A Capstone Project
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in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science

By
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To the ESSP Faculty:

The primary goal of my capstone is to determine if there has been any change in percent coral coverage (PCC) on the Las Redes Reef, in Akumal, Mexico between 1994-2001. The secondary goal of my capstone is to suggest a standardized monitoring protocol based on the past and current data collection methods used and on other monitoring projects that are currently being implemented. This will help to keep the collection methods of the reef consistent in order to obtain a larger data set in which to analyze the PCC of the reef.

Akumal, Mexico is located on the Caribbean side of Mexico between Cancun and the Belize border. It is the most accessible reef from shore along the Yucatan Peninsula, thus making it easier for researchers, such as myself, to collect data from this reef.

Coral reefs are very important to the survival of about half a billion people in this world. They provide food and income to those that have contact with these ecosystems everyday. I believe that coral reefs are a great indicator as to what is happening to our environment. They are so fragile and react to any small change in their environment. By implementing a monitoring program these reefs can give us a look at whether they are maintaining their health or if they are in decline. When a coral reef is dying or dead there are several people who suffer from this, especially the economic loss of the locals.

In the summer of 2001 I spent about 8 weeks as a student in a class called Tropical Marine Science offered through Cornell University, taught by Dr. John Bruno, which took place in Akumal, Mexico. While I was there I gained interest in their reef-monitoring program that they had in place. I implemented the collection of the data for this program for 2001. Because of my interest in what was being done I started to do some research as to what had been done in the past. I noticed that there were several years of data collected but there were no analyses done on these data. I had decided to analyze the data and report it for my capstone project. I had no idea what task I was taking on. There were several problems that needed to be solved such as, different collection methods were used over the years, not all transects were sampled each year, and in collecting the data the permanent transects were hard and time consuming to find. Because of these problems I decided that there needed to be an easier way for someone else in the future to collect and analyze the data on the Akumal Reef. Thus the “Akumal Reef Monitoring Project” was written to give guidance to those who, in the near future, will be collecting data from the Akumal Reef and will keep this project on going.

For the Capstone assessment the areas of depth that I am choosing are application of knowledge in the physical and/or life sciences (MLO#3) and acquisition, display, and analysis of quantitative data (MLO#5).

Thank you,

Liz Dries

ABSTRACT:

The value of coral reefs for developing countries and areas where tourism is on the rise make the management of the reef a high priority. Akumal, Mexico is no exception. For management to be effective, information for accurately evaluating the condition of the reef is critical. This study was done to test the hypothesis that there has been no change in percent coral coverage (PCC) on Las Redes Reef, in Akumal, Mexico between 1996 and 2001. To test this hypothesis I compared data I collected during the summer of 2001 to PCC data collected by interns and students working in Akumal from 1994 to 2000. A major challenge to testing this hypothesis was that PCC data were collected using different methods during different years. Consequently, statistically meaningful comparisons could only be made within the years 1996 – 1998 and 1998 – 2001. Within both of these time periods, there was no significant change in PCC. However, these results are questionable because of the small data sets they are based on. Based on these findings I am proposing a standardized monitoring protocol for the Las Redes Reef in Akumal, Mexico. This protocol suggests the most economical and streamlined method of collection for monitoring the Las Redes Reef. Collecting PCC using the point-intercept method on haphazardly placed transects will do this. It will assure that in the future when data is collected there will be a larger data set in which to analyze and obtain more accurate results. By having a standardized monitoring protocol in Akumal, Mexico it is my hope that data will be collected each year and in the future this data will be used to help manage the reef of Akumal, Mexico.

INTRODUCTION:

Coral Reefs are among the most diverse and valuable ecosystems on earth. Reefs are the most biologically productive of all marine ecosystems (Brown, 1993) and they provide economic and biological services to millions of people as shoreline protection, recreation and tourism, and sources of food, jobs, and revenues. On average, reef tourism provides about $7.6 million per 150,000-$km^2$ reef/year (Berg, 1998). This is a staggering figure for an ecosystem that covers less than one percent of the earth's surface (Eisman, 1996). While coral reefs may be invaluable to a nation, they are also vulnerable to environmental

changes, particularly those resulting from human activity. Some of these activities include pollution through eutrophication and sedimentation, over-fishing, destructive fishing practices, dredging and shoreline modification, vessel groundings and anchoring, snorkeling, and unsafe SCUBA diving practices (Eisman, 1996). Estimates that 10% of all coral reefs have been destroyed beyond recovery and that 30% are in critical condition and may die within 10-20 years, especially those near human populations.

With such a high value put on coral reefs and a high degradation rate, a strong need has evolved to ensure the continued survival of reefs in almost all of the communities that use these tropical ecosystems as their main source of revenue. Thus, there is also a strong need for long-term and large scale ecological studies to assess any changes that are occurring on the reefs, whether it be from human impacts or natural stresses (Pennisi, 1997). These long-term studies of reefs are useful for many reasons. First, many processes that occur on the reef cannot be detected in any short-term study. Second, by using long-term studies one can determine the history of the reef community, which can help to explain the impacts that it has on today's reefs (Hughes, 1994). Third, monitoring is essential in analyzing natural and recurring events on the reef. Fourth, monitoring helps to assess the damage by human impacts throughout the years.

An easily accessible reef in Akumal, Mexico has been the study site of a monitoring program that was started in 1994. The Akumal Reef is the northern

part of the larger barrier reef that lies along the Eastern coast of Mexico, Belize, and Honduras, the second largest barrier reef in the world. The northern most section of this reef lies along the Yucatan Peninsula of Mexico, the Cancun-Tulum corridor. Akumal, Mexico is about 70 km south of Cancun and remains one of the smaller resorts. Akumal lies on approximately 3.4 km of coastline and has many rocky points and shallow bays with sandy beaches. This small resort of Akumal lies just behind Akumal Bay. It has several major hotels, two dive shops, several condominiums, several restaurants and a beach bar. The bay is used for snorkeling, swimming, and boating mostly by tourists. This area is highly populated by tourists that threaten the future of the Akumal reef through further development and direct contact with the reef.

In order to prevent further development and to preserve its marine resources, the ***Centro Ecologico Akumal*** (CEA), a grassroots ecological group, in cooperation with Cornell University's Tropical Marine Science class, began an ongoing, long-term reef-monitoring program in 1994. This program surveyed the Akumal reef yearly during the summer months to obtain percent coral cover (PCC) and to monitor the stability of the reef. Although there has been a program in place since 1996 and data collected since 1994, the complete data set has never been organized or analyzed.

The purpose of this study was to determine if the methods currently being used or the methods that have been used in past years are sufficient and efficient

enough in collecting data on the Akumal reef. The goals were to (1) collect PCC data for 2001, (2) collect, organize, and analyze the data collected from past years, (3) determine if the collection methods used were sufficient enough for collecting the data, (4) set up a recommended standardized protocol for data collection on the reef by comparing different collection methods from this and other monitoring programs.

METHODS:

Study Site:

The portion of the reef that was studied is called the Las Redes Reef and it is located at $20^{o}23'.25.08"$ N and $87^{o}18'.14.69"$ W. Data were collected at three different depths, 10, 15, and 20 meters.

Summer 2001 Data Collection:

Working with trained volunteer divers, I collected PCC for 2001. This involved looking at past sampling protocols and reviewing old data to see what and how it was collected to determine which method would be used for sampling that year. The permanent transects were found using maps from previous years and also through the knowledge of Dr. John Bruno, who had done the sampling on the same transects in past years. There were about 20 dives made in order to collect this data.

Historical Data:

There have been two different methods of data collection on the Akumal Reef to date: line-intercept was used from 1996 to 1998 and point-intercept was used from 1998 to 2001.

Line-Intercept Method:

The line-intercept method is performed by securing a transect line to both ends of the transect. 15m transects were placed in 1996 and 20m transects were placed in 1997 and 1998. Every live coral colony that crossed over or under that transect line was recorded. Each colony was identified to species-specific location and the length of the colony along the transect line was measured. The total length of live coral and of each species along each transect was calculated and used to compute PCC as follows:

PCC = (total length of live coral/transect length) x 100%

Point-Intercept Method:

The point-intercept method is similar to the line-intercept method and is performed by securing a transect line to both ends of the transect. 20m transects were placed for 1998 to 2001. Every 10 cm a reading was taken. PCC was computed as follows:

PCC = (number of points given by a live coral colony/total number of points) x 100%.

Both of these methods were used in 1998, thus allowing a comparison to be done between the two methods.

RESULTS:

Mark J. Brush, through Cornell University, collected baseline PCC data in 1994. In 1995 Cristin Amico, also through Cornell University, collected PCC data on the Akumal reef and compared this data to what Brush had. These data were collected using the line-intercept method mentioned above. Although data were collected for those two years they could not be used in the analysis due to the lack of permanent transects laid.

There were permanent transects placed in 1996 by the Tropical Marine Science class. These transects were very difficult and time consuming to find each year to collect data off of. Although there were maps drawn to help identify landmarks to find the transects with it was still difficult to locate these transects. Not each year was consistent in collecting data from these permanent transects. Because of this they were not used in the analysis for this study. Some of these transects have not been found since 1998. See chart 1, 2, 3, and 4 for transects that were sampled.

No data were collected for the year 1999 because Cornell University did not offer the Tropical Marine Science class through which the data has been collected in the past.

PCC for each transect for each year were calculated as indicated above. After PCC was obtained the organization was done by looking at maps and determining which transects were sampled and what was collected on each of those transects.

The transects selected for this study were used because the same sampling method was used for at least 3 transects at that site and for at least two consecutive years. A regression was done comparing the two different methods used in 1998. The regression was done to determine if there was a correlation between the line-intercept and point-intercept methods. I wanted to be able to combine the two different methods used in order to obtain stronger results. A non-parametric Kruskal-Wallis statistical test was performed on the PCC because of the small sample size.

Point-Intercept vs. Line-Intercept Method:

A regression analysis was done to determine if there was a correlation between the two different methods used for data collection, point-intercept and line-intercept (see chart 1). There was correlation between the two methods (r^2=0.087, p=0.2676). Data sets were analyzed separately based on which method was used for data collection.

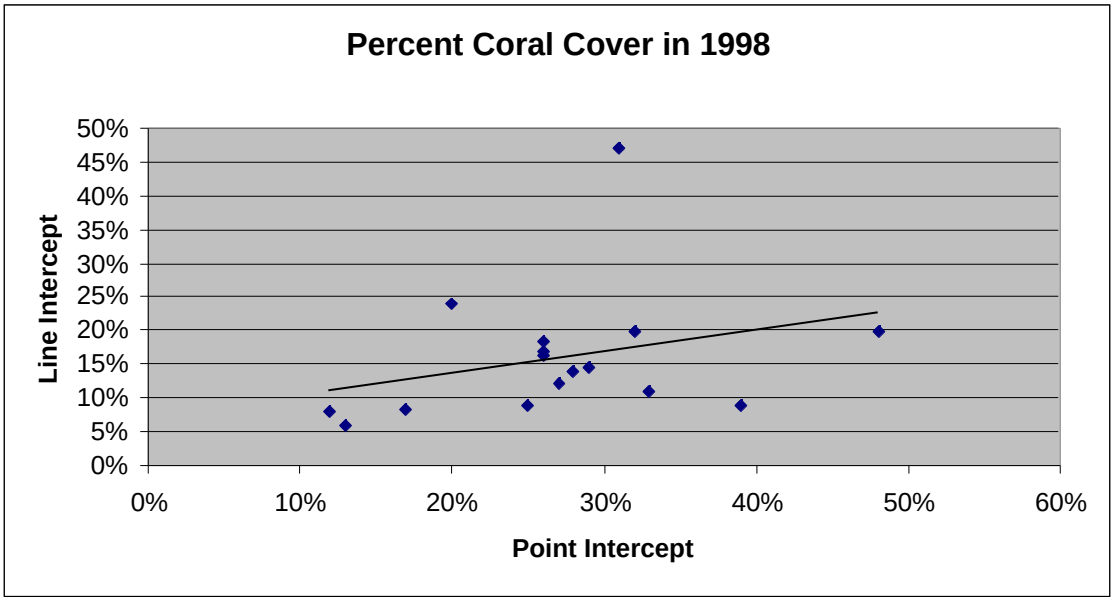

Chart 1 – This shows the comparison between the two different methods, point-intercept and line-intercept, in the year 1998 for all the data collected that year. This graph shows that there is not a significant correlation between the two methods. (y = 0.3174x + 0.0726)

Las Redes Inner Reef (10m):

The first comparison done was for the years 1996-1998 for transects 34, 50, and 66R using a Kruskal-Wallis statistical test. These were the only transects at that site sampled for all three years. The results were that there was no significant difference in PCC throughout those years between those transects (p=0.8752).

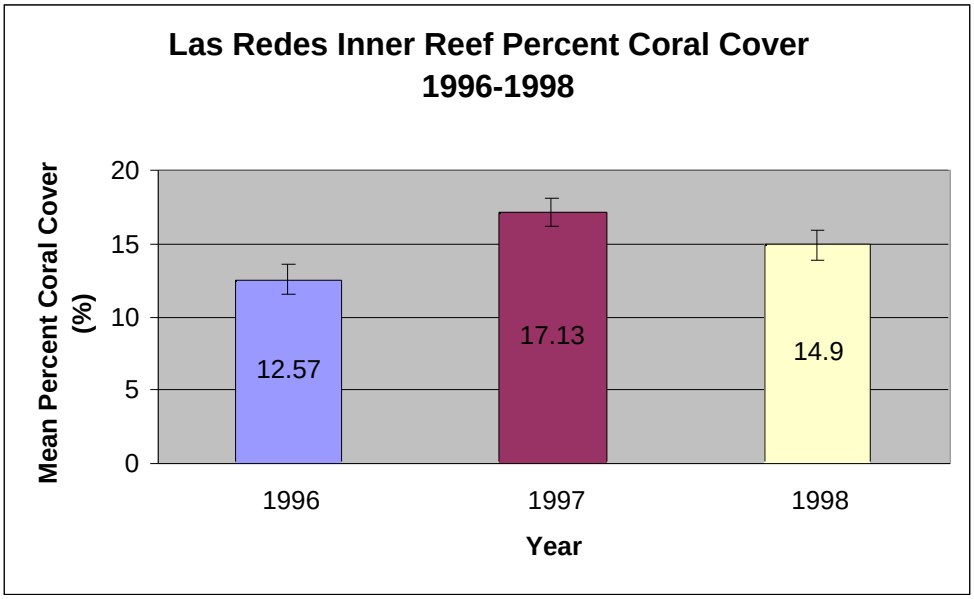

Chart 2 – This shows the mean PCC for Las Redes Inner Reef transect #'s 34, 50, and 66R between the years 1996 and 1998. Standard error is +/- 1.0.

Las Redes Mid-Deep (20m):

The second comparison was done for the years 1996-1998 for transects 26, 42, and 58 using a Kruskal-Wallis statistical test. The results were that there was no significant difference in PCC throughout those years between those transects (p=0.4298).

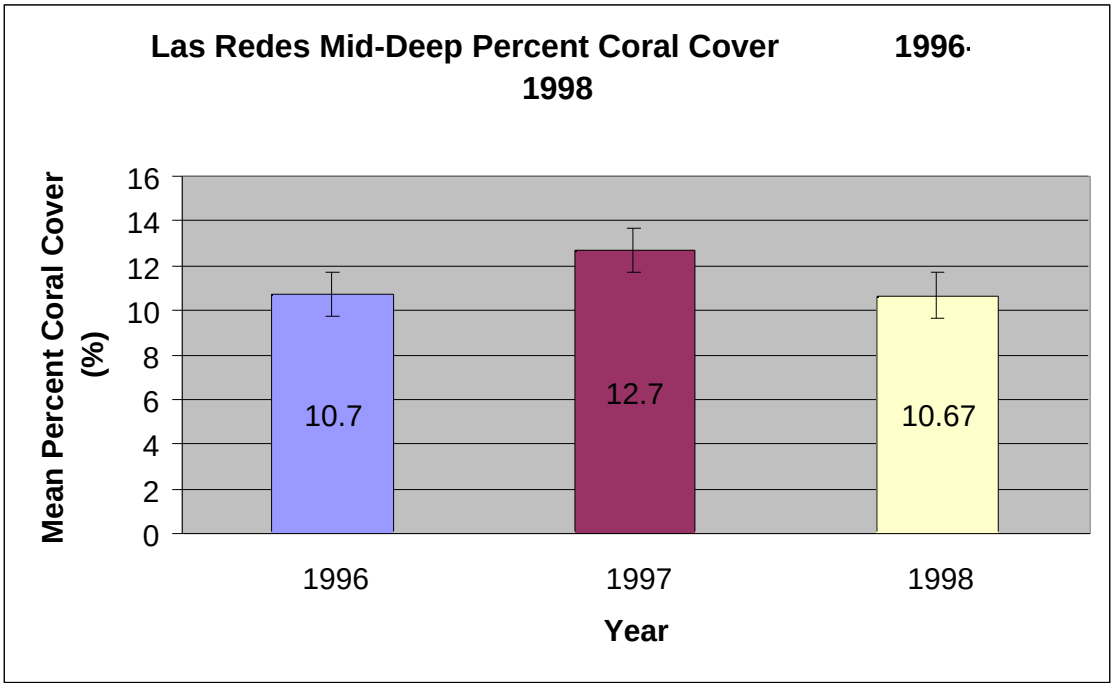

Chart 3 – This shows the mean PCC for Las Redes Mid-Deep Reef transect #'s 26, 42, and 55 between the years 1996 and 1998. Standard error is +/- 1.0.

Las Redes Mid-Shallow (15m):

The third comparison was done for the years 1998-2001 for transects 65, 67, and 69 using a Kruskal-Wallis statistical test. The results were that there was no significant difference in PCC throughout those years between those transects (p=0.0794).

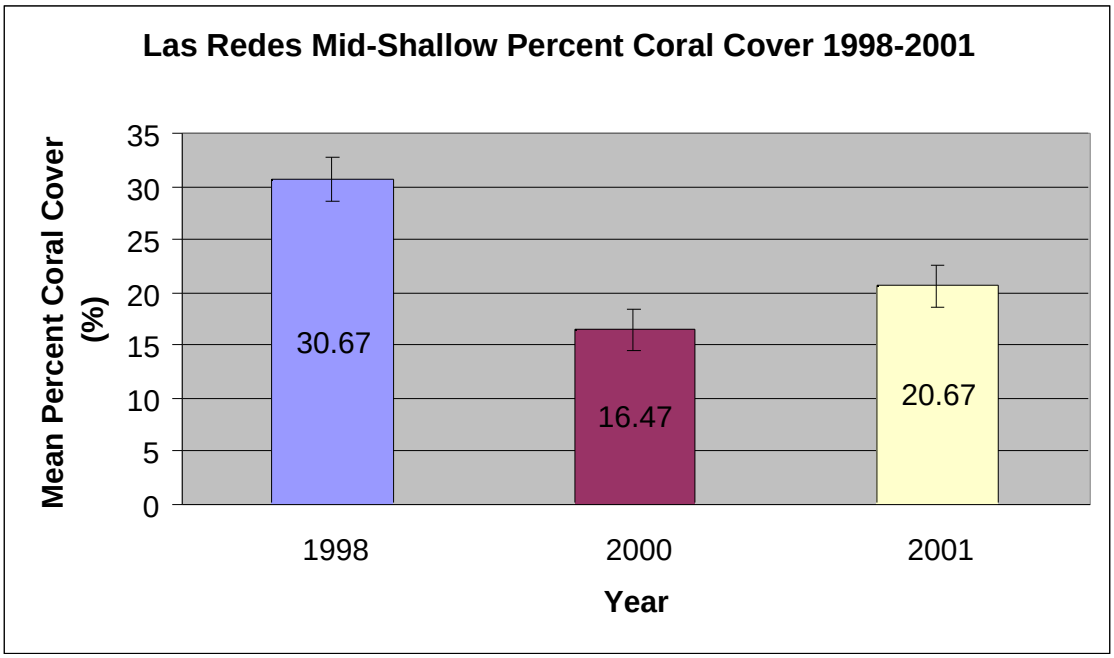

Chart 4 – This shows the mean PCC for Las Redes Mid-Shallow Reef transect #'s 65, 67, and 69 between the years 1998 and 2001 (excluding 1999). Standard error is +/- 2.0.

Las Redes Inner Reef (10m):

The fourth comparison was done for the years 2000-2001 for transects 66R, 66Y, and 68 using a Mann-Whitney statistical test. The results were that there was no significant difference in PCC throughout those years between the transects (p=0.8273).

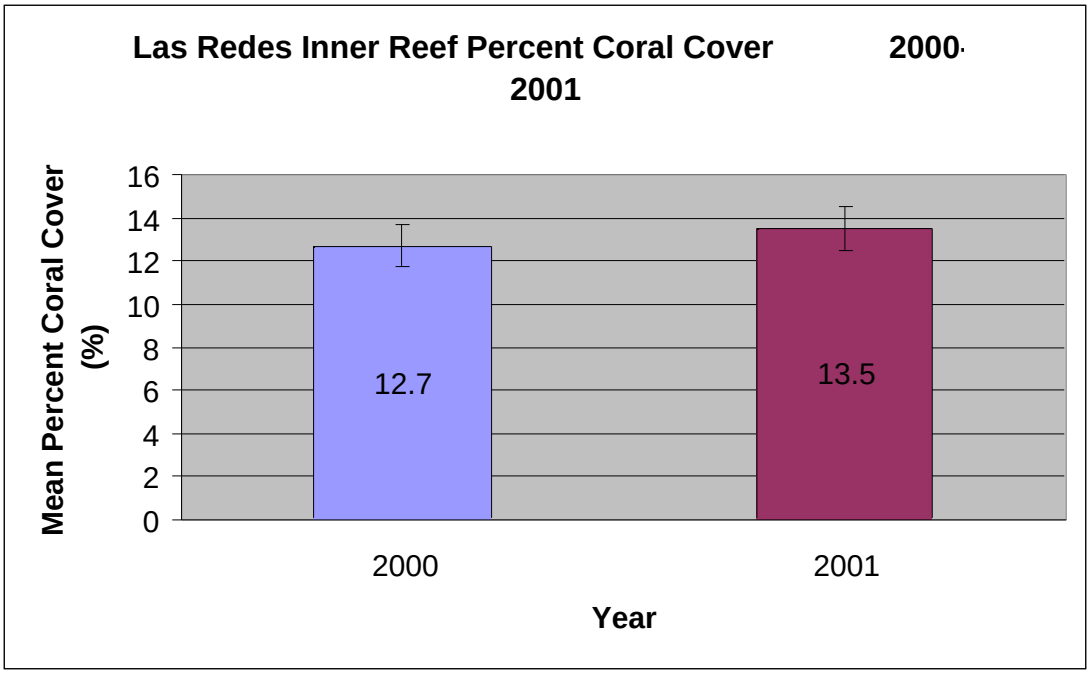

Chart 5 – This shows the mean PCC for Las Redes Inner Reef transect #'s 66R(154), 66Y(153), and 68(152) between the years 2000 and 2001. Standard error is +/- 1.0.

DISCUSSION:

Although the data show that the PCC has not changed significantly throughout the years it is a very weak conclusion. This is because of the small data set that were analyzed due to the different methods used over the years.

The results were marginally significant for PCC at Las Redes Shallow from 1996-1998, which could be due to diver discrepancies. Each diver is trained in a different way and therefore would have their own opinion as to what exactly is to be recorded from the transect. Some divers do not know the corals to genus and species while others do not know the difference between encrusting sponges and algae. This would cause the numbers for either algae or coral to be higher than it really is. This is one reason to have trained scientific divers that know exactly what they are going to be observing and know the corals to both genus and species or know the difference between corals and algae, collect the data on these transects.

There were only a few transects at Las Redes reef that could be used in this analysis. Most of the data collected between 1996-2001 were not used in the analysis because there were different sampling methods used to obtain this data. This was frustrating to me because a lot of time and effort was put into collecting that data and they could not be analyzed. There needs to be a standardized protocol for collecting data on the Las Redes reef in order to have a more confident statistical analysis outcome. A standardized protocol will also keep the

data collection consistent over the years and also with what other monitoring programs are doing.

With the increasing decline in coral reefs there needs to be an explanation as to why they are dying. In order to gain a greater knowledge of reef composition and better understanding of why these reefs are dying data need to be collected in order to monitor coral reefs over a long period of time. A short term monitoring program only gives a small amount of data to be analyzed and no strong conclusions can be made from these. To have a strong data set there needs to be monitoring programs put into place on accessible reefs that are in danger of dying or are dying. Within in these monitoring programs there needs to be a standard protocol for collected and analyzing the data.

Other Monitoring Programs:

There have been several monitoring programs put into place and have been implemented throughout the years. Following are some examples of what is being done today and what their program consists of:

Vieques Island, Puerto Rico:

The U.S. Navy is complying with Executive Order 13089 (implemented by President William Jefferson Clinton in June 1998) and the Initiative for Coral Reef Protection at Naval Station Roosevelt Roads (NSRR), Puerto Rico. This study includes the reefs in and around Vieques and St. Croix.

The Navy is collecting baseline assessment of coral reefs at the eastern ends of Vieques. This study has a total of 24 permanent monitoring sites and has a total of 64 permanent transects. Each transect is 20 m long with permanent end stakes. Each transect has a width of 1.5 m for a total of 30 m^2. At each transect, the data parameters collected include coral species richness as well as incidence of coral injury, including disease, damage, and bleaching. A photographic record of the 30 m^2 transects are taken (40 quadrats each .75m x 1m) with an underwater digital camera and quadrapod quadrat framer. A total of 1,440 m^2 of reef are photographed at Vieques and 480 m^2 at St. Croix. Quadrat images are processed via point counting software to determine percent coverage of corals and other organism or substrate classifications. Fish populations are also counted. Data will be collected from these permanent transects once a year using the same methods.

Caribbean Coastal Marine Productivity Program (CARICOMP):

This is a manual put out by CARICOMP that has preferred survey methods for the Caribbean. They suggest that 10 randomly placed permanent transects 10 m in length be placed per site or depth. The data are collected using the line intercept method. They suggest that corals be identified to genus and species, algae be identified in specific categories (turf algae, fleshy algae, calcareous algae, and encrusting calcareous algae), and non-living substrata be identified in specific categories (bare

rock, bare sediment, rubble, boulders and overhangs). CARICOMP recommends recording data from these transects once a year, at the same time each year. Because this should be an ongoing survey of the reef permanent transects should be placed in order to have a more statistically confident outcome.

Coral Reef Assessment and Monitoring Program (CRAMP) in Hawaii: CRAMP examined the ability to detect change in coral cover using various methods on a reef in Hawaii. These three different methods, photo quadrats, point intercept, and video transects, were used to investigate sampling precision, observer variability, and statistical power. This study was done at 6 different sites using permanent transects 10 m in length. CRAMP recommended that photoquadrats be used and also video transects. They found these to give the most precise and accurate analysis of the reef. Although they are both initially more expensive than the point intercept method they have a stronger statistical power and they also have archival data that can be looked at in the future.

These are all great examples of how monitoring programs have been implemented and are still active today using specified data collection to be followed each year. Vieques Island and Hawaii are both located in the United States and they both use photoquadrats to collect their data. This may be the most accurate and best method for PCC collection; it is also the most expensive

(CRAMP, 2001). However, these programs do not work for every reef in the world. Most of the funding for these programs comes from government-funded programs, non-profit organizations and donations. Because of this there are several reefs all over the world that are in need of a monitoring program that their country cannot afford to implement. Unlike the United States, most other countries do not have the government support to help set up a monitoring program for their local reefs. This is surprising because most developing countries depend and rely on their local reef for food and income (Benoit, et al, 1999). Globally, half a billion people are estimated to live within 100 km of a coral reef and benefit from its production and protection, so why are there so few monitoring programs (Benoit, et al. 1999)?

Akumal, Mexico is a small pueblo in the heart of the Yucatan Peninsula. Most of its residence depend on the reef for their survival based on tourism and fishing. In order for them to be able to survive they need to protect their reef and the activities that occur in and around it. This would be done through a reef monitoring program. As mentioned before, there have been several years of data collection on the reef but with no consistency over the years.

During the summer of 2001 I was in Akumal collecting data for this program in the hopes that the compilation of this data will aid in Akumal proposing to the government that they make their reef a Marine Protected Area. While I was collecting this data and reading other monitoring programs I noticed a few

discrepancies in the collection that needed to be addressed. I noticed that the more experience one had in collecting data, via transects, the more accurate and faster data could be collected. You must know what type of data you are collecting and it helps to understand the reef before collecting data. Trained scientific divers that can train other scientific divers are a great example of how to pass on excellent skills needed to lie transects. I also noticed that it was very time consuming to find the permanent transects. Although it is the best way to monitor a reef, it is not always the most efficient. When you are on a timed schedule you need all the hours under water collecting data that you can get. Spending half of your time just trying to find those transects is not practical, although it is suggested in most monitoring programs. In Akumal, because there is no government funding and all of the data collection so far has been from students in the Tropical Marine Science course, there are very few options as to what is practical for data collection on the reef there.

Suggested Data Collection Protocol For Akumal, Mexico:

Based on my experience in data collection on the reef in Akumal, on other monitoring programs currently in place and their collection methods, I am proposing a standardized monitoring protocol for this reef.

PCC Collection:

Because PCC can give an overall picture of the reef by determining how much PCC has changed over the years, it is the only data that should be

collected on the reef in Akumal. Of course, this is time permitting. If there is time then other data such as fish abundance and an overall picture of the reef, done by a manta tow, can be collected. PCC is the most practical and economical method for analyzing the reef in Akumal, Mexico due to time constraints and funding.

Although permanent transects have been used in the past I am suggesting that transects are chosen using the haphazard method. Dr. John Bruno, who teaches the Tropical Marine Science Course in Akumal, Mexico, suggests that this would be the best way for data collection on that reef. This will save a large amount of time in finding the permanent transects, as I have experienced. At Las Redes Reef there were three different depths sampled in the past; this should be kept a constant at 10 m, 15 m, and 20 m. At each depth there should be at least 20 transects laid at 20 m in length. The larger the number of transects sampled at each site the better the confidence level in the analysis will be. Most monitoring programs today do 10 – 20 m permanent transects.

The point-intercept method should be used in data collection on the Akumal Reef. This seems to be the fastest way in collecting PCC. As stated earlier, a reading should be taken every 10 cm for the length of the transect starting at 0 cm and ending at the 20 m mark. Hard corals should be recorded to genus and species, soft corals and algae should be

recorded to at least genus, crustose coralline algae (CCA) should be recorded as CCA, sponges should be recorded as sponges, and other substrata should be recorded as rock, rubble, sand, and dead coral. This will not only give the PCC of that transect but also it will also give live coral abundance, percent algal coverage, and algal abundance. So, by just doing one run of the transect several points of data can be recorded and analyzed. Each transect's data should be put into a spreadsheet in raw form so as to be analyzed later. Data collection on the reef should occur at least once a year if not every other year, time permitting. Although just doing transects does not seem like much, it is a lot of work and large amounts of information can be gained from doing these if done the same each year.

As stated earlier there may be a difference in opinion between divers collecting this data. Therefore, before collecting the data for this reef each diver should be knowledgeable in identifying the hard corals to genus and species, soft corals and algae to genus and sponges. This took me about 2 weeks of intense classroom courses and diving to be able to feel confident enough in identifying all of the organisms and substrata on the reef in Akumal. If a class in not available to the diver then they should refer to the Humann – ***Reef Coral Identification*** manual for exact descriptions of corals on the reef in Akumal.

CONCLUSION:

Monitoring the coral reefs all over the world is becoming a task that needs to be done in order to preserve the livelihood of these amazing ecosystems. More studies and monitoring needs to be done but there is always the issue of funding and where the money comes from. With the suggested monitoring protocol it is very low cost thus allowing the Akumal Reef to be analyzed by those that are trained. Although the suggested monitoring protocol may not work on other reefs in other countries, I believe that it is the most practical solution for Akumal to monitor their reef. If this method is used in the future then analysis can be done with data collected in 1998-2001. It is my hope that sometime in the near future the data from this monitoring program can be used to help the people of Akumal protect their reef by proposing to the government of Mexico that their reef's health is being threatened and there needs to be a action taken. Hopefully this will lead to a Marine Protected Area for the Akumal Reef and it will be thriving when I come back there in 30 years.

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