has shown substantial changes since 2005 surveys. Most importantly, the abundance and biomass of surgeonfishes has declined quite substantially. Parrotfish abundances are slightly higher than that recorded in 2005, but the biomass for the two time periods is virtually the same, suggesting the average size of individual fish has declined over this period. In sites closest to the fishing village (0 to 10 miles) the total biomass declined by 36% and the biomass of herbivores declined by 46% between 2005 and 2012. The biomass also markedly increased at a distance of 10 miles from the fishing village in 2005, while the biomass was similar at all sites, increasing only at distances of 20 miles or more from the Cays.

Motile invertebrates

Commercially important (*Panulirus, Strombus*) and ecologically important (sea urchins, sea cucumbers, large crabs, octopus) motile invertebrates were seen in many locations, but abundances were extremely low. Queen conch were found on 9 reefs, with highest densities (0.1/m^2) at six sites. This is not necessarily indicative of the population size on Pedro Bank, however, as key *Strombus* habitats were not examined. Lobsters were rarely seen (animals were present at 12 sites but density was <2 lobster/100 m^2), which is worrisome as these were under high pressure from fishers. Large *Diadema* populations occurred in two locations; low densities in other sites suggests they have shown limited recovery since the die-off in the 1980s.

Drivers of community structure

Relationships between benthic attributes, coral and fish community structure and physical structure (relief) were examined for the 19 reefs to determine possible drivers of community structure and health. Sites could be delineated into three groups based on benthic attributes, with macroalgae, crustose coralline algae (CCA) and non-living substrate contributing most to the differences. Sites were subdivided into eight groups based on the contribution of different fish taxa to biomass, with groupings differentiated mostly due to relative amounts of parrotfish, surgeonfish and/or triggerfish. Most other variables were fairly homogeneous between locations. For instance, coral cover and colony size, fish abundance and biomass, and *Diadema* abundance were uniformly low among all sites. With exception of a few sites, dominant taxa were similar in size structure and abundance, and the condition of the substrate and health of corals showed minimal differences. Linear relationships between CCA, fleshy macroalgae and herbivores (parrotfish biomass and surgeonfish abundance) existed, although R^2 values were very low. The vertical relief (height between the substrate and the tops of the corals) also had a minor effect on CCA, macroalgae, and biomass of commercially significant fishes and invertivores.

Resilience and health of reefs

A resilience analysis using data on coral cover, coral recruitment, coral disease, fleshy algae biomass, herbivore abundance (*Diadema*, parrotfishes and surgeonfishes), and commercially important reef fish provides some useful information on the health of these reefs. The combination of all these variables results in a Reef Health Index (RHI) that varied from 2-3 (poor to fair condition). Although the RHI is fairly low, this must be viewed with caution as this is based on only a subset of variables that affect resilience. A more detailed examination highlights many positive trends observed:

- Disease prevalence (% affected colonies) appears to be high when pooling all species and types of diseases, however, the most virulent diseases reported from the Caribbean were uncommon (white plague and yellow band disease) with exception of a moderate prevalence of YBD at one site. Furthermore, there was very little partial mortality overall and colonies had virtually no recent mortality (<1%). The most common disease observed was dark spots disease, which was causing minimal tissue loss.
- Fleshy macroalgae cover and biomass was lower than that observed off mainland Jamaica, and in other locations examined during the GRE. Most fleshy algae was concentrated at the margins of corals and the bases of coral heads. Open substrates were devoid of macroalgae and had a high cover of crustose coralline algae.
- Herbivore abundance was high. There were warning signs of overfishing, though, as the mean size of herbivores was extremely low, indicating the large numbers of juveniles and small adults; large bodied parrotfish were rare. Stoplight, blue, midnight, rainbow, queen, and princess parrotfish, when present, consisted of juveniles and very small initial phase and terminal phase fish. The population of herbivores was dominated by small *Sparisoma aurofrenatum* (redband parrotfish), and acanthurids were only observed in small groups or as single individuals with a single large school noted.
- Promising signs of recovery were noted within *Acropora palmata* thickets. One large stand was identified and many other areas had numerous surviving fragments, small colonies, and tissue remnants on skeletons; disease was rare among this taxon. Some populations did have a high number of snails, possibly due to a reduction in their predators.
- One area within the Fishery Reserve had a flourishing population of *Acropora cervicornis*; this coral was also noted on many other reefs forming small stands.
- *Montastraea faveolat*a and *M. annularis* colonies were generally in good shape, with much less mortality that that being seen throughout the Caribbean. This important frame builder appears to be surviving well on these reefs.
- The overall condition of these reefs was better than most reefs off mainland Jamaica, and certain areas were unusual, very healthy and worthy of protection (see page 6).

Plankton communities

The waters surrounding the fish sanctuary contain a very high proportion of fish eggs/larvae. The abundance and richness of larvae of decapod crustaceans were also particularly high, and these samples included lobster phyllosome. Conch larvae were not seen but this could be an artifact of the net size used.

Habitat mapping

The pilot mapping effort focused on collection of baseline side scan sonar data for each of the different habitat types observed on Pedro Bank and relating these to drop-camera video images collected in the same area. These data show the potential to discriminate habitat types using this tool. One of the main disadvantages is the limited amount of coverage from a single pass; extensive time would be needed to collect adequate data to map an area the size of Pedro Bank and mosaicing the strips of sea bottom together into a single map.

An unusual mushroom-shaped *M. faveolata* colony at the Northwest Ridge.

RECOMMENDATIONS

1) The designated area for the Fish Sanctuary would benefit from a slight modification in its boundaries, and an expansion in size to include grassbed habitats located to the southeast.

The existing boundaries of the proposed sanctuary encompass some of the best developed reefs on Pedro Bank. They include habitats with rare or endangered corals including *Acropora cervicornis* thickets seaward of Southwest Cay and *Acropora palmata* framework surrounding the north, east and south sides of the Cay. The deeper fore reef communities have moderately high cover of living corals with healthy populations of long lived massive corals (*M. faveolata*, *C. natans*). The sites are likely to have high physical resilience as a) they are adjacent to deep water and are exposed to clean oceanic waters originating in the east and south; b) sediment transport/turbidity is lower than that observed on the bank and on reefs located closer to Northeast and Middle Cay; and c) land based pollution and the potential for runoff (sewage/nutrients) is low since the area is distant from the populated Cays. Dense seagrass beds and additional well developed reefs were identified immediately south of the boundaries of the existing Sanctuary. Because of the important nursery function of grassbeds, and the fact that they represent the only seagrass beds within the immediate vicinity of the Fish Sanctuary, significant benefits would come from their inclusion in the protected area.

Seagrass beds near the Fishery Reserve.

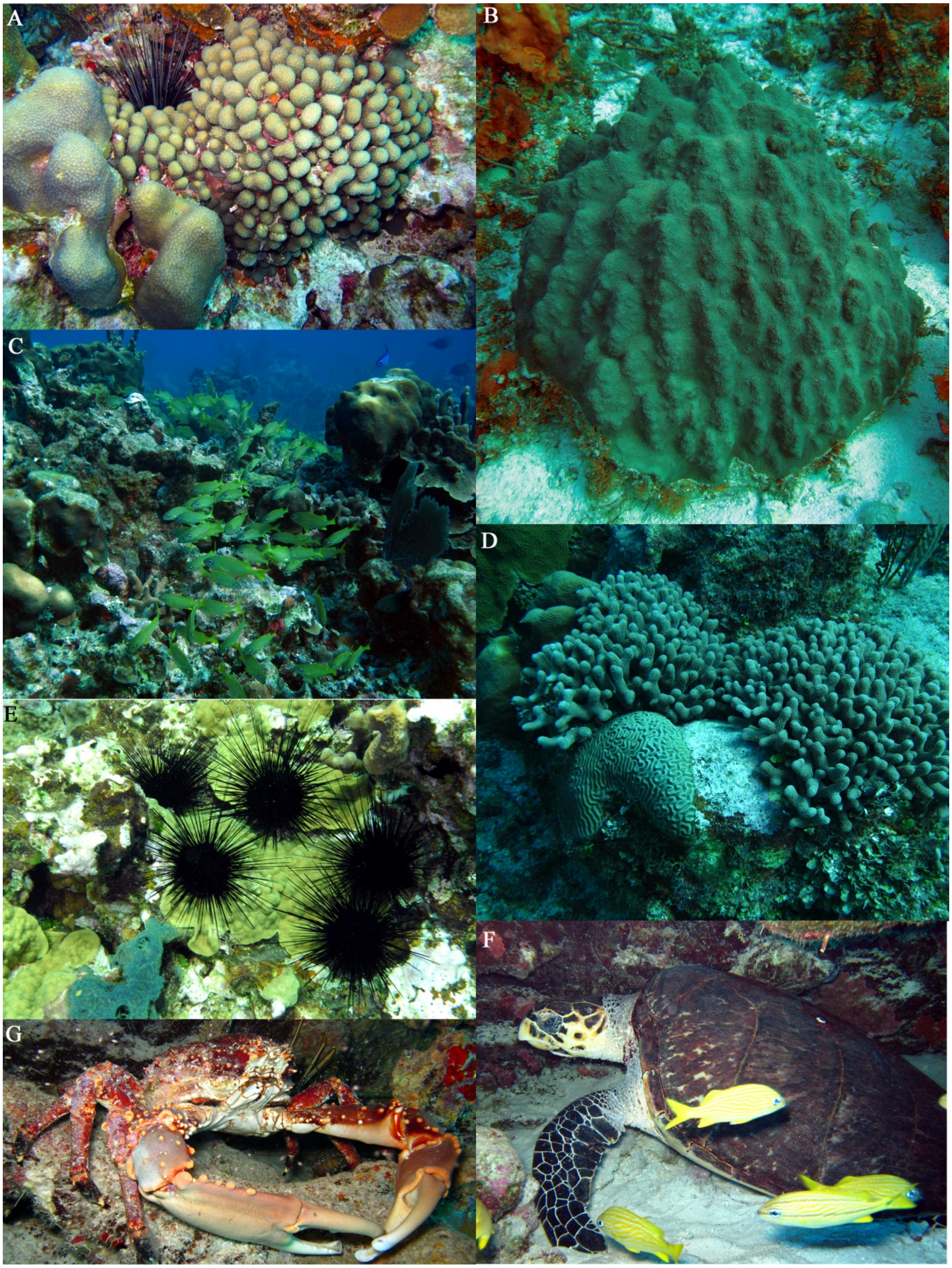
2) Create a Network of MPAs in other locations, with emphasis of the waters around Banner Reef, Blower's Rock, C Shoal SW, and D Shoal S.

Banner reef should be considered a high priority for protection, due to the large number of different marine habitats associated with this area. Banner Reef had a very diverse shallow water reef on its southwestern end that was dominated by large *Montastraea faveolata* and *M. annularis* colonies intermixed with extensive stands of *Porites porites*, *A. cervicornis* patches, large colonies of *Dendrogyra cylindrus* and high relief coral bommies in deeper sandy areas surrounding the main reef. There were also very diverse habitats in other areas, including 1) extensive *Acropora* framework off the east side of the island; 2) an elongate ridge with steeply sloping sides, caves, and ledges that provided considerable habitat for large crabs, lobsters, octopus, groupers and other high value species; and 3) a deeper coral-dominated reef slope. Banner reef also had the highest diversity of fish families seen during this study, as well as a high biomass of fish composed of schools of grunts, parrotfishes and surgeonfishes. This reef also had the largest population of *Diadema* seen on Pedro Bank.

Blowers Rock had the largest *Acropora palmata* framework seen on Pedro Bank. While much of the associated coral had died, there were some extensive patches of live *A. palmata.* These corals provide considerable three-dimensional habitat for associated species, yet they are very vulnerable to breakage from anchoring. A very unusual *Montastraea* dominated reef was also identified to the south, in 15-20 m depth. This reef had unusually large (2-4 m diameter/height) and old *Montastraea faveolata* colonies, the largest seen on the bank. While some had extensive partial mortality, there were many undamaged colonies and coral diseases were rare. Because these areas are east (and up-current) of inhabited Cays and the Fish Sanctuary, the endangered corals that occur here (*Montastraea* and *Acropora*) could serve as seed stock for other areas on the bank to the west. They also provide considerable habitat for other species as a result of their high relief.

Large *Montastraea faveolata* colonies were abundant at PB-15.

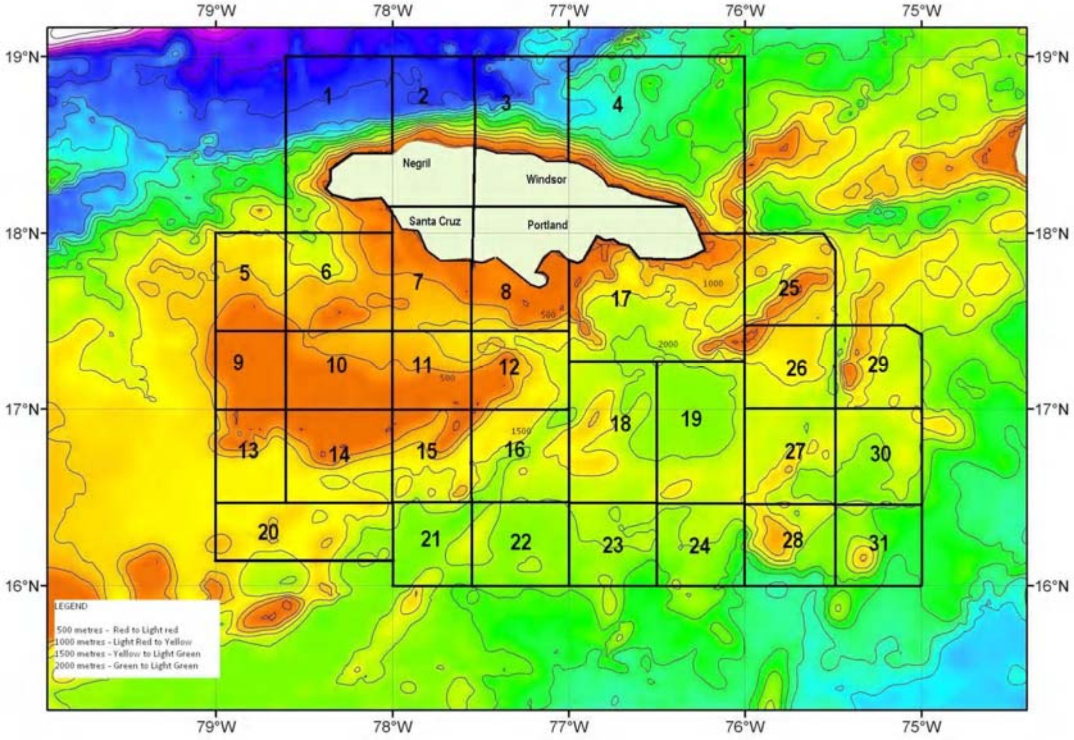
C Shoal and D Shoal had extensive *Acropora palmata* framework with small stands of living *A. palmata* scattered throughout the shallow (2-5 m depth) areas and extensive diverse coral habitats slightly deeper. There were large *Montastraea*-dominated communities as well as some of the largest patches of *Acropora cervicornis* seen on Pedro Bank. One reef also had the only large aggregations of *Madracis mirabilis* and *Porites porites* stands seen in the region.



Scenes from Banner Reef. Healthy coral (A, B, D), large schools of fish (C), *Diadema* populations (E), motile invertebrates (G) and green turtles (H) were seen in different habitats.

3) Map and characterize marine habitats around the northwest ridge.

The Northwest Ridge had some extensive coral habitats with a very high cover of live corals and the highest biomass of fish populations found on the Bank overall. The corals were very healthy and diverse. Fish biomass was substantially higher here than that observed anywhere else on the Bank, illustrating the importance of the coral habitats in these areas as shelter and feeding grounds for reef fishes. The reef areas were separated by large expanses of gorgonian hardground, rubble fields and sand flats, however. Because these habitats are much less sensitive than coral reef areas, any permitted exploration should be concentrated here, rather than in sensitive coral areas. A thorough assessment of the distribution and spatial extent of each habitat associated with the northwest ridge is needed, to ensure that coral reef habitats are identified and mapped before oil exploration or extraction is permitted. The mapping effort should emphasize Block 13 and 14 (see below) as these are located on the edge of the Bank in areas that could potentially support coral reefs. A more detailed examination and delineation of the spatial distribution and extent of different habitat types could allow environmentally friendly placement and operations of platforms, drills and other equipment, targeting less sensitive areas where impact to coral reef habitat is minimized. As an initial consideration, a buffer surrounding PB-17 should be considered to avoid unnecessary damage to precious coral reefs.



Mainland Jamaica and the surrounding waters have been divided into blocks for mineral and oil exploration. Block 13, 14 and 15 are the most sensitive areas on Pedro Bank due to the occurrence of diverse, high relief coral habitat.

4) Evaluate existing fishery regulations and adopt more sustainable fishing methods to reduce the potential for destructive fishing and overharvesting.

The amount of fishing pressure and the methods used to capture reef fish appear to be unsustainable. A combination of the large number of fishers and the small aerial extent of coral habitat has made fishing pressure the most significant negative human impact to Pedro Bank coral reefs. Fishers were observed using hookah and spearguns to target parrotfish, also spearing all other large bodied fish and lobsters when encountered. Small mesh fish pots were also deployed throughout and adjacent to reef habitats. These are destructive because they remove a wide diversity of fish, as well as small bodied fish and juveniles. Furthermore, an unusually high numbers of surgeonfish are collected in traps, and these species have declined most between 2005 and 2012. Heavy fishing pressure has also led to a depletion of large piscivores, which may take many years to rebound as nursery habitats for many of these fishes are rare or absent and their recovery is dependent on external sources of larvae. There has also been a substantial reduction in the size of parrotfish, which can have negative consequences on their life history (e.g. sex change at a smaller size). The absence of certain critical nursery habitats near the reef environments (e.g. mangroves) and limited amount of coral reef habitats further exacerbates the problem, possibly reducing the potential for reseeding of the area. Some of the options that should be considered include the elimination of surface supplied air for fishing (e.g. allowing only free-diving when spearfishing), the use of larger mesh sizes for traps, and limits (to increase the minimum size and reduce the overall catch to a more sustainable level) on harvest of certain species of fish, such as herbivores.

5) Complete habitat maps and implement a coral reef monitoring protocol for the areas within the Fish Sanctuary and the surrounding habitats.

Pedro Bank would benefit from a more detailed mapping program and long term coral reef monitoring. The current project involved a pilot effort to map the Fishery Reserve using Side Scan Sonar. While this method holds promise, it requires extensive tracks to cover a substantial portion of the bank. Using WorldView-02 satellite imagery in combination with rapid, but comprehensive groundtruthing (e.g. long-distance bathymetric tracks, drop-camera videos), it is possible to develop high resolution bathymetric maps and habitat maps with 12-16 classes in a very efficient and cost-effective manner. These maps can be used for marine spatial planning and delineation of monitoring stations. Through this study, rapid assessments of 20 coral reef locations were obtained. While this effort resulted in a considerable amount of baseline data (and in some cases repeat measurements to document change), it is critical to expand this effort with more rapid assessments and the addition of permanent sites that are reexamined on an annual basis if possible. Sites should be selected within the Sanctuary with similar habitats and depths adjacent to the Sanctuary to determine if the Sanctuary is working.

INTRODUCTION

The coral reefs located off the north coast of the Jamaican mainland are some of the best and most studied reefs in the world (Hughes 1994). In contrast, very few research studies have been conducted on the banks located off the south coast of Jamaica. The first and only comprehensive coral reef assessment was conducted on a portion of Pedro Bank in 2005 (Kramer 2006). Other studies have focused on fisheries assessments, socioeconomic studies and terrestrial work (Nicholson and Hartsuijter 1982; Munro 1983; Koslov et al. 1988; Espuet 2006; Hay 2006; Kramer 2006). Since the mid 1990s, human populations on the Cays have greatly expanded, and pressures on the reefs and associated resources have been exacerbated. Considerable work has been done in the development of management measures to address these changes and protect these resources. This includes development of a possible zoning strategy, including the adoption of marine protected areas (i.e. a fishery reserve off southwest Cay). At the time of the research, protective measures had not yet been adopted for these areas, although stakeholder consultations have been completed and recommendations have been provided to the relevant government agencies in Jamaica.

Pedro Bank is a submerged bank rising abruptly from about 500 m depth. It is located about 58 km off Jamaica at its closest point (Portland Point) and roughly 98 km from Kingston, Jamaica (latitude 16° 43’ N and 17° 35' N and longitude 77° 20’ and 79° 02’ W). It extends over an area of 8,040 km^2 and has a circumference of roughly 590 km. Much of the bank is relatively shallow (about 10-24 m depth) with extensive grassbed, rubble and sandy habitats and scattered patch reefs. A well developed coral reef fringes the eastern edge of the bank, dropping quickly into deep water. The bank gradually deepens in a NW direction; the shallowest (S and SW) end faces into the Caribbean current and has the best developed reefs.

Pedro Bank includes a group of three small emergent low-lying coralline cays, a fourth highly eroded Cay (South Cay), and a few small emergent rocks (Portland Rock, Blower Rock, Southwest Rock and Shannon Rock). Two of the cays are permanently inhabited and the third is used only as a temporary base for fishermen. Northeast Cay is the most northerly of the three cays. It is the second largest Cay. The dominant manmade structure on this cay is a lighthouse located on the northern shore. Many of the dwellings on this cay are located in the vicinity of the lighthouse, with others spreading westerly forming a line of buildings that stretch almost the entire length of the western coast. Middle Cay is the smallest of the three cays. It has experienced a rapid increase in the number of inhabitants since the 1990s. Today more than 50% of the Cay is occupied by housing, compared to less than 10 buildings in the late 1950s. NW Cay is almost completely ringed by houses with the exception of the eastern side. Southwest Cay is the largest of the three cays and has no permanent residents. South Cay is the smallest and southernmost Cay, consisting of a shallow shoal with a very small sandy beach which is frequently over washed by the tide and surge.

The relative importance of the Pedro Cays as a base for fishing has been steadily increasing as Jamaica's nearshore fishery continues to decline. Temporary fishing camps were first established in the 1940s. By the 1950s, the Cays were permanently inhabited by fishermen (70), but living conditions were extremely harsh (Espeut 2006). Fishing pressure remained low into the mid 1970s (560 t) and by 1986 the bank was still only moderately fished (1600t) (Munro 1983). Today, Pedro Bank is one of Jamaica's most valuable and largest fishing ground. A long history of fishing of lobster, conch, and fish has led to the overexploitation of these fisheries on Pedro Bank (Aiken et al. 1997; Gittens 2001; Koslow et al. 1988; Munro 1983; Nicholson and Hartsuijker 1983). Further, the number of people living on Pedro Cays has increased over the years resulting in increased resource extraction, destruction of coastal vegetation, excessive trash debris, no sewage treatment, and diminishing habitat for nesting turtles and seabirds (Espeut 2006, Hay 2006).

Beginning in mid 2000s, the Jamaica Country Programme of the Nature Conservancy (TNC) in partnership with NRCA, the JDF Coast Guard, UWI and the Fisheries Division, developed and implemented the Pedro Bank Coral Reef Management Project. This project included five components: 1) a coral reef assessment; 2) a biological and water quality assessment of Northeast, Middle and Southwest Cays; 3) a fisheries assessment; 4) a socioeconomic assessment; and 5) a feasibility study addressing the living conditions on Northeast and Middle Cays. The aim of the project was to work with the stakeholders and government agencies to develop a plan to control and minimize overfishing and degradation of coral reefs and coral cays due to unsustainable human settlement. One of the outcomes of this work was the proposal of a fishery reserve to protect fish stocks.

To help inform constituents of the value of these resources and the benefits that would ensue through the development of a network of marine protected areas, KSLOF and out partners conducted an extensive survey of coral reef habitats within Pedro Bank. The current research used the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol, which is the same methodology applied in 2005. Many of the same areas assessed in 2005 were evaluated during this study and we expand surveys to new locations. Special attention was given to the reefs located in the vicinity of the proposed fish sanctuary. Additional pilot efforts to map the proposed fish sanctuary using side scan sonar were undertaken.

OBJECTIVES

1) Habitat surveys: Conduct habitat surveys across the edge of Pedro Bank and collect oceanographic information on currents, temperature and circulation in these areas. Habitat surveys will be located in areas that are proposed as oil and gas exploration and drilling sites and in proposed fish sanctuaries. One goal of this work is to identify other high value coral reef habitats that would benefit for inclusion in a Pedro Bank network of MPAs;

2) Coral reef assessments: Characterize coral reef community structure and health at representative locations along the edge of the bank;

3) Invertebrate assessments: Characterize the population structure of conch, lobster, urchin and other motile invertebrates throughout reef environments;

4) Mapping: Evaluate the potential application of side scan sonar as a tool to develop habitat maps and collect relevant habitat and bathymetric data within a proposed fish sanctuary at the southern edge of the bank;

5) Larval research: Obtain plankton samples to characterize the distribution, diversity and size of larval fish, conch and lobster populations within the proposed sanctuary;

6) Megafauna assessments: Collect observational data on sea turtles, seabirds, sharks, whales and dolphins and unusual floating aggregations of Sargassum seaweed; and

7) Fishery status: Evaluate patterns of use of fisheries resources and relate this to existing coral reef fish populations.

METHODS

A. Study Sites

A total of 20 coral reefs were examined using SCUBA (Fig. 1) The sites were mostly concentrated on the edge of the bank, with one patch reef (site 1) and one leeward reef (site 3) examined (Table 1). Also, site 17 was located within the bank. Reefs were selected from: 1) coordinates of past AGRRA surveys; 2) randomly selected sampling sites chosen by TNC; and 3) coral areas identified through snorkel searches undertaken near the edge of the bank. An emphasis was placed on reefs located near SW cay, within the proposed fish sanctuary. The pilot mapping work undertaken by TNC and plankton tows implemented by UWI were concentrated within the boundaries of or immediately adjacent to the proposed fish sanctuary.

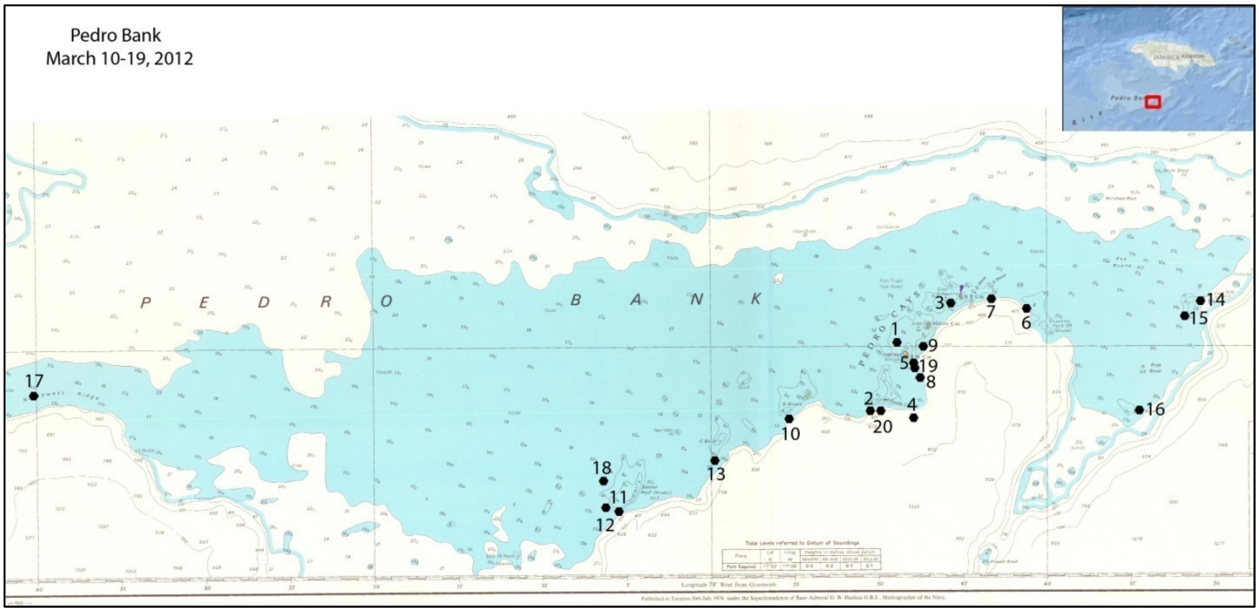


Fig. 1. Location of coral reef surveys conducted on Pedro Bank, Jamaica in March 2012.

B. Coral reef assessments

A combination of quantitative methods including belt transects, radial plots and quadrats were used to assess corals, fish and other benthic organisms. Five measures were recorded for corals: 1) benthic cover; 2) coral diversity and abundance (by species); 3) coral size class distributions (by species); 4) recruitment; and 5) coral condition. Additional information was collected on causes of recent mortality, including signs of coral disease and predation. For fish, data on abundance and size structure were collected along 2 m X 30 m belt transects for about 70 species of fishes, targeting species that have a major functional role on reefs or are major fisheries targets. Other indicators recorded along belt transects included large motile invertebrates (urchins, octopus, lobster, large crabs, sea cucumbers); cover and biomass of algae (fleshy macroalgae, turf algae and crustose coralline algae); and prevalence of nuisance species.

Table 1. Coordinates, depth and location of each site examined using SCUBA.

SITE #	DATE	COORDINATES		NAME	DEPTH (M)
		LONGITUDE	LATITUDE		
JA-PB-01	March 11	77.813490	17.006400	Northern leeward side of SW Cay	10.9
JA-PB-02	March 12	77.839630	16.938840	Bank edge, southwest of South Cay	13.9
JA-PB-03	March 12	77.796980	16.931920	Bank edge, S-SE of South Cay	23
JA-PB-04	March 13	77.760670	17.045090	Between NE and Middle Cay	10.4
JA-PB-05	March 14	77.797150	16.986050	S-SE of SW Cay	11.5
JA-PB-06	March 14	77.686070	17.039780	NW of Shannon Rock on edge	14
JA-PB-07	March 14	77.720600	17.049170	SE of NE Cay on edge	11
JA-PB-08	March 15	77.790700	16.971700	Bank edge, south of SW Cay	17
JA-PB-09	March 15	77.787440	17.002560	Bank edge, north of SW Cay	15
JA-PB-10	March 15	77.919800	16.930800	S-SW of D (2nd) Shoal	14
JA-PB-11	March 16	78.087100	16.839500	Banner Reef	20
JA-PB-12	March 16	78.100100	16.843500	Banner Reef	11
JA-PB-13	March 16	77.992650	16.889800	South of C Shoal	14
JA-PB-14	March 17	77.530160	17.032670	Blower's Rock	8
JA-PB-15	March 17	77.514620	17.047360	Blower's Rock	17
JA-PB-16	March 17	77.574680	16.939830	Beth Rock	15
JA-PB-17	March 18	78.663340	16.953510	NW Ridge	19
JA-PB-18	March 18	78.102480	16.869680	Banner Reef on western edge	12
JA-PB-19	March 19	77.796030	16.981220	Bank edge, south of SW Cay	20
JA-PB-20	March 19	77.829570	16.938900	Bank edge, southwest of South Cay	19

Benthic cover: Cover of benthic organisms (plants and animals) was estimated using a point intercept method. At each site, a minimum of six 10 meter long transects were deployed. The organism and substrate type were recorded every 10 cm for a total of 100 points per transect. Substrates included hardground, rubble, sand/silt, and dead coral. All corals were identified to species and recorded as live, bleached, recently dead or long dead. Invertebrates were identified to the lowest taxonomic level possible. Sponges, if present, were differentiated into crustose, rope, massive, tube and barrel sponges, unless identification was possible. Algae were divided into five functional groups (fleshy macroalgae, erect coralline algae, crustose coralline algae, turf algae, cyanobacteria). Additional measurements of algal height were recorded for macroalgae.

Coral: Coral species diversity, abundance, size structure and health were assessed using belt transects, 1X 10 m in length. Each coral within this belt that was 4 cm or larger in diameter was identified, measured (length, width and height) and assessed. Visual estimates of tissue loss were recorded for each colony over 4 cm in diameter using a 1 m bar marked in 1 cm increments for scale. If the coral exhibited tissue loss, estimates of the amount of remaining tissue, percent that recently died and percent that died long ago were made based on 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, extent of bleaching, predation, competition, overgrowth or other cause of mortality. Each coral was first carefully examined to identify cryptic predators. Lesions were initially diagnosed into four categories: recent tissue loss, skeletal damage, color change, and unusual growth patterns; an individual colony could have multiple characteristics (e.g. color change and recent tissue loss). The location (apical, basal, and medial) and pattern of tissue loss (linear, annular, focal, multifocal, and coalescing) were recorded, and when possible a field name was assigned.

Assessment of abundance of corals smaller than 4 cm was done using a minimum of five 0.25 m^2 quadrats per transect, with each quadrat located at fixed, predetermined intervals (2, 4, 6, 8, 10 m), alternating between right and left side of the transect line. Recruits were identified using these smaller quadrats for both point intercept surveys and belt transects. Recruits/juveniles were divided into two categories: corals up to 2 cm diameter and larger corals, 2-3.9 cm diameter.

Motile Invertebrates: The abundance of motile invertebrates (crustaceans, molluscs and echinoderms) was quantified using random circular plots, each 10 m diameter (total area = 314m^2). One diver would extend a 10 m line from a central point and then swim slowly in a circle while a second diver would record the numbers of each species of invertebrate seen within the plot. Additional roving surveys were undertaken to assess presence of invertebrates in cryptic areas, including ledges and caves. These invertebrates were also counted and recorded within belt transects used for coral surveys.

Reef fish: On each reef two divers completed a minimum of six 30 X 2 m belt transects to assess the community structure of the dominant reef fish assemblages. All species were identified and their size was estimated to the nearest 5 cm using a T-bar marked in 5 cm increments for scale. The assessment focused on species that are ecologically relevant to the health of reefs and also important for commercial or recreational fisheries. The emphasis was on herbivores, invertivores and larger piscivores. Roving surveys were also undertaken to characterize species diversity.

Larval fish and invertebrates: All plankton tows and algal assessments were done within the boundaries of the proposed sanctuary. Sampling included 1) plankton tows for fish and conch larvae; 2) water samples for phytoplankton to identify potentially harmful species that may affect conch larvae; and 3) macroalgal samples for epiphytic species to determine if ciguatoxic dinoflagellates or other toxic species are present that would affect bottom feeders such as *Strombus gigas.* A standard plankton net was towed off the back of the Calcutta or Twin V for 15 minutes and samples were collected, and preserved in 500 ml nalgene bottles for analysis in the laboratory.

Data analysis : All data were initially entered into Microsoft Excel spreadsheets and PRIMER software were used for graphical and comparative analysis. Species diversity, richness and evenness were calculated using:

1) The Shannon – Weiner index (H`): $[H` = - \Sigma i\ pi\ (\log pi)]$;

2) Margalef's species richness (d): $d = (S - 1)/ \log (N)$, where S= number of species; N = number of individuals; and

3) Pielou's evenness (J`): $J` = H`/ \log (S)$ to determine how evenly individuals were distributed among different species.

Clustering of benthic data, coral composition and fish biomass/abundance by site was examined using multi-dimensional scaling (MDS) and similarity profiles (SIMPROF) analysis was used to determine the factors that contribute most to a particular grouping. Individual contribution (e.g. fish taxa, fish functional groups, coral species) to the similarity of resulting groups (and dissimilarity between groups) was estimated using the similarity percentage (SIMPER) analysis of untransformed datasets (Clarke and Warwick 2001; Clarke and Gorley 2006; Somerfield et al. 2008). SIMPER analysis results were visually inspected and biotopes were determined based on similarities, dissimilarities, taxa distribution and relative abundance (semi-quantitative data).

Analysis of Similarity (ANOSIM) testing was also employed to evaluate the relationship between benthic and fish attributes recorded in different sites. These tests compare sites based upon ranked, species similarity measures. Coral species abundances were log transformed to create a Bray-Curtis dissimilarity matrix (d). The greater the dissimilarity between sites, the larger d. The tests yielded R-statistics, which serve as a measure of site separation. R-values can range between -1 and 1. R values > 0.75 show complete separation between sites; R values > 0.5 show overlapping but clearly different sites; and R values < 0.25 shows sites that are barely distinguishable from each other. P-values were calculated for each R-statistic using a permutated test of random rearrangement, and comparing the true R-value with the randomly generated distribution. Similarity percentages (SIMPER) were subsequently calculated to examine the percent contribution of each coral or identified category to the measured ANOSIM differences. ANOSIM results were graphically interpreted using non-metric, multi-dimensional scaling (MDS). MDS is an ordination procedure that projects a dissimilarity matrix into two-dimensional space while preserving as much of the variation (distance) between sites as possible. A low stress value is an indicator of low error, similar to a measure of standard deviation (Clarke and Warwick 2001).

RESULTS

1. Habitat assessments

To aid in the selection of dive sites, a snorkel survey from the surface of the water was undertaken. Most assessments were focused on the edge of the bank on the south/southwest side. Surveys were not undertaken on the central or north/northwest portions of the bank.

Shallow areas surrounding the islands were predominantly rubble, algae and *Acropora palmata* framework, with some isolated patches of recovering *Acropora*, fragments, and dead skeletons. Further away, on top of the bank, were rubble fields with a low density of small coral heads, sand, gorgonian/algae hardgrounds, and some grassbed areas. In general, coral areas were confined largely to the edge of the bank, with poor coral development within the confines of the bank, except for a few patch reefs (Table 2). The best developed grassbed found near the Cays was located around Northeast Cay and west of South Cay, all outside of the proposed fishery reserve. The dominant coral reef habitats were located along the south and southwest end of the banks with some patches reefs identified predominantly in shallow areas near Pedro Cays.

Extensive searches were made for coral reef habitats between the northwest ridge and Banner reef, but these areas do not appear to have any true reef framework. Most areas were low-relief algal-covered hardground, rubble fields, or sand flats. A few low relief mounds were identified. These had isolated gorgonians and sponges and several also had piles of rubble. In one case an extensive patch (>500 m) of *A. cervicornis* rubble was found; no living coral occurred on these mounds. An absence of a coral build-up at the edge of the drop-off was also apparent in this region. Generally, the bank sloped very gradually from about 15 m depth to the limits of visibility (30-40 m depth) with only isolated corals.

Snorkel surveys were conducted near Portland Rock in attempt to find coral reef habitats. On the southern end of the rock, there were several rock ridges (10-12m) surrounding deeper areas, but few corals had colonized these areas. A larger ridge extended from Portland Rock to the northeast, between roughly 5 m and 15 m depth. This ridge had some limited coral colonization (mostly *Agaricia* spp., encrusting *Diploria clivosa* brain corals and *Porites astreoides*), dense patches of brown macroalgae (mostly *Sargassum* and *Turbinaria*), and isolated gorgonians.

The most diverse fore reef locations, with high cover of healthy massive, plating and branching corals were located within and adjacent to the proposed fishery reserve (PB-19, 08, 04) and at the western end of the bank (PB-17). Highly diverse coral reef habitats were also found around Banner Reef (PB-11, 12, 18). In these areas a spur and groove framework was apparent, with highest cover at the edge of the reef slope in 15-25 m depth.

Considerable amounts of *Acropora palmata* framework were identified in shallow water around Pedro Cays and in some of the emergent areas to the west of the Cays. These areas were mostly dominated by dead skeletons, with scattered live colonies, fragments and tissue remnants. The largest former *Acropora palmata* reef (with small patches of living coral) was identified at PB-15 (Fig. 2). This site had a large build-up (3-5 m tall) of *Acropora* skeletons, with two small patches of living *Acropora.* Additional living *Acropora palmata* was identified near C shoal, D Shoal and Banner Rock.

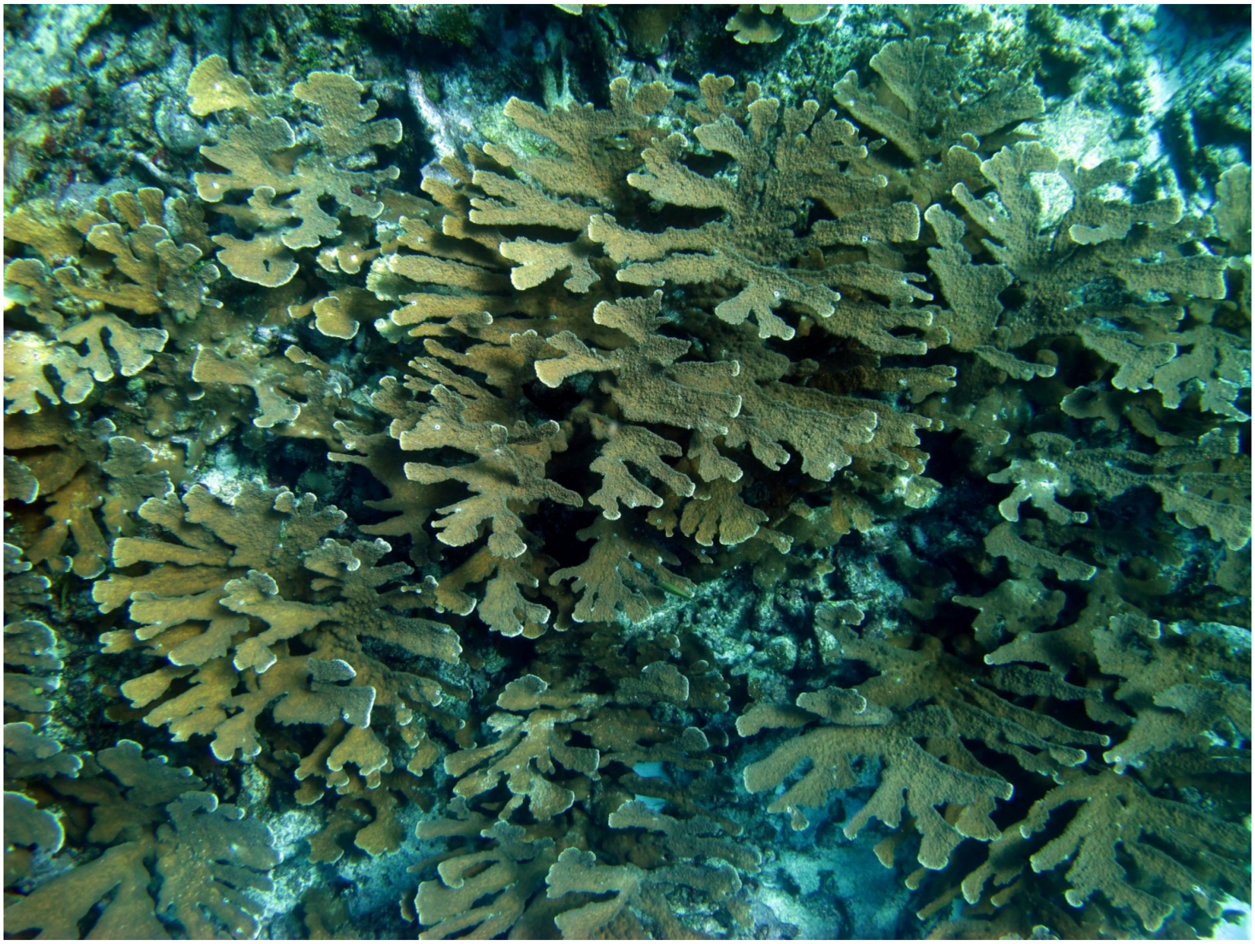


Fig. 2. A large thicket of *A. palmata* occurred at the base (9 m depth) of an extensive, mostly dead, *Acropora palmata* framework at the eastern end of Pedro Bank (PB-15).

The best developed *A. cervicornis* stands were found just off Southwest Cay (including PB-05) on the southeast side at the edge of the reef slope. At the center of the stand were several elongate spurs with *A. cervicornis* and other corals (Fig. 3). Additional smaller patches, fragments and spurs with some living *A. cervicornis*, numerous fragments and large accumulations of skeletal debris occurred slightly deeper and shallower, seaward of Southwest Cay. Additional moderate-sized patches found at sites PB-08 and PB-13 and rubble patches with little or no living *A. cervicornis* was identified in several other locations.

Fig. 3. An *Acropora cervicornis* thicket at PB-05, within the proposed fishery reserve (8-12 m).

Colonies of *Montastraea annularis* (complex) were found on most reefs along the edge of the bank at low abundances. Unusually high numbers of large colonies of *M. annularis* and/or *M. faveolata* were noted at sites PB-10, 15, 18, and 19 (Fig. 4). These colonies were mostly in good shape, except site PB-10 where a high prevalence of yellow band disease affected many of the corals.

Fig. 4. PB-15 was dominated by unusually large colonies of *Montastraea faveolata* (left) and *M. annularis*.

PB-15 was a very unusual reef, with a dominance of particularly large (3-5 m) colonies of *M. faveolata.* This site included a mix of live and dead corals and living corals were recovering from bleaching.

Many of the hardground areas examined on Pedro Bank consisted of low relief spurs with low cover of live scleractinian corals and a dominance of soft corals or other organisms (Fig. 5). Typically, these reefs contained low densities of large corals (1-2m) especially *M. faveolata, Dendrogyra cylindrus, Diploria* spp. and patches of branching *Porites porites* within dense assemblages of *Pseudopterogorgia* spp.

Fig. 5. Shallow (12 m depth) reef community (PB-02) dominated by soft corals (*Pseudopterogoria*).

Table 2. Description of study sites examined using SCUBA.

SITE #	GENERAL DESCRIPTION
JA-PB-01	Patch reef. On bank. Low relief with isolated coral heads; dominated by *M. annularis* with large expanses of *P. porites* and *A. cervicornis* rubble; high numbers of *Diadema*.
JA-PB-02	Windward fore reef. Low relief spur and groove with high abundance of branching gorgonians, scattered massive corals, outcrops of large *M. faveolata*, and smaller branching and massive corals growing on a *Montastraea* framework. Low cover of macroalgae and an absence of *Diadema*.
JA-PB-03	Deeper windward fore reef. Low relief spurs (0.5m), with large sand channels. Dominated by medium-sized *M. faveolata* and *M. cavernosa* and smaller massive corals. Coral cover 10-15%, up to 20% in some places. Corals mostly low-lying, flattened or slightly concave. Moderate abundance of branching gorgonians. No macroalgae; substrate had turf and fine sediment layer. No *Diadema*.
JA-PB-04	Leeward reef. Inside on Bank, near NE Cay. Very low relief. High abundance of *M. annularis*, smaller massive corals and erect lettuce corals (*A. agaricites*). Moderate abundance of gorgonians, mostly *Pseudopterogoria*. Some macroalgae, mostly *Dictyota* and *Halimeda* and good cover of CCA (crustose coralline algae).
JA-PB-05	Windward fore reef. Spurs which extend 1-3m off sandflat; most with small massive and isolated branching corals. Three spurs dominated by *A. cervicornis* intermixed with *M. faveolata*, *C. natans* and *P. porites*. Densest ridge had approx. 60% coral cover; colonies fairly low-lying (20-40cm tall). Uncolonized areas were fused *A. cervicornis* rubble with *Halimeda* and *Dictyota*.
JA-PB-06	Leeward fore reef. Low relief spurs with patches of massive corals including *M. cavernosa, M. annularis, S. siderea* and *M. faveolata*, 50-80cm in diameter. Corals interspersed with branching gorgonians; coral cover about 10%. Abundant pillar corals (6 colonies within 100 m^2). Low cover of macroalgae, turf on substrate with fine sediment and CCA underneath sediment.
JA-PB-07	Leeward fore reef. Low relief spurs with high abundance of branching gorgonians and sea fans. Outcrops dominated by medium to large *M. faveolata*, many 150cm in diameter or larger. Low cover of macroalgae except *Dictyota* and *Halimeda* that surrounded base of coral heads.
JA-PB-08	Windward fore reef. Low relief hardground with high density of branching gorgonians. Mounds of massive *M. annularis*, *M. faveolata* and *Diploria*. Large ridge colonized by a large stand of *M. mirabilis, A. cervicornis* and *P. porites*. Moderate cover of *Dictyota*.
JA-PB-09	Windward fore reef. Spurs built up of *Montastraea* skeletons. Scattered live colonies of *M. annularis* and *M. faveolata*, and large patches of *P. porites*. Extensive areas of uncolonized framework with turf algae, brown *Cliona* sponges, *Erythropodium* gorgonians, *Palythoa* colonial anemones and CCA. *Dictyota* and *Halimeda* encircles the bases of corals. Coral cover 5-10%. Two *M. faveolata* recruits identified!
JA-PB-10	Windward fore reef. High relief spur and groove. Spurs constructed of *Montastraea* framework. Many large (1-2m) *M. faveolata* and *M. annularis* colonies. High prevalence of disease, primarily yellow band disease. Dead *Montastraea* colonies colonized by brown *Cliona* and turf algae. *Halimeda* and *Dictyota* at bases of corals. Substrate colonized by turf; low cover of macroalgae. High number of recruits.
JA-PB-11	Deeper windward fore reef. Low relief spurs with large *M. faveolata, M. annularis* and *Diploria* colonies. Patches of *P . porites* and medium-large *Agaricia* colonies. In areas with *Montastraea* were high number of small massive corals (10-20cm) and a low abundance of branching gorgonians. *Halimeda* and *Dictyota* at bases of corals. Substrate colonized by turf; low cover of macroalgae and moderate cover of CCA.

SITE #	GENERAL DESCRIPTION
JA-PB-12	Fore reef, closer to reef crest. Large ridge with sparse coral colonization. Ridge comes to within 8-10m from surface. Mostly small *Agaricia, P. astreoides* and *P. porites* colonies (< 10cm) and small gorgonians on top of ridge. < 5% cover. Low algal cover except in depressions and at base of reef. Small spurs, caves, and an undercut ledge at base of ridge (12-15m depth) with better coral development (*Montastraea* and *Colpophyllia* colonies).
JA-PB-13	Windward fore reef. Low relief spurs with high abundance of branching gorgonians, sea fans and small massive corals. High numbers of *Diploria* brain corals and small patches of *A. cervicornis.* A lot of corals with recent mortality from snails. Low cover of macroalgae and dead corals colonized by coralline algae.
JA-PB-14	Leeward fore reef. *Acropora* reef surrounded by deeper hard ground. The *Acropora* framework was up to 5 m tall and mostly dead, colonized by *Peysonnellia*, CCA, *Halimeda* and brown *Cliona* with lots of crevices and holes between skeletons. Most colonies had collapsed on the tops and were fused together, with erect skeletons on the sides and base of the mound. Very few other corals had colonized skeletons except in depressions and between branches were small *Agaricia, Porites* and *Millepora* existed. One large patch of live *A. palmata*, about 5 m in diameter, at base of mound (8-9 m depth) and 2 other areas with small patches of live colonies at 5 m depth. Several colonies had large aggregates of coral-eating snails and small patches of white, recently denuded skeleton. Surrounding hard ground had low abundance of branching gorgonians and small massive corals, mostly *Diploria* and *Siderastrea*. Little macroalgae except for small patches of *Dictyota* and *Stypopodium*. Only location found with a large school of blue tangs. No *Diadema*.
JA-PB-15	Leeward fore reef. Western leeward side of Blowers Rock. Low relief habitat with large *Montastraea annularis* and *M. faveolata* colonies, many up to 2m in diameter. Many of the larger colonies had old mortality but also many completely live colonies. Colonies recovering from bleaching with some still showing pale patches. Surrounding hard ground had thin layer of sediment and very little algae, with extensive CCA on dead massive coral skeletons.
JA-PB-16	Windward fore reef. Low relief hard ground with scattered large *Montastraea* corals, *Dendrogyra* pillar corals and moderate abundance of branching gorgonians. Numerous small massive and plating corals (5-20cm in diameter). Some dead *Montastraea* colonies were colonized by brown *Cliona*.
JA-PB-17	Bank reef. Deeper spurs located on the bank at the northwestern end with 2-3m relief. The highest coral cover (up to 40%) noted on Pedro Bank, dominated by medium to large *Montastraea* colonies (all 3 species), and intermixed with branching gorgonians and smaller massive, plating and branching corals. *Dictyota* at base of corals and *Caulerpa racemosa* growing on dead corals and around live corals, but not killing coral. Site with notably larger parrotfish than seen elsewhere (large terminal phase stoplight, princess, and queen parrotfish) and larger predatory fish (the only hogfish observed during the mission.
JA-PB-18	Leeward fore reef. *Montastraea* dominated reef surrounded by sand with small coral bommies. Large mounds of *M. annularis* and *M. faveolata* with dead areas colonized by other species. Substrate between *Montastraea* colonies had small to medium sized brain corals, clumps of *Agaricia* and patches of *Porites*. Some bioerosion, low macroalgal cover and a high number of *Diadema*. Some macroalgae at bases of corals in areas without *Diadema* and lots of CCA on dead patches of coral and reef framework. Relatively significant no. and species of fish.
JA-PB-19	Windward fore reef. Well-developed spur and groove system, esp. near drop-off. Higher live coral cover at drop-off. Large *M. faveolata* colonies (1-3m diameter) intermixed with large *C. natans, M. annularis, S. siderea* and *Diploria* colonies. Several *A. cervicornis* colonies. Halimeda around bases of colonies and some *Dictyota* on reef substrates. More gorgonians in shallower area. Greater no. of lionfish than at previous sites.
JA-PB-20	Windward fore reef. Well-developed spur and groove with high live coral cover. Spurs had moderate relief (1-2m), high nos. of large *M. faveolata* colonies and many other large colonies (50-200cm) inc. *Eusmilia, C. natans, P. porites, S. siderea* and *D. strigosa*. High diversity of other species (*A. cervicornis, Mycetophyllia, Mussa* and *Dendrogyra)*. Low abundance of branching gorgonians; low cover of macroalgae except *Halimeda* in lobes of *M. annularis* and at bases of corals. Greater no. of lionfish than previous sites.

2. Benthic community structure and cover

Biotic and abiotic cover categories were determined for 19 reefs using a 158 point intercept transects, each ten meter in length, for a total of 15,800 points. In addition, benthic cover for site PB-05 was determined from replicate 10 m X 1 m phototransects. Within the 19 reefs, 50-70% of the bottom was covered by algae (crustose coralline algae, erect coralline algae, fleshy macroalgae, turf algae or cyanobacteria), 10-30% was colonized by some type of invertebrate (coral, aggressive invertebrate, other invertebrate, recently dead coral), and 5-25% was uncolonized substrate (sand, hardground or rubble). Macroalgae (including erect coralline algae and fleshy macroalgae) was the dominant constituent (mean=31 %), followed by crustose coralline algae (18.5%) (Fig. 6).

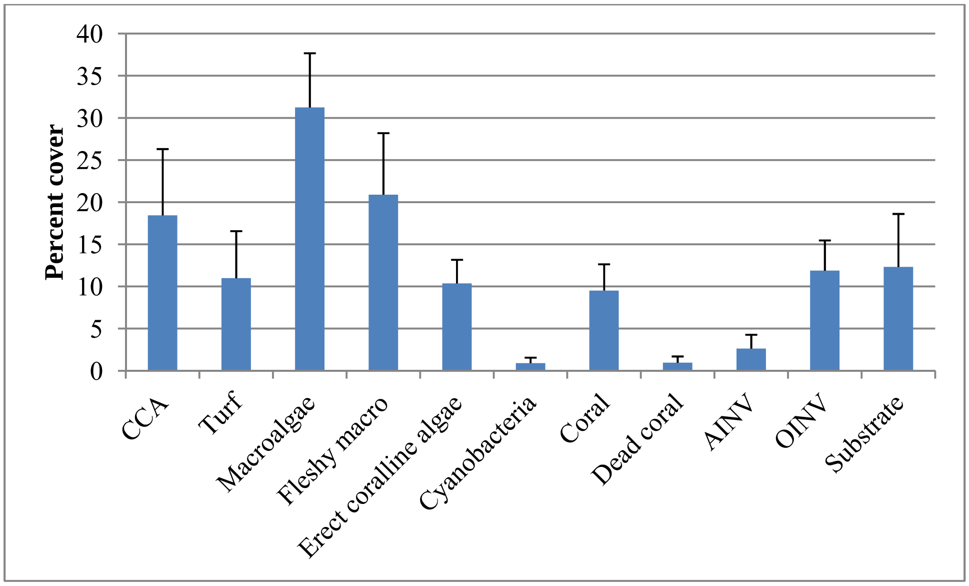


Fig. 6. Percent cover of benthic attributes examined within coral reefs on Pedro Bank. Data are presented as mean and standard deviation, pooled for 19 sites. Crustose coralline algae (CCA), turf algae (turf), macroalgae (fleshy macroalgae and erect coralline algae), fleshy macroalgae (fleshy macro), erect coralline algae, cyanobacterial mats, live coral (coral), dead coral, aggressive invertebrates (AINV), other invertebrates (OINV) and substrate (sand, hardground or rubble) are shown.

While most of the substrate was colonized by algae, coral, aggressive invertebrates and other invertebrates also made up a significant percent of bottom cover (Fig. 7). On some reefs high abundances of erect gorgonians were seen (Fig. 5), but the point intercept method likely underestimated the cover of these organisms because their holdfasts cover only a small portion of the substrate. Total live coral cover ranged from 4.9% (PB-01) to 19.2 % (PB-20). Aggressive invertebrates, including bioeroding and encrusting sponges (e.g. *Cliona*), colonial anemones (*Palythoa*), and fire coral did not show up in the transects very frequently, exceeding 4% cover only at sites PB-02,08,10,15, 17 (Fig. 7). There were, however, many massive corals that had partial or total mortality and skeletal surfaces were colonized by the brown clionid (Fig. 8).

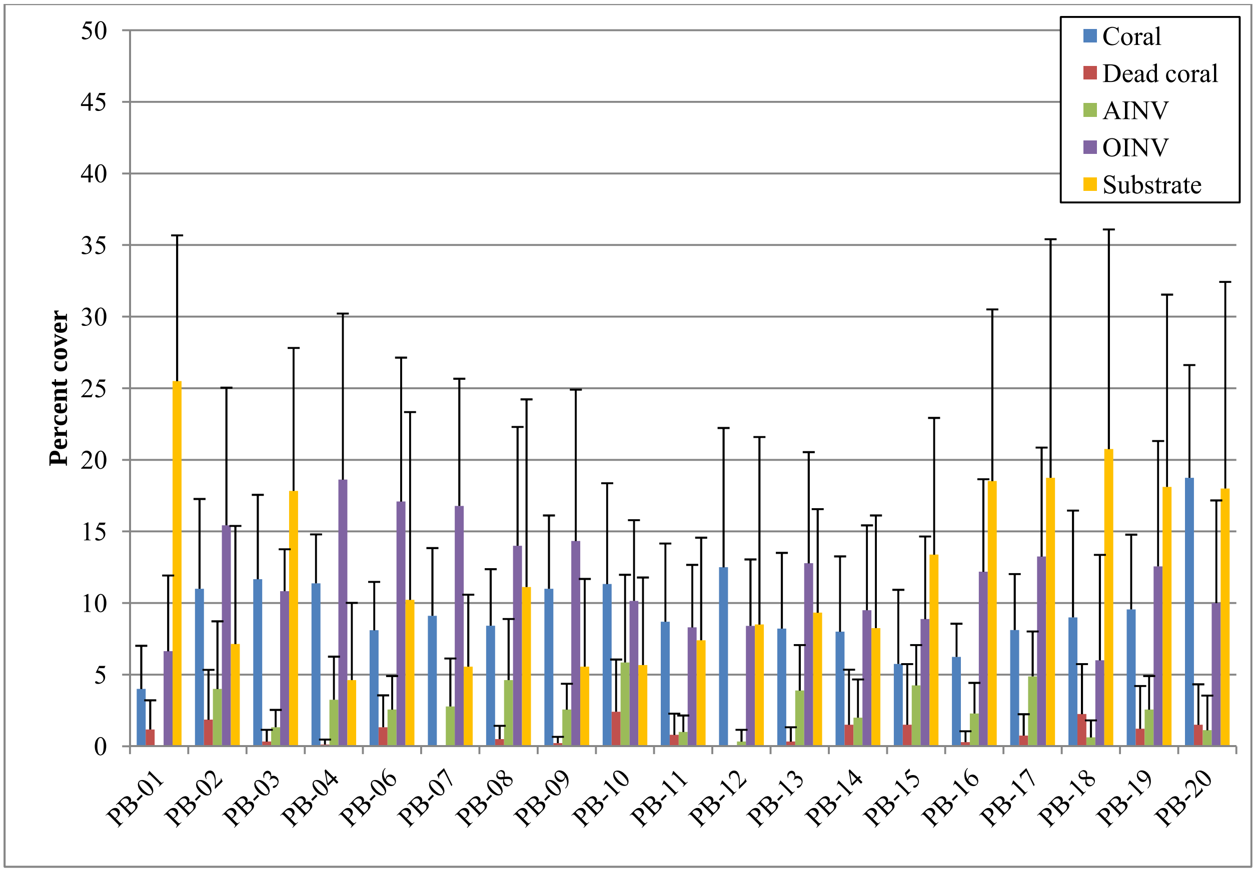


Fig. 7. Percent cover of invertebrates and uncolonized substrate within 19 locations on Pedro Bank. Data are shown for live coral (coral, blue), recently dead coral (dead coral, red), aggressive invertebrate (AINV, green), other invertebrate (OINV, purple) and uncolonized reef substrate (sand, rubble or hardground are pooled, yellow). Mean and standard error are shown.

Fig. 8. Colony of *M. faveolata* that died and is now colonized by *Cliona* spp., a bioeroding sponge.

Fleshy macroalgal cover at all sites was relatively low, with only three sites (PB-01,18, 19) having greater than 30% cover. Crustose coralline algae ranged from 8% to 34% cover, with eight sites exceeding 20% (PB-02, 06, 10, 11, 12, 13, 14, 15) and two of these exceeding 30% (PB-14, 15). Macroalgal cover was weakly correlated with CCA cover (r^2= 0.26, p=0.03). Turf algae was high at two sites (>20%, PB-06, 07), while cover of cyanobacteria was less than 2% at all sites (Fig. 9).

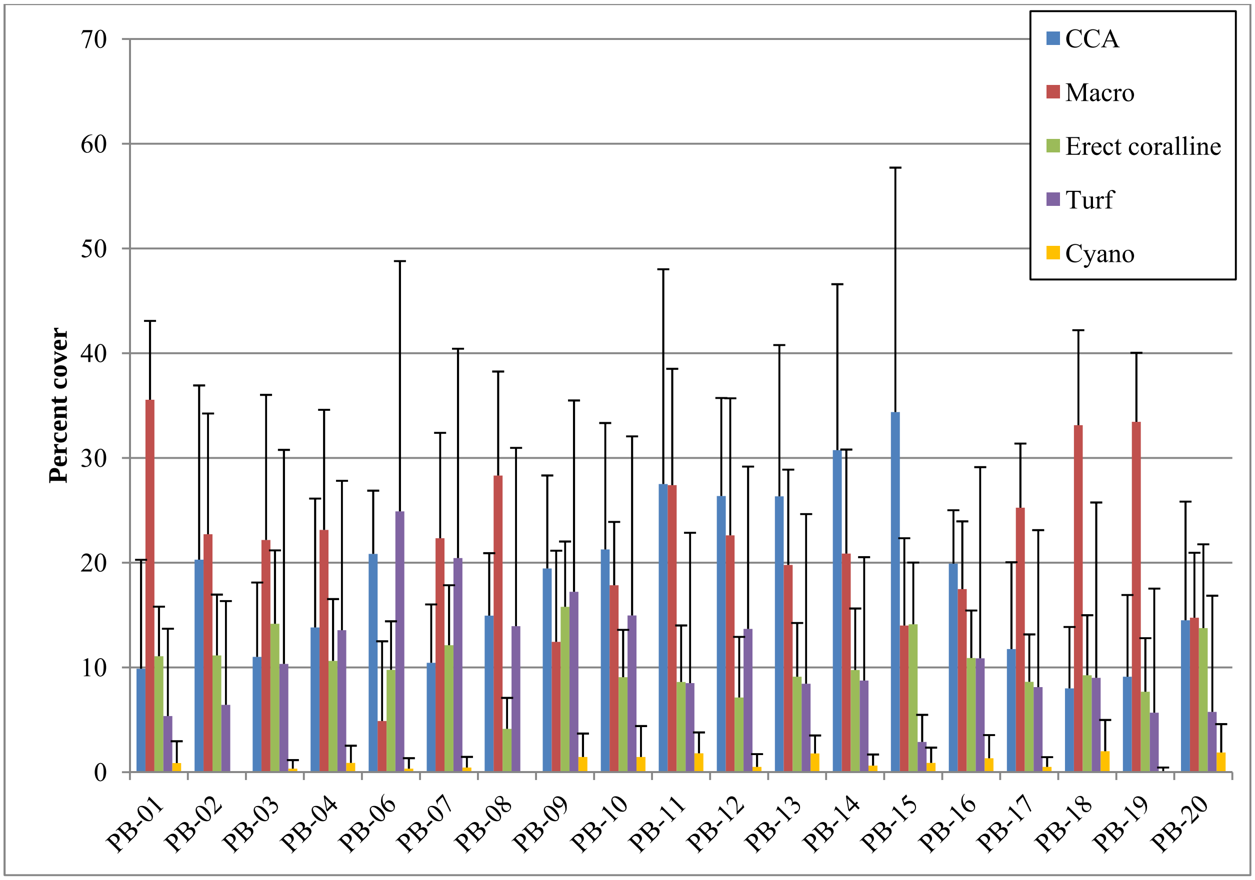


Fig. 9. Percent cover of algae within 19 locations on Pedro Bank. Algae are divided into the following functional groups: crustose coralline algae (CCA), fleshy macroalgae (macro), erect coralline algae (erect coralline), turf algae (turf) and cyanobacteria (cyano). Mean and standard error are shown.

The dominant genera of macroalgae seen on these reefs was *Dictyota*, with lesser amounts of *Sargassum* and *Stypopodium*. The only exception to this was site 17, at the northwestern end of the bank, where reefs were dominated by *Caulerpa racemosa*. Erect coralline algae consisted primarily of species of *Halimeda.* Fleshy and erect coralline algae predominantly colonized the margins of corals and bases of coral heads, with turf algae on exposed substrates and dead corals. Macroalgal height ranged from 1- 2.3 cm. The cover of macroalgae did not appear to be correlated with the height of the macroalgae (r^2= 0.01, p=0.66). The relative biomass, as determined from height and cover, are shown for each site in Fig 10.

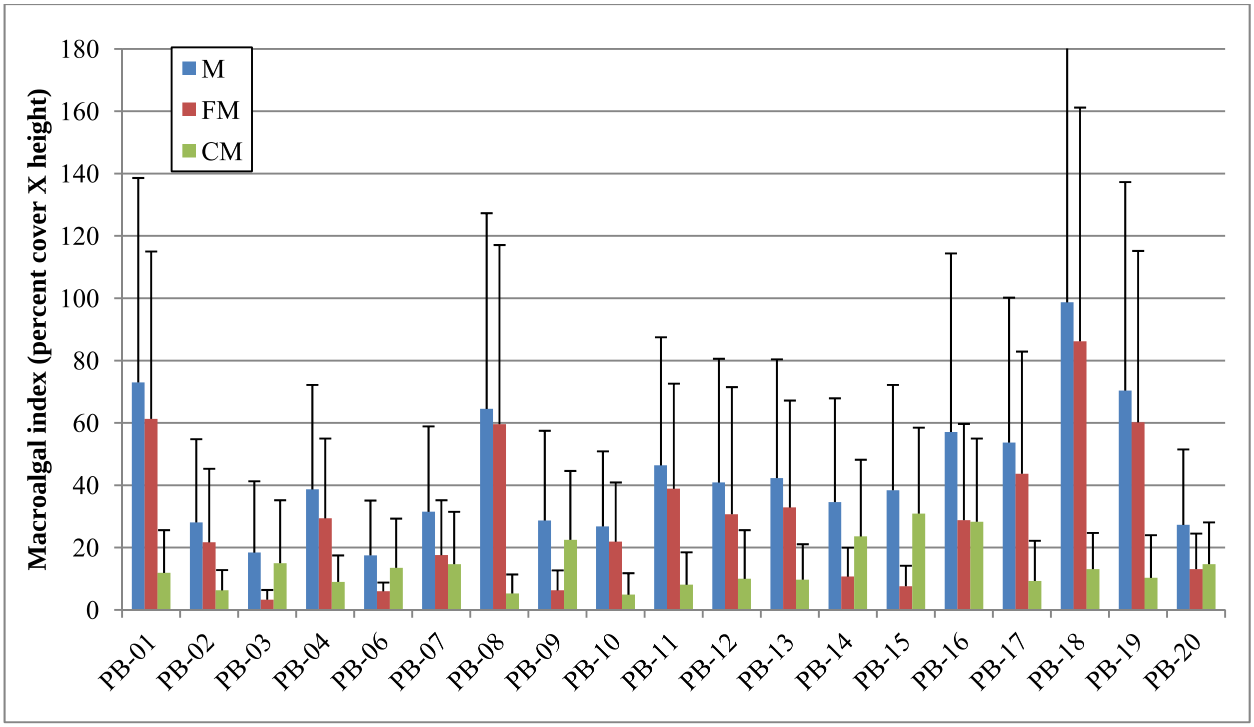
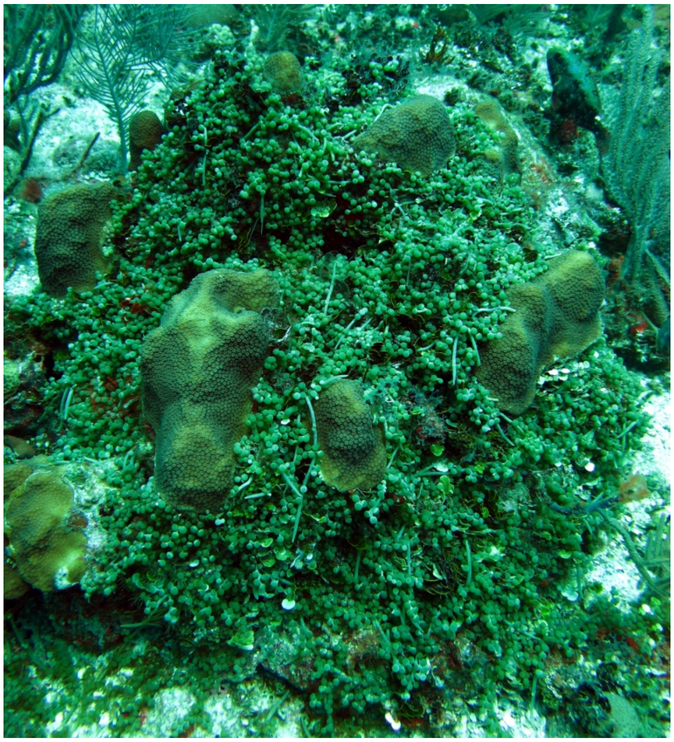


Fig. 10. Macroalgal index for 19 locations on Pedro Bank. Algae are divided into the following functional groups: macroalgae and erect coralline algae (M), fleshy macroalgae (FM), and erect coralline algae (CM). The index is calculated from the height (cm) and percent cover. Mean and standard error are shown.



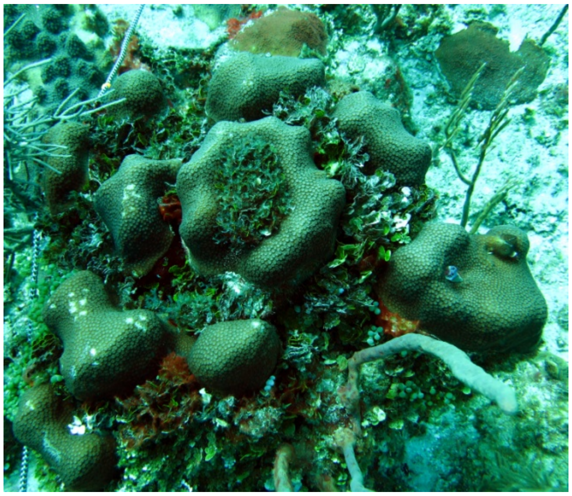


Fig. 11. Examples of macroalgae on the margins of scleractinian corals. *M. annularis* at PB-17 colonized by *Caulerpa racemosa* (left). Colony of *M. annularis* with *Halimeda* and *Dictyota* (right).

3. Coral composition, abundance and density

Coral community structure was determined from 3121 corals, 4 cm in diameter or larger, that occurred within 72 transects on the 19 reefs. The density of corals within transects varied between sites from <1 coral/ m^2 to a maximum of 8, with the highest densities recorded at sites PB-02,03,06, 07, 08, 09, 11 and 20 and the lowest at PB-15 (Fig. 12). Part of this difference could be attributed to the habitat/depth and also the abundance of each taxon (Fig. 13), which varied considerably among sites (Fig. 14).

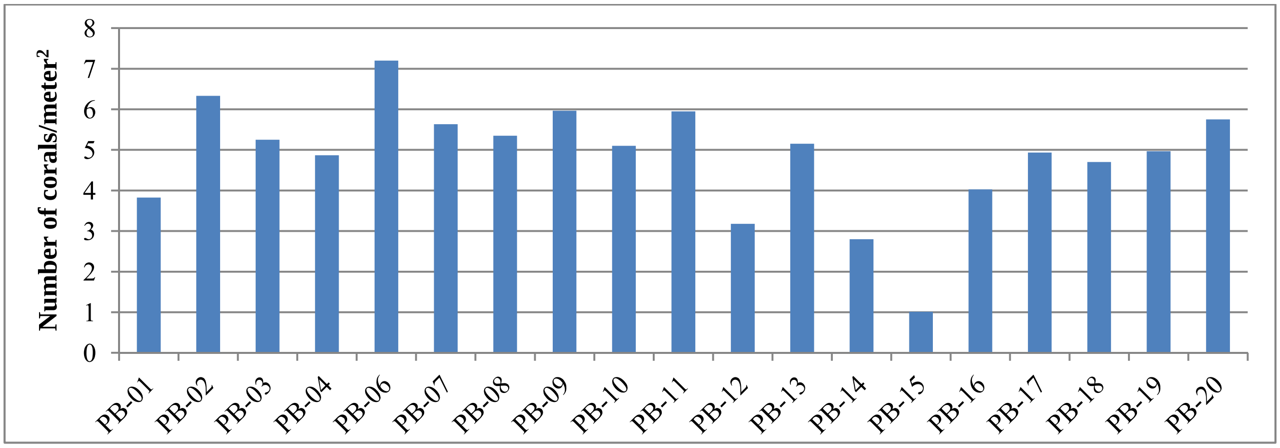


Fig. 12. Density of scleractinian corals (4 cm or larger in diameter) observed within belt transects (10 m X 1 m) on 19 reefs.

A total of 33 species were identified within these transects, with 13 occurring on more than 80% of the reefs surveyed and two species each occurring on a single reef. Nine species made up 94% of all corals assessed on the 19 reefs (Fig. 13).

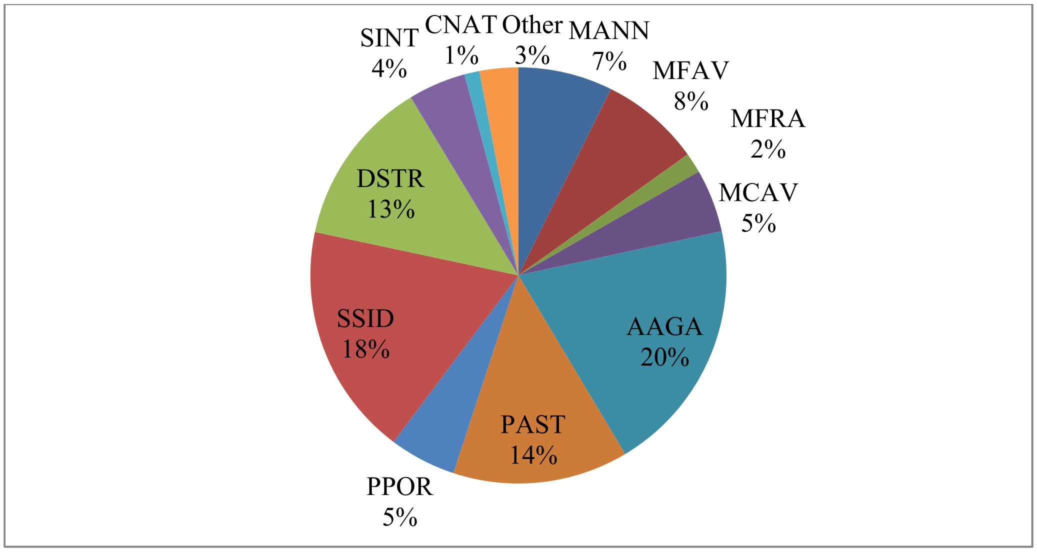


Fig. 13. Relative abundance (percent of the total population of corals) of the scleractinian corals pooled for the 19 sites. "Other" includes 22 species of scleractinian corals.

Table 3. Coral species richness (d), evenness (J') and diversity (H') for each site examined on Pedro Bank.

site	d	J'	H'
JAPB-01	2.392	0.8992	2.493
JAPB-02	2.411	0.8762	2.482
JAPB-03	2.246	0.8915	2.472
JAPB-04	2.142	0.9314	2.522
JAPB-06	2.744	0.9257	2.726
JAPB-07	2.572	0.9031	2.610
JAPB-08	2.593	0.8954	2.588
JAPB-09	2.603	0.9050	2.616
JAPB-10	2.236	0.8678	2.406
JAPB-11	2.401	0.9221	2.612
JAPB-12	2.178	0.9405	2.482
JAPB-13	2.600	0.9362	2.706
JAPB-14	2.117	0.7783	2.108
JAPB-15	1.972	0.8106	1.944
JAPB-16	2.693	0.8936	2.583
JAPB-17	1.668	0.9168	2.278
JAPB-18	2.099	0.8264	2.238
JAPB-19	2.306	0.8876	2.515
JAPB-20	2.425	0.9292	2.633

Coral species richness, evenness and diversity generated by PRIMER, using data from belt transects on 19 reefs, are presented in Table 3. The greatest value of richness and the highest diversity of species was seen at PB-06, while PB-05 had the highest value of evenness. In contrast, PB-14 had the lowest value of evenness and diversity and PB-17 had the lowest value of richness. Overall, the most numerous corals were *Agaricia*, *Siderastrea*, *Porites* and the *M. annularis* complex, respectively. *M. annularis* exhibited the highest abundance at five sites (PB-01, 07, 18, 20), while large populations of *M. faveolata* were recorded at six sites (PB-08, 10, 14, 17, 19, 20) and this taxon was dominant at one site (PB-14) (Fig. 14). *Agaricia agaricites* made up more than 20% of all corals, 4 cm or larger, at 10 of the 19 sites (PB-01, 03, 06, 07, 09, 15, 17, 18, 19, 20) and was the most abundant coral at 9 sites (Fig. 15). *Porites astreoides* was the most abundant coral at four sites (PB-10, 12, 15, 16) (Fig. 15) while *S. siderea* was the most abundant coral at 6 sites (PB-02, 08, 11, 12, 14, 16) (Fig. 16). Five reefs contained large monospecific stands of *P. porites* (PB-04, 09, 10, 13, 18), but it was not numerically dominant at any site.

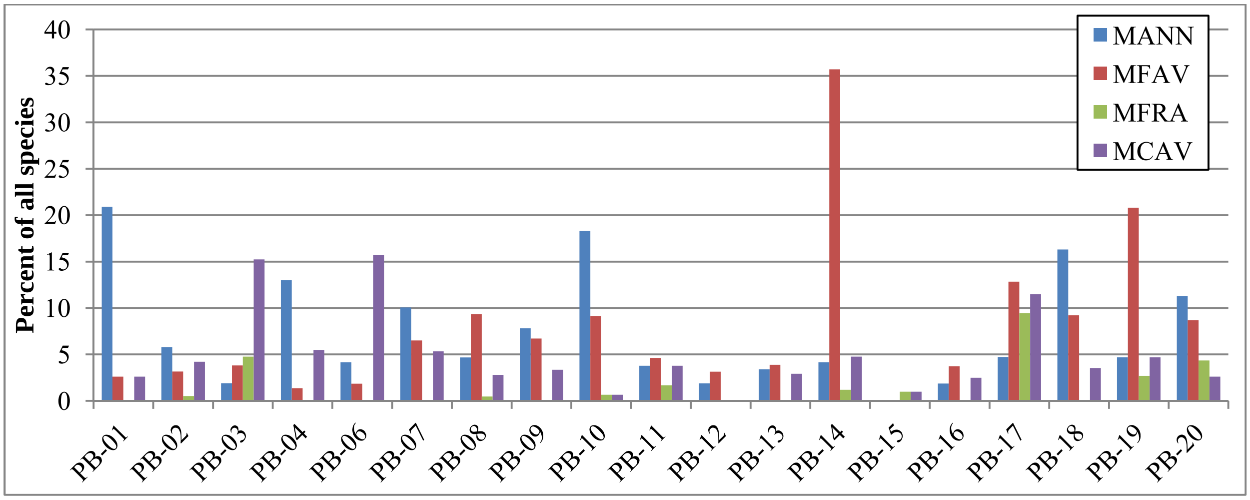


Fig. 14. Relative abundance (percent of the total population of all species of corals) of each of the four species of *Montastraea* recorded along belt transects at 19 locations off Pedro Bank, Jamaica. Abundance data are for corals within belt transects that are 4 cm or larger diameter. MANN = M. annularis; MFAV = *M. faveolata*; MFRA = *M. franksi*; MCAV = *M. cavernosa*.

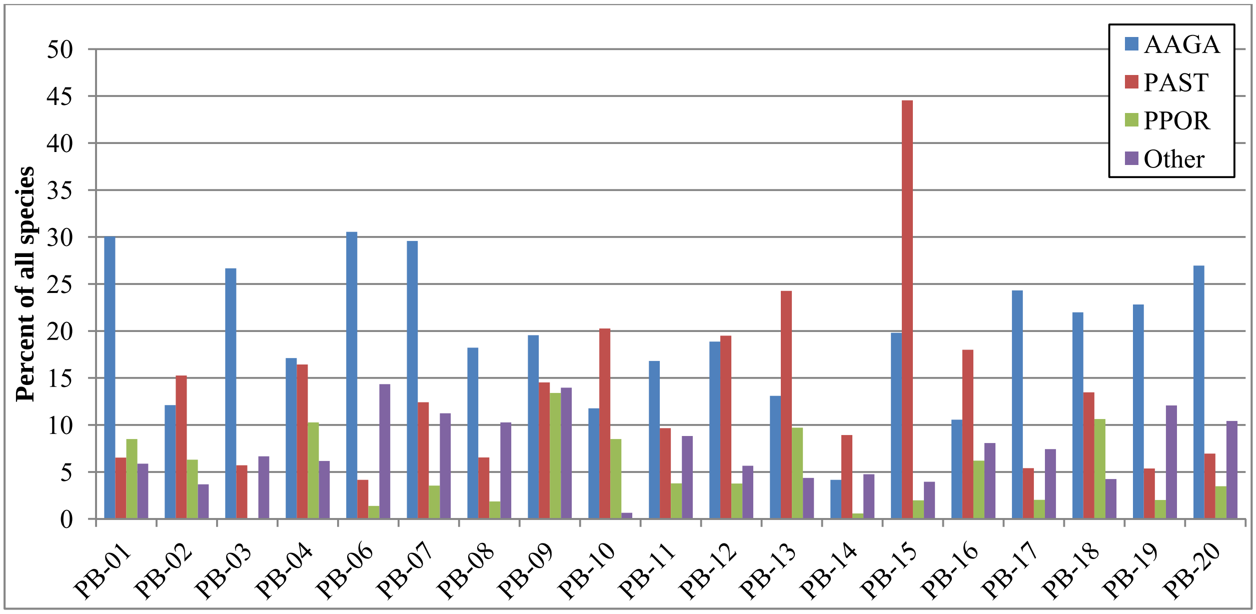


Fig. 15. Relative abundance (percent of the total population of all species of corals) of two common brooders (*Agaricia* and *Porites*) and other species recorded along belt transects at 19 locations off Pedro Bank, Jamaica. Abundance data are determined for corals that are 4 cm or larger diameter. PPOR = *P. Porites* and *P. furcata*. Other includes: *Madracis, Dichocoenia, Acropora, D. labyrinthiformis, Mycetophyllia, Dendrogyra, Manacina.*

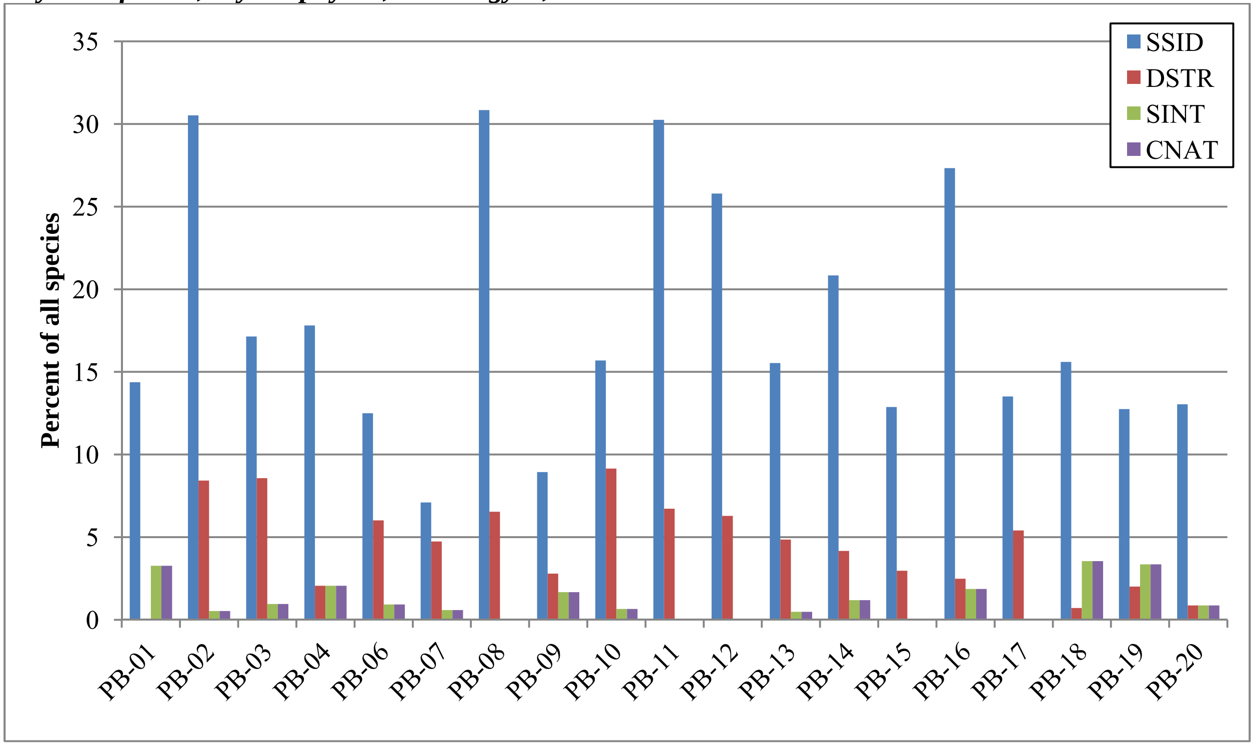


Fig. 16. Relative abundance of massive corals (*S. siderea, D. strigosa, S. intersepta* and *C. natans*), 4 cm or larger diameter, recorded on 10 m X 1 m belt transects at 19 locations off Pedro Bank, Jamaica.

4. Benthic community structure: *Acropora* reef (PB-05)

A shallow reef community dominated by living *Acropora cervicornis* occurs within the proposed fish sanctuary (PB-05). This reef contained three elongate spurs with a mix of *A. cervicornis, C. natans, S. siderea, M. annularis* (complex) and other species. Total living coral cover exceeded 18% (Fig. 17). The dominant coral was *A. cervicornis*, covering 16% of the bottom over the length of the spurs, but forming thickets that were much higher in cover on small parts of the spurs. Colonies were 20-80 cm tall and were intermixed with algae, predominantly *Halimeda* and *Dictyota*. This was the only reef identified that had living thickets of this endangered coral. Living staghorn coral was also intermixed with coral rubble and dead fragments (19% cover), most colonized in turf algae and *Dictyota*. Interestingly, the substrate did not appear to have been colonized by CCA, although CCA was observed on some dead skeletons. It is possible that this was not detected in the photoquadrats, as the CCA was covered in a layer or turf and macroalgae. Numerous gorgonians as well as sponges and colonial anemones were also observed.

Small patches of *A. cervicornis* along with numerous piles of rubble, living fragments and isolated colonies were observed at shallower depths (3-10 m). Individual *A. cervicornis* colonies were also identified in other sites; large patches of *A. cervicornis* rubble that did not contain any living coral were also identified in several locations west of Banner Reef.

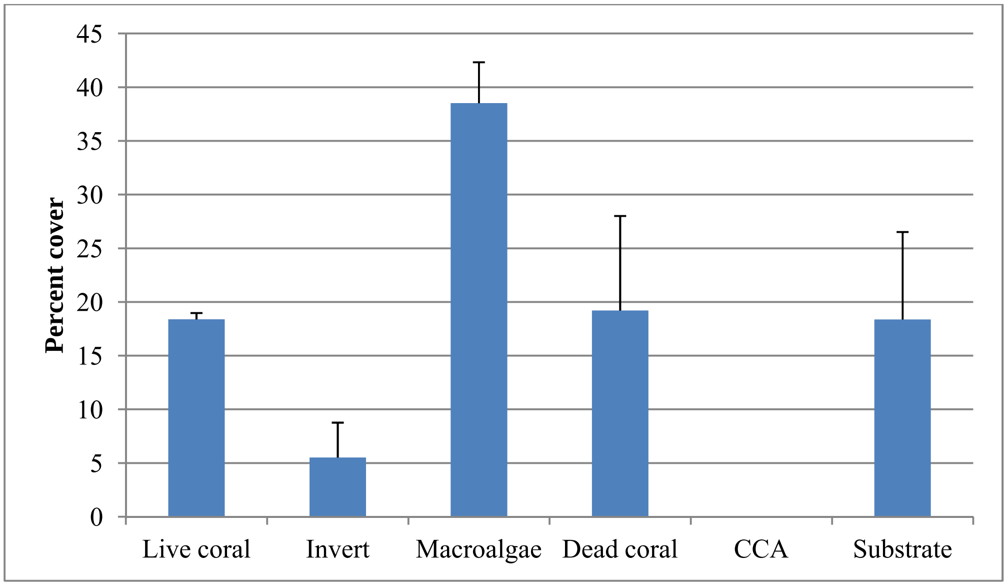


Fig. 17. Cover of benthic attributes identified from photo-transects conducted at PB-05. Mean cover of scleractinian corals (live coral), sessile non-coral invertebrates (invert), macroalgae, dead coral with turf algae (dead coral), crustose coralline algae (CCA) and uncolonized sand, pavement and rubble (substrate) are shown.

5. Coral size structure

Size structure of coral populations was determined from the 3121 corals, 4 cm diameter or larger, identified within 79 belt transects on 19 reefs on Pedro Bank. The coral populations were dominated by small corals (mean diameter = 20 cm), with 30% of all colonies 21 cm or larger and 2% of the corals 100 cm or larger (Fig. 18).

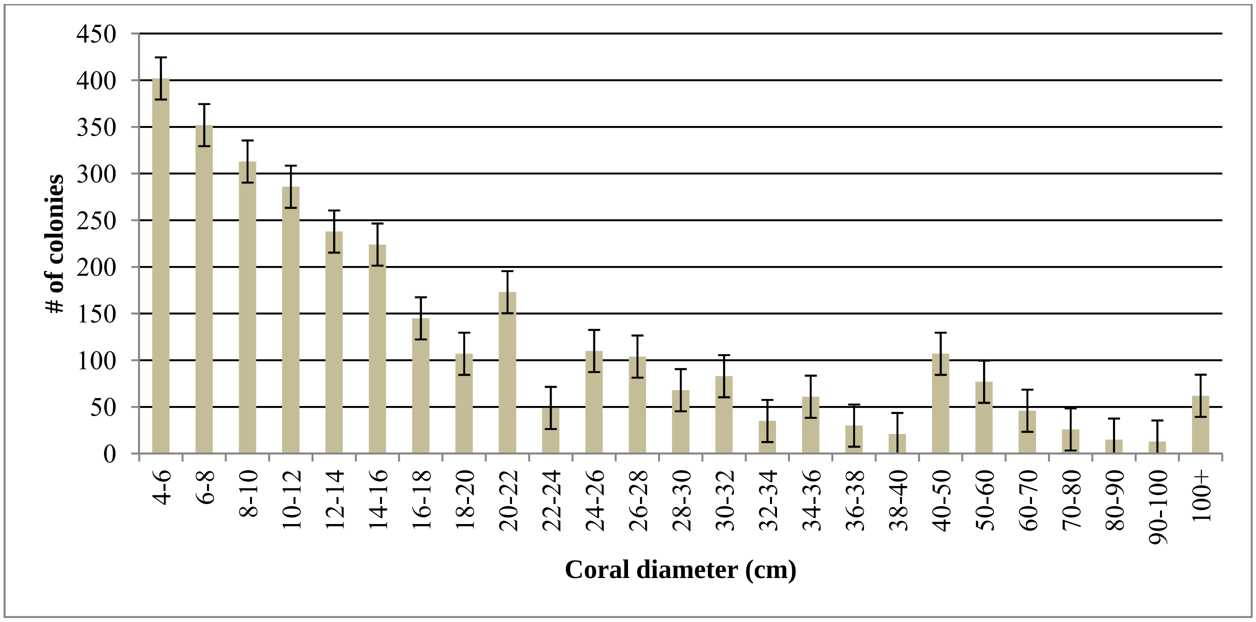


Fig. 18. The size frequency distribution (diameter) for 3121 corals surveyed on Pedro Bank (pooled species). One third (1041 colonies) of all corals were 10 cm or smaller. Only 7.5% (239 colonies) were 50 cm and larger.

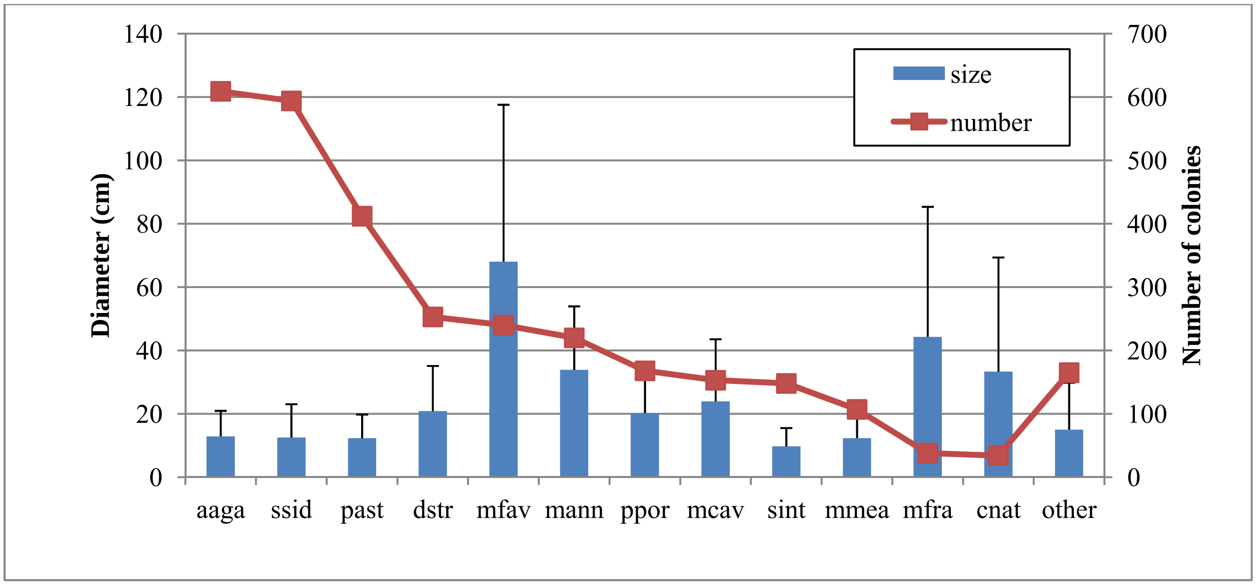


Fig. 19. Diameter of the dominant species of corals observed within belt transects (pooled for 19 reefs).

The size structure of corals varied among species (Fig. 19). The dominant taxa (*A. agaricites, S. siderea* and *P. astreoides*) were the smallest overall, exhibiting a mean diameter of <13 cm. Most other taxa were similar in size, except for the *M. annularis* complex, *C. natans* and some of the rarer corals (*Dendrogyra cylindrus*, *Acropora palmata* and *A. cervicornis*). *M. faveolata* was the only taxon that had a mean diameter exceeding 50 cm. (Fig. 19). There was substantial variation in size among individual species for certain species (e.g. *M. faveolata, M. franksi, P. porites, C. natans* and *Diploria* spp.) while the size structure of other taxa were similar among reefs (Fig. 20, 21, 22, 23).

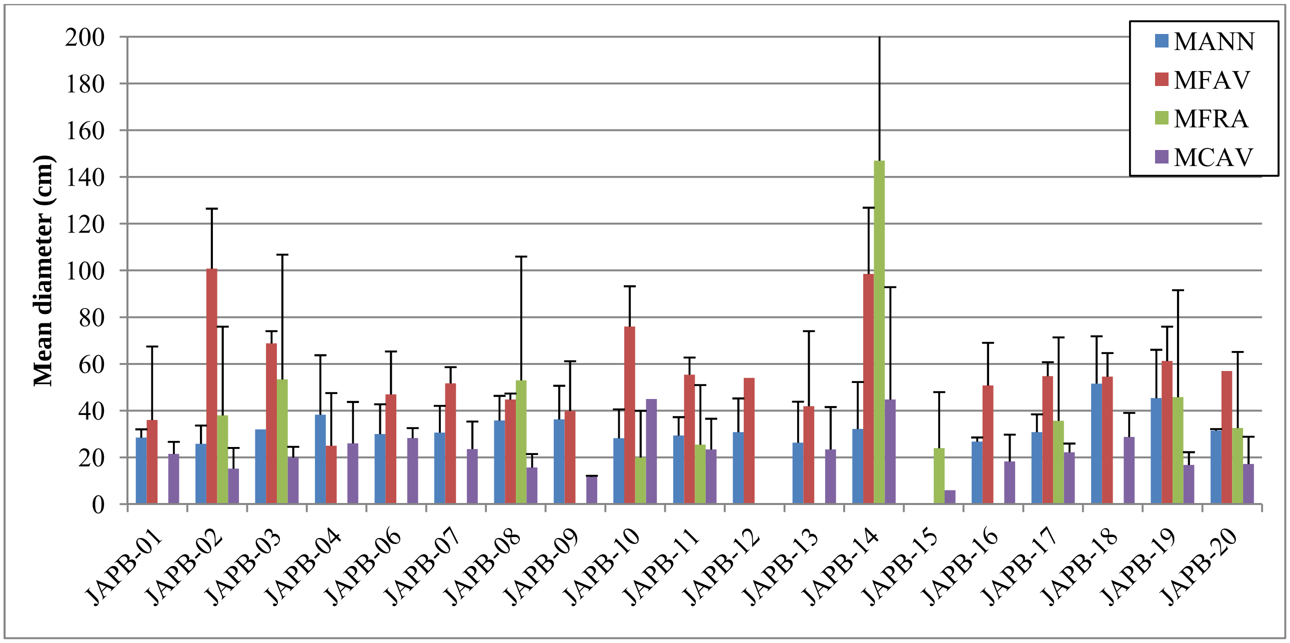


Fig. 20. Mean size (diameter in cm) of the dominant frame-building corals in the genus *Montastraea* pooled from 19 reefs on Pedro Bank, Jamaica. Only corals 4 cm or larger in diameter are included.

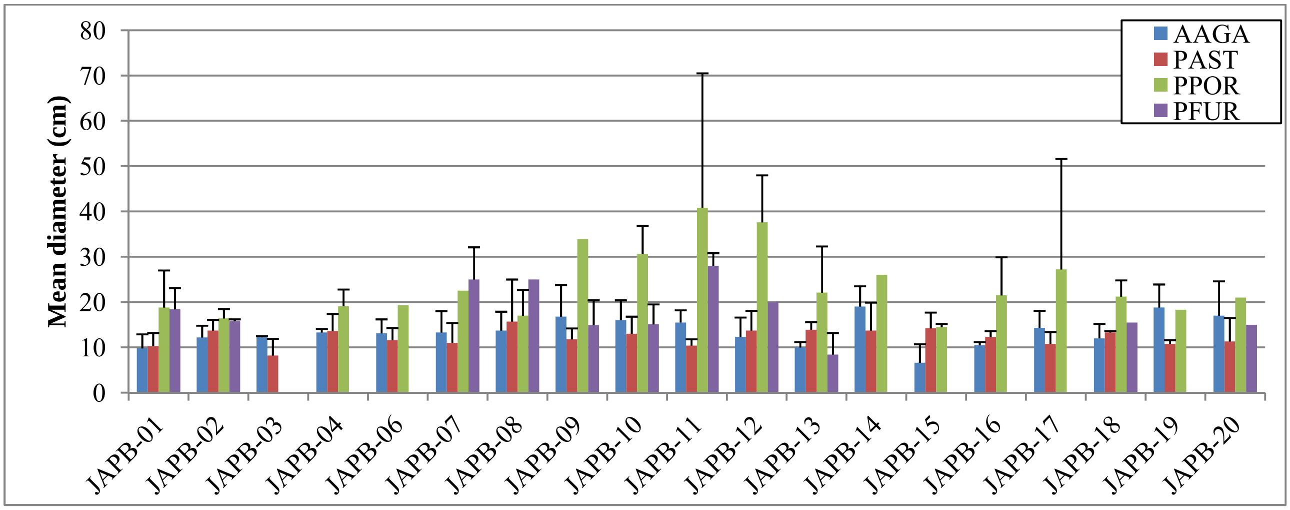


Fig. 21. Mean size (diameter in cm) of brooding corals, 4 cm or larger in diameter, in the genus *Agaricia* and *Porites* for each of the 19 reefs examined on Pedro Bank, Jamaica.

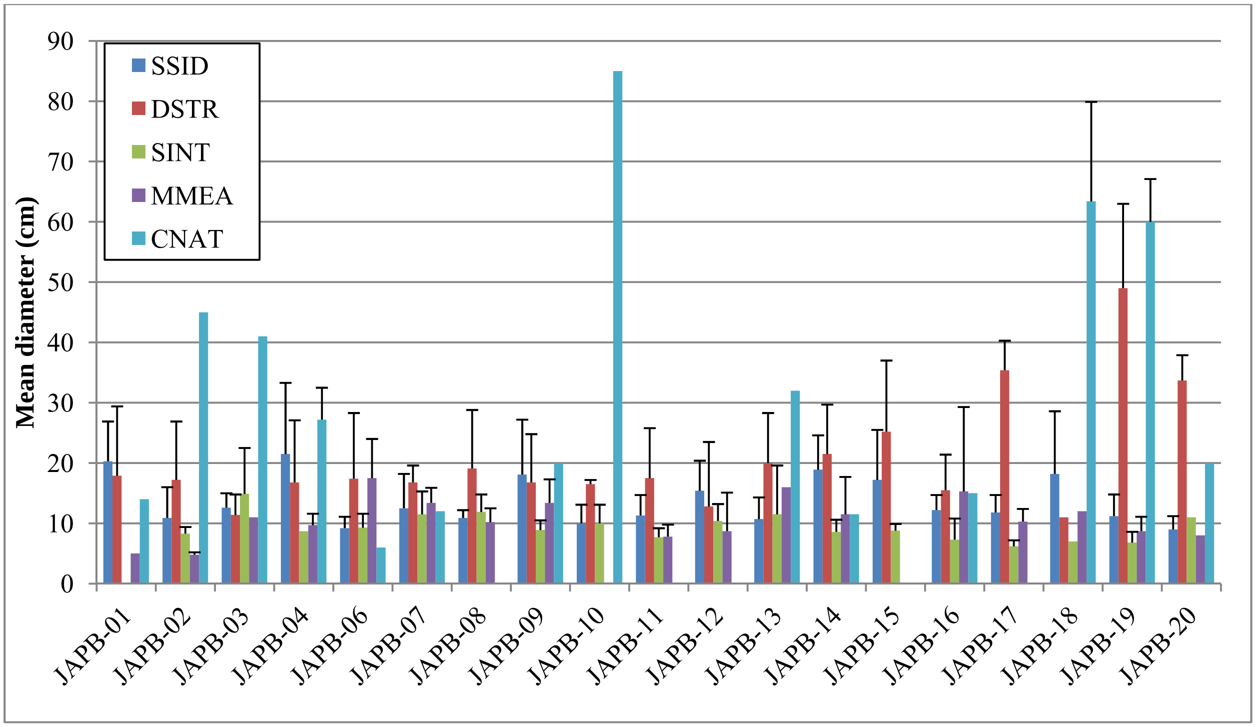


Fig. 22. Mean size (diameter in cm) of the dominant massive corals [*S. siderea* (SSID), *D. strigosa* (DSTR), *S. intersepta* (SINT), *M. meandrites* (MMEA) and *C. natans* (CNAT)] for each of the 19 reefs examined on Pedro Bank, Jamaica. Only corals 4 cm or larger in diameter are included.

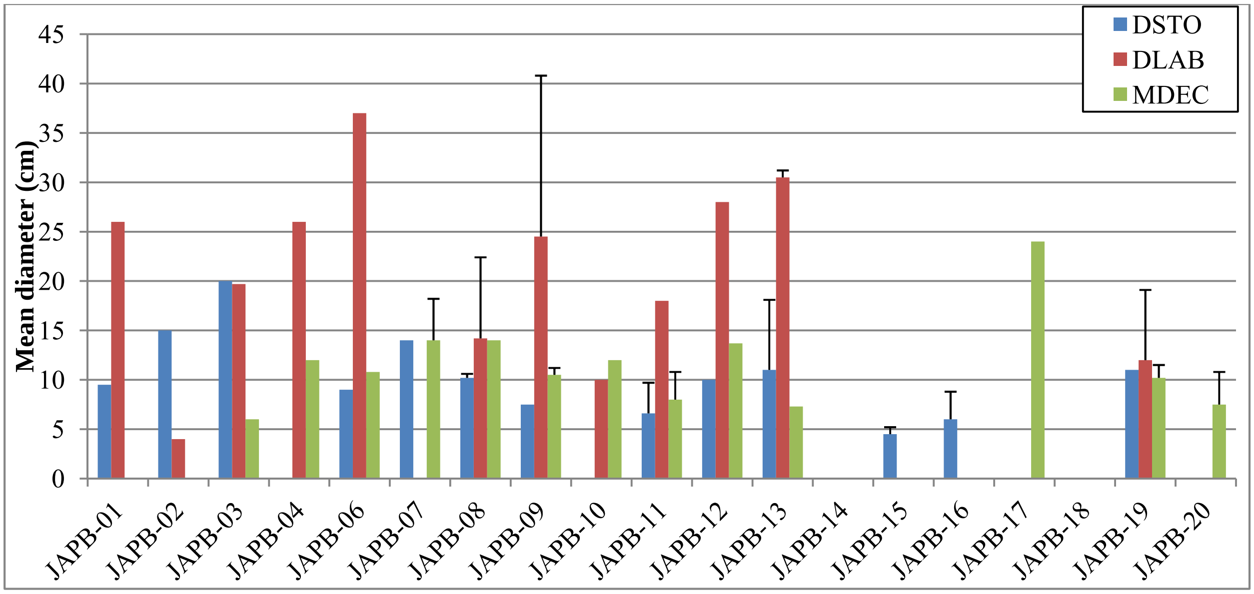


Fig. 23. Mean size (diameter in cm) of other important scleractinian for each of the 19 reefs examined on Pedro Bank, Jamaica. *Dichocoenia stokesi* (blue), *Diploria labyrinthiformis* (red) and *Madracis decactis* (green) are shown.

6. Extent of partial mortality

Colonies were missing on average only about 10% of their tissue (all corals pooled form all reefs), most of which was due to old mortality (9.6%) with very little recent mortality (0.19%) or transitional mortality (0.19%). The highest amount of old mortality was recorded at PB-14, while the lowest was at PB-02. Transitional and new mortality ranged from 0-1.1%, with the highest amount of recent mortality (transitional and new mortality pooled) observed at PB-10 (1.1%) and PB-11 (0.9%) (Fig. 24).

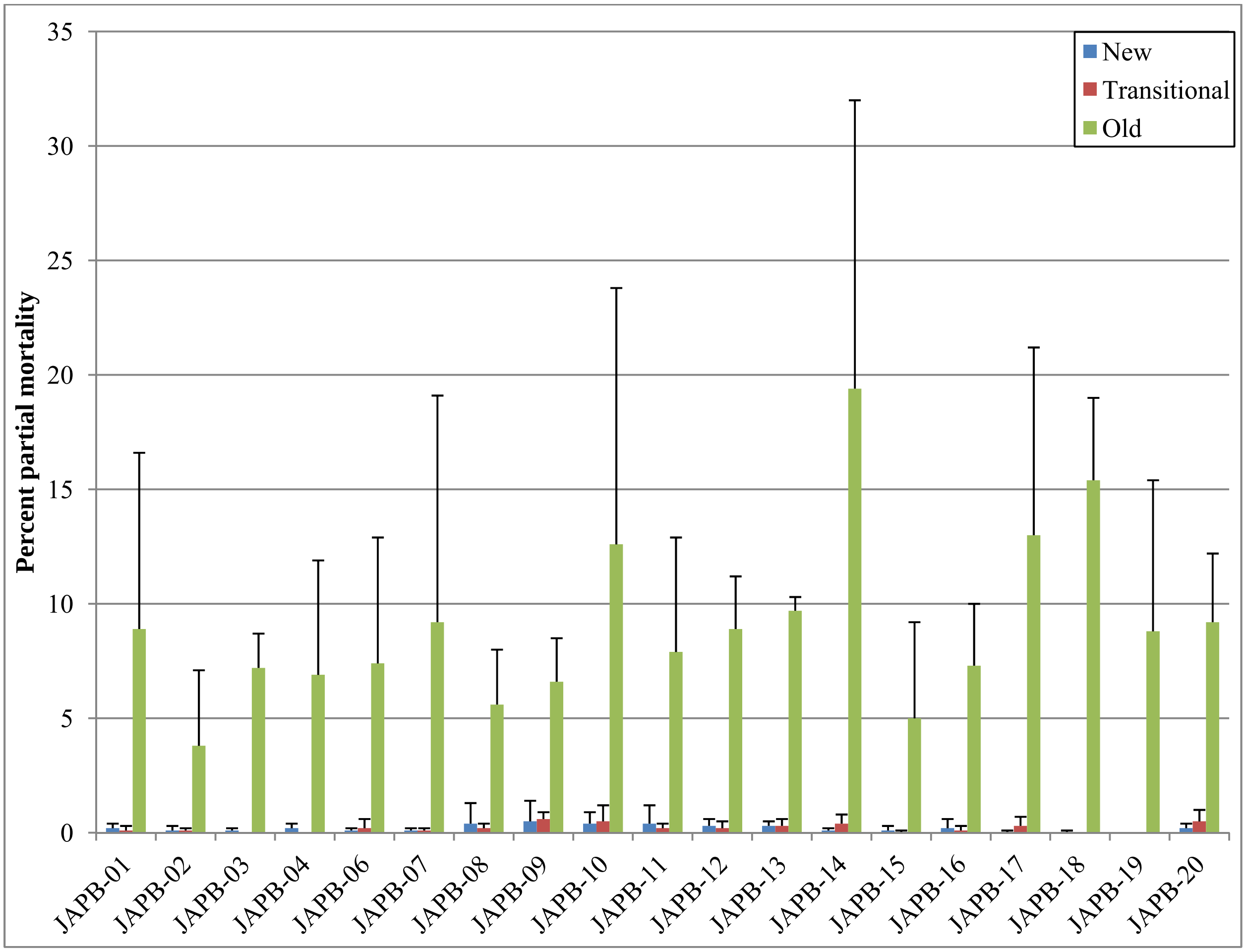


Fig. 24. Amount of partial tissue loss to living corals separated into recent mortality (new, blue bars), transitional mortality (red bars) and old mortality (green bars). All corals are pooled for each site.

An examination of mortality among individual species illustrates the low amount of partial mortality in most corals, especially the brooding corals and the smaller massive corals (Fig. 25). The highest amount of partial mortality was observed in *M. annularis* (27%), *M. faveolata* (22%) and *C. natans* (20%). Very few corals (4% of the total) showed recent or transitional mortality. Overall, the amount of partial mortality is substantially less than that recorded in other locations around the Caribbean, especially on the large frame builders such as *Montastraea annularis* (complex).

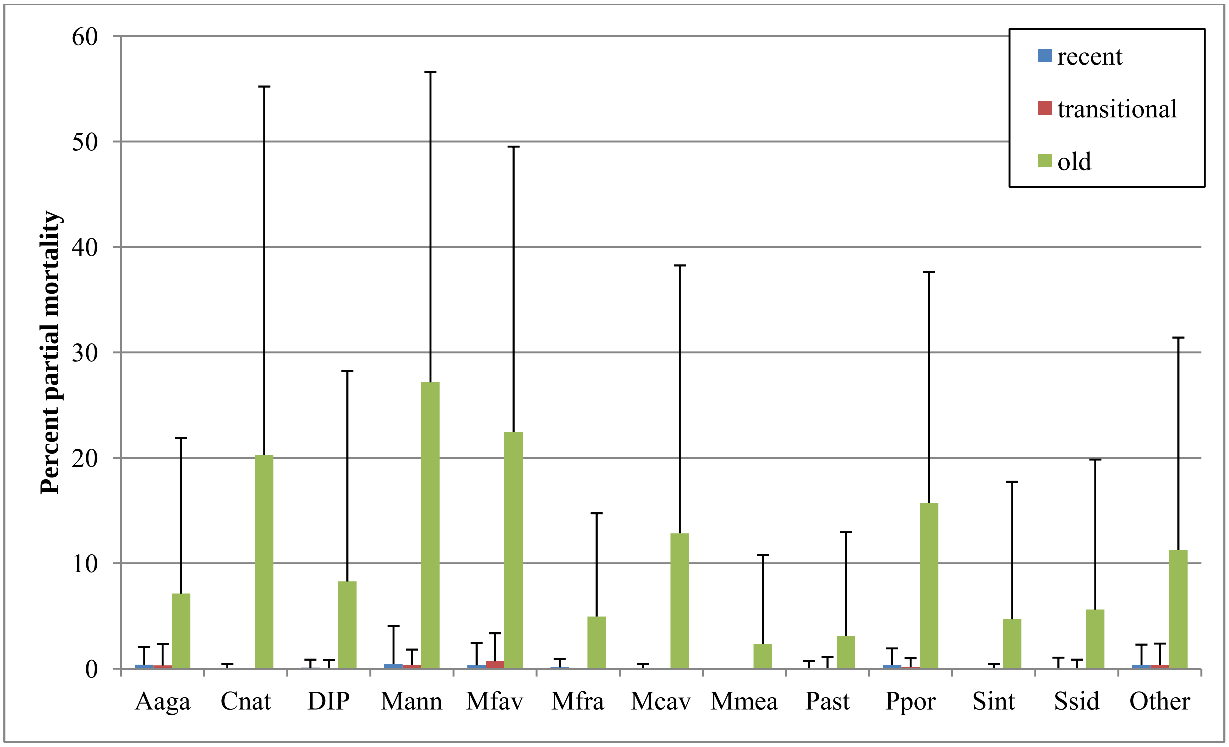


Fig. 25. Amount of partial tissue loss in scleractinian corals found on Pedro Bank. Data are pooled by species from 19 reefs. DIP includes *D. clivosa, D. strigosa* and *D. labyrinthiformis*; Ppor includes *P. porites, P. divaricata* and *P. furcata*. Other includes *A. cervicornis, D. cylindrus, D. stokesi, E. fastigiata, M. mirabilis, M. decactis, M. ferox, I. rigida, I sinuosa, Leptoseris cucullata*.

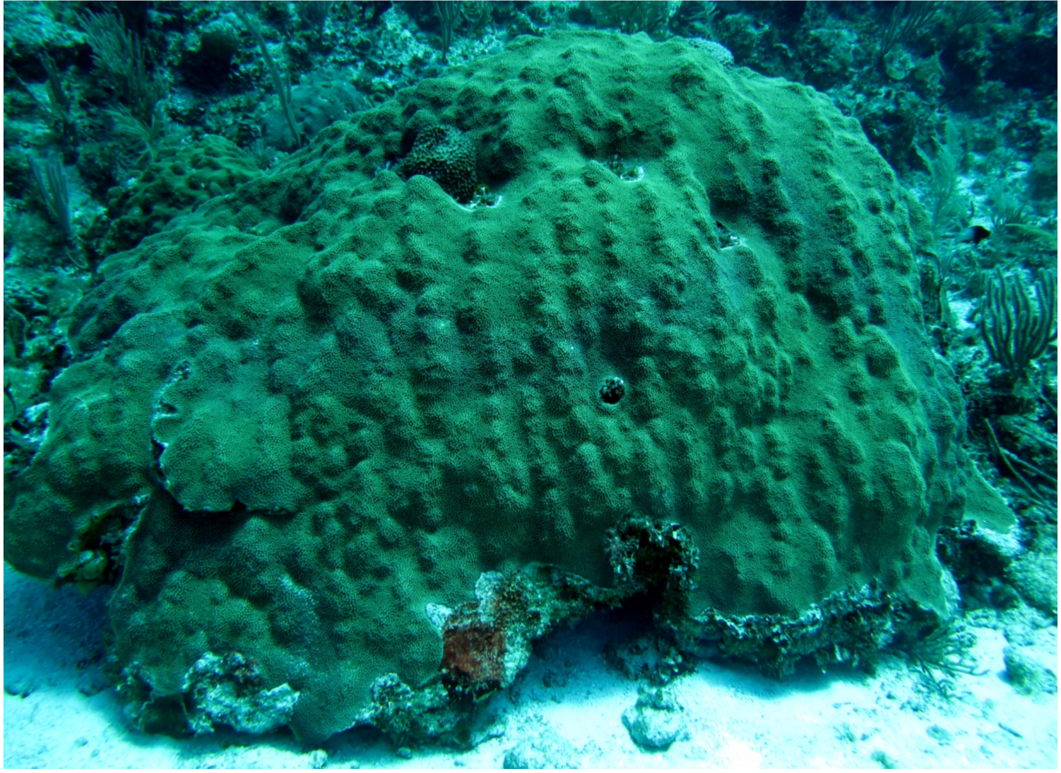


Fig. 26. A large colony of *M. faveolata* with very little partial mortality.

7. Recruitment

A total of 746 quadrats, each 0.25 m^2 in area, were assessed for coral recruits (0-2 cm diameter) on 19 reefs. Overall, 153 recruits were identified within 12% of the quadrats examined; 88% of the quadrats contained 0 recruits. Recruits occurred at a mean density of 3.28 recruits/m^2, with the highest density recorded at PB-06, 09, and 12 (Fig. 27). Recruits consisted of 16 species of reef building corals, with 6 species making up 80% of all recruits. The dominant recruits were *S. siderea* (27%), *P. astreoides* (19%), *A. agaricites* (14%), *M. cavernosa* (7%), *Favia fragum* (6.5%) and *Meandrina meandrites* (5.8%) (Fig. 28). Two *M. annularis* (complex) recruits were identified.

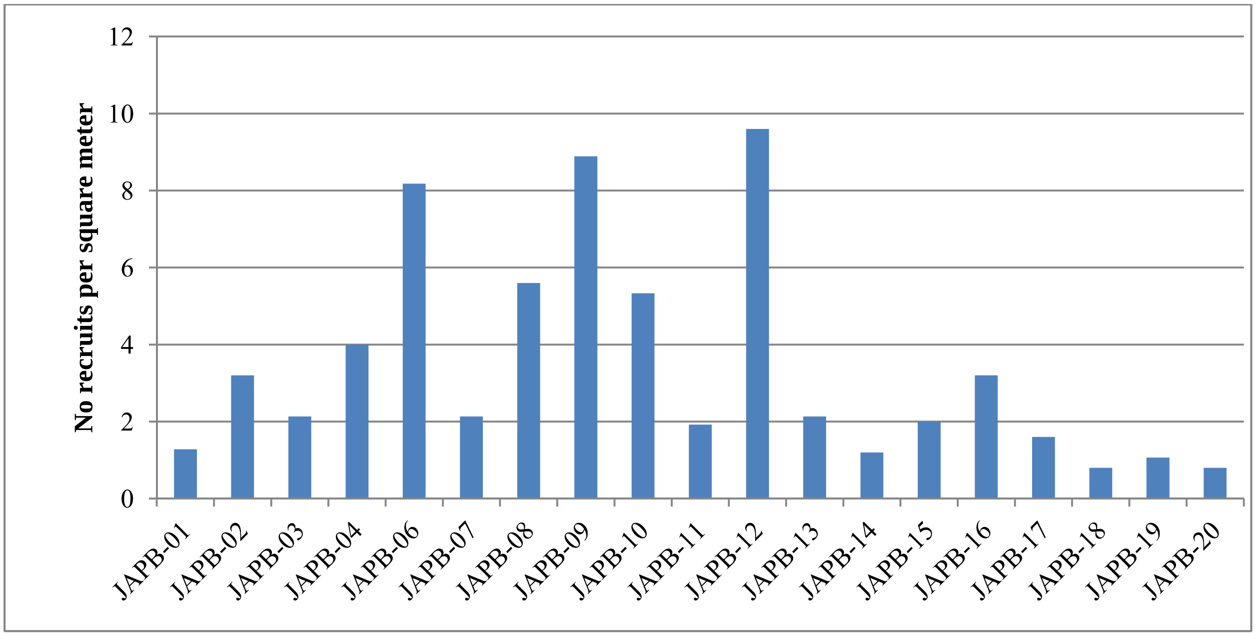


Fig. 27. Density of recruits within the 19 reefs examined on Pedro Bank. All species are pooled.

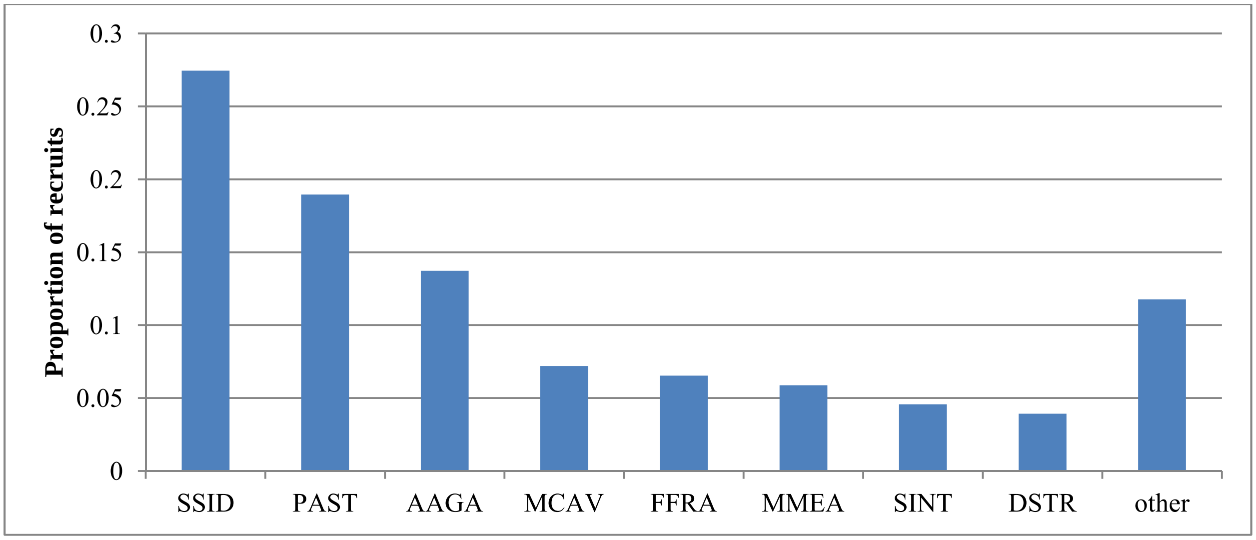


Fig. 28. Proportion of recruits for each coral taxon. Data are pooled for all sites examined on Pedro Bank, Jamaica.

Individual sites had 1-8 species of recruits. *Siderastrea* was the dominant recruit observed in the three sites with the highest number of recruits (PB-06,09,12), while all other species of recruits were dispersed throughout other sites at low densities (Fig. 29).

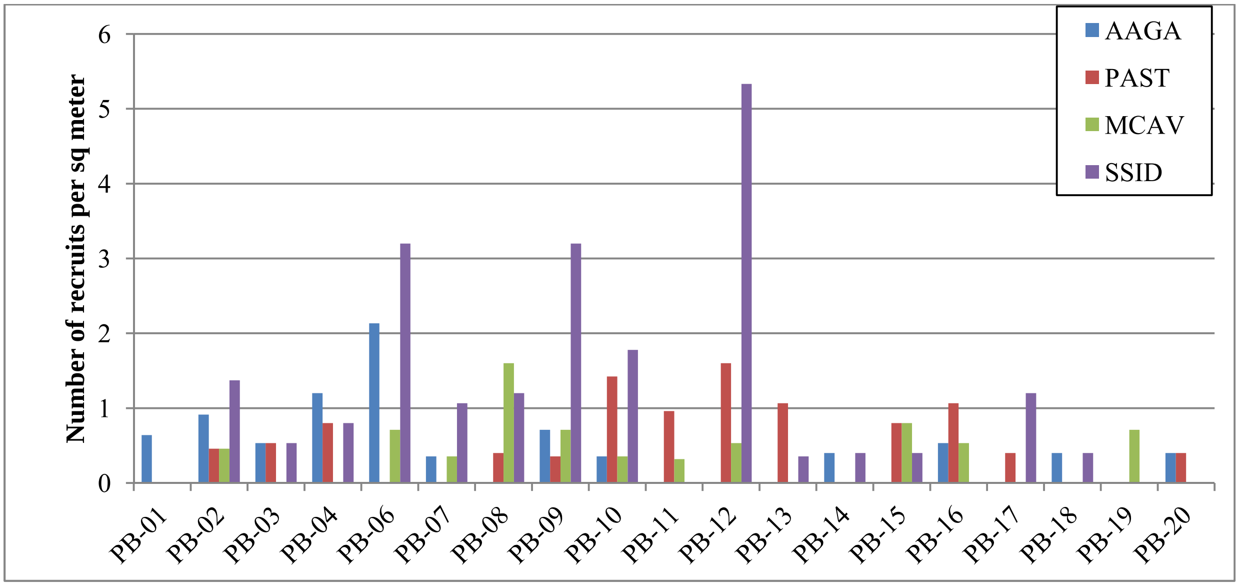
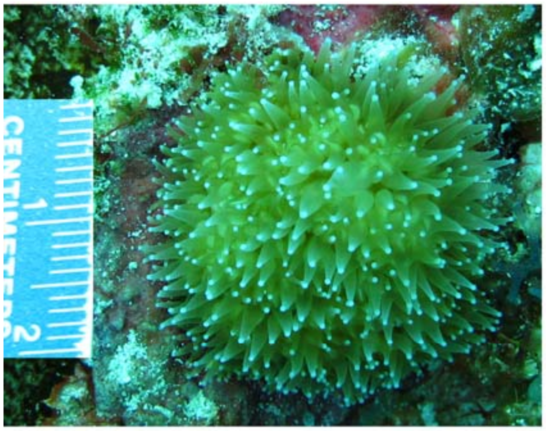


Fig. 29. Density of recruits observed on each reef for the four most common corals.

Fig. 30. Examples of recruits seen on Pedro Bank (next page). A. *Dendrogyra cylindrus*. B. *Montastraea cavernosa*. C. *Diploria strigosa*. D. *M. annularis*. E. *Meandrina jacksoni*. F. *Isophyllia sinuosa*. G. *Siderastrea siderea* and *D. strigosa*. H. *Stephanocoenia intersepta* and *S. siderea*.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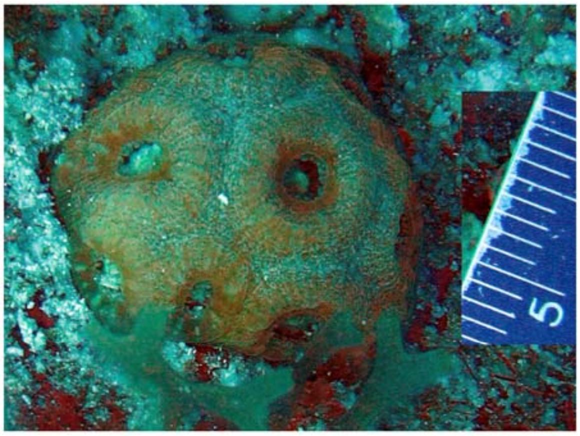
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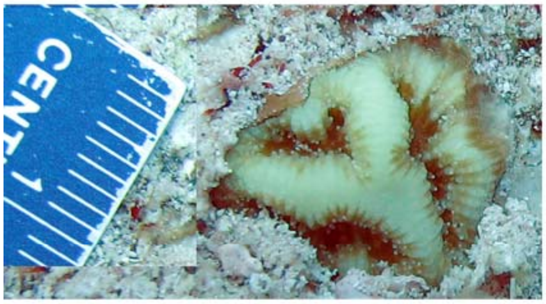
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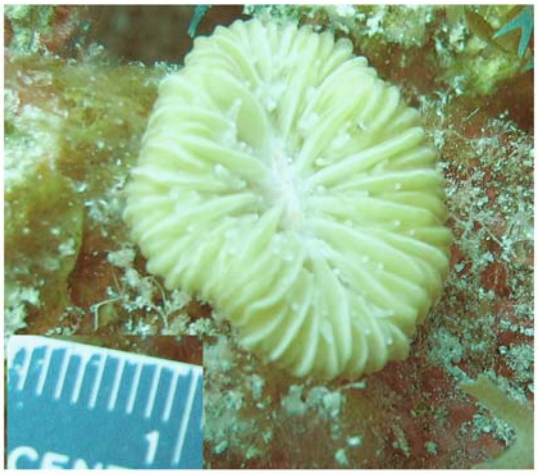
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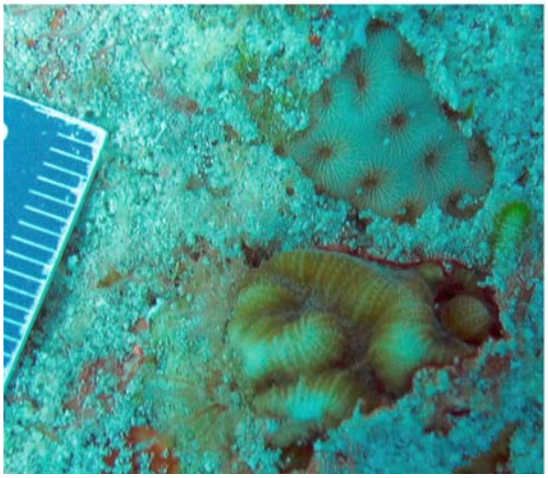

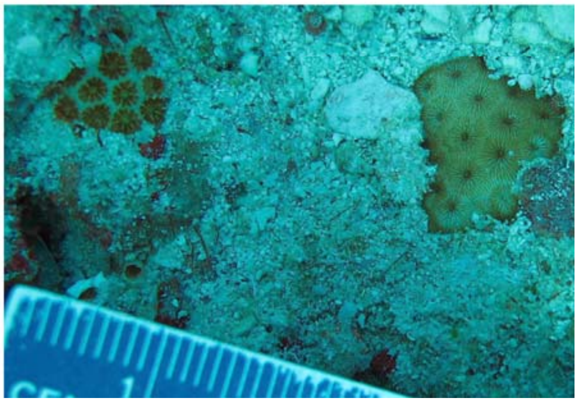
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8. Reef fish community structure

A total of 116 species of reef fishes were identified within 19 reefs, with an average of 44 species per reef and a maximum of 57 recorded on Banner Reef (PB-11). Twenty four species were each observed only once, while 22 species were recorded on most (>80%) of the reefs. The highest values of richness were recorded on PB-16 and PB-20, while the lowest was observed in a lagoonal patch reef (PB-01). Evenness and diversity were fairly similar among sites, with lowest values recorded on PB-17 and PB-18. Many species were rare or absent including all snappers, large serranids (populations consisted only of hinds and graysbys), barracuda, and many of the species of morays, grunts, and angelfish.

Table 4. Diversity (species and family), species richness (d) and evenness (J') of reef fish by site.

Site	Species	Family	d	J'	H'
JAPB-01	35	15	2.754	0.798	1.914
JAPB-02	42	19	4.578	0.7814	2.214
JAPB-03	33	17	4.218	0.798	2.161
JAPB-04	No data	No data	4.428	0.7459	2.068
JAPB-06	44	20	3.608	0.7167	1.838
JAPB-07	44	20	4.366	0.7502	2.08
JAPB-08	49	23	4.069	0.8141	2.088
JAPB-09	43	19	4.41	0.7845	2.175
JAPB-10	48	23	4.885	0.8037	2.323
JAPB-11	57	25	4.608	0.759	2.15
JAPB-12	46	22	4.309	0.7464	2.069
JAPB-13	45	21	4.387	0.6933	1.964
JAPB-14	52	21	5.425	0.7745	2.358
JAPB-15	44	23	3.842	0.8348	2.365
JAPB-16	41	19	6.063	0.7909	2.408
JAPB-17	24	13	3.911	0.642	1.647
JAPB-18	51	23	4.041	0.5882	1.732
JAPB-19	48	24	4.852	0.7963	2.256
JAPB-20	38	18	5.778	0.7616	2.242

Reef fish populations exhibited a fairly low abundance (65 fish/100 m^2), size (mean=13 cm) and biomass (9430 grams/100 m^2). Populations were dominated by herbivores, with the highest density recorded among parrotfish (25 fish/100 m^2; most *Sparisoma aurofrenatum* redband parrotfish) followed by surgeonfish (11 fish/100 m^2). Other common species included wrasses (9 fish/100 m^2) and grunts (6 fish/100 m^2), while most other functional groups had a density of <1 fish/100 m^2 (Fig. 31). All species of fish were very small; over 78% were less than 20 cm and only 3.5% were over 30 cm (Fig. 32). Overall biomass of these species was also low; herbivores had the greatest biomass (5500 grams/100 m^2) followed by invertivores (2965 grams/100 m^2) (Fig. 33).

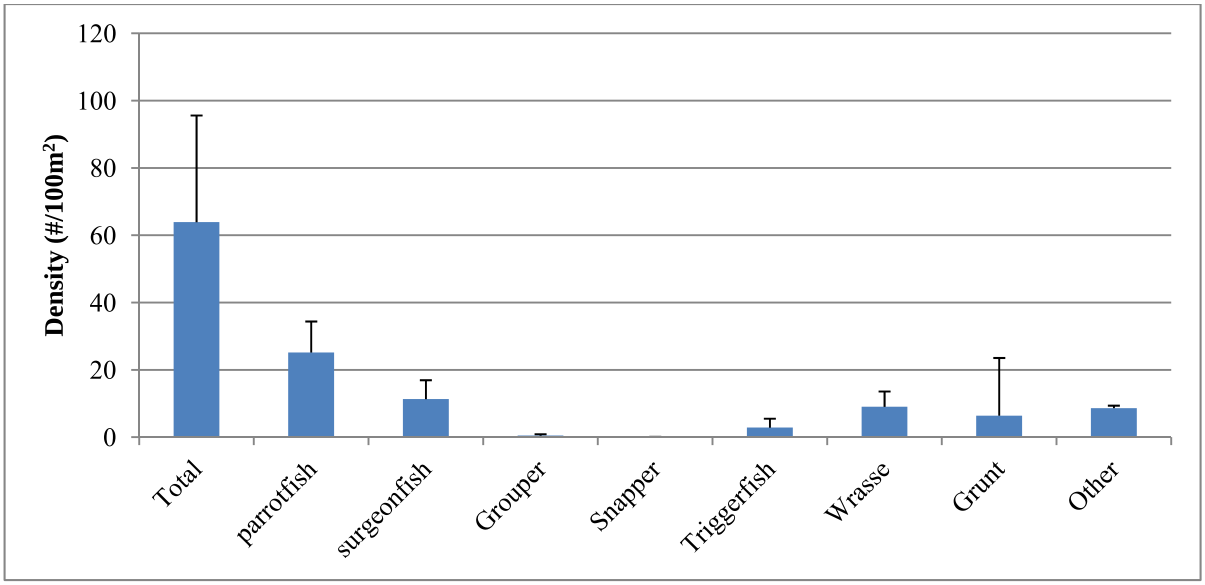

Fig. 31. Density of reef fish reported as number of fish per 100 sq meter. Data are pooled from 19 sites on Pedro Bank.

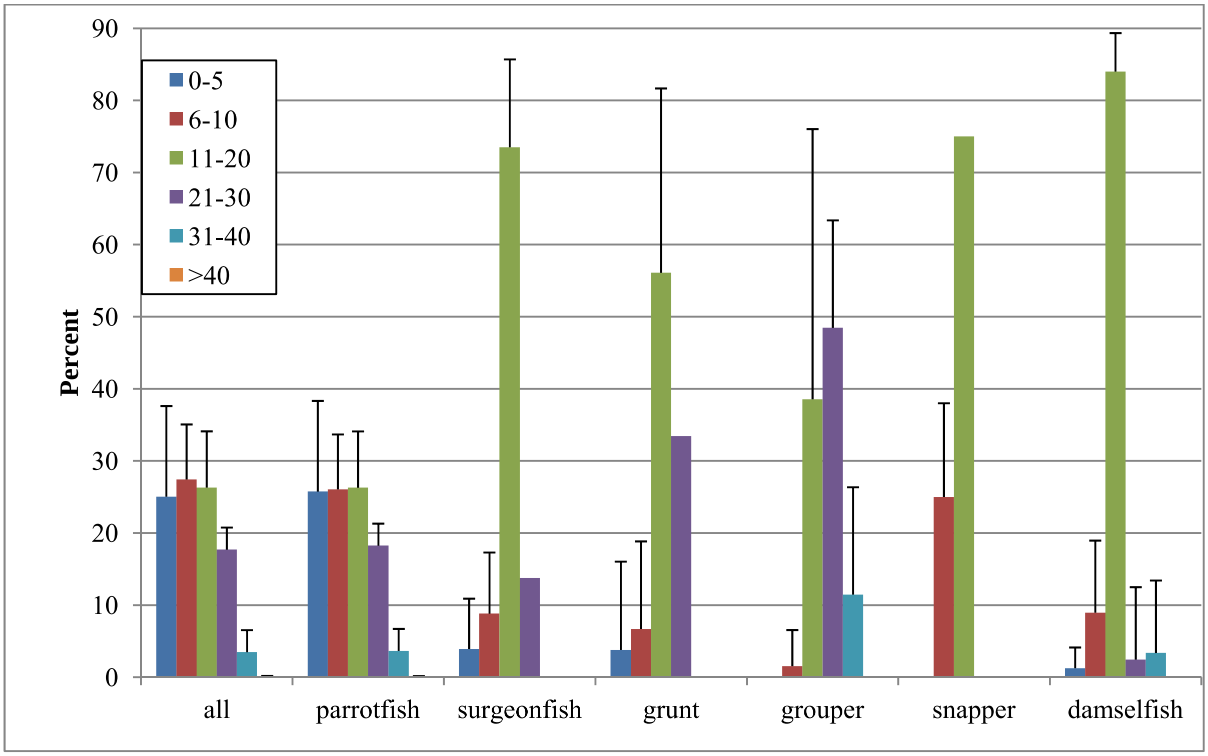

Fig. 32. Total length of reef fish observed on 19 reefs off Pedro Bank, Jamaica binned into 5 cm size classes for all fish (pooled species) and for specific indicator groups. Sizes are pooled for all species in each group.

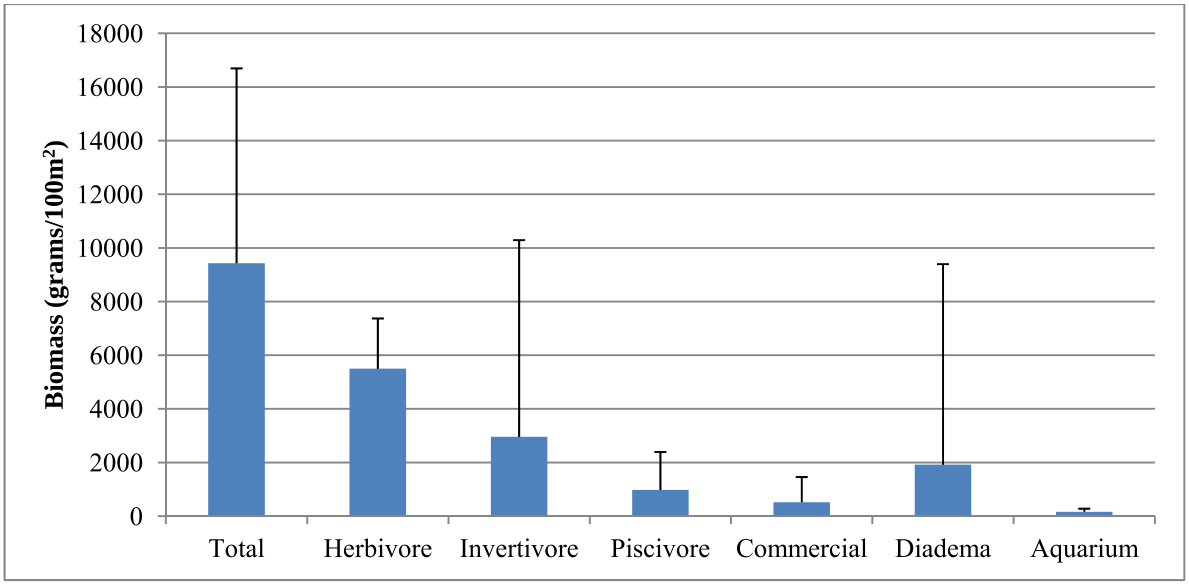

Fig. 33. Biomass of reef fish observed within 19 sites on Pedro Bank. All species are pooled into functional groups. Mean and standard deviation are shown.

The density, size and biomass of major functional groups showed considerable variation among sites. The dominant fish assemblage on these reefs, in terms of biomass were herbivores. Herbivores biomass was lowest at PB-08 (1774 grams/m^2) and highest at PB-02, and PB-03 (>8600 grams/m^2) (Fig. 34). Parrotfish biomass was higher than surgeonfish at all sites except PB-13 (3431 grams/m^2 vs. 1608 grams/m^2) (Fig. 35). The highest biomass of parrotfish was recorded at PB-18 (3728 grams/m^2), PB-01 (3708 grams/m^2), PB-08 (3310 grams/m^2), PB-06 (3159 grams/m^2) and PB 17 (3014 grams/m^2), and the lowest at PB-02 (1109 grams/m^2) and PB-15 (1134 grams/m^2). PB-13 was the only site where large schools of surgeonfish were recorded; in all other locations these occurred as individuals or small schools. The dominant parrotfish was the redband parrotfish (Fig. 36).

The next most abundant group of fishes were invertivores, especially grunts and triggerfish. The biomass of invertivores was <1000 grams/m^2 at 9 sites, and < 2000 grams/m^2 everywhere except PB-15, 18 and 17 (Fig. 37). PB-17 was an outlier with more than a 3 fold higher biomass (>35000 grams/m^2) than all other sites (Fig. 36). This difference was attributed primarily to an unusually large abundance of invertivores, in particular triggerfish. PB-17 was also located distant from other sites, occurring at the opposite (northwest) end of the bank.

Piscivores occurred at a very low biomass everywhere. The highest biomass overall was recorded at PB-19 (5310 grams/m^2), followed by PB-10 (2922 grams/m^2), PB-11 (2463 grams/m^2) and PB-13 (2066 grams/m^2) (Fig. 38). There was a complete absence of barracuda at all sites, few snappers, and very few larger groupers. The dominant groupers were hinds and graysbys (Fig. 39).

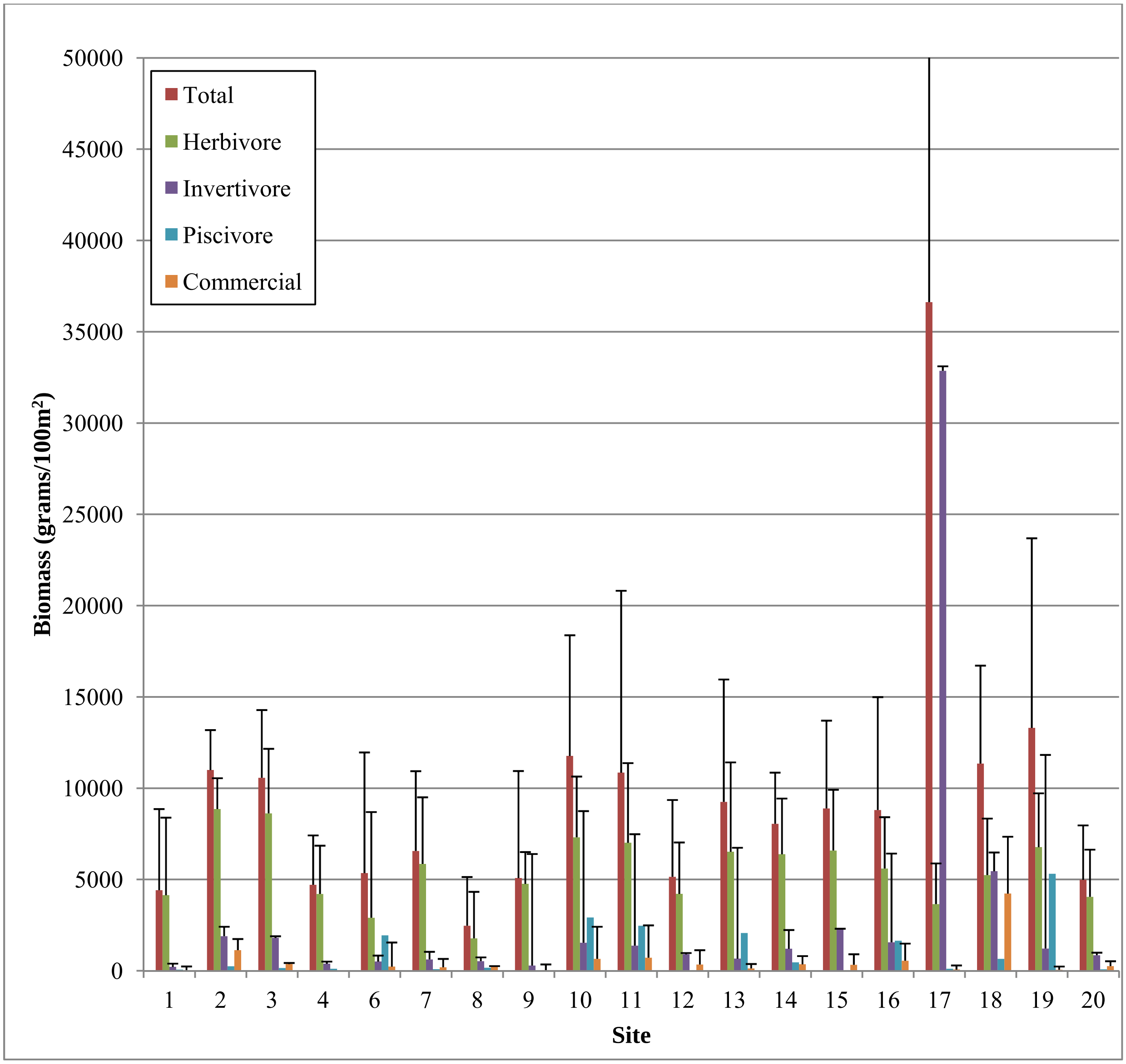

Fig. 34. Biomass of the major functional groups of fishes on 19 sites in Pedro Banks. Total biomass (red) for all species, herbivore biomass (parrotfishes, surgeonfishes and damselfishes), invertivore biomass, piscivore biomass and biomass of commercially important species are shown.

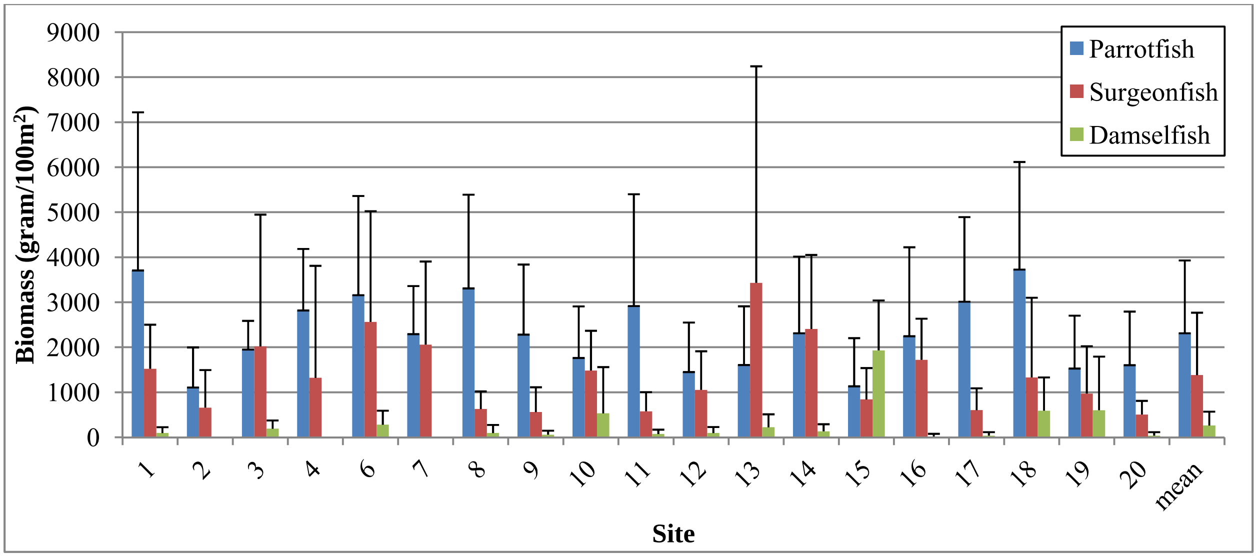

Fig. 35. Biomass of herbivores, separated into parrotfish, surgeonfish and damselfish (mean and standard deviation) for each reef examined on Pedro Bank.

Fig. 36. The typical size of the dominant parrotfish, *Sparisoma aurofrenatum* on Pedro Bank.

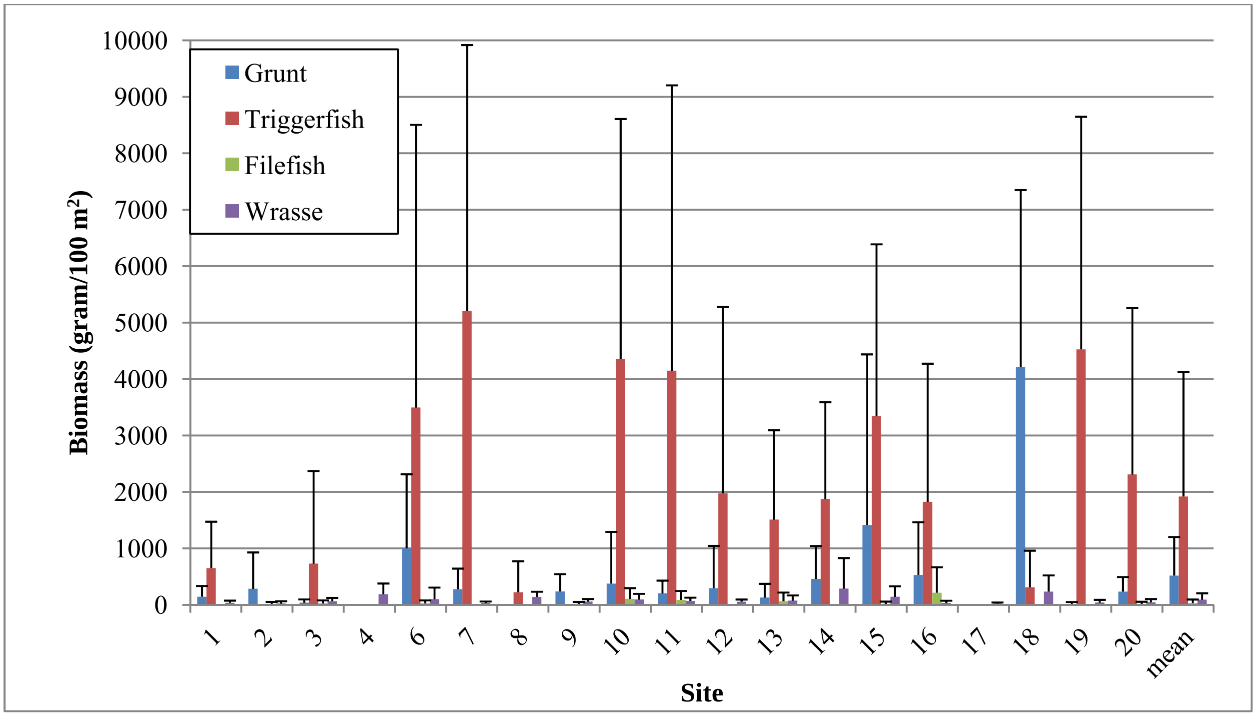

Fig. 37. Biomass of the four most common invertivores, grunts, triggerfish, filefish and wrasses shown for each reef examined on Pedro Bank.

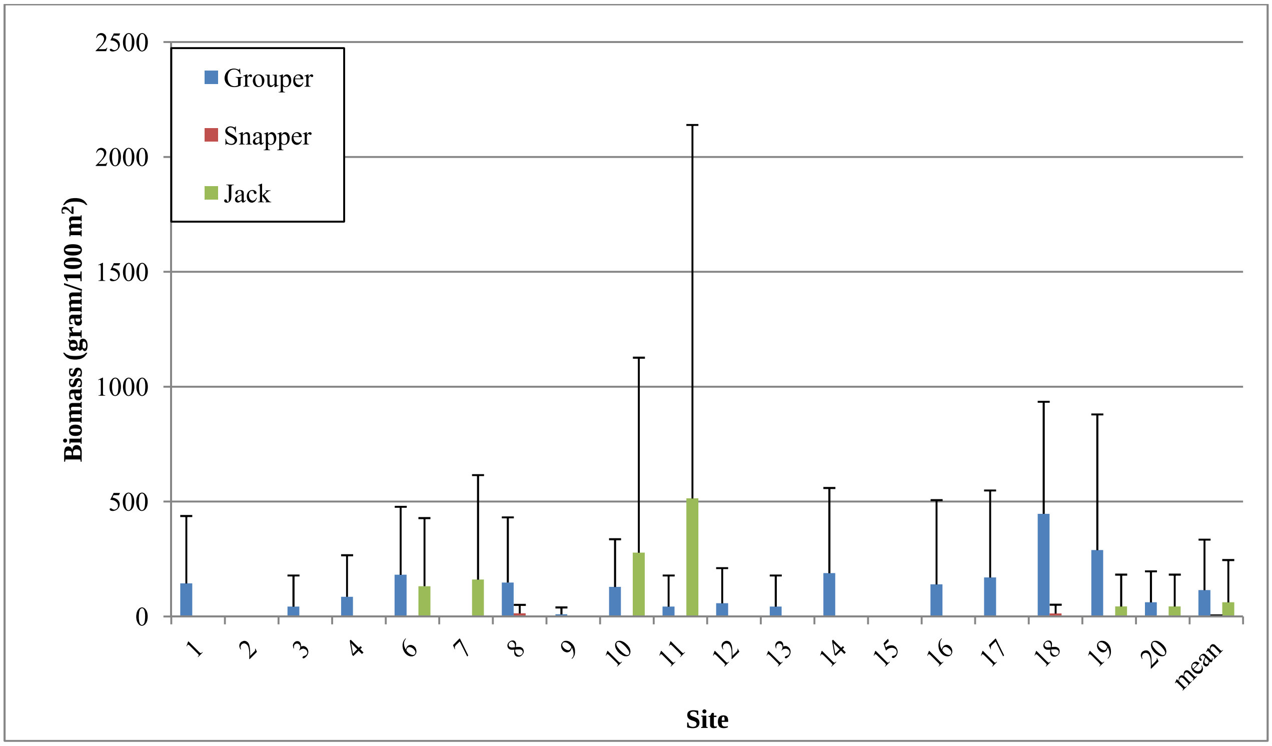

Fig. 38. Biomass of the dominant piscivores, grouper, snapper and jacks shown for each reef examined on Pedro Bank.

Fig. 39. The largest and most abundant serranids seen on Pedro Bank were red hinds, rock hinds and graysby [*Epinephelus adscensionis* (above), *Epinephelus guttatus and Cephalopholis cruentata*].

Spatial and temporal variation in fish populations

Fish data collected on Pedro Bank during this expedition were compared with fish data from Pedro Bank in 2005 and mainland Jamaica in 2000. For the Pedro Banks data sets an initial examination of the relationship between the size of fish populations (abundance and/or biomass) and distance from the fishing village was undertaken. In 2005, the biomass for all species and herbivores was substantially higher on reefs that were at least 10 miles away, while the biomass of invertivores was greatest 5-10 miles away, with lower values recorded both closer to the village and in more distant reefs (Fig. 40).

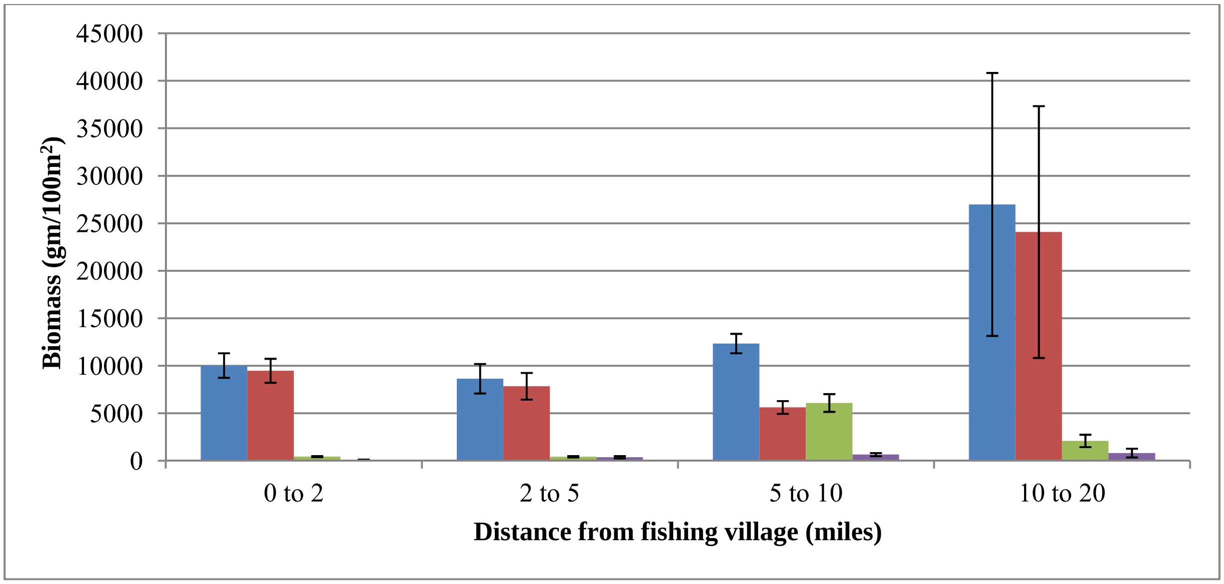

Fig. 40. Relationship between biomass of fish and distance from the populated Cays in 2005. The mean and standard error for total biomass of all species pooled (blue bars) herbivores (red bars), invertivores (green bars) and commercial species (purple bars) are shown.

In 2012, populations of reef fish did not appear to show any significant relationship with distance from the inhabited Cays, with exception of the invertivores, which were much more abundant at PB-15, 18, and 17 respectively (Fig. 41, 42).

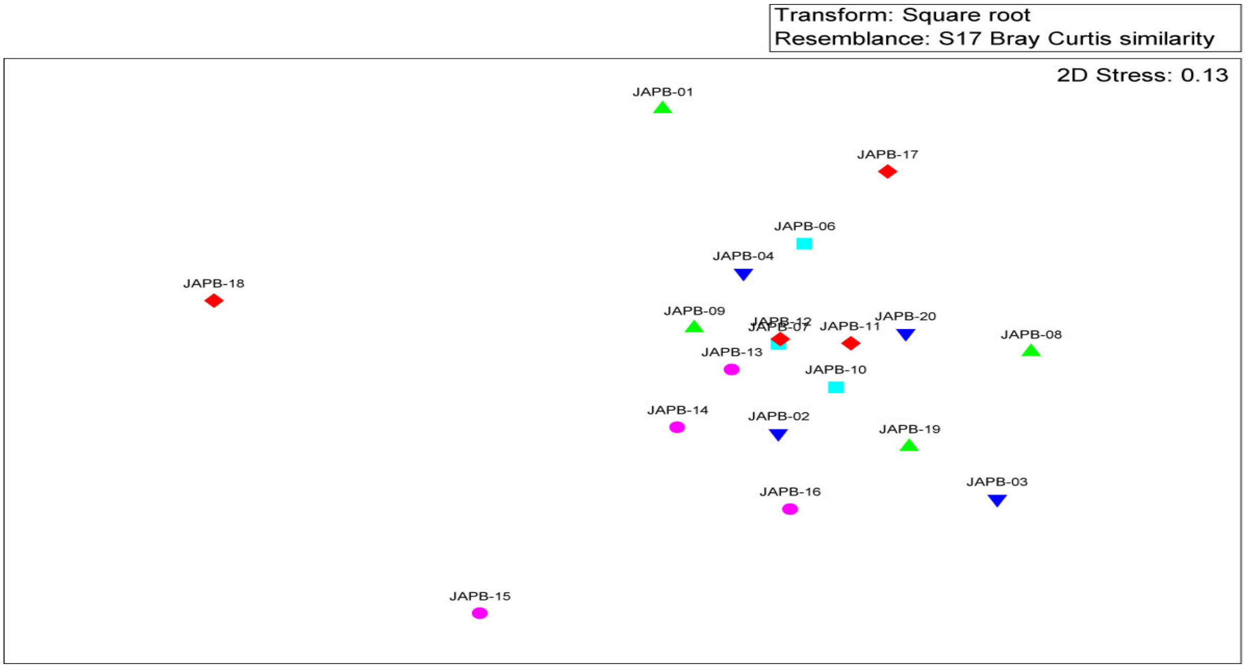

Fig. 41. nMDS plot showing relationship between surveyed fish abundance and distance from the main fishing village on Pedro Bank. Each point is an individual site. The distance increases in the following order: green triangle, blue inverted triangle, blue square, purple circle and red diamond.

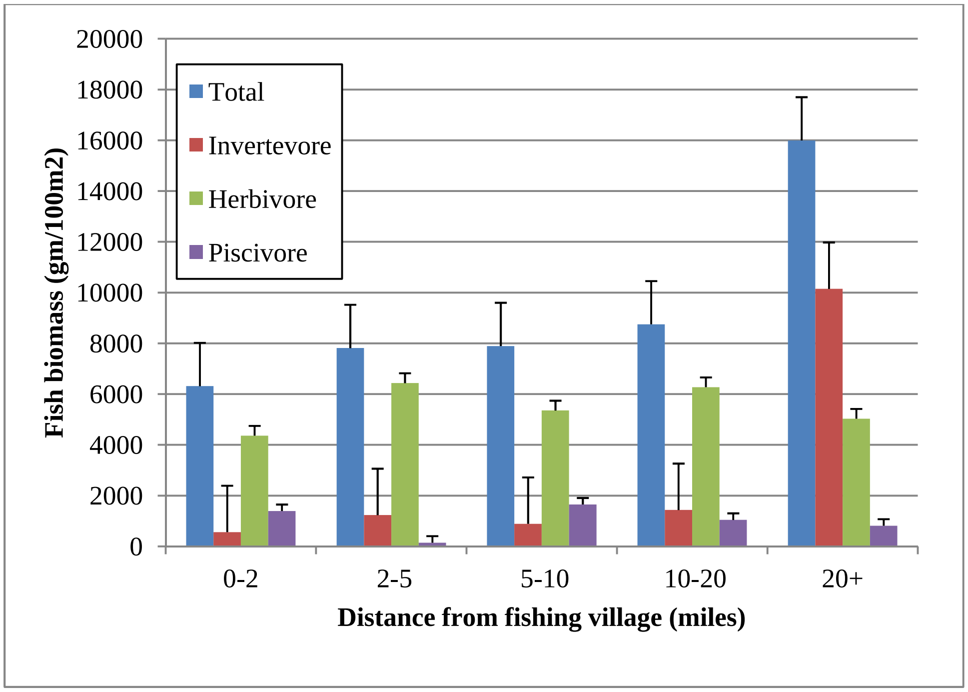

Fig. 42. The average fish biomass for sites grouped by distance from the main fishing village on Pedro Bank using data collected in 2012. Total fish biomass is represented by the blue bar which is then broken down into the three functional groups represented in red, green and purple.

The total abundance and biomass of all fish and of the major functional groups were significantly lower on mainland Jamaica when compared to either 2005 or 2012 Pedro Bank data. The total abundance and biomass on Pedro Bank declined between 2005 and 2012, largely due to a significant decline in surgeonfishes (Fig. 43a). The abundance of parrotfish was slightly higher in 2012, but the biomass was virtually the same, suggesting the size of parrotfish has declined over this period (Fig. 43b). Interestingly, the biomass and abundance of invertivores was also higher in 2005 if the data for PB-17 is removed (no surveys were done in this location in 2005).

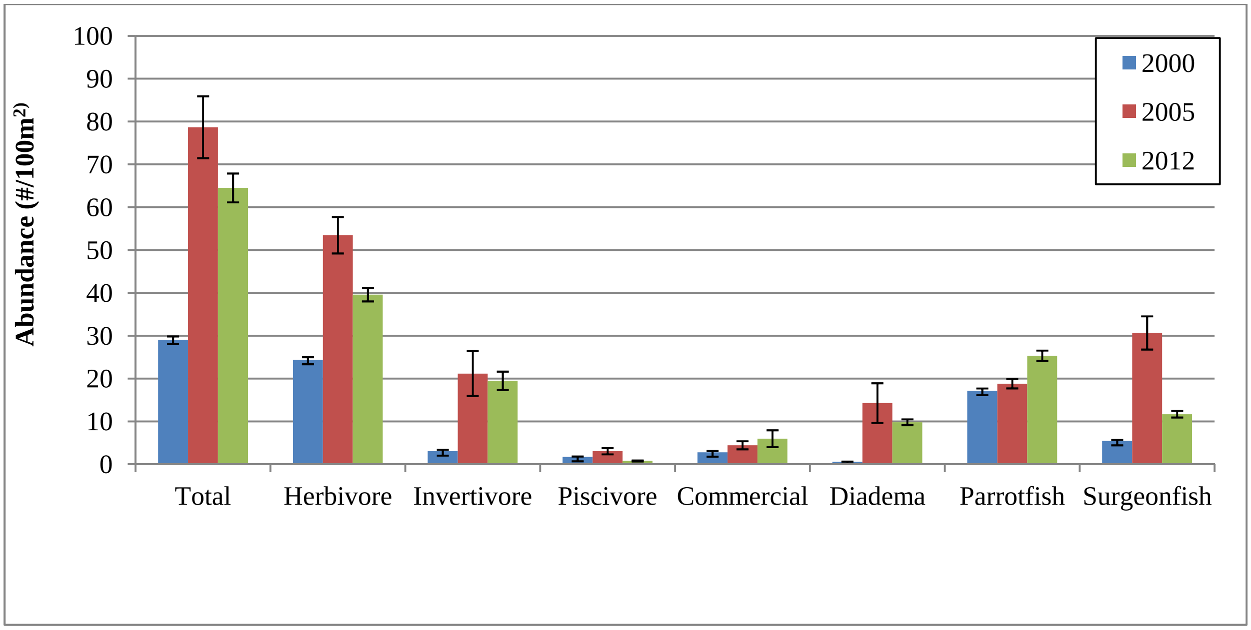

Fig. 43a. The abundance of functional groups of fishes from mainland Jamaica (2000) and Pedro Bank (2005, 2012). Data from PB-17 are not included. Mean and standard error are shown.

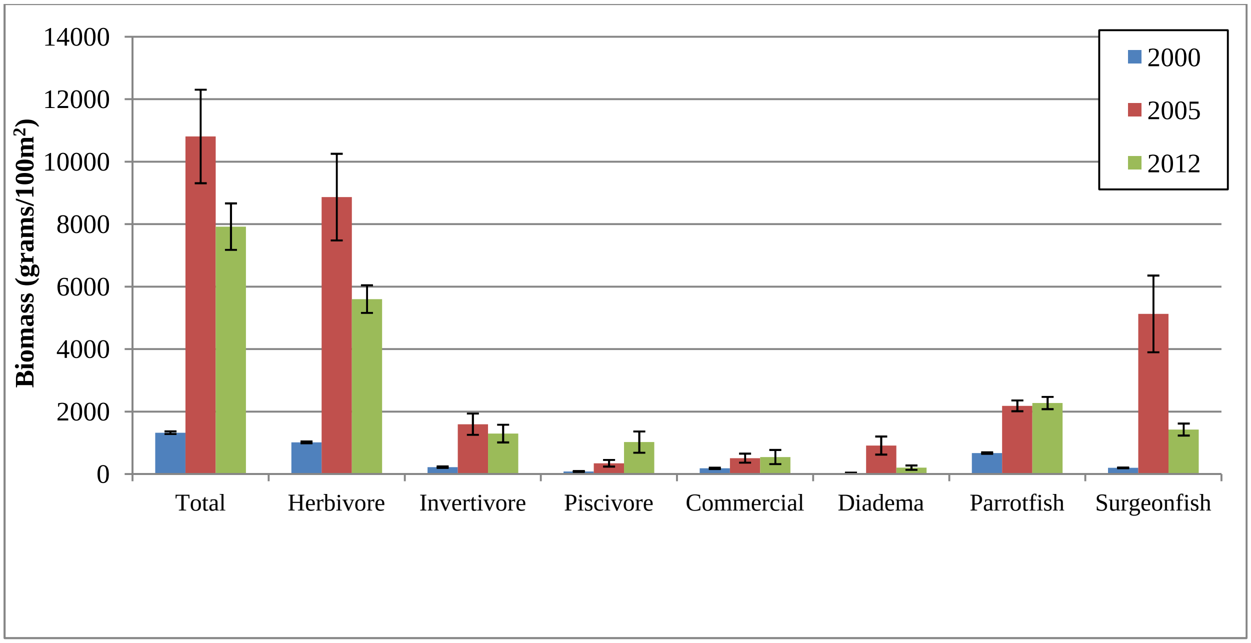

Fig. 43b. The biomass of reef fish reported by functional group for mainland Jamaica (2000) and Pedro Bank (2005, 2012). Mean and standard error are shown. Pedro Bank 2012 data does not include PB-17, as this location was not examined in 2005.

9. Motile invertebrates

The total abundance of motile invertebrates was quantified within 40 radial transects, covering an area of 10,922 m^2 on 19 reefs. Lobster were identified on 12 or the 19 reefs at very low densities (maximum of 0.01 lobster/m^2). Conch were observed on 9 reefs at a very low density, with slightly higher abundances in six locations (>0.1 animal/m^2). *Diadema* were rare or absent in all locations except on a leeward patch reef near southwest Cay (PB-01) and a shallow reef community near Banner Reef.

Table 5. Motile invertebrates recorded within the 20 sites.

Site	1	2	3	4	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Lobster	2	3	0	5	0	6	0	6	1	0	8	0	4	0	6	0	2	2	5
Conch	16	0	0	10	3	2	2	1	0	14	15	7	0	0	1	1	5	9	2
Crabs	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0
Sea Cucumber	1	0	0	2	2	2	0	0	1	0	3	5	0	0	0	0	1	1	1
Diadema	30	0	0	4	0	0	0	0	0	0	0	0	0	0	0	4	123	0	0
Lionfish	0	0	0	0	0	0	0	0	1	2	1	0	0	0	0	1	1	3	2
# of transects	3	2	1	3	3	3	1	2	2	2	2	2	2	2	2	2	2	2	2
Radius (m)	5	10	5	10	10	5	10	10	10	10	10	10	10	10	10	10	10	10	10
Total area (m^2)	240	628	80	942	942	240	314	628	628	628	628	628	628	628	628	628	628	628	628

Fig. 44. Caribbean spiny lobster (*Panulirus argus*) were seen very infrequently on Pedro banks, but these were a common target of fishermen.

10. Spatial Comparisons

An initial examination of the degree of similarity between sites for benthic, coral and fish data were undertaken for the 19 sites on Pedro Bank. Data were examined using Similarity profiles (SIMPROF) analysis and displayed using nMDS plots and over the site map. SIMPROF is a permutation test of a null hypothesis stating that a specified set of samples, which are **not** *a priori* divided into groups, do not differ from each other in multivariate structure producing an ordination of significantly different groups/clusters. Nonmetric multidimensional scaling (nmMDS) was used to express similarity of site-averaged datasets and plotted over two dimensions. Points were labeled by site, with SIMPROF ordinations for better interpretation (Clarke and Gorley 2006).

An examination of benthic data (cover of non-living substrates, corals, algae by functional group, other invertebrates, and nuisance species) revealed three distinct groupings of sites (Fig. 45). Macroalgae, crustose coralline algae and non-living substrates contributed most to the similarity among the groups (Appendix 4).

The sites formed five distinct groupings based on coral species composition (relative) (Fig. 46). The average abundance and contribution of different taxa to specific groups are shown in Appendix 5.

The site-averaged contribution of different fish taxa groups to biomass resulted in eight distinct groups (Fig. 47). The contribution of different taxa to the distinct groupings is shown in Appendix 6.

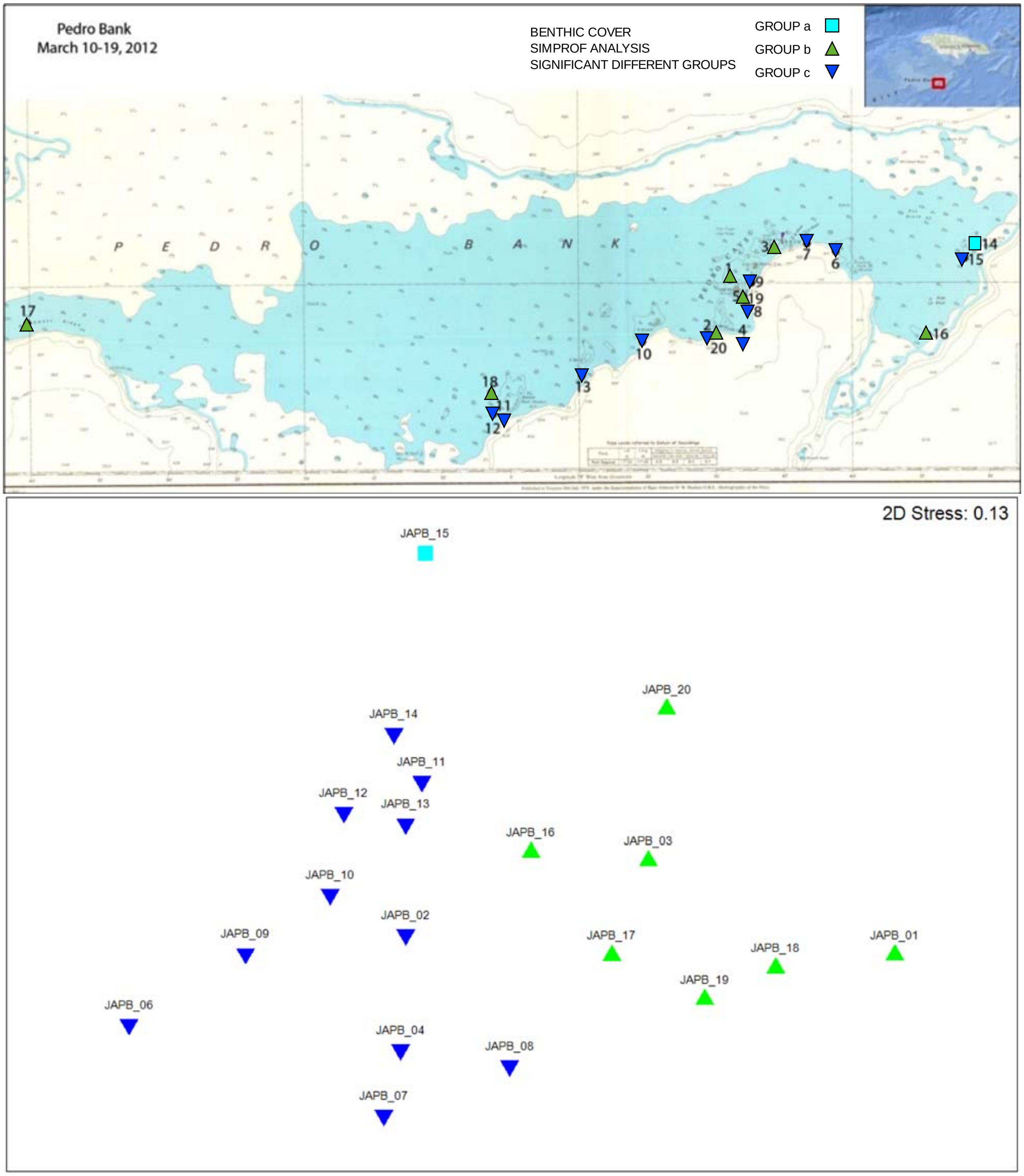

Fig. 45. Similarity of site-averaged benthic data plotted over the Jamaica site map (top) and two dimensional nonmetric multidimensional scaling (nmMDS) plot (bottom). Three distinct groupings were identified.

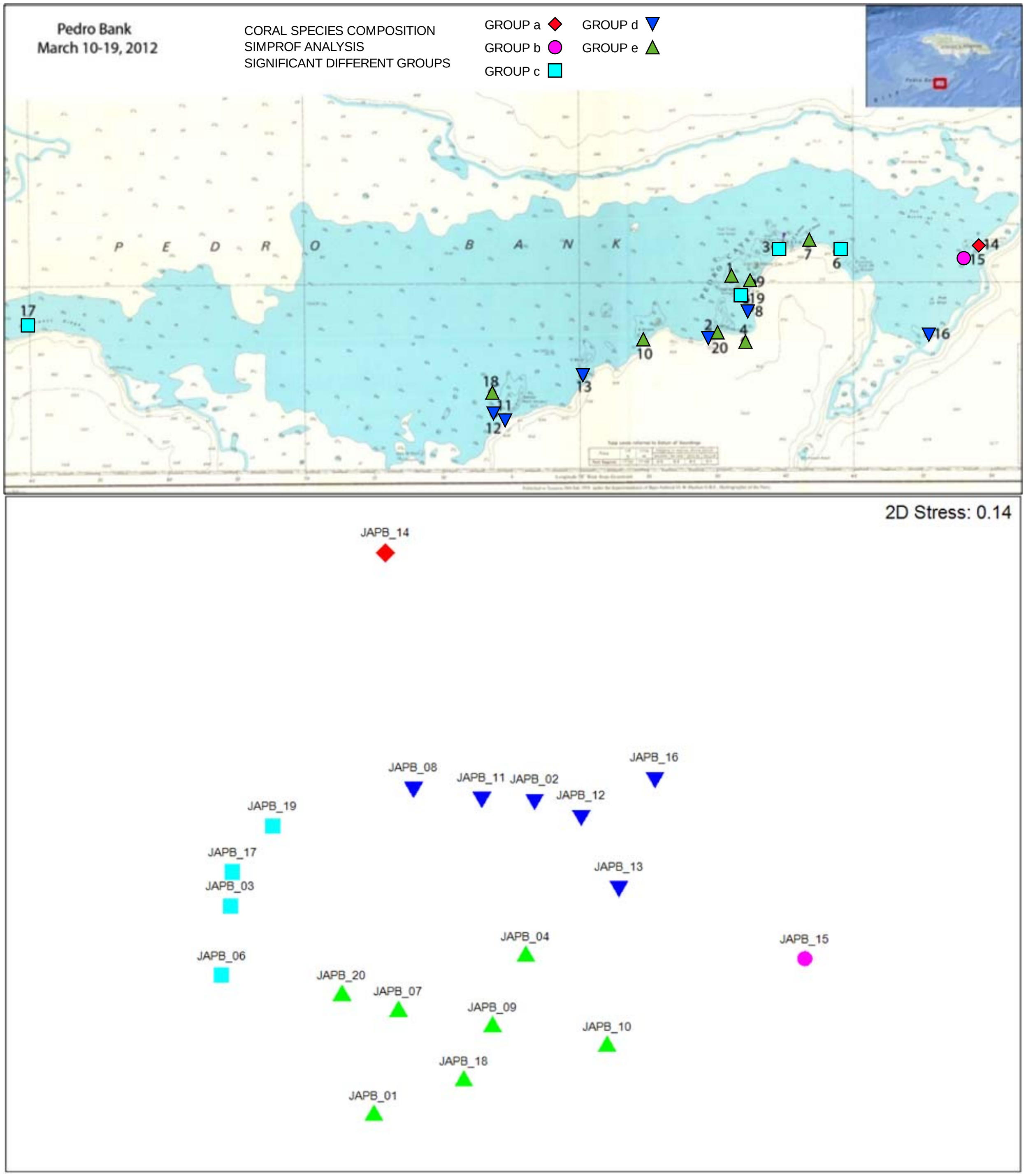

Fig. 46. Similarity of site-averaged coral species composition (relative) plotted over the Jamaica site map (top) and two dimensional nonmetric multidimensional scaling (nmMDS) plot (bottom). Five distinct groupings were identified.

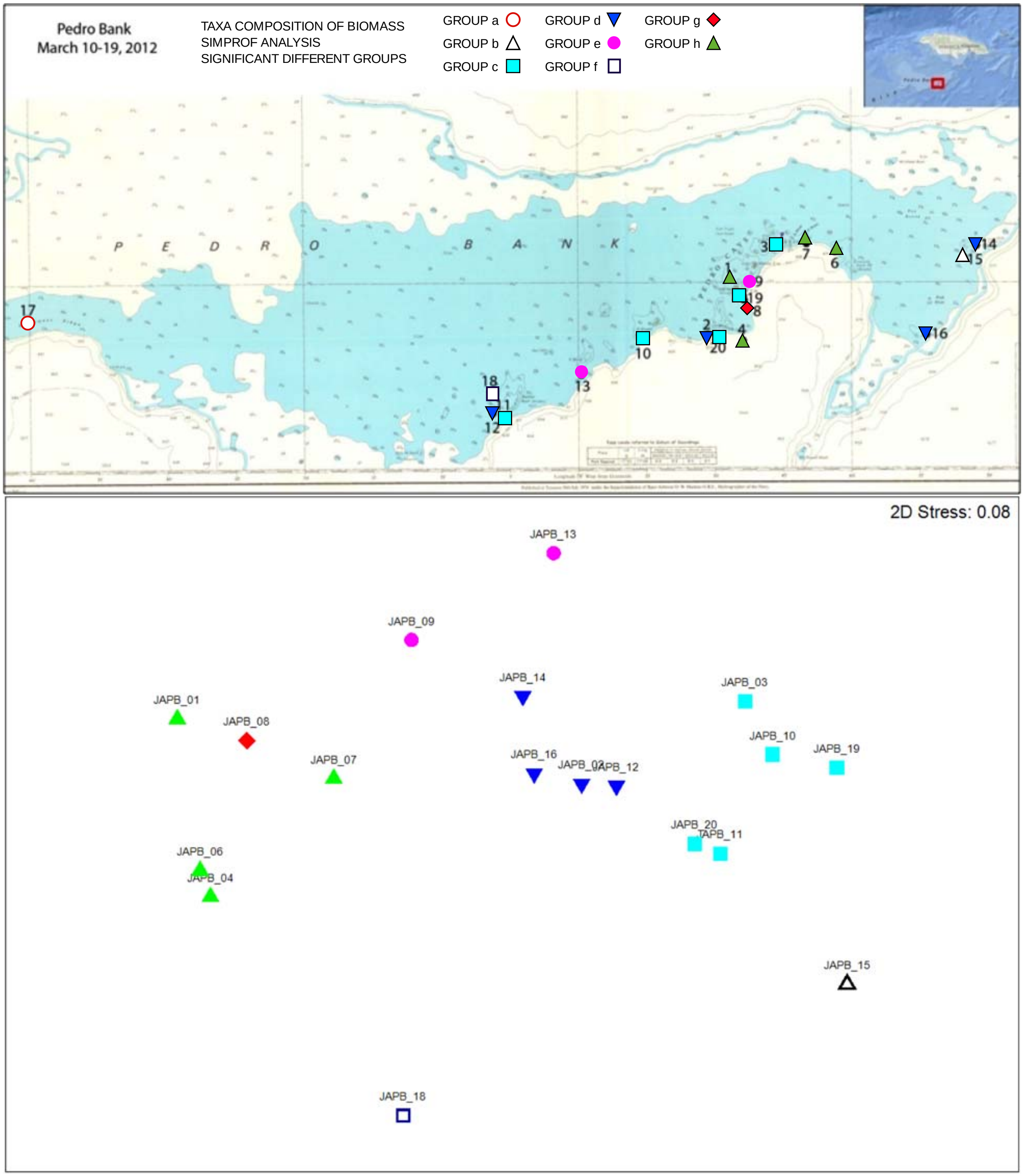

Fig. 47. Similarity of site-averaged contribution of fish taxa groups to biomass plotted over the Jamaica site map (top) and two dimensional nonmetric multidimensional scaling (nmMDS) plot (bottom). Eight distinct groupings were identified.

Analysis of Similarity (ANOSIM) testing was employed within the 19 sites to determine whether any of the trends in fish, coral and algal abundance, cover and/or biomass were driving factors of the attributes recorded in different sites. Coral abundance did not appear to be related to macroalgal cover (Fig. 48), fish abundance, or distance from fishing village. There was, however, a significant relationship between coral abundance and fish biomass, but the R-value was very low (Table 6).

Table 6. - 1-way ANOSIMS performed on the various habitat variables in relation to the coral abundance. R and p values are reported and significant results are in bold.

Factor	R	p-value
macroalgae	0.155	0.161
distance from fishermen	0.09	0.157
fish biomass	0.249	**0.006**

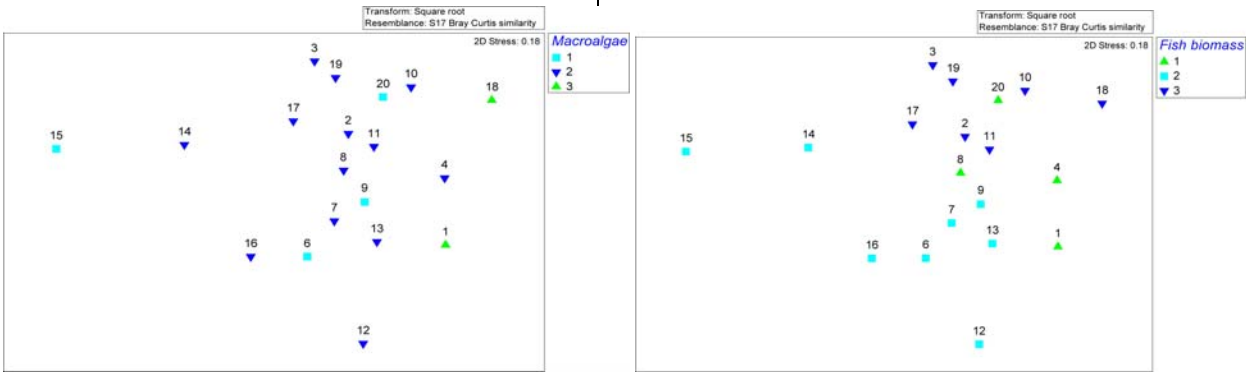

Fig. 48. nMDS plot showing relationship between coral abundance and macroalgae cover (a, left) and coral abundance and average fish biomass (b, right). Each point is an individual site.

There did not appear to be a significant relationship between macroalgal cover (ranked into three categories: 1=0-15%, 2=15-30% and 3=30+%) and coral cover (ranked into four categories, 1=0-5%, 2=5-10%, 3= 10-15%, and 4=15+%) (Fig. 49).

Fig. 49. nMDS plot showing relationship between surveyed fish abundance and live coral cover (a, left) and fish abundance and macroalgae cover (b, right). Each point is an individual site.

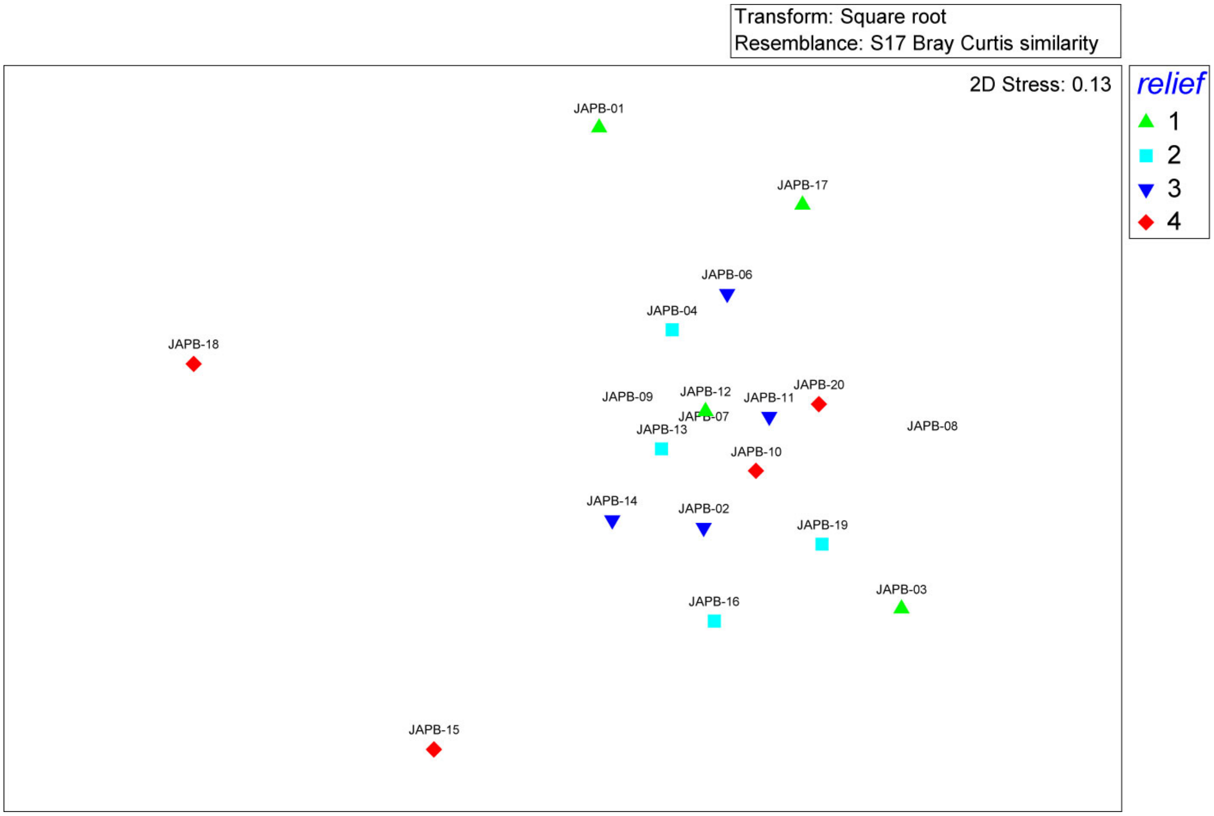

Fig. 50. nMDS plot showing relationship between surveyed fish abundance and vertical relief of the reef. Each point is an individual site.

Fish abundance also was not related to coral cover (Fig. 49a) or vertical relief (Fig. 50), but it was related to macroalgal cover (Fig. 49b), although the R value was low (Table 7). The PRIMER grouping factor for average benthic relief associated with each site was as follows: 1(0-40cm), 2(40-50cm), 3(50-60cm) and 4(60+cm).

Table 7. 1-way ANOSIMS performed on the various habitat variables in relation to the surveyed fish abundance. R and p values are reported and significant results are in bold.

Factor	R	p-value
coral cover	0.011	0.444
macroalgae	0.428	**0.013**
distance from fishermen	0.005	0.495
relief	0.059	0.778

11. Resilience assessment

Biological indicators

A ***Reef Health Index*** (RHI) was calculated for each dive site using seven specific biological indicators assessed during the field surveys (Fig. 51). The grades were calculated by converting the mean for each indicator into a rank of 1 (critical) to 5 (very good). Seven parameters, grouped into two categories, were used in this assessment. The first category is a *Coral Index*, comprised of coral cover, coral disease prevalence and coral recruitment. The second category is a *Reef Biota Index*, comprised of a macroalgal index, herbivorous fish abundance (parrotfish and surgeon fish only), commercial fish abundance (grouper and snapper only), and *Diadema* abundance. Threshold values for each rank were based on data ranges presented in the Healthy Reef Initiative (HRI 2008) report (summarized below in table 8). The ranked scores of the three *Coral* measures and the four *Reef Biota* measures and these two sub-indices were then averaged to calculate an integrated reef health index. This approach was applied to the Mesoamerican reef system in 2008 (see: **www.healthyreefs.org**). A ***Simplified Reef Health Index*** (SRHI) was used to categorize these same reefs in 2012. This approach uses only four parameters (coral cover, macroalgal index, herbivore abundance and commercial fish abundance), each weighted equally. A comparison of the two measures is presented using the mean value from the 19 sites examined on Pedro Bank in Fig 52 and for each reef in Fig. 53. The *Reef Health Index* for each site is presented graphically in Fig. 54. Points for each location have been scaled from the lowest to highest value observed on these reefs. The raw data are presented in Appendix 8.

Table 8. Threshold values used to determine the ranks. Adopted from HRI (2008).

INDICATORS	VERY GOOD (5)	GOOD (4)	FAIR (3)	POOR (2)	CRITICAL (1)
Coral cover (%)	≥40	20.0-39.9	10.0-19.9	5.0-9.9	<5
Coral recruitment (#•m^2)	≥10	5.0–9.9	3.0–4.9	2–2.9	<2
Coral disease prevalence (%)	<1	1.1–1.9	2.0–3.9	4.0–6.0	>6
Fleshy macroalgae cover (%)	0-0.9	1.0-5.0	5.1-12.0	12.1-25	>25.0
Key herbivorous fish (g•100 m^2)	≥3480	2880-3479	1920-2879	960-1919	<960
Key commercial fish (g•100 m^2)	≥1680	1260-1679	840-1259	420-839	<420
Diadema abundance (#•m^2)	>2.5	1.1–2.5	0.5–1.0	0.25–0.49	<0.25

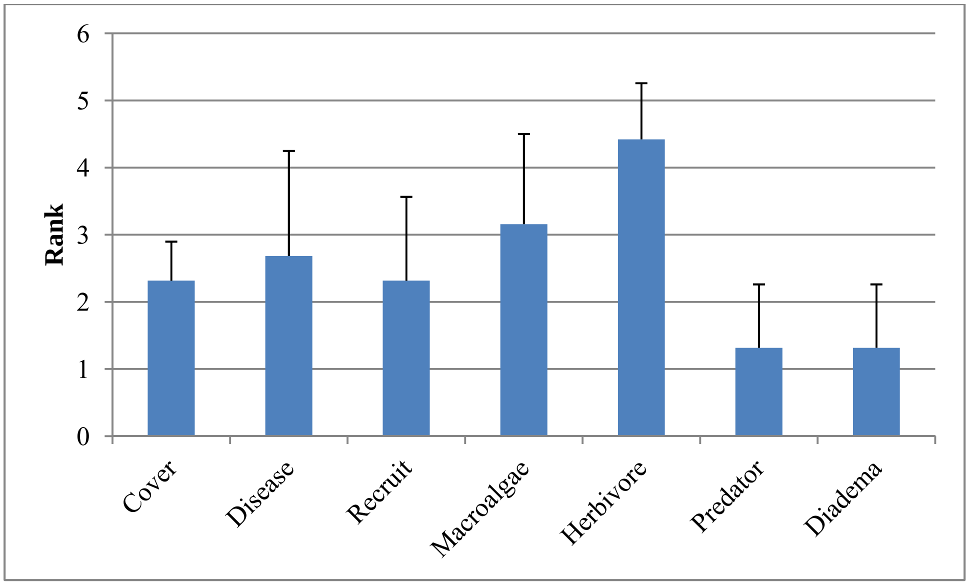

Fig. 51. Mean rank (and standard deviation) for each of the seven parameters pooled for all sites examined on Pedro Bank.

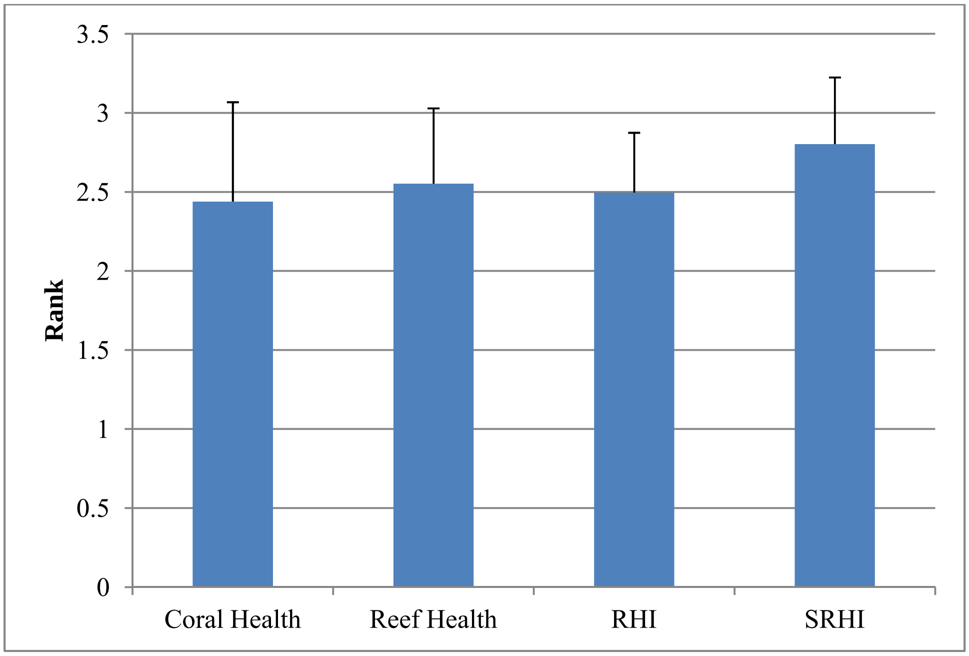

Fig. 52. Indicators of reef health on Pedro Bank. The mean and standard deviation of the coral health index (coral cover, recruitment and coral disease), reef health (macroalgal cover, herbivore fish biomass, commercial fish biomass and Diadema abundance), overall *Reef Health Index* (RHI; average of coral health and reef health) and a *Simplified Reef Health Index* (SRHI) using only coral cover, macroalgal cover, herbivore fish biomass and commercial fish biomass) for the 19 sites (pooled).

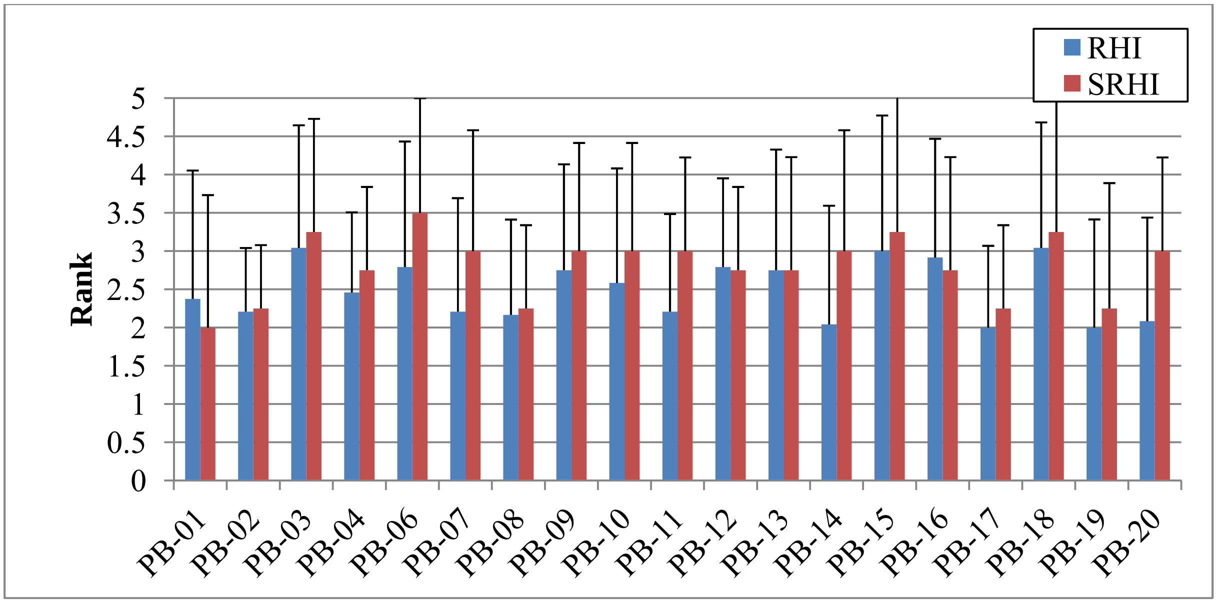

Fig. 53. The integrated Reef Health Index (RHI; blue) and a Simplified Reef Health Index (SRHI; red) based on four equally weighted measures for each of the 19 sites examined on Pedro Bank. Mean and standard deviation are presented for the indicators of reef health.

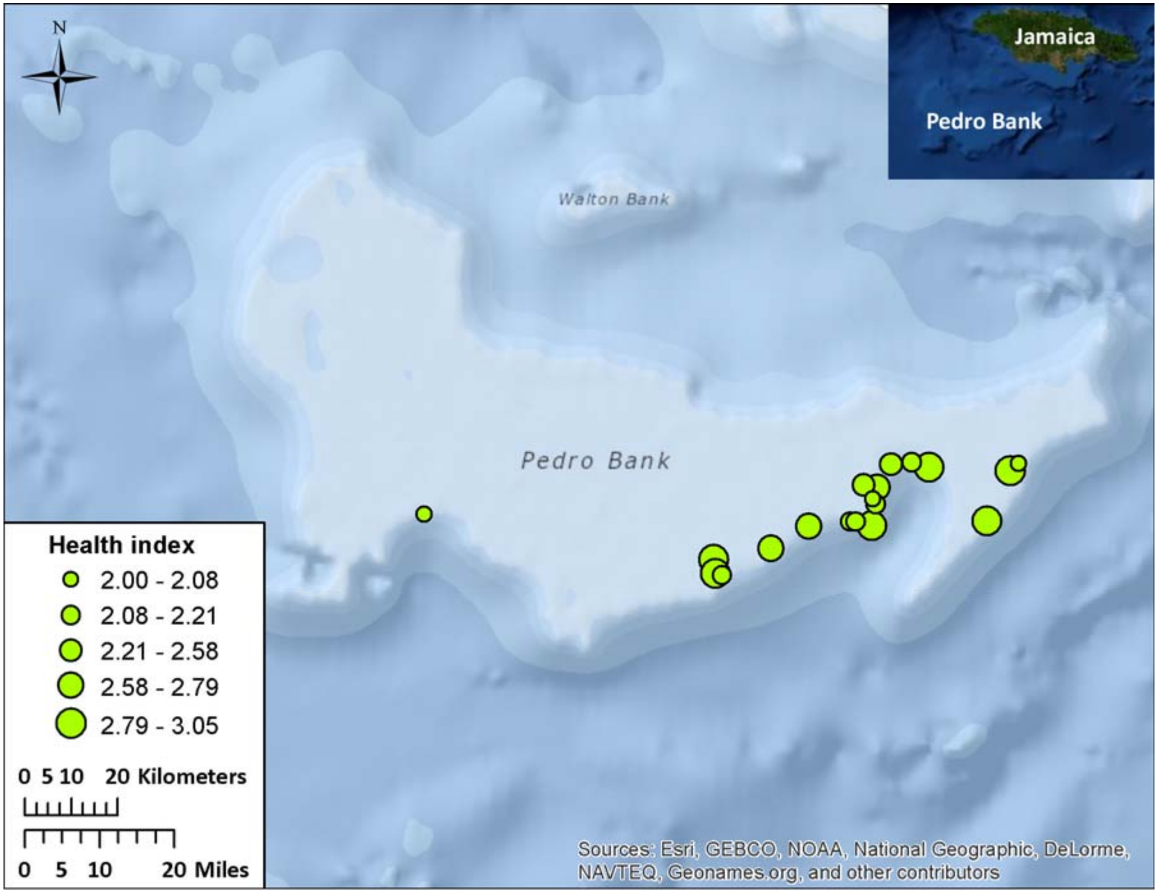

Fig. 54. The Reef Health Index (RHI) for each of the 19 sites examined on Pedro Bank. Larger circles refer to more resilient sites.

Factors that affect coral reef resilience

The average values for the *Reef Health Index* (RHI) and *Simplified Reef Health Index* (SRHI) were fairly similar between sites, ranging from a low of 2 (poor) to a high of 3.25 (fair). Individual parameters that make up these measures showed more variation. The Coral Index (cover, recruitment and disease prevalence) ranged from 1.33 at PB-14 to 3.33 at PB-03, 11, 16, while the Reef Biota Index ranged from a low of 1.75 at PB-02 to a high of 3.75 at PB-18. The overall Health Index ranged from 2 (PB-17, 19) to 3 (PB-03, 15, 18). The Simplified Reef Health Index, which relies on fewer measures, results in somewhat different indices: the highest measure was recorded at PB-06 (3.5), followed by PB-03, 18 (3.25), while the lowest was at PB-01. It is apparent that changes in the number of variables used and the weighting can result in different grades of health. Seven of the 19 sites increased by one grade, from poor to fair, when using the SRHI instead of the RHI.

It is important to understand that the values represent "*a compromise position between grading for the ideal "pristine" reef conditions and what we can realistically hope to achieve in modern times and conditions*." For instance, coral cover observed on Pedro Bank is relatively low compared to historical cover estimates (e.g. 30-50%) which resulted in ranked data that was fairly uniform at all sites. Coral cover did show considerable variation among sites, however, ranging from a low value of 4% (PB-01) to a high of 19%.

A. Coral diseases and other biotic stressors

A number of biological factors affected the health of corals including bleaching, coral disease, overgrowth by clionid sponges, predation by *C. abbreviata*, *Stegastes planifrons* algal lawns, and fish bites (Fig. 55-57). Of all these factors, the mean prevalence of disease was fairly high (>5%) which translated to a low rank (1 or 2) in the Reef Health Index for more than half of the sites. In fact, six of the sites had a large number of corals showing signs of disease (PB-06, 07, 08, 10, 14 and 20) with a prevalence of over 7%. This must be placed in context of the type of disease and the species affected, however. The most virulent diseases affecting Caribbean reefs today are white plague and yellow band disease, especially among *Montastraea annularis* complex (Fig. 55). While these diseases were observed on Pedro Bank, they affected a very small proportion of colonies (20 colonies of *M. annularis* complex were identified with YBD and 8 with white plague, most of which were in two locations). In contrast, the most widespread condition affecting corals was dark spots disease (DSD), but very few colonies showed any partial mortality attributed to this syndrome. DSD was observed on eight species (122 corals), with most cases (75%) observed on *Agaricia agaricites.*

In general, corals exhibited very low levels of tissue loss. Most corals were almost completely live (mean % partial mortality was 10%) and there was very little recent mortality. The overall partial mortality, when compared to the rest of the Caribbean, was considerably less.

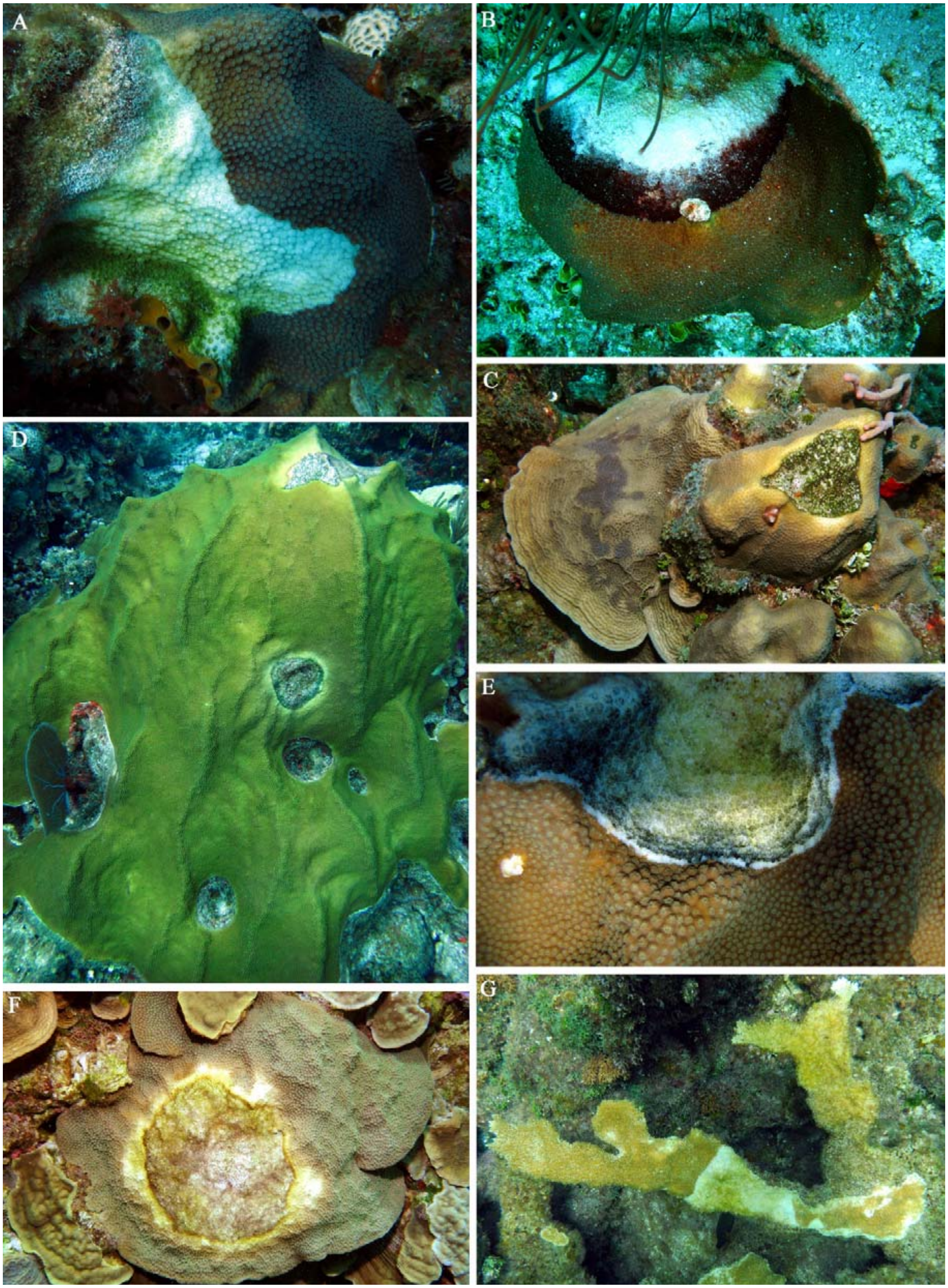

Fig. 55. Corals observed on Pedro Bank reefs with disease. A. *Montastraea faveolata* with white plague. B. *M. franksi* with black band disease. C. *Agaricia agaricites* with dark spots disease (YBD also on *Montastraea)*. D, F. *Montastraea faveolata* with yellow band disease. E. Caribbean ciliate infection on *M. faveolata*. G. White band disease on *A. palmata*.

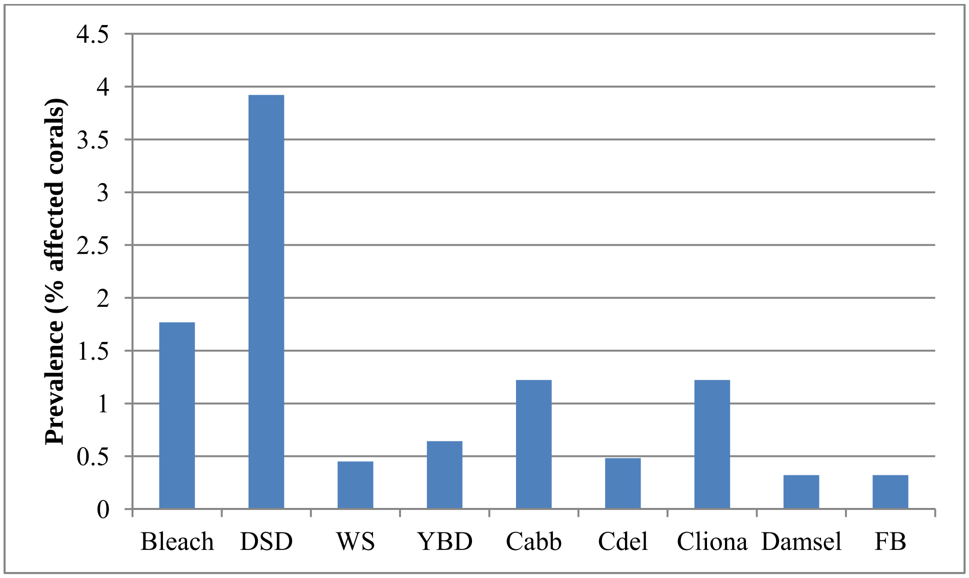

Fig. 56. Stressors affecting reef building corals. The categories included bleaching (Bleach; colonies that were pale, mottled or completely bleached), diseases [dark spots disease (DSD), white plague (WS), yellow band disease (YBD)], Coral eating snails (Cabb); sponge overgrowth by *Cliona delitrix* (Cdel) or the brown *Cliona* (*Cliona*), *Stegastes planifrons* algal lawns (damsel), and fish bites (FB). Data are pooled for all species.

B. Algae and herbivory

Most reefs around the Caribbean have seen a dramatic increase in the cover and biomass of fleshy macroalgae. This began after the die-off of *Diadema* in 1982-1983, and proliferated over the last two decades as coral cover declined. In many cases, this has been at the expense of corals, through direct competition and overgrowth and by reducing substrate quality and inhibiting recruitment. On Pedro Bank, there was relatively little turf algae, moderate cover of CCA, and only moderate cover of fleshy macroalgae and calcareous macroalgae. At all sites, macroalgal cover was greater than coral cover. However, in eight of the 19 sites (PB-03, 04, 06, 07, 09, 14, 15, 20) macroalgal cover was relatively low (<15% cover). Most algae occurred at the bases of boulders and coral heads and around the margins of corals, and open substrates were largely devoid of fleshy macroalgae. Six of these sites also had a high biomass of herbivorous fish. Nevertheless, there was no significant relationship between herbivore biomass and algal biomass (R^2 =0.0004, p=0.79), as other sites with high algal cover also had high biomass of herbivores. It is important to note that, although the biomass of herbivores was fairly high, the size of these fish was unusually small (most < 15 cm) and large excavators were rare. Due to their small size, and their feeding behavior (most were browsers and scrapers) is seems that they would be unlikely to consume substantial amounts of macroalgae. Furthermore, *Diadema* were extremely rare, occurring only at the two sites with the highest macroalgal biomass overall.

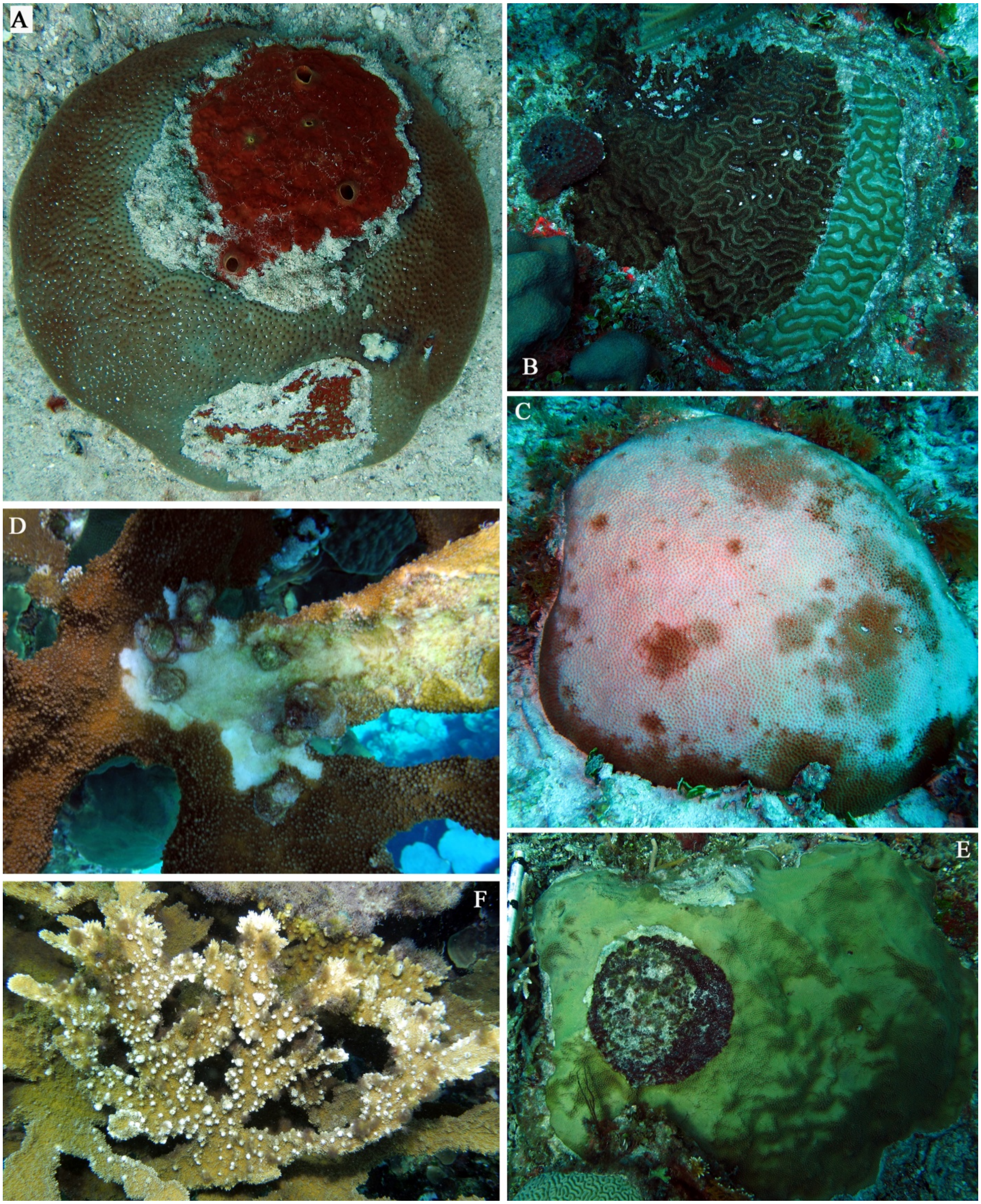

Fig. 57. Stressors affecting corals on Pedro Bank. A. Overgrowth of *S. siderea* by *Cliona delitrix*. B. Overgrowth of *Diploria strigosa* by *Cliona* spp.. C. Bleaching in *S. siderea*. D. *Coralliophila abbreviata* predation on *Acropora palmata*. E. A cyanobacterial mat that has colonized a dead patch on *M. faveolata*. F. Chimneys produced by *A. palmata* in response to damselfish (*Stegastes planifrons*) bites.

C. Reef Fish and Fisheries

Reef fish populations throughout Pedro Bank appear to be undergoing overfishing, with a significant depletion of all commercial species and a decline in the size structure of herbivores. In all sites except PB-18, the ranks for commercially important fishes was very low (1 or 2). In contrast, herbivore abundance was relatively high (4 or 5) in all locations except PB-02. Even though this value was high in most sites, the high biomass was due to a large number of parrotfishes, all of which were very small in size and hence, the biomass per fish was actually low.

Intensive fishing pressure using spearfish and hookah was observed throughout the Bank, with fishers from the Cays targeting reefs between approximately Banner Rock and Blowers Rock. There were several fishers who operated every day, collecting 50-100 kg, mostly parrotfish, as well as invertivores, piscivores and lobsters when seen. In addition, a high number of fish traps were seen on reefs. These generally had very few fish in them, but they contained a high diversity of small bodied fish, due to the small mesh size, and the highest abundance of surgeonfish. There were also several larger vessels seen at the western end of Pedro Bank. These tended to send out multiple smaller boats, each containing one to two hookah divers and a driver. They also collected primarily parrotfish, filling up large burlap bags (50-60 kg) on each dive (Fig. 58).

The absence of some species, including large bodied groupers, snappers and grunts, may be due to a lack of nursery habitat. Very few mangroves occurred in the vicinity of coral habitats and grassbeds were limited to a few locations around the Cays. There was also an increasing abundance of lionfish, which may be beginning to have an impact on small bodied fish and juveniles. What was unusual was the very high abundance of nurse sharks seen in every location.

Fig. 58 (following page). Examples of fishing practices and catch on Pedro Bank Jamaica. A. Group of fishers in a small motorized canoe with a fish pot on the bow. B. An Antillean z-trap deployed near a reef on Pedro Bank. C. Lobster catch of one fisher on Middle Cay. D. Catch from fish traps deployed on Pedro Bank. E. G. Hookah apparatus (hose and compressor). F. Large Industrial fishing boat from mainland Jamaica fishing on the northwest ridge. H. An old pile of conch shells on South Cay.


A
B
C
D
E
F
G
H

12. Plankton Surveys

Report provided by Azra Mallet and Dr. Mona Webber

Baseline data on plankton communities was obtained from sites located within the proposed fishery reserve. Sampling included 1) plankton tows for fish and conch larvae; 2) water samples for phytoplankton to identify potentially harmful species that may affect conch larvae; and 3) macroalgal samples for epiphytic species to determine if ciguatoxic dinoflagellates or other toxic species are present that would affect bottom feeders such as *Strombus gigas.* Zooplankton tows were conducted using a 335µ mesh, 0.5 m hoop diameter neuston net at 10 stations located within the boundaries of the proposed fish sanctuary at Pedro Bank. Exact locations indicated in table 9. The Depth and Location parameters were taken at the beginning of each tow. Each tow lasted for 15 minutes except for bottle #7 which consisted of 2 short hauls for about 100m each way.

Table 9. Plankton tows completed on Pedro Bank within the proposed fishery sanctuary.

DATE	TIME	SPEED (knots)	DEPTH (meters)	LOCATION	BOTTLE #
13/03/2012	12:53pm	1.8	10	N 17°02.617’ W077°45.668’	1
14/03/2012	10:05am	3	4.5	N 16°59.527’ W077°48.541’	2
14/03/2012	10:41 am	4	8	N 16°58.927’ W077°48.256’	3
14/03/2012	11:50am	3	5	N 16°59.337’ W077°48.661’	4
14/03/2012	2:07pm	2.5	9.6	N 16°59.734’ W077°48.810’	5
14/03/2012	4:03pm	3.5	9.5	N 16°59.734’ W077°48.810’	6
15/03/2012	9:00am	3	6.5	N 16°59.469’ W077°48.580’	7
15/03/2012	10:50am	3.5		N 16°58.923’ W077°47.906’	8
15/03/2012	3:20pm	2.8	12	N 16°58.926’ W077°47.911’	9
15/03/2012	4:27pm	3	11	N 17°00.712’ W077°48.305’	10

Zooplankton taxonomic richness:

94 different zooplankton taxa were identified from the zooplankton collections made in March 2012 at the Pedro Bank (Table 10). This overall richness is comparable to 107 taxa found in Discovery Bay, but far less than 171 found by Lue (2011) off the south coast shelf and banks (California Bank) area of Jamaica. However Lue sampled intensively for ~ 6 months using plankton nets of three different mesh sizes: 64, 200 and 600 µm. The 64 and 200 µm nets are particularly good for collecting invertebrate larvae and so these may have been under-sampled in the present study.

Table 10. Zooplankton species list for the sampling area.

Taxa		
Cnidaria (9)	**Calanoida (continued)**	**Decapoda (>>3)**
Abylopsis sp	*Labidocera sp.*	Unidentified Decapods
Aglama sp.	*Mecynocera sp.*	*Lucifer faxoni*
Aglaura sp	*Neocalanus sp.*	*Mysidium sp.*
Eutima sp.	*Paracalanus sp.*	**Larvacea (2)**
Liriope tetraphylla	*Paracalanus aculeatus*	*Oikopleura sp.*
Muggiea sp.	*Paracalanus parvus*	*Fritillaria sp.*
Obelia sp.	*Pontella mimocerami*	**Mollusca (2)**
Solamaris sp.	*Pontellina sp.*	Bivalve
Solmunella sp.	*Rhincalanus cornutus*	Gastropod larvae
Cladocera (2)	*Temora longicornis*	**Pteropoda (1)**
Penilia sp.	*Temora stylifera*	*Creseis sp.*
Evadne sp.	*Temora turbinate*	**Thaliacea (1)**
Chaetognatha (7)	*Undinula vulgaris*	*Doliolum sp.*
Khronitta subtilis	**Cyclopoida (14)**	**Larvae (invertebrate- 17)**
Sagitta bipunctata	*Copilia sp.*	Actinula
Sagitta decipens	*Corycaeus carinata*	Auricularia
Sagitta enflata	*Coryceaus catus*	Bipinnaria larva of starfish
Sagitta hispida	*Corycaeus latus*	Copepodites
Sagitta tenuis	*Corycaeus lautus*	Cirrepide (Barnacle nauplius)
Pterosagitta draco	*Corycaeus speciosus*	Euphasiid
Calanoida (27)	*Corycaeus typicus*	Echinopluteus larvae
Acartia lilljeborji	*Farranula carinata*	Lanice larvae
Acartia spinata	*Farranula gracilis*	Ophiopluteus larvae
Acartia tonsa	*Oithona hebes*	Pontellid nauplius
Calocalanus spp.	*Oithona nana*	Phylossoma larvae
Calanopia Americana	*Oithona plumifera*	Polychaete spp.
Candacia bipinnata	*Oncea meditteranea*	Porcellanid larvae
Candacia longimana	**Harpacticoida (7)**	Sergestid
Candacia pachydactyla	*Clytemnestra sp.*	Spionid larvae
Centropages velificatus	*Euterpina sp.*	Stomatopod larvae
Centropages violaceous	*Macrosetella sp.*	Zoea
Clausocalanus sp.	*Microsetella sp.*	**Fish eggs**
Eucalanus spp.	*Miracia efferata*	**Fish larvae**
Eucheata marina	Monstrilloida	
Eutima sp.		

Richness across the 10 stations sampled in the area of the fish sanctuary ranged from a high of 166 at station 10 to 18 at station 3 (Fig. 59). Stations 1 and 6 were the next most speciose stations but still almost half the number of species seen at station 10.

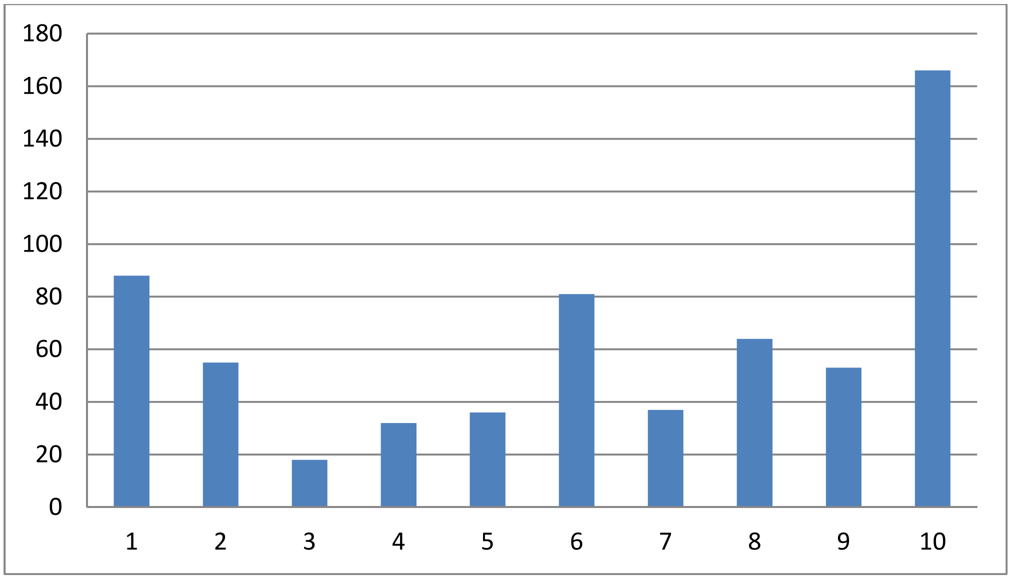

Fig. 59. Zooplankton taxonomic richness across the 10 stations sampled at Pedro Bank.

Zooplankton abundance

Zooplankton total abundance across the ten stations ranged from a high of 980 animals m^{-3} at station 1 to 8 animals m^{-3} at station 7 (Fig. 60). However, such low numbers at station 7 may be an artifact of the change in the sampling method used (cf. methods section above). Stations 1, 6 and 10 again showed greatest overall abundance and as expected copepods dominated the overall numbers across stations. The total abundance found in this one-off sample were far lower that values found at Discovery Bay by Webber et al. 2005 (max of 3,794 animals m-3) and the average for the south coast shelf and banks by Lue (2011) of 5,963 animals m-3.

The waters of the banks and in the area of the fish sanctuary contain a very high proportion of fish eggs/larvae (see figure 59 above), especially station 4 which had a higher proportion of fish eggs than copepods (Fig. 61). Copepods normally dominate zooplankton assemblages. The abundance and richness of larvae of decapod crustaceans were also particularly high and a few lobster phyllosome were seen. Conch larvae were not seen but this could be an artifact of the net size used. 200 µm and 64 µm nets as used by Lue (2011) would need to be deployed over the annual cycle to indicate annual variation in larval abundance. However this could be done at fewer stations.

Based on this preliminary, one-off sampling, Stations 1, 4, 6 and 10 would be the areas of greatest interest for further plankton sampling as they contain the greatest abundances and greatest proportion of larvae.

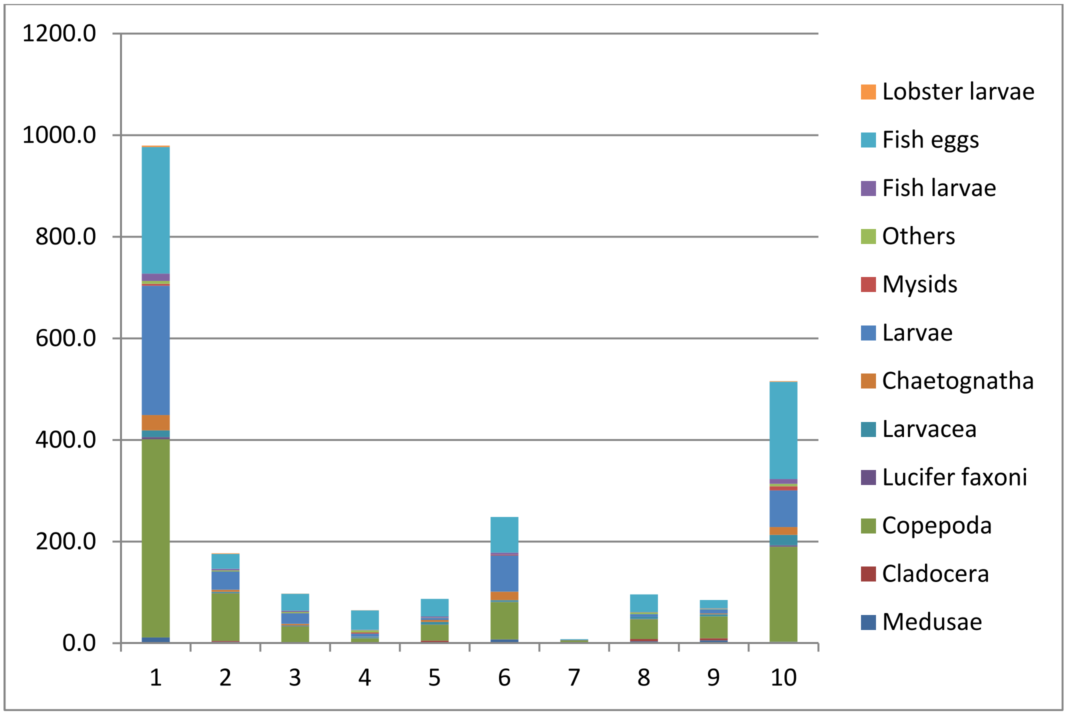

Fig. 60. Stacked bar graph showing numbers per m3 at the 10 stations sampled with the main taxonomic groups (12) displayed.

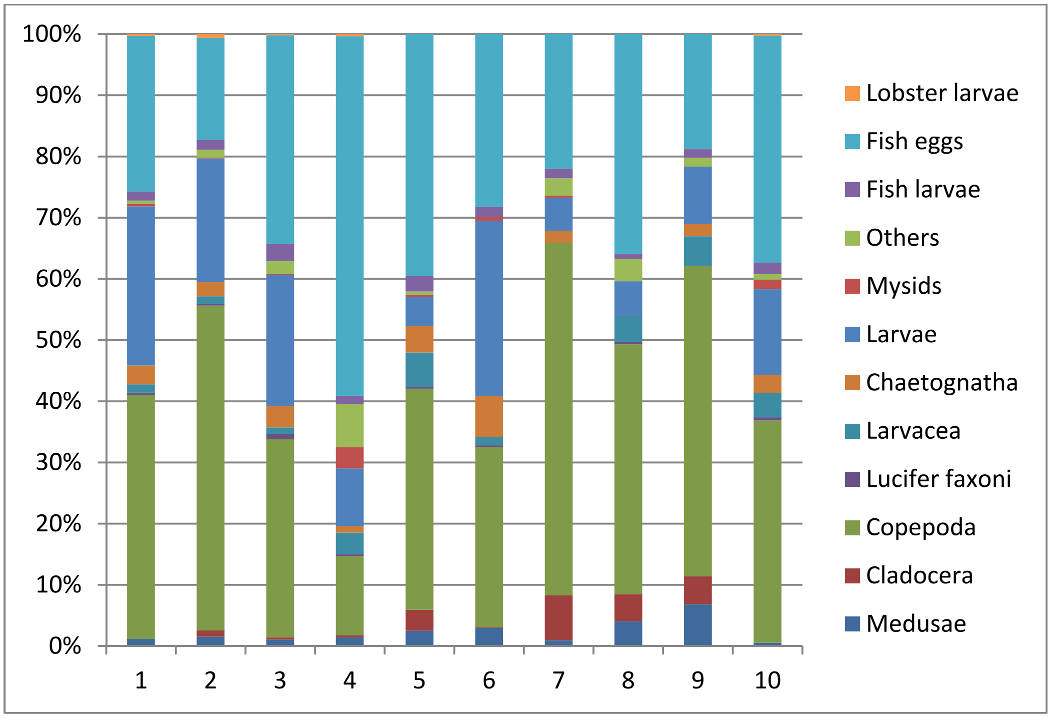

Fig. 61. Stacked bar graph showing % abundance of the main taxonomic groups (12) at the 10 stations sampled.

13. Habitat mapping and characterization

A pilot project using a Tritech Starfish 990f sidescan sonar was undertaken to:

1) Create a library of sonar data that matches the different habitat types;
2) Understand what each habitat class looks like using sidescan; and
3) Determine how much time is needed to map a site using side scan.

The pilot effort focused primarily within about 2 miles of Southwest Cay, within the proposed fishery reserve. The Twin V slowly navigated back and forth collecting backscatter data (acoustic reflections) along the track to obtain a continuous image of the seafloor. At varying distances a drop camera was deployed to correlate backscatter data with actual video imagery of the habitat.

Surveys were run throughout the proposed reserve from just below the water's surface to about 25 m depth. Additional tracks were run across habitat types not included in the reserve (sea grass beds). A total of 15 sq km of backscatter data and 96 drop camera videos were acquired (Fig. 62).

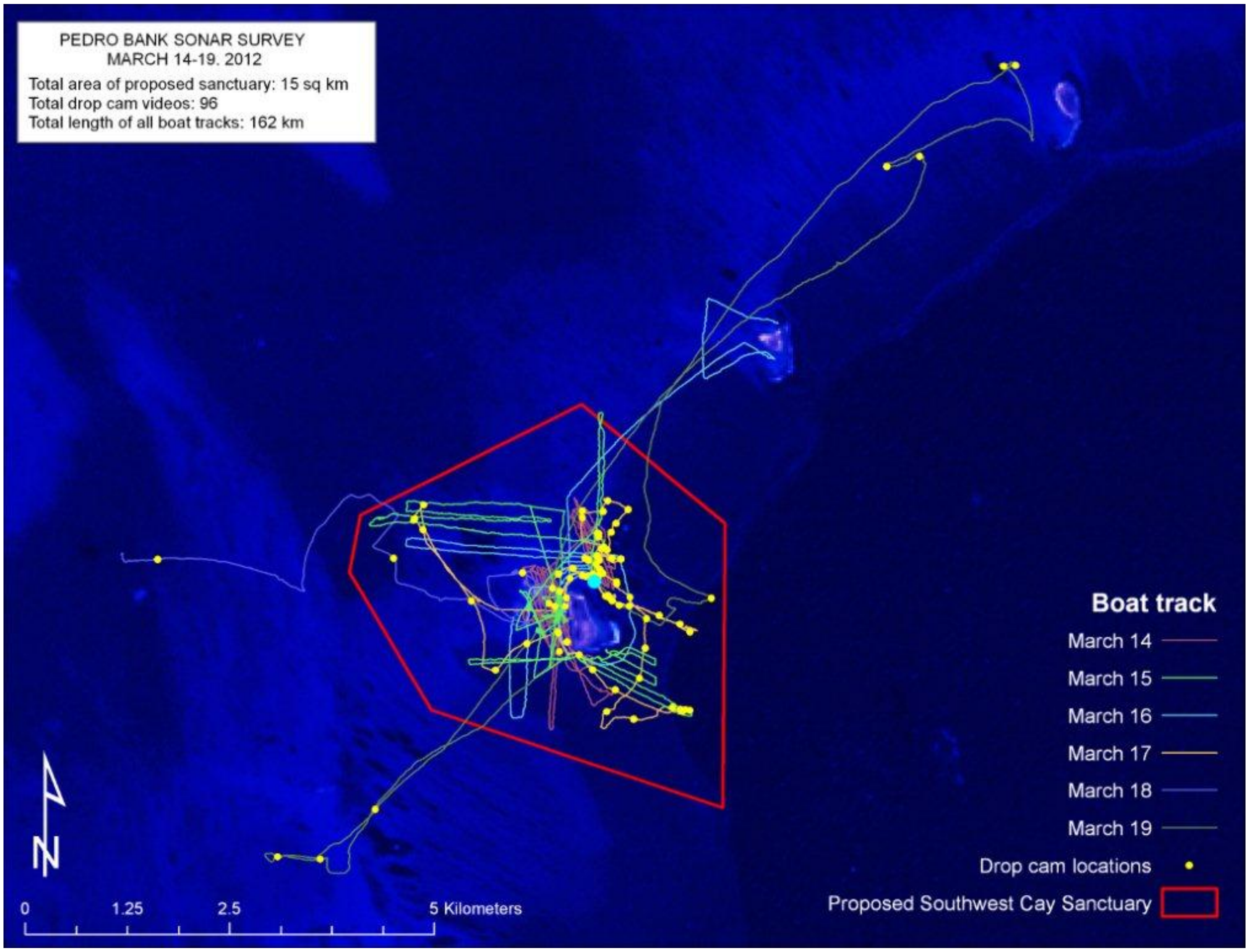

Fig. 62. Side scan sonar tracks and locations of drop camera videos completed within and outside the proposed Southwest Cay Sanctuary.

DISCUSSION

Pedro Bank supported a wide variety of shallow marine habitats including seagrass beds, gorgonian hardgrounds, rubble fields, deep algal hardgrounds and sand flats. Only a small percentage of the bank supported coral reef habitats, most which were concentrated at the eastern edge of the bank, adjacent to the drop-off. There were few reefs located on the bank and extensive areas along the western margin, between the emergent Cays and rocks, consisted of steeply sloping hardground and sandy areas with little coral growth.

Some of the best reef development occurred within the proposed fishery reserve, and along the edge of the bank to the south and west, between PB-09-PB-02. Prominent reef growth began just below the shallow *Acropora palmata* framework (below 5 m depth), continuing down the reef slope to about 25-30 m depth. There were also some well developed reefs around emergent rocks near D shoal, C shoal, Banner Rock and Blower Rock. Shallow areas on top of the bank, and around emergent Cays consisted of dead, fused *Acropora* colonies, hardground areas with low cover of live coral, sand patches, and grass beds. Coral growth was much more patchy along the remainder of the bank, with a very low abundance of live coral colonies occurring within extensive gorgonian hardground and algal-covered hardground habitats. In addition, sites located to the east of the Cays, extending from PB-03-PB-06 and continuing to the tip of the eastern point had poor coral development possibly due to extensive sediment transport and burial. At least two of the AGRRA sites surveyed in this area 2005 (site 20 and 21) have been destroyed. A shallow submerged reef crest was apparent near these coordinates, but the areas near the position, at the same depth contained few or no corals and were covered in sand. At one of the sites, the tops of coral skeletons were visibly protruding above the sand, but no living coral was observed. It appears that these sites have been buried by sediment.

Within reef habitats, coral cover was fairly low (<20%) in most locations and was dominated by small corals, especially early colonizing brooding species (*Agaricia* and *Porites*) and high numbers of small *Siderastrea*, *Diploria*, *Meandrina* and other massive corals. Some areas had populations of larger massive framework corals such as *Montastraea annularis* (complex), as well as stands of *Madracis mirabilis*, large *Dendrogyra* colonies and other rare corals, and these corals were generally in good condition. *Montastraea annularis* (complex), once the most important frame builders in the Western Atlantic, has declined throughout its range since the mid 1990s, primarily from recent bleaching events and disease (white plague and yellow band disease) (Edmunds and Elahi 2007; Miller *et al.* 2009; Bruckner 2012a). These corals formerly made up 50-80% of the live coral cover, but recently have been reduced to 2-5% cover; what were once large (several meter) colonies are now skeletons colonized by other corals, algae and invertebrates, with small *M. annularis* tissue remnants. These species were the most important frame builders in the Caribbean, yet they show very slow rates of growth and little to no recruitment. On Pedro Bank, most of the larger *M. annularis* and *M. faveolata* colonies were completely live, and very little disease, bleaching and recent mortality was noted on these species. The presence of healthy populations of *M. annularis* complex is one reason why Pedro Bank coral reefs are especially important.

There was also extensive *Acropora* framework near the Cays and emergent shoals and islands. Much of this consisted of dead skeletons, some in growth position, but considerable amounts of live *A. palmata* were also noted. Scattered colonies of *A. cervicornis* were identified on many of the deeper reefs (10-30 m depth) and some larger stands were found within the Fish Sanctuary. Acroporid corals have become rare in most Caribbean locations as a result of white band disease outbreaks in the 1980s, recent bleaching events, storm damage and a host of other factors. These corals have been listed on the U.S. Endangered Species Act (Bruckner 2003).

One of the most positive findings among the stony corals examined on Pedro Bank was the low amount of partial mortality. In general, AGRRA surveys that have been conducted throughout the Caribbean (Lang 2003, Bruckner and Hill 2009, Bruckner 2012b), as well as the Caribbean surveys completed during the Global Reef Expedition, have recorded a mean of about 20-30% partial mortality on all species pooled and upwards of 50-80% partial mortality in *M. annularis* complex and other larger massive corals. On Pedro Bank most colonies were intact; partial mortality was usually less than 10% and colonies of *M. annularis* (complex) showed about 20% partial mortality. The presence of healthy, undamaged colonies may be an indication of higher resilience, better environmental conditions and a greater potential for successful reproduction, as corals have not been reduced below the minimal size threshold necessary for gametogenesis (Szmant-Froelich 1985, Szmant 1991).

The benthos also appeared to be in fairly good condition. Even though *Diadema* were rare (substantial urchin populations were only seen on two reefs), and algal cover exceeded the cover of living coral, there was a general impression that fleshy macroalgae was less abundant than that seen in many other Caribbean locations. The substrate had a prominent cover of crustose coralline algae, with small patches of erect coralline algae and some macroalgae, most of which were concentrated at the margins of corals and not on open reef substrates. Unlike other areas in the Caribbean, the reef was not being smothered by thick mats of *Dictyota, Microdictyon* was absent, *Lobophora* occurred in low abundances only on a few corals with partial mortality, other brown algae (e.g. *Turbinaria, Sargassum*) were found only in exposed shallow locations on a few reefs, and cyanobacterial mats were rare.

A number of nuisance species were observed but these were generally rare. For instance, the brown boring sponge (*Cliona*) was observed on massive corals and *Acropora* framework, *Cliona delitrix* was found on *Siderastrea* and other species, large patches of *Palythoa* occurred in shallow (< 5 m) *Acropora palmata* habitats, and high abundances of gorgonians (*Pseudoterigorgia*) were found in areas with low coral cover. All of these organisms compete for space with reef building corals and they have the potential to smother, overgrow or bioerode coral skeletons. Coral eating snails (*Coralliophila abbreviata*) were also identified on about 1.5% of the corals.

The largest concern to Pedro Bank reefs is overfishing of the fishery resources. Exploitation of Pedro Bank began in the 1960s, but has progressively increased as the densities of humans on the cays increased (Munro 1983). Most fishing effort is concentrated on the southeast (SE) portions of the bank, near the cays, which is also the location of some of the best developed coral reefs. As a result, the biomass of reef fish was lowest surrounding the fishing village with higher biomass (mainly invertivores) seen at distances of 20 miles or further from the village. This is probably related to the distance that the fisherman can realistically travel from the fishing village. Fishers tend to go to their farthest point (under ten miles in one day) and then work their way back, fishing at different spots as they return. Fishers that travel greater distances (e.g. the northwest ridge or blower's rock) may fish in these areas and camp for several days before returning.

Intensive fishing pressure appears to have affected most species as all reefs had a fairly low biomass of fishes and many key species were extremely rare or absent. The current targets of the fishery appeared to be two families of herbivores which made up the bulk of the catch, scaridae and acanthuridae. Very few schools of surgeonfish were documented and individuals were small (5-15 cm). Many of the larger-bodied scarids were infrequently seen. In addition, the dominant parrotfish on these reefs (and in the catch) was the red band parrotfish followed by stoplight parrotfish. While the red band parrotfish were still fairly abundant, both species were very small (most < 15 cm). These species were changing sex from initial phase (females) to terminal phase (males) at a much smaller size than that seen historically (TP fish of 10 cm were fairly common). The smaller than average size in sex change may be a survival mechanism that is a direct outcome of high fishing pressure (Hawkins and Roberts 2003). However, the decline in the average size of the population will cause a disproportionate decline in the reproductive output, because there is an exponential relationship between body length and egg production (Bohnsack 1990), which may have negative consequences on the long term persistence of these fish.

Two main fishery approaches are now undertaken on Pedro Bank, trap (pot) fishing and spearfishing using hookah (Aiken and Kong 2000; Gustavson 2002). The Antillean z-traps were observed on or adjacent (in sand) to coral reef habitats in many of the sites we surveyed. Traps typically contained a very low biomass of fish, but the fish consisted of a broad spectrum including piscivores (small serranids, lutjanids, grunts, balistids, pomacanthids), as well as herbivores (scarids), but surgeonfish were the dominant species noted. These traps seemed to favor smaller species and individuals (partially because no large fish remain), which may contribute to growth overfishing. Further, the depletion of large predatory fishes has triggered a shift from high value species to a high diversity of lower value species, especially species that formerly were considered non-target species and are important indicators of a healthy reef system (e.g. butterflyfish, angelfish); this is suggestive of ecosystem overfishing (Pauly 1979). As traps have become less economical, there has been expanded use of hookah, primarily targeting parrotfish with incidental catch of other “large” fish and lobsters, which may lead to Malthusian overfishing (Pauly 1990). A continued decline of herbivores will also cause ancillary damage as reef substrates become monopolized by increasing amounts of fleshy algae, reducing the area available for encrusting coralline algae, and inhibiting coral settlement. Over the longer term, the reefs will be less likely to resist future disturbances and their potential to rebound may be unlikely.

At this time, the overall condition of Pedro Bank's coral reefs remains far better than most reefs off mainland Jamaica, but these reefs are at a tipping point. The establishment of a Fishery Reserve is a key step forward in conservation of Pedro Bank's coral reef resources, as it will allow fish to grow larger, potentially producing more offspring and spill over into adjacent fished areas. However, this one reserve is far too small to adequately protect fishery resources and the amount of effort and types of fishing are currently unsustainable and are likely to trigger deleterious changes to the reefs. Additional conservation measures emphasizing an expanded network of protected areas may help maintain and restore Pedro banks precious coral reefs.

Fig. 63. Typical, meager landings from fish an Antillean z-trap on Pedro Bank

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APPENDICES

Appendix 1. Coral species identified within 20 sites examined on Pedro Bank, Jamaica.

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Acropora cervicornis					X			X	X	X			X						X	X
Acropora palmata	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
Colpophyllia natans			X	X	X	X		X	X	X								X	X	X
Dendrogyra cylindrus		X			X	X	X	X	X				X	X		X				X
Dichocoenia stokesii	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			X	
Diploria clivosa				X						X				X	X					
Diploria labyrinthiformis	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
Eusmilia fastigiata				X		X		X						X						X
Isophyllastrea rigida	X	X	X	X		X	X	X	X				X		X	X			X	
Isophyllia sinuosa																				
Leptoseris cucullata											X							X		X
Madracis decactis			X	X		X	X	X	X	X	X	X	X	X			X		X	X
Madracis auretenra (mirabilis)				X				X	X										X	
Manicina areolata	X																	X		
Meandrina meandrites	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								
Millepora complanata				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
Montastraea cavernosa	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
M. franksi		X									X						X		X	X
Mussa angulosa																				X

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mycetophyllia aliciae																				
Mycetophyllia daniana																				
Mycetophyllia ferox																				
Mycetophyllia lamarckiana																				X
Porites astreoides	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Porites divaricata	X						X				X									
Porites furcata	X	X		X			X		X	X	X	X	X					X		
Porites porites	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
Siderastrea radians														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
Stephanocoenia intersepta		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X	
Meandrina jacksoni			X	X		X	X	X	X			X	X			X			X	
Total	16	17	13	21	16	18	17	21	20	18	17	16	19	16	12	17	12	14	19	19

Appendix 2a. Reef fish diversity and abundance at Pedro Bank Jamaica survey sites 1-10. Species are listed as single (1), few (2, 2-10), many (3, 11-100) and abundant (4, >100).

Common Name	Scientific Name	JAPB-01	JAPB-02	JAPB-03	JAPB-06	JAPB-07	JAPB-08	JAPB-09	JAPB-10
Balloonfish	*Diodon holocanthus*			2					
Banded Butterflyfish	*Chaetodon striatus*		2	2			2		1
Bandtail Puffer	*Sphoeroides spengleri*						2		
Bar Jack	*Caranx ruber*		3			3			3
Barred Hamlet	*Hypoplectrus puella*								
Barsnout Goby	*Gobiosoma illecebrosum*	2							
Beaugregory	*Stegastes leucostictus*	2	2	1	2	2		2	2
Bermuda Chub/Yellow Chub	*Kyphosus sectatrix/incisor*								
Bicolor Damselfish	*Stegastes partitus*	3	3	3	3	3	4	3	2
Black Durgon	*Melichthys niger*		3	3	2	3	2	3	3
Blackbar Soldierfish	*Myripristis jacobus*		2				1		2
Blue Chromis	*Chromis cyanea*	2	3		2	3	3	2	3
Blue Runner	*Caranx crysos*								
Blue Tang	*Acanthurus coeruleus*	3	3	3	2	3	3	3	3
Bluehead wrase	*Thalassoma bifasciatum*	3	3	3	3	4	4	4	4
Bluelip Parrotfish	*Cryptotomus roseus*						2		
Bluestriped Grunt	*Haemulon sciurus*								
Bridled Goby	*Coryphopterus glaucofraenum*	2		2	2	2			
Broadstripe Goby	*Gobiosoma prochilos*	2	2	2	2	2	2	2	2
Brown Chromis	*Chromis multilineata*	1	3		3	3	3	3	3
Caesar Grunt	*Haemulon carbonarium*		2			1	1		2
Cardinal Soldierfish	*Plectrypops retrospinis*						2		
Cero	*Scomberomorus regalis*								1
Chalk Bass	*Serranus tortugarum*				1				
Clown Wrasse	*Halichoeres maculipinna*	1					2	2	1
Cocoa Damselfish	*Stegastes variabilis*	2		1	1				
Colon Goby	*Coryphopterus dicrus*	2	2				1		1
Coney	*Cephalopholis fulva*		1		1	1			

Common Name	Scientific Name	JAPB-01	JAPB-02	JAPB -03	JAPB -06	JAPB -07	JAPB -08	JAPB -09	JAPB -10
Creole Wrasse	*Clepticus parrae*		3	2	3	2		3	3
Doctorfish	*Acanthurus chirurgus*							2	
Dusky Damselfish	*Stegastes adustus*								
Dusky Squirrelfish	*Sargocentron vexillarium*		2		2	2		1	2
Fairy Basslet	*Gramma loreto*	2			2			2	1
Flamefish	*Apogon maculatus*	1							
Foureye Butterflyfish	*Chaetodon capistratus*			2					
French Angelfish	*Pomacanthus paru*								
French Grunt	*Haemulon flavolineatum*		3	3	2	3	3	2	3
Glasseye Snapper	*Heteropriacanthus cruentatus*								2
Goldentail Moray	*Gymnothorax miliaris*						2		
Goldspot Goby	*Gnatholepis thompsoni*						1		
Gray Angelfish	*Pomacanthus arcuatus*							1	
Graysby	*Cephalopholis cruentata*	2	2	1	2	2	2	2	2
Great Barracuda	*Sphyraena barracuda*							1	
Green Razorfish	*Xyrichtys splendens*				1	2			
Greenblotch Parrotfish	*Sparisoma atomarium*	2	2			2	2	2	
Harlequin Bass	*Serranus tigrinus*	2	1		2	2		2	
Hawksbill Sea Turtle	*Eretmochelys imbricata*								
Highhat	*Equetus acuminatus*						1		
Honeycomb Cowfish	*Lactophrys polygonius*			2		2			
Longfin Damselfish	*Stegastes diencaeus*	2			2	2		2	3
Longjaw Squirrelfish	*Neoniphon marianus*		1			1			
Longspine Squirrelfish	*Holocentrus rufus*		2	2			1		2
Masked Goby	*Coryphopterus personatus/hyalinus*								
Neon Goby	*Gobiosoma oceanops*			1	2	2	1		
Nurse Shark	*Ginglymostoma cirratum*								
Ocean Surgeonfish	*Acanthurus bahianus*	3	3	3	3	3	3	3	4
Ocean Triggerfish	*Canthidermis sufflamen*								
Orange Filefish	*Aluterus schoepfii*								

Common Name	**Scientific Name**	**JAPB-01**	**JAPB-02**	**JAPB-03**	**JAPB-06**	**JAPB-07**	**JAPB-08**	**JAPB-09**	**JAPB-10**
Orangespotted Filefish	*Cantherhines pullus*		1	1	1			2	2
Pluma	*Calamus pennatula*								
Porcupinefish	*Diodon hystrix*								
Princess Parrotfish	*Scarus taeniopterus*		2	2	3	3	3	3	3
Puddingwife	*Halichoeres radiatus*							1	
Queen Angelfish	*Holacanthus ciliaris*								
Queen Parrotfish	*Scarus vetula*								2
Queen Triggerfish	*Balistes vetula*								
Rainbow Wrasse	*Halichoeres pictus*	3	2	3	3	3	2	3	3
Red Lionfish (exotic)	*Pterois volitans*		1		1				2
Redband Parrotfish	*Sparisoma aurofrenatum*	3	3	3	4	4	3	4	4
Redlip Blenny	*Ophioblennius atlanticus*								
Redspotted Hawkfish	*Amblycirrhitus pinos*	1	2		1		2	2	1
Redtail Parrotfish	*Sparisoma chrysopterum*								
Reef Butterflyfish	*Chaetodon sedentarius*								
Reef Shark	*Carcharhinus perezi*			1					
Reef Squirrelfish	*Holocentrus coruscus*								
Rock Beauty	*Holacanthus tricolor*	2	2	2	3	2	2	2	3
Rosy Razorfish	*Xyrichtys martinicensis*								
Roughhead Blenny	*Acanthemblemaria aspera*						1		
Saddled Blenny	*Malacoctenus triangulatus*	1	1			1	1	2	
Sand Diver	*Synodus intermedius*								
Sand Tilefish	*Malacanthus plumieri*	1	1	2	2	2	2	2	2
Scrawled Filefish	*Aluterus scriptus*						1		
Sergeant Major	*Abudefduf saxatilis*							1	
Sharksucker	*Echeneis naucrates*								1
Sharpnose Puffer	*Canthigaster rostrata*	2	2	2	2	2	3	3	3
Shy Hamlet	*Hypoplectrus guttavarius*								
Slippery Dick	*Halichoeres bivittatus*	3	2		2	3	2	2	2
Smooth Trunkfish	*Lactophrys triqueter*				2		1		
S. Stingray	*Dasyatis americana*				1				

Common Name	Scientific Name	JAPB-01	JAPB-02	JAPB-03	JAPB-06	JAPB-07	JAPB-08	JAPB-09	JAPB-10
Spanish Hogfish	*Bodianus rufus*					1			1
Spinyhead Blenny	*Acanthemblemaria spinosa*					1			
Spotfin Butterflyfish	*Chaetodon ocellatus*								
Spotted Drum	*Equetus punctatus*								
Spotted Goatfish	*Pseudupeneus maculatus*			1		2			
Spotted Moray	*Gymnothorax moringa*								
Spotted Scorpionfish	*Scorpaena plumieri plumieri*								
Spotted Trunkfish	*Lactophrys bicaudalis*					1	1	1	
Squirrelfish	*Holocentrus ascensionis*	2	1	2	2		2	1	1
Stoplight Parrotfish	*Sparisoma viride*	2	2	2	2	2	2	3	3
Striped Parrotfish	*Scarus iseri*	3	3	3	3	3	3	3	2
Threespot Damselfish	*Stegastes planifrons*	1	1		1	2	1		3
Tobaccofish	*Serranus tabacarius*				1				
Tomtate	*Haemulon aurolineatum*			1			3		
Trumpetfish	*Aulostomus maculatus*				2	1	2	1	2
White Grunt	*Haemulon plumieri*		1						
Whitespotted Filefish	*Cantherhines macrocerus*							2	1
Yellow Goatfish	*Mulloidichthys martinicus*		1	2					2
Yellow Stingray	*Urobatis jamaicensis*				1	2	1		
Yellowcheek Wrasse	*Halichoeres cyanocephalus*	2					2	1	
Yellowhead Jawfish	*Opistognathus aurifrons*	2				2	2		
Yellowhead Wrasse	*Halichoeres garnoti*	3	3	3	4	4	3	3	4
Yellowline Goby	*Gobiosoma horsti*				2		2	2	2
Yellowtail (Redfin) Parrotfish	*Sparisoma rubripinne*								2
Yellowtail Damselfish	*Microspathodon chrysurus*	2	2		3	2	2	2	3
Yellowtail Snapper	*Ocyurus chrysurus*								
	totals	**35**	**42**	**33**	**44**	**44**	**49**	**43**	**48**

Appendix 2b. Reef fish diversity and abundance at Pedro Bank Jamaica survey sites 11-20. Species are listed as single (1), few (2, 2-10), many (3, 11-100) and abundant (4, >100).

Common Name	Scientific Name	JAPB -11	JAPB -12	JAPB -13	JAPB -14	JAPB -15	JAPB -16	JAPB -17	JAPB -18	JAPB -19	JAPB -20
Balloonfish	*Diodon holocanthus*										
Banded Butterflyfish	*Chaetodon striatus*	1					2	1			
Bandtail Puffer	*Sphoeroides spengleri*										
Bar Jack	*Caranx ruber*	2		1			2		2	2	
Barred Hamlet	*Hypoplectrus puella*								2		1
Barsnout Goby	*Gobiosoma illecebrosum*										
Beaugregory	*Stegastes leucostictus*	2	2	1	3	3	1		3	2	1
Bermuda Chub/	*Kyphosus sectatrix/*					4					
Bicolor Damselfish	*Stegastes partitus*	3	4	3	3	4	3	3	3	3	3
Black Durgon	*Melichthys niger*	3	3	3	3	3	3	2		3	2
Blackbar Soldierfish	*Myripristis jacobus*				2						
Blue Chromis	*Chromis cyanea*	4	3	3	4	4	3		4	4	4
Blue Runner	*Caranx crysos*				2						
Blue Tang	*Acanthurus coeruleus*	3	3	3	3	4	4	3	4	3	3
Bluehead	*Thalassoma bifasciatum*	4	4	4	4	4	4	3		3	3
Bluelip Parrotfish	*Cryptotomus roseus*										
Bluestriped Grunt	*Haemulon sciurus*					1					
Bridled Goby	*Coryphopterus glaucofraenum*	1			1		1	2		1	
Broadstripe Goby	*Gobiosoma prochilos*	2	1	2	2			2	2	2	2
Brown Chromis	*Chromis multilineata*		3	3	4	4	3		3	3	2
Caesar Grunt	*Haemulon carbonarium*	2	2	2	1	4	1				
Cardinal Soldierfish	*Plectrypops retrospinis*										
Cero	*Scomberomorus regalis*									1	
Chalk Bass	*Serranus tortugarum*	2							2		
Clown Wrasse	*Halichoeres maculipinna*	1	2	1	2	2					
Cocoa Damselfish	*Stegastes variabilis*		1		2						
Colon Goby	*Coryphopterus dicrus*	1			1			1		2	1
Coney	*Cephalopholis fulva*		1				2				

Common Name	Scientific Name	JAP B-11	JAP B-12	JAP B-13	JAP B-14	JAP B-15	JAP B-16	JAP B-17	JAP B-18	JAP B-19	JAP B-20
Creole Wrasse	*Clepticus parrae*	2		2	4					4	4
Doctorfish	*Acanthurus chirurgus*	2	2		2		3		2		
Dusky Damselfish	*Stegastes adustus*					4					
Dusky Squirrelfish	*Sargocentron vexillarium*			2			2		2		
Fairy Basslet	*Gramma loreto*	2	3	2	3	2	2		2	2	
Flamefish	*Apogon maculatus*										
Foureye Butterflyfish	*Chaetodon capistratus*								1		1
French Angelfish	*Pomacanthus paru*							1			
French Grunt	*Haemulon flavolineatum*	3	4	3	3	3	3		4	3	2
Glasseye Snapper	*Heteropriacanthus cruentatus*	1				1			1	2	
Goldentail Moray	*Gymnothorax miliaris*	1					1				
Goldspot Goby	*Gnatholepis thompsoni*	1							2		
Gray Angelfish	*Pomacanthus arcuatus*										
Graysby	*Cephalopholis cruentata*	2	2	2	2	1	1	2	2	2	2
Great Barracuda	*Sphyraena barracuda*										
Green Razorfish	*Xyrichtys splendens*	2		2					1		
Greenblotch Parrotfish	*Sparisoma atomarium*	2		2	2				2	2	2
Harlequin Bass	*Serranus tigrinus*	2		2	1				1		
Hawksbill Sea Turtle	*Eretmochelys imbricata*		1								
Highhat	*Equetus acuminatus*									3	
Honeycomb Cowfish	*Lactophrys polygonius*	1			1						
Longfin Damselfish	*Stegastes diencaeus*	2	2	1	2	4	2		4		3
Longjaw Squirrelfish	*Neoniphon marianus*	2	1		2		1			2	1
Longspine Squirrelfish	*Holocentrus rufus*	2	2	2	2		2	2	2		1
Masked Goby/	*Coryphopterus personatus/*									2	1
Neon Goby	*Gobiosoma oceanops*										
Nurse Shark	*Ginglymostoma cirratum*				1	2					1
Ocean Surgeonfish	*Acanthurus bahianus*	3	3	4	4	4	4	3	4	4	3
Ocean Triggerfish	*Canthidermis sufflamen*				2						

Common Name	Scientific Name	JAPB -11	JAPB -12	JAPB -13	JAPB -14	JAPB -15	JAPB -16	JAPB -17	JAPB -18	JAPB -19	JAPB -20
Orange Filefish	*Aluterus schoepfii*									2	
Orangespotted Filefish	*Cantherhines pullus*	2		2		2	1			1	
Pluma	*Calamus pennatula*	1							2		
Porcupinefish	*Diodon hystrix*	1						1			
Princess Parrotfish	*Scarus taeniopterus*	3	3	3	3	3	3	2	3	4	2
Puddingwife	*Halichoeres radiatus*			1	2	2	2		1		
Queen Angelfish	*Holacanthus ciliaris*		1						1		
Queen Parrotfish	*Scarus vetula*	1		2					2	1	
Queen Triggerfish	*Balistes vetula*	1	1	2					2		
Rainbow Wrasse	*Halichoeres pictus*	2	2	3	2	3	2		3	3	
Red Lionfish (exotic)	*Pterois volitans*			1	1					2	1
Redband Parrotfish	*Sparisoma aurofrenatum*	4	4	4	4	4	3	3	3	4	4
Redlip Blenny	*Ophioblennius atlanticus*		1			3					
Redspotted Hawkfish	*Amblycirrhitus pinos*				2		1				
Redtail Parrotfish	*Sparisoma chrysopterum*				1			1			
Reef Butterflyfish	*Chaetodon sedentarius*									1	
Reef Shark	*Carcharhinus perezi*		1			1				1	1
Reef Squirrelfish	*Holocentrus coruscus*								1		
Rock Beauty	*Holacanthus tricolor*	3	3	2	2	2	3	2	2	2	2
Rosy Razorfish	*Xyrichtys martinicensis*	2	1								
Roughhead Blenny	*Acanthemblemaria aspera*			1							
Saddled Blenny	*Malacoctenus triangulatus*		2	1	2	1	2	1			
Sand Diver	*Synodus intermedius*								1		
Sand Tilefish	*Malacanthus plumieri*	2	2	2		2		1	1	1	1
Scrawled Filefish	*Aluterus scriptus*						1			1	
Sergeant Major	*Abudefduf saxatilis*		2							2	
Sharksucker	*Echeneis naucrates*	1							1		1
Sharpnose Puffer	*Canthigaster rostrata*	3	2	3	2	2	2	1	2	2	2
Shy Hamlet	*Hypoplectrus guttavarius*								1		

Common Name	**Scientific Name**	**JAPB -11**	**JAPB -12**	**JAPB -13**	**JAPB -14**	**JAPB -15**	**JAPB -16**	**JAPB -17**	**JAPB -18**	**JAPB -19**	**JAPB -20**
Slippery Dick	*Halichoeres bivittatus*	2	2		3	3	2		3		
Smooth Trunkfish	*Lactophrys triqueter*			1	1	1				1	
Southern Stingray	*Dasyatis americana*		1								
Spanish Hogfish	*Bodianus rufus*	2	2		1	2	2		2	1	
Spinyhead Blenny	*Acanthemblemaria spinosa*										
Spotfin Butterflyfish	*Chaetodon ocellatus*										2
Spotted Drum	*Equetus punctatus*	1							2	1	
Spotted Goatfish	*Pseudupeneus maculatus*				1	1					1
Spotted Moray	*Gymnothorax moringa*	1	1				1		1		
Spotted Scorpionfish	*Scorpaena plumieri*			1							
Spotted Trunkfish	*Lactophrys bicaudalis*					1			1		
Squirrelfish	*Holocentrus ascensionis*	2	2	2	1	2	2		2	1	
Stoplight Parrotfish	*Sparisoma viride*	2	3	3	3	4	3		3	2	2
Striped Parrotfish	*Scarus iseri*	3	3	3	2	4	3	2	4	4	3
Threespot Damselfish	*Stegastes planifrons*					3			4		2
Tobaccofish	*Serranus tabacarius*										1
Tomtate	*Haemulon aurolineatum*										
Trumpetfish	*Aulostomus maculatus*	1	1	1	1	2				2	
White Grunt	*Haemulon plumieri*				1						
Yellow Goatfish	*Mulloidichthys martinicus*	2				3	2			2	
Yellow Stingray	*Urobatis jamaicensis*		2	2	1						
Yellowcheek Wrasse	*Halichoeres cyanocephalus*	1								1	1
Yellowhead Jawfish	*Opistognathus aurifrons*	2	2						2		
Yellowhead Wrasse	*Halichoeres garnoti*	4	4	3	4	4	3	3	4	4	3
Yellowline Goby	*Gobiosoma horsti*	2		2	2			2		1	
Yellowtail Parrotfish	*Sparisoma rubripinne*										
Yellowtail Damselfish	*Microspathodon chrysurus*	2	2	3	2	4	2	2	2	2	2
Yellowtail Snapper	*Ocyurus chrysurus*					1					
	totals	**57**	**46**	**45**	**52**	**44**	**41**	**24**	**50**	**48**	**38**

Appendix 3. Reef fish species considered *Commercially Significant*	
Black Margate	*Anisotremus surinamensis*
Ocean Triggerfish	*Canthidermis sufflamen*
Bar Jack	*Caranx ruber*
Coney	*Cephalopholis fulva*
Rock Hind	*Epinephelus adscensionis*
Red Hind	*Epinephelus guttatus*
Dusky Grouper	*Epinephelus marginatus*
Red Grouper	*Epinephelus morio*
Nassau Grouper	*Epinephelus striatus*
White Margate	*Haemulon album*
French Grunt	*Haemulon flavolineatum*
Mutton Snapper	*Lutjanus analis*
Schoolmaster	*Lutjanus apodus*
Cubera Snapper	*Lutjanus cyanopterus*
Gray Snapper	*Lutjanus griseus*
Dog Snapper	*Lutjanus jocu*
Mahogany Snapper	*Lutjanus mahogoni*
Lane Snapper	*Lutjanus synagris*
Black Grouper	*Mycteroperca bonaci*
Yellowmouth Grouper	*Mycteroperca interstitialis*
Gag	*Mycteroperca microlepis*
Scamp	*Mycteroperca phenax*
Tiger Grouper	*Mycteroperca tigris*
Yellowfin Grouper	*Mycteroperca venenosa*
Yellowtail Snapper	*Ocyurus chrysurus*

Appendix 4. CONTRIBUTION OF BENTHIC RELATIVE COMPOSITION CLASSES TO ORDINATION OF SIGNIFICANT DIFFERENT GROUPS

Group b
Average similarity: 81.35

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
% Algae-Macro-Fleshy	23.84	18.96	3.36	23.31	23.31
% Other (Sand, Rock, Rubble, etc.)	19.64	18.25	28.13	22.44	45.74
% Algae-Crustose	12.02	9.72	5.82	11.94	57.69
% Algae-Macro-Calcareous	10.78	9.27	5.75	11.4	69.08
% Invertebrates-Other	10.21	8.51	3.42	10.46	79.54
% Live Coral	9.62	6.93	2.97	8.52	88.06
% Algae-Turf	7.87	6.48	4.15	7.97	96.03

Group c
Average similarity: 81.05

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
% Algae-Crustose	21.09	17.35	3.47	21.41	21.41
% Algae-Macro-Fleshy	19.7	15.97	2.51	19.7	41.11
% Invertebrates-Other	13.22	11.03	3.92	13.61	54.72
% Algae-Turf	13.71	10.45	2.99	12.89	67.61
% Live Coral	9.8	8.84	7.87	10.91	78.53
% Algae-Macro-Calcareous	9.75	8.12	3.71	10.02	88.54
% Other (Sand, Rock, Rubble, etc.)	7.58	6.32	4.35	7.8	96.34

Group a
Less than 2 samples in group

Groups b & c
Average dissimilarity = 26.70

	Group b	Group c				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
% Other (Sand, Rock, Rubble, etc.)	19.64	7.58	6.03	3.68	22.58	22.58
% Algae-Crustose	12.02	21.09	4.89	1.6	18.32	40.9
% Algae-Macro-Fleshy	23.84	19.7	4.29	1.36	16.06	56.97
% Algae-Turf	7.87	13.71	3.26	1.3	12.21	69.17
% Invertebrates-Other	10.21	13.22	2.21	1.47	8.26	77.44
% Live Coral	9.62	9.8	1.78	1.19	6.67	84.11
% Algae-Macro-Calcareous	10.78	9.75	1.49	1.29	5.56	89.67
% Invertebrates-Aggressive	1.83	2.99	1	1.44	3.73	93.4

Groups b & a
Average dissimilarity = 30.06

	Group b	Group a				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
% Algae-Crustose	12.02	34.38	11.18	5.51	37.18	37.18
% Algae-Macro-Fleshy	23.84	13.5	5.22	1.33	17.37	54.56
% Other (Sand, Rock, Rubble, etc.)	19.64	13.38	3.13	2.27	10.42	64.97
% Algae-Turf	7.87	2.88	2.5	2.16	8.31	73.28
% Live Coral	9.62	5.75	2.19	1.05	7.27	80.55
% Algae-Macro-Calcareous	10.78	14.13	1.68	1.36	5.59	86.14
% Invertebrates-Other	10.21	8.88	1.4	2.52	4.65	90.78

Groups c & a
Average dissimilarity = 27.43

	Group c	Group a				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
% Algae-Crustose	21.09	34.38	6.64	2.11	24.22	24.22
% Algae-Turf	13.71	2.88	5.42	1.93	19.75	43.97
% Algae-Macro-Fleshy	19.7	13.5	4.01	1.99	14.62	58.59
% Other (Sand, Rock, Rubble, etc.)	7.58	13.38	2.9	2.74	10.56	69.16
% Algae-Macro-Calcareous	9.75	14.13	2.34	1.99	8.53	77.68
% Invertebrates-Other	13.22	8.88	2.27	1.33	8.26	85.94
% Live Coral	9.8	5.75	2.02	2.45	7.38	93.32

Appendix 5. Coral species abundance and contribution to significant groups

Group e
Average similarity: 73.73

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Undaria agaracites	11.43	19.55	3.4	26.52	26.52
Montastraea annularis	6.88	12.71	4.43	17.24	43.76
Siderastrea siderea	6.62	11.94	4.04	16.19	59.95
Porites astreoides	6.69	10.55	2.52	14.3	74.26
Montastraea faveolata	3.33	4.8	1.48	6.52	80.77
Porites porites	2.85	4.13	1.89	5.6	86.37
Diploria strigosa	2.82	3.52	1.28	4.78	91.15
Montastraea cavernosa	1.74	2.49	1.8	3.38	94.53

Group d
Average similarity: 73.23

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Siderastrea siderea	13.51	22.29	3.92	30.44	30.44
Undaria agaracites	7.4	12.94	4.78	17.67	48.11
Porites astreoides	7.48	12.13	2.98	16.56	64.68
Diploria strigosa	5.39	9.62	3.37	13.14	77.82
Stephanocoenia intersepta	3.06	4.4	2.62	6	83.82
Montastraea faveolata	2.38	3.34	4.17	4.56	88.39
Porites porites	1.87	2.81	1.92	3.84	92.22
Montastraea annularis	1.92	2.49	2.07	3.4	95.62
Montastraea cavernosa	1.49	1.81	1.3	2.48	98.1

Group c
Average similarity: 72.69

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Undaria agaracites	14.83	24.06	14.16	33.1	33.1
Siderastrea siderea	7.75	13.77	9.14	18.95	52.05
Montastraea cavernosa	6.83	8.61	2.02	11.85	63.9
Porites astreoides	2.83	5.47	13.87	7.52	71.42
Montastraea faveolata	5	5.02	1.1	6.91	78.34
Diploria strigosa	3.25	4.43	3.98	6.1	84.44
Stephanocoenia intersepta	3.13	4.12	1.71	5.67	90.11
Montastraea annularis	2.17	3.35	2.26	4.6	94.71
Montastraea franksi	2.13	1.86	0.84	2.56	97.27
Porites porites	0.75	1	0.91	1.38	98.64

Group a
Less than 2 samples in group

Group b
Less than 2 samples in group

Appendix 6. FISH TAXA RELATIVE CONTRIBUTION TO BIOMASS ORDINATION OF SIGNIFICANT GROUPS

Group h
Average similarity: 82.82

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Parrotfish (all species in family) density (#/100m2)	64.41	60.74	13.2	73.34	73.34
Surgeonfish (all species in family) density (#/100m2)	20.72	16.01	4.16	19.33	92.67

Group d
Average similarity: 86.44

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Parrotfish (all species in family) density (#/100m2)	29.54	28.47	98.23	32.93	32.93
Triggerfish (all species in family) density (#/100m2)	29.96	25.73	7.74	29.77	62.7
Surgeonfish (all species in family) density (#/100m2)	24.65	22.15	11.45	25.62	88.33
Grunts (all species in family) density (#/100m2)	7.05	6.04	7.64	6.99	95.32

Group c
Average similarity: 82.88

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Triggerfish (all species in family) density (#/100m2)	48.61	46.61	49.15	56.23	56.23
Parrotfish (all species in family) density (#/100m2)	24.77	20.55	4.79	24.8	81.03
Surgeonfish (all species in family) density (#/100m2)	12.7	9.55	3.09	11.52	92.55

Group g
Less than 2 samples in group

Group e
Average similarity: 82.33

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Surgeonfish (all species in family) density (#/100m2)	43.33	39.78	#######	48.31	48.31
Parrotfish (all species in family) density (#/100m2)	30.18	21.96	#######	26.68	74.99
Triggerfish (all species in family) density (#/100m2)	17.5	14.37	#######	17.45	92.44

Group b
Less than 2 samples in group

Group a
Less than 2 samples in group

Group f

Less than 2 samples in group

Appendix 7. Linear regressions comparing transect data for the 19 sites. FMA=fleshy macroalgae, T=total, I=invertivore, P=piscivore, CS=commercially significant, H=herbivore. Significant values are shown in bold. Although a few relationships appeared to be significant, R^2 values were very low.

x	y	R^2
Coral cover	FMA cover	0.0801
Coral cover	CCA cover	0.0208
Coral cover	T biomass	0.0157
Coral cover	I biomass	0.0134
Coral cover	H biomass	0.0013
Coral cover	P biomass	0.0084
Coral cover	CS biomass	0.00006
Coral cover	Parr biomass	0.0179
Coral cover	Surg biomass	0.014
Coral cover	Trig biomass	0.0678
Coral cover	T abundance	0.0775
Coral cover	CS abundance	0.0028
Coral cover	Parr abundance	0.063
Coral cover	Surg abundance	0.0477
Coral cover	Trig abundance	0.0706
FMA cover	**CCA**	**0.2084**
FMA cover	T biomass	0.0239
FMA cover	I biomass	0.0187
FMA cover	H biomass	0.00001
FMA cover	P biomass	0.0074
FMA cover	CS biomass	0.0709
FMA cover	**Parr biomass**	**0.1112**
FMA cover	Surg biomass	0.0086
FMA cover	Trig biomass	0.0045
FMA cover	T abundance	0.0437
FMA cover	CS abundance	0.0753
FMA cover	Parr abundance	0.0442
FMA cover	Surg abundance	0.0682
FMA cover	Trig abundance	0.00008
CCA cover	T biomass	0.0274
CCA cover	I biomass	0.048
CCA cover	H biomass	0.0473
CCA cover	P biomass	0.0001
CCA cover	CS biomass	0.0384
CCA cover	**Parr biomass**	**0.1904**
CCA cover	Surg biomass	0.0479
CCA cover	Trig biomass	0.0646
CCA cover	T abundance	0.0004
CCA cover	CS abundance	0.0646
CCA cover	Parr abundance	0.0008
CCA cover	**Surg abundance**	**0.2818**
CCA cover	Trig abundance	0.0323
relief	Coral cover	0.0372
relief	**FMA cover**	**0.1147**
relief	**CCA cover**	**0.1055**
relief	T biomass	0.0975
relief	**I biomass**	**0.2229**
relief	H biomass	0.018
relief	P biomass	0.0043
relief	**CS biomass**	**0.1279**
relief	Parr biomass	0.0354
relief	Surg biomass	0.0337
relief	Trig biomass	0.03553
relief	**T abundance**	**0.2208**
relief	**CS abundance**	**0.113**
relief	Parr abundance	0.0744
relief	Surg abundance	0.0146

Appendix 8: Resilience parameters. Raw data used to calculate ranks according to table 8.

Site	Depth (m)	Coral Cover	Disease	Recruits	FMxHavg	Herbivores	CommFish	Diadema
JAPB-01	10.5	4.0	1.961	1.280	61.3	5853	192	1.25
JAPB-02	12.6	11.0	5.789	3.200	21.7	1774	219	0.00
JAPB-03	21.3	11.7	0.000	2.133	3.3	4760	37	0.00
JAPB-04	9.6	11.2	4.110	4.000	29.4	4141	0	0.04
JAPB-06	14.5	8.1	8.796	8.178	6.0	8861	1132	0.00
JAPB-07	10.5	9.1	13.609	2.133	17.6	8621	371	0.00
JAPB-08	15.6	8.0	7.009	5.600	59.6	4209	14	0.00
JAPB-09	14.0	11.0	5.028	8.889	6.3	2903	227	0.00
JAPB-10	13.7	11.3	7.843	5.333	21.9	7310	654	0.00
JAPB-11	14.8	8.5	4.622	1.920	38.9	7012	717	0.00
JAPB-12	12.5	12.5	3.774	9.600	30.7	4214	343	0.00
JAPB-13	12.6	8.2	0.971	2.133	32.9	6519	129	0.00
JAPB-14	14.6	8.0	7.143	1.200	10.7	6382	354	0.00
JAPB-15	8.6	5.8	0.990	2.000	7.6	6588	329	0.00
JAPB-16	15.2	6.0	0.621	3.200	28.8	5600	551	0.00
JAPB-17	18.3	8.1	3.378	1.600	43.7	3652	70	0.06
JAPB-18	11.3	9.0	1.418	0.800	86.2	5243	4227	1.96
JAPB-19	18.5	9.6	2.013	1.067	60.2	6772	56	0.00
JAPB-20	17.8	18.8	13.913	0.800	13.1	4048	256	0.00

Appendix 9. Zooplankton Numbers/m^3 at the 10 stations sampled on the Pedro Bank.

Taxa	1	2	3	4	5	6	7	8	9	10
Medusae	11.3	2.7	1.0	0.9	2.2	7.4	0.1	3.9	5.8	2.7
Cladocera	0.0	1.8	0.3	0.2	3.0	0.2	0.6	4.3	3.9	0.0
Copepod	390.2	93.9	31.6	8.4	31.5	73.3	4.6	39.2	43.2	187.3
Lucifer	4.2	0.5	0.8	0.2	0.3	0.6	0.0	0.4	0.0	2.7
Larvacea	13.2	2.3	1.0	2.3	4.9	3.3	0.0	4.1	4.1	20.4
Chateognaths	30.2	4.1	3.4	0.7	3.8	16.7	0.2	0.0	1.7	15.6
Larvae	254.7	35.7	20.9	6.1	4.1	71.2	0.4	5.4	8.0	72.0
Mysids	3.8	0.2	0.2	2.3	0.3	1.6	0.0	0.0	0.0	8.1
Others	5.7	2.3	2.0	4.5	0.5	0.0	0.2	3.5	1.2	4.8
Fish larvae	14.3	2.9	2.7	0.9	2.2	4.1	0.1	0.8	1.2	9.5
Fish eggs	249.1	29.4	33.3	38.0	34.5	70.2	1.8	34.5	16.0	191.4
Lobster	3.0	1.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0	1.4
Total	979.6	176.9	97.5	64.7	87.2	248.4	8.0	96.0	85.1	515.9
Richness	88	55	18	32	36	81	37	64	53	166

Appendix 10. Taxonomic revisions of corals.

Since completion of these surveys, taxonomic revisions have been made for several corals. All of the taxa listed in this report use the previous nomenclature. The taxonomy has been revised using molecular tools for the following corals:

Nomenclature used in this paper (Veron 2000)	**New nomenclature (C Pinzon and Weil 2011; Budd et al. 2012)**
Diploria strigosa	*Pseudodiploria strigosa*
Diploria clivosa	*Pseudodiploria clivosa*
Montastraea faveolata	*Orbicella faveolata*
Montastraea annularis	*Orbicella annularis*
Montastraea franksi	*Orbicella franksi*
Isophyllastrea rigida	*Isophyllia rigida*
Meandrina meandrites	*Meandrina meandrites; Meandrina jacksoni*
Madracis mirabilis	*Madracis aurentera*
Agaricia agaricites	*Undaria agaricites*

Veron JEN (2000) *Corals of the world*, 3 vols. Townsville, Qld: Australian Institute of Marine Science.

Budd AF, Fukami H, Smith ND, Knowlton N (2012) Taxonomic classification of the reef coral family Mussidae (Cnidaria: Anthozoa: Scleractinia) *Zoological Journal of the Linnean Society*, 166: 465–529.

C Pinzon JH and Weil E (2011) Cryptic species within the Atlantic Caribbean Genus *Meandrina* (Scleractinia): a multidisciplinary approach and description of the new species *Meandrina jacksoni*. *Bulletin of Marine Science*. 87(4):823–853.

The following abbreviations for corals have been used in this report:

Species	Abbreviation	Species	Abbreviation
Montastraea annularis	MANN	*Diploria strigosa*	DSTR
M. faveolata	MFAV	*Diploria* spp.	DIP
M. franksi	MFRA	*Colpophyllia natans*	CNAT
M. annularis complex	MONT	*Dichocoenia stokesi*	DSTO
M. cavernosa	MCAV	*Meandrina meandrites*	MMEA
Agaricia agaricites	AAGA	*Madracis decactis*	MDEC
Agaricia spp.	AGA	*Stephanocoenia intersepta*	SINT
Porites astreoides	PAST	*Siderastrea siderea*	SSID
P. porites; P. furcata; P. divaricata	PPOR	*Siderastrea siderea, S. radians*	SID
P. furcata	PFUR	*Favia fragum*	FFR
Porites spp.	POR		

Appendix 11. Science Team

Name	Institution	Role
Phil Renaud	KSLOF	Executive Director/phototransects
Andy Bruckner	KSLOF	Chief scientist/coral surveys
Brian Beck	KSLOF	Benthic surveys
Judy Lang	AGRRA	Coral surveys
David Grenda	Fl Aquarium	Fish surveys
Kenneth Marks	AGRRA	Fish surveys
Alex Dempsey	NCRI	Benthic surveys
Rachel D'Silva	UWI	Benthic surveys
Oliver Squire	Fisheries	Fish surveys
Steve Schill	TNC	Habitat mapping
Llewelyn Meggs	TNC Jamaica	TNC Pedro Bank project lead, Invertebrate surveys
Nathalie Zenny	TNC Jamaica	Invertebrate surveys
Andrew Ross	Eco Reefs	Benthic surveys
Anna Ebanks	Fisheries	Fish surveys
Mr. Sean Green	NEPA	Habitat mapping
Azra Blythe-Mallet	VSD	Plankton tows