Benthic community and environmental analysis of *Scleractinian* coral habitat in Tela bay, Honduras

Scleractinian species at dive site Banco Capiro, Tela, Honduras.

Jordan Lucas

Submitted in partial fulfillment of the requirements for Biology 489

Concordia University College of Alberta

Dr. Dalton

CONCORDIA
UNIVERSITY COLLEGE OF ALBERTA

Abstract

Coral reef degradation and loss of coral species is occurring at increasing rates throughout the world's oceans, where corals are faced with the effects of a destructive combination of natural and anthropogenic stressors. Overfishing, tourism, extraction of fossil fuels, coral mining, increased CO_2 emissions from industry, and climate change all contribute to this, and a greater understanding of coral ecology is needed. It was the goal of this study to characterize benthic communities and the environmental parameters that have the potential to influence community structure of a healthy population of *Scleractinian* coral species in Tela Bay, Honduras (hard coral coverage as high as 80%), and then compare that area to a less healthy, but typical (coverage of 17%), reef nearby. Data collections took place from June 18-July 26, 2014 at the Tela Marine Research Centre and represent the first analysis of these unique reef systems. There were distinct differences between the reefs, including reef depth; turbidity levels; and sedimentation rates. Three transects at 5 different dive sites on the main reef at 10m and 15m and then three transects at a nearby reef of 3 sites at 5m were conducted to determine coral and macroalgae cover, relative abundance, species diversity, and dominant species. Results of low turbidity and high sediment may have an important role in reef protection and resilience in regard to anthropogenic influences. Assessment of the benthic community and the environmental conditions can then determine which parameters in particular are helping to shape this reef community where the *Scleractinian* species in Tela Bay are doing so well.

Key Words: Caribbean Coral Reef; Stony Coral; *Scleractinian*; Benthic Community; Turbidity; Sedimentation; Honduras

TABLE OF CONTENTS

Acknowledgments

Thank you to all the staff and fellow students who took part in Operation Wallacea's Marine Ecology research project in Tela Bay, Honduras summer of 2014. Without the support of the locals and NGO's involvement in the area, research here would not be possible. I would like to thank Alex Willcox for field work help and for being my dive master guide. To Dr. Exton I am grateful for the feedback on narrowing down the topic with suggested literature and his familiarity with current research. The opportunity, approval, feedback and constant support of the project would not be possible without Dr. Dalton. Finally, thanks to my family and friends for help with funds and support through it all.

Introduction

The Wider Caribbean region includes 28 island and continental countries. The Caribbean coral reefs only account for 7% of the world's total coral reef area. There are only 62 *Scleractinian (*stony) corals, compared to 719 in the Indo-West Pacific. However, these corals are known to house some of the most unique biodiversity of marine organisms endemic to the region.

Three million years ago the land that is now Central America rose up from the ocean and divided the connection between the Atlantic and Pacific Oceans, allowing, the Caribbean coral reefs to evolve in isolation from those in the rest of the world. Fossilized studies of coral show that Caribbean reefs were stable in their community composition and zonation pattern for at least 125, 000 years (Pandolfi & Jackson 2006; Precht & Aronson 2006).

It was common to find an abundance of coral species such as *Acropora palmata* (Elkhorn coral) and *Acropora cervicornis* (Staghorn coral). These two species were important in providing a three dimensional structure to many reefs (Pandolfi & Jackson 2006). *A. palmata* were located at shallow depths in the reef crest zone; *A. cervicornis* located at the shallow fore-reef zone. Other important reef building species were *Montastraea spp.* and *Agracia spp.* These species colonized at the reef slope and the deep reef slope, respectively.

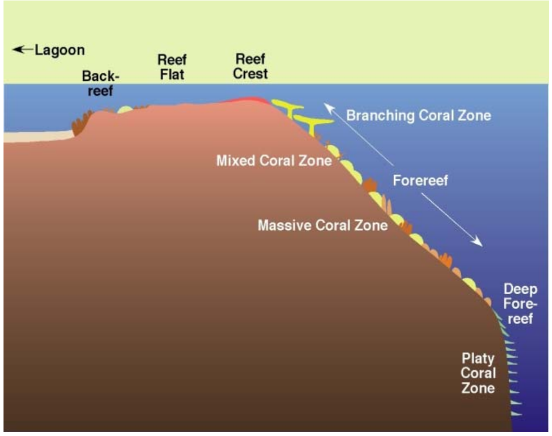

Figure 1. Coral reef zones. http://www.oberlin.edu/faculty/dhubbard/PersWebPage/Courses/CoralReefs/Reefs%20Photos/Coral%20ID%20page.html

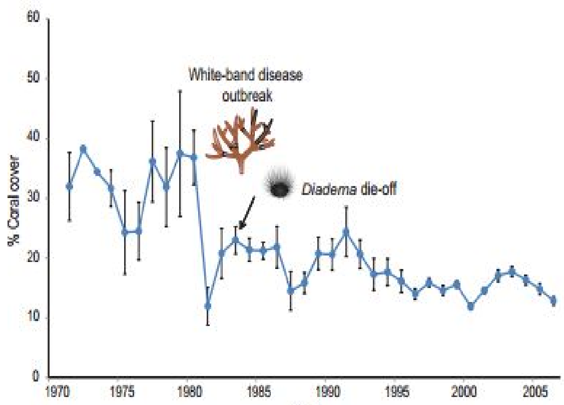

Figure 2. Record of annual average coral cover for the Caribbean region (Mumby et al 2014). http://www.marinespatialecologylab.org/force/Biogeography%20p.10-23.pdf

Throughout history corals have faced both natural and anthropogenic stressors, changing community structure. The coastal corals faced decades of hurricanes, disease, bleaching events and ecological imbalance catalysed by invasive species. In the 1970's to the 1980's coral cover showed its sharpest decline due to what is now known as white-band disease, which targeted the important branching corals. These corals primarily reproduce through asexual fragmentation, and their low genetic diversity resulted in little recovery after the mass mortalities. Factors contributing to the degradation of more coral species in the Caribbean include various anthropogenic disturbances. A list of examples includes: sediments from dredging or land clearing; nutrient influx from sewage; agricultural runoff of pesticides and nutrients; boat groundings and anchors; physical damage from SCUBA, snorkeling and swimming, shoreline development; industrial pollution; over-fishing; collecting for aquariums; oil spills; urban runoff and induced thermal stress (Hughes 1994).

The exact structure and appearance of a coral reef can vary in different areas of the world and based on differing environmental conditions and anthropogenic impacts acting upon them. Coastal Caribbean reefs typically have clear blue water surrounding it; an image which is more often than not accurate. The photosynthetic processes present on the reefs, most importantly by symbiotic microalgae called zooxanthellae which live within coral tissue and drive some of the ecosystem's most vital processes, makes light availability an important component of reefs, making clear water advantageous. *Scleractinian* corals, the ecosystems architects of complex reefs, also thrive in low nutrient, or oligotrophic water, which limits macroalgal growth rates and helps corals to dominate the benthic community. Clear water is a common symptom of low nutrient availability through inhibition of phytoplankton growth.

Corals are highly susceptible to the effects of sedimentation, where particles settle onto the reef and smother coral polyps, meaning reefs struggle to survive in sites with high sediment loading, for example near to riverine outputs or where land runoff is high. Turbidity refers to sediment in suspension within the water column, whereas sedimentation describes the process of sediment deposition onto the reef itself, which creates the impact of coral smothering.

Quantifying the benthic community structure is a useful indicator of overall ecosystem health and function. Particularly useful parameters in coral reef monitoring include the percentage benthic cover of key functional groups such as hard (*Scleractinian*) corals and macroalgae. Coral cover, or the percentage of hard substrate covered by living tissue, is a key measurement of coral ecosystem health (Selig and Bruno 2010). These data can then be used to help explain trends in other monitoring data sets such as patterns in the abundance and diversity of fish and invertebrates, as well as identify major threats to a particular reef.

Maintaining reefs biodiversity can be a challenge as was revealed in Richards and Berger's (2013) paper on the conservation status of hard *(Scleactinian* species) of coral. They showed that due to obvious structural changes in coral species composition the reef dynamics would change as well. This exemplified need for up to date monitoring and assessment of reefs.

The general efficacy of MPAs (Marine Protected Areas) in preventing coral loss was tested by Selig and Bruno (2010). They compiled a global database of 8543 live coral cover surveys from 1989-2006 to compare annual changes in coral cover inside MPAs to unprotected areas. It was concluded MPAs are useful for monitoring coral cover. The benefits increase with the number of years since the establishment of the MPA. However, MPAs do not mitigate coral loss from global stressors such as climate change and coral disease.

Williamson et al (2014) compared coral habitat dynamics between a No take Marine Reserve (NTR) to a fishing area in the southern Great Barrier Reef area. The climatic disturbances were shown to influence cycles of decline and recovery of the coral. There were community phase-shifts evaluated that changed from a coral dominated state to an algae dominated state. The benthic habitat changes showed changes to fish communities. When there was low coral cover there was also low fish diversity and abundance. Between a NTR site and fishing site dynamics of benthic or fish communities in correlation to these patterns had little effect. However, due to fish refuge in an NTR site it was discussed that this would be critically important for the long term, persistence of reef recovery.

Today corals may seem doomed. In the last three decades studies including a meta-analysis done by Gardner et al (2003) show patterns of change in average hard coral on reefs being reduced from about 50% to 10%. Percent cover higher than this would have impacts on current coral studies. Honduras is 112,492 square kilometers large, with a population of 5.5 million people. Urban growth, deforestation and soil erosion all impact the country. The first national environmental law was passed in 1993. Numerous environmental groups address issues from local, national and regional perspectives and are entrusted in the administration of the nation's protected areas and parks. The majority of Honduran coral reefs are representative of the Caribbean region; located in clear water sites and with declines in *Scleractinian* coral cover (Honduras Parks 1998).

Resilience of Caribbean coral was analyzed by Mumby et al (2007). In this paper the characterization of coral health is stated to be dependent on increases of macroalgae. The investigations of algae-dominated reefs are of interest to see if they can be as stable as a coral-dominated habitat. Coral reef habitat dynamics research knowledge is highly involved it's the ecological relationship between all living organisms in the reef. However Guadayol et al (2014) highlight the importance of environmental variance and the relationship with the coral.

The expected results are to show a reef system that is in an unusually healthy state and high coral cover, despite degradation of surrounding reefs and heavy anthropogenic influence to the area.

Research objectives were to fully characterize the abiotic conditions present in the main patch reef in Tela bay. This includes ambient water temperature; turbidity of the vertical water transparency and estimated sedimentation deposits on the reef. Secondly, objectives were to fully characterize the benthic community, in particular *Scleractinian* corals. Continuous line transects were then used to determine the percent coverage of the hard coral and macroalgae; calculated species diversity; relative abundance; and dominant species in the coral community. Data was then compared to results, using the same methods, at the small patch reef off the village bank of Ensenada. A comparison to a reef in a much poorer state was then used in hopes of determining which factors were significantly different between the sites in order to assess if it is an abiotic reason why the reefs in Tela are doing so well.

Methods

The study was based in the bay of Tela, Honduras. Initial surveys indicated an unusually healthy *Scleractinian* coral ecosystem for a contemporary Caribbean reef system, despite environmental conditions appearing unfavourable for reefs to thrive. Several sites were included in this study to ensure an accurate representation of the reefs of Tela Bay.

The study site:

A handheld GPS (Global Positioning System) was used to determine coordinates of the site's latitude and longitude. The main reef coordinates at Banco Capiro were: 15°52'48.0"N 87°30'25.0"W and the smaller patch reef Ensenada was: 15°48'32.9"N 87°27'14.1"W.

Figure 1. A map of the mainland bay. The star on the map indicates Tela Marine Research Centre where the dive boats were launched. The dive sites, main reef (Banco Capiro) 15°52'48.0"N 87°30'25.0"W and the smaller patch reef (Ensenada) 15°48'32.9"N 87°27'14.1"W, are labelled. Within the dive site Banco Capiro were 5 different dive points to cover and account for a much larger reef.

Arrival in Honduras was on June 17, 2014. The first two weeks were spent on certification and qualifications for SCUBA diving and specific reef ecology examinations. The data collection was started in the first two weeks of arrival and ran for the entire Operation Wallacea (OpWall) season, ending on August 18, 2014. Independent collection ended on July 29, 2014, a total of 6 weeks of research. However, data was combined with the further collection done by OpWall staff up to the end of season.

Data collection was separated into two categories: **1.** Environmental assessment **2.**Benthic community characterization

<u>Environmental assessment</u>

Figure 2. Homemade Secchi

The environmental investigation included abiotic stressors and environmental conditions that may have shaped the coral community in Tela Bay. The water's vertical transparency was measured using a homemade Secchi Disk. A checkered white and black pattern was painted on to a wooden circle (30cm diameter). Attached above it was a line of rope; meters marked off to 20m. Attached below it was a block of set cement in order to weigh the disk down. The secchi disk was lowered until the checkered pattern was no longer visible. Then the disk was raised until it could be viewed again. The depth at its reappearance was recorded. At each dive point an aim of 6 readings at five Banco Capiro sites on alternating days was set. A total of 28 readings within Banco Capiro were recorded. A total of 3 readings on alternating days at Ensenada were recorded. The readings for all sites were then averaged and this then gave turbidity level results at different points along the reefs.

Figure 3. Homemade sediment trap at Ensenada 5m.

Sediment deposition was measured with a homemade sediment trap approach. Hollow pipe (4.2cm diameter opening) was cut in relatively equal heights; each pipe was then placed in a cement base and set for 2-3 days (drying time). Four sediment traps for each dive point, Butterfingers; Canyon/Rotonda; Kisci's Garden; and Mushroom Mountain, at 10m depth. This was then repeated at 15m depth. Again traps were repeated at 5m depth for Ensenada. All traps were placed at the beginning of the season and brought up again at the end. Only traps from Kisci's Garden; Mushroom Mountain and Ensenada were brought up due to insufficient time and resources needed for a complete trap season.

Next, the traps were filtered for sediment collection. Any large organisms were first removed. Then using empty 2L pop bottles and filter paper the traps were drained over several hours, until all sediment was collected. Filters were rinsed with bottled drinking water a few times to remove salts from the sediment. The sediment filters were then placed in an oven at 30 ^{0}C until a constant weight was attained. Sedimentation rate was then calculated as mg of sediment per cm squared fallen per day. The sediment weight is the total weight minus the filter weight (Parson et al 1984).

Benthic community

Research aimed for accuracy and time efficiency in collection techniques for characterization of the benthic communities. Therefore, methodology for estimated percent cover, relative abundance, diversity, and dominance used 25m continuous video transects. This method allows for a more thorough, close, inspection of benthos. Other methods such as line and point intercept transects, quadrant or chain transects require longer time underwater and a greater number of dives (Ohllhorst et al 1988).

Continuous 25m transects used a GoPro underwater camera to record reef community. Tape measure was laid out and secured at both ends of each transect. The tape was draped over the reef in order to record each species and substrate component in approximate length under the tape. 3 transects were done at each established site and depth (5m at Ensenada; 10m and 15m at Butterfinger, Canyon/ Rotonda, Kisci's Garden, Mushroom Mountain). Videos were then watched to identify absolutely everything directly under the tape and measured (in centimetres) the distance travelled along transect before switching to the next subject. The distance of all hard coral species were combined for each transect and an average percent coverage for hard corals was determined for each site. The same was done for all microalgae and the two groups of important reef organisms were compared to determine dominance among the reefs. Relative abundance was then calculated for each identified hard coral and macroalgae present in Banco Capiro and Ensenada to determine was dominant species at each reef. Finally, Simpson's Diversity of Index was used to determine levels of biodiversity of each dive site. Simpson's Diversity of Index was calculated using D=1 $-\left(\frac{\sum \quad n(n-1)}{N(N-1)}\right)$.

Results

Environmental Parameters

Turbidity of the reef is shown in Figure 1. The turbidity averages of the main reef, Banco Capiro, show: Butterfingers (BF) 14.84m ±3.85 standard deviation; Canyon (CN) 14.95m ±4.11; Kisci's Garden (KG) 14.67m ±1.95; Mushroom Mountain (MM) 15.33m ±1.40; Rotonda (RT) 13.18m ±0.95. The side patch reef of Ensenada (EN) had turbidity levels of ~5.67m ±2.62.

Sedimentation at Banco Capiro and Ensenada is shown in Figure 2. Sediment rate averages were obtained for EN at 5m 16.66 mg cm^{-2} day^{-1} ±2.23. The main reef sites show KG at 15m 14.78 mg cm^{-2} day^{-1}; KG at 25m 16.80 mg cm^{-2} day^{-1}; MM at 15m 14.84 mg cm^{-2} day^{-1}; and MM at 25m 14.62 mg cm^{-2} day^{-1}.

Grey literature compiled by (Rogers 1990) was used to show a comparison of sediment rates and turbidity levels for different Caribbean reefs, shown in Table 1 as none are currently available for the Tela patch reefs. Caribbean reefs in Jamaica at 4m turbidity correlated with 0.5-1.1mg cm^{-2} day^{-1}, 1974; St. Thomas 3-5m turbidity correlate a 0.4-5.8mg cm^{-2} day^{-1}, 1982; Puerto Rico 9-33m turbidity correlate a 1-15mg cm^{-2} day^{-1}, 1974; Puerto Rico 4m turbidity correlate a 0.9-2.6 mg cm^{-2} day^{-1}, 1983; Costa Rica 13.5-45m turbidity correlate a 30-360 mg cm^{-2} day^{-1}, 1984; Barbados 13.5-45m correlate a <10to>40 mg cm^{-2} day^{-1}, 1975. The Tela patch reefs environmental parameters are shown to fall similar to the Costa Rica 13.5-45m turbidity and 30-360 mg cm^{-2} day^{-1}, 1984.

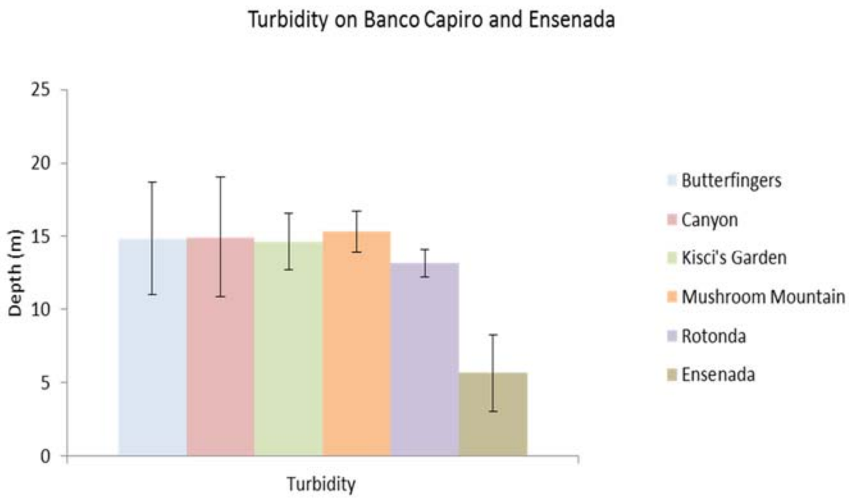

Figure 1. Shows the average turbidity in metres recorded at each dive site.

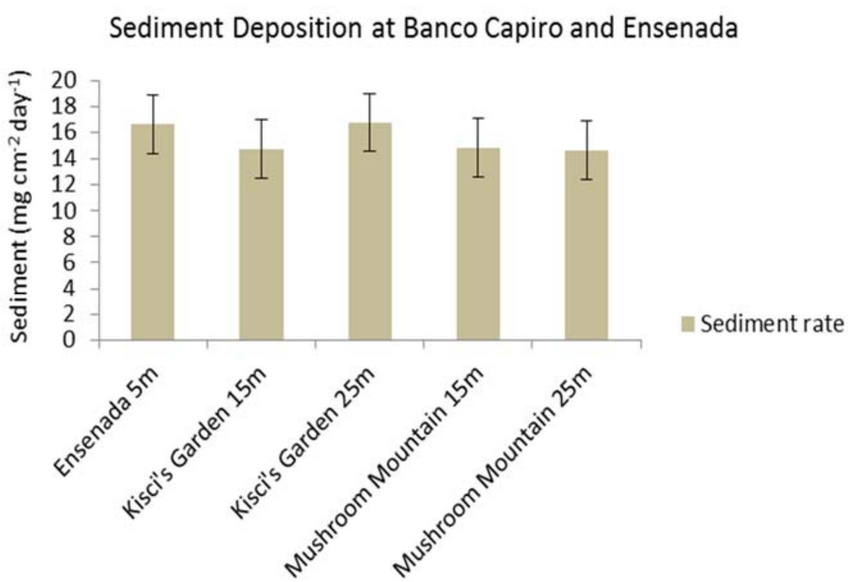

Figure 2. Average sediment rates as sediment collected per cm^2 per day between dive sites.

Table 1. (Roger's 1990) literature compilation used to show comparison of sedimentation rates and turbidity levels for different Caribbean reefs as none are available for the Tela patch reefs.

Location	Rates ($mg\ cm^{-2}\ d^{-1}$)	Total suspended solids ($mg\ l^{-1}$)	Comments	Source
Caribbean				
Jamaica (Discovery Bay)	0.5 – 1.1 (means for traps 50 cm above substrate)		Reef lagoon, ca (4 m deep)	Dodge et al. (1974)
St Thomas, USVI	0.8 ± 0.4 – 5.8 ± 13.3 (means ±SE for traps 10 cm above the substrate)		Five coral reef areas, 3–5 m deep	Rogers (1982)
	0.1 ± 0.1 – 1.6 ± 0.7 (means ±SE for traps 50 cm above the substrate)			
Puerto Rico	1 – 15		Reef 9–33 m deep	Cintron et al. (1974)
Puerto Rico	2.5 ± 0.9 – 2.6 ± 1.2 (means ±SE for traps 50 cm above the substrate)	0.8	Backreef 4 m deep	Rogers (1983)
	9.6 ± 2.4 (means ±SE for traps 10 cm above the substrate)			
Costa Rica (Cahuita)	30–360			Cortes & Risk (1984)
Barbados	< 10 to > 40	4.3 to 73		Tomascik & Sander (1985)
Barbados	ca 5 to 10 (means for traps ca 5 cm above the substrate – 7 stations)		Barrier reef 13.5–45 m	Ott (1975)
	1 (means for traps ca 1 m above the substrate – 1 station)			

<u>Benthic Community</u>

Percent coverages for *Scleractinian* corals and algae cover are shown comparably at each dive site in Figure 3. The Banco Capiro sites have calculated cover at depths of 10m and 15m. Ensenada side reef has cover at 5m depth. At Banco Capiro coral coverage and algae cover are BF10m 73.34±22.09 coral and 8.61±12.39 algae; BF15m 48.96±22.5 coral and 25.41±19.45; CR10m 78.73±11.2 coral and 3.75±4.1 algae; CR15m 42.84±23.79 coral and 5.08±2.14 algae; KG10m 54.17±10.25 coral and 9.07±3.8 algae; KG15m 37.43±8.98 coral and 23.01±8.88 algae; MM10m 84.24±5.94 coral and 3.05±2.54 algae, MM15m 46.88±1.74 coral and 17.04±5.43 algae. At Ensenada coral coverage and macroalgae cover at 5m are 11.26±9.19 coral and 37.13±5.81 algae.

Species presence for coral and algae at Banco Capiro, Ensenada or at both are displayed in Table 2. As well as, calculated relative abundance for each species among coral grouping and relative abundance among algae grouping. Species of coral and algae were placed in the table composed of known species to the area that had been noted by Operation Wallacea's previous work in the Caribbean. For the coral species abundance at Banco Capiro values are. *A.cervicornis* 0.03±0.1; *A.agaricites* 1.2±2.94; *A.lamarcki* 3.9±6.38; *A.tenuifolia* 73.21±21.35; *C.natans* 0.19±0.6; *D. stokesii* 0.97±1.77; *D. labryinthiformis* 0.36±1.16; *E. fastigiata* 0.38±1.56; *M.mirabilis* 0.46±0.96; *M.meandrites* 1.12±2.61; *Millepora spp.* 0.07±0.26; *M.cavernosa* 2.45±2.88; *M. faveolata* 0.69±1.68; *Mycetophyllia spp.* 1.48±2.78; *P.astreoides* 10.64±17.74; *P.porites* 0.16±0.47; *P.strigosa* 0.08±0.37; *S.siderea* 2.65±5.69; and *S. intersepta.*0.02±0.11. The coral species abundance at Ensenada values are *A.tenuifolia* 40.15±15.99, *C.natans* 2.27±5.56, *D.labyrinthiformis* 8.71±21.33, *M.meandrites* 4.48±10.97, *M.cavernosa* 2.89±3.5, *M.faveolata* 1.58±3.88, *P.astreoides* 0.27±0.66, *P.strigosa* 9.34±10.23, *S.siderea* 30.31±12.39. Macroalgae abundance among species at Banco Capiro are *Amphirora* 8±14.73, *Caulerpa spp.* 4.82±10.36, *Crustose coralline algae (CCA)* 3.38±7.78, *Dictyota spp.*70.86±30.96, *Halimeda spp* 9.24±20.94, *Lobophora spp.* 0.88±2.88, *Sargassum spp.* 1.13±2.63, *Valonia spp.* 0.37±1.1. Macroalgae abundance among species at Ensenada is *Amphirora* 1.68±1.14, *Dictyota spp.* 97.37±1.89, *Halimeda spp.* 0.3±0.6, *Lobophora spp.*0.18±0.45, *Sargassum spp.* 0.08±0.2.

Simpson's diversity of index is shown in Figure 4. Calculations show EN 5m DI= 0.634 ± 0.06; BF 10m DI=0.577 ±0.31; BF 15m DI=0.875 ±0.09; CR 10m DI=0.518 ±0.223; CR 15m DI=0.697±0.02; KG 10m DI=0.808 ±0.05; KG 15m DI=0.859 ±0.03; MM 10m DI=0.459 ±0.143; MM 15m DI=0.763±0.71.

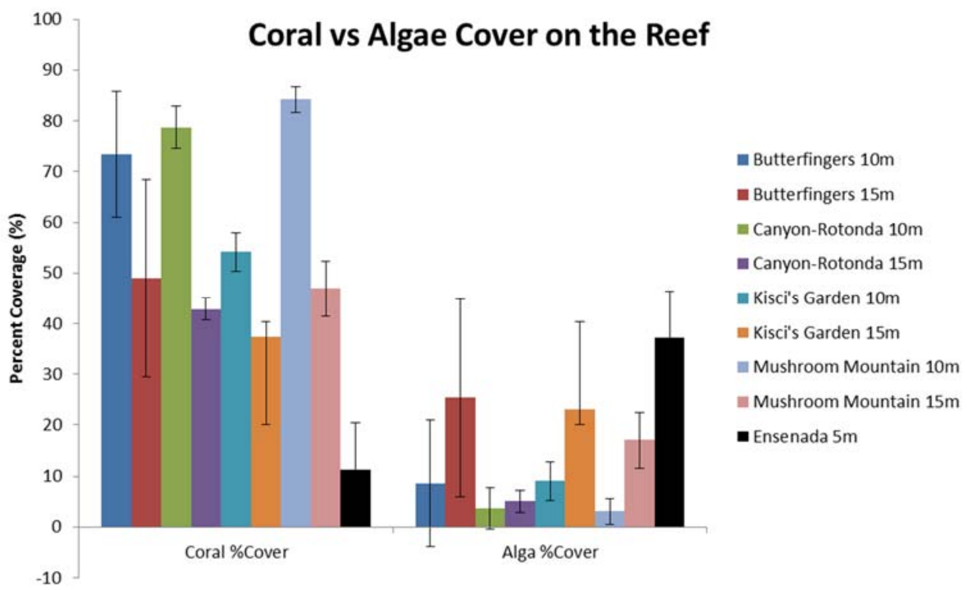

Figure 3. Percent Coverage comparison of the coral and macroalgae cover at each dives site.

Table 2. The presence and absence of coral and algae species prevalent in adjacent oceans to Honduras is shown. *Scleractinian* corals present in Banco Capiro and Ensenada show a calculated relative abundance. Information among macroalgae for presence and relative abundance at each site is also shown.

Vernacular Name	Latin Name	Banco Capiro	Abundance (%)	Ensenada	Abundance (%)
Coral					
Staghorn	*Acropora cervicornis*	✓	0.03 ±0.1		0
Elkhorn	*Acropora palmata*		0		0
Lettuce Coral	*Agracia agaricites*	✓	1.2 ±2.94		0
Lamarck's Sheet Coral	*Agracia lamarcki*	✓	3.9 ±6.38		0
Thin Leaf Lettuce Coral	*Agracia tenuifolia*	✓	73.21 ±21.35	✓	40.15 ±15.99
Boulder Brain Coral	*Colpophyllia natans*	✓	0.19 ±0.6	✓	2.27 ±5.56
Elliptical Star Coral	*Dichocoenia stokesii*	✓	0.97 ±1.77		0
Grooved Brain Coral	*Diploria labyrinthiformis*	✓	0.36 ±1.16	✓	8.71 ±21.33
Smooth Flower Coral	*Eusmilia fastigiata*	✓	0.38 ±1.56		0
Yellow Finger Coral	*Madracis mirabilis*	✓	0.46 ±0.96		0
Maze Coral	*Meandrina meandrites*	✓	1.12 ±2.61	✓	4.48 ±10.97
Fire Coral	*Millepora spp.*	✓	0.07 ±0.26		0
Great Star Coral	*Montastraea cavernosa*	✓	2.45 ±2.88	✓	2.89 ±3.5
Mountainous Star Coral	*Montastraea faveolata*	✓	0.69 ±1.68	✓	1.58 ±3.88
Cactus Coral	*Mycetophyllia spp.*	✓	1.48 ±2.78		0
Mustard Hill Coral	*Porites astreoides*	✓	10.64 ±17.74	✓	0.27 ±0.66
Finger Coral	*Porites porites*	✓	0.16 ±0.47		0
Symmetrical Brain Coral	*Pseudodiploria strigosa*	✓	0.08 ±0.37	✓	9.34 ±10.23
Massive Starlet Coral	*Siderastrea siderea*	✓	2.65 ±5.69	✓	30.31 ±12.39
Blushing Star Coral	*Stephanocoenia intersepta*	✓	0.02 ±0.11		0
Algae					
red alga	*Amphirora*	✓	8 ±14.73	✓	1.68 ±1.14
green alga; Sea grape	*Caulerpa spp.*	✓	4.82 ±10.36		0
red alga; CCA	*Crustose coralline algae*	✓	3.83 ±7.78		0
brown alga	*Dictyota spp.*	✓	70.86 ±30.96	✓	97.37 ±1.89
green alga	*Halimeda spp.*	✓	9.24 ±20.94	✓	0.3 ±0.6
brown alga	*Lobophora spp.*	✓	0.88 ±2.88	✓	0.18 ±0.45
brown alga	*Sargassum spp.*	✓	1.13 ±2.63	✓	0.08 ±0.2
green alga; Bubble alga	*Valonia spp.*	✓	0.37 ±1.1		0

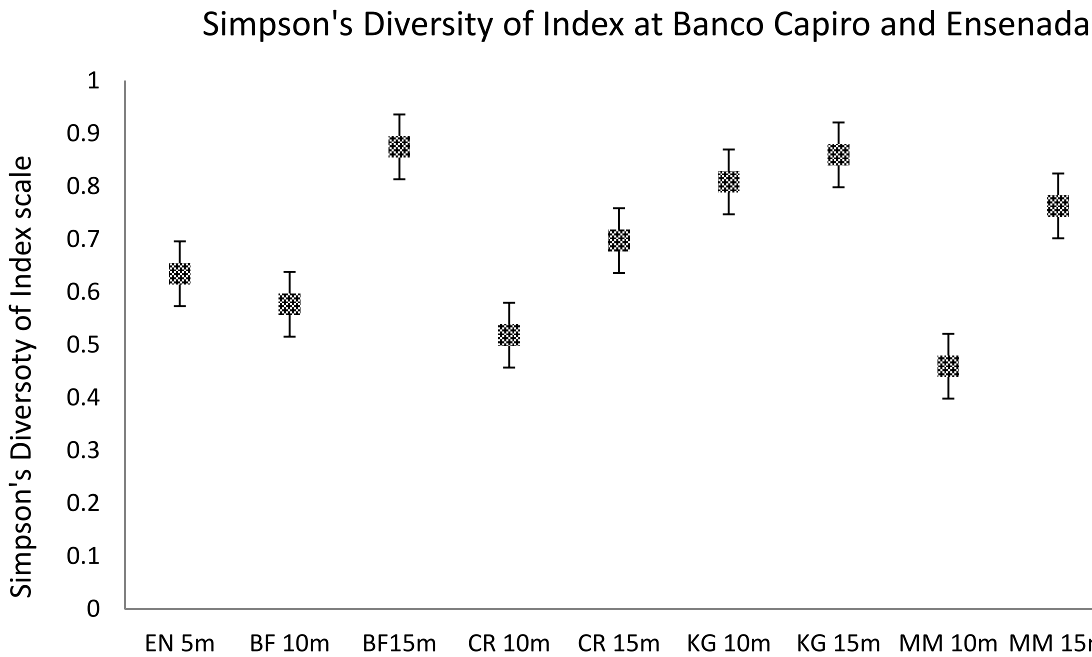

Figure 4. Simpson's Diversity of Index at each dive site displayed on 0-1 scale. Values closer to 1 represent a higher diversity of index.

Discussion

This study was to evaluate important environmental components that play a role on the *Scleractinian* coral habitat in Tela Bay, Honduras. This was carried out by data collection describing environmental conditions and benthic communities present in the Bay. Turbidity levels and sediment rates are important environmental parameters that were evaluated. Data collection for coral and macroalgae cover, species diversity, relative abundance, and dominance were analyzed from numerous benthos transects. Characterization of the reefs conditions and species present is important for initial analysis in the monitoring of Tela bay.

Environmental Parameters

The physiological condition of corals is likely to closely reflect variations in the environment. Corals expose large surface areas of relatively thin, transporting tissues to the ambient environment. Therefore, variation in resources such as light or flux of fine suspended particulate matter are likely to impact directly on coral physiology (Anthony and Lacombe 2002).

Turbidity levels of Banco Capiro had average range of 13-15m and Turbidity levels of Ensenada 5.67m ±2.62. Banco Capiro is located further from the shoreline and extends to greater depths than the small patch reef of Ensenada, which averages a bottom depth of 10m. Turbidity levels are lower in Ensenada increasing proximity to human activities such as dumping, dredging and runoff (Hughes 1994). *Scleractinians* function as phototrophs, through their association with zooxanthellae, as well as heterotrophs (Anthony 2000). Therefore, they are able to capture and ingest a wide variety of food types, including large sediment particles (Stafford-Smith and Ormond 1992) and fine particulate (Anthony and Lacombe 2002). Low turbidity values may create shading and impair phototrophy by reef corals. However, heterotrophy will potentially be enhanced by increased availability of food particles (Anthony 2000). This makes low turbidity potentially advantageous. High turbidity levels in Banco Capiro allow for greater photosynthesis productivity. High turbidity may result in problems from thermal bleaching events (Bellwood et al 2006). Therefore, again the reduced light quantity and quality in turbid waters may provide a useful buffer against thermal bleaching. This can be supported by the discovery of several reefs in turbid water, where significant coral communities were thriving. An example of this was in the Seychelles where, after the 1998 El Nino event caused mass coral bleaching mortality in the region, large colonies of thermally sensitive coral species were found successfully inhabiting turbid lagoons (Smith et al 2008).

Sediment rates estimate fallen sediment settled on the reefs per cm^2 per day. Collection, filtration and drying showed 14-17mg $cm^{-2} day^{-1}$ ±2.23 at Banco Capiro and 16.66mg $cm^{-2} day^{-1}$ ±2.23 at Ensenada. Difference between sediment rates may be insignificant as similar amounts of sediment seem to reach both reefs. Sediment particles smother reef organisms and reduce light available for photosynthesis. Excessive sedimentation can adversely affect the structure and function of the coral reef ecosystem by altering both physical and biological processes. Reefs that are not subject to human activities typically show Mean sediment rates <1 to 10mg $cm^{-2} day^{-1}$. "High" sediment rates would then be chronic rates and concentrations above these values (Rogers 1990). Therefore, both reefs show high sediment rates and potential causation due to anthropogenic stressors in the area. High sedimentation may be associated with fewer coral species, reduced coral recruitment, decreased calcification, and decreased net productivity (Rogers 1990). Sediment rejection may be seen as a function of morphology, orientation, growth habitat, and behaviour; subject to coral species present (Anthony and Lacombe 2002).

Roger’s literature review on reef sediment and turbidity could fit the Tela reef patches as similar levels and rates to the survey results in Costa Rico <10-40> mg $cm^{-2}day^{-1}$ and turbidity levels of 4.3-44m. This range is wide and varied but is a good start in comparison characterizations as none are available in Tela currently. Monitoring sites over decades is important in reef management in order to show relative trends in community resilience and structure.

<u>Benthic Community</u>

Coral coverages around the world have been shown to decrease from an average of 50% cover to 20%, which may potentially reduce the ability of the reefs to provide the ecosystem services that many people rely upon, including habitat for reef fisheries, tourism appeal and coastal defense from storms (ref). Percentage coverage comparisons (Figure 3.) show a trend of highest coral coverages at Banco Capiro at 10m depth. Coral cover ranges anywhere from an expected 23% to an unheard of 84% (Mushroom Mountain 10m). This *Scleractinian* coral cover results are among the highest in the entire Caribbean. High coral is important as it provides habitat for fish and invertebrates. Ensenada show similar to current typical results of low coral cover (11%) and high macroalgae cover (37%). This relationship is important to show as it known that coral and algae compete for space and nutrients. Disturbance phenomena resulting in phase-shift in reef dominance between corals and algae include reduction in urchin density; overfishing of herbivorous fish; coral death from bleaching; and rise in nutrients from land-runoff (Mumby et al 2005). Following the mass mortality of important algae grazers such as *Diadem* (sea urchin) in 1983 and the heavily overfished reefs, algal blooms ensued. The initial stages of the bloom algae were small, but within 2-3 years weedy species were replaced with longer, lived late successional taxa. Notable taxa that dominated the reefs included *Dictyota,* *Halimeda, Lobophora* and *Sargassum* Phase-shifts from a coral dominated system to a fleshy macroalage dominated system were a common occurrence. Coral larval recruitment failed for decades following such catastrophic events such as urchin loss and bleaching events (Hughes 1994; Mumby 2007). High coral cover at Banco Capiro may help in research on coral resilience. For instance, reefs with high coral cover may indicate a form or adaptation or acclimatise to variable conditions. Anthony and Lacombe (2002) hypothesized adaptations for reefs in turbid zones. They suggested rapid replenishment of energy reserves in between events; or corals have shifted between primarily phototrophic to primarily heterotrophic; or rapid rates of photoacclimation, which corals may use to maintain positive energy balance.

Species abundance was highest at both Banco Capiro and Ensenada for coral species *Agaricia tenuifolia* (Banco Capiro 73%; Ensenada 40%) and the macroalgae *Dictyota* (Banco Capiro 70%; Ensenada 97%). There was mass coral mortality (75-90%) loss for *A.tenuifolia* following El Nino Southern Oscillation in 1999. Robert et al (2004) suggests perhaps *A.tenuifolia* had such high loss because it has a lesser ability to produce HSP (heat shock protein) for protection. High abundance of this species may then be a result of reef found at slightly lower depths for protection needed to survive. The advantage that algae's like *Dictyota* have over coral is reproductive rates. Macroalgae's have high reproductive rates whereas corals have slow growth and low reproduction (Tanner 1995). Chornesky and Peters (1987) attributed coral abundance to its restricting reproduction mechanisms. They found onset of reproduction is related to colony size; whereas the fecundity of individual polyps is related to colony age. Mumby et al (2005) suggested patch dynamics have great ecological importance, particularly when considering processes of coral recruitment. *Dictyota* tended to dominate and out-compete recruits by colonizing large patches of space.

Species diversity was highest at Butterfingers 15m 0.875. Unlike coral coverage which were highest at 10m depth at Banco Capiro. Diversity values closest to 1 were shown to be at 15m reef depth. According to Wiley and Sons (2010), high biodiversity has been shown to enhance ecological stability on small spatial scales. Reefs are the most complex and diverse communities in the sea. Diversity is not found in the organisms that create the three-dimensional structure of reefs- reminder there is only 66 *Scleractinian* species in the Caribbean. It is rather, the multitude of small organisms living within the corals that are responsible for the staggering number of species associated with reefs. Wiley and Sons (2010) state that there is a serious lack of attention to overall biodiversity. They attribute this to assumptions that extinction is less common in the ocean and also from the vast unknown diversity associated with corals; this makes it difficult to assess its loss.

<u>Limitations</u>

With field research there are always limitations to a study. For this project time and retrieving equipment containing data were major limiting factors. The study was short, only six weeks of data collection. Banco Capiro turbidity readings should be taken over a longer period of time and comparisons to other reefs further from the shoreline. Turbidity readings can be difficult in times of high sun or wave intensity. They may also show very different, next day readings, following a night of rain. Not all sediment traps were retrieved due to lack of time and resources needed at the end of the season. Some dives were restricted by days of bad weather: storms, high winds and high waves. Hobo loggers placed to record temperature and water chemistry every 5 minutes were lost at sea. Taking the cameras down to record transects glitches at times.

Further Research

Further investigation on the importance of environmental parameters shaping a healthy reef system would include a study involving both the dry season and the rainy season of the bay. As seen in research done by (Mumby et al 2014), it is thought that coral species can only survive within narrow salinity and temperature ranges. As sea-surface temperatures increase effects on climate change can result in problems for coral such as thermal bleaching and ocean acidification. Temperature was recorded an average of 29^{0}C throughout the season and bay. It was a degree higher than recorded averages of 28^{0C} from dive sites outside the bay on, the island, Utila, Honduras. Salinity samples read a consistent Caribbean salt content. These conditions may differ when compared to rainy season values. The lagoon lined with mangrove forests open up and a cool freshwater silt channels into the bay starting in the fall months. This experiment did not account for further investigation of these parameters.

Studies involving important reef organisms in further investigations to the Bay's health may include *Diadema* sea urchin, fish abundance, or studies on the invasive lionfish.

Studies of long temporal range for macroalgae and coral cover as they demonstrate the trends in reef dynamics needed for future reef monitoring programs (Selig and Bruno 2010).

Conclusion

It was the goal of this study to characterize benthic communities and the environmental parameters that have the potential to influence community structure of a healthy population of *Scleractinian* coral species in Tela Bay, Honduras (hard coral coverage as high as 80%), and then compare that area to a less healthy, but typical (coverage of 17%), reef nearby. There were distinct differences between the reefs, including reef depth; turbidity levels; and sedimentation rates. Turbidity levels were very low at Ensenada and high at Banco Capiro in comparison. Turbidity may create shading from sunlight and prevent phototrophic photosynthesis process or it may stimulate heterotrophic mechanisms and provide protection from increasing sunlight intensities. Sedimentation are high at both reefs resulting from anthropogenic stressors to the area. Despite high sediment coral cover is incredibly high with low algae at Banco Capiro. Ensenada demonstrates a phase shift to a macroalge dominated system. Three transects at 5 different dive sites on the main reef at 10m and 15m and then three transects at a nearby reef of 3 sites at 5m were conducted to determine coral and macroalgae cover, relative abundance, species diversity, and dominant species. Assessment of the benthic community and the environmental conditions determine that coral ecosystems are variable to levels of abiotic conditions. No one parameter was determined to be the result of a healthy Tela Bay reef.

REFERENCES

Anthony K.R.N. 2000. Enhanced particle feeding capacity of corals on turbid reefs (Great Barrier Reef, Australia). *Coral Reefs, 19(1), 59-67.*

Anthony K.R.N. Lacombe P. 2002. Coral reefs in turbid waters: sediment-induced stresses in corals and likely mechanisms of adaptations. *Proceedings 9th International Coral Reef Symposium, Bali, Indonesia.*

Bellwood, D.R., Hoey, A.S., Ackerman, J.L., Depczynski, M. (2006). Coral bleaching, reef fish community phase shifts and the resilience of coral reefs. *Global Change Biology 12(9): 1587-1594*

Bruno J.F. Selig, E.R.Casey, K.S. Page C.A. Willis B.L. Harvell C.D. Sweatman H. Melendy A.M. (2007). Thermal stress and coral cover as drivers of coral disease outbreaks. *PLoS Biology 5(6), e124*

Chornesky E.A. Peters E.C. 1987. Sexual reproduction and colony growth in the *Scleractinian* coral *Porties Astreoides. The biological bulletin, 172(2), 161-177.*

Diaz-Pulido G. Garzan-Ferreira J. 2002. Seasonality in algal assemblages on upwelling-influenced corals in the Columbian Caribbean. *Bot Mar, 45, 284-292.*

Gardner T.A. Cote I.M. Gill J.A. Grant A. Watkinson A.R. 2003. Long-term region wide declines in Caribbean corals. *Science, 301(5635), 958-960.*

Guadayol, O. Silbiger, NJ. Donahue, MJ. Thomas, FIM. 2014. Patterns in temporal variability of temperature, oxygen and pH along an environment gradient in a coral reef. *PLoS ONE, 9(1), e85213.*

Hughes, T. P. 1994. Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science 265(5178), 1547-1551*

Lidell W.D. Ohlhorst S.L. 1986. Changes in benthic community composition following the mass mortality of *Diadema* at Jamaica. *J Exp Mar Biol Ecol, 95, 271-278.*

Miller, J.W. 1991. “Scientific Diving Procedures,” NOAA *Diving Manual,* National Oceanic and Atmospheric Administration, Manned Undersea Science and Technology Office, U.S Department of Commerce, Washington, D.C., pages 8-28 to 8-30.

Mumby P.J. Foster N.L. Glynn Fahy E.A. 2005. Patch dynamics of the coral reef macroalgae under chronic and acute disturbances. *Coral Reefs, 24, 681-692.*

Mumby, P. J., A. Hastings, and H. J. Edwards. 2007. Thresholds and the resilience of Caribbean coral reefs. Nature 450: 98-101

Ohllhorst, S.L. Liddell, W.D. Taylor, R.J. Taylor, J.M. 1988. “Evaluation of reef census techniques”, Proceedings of the 6th International Coral Reef Symposium, 2, 319-324.

Parsons, T.R. Maita, Y. Lalli, C.M. 1984. *A Manual of Chemical and Biological Methods for Seawater Analysis,* Pergamon Press, New York, NY.republic of the marshall islands. 2013. *Diversity, 5(3), 522-540.*

Robert M.L. Peckol P. Scordis Curran H.A. Brown-Sacacino J. 2004. Population recovery and differential heat shock protein expression for the corals, *A.agaracite, A. tenuifolia,* in Belize. *Mar Ecol Prog Ser, 282, 151-160.*

Rogers C.S. 1990. Responses of coral reefs and reef organisms to sedimentation. *Mar Ecol Prog Ser, 62, 185-202.*

Selig E.R. Bruno J.F 2010. A global analysis of the effectiveness of marine protected areas in preventing coral loss. DOI: 10.1371/journal.pone.0009278

Smith D.J., Etienne M., Springer N., Suggett D.J. 2008. Tolerance, refuge and recovery of coral communities to thermal bleaching: evidence from reefs of the Seychelles. Proceedings of the 11th International Coral Reef Symposium, Fort Lauderdale, Florida. http://www.nova.edu/ncri/11icrs/proceedings/files/m12-04.pdf

Suggett, D.J., Smith, D.J. (2011). Interpreting the sign of coral bleaching as friend vs. foe. Global Change Biology 17(1): 45-55

Tanner J.E. 1995. Competition between *Scleractinian* corals and macroalgae. An experimental investigation of coral growth, survival and reproduction. *J Exp Mar Biol Ecol, 190(2), 151-168.*

Wiley J. Sons. 2010. Life in the World's Oceans: Diversity, Distribution, and Abundance. *Technology and Engineering ebook, Chp.4, 14-38.*

Williamson, DH. Ceccarelli, DM. Evans, RD. Jones, GP. Russ, GR. 2014. Habitat dynamics, marine reserve status, and the decline and recovery of coral reef fish communities. *Ecology and Evolution, 4(4), 337-354.*

Appendix I Risk Assessment

Risk	Likelihood	Severity	Control Measures
On site Safety	L	M	Security guards 24 hrs per day
Dive sites not appropriate for in-water activities	L	VH	Certification in pools Boats only depart once all clear is given
Malaria	M	M	Bring and take adequate malaria medication
Insufficient communication facilities	L	H	Continuous communication. Land lines and cell phone coverage to contact doctor. Private hospital 20 minutes away, with 24 hour emergency care.
Injury or illness requiring treatment at Tela; Additional treatment	M	M	An on site doctor and several only 20 minutes away. 24 hour emergency line available to volunteers with insurance
Diver with decompression sickness requiring a recompression chamber	L	H	Recompression chamber 90 minutes away. Trained personal to handle situation in meantime.
Crocodile monitoring in mangrove Lagoons	L	M	Monitored by experienced staff. No water entry containing crocodiles.
Tanks falling off dive benches; Falling over in and out of boat; Falling over whilst on route; Hitting head when backwards roll into water; Decompression sickness; Hit boat when surfacing; Left at the end of the day; Separated from	L M L L L L	M H H M VH VH	Ensure all staff and volunteers are instructed and aware at all times in all situations. Communication and maintaining balance and safety in the boats is important. Proceed diving activities with caution and followed completely!

buddy; Carried away by down currents			
Barotraumas	M	M	Abort dive is equalisation is not possible. Be aware of seriousness of not following proper respiration procedures.
Hurricane or severe weather warnings	M	H	Camp manager monitors weather on daily basis If serious, HCRF Director ensures safe accommodations and transportation for all volunteers and staff