EXPEDITION REPORT

Expedition dates: 20 March - 1 April 2011

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Diving the Caribbean to safeguard the coral reef of the Cayos Cochinos marine protected area, Honduras

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Authors:

Marcio Aronne
HCRF

Jonathan Shrives
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Matthias Hammer and Adam Stickler (editors)
Biosphere Expeditions

ABSTRACT

The Cayos Cochinos Natural Monument, located off the coast of Honduras in the Caribbean Sea, was declared a protected area by the Honduran government in 1992 and in 2003 was awarded the status of a Marine Nature Monument. The Cayos Cochinos Natural Monument is an important and protected part of the Meso-American barrier reef, the world's second largest barrier reef system, which has been identified by the Smithsonian Institute, The Nature Conservancy, the Word Wildlife Fund and the World Bank as one of the key sections of the barrier reef system in need of preservation. In 2004 the first management plan was published and new zoning and regulations were approved. This was updated by the 2008 - 2012 management plan, which was also based on the important findings provided by the joint Biosphere Expeditions and Honduras Coral Reef Fund expeditions. This report summarises the findings of the 2011 survey (the fifth in the series) of this long-term monitoring program, which was conducted from 20 March to 1 April 2011.

The methodology selected for this survey is called Reef Check and involves volunteer divers. It was designed to assess the health of coral reefs and it is different from other monitoring protocols in that it focuses on the abundance of particular coral reef organisms that best reflect the condition of the ecosystem and that are easily recognisable to the general public. This study also includes a comparative Reef Check analysis over five years.

From the beginning of the monitoring efforts in 2006 to date, we have observed a gradual decrease in the average abundance of large predators such as groupers. We have also observed a high average abundance of herbivore indicator species, showing a slight reduction in 2011. This reduction of predators and increase of herbivores could be the beginning of significant changes within the coral reef ecosystem, which we will have to continue monitoring to establish appropriate management measures.

It is important to note the increasing fishing pressure on commercial species such as *Ocyurus crysurus*, *Lutjanus cynagris*, *Haemulon plumieri* and *Mycteroperca bonaci*. The conch and lobster have also shown low abundance since monitoring began, as these two invertebrates are traditionally exploited most in Honduras. However, management efforts to reduce fishing pressure, especially the efforts to provide viable economic alternatives for the community as well as to establish temporary no fishing zones at spawning aggregation sites, are beginning to show positive results.

The sea urchin, which feeds on algae, was found to be abundant, especially at the El Avión site. The high number of sea urchin at this site could indicate the beginning of a coral recovery.

Overall, coral coverage is still low around Cayos Cochinos, but the reduced areas affected by bleaching are significant. Nonetheless, we observed high levels of detrimental sedimentation originating from the mainland and landslides on Cayo Mayor.

Our recommendations for future expedition work is to (1) continue monitoring the effectiveness of management plan regulations, (2) implement an environmental education programme, (3) continue biological monitoring and (4) initiate a study to determinate the levels of fish extraction during the spawning aggregation periods.

RESUMEN

El Monumento Natural Cayos Cochinos, situado frente a la costa de Honduras en el Mar del Caribe, fue declarado área protegida por el gobierno de Honduras en 1992, y en 2003 fue reconocido como Monumento Nacional Marino.

El Monumento Natural Cayos Cochinos es una importante y protegida parte de la barrera de coral Meso-Americana, la segunda barrera coralina mas larga del mundo, que ha sido identificada por el Smthsonian Institute, The Nature Conservancy, la World Wildlife Fund (WWF) y el Banco Mundial como una de las porciones clave de esta gran barrera de coral, en aras a su conservación.

En 2004 fue publicado el primer plan de gestión, que significó nuevas regulaciones y delimitación de zonas. Este plan fue actualizado por el plan de manejo del 2008-2012, que estuvo también basado en las importantes aportaciones realizadas por el trabajo conjunto de las expediciones de Biosphere Expeditions y la Honduras Coral Reef Fund. Este informe recoge los resultados de las investigaciones del 2011 (la quinta de la serie) de este programa de seguimiento a largo plazo, que se desarrolló desde el 20 de Marzo al 1 de Abril del 2011.

La metodología seleccionada para esta investigación se denomina "Reef Check", e involucra diversos voluntarios. Fue diseñado para determinar el estado de salud de los arrecifes coralinos, y se diferencia de otros protocolos de seguimiento en que pone el foco en la abundancia de aquellos organismos de la barrera de coral que reflejan mejor el estado del ecosistema, y que sean reconocibles por el gran público. Este estudio también incluye un análisis comparativo "Reef Check" durante cinco años.

Desde el inicio del seguimiento en 2006 hasta la fecha, hemos observado un descenso gradual de la abundancia relativa de grandes predadores como grupo. Hemos constatado también una elevada proporción en la abundancia de especies herbívoras indicadoras, mostrando una ligera reducción en 2011. Esta disminución de predadores y el incremento de herbívoros, podría ser el comienzo de cambios significativos en el seno del ecosistema de la barrera de coral, que tenemos que continuar monitorizando para establecer adecuadas medidas de gestión.

Es relevante tomar nota del incremento de la presión pesquera en especies comerciales como Ocyurus crysurus, Lutjanus cynagris, Haemulon plumieri y Mycteroperca bonaci. Las caracolas y langostas han mostrado también poca abundancia desde que empezó el seguimiento, ya que estos dos invertebrados son tradicionalmente explotados en Honduras. De todas formas, los esfuerzos para reducir la presión pesquera, especialmente los destinados a proporcionar alternativas económicas viables a la comunidad, así como a establecer zonas de veda temporal en sitios de desove, están empezando a mostrar resultados positivos.

El erizo de mar, que se alimenta de algas, fue hallado en abundancia, especialmente en el área de El Avión. El elevado número de erizos de mar en esta zona, podría indicar el inicio de la recuperación del coral.

En general, la cobertura de coral es aún escasa alrededor de Cayos Cochinos, pero las áreas afectadas por la reducción de blanqueo son significativas. Sin embargo hemos observado altos niveles de sedimentación perjudicial procedentes de la parte continental, y deslizamientos de tierra en Cayo Menor.

Nuestras recomendaciones para futuras expediciones de trabajo son (1) continuar el seguimiento de la eficacia en las normas del plan de gestión, (2) implementar un plan de educación ambiental, (3) continuar los estudios biológicos y (4) iniciar un estudio para determinar los niveles de pesca adecuada durante los periodos de desove.

Contents

Please note: Each expedition report is written as a stand-alone document that can be read without having to refer back to previous reports. As such, much of this and the following sections, which remains valid and relevant, is a repetition from previous reports, copied here to provide the reader with an uninterrupted flow of argument and rationale.

1. Expedition Review

M. Hammer and A. Stickler (editors)
Biosphere Expeditions

1.1. Background

Biosphere Expeditions runs wildlife conservation research expeditions to all corners of the Earth. Projects are not tours, photographic safaris or excursions, but genuine research expeditions placing ordinary people with no research experience alongside scientists who are at the forefront of conservation work. Expeditions are open to all and there are no special skills (biological or otherwise) required to join. Expedition team members are people from all walks of life and of all ages, looking for an adventure with a conscience and a sense of purpose. More information about Biosphere Expeditions and its research expeditions can be found at www.biosphere-expeditions.org.

This report deals with an expedition to the world's second largest reef system located on the Cayos Cochinos Natural Monument in the Caribbean Sea, off the coast of Honduras. The expedition ran from 20 March to 1 April 2011. The purpose of the survey programme was to provide data on the current biological status of the reefs and islands and on population levels of protected species within the marine protected area.

1.2. Research area

The Cayos Cochinos are a group of two small islands (Cochino Pequeno and Cochino Grande) and 13 small coral cays situated 30 kilometres northeast of the town of La Ceiba on the northern shores of Honduras. In November 1993, a Presidential Decree designated the Cayos Cochinos a Natural Protected Area and the Honduras Coral Reef Fund (HCRF) as the managing agency responsible for the conservation of the islands. In August 1994 a second Presidential Decree confirmed the protected status of the islands. In November 2003 a Legislative Decree declared a Marine Natural Monument. The protected area covers 460 km^2 and HCRF are responsible for its management.

The Cayos Cochinos form part of the world's second largest barrier reef system, known as the Meso-American Barrier Reef, and have been identified by the Smithsonian Institute, The Nature Conservancy, the Word Wildlife Fund and the World Bank as one of the key sections of the barrier reef system to preserve. The reefs are the least disturbed ecosystems in the so-called Bay Islands Complex and have had a strong and active NGO working with local communities, private sector bodies and government organisations to help manage the reefs and their fisheries over the last 10 years.

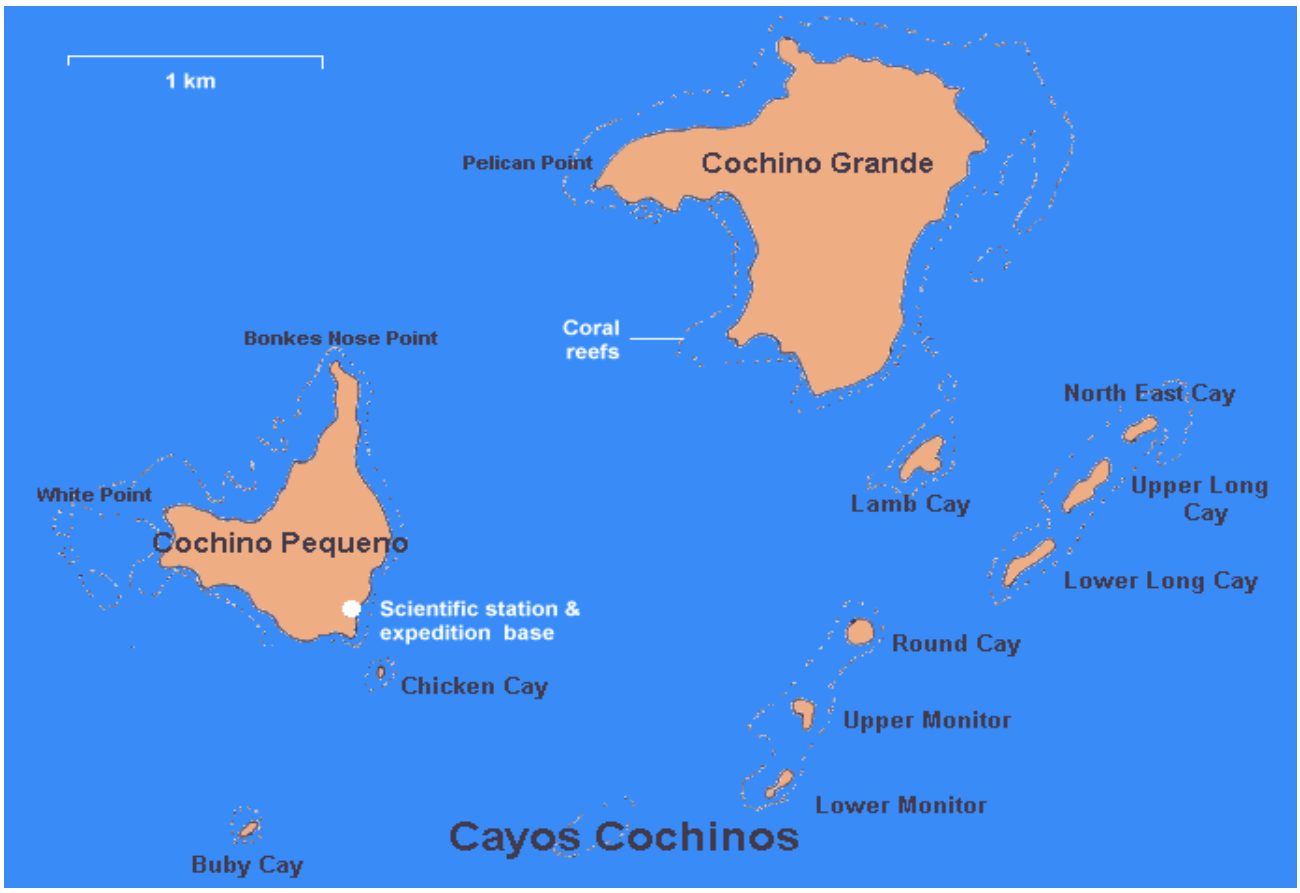

Figure 1.1. Map of the study area. See also See also Google Maps for an internet-driven view of the study site.

1.3. Dates

The expedition ran over a period of 12 days, composed of a team of international research assistants, scientists and an expedition leader.

20 March - 1 April 2011.

Dates were chosen when survey conditions such as the clarity of water and therefore visibility were best.

1.4. Local conditions & support

Expedition base

The expedition team was based on the island of Cochino Pequeño at the scientific station of Cayos Cochinos. The scientific station was set up by the Honduras Coral Reef Foundation (HCRF) in 1994 and features spacious bungalow-style cabins, a fully equipped dive centre with compressors and equipment for hire, wet and dry labs, a computer and lecture room, common areas and a dining area. 4 – 8 team members shared a spacious bungalow-style cabin (2 – 4 persons to a room). Each cabin had a shower and toilet, a small kitchen with lounge and a veranda overlooking the beach. A cook provided all meals and vegetarians and special diets were catered for.

Field communications

Each dive boat carried one radio for communication with other boats and with the scientific station. Mobile phones worked on the island and within a few kilometres out at sea, but very few European and North American providers seemed to have a roaming agreement with Honduran providers. There was an internet connection on the island for staff for communications.

Transport, vehicles & research boats

Team members made their own way to the La Ceiba assembly point. From there all transport was provided for the expedition team and on the island a variety of HCRF boats were used to move to survey sites and back.

Medical support & insurance

The expedition leader was a trained divemaster and first aider, and the expedition carried a comprehensive medical kit. Further medical support was provided by a hospital and doctors within easy reach at La Ceiba. All dive boats carried safety equipment and oxygen. For urgent emergency cases there was a helicopter landing pad on Cochino Pequeño and a recompression chamber on nearby Roatan Island. All team members were required to carry adequate travel insurance covering emergency medical evacuation and repatriation. Emergency plans were in place, but did not have to be invoked because there were no serious medical incidences or other emergencies during the expedition.

Diving

The minimum requirement to take part in this expedition was a PADI Open Water or equivalent qualification. Team members who had not dived for twelve months prior to joining the expedition were required to complete a PADI Scuba Review before joining the expedition.

Standard PADI diving and safety protocols were followed.

Dive groups were divided into different teams, each working on specific areas of survey work. Divers were allocated to teams based on a mixture of personal preference, diving skills and knowledge of the species.

1.5. Local scientist

Marcio Aronne is a reef biologist and Reef Check trainer who has worked with HCRF since 1998. Marcio has worked with community development programmes, fish, reef, fisheries and spawning aggregation monitoring programmes in close relation with international institutions such as The Nature Conservancy, the Word Wildlife Fund, Inter American Foundation, Avina Foundation and Rare Conservation.

1.6. Expedition leaders & chief scientist

Jon Shrives was one of the expedition leaders and also chief scientist. Jon was born and educated on Jersey in the Channel Islands, where he developed a love of diving and marine biology from an early age. He graduated from Southampton University with a BSc in Biology, specialising in behavioural ecology, evolutionary ecology and marine tropical ecology. As part of his honours thesis research project, he travelled out to the remote Wakatobi islands of Sulawesi, Indonesia, and was bitten by the 'expedition bug' and diving science. Since then he has worked with several NGOs and ecotourism companies, teaching marine ecology and SCUBA diving. He has supervised several undergraduate research projects and led marine ecology programs in Indonesia, Honduras, Egypt and the UK. His experience varies from providing logistic management of a live-aboard research vessel, to completing baseline surveys for international organisations such as Reef Check and acting as head scientist to a team of five scientists and over a hundred volunteers in Honduras. Jon also recently became the UK's first Reef Check Course Director, teaching others how to instruct Reef Check to divers.

Expedition leader Paul o'Dowd was born in Melbourne, Australia. From the beginning, his primary interests have been natural history and adventure. As a teenager he learned to dive and at 19 years old left Victoria to move to Cairns to work on the Great Barrier Reef in the dive industry. Shortly thereafter he was offered a job managing a dive facility in Papua New Guinea. In PNG Paul became involved in expeditionary and documentary film work. Paul has worked for the BBC's Natural History Unit and various other companies on documentary projects as well as with assorted tourism-based expeditions to places such as the Sepik Basin and the Kokoda Track. Paul also delivers a lecture programme in rainforest ecology, conservation and sustainability for a study abroad programme for American university students. A broad base of scientific literacy and a genuine interest in communication has led to a career in introducing diverse audiences to the natural world. Diving, rock climbing and just about anything that provides a good opportunity to get into nature and help others to do the same is Paul's idea of time well spent.

1.7. Expedition Team

The expedition team was recruited by Biosphere Expeditions and consisted of a mixture of all ages, nationalities and backgrounds. They were (with country of residence):

20 March – 1 April 2011

Steve Brkich (USA), Odilo Esser (Germany), James Griffith (USA), Melissa Kramer (USA), Kean Mitchell (Canada), Sue Mitchell (Canada), Martin Piehslinger (Austria), Eva Piehslinger (Austria), John Sainato (USA), James Sarrett (USA), Marlies Stabel (The Netherlands).

1.8. Expedition budget

Each team member paid towards expedition costs a contribution of £1,390 per person per two week slot. The contribution covered accommodation and meals, supervision and induction, special non-personal diving and other equipment and air, and all transport from and to the team assembly point. It did not cover excess luggage charges, travel insurance, personal expenses like telephone bills, souvenirs etc., as well as visa and other travel expenses to and from the assembly point (e.g. international flights). Details on how this contribution was spent are given below.

Income	£
Expedition contributions	17,919
Expenditure	
Accommodation and food includes all board & lodging	4,112
Transport includes fuel, boat maintenance, car transfers	880
Equipment and hardware includes research materials, research gear	388
Staff Includes all salaries, travel and expenses	4,064
Administration includes registration fees, sundries, etc	478
Team recruitment Honduras as estimated % of PR costs for Biosphere Expeditions	3,940
Income – Expenditure	4,057
Total percentage spent directly on project	77%

1.9. Acknowledgements

This study was conducted by Biosphere Expeditions, which runs wildlife conservation expeditions all over the globe. Without our expedition team members (who are listed above) who provided an expedition contribution and gave up their spare time to work as research assistants, none of this research would have been possible. The support team and staff (also mentioned above) were central to making it all work on the ground. Thank you to all of you, and the ones we have not managed to mention by name (you know who you are) for making it all come true. Biosphere Expeditions would also like to thank members of the Friends of Biosphere Expeditions and donors and Swarovski Optik and for their sponsorship.

We would also like to thank the Honduras Coral Reef Fund (HCRF), the Honduras National Fisheries Department (DIGEPESCA), the Honduras Protected Areas Unit (DAPVS/ ICF), the Honduras Ministry of Defense (Naval Base), Secretaría de Recursos Naturales y Ambiente (SERNA), Honduras Tourism Board (IHT), Instituto de Conservación Forestal (ICF), Sociedad de Inversiones Ecológicas (SIEC), WWF, MARVIVA, USAID, The Nature Conservancy, the Smithsonian Institute, SAM - Meso-American Barrier Reef Project, as well as the United Nations Environment Programme (UNEP), the World Conservation Monitoring Centre (WCMC), the Marine Conservation Society (MCS), the International Coral Reef Action Network (ICRAN) and Operation Wallacea. We also thank local subsistence fishermen communities and local schools.

1.10. Further information & enquiries

More background information on Biosphere Expeditions in general and on this expedition in particular including pictures, diary excerpts and a copy of this report can be found on the Biosphere Expeditions website www.biosphere-expeditions.org.

Enquires should be submitted via www.biosphere-expeditions.org/offices.

2. Reef Check Survey

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Jonathan Shrives
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Biosphere Expeditions

2.1. Introduction

Study site

The Marine Natural Monument Archipelago Cayos Cochinos (MNMACC) is located at latitude 15º 57' N and longitude 86º 30' W in the Caribbean. The MNMACC belongs to the Honduran Bay Islands Department and covers an area of 485.337 square km, consisting of a core area (Figure 2.1a) and a five nautical mile buffer zone (Figure 2.1c).

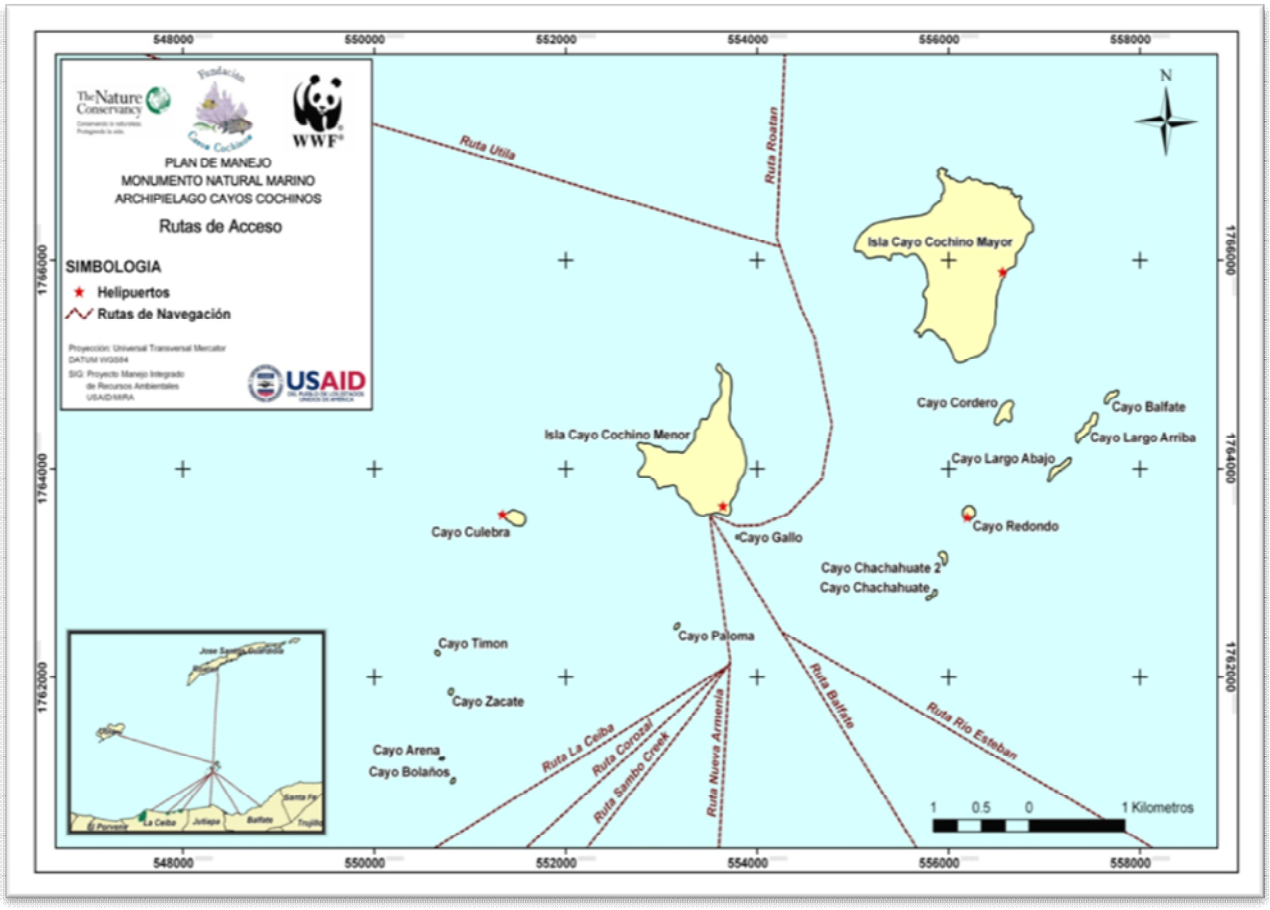


Figure 2.1a. Cayos Cochinos.

More recently a fishing buffer zone has been established south of the MNMACC up to the coast of mainland Honduras and extending three nautical miles beyond its eastern, western and northern limits (Figure 2.1b). Within this zone it is intended that industrial scale fishing will be banned, thus protecting the marine ecosystem beyond the boundaries of the MNMACC.

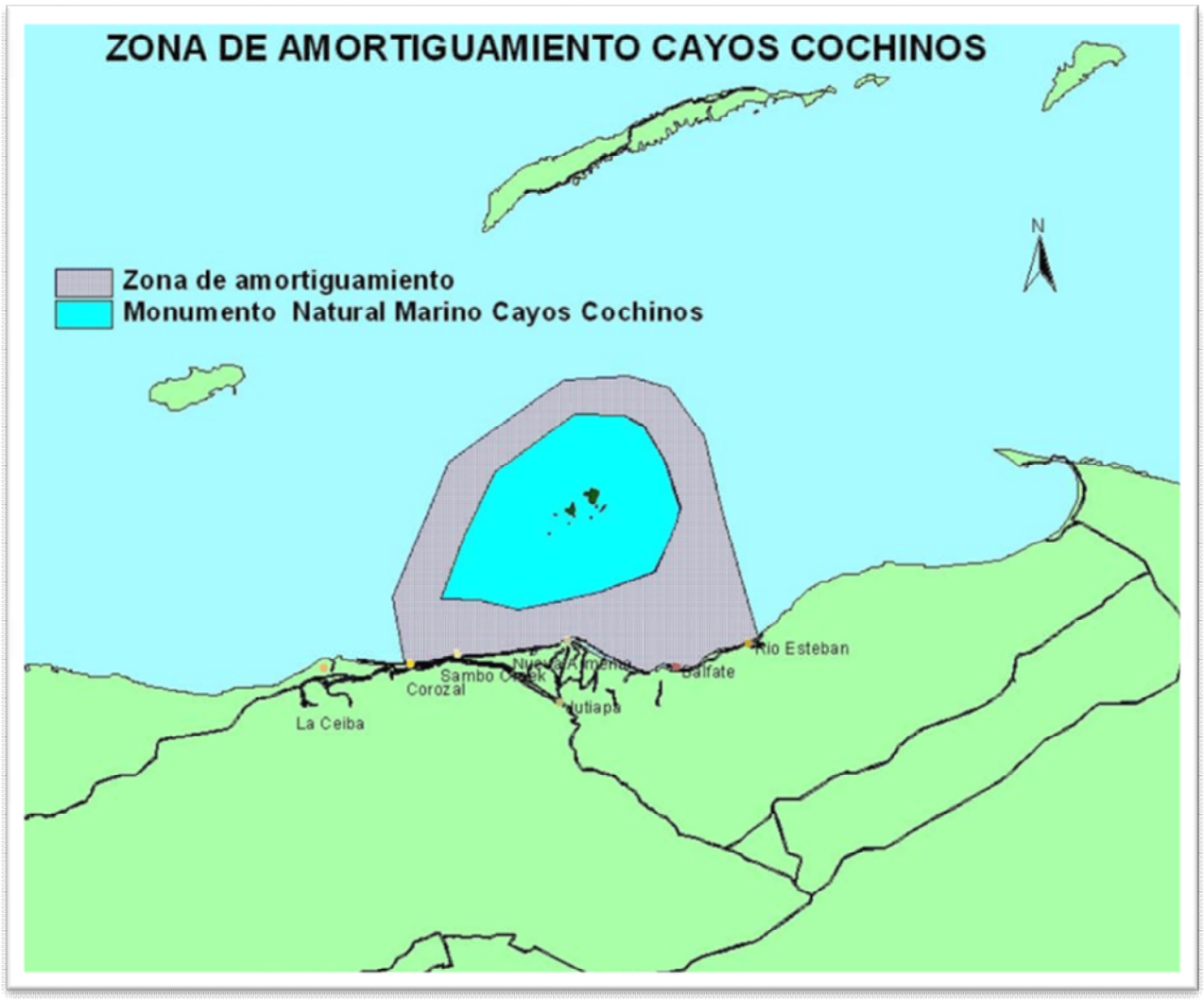


Figure 2.1b. Cayos Cochinos buffer zones.

The main areas influencing Cayos Cochinos from east to west are the city of La Ceiba (39.35 km); the Garífuna communities of Sambo Creek (25.83 km) and Nueva Armenia (18.53 km), which belong to the municipality of La Ceiba and Jutiapa in the Department of Atlántida; the Garífuna communities of Balfate (23.27 km) and Río Esteban (23.27 km), within the Department of Colón; and finally on the north side Roatán island (39.00 km) (Fig. 2.1c).

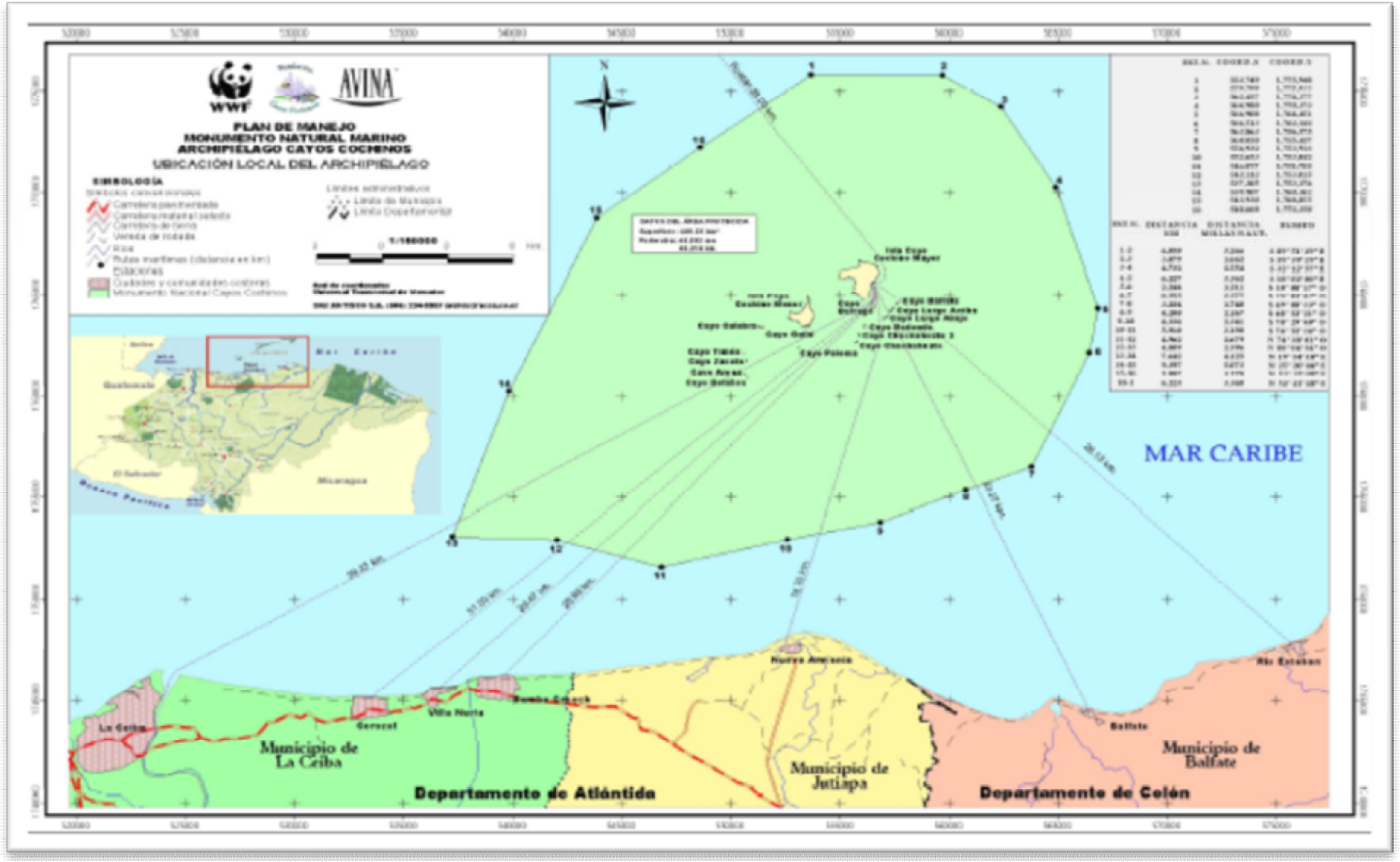


Figure 2.1c. Areas influencing Cayos Cochinos.

Type and structure of coral reefs at Cayos Cochinos

Given that part of the archipelago is inside the continental platform, the type of coral reefs present at Cayos Cochinos are barrier reefs. These develop only marginally into the deep sea, compared with further north where they extend further into the deep sea to a depth of up to 25 metres. (CRPMS-MNMCC 2004).

The *Plan de Manejo del Monumento Natural Marino Archipiélago Cayos Cochinos* (CRPMS-MNMCC 2004) reported 66 hermatypic coral species, 44 octocoral and five antipatharia species. (Guzmán and Guevara 1998) identified the star corals of the *Montastraea* genus, brain corals of the *Diploria* genus and the *Colpophyllia natans* species as being the most common.

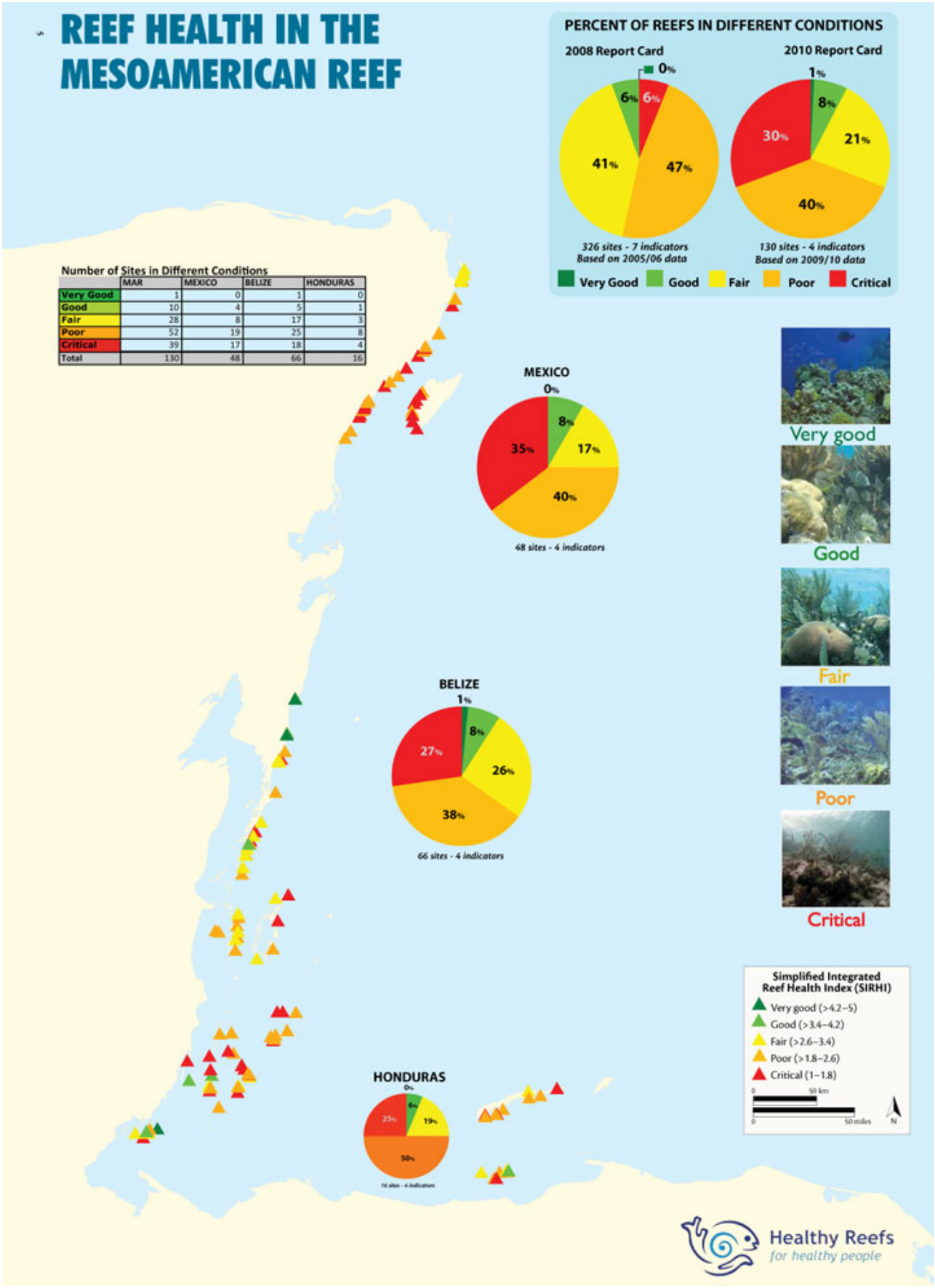
Conservation status

The results of the monitoring carried out by the Mesoamerican Barrier Reef System Project (MBRS) between 2004 and 2005 (Garcia-Salgado et al. 2006), showed the coral reefs at Cayos Cochinos to be in good to excellent condition within the context of the Mesoamerican Barrier Reef, despite having been considerably affected in 1998 by bleaching and Hurricane Mitch (HCRF/TNC 2008).

The Garcia-Salgado et al. (2006) study also showed that hard coral coverage (24.88%) was higher than the regional average and that average death in colonies sampled (15.8%) was much lower than the regional average of 40.1%. The deep reef front showed a higher species richness than the shallow sites, but also a higher death percentage. Project MBRS did not monitor bleaching, but Shrives (2006) reported that the incidence of white band disease was low in Cayos Cochinos.

More recently, Mesoamerican reef system health was analysed in 2010 by “Project Healthy Reefs for Healthy People” (Healthy Reefs Initiative 2010) using the Rapid Assessment methodology Reef Atlantic and Gulf (AGRRA). The study showed a pattern of degradation and some recovery, with 30% of reefs in a critical state of health (Figure 2.1d), and other “regular” study sites in decline, which suggests that the reef ecosystem is approaching a point where damage to it will be irreversible. The report also describes the reef health in Honduras, including Cayos Cochinos, stating that “the percentage of coral cover remains in good health compared to previous years”, but that “there is a reduction of other indicators such as herbivorous and commercial fish”, which could be the result of heavy fishing pressure in the Cayos Cochinos, www.healthyreefs.org.

According to *Sistema Nacional de Areas Protegidas* (SINAPH), protected areas in Honduras must be evaluated every five years. This entails inspecting and modifying, where necessary, the protected area management plan. In 2004 a first management plan was elaborated for the MNMACC, which was later modified for the period 2008-2012. This modification was made with the participation of all groups involved in resource management (Honduras Coral Reef Foundation/TNC 2008). One of the changes included in this management plan was how resource use is zoned, establishing two macrozones instead of three, a nuclear zone around the larger key and a restricted zone of public use, It also established four temporary fishing zones, located at Pelican Point, Mariposales, La Grupera and Roatán Bank (Figure 2.1e) (Honduras Coral Reef Foundation/TNC 2008).



	MAR	MEXICO	BELIZE	HONDURAS
Very Good	1	0	1	0
Good	10	4	5	1
Fair	28	8	17	3
Poor	52	19	25	8
Critical	39	17	18	4
Total	130	48	66	16

Figure 2.1d. Mesoamerican reef health, courtesy of www.healthyreefs.org.

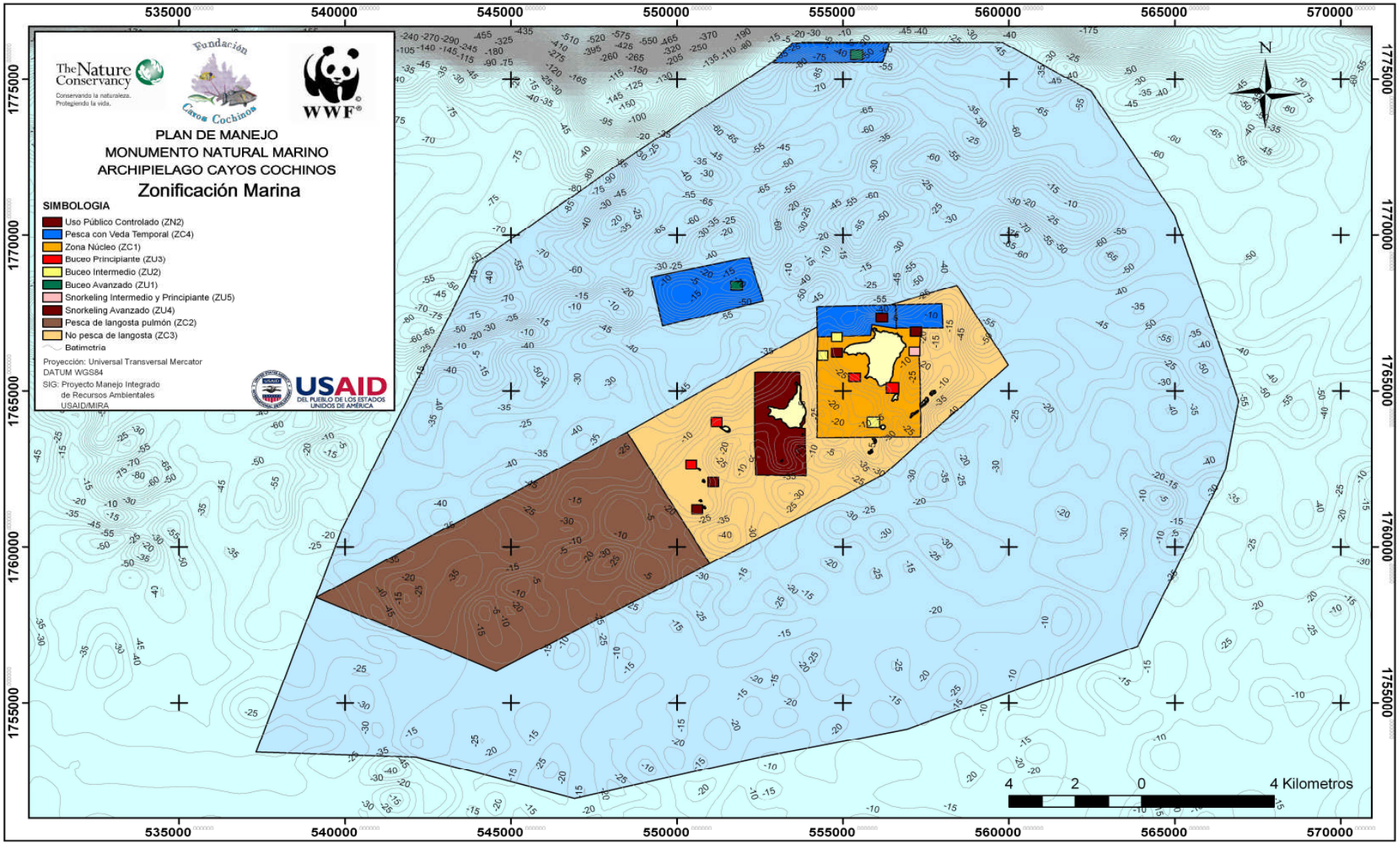


Figure 2.1e. Zoning of Cayos Cochinos

Honduras Coral Reef Foundation

The Honduras Coral Reef Foundation (HCRF) was founded in 1993 and is the non-governmental organization (NGO) officially responsible for the management and conservation of the MNMACC. The main tasks for HCRF are to enhance conservation and management activities; to enforce natural resource use regulations; to increase scientific station development; and to promote sustainable development options for local fishing communities. To achieve these objectives in the long term, HCRF has been supported mainly by AVINA/MARVIVA, the World Wildlife Fund (WWF), The Nature Conservancy (TNC), Operation Wallacea and Biosphere Expeditions, amongst other international institutions. In 2004 HCRF, along with WWF and the support of the Cayos Cochinos local communities, published the first management plan for the area specifying regulations to further the conservation and protection of all natural resources. In the same year a sustainable development plan for tourism was created, thus giving HCRF the tools to measure the carrying capacity and public use of the whole area.

Biosphere Expeditions was invited in 2004 to help with the implementation of this plan, with the first research expedition taking place in 2005. As part of the management plan several zones with different use regulations were established. In order to find out if these zones and their regulations have been effective for the conservation of natural resources, a long-term monitoring programme of the reef's conditions needed to be conducted. The Reef Check methodology (Hodgson et al. 2006) provided an easy protocol for this purpose that is replicated all over the world and allows for the use of volunteer divers provided by Biosphere Expeditions, Operation Wallacea and other NGOs.

Reef Check

Reef Check is the name of both the most widely used coral reef monitoring protocol and an international coral reef conservation programme. The Reef Check programme brings together community groups, government departments, academics and other partners to fulfil its objectives. These include: educating the public about the coral reef crisis; creating a global network of volunteer teams to regularly monitor and report on reef health; scientifically investigating coral reef ecosystem processes; facilitating collaboration between academic institutions, NGOs, governments and the private sector; and stimulating local community action to protect remaining pristine reefs and rehabilitate damaged reefs worldwide (Hodgson 2000).

Reef Check was designed to assess the health of coral reefs and is quite different from other monitoring protocols. Since its inception Reef Check has focused on the abundance of particular coral reef organisms that best reflect the condition of the ecosystem and that are easily recognisable to the general public. Selection of these "indicator organisms" was based on their economic and ecological value, their sensitivity to human impacts and ease of identification. Sixteen global and eight regional indicator organisms serve as specific measures of human impacts on coral reefs. These indicators include a broad spectrum of fish, invertebrates and plants that indicate human activities such as fishing, collection or pollution. Some Reef Check indicator groups are individual species, whilst others are families (Hodgson et al. 2000).

For instance, in the Caribbean the Nassau grouper (*Epinephelus striatus*) is the most desired fish in the live food fish trade, whereas the trumpet triton (*Charonia variegata*) is collected for the aquarium trade. Both species are very distinctive organisms and excellent indicators of human predation. On reefs where these organisms are heavily exploited, their numbers are expected to be low compared to their abundance on unexploited reefs. (Hodgson and Liebeler 2002).

Reef Check teams collect four types of data: (1) a description of each reef site based on over 30 measures of environmental and socio-economic conditions and ratings of human impacts, (2) a measure of the percentage of the seabed covered by different substrate types, including live and dead coral, along four 20 m sections of a 100 m shallow reef transect, (3) invertebrate counts over four 20 m x 5 m belts along the transect and (4) fish counts up to 5 m above the same belt (Hodgson et al. 2006).

2.2. Methods

Site selection & sampling design

Reef Check's regional coordinator advised us on the site selections as well as other aspects of setting up our Reef Check teams. All teams had a team scientist and a team leader trained by a Reef Check trainer.

The Reef Check protocol is designed to be as simple as possible so that untrained volunteer divers can participate. Practical team sizes are two, three or four pairs of divers. However, larger or smaller groups are possible. Divers should be sufficiently experienced (>30 dives or equivalent experience) that they are able to perform simple activities underwater. It is the role of the team leader to decide if the team members are adequately qualified to undertake these activities.

Reef Check surveys can be carried out by snorkellers in shallow water (Hodgson et al. 2006). An ideal Reef Check team includes six members (three buddy pairs) plus support crew, each with different specialties and experience. In our case we selected a team of six members plus the team leader and the scientific leader of the expedition. Some adaptations to local conditions were made (i.e. substrate underwater hand signals) for the team members.

Seven dive sites (Table 2.2a & Figure 2.2a) within the different management zones inside the Marine Protected Area were selected according to their level of use in relation to the regulations of the management plan. Selections were made so that over time the effectiveness of the recently established zoning and regulations can be monitored.

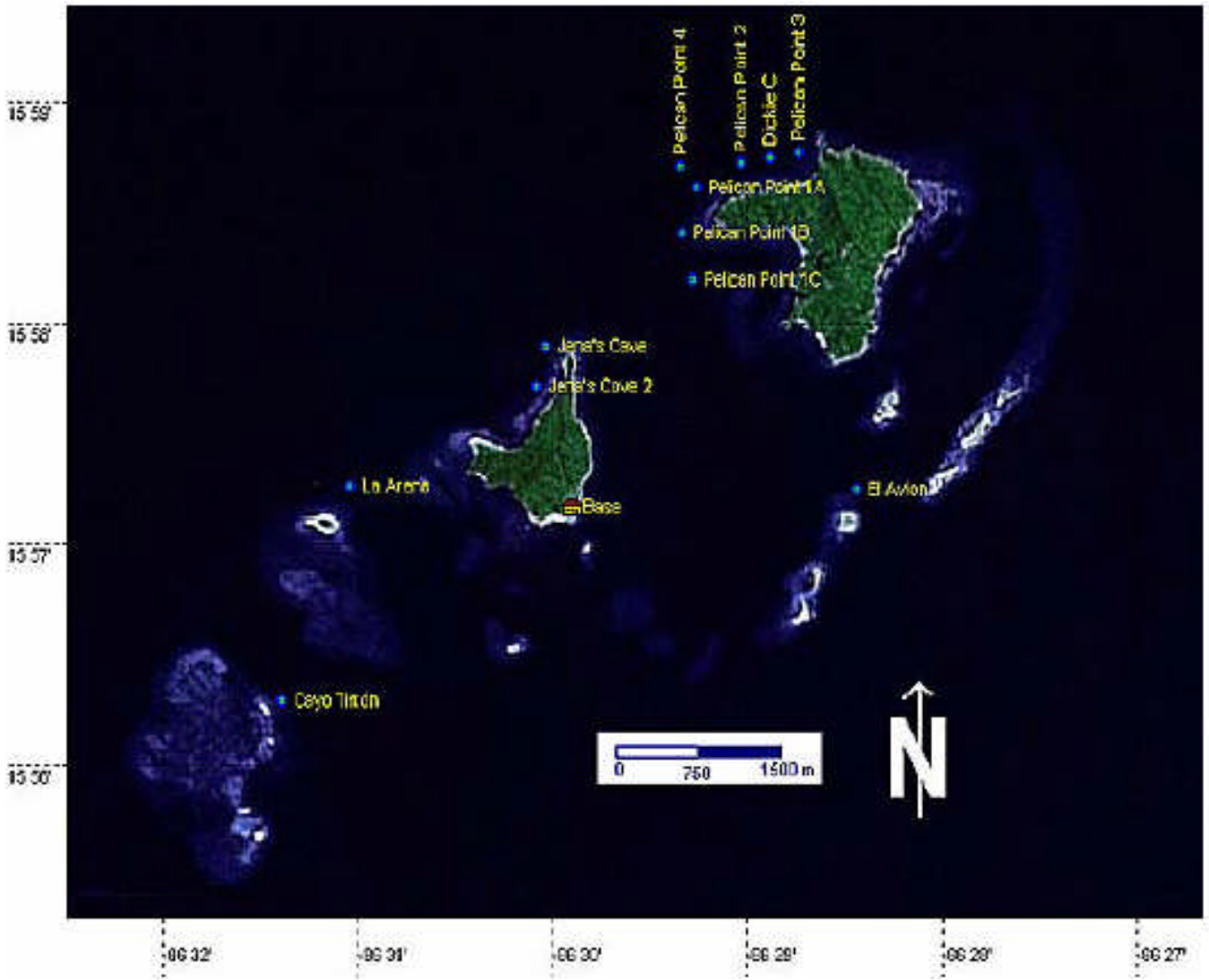


Figure 2.2a. Overview of dive sites 2006 - 2011 in relation to base and longitudinal/latitudinal grid. Map of the study area. See also Google Maps for an internet-driven view of the study site.

Table 2.2a. Dive sites and impact patterns.

Dive site name	Fishing allowed	Tourism impact (2006)	Tourism impact (2007)	Tourism impact (2008)	Tourism impact (2009)	Tourism Impact (2011)
Arena	Yes	Medium	Medium	Medium	Medium	Medium
Timón	Yes	Medium	High	Medium	High	High
El Avión	No	High	High	High	High	High
Pelican Point 2	No	Medium	Medium	Medium	Medium	Medium
Dickie C (Pelican Point 2.5)	No	Medium	Medium	Medium	Medium	Medium
Pelican Point 4	No	Low	Low	Low	Medium	Medium
Pelican Point 0.5	No	Not surveyed	Not surveyed	Not surveyed	Medium	Not surveyed
Pelican Point 1A	No	High	High	Not surveyed	Not surveyed	Not surveyed
Pelican Point 1B	No	Medium	Not surveyed	Not surveyed	Not surveyed	Not surveyed
Pelican Point 1C	No	Medium	Not surveyed	Not surveyed	Not surveyed	Not surveyed
Pelican Point 3	No	Medium	High	Not surveyed	Not surveyed	Not surveyed

All sites were recorded by Global Positioning System (GPS) coordinates for future comparative surveys. All positions were collected in degrees, minutes and seconds NAD27 Central, in accordance with Reef Check methodology.

Training of expedition team members

The first three days of each expedition slot were spent on land and in the water with training. Each group was prepared for its fieldwork, and received lectures on the research methods and goals over and above what is recommended by Reef Check. Open water dives were organised so that everyone could get comfortable in the water and put into action the fish, invertebrate and other ID skills taught before the actual survey work began.

Talks were organised to make team members familiar with the research and the area and to tell teams about species assemblages and their function in the ecosystem. Once the survey work started, the tasks of the expedition team as a whole were dive-based and consisted of several distinct underwater activities. Diving ability was assessed and team members were allocated to suitable tasks. Training in organism, substrate and disease identification skills was given using Reef Check teaching materials and special slide shows and discussion forums (Cubas et al. 2006).

Survey procedures & data collection

Data collection was based on methods described in Hodgson et al. (2006) with some minor adaptations to local conditions, such as designing a new set of hand signals to simplify underwater communication between team members.

Data were recorded using underwater slates and then transferred at the end of the day onto one of the computers provided by HCRF using standard Reef Check Excel datasheets. These Excel sheets were then submitted to Reef Check.

Analysis of data

For the analysis of the data a multivariate analysis of variance (ANOVA) statistical test was performed. This test compares if the samples differ significantly in the amount of indicator species recorded.

2.3. Results

2.3.1. Fish

In five years of monitoring (Cubas et al. 2006, Shrives et al. 2007, Shrives et al. 2008, Aronne et al. 2009, all relevant Biosphere Expeditions reports from www.biosphere-expeditions.org/reports), a total of 4,591 fish were registered of which 31.67% (n=1,454) were parrotfish, followed by Haemulidae with 25.75% (n= 1,182), snapper at 18.64% (n=856), butterflyfish at 12.94% (n=594), moray eel at 9.28% (n=426), and groupers with 1.72% (n=79).

In 2011 the most abundant indicator fish were Haemulidae with an average (n= 4.9), followed by parrotfish (n = 4.0), snappers (n = 3.4), with Nassau groupers being absent (n = 0) (Fig. 2.3.1g). The site showing the highest total average abundance of all fish indicators was Pelican 4 (n = 42), followed by Timon (n = 38.29) and El Avion (n = 18.57).

A two-way ANOVA was performed (Figure 2.3.1g) to determine the interaction between the categories of fish from sites in 2011 and shows that there is a significant difference $p = 0.000$ between the means ($p \leq 0.05$ with 95% confidence).

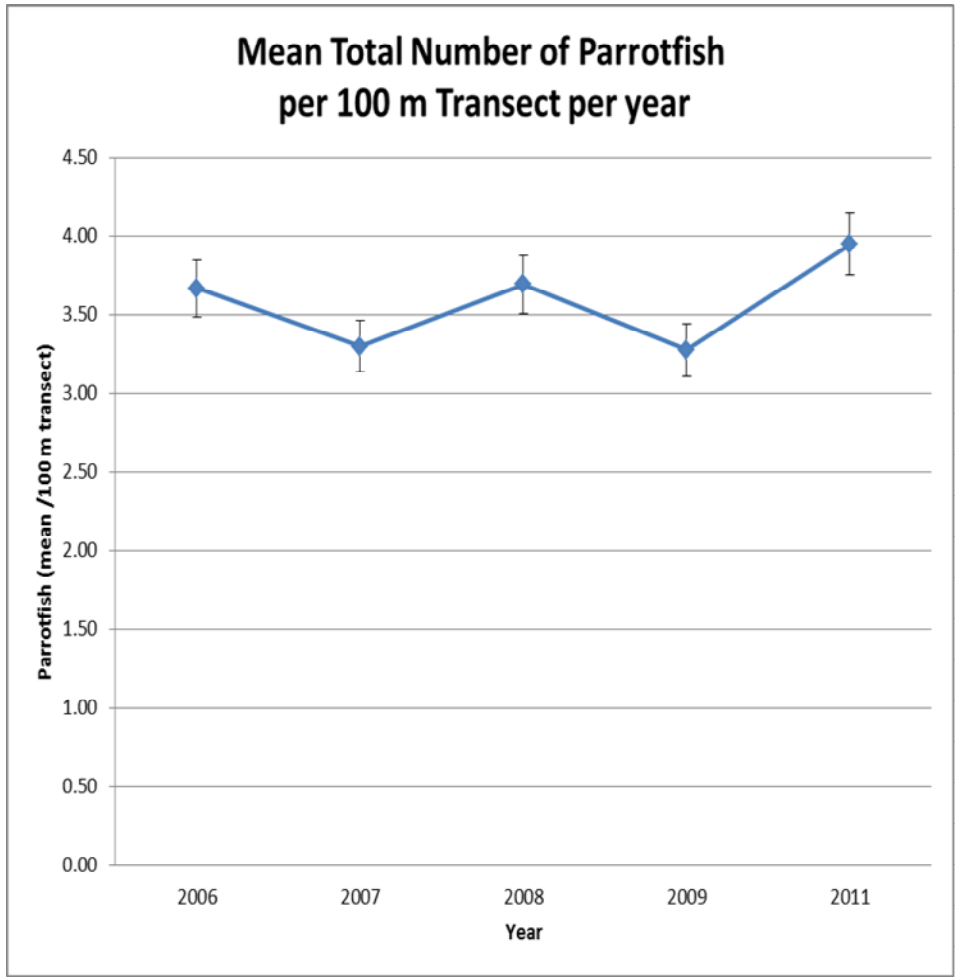


Figure 2.3.1a. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects 2006-2011. Bars are +/- 1 standard error. Parrotfish abundance of 2006-2011 was estimated at 3.48 fish on average with p = 0.00000961395 (p ≥ 0.05 with 95% confidence), which shows that there is a statistically significant difference between monitoring years. However, as can be seen from the graph, there is no trend in the development of abundance with values oscillating around the 3.48 mean.

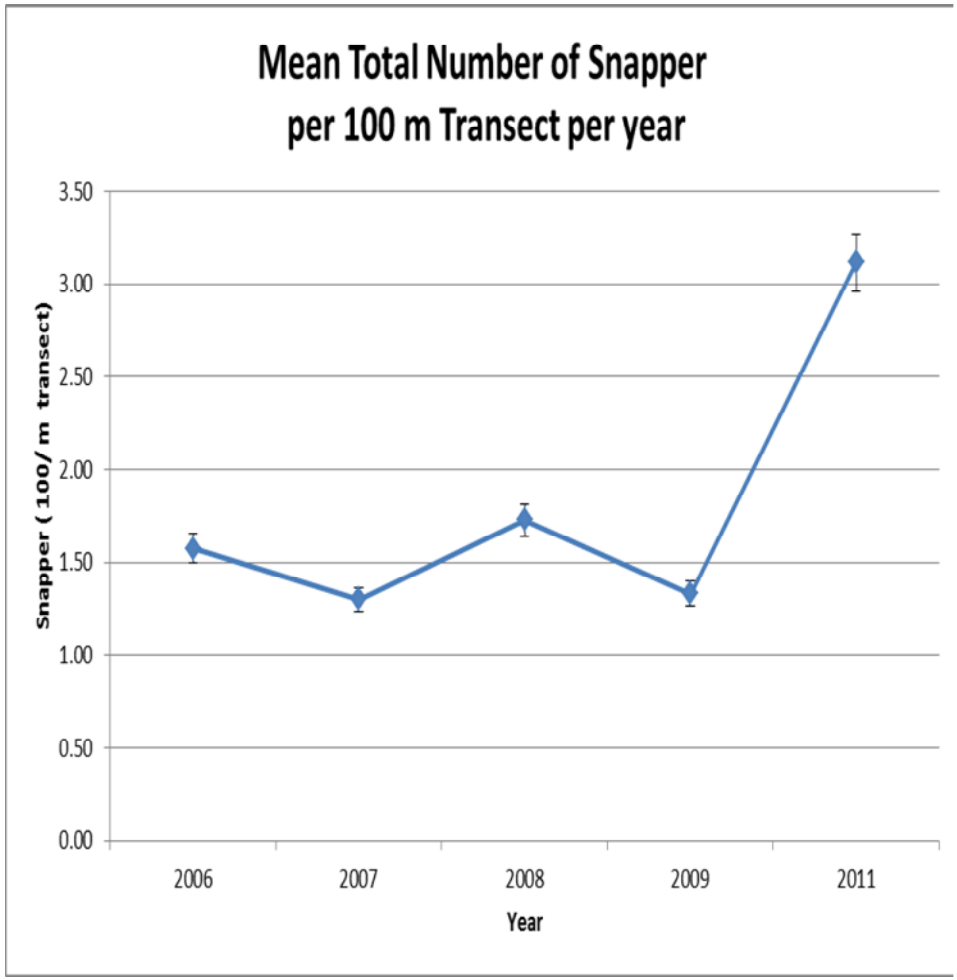


Figure 2.3.1b. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects in 2011. Bars are +/- 1 standard error. The abundance of snapper from 2006-2011 averages 1.81 fish. When applying the Kruskal-Wallis test to determine whether there is any significant difference between year averages, then p = 0.36; since the p-value is greater than or equal to 0.05, there is no statistically significant difference between the averages with a 95.0% level of confidence.

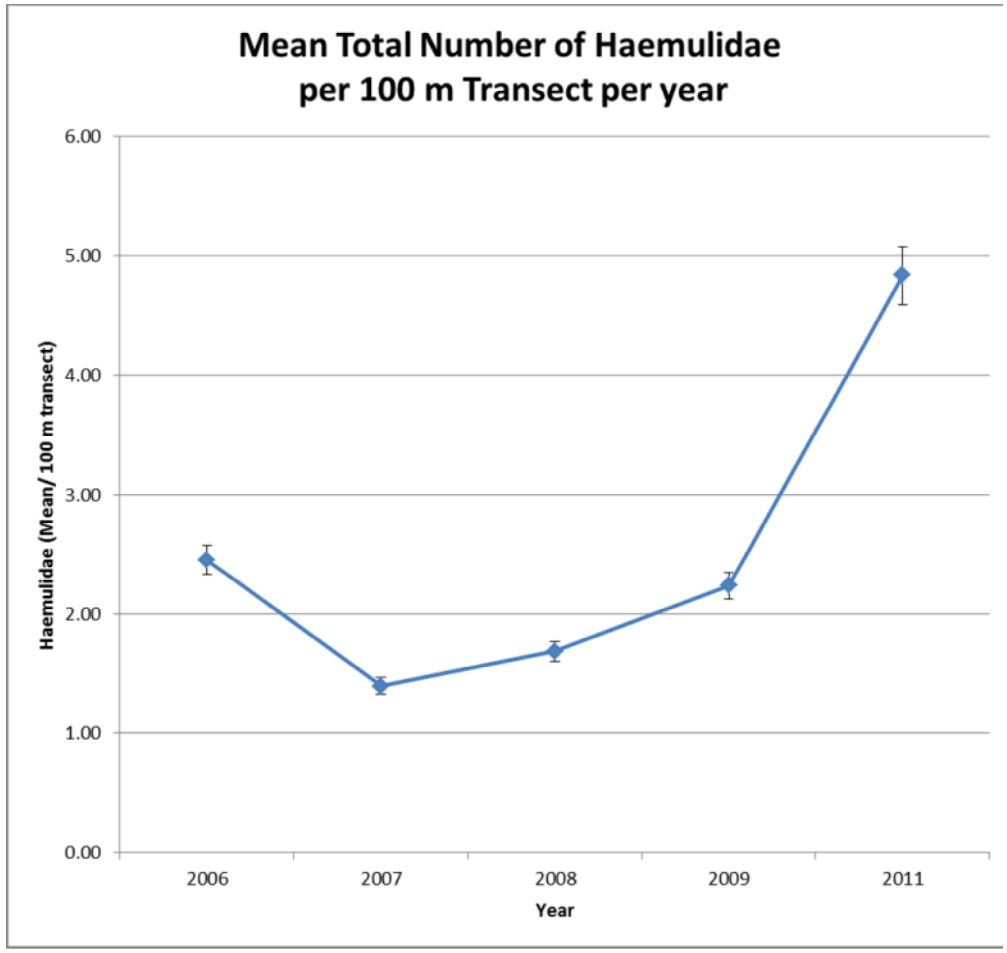


Figure 2.3.1c. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects in 2011. Bars are +/- 1 standard error. The abundance of Haemulidae from 2006-2011 averages 1.94 fish, with p = 0.0144143 (p ≥ 0.05 with 95% confidence), which shows that there is a statistically significant increase of Haemulidae in five years of monitoring at Cayos Cochinos.

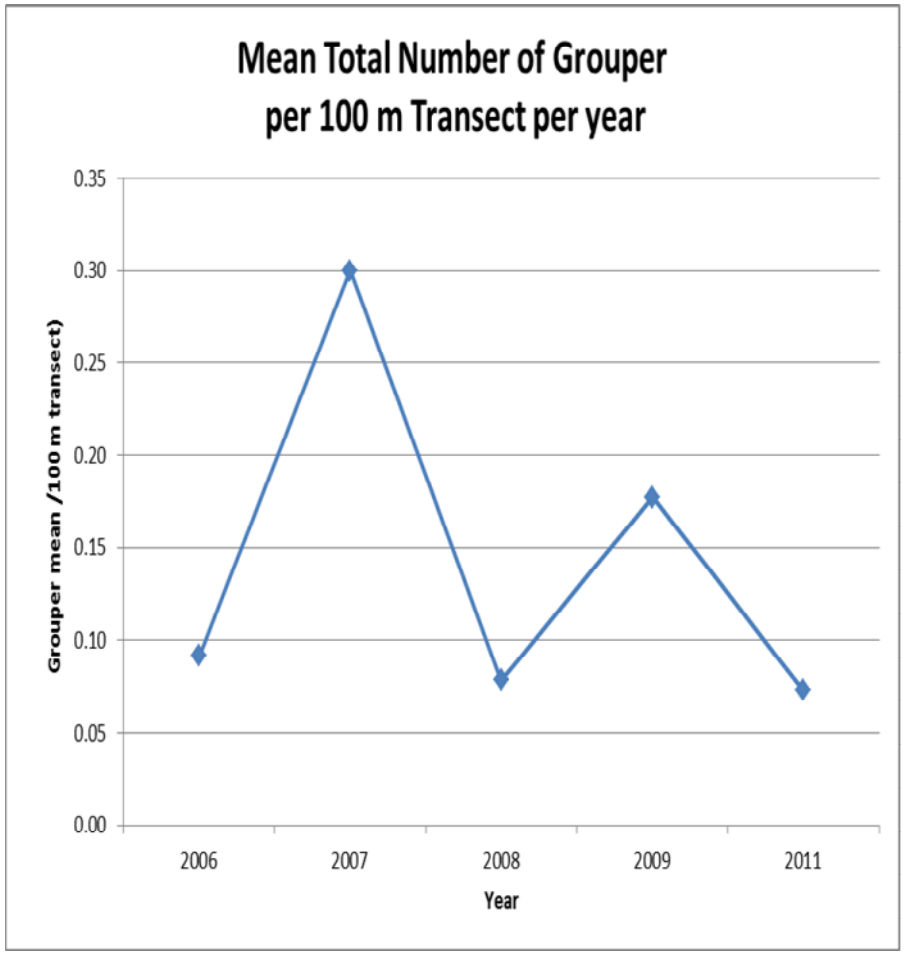


Figure 2.3.1d. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects in 2011. Bars are +/- 1 standard error. Grouper abundance in five years of monitoring at Cayos Cochinos is 0.14 fish on average, with p = 0.0295335 (p ≥ 0.05 with 95% confidence), which shows that there is a statistically significant difference between monitoring years. However, as can be seen from the graph, there is no trend in the development of abundance with overall means remaining very low.

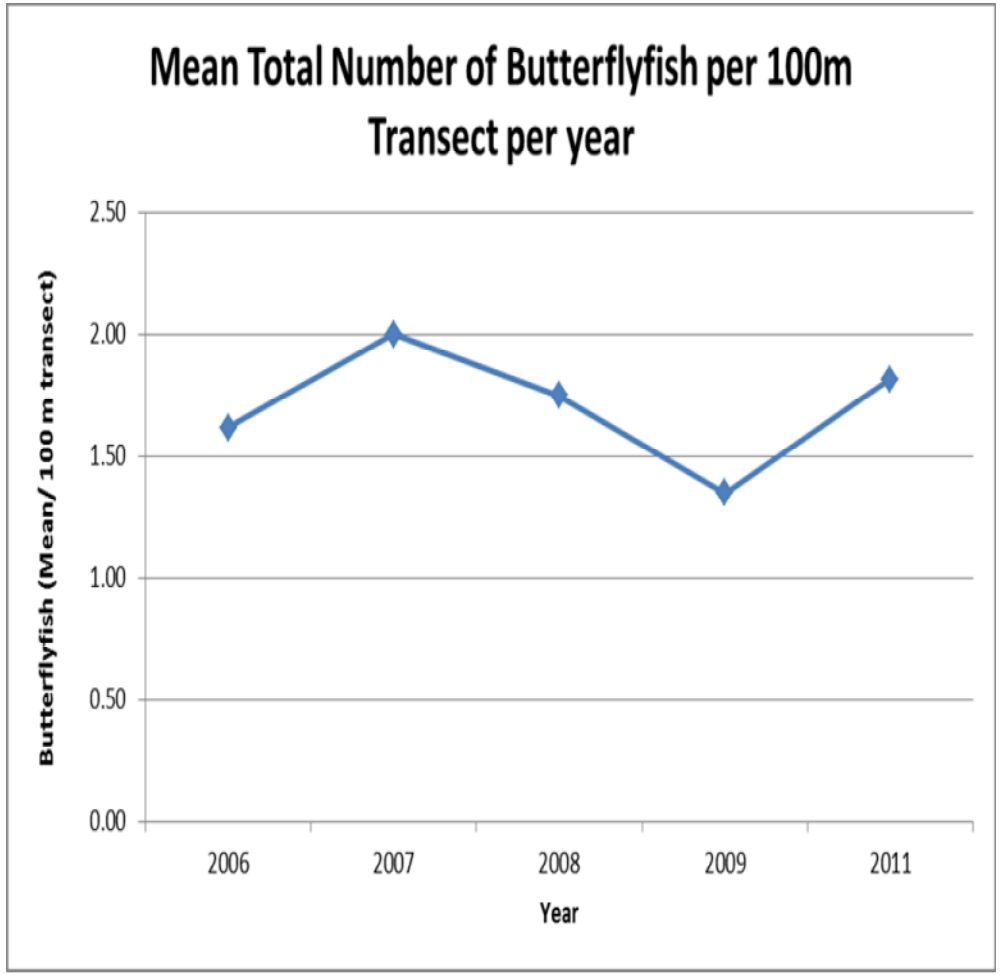


Figure 2.3.1e. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects in 2011. Bars are +/- 1 standard error. The abundance of butterflyfish in five years of monitoring at Cayos Cochinos is averaging 1.71 fish, with p = 0.000130603 (p > 0.05 with 95% confidence), which shows that there is a statistically significant difference in five years of monitoring at Cayos Cochinos. No trend is apparent with averages oscillating around the 1.71 mean.

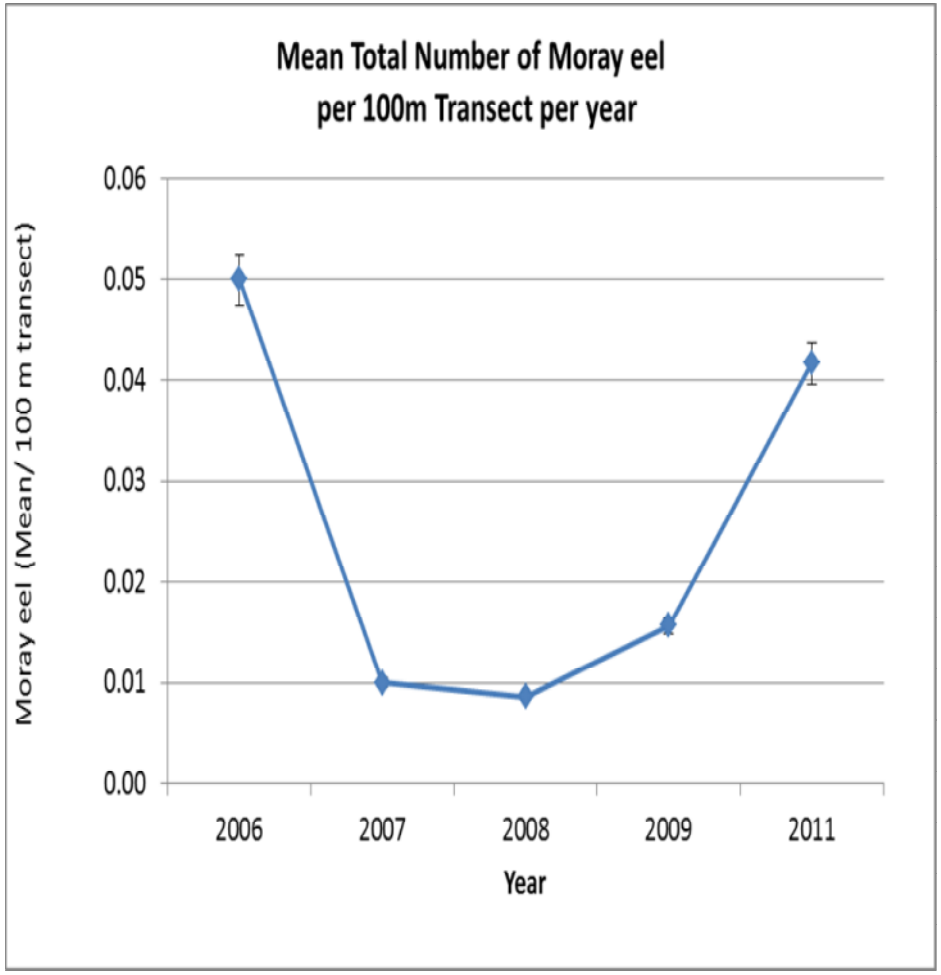


Figure 2.3.1f. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects in 2011. Bars are +/- 1 standard error. Moray eel abundance in five years of monitoring at Cayos Cochinos is 0.02 fish average with p = 0.0858093 (p > 0.05 with 95% confidence), which shows that there is no statistically significant difference in five years of monitoring at Cayos Cochinos and overall numbers very low.

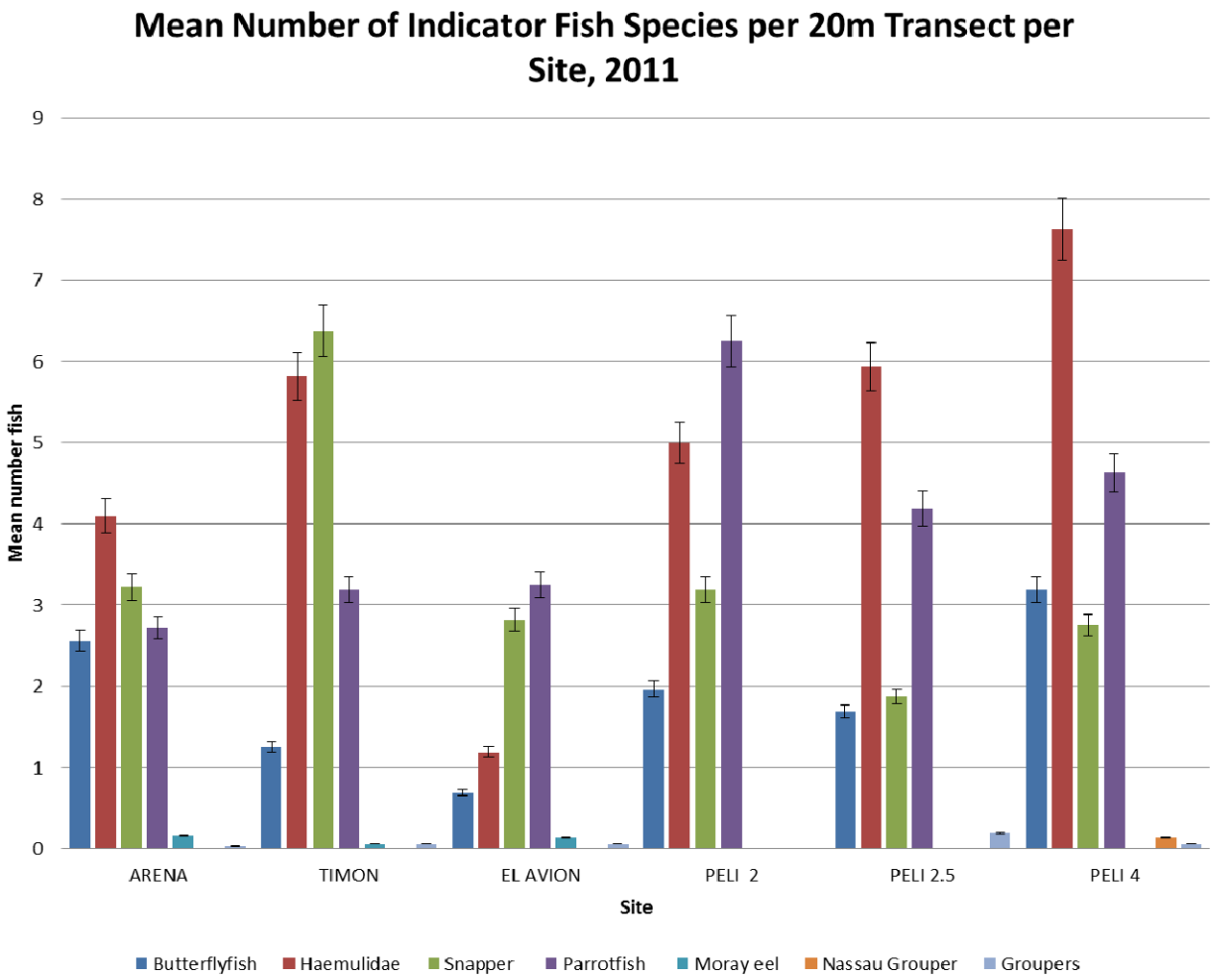


Figure 2.3.1g. A comparison of between and within survey sites for average number of fish per category of indicator species seen on transects in 2011. Bars are +/- 1 standard error.

A one-way ANOVA was also performed on the indicator species observed within the zones where fishing is allowed and where fishing is not allowed. Parrotfish abundance is significantly different between fished and un-fished sites ($p < 0.05$), with none of the other categories of fish showing any difference (Table 2.3.1g).

Table 2.3.1g. Results of one-way ANOVA for the categories of Reef Check fish indicator species, tested for differences in mean abundance between fished and non-fished sites. * indicates a significant difference.

Indicator species	*p* value 2011
Butterflyfish	0.139
Haemulidae	0.005
Snapper	0.396
Parrotfish	0.004*
Moray eel	0.049
Groupers	0.779

2.3.2. Invertebrates

Diadema

During the years of analysis (2006 to 2011, with the exception of 2010, when no expedition took place), we observed a high abundance of Diadema sea urchins at El Avión (mean n=27.71) when compared to the other sites. Abundance peaked in 2008 (n=56.44) and was lowest in 2006 (n=4.8).

In 2011 the abundance was lower than in 2008, but there was an increase compared to 2009. As in previous years, Diadema abundance is low at Pelican sites compared to other sites (Figure 2.3.2a).

However, a multivariate ANOVA analysis with the Kruskal-Wallis test shows $p = 0.11$, and given that $p \geq 0.05$, there is no statistical difference between the means of El Avión and the rest of the sites with a 95.0% confidence level (Figure 2.3.2b).

Gorgonia

A comparison of the abundance of Gorgonia at the different sites over the monitoring period (2006-2011, except 2010) shows a larger average abundance of Gorgonia at Pelican 4 compared to the other sites (mean=484.41, max=747.5 in 2008, min=350 in 2007). However, during this study in 2011 we observed the highest average abundance at Timón (mean=984.50) and the lowest abundance at El Avión (mean=122.69) (Figure 2.3.2c).

A multivariate ANOVA Kruskal-Wallis test was used to determine the significance of the differences between Gorgonia abundances at the various sites. This yield $p = 0.004$ with $p < 0.05$, meaning that there is a statistically significant difference with a 95.0% level of confidence between the medians of Pelican 4 compared to Timón and Pelican 2 (Figure 2.3.2d).

Overall

An ANOVA analysis of average abundance of invertebrate indicators per site in 2011 yielded a significance level of $p = 0.711$ ($p \geq 0.05$ with a 95% level of confidence), indicating that there is no statistical significant difference between the levels of invertebrate indicator species at the different sites in 2011 (Figure 2.3.2e).

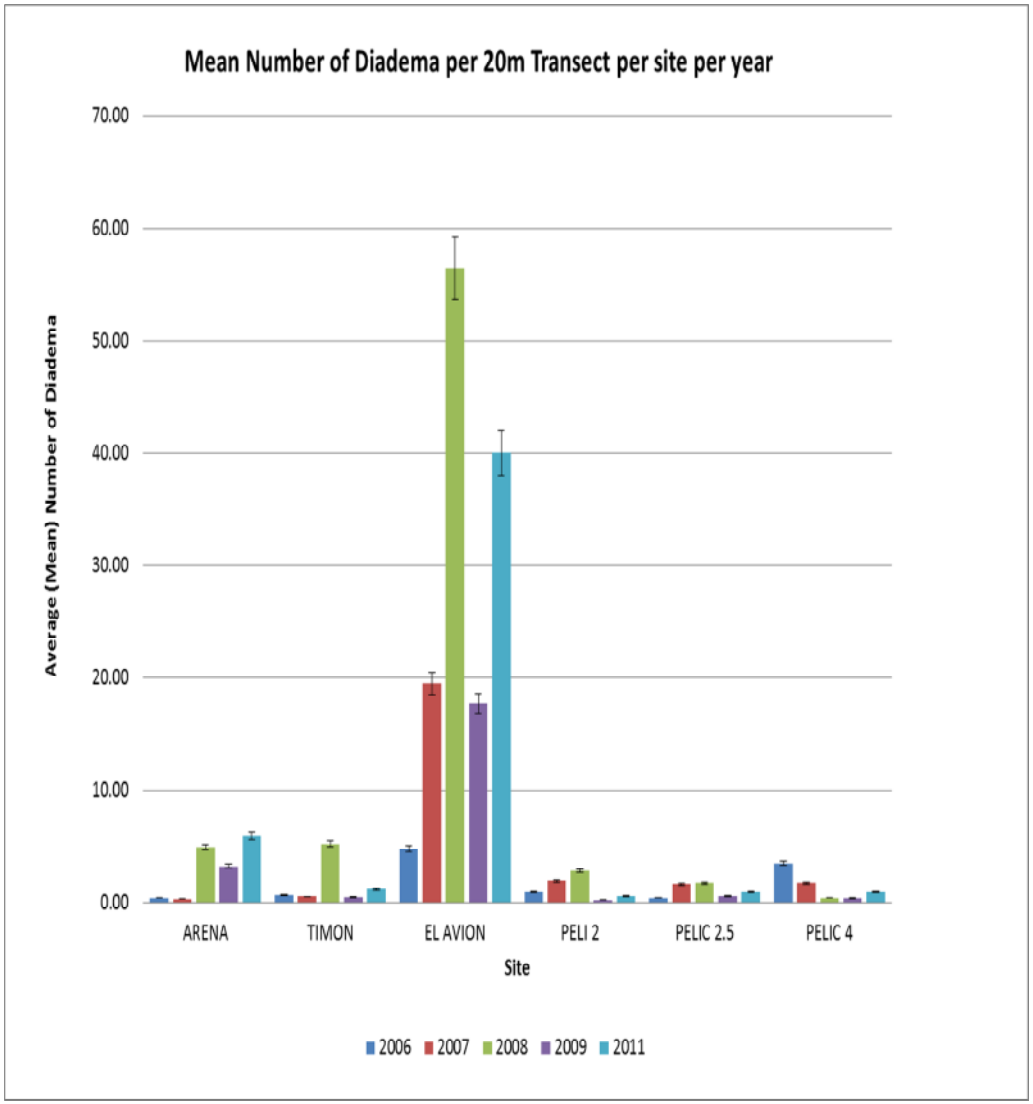


Figure 2.3.2a. Mean number of Diadema recorded at each site each year (2006-2011). Bars are +/- 1 standard error.apparent with averages oscillating around the 1.71 mean.

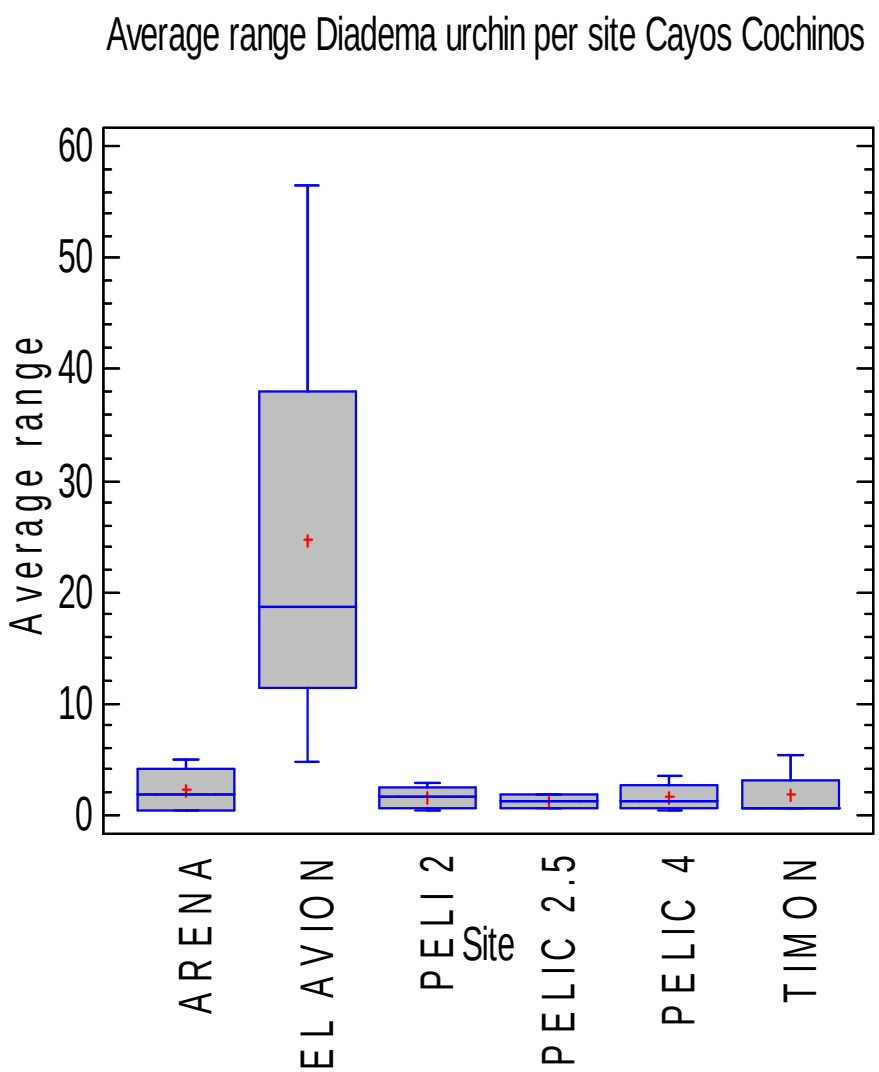


Figure 2.3.2b. The range of Diadema abundance at all sites over all surveyed years. Lines show medians and error bars show +/- 1 standard error.

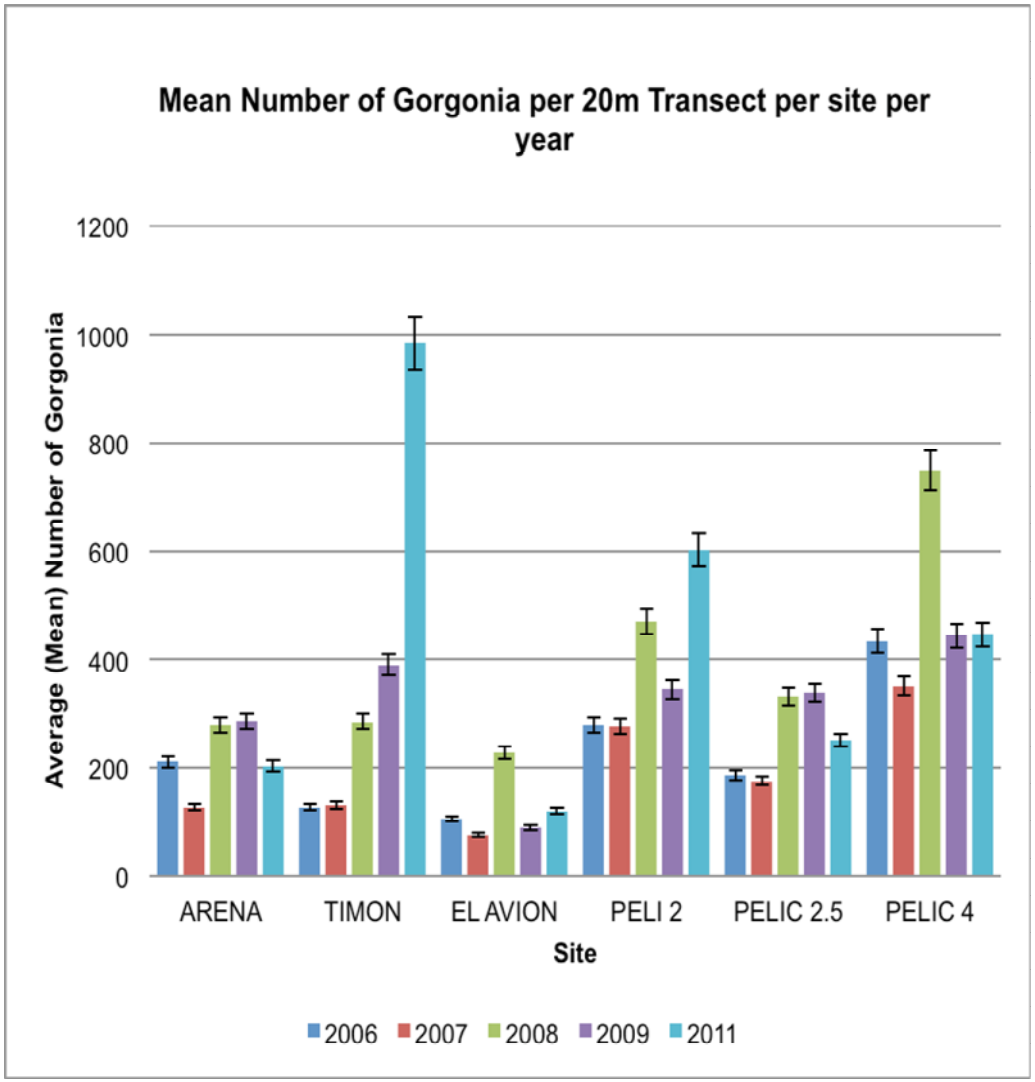


Figure 2.3.2c. Mean number of Gorgonia recorded at each site each year (2006-2011). Bars are +/- 1 standard error.

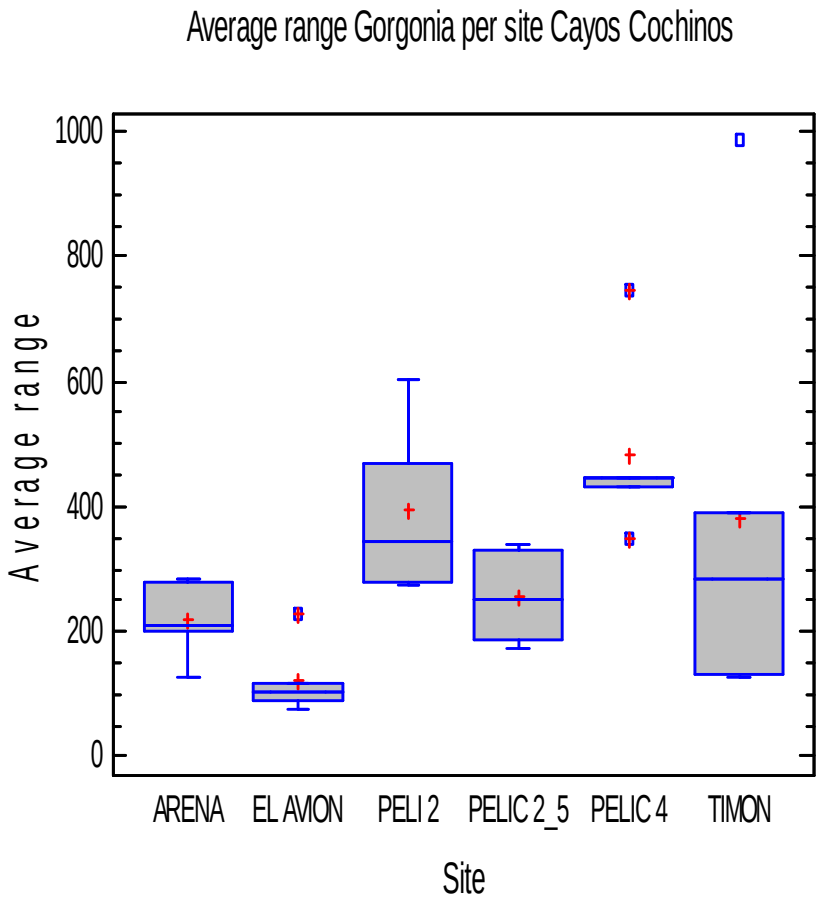


Figure 2.3.2d. The average range of Gorgonia abundance at all sites over all surveyed years. Lines show medians and error bars show +/- 1 standard error

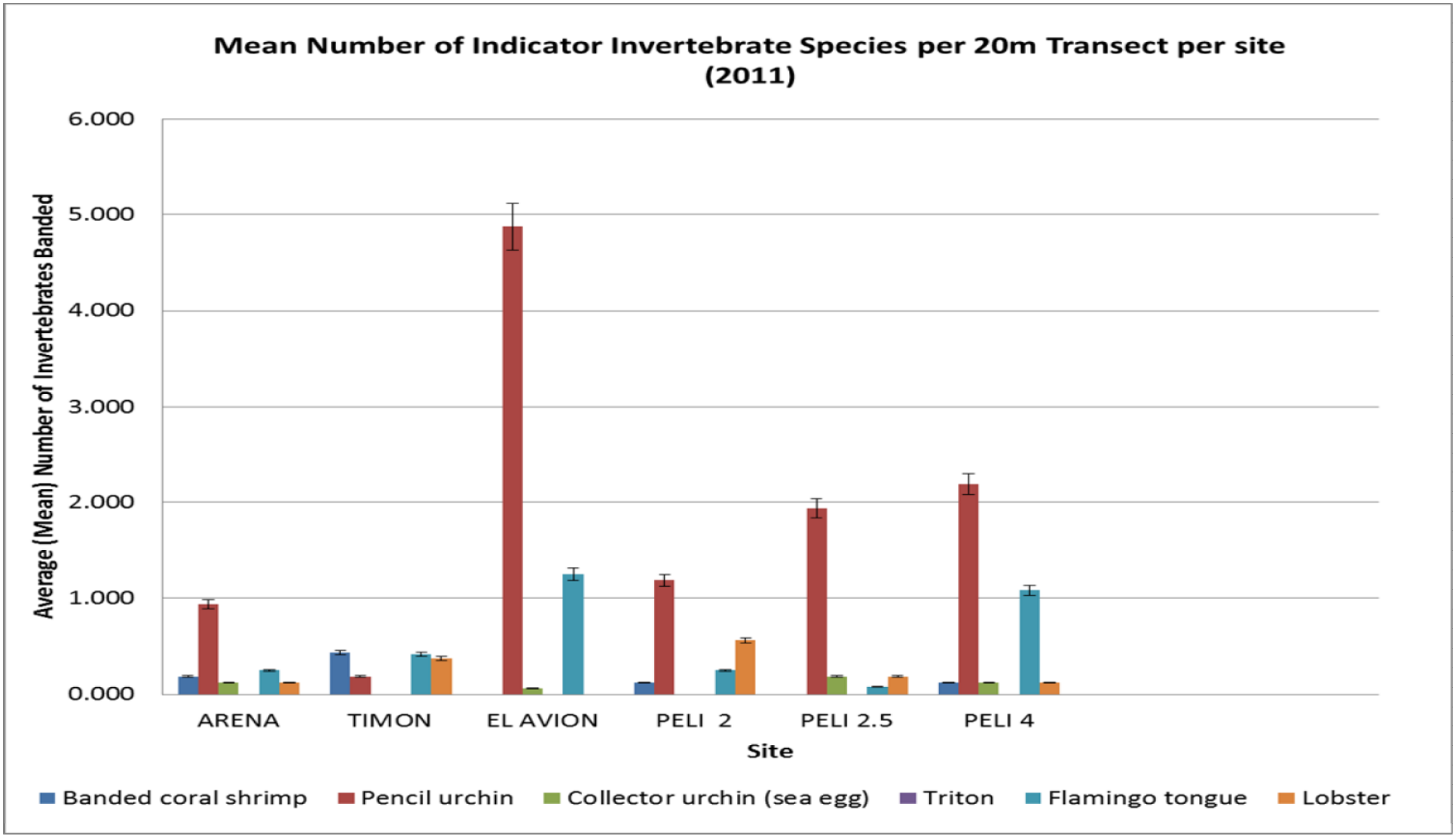


Figure 2.3.2e. Mean numbers of each invertebrate indicator species category In each site in 2011. Gorgonia and Diadema were excluded due to their comparatively high abundance and subsequent effect on scale. Bars indicate +/- 1 standard error.

2.3.3. Substrate Structure / Benthic Communities

An analysis of the substrate around Cayos Cochinos from 2006 to 2011 shows that significant changes in this period occurred in the rock (RC), hard coral (HC) and nutrient indicator algae (NIA) substrate categories. For RC the average was 26.79% (max = 44% in 2011 and min = 7.82% in 2008), for HC the average percentage was 17.12% (max = 23.78% in 2009 and min = 7.37% in 2008) and for NIA the average was 16.40% (max = 20.42% in 2006 and min = 13.10% in 2009) (Figure 2.3.3a).

Applying the ANOVA Kruskal-Wallis test to the data and comparing the means of the different substrate categories reveals a statistically significant change for RC, which is increasing, and HC, which is decreasing, with $p < 0.05$ ($p = 0.0000046$). The other categories did not show any significant difference throughout the different years of monitoring (Figure 2.3.3b).

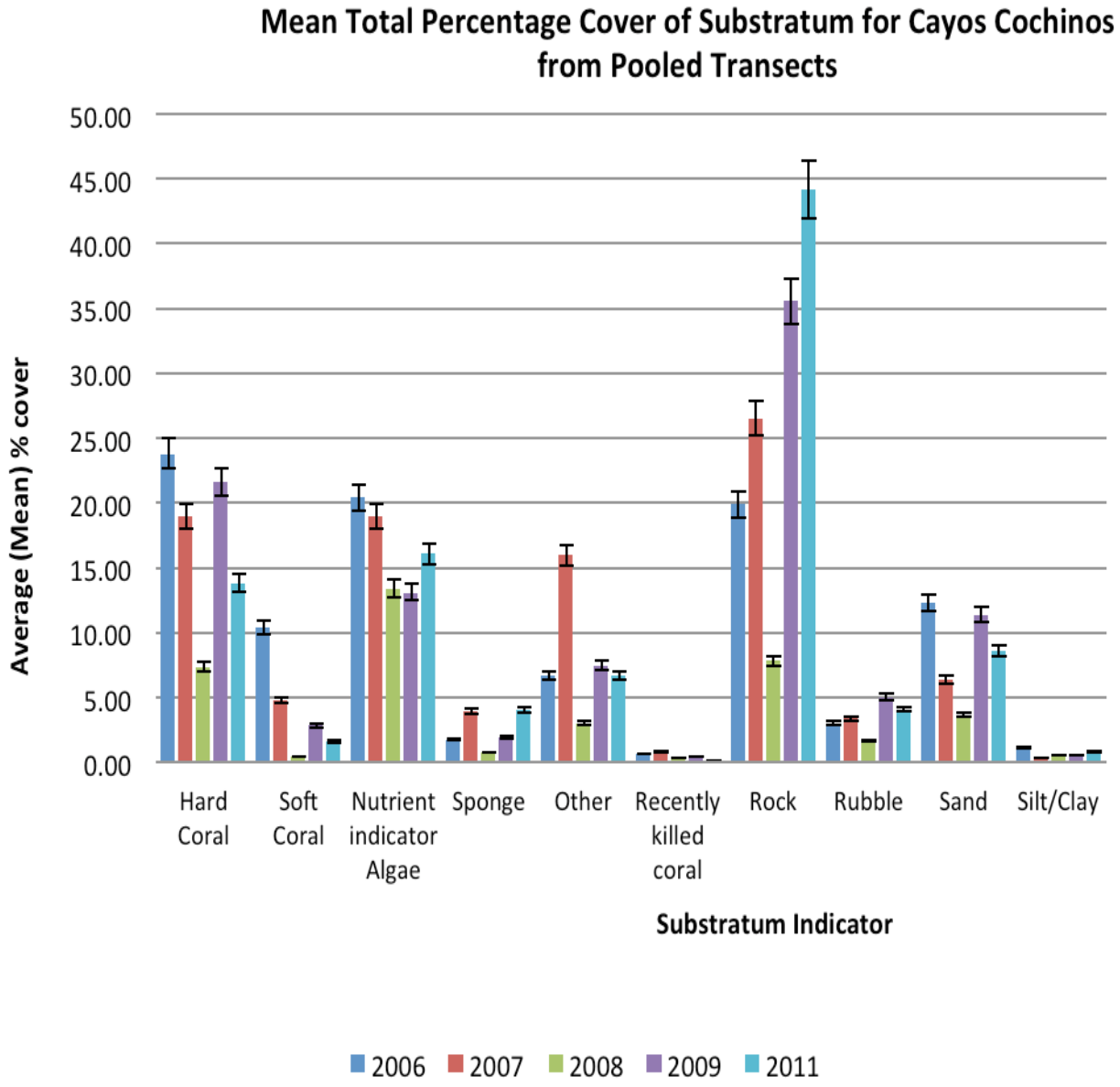


Figure 2.3.3a. Mean percentage cover of substrate categories from pooled data of all transects 2006-2011. Bars indicate +/- 1 standard error.

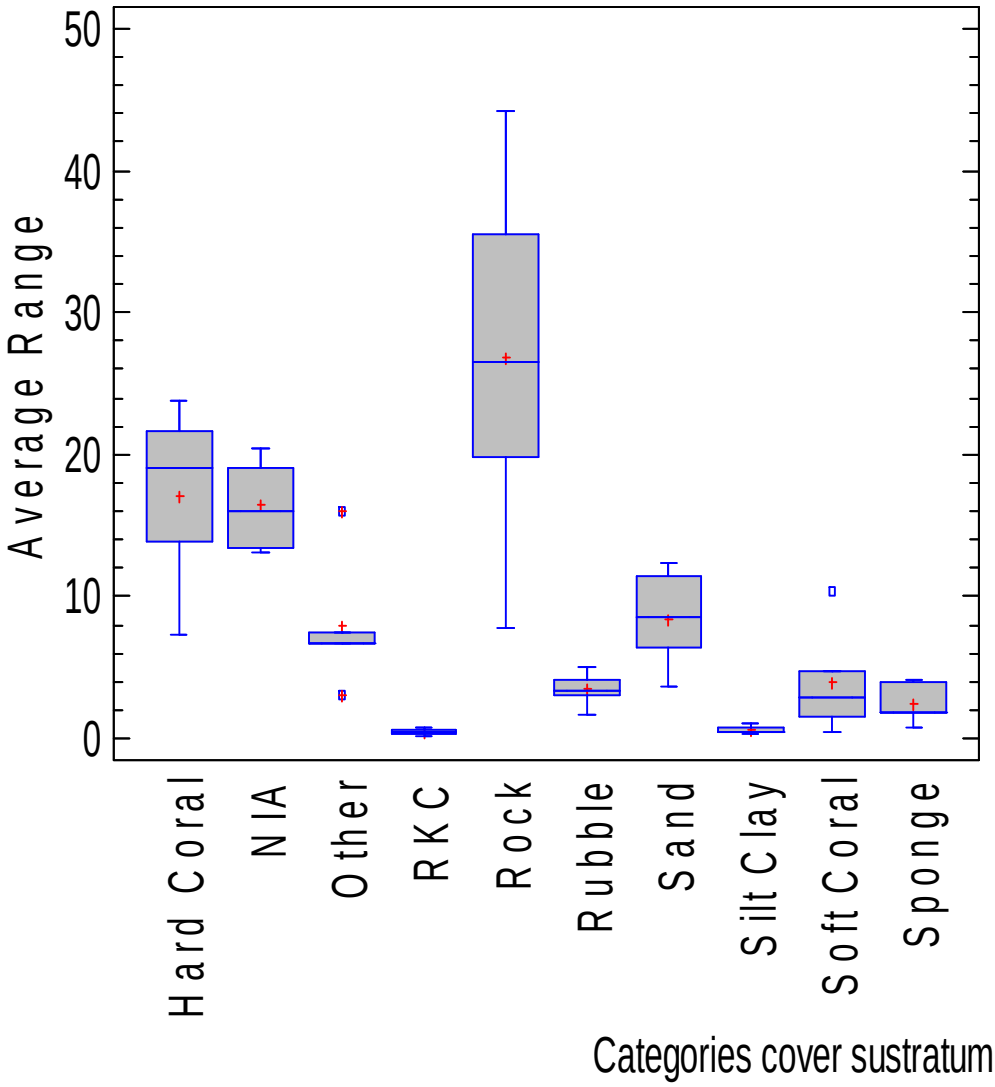


Figure 2.3.3b. The average range of coverage of substrate indicators. Data are pooled from all sites and all years (2006 to 2011). Lines show medians and error bars show +/- 1 standard error.

Applying the ANOVA Kruskal-Wallis test to the data and comparing the mean percentages of the average cover of non-living substrate at the different sites in 2011 yields a significance level of $p = 0.92$ ($p \geq 0.05$ with a 95% level of confidence), indicating no significant statistical difference between them (Figure 2.3.3 c & d).

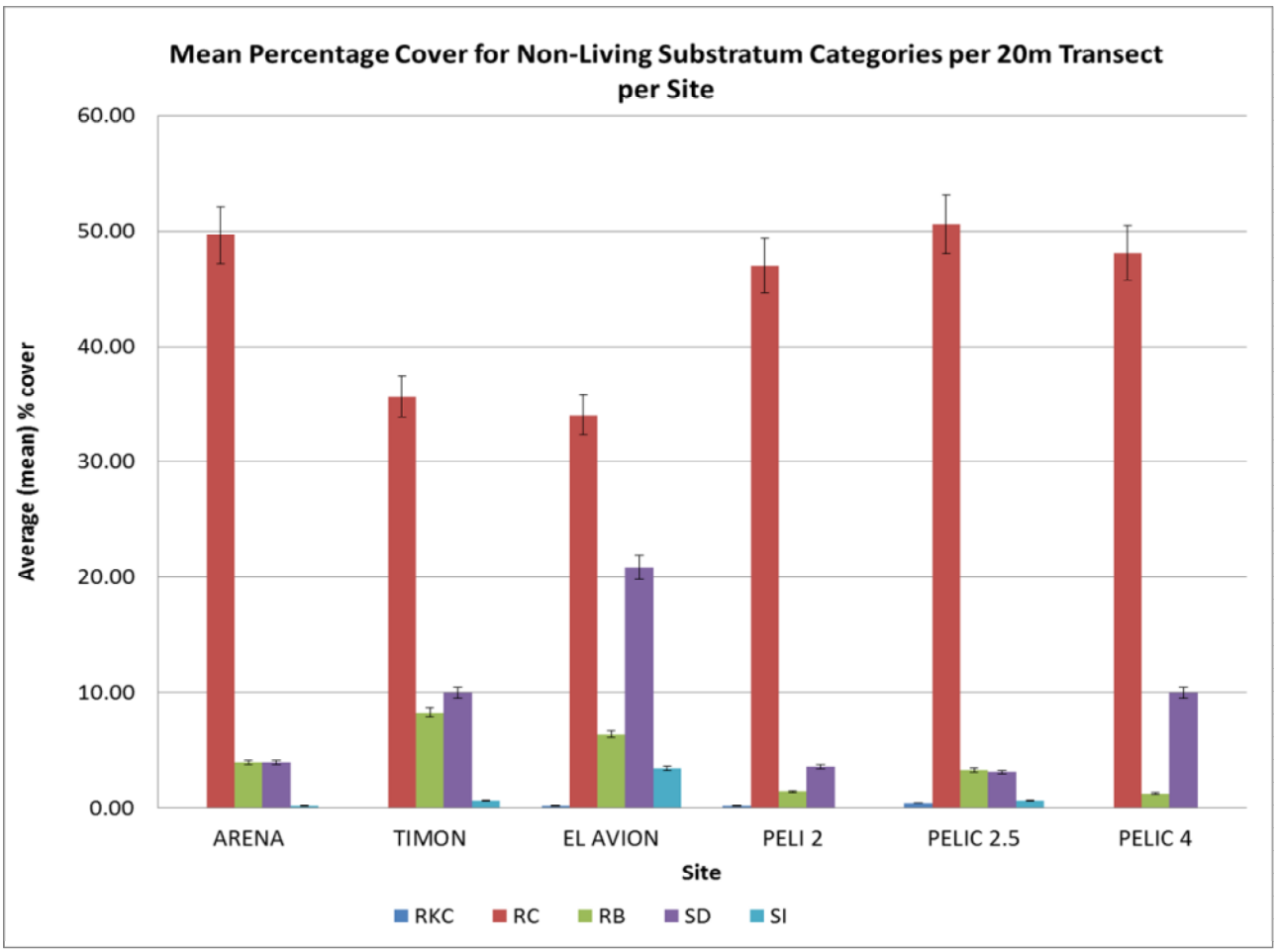


Figure 2.3.3c. Mean percentage cover of non-living substrate indicator categories at all Cayos Cochinos sites in 2011. Bars indicate +/- 1 standard error. RKC = recently killed coral, RC = rock, RB = rubble, SD = sand, SI = silt.

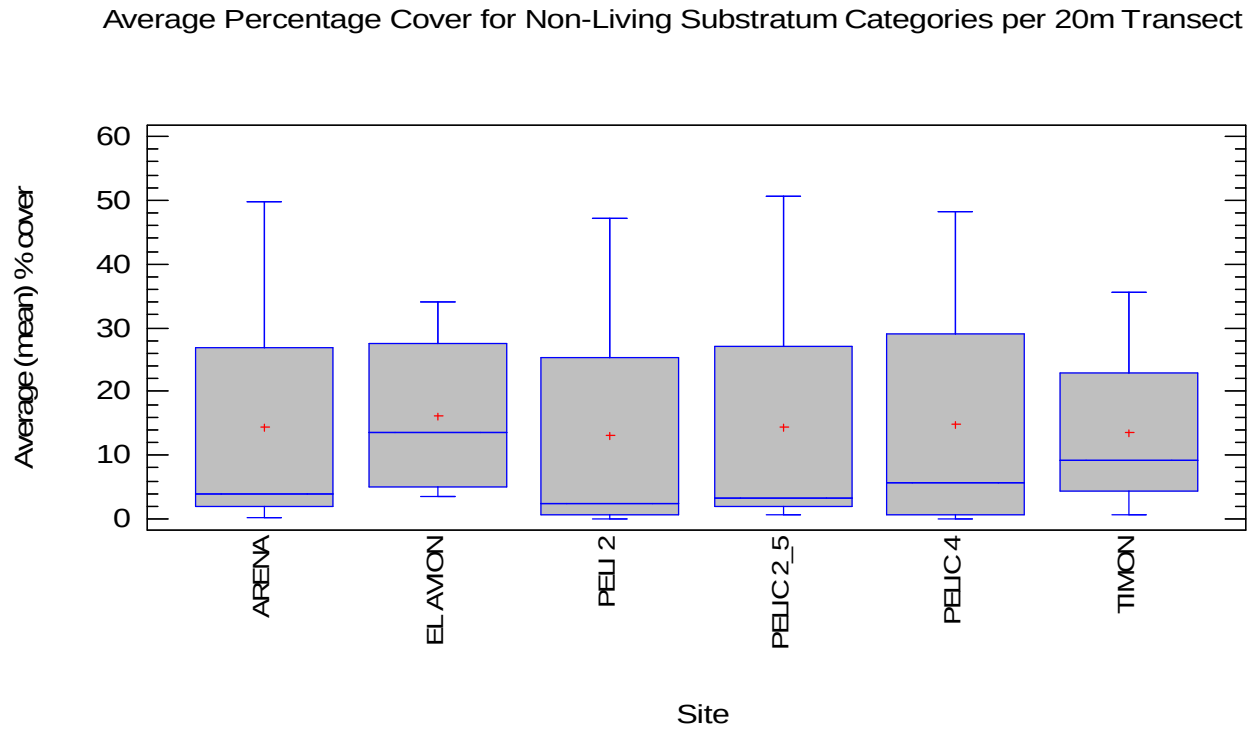


Figure 2.3.3d. Average range cover for non-living substrate categories. Data are pooled from all sites and all years (2006 – 2011). Lines show medians and error bars show +/- 1 standard error.

Applying the ANOVA Kruskal-Wallis test to the data and comparing the means percentage of the average cover for living substrate at the different sites in 2011 yields a significance level of p = 0.98 (p ≥ 0.05 with a 95% level of confidence), indicating no meaningful statistical difference between them (Figure 2.3.3 e & f).

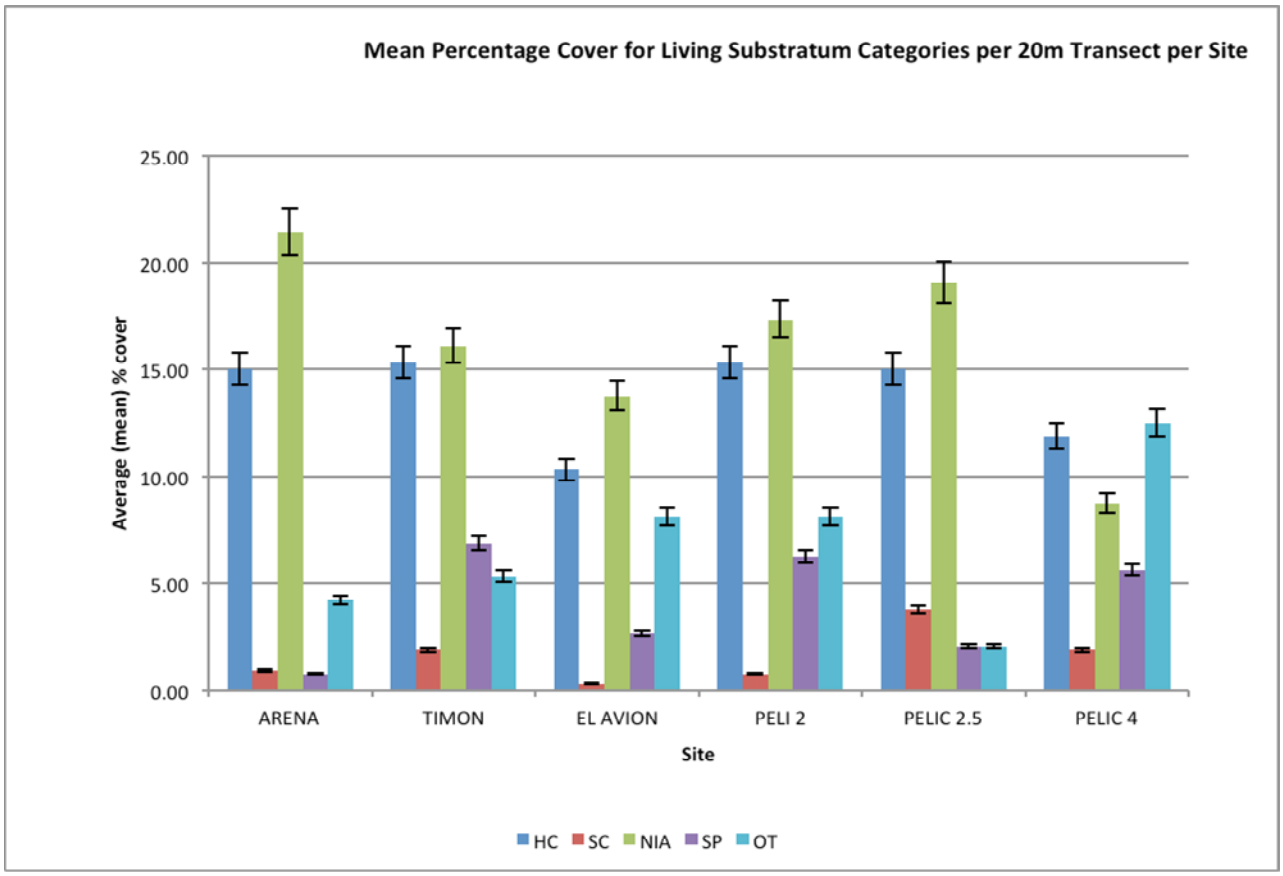


Figure 2.3.3e. Mean Percentage Cover for living substrate indicator categories at all Cayos Cochinos sites in 2011. Bars indicate +/- 1 standard error. HC = hard coral, SC = soft coral, NIA = nutrient indicator algae, SP = sponge, OT = other.

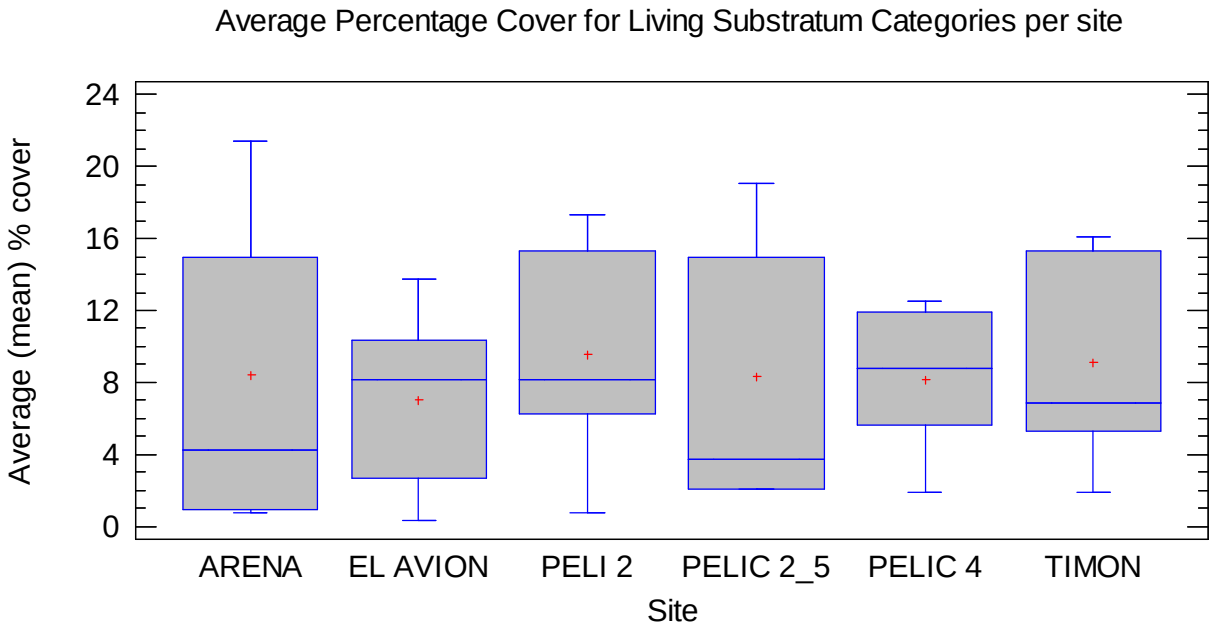


Figure 2.3.3f. Average range of cover for living substrate categories. Data are pooled from all sites and all years (2006 – 2011). Lines show medians and error bars show +/- 1 standard error.

Analysis of the six sites monitored from 2006-2011 (Pelican 4 was not monitored in 2006), Arena has the highest percentage of hard coral cover (mean = 20%, max. = 38% in 2006, min. = 9% in 2008) and El Avion has the lowest percentage cover (mean = 9%, max. = 12% in 2006, min = 6% in 2008). Other sites had similar mean percentage coverage, namely Pelican 2 at 19%, Pelican 4 at 18%, Pelican 2.5 at 18%, and Timón at 17% (Figure 2.3.3 g).

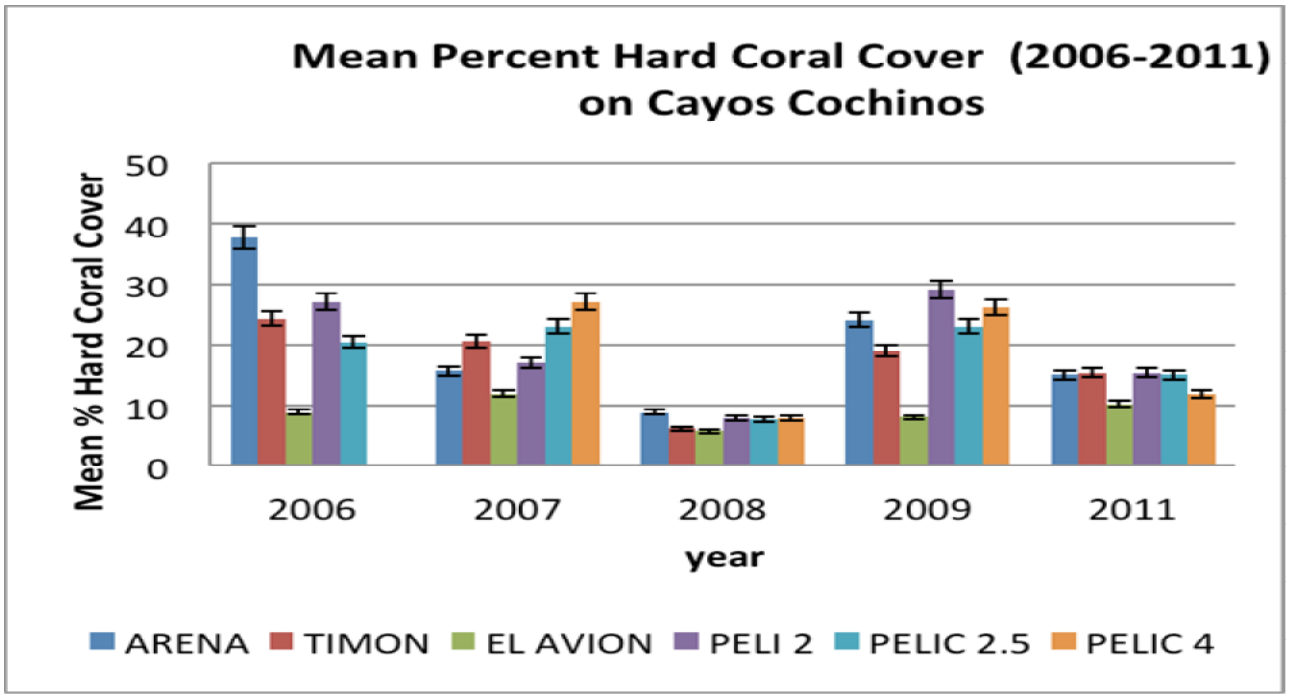


Figure 2.3.3g. Mean percentage hard coral cover at all Cayos Cochinos sites from 2006- 2011. Bars indicate +/- 1 standard error.

An ANOVA and Kruskal-Wallis test to compare the average percentage of hard coral cover over the five years of monitoring at the six sites shows that p = 0.293 and therefore that there is no statistically significant difference between the median with a 95.0% level of confidence (Figure 2.3.3h).

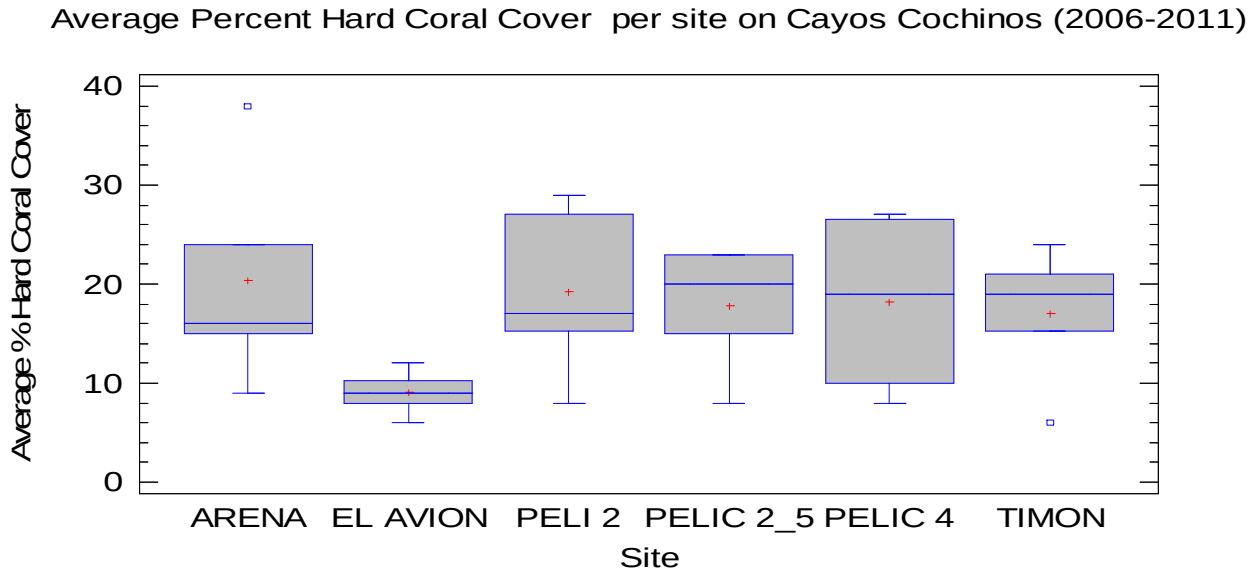


Figure 2.3.3h. Average range of hard coral percentage coverage from 2006-2011 Data are pooled from all sites. Lines show medians and error bars show +/- 1 standard error

2.3.4. Site Condition and Coral Disease

Timon was the site most affected by coral bleaching from 2006-2011 (mean=21%, max. =27% in 2006, min. =3% in 2011), followed by Pelican 2.5 with an average 18% of bleached colonies (max. = 25% in 2008, min. = 8% in 2011(Figure 2.3.4a).

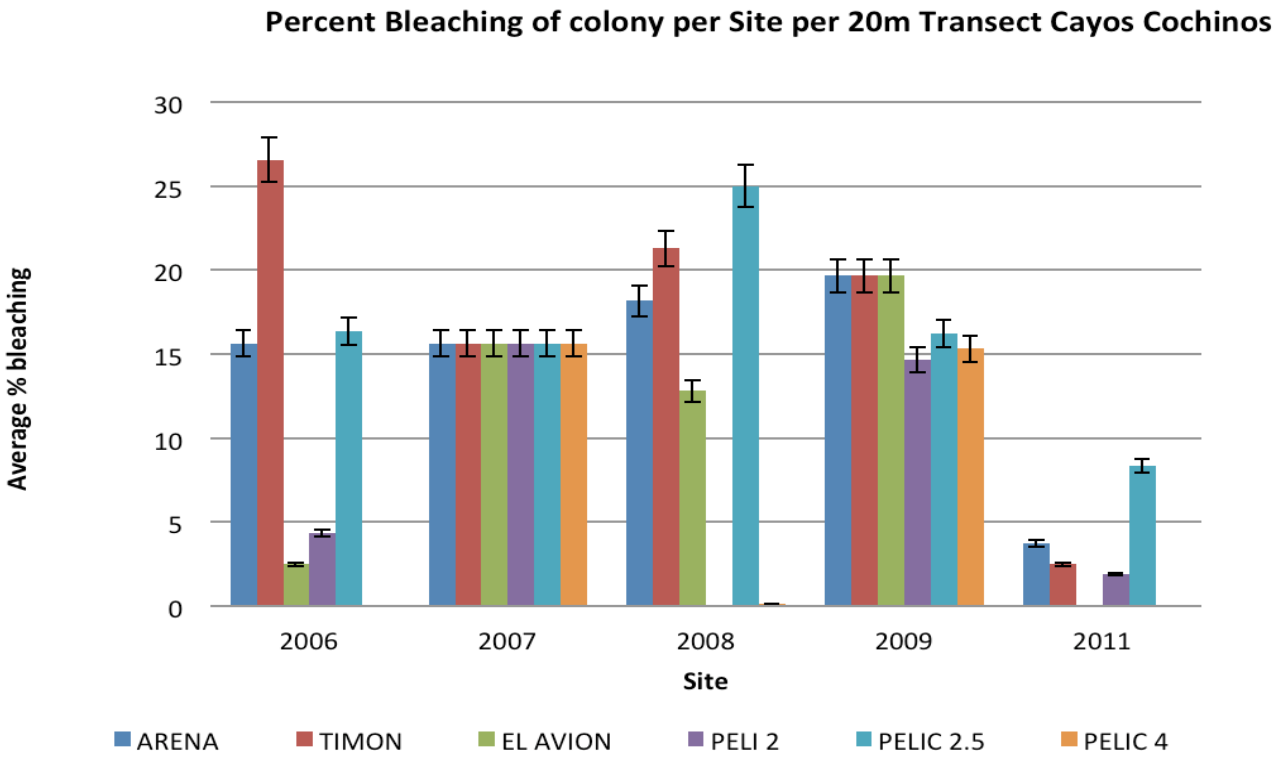


Figure 2.3.4a. Average percentage of bleached colonies at all Cayos Cochinos sites for each year of monitoring (2006-2011). Bars indicate +/- 1 standard error.

An ANOVA and Kruskal-Wallis test to compare the average percentage bleaching of colonies between the means of Timón and all other sites yielded P=0.7315, meaning there is no statistically significant difference between the medians with a 95.0% level of confidence (Figure 2.3.4b).

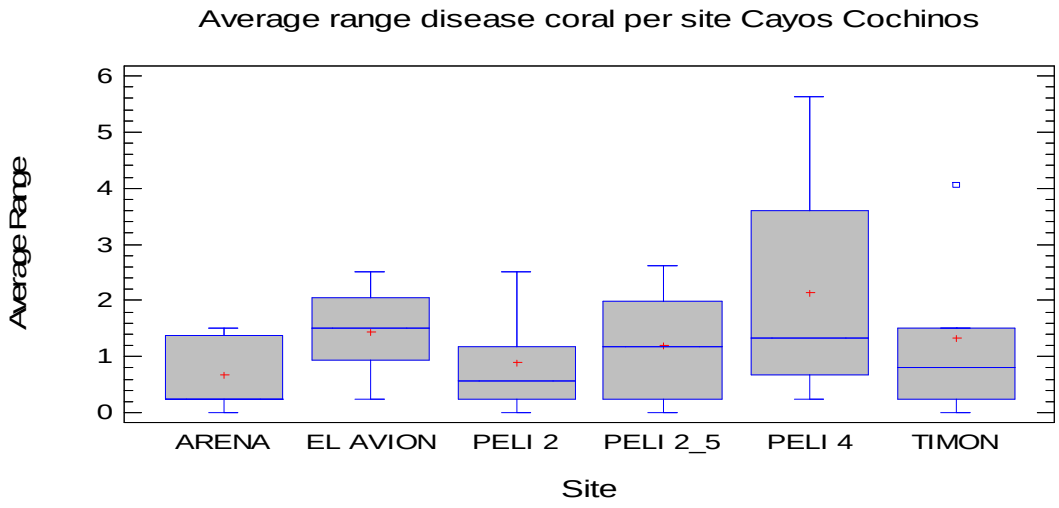


Figure 2.3.4b. The average range of percentage bleaching of coral colonies at all Cayos Cochinos sites. Data are pooled from all transects and all years (2006-2011). Lines show medians and error bars show +/- 1 standard error.

The site with the highest average percentage of coral disease over the monitored period was Pelícano 4 with 2.5% (max. = 5.6% in 2011, min. = 0% in 2011), whilst Pelican 2 had the lowest average with 0.4% (max. = 1.18% in 2009, min. = 0% in 2006) (Figure 2.3.4c).

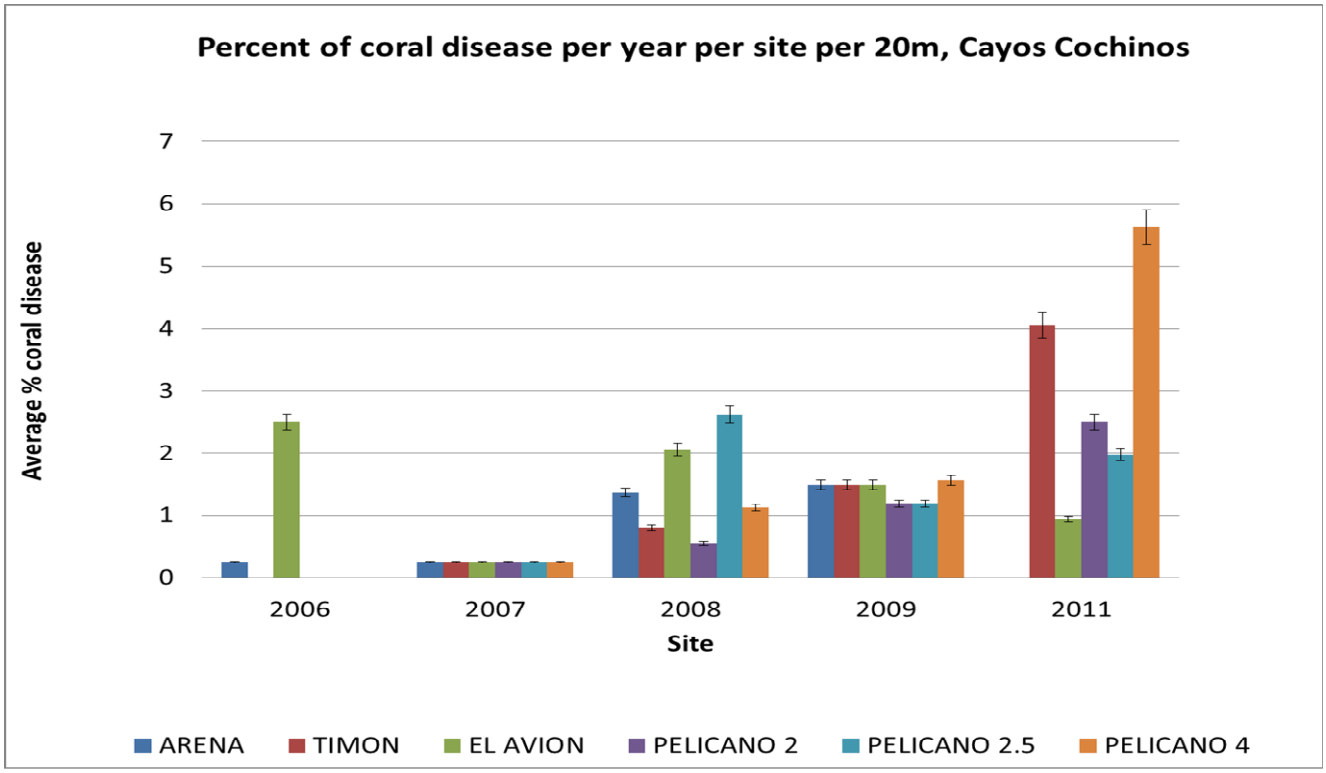


Figure 2.3.4c. Average percentage of diseased colonies at all Cayos Cochinos sites for each year of monitoring (2006-2011). Bars indicate +/- 1 standard error.

A multivariate Kruskal-Wallis test yielded a significance value of p = 0.73, meaning there is no statistically significant difference between any of the sites monitored with a 95% confidence level (Figure 2.3.4d).

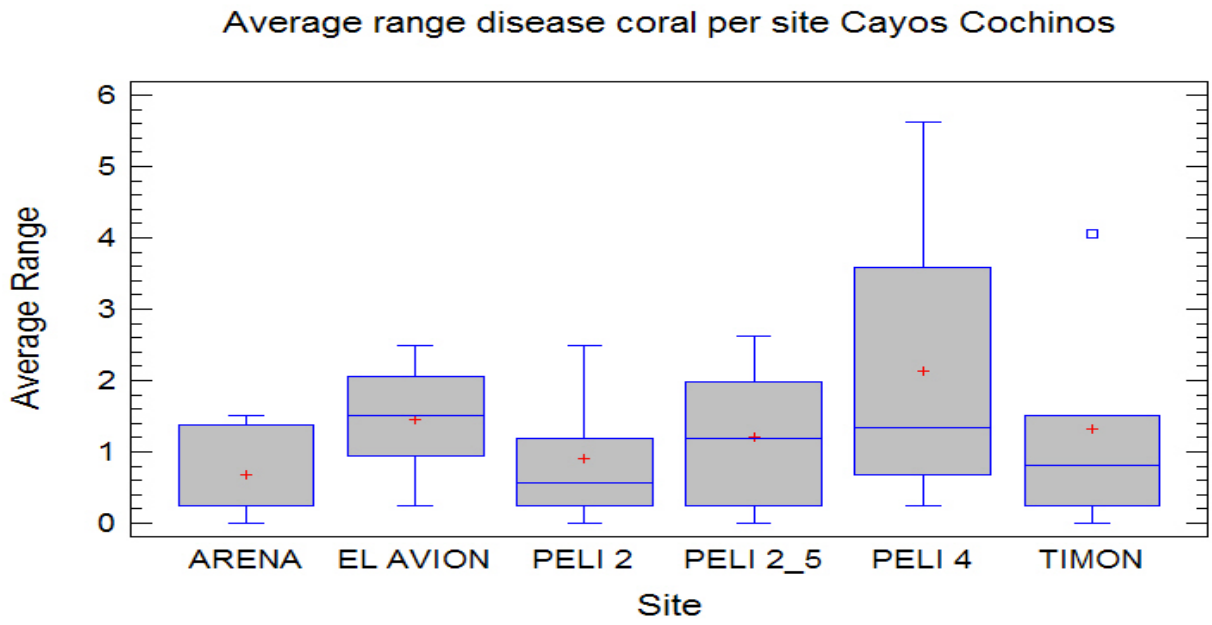


Figure 2.3.4 d. A comparison between range average medians diseased coral for pooled data of all transects, per year (2006-2011) per site.

2.4. Discussion

2.4.1. Fish

The reef fish in the Mesoamerican Barrier Reef System (MBRS) are important economically, socially and ecologically. The main threats to reef species are overfishing, habitat destruction, including effects on spawning and breeding sites (mangroves and seagrasses) and pollution or modification of water quality by the effect of watershed runoff towards the coast (Garcia-Salgado et al. 2006). In the MBRS the most abundant families are Acanthuridae, Haemulidae, Lutjanidae and Scaridae (Garcia-Salgado et al. 2006). In Cayos Cochinos according (Zaragoza 2008) the richest families were Serranidae, Labridae, Pomacentridae and Haemulidae.

According to the monitoring conducted by Biosphere Expeditions in Cayos Cochinos in comparison to previous years (Cubas 2006, Shrives et al. 2007, Shrives et al. 2008 and Aronne, et al. 2009, see www.biosphere-expeditions.org/reports), we observed a low average abundance of big predators such as grouper and moray eel (Figures 2.3.1d & f). This could be an effect of overfishing for grouper or a lack of suitable habitat for moray eel. On the other hand, we also observed a slight reduction of herbivores (parrotfish), although they continue to be the fish indicator species of highest average abundance (Figures 2.3.1a & c). The ANOVA test in 2011 showed that there is no significant difference between the parrotfish fishing and no-fishing areas ($p = 0.004$, see Table 2.3.1g). This trend was also observed by Shriver et al. 2007, Shriver et al. 2008 and Aronne et al. 2009, corroborating Aronne (2008) that there is no fishing pressure for these species and any catch is bycatch.

Another species of commercial importance is the snapper. Here a slight decrease in average abundance was observed in 2011 compared to 2008 and 2009. However, the ANOVA test between fishing areas and no-fishing areas in 2011 yielded a significant difference ($p = 0.396$, Table 2.3.1g). This result is different from those described by Shriver et al. 2007, who observed a reduction of fishing for these species. This reduction is probably due to several reasons: one of them is that fishing is changing over the season caused by differences in natural conditions of water, larval dispersal, migration, etc. (Cheung et al. 2008).

For Haemulidae an increase compared to the low values registered in 2007 was observed. There is no statistically significant difference between the indicator fish species ($p = 0.005$, Table 2.3.1g). The Haemulidae are a group of commercially important fish, similar to snapper. However, there is no statistically significant difference when comparing the fishing and no-fishing areas. One of the probable reasons for the increase in abundance of Hamulidae observed in 2011 is the reduction of fishing pressure on this species, which is traditionally one of the seven species of higher extraction (see Table 2.4.1a) (Aronne, 2008), with the snapper fish group seeing increased fishing pressure due largely to supply the demand of tourists visiting Cayos Cochinos.

Fisheries assessments on Cayos Cochinos have taken place since the 1990s. Table 2.4.1a shows a comparison of fishing records from several publications on the different fish species of commercial interest reported around Cayos Cochinos (taken from Mug & Bolaños 2003).

Table 2.4.1a. Percentage composition of larger commercial value fish on Cayos Cochinos.

Nombre común	Nombre científico	Guzmán y Jácome (1998)	Gamboa (1997)	Medina, et al (2000)	Aronne (2008) ***	
		% Chachahuate, East End y Bolaños	% Chachahuate, East End y Bolaños	% Chachahuate, East End y Bolaños	% Nueva Armenia	% Chachahuate
Yalatel	*Ocyurus chrysurus*	53%	52%	43%	1%	25%
Ronco	*Haemulon plumieri*	15%	15%	15%		17%
Calale	*Lutjanus synagris*	6%	10%	25%	51%	29%
Pejepluma	*Calamus calamus*	7%	8%	7%		11%
Saraza	*Cephalopholis cruentata**		5%	3%	3%	6%
Mantequilla	*C. fulva***	4%	1%	1%		
Culila	*Caranx Crysos*				13%	1%
Blanca	*N/D*				9%	
Corvina Blanca	*Cynoscion sp*				4%	
Macabi	*Albula vulpes*				3%	
PezSierra	*Scomberomorus regalis*				3%	
Palometa	*Trachinotus goodei*				1%	
Caulas	*Haemulon striatum*				1%	
Ronco Piedra	*Haemulon macrostomun*				1%	
	Cephalopholis guttatus					1%

***** *Previously known as Epinephelus cruentatus*. ** Previously known as *Epinephelus fulvus*, *** Biosphere Expeditions report for year 2007.

It is apparent that fishing on Cayos Cochinos is aimed at three families of fish, namely Lutjanidae, Haemulidae and Serranidae. This, according to Aronne (2008), is very similar to the observations of Guzmán and Jácome (1998) and Medina et al. (2000) and could indicate an imbalance in species composition and changes in ecosystem structure.

Aronne (2008) also asserts that the major fishing pressure on Cayos Cochinos is being exerted by two communities: Chachahuate and Nueva Armenia, in three zones (north, centre and south) (Table 2.4.1b). According to Mug and Bolaños (2003) one of the reasons for fishing these groups of fish within the protected area and inside the influence zone is that they are rapidly growing species (as for example the yellowtail and lane snappers).

HCRF has incorporated within the *Plan de Manejo de las Pesquerías con un Enfoque de Ecosistemas* (management of fisheries focused on ecosystems), a new system which changes the order of priorities, now focusing on the ecosystem instead of species (WWF 2006). Zaragoza (2008) evaluated the fishing areas of commercial importance on Cayos Cochinos, which were previously defined through a consultation process with the users and managers of the fishing resources. The sites selected were Roatán Bank, La Grupera, Mariposales, Salamandinga and Pelican Point. Zaragoza's (2008) study reports that Roatán Bank has the largest total reef fish biomass, followed by La Grupera and Mariposales, with Pelican Point and Salamandinga of lower biomass.

Table 2.4.1b. Average size (cm) of catch and catch per unit effort (CPUE, kg/boat/day), per community and fishing zone, number (N) of surveys and percentage (%) of fishing per zone and community.

Community	Zone	N	%	kg	Average size	Max. size (cm)	Min. size (cm)	Average CPUE*
Chachahuate	North	124	23	477	32	150	12	23.84
	Centre	96	18	250	27	120	15	12.48
	South	112	21	297	26	118	15	14.87
Total		**332**						**17.07**
Nueva Armenia	North	80	15	263	23	100	14	13.14
	Centre	37	7	175	23	175	14	8.74
	South	88	16	333	24	94	14	16.65
Total		**205**						**12.84**
Grand Total		**537**						

The present study shows a larger abundance of groupers at the four Pelican Point sites compared with El Avión, Timón and Arena. This is similar to what was observed in previous years. Such high abundance at the Pelican Point sites is possibly due to reproductive aggregation, based on data from five years of monitoring fishermen's reports (Aronne et al. 2009). Pelican 0 is one of the sites where there has been an increase in grouper abundance, a total of 37 individuals of *Mycteroperca bonaci* (black grouper) were recorded in February 2007 with lengths estimated at between 71 and 90 cm. Likewise changes in colour and reproductive behaviour in this species have been observed. Different studies have described the reproductive behaviour of groupers and the change of colour, showing a bicolour phase white and dark brown (Shapiro 1987, Heyman et al. 2002, Claro and Lindeman 2003).

2.4.2. Invertebrates

El Avión had the largest number of sea urchins, which is consistent with previous years' observations, while abundance at other sites remained low. This low abundance is similar to the rest of the Caribbean, despite urchins being considered organisms in a state of recovery after their sharp population declines in the 1980s (Wilkinson and Souter 2008).

Jordan (2002) argues that there are local factors (availability of substrate and local environmental conditions) and regional (functional larval supply, water circulation, connectivity between sites) affecting the distribution and density of gorgonians on the reef. In the present study local factors (such as and why?) best explain the decreasing tendency in the abundance of gorgonians,

The abundance of Gorgonia has been analysed using one-way ANOVA (2.3.2d). Pelicano 4 is the site that has a significant difference in abundance, followed by Timon and Pelican 2; the other sites do not show a significant difference from the mean.

Kinzie (1973) argues that the diversity of gorgonians depends on the diversity of the substrate and that the number of colonies of gorgonians that can be found in an area is related to the area available for colonisation. The average percentage of live coverage per site substrate (Figure 2.3.3e) shows no significant difference between the sites studied. However, Pelican sites have a greater abundance, so that substrate availability may be related to the greater abundance of sea fans in these places. Moreover, Zaragoza (2008) indicates that the availability of coral structure in these areas allows high fish abundance, which is due largely to the contribution in the abundance of soft corals that provide the coral reefs.

The other categories of invertebrates show low levels of abundance, especially lobsters, which is a species of high economic importance. These low levels are similar to those observed during previous years (Figure 2.3.2e). According to interviews carried out with local lobster fishermen, the low costs of lobster tails on the international market ($7.8 per lobster tail at the time of writing) has caused a major extraction of this product in order to maintain profitability. Alternatively, in some cases the entire fishery has been abandoned in favour of other species such as giant clams, whose extraction is forbidden within the protected area (Francisco Solís, personal communication 2009) This increase of illegal fishing correlates with the threefold increase in the number of recorded violations in the last trimester (April to June 2011) (Aguilar 2011). This higher pressure can lead to a deterioration of the ecosystem due to overfishing.

2.4.3. Substrate Structure / Benthic Communities

Rock substratum has the highest mean number observed over the five years of monitoring, especially in 2011 (Figure 2.3.3 a & b), followed by the lowest hard coral cover in 2008, possibly due to an error in data collection (Figure 2.3.3 a). This is in agreement with Zaragoza (2008) who associated the Pelican and Mariposales sites with low diversity and intermediate coverage of hermatypic coral when compared to those of Roatán Bank, which showed high diversity.

Coral cover is one of the parameters measured in reef monitoring programmes to determine the condition of reef-building corals and is the product of all reef processes (e.g. competition, herbivore, mortality, reproduction) (McField and Kramer 2007). The average percentage of hard coral cover from 2006-2011 (excluding 2008, which probably contains an apparent error, and 2010, when monitoring was not performed) was 17%, with the lowest average this year at different monitoring sites with just 13% of hard coral cover. According to the Healthy Reefs Initiative Program (2010) the overall percentage of live coral cover for Honduras was 24%, so at first coral cover at Cayos Cochinos appears disappointingly low. However, according to the Index Integrated Reef Health Simplified (IISAS) used by the Healthy Reefs Initiative (2010), the only reefs in Honduras in "good" were found at Cayos Cochinos.

There is a third significant substrate category on the ANOVA analysis, namely nutrient indicator algae (NIA), with an average percentage of 16.40%. In 2011 coverage was especially high at Arena (Figure 2.3.3e). When this indicator was compared with the coverage of hard coral from previous years (Figure 2.3.3e), there is a slight reduction of NIA in relation to hard coral cover, which could be related to several factors such as the accumulation of sediments from coastal rivers or storm and hurricane activity (see also Shriver 2007), with less intensity and force than the events that occurred between 2008-2011 to the events of 2006- to 2007.

2.4.4. Site Condition & Coral Disease

Analysing all sites of 2006-2011, it appears that the sites most affected by bleaching are Timón and Pelican 2.5 (Dickie C). 2006 and 2009 were the years when most bleaching events were reported (Figure 2.3.4a). The present study in 2011 is the year that recorded the lowest percentage of colonies affected by bleaching. After the significant bleaching events of 1995 and 1998, which strongly affected the coral reefs around Cayos Cochinos (Guzmán & Guevara 2008), the same phenomenon occurred again in 2005, affecting 40% of coral on the Mesoamerican Reef (Wilkinson & Souter 2008).

In relation to coral death, Pelican 4 registered a high percentage of coral mortality in 2011 (Figure 2.3.4 c & d). It is difficult to pin down reasons for this; probable causes could be increased tourists activity or the effects of tropical storms that occurred in 2011.

2.4.5. Additional External Factors Affecting the Area

HCRF is currently monitoring the short, medium and long-term impacts of tourism and the accomplishment of *Tourism Without a Trace* policies through the Acceptable Change Limits within the Protected Marine Area (Aronne 2009).

Thiebaud (2009) analysed tourism activities in Easter week 2009. She used indicators such as the presence of garbage at visited sites, the tourists' perceptions and level of satisfaction, and the impact of tourism on the ecosystem. In general tourists expressed a high level of satisfaction with the service offered by tour operators (81% were satisfied and 96% would consider coming back). Their impact on the ecosystem was, however, less favourable. Identified issues included the anchorage of many vessels in a small area and the concentration of tourist numbers at the different sites, affecting not only the quality of their holiday experience, but also increasing the pressure on a sensitive ecosystem. Another negative impact that was identified was apparent disrespect on the part of the tour operators regarding following regulations concerning operating motorised canoes at high speeds within protected areas.

The Foundation has also evaluated activities related to all types of tourism to determine their impact on the reef ecosystem. Such studies have included monitoring the operations of reality TV shows from Spain and Italy, and observing the people in charge of diving operations. Additionally the Foundation has minimised the impact of students and volunteers who have, for example, caused damage to the reef through poor buoyancy control (Thiebaud, personal communication 2009).

As regards the impact of TV reality shows on the marine and coastal ecosystems, both reversible and irreversible effects have been observed. For example, at Cayo Paloma the nesting of birds was irreversibly impacted. Similarly, the nesting of sea turtles on various beaches was affected by the activities of the television production workers, particularly by the constant use of canoes over the 2.5 month filming period (TNC/HCRF 2009). Studies have indicated that the presence of visitor, tourism infrastructure and even climate change have disrupted the nesting behaviour of the sea turtles (Witherington and Martin 1999, Ga-Young and Eckert 2009, Hawkes et al. 2009). It is important to note that marine turtles, especially the hawksbill turtle, are endangered and any disturbance is considered to be an irreversible damage to the populations (Meylan and Donnelly 1999).

HCRF in 1998 established a programme of sea turtle monitoring and research, which found changes in the number of turtles nesting at Cayos Cochinos (Aronne in press). In the case of Cayo Paloma, it is not known whether the reduction of nesting is exclusively due to the presence of the TV production company or also influenced by other, external factors (for example nesting birds). It is, however, necessary to continue with the recommendations to restrict access to these sites during the nesting season increased (Aronne in press).

In the present study there were seven lionfish (*Pterois volitans*), an invasive and highly destructive species, recorded at Pelican 2 & 4 and Timon. Lee (2011) recently monitored this species in Cayos Cochinos, spending one hundred man-hours searching for lionfish over the course of three months. A low density of lionfish was found, suggesting that the lionfish population in Cayos Cochinos is still in the early stages of growth after the initial invasion, which is positive for management as it provides an opportunity to begin control measures in order to maintain a low lionfish population, rather than having to reduce a large population.

In Belize, the lionfish has invaded almost the entire reef system in fewer than two years. In Honduras, there were more than 530 lionfish in one study conducted at the Roatán Marine Park between May 2009 and March 2010. Lionfish were found in six of the 21 sites that were studied. The adults are mainly located in the reef habitats, while juveniles live amongst sea grasses (Healthy Reefs Initiative Program 2010).

2.5. Conclusions

During the five years of monitoring the percentage coverage of dead and live coral (including Gorgonia) have remainned fairly similar, suggesting that the substrate is able to support an absence of predator fish and an increase in herbivores. This ability is of great importance within the ecological assembly of the reef, giving it stability and suggesting a degree of robust health within the ecosystem. However, the evidence also indicates that the Cayos Cochinos coral reefs have suffered from moderate to high pressure by resource users and high rates of sedimentation from coastal rivers. The high pressures identified in this study and the fact that mortality rates reef organisams in 2011 were highest also indicates the high degree of fragility of these ecosystems.

Overfishing violations have increased three-fold between April and June 2011, tourism and TV reality shows and the lack of care and disregard for regulations shown by operators involved in these two activities, are reasons for serious concern. The invasive and highly destructive lionfish needs to be monitored and managed.

On the bright side, it is encouraging to note that the only reef in Honduras in a “good” state of health as defined by the Healthy Reef Initiative (2010) was found at Cayos Cochinos. In order to build on this achievement, new regulatory structures to control the threats detailed above and means to enforce these regulations need to be found and, most importantly, implemented by local managers.

Review of previous recommendations and new recommendations

Since the start of expeditions in 2006 Biosphere Expeditions’ support to HCRF has been crucial in guiding HCRF’s efforts to manage the protected area. This became evident during the review process of the management plan 2004-2009, highlighting the need to redirect management efforts in particular to reduce the impact of sedimentation from land. Another recommendation emerging from previous Biosphere Expeditions reports was to establish a programme monitoring the impact of tourism on coral reefs, in addition to defining more clearly the sites not intended for fishing. Several of these recommendations were incorporated into the management plan currently in force (2008-2012). With the support of organisations such as The Nature Conservancy, monitoring efforts have been increased and a surveillance programme increasing patrols systems has been implemented and enforced, especially in the no-fishing zones, as well as sites protected by national bans such as spiny lobster sites. Closer ties with agribusinesses in the area to make them aware of the release of nutrients and sediments into the sea have been built. However, this effort has not been successful so far, probably due to the lack of a concurrent environmental education programme and the lack of environmental education and awareness in business decision-makers. HCRF is also constantly monitoring the health status of coral reefs and associated ecosystems, as well as fish catches and landings. Local communities have consistently validated stocks and HCRF has evaluated the impacts of tourism under the policies on the Limits of Acceptable Change.

Recently HCRF has initiated an environmental education programme with the long-term goal to increase resource use awareness by promoting direct participation and involvement of different stakeholders in environmental issues in the protected area. Biosphere Expeditions has contributed to this programme through the production of educational booklets, which are distributed by local stakeholders and also handed out as part of the expedition (see Figure 2.6a and here for a copy of the educational booklet).

Figure 2.6a. Expedition participant handing out the educational booklet.

One of the challenges in the short- and medium-term is the management and evaluation of the buffer zone to determine the degree of connectivity between coastal ecosystems and coral reefs. Therefore it is recommended to include Cheek Reef monitoring in this area to determine the degree of effectiveness of the implementation of management measures within the Protected Area and areas with recent conservation measures.

It is important to continue in a systematic monitoring programme and control the lionfish. Participation of communities will be essential in this, as will be raising awareness of the problems associated with the presence of this species on the reefs of Cayos Cochinos. An immediate and excellent opportunity is to provide options to generate revenue through the sale of these species.

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Appendix 1: Expedition leader's diary by Paul o'Dowd

8 March

Hello everyone and welcome to the Honduras 2011 diary. I'm Paul, your expedition leader, and you will be hearing from me regularly over the next few weeks. I am writing this from Muscat, Oman, where I have just finished with the Arabian leopard expedition.

Next for me is Honduras, and another tropical marine adventure, but the first for me in the Caribbean. With me to settle me in will be a much more experience hand, marine biologist John Shrives, who has been to Cayos Cochinos many times before. I am looking very much forward to meeting our research team and to getting my teeth into the Reef Check process there in what looks like a diver's paradise. The research base is a spectacular location. The sort of place you would think might be reserved for the rich and famous. Strange then to learn that we are amongst the only people permitted here as it is off limits to those outside the research community. So get ready for some great diving and some hard and satisfying work under the waves.

I'll see slot 1 at the Quinta Real on Sunday. If you are around and would like to go out for a drink before the official start of the expedition on Sunday morning (be there at 07.00 or miss the boat, literally!), then I or Jon be hovering around the lobby at 20.00 on Saturday.

I must be off to finish errands in Oman and then catch a flight to Honduras via the US. If you are still trying to swot up for the expedition, remember to read the published reports from previous expeditions available via www.biosphere-expeditions.org/reports.

So long

Paul o'Dowd
Expedition leader

15 March

I've just hit the ground in Honduras and I am finding it quite a familiar scene after my years in Papua New Guinea. It is beautiful, green, tropical and, from the plane, the water and reef look very exciting indeed. The temperature is around 30 Celsius and the weather is fine and sunny.

A reminder to all to make sure to change to US dollars before you get here. The airport money change outlets do not change any other currency and we do not have the ability to act as a backup for-ex service for those who aren't prepared. Expect an exchange rate of around 18.5-ish local units for the dollar.

Tomorrow I will meet Jon, our man for all things scientific and from there we will start the job of preparing the expedition for the team's arrival. Again, I am looking forward to meeting the team.

Finally, a bit of admin. My mobile number in Honduras is +504 98962241, Jon's number is +504 98947952. Remember these are for emergency purposes only, for example if you are going to miss assembly. Coverage on the island is intermittent, so you may not get through, but one of us is going to be in La Ceiba on 5 March, the day before assembly, in case you have any nightmares, so you should be able to get through.

See you all soon.

17 March

Jon and I have arrived on the Cayos Cochinos islands after a hectic couple of days organising provisions and logistics in La Ceiba. The island is a storybook picture of a Caribbean paradise. There are big iguanas everywhere under the coconut trees and giant ghost crabs patrolling the beach. We haven't been in the water yet, but it is crystal clear and warm (we know this from the drenching we got coming over in the boat). Tomorrow we will be setting up the lab and finalising the preparations in readiness for the team's arrival on the island on Sunday.

Just remember that water is a precious resource here and showers won't be available on tap, excuse the pun. Remember also that the boat ride over here is not a luxury cruise. Think about how to protect your stuff from the water, which will be coming over the gunnels as we make the crossing. Dry bags are good. Make sure you have all your paperwork for me when you land, i.e. checklist, insurance details, PADI or other dive qualification and medical paperwork, etc. And maybe keep it in that dry bag I mentioned, (not to labour the point, but my passport got soaked). Both Jon and I are looking forward to meeting you all.

20 March

A video diary entry is now at www.facebook.com/biosphere.expeditions1 (and you do not need a Facebook account to see this, just click on the link and then go to the "wall").

21 March

Today saw the first aquatic day for the Honduras Reef Check expedition. The team of eleven are all experienced divers and after a day spent brushing up on critical skills such as buoyancy control, they are ready to go underwater with the tools of research.

The Cayos are a fantastic location, as the Italian film crew working in the region will attest. We find ourselves marvelling over hummingbirds, big iguanas, pink boas (not the feather variety) and fluorescent green tree lizards on a daily basis. That's to say nothing of the landscape.

Tomorrow we will be running the first trial underwater survey. It will be a challenging exercise as it entails the use of various apparatuses, the identification and counting of numerous indicator species and the usual load of regular diving-related tasks. I've no doubt the crew will shine in their duties.

23 March

A video diary entry is now at www.facebook.com/biosphere.expeditions1 (and you do not need a Facebook account to see this, just click on the link and then go to the "wall").

24 March

As I sit and type, a huge iguana has just run over a merely large iguana in pursuit of a relatively small iguana. All a couple of meters away.

We are now well into the survey phase and the team has come together as a well oiled critter counting machine. The set-up of the sites for the Reef Check process is quick and the processing of the sites enjoyable and efficient. People are logging their data before lunch and with very little direction. All this after only two days on actual survey!

The HCRF crew are enthusiastic and knowledgeable. We have very capable dive leaders looking after the wet side and a great local scientist working with Dr Jon (see him in a new video diary entry on www.facebook.com/biosphere.expeditions1) in the lab. I havn't even mentioned the weather and the viz yet, have I?...

27 March

A well-earned day off from survey diving was almost unanimously spent diving. The three team members who did not come to the Roatan Banks for a morning of pleasure diving, walked through the lush and beautiful rainforest of the island. Those who did dive the Banks saw something big. The first person to get in the water put their head under and came out swearing in three different languages. "WHALE SHARK" and the boat ditched its contents like a cliff full of lemmings. We spent the next 10 minutes following the worlds biggest fish as it rose and fell below us. I have seldom seen a more excited bunch of divers in nearly 25 years of diving. The Roatan Banks seamount itself was pretty awesome as well, absolutely pristine, with visibility at easily 30m and probably more.

Tomorrow morning we plunge back into the surveys, reinvigorated and doubly aware of what it is that we are working to protect.

30 March

The final day of data collection has capped off a perfect sequence of survey dives. The team did not need to repeat any of the numerous site surveys in the two weeks of intensive work. We had a dive without our slates to celebrate the completion of a very successful expedition. All that remains is to pack it all up and ship out, which we will do over the next day, our last on Cayos Cochinos.

Thanks to the team and the fantastic support crew from the HCRF. Stay tuned for some incredible photos and video which will be uploaded to the Biosphere website shortly. Meanwhile, a bit of fun from the team in Honduras at www.facebook.com/biosphere.expeditions1. Don't try this at home ;)