Interim Marine Field Report

Honduras Marine Site
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IN COLLABORATION WITH

FUNDACIÓN CAYOS COCHINOS, HCRF.

CORPORACIÓN HONDUREÑA DE DESARROLLO FORESTAL, AFE-COHDEFOR.

Executive Summary

Operation Wallacea is a research organisation which undertakes studies and experimentation into conservation methods and conservation based research within the Cayos Cochinos Marine Protected Area, in collaboration with the Fundación Cayos Cochinos. During the 2005 field season a variety of studies were undertaken, some of these studies represent repeated studies thus supporting previous years research. The research programme, developed by Dr David J. Smith, Head Marine Scientist Operation Wallacea, Director of the Coral Reef Research Unit, University of Essex, UK, represents an adaptive approach and as such novel studies were also undertaken during this field season. The following represents some of the major findings of the 2005 field season categorised by research theme. It is important to note that not all data has yet been analysed or interpreted and therefore this document and data herein represents an interim report of the field activities. A full report will be made available later on in the year by request.

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1.0. Project Background

Operation Wallacea is a research based organisation that undertakes scientific studies and experimentation within the Cayos Cochinos Marine Protected Area (CCMPA) Honduras. Since 2003 Operation Wallacea has utilised a thematic approach for it's scientific approach that generally aims to examine the marine biodiversity and ecology of the CCMPA and to evaluate conservation methodology through primary research. Consequently a variety of long term studies were continued throughout the 2005 season, new long term studies were initiated and these were coupled with novel investigations, studies and pilot investigations. The thematic research incorporates a cross disciplinary approach to marine and terrestrial conservation science and the information contained within this interim report contains examples of the data collected. Where relevant, and to put the data collected during 2005 into context, some results obtained in previous years are included.

Operation Wallacea's research programme encompasses several facets and plays several roles within the management set-up and conservation bodies currently working within the park. It is important to note that Operation Wallacea has expertise in primary research and produces research outputs which are applicable for publication in top flight international peered review journals. Publication in such journals will help put the CCMPA and it's managers on to an International stage. Operation Wallacea does not directly undertake conservation management in the historical and traditional sense. The management of the CCMPA is the responsibility of the Fundación Cayos Cochinos, and the Operation Wallacea research programme is designed to provide important information to the park managers which will aid in the design of the most appropriate management strategies which include ecosystem monitoring. Therefore Operation Wallacea would like to increase the trade of information of interested parties working within the CCMPA and would like to facilitate trade in information by providing a stimulating research and education environment which should be to the benefit of the conservation objectives. The thematic research structure has been designed to take these points in mind and the research endeavours to for fill its role in providing information that will allow active and strategic conservation management actions and decisions to be based on detailed biological information, thereby maximising the potential for the success of future management plans.

Due to large number of specific research tasks undertaken during the 2005 field season, this introduction only intends to introduce the reader to the research background, scientific approach an on going research structure. To enable the research projects to be put into context of the overall research strategy of Operation Wallacea, some information is also given to the thematic research programme. This information was also contained in previous reports, however for convenience to the reader I thought it appropriate to once again include this information with this therefore independent report. For those readers who are familiar with the thematic research programme I suggest that you go directly to the Methods and Materials section.

As in previous reports, so as to allow for continuity and ease of understanding, a brief introductory paragraph setting the scene for each individual research project is included where the methods and aims of each research project are described within the relevant place in the Materials and Methods section. Although not the normal format, we as the authors feel that such a format will increase the continuity of the report and ultimately the ease at which the scientific rationale, methods and research outputs are understood.

1.1 Scientific Rationale and Approach

Operation Wallacea is a scientific organisation that has clearly defined research objectives that have been designed with the naturally high biodiversity of the region, local communities, and management requirements in mind. Broadly speaking the Marine Research Strategy therefore aims to examine:

a. Coral reef and associated habitat biodiversity and ecology.
b. How reefs and associated habitats change in time an d respond to environmental change and anthropogenic influences.
c. Ecosystem responses to management.
d. The most scientifically appropriate and efficient way to monitor and manage coral reef systems.

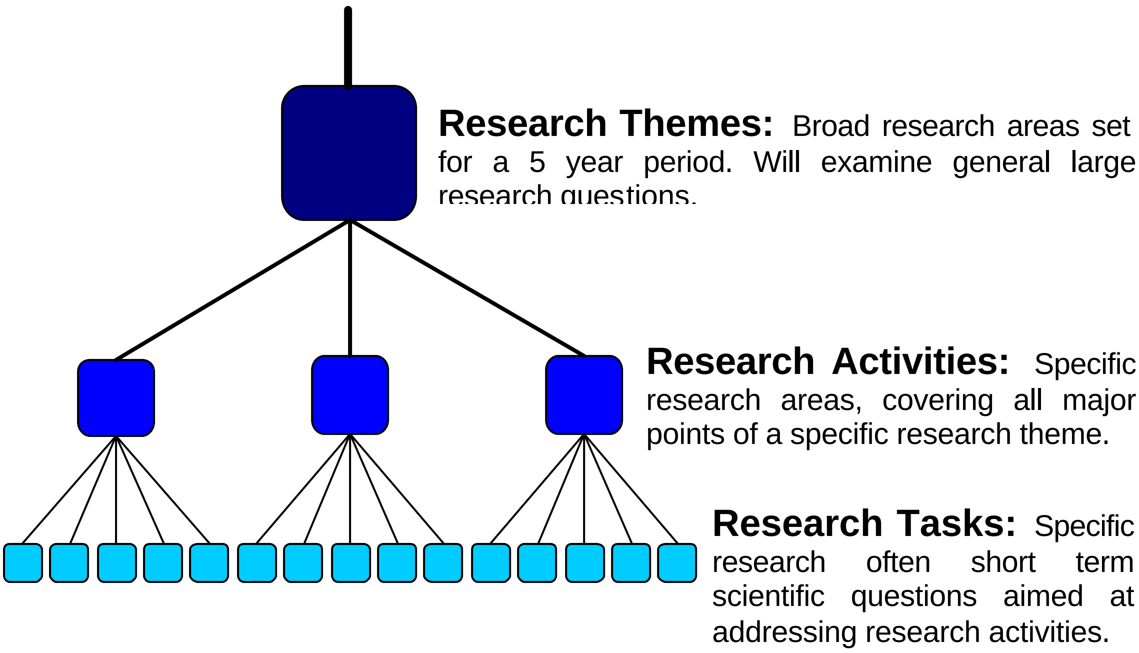
The research programme creates a focused directional approach but also allows for adaptability, therefore maximising the production of the most appropriate and scientifically robust research outcomes. A hierarchical three-tiered structure was utilised during the 2003, 2004, and once again in the 2005 field research season (see Figure 1.)

The first and most general structure of the hierarchical research structure are termed research themes (see Figure 1.). Research themes cover broad scientific subject areas that encompass all conservation and research objectives necessary to examine major management concepts. It is deemed most appropriate to set research themes for at least a 5 year period, a time scale which is appropriate to coral reef systems and therefore represents the minimum period of time needed to address many of the complex dynamics and ecological relationships common to reef systems, particularly those affected by local community resource extraction and management practises.

Under each research theme, at a secondary level, are a number of research specific activities (see Figure 1.). Research activities encompass specific areas of research that rigorously and robustly examine all aspects of the research theme.

An adaptive participatory strategy is essential for the long-term sustainable management of marine parks that are heavily utilised as a resource base. Adaptability has been built into the programme by way of the specific research tasks. The specific tasks are designed on an annual basis and will be dependent on the research outcomes of previous years research (biological and social) whilst also considering changes in local and/or regional resource usage and requirements. The research tasks are topic-specific and represent individual research projects (see Figure 1.). The research tasks may be repeated from year to year of long term repeated measures are deemed necessary as for example is the case for coral reef biodiversity monitoring which is aimed to provide managers with management biodiversity performance criteria rates of change in which can be considered measures of management success. Some research tasks will also be repeated each year dependent on the outcome of previous years research. Other tasks will be novel and add adaptability to the research structure.

Figure 1: Schematic diagram of the hierarchical themed research structure.



Research themes are not independent, but are designed to be supportive therefore maximising the focus and efficiency of all scientific investigations carried out. In time it would be desirable if specific individuals or committees (e.g. WWF and management authorities) of the local user-group be involved with the design of annual research tasks, which would therefore increase reciprocity and relations of trust between the park authorities.

1.2 Research Themes and Areas

1.2.1. Theme 1: Coral Reef Biodiversity and Ecology

Coral reefs are renowned for their biological diversity and the CCMPA is positioned within an area of extreme biological diversity. Consequently one of the major research themes of the Operation Wallacea Marine Team is to examine coral reef biodiversity, the causative factors influencing diversity, the factors that adversely effect diversity and possible indicators of system diversity. Coral reefs are characteristically complex systems and offer an excellent opportunity to study fundamental ecological principles and interactions and also to carryout ecological behavioural studies.

Many different factors impact coral reef systems. Some of these factors result from natural phenomena such as short-term (e.g. El Nino effects) and long-term (e.g. global warming and concomitant sea level rise) climate change, storm damage, disease (which in part can be enhanced by anthropogenic factors such as organic input) and natural increases in corallivores. Unfortunately, often coupled with natural disturbance events are anthropogenic impacting factors that can severely decrease coral reef diversity, productivity and also the physical integrity of coral reefs. So that the impacts of such factors can be appropriately managed it is necessary to determine how coral reef communities respond to disturbance events, in particular, disturbance events that could lead to a decrease in reef health. Therefore this research theme will examine coral communities that are adversely impacted by factors such as high sedimentation, light-limitation, potential eutrophication, and physical abrasion.

1.2.2. Theme 2: Seagrass Ecology

Seagrass beds are also common within tropical marine environments and are extremely important for the health and productivity of coral reef systems and also as a source for local communities. Despite their importance however there is an alarming global decrease in the area coverage of tropical seagrass and active research and monitoring is required of seagrass so that managers gain a better understanding of the system dynamics, ecological connectivity, resilience, diversity and importance to local communities. Therefore Operation Wallacea have instigated several research activities into seagrass ecology.

In a similar fashion to the mangrove forests (which the CCMPA are lacking), seagrass biostabilise sediments which could otherwise be deposited onto the coral reef and impact diversity and productivity of reef systems. They biostabilise sediments by means of their subterranean root system which bind sediments together. The presence of the blades, which can often be extremely dense, also slow water motion and results in high rates of deposition within the seagrass habitat. Therefore sediments suspended within the water overlaying seagrass beds are often deposited before they reach the reef system. Consequently seagrass beds act as a sediment filter as well as a stabiliser and their integrity is key to ecosystem health.

As well as being important for coral reef systems, seagrass habitats also represent very productive systems within an oligotrophic environment due to the ability of seagrass species to tap into sediment based nutrients which would otherwise be lost from the system. This high level of productivity cascades through the trophic level and consequently the abundance of macrofauna is high. Invertebrates in particular do very well within seagrass beds and these invertebrates form an important food commodity to local communities. As well as invertebrates fish are also abundant, and many fishing practices utilise seagrass fisheries as a source of economics and food. Unfortunately many species of fish utilise the seagrass beds and nursery grounds and therefore fishing in this area can have severe impacts on all of the systems fish productivity.

1.2.3. Theme 3: Ecotourism and its Impacts.

The activities of Operation Wallacea and its volunteers are synonymous with most definitions of ecotourism in the current literature, reflecting the high degree of integration with the local economy and society as well as the focus on conservation-orientated activities. Operation Wallacea functions as an important generator of income within the Cayos Cochinos Marine Protected Area (CCMPA) through the supplies and services which are sourced from local communities, as well as the direct economic impact through employment, rental of boats and other income streams. The purpose of this research theme is to promote the means by which this income can be sustained and directed towards the poorer sectors of local communities, which are commonly known as 'pro-poor tourism strategies' in the literature. This theme builds upon case studies of ecotourism elsewhere in the world and long-term monitoring programmes in order to provide a comparative background to evaluate the activities and impacts of Operation Wallacea in the CCMPA. This will enable strategies to be established which will enhance the flow of economic and other benefits to those most in need within local communities.

The "ecotourism social science" project was intended to garner information about the socioeconomic impacts of the Cayos Cochinos Marine Protected Area (MPA) on the Garifuna population that lives within the MPA and the coastal communities who access the MPA. Specifically, a study was designed to collect data on the sources of income for Garifuna communities within the Cayos Cochinos Marine reserve (located off the North coast of Honduras), as well as analyze the socioeconomic impacts of the fishing restrictions placed on local fisherman in the marine reserve. The goal was to quantify from interview data the income foregone by having fishing limited in the protected area and determine how tourism income was spread among the island communities, as well as suggest ways in which it could be enhanced.

2.0 Methods and Materials

2.1. The Study Site.

The Cayos Cochinos are a group of two small islands (Cayo Menor and Cayo Grande) and 13 small coral cays lying 19 miles north-east of La Ceiba on the northern Honduran coast. The Cayos Cochinos form part of the second largest barrier reef system in the world known as the Meso-American Barrier reef system, and have been identified by the Smithsonian Institute, TNC, WWF, and the World Bank as one of the key sections of the Barrier Reef to preserve. The reefs are the least disturbed ecosystem in the Bay Islands complex and have a strong and active NGO working with local communities, private sector bodies and government organisations to help manage the reefs and fisheries over the last 9 years.

In 1993 a team of business leaders concerned with the conservation of the Honduran Coast and its' wildlife together with the Swiss conservation foundation (AVINA), formed the Honduran Coral Reef Foundation (HCRF) which lobbied the Honduran government to obtain protection for the Cayos Cochinos. In November 1993 a Presidential Decree designated the Cayos

Cochinos as a Natural Protected Area and the HCRF as the managing agency responsible for the conservation of the islands.

2.2. Specific Research Methodology

2.2.1. Coral Reef Biodiversity and Ecology

2.2.1.1. Coral Disease

Method

Where ever possible, it has been a general aim of this season to create a high quality methodology, which will provide both a wealth of information for my Thesis, as well as significantly contribute to the management of Los Cayos Cochinos. Throughout this section, the methodology has been broken into three main themes: Substratum assessment, Environmental assessment and Disease assessment. Within each of these themes, the various methods employed to achieve these objectives, have been broken down further and described.

Substratum assessment

<u>Permanent transect installation</u>

The method for installation of the permanent transects was based upon the advice of several experienced field researchers via the NOAA coral list web ring.

For the 5, 10 and 15m transects, 2cm (¾ inch) rebar was cut to an approximate length of 66cm (2ft). For the reef flat, shorter pins were more suitable, and cut to around 33cm (1ft). The rebar was initially cut into 132cm (4ft) lengths, and then cut diagonally in half to give two pins with sloping edges that form the pointed end driven into the substratum.

SCUBA was used to install the pins upon the reef in conjunction with 12Kg (6lb) mallet. Due to the strenuous nature of hammering pins in and increased air consumption, twin 12L tanks were used on the 10 and 15m depth transects. A normal single 12L aluminium tank was sufficient at 5m and on the reef flat.

Often the easiest way of installing pins was to exploit the natural topography and insert pins into natural holes such as the gaps between *Montastrea annularis* columns, thus not requiring the use of cement. The reef flat is less variable and thus pins had to be made squatter to allow direct hammering into the rock substratum.

The pins were installed approximately every 10m along a 50m length transect, at the three different depths and upon the reef flat. This totals six pins per transect, 24 per site. However the pins were not always exactly 10m apart due to reef topography, or for example live Scleractinia being directly under that portion of the tape. Regardless of this, all transects run at least 50m. The system of having transects at depths of 15m,10m, 5m and upon the reef flat, was replicated at three sites; Pelican 3, Pelican 1 and Arena. These sites represent healthy, intermediate and degraded sites respectively. Site choice was based upon 2004 and 2003 baseline surveys.

The resulting system of transects should last 3 to 5 years, and allows accurate, continued monitoring of the reef. The pins are also useful for forming the backbone of undergraduate dissertations, which use the pins as either a guide for the size of their study plots, or as reference points for mapping out the reef and conducting transects.

Community assessment with horizontal, 50m point transects

A fibreglass transect tape was stretched from the first pin, to the next pin in succession, swimming reef on left. The tape covers 50m, stopping at pin number 6. The substratum was then photographed digitally at 10cm intervals, along the entire length of all transects. Photographs were taken directly above the transect, in all circumstances. All photos will then be analysed as point and line transects to species level. This will provide 500 data points per transect, for a total of 2000 per study site. This community data will then be analysed in CAP or PRIMER for comparison. A pilot study of 5m was initially used to successfully verify the accuracy and feasibility of this method.

Rugosity

A 10m length of ball-bearing plumbing chain, was used to gather rugosity data. The chain is fed into all cracks and crevices, parallel to the transect tape. The total length the chain stretches, is then read from the transect tape to give raw rugosity. The distance the chain stretches is then divided by the total length of the chain flat (10m) to give a Rugosity Index. This measurement was repeated every 10 meters over the length of every 50m transect, at every site.

Permanent quadrats

Two methods were used for quadrat assessment of the reef. In both cases a 25cm x 25cm white PVC plastic tube quadrat was used. Pilot studies found this to be the optimum size for use with a digital camera. Although encompassing a smaller area than the usual $1m^2$ quadrat, it allows more detail to be captured, and thus a more accurate analysis of substratum to species level.

The first method focused on the use of the permanent transect pins. The quadrat was placed with bottom left corner against the right-hand side of the permanent pins on each transect. The quadrat was also placed with the bottom edge parallel to the direction of the transect tape, on the side closest to the reef. Two or three photos were then taken with an underwater digital camera, for later analysis. This allowed 6 replicates per transect, at all transects and all sites.

A second method was chosen to supplement the above. It was believed that the first method may be subject to bias and unrepresentative of the reef or transect, due to its reliance upon the permanent pins. Often the pins were installed in the most expedient substratum that could be found, for example cracks between *M.annularis* pillars. This could lead to a bias in the community analysis. As such a random number generator was designed in MS Excel. For each transect, 12 different random numbers were generated between 0 and 50. Each number then corresponded to the distance in meters along a transect, that a photo quadrat should be taken. Again the quadrats were aligned with bottom left corner against the distance mark on the transect, and bottom edge was parallel to the tape. Again the quadrat was on the reef side of the tape, with the photographer's back to the open sea, on the opposite side of the tape to the quadrat.

Environmental assessment

<u>PPF Levels and turbidity</u>

An Apogee industries BQM Photosynthetic Photon Flux Quantum meter was used to assess the amount of light reaching photosynthetic members of the reef community. Unlike a standard photographic Lux meter, the Apogee PPF Quantum meter measures a wider portion of the electromagnetic spectrum, with wavelengths of blue and red that are used by various photosynthetic pigments in algae and zooxanthellae.

The Quantum meter was installed inside a disused Sony Handycam Marine Pack – a VHS camcorder underwater housing. This allowed measurements to be taken at 15m, 10m, 5m and at the surface for calibration / comparison. In all cases the Quantum meter's digital read out could be read through the clear plastic port on the back of the housing.

These measurements were taken on every dive, at every site, alternating the time of day each site was visited, to eliminate any bias generated by time of day or cloud cover.

Sediment traps

Sediment traps were constructed using a modified method of English, *et al* (1997). The traps were designed to fit on top of the third pin in the series of the 15m,10m and 5m transects. Each trap array had four arms, 50cm long, made from two 80cm long lengths of ¼ inch rebar (10cm on the end of each length was bent up 90^o to hold the traps). These lengths were bound in a cross by lengths of wire, and secured to a stem of ¾ inch PVC plastic pipe by two cable ties. This allowed the trap array to be placed both over the permanent transect pins, and to be 'gimballed' level if the pins were not straight.

Each of the four traps consisted of a 50ml centrifuge tube and a plastic funnel. The funnel was constructed from Acetate and held in place by cable ties. The funnels acted as both a baffle, to prevent obstructions, and increased the catchment area of each trap to ¼ m^2.

All traps were installed on all transects on the 24th of July, and left until the 5th of September, totalling 42 days of sediment collection.

Traps were removed as they were installed, by the use of SCUBA. All traps were removed on the same day, within 20-30 minutes of each other. Starting at 15m, and working up to 10m and then 5m, the centrifuge tubes and funnels were removed systematically. First each funnel was removed and placed into a numbered sample bag. Each trap was numbered with site, depth and trap number. Trap number is 1 to 4, working clockwise, with 1 being the closest trap to the reef. Each centrifuge was then screw capped for transport. Each lid was again numbered and displayed site and depth. The bagged funnels and corresponding centrifuge tubes, when then placed in a diver's mesh bag, as they are slightly positively buoyant. After stripping the arrays of traps, all arrays were removed and brought back to the surface, to be used again, in July 2006.

Once on the surface, all traps were filtered out in the wet lab using funnels and Whatman No 4 110mm filters. The filtered sediment was then left in the sun to be desiccated, then placed in marked sample bags.

The sediments will then be transported back to the UK for weighing and analysis.

Meteorology

Rainfall was recorded on the island, as well as daily changes in cloud cover, Beaufort scale wind and sea state. Although basic, this data will be compared with that from mainland Honduras over the study period. Hopefully this will in turn be compared with SeaWIFIS and other satellite data to see what are the main drivers for sedimentation and river hydrology in the region.

Algae isotopes

Dictyota, *Halimedia* and *Lobophora* were to be sampled from various depths and locations from the around the three study sites. These samples would then be desiccated in the sun and placed in sample bags for transport back to the UK. In the UK, samples would be analysed for composition of Nitrogen stable isotopes. Depending on where the algae assimilated their nitrogen from, different ratios of these isotopes, or 'fingerprints' would be found. This would allow the determination of primary sources of nitrogen for the over abundant and dominant macro-algae.

Disease assessment

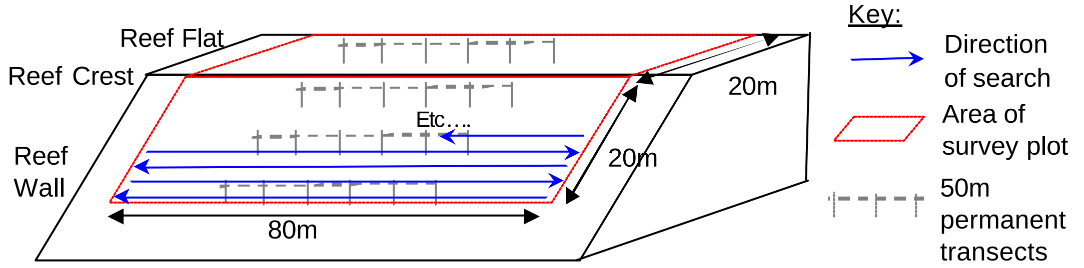
Plot / study section of reef (40 x 80m)

It was found that belt transects did not cover sufficient an area for detection of Scleractian disease which until August, were extremely sparse in MNMCC. As such a continuous patrol / survey using a 40m x 80m plot was devised.

Under Operation Wallacea's diving procedures, dives are limited to no longer than 50 minutes for safety and insurance purposes. Pilot studies found that the optimum plot size for such a dive time is no larger than 40m x 80m when assessing disease levels. The plot is bisected by the reef crest with approximately 20m of the plot on the reef wall and 20m on the reef flat. The width of the plot is 15m either side of the 50m permanent transects, for a total of 80m.

Using SCUBA, divers then monitor the plot starting at the deepest depth and progressing along and up the plot, gradually working shallower, as in Fig 2.

Figure 2. Diagram of 40m x 80m plot area with respect to permanent transects



When a diseased colony was detected, its' bearing and distance to the nearest reference point, usually a permanent transect pin, was recorded. The time and date was also recorded, allowing the generation of an accurate map of diseased colonies upon the reef.

Bleaching and disease progression monitoring – small pins

When encountered, a colony suspected of disease was photographed digitally, date recorded and mapped, as explained previously. Although cases of BBD are conspicuous, some other diseases such as White Plague and Yellow Blotch can be mistaken for bleaching or Coralivore damage. Macro photographs were analysed on computer, looking for tell-tale signs of disease, such as tissue sloughing and intact septae / corallites.

When confirmed as a disease, a colony was then pinned with simple steel tacks, approximately 200m long with a 3mm diameter head. These pins were inserted into the dead portion of the coral, with the shaft of the pin touching the boarder of diseased tissue. Digital photographs were then made at intervals ranging form every other day, to two weeks, allowing a comparison of disease development and rate of destruction.

The universal use of the 3mm wide tacks, allowed photographs to be compared in UTHSCSA's Image Tool 3.0. This then allowed distance measurements to be taken, calibrated against the pixel dimensions of an object of known size, i.e. the 3mm head of the pins. Using this tool, several measurements and rates can be calculated, including changes in area of live tissue, dead tissue, changes in thickness of BBD and changes in rate of progression. This powerful tool, also allows the mapping and study of community change in the primary colonisers of exposed, dead coral skeletons.

2.2.1.2. An Investigation of the Incidence of Scleractinia Coral Associated Disease and Factors Affecting this Distribution.

Introduction

The Cayos Cochinos MPA is a reserve that was severely impacted by Hurricane Mitch in 1998. The reefs have since been recovering, however many are exhibiting a phase shift towards macro-algal dominance, since macro-algae species have been able to recolonise the available substrate more successfully, partly due to there being insufficient algae-grazing fish to keep algal populations in check and allow spawning coral to establish on the substrate without being out competed by the algae. Not all regions of the MPA were affected by the hurricane to the same degree, and the sites naturally vary in quality due to variation in the abiotic factors they are subjected to, such as sedimentation from riverine output, nitrate levels from untreated waste, light levels and water turbidity, where site quality relates to hard coral abundance at each site as well as species diversity with respect to species richness and equitability. Most of the coral diseases that Caribbean species are known to contract have been recorded in the Cayos Cochinos, however they do not appear to behave as they have been observed to in other areas of the Caribbean, such as the Florida Keys, and disease severity does not appear to be as extreme as may be expected of such an impacted area. Therefore, the aim of this study is to conduct a detailed study of the incidence and distribution of disease in the Cayos Cochinos by conducting surveys at three different reefs of varying quality with respect to anthropogenic and abiotic impacts. The first of these is Arena, which is a highly impacted site with low coral cover and high algal dominance. Pelican point 1 is an intermediate site and Pelican point 3 is a pristine site, in that there is extensive coral cover with little damage to the site despite Hurricane Mitch. The methods carried out for this assessment are discussed in the following section in detail. Below is a brief introduction to the scleractinia and some of the main diseases they are subjected to.

Scleractinian corals, otherwise referred to as hard corals due to the deposition of a rigid calcium carbonate skeleton, are essential to the functioning of the aquatic ecosystem as not only do they provide a valuable habitat for numerous species but they also constitute the primary producers that support all other trophic levels of the ecosystem. Consequently if hard coral populations are reduced for any particular reason this could indirectly lead to a decreased abundance and diversity of life within the marine ecosystem. As such, coral diseases harbour the potential to be devastating to marine communities if they are prevalent enough to diminish coral cover at a rate greater than the population can recover, and so to what extent particular diseases are present in a population and how they are caused is of particular importance. Also whether the incidence and distribution of disease appears to be at a natural prevalence in the MPA or changing with respect to anthropogenic activity is of utmost importance, for if disease abundance is being affected by factors such as sedimentation levels then active measures may be incorporated into the management plan to try an curb unnatural variation in disease abundant and distribution. Three of the main diseases under investigation are black band, white band and white plague.

Black band disease is where a black mat, several millimetres in width, is seen to move over the surface of the coral usually from apex to base, leaving behind a white skeleton. The major component of the black band is the cyanobacterium *Phormidium corallyticum*, although numerous other microorganisms are often present as well, such as sulphur oxidising and sulphur reducing bacteria, which also contribute towards the loss of coral tissue. The induced anoxia and high sulphide levels near the tissue are thought to cause this loss. Infection is thought to occur through contact, although wounded colonies are undoubtedly more vulnerable.

White band disease appears to predominantly affect branching corals, such as the staghorn coral *Acropora cervicornis*, and results in tissue sloughing off from the skeleton as the band of infected tissue progresses from base to apex. Unlike black band disease, however, there is no microorganism that has been found associated with all observed cases. This disease is also more difficult to identify than black band, as pale growing tips and predator grazing can produce similar symptoms, though usually of a different pattern.

White plague is highly infectious and progresses at a far greater rate than either of the other two diseases; it generally causes tissue loss at a rate of one or more centimetres per day. Like the others it leaves behind a white skeleton, but there is a very defined boundary between living and dead tissue as opposed to a band. It is thought to be a bacterial infection, though the exact cause is unclear.

Method

The data has been obtained over a 5 week period, via direct observation along underwater transects at the three sites. For each site a variety of measurements has been taken; the depth from which the data is collected, the total number of hard corals encountered, the number that exhibit any signs of pathology (of which a digital photo will be taken of each), the nitrate levels at the site of each transect as well as the turbidity of the water. At each of the sites there are a set of pins that have been put in place to map out the locations of permanent transects, so that the same transect line may be laid out as it has not been possible to complete a transect in a single dive due to the number of coral colonies and safety limitations on dive times. These pins have been placed at three depths; 5, 10 and 15m, such that the required transects can be conducted at the respective depths, incorporating depth as a variable into the investigation. Three dives were required to complete each transect of 25m, which were conducted as belt transects, where for the entire length of the transect every coral species within a 2m band either side of the transect line was recorded (so 4m wide belt). For every colony it was noted whether the colony was healthy, had been predated upon or exhibited suspect disease/bleaching. Any suspect pathology was photographed for reference, allowing more objective identification and analysis on shore. This method was performed for each transect, providing a sample survey area of 100m^2 at each depth at each site. Also for every dive as many abiotic factors were recorded as possible; photosynthetic flux readings for each depth (from which the turbidity can be inferred), nitrate levels, water temperature, amount of rain since the previous dive, sea state, wind speed and cloud cover. Four sediment traps were also installed at each depth at each site, with a known funnel capture area such that the amount of sediment trapped of the period of, say, a month and be quantified with respect to the water column above it. Recording as much abiotic information as possible provides a library of data from which analyses can be performed to ascertain whether any of the abiotic factors may be employed as explanatory variables with regards to the incidence and distribution of coral disease within and between sites.

Subsequent to this initial survey a second phase of investigation was embarked upon. This involved actively searching for and mapping diseased colonies at each site over a plotted area that incorporates the conducted transects to allow for extrapolation of information to the larger area. The plots were designed such that they spanned for 20m either side of the 5m transect line (which is 50m in length), so incorporating both reef crest as well as wall on which there are the deeper transects. The plot was also extended 15m beyond each end of the transect lines, essentially producing an 80m by 40m rectangular plot. Within this plot diseased colonies were actively sought after using a systematic method of search such that the same ground was not covered on separate dives. For every potentially diseased colony found, it was pinned with inert lead nails such that the progression of the disease in question may be recorded over time. The bearing, distance and depth of each colony to a reference point within the plot was also recorded, allowing for the diseased colonies to be mapped out within the plot. In doing this it encompasses a larger sample area and allows for comparison of disease distribution patterns between sites and depth, as well as information of progression rates and potentially transmission of diseases such as black band disease and white plague. Again each site will be visited an equal number of times to allow to prevent there being a bias in the search effort expended at each site. These data in conjunction with the preliminary survey of disease incidence will allow for the implementation of statistical analyses that may be used to test the hypotheses stated above.

2.2.1.3. Corallivore Activity on Scleractinian Coral Colonies.

Introduction

It is now generally acknowledged that coral reefs are among the most threatened global ecosystems, and among the most vital [1]. In 1998 alone, one percent of the entire reef system in the Atlantic/Caribbean area was destroyed [1]. In 2001, a report from the United Nations Environment Programme, in conjunction with the World Conservation Monitoring Centre stated that, twenty-two percent of Caribbean reefs are already dead, and another twenty-two percent are likely to die in the next ten to thirty years. The detrimental processes affecting coral reefs include anthropogenic and natural causes. The increasing coral reef degradation seems to have a close correlation to anthropogenic impacts such as, overexploitation (depletion of integral fish populations), destructive fishing methods (blast/cyanide), increased sedimentation and eutrophication. The natural detrimental processes affecting coral reefs include hurricanes, flooding, adverse temperature extremes, El Nino Southern Oscillation events, predatory outbreaks and epizootics.

These predatory and epizootic mechanical outbreaks can lead to coral degradation. This can be attributed to the potential abundance of corallivores (coral-eating animals, which predate upon corals) on a reef, such as the Green clinging crab (*Mithrax* *sculptus),* coral snails (*Coralliophila spp.),* the Bearded fireworm *(Hermodice carunculata),* and also a few species of fish-particularly parrotfish (*Scaridae)* and some butterfly fish (*Chaetodontidae)* to name but a few. The corallivore activity will ultimately lead to an increase in coral stress-which could potentially give rise to possible coral diseases. The abundance of the Caribbean corallivore species, the parrotfish; such as the Stoplight parrotfish (*Sparisoma viride),* the Queen parrotfish (*Scarus vetula)*, and the Rainbow parrotfish (*Scarus guacamaia),* these species facilitate a particular form of detrimental activity known as *spot-biting*. This behaviour is associated with these fish, due to the fact that they take many small bites over the surface of the coral, ultimately creating obvious large grazing scars within the colonies.

An important ecological question to be asked is, does macroalgae abundance around the coral colonies influence the behaviour of corallivore activity upon the corals? If there is a higher level of macroalgae cover around healthy colonies, then this could potentially mean that colonies which are highly predated may have low % cover of surrounding macroalgae. Therefore the only factor, which determines repeated feeding behaviour on a particular colony, may be simply due to the presence/lack of macroalgae. The lack of predation on some particular colonies may be due to corallivores preferentially eating the macroalgae instead of the coral. These questions will be answered during the research and investigations when writing up this project.

Although a large area of the Caribbean and Florida coral reefs have been studied at some depth, the group of Islands 35 kilometres of the coast of Honduras- Cayos Cochinos have had very little research. A large proportion of the Cayos Cochinos has now been labelled a Marine Protected Area (MPA), due to the conservation work guarded by the Honduran Coral Reef Foundation. Therefore, the surrounding waters are now under protection, thus detrimental factors, for example, exploitive fishing methods have been eradicated. The aim and evident objective is to significantly expand the health of the reefs and ecosystems that co-exist symbiotically. However, scleractinian reef development and growth is extremely slow, therefore research implemented now will only be evident and observed in many years to come. Thus improvements to coral reef health are a long-term investment.

Method

The Cayos Cochinos, marine protected area, contain reefs, which differ significantly, from impacted to pristine. Because of this factor, three varying sites were selected to obtain an overall representation of the marine park. The three suitable sites ranged from the North to the Southside of the Cayos Cochinos. The two sites Peli 1 and Peli 4, located to the North are most pristine, this maybe due to the abundance of fresh nutrients up-welling over the reef- these two reefs are walls which run down into deep water.

However, to the South, Arena, the impacted site, is situated in shallower waters, and due to the topography, this particular site maybe prone to detrimental abiotic factors, such as sedimentation-via River run off. But, the elucidation of this theory will be investigated when the data has been obtained.

The data collection for this research will be separated into three 'Phases', each phase will ultimately lead on from the previous, thus leading from a broad scale data collection, to a specific, fine scale analysis of data:

<u>Phase 1</u>

This particular area was the start of the initial research. This marked the beginning of the broad scale data collection. The data collection involved three different coral reefs. Each reef had three transects, all at varying depths- 5, 10, & 15 metres respectively. To quantify the collated data each transect was the same size, using 25 x 4 metre belt transects (100metres^2). Every scleractinian colony that is within that area was logged, for example:

SITE:		**DEPTH:**		**DATE:**			
SPECIES:	**LENGTH:**	**SIZE:**	**H:**	**D:**	**P:**	**B:**	**PH/No**

NB: Species being, coral species. Length being, the distance along the transect. Size being, the size of the colony. H meaning, if the colony is healthy. D meaning, if the colony is diseased. P meaning, if the colony is predated. B meaning, if the colony is bleached, and PH/No meaning, photo number.

Once all the transects had been completed, the data obtained from each could then be analysed to ascertain the % of healthy, diseased, predated, & bleached corals within the designated transect areas. This information could then elucidate- at which depth, species, condition, & reef was the most healthiest/impacted.

Phase 2

'Phase: 2' involves a two-way approach. To correlate with the broad scale data collection, using the same methodology- fish transects will be performed. Although they will be limited and quantified via transect distance, duration of dive time will also have an integral part, this is mainly due to the fact that corallivore activity is not definite or permanent. Thus the amount of predation on the corals will have to be measured in time, for example: 25 metre transects will be used. These transects will be in the same area as the previous belt transects used for the coral identification. To compliment the same environmental conditions, the fish transects will be performed during the same time of day as were the belt transects for the initial coral identification. However, this is fairly irrelevant due to the fact that corals are sessile, therefore they remain at their position.

Due to the fact that fish behaviour may differ at different times of the day, for example-feeding strategies, the fish transects will be recorded at each depth and site at each time. Therefore, there will be no bias when analysing the data.

A 5metre by 5metre area will be monitored above the transect, thus every 25m^2 area of transect will be studied for 6mins approx. Therefore the information obtained from the observations made, will establish the corallivore activity/abundance on the reef for 6mins every 25m^2, or to quantify the information in a more realistic format- the corallivore activity in 30mins every 125m^2 of reef environment. The fish transect information will be logged thus:

DATE:		**SITE:**		**DEPTH:**		**D.TIME:**	
FISH:	**CORAL:**	**PRED:**	**DEF:**	**SW/T**	**REPEATS:**	**ALGAE:**	**TIME:**

NB: Fish being, the corallivore species. Predation being, if the colonies are predated against. Defended being, if Damselfish ward the predators away. SW/T being, if the corallivores simply swim through the transect area. Repeats being, if the corallivores repeatedly bite the colonies. Algae being, if the corallivores consume macroalgae.

The second part of Phase: 2, is to closely monitor a particular scleractinian coral, the species used will be determined from the results obtained from the broad scale data collection in Phase: 1.

When the species has been selected, nine individual colonies will then be selected from each transect and site. Therefore each site will have a total of 27 colonies that will be closely monitored. Three colonies will be healthy (zero predation), three colonies will have minimal predation, and three colonies will have a moderate to high predation activity. The categorisation is based from the observations in the Phase: 1 data collection. Obviously, a 'healthy' colony will constitute zero predation, whereas the determination between low and high predation could be fairly ambiguous, due to relativity towards other colonies. However, during the observations in Phase: 1, an average number of colonies per transect for each site at each depth can be obtained. Then, from the average number of colonies, the number of predation scars will then be counted (at random). The total number of predation scars would then be divided by the number of colonies included, which would elucidate an average number of predation scars. Therefore, the number of bite scars that fall below this 'average' number, will be labelled 'low', and any colonies with bite marks above this number will be labelled 'high'. However, the average 'bite scar' per colony will possibly differ between the three sites due to the possible varying corallivore activity between the sites. Therefore, each site will have an independent 'average bite scar count' per colony.

The substratum around the colony will also be recorded, ie- % of macroalgae cover-using a quadrat, 12.5cm by 12.5cm ($156.25cm^2$). This method will be used for each depth at each site (principle component analysis). One of the questions that will be asked, does immediate neighbour affect predation? The $156.25cm^2$ quadrat will be placed around the perimetre of the colony to obtain an accurate nearest neighbour composition. Digital photo analysis of the substratum within the quadrats will be analysed to ascertain the percentage of macroalgae surrounding the colony. There will be 8 quadrat photos for every colony, each transect will contain 9 monitored colonies, which gives a total of 27 colonies per site. However, 3 sites will be investigated, thus 3x27= 81 colonies. A total of 648 photos will be analysed. The use of a metre quadrat will not be used, due to the fact that colony size will vary, therefore this would give an inaccurate representation of the surrounding substratum-as a consequence the substratum area would decrease as the colony size increases. Thus, the use of separate smaller quadrats will be used to record the data, giving unbiased information. The predated coral colonies will be tagged and mapped so that their bite scar counts can be monitored.

Phase 3

This phase will involve a weekly check on the 'marked' coral colonies to ascertain if the predation activity is increasing on that particular colony. The area around the colony, which will be analysed, is 1250 cm^2 (8 x 156.25cm^2 the area of substrate quadrats). Each photo analysed will have a grid placed on, using 'Power point'. This grid will create 25 small squares within the quadrat. Each square will be analysed to obtain the percentage cover of macroalgae. When the percent for each square has been elucidated, all 25 individual percentages will be added together and then divided by 25 to obtain an average percentage for that particular quadrat. When all of the surrounding 8 quadrats have been analysed (using the same methodology), each individual quadrat percentage will be added together and then divided by 8 to obtain an average percent of surrounding macroalgae in an area of 1250cm^2.

2.2.1.4. The Factors Affecting the Incidence and Distribution of Coral Disease; in Relation to Predation and Disease on Acropora cervicornis.

Introduction

The prevalence and severity of marine diseases in corals has increased over the last 20 years (Bruno *et al.,* 2003). The study of coral diseases is important as it has been associated with a decline in the quality of the reef environment by many authors (Harvell et al, 1999; Porter et al, 1999; Green and Bruckner 2000).

One of the important, and least understood, aspects of the observed increase in coral diseases and degradation is predation of corals by many corallivores, this includes the well documented Parrot fish, damsel fish and butterfly fish species this also spreads to the less studied fire worms and the corallivorous snail, *Coralliophila abbreviata (C. abbreviata*) the short coral snail.
Studies have been carried out in the Florida keys on this corallivorous gastropod *C. abbreviata*, no work however has yet been carried out in the Cayos Cochinos marine park on this predation, (Baums et al 2003, Miller and Szmant 2001).

From the preliminary research carried out corals that have been documented to be predated by this gastropod *C. abbreviata* are *Montastria spp., Diploria spp* and *Acropora spp.* The preliminary literature studied has been found to be mostly concerned with *Acropora palmata,(A. Palmata)* little work has been carried out on the *Acropora cervicornis* (*A. cervicornis),* and no literature from the preliminary study has been carried out on *Agaracia tenufolia (A. tenufolia)*.

From the preliminary pilot studies carried out in Cayos Cochinos it has been observed that there is much predation by the short coral snail *(C. abbreviata)*, and some evidence of predation by the bearded fire worm *Hermodice carunculata*. The predation by *C. abbreviata* has been observed mostly on the fragile branching coral *A. cervicornis* and on the fragile foliose coral *A. tenufolia.*

A. cervicornis is as mentioned a fragile coral that has been considered for the endangered species list in past studies (Baums et al 2003), it is also *A. cervicornis* along with *A. palmata* that create a great impression upon the landscape and ecology of the reef.

A. tenufolia although a fragile species is not considered as an endangered species and is also considered as a species that can tolerate poorer conditions with increased sedimentation and is often seen to colonise sites where other corals such as the *Acropora spp.* have declined.

It has also been noted that there may be an increase of White Band Disease (WBD) on colonies with snail predation *C. abbreviata* has been noted to aggregate in certain areas or certain colonies, (Miller and Szmant 2001) discovering the factors that cause these aggregations or distributions of snails and WBD to occur, and the amount of tissue loss due to this would be extremely valuable information to help discover the impact of the snails on any reef studied world wide. It may also help implement management plans to help the re-colonisation and recovery of the fragile *Acropora spp* that form an important part of the reef ecosystem.

Studies have shown that removing *C. abbreviata* from *A. palmata* has halted the progression of tissues loss on *A. palmata* the Florida,(Miller and Szmant 2001). There has also been some work on the preference of diet of this corallivorous gastropod studies have shown that snails predating *A. palmata* grew larger over a shorter period of time (Baums et al 2003).

Method

Three sampling sites were chosen in the park, sites were chosen that differ in environmental and anthropogenic factors affecting them, this was done by using results from past research.

The First site is Arena this site is the most impacted site, the currents that effect this island come from the river outflows of the mainland bringing much nutrient and sediment rich water with this current. Arena was also severely impacted by Hurricane Mitch in

1998, this impacted the corals especially the fragile *Acropora spp.* Following the hurricane the fastest colonisation of the newly created substrate was by macro algae such as *Dictyota* and *Halimeda* this also reduces the available substrate space for new coral species to occupy.

The second site is Pelican 1 this site is only slightly impacted by the currents that effect the first site. This site was also much less impacted from the Hurricane than Arena.

The third site is Pelican 4 this is the most pristine site of all three locations and has the least anthropogenic factors effecting it. This site was also the most protected of the sites during the Hurricane.

Methodology for the abundance and distribution of *C. abbreviata,* (Phase 1)

At each of the 3 sites previously mentioned the following surveys will be carried out to determine the abundance and distribution of *A. cervicornis*, *A. tenufolia*, *C. abbreviata* and white Band disease. The average number of *C. abbreviata* per meter square of *A. cervicornis* and *A. tenufolia* in the Cayos Cochinos marine park and the distribution, possible aggregation of *C. abbreviata* across the three sites.

At each of the three site, every colony of *A. cervicornis*, and *A. tenufolia* within the 70m by 15m depth and 5m on to the reef crest plot is studied. Each colony is tagged with a number date time and location written on the tag, this is then photographed.

The depth, diameter (longest length across the colony) and height from the substrate are measured. The percentage of dead coral, diseased coral, the predated coral is also estimated colony. With *A. cervicornis* the number of healthy branches and diseased/predated branches are noted. Each diseased branch is measured from the base to the tip, the length of recently predated or diseased tissue, old predated or diseased tissue and healthy tissue is recorded, the number and size of any snails on the colony is also recorded. Digital photographs were taken of all the colonies and diseased branches to help with any possible difficult identification of disease or predation. This more in depth methodology is not possible with *A. tenufolia* as the structure is of densely packed foliose leaves.

To determine if there is any aggregation of snails within the 3 sites each colony that is studied is mapped to a central marker using a compass bearing and a transect line to calculate the distance from the marker, this can then be mapped to determine potential aggregation of *C. abbreviata.*
Using the height and diameter of the colonies as an estimation of the size of the colony it is then possible to calculate the average number of snails per m^2 of *A. cervicornis* and *A. tenufolia*.

<u>Methodology to calculate the impact of *C. abbreviata* on *A. cervicornis* (phase 3):</u>

Again due to the close foliose leaf structure of *A. tenufolia* it is not possible to calculate the surface area of the leaves with out removing leaves and damaging the coral, so *A. cervicornis* was chosen to study the amount eaten per snail per day.

Branches from selected colonies with snails already predating upon them were chosen, these branches were individually tagged and the number length and diameter of the snails present was taken, and the distance from the tag, with the white predated area was taken. From this the amount of predated tissue can be calculated and the amount of predated tissue per cm length of snail can be calculated.

2.2.1.5. Comparison of Cleaner Preferences of Three Cleanerfish Species for Different Client Species.

Introduction

On coral reefs around the world certain species of cleaner fish and shrimp clean ectoparasites, mucus (Gorlick 1980) and host tissue from client fish species bodies including the flank, fins, mouth cavity, lips and gills. Some species of cleaner, for example *Labroides dimidiatus*, have been shown to be highly specific in their choice of client species (Potts 1973) and it has been suggested that this selectivity may be due to learning through experience (Potts 1973). Gorlick (1980 and 1984) working with *L. phthirophagus* suggests that ectoparasite load and the mucus characteristics, especially when parasite burden is low, of the client are important factors affecting cleaner selectivety.

Size of a fish is typically associated with parasite load, however even though Grutter and Poulin (1998) found both client size and regional occurrence were positively correlated with duration and frequency of cleaning, these relationships disappeared when phylogeny of clients was taken into account. Sazima *et al.* (1999), though working on a different cleaner species, juvenile angelfish, *Pomacanthus paru,* found that there was no correlation between size of client and duration of a cleaning interaction, supporting what was found by Grutter and Poulin (1998).

Therefore, for *Labroides spp.* selectivity of clients appears to be based on learning through previous interactions, ectoparasite load, mucus characteristics and the co-evolutionary history of the client species with the cleaner, though not directly the size of the client species.

Some work has also been done into client selectivity of cleaners, as opposed to cleaner selectivity of clients. For example Bshary and Schaeffer (2002) showed that clients often select cleaners depending on how prior interactions with that cleaner had fared, whether the cleaner had cleaned properly or 'cheated' by taking chunks of healthy flesh.

Milinski and Heller (1978) showed that when a predator was present sticklebacks change to feeding on lower density swarms of daphnia, which is less efficient in terms of amount of food captured per unit time, but presumably allows the sticklebacks to be more vigilant for predators. Could this be the same with cleaner fish, especially facultative cleaners like Blue-head wrasse? For the same reasons could reduced visibility affect the cleaning rate of facultative cleaners?

There has been some work on the Blue-headed wrasse (*Thalassoma bifasciatum*) (e.g. Itzkowitz 1979; Darcy *et al.* 1974) and gobies (*Gobiosoma spp.*) (Darcy *et al.* 1974), though little study into the Spanish hogfish, (*Bodianus rufus*), (only piece found was by Johnson and Ruben 1988). This project aims to take the study of cleaning selectivity of *T. bifasciatum, G. oceanops* and *B. rufus* further.

Darcy *et al.* (1974), working mainly in aquaria, showed that the cleaning gobies *Gobiosoma evelynae* and *G. pochilos* will clean any clients whether they are piscivorous, non-piscivorous carnivores or herbivorous and have cleaning stations where clients come to be cleaned. The gobies have black and yellow lateral stripes and a 'dance' that seems to distinguish them, to potential clients, as cleaners. In contrast Darcy *et al.* (1974) found that the blue-headed wrasse (*Thalassoma bifasciatum*) would not clean piscivorous clients and in fact fled when they were introduced to the same tank, often actually being predated on by the piscivorous potential client. Wrasse also did not seem to display themselves at any specific location but swam about the reef in small schools, and lost their dark lateral stripe when chased. Itzkowitz (1979) actually observed three different colour morphs for blue-headed wrasse depending on their mode of cleaning behaviour; a barred lateral stripe indicated the individual was part of a "far-ranging cleaning group", a solid lateral stripe indicated a solitary individual with a small home range that tended to clean clients from a coral block. The third morph, bright yellow without a stripe, was thought to attract conspecifics to a source of food.

The neon goby (*G. oceanops*) like *G. evelynae* and *G. pochilos* is an obligate cleaner and can be found throughout the Caribbean. As blue-head wrasse are facultative cleaners, supplementing their diet by foraging on bits of algae etc, differences in cleaning preferences may be expected between the blue-head wrasse and neon goby.

The one piece of work on Spanish hogfish (*B. rufus*) found in the literature (Johnson and Ruben 1988) showed that cleaning rates varied at different depths. Juvenile Spanish hogfish apparently have higher cleaning rates at depths greater than 15 metres whereas juvenile Blue-head wrasse have much lower cleaning rates at these depths. This may imply there are some sort of cleaning niches with the two species cleaning at different depths so as to reduce competition for clients.

It has been shown that cleaner fish affect the diversity of fish species on a coral reef (Bshary 2003). In the long term removing cleaner fish reduces the diversity of fish on a reef, but extra cleaners on a reef increases the diversity of fish on a local area of reef within just a few weeks (Bshary 2003). Not only this but the presence of cleaner fish was found to increase the presence of fish species that *don't* associate with cleaner fish. Therefore increased knowledge about cleaner species could have important applications in reef conservation and maintaining species diversity, not just on the Meso-American reef, but on reefs globally.

Method

Three sites were used during this project. This will allow a comparison between the different sites as well as comparing between the different species.

<u>Part 1 – measuring cleaner fish abundance at different depths.</u>

At each of the three sites transects were taken at three depths, five metres, ten metres and 15 metres and number of; neon gobies, juvenile blue-head wrasse and juvenile spanish hogfish recorded. Transects were a total of 100m long, two metres high and five metres wide. From this differences in cleaner fish abundances can be compared between different depths and between different sites.

<u>Part 2 – comparison of cleaner species cleaning activity.</u>

At the three sites cleaners of each of the three species listed above were observed for 15 minutes at a time. Information recorded includes;

- Depth and approximate visibility.
- Client species cleaned.
- Size (approx.) of each client.
- Time spent cleaning each client.
- Area of client cleaned; flank, fins (including tail), gills, mouth (including lips).
- Species of client inspected but not cleaned.

Observations were made at different depths at each site. The species of cleaner and approximate depth they should be observed at were decided before diving using a random number generator.

Part 3 – determination of proportion of time different cleaner fish species spend on different activities.

During the observations in part 2, the amount of time cleaners spent on the following activities was recorded:

- Advertising – for gobies this involves sitting at their cleaner station, and for the wrasse and hogfish involves swimming about above their cleaning station.
- Inspecting – swimming close to (within two cm) and orientating towards a potential client without actually cleaning the client.
- Cleaning – The time spent actually picking at ectoparasties, mucus etc. on the client.
- Chasing a client.
- Being chased by a client.
- Chasing conspecifics.
- Foraging - for bits of algae etc, food obtained other than by cleaning.

The data recorded here will allow for a time budget to be produced showing the proportion of time the different cleaner species spend on different activities.

2.2.2. Seagrass Ecology

2.2.2.1. The Ecological Importance of the Cayo Menor Seagrass Beds as Recruitment Zones for Juvenile Reef Fish.

Introduction

It is only since relatively recent times that there has been an improved understanding of the true ecological and economic value of Seagrass beds. Up until the last few decades, Seagrass ecology was a virtually non existent field within marine ecology. However due to an ever expanding global population that continues to disproportionably colonise in coastal areas, the production of a comprehensive overview of coastal resources and ecologically critical habitats becomes increasingly important to ensure the sustainable management of coastal environments in the future (WCMC 2005 – The Global Seagrass database).

Despite the increased general interest and awareness, in some localities Seagrass habitats remain under appreciated and their role for maintaining regional or global diversity is still misunderstood. Due to this lack of education and understanding it is unfortunately the case that Seagrass habitats are rarely incorporated into coastal management plans, making these delicately sensitive environments vulnerable and susceptible to degradation via a plethora of both natural and anthropogenic threats.

Table 1 – Threats to Seagrass environments.

Natural Threats	**Anthropogenic threats**
Terrestrial runoff of nutrients and sediments can have a major impact on the coastlines on which Seagrasses thrive, by decreasing water clarity via increased phytoplankton production or increased suspended sediment. Decreased water clarity will then reduce rates of photosynthesis within the Seagrass communities.	Boating – One of the major destructive impacts to Reef flats due to the recreational activities of tourism and over fishing.
	Land reclamation and construction in the coastal zone – An apparent problem on popular stretches of coastline, with rapidly developing tourism.
	Dredge and fill activities
	Destructive fishing practises – A huge probably particularly in developing regions such as southeast Asia. Destructive techniques include – Cyanide fishing and Dynamite fishing.

The potential risks highlighted above further emphasise the importance of continued research into the ecology of Seagrass Meadows. Continued research will aid conservation managers and assist them into making appropriate Marine management plans that incorporate the undervalued Seagrass habitats, thus ensuring they are not left exposed to being victims of anthropogenic development and growth in the future. This Project will focus on the hypothesis that Seagrass beds are important Nursery grounds that will have greater Juvenile species richness and Diversity in comparison to adjacent low vegetation sand habitats.

Method

Species richness was analysed via the visual census technique (Counting species, and taking note of frequencies) across 3 varying Seagrass beds/ reef flats. One with No> Patchy Seagrass (<33%), One with Low>medium density Seagrass (33-66%), and one with high density coverage (>66%).

How the variables of Seagrass density and Time of day influence juvenile fish recruitment on the Seagrass beds was also analysed.

Daily monitoring consisted of the measurement of six 20m Line transects. Three transects were monitored across the 3 varying density Seagrass beds in the morning, then three more Transects were monitored on the Same Seagrass beds in the evening.

Once the Line transects were measured with 30m measuring tapes, the Transect line was indicated by placing four fishing floats attached to weights (see Photo 1) along the 20 metre transect. The Florissant fishing floats are buoyant in the water column (above the monitoring area) thus depicting the sample area. The measuring tape was then reeled in, to eliminate biased fish distribution. For example, the white measuring tape may attract certain species.

All fish species that interact with the Seagrass were counted, one meter either side of the line transect and 1m above the transect. Using this method it is possible to calculate the total Seagrass area that was analysed in each habitat. The line transects were conducted between 7.00am-9.00am and between 4.00-5.00pm every evening so it is possible to detect how orbital variation and the moons influence affects the recruitment of the Juveniles.

Any Juvenile reef fish that were not possible to identify in the field were photographed by an underwater digital camera. These species were then subsequently identified with the help of reef fish identification guides.

The Monitoring Period will last for duration of 25 days.

A host of statistical tests were conducted during the synthesis of the data pool. One way ANOVA was used to determine Species richness Variances between Data sets. Shannon-Weaver diversity index values were also be calculated to gain actual scaling figures to help identify differences in diversity between the various reef flat habitats. Using Cluster Analysis it is possible to determine whether particular juvenile fish species have a habitat preference.

2.2.2.2. An Investigation into the Lunar Activity Cycles of Shrimps Living in Seagrass Beds on Cayo Menor.

Introduction

Two years ago, a dissertation project was carried out on Cayo Menor investigating the daily activity cycles of shrimps found in the seagrass. Sweep net samples were taken from the seagrass beds once every hour for 24 hours on three different occasions, in order to determine which times of day the shrimps are most active in the seagrass. In addition to the main conclusions of the project (which found that only a few species were active during the day, and the majority were only recorded at night, with peaks soon after sunset and in the early morning before dawn), it was noted that population sizes of individual species were different on the three different days of sampling.

The three repeat samples had been done at different stages of the lunar cycle – one at full moon, one waning and one waxing. It was suggested that the differences found between the three days might be a result of variation in the activity of the shrimps controlled by the lunar or tidal cycle. However, with only three days to compare, the differences could have been due to any number of factors and there was no way to be sure of any connection between the lunar cycle and the activity of the shrimps.

Seagrass beds are well known as important habitats for a number of fish and invertebrate species, due to their relatively high photosynthetic productivity. In addition, they have been identified as nursery sites for other habitats, most importantly coral reefs. As habitats, they are therefore closely interlinked with the ecology of their surrounding habitats.

Not so much is known of shrimp ecology in seagrass (their relatives living on reefs have received more attention). It has been noted, as in the investigation described above, that the shrimps show variation in their activity and when they are found in the seagrass – there are times (most obviously, during daylight hours) when, except for a few species which live permanently in the seagrass, they appear absent from the beds entirely. During these periods the shrimps are either hidden, buried in the substrate, or have migrated to neighbouring reef or rocky areas to hide away.

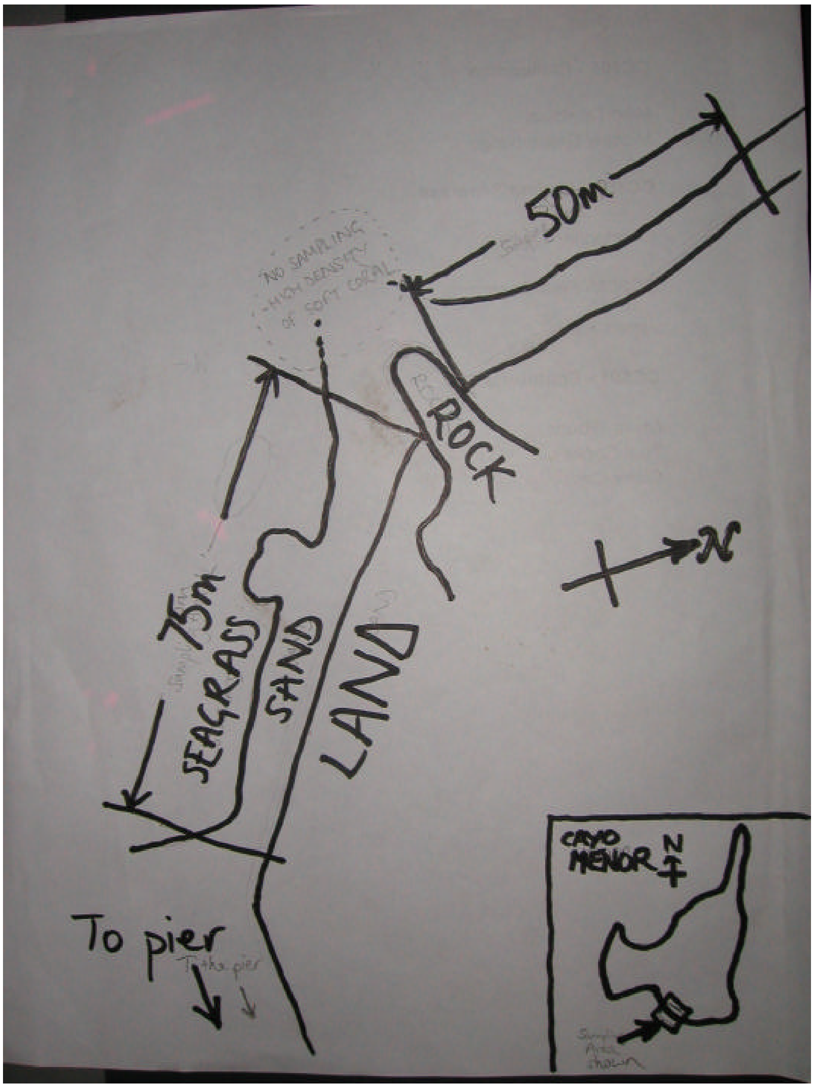
The most likely reason for this behaviour is that the shrimps are evading predators, predominantly fish, which use mainly sight to locate their prey. The daytime is therefore a dangerous time, and it is best to stay hidden, whereas at night the shrimps come out onto the seagrass to feed.

As regards variation from day to day, very little has been concluded about the presence or otherwise of any lunar cycling, although it has been well studied in some other groups of crustaceans, such as crabs and lobsters. It appears that these do indeed follow lunar cycles, using mainly light levels during the night as their cue.

Method

Enclosed is a map of the area under study. Since the beach runs in roughly straight lines either side of the rock, the rock was used as a reference point and mapped using primarily distances (measured with a tape) from the rock. Distances have been coded with a number, giving distance from the rock in metres, and L or R, denoting left or right of the rock (looking out to sea). Positions of various landmarks along the beach were also recorded(not shown) so that start points were easily located in the dark.

The area to study was decided on after snorkelling reconnaissance of the area (which was used to add detail to the map). Directly offshore from the rock lies an area of low density sea grass with a large number of soft coral colonies, from which sampling was avoided, since it represents a different type of habitat. A similar area limits the extent of sampling to the right of the rock. To the left, the edge of the seagrass curves outwards and runs to deeper water in which it is impossible to wade.



Using the map of the sample area, a starting point for the transect was randomly selected. From this point on the shore, the starting point of the transect is laid perpendicular to the shore, a few yards into the area of live seagrass. The transect was laid parallel to the edge of the seagrass (always in the same direction, towards the south-east), to mark out a 15m transect.

Walking back along the transect the area was sampled, dragging the sweep net through the seagrass approximately one metre to the seaward side of the marked transect (so that there was no sampling across an area which has just been walked over). The net is dragged through the seagrass as low as was possible without digging into the substrate below. Once the 15m sweep was completed, the net was closed off to prevent any escape and brought back in to shore.

Four samples were taken each night, ensuring that they were not overlaping, working from the far end of the beach (roughly NW) back towards the camp. After each one, the net was rinsed into a numbered bucket, with close inspection ensuring that all shrimp were transferred into the bucket, which contains a small volume of seawater. The four samples were completed within as short a time period as possible (approximately 45 minutes) and always taken within the period 7pm to 8.15pm, by which time it is dark. This minimized the effect of any temporal variation over the course of the day (as identified in the study of two years ago).

The next morning, by which time the shrimps have all died, each sample was sorted in turn. The sample was poured into a tray and, by inspection, all shrimp specimens removed and placed together in a sample bag in a small volume of sea water. A small quantity of formaldehyde was added in order to preserve the sample. The sample bag was then labelled, sealed and eventually transported back to the UK where each shrimp will be identified, under the microscope, to species level.

Each night the following weather and sea conditions were noted:

Temperature – measured with a thermometer at the surface of the water

Sea conditions – an estimate of the level of swell, from 0 (calm) to 4 (high swell, beyond which I would not sample)

Cloud cover – an estimate of the percentage cloud cover, numbered from 1 (being clear) to 8 (being completely overcast)

Wind – an estimate of strength, from 0 (calm) to 4 (very strong), and direction

Precipitation – a note of any rain during sampling or during the previous 24 hours, then categorised according to time since it rained

0 - none in the last 24 hours, to 4 - raining at the time of sampling

Moon – an approximate note of the phase, to be later confirmed by information on the internet, and whether it is visible or obscured.

At five metre intervals along the sampled area, the following information about the seagrass was recorded, which can then be related to each sample according to the recorded sample location:

- Density – number of shoots within a 5x5cm quadrat, scaled up to give density per square metre, measured for the two species of seagrass present: Turtle grass, *Thalassia testudinum*, and Manatee grass, *Syringodium filiforme*.
- Percentage cover – an estimate of cover within a 20x20cm quadrat.
- Shoot length – the maximum length of 80% of the shoots, when fully straight
- Canopy height – the maximum height above the substrate of 80% of the shoots

- Depth – related to water level at a standard point on the pier, which is also measured at the end of each set of samples, so that actual depth at time of sampling can be calculated.

2.2.2.3. Hermit Crab Ecology

Introduction

Hermit crabs rely on empty gastropod shells in order to provide them with the protection that they lack. Competition for shells seems to be a limiting factor on hermit crab population growth and hermit crabs will often enter into fierce battles for a new home. When a new shell becomes available the hermit crab will undertake extensive investigation before finally accepting its new shell. Their soft asymmetrical abdomen is twisted to fit into the coils of the host shell and their right claw is usually larger than the left and acts as a protective door whenever the hermit crab retreats into its shell. The last pair of abdominal appendages are modified to form hooks which are used to attach to the inside of the shell so that it is impossible to drag a crab out of its shell without harming it.

Previous studies have investigated hermit crab distribution and abundance on Playa Uno on Cayo Menor in the Cayos Cochinos marine protected area. This investigation set out to assess distribution and abundance on various other sites around Cayo Menor in order to make a comparison between the different sites.

Method

Distribution and abundance of hermit crabs was measured at each of 3 sites; biological station beach, Playa Dos and Playa Oriental. The intertidal region was the main focus to determine substrate preference and the influence of shell availability on hermit crab density.

Mapping of habitats

On each on the beaches under investigation a profile of the beach was taken. Readings were taken of the depth of water every 2m from the shoreline to approximately 20m out. No readings were taken past a depth of 1m as this was beyond the intertidal range and thus not useful for studying hermit crab populations. This was repeated at 15m intervals along the beach (at 0, 15m, 30m and 45m) so that they average profile could be calculated.

Distribution and abundance

The distribution and abundance of hermit crabs was measured using a variety of methods in order to gain the best understanding of how hermit crab density varies. One method alone would not allow enough information to properly assess the whole situation.

Biological station beach

During our pilot study no hermit crabs were found at this beach so no further investigations apart from the beach profile were taken here.

Playa Dos

Playa Dos consists of a large sandy beach with rocky patches that become exposed at low tide. Beside the rocky patches there is a band of seagrass which then leads to sand all the way to the shoreline. Hermit crab density and distribution was measured at this site and at another site at the far end of the beach where a rocky outcrop provides a good habitat for hermit crabs.

In order to measure the abundance of hermit crabs in the rocky area a method of random quadrating was employed. The area was first mapped out and measurements taken of all its dimensions. Then a stone was thrown randomly into the area and wherever it fell, a 25cm by 25cm quadrat was placed and the number of hermit crabs within that quadrat counted. During the time of investigation, the water would ebb and flow with the tides so to ensure consistency of results, the percentage exposure from the water was measured for each quadrat. Also for each quadrat the percentage cover of seagrass was taken as it varied within the area. It was later categorized into 4 groups and these were 0-25% cover, 25-50% cover, 50-75% cover and 75-100% cover. In this way hermit crab abundances in each of the different substrates could be calculated.

The same method of random quadrating was employed in the rocky outcrop at the far end of the beach. Here a total of 100 quadrats were taken which covered the whole of the rocky area. The amount of water covering each quadrat was recorded. The sandy area around the rocks was also quadrated a total of 50 times and each time the percentage of sand was recorded.

Playa Oriental

Playa Oriental consists of a rocky shoreline, which at about 3m from the shoreline turns to sparse seagrass and then to more dense seagrass. During the pilot study at this beach, few hermit crabs were found in the seagrass while many were found on and underneath the rocks on the shoreline. At this site 1m quadrats were used in a belt transect along the rocks at regular 1m intervals. Within each quadrat, all of the rocks were overturned and the number of hermit crabs found was recorded. The number of gastropods and empty shells was also recorded within each quadrat.

Diurnal pattern measurement

On the first day of investigation it was noted that the hermit crabs tended to move from the seagrass towards the rocks during the day. In order to study this type of diurnal pattern, belt transects were taken along the seagrass, along the sand adjacent to the seagrass and along a sandbelt at the shoreline at 15 minute intervals throughout the day. At o’clock and at half past the hour the seagrass measurements were taken, and at quarter past and quarter to the hour the sand measurements were taken. The quadrating began at 11.30am and ended at 3.30pm. At regular intervals along the belt transect, a 25cm by 25cm quadrat was placed and the hermit crabs within it were counted. This method allowed observations on whether hermit crab numbers in each of the different substrates varied throughout the day.

Cluster analysis and mapping

In order to analyse whether hermit crabs tended to cluster together with similar shell sizes, measurements were taken within the rocky patches exposed at low tide on Playa Dos. 5m by 5m quadrats were taken and the location of each cluster within the quadrat was noted as well as the number of hermit crabs in each of the clusters. A total of 5 quadrats were taken in order to cover the whole area.

Aquaria experiments: rock type and size preference, substrate preference, cluster analysis

Hermit crabs were collected from Playa Dos and brought back to the wet lab in sealed containers with seawater. They were released into tanks containing rocks from Playa Dos and allowed to settle. Male and female crabs were used without distinction and each individual was used only once for experimentation.

The first experiment consisted of offering the hermit crabs two different types of rock; one from the beach where the hermit crabs were recovered, and one from the beach beside the biological station where no hermit crabs had been found in the pilot study. The rocks found on Playa Dos were a dark green/ purple colour and closely matched the colour of the hermit crab shells found at that beach. The rocks found beside the biological station were white marble type rocks on which the hermit crab shells stood out. This experiment allowed an assessment of hermit crab rock type preference which may play a part in varying distributions around the island. For this experiment, 3 tanks were set up; one containing only 1 hermit crab, one containing 25 and the last containing 50. Each rock was placed at a separate end of the tank and the hermit crabs were placed in the sand between the two. The number of hermit crabs on each rock and in the surrounding sandy area was then counted every 3 hours several days.

The second experiment consisted of offering the hermit crabs two of the same type of rock, either two white rocks or two green rocks. Three tanks were set up for each experiment, each containing two rocks of the same type at either end of the tank while the hermit crabs were placed in the centre between the two. In the first tank only one hermit crab was left in the centre, in the second tank 25 crabs were placed between the rocks and in the third tank 50 crabs were used. The position of the crabs was recorded every 3 hours for several days. This experiment allowed cluster analysis of the hermit crabs as we were able to see whether they would divide themselves equally between the two rocks or all end up on the same rock.

2.2.3. Ecotourism and its Impacts

2.2.3.1. Social Impacts within the Cayos Cochinos

Introduction

The Cayos Cochinos is a series of fourteen small island keys off the north coast of Honduras; its surrounding waters are home to a rich variety of fish, lobster, and conch. Most of the islands are privately owned by wealthy Hondurans who rent them to wealthy national and foreign vacationers. There are two Garifuna settlements: Chachaute, an island without water, sanitation, or electricity; and, East End, a small settlement on Cayo Mayor. The Garifuna claim to have occupied these cays for over one hundred years, relying on fishing as their main livelihood strategy. Garifuna residents of other coastal communities, primarily Nueva Aremenia, Rio Esteban, Sambo Creek, and Corozal also fish in the Cayos Cochinos.

The Garífuna are descendants of marooned Africans and Amerindians, who were forcibly exiled by the British from the island of St. Vincent to Roatan, Honduras in 1797. From there, they established settlements along Central America's North Coast from Nicaragua to Belize, and have since extended their communities to major cities in the United States. Honduras has the largest Garifuna population, with settlements stretching along its north coast and islands. The two main groups of Amerindians from which the Garifuna descended are the Arawaks and Caribs. While the Arawak economy was based on cassava farming, hunting, and fishing, the Caribs were fisherman and warriors, but not agriculturalists. The Garifuna inherited these livelihood strategies and still identify as principally fisherman ("*siempre somos pescadores"*) and cassava farmers (*"nuestra cultura es la yuca"*). That the Garifuna place such emphasis on these traditions as something that contributes so heavily to defining them as a unique people is especially significant given the recent development strategies of the Honduran nation.

Tourism development and "ecotourism" or "adventure" tourism is receiving significant backing by the World Bank and other major international funding agencies. The nation hopes to see tourism develop both on the coast and within the Cayos Cochinos, and this has huge impacts on Garifuna livelihood strategies and cultural identity. On the coast, the Garifuna ability to participate in agriculture has been significantly reduced as a result of neoliberal agrarian reform that is put in place to encourage coastal tourism development. In the Cayos Cochinos, the establishment of the MPA and the 2005 implementation of the management plan has placed severe restrictions on Garifuna fishing and essentially taken away their other main economic tradition (i.e., fishing). Both of these occurrences have significant implications for cultural identity, let alone livelihood.

When the Cayos Cochinos was granted protected status as a Marine Protected Area in 1993, industrial fishing was banned and a moratorium was placed on all fishing. A system of surveillance and policing was established, which ended up militarising the area. These acts were met with resistance from Garifuna organizations

(OFRANEH in particular), who claim that the Garifuna were left completely out of the decision-making processes. Since 1993, with the aid of human rights organizations, the Garifuna have continued to struggle against the government to remove the regulations.[1] In 2004, the Honduran Coral Reef Foundation (HCRF) and the World Wildlife Fund developed a management plan for the MPA. The management plan built in a participatory process and representatives from the Garifuna community were invited to help shape the plan.

83 people are listed in the management plan having contributed to its development. Of these 83 people, 20 are residents of Garifuna communities. The representatives included: 2 men from Chachautate, 2 men from East End, 4 men from Sambo Creek, 2 men and one woman from Nueva Armenia, and 6 men and 2 women from Rio Esteban. HCRF staff reported that they invited the leaders of each community to participate in the meeting. The management plan publication states that not all names listed actually signed onto the plan in the end. However, the publication does not indicate who resisted the final plan.

In addition to the ban on industrial fishing, the 2004-2009 management plan bans local fisherman from diving for lobster or any other marine species. Lobster traps are permitted during an established season and female lobsters must be returned to the sea. Moreover, the collection of conch is prohibited. Like lobster,

[1] See Mark Anderson's (2000) *Garífuna Kids: Blackness, Modernity, and Tradition in Honduras*. Unpublished dissertation. University of Texas at Austin.

conch is a key ingredient in traditional Garifuna recipes. Hook and line fishing of select species is permitted. Navy boats patrol the MPA twenty-four hours a day to ensure compliance; fisherman caught breaking the rules can be subject to having their boats and equipment taken from them and incarceration in Roatan.

However, despite the fact that the 2004-2009 management plan states as an explicit objective "the promotion of ecotourism as an economic alternative to fishing," to date there are still no formalized ecotourism projects underway. Adventure tourism, scientific tourism, and dive resort tourism are present. Wealthy tourists overnight at the Plantation Beach Resort or rent one of the privately-owned homes. Tourists also take day trips from coastal hotels through tour operators based out of La Ceiba or Sambo Creek. While there are a few options for tourists to stay on Chachauate, those who stay on the island are usually backpackers or "adventure tourists." However, Chachauate does get a substantial number of drop-in visitors who are interested in 'experiencing Garifuna culture.' These tourists come to eat traditional Garifuna dishes, buy jewellery, and interact with community members. The most popular postcard of the Cayos Cochinos is in fact, an aerial view of Chachauate. Clearly, tourists are interesting in consuming "Garifuna culture." While East End has more amenities than Chachauate (it has water and electricity), it does not have cabanas for tourists and thus receives very few visitors.

Method

The data collection occurred from July 13 to August 23, 2005 and the methods included semi-structured interviews, focus groups, closed-ended questionnaires for quantitative analysis, participant observation, direct observation, participatory mapping activities, and collection of primary and secondary data.

Upon arrival in Honduras, the first week was spent designing a household income survey that was planned to be carried out in every household in Chacahuate, East End, and with the samples in the three mainland communities. The survey developed covered the following areas: participant demographics, household demographics, household income and expenditures, fishing history, nutritional levels, and opinions about tourism and the management plan. A timeline for data collection was also developed, a budget to cover research expenses, and the management plan read through. In week two, the survey was with two households in Chachauate. During the pre-tests a number of questions were identified that did not generate the data required. Moreover, the survey took between 2-3 hours to complete. If the survey was to occur with all households, it had to be reduced. The survey was reduced 10 questions.

In total of 22 interviews were conducted.

2.2.3.2. The Impacts of Ecotourism on Livelihoods of the Garifuna Communities of the Cayos Cochinos.

Introduction

The term ‘ecotourism’ was first published in literature in the early 1980’s by an academic called Ceballas-Lascuráin (Fennel, 2003). However, it’s origination is hotly debated, some arguing that the phrase emerged as early as the 1960’s (Fennel, 2003). Since this time, many definitions have been developed that have all centred on the fact that ecotourism has evolved from alternative tourism and then from nature-based tourism, concepts that are much older in literature. The activities undertaken in ecotourism overlap with different subsets of nature-based tourism, consequently linking adventure, 3S (sun, sea and sand) and culture-based tourism to ecotourism (Weaver, 2001). However, the identifying factor to define ecotourism is its focus on the natural environment, on both the living and the non-living natural phenomena, and its pursuit of sustainability. Four main criteria for classifying ecotourism have been identified from the culmination of the many definitions:-

1) Ecotourism is a form of tourism;
2) It is primarily nature-based and has a secondary cultural component;
3) It provides experience for learning, education and appreciation;

4) It must appear to be environmentally friendly and socio-culturally sustainable, and be in pursuit of these factors' enhancement.

Ecotourism's popularity has undoubtedly risen since the 1980's when much literature began to be published surrounding the idea. However, to what extent globally is debatable with figures ranging from a rise of 10% up to increases of 40% (WTO, 2000). These discrepancies stem from the fact that its definition is still debated and figures submitted are not universally consistent in depth and frequency (Weaver, 2001). An example of ecotourism's growth is through whale watching which has become a multi-million dollar industry in the last 10 years (Elander and Widstrand, 1998). Laguna San Ignacia in Baja California in Mexico sees 3000 tourists visit each year with the revenue generated from this ecotourism contributing greatly to the immediately surrounding economies.

Honduras seems to be experiencing the lower scale of the increasing popularity of ecotourism. As Lindberg states, 'ecotourism has never attained a significant profile within the region' of Central America compared to other global destinations, for example Central Africa having huge popularity for its safari vacations (1993, p.160). Weaver outlines three main reasons for this: its limited land base, being the second smallest country in Central America, its already densely populated land area and the fact that the region has been extensively degraded in the last 500 years through natural and human caused disasters, the most recent and the one with perhaps the most influence on the Cayos Cochinos being Hurricane Mitch that occurred in 1998. Despite these observations, mainland Caribbean, including Honduras, has great potential for ecotourism to grow in popularity and importance due to its broad array of cultural, historical and ultimately environmental attractions, other than merely 3S tourism that the Insular Caribbean can offer. The start of the twenty-first century has seen Honduras, among other mainland countries, beginning to exploit such potential (Lindberg et al. 1993). Research in the Cayos Cochinos has shown that tour operators servicing the area, and coastal locations have, in the last year or so, taken notice of this growing demand and offered tours to see the Marine Protected Area and surrounding destinations, for example Paraiso Tours in La Ceiba. As 53% of Honduras' population classified as living in poverty, having US $1 or less to live per day (DFID, 1999). Its economy is strongly agricultural based, with there being a significant imbalance in the proportion living in urban and rural areas, the majority residing in the latter. Therefore, such vast expanses of rural area provide the perfect basis on which to develop ecotourism, but with the challenge of ensuring that it is sustainable.

Recent surveys have shown that there has been an increase in ecotourisms' popularity in the country, with statistics by BIMSA (from Let's Go Honduras, 2003) showing that natural attractions ranked second in preferred attractions for tourists between 2003 and 2004, with a percentage of 35.2%. Culture and its people ranked third with 15.5% also an indication of ecotourisms' growing popularity in Honduras. Designated tourist attractions ranked first with 42.8% of tourists favour, with the remaining percentages being made up by shopping, archaeology and other attractions. As tourism in general was surveyed as having increased by 10% between 2003 and 2004, it is a good indication that ecotourism will continue to increase in popularity and reach its full potential in the coming years with factions of ecotourism, the environment and culture, being voted by just over half of all surveyed tourists in this period as the popular attractions.

The relationship between ecotourism in the Garifuna communities, as with like developments in any community, and their livelihoods is delicate. For the majority of the Garifuna population their primary source of income for the last 200 years since colonisation has been fishing. However, as this is now restricted due to the rules and regulations of the Marine Protected Area of the Cayos Cochinos, people are looking for alternative sources of income. With fishing, their livelihoods, their way of life, their social status and their culture and environment, has not altered, or even had to alter. However, with the possible onset of increased ecotourism and all associated developments, both socially and economically, livelihoods are at risk of changing. Smith and Scherr (2003) state that livelihood issues have a strong basis in the Kyoto Protocol of 1997 suggesting that development should be sustainable and be induced by ‘clean development mechanisms’. Tourism is one such form of development and therefore, should be carried out with caution, with the overall aim of ‘improving local livelihoods’ (p.2143-2144). The impacts of ectourism on the livelihoods of Garifuna communities in North East Honduras are not widely written about in literature as yet, therefore the extent of such impacts, if any at all, is unknown. However, as the effect of ecotourism on local livelihoods and the environment are huge issues and ones that are clearly identified in ecotourism's defining criteria (Weaver, 2001) the study will be focused around them.

Through studying the literature surrounding the issue of ecotourism in this preliminary literary review there seems to be questions that have arisen as to whether or not the definition's stated criteria (see p.1) are fully met in ecotourism destinations throughout the world. I propose to use the Cayos Cochinos in Honduras to study this gap in the literature further, using 4 locations that from the outset seem to hold good comparisons in general indicators: -

- Chachahuate;
- Nueva Armenia;
- East End;
- Rio Esteban.

These Garifuna communities will be the centre of attention in the study to find out and understand the impact of ecotourism and its associated developments on their livelihoods and on the environment on which it focuses. Lohmann makes links to the idea of Green Orientalism and the debates produced questioning whether one aspect, of either the environment or livelihoods, is prioritised over another through ecotourism (1993). For example, is it prioritising nature in ecotourism both in name and practice, or is it less 'eco' and more livelihoods based. Consequently, probing to what extent is the process of ecotourism assisting the environment at the expense of the local people and their development, or vice versa (Lohmann, 1993). The term sustainability has been used in conjunction with ecotourism in its definition to give the impression, at least, of that this form of tourism is working with the environment and the inhabitants on which it focuses itself to conserve the two. However, its credibility is somewhat questionable and it is suggested by Mowforth and Munt (1998, p.80) that the relationship between ecotourism and the term sustainability is merely to 'give moral rectitude and 'green' credentials to…[the activities' undertaken within it. Weaver (2001) summarises the problem beautifully:

'Ecotourism must strive to be environmentally, socio-culturally…and financially sustainable…Some argue that an ecotourism operation can achieve one type of sustainability or the other, but not both.'
(Weaver, 2001, p.336)

Therefore, the sustainable livelihood approach in ecotourism must be addressed to reinforce the positive aspects of ecotourism and mitigate its constraints and negative influences to ultimately improve the livelihood of the Garifuna communities by discovering alternatives and increasing their options. All issues have been considered researched during the research period in the Cayos Cochinos.

Background on the Cayos Cochinos: The Place and its People

Garifuna population in Honduras is approximately 250,000 with roughly 58 communities throughout the country. The four communities that I chose, indicated by white stars on the map below, are well established and links exist within and between each community.

Cayo Chachahuate is the sister community of Nueva Armenia on the mainland, while East End on Cayo Mayor is the sister community of Rio Esteban. The island communities are under the Departmento de Atlántida along with Nueva Armenia on the mainland, while Rio Esteban is under Departmento de Colón. They are all Garifuna communities, each established in varying times past. The island communities are much smaller than their relative communities on the mainland. The islands were established as a second location in which fishermen and their families could live during the fishing season. Some families live there permanently but this is not common. Families usually return to the mainland for a couple of weekends in a month. There is a primary school in East End for children aged between 5 years and 12 years old. This education is free but once they reach graduation, education is to be paid by their families. Therefore, only those children whose parents can afford to send them to high school continue further education. Their religion is primarily Methodism, with a Church in each of the mainland communities and services held on the beach once every 21 days on the island communities. Symbols and religious messages are in all houses, with many members of the communities wearing signs of the cross.

Despite the close relationships between the communities, they each have a different atmosphere and standard of living due to a vast number of reasons. Each of the communities has its own

Patrinato, or council, which makes all decisions on behalf of the community. This usually consists of all males from within the community, with the exception of Rio Esteban whose President is a female and many of the council members also. The communities' primary source of income has been fishing for centuries. With this occupation there is a certain way of life, with females having typically five or more children as young as 16 years old and staying at home to look after them as housewives, while males supporting their families by spending days and nights out in the Cayos Cochinos during fishing season. Garifuna way of life is humble and relaxed, with time keeping and urgency a rarity. As people have very little schedule to their day, members of the community, of all ages, tend to sit together and chat, and it not being unusual to see men consuming alcohol throughout the day. Women, although do not usually have the political power in the communities can be seen to be much more dynamic and active than the men.

With the implementation of the Plan de Manejo by the Fundaci?n in 2004 and associated rules and regulations on fishing activities in the MPA, their source of income is having to be altered and consequently resulting in potential impacts on their livelihood. Ecotourism is a definite viable alternative source of income to the more traditional method of fishing, with other alternatives being carpentry, masonry, furniture making and clothes making. However, with their previous way of life being identified by a much more laid back approach, and with organisational assistance being slow to aid the communities, alternative sources of income have not yet been established and require much more effort and work until they can be seen as being able to sustain the communities. Garifuna communities are often discriminated against outside of their communities, as Hondurans don't believe them to be natives as they only settled and colonised Honduras 200 years ago. Therefore, as this discrimination is an issue aside and a great barrier to conquer, development within each community is the most viable option.

On first impressions of the communities, differences, some obvious, others subtler, can be seen in their ways of life, with regard to their levels of income and standard of living attributed to a range of reasons. However, a theme of opinions runs through the communities on the topic of development for the future, with the most prominent being education for the young and training for the older generations, with the idea that this should assist in the issue of finding alternative sources of income for a sustainable future.

Methods

Data and Information Collected

Secondary Data:

- Official statistics on tourism in Honduras:
    - Tourism numbers since 2000;
    - Nationalities;
    - Destinations and purposes;
- Official statistics on tourism for comparative demographic countries;

- Official Honduran statistics via HCRF from the last census carried out in 2001 for Cayos Cochinos and influential coastal communities;
- Restriction zone map of Cayos Cochinos;
- Map of Cayos Cochinos and north east coast, Honduras, showing research locations.

Secondary data provides vital geography of the local and national area and also a context in which to set the research (Flowerdew and Martin, 1997).

Primary Data and Information:

- Level of tourism in the Cayos Cochinos and/or communities at present:
    - Subjectively- by Garifuna opinions;
    - Objectively- through data collected by HCRF in last 3 months;
- Evidence of developmental assistance given by outside organisations and/or HCRF;
- Garifuna opinions on communities' present status and community development;
- Garifuna views on the impact of tourism;
- Garifuna opinion on future developments in ecotourism;
- Garifuna views on ecotourism present in the communities being seen as sustainable for the future.

Data Collection Methods

The research area was in the Cayos Cochinos and along a 60km stretch of the north east coast of Honduras, extending from La Ceiba to Rio Esteban. Within this research location 4 locations were compared, namely Chachahuate, East End, Nueva Armenia and Rio Esteban, as focusing on the level of tourism within the communities with a specific emphasis on ecotourism, its impacts on the livelihoods of the communities and the extent to which ecotourism can be viewed as a sustainable form of tourism in the future. Related persons to the topic were also asccessed in Sambo Creek, another community along the coast line, and HCRF employees and tour operators in La Ceiba. All research methods were carried out with the assistance of translators, namely Dr. Keri Brondo from Michigan State University, 4 US Peace Corps Volunteers, Antony Ives, Kemi, Lynnette and Max Wilson, and Alicia Glassco who is Schools Coordinator with Operation Wallacea.

The methods were both qualitative and quantitative, which allows a good statistical grounding to support a very deep understanding of the present situation and specific views and opinions of Garifuna in Cayos Cochinos. Triangulation methods were used by using multiple research methods or research from a number of sources in an attempt to ‘maximise understanding of the research question’ (Valentine, 1997).

Questionnaire

Each questionnaire took between 1.5 and 2.5 hours. The reasons for this were that using a translator to carry out any research method slows the process and that each question had to be explained thoroughly to the interviewee, including repetitive explanations on how to answer the questions. The table below indicates the community and respondents to the questionnaire in each:

COMMUNITY	RESPONDENT
Chachahuate	Fausto Nahun Sabina Avier
Nueva Armenia	Alba Olga Marina Nue Renee Arzu Santa Cleotine
East End	Jolanda Gutierrez Sylvia Lionel
Rio Esteban	Cornelia Murella Albarado Lucilla Interview Eli Andrade Puerto Mario Luis Andrade

A number of "rules" were followed when producing the questionnaire but was not restricted by them as every questionnaire is unique (Oppenheim, 1992, p.130). Incuded were:

- Short introduction that was polite and informative, outlining why research was being carried out, the importance of their response, what was to be gained from it and how it will benefit the respondents, and concise instructions on how to answer;
- Introductory sentences to each new section of the questionnaire to reiterate the importance of the respondent and maintain their attention;
- Short, statistical seeking, closed questions for the sections in the first part of the questionnaire, providing a non-opinion option where appropriate as a great deal can be drawn in analysis from those without an opinion as from those with (Oppenheim, 1992);
- Open questions in the remaining sections of the questionnaire toprovide more in-depth answers.

- The Likert scale was used in the form of closed questions which will allow me to employ quantitative techniques and produce simple descriptive statistics. Below is a sample question that I asked all respondents in questionnaires, and interviewees if they belonged to a community:

Translator: Please could you rate the following on a scale from 1 to 5 using the table below; 1 being very bad, 2 being poor, 3 being neither good nor bad, 4 being good and 5 being very good.
XXXXXX:

	1	2	3	4	5
a) Rules for fishing					X
b) Level of income per week	X				

c) Amount of food available per week			X		
d) Sanitation on Nueva Armenia			X		
e) Quality of drinking water			X		
f) Availability of drinking water			X		
g) Relationship with residents of other communities				X	
h) Relationship with Fundación				X	
i) Level of communication given by Fundación				X	

<u>Interviews</u>

I interviewed those people who I thought were 'official' sources, such as key informants within the communities and those who may have been able to provide me with more specific information and statistics. The list of interviewees is below:

SOURCE	POSITION
1) Corbis Delsun Solis Arbit	PBR worker
2) Staff member	PBR worker
3) Nancie Judid Nunes	Cabaña owner
4) Joses Fransisco Valasquez Arriola	Teacher, East End
5) Modesto Suazo	Head of Fishermen
6) Enrique Garcia	President, Sambo Creek
7) Adoni Cubas	Dir. Of Science and Management, HCRF

8) Adrian E. Oviedo	Executive Director, HCRF
9) Gilmer Renée Aranda	Fisherman,
10) Raúl Perez	Head of Marketing at Saracien Hotel, Nueva Armenia Saracien Hotel owner, Nueva Armenia
11) Rosa Abulia	Hotel owner, Nueva Armenia
12) Luis Alonso Alvarez Suazo	President, Nueva Armenia
13) Tim Coles	Director, Operation Wallacea
14) Opwall staff member A	Operation Wallacea staff member, Cayo Menor
15) Zoe Stevens	Operation Wallacea Assistant Camp Manager, Cayo Menor
16) Elisabeth David	Cabaña project worker, Rio Esteban
17) Rosie	President, Cameréra de Tourismo
18) Wilmer Puerto	Manager, Dominique Restaurant
19) Sherissa Rodriguez-Campbell	Tour Operator

The interviews were produced with a similar format to the questionnaire but slightly longer in length and included more open-ended questions. The respondent’s answers to questions posed were recorded and also his or her actions and behaviour throughout the interview as it is not just what they say but how it is said, and what is not said interviewee agreed to a requested time extension if needed during the interview.

Focus Groups

Focus groups are an excellent method for collating research on broad topics and a variety of different views as different members of societies or groups come together and express their own opinions on different topics. A translator was used to assist in the focus groups that required it. This brought with it difficulties as interpretation is lost in translation and it is difficult for the interpreter to keep pace with the conversation at the same time as trying to translate what is being said. However, the focus group with Chachahuate community members and Fundación employees was recorded in an attempt to gain more accurate transcription, which also allowed more substantial notes on behaviour.

The focus groups were run by suggesting topics for discussion and allowing the members of the group to converse and discuss each one in turn. The focus groups were held with 8 participants as Bedford and Burgess (2001) state that this number of people holds the greatest potential as it should allow the best atmosphere for optimum responses, and would not only allow more in-depth views to be voiced but also allow all members the chance to express their views.

During the research period 3 focus groups were carried out:

1) School students and teachers, day trip to Chachahuate

The students and teachers were essentially a group of tourists on an organized day trip to the communities. Following each of the trips on consecutive days, a focus group was held to compare views on each of the island communities. The topics discussed were of first impressions of the communities, amenities for tourists, preparations for increased tourism, what is ecotourism, impacts of tourism, impact of westernisation and the limiting factors of communities in terms of receiving tourism.

2) Chachahuate community members and Adoni Cubas, Director of Science and Management with the HCRF

Again, there were 8 participants. The purpose was to attempt to get members of the society and employee of the HCRF discussing issues that may not otherwise be talked about, such as the communities preparation for tourism, forms of alternative sources of income, the assistance given by the Fundación into such developments, the Plan de Manejo implemented by the Fundación in 2004 and its impacts on the communities and tourism within the communities with a specific emphasis on ecotourism to name but a few.

3) Children of East End, girls and boys

Participant Appraisal

Two RRA methods were used, namely mental maps and matrix scoring. These were carried out in each of the 2 island communities. These methods are a family of methods that are supposed to enable people to share, enhance and analyse their knowledge of ecotourism, to ultimately plan for the future and act on what they discuss and think should happen. However, there were significant differences in the success of the methods in the communities there were carried out in, with East End having less successful results that Chachahuate, yet still useful and comparative for analytical purposes.

A) Mental map

This method involves community members assisting in mapping the community, noting down each residence, all outhouse buildings, features of interest, amenities, and from this asking them to show and discuss what developments structurally or environmental improvements they would like in the communities. This was first carried out on East End with 7 community members. For a number of reasons this did not run entirely smoothly with members of the group not wanting to walk around and some leaving and joining the group during the exercise and a general lack of interest. When carried out on Chachahuate it worked well and a group of approximately 14 people walked around the island assisting the research. The results from this in both communities was useful in that it will allow visual understanding of what the communities have envisioned for the future, and provides information showing they do have an ambition and knowledge of what is required to develop.

B) Matrix Scoring

Again this method was first carried out in East End and it did not seem to work as well as in Chachahuate. In East End 7 community members agreed to do the matrix scoring, while 16 opted to participate in Chachahuate. The method used was laying out a grid on the sand with twigs and sections of palm leaves, and asking the participants to rate each of the 4 pre-determined questions on a scale of 1 to 5 using mangoes, 1 being very poor and 5 being very good. Mangoes were used as they grows abundantly in all studied communities and therefore it seemed an appropriate symbol with which to carry out the exercise. The issues rated were the Fundación, the potential for increased tourism within the community, the ambition of the community, and finally the present state of preparation for tourism within the community. Notes were taken of behaviour during each exercise, and through the aid of a translator on the discussions that took place prior to deciding upon a final number on the scale. It was extremely obvious that this method made people discuss their differing views on the topics raised in such a way that gives great optimism for the future as it is methods such as this that must develop within the community as ways of guiding and leading community development in a bottom-up approach. Such forms of democracy are not common in these communities.

Direct Observations

This technique was used throughout the research process, creating a field diary following every day progress plus official direct observation documents separate from the field diary. This method was been extremely useful as it created a mental picture of the field work at every stage during the study period. Specific direct observations of events were recorded, that have occurred during the study period that have been particularly poignant and specific to the topic of ecotourism and associated issues which have included a greater depth of detail. For example, observing the welcome of tourists onto Chachahuate or observations of a community. This method has provided an excellent method for use in triangulating data.

Participant Observations

Again, this method involved 'cultural immersion' throughout the research period. Notes for participant observations were recorded in the field diary and more in-depth observations written up separately. Examples of these observations are going fishing with Nahun, a 29 year old man from Chachahuate, at dusk using traditional methods in his motor boat, and playing with the children in Nueva Armenia with them teaching me Spanish and also staying in Rio Esteban for a night in a cabaña. This method essentially involves putting yourself in the position of a tourist and attempting to get an idea of the potential in the communities to offer tourists.

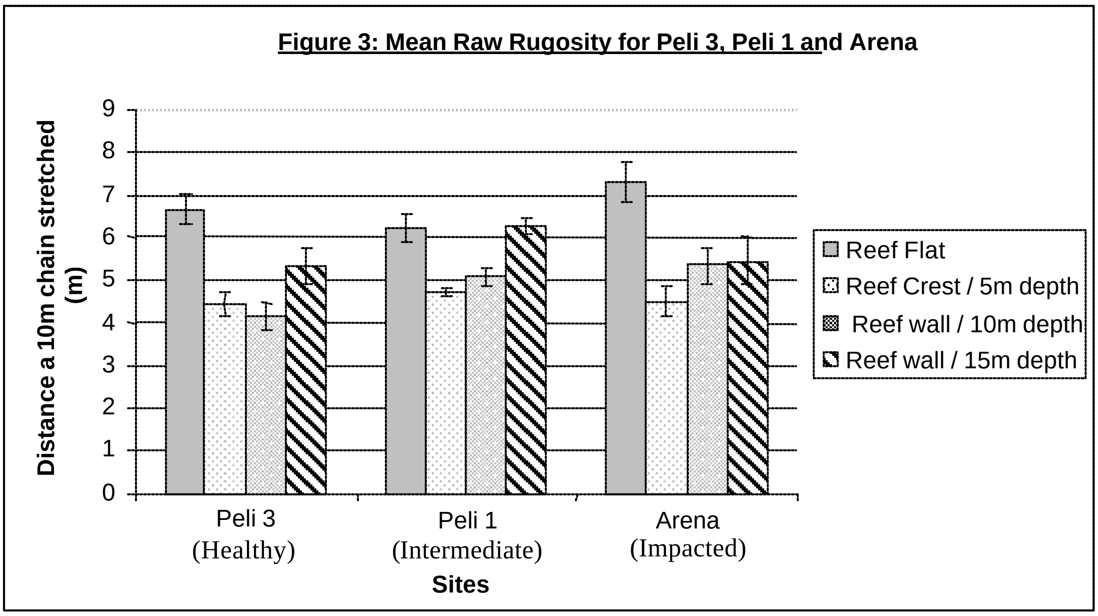
3.0. Results

3.1. Coral Reef Biodiversity and Ecology

3.1.1. Coral Disease

<u>Rugosity</u>

Figure 3 is a graph showing average raw rugosity for each transect at each depth.



<u>Disease assessment</u>

In total 3 colonies of BBD were found at Arena, 4 at Peli 3 and 20 found at Peli 1. Most of these infections were found on the reef flat, near the crest, however the data will be further analysed in the UK, looking for significance and nearest neighbour analysis. It is possible a proximity program will be designed with VC++ to analyse clustering of infected colonies. Also community data has yet to be analysed to see if the difference in incidence of BBD between sites is an artifact of the abundance of colonies such as *D.strigosa* and *D.labyrinthiformis*, or is truly the result of a difference in site epizoology and ecology.

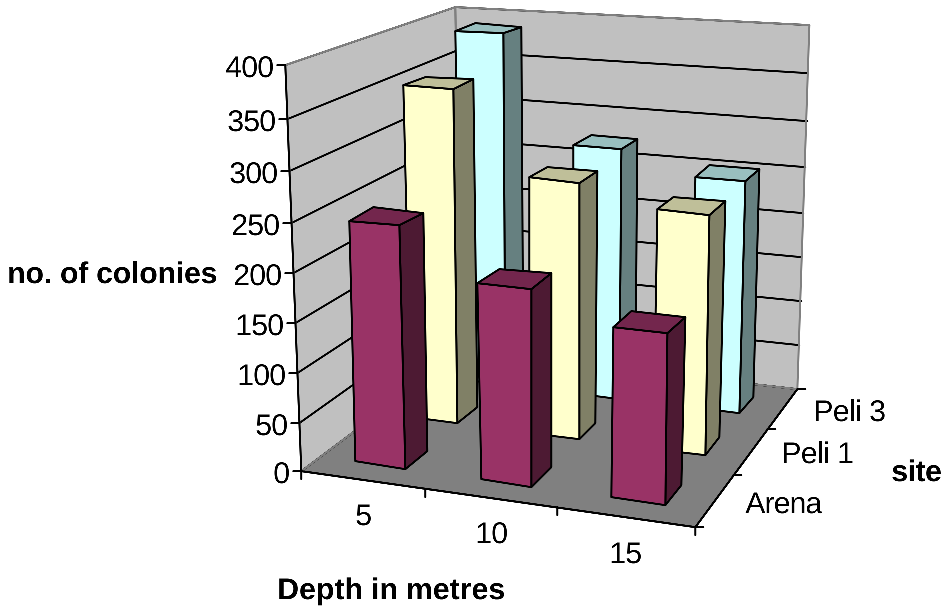
<u>Bleaching and disease progression monitoring</u>

The majority of initial analysis has been conduced on only a few BBD colonies of Peli 1, and only one measurement of rate has been made. Once returned to the UK, further photographic analysis will be made, and a multitude of rate measurements will be made and analysed for statistical significance. So far BBD has been shown to conform to published data, with the characteristic dark band of the microbial community moving at 6mm d^{1}. The slowest rate published is 3mm d^{-1} and the fastest 1cm d^{-1} (Sutherland, 2004). This is a interesting intermediate, and further analysis should show if this rate waxes or wanes due to changes in weather or water quality.

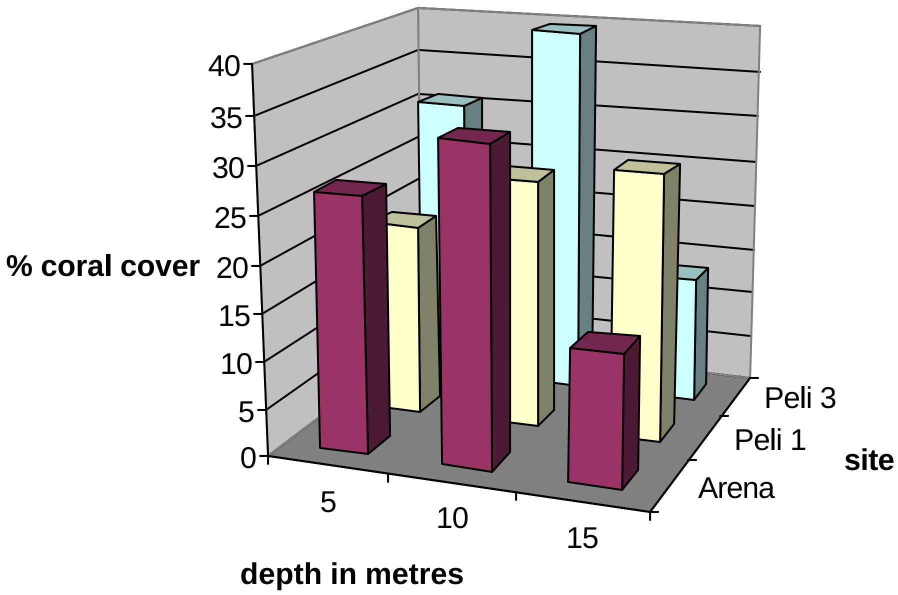
3.1.2. An Investigation of the Incidence of Scleractinia Coral Associated Disease and Factors Affecting This Distribution.

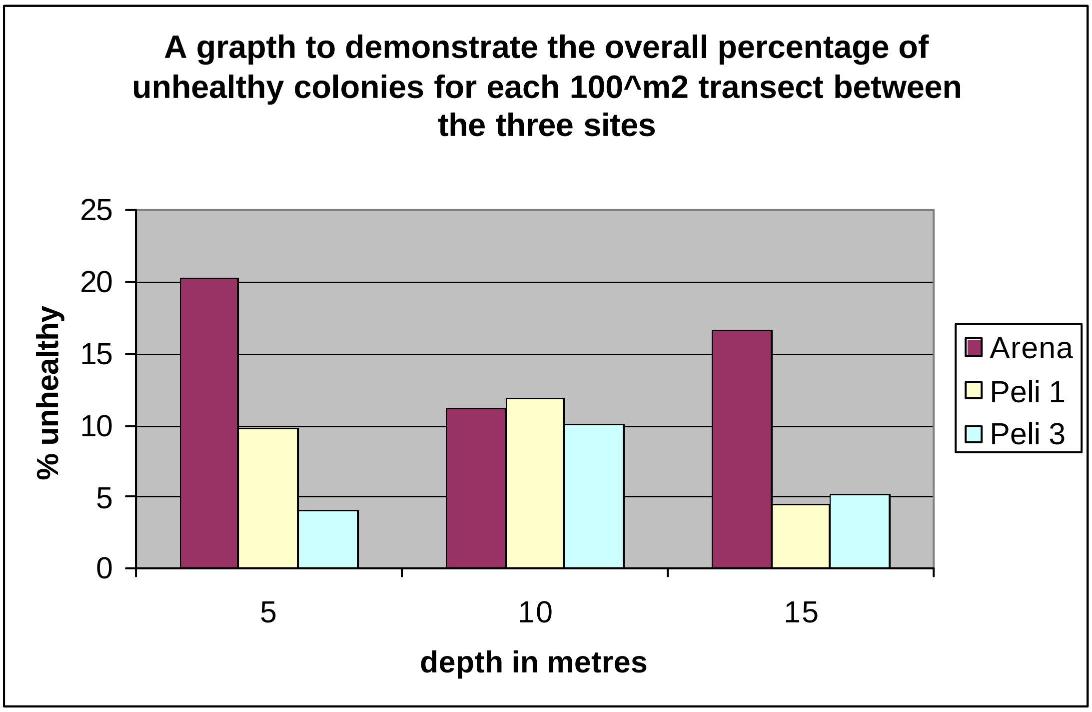
The figures that follow below summarise some of the transect data obtained. Where the percentage of unhealthy colonies is mentioned it refers to the proportion with any sort of disease or bleaching, as these categories have currently been lumped due to incomplete scrutiny of the transect photos. Some trends, however, are already apparent across the three sites:

A graph to illustrate the difference in the number of colonies per 100m^2 transect for each site



A bar chart to illustrate the % coral cover for each depth at each site

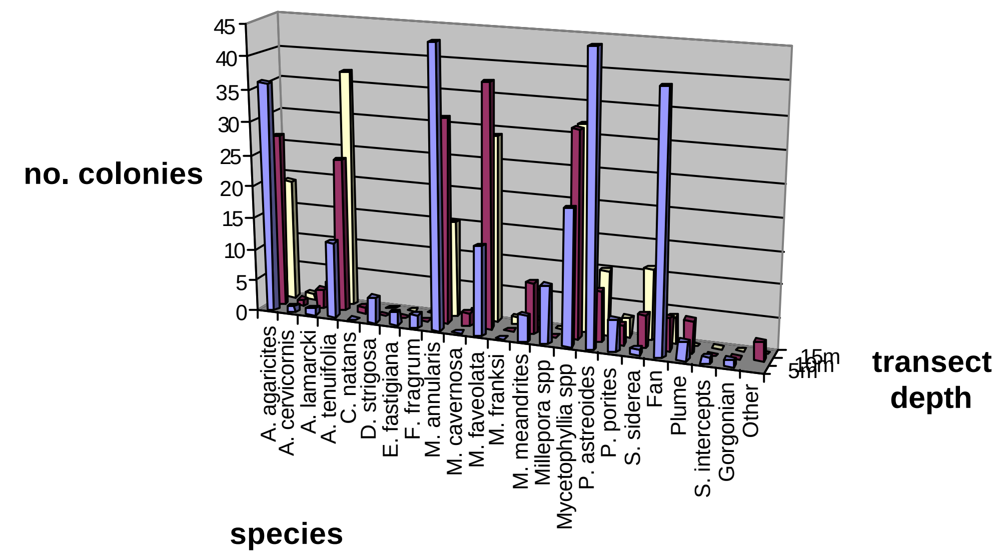




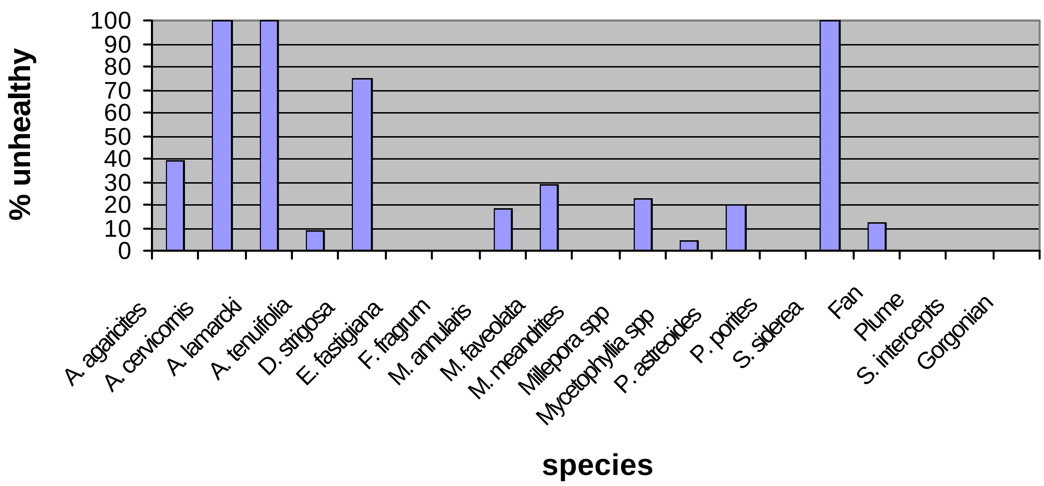
The graphs that now follow are site specific and have been constructed primarily to highlight the effects of depth on species composition and how disease is distributed among those species at each site.

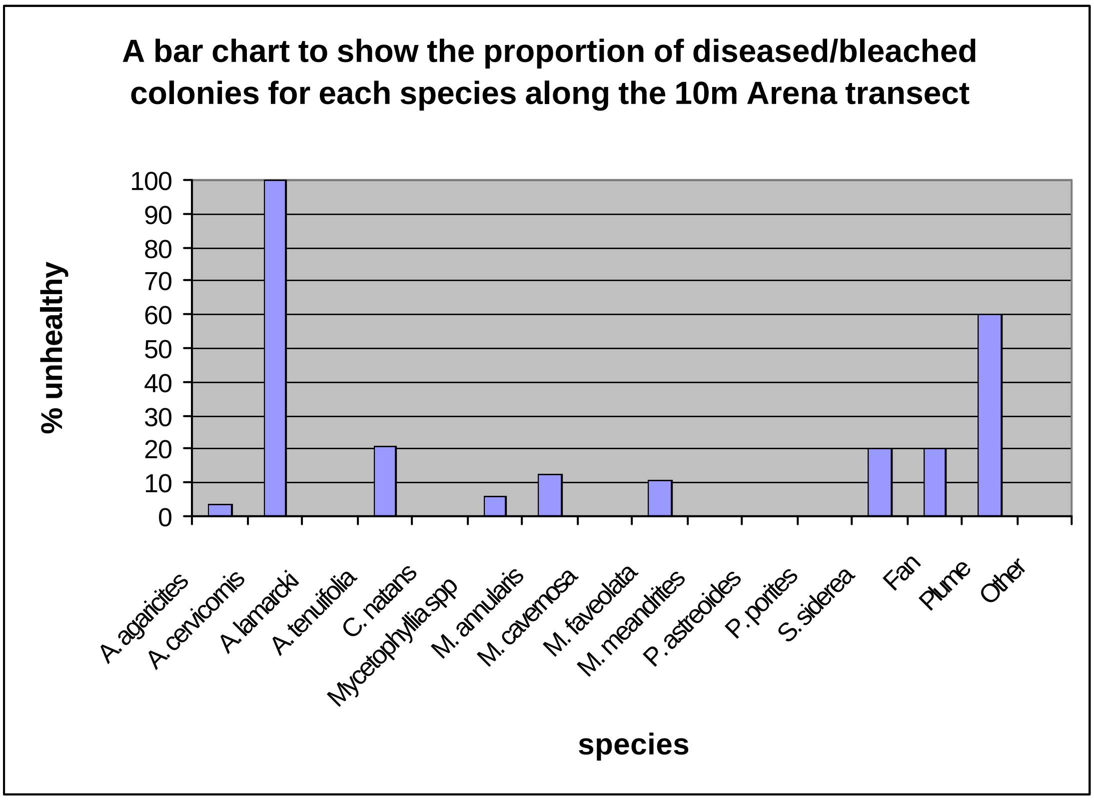
Arena

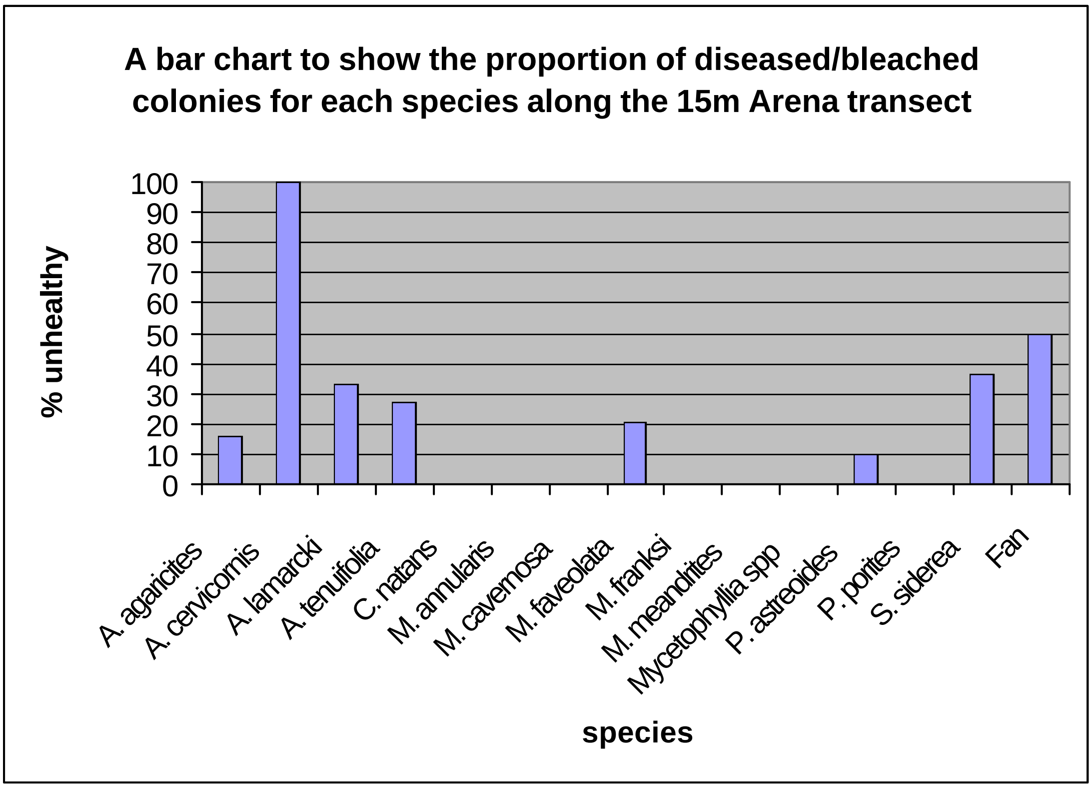
A graph to show the species composition for each of the three Arena transects



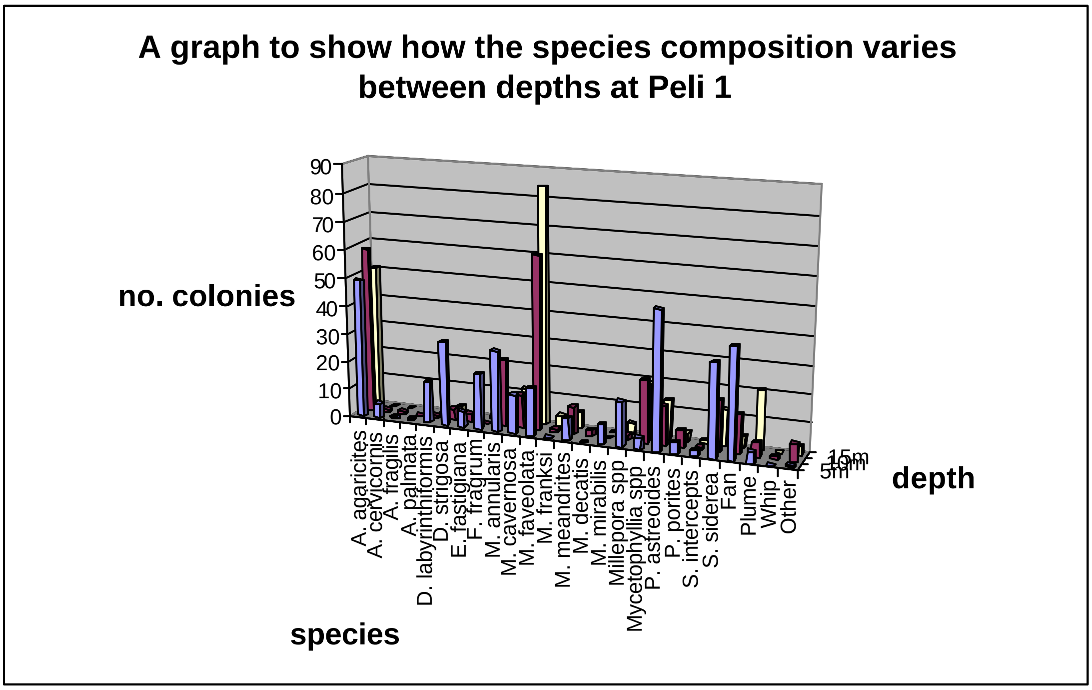
A bar chart to show the proportion of colonies exhibiting disease/bleaching for each species along the 5m Arena transect

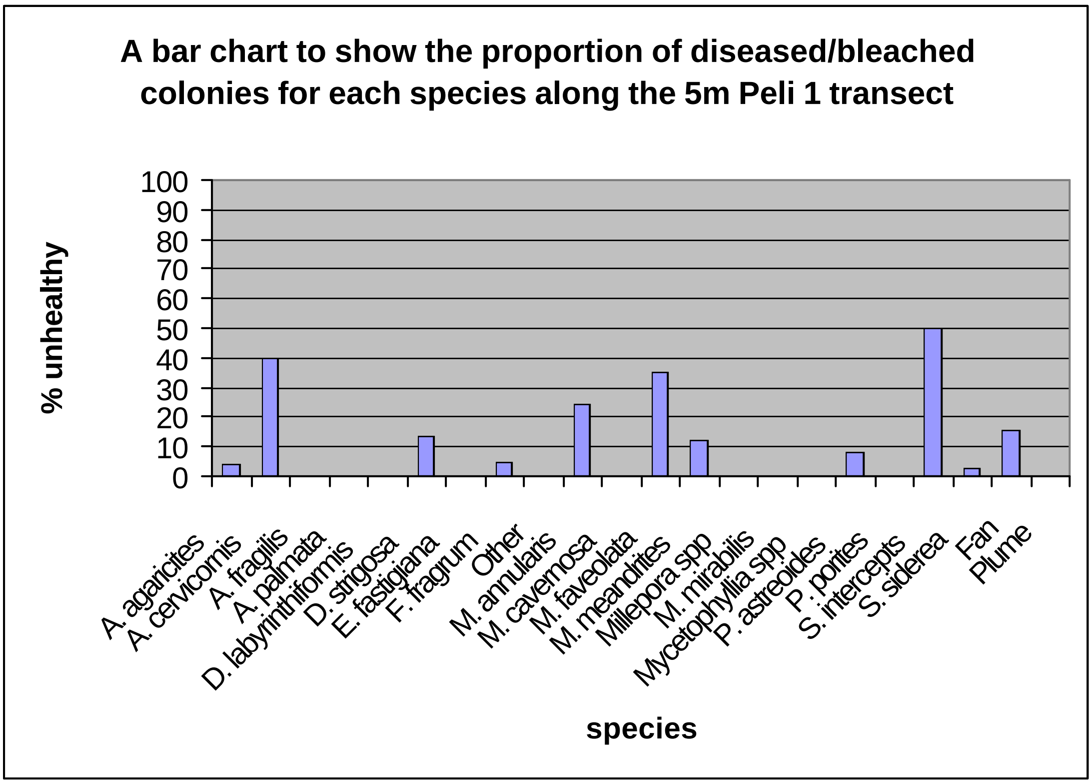


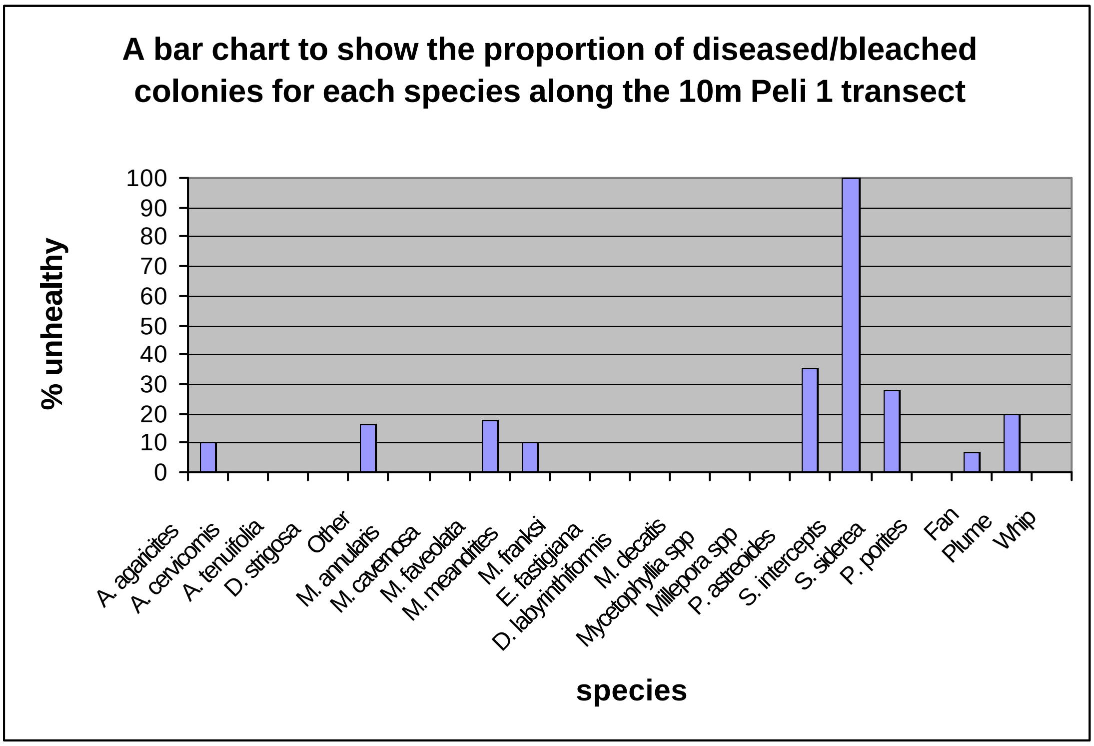

A bar chart to show the proportion of diseased/bleached colonies for each species along the 10m Arena transect
% unhealthy
100
90
80
70
60
50
40
30
20
10
0
A. agaricites
A. cervicornis
A. lamarcki
A. tenuifolia
C. natans
Mycetophyllia spp
M. annularis
M. cavernosa
M. faveolata
M. meandrites
P. astreoides
P. porites
S. siderea
Fan
Plume
Other
species

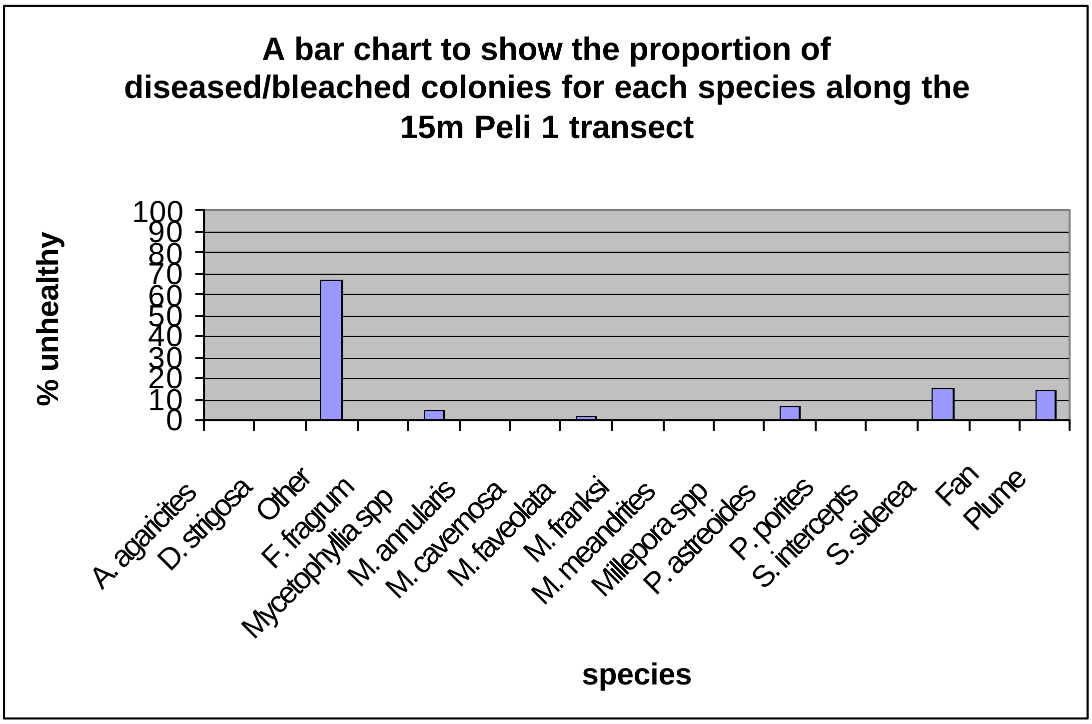

A bar chart to show the proportion of diseased/bleached colonies for each species along the 15m Arena transect
% unhealthy
100
90
80
70
60
50
40
30
20
10
0
A. agaricites
A. cervicornis
A. lamarcki
A. tenuifolia
C. natans
M. annularis
M. cavernosa
M. faveolata
M. franksi
M. meandrites
Mycetophyllia spp
P. astreoides
P. porites
S. siderea
Fan
species

<u>Pelican Point 1</u>

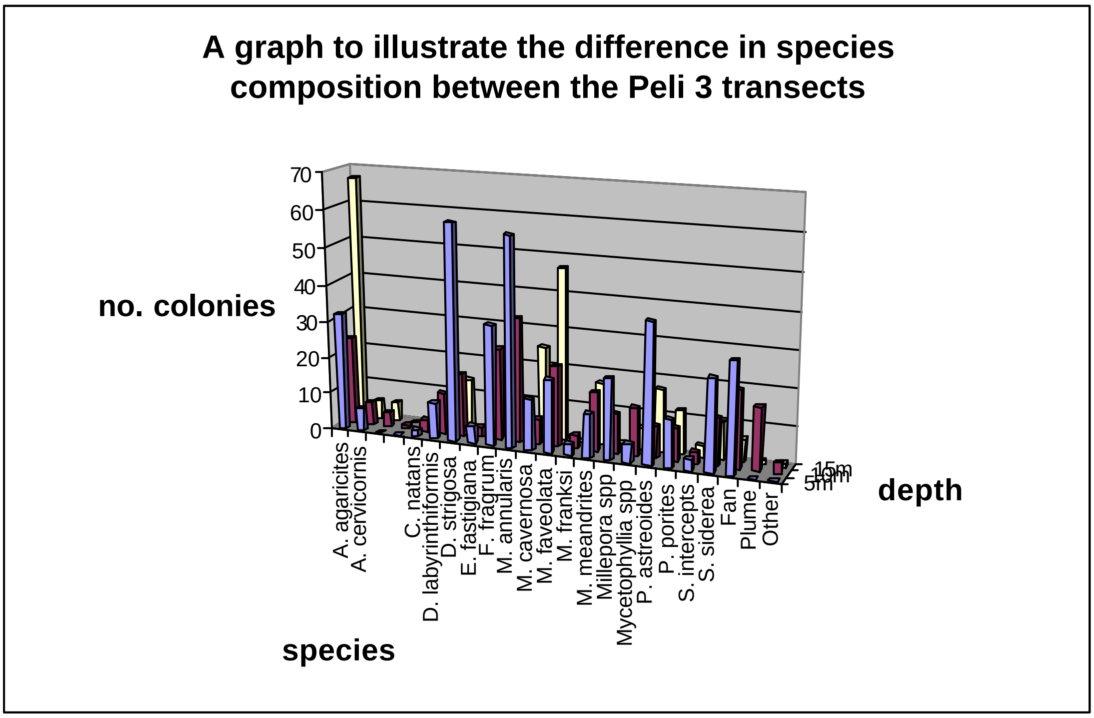


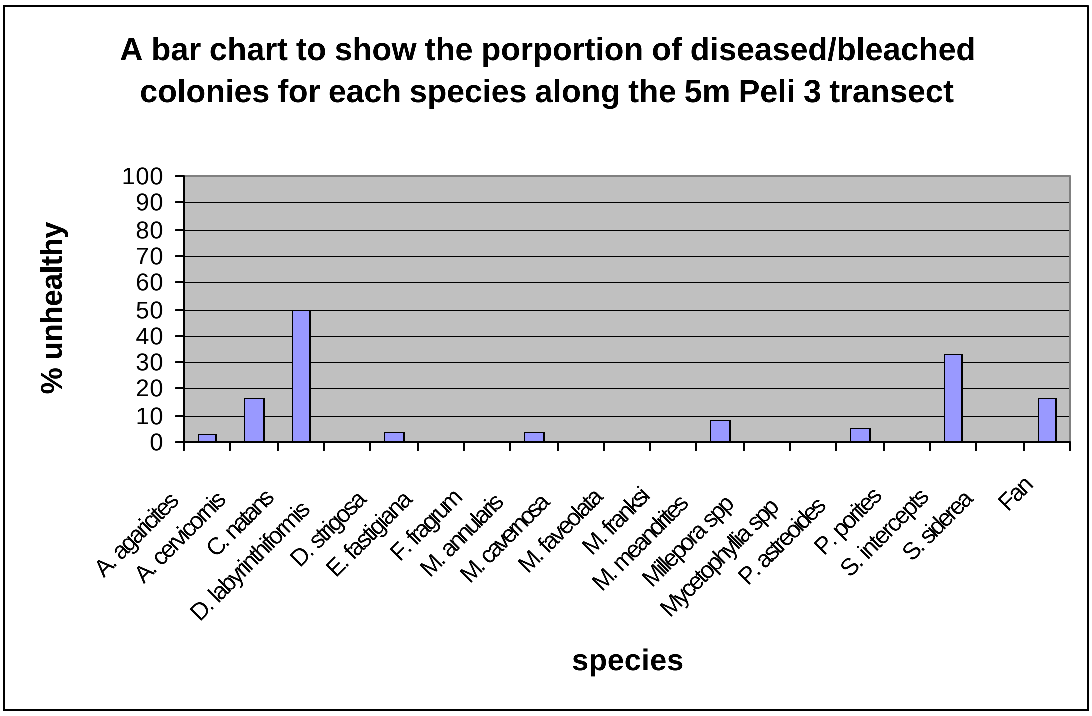


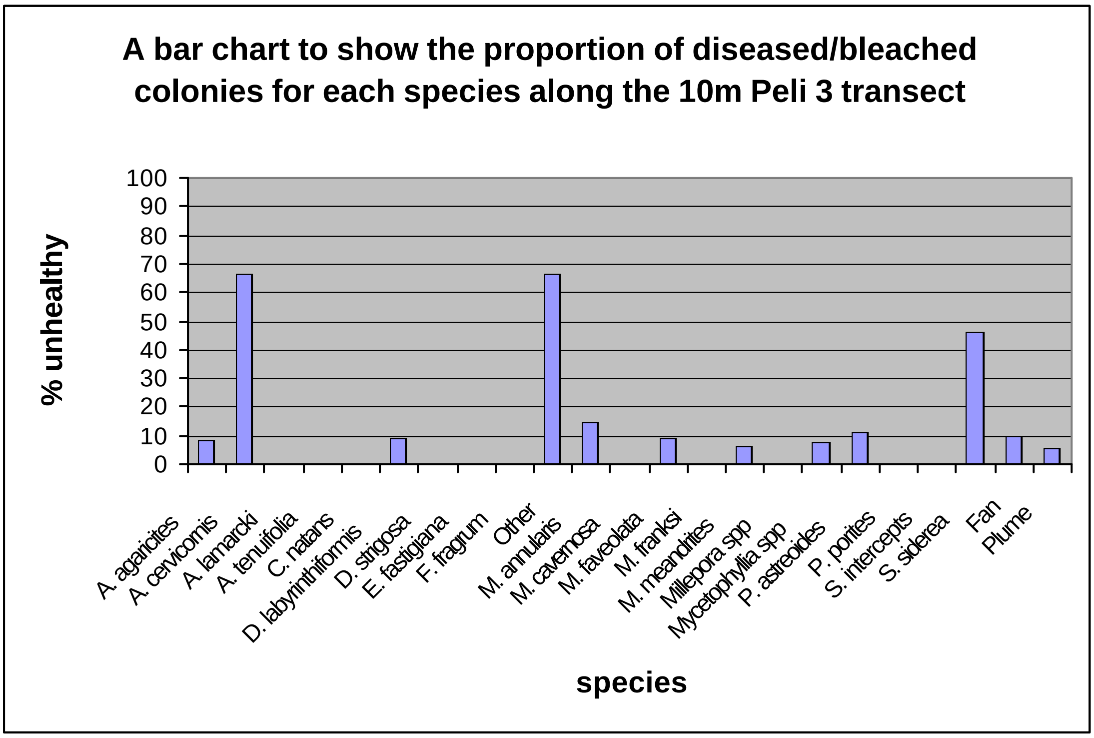

A bar chart to show the proportion of diseased/bleached colonies for each species along the 10m Peli 1 transect
% unhealthy
0
10
20
30
40
50
60
70
80
90
100
A. agaricites
A. cervicornis
A. tenuifolia
D. strigosa
Other
M. annularis
M. cavernosa
M. faveolata
M. meandrites
M. franksi
E. fastigiana
D. labyrinthiformis
M. decatis
Mycetophyllia spp
Millepora spp
P. astreoides
S. intercepts
S. siderea
P. porites
Fan
Plume
Whip
species

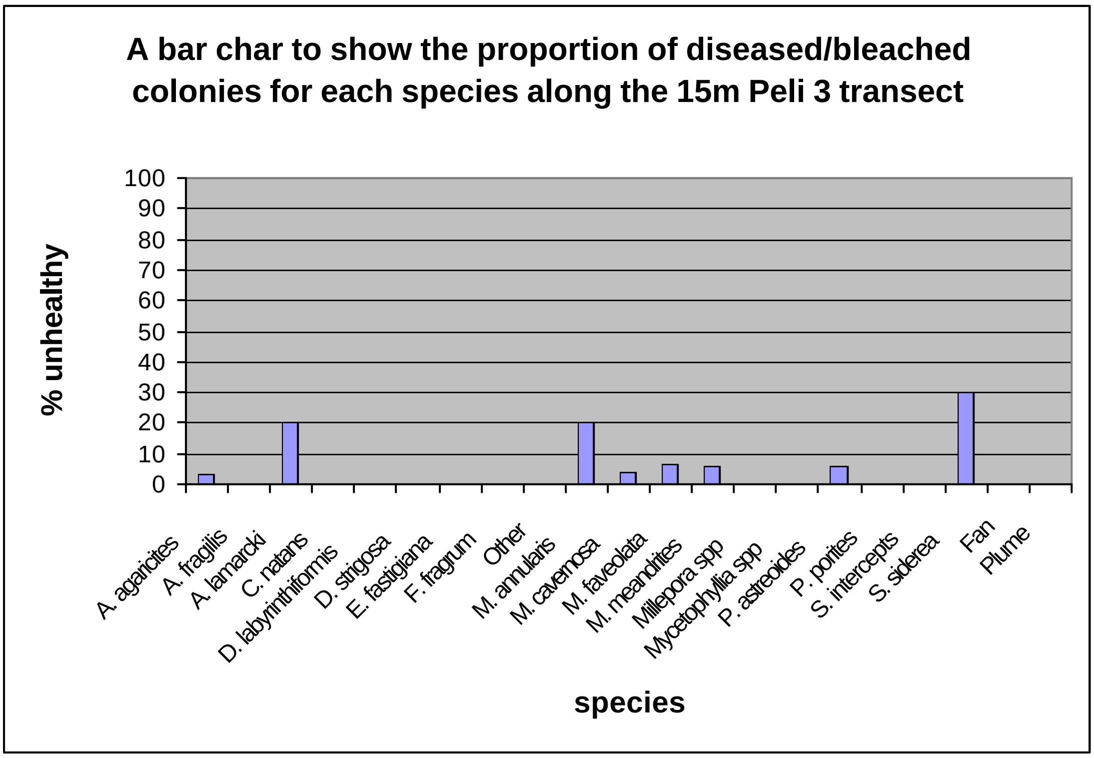

A bar chart to show the proportion of diseased/bleached colonies for each species along the 15m Peli 1 transect
% unhealthy
0
10
20
30
40
50
60
70
80
90
100
A. agaricites
D. strigosa
Other
F. fragrum
Mycetophyllia spp
M. annularis
M. cavernosa
M. faveolata
M. franksi
M. meandrites
Millepora spp
P. astreoides
P. porites
S. intercepts
S. siderea
Fan
Plume
species

Pelican Point 3

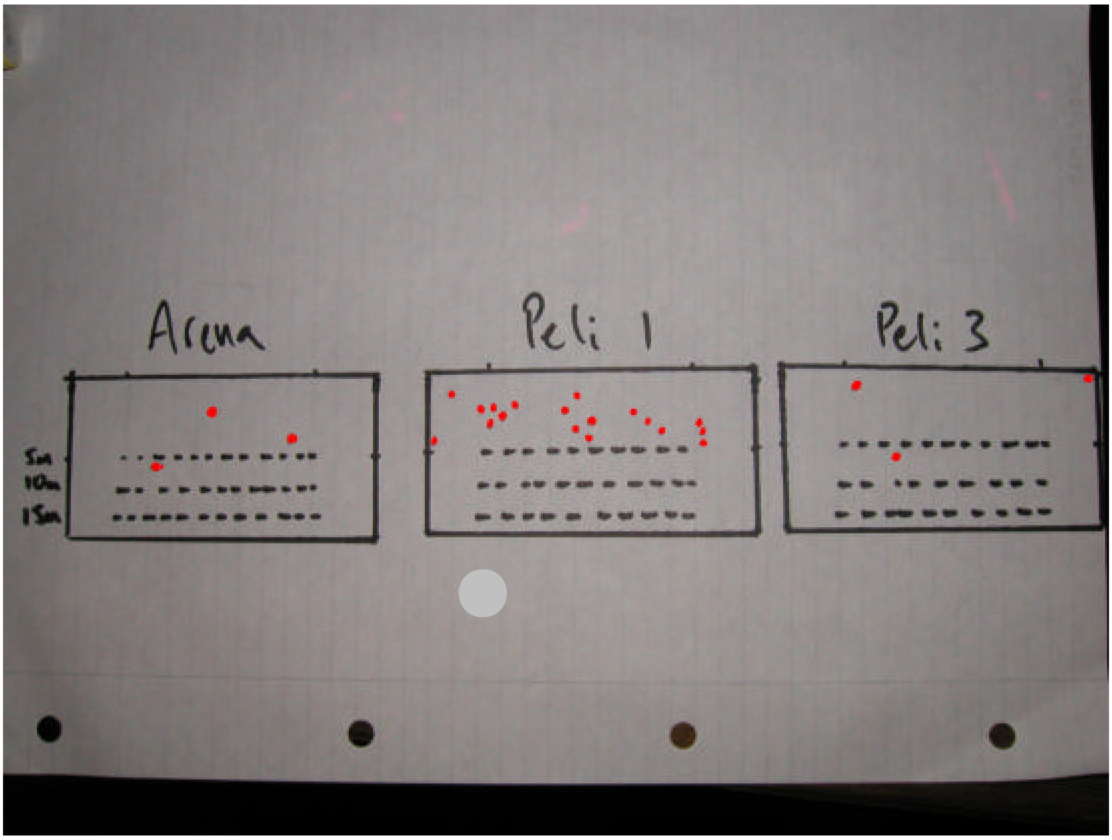





A bar chart to show the proportion of diseased/bleached colonies for each species along the 10m Peli 3 transect
% unhealthy
100
90
80
70
60
50
40
30
20
10
0
A. agaricites
A. cervicornis
A. lamarcki
A. tenuifolia
C. natans
D. labyrinthiformis
D. strigosa
E. fastigiana
F. fragum
Other
M. annularis
M. cavernosa
M. faveolata
M. franksi
M. meandrites
Millepora spp
Mycetophylia spp
P. astreoides
P. porites
S. intercepts
S. siderea
Fan
Plume
species


A bar char to show the proportion of diseased/bleached colonies for each species along the 15m Peli 3 transect
% unhealthy
100
90
80
70
60
50
40
30
20
10
0
A. agaricites
A. fragilis
A. lamarcki
C. natans
D. labyrinthiformis
D. strigosa
E. fastigiana
F. fragum
Other
M. annularis
M. cavernosa
M. faveolata
M. meandrites
Millepora spp
Mycetophylia spp
P. astreoides
P. porites
S. intercepts
S. siderea
Fan
Plume
species

Below is a preliminary representation of the distribution of black band disease across the three sites constructed merely to provide an idea of the differences between sites that will be more accurately represented through GIS, where each red dot represents a colony with black band disease:



<u>Analysis</u>

For the analysis in order to gain useful information from the data from which reliable conclusions may be drawn various statistical tests have and will be conducted. Once again due to time constraints, as well as limited facilities, only Chi-squared tests have been performed to date on a limited number of the data. However, upon return to the UK and once the abiotic data has been compiled ANOVAs shall then be carried out with regards to a model along the lines of:

INCIDENCE = DEPTH + NITRATE + TURBIDITY + TEMPERATURE

By performing this it will then be possible to asses which of the abiotic variables explain the variance observed with any significance and gain insights as the whether factors that are influenced by human activity may be important. Regression analyses may also be conducted to look for individual correlations between variables. The data obtained from the mapping will be plotted out using GIS and then cluster analyses may be performed to asses whether any significant clustering exists on the three reefs with respect to black band disease and white plague. Image analysis tools will also be used on the photographs of progressing diseases to obtain progression rate data, on which Chi-squared tests and regressions may be performed.

If the project succeeds in demonstrating links between cause and effect its data may be used for planning measures to control the disease and form part of an ongoing study to asses the prevalence of coral disease in the area over time. This is important for the overall management strategy for Los Cayos Cochinos, which aims to promote the recovery of fish stocks that are desperately needed by locals as a source of both food and economic revenue.

As mentioned the analyses performed to date has consisted of merely chi-squared tests, predominantly on the information represented in the graphs above; number of colonies between depth, percentage of unhealthy colonies between depth at each site as well as on the percentage unhealthy colonies at each depth between sites.

From the Chi-squared tests performed it is possible to say whether the observed data are significantly different from what might be expected by chance. It appears that the absolute number of colonies increases with depth as well as site quality. The relationship with depth is statistically significant for all sites with Chi-sq values of 15.26, 21.65 and 30.12 for Arena, Peli 1 and Peli 3 respectively. At a given depth Arena is shown to have significantly fewer colonies than the other two sites, although Peli 1 and Peli 3 do not; perhaps reaching an asymptote or carrying capacity for the number of colonies that can be sustained. Although this has not been done yet, diversity indeces will be used to hopefully show that there is significant variation in biodiversity and species composition between the sites.

Fig. 1.3 can be used to show how the % unhealthy colonies varies within and between sites. At Arena the 5m transect has significantly more disease than the 10m transect (chi-sq = 2.63), but not more than 15m (chi-sq = 1.12). There is also no significant difference between the 10 and 15m transects. At peli 1 there appear to be no significant deviations from chance apart from the 15m transect having significantly less disease than the 10m transect (chi-sq = 3.92). For Peli 3 there was no significant deviation for what would be expected by chance between any of the transects. In terms of between sites there was no significant difference in % unhealthy colonies between the Peli 1 and Peli 3 5m transects or the Peli 1 and Arena 5m transects, however the difference between Peli 3 and Arena was statistically significant (chi-sq = 9.30) arena having a much higher %. For the 10m transects there were no significant deviations between the sites. For the 15m transects however, Arena was statistically different from both Peli 1 and Peli 3 (chi-sq = 6.37 & 5.94 respectively) and there was no significant difference between Peli 1 and Peli 3.

The only other test that has been performed to date is to show with certainty that the Peli 1 mapping plot has significantly more black band disease than either of the sites, again using a chi-squared test. Peli 1 black band abundance is significantly greater than both Peli 3 and Arena (chi-sq = 12.8 & 10.7 respectively), and there is no significant difference in the abundance of black band disease between Peli 3 and Arena.

3.1.3. Corallivore Activity on Scleractinian Coral Colonies.

<u>Phase 1</u>

FIG: 3

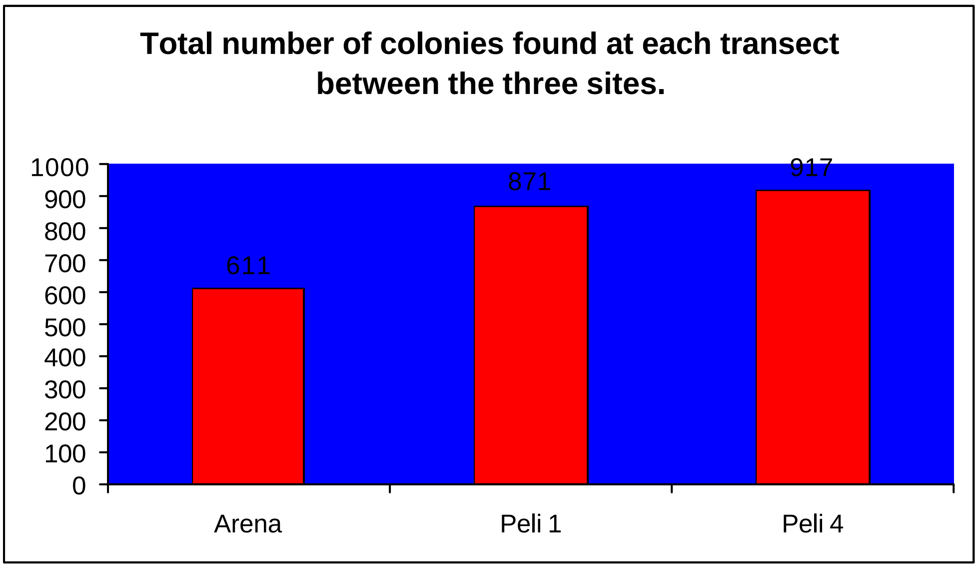


Figure: 3 represents the total number of scleractinian coral colonies found at each belt transect and at each depth from each site.

FIG: 4

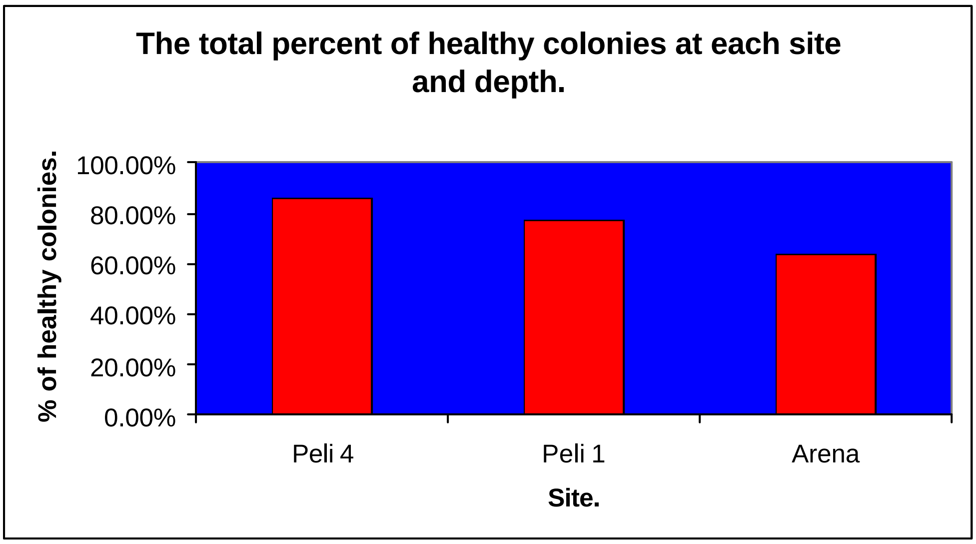


Figure: 4 represents the total percentage of healthy corals from each of the sites, at each depth. This chart clearly shows that Peli 4 is the healthiest, and Arena is the most impacted of the three, whereas Peli 1 is intermediate between the two.

FIG: 5

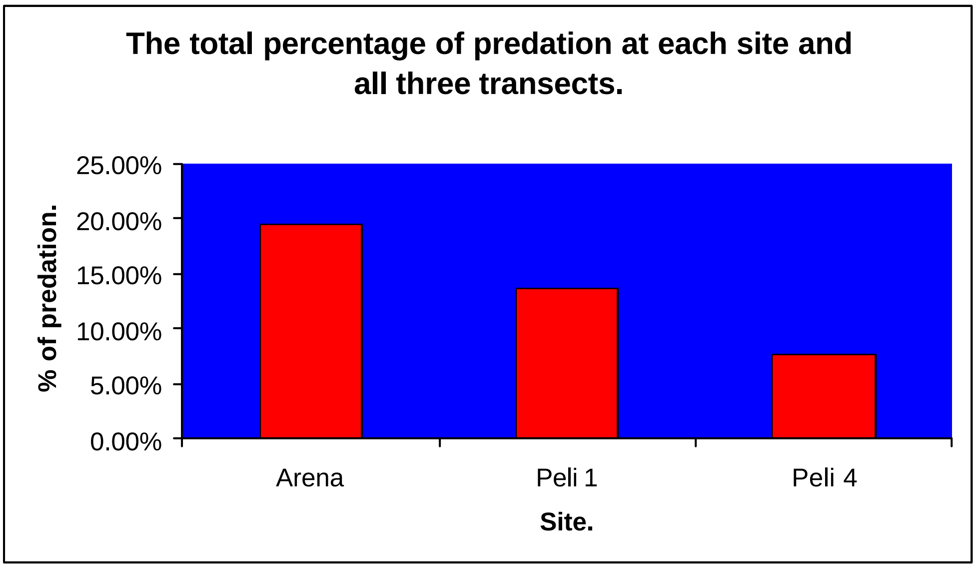


Figure: 5 shows the amount of predated colonies found within each transect at each depth and site. Again, Peli 4 is the most pristine when compared to the other sites. Thus, only 7.63% of colonies from Peli 4 are predated upon.

FIG: 6

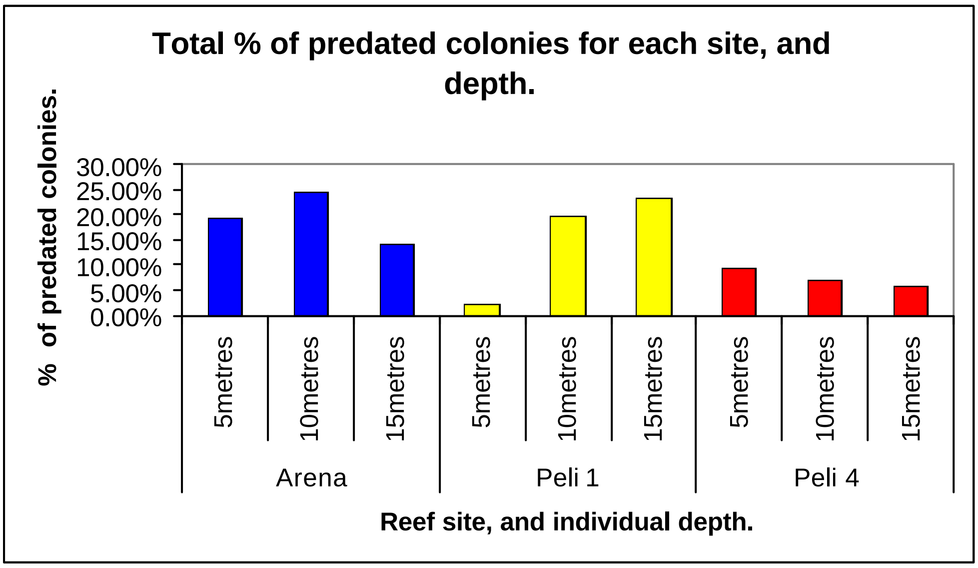


Figure: 6 shows the amount of every predated colony found within the belt transects of each site and depth.

FIG: 7

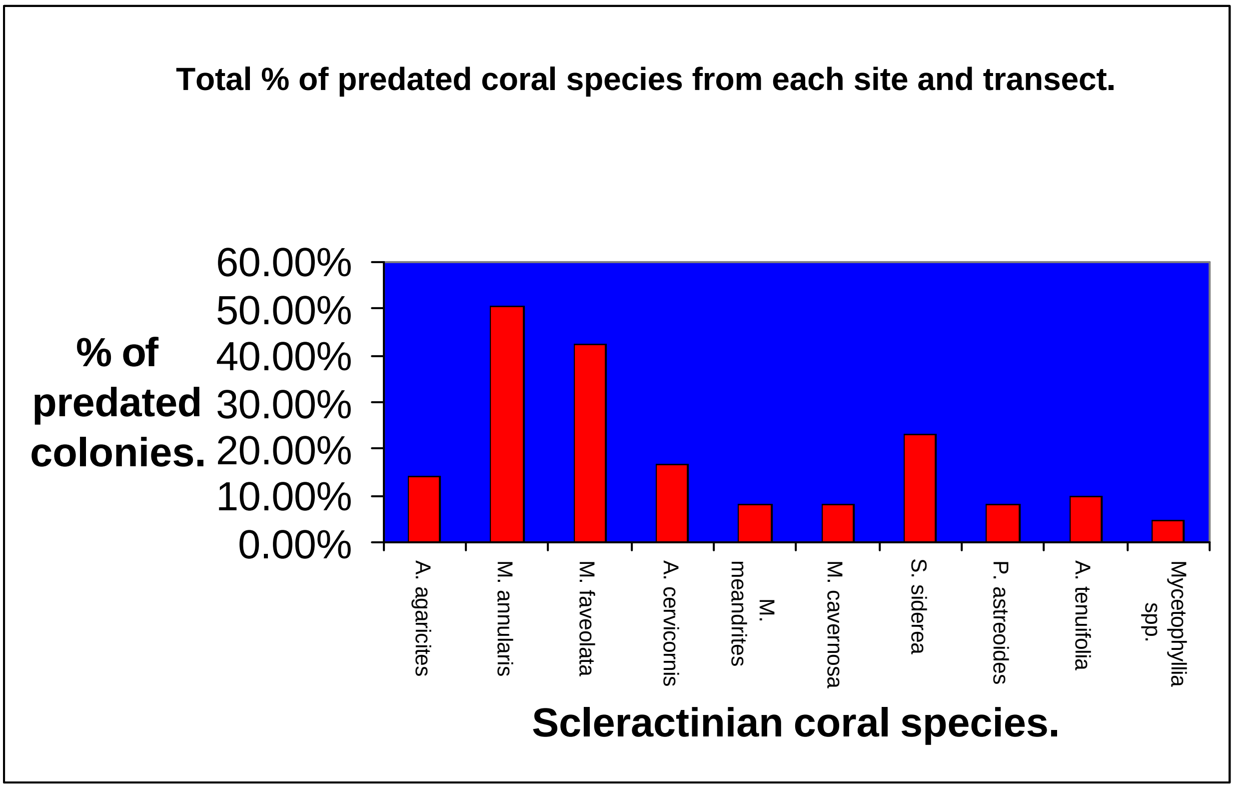


Figure: 7 represents the total amount of each individual predated scleractinian colony found at each depth and site. The results obtained revealed that *Montastrea annularis* is the most predated colony between the three sites; in total 50% of this particular species is predated on in the marine park.

FIG: 8

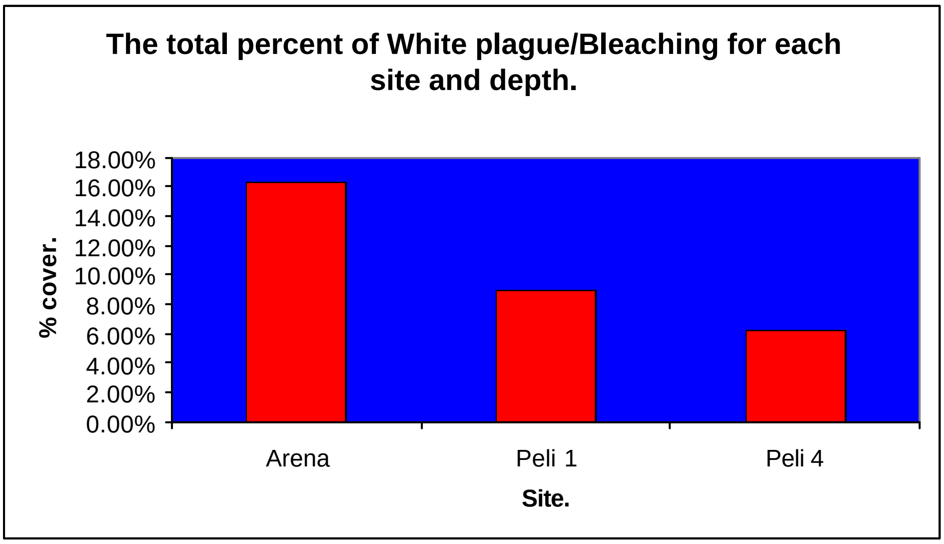


Figure: 8 represents the amount of disease/bleaching between the three sites at each depth. The chart shows that Arena is most impacted. The investigation to establish between bleaching and disease would have been time consuming. Therefore, due to the frequent anomalies that arise within the data set, the categories marked, “Disease & Bleached” were combined to form one group- which is labelled, “ White plague/Bleaching”. Thus, the data analysis will not be compromised, therefore the validity of the results will remain accurate when comparing between the three sites.

Phase 2

FIG: 9

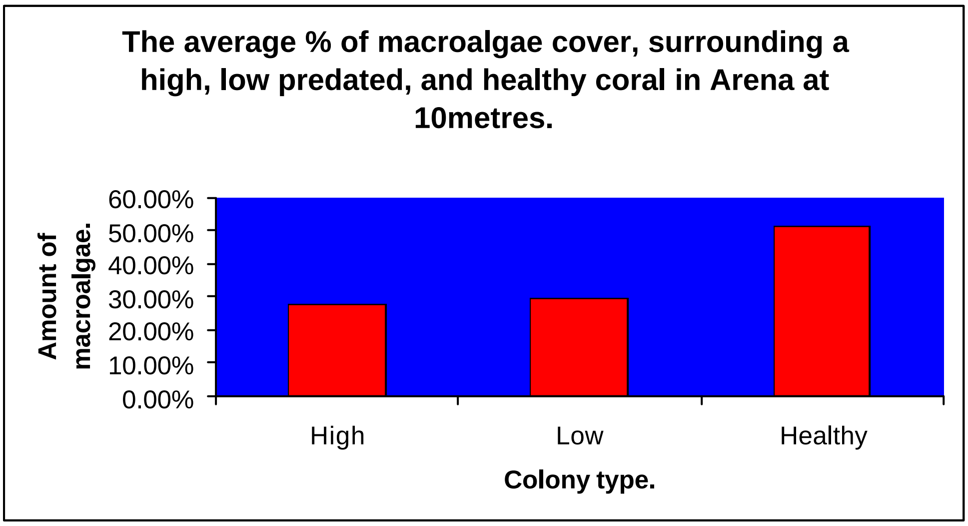
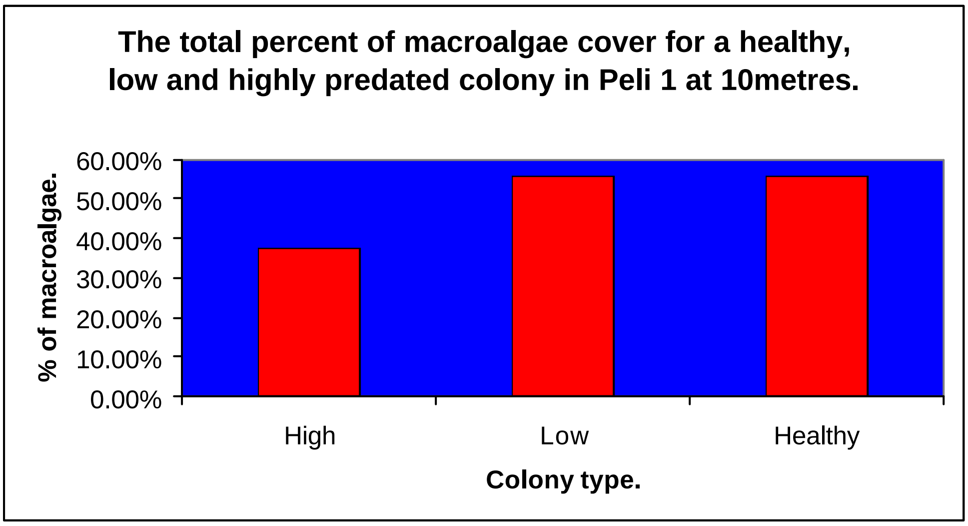


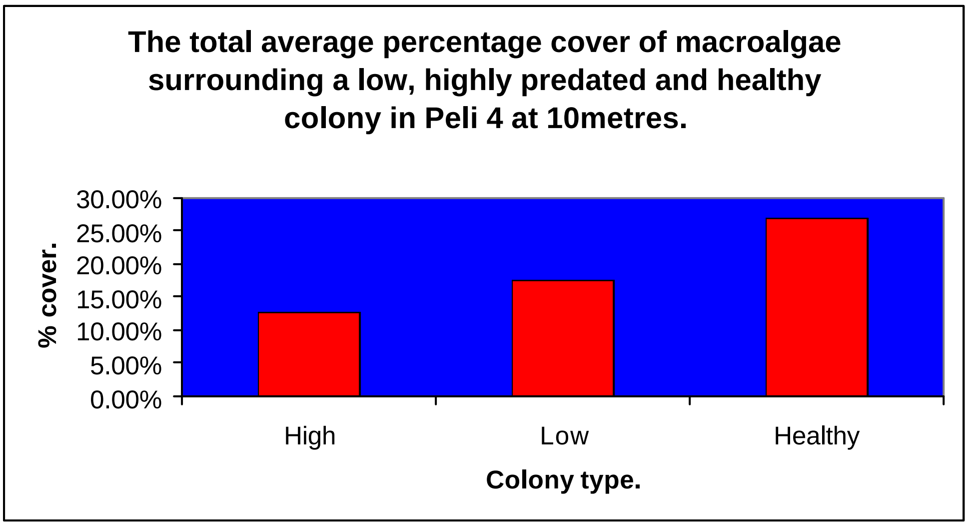
Figure: 9 represents the average amount of surrounding macroalgae around each of the 3 types of colonies. The area surveyed was 1250cm^2 for each colony. Although the data analysed for this report is minimal, the results obtained do show that there is higher abundance of macroalgae cover when compared to the highly predated colonies. This is also observed when 3 colonies where investigated in Peli 1 and Peli 4 at a depth of 10metres (Figure: 8, 9 respectively). However, there will be in total, 81 colonies analysed to elucidate a more accurate result for analysis.

FIG: 10



It is interesting to note that the low and high predated colony from Arena (Fig: 9), are very similar in surrounding macroalgae cover. However, the low and healthy colony from Peli 1 (Fig: 10), are very similar in surrounding macroalgae cover.

FIG: 11



The results from Figure: 11 show that Peli 4 has a much lower average percentage cover of macroalgae when compared to

Arena and Peli 1 (Table: 2). This may be due to the fact that Peli 4 has more colonies per area, therefore less available space for macroalgae to colonise. Peli 4 has 276 colonies at 10metres/100m^2 of substrate, whereas Peli 1 has 269 colonies, and Arena has 197 colonies at 10metres/100m^2 of substrate.

TABLE: 2

Coral type:	Arena:	Peli 1:	Peli 4:
Healthy	51.15%	56.00%	26.87%
Low	29.40%	55.80%	17.62%
High	27.70%	37.75%	12.70%

Table: 2 shows the percentage abundance of surrounding macroalgae for each colony type found at 10metres.

<u>FIG:</u> 12

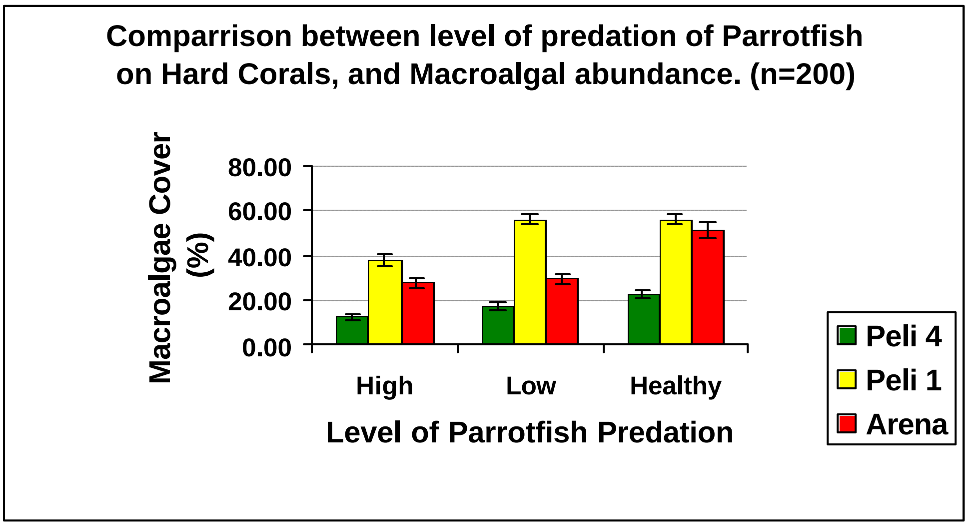


Figure: 12 shows the level of predation of corallivores on all 3 colony types, with relation to the amount of the surrounding macroalgae abundance-in all 3 sites at 10metres [P.Denning, & J. Shrives, 2005].

3.1.4. The Factors Affecting the Incidence and Distribution of Coral Disease; in Relation to Predation and Disease on Acropora cervicornis.

Figure 13

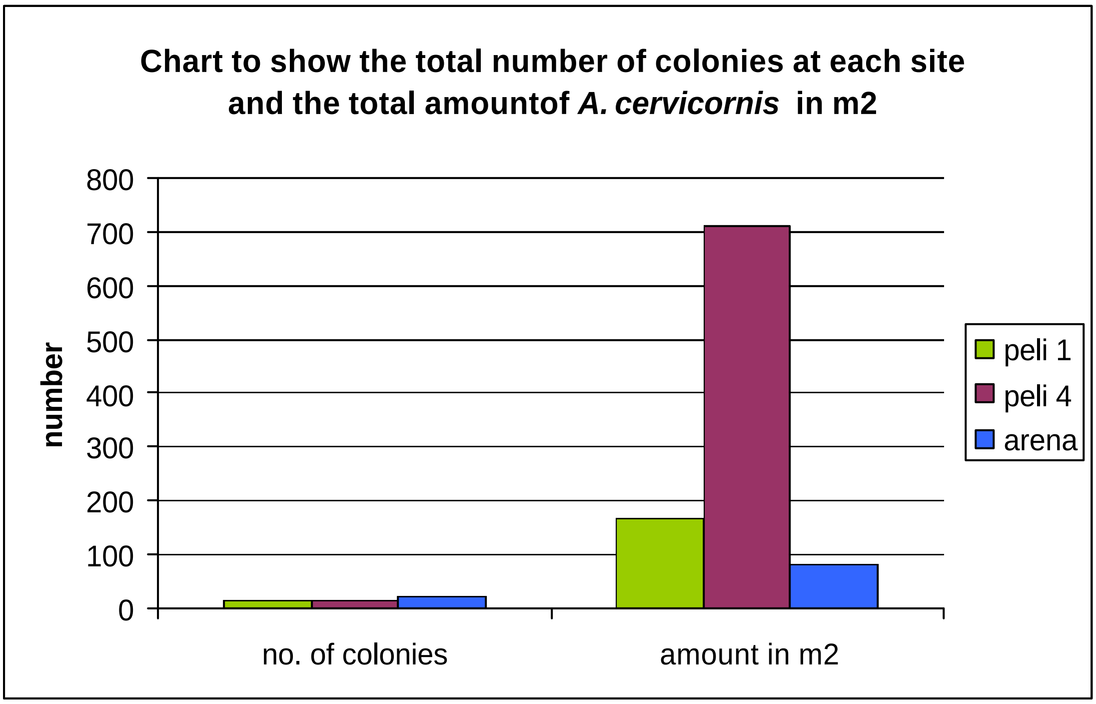


Figure 13 shows the abundance of *A. cervicornis* at the 3 study sites of 70 m by 15m depth and 5 m on to the reef crest. The chart also shows the amount of *A. cervicornis* in m^2 at each site although there is not significantly different numbers of colonies at any site there is significantly greater volume of *A. cervicornis* at

Pelican 4 than the other two sites, as shown with a ? ^{2} p = < 0.005 (p= 1.348 x 10 $^{-}$ 158).

Figure 14

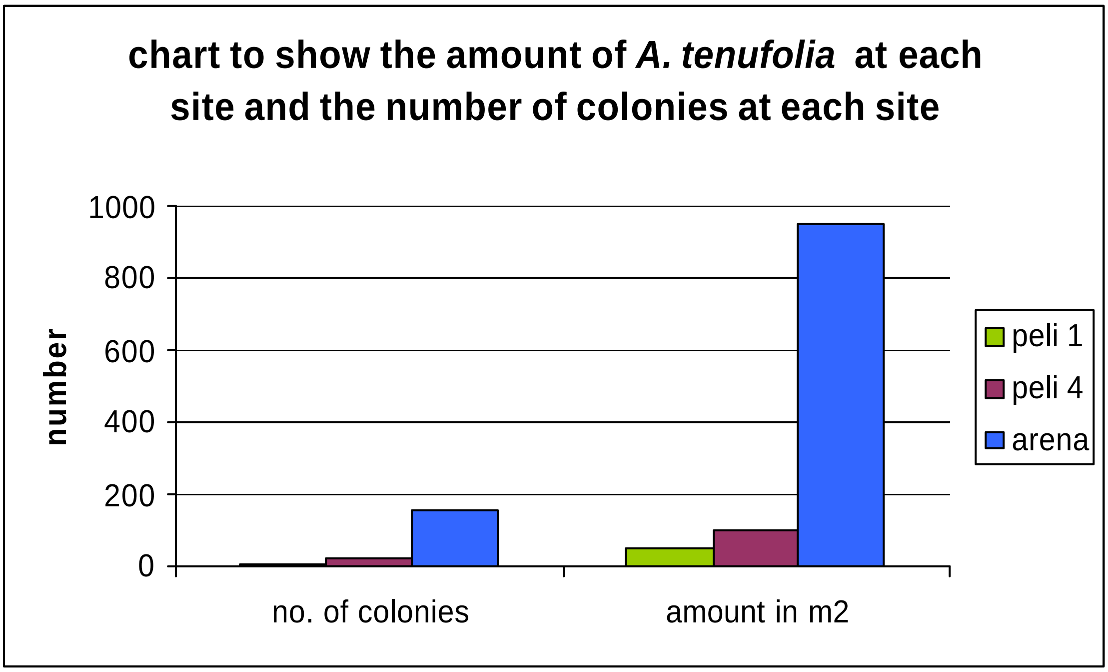


Figure 14 Shows the abundance of *A. tenufolia* at the 3 study sites of 70 m by 15m depth and 5 m on to the reef crest, the chart also shows the amount of *A. tenufolia* in m^2 at each site. There is significantly different numbers of colonies between the 3 sites as shown with a ? ^{2} p = < 0.005 (p = 1.20917 x 10 $^{-}$47).

There is significantly different amounts of *A. tenufolia* at the 3 sites also as shown with a ? ^{2} p = < 0.005 (p=4.0495E-304).

Figure 15

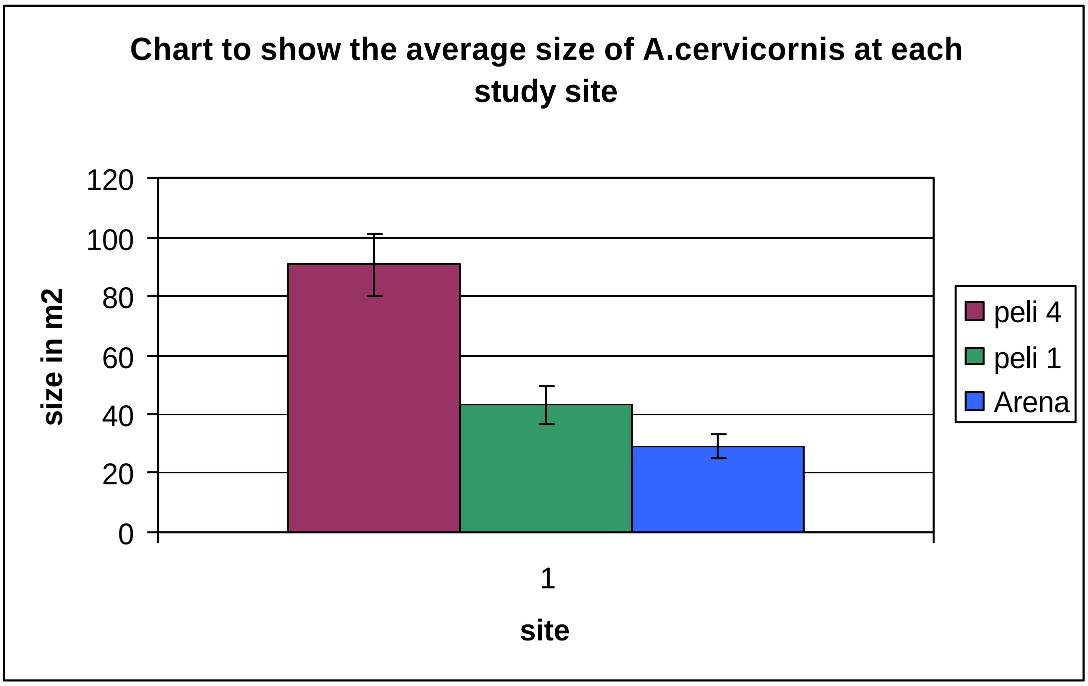


Figure 15 shows the average size of *A. cervicornis* colony at each study site, from this chart and a ? ^{2} test it can be shown that there is a significant difference in the sizes of colonies at each site. ? ^{2}p = < 0.005 (p = 4.39626 x 10 $^-$09)

Figure 16 chart to show the average size of tenufolia at each site

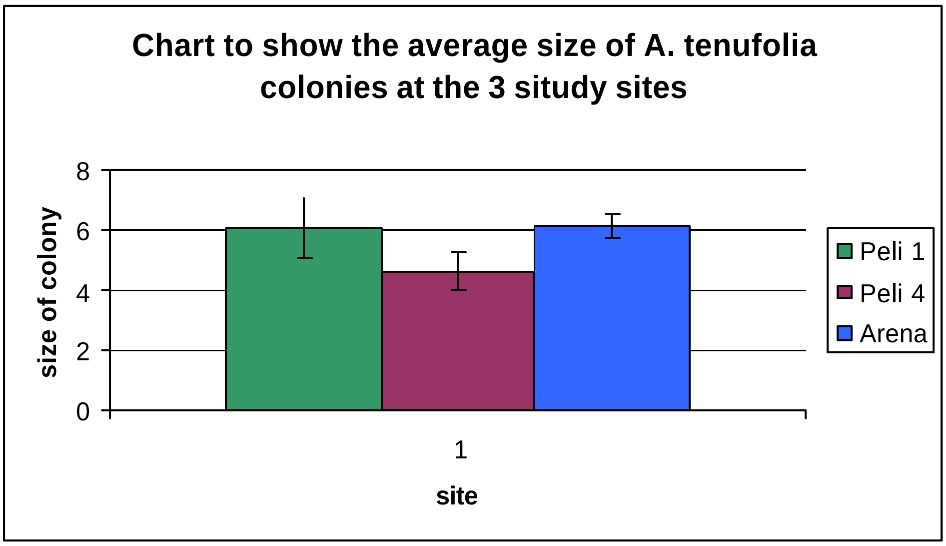


Figure 16 shows the average size of *A. tenufolia* at each site a ? 2 test shows there is not significantly different sizes of colony at the three study sites.

? 2p => 0.005 (p =0.874)

Figure 17

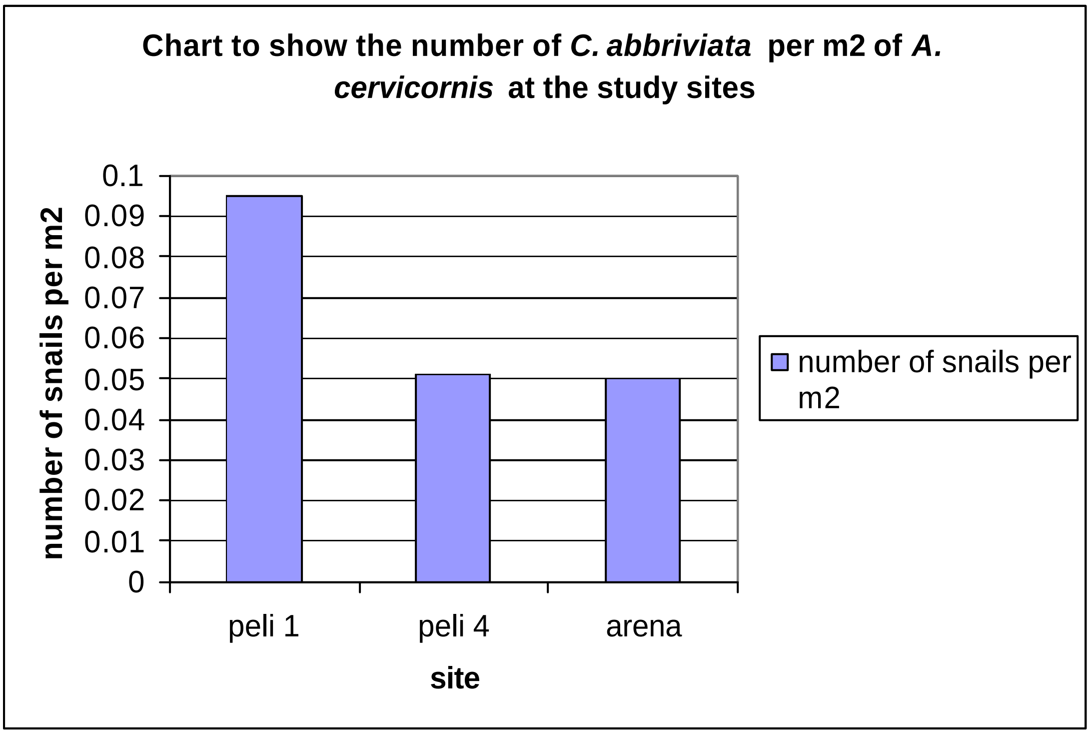


Figure 17 shows the number of snails per m^2 of *A. cervicornis* this shows that there is a greater number of snails per m^2 of *A. cervicornis* at Pelican 1. However this is not a significant difference, ? ^{2} p = > 0.005 = 0.989

Figure 18

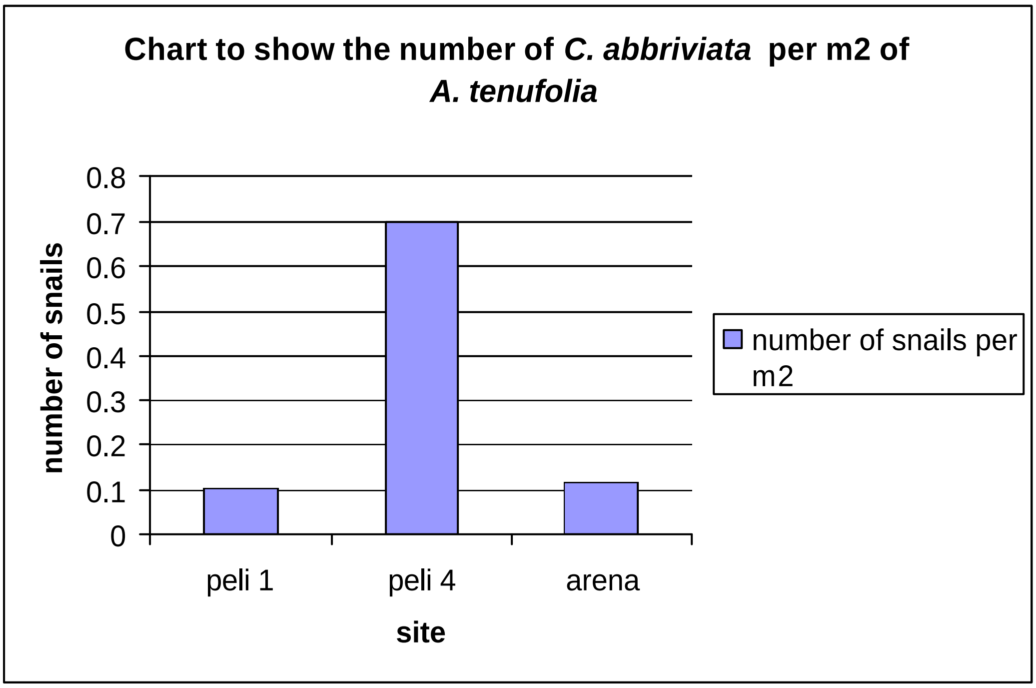


Figure 18 shows the number of *C. abbreviata* per m^{-2} of *A tenufolia*, there is no significant difference in the number of *C. abbreviata* per m2 of *tenufolia* $?^2$ p = > 0.005 p =0.684455154

Figure 19

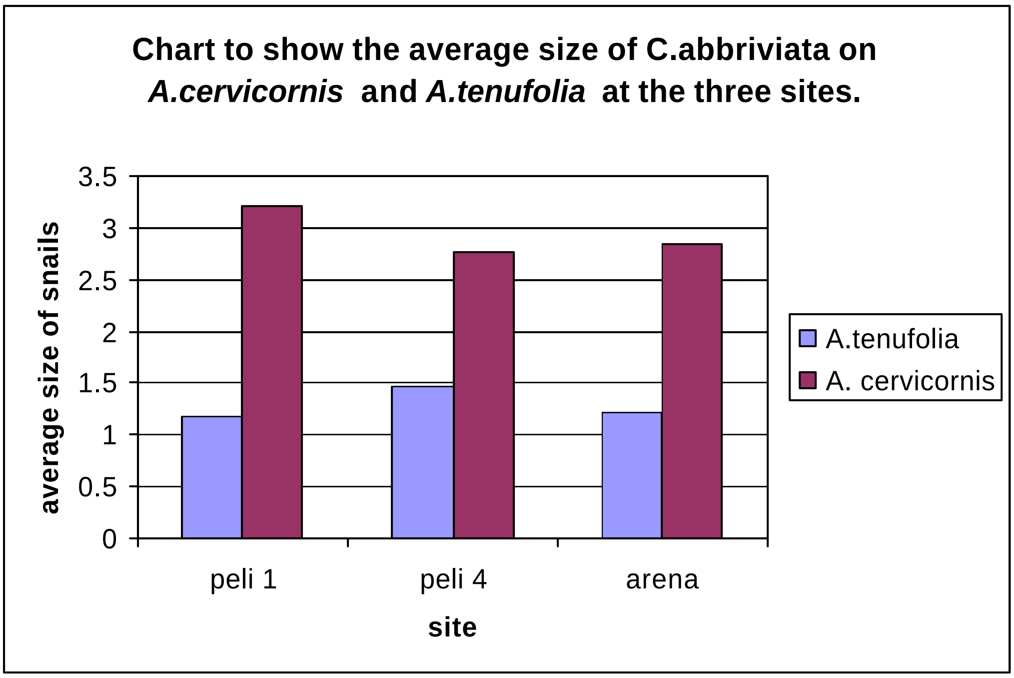


Figure 19 shows the size of snails in relation to the coral species and the site, while there is no significant difference between the sizes of snails with in the species there is a significant difference between the size of snails between the 2 species, significance is shown with a ? ^{2} test: ? ^{2}p = < 0.005 (3.05729 x10 $^-$10).

Figure 20

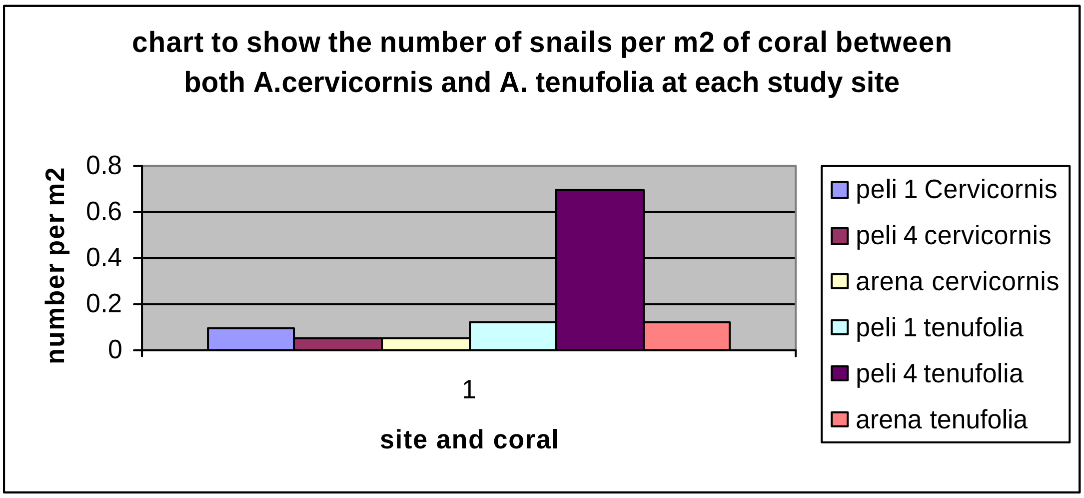


Figure 20 shows that the number of snails per m ^{2} is greatest at Pelican 4 on *A.tenufolia* however the chi ^{2} test shows that there is no significant difference in the numbers of snails per m ^{2} of the corals or species ? ^{2} test: ? ^{2}p = >0.005 (0.887).

Figure 21

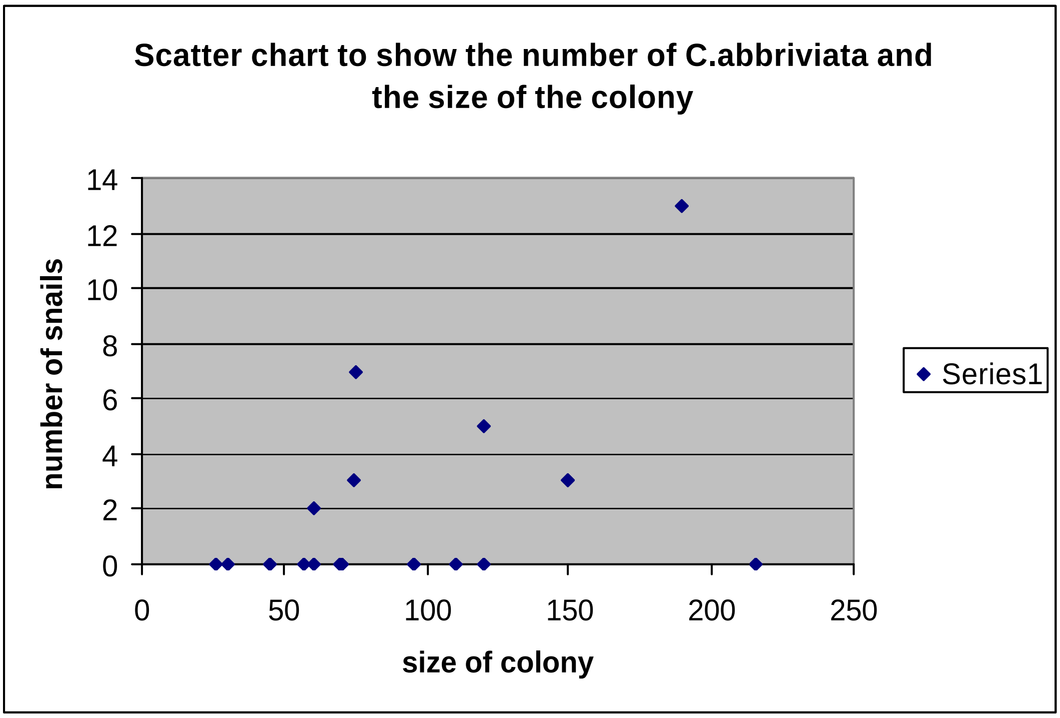
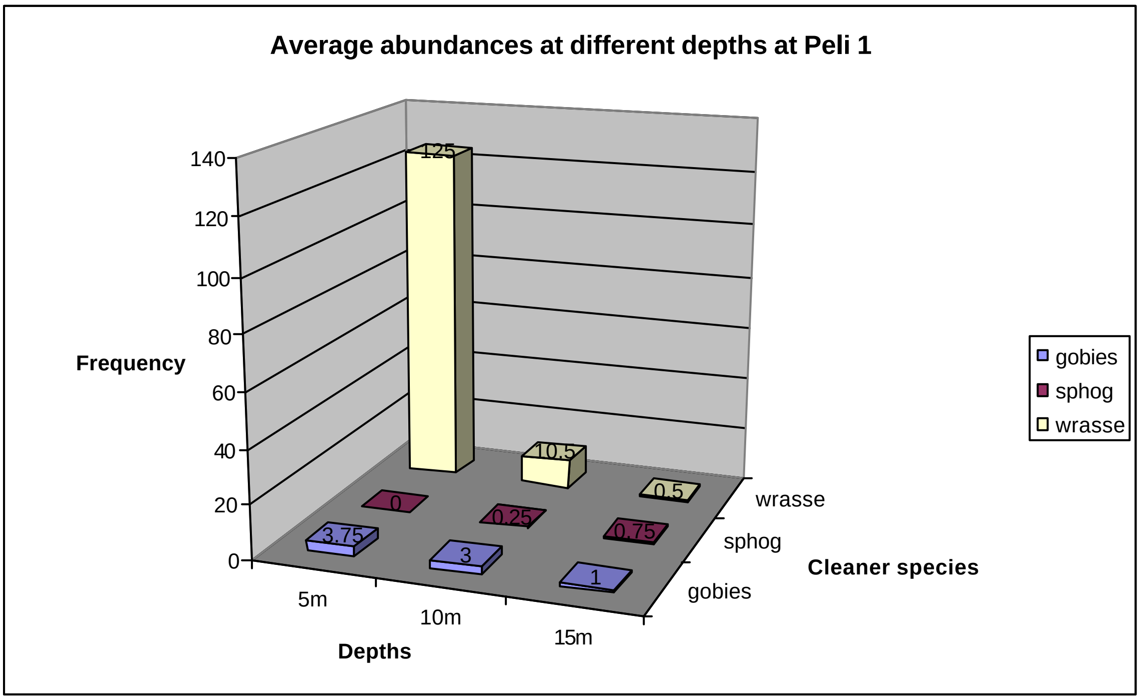


Figure 21 shows a scatter plot to determine if there is a relationship between the size of the colony and the number of snails present. Further analysis is needed however from this chart it would appear that there is no association between the size of the colony of coral and the number of snails.

3.1.5. *Comparison of Cleaner Preferences of Three Cleanerfish Species for Different Client Species.*

<u>Part 1 – measuring cleaner fish abundance at different depths.</u>



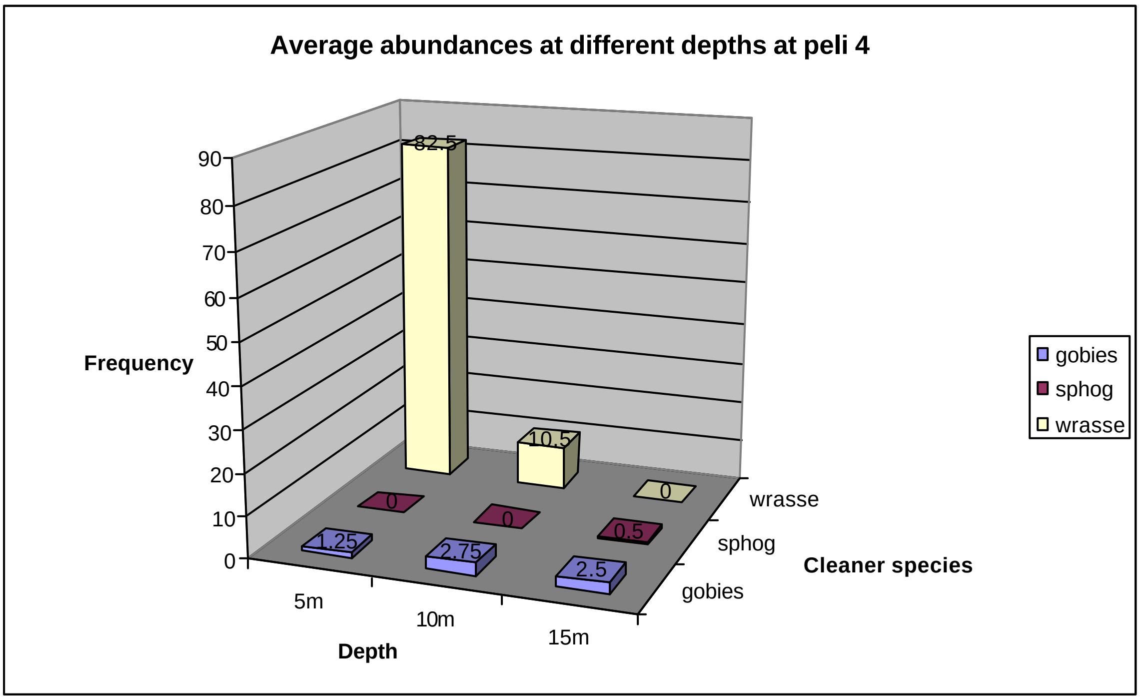
A chi-squared test was carried out to determine whether abundances varied significantly at different depths for each cleaner species;

Gobies – $?^2_2 = 1.56$, $p = 0.46$

Spanish hogfish - $?^2_2 = 0.88$, $p = 0.65$

Wrasse - $?^2_2 = 211.11$, $p = 1.44 \times 10^{-46}$ ($p < 0.001$).

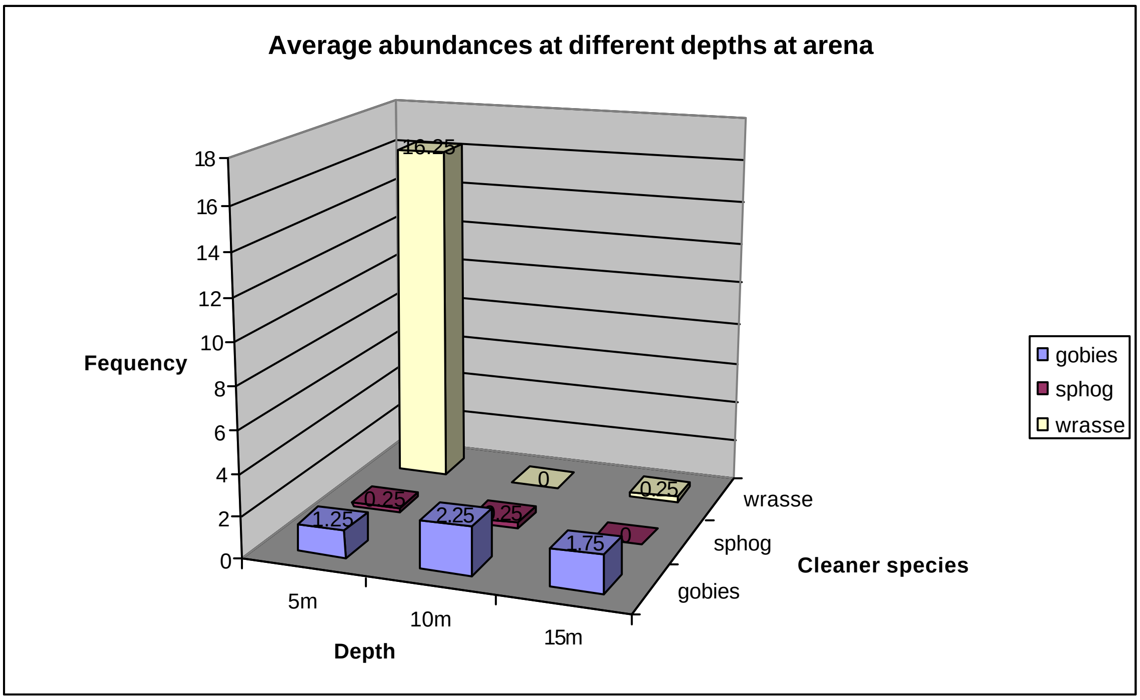
The same tests were carried out for the results from peli 4 and arena.



Gobies - $?^2_2 = 0.60$, $p = 0.74$

Spanish hogfish - $?^2_2 = 1$, $p = 0.61$

Wrasse - $?^2_2 = 130.11$, $p = 5.58 \times 10^{-29}$ ($p < 0.001$).



Gobies - $?^{2}_{2} = 0.29$, $p = 0.87$

Spanish hogfish - $?^{2}_{2} = 0.25$, $p = 0.88$

Wrasse - $?^{2}_{2} = 31.52$, $p = 1.43 \times 10^{-7}$ ($p < 0.001$).

3.2. Seagrass Ecology

3.2.1. The Ecological Importance of the Cayo Menor Seagrass Beds as Recruitment Zones for Juvenile Reef Fish.

Table 3 shows the One-Way ANOVA results for Species Richness Variance within and between the Morning and Afternoon Transects. The relatively high F value 57.349 (df- 5, 144) P=<.0001, indicates that there is a significant variance in Species richness between the varying density Seagrass beds.

Table 3

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	742.033	5	148.407	**57.349**	**.000**
Within Groups	372.640	144	2.588		
Total	1114.673	149			

Table 4 – When Tukey is run in conjunction with One-way ANOVA it enables the identification of the significant variances within the

Multiple comparisons. The significant differences are illustrated by (*)

Multiple Comparisons

Dependent Variable: Species Number

Tukey HSD

Table 4

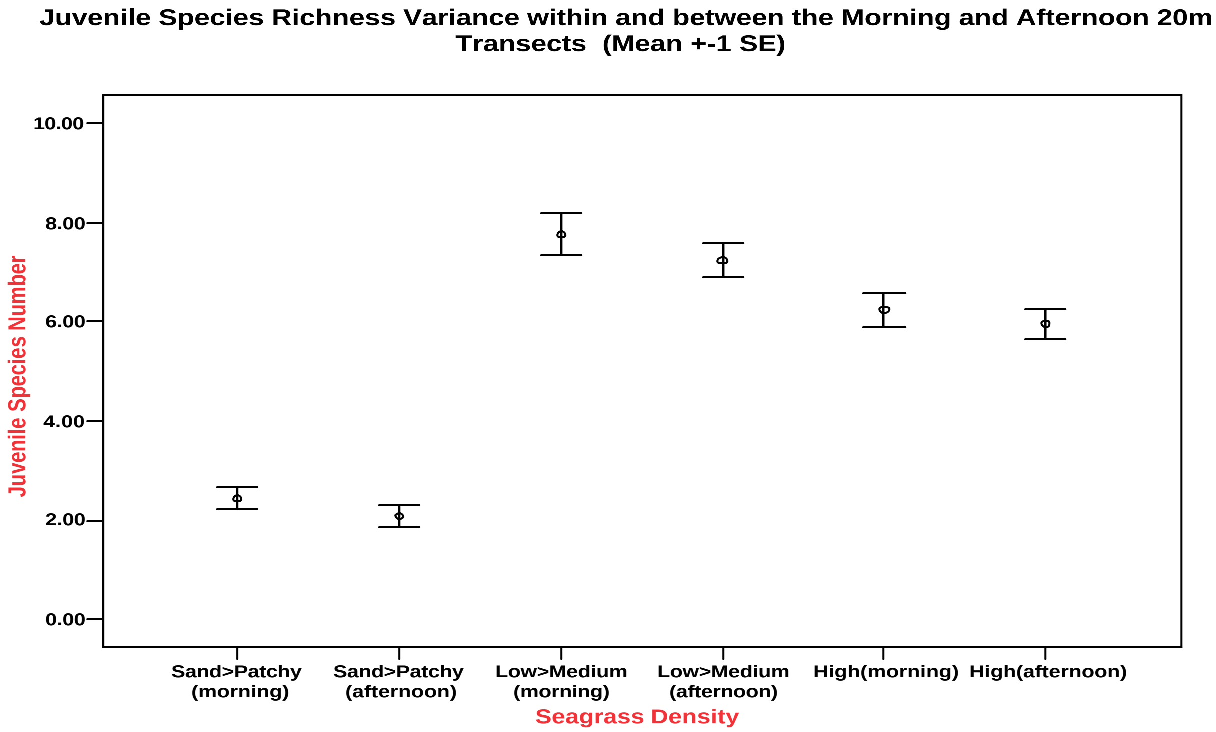
(I) Seagrass Density	(J) Seagrass Density	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
					Lower Bound	Upper Bound
Sand>Patchy (morning)	Sand>Patchy (afternoon)	.36	.45	.96	-1.20	1.92
	Low>Medium (morning)	***-5.32(*)***	.45	.00	-6.88	-3.75
	Low>Medium (afternoon)	***-4.80(*)***	.45	.00	-6.36	-3.23
	High (morning)	***-3.80(*)***	.45	.00	-5.36	-2.23
	High (afternoon)	***-3.52(*)***	.45	.00	-5.08	-1.95
Sand>Patchy (afternoon)	Sand>Patchy (morning)	-.36	.45	.96	-1.92	1.20
	Low>Medium (morning)	***-5.68(*)***	.45	.00	-7.24	-4.11

	Low>Medium (afternoon)	***-5.16(*)***	.45	.00	-6.72	-3.59
	High (morning)	***-4.16(*)***	.45	.00	-5.72	-2.59
	High (afternoon)	***-3.88(*)***	.45	.00	-5.44	-2.31
Low>Medium (morning)	Sand>Patchy (morning)	***5.32(*)***	.45	.00	3.75	6.88
	Sand>Patchy (afternoon)	***5.68(*)***	.45	.00	4.11	7.24
	Low>Medium (afternoon)	.52	.45	.86	-1.04	2.08
	High (morning)	1.52	.45	.01	-.04	3.08
	High (afternoon)	***1.80(*)***	.45	.00	.23	3.36
Low>Medium (afternoon)	Sand>Patchy (morning)	***4.80(*)***	.45	.00	3.23	6.36
	Sand>Patchy (afternoon)	***5.16(*)***	.45	.00	3.59	6.72
	Low>Medium (morning)	-.52	.45	.86	-2.08	1.04
	High (morning)	1.00	.45	.24	-.56	2.56
	High (afternoon)	1.28	.45	.06	-.28	2.84
High (morning)	Sand>Patchy (morning)	***3.80(*)***	.45	.00	2.23	5.36

	Sand>Patchy (afternoon)	***4.16(*)***	.45	.00	2.59	5.72
	Low>Medium (morning)	-1.52	.45	.01	-3.08	.04
	Low>Medium (afternoon)	-1.00	.45	.24	-2.56	.56
	High (afternoon)	.28	.45	.99	-1.28	1.84
High (afternoon)	Sand>Patchy (morning)	***3.52(*)***	.45	.00	1.95	5.08
	Sand>Patchy (afternoon)	***3.88(*)***	.45	.00	2.31	5.44
	Low>Medium (morning)	***-1.80(*)***	.45	.00	-3.36	-.23
	Low>Medium (afternoon)	-1.28	.45	.06	-2.84	.28
	High (morning)	-.28	.45	.99	-1.84	1.28

*** The mean difference is significant at the .01 level.**

Figure 22

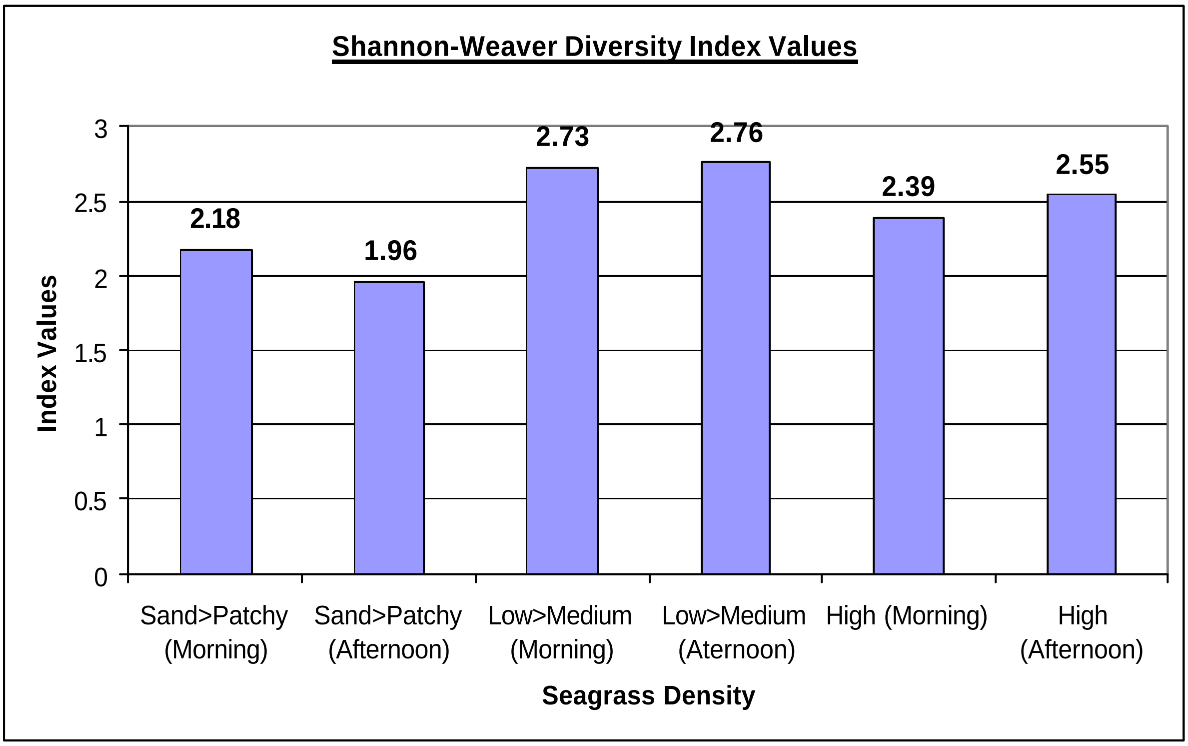


From Figure 22 it can be clearly identified that the Species richness of Juvenile reef fish was significantly higher On the Low>Medium and High density Seagrass transects, when compared to the Sand dominated habitat (Sand>Patchy transect). This significant difference or variance in Species richness is also illustrated Tukey test results table, where the variances are highlighted in bold Italic.

Shannon-Weaver Diversity Index values

Transect	Total Species identified	Total Individuals identified	Index value
Sand>Patchy (Morning)	19	118	***2.18***
Sand>Patchy (Afternoon)	14	98	***1.96***
Low>Medium (Morning)	30	416	***2.73***
Low>Medium (afternoon)	32	420	***2.76***
High (Morning)	20	472	***2.39***
High (Afternoon)	22	371	***2.55***

Figure 23



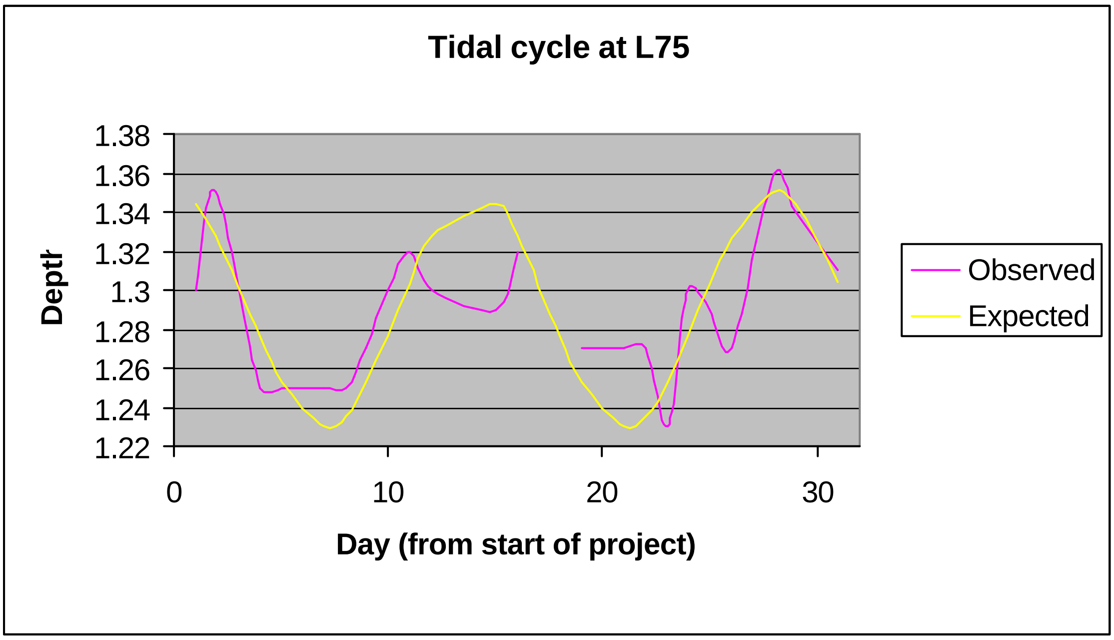
The Shannon Weaver index gives Diversity values for each of the varying habitats. From Figure 23 it can be noted that the Sand>Patchy Seagrass habitats have significantly lower Index values in comparison to the Medium and High Density Transects, this helps confirm the greater Species richness and diversity of juveniles that were recorded for the Seagrass dominated habitats. What should be noted here is that Diversity indices such as these can only be used to ‘compare like with like’ these obtained values could not be compared to another significantly different set of data from another sample site.

3.2.2. An Investigation into the Lunar Activity Cycles of Shrimp Living in Seagrass Beds on Cayo Menor.

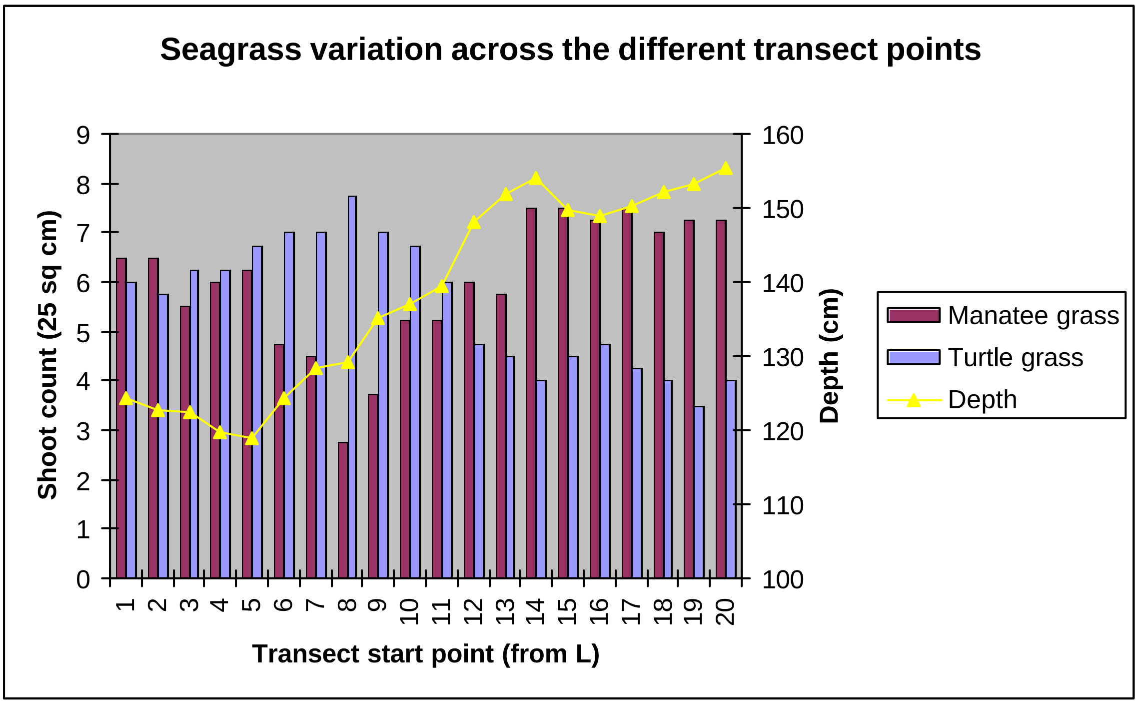
The research has covered just more than a full lunar cycle, starting roughly at full moon. After the first couple of days, while the moon was waning, it has not been risen at the time of sampling. During the second half of the sampling period, it has been visible most nights but on some nights obscured by cloud. Light levels have therefore been affected by both the phase of the moon and the cloud cover.

Wind strength and sea swell have varied considerably, closely correlated with each other. Wind direction has been almost completely constantly from the east. Sea surface temperature has remained almost constant, from 27.5C to 28.5C. Rain has been an occasional feature.

The height of the tide has varied over approximately 15cm of depth – a very small range. It has followed roughly the cycle expected, though with considerable error from the expected due to the difficulties of estimating the average sea level during swell.



The canopy height of the seagrass varied between 10 and 25cm, and the shoot length between 15 and 30cm. The percentage cover was an average of approximately 85%. Depths varied from 116 to 163cm (at low tide), in general increasing towards the NW end of the sampling area. The density of the two species also varied in a continuum across the sampling area, with three general areas: similar abundance (closest to the pier), then turtle grass dominant (right of the rock) and manatee grass dominant (left of the rock). The graph below shows averages across the length of a transect (that is, from 4 different points). The rock lies between transects 13 and 14.



Seagrass variation across the different transect points
Shoot count (25 sq cm)
Depth (cm)
Transect start point (from L)
Manatee grass
Turtle grass
Depth
0
1
2
3
4
5
6
7
8
9
100
110
120
130
140
150
160
1
2
3
4
5
6
7
8
9
10
11
12
13
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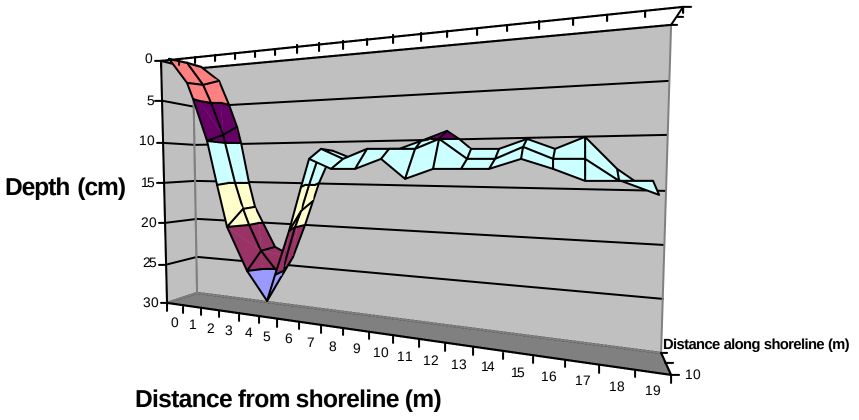
17
18
19
20

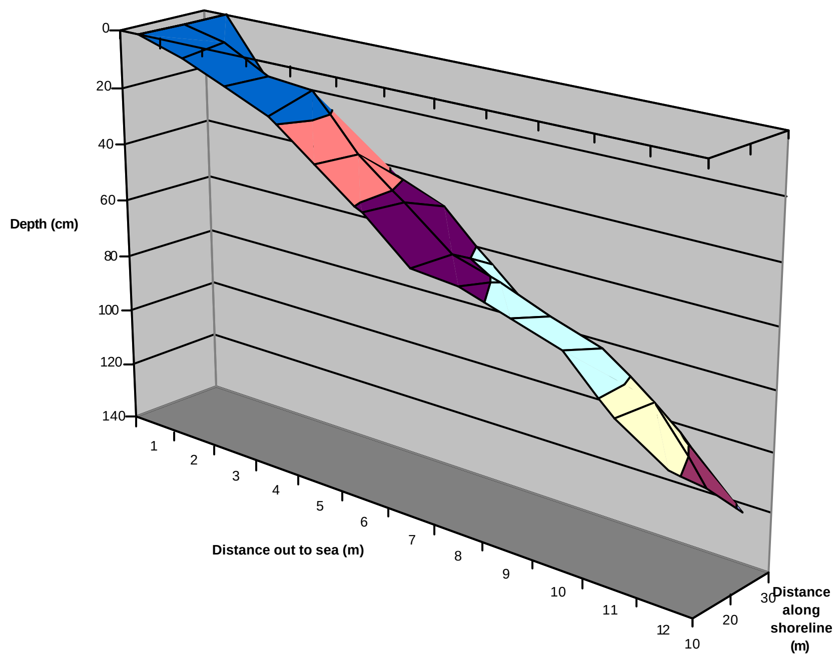
3.2.3. Hermit Crab Ecology

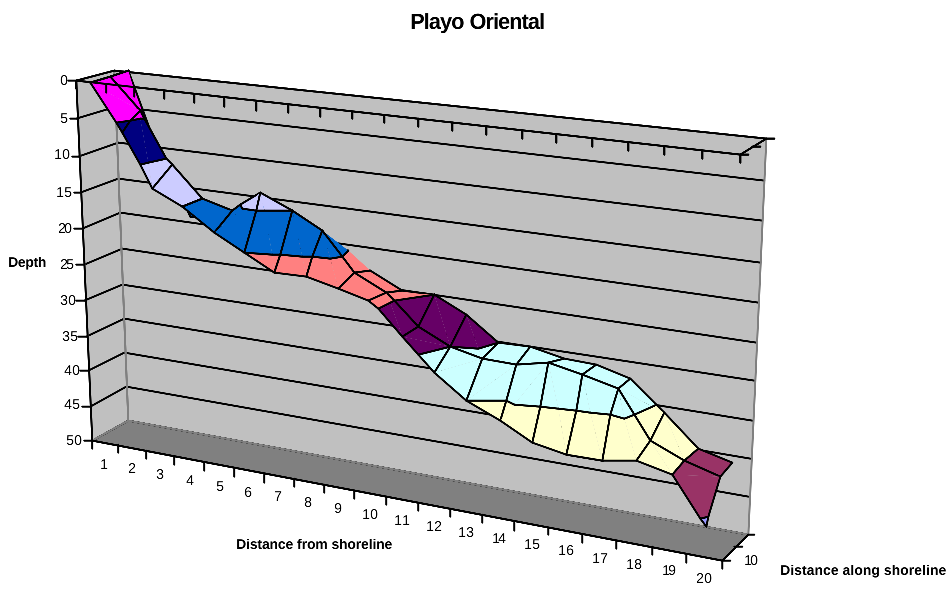
Beach Profiles

Playa Dos



Playo Biologica



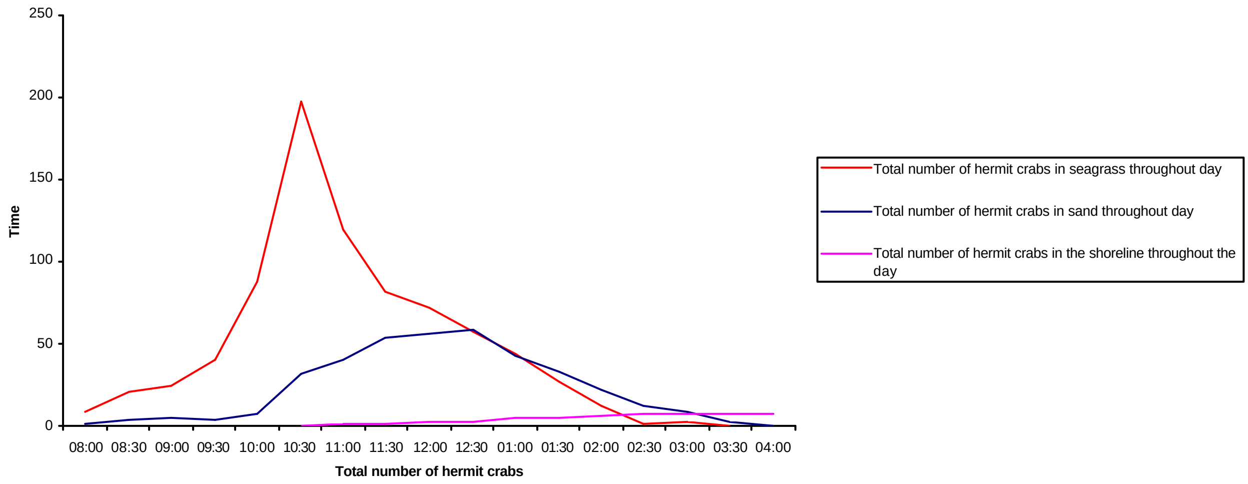


These beach profiles show the large intertidal zone at Playa Dos compared to the steep gradient found at the biological station beach. Playa Oriental has an intertidal zone though it is not as shallow as that Playa Dos. This shows how hermit crabs tend to prefer the intertidal region of the shoreline as they are not found in deeper waters such as those at the biological station beach.

<u>Diurnal patterns</u>

The investigation into diurnal movement of hermit crabs seemed to show that hermit crabs do indeed show a pattern of movement throughout the day. As readings were taken over a period of low tide followed by high tide, it was possible to assess the number of hermit crabs in the sand and seagrass during both the high tide and the low tide. During the low tide the hermit crabs were abundant in both the sand and the seagrass and seemed to migrate towards the sand as the day progressed. There were higher numbers of hermit crabs in the seagrass than in the sand but these numbers fell as the hermit crabs moved out of the seagrass towards the sand. During high tide, the number of hermit crabs in the sand and seagrass was much lower than at any time during low tide. The temperature readings seem to show that hermit crab movement varies as does temperature, possibly even closely following these fluctuations.

A comparison of the total number of hermit crabs in the sand and in the seagrass throughout the day on 14.08.05



This shows how hermit crab numbers increase first in the seagrass, then in the sand and finally slightly at the shoreline. The numbers are always greatest in the seagrass and possibly peak when temperatures are high.

Aquaria experiments

The various aquaria experiments set up show a wide variety of results. Each of these experiments was later repeated to obtain replicas, but these results are from experiment 1 only. In every tank set up with one green rock and one white rock, the hermit crabs invariably prefer the green rock. This result was evident whether 1, 25 or 50 hermit crabs were used (See Fig. 24-26). Fig. 27 shows the total number of hermit crabs on each rock from all tanks and clearly shows the definite preference for the green rock.

Fig.24

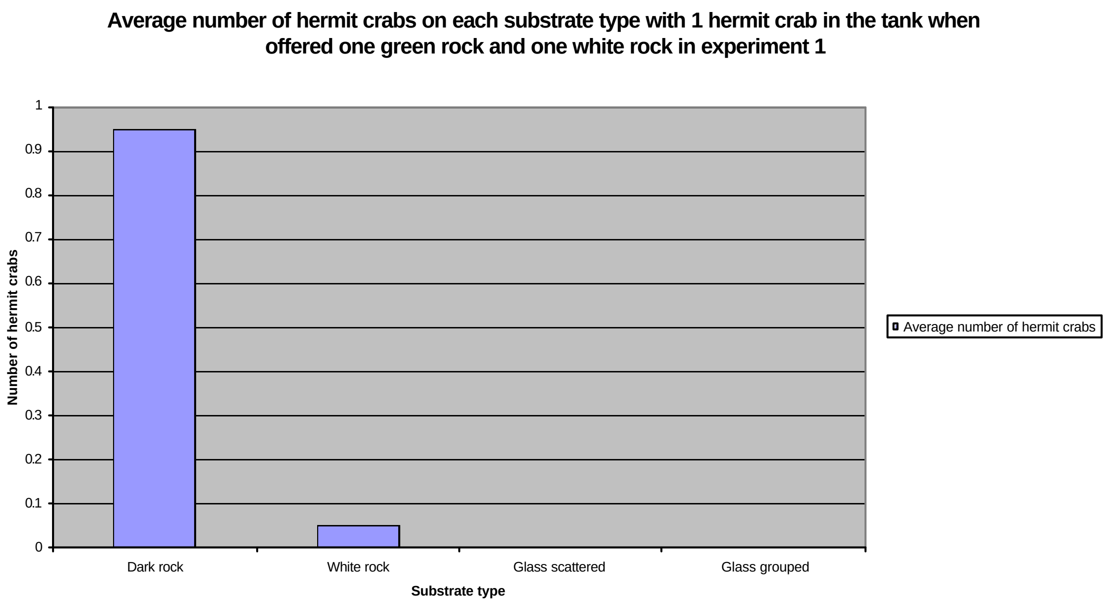


Fig. 25

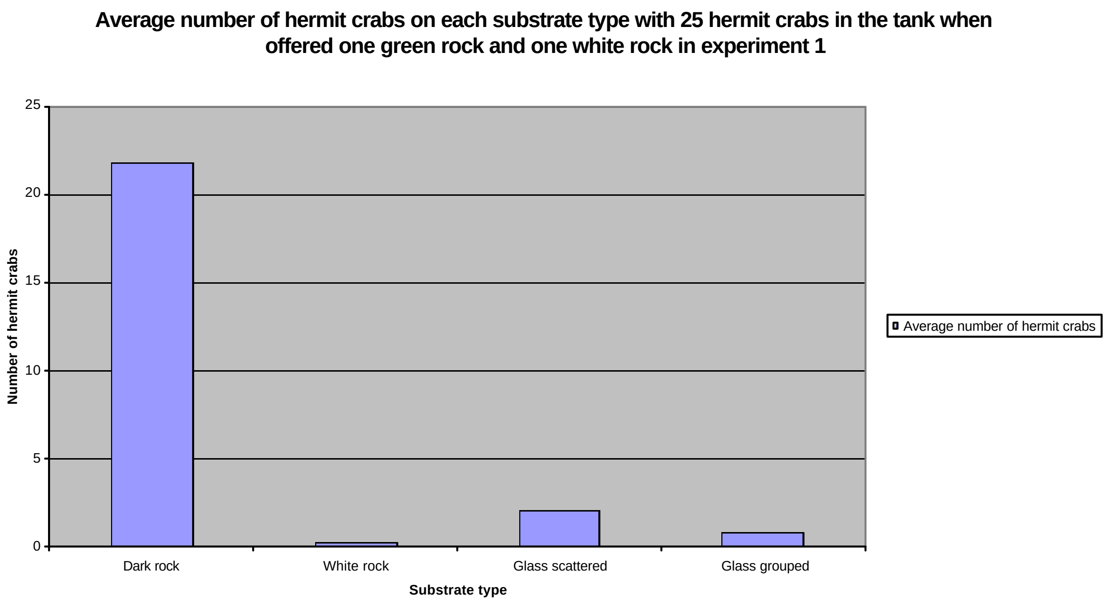


Fig. 26

Average number of hermit crabs on each substrate type with 50 hermit crabs in the tank when offered one green rock and one white rock in experiment 1

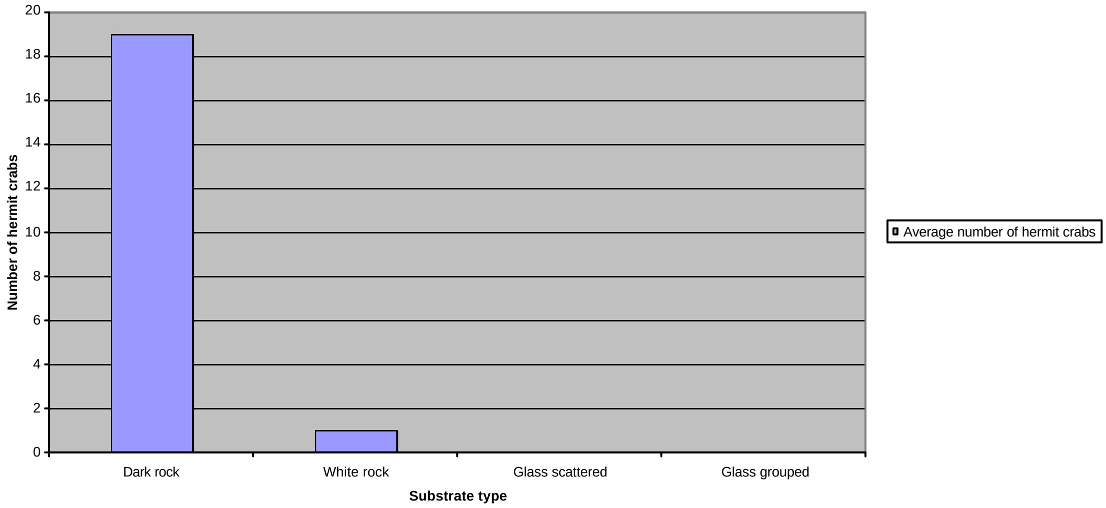


Fig. 27

Total number of hermit crabs in all tanks when offered one green rock and one white rock in experiment 1

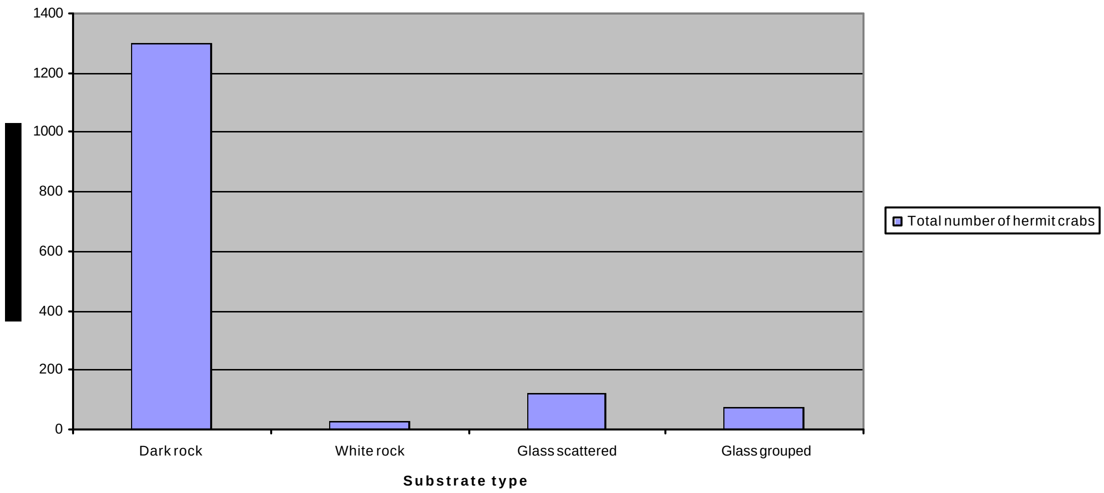


Fig.28

Average number of hermit crabs with 1 hermit crabs in the tank when offered two white rocks in experiment 1

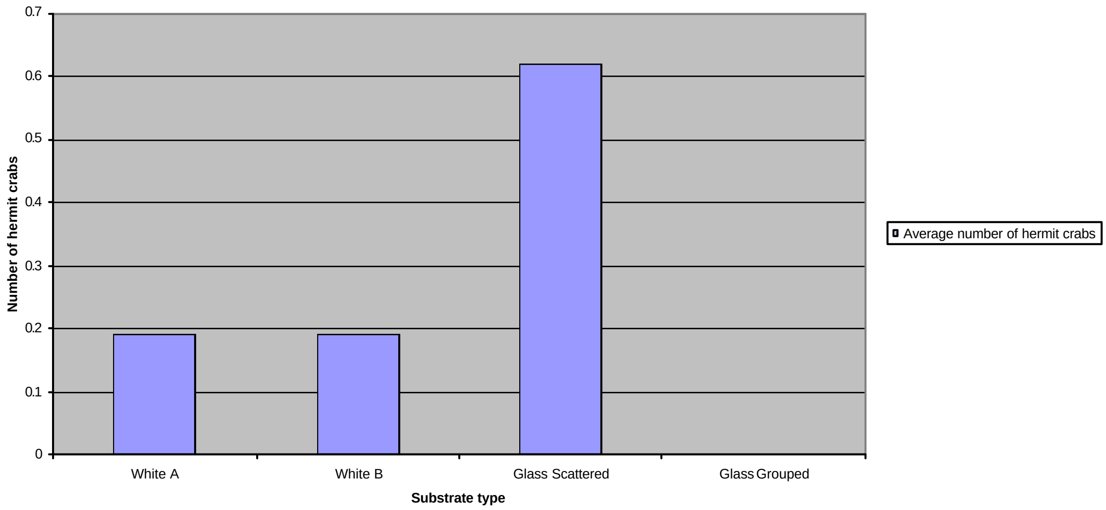


Fig. 29

Average number of hermit crabs on each substrate type with 25 hermit crabs in the tank when offered two white rocks in experiment 1

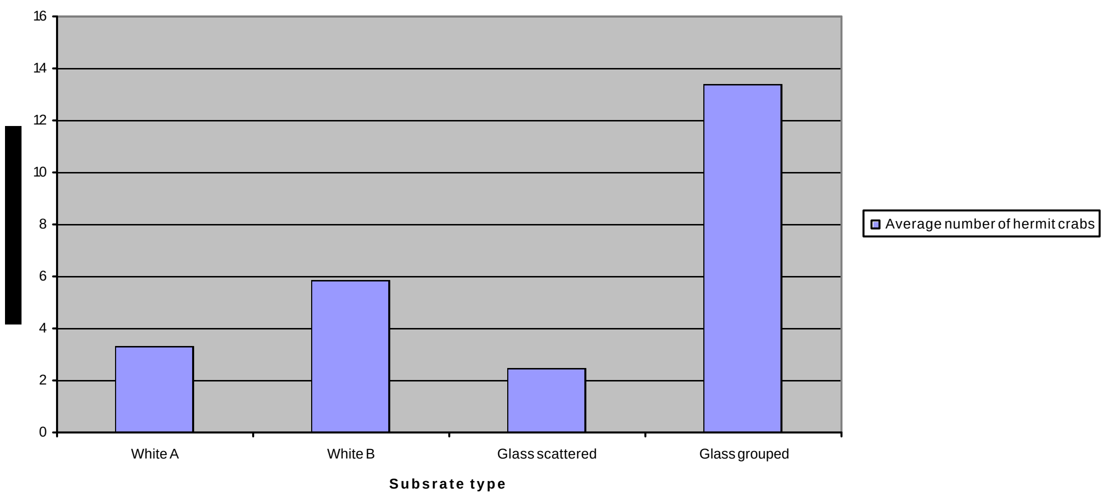


Fig. 30

Average number of hermit crabs in each subsrate type with 50 hermit crabs in the tank when offered two white rocks in experiment 1

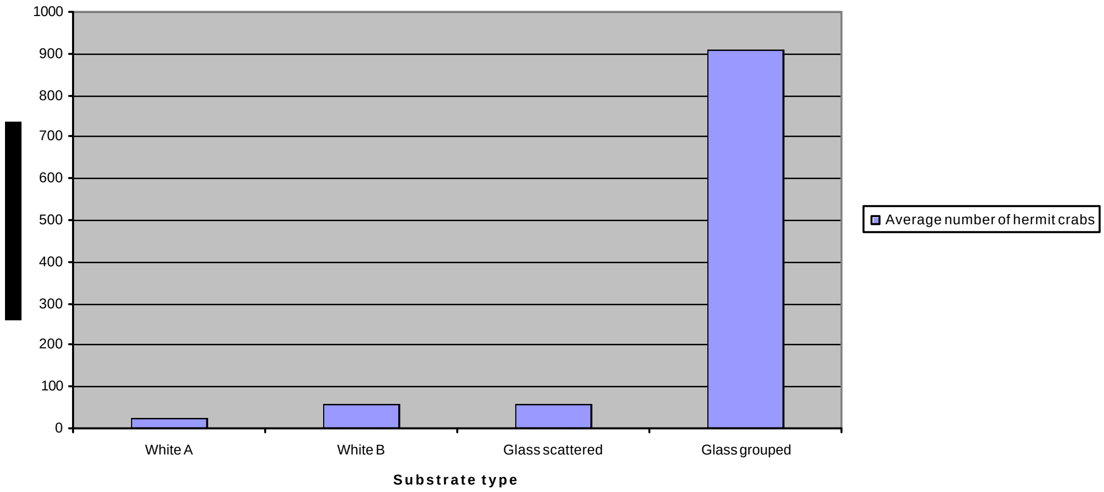
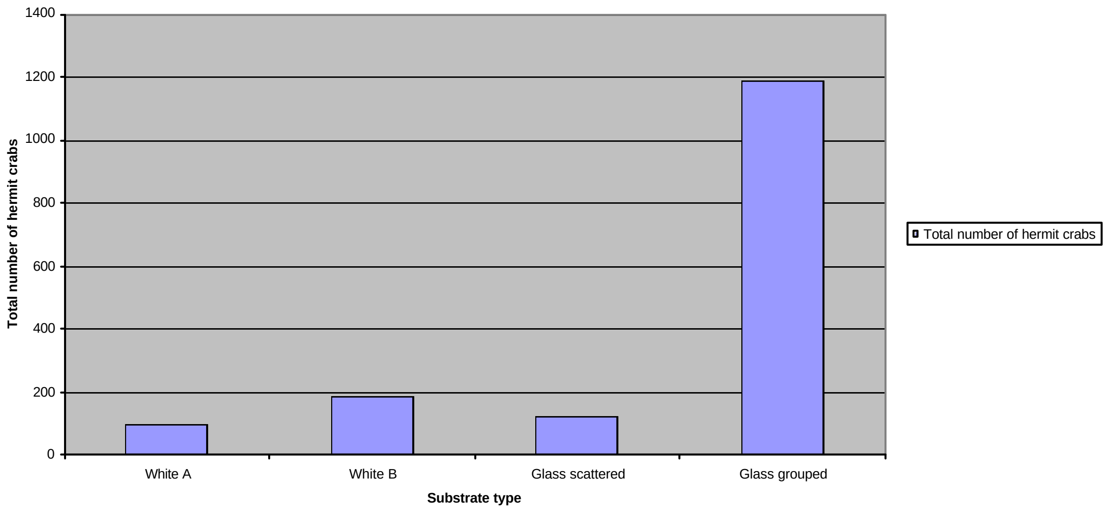


Fig. 31

Total number of hermit crabs on each substrate type from all tanks when offered two white rocks in experiment 1



The preliminary results for the experiment involving two green rocks are a little more complex than the other two experiments. When there are 25 and 50 hermit crabs in the tank, they seem to prefer the green rock labeled rock B (Fig.33-34). This was an arbitrary labeling to distinguish between the two rocks, with A being the rock on the left and B being the rock on the right hand side of the tank. However, when there was only 1 hermit crab in the tank, it seemed to prefer either rock A or the bottom of the glass tank (Fig.32). Fig. 35 shows the total number of crabs on each rock from all tanks but is likely to mostly reflect the results from the tank with 50 hermit crabs as this has two thirds of the total number of crabs in it. The most likely explanation for this is the positioning of the two rocks. In all cases, the preferred rock is furthest away from the back wall and closest to the light. In order to establish whether the crabs preferred a particular rock or simply the positioning of the rock, it was necessary to switch the position of the rocks around and repeat the experiment. These results have not yet been analysed.

Fig. 32

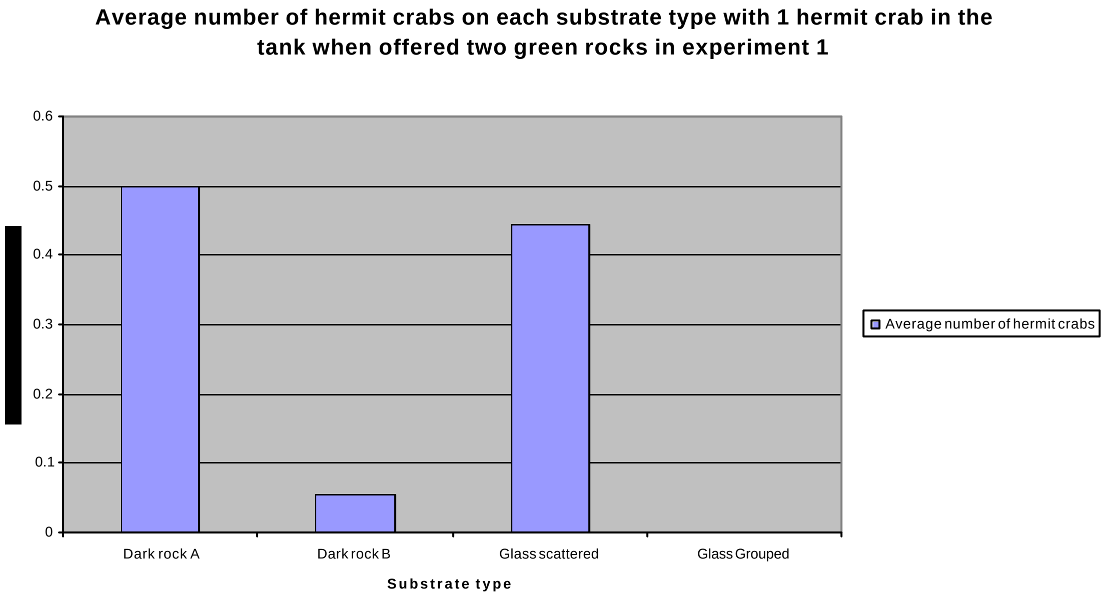


Fig.33

Average number of hermit crabs on each substrate type with 25 hermit crabs in the tank when offered two green rocks in experiment 1

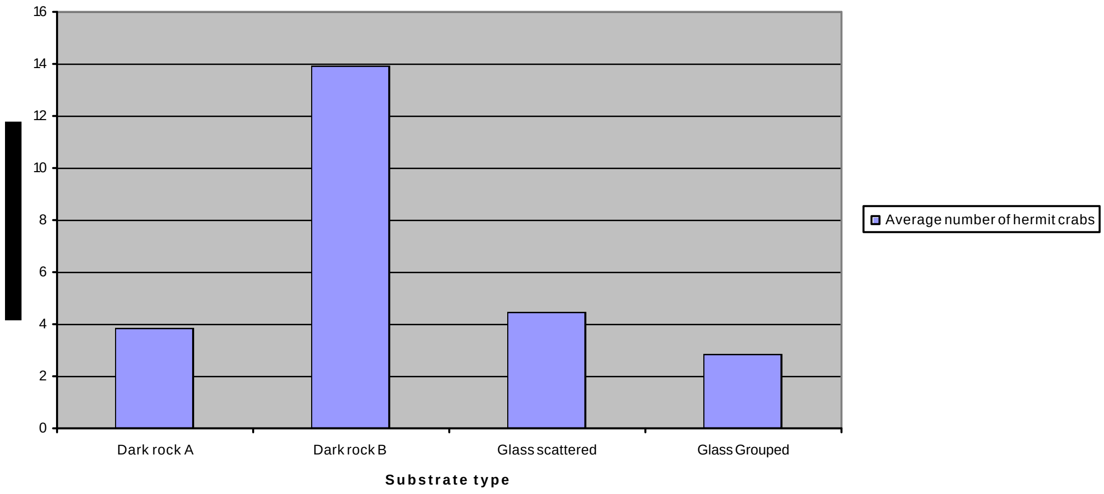


Fig. 34

Average number of hermit crabs on each substrate type with 50 hermit crabs in the tank when offered two green rocks in experiment 1

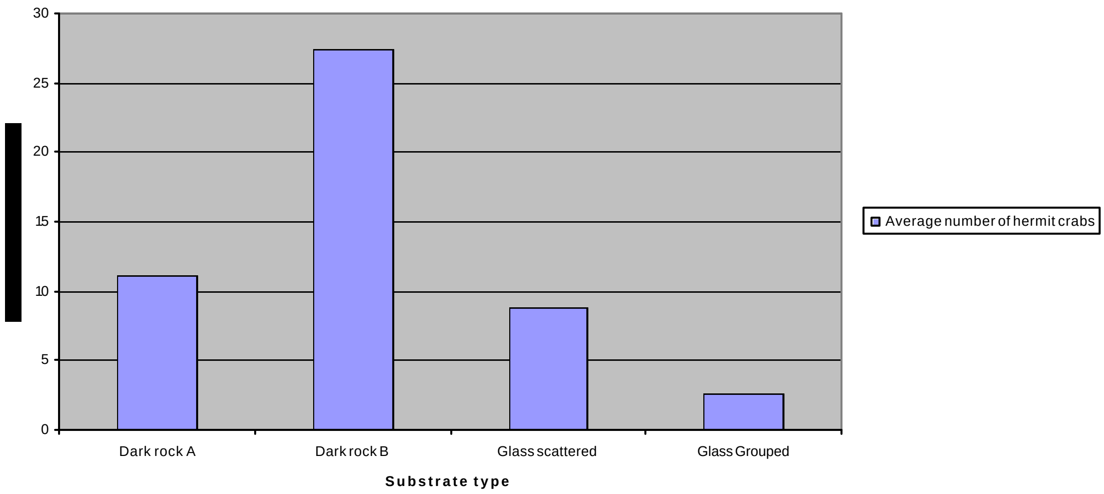
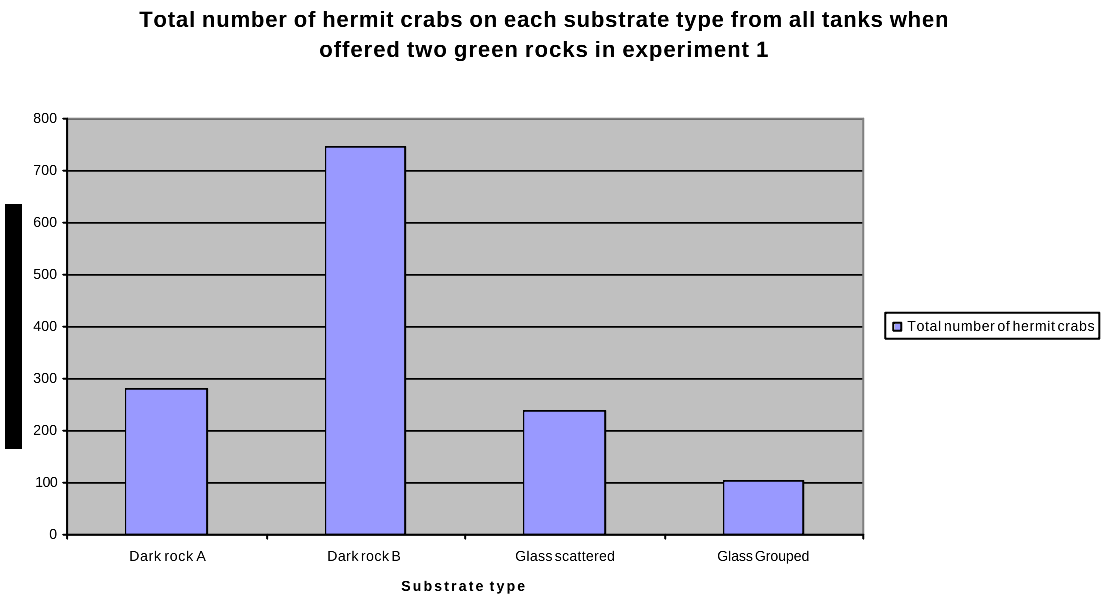


Fig. 35



3.3. Ecotourism and its Impacts

3.3.1. Social Impacts within the Cayos Cochinos

Entrance fees were implemented in January 2005. Upon review the meeting minutes and legislative proceedings that led to the establishment of the park fees. There was no representation from the Garifuna community at the October 14, 2004 meeting at the *Secretaria de Estado en los Despachos de Recursos Naturales y Ambiente* (SERNA) when the park fees were under consideration. According to the documents detailing the development of this tax, the group considered a number of items including:

1. The importance of Legislative Decree 114-2003, which assured the operating capacity and maintenance of the Marine Protected Area.

2. To protect and develop the tourism sector in agreement with the management plan.

3. To promote tourism opportunities for local communities.

4. To manage and control the impact of tourism.

5. To facilitate access of the national community to the MPA with education and recreation fines.

6. To implement the success of the tariff with a support base.

7. To promote self-sufficiency in the management of the MPA and the local economy (Author's translation).[2]

The entrance fee was established to improve tourism opportunities both for the tourists (by ensuring conservation of the area) and for those who live within the MPA. As the same document states:

> It is very important for the success of the MPA that the communities that live within it and the influenced zones receive benefits from the conservation of the MPA. Promoting tourism as an economic alternative for the communities is a good opportunity to share with local communities in the management and conservation of the MPA. With the proposal to promote community tourism initiatives, the foreign tourists that visit the MPA through tour

[2] *Régimen Tarifario del Monumento Natural Marino Archipiélago Cayos Cochinos*.

operators from the communities within the MPA and its zone of influence, pay a reduced rate (author's translation).

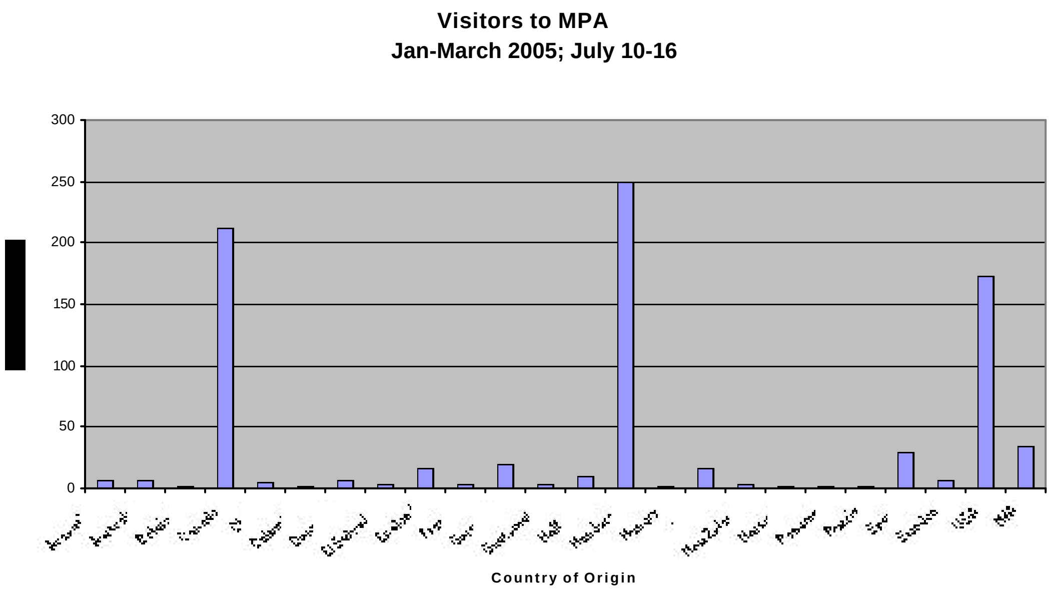
The tariffs apply to both visitors to the MPA and boats that enter the water within the limits. The amount of the fee varies by amount of time the tourist remains in the park (i.e., visitors who stay a year pay less). The following are the actual fee schedule:

<u>Visitor fees:</u>
Foreigners: $10/day; 20/month; 40/year
With community operators: $5/day; $10 month/$20 year
Hondurans: $2/day; $4 month; $8 year

<u>Dockings</u>:
Of community property less than 30 feet: $2/day; $4/month; $8/year
Less than 50 feet: $5/day; $10/month; $20/year

<u>Commercial boats:</u>
Less than 30 feet: $5/day; $10/month; $20/year
Less than 55 feet: $10/day; $20/month; $40/year

The following bar graph depicts visitor by their region of origin.



817 visitors were recorded as entering the MPA in the 3.25 months of data we reviewed. The primary nations represented by the visitors were Honduras (n=250), followed by Canada (n=212) and the United States (n=173.) At the very least, the income derived for the management of the MPA would have been approximately \$3165[3], and \$8165[4] at most.[5] HCRF operates under a limited budget and is dependent upon external funds.

Women and children typically sell products to tourists who arrive on Chachauate.

The potential gender implications of the management plant became clear after the first trip of 45 students, teachers, and volunteers to Chachauate. The day after the trip, our research team interviewed the community members who sold products or services to the community in order to discern how income was spread amongst resident families. Thirteen community members earned money during the two-hour trip. Three women braided hair for 100 lempiras each, and ten women and one man sold jewelry. The women we interviewed made between 150 and 500 lempiras each; the one man earned US \$70.

[3] Assuming all Honduran visitors paid \$2 and all foreigners were brought in by a local tour operator and paid the minimum payment of \$5. This figure also does not include a fee for the 34 individuals recorded in the NA category (i.e., reflecting that the fees were either not applicable or the information was not available to log).

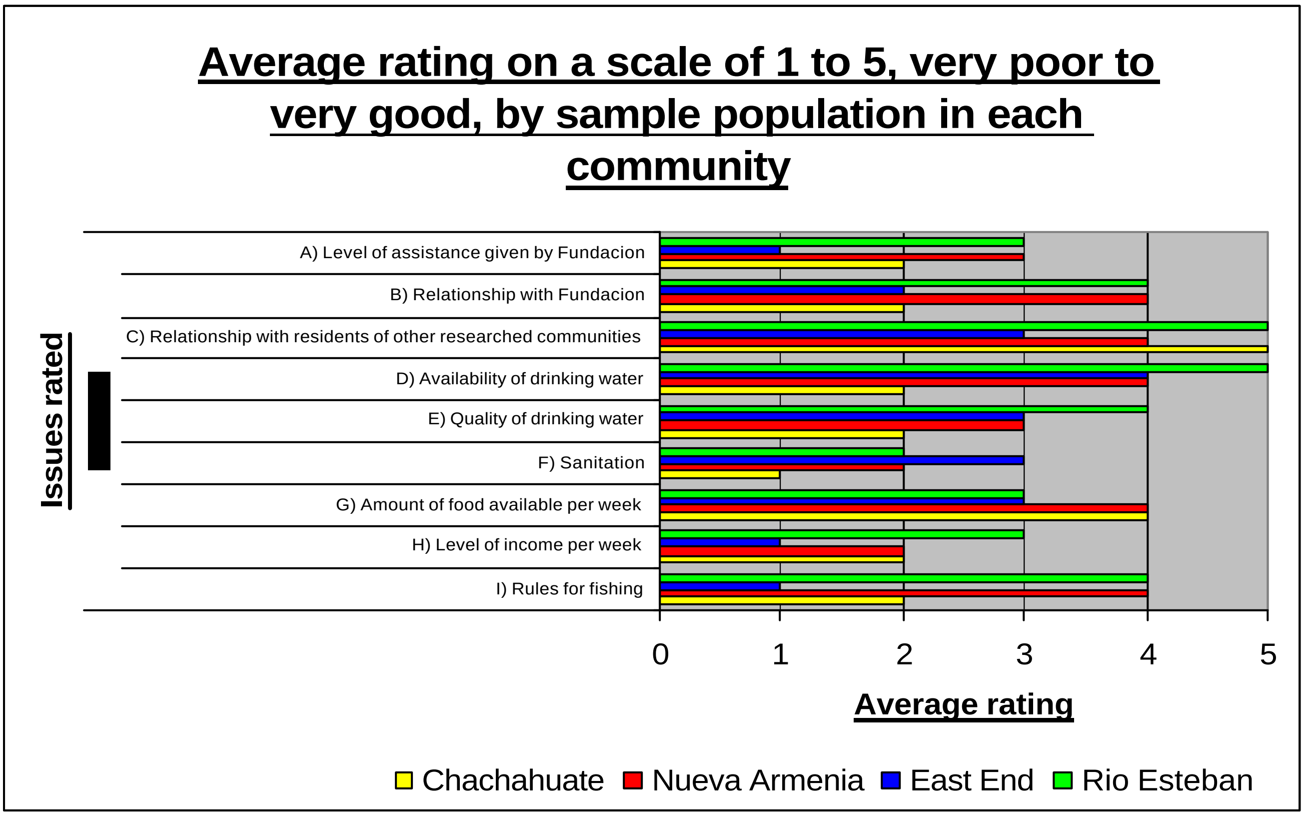
[4] Assuming all Honduran visitors paid \$2 and all foreigners arrived in boats not operated by a local tour operator and thus each paid \$10. This figure also does not include a fee for the 34 individuals recorded in the NA category (i.e., reflecting that the fees were either not applicable or the information was not available to log).

[5] It will be possible to ascertain exactly how much money was generated through the park fees in time. It will take additional research and analysis to determine which boats community members operate, and which boats are commercially operated.

Years ago INA issued a title to the Garifuna for the cays, but it was contested because INA is an administrator of rural, agricultural land, not “urban land.” Under Decree 90/90, all of the Cayos Cochinos were declared urban land and now fall under the jurisdiction of Roatan, who holds the authority to title the land. Chachauate was in the process of working with Roatan to issue the title in 2005.

Two excellent opportunities for cultural exchange were implemented during the 2005 season: a weekly BBQ and boat trips to Chachauate and East End. Adding an educational component whereby locals share their ecological and cultural knowledge with the student visitors could enhance these opportunities.

3.3.2. The Impacts of Ecotourism on Livelihoods of the Garifuna Communities of the Cayos Cochinos.



This graph shows initial overall views for each of the communities. Preliminary analysis indicates that:

- views of the mainland communities of Rio Esteban and Nueva Armenia are never below 2 out of 5, or an opinion of poor;
- communities members view's in Rio Esteban is highest out of all 4 communities in 7 out of 9 questions, twice reaching 5 out of 5, or very good;
- Community members view's in Nueva Armenia are also generally high. With highest ratings, or joint highest in 4 out of 9 questions. Their highest rating reached 4, or good, for

the questions of relationship with the Fundación, the amount of food available per week and the rules for fishing;

- for issues of income and basic amenities within the communities, Chachahuate and East End, the 2 island communities seem to give the lowest ratings. For example, question F, or sanitation, Chachahuate gave an average rating of 1, and for question I, or rules for fishing, the rating that East End gave was also a 1, and similarly for question H, or level of income per week in which East End also gives a rating of 1;
- the island communities also seem to rate their relationship with the Fundación and the assistance given by the Fundación in community development the lowest out of all 4 communities, with the lowest rating of 1, or very poor, rated by East End for level of assistance in development given by the Fundación, Chachahuate for the same issue gave a rating of 2, or poor, and for relationship with Fundación both communities gave a rating of 2, or poor;
- for questions A, B and H, again about the Fundación and rules implemented in the Plan de Manejo, Rio Esteban and Nueva Armenia give higher average ratings than the island communities, each of the mainland communities giving equal results for the same question.

Comparison of 4 communities for level of ecotourism at present::

- East End receives least amount of tourism- tour operators do not offer East End as a tour destination possibly because it has a poor quality docking area and there is no form of accommodation in the village. Residents say that all tourists that come to the Cayos Cochinos go to Chachahuate rather than to East End;

- Chachahuate receives more tourism on the island than East End- tour operators offer trips there up to 4 times a week. It is seen as a more typical resort and has a cabana on the island that can accommodate 4/5 people per night;

- Rio Esteban is the most developed of all the communities, as can be seen with the newly established Internet café and telephone network. Despite it having 4 cabanas in the town that can hold 16 people per night between them, a small hotel, restaurant, café and a number of small shops and is situated along a long stretch of beach in view of the Cayos Cochinos, all its residents say that they receive little amounts of tourism, and not specifically ecotourists. The reason for this may be that the town is approximately a 2 and a half hour bus journey from La Ceiba, and tourists must use the public transport, which is not very reliable. Much more publicity and development on access to the community is required for it to gain its full tourism capacity;

- Nueva Armenia has 2 good hotels in the town, both no more than 2 years established. It also has a restaurant, small snack shops, a bar and a disco in the town, has access to a beach within a 30 minute walk, overlooks Cayos Cochinos, and it is only a 1 and a half hour bus ride from La Ceiba. The basic amenities for tourists are established, but again, the community says that they are not receiving many tourists, perhaps 20 per week at the most.

- The majority of people in the communities do not understand what the term ecotourism actually is and therefore answer questions primarily thinking of general tourism only;

- All community members spoken to feel that tourism will be good for the communities in whatever form it arrives as they feel that the communities will improve in living standards through better amenities and higher incomes;

- A small proportion of people interviewed understood what ecotourism was and that this was the reason why most tourists visit the Cayos Cochinos and surrounding mainland areas. They also understood the potential for increased ecotourism and how to go about fulfilling this potential, primarily in Nueva Armenia but with some acknowledgement of this in Chachahuate;

- A small number of people understood about the need to conserve the environment and the culture at the same time as increasing ecotourism, or tourism;

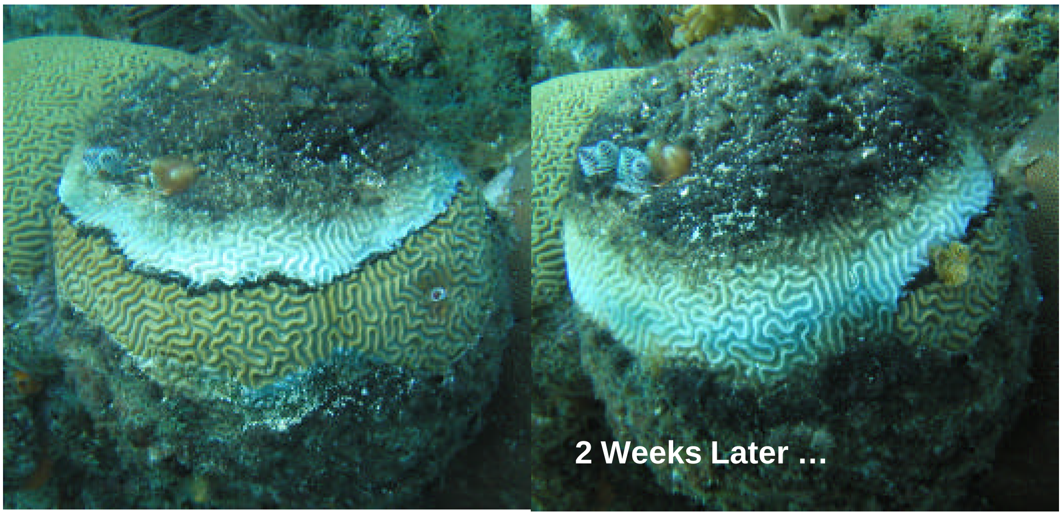
- A small proportion had an idea of the damaging effects on the communities and the bad impacts of increased ecotourism. For example, prostitution, drug-taking and increased pressure on the environment were all mentioned among others.

4.0. Discussion

4.1. Coral Reef Biodiversity and Ecology

4.1.1. Coral Disease

What is clear without much analysis is that BBD prevalence, and capacity for destruction varies within MNMCC. For example, some colonies seem to ‘tolerate’ BBD, which seems to lie stagnant, not advancing. In some cases the characteristic black band disappears altogether, leaving behind dead skeleton. In other cases, it comes back a new after several weeks. However it is also startlingly clear that the disease can be responsible for wiping out whole colonies, as is clear in Plate 1.



<u>Plate 1.</u>

A colony of *D.strigosa*, infected by the distinctive microbial consortium of Black Band Disease. Note the progression of colonising algae in relation to the Christmas Tree Worms.

4.1.2. An Investigation of the Incidence of Scleractinia Coral Associated Disease and Factors Affecting This Distribution.

The 5m transect being significantly different between Peli 3 and Arena but not between Peli 1 and Arena/Peli 3 is most likely to be partly an artefact of the fact that Peli 1 is an intermediate site, and so is closer is quality to both Peli 3 and Arena than they are to each other. The 10m transects all being statistically the same is more interesting, as despite obvious variation in site quality the levels of disease and bleaching do not appear to vary, and so presumably this will be the result of some other factor, such as light, turbidity levels and water temperature, for many disease such as black band tend to be light limited and the cooler temperatures at depth will limit both disease progression and bleaching. As for the 15m transects and Arena being significantly more unhealthy than either of the other sites, it is believed this will predominantly be due to sedimentation, for the reef structure of Arena essential produces a sand bowl that is a giant sediment trap, within which sediment can build up and not escape particularly well. As a result physical stress and damage inflicted upon the coral by sedimentation may make them more susceptible to disease contraction through stress, or even perhaps directly transmit disease itself.

As mentioned in the results section Peli 1 has significantly more black band colonies than either Peli 3 or Arena, harbouring 18 of the total 26 colonies with black band encountered. This is particularly interesting having done the transects, as in the survey only 1 black band colony was ever encountered and that was along the 5m transect of Peli 3. Perhaps this could imply that black band is relatively seasonal and is only starting to spread with the increasing water temperatures or some other factor, although seasonal monitoring studies over the plots would be required to see if this were the case. What is also surprising is the similarity of black band distribution between Peli 3 and Arena; both have an identical number of colonies with the disease and yet vastly different coral cover and species compositions. This could be due to Peli 3 being a pristine reef and so there is such little disease as the corals are under little stress and are perhaps more resilient to infection. Wherever black band has been recorded it has been almost invariably been associated with fuzz-ball algae, which could potentially act as a reservoir for black band disease and be involved in the transmission and infection process. So, with Peli 3 being a pristine site there is not much fuzz-ball algae present, and so perhaps a lower probability of a colony contracting the disease than an analogous colony at Peli 1. As for Arena, despite being a heavily impacted site there is again very little black band disease present. This could possibly be due to the area being so impacted that those few colonies that do remain are resistant and resilient enough to black band to prevent prolific spread. It could also be the case that although the exact mode of black band transmission is unknown the lower coral cover at arena and so greater distance between colonies reduces the probability of transmission.

Looking at the plots it is apparent that the black band colonies are all found at shallow depths along the reef flat and crest, supporting the fact that black band is light limited in its progression, but also – particularly at Peli 1 – that the colonies infected with black bend tend to be clustered and situated near the crest of the reef. The clustering of colonies is perhaps associated with the mode of transmission, which could conceivably involve coralivore activity; in that, say, a parrotfish of a fireworm feeds on an infected colony and then transmits the disease to the subsequent colonies it feeds upon. It was noted that on more than once occasion feeding invertebrates were found on the interface of healthy/dead tissue on diseased colonies. This may also be a factor that affects the progression rate of the disease on a given colony, for it was noted that two colonies with the disease at Peli 1, both *D. strigosa*, no more than a metre apart progressed at radically different rates. The slower of the two did not progress too far and the band has started to diminish. This could perhaps be due to the immune system of the coral playing a part, or perhaps it being an evolutionary advantage for the cyanobacteria not to exhaust their source of hosts. However, this was one of the colonies that fireworms were found to be grazing along the boundary, presumably as the tissue sloughing off is easier to remove/digest. Incidentally it may then be possible that the fireworm also disrupted the progression of the black band by also consuming some of the bacterial film. In any case, both black band disease and white plague appear to vary significantly in progression rates, which is something that shall have to be addressed in light of the abiotic data. As well as being apparently clustered together the colonies with black band disease also appear to be clustered with a bias towards the reef crest. If invertebrates and other coralivores are involved in transmission then this may be an artefact of their greater abundance along the reef crest, although it could also be related to age of the reef, for the colonies along the flat tend to be far older, with the crest being the region of most rapid growth and turnover. As a result those colonies along the flat may be those that are resistant and survived through background levels of black band, whereas those on the crest are more recently established and so perhaps more susceptible due to reduced incidence of previous exposure. Also the colonies on the crest may be subject to more stress than those established on the flat; through things such as competition for substrate, increased coralivore activity and increased impact of wave action.

4.1.3. Corallivore Activity on Scleractinian Coral Colonies.

The preliminary results from this report show that the *Montastrea spp.* are the most frequently predated corals. This particular species is a major hermatypic scleractinian reef builder. The morphology of the *Montastrea* colonies is very prominent, and the colonies are usually very large structures that stick out of the reef and are therefore exposed to potential corallivore activity. However, coral species such as *Mycetophyllia spp* and *Meandrina meandrites* are not so large or conspicuous. Both of these species are very low to the substrate and therefore do not offer themselves to obvious danger. Hence, the corallivore activity on these colonies when compared to *M. annularis* and *M. faveolata* is very low.

The results obtained from the Phase: 2 analysis indicates that there is a correlation between corallivore activity and the abundance of macroalgae. Although the data input for this report was minimal, there is still a very clear indication that the healthy *Montastrea annularis* colonies do have a higher abundance of surrounding macroalgae when compared to colonies, which have been predated upon. Also, *M. annularis* colonies grow in clusters, therefore if a particular colony is surrounded by many other colonies-this may potentially influence the corallivore behaviour on a particular colony-this will be investigated when the whole data set has been analysed.

Thus, this could potentially mean that when corallivores, such as Parrotfish are feeding, they will preferentially eat macroalgae rather than the algae found in coral, even though they have the trophic apparatus to do so. It has also been hypothesised that Stoplight Parrotfish will repeatedly predate a particular colony due to the grazing scars (as a beacon). However, this could be simply due to the amount of surrounding macroalgae around the colony.

3.1.4. The Factors Affecting the Incidence and Distribution of Coral Disease; in Relation to Predation and Disease on Acropora cervicornis.

The abundance of *A. cervicornis* colonies was not significantly different at any site, where as there was a significant difference in amount of *A. cervicornis* in m^2 at each site, and significantly different average sizes of *A. cervicornis* with Pelican 4 having the largest average size of colony.

Pelican 4 has significantly more *A. cervicornis* this may be attributed to by environmental factors, Pelican 4 is the most pristine site, from the A-biotic data it will be possible to analyse whether there is a significant difference in the water qualities at the 3 sites. Pelican 4 is also thought to be effected least by Hurricane Mitch in 1998, *A. palmata* and *A. cervicornis* are relatively fast growing corals but are also very susceptible to mechanical damage. This could account for the significantly lower volume of *A. cervicornis* at the less pristine sites, Pelican 1 and Arena.

The abundance of *A. tenufolia* was found to be significantly different with in this case Arena the most impacted site having the greatest volume of this species compared to the other 2 sites, although the sizes of the colonies did not significantly differ at any site. *A. tenufolia* although a fragile foliose coral species has been shown to grow at a faster rate than *A. cervicornis*, it has also been documented to be a coral that is known to colonise areas of damaged reefs.

Both *A. tenufolia* and *A. cervicornis* due to their foliose and branching structure are not prone to sedimentation damage, the sediment trap data will be able to determine, if here in the Cayos Cochinos there is an association between the amount of sedimentation and the abundance of the two corals, it is thought that massive corals competing for space on the reef will not be as successful at sites with increased sedimentation allowing the *A. tenufolia* and *A. cervicornis* to colonise these sites.

From the data analysed there is no significant difference in the number of snails per m^{-2} of the two coral species, this shows that *C. abbreviata* shows no preference over the three sites and no preference over the coral species.

Figure 12 shows that the average size of *C. abbreviata* is significantly smaller on *A. tenufolia* than on *A. cervicornis* at all the sites. This may be due to close foliose leaf structure of the coral, enabling only the smaller snails to live in the *A. tenufolia.*

4.2. Seagrass Ecology

4.2.1. The Ecological Importance of the Cayo Menor Seagrass Beds as Recruitment Zones for Juvenile Reef Fish.

After continued analysis which will include the formulation of a similarity Matrix, followed by Cluster analysis (to interpret the possibilities of Juvenile habitat preference), much of the Write up and Discussion will focus on the possible theories for why Seagrass habitats seem to be complimentary for acting as Juvenile reef fish nursery grounds.

These theories include;

- The Structural Complexity of Seagrass Habitats provides more refuges for Juvenile reef fish to avoid being victims of predation.
- The exploitation of edge habitats within the Seagrass environment. There is generally a high abundance of juveniles along the edge of the Seagrass adjacent to sand patches, so they can utilize both environments. (The Seagrass to seek refuge, and feeding/grazing on the sand patches).
- The Seagrass biotope provides a great abundance of food, in the form of Epiphytes that grow on the Seagrass shoots, algae, and crustacean that live within the Seagrass canopy.
- The relatively turbid waters that can occur on shallow Seagrass environments could decrease the foraging efficiency of predators.
- The Seagrass environment is often depicted as being a safer environment for juveniles with fewer predators compared to a coral reef biotope.

4.2.2. An Investigation into the Lunar Activity Cycles of Shrimp Living in Seagrass Beds on Cayo Menor.

It is impossible to assess the results in detail since all the shrimp have yet to be identified. However, simply from observing the shrimps that have been caught, it is possible to recognize various different forms which are almost certainly from different species (though each one may contain several closely related species) and a very rough impression of the variation from day to day and between sites can be obtained.

There is clear variation through time and space in certain key, easily recognizable groups. Most obviously, there appears to be considerable variation between sites, with those on the west side of the rock generally more diverse but perhaps with lower overall abundance. In that area, there is generally a lower density of seagrass, but more corals nearby, which perhaps gives a larger number of niches, or more places to hide away during the daytime.

There is also clear variation from night to night, but it is more difficult to tell here if there is a clear pattern. Overall abundances seem generally lower on brighter nights when the moon is visible, though it is not clear how this breaks down at species level – it may well be that some species are more affected than others. If this general observation is confirmed when the identification is complete, it would suggest that weather (in terms of cloud cover) has an effect, as well as the phase of the moon. In addition to overall numbers, variation in individual forms were observed, some of which appear to become more abundant even while overall the numbers of shrimp are lower. This will have to wait for confirmation after identification.

4.2.3. Hermit Crab Ecology

It is possible that the hermit crabs hide out beneath rocks during high tide in order to remain safe from external environmental dangers such as predation. When the tide is low, the conditions are calmer and predation may be less likely as the waters are shallower.

It seems that even if the amount of hermit crabs in the tank is so great that the rock would be fully occupied and thus there would be a competition for resources, the hermit crabs would still prefer to remain on the green rock rather than transfer to the white rock. The hermit crabs that were not found on the green rock were rarely found on the white rock and instead preferred to cluster together on the glass bottom of the tank. The green rocks used were those taken directly from the natural habitat of the hermit crabs, while the white rocks were taken from an area without hermit crabs and thus 'foreign'. This could explain why the hermit crabs preferred the green rocks as they more closely mimicked their natural environment. Also the green rocks were substantially more covered in algae compared to the white rocks which may affect the feeding behaviour of the hermit crabs.

When hermit crabs were offered two white rocks of the same type, a small number of them divided themselves almost equally between the two white rocks, but the majority tended to cluster on the bottom of the glass tank. Fig. 28-30 show the average number of crabs on each substrate type in each tank while Fig. 31 shows the total number of crabs on each substrate type from all tanks. When looking at Fig. 31 it is clear that the hermit crabs have a preference for clustering together off the white rock. Obviously when there is only one hermit crab in the tank, it is not able to form a cluster, but it still prefers the glass tank to the white rock. The hermit crabs seemed to dislike the white rocks even if there was no other rock choice. This could begin to explain the reason why there are no hermit crabs on the biological station beach as the only rocks found there are of the white variety.

4.3. Ecotourism and its Impacts

4.3.1. Social Impacts within the Cayos Cochinos

Despite the fact that entrance fees are reduced for tourists who choose to enter the MPA in boats operated by members of communities within the marine park or the mainland communities that access the park, interviews revealed that the very existence of entrance fees is a major source of discontent in the communities of Chachauate and East End. (Neither of these communities have tour operators.)

Residents of Chachauate and East End questioned what the HCRF did with the all the money they collected, believing that some of the fees should be returned to the communities. One of the objectives of our research team was therefore to document how much income came into the marine park since the start of the fees, and to discern what costs they went to.

The entrance fees help sustain the management of the MPA. Unfortunately, however, because community members in Chachauate and East End are not well-informed about the HCRF's operating costs, skepticism about the organization's intentions persist. I therefore recommend transparency of HCRF budget in order to build trust with communities. I further recommend that between 10-20% of all park fees go back to the community in the form of development projects to promote tourism (which is one of the main objectives).

With fishing restrictions, women's economic activity is becoming increasingly important to community livelihood. Garifuna women have a long history of vending and craft production (although men also produce crafts).

"Cultural entertainment" (in particular, the performance of *punta* dancing and music) will likely become key livelihood strategies for island residents as the tourism industry grows.

Ecotourism could certainly be developed in the MPA and dissertation students could help facilitate the planning and marketing of these experiences. Students could apply their knowledge from readings on participatory development (which is common background reading for social scientists doing international research) to work with the Cayos Cochinos settlements and their mainland sister communities to develop an all-inclusive ecotourism experience. In addition to providing transportation and accommodation, Garifuna community members have a wealth of cultural and ecological knowledge to share with ecotourists. Activities could include learning to make traditional foodstuffs (e.g., *ereba, machuca, pan de coco, guifiti*), education in *dugu* religious rituals, training in *punta*, *wanaragua* and other dances and drumming, or leading a boa sweep.

4.3.2. The Impacts of Ecotourism on Livelihoods of the Garifuna Communities of the Cayos Cochinos.

It is quite significant that the island communities give lower ratings in general than the mainland communities because it indicates that their feelings towards the Fundación are not as high as on the mainland. This is perhaps due to the fact that their livelihoods are more dependent on fishing and they see the Fundación as the instigating body of such rules and regulations that impact their traditional livelihood, and regard them as being of little assistance in community development. In the mainland communities, although many of the men are fishermen and have been for generations, there is a proportion of the population that already has alternative sources of income, and because of this is able to reflect on the decisions made by the Fundación and appreciate that they are implemented for conservation of the Cayos Cochinos. The island communities also give lower ratings for basic amenities which may be due to the fact of low community development but also of restrictions within the communities such as not possessing their land titles and having no land space on which to expand.

At present, the impacts are good, as working to receive more ecotourism is empowering most of the communities, with the possible exception of East End, and Chachahuate to some extent, to ensure that their environmentis cleaned up and maintained to a high standard. For example Nueva Armenia wants to clean up their lagoons so as ecotourists can take guided walks around them. Chachahuate would like their rubbish to be removed on a more regular basis so they do not have to store it on the beach, and would like tools such as rakes to clean up the beach area.

There have also been impacts on actions to improve basic amenities in the communities. For example, Chachahuate would like better sanitation system and have put in a request to the Fundación to begin this process. Nueva Armenia have expressed their need for better quality drinking water, but as yet I do not think any action has been taken. Rio Esteban are currently in the process of putting in an application for better access to the community, through the construction of 2 bridges and maintenance of the road through the municipality.

East End have an idea about what is needed to receive more tourism but as yet, no actions have been taken to begin this process. One limiting factor for them is that they do not have a land title as yet and there are few organisations that are willing to invest in such an unstable venture. Chachahuate do not have their land title yet but their application for one is further along in processing that its neighbouring island community so actions. This and the fact that tour operators are offering the island as a tour destination is empowering the community to begin thinking about developments that can be made.

The impacts are in the form of actions beginning to take pace, and as yet little work has actually begun in the communities.

From observations of the communities development seems to be emphasised at present. The majority of the development that is taking place is not having a huge impact on the environment as only macro-businesses are being established rather then larger companies coming in from outside the communities. Other development taking place is by improving the quality and availability of drinking water in all communities, and the amelioration of sanitation systems. The construction and improvement of the road from Jutiapa through to Rio Esteban is the biggest development in process at the moment. This is definitely prioritising development over nature as the road passes through estuaries, and winds through countryside and farm land at present, therefore will cause much disruption of the environment when construction gets underway in the next year;

Such development however is necessary if ecotourism is going to become fully successful within the communities studied and therefore it could be argued to be justifiable;

The environment is beginning to be seen as important as people begin to recognize that ecotourism hinges on the communities environments being conserved and maintained to the highest standard. For example, there is growing acknowledgement in Nueva Armenia that actions to improve the quality of the lagoons and surrounding forest area, creating a nature trail to be advertised as ecotourism, will eventually ensure that the environment is given priority over development. It is evident that the environment may not be able to be fully prioritised within the communities until essential development takes place to accommodate the amount of ecotourism that will be attracted in coming years.

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