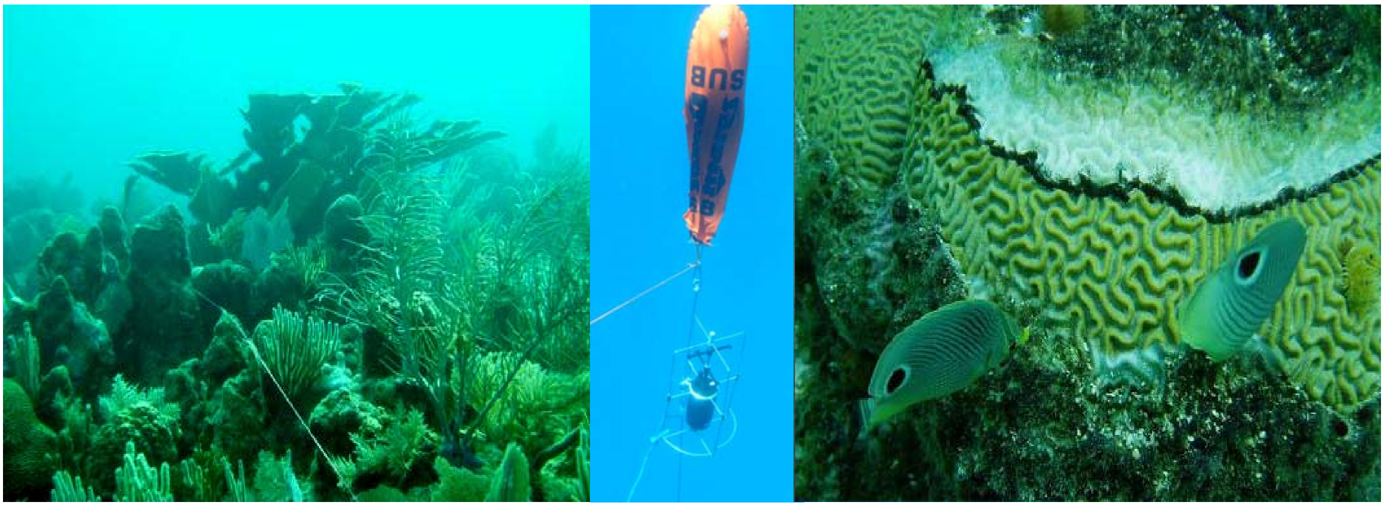
Reef Benthic Ecology, Coral Disease and Nutrient Flow Pilot Project: A Combined Summary Report for Cayos Cochinos 2006



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1. General Introduction

1.1 THEMATIC APPROACH

Reef ecology surveys for Operation Wallacea in Cayos Cochinos started in 2003 and 2004, with the author's supervision of reef check surveys and a fledgling coral disease project. The 2005 season saw the integration of these projects into a new three pronged thematic system of research that would provide both data for the management of the Marine Protected Area (MPA) and the start of the author's D.Phil research. These themes were broadly classified as 'Benthic Ecology Assessment', 'Disease Assessment' and 'Environmental Assessment'. 2006 saw the continuation of the projects started in 2005, but also the resolution of the three broad 2005 themes, into more clearly defined projects, which will be further added to and defined in 2007. Thus this report has been broken into the three relevant sections for each project:

- Coral Reef Benthic Ecology Project
- Black Band Disease Project
- Nutrient Flow Pilot Project

It is hoped that above three projects can be combined with the fisheries and social science projects planned for 2007. This would create an inter-disciplinary and integrated thematic approach to the research being conducted in Los Cayos Cochinos. The data from the different projects / themes could then be compiled into different 'layers' for a central GIS database. This database would in turn provide a powerful tool for both research and management within the MPA.

Much of the data presented is still undergoing analysis, and in some cases is part of a long-term data set that requires comparison and analysis over time. Therefore this report constitutes an 'interim progress report' or 'field report' based on the summary of 2006 activities. A full and final report will be made available upon completion and submission of the author's thesis.

1.2 LOCATION

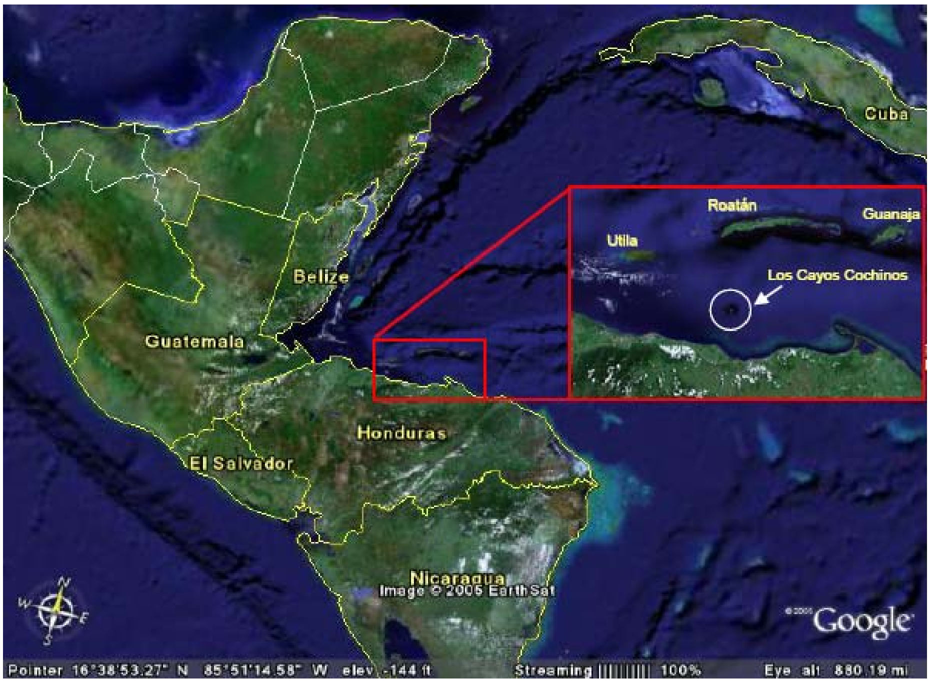

Figure 1. Satellite imagery showing the location of Los Cayos Cochinos and the Bay Islands off the coast of Honduras, Central America. (*Images from Google Earth 2006*)

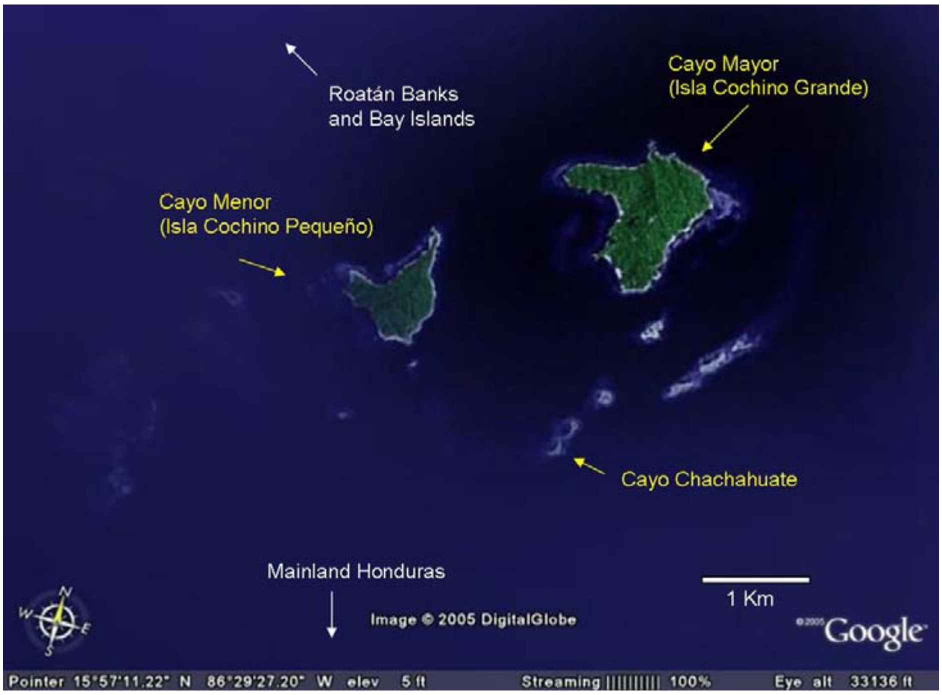

Figure 2. Composite satellite image of Los Cayos Cochinos, showing the two main islands and surrounding keys and reefs. (*Image from Google Earth 2006*)

Los Cayos Cochinos archipelago is situated approximately 19 Km off the north coast of Honduras, Central America (Fig. 1.). These islands are about 39 Km to the south of the larger Bay Islands of Roatán, Utila and Guanaja. Los Cayos Cochinos consist of two main islands, Cayo Menor (a.k.a. Cochino Pequeño) and Cayo Mayor (a.k.a. Cochino Grande) in conjunction with 13 smaller sand keys. Cayo Menor is approximately 1.3 Km in length and 1 Km in width with no permanent residents other than a small research base, rangers and support staff. Cayo Mayor is larger, approximately 1.7 Km in length and 1.8 Km in width (Fig. 2.). There are several private homes, a small hotel and a village of local Garifuna artisanal fishers. The only other area of significant population is a small and very densely populated sand key called Cayo Chachahuate, also home to Garifuna.

Los Cayos Cochinos are situated on a shallower section of continental shelf than the more northerly Bay Islands, and as such the local fringing reefs are younger, and less influenced by oceanic currents. Between Los Cayos Cochinos and the Bay Islands, are a group of sea mounts in deep water, known as the Roatán Banks, where coral cover, community diversity and water quality is noticeably higher. The Cayos Cochinos consist mainly of sedimentary shale uplifted by the separation of the Caribbean plate away from Central America (Abt and WHG 2003).

2. Reef Benthic Ecology Project

2.1 INTRODUCTION

As part of the continuing research in Cayos Cochinos, three ‘core’ study sites (Fig. 3.) have been chosen for detailed surveys and comparison. The sites called Peli 4, Arena and Peli 1 were chosen to reflect healthy, impacted and intermediate conditions respectively. This triage of sites was based upon a ‘site health index’ derived from benthic surveys of several sites around Cayos Cochinos in 2003 and 2004. These past surveys were based around low resolution, rapid data collection techniques. The current benthic ecology project is designed to provide a more detailed analysis of the benthic ecology at the three chosen sites. The project uses image analysis to identify members of the community to species level, as well as providing quantative data on species richness and distribution.

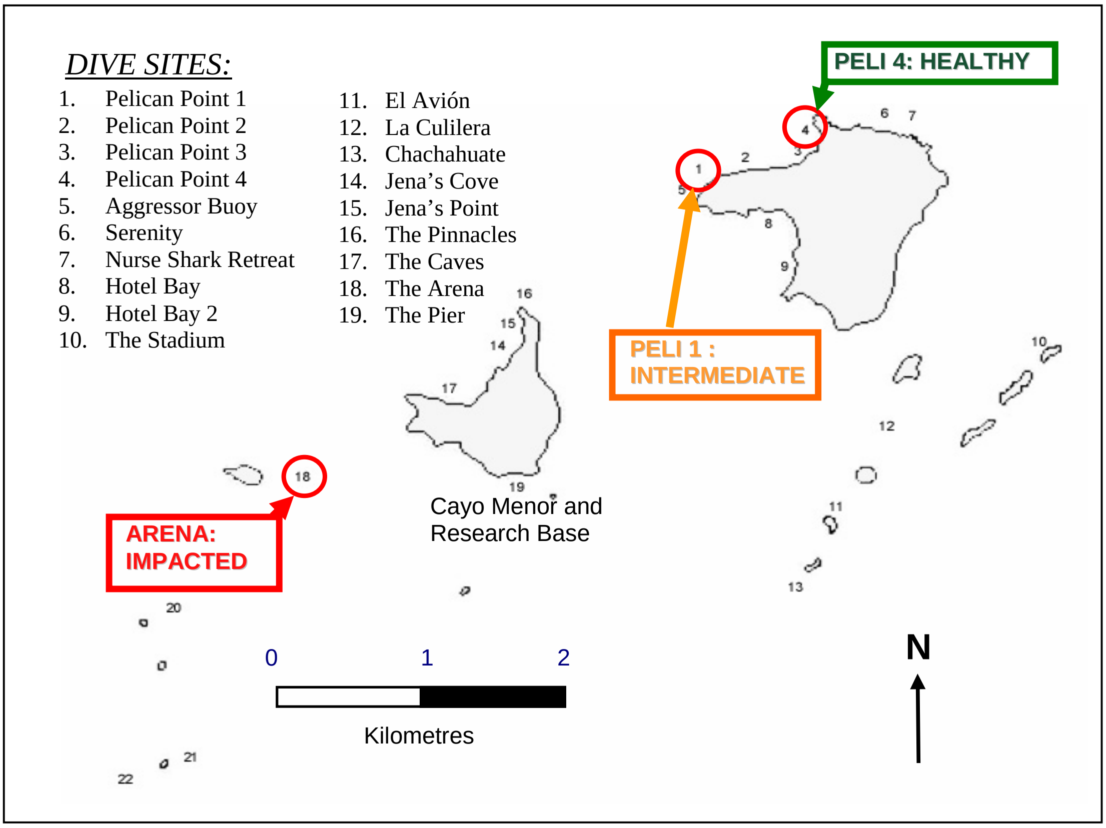

Figure 3. Map showing the location of the three ‘core’ study sites in the Cayos Cochinos Marine Protected Area.

2.2 METHOD

At each of the core sites, a series of permanent pins have been installed. The 24 pins are placed in four lines of 6, each 50 meters long, and each pin approximately 10 meters apart. Each line represents a transect, parallel to the reef, and at four different locations; 15 meters depth, 10 meters depth, the reef crest and the reef flat. These transects have been photographed digitally and also used for permanent and random photo quadrat assessment of the reef benthic community. Each photograph is then analysed digitally to determine differences in percentage cover of the different members of the benthic community, and can be compared between depths and between sites. Permanent quadrats can also be returned to in future seasons, and compared for changes in mortality and growth rates of corals, algae or other members of the benthic community.

2.3 RESULTS / DISCUSSION

Photographs are currently undergoing analysis to identify and quantify all members of the benthic community. The following results are from the analysis of the distribution and abundance of Scleractinian hard coral species within quadrats from the reef crest transects of the three core sites.

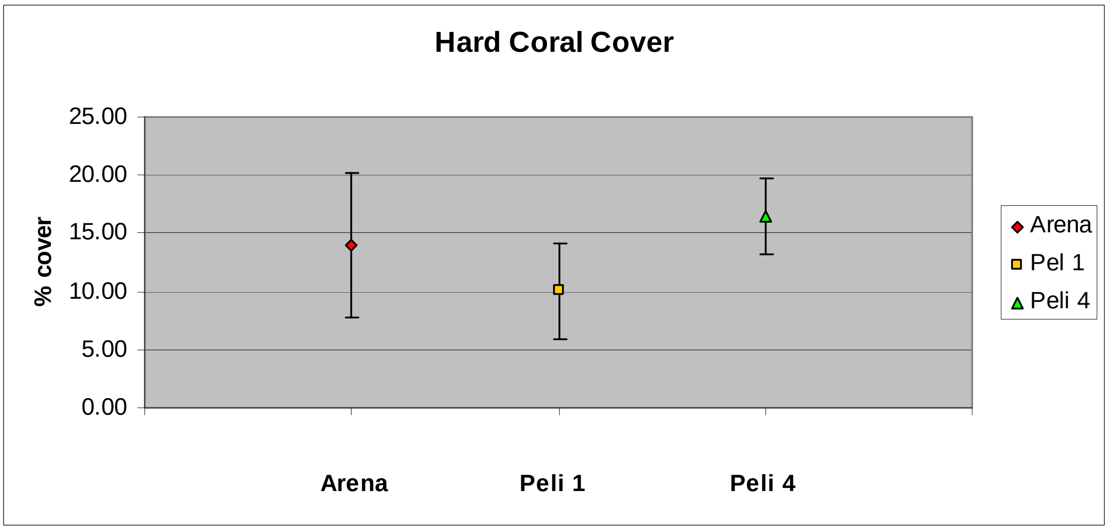

Figure 4. A comparison of percentage hard coral cover between the three core study sites. A one-way Analysis of Variance showed no significant difference between sites ($P<0.05$).

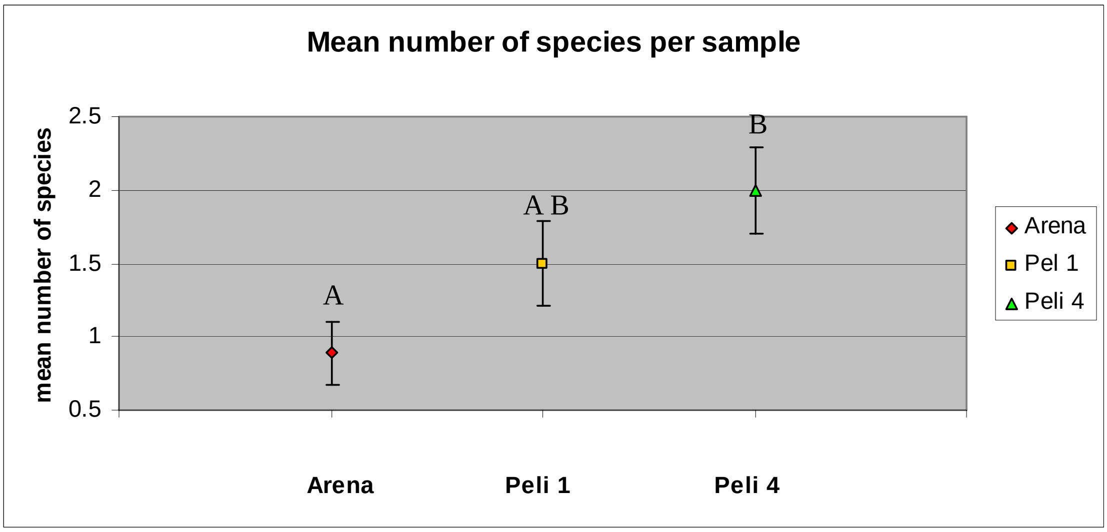

Figure 5. A comparison of the mean number of species of Scleractinia (hard corals) found at each site. A one-way analysis of variance showed a significant difference at the P=0.05 level between Arena (A) and Peli 4 (B), but not between Peli1 and the other sites.

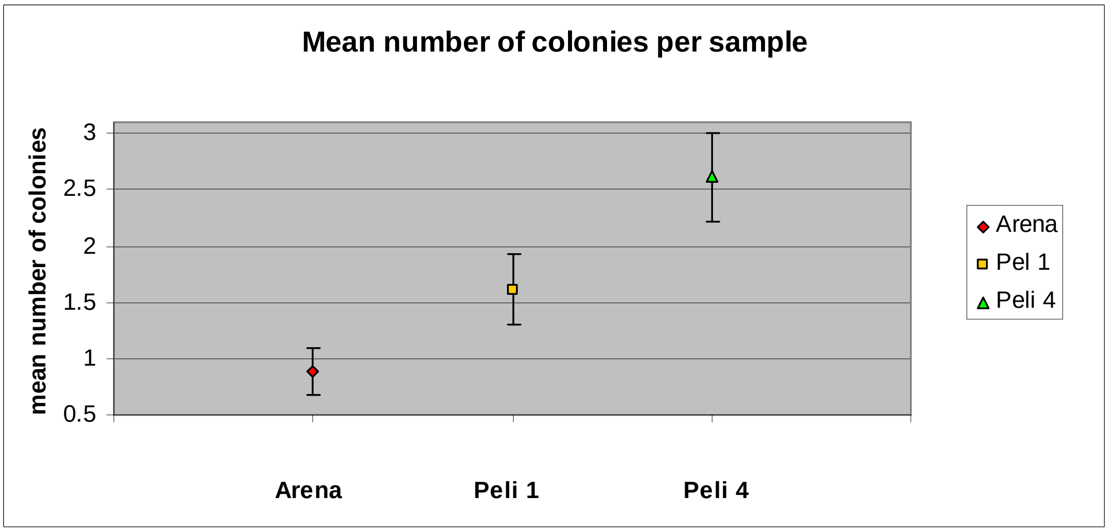

Figure 6. A comparison of the mean number of individual coral colonies observed at each site. A Kruskal-Wallis test showed that there is a significant difference between sites at the P=0.05 level, but not the direction of significance.

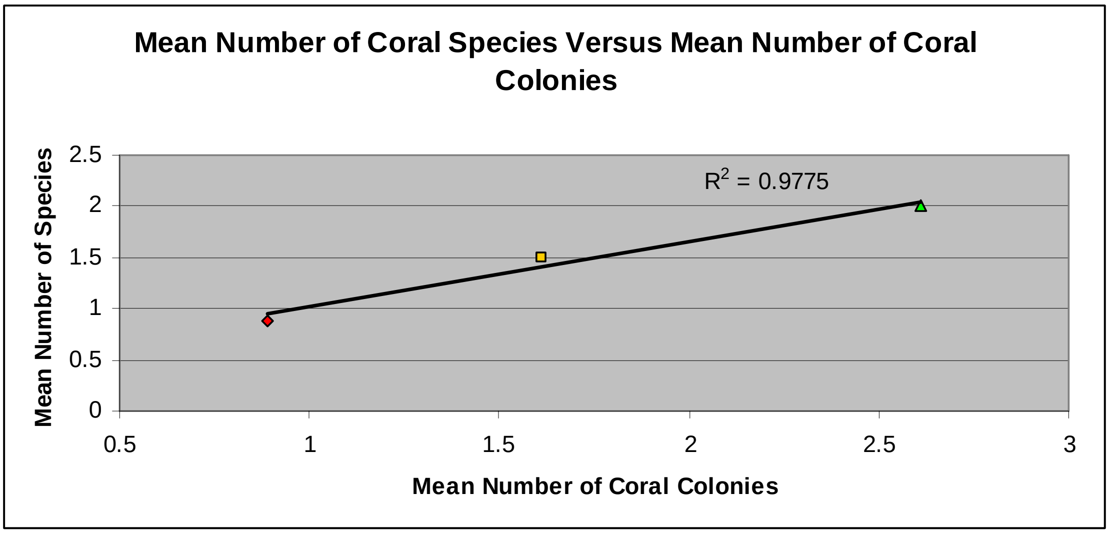

Figure 7. A comparison of the mean number of coral species observed at each site, versus the mean number of individual coral colonies observed at each site.

Although figure 4, shows that there is no significant difference in coral cover between sites, figures 5 and 6 do show that there is a difference in the number of coral species and number of individual coral colonies observed at each of the sites. Generally Arena, the impacted site, has the lowest number of coral species and individuals, with Peli 4 having the highest number of observed species of corals and more individuals. Peli 1 is an intermediate between the two. When the number of observed species is compared against the number of individual coral colonies, there is a strong, positive correlation (R^2= 0.98) between the two, as seen in figure 7. This taken into account with the general uniformity of coral cover in figure 4, indicates that the corals at Arena tend to be fewer in number and thus logically individually larger to equal a similar hard coral cover to that of the 'healthier' site, Peli 4. Peli 4 has more individual corals and more species richness, but at similar level of hard coral cover to Arena, thus suggesting these individuals are generally smaller. One reason for this maybe the higher diversity of corals at Peli 4 has increased spatial competition – i.e. there is literally less space for competing corals, so colonies therefore tend to be smaller. A different argument could be that poor conditions at Arena have selected for only large corals of a particular species, such as *Montastrea annularus* or *Agaricia tenufolia*. In this scenario small colonies or new recruits would be rapidly overwhelmed by macroalgae, or buried by increased sedimentation. Either way, understanding the ecology of these sites will require further analysis and exploration of the data.

3. Black Band Disease Project

3.1 INTRODUCTION

This season's coral disease investigation concentrated solely on 'Black Band disease' (BBD), which affects shallow water scleractinia such as brain corals of the *Diploria* genus. Previous investigations (2004, 2005) had shown BBD to be one of the most abundant diseases in the region, and thus a logical choice for further investigation of disease ecology on the reefs of Cayos Cochinos.

3.2 METHOD

The three 'core' study sites Peli 1, Arena and Peli 4 are again used for the assessment and study of the disease. Each site had an 80m x 40m search area centred over the permanent pin system. The search area was defined so as the reef crest bisected it, with 20m x 80m extended over the reef flat, and the other 20 x 80m extending down the fore reef. Within this survey area, divers completed a zig-zag 'mowing the lawn' style search. This allowed the entire area to be surveyed in one dive by two buddy pairs (4 divers). This visual census technique was repeated at all sites, at least every two days, so as an initial incidence and occurrence of new infections could be calculated. Coral colonies observed as being infected by BBD were then tagged and had their position mapped. Tagging of the corals allowed image analysis of disease progression rates and colonization and succession of dead coral over time. Positions of infected colonies were mapped relative to the permanent pins.

3.3 RESULTS / DISCUSSION

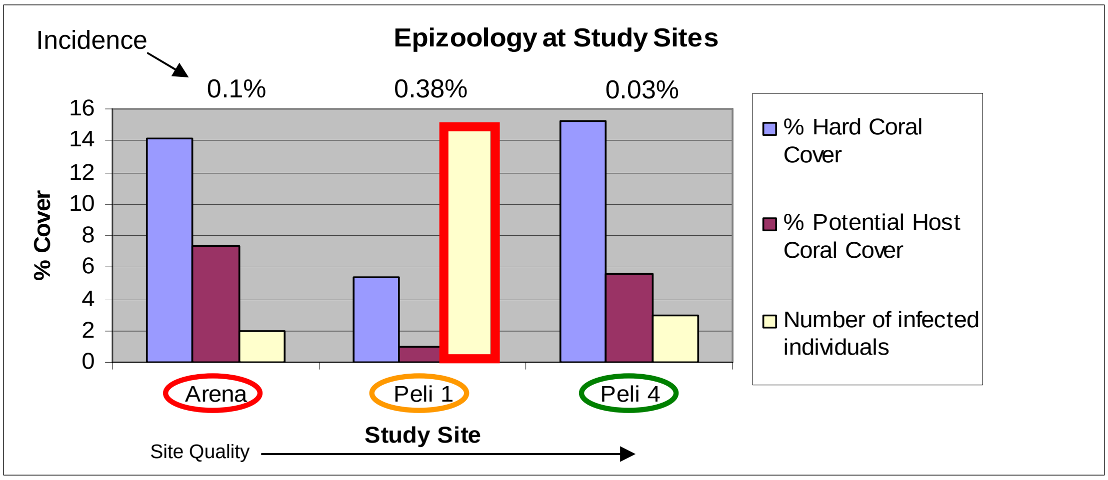

Figure 8. Epizoology at the three core study sites. Coloured ovals indicate site quality. Incidence of Black Band Disease, number of infections, and incidence are also shown.

As the above figure 8 shows, incidence of BBD is low in Cayos Cochinos. Even the highest rate of incidence at Peli 1, is under 1 infected individual to every 250 healthy corals. However it is interesting to note that Peli 1 is considered the intermediate health reef from the 2004 / 2005 triage of sites, yet has the least amount of potential hosts (20% of all corals, compared to 50% and 33% of all corals for Arena and Peli 4 respectively). It also has the highest rate of infection (incidence of BBD). Arena is considered the most impacted site and has the greater number of hosts and should thus have the highest amount of disease. However it has the intermediate rate of incidence, at 1 infected individual in every 1000. Peli 4 is the least impacted site and has the least amount of disease with 1 infected individual for every 3333 individuals. It is suggested that this due to a ‘Goldilocks’ effect, with Peli 4 being too healthy a site for disease, Arena being too impacted (e.g. turbidity) and Peli 1 having just the right ‘intermediate’ conditions for the disease. Even if this is not the case the data analysed so far, suggests that the causes behind BBD infection and virulence maybe more synergistic than current literature suggests.

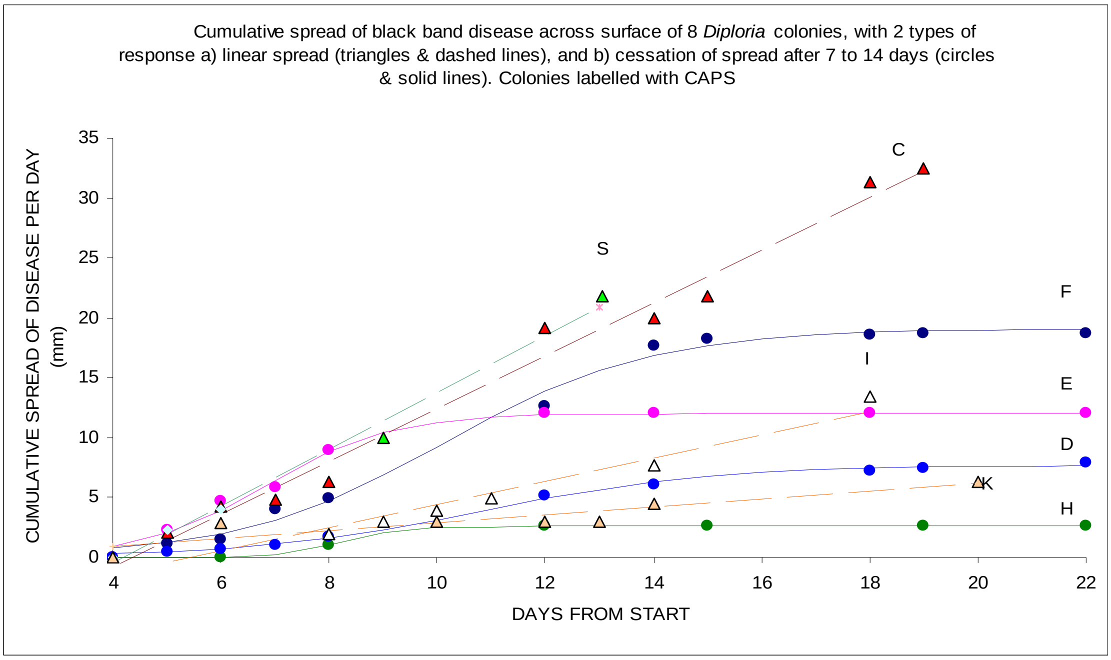

Figure 9. The cumulative spread of BBD across 18 tagged *Diploria* colonies.

Figure 9, above shows that not all disease infections progress at the same rate or same pattern. Interestingly, some colonies were shown to have a linear rate of disease progression across the colony, and some with a more asymptotic response. These patterns are independent of site, colony size or aspect ratio. Further analysis of the data and future study of these colonies, plus an increase in replicates, will elucidate upon this difference.

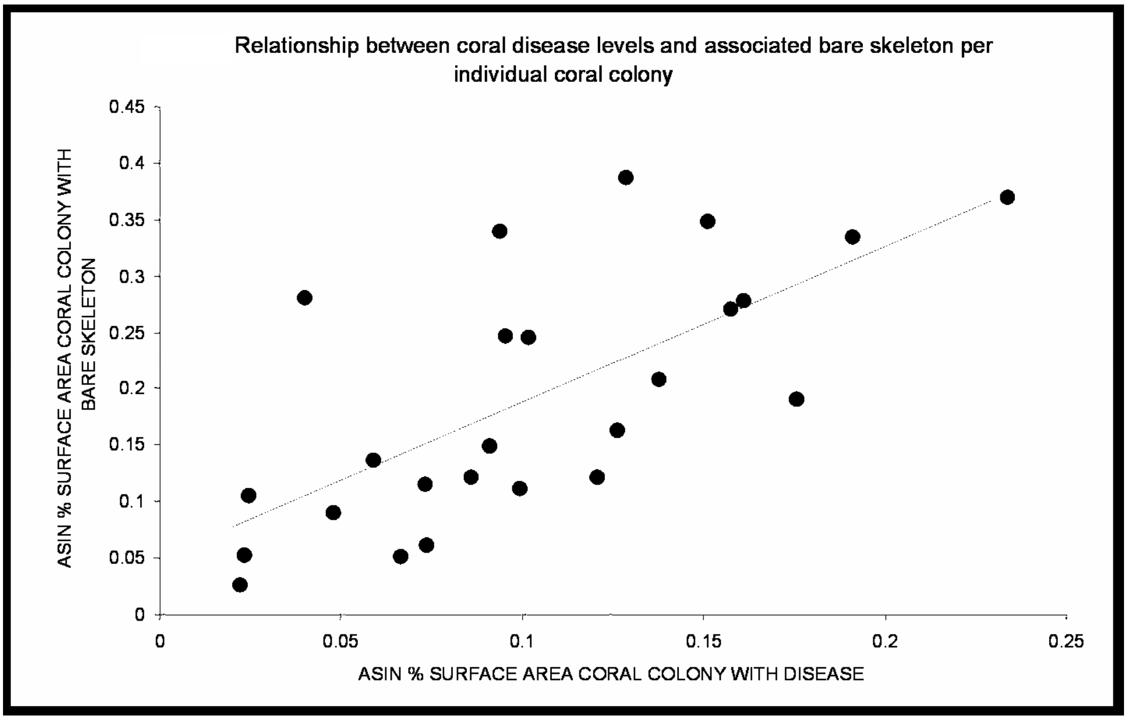

Figure 10. The cumulative spread of BBD across 18 tagged *Diploria* colonies.

There is a strong relationship (R^2=0.75) between area of coral infected by disease, and amount of bare skeleton rendered for colonization by benthic competitors such as algae (Fig. 10.). Effectively the bigger the band of BBD, the bigger the band of white, bare skeleton (dead coral polyps) is left behind by the disease.

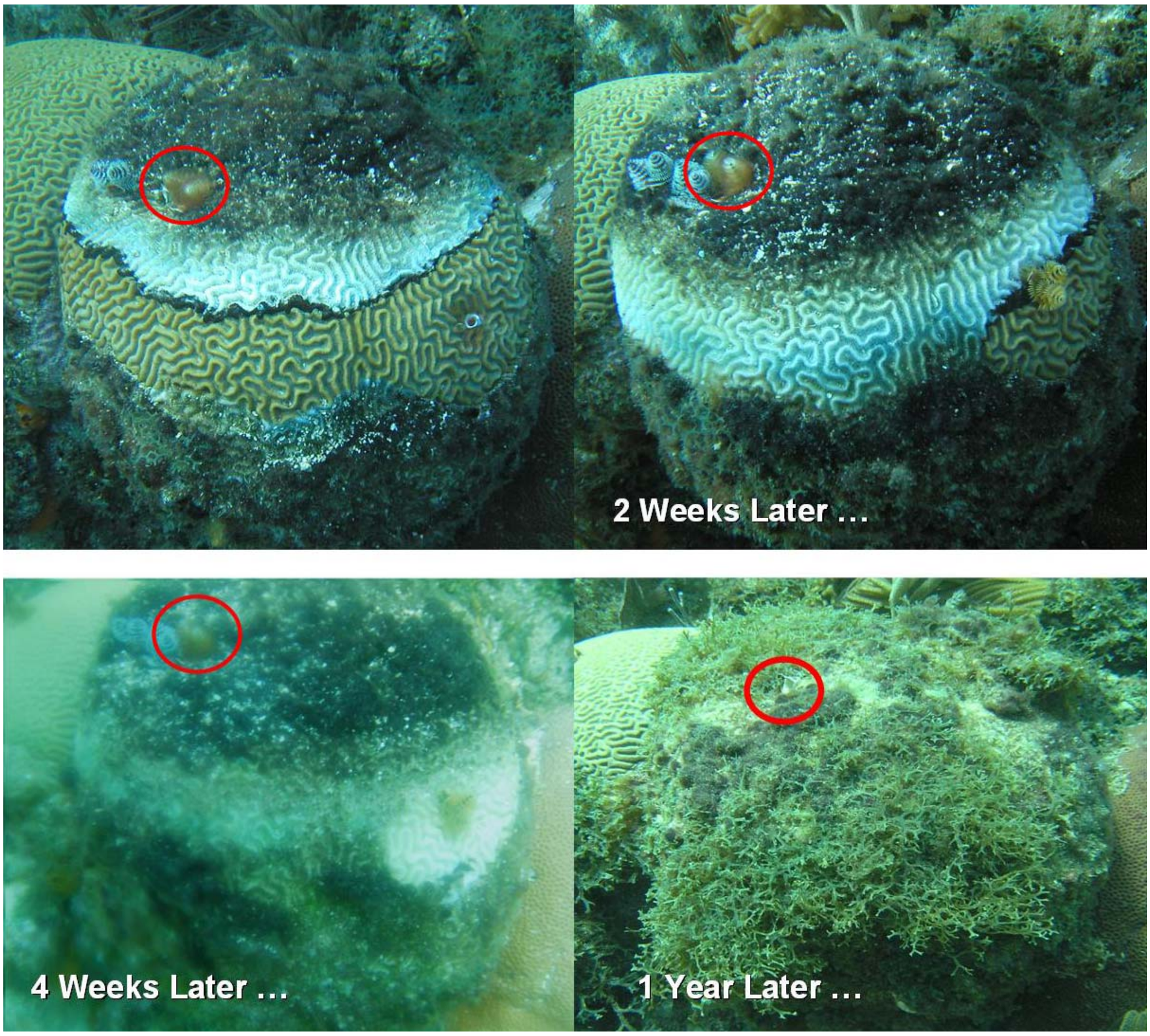

Figure 11. Photographs comparing the progression of Black Band Disease, and subsequent colonization over one year, upon a study colony of *Diploria strigosa*. Red circles references the same Christmas tree worm for ease of comparison.

Colonies tagged from 2005, were revisited and re-photographed (Fig. 11.) to compare settlement and succession. The 3mm panel pins originally used for measuring BBD progression in 2005, were re-used to calculate cover of subsequent colonizers through digital image analysis. Each species of benthic colonizer can then have their changes in cover tracked over time and compared in graphical format, such as in figure 12.

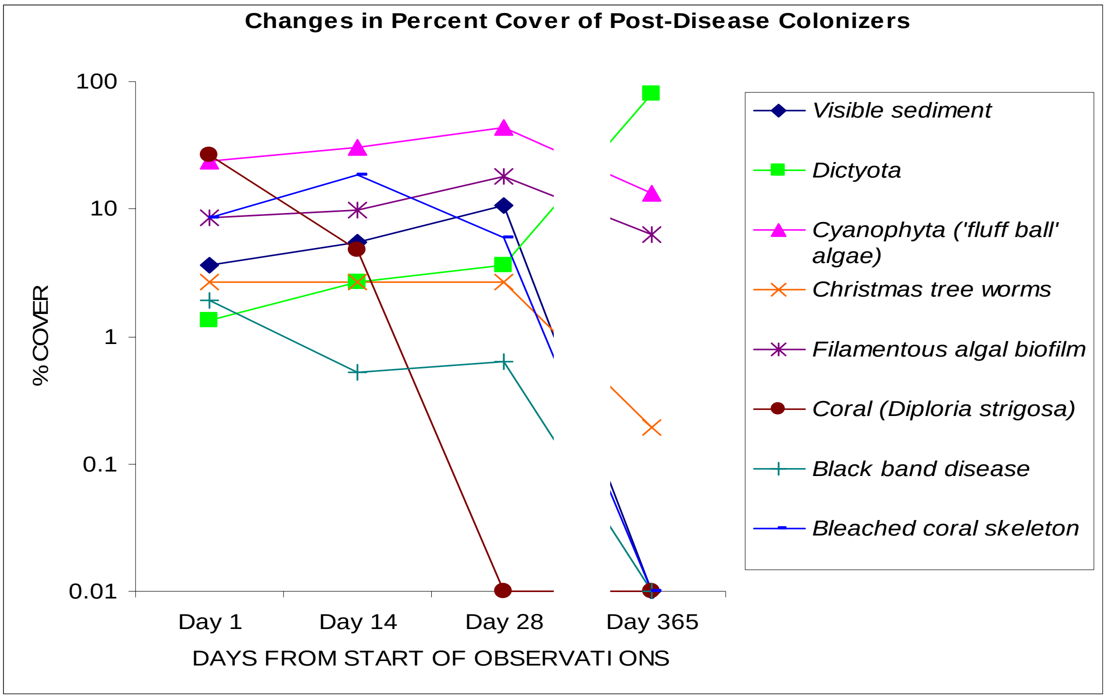

Figure 12. Changes in percent cover of various colonizers over time, showing benthic settlement and succession over time.

The above figure (Fig. 12.) is a graphical representation of the photographs and benthic succession shown in figure 11. Note how the majority of the benthic substratum types decrease over time as the macroalgae, *Dictyota*, increases in percent cover. This is consistent with the literature in concerning one-way phase shifts to macroalgal domination. However pilot studies from 2004, show that a macroalgal climax community is not guaranteed (Fig. 13.). Returning to colonies in 2007 will determine as to whether the colonies tagged in 2005 will retain a macroalgae climax, or continue succession to a different type of benthic community ecology.

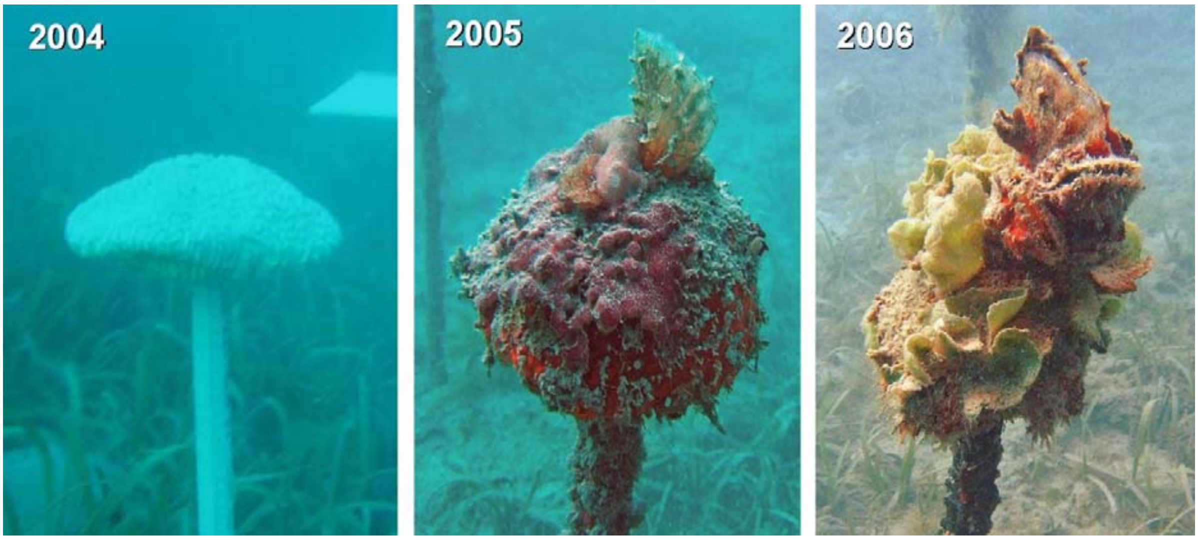

Figure 13. Photographs comparing settlement and succession over time, upon the same head of *Diploria strigosa* from a 2004 pilot study.

4. Nutrient Flow Pilot Project

4.1 INTRODUCTION

In previous seasons, collection of environmental data for the MPA had been relatively unsophisticated and in some cases anecdotal. One of the primary concerns for recovery of the reefs in the region is the impact of nutrients and sediments. The proximity of the reefs to the mainland has led to concern over increased terrestrial run-off and river influence having a chronic negative effect upon the local ecology. The 2006 season saw the start of a new joint project with Dr Greg Cowie from the University of Edinburgh. This project will investigate the quality and direction of flow of the water column around the reefs of Cayos Cochinos.

The 2006 season acted as a ‘pilot study’ for the development of a long-term project, that will be greatly expanded in 2007 and future seasons. The data collected will eventually be compiled into a GIS map. This map will be created by the integration of marine geochemistry techniques such as nutrient, sediment and isotopic analysis, with physical oceanography surveys of water column flow and dynamics around the MPA. The following is a brief summary of the methods and some of the results from the 2006 pilot survey.

Figure 14 shows the location of the sampling stations / sites used for both average current measurements (ACM) and collection of water samples for analysis of nutrients, suspended solids and chlorophylls. Figure 15 shows the sample sites used for deployment of the Conductivity, Temperature and Depth (CTD) probe deployed for assessment of the water column, and detection of any thermo / haloclines and any freshwater effect upon the reefs.

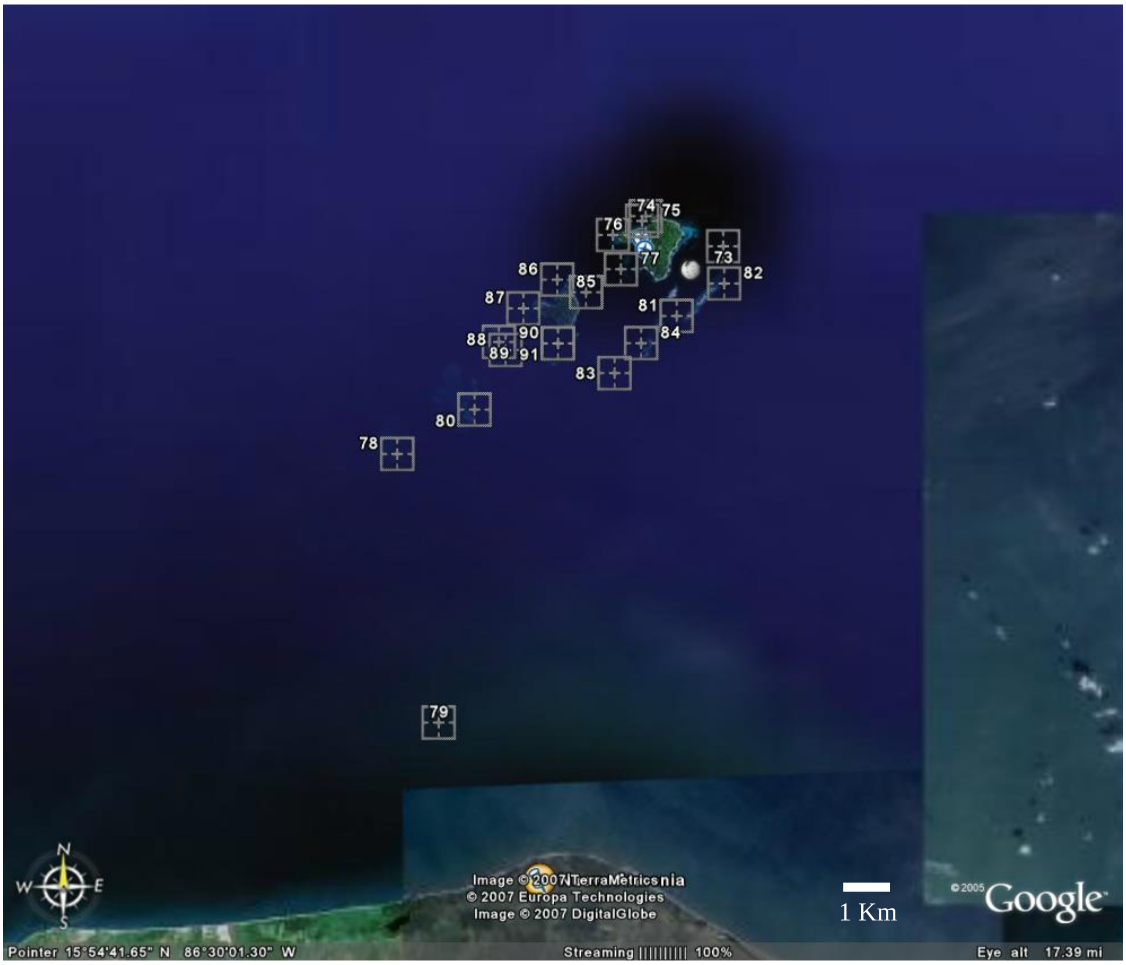

Figure 14. Location of Average Current Measurement (ACM) deployment and water sampling sites. Numbers correspond to GPS waypoint references rather than station number.

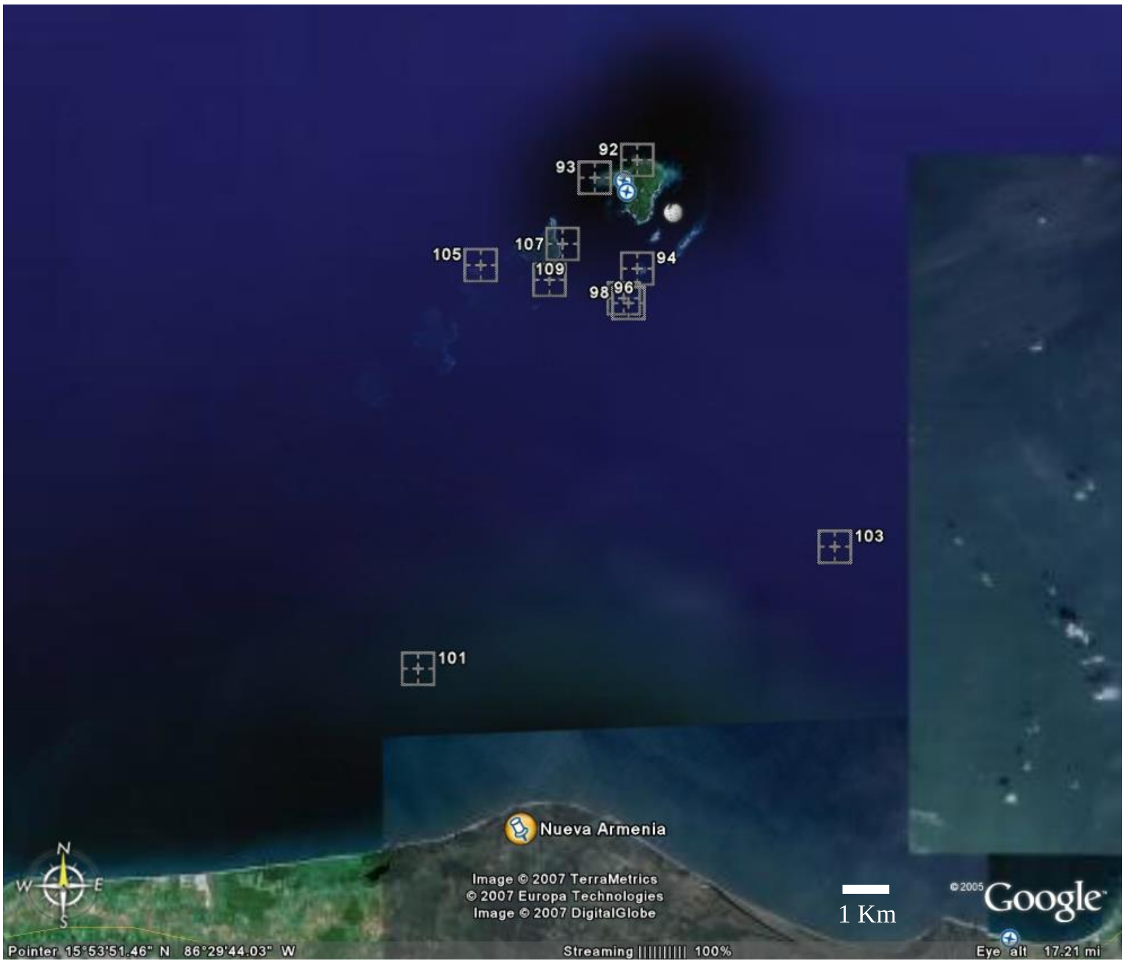

Figure 15. Location of Conductivity, Temperature, Depth (CTD) profile sites. Numbers correspond to GPS waypoint references rather than station number.

4.2 METHOD

Site selection

A grid of 18 sites were chosen for Average Current Measurement (ACM), five of which were also profiled by a Conductivity Temperature Depth (CTD) probe and sampled for nutrients. A supplementary 5 sites were then profiled and sampled to increase the grid of CTD profiles and nutrient samples. In total this yielded 29 samples at 23 sites.

Initially an arbitrary grid was constructed across the Cayos Cochinos MPA. However several of the points chosen as sample sites were adjusted and moved to take into account points of interest, such as dive sites used for ecological projects, putative polluted sites and important topographical features such as channels between islands.

Average Current Measurement

A total of 19 samples were taken at 18 sites (3 of which the core study sites Peli 3, Peli 1 and Arena). Peli 3 was visited twice for an AM/PM diurnal comparison.

Current direction and flow rate was measured every 15 seconds by a Doppler ultrasound flow meter coupled to the CTD. Deployments lasted a minimum of 15 minutes and were taken 2 meters from the surface by use of a weighted line and float. From this data an average flow and direction of current was calculated. Conductivity, temperature and depth were also recorded every 15 seconds within the deployment.

Conductivity, Temperature, Depth Profiles

A total of 10 samples were taken at 10 sites (3 of which are the core study sites Peli 3, Peli 1 and Arena, and a further 2 are re-samples of ACM sites.).

Like the ACM deployments, the chosen sample sites were plotted on a chart of the MPA and then coordinates transferred into a handheld GPS. Sites were then visited using a small boat. The CTD was then deployed on a line with just weights and no float. The probe was gently lowered through the water column over several minutes, until it made contact with the bottom. Unlike the ACM deployments, the CTD was set to continuous data collection and thus provided an accurate vertical profile of salinity (conductivity method) and temperature as it slowly sank through the water column. Several of the sample sites chosen were outlying sites in closer proximity to the mainland than the rest of the MPA. These sites were chosen to detect any evidence of fresh water lensing that may result from riverine and terrestrial run-off influencing the southern reefs of the MPA.

Water Sampling and Analysis

The 10 sites used for the above CTD profiling, each had a counterpart 3 Litre sample of sea water collected from approximately 1 meter bellow the surface. The samples for each site were then processed and analysed for pigments, nutrients, suspended solids and Carbon and Nitrogen Isotopes.

For pigment content analysis, water samples were first filtered through a pump fed pressurized filtration system. The filters were then treated with acetone and analysed in-situ with a bench-top spectrophotometer shipped on site by the University of Edinburgh. Samples were measured for Chlorophylls a, b, c1 and c2.

For nutrients, samples were again pressure filtered, but this time on to pre-weighed filters, that were then sent back to the University of Edinburgh for analysis of suspended solid content. The filtered water was then analysed for phosphate, ammonia and nitrate content with the spectrophotometer.

Water samples were also filtered onto Gas Fired Filters (GFF) for Carbon and Nitrogen isotopic analysis in Edinburgh.

4.3 RESULTS / DISCUSSION

The following are interim results only, as the majority of the data collected is still undergoing analysis and statistical testing.

Average Current Measurement

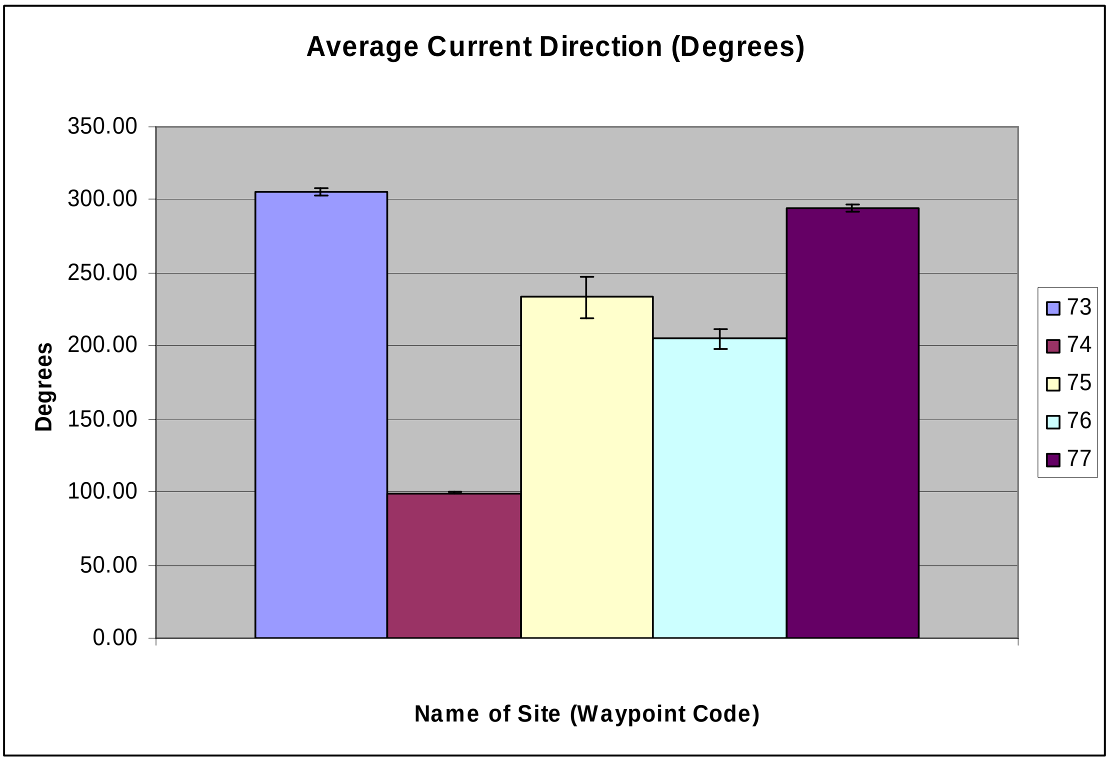

Figure 16. Average Current Direction at five sample sites measured around Cayo Mayor on the morning of 1-07-06

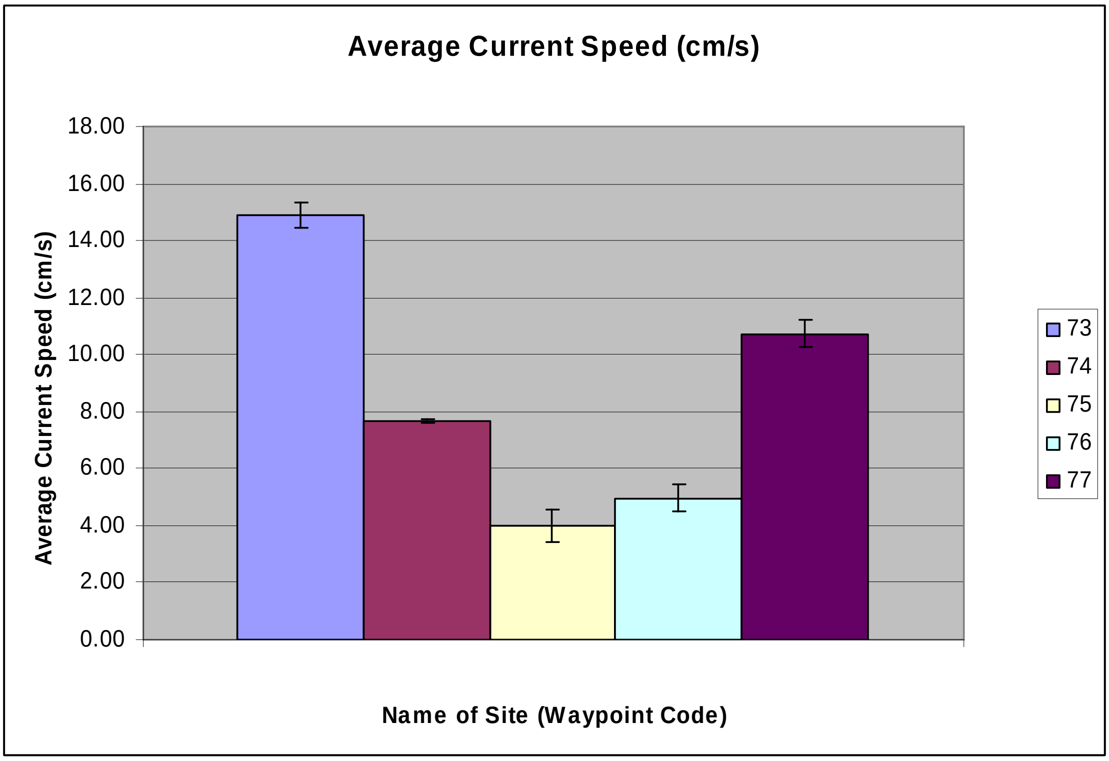

Figure 17. Average Current Speed at five sample sites measured around Cayo Mayor on the morning of 1-07-06

The 5 sites shown in figures 16 and 17 were compared for significant difference in average direction and flow rate (speed meters per second). Both data sets were tested for homogeneity of variance. In both data sets $P<0.05$, so a Kruskal-Wallis test was used in lieu of ANOVA. The Kruskal-Wallis gave both data sets a $P<0.01$, rejecting the null hypothesis that there is no significant difference between sites in average direction of current, or current flow rate.

Looking at figure 17 and referencing the sites to figure 14, the two highest flow rates were in sites that are channels. These sites also had the least amount of variance in current direction (Fig. 16.). This could be due to laminar flow, which would be disrupted by reef topography at those sample sites taken in closer proximity to reefs. This is an important consideration in future sampling grid designs for 2007.

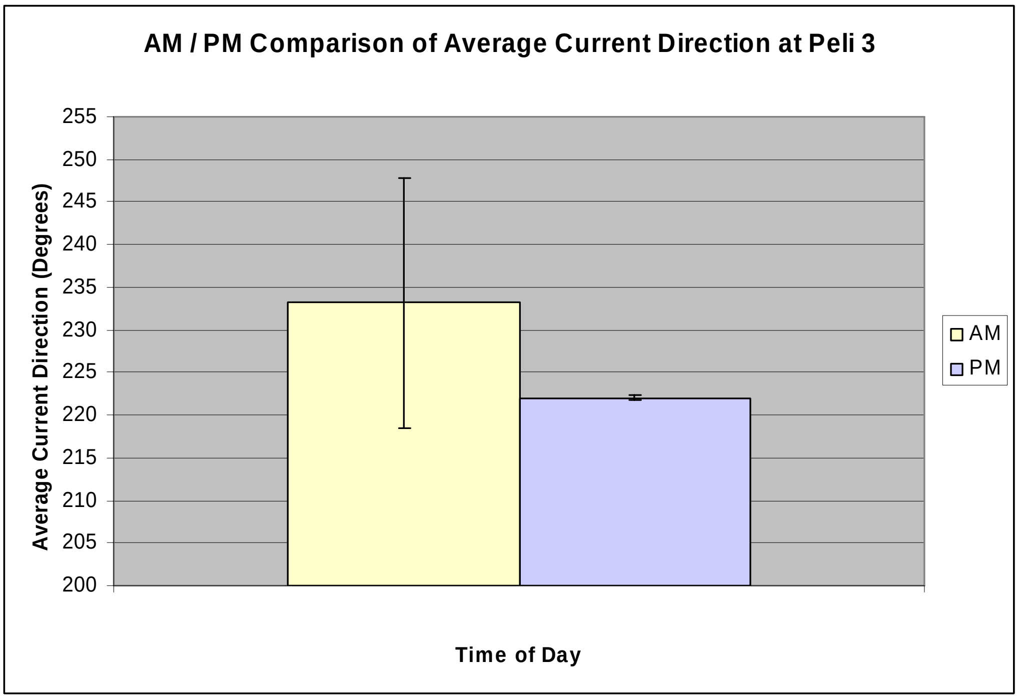

Figure 18. Morning and Afternoon comparison of average current direction at the sample site ‘Peli 3’.

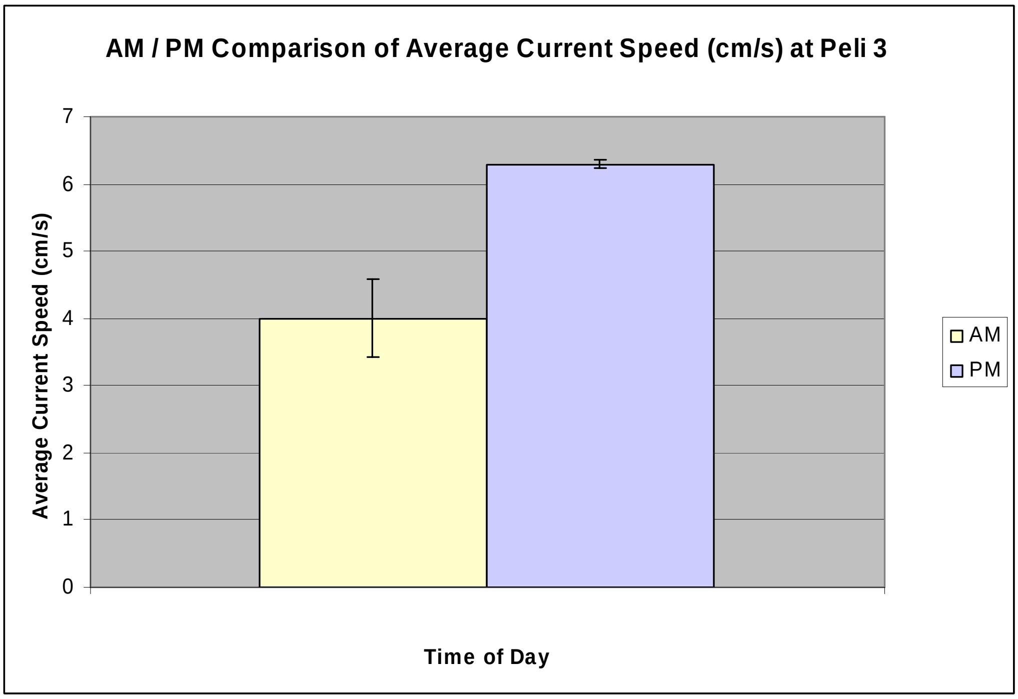

Figure 19. Morning and Afternoon comparison of average current flow rate at the sample site ‘Peli 3’

The site Peli 3 was sampled both in the morning (AM) and afternoon (PM) for detection of any temporal and tidal variation on current direction and flow. Using a paired T-test, there is no significant difference ($P=0.310$) in average current direction between AM and PM samples. However it is interesting to note in figure 18 that the AM sample has a much larger variation in direction of flow than in the PM sample, as illustrated by the difference in size of the error bars. Again using a paired T-test, there is however, a strongly significant difference ($P<0.01$) in current flow rate between AM and PM samples (Fig. 19.) with the current flowing faster in the afternoon.

In summary, this suggests that although there is little difference in the average direction of flow between AM and PM, there is a significant difference in flow rate. Thus it will be necessary to create a sampling schedule that takes into account this temporal variation and samples sites at different times to take into account tidal influence.

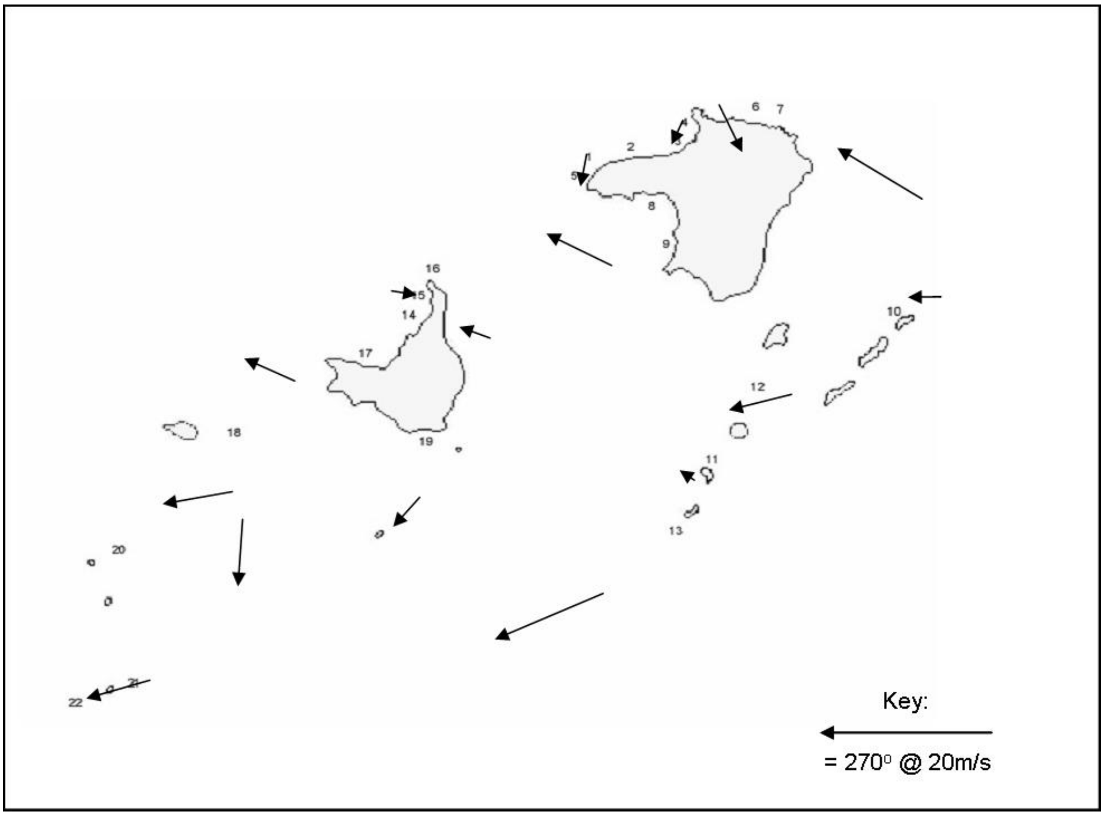

Figure 20. Vector map of ACM data. The angle of arrows indicates direction of flow (degrees, grid) and length of the arrows indicates speed of flow (meters per second). Sampling sites are located at the arrow's origin.

Using the ACM data from each sampling site, it is possible to plot vectors of the average current direction and flow rate on to a map of the MPA (Fig.20.). Ultimately the 2007 study will make use of a GIS package to plot these vectors over the top of other useful information such as bathymetry and topography of the region. Looking at figure 20, it is interesting to note that many of the reef sites have a lower flow rate and very different direction of flow compared to the more 'offshore' channel sample sites. This suggests an interaction between the water column and reef topography that needs to be studied in more detail with more replicate sites in the 2007 season. Some of the vectors in figure 20 are completely reversed in direction and counter to the rest of the sample sites. This could be due to an 'eddy effect' caused by prominent headlands and other topographical features, but again this needs further investigation in 2007. Either way, this initial vector map of current flow shows that there are some interesting and significant differences in flow occurring, which in turn has a significant effect on understanding nutrient and sediment flow dynamics as well as fish and invertebrate larval distribution in the region.

Conductivity, Temperature, Depth Profiles

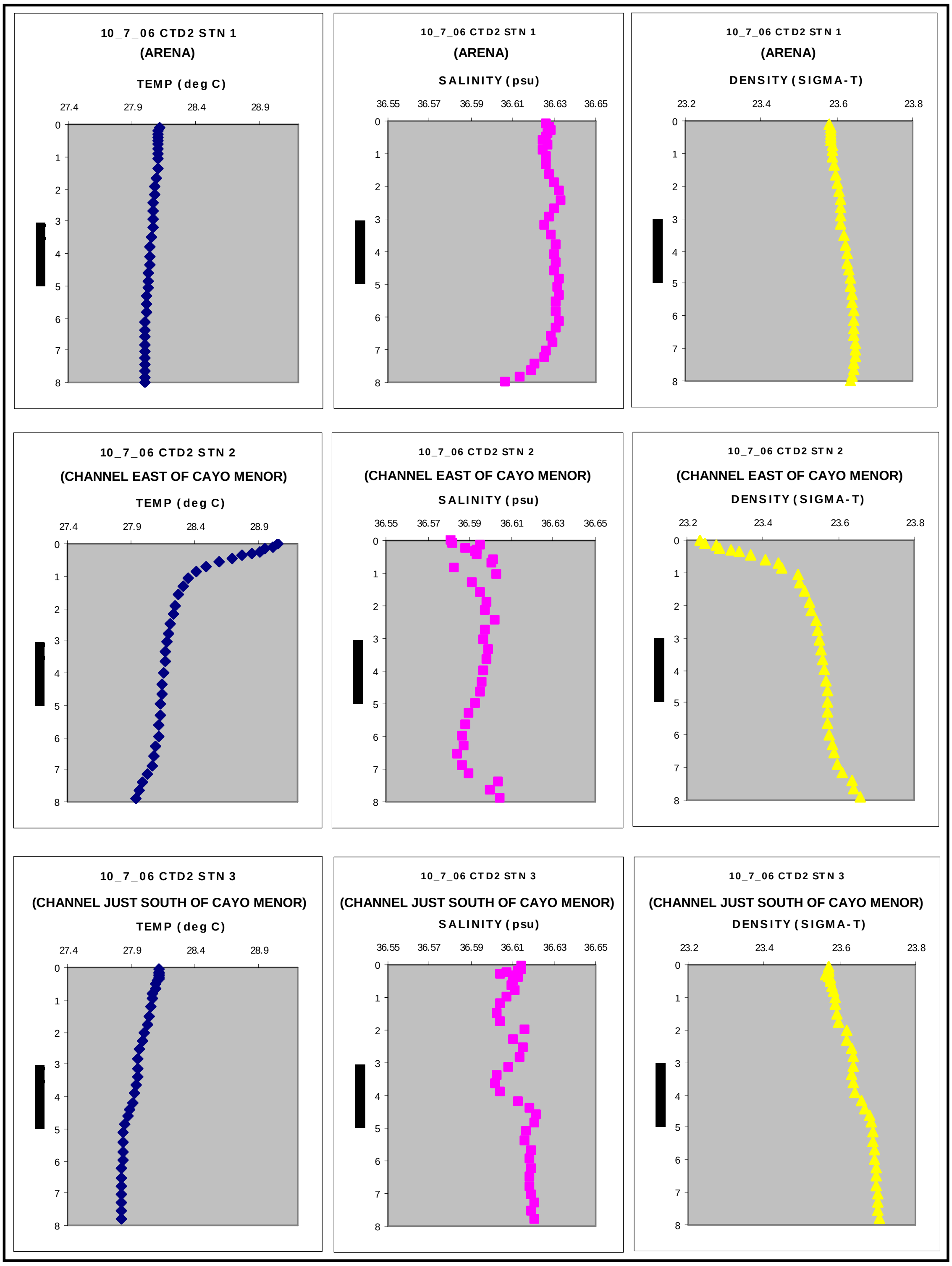

Figure 21. Comparison of Temperature, Salinity and Density profiles over depth for one reef and two channel sample sites.

The conductivity, temperature and depth (CTD) profiles have shown a difference between sites (Fig. 21.). It was found that reef sites tended to have a more uniform profile for temperature, salinity and density, than the more offshore channel sites. The salinity for stations 2 and 3 in figure 21, are good examples of this, with salinity fluctuating in correspondence to changes of temperature and density. It is possible that these small differences in salinity are due to stratification in channel water, not found at reef sites. The undisrupted laminar flow of these sites is in contrast to the turbulent flow of water passing over reefs. Thus the comparatively uniform profiles of reef sites such as station 1, ‘Arena’ (Fig. 21.), could be due to the mixing of water layers from this turbulent interaction of water column and reef. Again further replication of sites in 2007 will elucidate upon this and the extent of freshwater lensing.

Water Sampling and Analysis

At all sites, nutrients and chlorophylls within the water column were found at trace levels, bordering on the level of detection, with little to no site effect. This fits with the known model of reefs as highly efficient systems, where nutrients are recycled and used up rapidly, thus leaving the surrounding waters oligotrophic. It may be that macroalgae are using up any dissolved nutrients preventing detection. Thus in 2007 macroalgae will be sampled for C and N isotope analysis. Previous studies in the Caribbean have used N isotope tests to ‘finger-print’ the origin of nitrogen being used by macroalgae, and will elucidate upon any river effect upon the reefs. Also in 2007 their will be more focus upon transecting away from potential local point sources of nutrients, such as the toilets on Chachahuate and the outflow pipes on Cayo Mayor and Cayo Menor. Filtrate is still undergoing analysis for weight and C and N isotopic ratios.

5. Acknowledgements

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University of Oxford
Operation Wallacea
Honduran Coral Reef Fund
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Linacre College, University of Oxford
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