Honduran Marine Research Report 2012

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a. Executive Summary

Between June and August 2012, Operation Wallacea continued its long term research activities in Honduras, with marine activities taking place in the Cayos Cochinos Marine Protected Area (CCMPA) and on the island of Utila. Research was led by a team of scientists with significant contribution from university level volunteers. Data on benthic community structure, fish abundance and fish biomass were collected in triplicate from reef crest (ca. 8m) and reef slope (ca. 12m) environments at six study sites at both locations. Point intercept transects were used to assess the percentage cover of benthic organisms and abiotic types, whilst belt transects were used to conduct underwater visual censuses of fish communities. To accurately quantify fish biomass, stereo-video surveys were conducted and analysed using published biometric relationships.

Despite long term management within CCMPA, the benthic state of the reefs is a cause for concern. Mean hard coral percentage cover within the park is currently 18.42 ±1.34 % whilst macroalgal cover is 47.12 ±5.41 %, although this latter value is a slight decrease on data from 2011. In comparison, the reefs around Utila demonstrated a mean hard coral cover of 25.51 ±2.15 % and a macroalgal cover of 23.24 ±2.26. This provides a clear demonstration that the benthic state of reefs within CCMPA are significantly worse than those on Utila. This clear phase shift towards an algal dominated state, a problem suffered throughout the Caribbean in recent decades, is typically caused by a combination of reduced water quality stimulating macroalgal growth and the removal of herbivores needed to keep algae in check. However, fish abundance, diversity and biomass data showed no significant difference between CCMPA and Utila, including for herbivores specifically, suggesting that the total provision of herbivory by fish communities is at a similar level. Although invertebrate contribution to overall herbivory could account for some variation, there is no evidence to suggest this is the case, especially to explain the level of macroalgal overgrowth seen in CCMPA. This would suggest that water quality is the main cause of reef decline in CCMPA, and should be a priority of conservation managers there.

Despite the poor benthic state of the reefs, this data also provides evidence that fishing restrictions in CCMPA appear to be having a beneficial impact on the fish communities, as the compromised resource base could be expected to negatively impact associated fisheries. If the benthic quality of reefs throughout the park can be improved, fish abundance and biomass could be expected to increase significantly further.

b. Contents

1. Introduction

Operation Wallacea has been conducting marine research in Honduras since 2003. The program, which started in the Cayos Cochinos archipelago, has now developed to encompass research groups in a number of locations in the Honduran Bay Islands and on the mainland (Figure 1.1), in addition to various associations with local and national groups within Honduras. The marine research effort forms part of a holistic effort by Operation Wallacea within Honduras, a program that also incorporates a large terrestrial research site in the cloud forests of the Cusuco National Park.

Figure 1.1. Map of Honduras showing the Operation Wallacea research sites: (1) Cusuco National Park terrestrial research site, (2) Cayos Cochinos Marine Protected Area marine and terrestrial research site, (3) Utila marine research site located at the Coral View Research Centre, and (4) Tela Bay marine research site located at the Tela Marine Research Centre.

Operation Wallacea is a network of academics from European and North American universities, who design and implement biodiversity and conservation management research programmes. Research is supported by students who join the programme, to strengthen their CV or resume, gain course credit, or collect data for a dissertation or thesis. Academics benefit from funding for high quality fieldwork enabling them to publish papers in peer reviewed journals. This model enables the collection of large temporal and spatial datasets used for assessing the effectiveness of conservation management interventions.

The overall structure of this work is to bring academics and world leaders into the field to run small specialist research groups within the overall project framework. These groups consist of principle researchers, Ph.D. students, dissertation and thesis students and research assistant volunteers. The projects run over a 10 week period every summer (June - August). This format gives many advantages to field research, such as bringing together a wide variety of multidisciplinary field scientists into the same place with a central organisation coordinating the research. Funding for the research is entirely based on volunteers, this ensures that projects can be run over prolonged periods and datasets can be built up over many years. The research is based on collecting data on the local ecosystems that can be channelled into high quality research publications and grant applications to establish examples of best practice conservation in the local communities.

The marine research and conservation objectives of Operation Wallacea in Honduras often require a multidisciplinary approach, utilising expertise from a variety of research backgrounds or data collection from a variety of locations. To achieve this, Operation Wallacea has established three independent research operations within the marine program. They are based at permanent research centres and concentrate on studying the biodiversity and ecology of the local marine and terrestrial ecosystems, which in turn facilitates high level scientific research conducted by internationally renowned academics that form an integral part of the Operation Wallacea research model. The first marine research site in Honduras is run from the Marine Research Station on the island of Cayo Menor within the Cayos Cochinos Marine Protected Area (CCMPA) in partnership with the Honduran Coral Reef Foundation (HCRF), whilst the second is based at the Coral View Research Centre on the island of Utila. A third operation is currently being established at the mainland site of Tela, in partnership with the Tela Marine Research Centre, and will become operational in 2013.

2. Standardised Methodologies

To address the aim of assessing coral reef ecosystem health and function on both Cayos Cochinos and Utila, a set of standardised methodologies were used to collect data on the benthic, fish and invertebrate communities. These methods were an improvement on previous data collection efforts, aimed at increasing the accuracy and level of scientific detail obtained. Survey teams were made up of university-level volunteers led by a member of the Operation Wallacea science team, comprising experienced scientists trained in the data collection methods outlined below.

2.1. Benthic habitat surveys

Quantifying the benthic community structure is a useful indicator of overall ecosystem health and function. Particularly useful parameters in coral reef monitoring include the percentage benthic cover of key functional groups such as hard (Scleractinian) corals, macroalgae, sponge and soft corals. These data can then be used to help explain trends in other monitoring data sets such as patterns in the abundance and diversity of fish and invertebrates, as well as identify major threats to a particular reef.

Benthic habitat surveys were performed using 50m line intercept transects (English et al 1997). These transects were replicated in triplicate at both 8m and 12m depths at each study site, with a 10m separation between each transect. Members of the benthic survey team collected data each 0.25m along the transect, recording data on the benthic biotic or abiotic classification under the transect tape at that point. In the case of hard corals and macroalgae, species level identification was performed, or genus level identification where more suitable. Sponges and soft corals were identified to growth form (e.g. encrusting, rope, vase etc. in the case of sponges).

2.2. Fish abundance and diversity

Fish perform vital ecosystem services to coral reefs, but their abundance in many areas has been significantly impacted by fishing pressure. Monitoring their abundance and diversity provides an indication of the relative success of fisheries management efforts, whilst assessing the trophic structure of fish communities gives an indication of the ecosystem services which may be lacking.

Fish abundance and diversity surveys were performed using the underwater visual census method (Jokiel et al 2001). For this, 50m belt transects (5m wide) were repeated in triplicate at each study site, both on the reef crest (ca. 8m depth) and the reef slope (ca. 12m depth). Ten minutes was taken to complete each transect, and each individual fish observed within the belt was identified to species level, and care taken to record individuals only once, and to incorporate both benthic and pelagic species into census data.

2.3. Fish biomass estimation

Understanding the biomass present in an ecosystem is a significant improvement on simple population estimates. The ecological service provided by an individual, as well as its value to the overall fishery, is determined by its biomass. A fishery with fewer individuals is not necessarily a less valuable or ecologically healthy community, but instead it is the overall biomass of fish, and specifically of key trophic groups such as herbivores, which provides the most accurate indicator of ecosystem value to both ecologists and fisheries scientists.

Stereo-video surveys (SVS) were conducted as outlined in Watson et al. (2010). The equipment consists of two Canon HD cameras (VIXIA HFS21) in waterproof housings and mounted on an aluminium bar (Figure 4.1). A diode extends centrally in front of the cameras, which are angled slightly inwards towards the diode, and is used to synchronize the video footage during analysis. Before any surveys were conducted the cameras were calibrated in water using footage of a specially-designed calibration cube at different orientations. Calibration of the stereo-video cameras is essential to obtain and maintain accurate length measurements of the fish from the stereo-video footage.

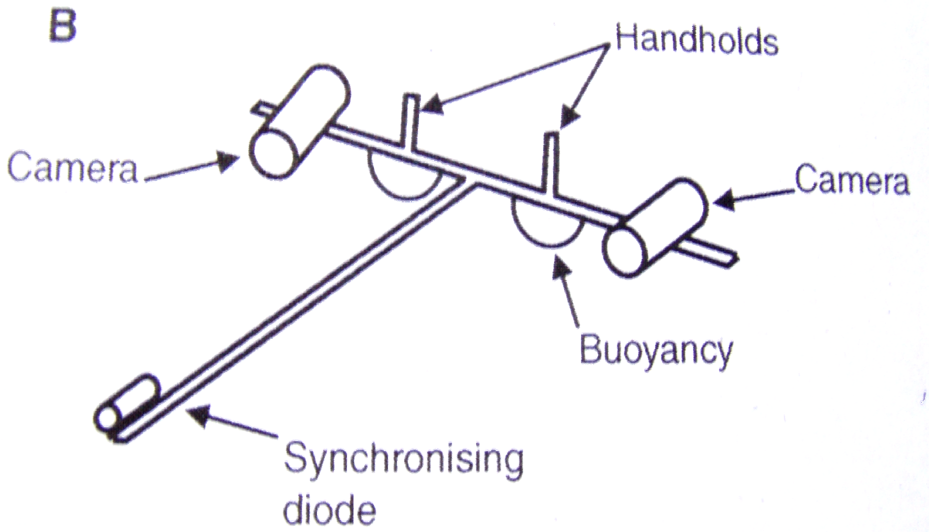

Figure 2.1. The stereo-video apparatus uses two cameras mounted on either side of an aluminium bar with a central diode extending in front of the cameras used to synchronize the video footage during analysis.

The SVS monitoring team consisted of three SCUBA divers: one operating the SVS system, one measuring the length of transects using a tape reel, and one to provide additional support to help the team operate safely. The SVS operator swam slowly along each transect with the cameras angled slightly downwards toward the reef, as instructed in the SVS system user manual. Six 25m transects, separated from one another by 10m, were conducted at depths of both 8 m and 12m at each study site.

SVS footage was converted from MTS to AVI format using MTS converter software and then analyzed using *EventMeasure* dedicated software. Footage from left and right cameras was synchronized in *EventMeasure* using the synchronizing diode. Fish were only recorded if they were within the 5m width of the transect (i.e. 2.5m to the left and 2.5m to the right of the cameras). Individual fish were identified by family, genus, and species. Length measurements, snout to base of tail, were computed using *EventMeasure*, and biomass calculated using published ratios from Fishbase online database.

3. Cayos Cochinos Marine Research

The Cayos Cochinos Islands were established as a Honduran National Monument in 1993 and given protection through the establishment of the Cayos Cochinos Marine Protected Area (CCMPA) at the same time under the management of the newly established Honduran Coral Reef Foundation (HCRF). Operation Wallacea started working with the HCRF within the CCMPA in 2003 at the Marine Research Station situated on Cayo Menor.

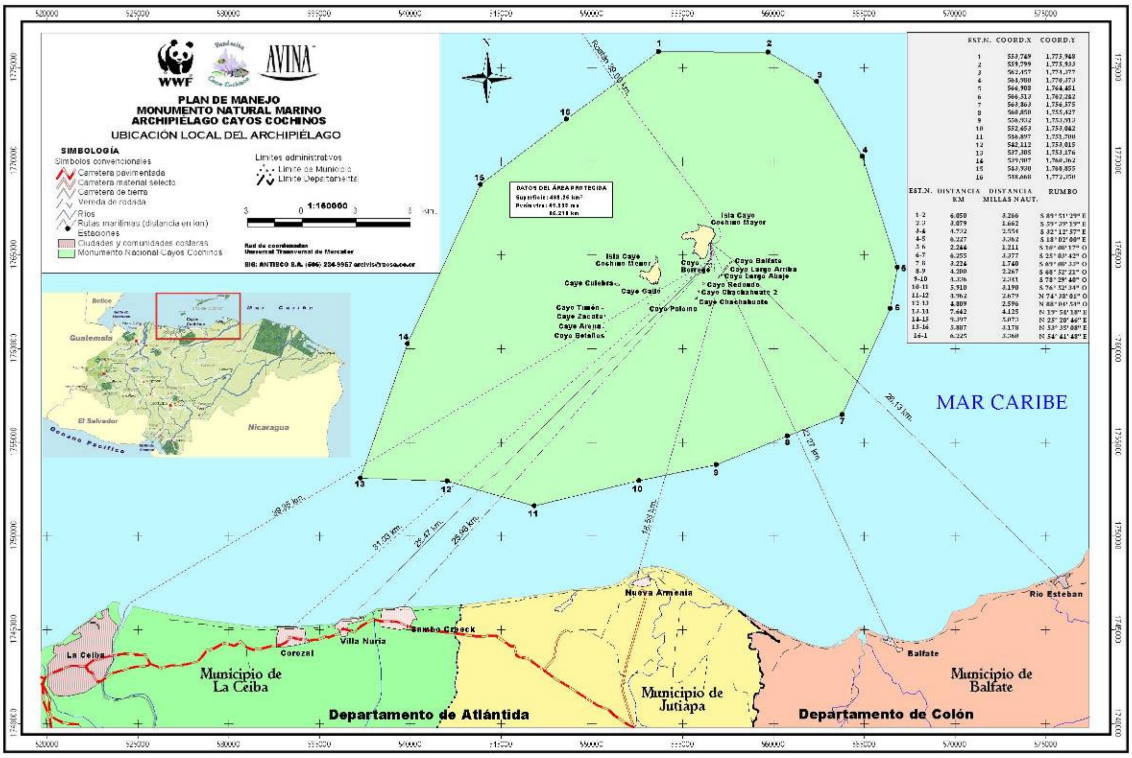

Figure 3.1. Map of the Cayos Cochinos Marine Protected Area (CCMPA) showing the management plan.

The Cayos Cochinos Islands are located about 18km off the northern Honduran shore and comprises the very southern end of the Meso-American Barrier Reef System (MBRS), the second largest barrier reef in the world. The islands and surrounding seas were designated as a National Marine Monument by the Honduran Government in 1993 and remains the only such area in Honduras. The islands have been established as a protected area by the Honduran Government under the banner of the Cayos Cochinos Marine Protected Area (CCMPA) and managed by the

Honduran Coral Reef Foundation (HCRF). This agreement established specific protection for the reefs and the wildlife on the islands. These included a limit on fishing in volume and species and established protection for the indigenous reptile species on the islands.

The protection of the Cayos Cochinos archipelago was formed in partnership with the World Wildlife Fund (WWF), The Nature Conservancy (TNC) and the HCRF and resulted in the publication of the Cayos Cochinos Management Plan (www.cayoscochinos.org). The main objectives of the Management Plan included the protection of the reefs and terrestrial systems and to ensure that local artisanal fishing communities were appropriately compensated for their loss of income, due to the proposed fishing restrictions, through the establishment of alternative incomes.

3.1. Cayos Cochinos Marine Protected Area

The Cayos Cochinos Marine Protected Area (CCMPA) is based around an archipelago of small islands and shallow seas. There are two main islands within the area, Cayo Mayor and Cayo Menor. Cayo Mayor with a width of 1.8km and length of 1.7km is slightly larger than Cayo Menor that has a width of 1km and length of 1.3km. In addition to these two main islands there are 14 small Cays within the archipelago. The CCMPA contains a wide variety of marine habitats, with reefs to depths of 30m+, extensive seagrass systems and large areas of bare sediment. These habitats are distributed around the park, often nearer the islands and cays, although several shallow reefs are found in the open sea. Despite this diversity of habitats and islands the reserve does not have a significant mangrove system, with only a few mangrove trees found on Cayo Mayor within the MPA.

3.2. CCMPA settlements and industry

Cayo Mayor has a resident population year round, with a small artisanal fishing community in East End, in addition to a small hotel called the Plantation Beach Resort and several private homes. Cayo Menor has no local communities or industry and has been preserved solely for research purposes. This research is based at a small research centre that contains a dive centre, laboratory facilities, several permanent accommodation buildings and catering facilities. The only long term residents on the island are a handful of Navy guards and occasional researchers. The other settlement within the CCMPA is a second fishing community on Cayo Chachahuate.

Historically, the industry of the area was largely based on artisanal fisheries within the two communities of East End and Chachahuate; these have both been impacted by the restricted fishing rights dictated by the CCMPA management plan. However, part of this plan ensured that alternative income sources were established for these communities, and those on the North Honduran Coast, to compensate for the loss of revenue from fishing activity. This has involved the promotion of ecotourism and the research station in the area. The Islands are now also used as the setting for the Spanish, Italian and Colombian versions of the Survivor television series, generating considerable income for the area.

3.3. CCMPA research objectives

The main objectives of the research within the CCMPA are;

- Yearly monitoring of the status of the reefs within the Marine Protected Area, to determine the health of the reef system and the success of the CCMPA in protecting the reef systems.
- Conducting high quality marine and terrestrial research within the MPA, producing publications suitable for peer review and establish the Cayos Cochinos MPA and Marine Research Station as an internationally recognised centre for quality marine research.
- Assess the population levels, ecology, behaviour and phylogenetic distinctiveness of the Cayos Cochinos Boa Constrictor.
- Assess the population levels, ecology and behaviour of the critically endangered Spiny tailed Iguana (*Ctenosaura melanosterna*).

3.4. CCMPA study sites

In 2012, six sites were chosen for detailed ecosystem monitoring around the Cayos Cochinos MPA (Figure 2.2). This corresponded to a slight decrease on the number of sites used in previous years, but enabled a significant increase in both the quantity and quality of data collected (see methodology). The sites were chosen based on a number of criteria, in particular (1) their use in previous monitoring time points allowing temporal patterns to be identified, (2) logistical considerations such as distance and conditions to ensure data collection was completed at each site, and (3) to represent a gradient of habitat types throughout the Cayos Cochinos. These sites will now form the basis of all monitoring efforts in the coming years.

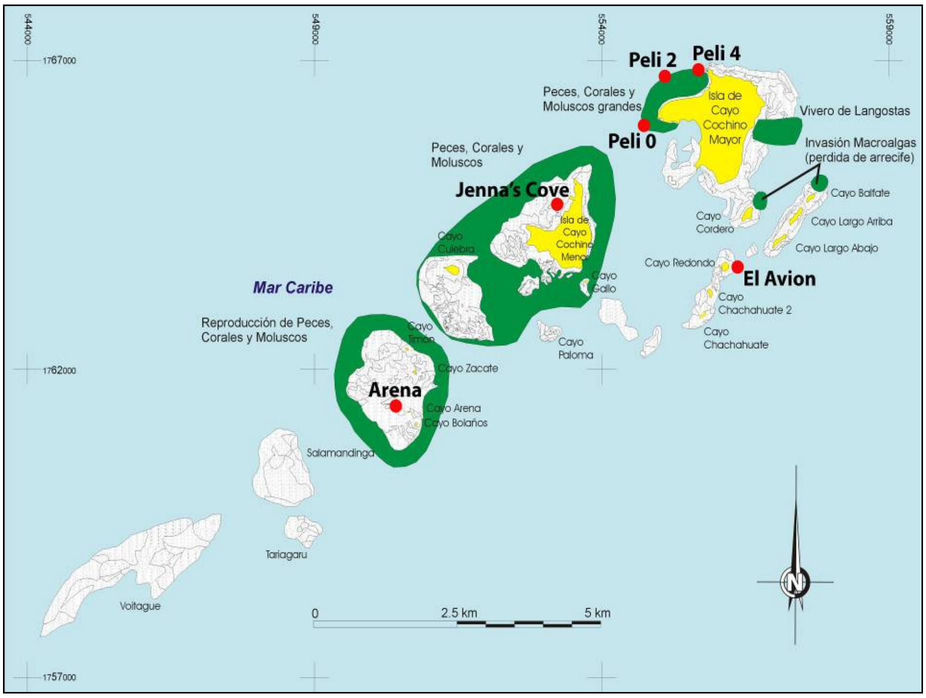

Figure 3.2. Map of the Cayos Cochinos Archipelago showing the location of the six study sites used for data collection by Operation Wallacea scientists in 2012.

The sites chosen were as follows:

Arena (15°55’56.47”N 86°31’51.04”W): A large bowl near Cayo Arena formed by a rounded coral wall and a surrounding crest at approximately 6m depth. The centre of the bowl reaches a maximum depth of 13m.

Jenna’s Cove (Buoy 2) (15°57’47.39”N 86°30’03.46”W): A steep reef wall on the northwest coast of Cayo Menor reaching depths of approximately 15m with large coral outcrops extending seawards.

El Avion (15°57’03.72”N 86°28’25.41”W): A moderately exposed reef slope near Cayo Redondo exhibiting a gradual gradient reaching between 14 – 20m depth.

Peli 0 (15°58’28.19”N 86°29’17.71”W): A gradual reef slope situated on a promontory of the larger island Cayo Meyor in the channel between the two islands. The reef extends to a depth of over 30m.

Peli 2 (15°58’46.78”N 86°28’53.54”W): A steep reef wall extending to a maximum depth of between 20 – 25m on the northwest coast of Cayo Meyor.

Peli 4 (15°58’51.28”N 86°28’42.66”W): A steep reef wall surrounded by extensive sand flats at approximately 15 – 20m depth on the northwest coast of Cayo Meyor.

3.5. CCMPA benthic habitat quality

Benthic habitat quality data in 2012 indicated no significant difference in Scleractinian coral cover between the six study sites, with percentage cover ranging from 15.52 ±4.81 % at El Avion, to 24.82 ±2.06 % at Peli 4 (Figure 3.3). This was also the case for soft corals and sponges. However, macroalgal cover was found to vary significantly between sites ($H_{5,36}$=19.14, P<0.05), ranging from 25.56 ±2.98 % at Peli 4, to 62.14 ±5.02 % at Jenna's Cove. The remaining four sites all showed macroalgal cover of between 40 % and 60 %. In total, three of the six sites studied are now dominated by macroalgae (>50 % cover), and a further two are within 10 % of this threshold. There was no significant difference between coral or macroalgal cover at reef crest (ca. 8m depth) and reef slope (ca. 12m depth) zones, either at individual sites or when data were combined, suggesting a homogenous benthic community across depths.

Annual monitoring data sets between 2009 and 2012 indicated a significant change in coral cover when all sites were combined ($H_{3,206}$=20.08, P<0.001), although 2012 values were not significantly different to any previous year, suggesting that sampling fluctuations are greater than temporal variation within the ecosystem (Figure 3.4). Treating each study site independently, there was no significant difference in coral cover found over time at Arena, El Avion and Peli 2. However, significant differences were found at Jenna's Cove ($H_{3,35}$=8.48, P<0.05), Peli 0 ($H_{3,32}$=8.63, P<0.05), and Peli 4 ($H_{3,39}$=15.02, P<0.01). Jenna's Cove demonstrated no significant change in 2012 compared to any previous year, whereas 2012 coral cover was significantly lower than in 2010 at Peli 0 ($U_{1,12}$=5.00, P<0.05), and significantly lower than in 2011 at Peli 4 ($U_{1,23}$=22.0, P<0.05).

A significant change in macroalgal cover between years was also found when all sites were combined ($H_{3,206}$=19.82, P<0.001), although 2012 was not significantly different to any previous year. Testing site-specific data individually, no significant difference in macroalgal cover over time was found at Arena, El Avion and Jenna's Cove (Figure 3.4). However, significant differences were found at Peli 0 ($H_{3,32}$=15.53, P<0.01), Peli 2 ($H_{3,36}$=12.63, P<0.01), and Peli 4 ($H_{3,39}$=18.48, P<0.001). These three sites all showed a significant decrease in macroalgal cover between 2011 and 2012: Peli 0 ($U_{1,18}$=0.00, P<0.01), Peli 2 ($U_{1,21}$=11.00, P<0.01), Peli 4 ($U_{1,23}$=0.00, P<0.001). Of particular interest is Peli 2, which saw macroalgal cover fall beneath the 50 % threshold between 2011 and 2012, although macroalgal density remains worryingly high.

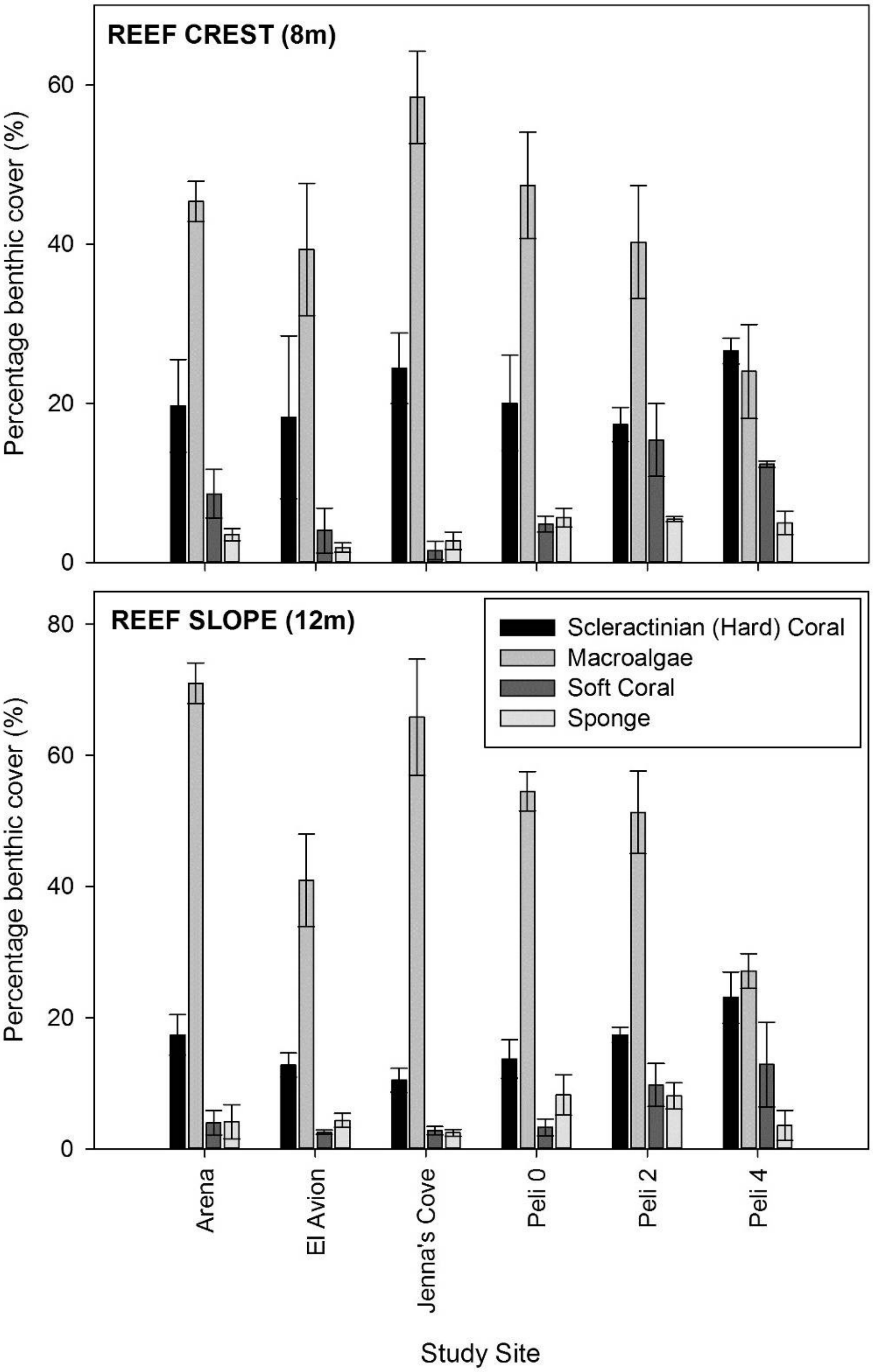

Figure 3.3. Benthic community structure on six coral reefs in the Cayos Cochinos Marine Protected Area (CCMPA) in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from point intercept transects (n=3).

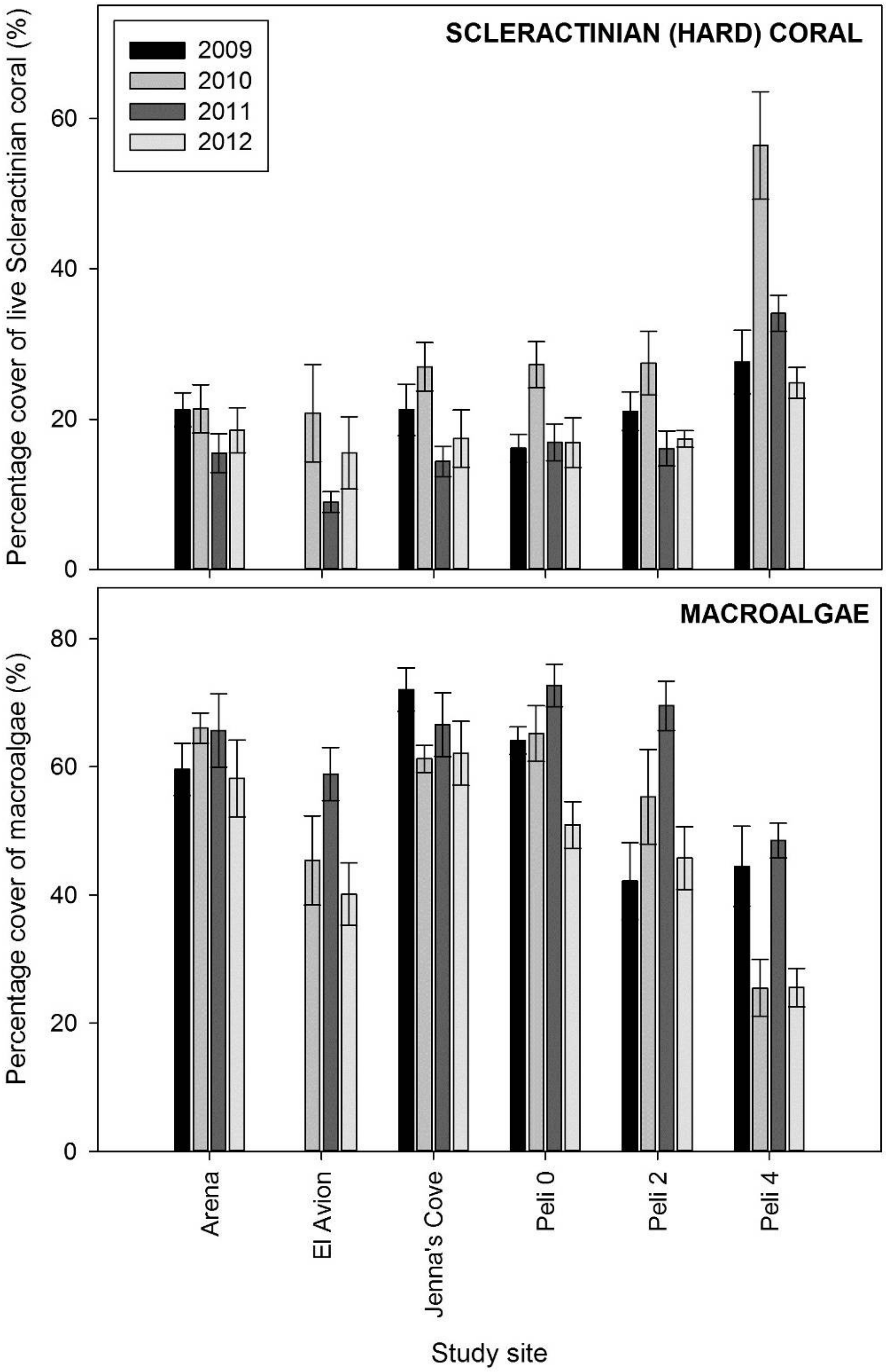

Figure 3.4. Temporal variation in Scleractinian coral and macroalgal percentage cover on six coral reefs in the Cayos Cochinos Marine Protected Area (CCMPA) between 2009 and 2012. Data are mean values ±SE calculated from point intercept transects (n=6).

3.6. CCMPA fish community structure

3.6.1. CCMPA Fish abundance and diversity

No significant difference in total fish abundance over time when all sites are combined, with abundance ranging from 4790 ±567 individuals ha^{-1} in 2012 to 8646 ±842 individuals ha^{-1} in 2010 (Figure 3.6). Treating sites individually, total fish abundance was significantly different over time at Arena ($H_{3,37}$=14.06, P<0.01) and El Avion ($H_{3,28}$=11.74, P<0.01). Specifically, Arena has seen a significant decrease between 2011 and 2012 ($U_{1,\ 21}$=12.00, P<0.01), although this appears to be within the range of regular fluctuations over the monitoring period at this site, while El Avion has seen a significant increase between 2010 and 2012 ($U_{1,\ 20}$=9.00, P<0.01). No significant change over time was seen at Jenna's Cove, Peli 0, Peli 2 and Peli 4. Site comparisons in 2012 indicated a significant spatial difference in total fish abundance ($H_{5,64}$=17.20, P<0.01), with the highest abundance found at El Avion (9480 ±1473 individuals ha^{-1}) and Peli 4 (8560 ±2381 individuals ha^{-1}) (Figure 3.5). The lowest abundance was found at Peli 0 (1184 ±558 individuals ha^{-1}).

There has been an overall significant decrease in the abundance of herbivores over time when all sites are combined ($H_{3,200}$=100.36, P<0.001), although abundance has increased in since 2011 from a minimum abundance of 699 ±35 individuals ha^{-1} to an increased value of 1075 ±90 individuals ha^{-1} in 2012 (Figure 3.7). Treating sites individually, total herbivorous fish abundance has changed over time at Arena ($H_{3,36}$=12.32, P<0.01), El Avion ($H_{3,28}$=13.85, P<0.01), Jenna's Cove ($H_{3,36}$=30.06, P<0.001), Peli 0 ($H_{3,28}$=15.63, P<0.01), and Peli 4 ($H_{3,41}$=29.78, P<0.001). Each of these sites demonstrated significant increases in the 12 months from 2011 to 2012, but a decrease since monitoring began in 2009 (P<0.05), with the exception of El Avion where monitoring did not commence until 2010. No significant change over time was seen at Peli 2. No significant difference was found between sites for herbivore abundance in 2012, with values ranging from 664 ±208 individuals ha^{-1} at Peli 2 to 1893 ±702 individuals ha^{-1} at Peli 4.

There has also been a significant temporal change in the abundance of commercially valuable fish species when data from all sites are combined ($H_{3,200}$=31.72, P<0.001), ranging from 566 ±57 individuals ha^{-1} in 2009 to a low of 290 ±15 individuals ha^{-1} in 2011 (Figure 3.7). Treating sites individuals revealed significant changes over time at Arena ($H_{3,36}$=18.70, P<0.001), El Avion ($H_{3,28}$=15.87, P<0.001), and Peli 4 ($H_{3,41}$=7.93, P<0.05). Both Arena ($U_{1,20}$=19.00, P<0.05), and El Avion ($U_{1,20}$=10.50, P<0.01) have experienced significant increases in the abundance of commercially valuable fish species between 2011 and 2012, whilst Peli 4 has experienced a significant increase since 2010 ($U_{1,24}$=32.00, P<0.05). No temporal change was found at Jenna's Cove,

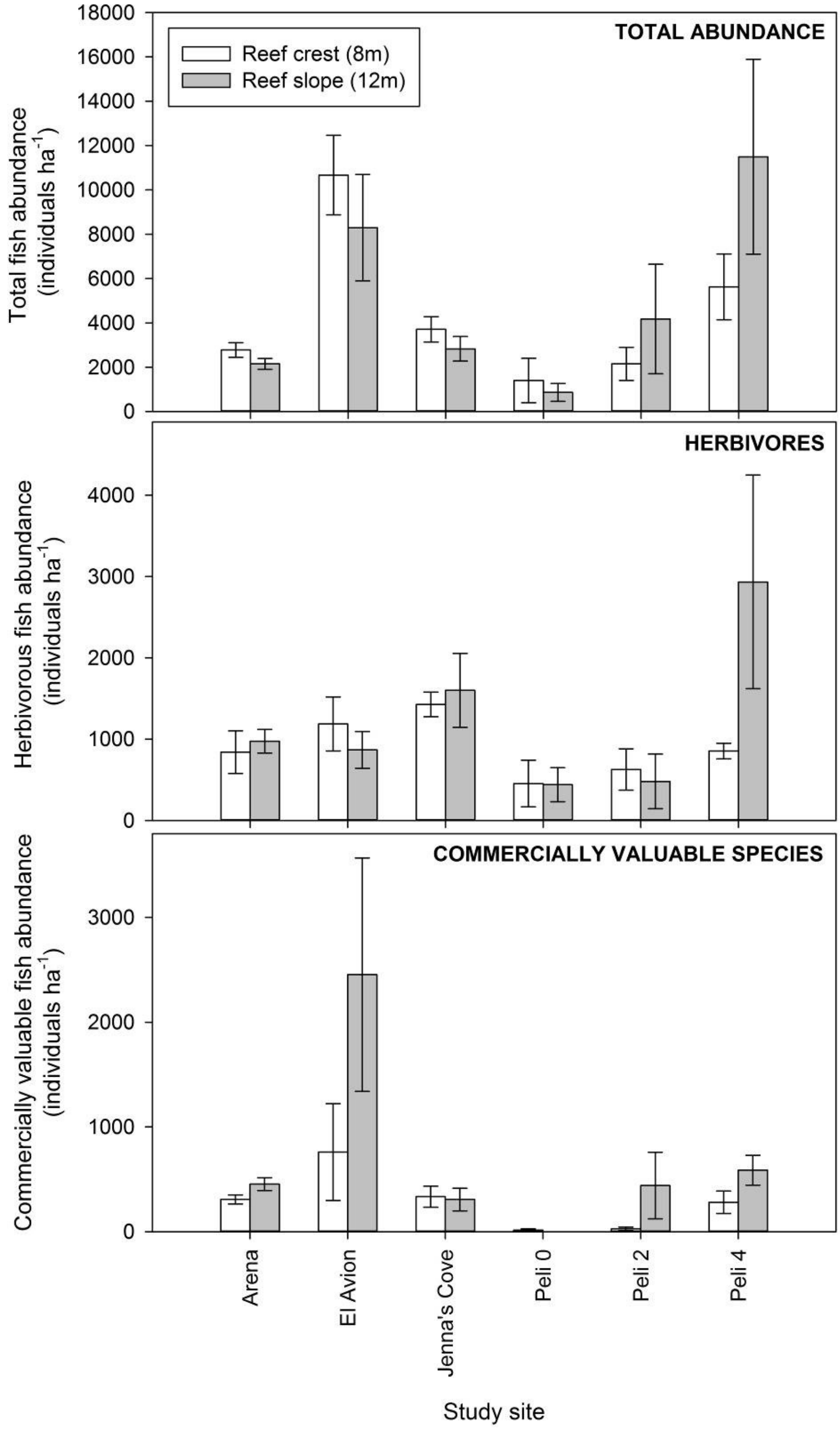

Figure 3.5. Total fish abundance, abundance of herbivorous fish, and abundance of commercially valuable fish species on six coral reefs in the Cayos Cochinos Marine Protected Area in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from underwater visual census transects (n=3).

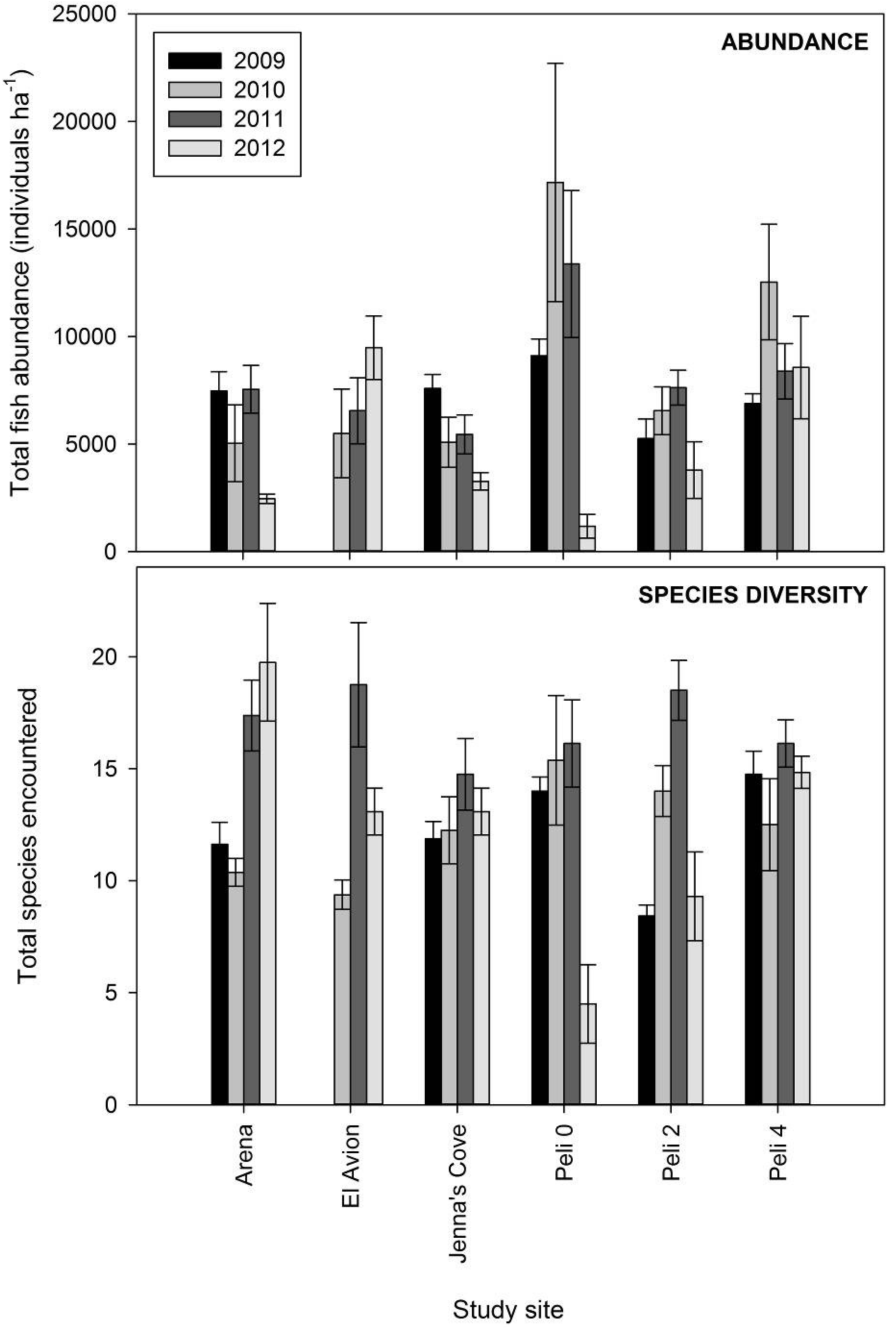

Figure 3.6. Temporal variation in total fish abundance and diversity on six coral reefs in the Cayos Cochinos Marine Protected Area (CCMPA) between 2009 and 2012. Data are mean values ±SE calculated from point intercept transects (n=6).

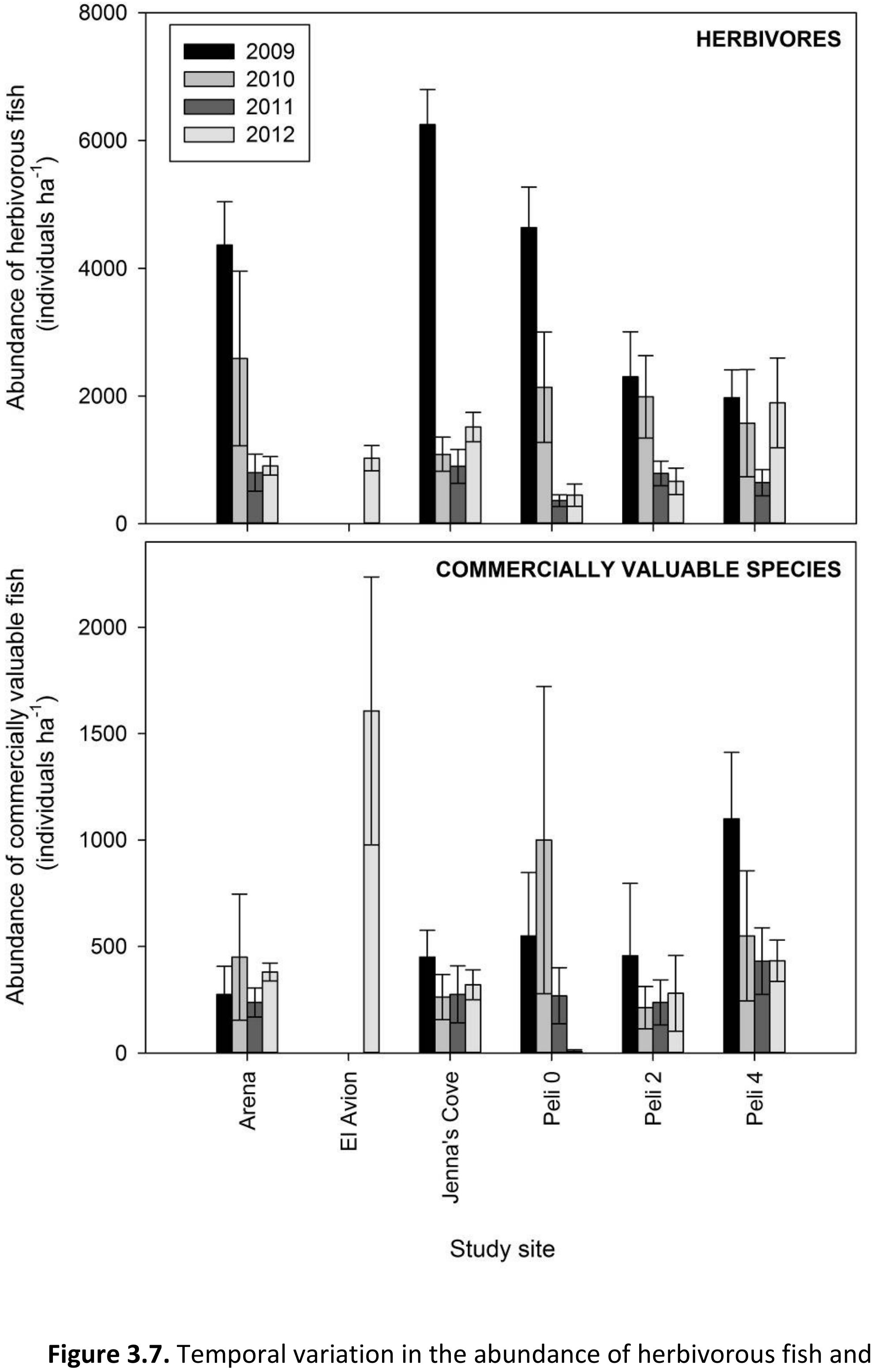

Figure 3.7. Temporal variation in the abundance of herbivorous fish and commercially valuable fish species on six coral reefs in the Cayos Cochinos Marine Protected Area (CCMPA) between 2009 and 2012. Data are mean values ±SE calculated from point intercept transects (n=6).

Peli 0 and Peli 2. Treating 2012 data separately for the six study sites, there was found to be a significant spatial difference in the abundance of commercial fish species (H5,64=13.03, P<0.05). Abundance was highest at El Avion (1607 ±630 individuals ha^{-1}), and lowest at Peli 0 (8 ±7 individuals ha^{-1}).

The number of fish species encountered per transect was shown to have significantly increased over time when all sites were combined ($H_{3,203}$=24.88, P<0.001), with a significant increase observed since 2010 ($U_{1,112}$=118.83, P<0.05) in particular (Figure 3.6). Site specifically, significant increases over time have also occurred at Arena ($H_{3,37}$=10.74, P<0.05), El Avion ($H_{3,28}$=11.21, P<0.01), and Peli 2 ($H_{3,31}$=16.47, P<0.01). No significant change at Jenna's Cove, Peli 0 and Peli 4. Data collected in 2012 showed no significant difference in fish species diversity between sites, ranging from 5 ±2 species per transect at Peli 0 to 20 ±3 species per transect at Arena.

3.6.2. CCMPA fish biomass and trophic structuring

When sites are compared across both study depths, there was a significant difference in the total fish biomass between the study sites ($H_{4,60}$=23.49, P<0.001) (Figure 3.8), with the highest biomass found at Peli 0 (1057.24 ±421.95 kg ha^{-1}) and Peli 4 (320.91 ±73.61 kg ha^{-1}), and the lowest at Peli 2 (43.18 ±10.25 kg ha^{-1}). Biomass of herbivore species also varied significantly across study sites ($H_{4,60}$=13.79, P<0.01), with herbivore biomass highest at Peli 0 (289.82 ±114.51 kg ha^{-1}) and Peli 4 (130.49 ±45.38 kg ha^{-1}), and lowest at Jenna's Cove (18.29 ±6.38 kg ha^{-1}) and Peli 2 (18.11 ±6.81 kg ha^{-1}). Commercial fish species biomass was also highest at Peli 0 (558.43 ±360.38 kg ha^{-1}) ($H_{4,60}$=20.96, P<0.001), but lowest at El Avion (0.11 ±0.11 kg ha^{-1}) and Peli 2 (3.29 ±3.29 kg ha^{-1}).

No significant difference in the proportion of total fish biomass represented by herbivorous species was found between sites (Figure 3.9). The contribution of this trophic group to total biomass ranged from 33.68 ±7.81 % at Peli 4 to 48.77 ±7.45 % at El Avion. However, a significant difference between sites was found for the contribution of predatory fish species to total fish biomass (H4,60=18.12, P<0.01), with the highest proportion found at Peli 0 (32.24 ±9.94 %) and the lowest found at El Avion (0.05 ±0.05 %).

Comparing reef crest (ca. 8m depth) and reef slope (ca. 12m depth) data found no significant differences between the zones for any of the variables (total fish biomass, herbivorous fish biomass, commercially valuable fish species biomass, proportion of herbivorous biomass and proportion of commercially valuable biomass). This was the case at each individual site, and when data for all sites were combined.

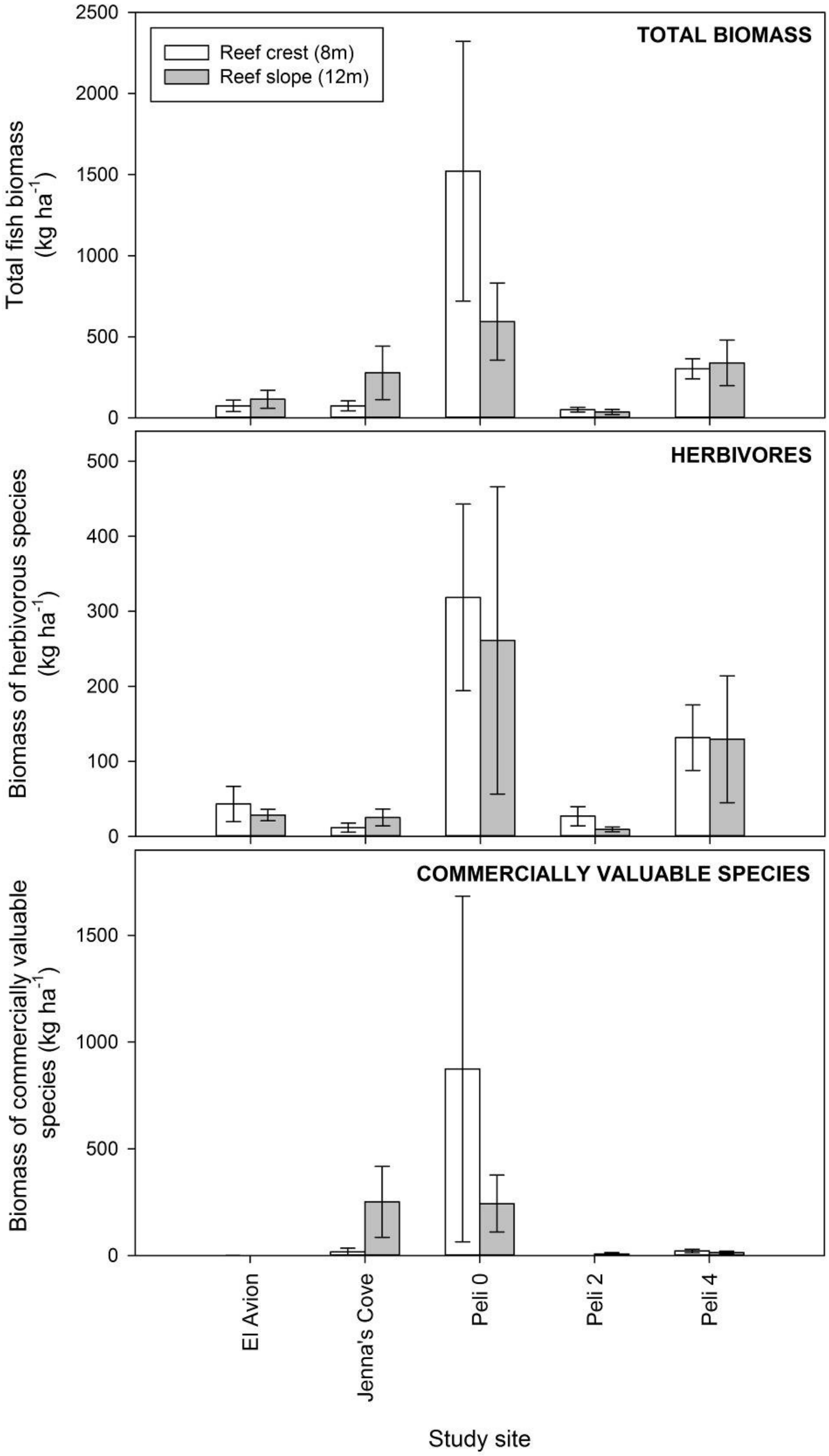

Figure 3.8. Total fish biomass, biomass of herbivorous fish, and biomass of commercially valuable fish species on six coral reefs in the Cayos Cochinos Marine Protected Area in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from stereo-video surveys (n=6).

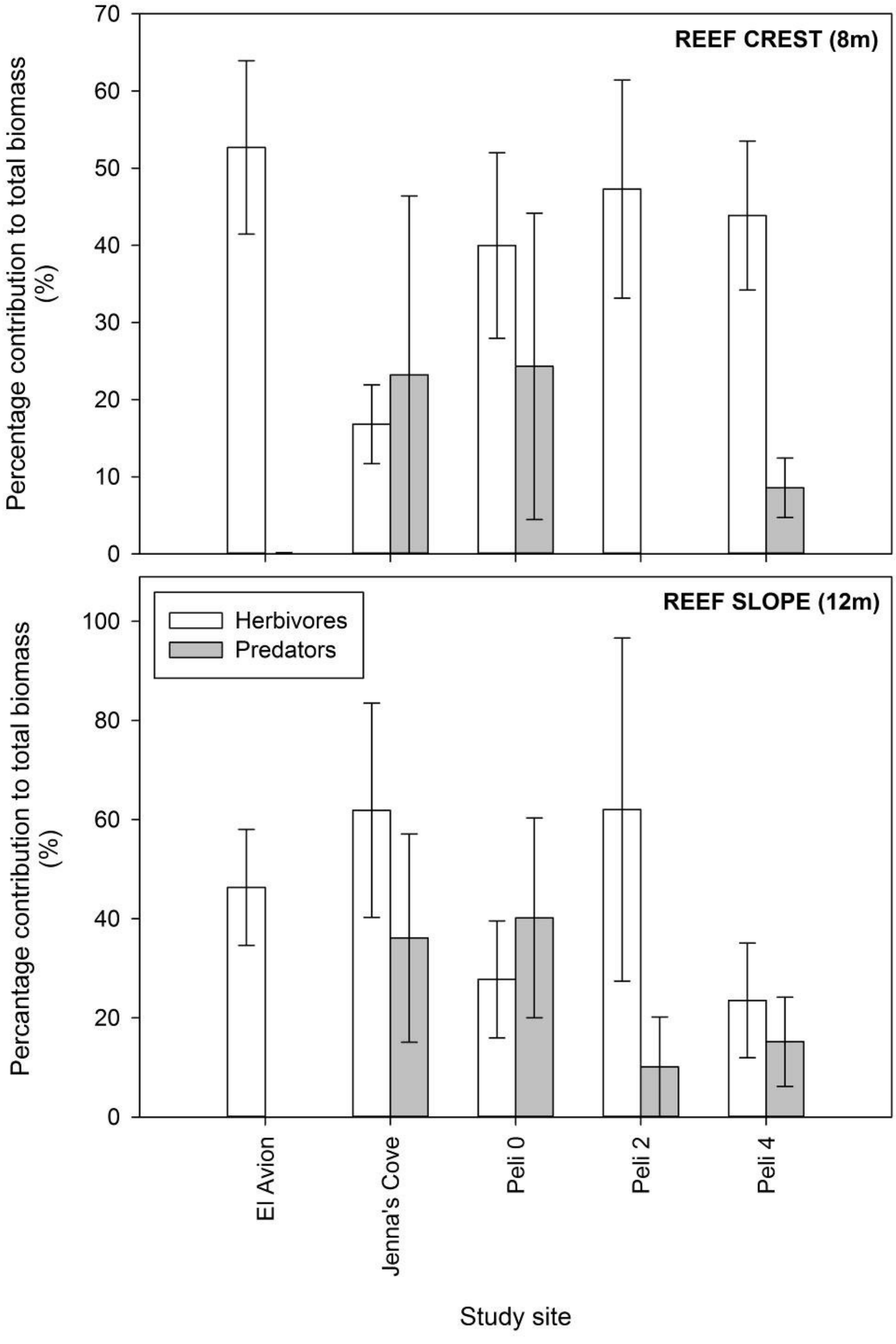

Figure 3.9. Percentage contribution of herbivorous fish species and predatory fish species to total biomass on six coral reefs in the Cayos Cochinos Marine Protected Area in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from stereo-video surveys (n=6).

3.7. CCMPA urchin ecology

Due to their status as a keystone species throughout the Caribbean (Carpenter 1986) and the well documented impact of a regional disease outbreak in recent decades (Lessios 1988; Mumby et al 2006), the sea urchin *Diadema antillarum* is an important species to study. As a pilot study for future research, the depth distribution and size frequency of *D. antillarum* at three reef sites around Cayos Cochinos were investigated. This study took place at Jenna's Cove, Peli 2 and Peli 4, due to the accessibility of a range of depth habitats. Belt transects (25m length, 2m width) were used parallel to the shore at depths of 1m, 4m, 6m and 10m. Along each transect, *D. antillarum* individuals were counted, and body size measurements taken. Transects were repeated in triplicate for each depth at each site.

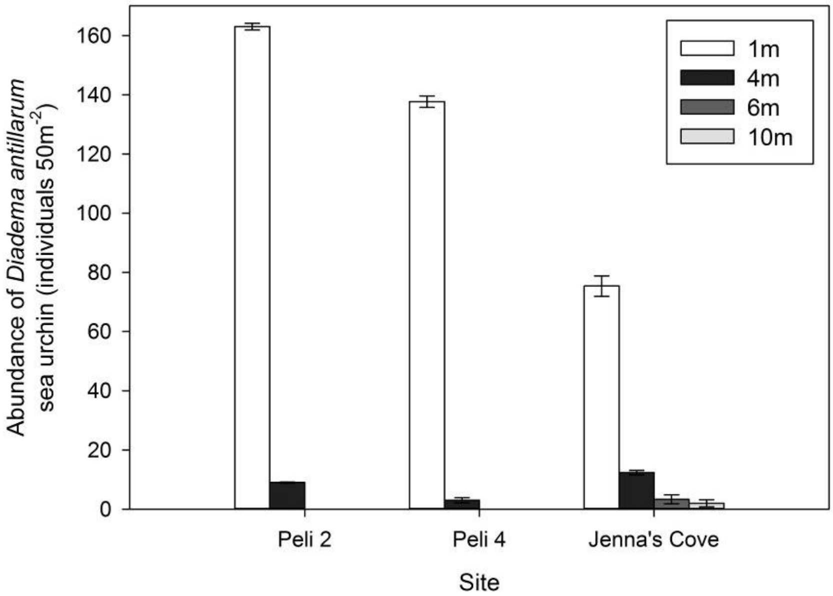

Figure 3.10. The abundance of the sea urchin *Diadema antillarum* on coral reefs of the Cayos Cochinos Marine Protected Area, showing abundance at four depths at three reef sites. Data shown are mean values ±SE (n=3).

The abundance of *D. antillarum* was highest at the shallowest depths, with no individuals encountered at 6m or 10m at either Peli 2 or Peli 4 (Figure 3.10). At Jenna's Cove abundance was found to be only 3.33 ±1.83 $50m^{-2}$ at 6m and 2.00 ±0.82 $50m^{-2}$ at 10m. Abundances at 1m ranged from 75.33 ±3.49 $50m^{-2}$ at Jenna's Cove to 163 ±1.11 $50m^{-2}$ at Peli 2, whilst abundances at 4m ranged from 3.00 ±0.88 $50m^{-2}$ at Peli 4 to 12.33 ±0.78 $50m^{-2}$ at Jenna's Cove. When data for all sites were combined, abundance was significantly higher at 1m than 4m ($U_{1,18}$=45.00, P<0.001), and the same was found at all sites when treated independently (P<0.05).

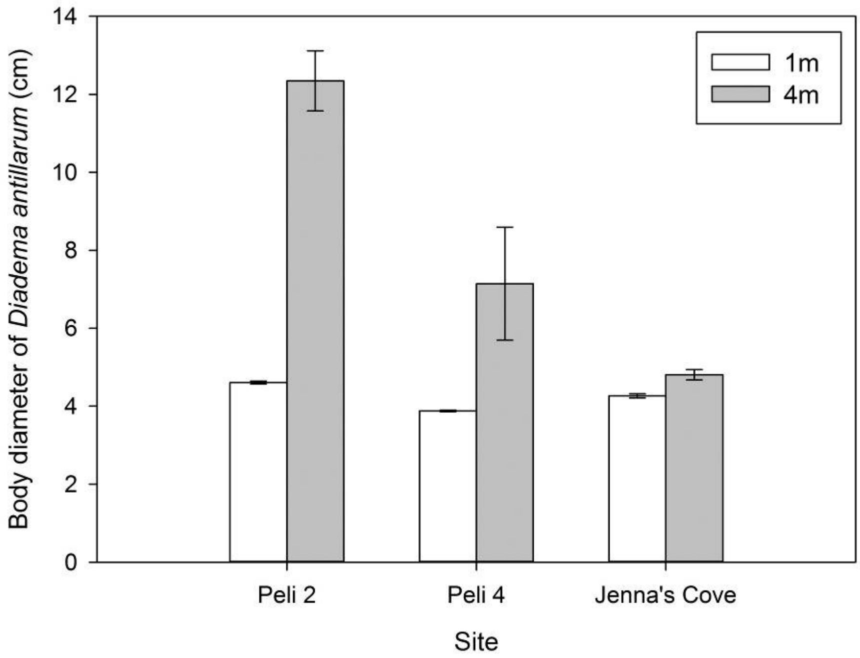

Figure 3.11. The size of *Diadema antillarum* sea urchins, demonstrated by body diameter, on coral reefs around the Cayos Cochinos Marine Protected Area, showing results from two depths at three study sites. Data shown are mean values ±SE.

With so few individuals found at deeper depths, body diameter measurements focused on individuals found at 1m and 4m. Overall, when all sites were combined, urchin body size was significantly higher at 4m ($U_{1,18}$=14.00, P<0.05), but when sites were treated independently, only Peli 2 showed a significant difference between depths ($U_{1,6}$=3.00, P<0.05) (Figure 3.11). Body sizes at 1m were consistent between sites, ranging from 3.88 ±0.02 cm at Peli 4 to 4.60 ±0.04 cm at Peli 2. At 4m though, there was more variation, with sizes ranging from 4.81 ±0.13 cm at Jenna’s Cove to 12.34 ±0.77 cm at Peli 2.

4. Utila Marine Research

Utila is one of the three main islands, along with Roatan and Guanaja, which make up the Bay Islands on the northern coast of Honduras. It is located approximately 30km from the Honduran mainland and comprises a single main island 13km in length and 5km wide (ca. 41 km^2), with a total of 11 small offshore Cays. The island is characterised by extensive mangrove forests with several large lagoon systems, combined with areas of lowland tropical forest. Much of the coast is surrounded by fringing coral reef, whilst a more extensive reef system can be found off the west coast of the main island surrounding the Cays. Operation Wallacea began working in Utila in 2006 alongside the research base at the Coral View Research Centre.

4.1. Utila conservation management

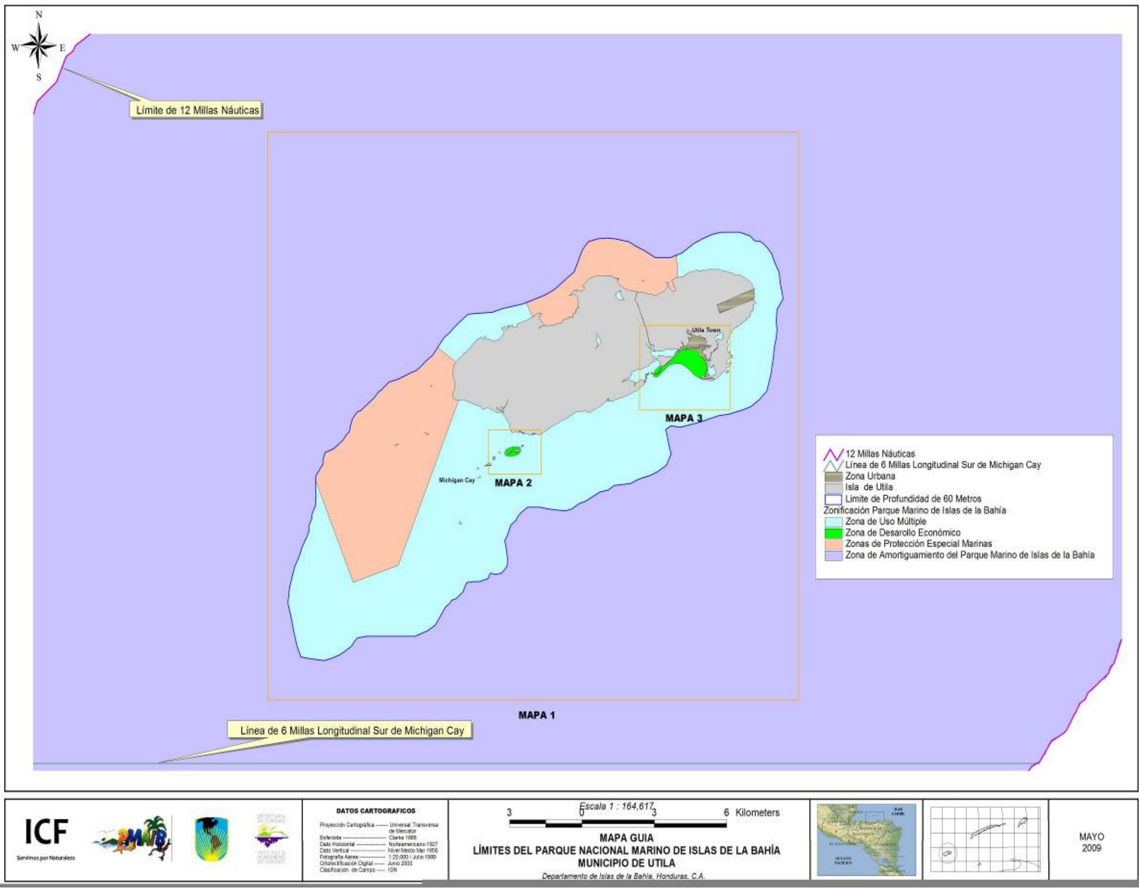

Figure 3.1. Map of Utila Island showing areas of marine conservation and the limit of municipal use around the island.

Conservation efforts on Utila are coordinated by the Bay Islands Conservation Association (BICA). BICA was formed in 1991 as a non-profit and non-governmental organisation aimed at designing and implementing efforts to protect the natural ecosystems throughout the Bay Islands. On Utila, management planning is ongoing, although there are currently two areas designated as zones of special marine protection (Figure 3.1). These are found on the north and west coasts of the Island, and as of yet do not include the southern reefs closest to major human settlements and tourism-related coastal development.

4.2. Utila settlements and industry

The human population on Utila is concentrated around a small town in the southeast of the island. Outside of 'Utila Town', human settlements are sparse and small, and are often formed by tourist developments rather than permanent residences. In 2000, a census of the island indicated a permanent population of approximately 5,000 people on the main island, and up to 1,500 additional people on the nearby Cays. The main industry on the island is tourism, specifically catering for the lower end 'backpacker' market. This tourism is focused to a large extent on dive tourists visiting the island to undertake training in SCUBA, and explore the surrounding coral reefs. Tourists are estimated to add between 500 and 1,500 people to the overall Utilan population, depending on the season (Claus and Wild 2002). There are now around 12 diving schools on the island, and the large majority of Instructors and Divemasters are foreigners.

4.3. Utila Research objectives

The main objectives of the research on Utila are;

- Yearly monitoring of the status of the reefs along the south coast of the island, to determine the health of the reef system and associated fishery.
- To quantify the importance of Utilan mangrove systems to the ecological functioning of the island as a whole.
- Conducting high quality marine research to address key questions relating to Caribbean wide ecological priorities, producing publications suitable for peer review and establish the Coral View Research Centre as an internationally recognised centre for quality marine research.

4.4. Utila study sites

In 2012, six sites were chosen for detailed ecosystem monitoring along the south coast of Utila island (Figure 3.2). The sites were chosen based on a number of criteria, in particular (1) logistical considerations such as distance and conditions to ensure data collection was completed at each site, and (2) to represent a gradient of habitat types and distances from the large human population of Utila town. These sites will now form the basis of monitoring efforts in the coming years, although modifications may be made to fit in with overall research objectives.

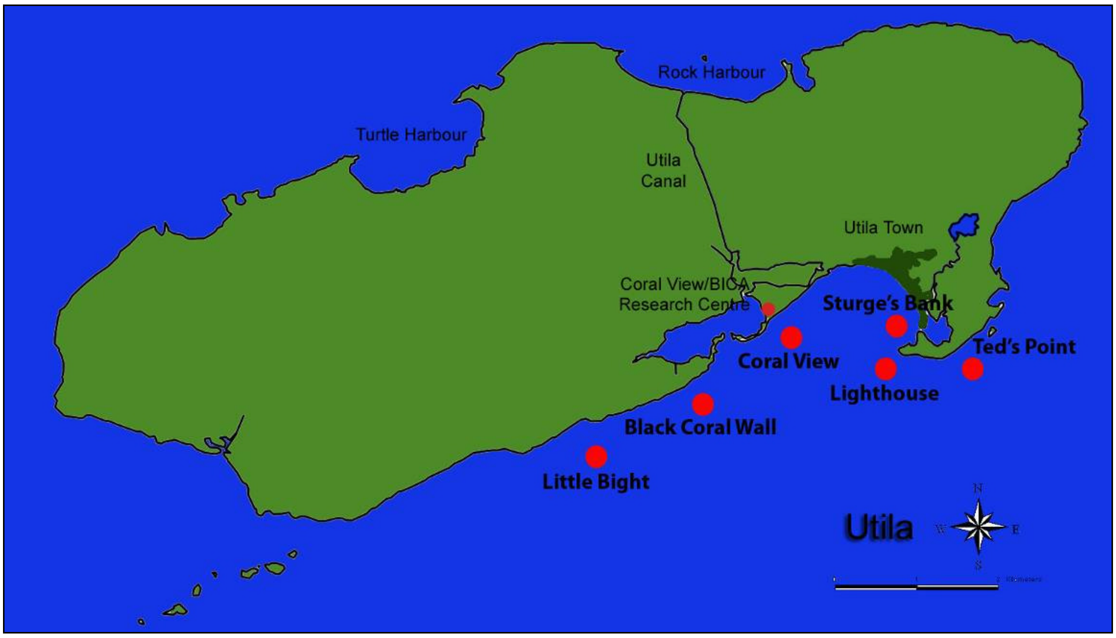

Figure 3.2. Map of Utila Island showing the study sites used for marine research by Operation Wallacea scientists in 2012.

The sites chosen were as follows:

Little Bight (16°04'44.74"N 86°55'42.44"W): A reef wall reaching depths of approximately 25m. This is the furthest study site from significant human settlement.

Black Coral Wall (Buoy 2) (16°04'58.35"N 86°55'02.34"W): A steep reef wall reaching depths of approximately 25m.

Coral View (16°05'17.96"N 86°54'38.27"W): A moderately exposed reef wall reaching depths of approximately 30m.

Sturge's Bank (16°05'19.00"N 86°53'46.46"W): A gradual reef slope close to the dense human population of Utila town. This site is situated within the bay of Tela Town itself.

Lighthouse (16°05'07.65"N 86°53'47.97"W): A steep reef wall extending to a maximum depth of over 30m outside the entrance to the bay of Utila Town.

Ted's Point (16°05'08.71"N 86°51'15.03"W): A steep reef wall extending to a maximum depth of over 30m. This site is situated up-current of the dense human population of Utila Town.

4.5. Utila benthic habitat quality

Benthic habitat quality data collected in 2012 indicated that there was no significant difference between the reef slope (ca. 8m depth) and reef crest (ca. 12m depth) habitat zones for the percentage cover of four main benthic organisms (Scleractinian coral, macroalgae, soft coral, and sponge). This was the case both for all sites combined, and at individual sites (Figure 4.3).

Benthic community structure variation between sites was found to be minimum, with sponge the only of the four main benthic categories showing a significant difference between sites ($H_{5,34}$=11.83, P<0.05). This difference was due to the particularly high sponge cover at Sturge's Bank compared to other sites: 13.5 ±2.49 % compared to the next highest cover of 6.76 ±0.46 % at Black Coral Wall. Scleractinian coral cover ranged from 18.22 ±3.15 % at Ted's Point to 32.67 ±1.68 % at Little Bight, whilst macroalgal cover ranged from 13.38 ±6.28 % at Ted's Point to 29.36 ±3.74 % at Sturge's Bank.

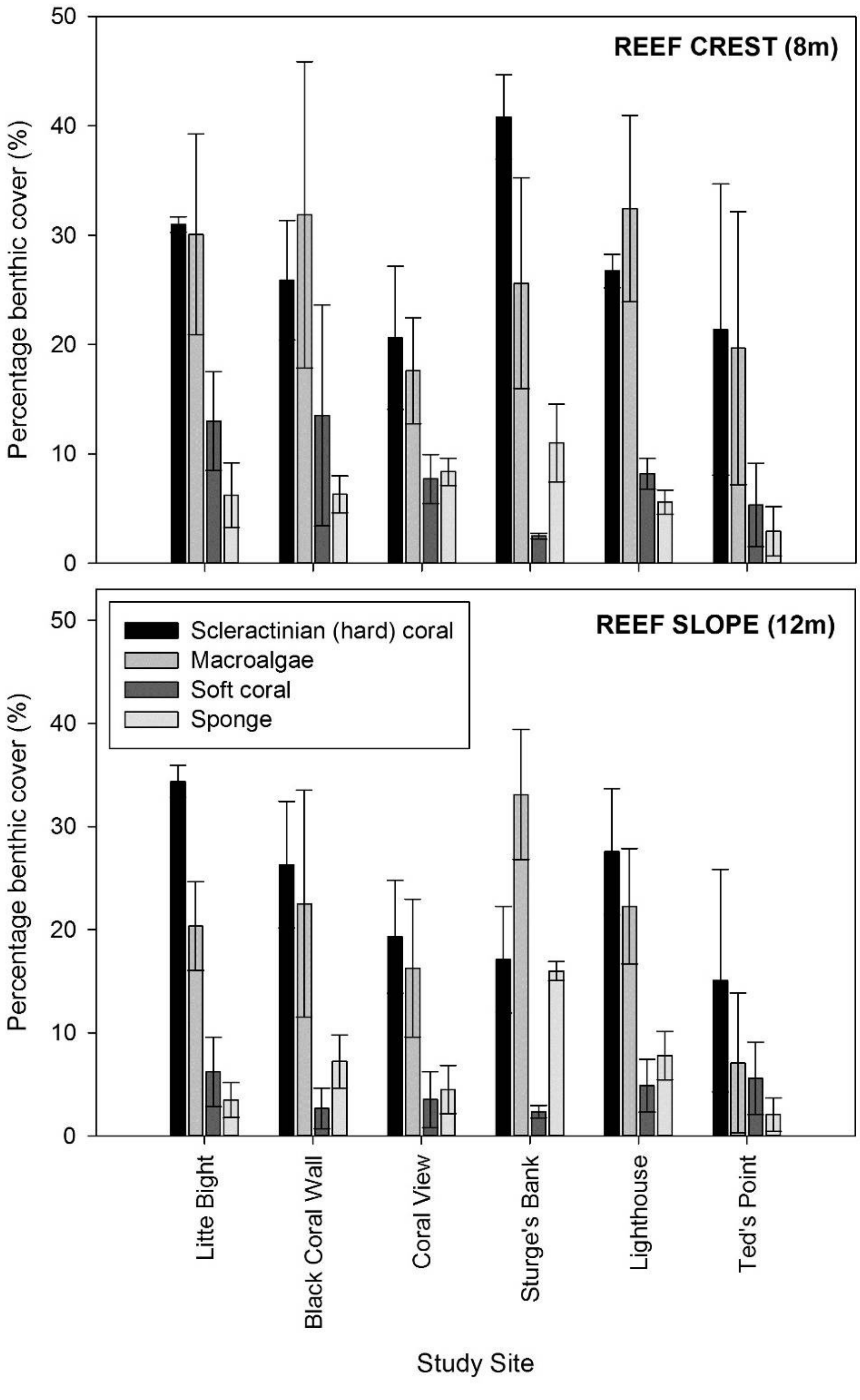

Figure 4.3. Benthic community structure on six coral reefs around Utila Island in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from point intercept transects (n=3).

4.6. Utila fish community structure

4.6.1. Utila fish abundance and diversity

No significant difference was found between sites for total fish abundance, with values ranging from 1920.00 ±718.52 individuals ha^{-1} at Black Coral Wall, to 5640.00 ±1404.37 individuals ha^{-1} at Ted's Point (Figure 4.4). Similarly, there was no significant difference between the abundance of herbivorous fish (ranging from 280.00 ±32.66 individuals ha^{-1} at Black Coral Wall to 960.00 ±109.30 individuals ha^{-1} at Little Bight) or the abundance of commercially valuable fish species (ranging from 160.00 ±32.66 individuals ha^{-1} at Coral View to 973.33 ±336.52 individuals ha^{-1} at Lighthouse) at the six study sites (Figure 4.5).

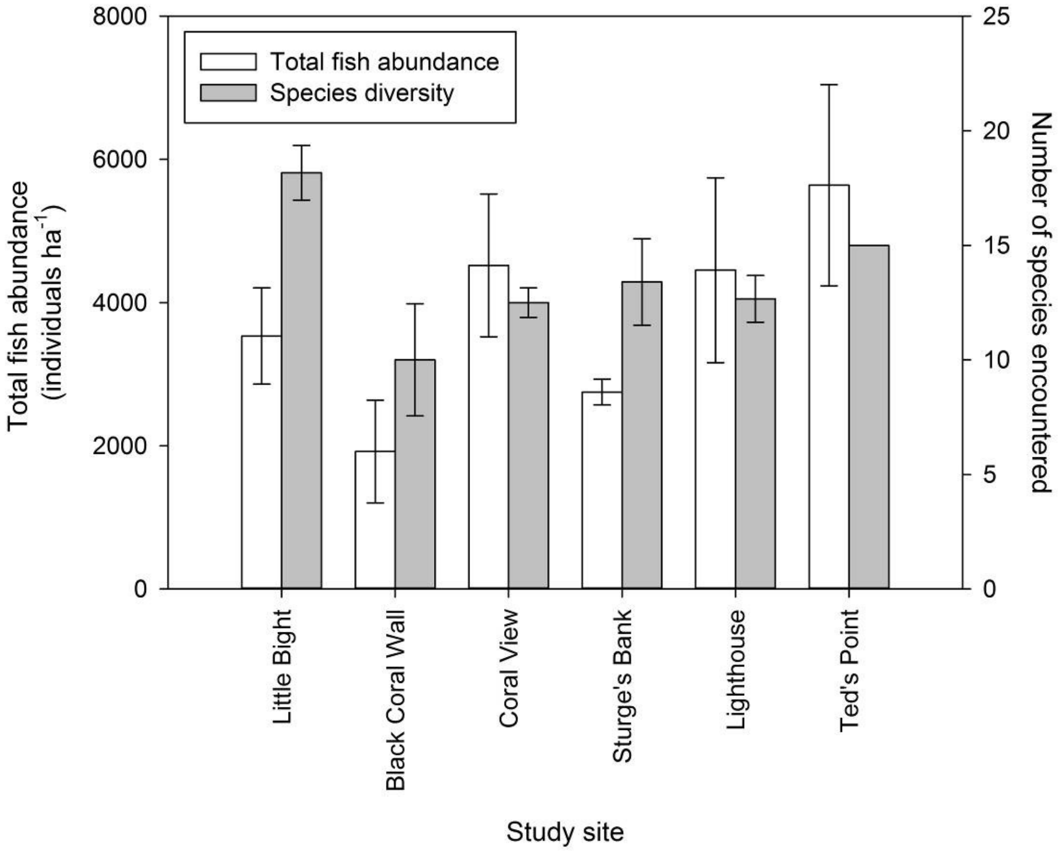

Figure 4.4. Total fish abundance and species diversity for six coral reefs around Utila Island in 2012. Data are mean values ±SE calculated from underwater visual census surveys (n=6).

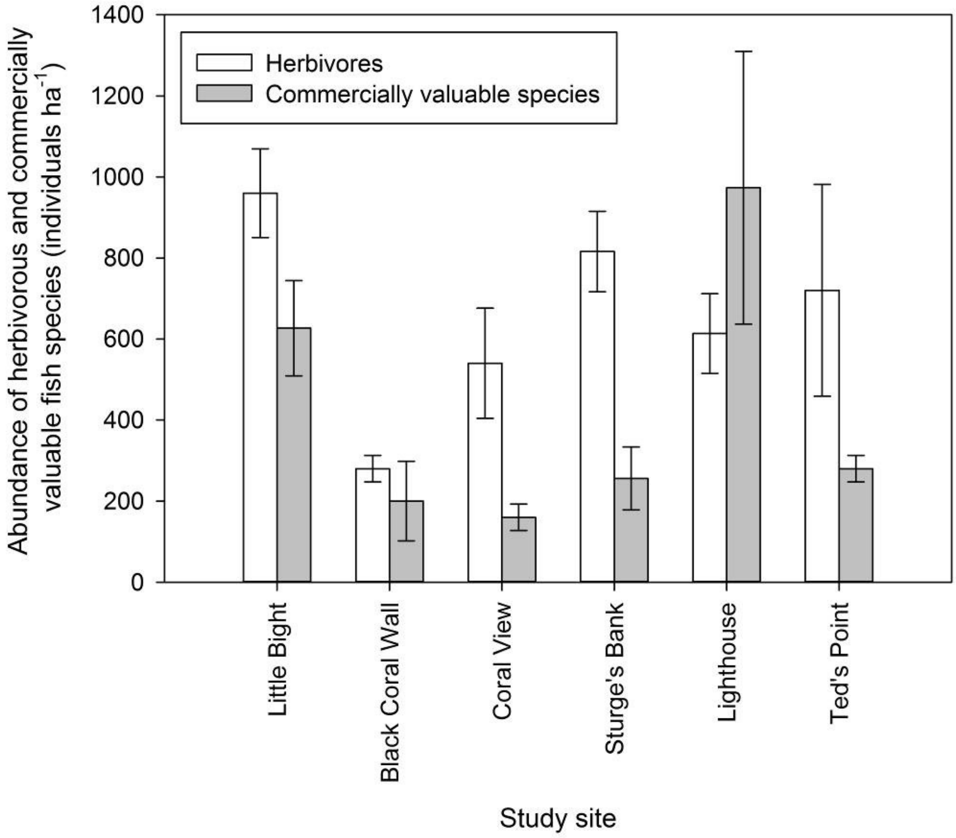

Figure 4.5. Abundance of herbivorous and commercially valuable fish species for six coral reefs around Utila Island in 2012. Data are mean values ±SE calculated from underwater visual census surveys (n=6).

There was, however, a significant difference in the number of species encountered between sites ($H_{5,25}$=11.73, P<0.05) (Figure 4.4). The greatest number of species was found at Little Bight (18.17 ±1.19 species per transect), whilst the lowest number was found at Black Coral Wall (10.00 ±2.45 species per transect).

4.6.2. Utila fish biomass and trophic structuring

When both study depths are combined, total fish biomass was found to vary significantly between sites ($H_{5,72}$=14.44, P<0.05). The highest total biomass was found at Black Coral Wall (319.86 ±175.06 kg ha^{-1}) and Lighthouse (272.64 ±78.43 kg ha^{-1}), with the lowest found at Coral View (85.85 ±30.47 kg ha^{-1}) and Sturge's Bank (84.57 ±18.18 kg ha^{-1}) (Figure 3.6). No significant spatial difference was found for biomass of either herbivorous or commercially valuable fish species. Herbivore biomass ranged from 20.97 ±5.08 kg ha^{-1} at Sturge's Bank, to 234.53 ±179.09 kg ha^{-1}

at Black Coral Wall, while the biomass of commercially valuable species ranged from 6.58 ±2.50 kg ha^{-1} at Sturge's Bank to 129.30 ±59.86 kg ha^{-1} at Lighthouse.

There was also no significant difference in the proportion of total fish biomass represented by herbivorous and predatory fish species between sites (Figure 3.7). Lowest proportions were found at Ted's Point for herbivorous species (20.80 ±4.68 %) and Sturge's Bank for predatory species (9.84 ±5.52 %). Highest proportions were found at Little Bight for herbivores (45.29 ±9.18 %) and at Lighthouse for predatory species (26.21 ±8.85 %).

When biomass data were separated by study depth, total fish biomass was shown to be significantly higher on the reef crest (ca 8m depth) than reef slope (ca. 12m depth) when all sites were combined ($U_{1,72}$=446.00, $P<0.05$) (Figure 3.6). When sites were treated individually however, crest biomass was only significantly higher at Coral View ($U_{1,12}$=3.00, $P<0.05$), with biomass of 136.68 ±54.12 kg ha^{-1} on the reef crest, and 35.03 ±11.07 kg ha^{-1} on the reef slope.

No significant differences were found in the biomass of either herbivores or commercially valuable species between reef crest and reef slope data at any site, or when all sites were combined.

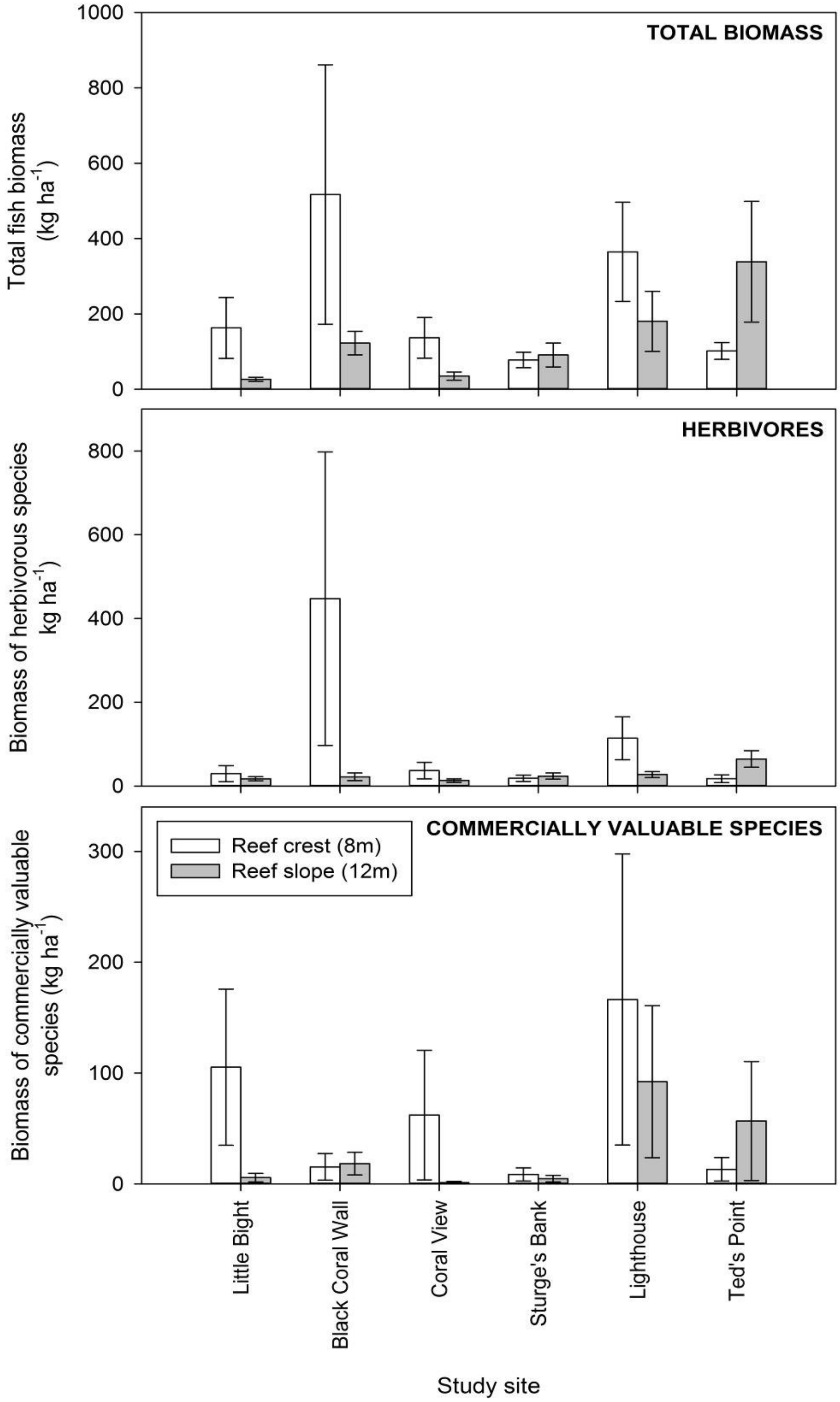

Figure 4.6. Total fish biomass, biomass of herbivorous fish species and biomass of commercially valuable fish species for six coral reefs around Utila Island in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from stereo-video surveys (n=6).

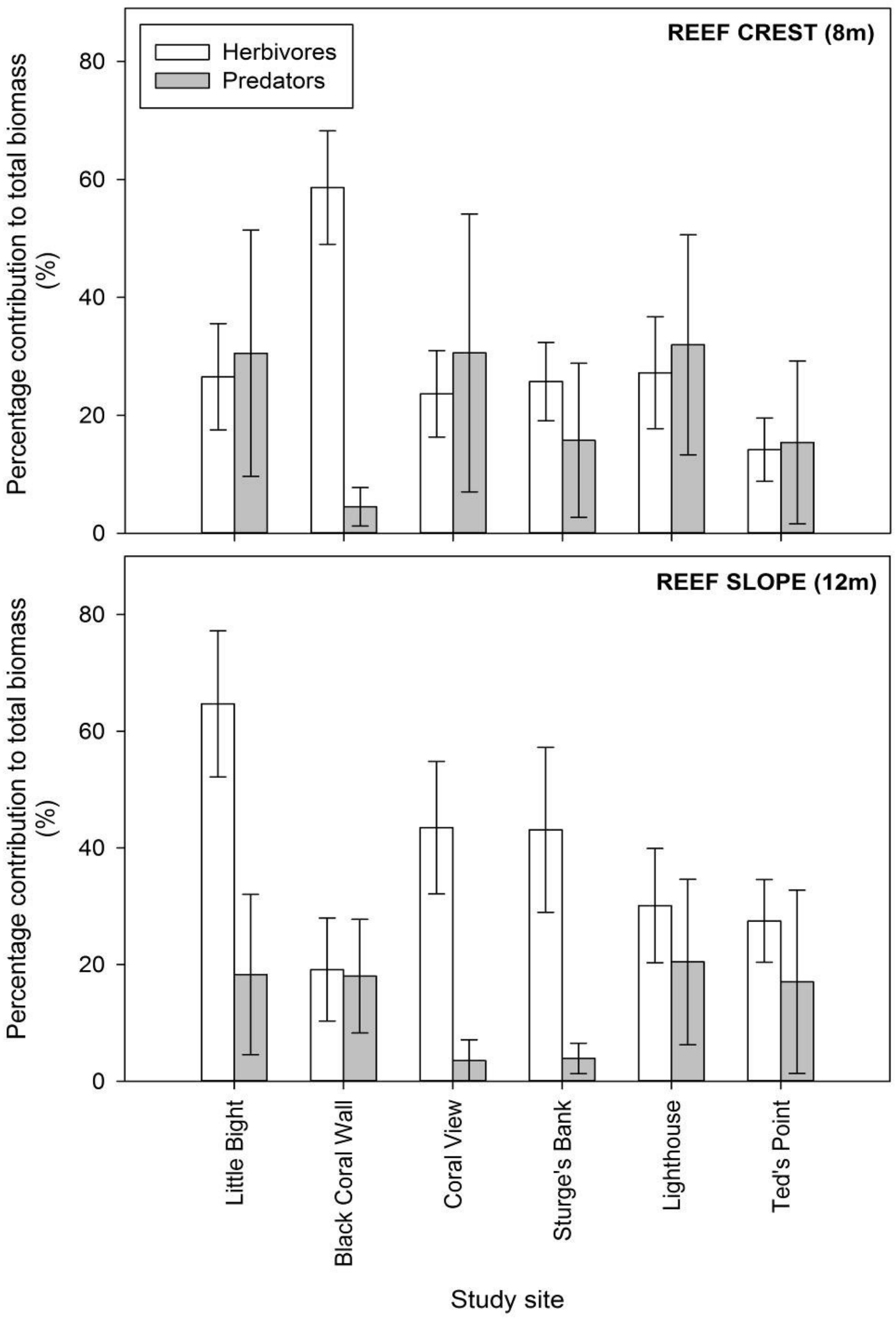

Figure 3.7. Percentage contribution of herbivorous fish species and predatory fish species to total biomass on six coral reefs around Utila Island in 2012. Data are mean values ±SE for reef crest (ca. 8m depth) and reef slope (ca. 12m depth) habitats calculated from stereo-video surveys (n=6).

5. Comparison between Cayos Cochinos and Utila

5.1. Coral reef habitat structure

Focusing on the two main benthic indicators of coral reef health, significant differences were found between Cayos Cochinos and Utila when all study sites were combined and overall mean values calculated. The percentage cover of hard coral was significantly higher on Utila than Cayos Cochinos ($U_{1,70}$=315.00, P<0.001), with Utila exhibiting over 25 % (Table 5.1). Macroalgae showed the inverse relationship, with percentage cover significantly higher on reefs on Cayos Cochinos ($U_{1,70}$=185.00, P<0.001), with cover approaching 50 % compared to below 25 % on Utila.

Table 5.1. Percentage cover of hard coral and macroalgae around the two main study sites of Utila and Cayos Cochinos in 2012. Data shown are overall mean values ±SE for all dive sites combined (n > 15).

	Cayos Cochinos	Utila
Scleractinian coral cover (%)	18.42 ±1.34	25.51 ±2.15
Macroalgal cover (%)	47.12 ±5.41	23.24 ±2.26

5.2. Reef associated fisheries

None of the seven indicators of fish community structure and health differed significantly between Utila and Cayos Cochinos when all sites were combined (Table 5.2). This was the case for total abundance, species diversity, or biomass. There was also no significant difference between the biomass of herbivores or commercially valuable species.

Table 5.2. Fish community indicators around the two main study sites of Utila and Cayos Cochinos in 2012. Data shown are overall mean values ±SE for all dive sites combined (n > 15).

	Cayos Cochinos	Utila
Total fish abundance (individuals ha^{-1})	68.67 ±8.23	47.44 ±5.30
Fish diversity (species transect^{-1})	14.22 ±0.70	14.08 ±0.74
Total fish biomass (kg ha^{-1})	338.32 ±97.45	179.67 ±36.71
Herbivore biomass (kg ha^{-1})	98.49 ±27.55	69.16 ±30.65
Commercially valuable biomass (kg ha^{-1})	134.24 ±76.18	45.50 ±13.13
Proportion herbivore biomass (%)	39.92 ±0.00	33.52 ±3.07
Proportion predatory biomass (%)	14.52 ±0.00	17.04 ±3.02

6. Cayos Cochinos Herpetofauna Research

The Herpetofauna Research Group is subdivided into four core areas of research: 1) Boa constrictor conservation and ecology, 2) Spiney-tailed Iguana (*Ctenosaura melanosterna*) conservation and ecology, 3) predicting the response of *Anolis* ('anole') lizard communities to climate change in the Bay Islands and Cayos Cochinos, and 4) impacts of an invasive gecko species. This report outlines the current progress and results of each of these core areas of research, while a more detailed discussion of the background and methods used can be found in the Operation Wallacea Cayos Cochinos Marine Report 2011 (www.opwall.com).

6.1. Boa constrictor conservation and ecology

The *Boa constrictor* research group was initiated in 2004 to determine the extent to which the Cayos Cochinos *B. constrictor* population had been impacted by illegal poaching for the pet trade, and to collect ecological and genetic data essential for implementing appropriate management strategies to ensure the successful conservation of the population. Nine years on, a huge wealth of data has been generated and is currently being analysed by teams of researchers at Universities in the UK and USA. Dr. Stephen Green has completed his Ph.D. at the University of Kent, UK, in collaboration with Operation Wallacea and his Ph.D. thesis, entitled "Evolutionary Biology and Conservation of the Hog Island Boa constrictor" is available on request from the University of Kent Library, or direct from Dr. Green (Steve.green@opwall.com). The following is a summary of the work carried out during the 2012 Operation Wallacea season.

Question 1*: Are there differences in prey availability between islands?*
Both of the dissertation students working on boas during the 2012 season were addressing questions related to the potential differences in large, terrestrial, mammalian prey availability between Cayos Cochinos Pequeño (CCP) and Cayos Cochinos Grande (CCG). We employed visual encounter surveys and motion activated game cameras to investigate prey availability between islands. We found that pacas, agouties, and armadillos all occur on CCG and are apparently absent on CCP.
Next Step: Program "Presence" will be used to calculate the probability of absents on CCP.

Question 2: *Do differences in prey availability affect Boa constrictor head shape?*

We did not detect differences in *Boa constrictor* head shape between islands. However, we did detect a sex difference in *Boa constrictor* head shape with females attaining a relatively larger head for a giving body size than males. Interestingly, the head morphology measurements that were relatively larger in females (such as head length, head width, and upper labial length) would allow females to ingest relatively larger prey than male boas of the same body size. Additionally, our failure to detect between island differences in boa head shape could have been because we also failed to sample boas of either sex that were of an appropriate size to consume any of the large, terrestrial mammalian prey items that occur on CCG.

Next Step: We will make an effort in subsequent seasons to sample (measure head shape) boas, from both CCP and CCG, of a large enough body size to consume any or all of the large mammalian prey items to further investigate the potential effects of differences in available prey size on boa head morphology.

Question 3: *Does differences in prey availability affect foraging site selection?*

We found that on CCG (where large, terrestrial prey items occur) larger boas forage closer to the ground than smaller boas. However, this result should be interpreted with care as large snakes have relatively fewer perch sites to choose from and expend proportionally more energy climbing to perch sites than smaller conspecifics. That being said, on CCP (where large, terrestrial mammalian prey do not occur) boa perch height was independent of body size suggesting that prey availability maybe affecting boa perch height selection on CCG.

Next Step: As stated above, we need to sample boas, from both CCP and CCG, of a large enough body size to consume any or all of the large, terrestrial mammalian prey items to further investigate the potential effects of differences in available prey size and habitat usage on boa foraging site selection.

Question 4: *Does differences in prey availability affect body condition?*

We found no differences in body condition between islands or sex.

Next Step: We will continue to compile these data in subsequent seasons.

Question 5: *Does prey availability and body condition affect tick load?*

We found a positive correlation between body size and tick load independent of island and sex.

Next Step: We will continue to compile these data in subsequent seasons.

6.2. Spiney-tailed iguana (*Ctenosaura melanosterna*) conservation and ecology

The Black-chested, Spiney-tailed Iguana (*Ctenosaura melanosterna*) is listed as critically endangered by the IUCN red list with its distribution restricted to the Rio Aguan Valley in northern Honduras and the Cayos Cochinos. The Rio Aguan Valley population is in decline and its future uncertain. The Cayos Cochinos population, therefore, represents an important refuge for this species and its protection is a conservation priority for the area. However, small insular populations are vulnerable to extinction as a consequence of stochastic events. Therefore, it is crucial that the parameters acting on this population are understood in order to implement appropriate management strategies.

Ongoing research is being carried out to monitor the population size of *C. melanosterna* on Cayo Menor through capture-mark-recapture methods. However, during the 2011 field season, in addition to the long-term objectives of the population estimate, the general health of individuals captured was assessed. Body Condition Index (BCI) and parasite load were used as general indicators of health, and blood hematocrit levels as an indicator of stress. These indicators of health and stress were then used to compare animals living in close proximity to the research centre, where anthropogenic disturbance is higher, with those animals living in more 'natural' conditions away from the research centre. A key objective was to determine whether the presence of researchers on the island was having a negative impact on the health of animals around the research facility on the south of the island.

Question 1: *Does the presence of Green Iguanas (Iguana iguana) affect the foraging behavior of Ctenosaura melanosterna?*
We found that in the presence of I. iguana, C. melanosterna spend less time in the study arena (where food was freely available), take more time to locate food, spent less time eating food, and eat less food than when there is not an I. iguana in the study arena.
Next Step(s): Assessment of C. melanosterna foraging behaviour in areas further away from the south beach of CCP and/or on CCG. Assessment of *C. melanosterna* foraging behaviour in the presence of conspecifics, other lizard species that are not food resource competitors (i.e. Basiliscus) or a predator (i.e. boas).

6.3. Predicting the response of *Anolis* ('anole') lizard communities to climate change

To date, the Anole Project has focused on predicting the response to climate change among *Anolis* ('anole') lizard communities in the Bay Islands and Cayos Cochinos of Honduras. Since 2008, numerous, high-profile studies (two in Proc. Roy. Soc., three in PNAS, two in Science, and one in Nature) have all forcasted massive extinctions in tropical lizards driven by anthropogenic climate change. However, the majority of these studies have used coarse measures of physiology (e.g. critical thermal maxima or field-active body temperature). Moreover, they have attempted to make global predictions, which by necessity require global temperature data sets. Unfortunately, global temperature data are only available at a maximum resolution of about 1 km^2, when the vast majority of tropical ectotherms experience temperature at a much smaller scale (usually less than 1 m^2). To examine the generality of these predictions, the Anole Project has employed a novel approach, integrating wholistic measures of thermal physiology (the entire thermal reaction norm of each species) with fine-scale measurements of contemporary thermal heterogeneity. By projecting climate change at a fine spatial scale onto thermal reaction norms, we are beginning to understand how lizard populations will respond in years to come. And as it turns out, not all species appear doomed, and the predicted outcome of climate change differs among islands (see data from previous years). In 2011, we began a project examining the effects of operative temperature, wind speed, and humidity on anole abundance, and in 2012 we simply added to that data set (although the new data has not yet been processed). We added an additional 20 abundance surveys for each species (a total of 40 new surveys) along with thousands of new temperature, wind speed, and humidity measurements. While it is likely that our basic conclusions will not change from 2011, we now have a much more extensive, multi-year dataset for publication.

6.4. The population dynamics of gecko species

Question 1: *To what extent does the endemic gecko species Phyllodactylus palmeus occur sympatrically with the invasive gecko Hemidactylus frenatus on CCP?*
We found that *P. palmeus* occurs sympatrically with *H. frenatus* on nearly all of the manmade structures near the south beach of CCP. Although *P. palmeus* outnumbered *H. frenatus* on nearly all of the structures surveyed, close attention should be paid to the relative densities of these two species as *H. frenatus* is known to out compete native species in other places it has been introduced.
Next Step(s): As *H. frenatus* has been introduced to CCP, CCG and likely some of the smaller cays as well, continued monitoring of the relative densities of both species throughout Cayos Cochinos in needed. For the immediate future, our monitoring efforts will be focused on the manmade structures near the south beach of CCP as well as East End and the Plantation Beach Resort on CCG.

6.5. Publication outputs: Cayos herpetology research

Boback, S.M., C.E. Montgomery, R.N. Reed, and S. Green (2006). *Oxybelis aeneus* (Brown Vinesnake). *Herpetological Review* 37(2):242.

Boback, S.M., C.E. Montgomery, R.N. Reed, and S. Green (2006). *Kinosternon leucostomum* (Mud Turtle). *Herpetological Review* 37(2):239.

Frazier, J.A., C.E. Montgomery, S.M. Boback, and R.N. Reed (2007). *Coniophanes imperialis* (Black–striped Snake) Diet. *Herpetological Review* 38(1):86.

Frazier, J.A., C.E. Montgomery, S.M. Boback, and R.N. Reed (In Press). *Leptophis mexicanus* (Mexican Vinesnake). *Herpetological Review*.

Green, S., Vuong H., Kundu S., Griffiths R. A., Montgomery C. E., Boback S. M., Reed R. N. and Groombridge J. J. (In Prep). Phylogeography and the origins of dwarfism in a giant snake.

Green, S., Montgomery C. E., Boback S. M., Reed R. N., Frazier J., Kundu S., Griffiths R. A. and Groombridge J. J. (In Prep). Genetic consequences of the pet trade induced decline of a dwarfed insular race of snake; the Hog Island Boa (*Boa constrictor imperator*).

Green, S., Montgomery C. E., Boback S. M., Reed R. N., Frazier J., Kundu S., Griffiths R. A. and Groombridge J. J. (In Prep). Population structure and gene flow of *Boa constrictor imperator* in the Cayos Cochinos and Bay Islands, Honduras.

Green, S., Montgomery C. E., Boback S. M., Reed R. N., Frazier J., Griffiths R. A. and Groombridge J. J. (In Prep). Assessing population recovery of a critically exploited insular *Boa constrictor* in the Cayos Cochinos, Honduras.

Logan, M. L., Montgomery, C. E., Boback, S. M., Reed, R. N., and Campbell, J. A. (2012). Divergence in morphology, but not habitat use, despite low genetic differentiation among insular populations of the lizard *Anolis lemurinus* in Honduras. *Journal of Tropical Ecology* 28:215-222.

Logan, M. L., Huynh, R. K., Precious, R., Calsbeek, R. (In Review). The impact of climate change measured at relevant spatial scales: new hope for tropical lizards. *Proceedings of the Royal Society B.*

Logan, M. L. (In Prep). Abiotic constraints on the abundance of tropical lizards. *Functional Ecology*.

Montgomery, C.E., R.N. Reed, H.J. Shaw, S.M. Boback, and J.M. Walker (2007). Distribution, habitat, size, and color pattern of *Cnemidophorus lemniscatus* (Sauria: Teiidae) on Cayo Cochino Pequéno, Honduras. *Southwestern Naturalist* 52(1):38-45.

Reed, R.N., S. Green, S.M. Boback, and C.E. Montgomery (2006). *Ctenosaura melanosterna* (Black-chested Ctenosaur). Predation. *Herpetologcial Review* 37(1):84.

Reed, R.N., S.M. Boback, C.E. Montgomery, S. Green, Z. Stephens, and D. Watson. (2007). Ecology and conservation of an exploited insular-endemic population of *Boa constrictor* (Squamata: Boidae) in the Cayos Cochinos, Honduras. In: Biology of the Boas and Pythons. R.W. Henderson, R. Powell, G.W. Schuett, and M.E. Douglas eds., Eagle Mountain Publishing.

Walker, J. M. Boback, S.M., C.E. Montgomery, R.N. Reed, and S. Green (In Press). Morphology, diet and habitat use of *Cnemidophorus lemniscatus* in the Cayos Cochinos, Honduras. Herpetological Conservation and Biology.

7. Future research directions

Now the Operation Wallacea marine expeditions in Honduras are well established, the next phase of development is to expand the scope of research activities to improve scientific outputs. The emphasis of this expansion is to establish the activities of Operation Wallacea and its partners in Honduras as a source of high quality internationally-recognised research, characterised by publication in peer-reviewed journals. The following paragraphs describe three key projects to be initiated in 2013.

7.1. Environmental profiling

Understanding the environmental conditions present at a study site is vital at explaining patterns in data investigating biodiversity and ecology. It is therefore extremely important that we characterise the environmental conditions present at each of our reef study sites in as much detail as possible. Spatial comparisons between sites will be conducted using an oceanographic probe fitted with sensors to measure (1) full spectrum photosynthetically active radiation (PAR, wavelength range 400-700nm), (2) ultra-violet B radiation (UV-B, wavelength range 280-400nm), (3) temperature, (4) depth, (5) soundscape (via a highly sensitive hydrophone). This will allow detailed and accurate measurements to be taken on light attenuation, temperature fluctuations and noise pollution, amongst others. This probe will be positioned on the benthos at a range of depths at each site, and at standardised times of day, and will remain constantly connected to a buoy housing solar panels for power. Temporal data on light and temperature will be obtained using HOBO pendant loggers placed on the reef for pre-determined time periods, allowing both diurnal and seasonal environmental fluctuations to be measured. The data from this project will be used to support the more specific research projects taking place.

7.2. Urchin population ecology

Urchins, in particular the long-spined urchin *Diadema antillarum*, are a keystone species on coral reefs in the Caribbean, and act as one of the most important herbivores protecting reef systems from overgrowth by macroalgae and subsequent phase shifts. However, *D. antillarum* was heavily impacted by a disease in the 1980s which caused a mortality rate throughout the Caribbean of approximately 98%, and most populations are sill showing little sign of recovery. In Honduras, populations are extremely low in general, although densities are significantly higher in Tela Bay. This study will investigate distribution patterns of *D. antillarum* around Utila, Cayos Cochinos and Utila, and explore potential reasons behind the partial population recovery at Tela. This will be achieved by addressing the contribution of (1) environmental conditions, (2) growth parameters and urchin morphology, and (3) population genetics in explaining the large variation in urchin post-disease success observed in Honduras. Environmental conditions at each site will be addressed via an independent study outlined earlier. Growth parameters and morphology will be investigated by collecting *D. antillarum* individuals from each study site (n≈30), and morphometric measurements taken, including spine length, body dimensions, weight, and spine density. Small spine samples will then be collected and stored in ethanol for later genetic analysis in the UK. This genetic component will incorporate full population similarity analysis to identify any genetic differences between the recovered population in Tela and non-recovered populations around Utila and Cayos Cochinos. These techniques are non-destructive, and individuals collected for morphological measurements and population genetic samples will be returned to the site of collection unharmed. A small number of additional individuals (n≈10) will be collected and tissue samples collected for RAD-DNA analysis in the UK. This 'ultra-sequencing' quantifies genetic selection, identifying any specific genes which are being selected for in the recovered Tela population compared to non-recovered populations around Utila and Cayos and could potentially be used to identify genes responsible for disease resistance.

7.3. Lionfish feeding preferences and ecosystem evolution patterns

The invasive lionfish *Pterois volitans* was introduced into the Caribbean from Florida in the 1990s, and their population now stretches throughout the region. This invasion, although swift, was gradual, and different reefs and reef systems have been impacted by the lionfish for differing periods of time. The impact of the lionfish invasion is well documented, but what is poorly understood is how native reef communities are adapting to the presence of this alien predator. This study is part of a collaborative effort with scientists in the Bahamas, Cuba, Mexico and Honduras, representing a range of distances from the invasion epicentre. The aim of this collaboration is to investigate the extent to which reefs are adapting to the lionfish presence, and the pressure acting on the lionfish population due to this adaptation. Lionfish will be caught using spear fishing around Utila, Cayos Cochinos and Tela and returned to the laboratory. Morphological measurements (maximum length, mouth size, spine length) and weight will be taken for each individual, with subsequent dissection to establish gender and signs of sexual maturity. Finally, gut content analysis will be performed to identify prey items recently fed upon. The data from this study will be entered into a Caribbean-wide database to help assess the changes in lionfish impact over time, and help predict the future of this invasive species in the region. These methods are destructive and individuals will be disposed of once data collection is complete.

8. References

Carpenter R.C. (1986). Partitioning herbivory and its effects on coral reef algal communities. *Ecological Monographs* **56:** 345–363.

Claus S., Wild C. (2002). Possibilities and bounds of sustainable tourism on the island of Utila, Honduras. *Iguana Research and Breeding Station, Utila, Honduras.*

English S., Wilkinson C., Baker V. (1997). Survey Manual for Tropical Marine Resources. *Townsville, Australia, Australian Institute of Marine Science, Townsville Australia: pp. 378.*

Jokiel P.L., Brown E.K., Friedlander A., Rodgers S.K., Smith W.R. (2001). Hawaii Coral Reef Initiative Coral Reef Assessment and Monitoring Program (Cramp) Final Report 1999-2000. *HCRI and NOAA Technical Report. Silver Spring, MD: pp. 66.*

Lessios, H.A. (1988). Mass mortality of *Diadema antillarum* in the Caribbean: what have we learned? *Annual Review of Ecology and Systematics* **19:** 371–393.

Mumby P.J., Hedley J.D., Zychaluk K., Harborne A.R., Blackwell P.G. (2006). Revisiting the catastrophic die-off of the urchin *Diadema antillarum* on Caribbean coral reefs: Fresh insights on resilience from a simulation model. *Ecological Modelling* **196:** 131-148.

Watson D.L., Harvey E.S., Fitzpatrick B.M., Langlois T.J., Shedrawi G. (2010). Assessing reef fish assemblage structure: how do different stereo-video techniques compare? *Marine Biology* **157(6):** 1237-1250.