An Assessment of Coral Reef Conservation Programs: Towards a Community-Based Approach

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Adam Howard Feldman

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Table of Contents

Abstract

The multiple-use benefits of coral reefs include tourism, food resources, medicinal uses, and building materials. However, many studies suggest that these important ecosystems are slowly declining and disappearing, which has lead to the creation of many coral reef monitoring and management programs. Approaches to monitoring and managing coral reefs can be divided into two broad categories: top-down and bottom up. Top-down approaches to monitoring and managing coral reefs don't involve the community, and tend not be as effective as bottom-up approaches that involve all community stakeholders. However, these bottom-up approaches vary in their degree of effectiveness. I reviewed 5 coral reef monitoring programs for the purpose of identifying their strengths and weaknesses and making recommendations on how to improve or establish effective community-based programs. Common strengths included a continuing education program, sustained interaction and communication with all community stakeholders, acceptance by the community, and community involvement in decision-making processes. Programs lacking these characteristics tended not to be as successful. Thus, to be effective, a community-based program should include ongoing educational programs, and involve the local community stakeholders in all aspects of the monitoring and management program. In addition, successful programs will also provide continuous feedback to local officials.

1.0 Introduction

Coral reefs contain some of the most breathtaking and diverse ecosystems on the planet. Not only are they complex and productive, but also they support hundreds of thousands of species. Over the past few decades, the importance of coral reefs for tourism, fishing, building materials, coastal protection and discovery of new drugs and biochemicals has increased (Hoegh-Guldberg, 1999). They also give us indications of whether or not ocean waters are healthy or not (Hoegh-Guldberg, 1999; Wilkinson, 2000).

As indicated by the Ecological Society of America (2000): 1) Coral reefs occupy less than 1% of the ocean floor, but are inhabited by at least 25% of all marine species; 2) scientists estimate that more than 25,000 described species from thirty-two of the world's thirty-three phyla live in coral reef habitats – four times the number of animal phyla found in tropical rain forests; 3) they also act as habitat and nursery grounds for 10 to 20% of the world's fisheries; and 4) they are intimately connected to other marine communities such as mangrove forests, sea grass beds, and to open seas as water currents transport larvae, plants, animals, nutrients and organic materials. Coral reef structures are home to thousands of fish, lobsters, sea turtles, and other species found no where else. U.S. coral reefs cover about 6,500 square miles, over 90 of them associated with U.S. islands in the western Pacific. The remainders are located off Florida, Texas, and the U.S. islands in the Caribbean. (NOAA, 2000*a*).

Corals are tiny plant-like animals that depend on clean, clear waters and sunlight to survive. Most corals are colonial organisms consisting of thousands of individual polyps (Souter and Lindén, 2000). Like other animals, coral polyps capture and eat food. The plant cells within the coral provide an additional source of nutritious compounds to the coral. The extra energy from the algae allows corals to secrete a calcium carbonate skeleton. When many living and dead skeletons fuse together over time, a coral reef is formed (Hodgson, 1998). Light is essential for the survival of reef-building corals and as a consequence, their distribution is limited to depths shallower than 100m (Hoegh-Guldberg, 1999).

Coral reefs are unique among marine ecosystems because they flourish in waters that are virtually devoid of nutrients (Hoegh-Guldberg, 1999). Early scientists such as Charles Darwin puzzled over the unusual positioning of these highly productive ecosystems in waters that are very low in the nutrients necessary for primary production (Darwin, 1842; Odum and Odum, 1955 in Hoegh-Guldberg, 1999). Coral reefs dominate coastal tropical environments between the latitudes 25^{o}S and 25^{o}N and roughly coincide with water temperatures between 18^{o}C and 30^{o}C (Veron, 1986 in Hoegh-Guldberg, 1999).

According to Wilkinson (2000), coral reefs of the world have continued to decline since the previous GCRMN (Global Coral Reef Monitoring Network) report in 1998. Assessments to late 2000 are that 27% of the world's reefs have been effectively lost, with the largest single cause being the massive climate-related coral bleaching event of 1998. This destroyed about 16% of the coral reefs of the world in 9 months during the largest El Niño and La Niña climate changes ever recorded. While there is a good chance that many of the 16% of damaged reefs will recover slowly, probably half of these reefs will never adequately recover. These will add to the 11% of the world's reefs already lost due to human impacts such as sediment and nutrient pollution, over-exploitation and mining of sand and rock and development on, and 'reclamation' of, coral reefs.

A complete understanding of the ecology is important for developing effective reef management and restoration. Ecology is the study of interconnectedness. By their very nature, coral reef ecosystems are complex and are not always easy to understand.

Ecological research has helped identify some of the causes of reef degradation, such as 1) the loss of large predatory fish and 2) the discovery of black-band disease and white plague that can kill coral in less than 1/100th of the time it takes for coral to grow (Ecological Society of America, 2000). This ecological knowledge is the key to reef management and restoration, and on-going monitoring and evaluation of the status of reefs are essential components of these efforts.

Traditional studies of reefs have been designed with a relatively narrow focus on either fish or hard coral ecology and have not captured sufficient information about a broad suite of reef organisms to allow an interpretation of reef health. “Coral reef health” is a general concept that refers to a balance in the ecosystem that may be shifted (Hodgson, 1999). Such shifting balance mostly comes from coral reefs being used as a “playground” by humans who don’t take care of them properly and neglecting what they have to offer, while using them for their own personal enjoyment and exploitment. What needs to be done instead is to understand the structure, function and productivity of these unique ecosystems. One way to capture information on a broad suite of reef organisms on a large number of reefs is to involve the community in monitoring the coral reefs. This will not only provide us with a snapshot of reef health, but also will build public support for management initiatives. With proper training and a carefully designed program, volunteers can play a productive role in assessing reef characteristics using SCUBA. Such community-based monitoring will facilitate sustainable use to coral reefs by minimizing negative human impacts (e.g. holding on to coral and having it break off and destroying coral with ones fins) on the reef system while maintaining its contribution to society. In addition with effective monitoring, efficient management can be established to allow for complementary policy to maintain coral reefs. This revolving systems framework of effective community-based monitoring leading to efficient management, can therefore be applied to all communities around the world where coral reefs are a part of individuals' livelihoods, such as in the Philippines where coral reefs provide economic and financial stability (Cesar et al., 1997).

What it comes down to is that as more community-based monitoring programs are developed, more and more volunteer divers will learn how to use their SCUBA techniques to not only accurately assess coral reefs, but also how to "hover" above them and take in their natural beauty. As well, the monitoring and management will initiate future survival of the reefs, rather than referring to coral reefs as "Paper-parks" with little effective management (Hodgson, 1992).

With the continued increase of threats to coral reefs, community-based management is key, as it will provide immediate results to coral reef health monitoring. The results of this study will generate a set of guidelines and protocols enabling both the scientific community as well as the local public in an effort to study, maintain and monitor coral reef areas. These results will derive from reviewing 5 coral reef monitoring programs for the purpose of identifying their strengths and weaknesses and making recommendations on how to improve or establish effective community-based programs. This information will also be useful to program coordinators worldwide involved with community-based coral reef monitoring programs.

1.1 Threats to Coral Reefs

In general, threats to coral reefs can be separated into two broad categories, those considered to be natural and those of anthropogenic origin. However, the distinction between the two is sometimes hard to distinguish. For example, a threat such as coral bleaching is considered natural, but increased sea surface temperatures (SST) have been linked to increasing global temperatures brought about by human activities.

1.1.1 Threats of natural origin: coral bleaching

Over the past 100 years, sea temperatures in many tropical regions have increased almost 1^{o}C and are currently increasing at ~ 1-2^{o}C per century, due to various environmental fluctuations such as El Niño and La Niña cycles (Hoegh-Guldberg, 1999). With this increased warming of the waters, temperatures have caused corals to bleach (Figure 1).

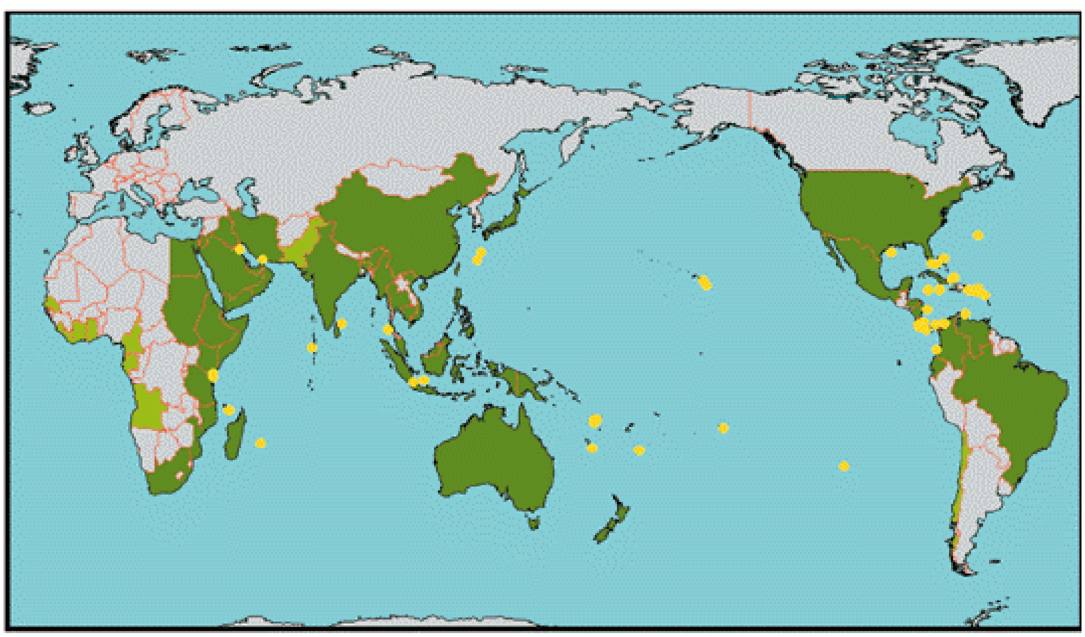


Figure 1 Regions where major coral reef bleaching events have taken place during the past 15 years (Yellow spots indicate major bleaching events) http://www.marinebiology.org

In order for coral survival, there lies a mutualistic symbiosis between the coral and zooxanthellae (dinoflagellate microalgae). The zooxanthellae benefit from this relationship by receiving nutrients such as nitrogen and phosphorous, which they require to grow, as well as housing (Brown and Ogden, 1993). Without the zooxanthellae, polyps cannot grow fast enough to build reefs. The zooxanthellae provide carbohydrate (energy) as products of photosynthesis to the coral polyp. The coral polyp then provides nutrients and carbon, by products of metabolism, to the zooxanthellae, which it uses to fix carbon. Thus, if the coral is stressed, mostly by increased sea surface temperature, the zooxanthellae may be expelled, resulting in coral bleaching.

Figure 2 Photograph of a bleaching hard coral (goniopora sp) from Pohnpei, Micronesia. Photo taken by J. Hoogesteger. Notice that the entire coral is not bleached; the polyps around the edges are still healthy. http://www.marinebiology.org/

As it has been documented within the last few decades, but most importantly recently, coral bleaching is increasing in its occurrence and severity. Events such as the 1998 mass bleaching event, the most severe on record, are only a preview of what to expect if SST continues to increase as predicted by many marine scientists (Wilkinson, 2000). With bleaching affecting coral reefs on a global scale, monitoring, management and policy is imperative for the survival of future coral reef ecosystems.

Some examples of coral bleaching events can be seen as follows:

1998 Mass Bleaching

The mass coral bleaching event of 1998 is considered to be the most severe on record, with bleaching affecting every geographic coral-reef realm in the world. The pattern associated with the 1997-98 bleaching episode strongly resembles patterns seen during the strong 1982-83, 1987-88, and 1994-95 bleaching episodes (Hoegh-Guldberg, 1999).

The Indian Ocean was seriously affected with mortality frequently exceeding 75% and sometimes approaching 90% (Wilkinson et al., 1999). Bleaching was most pronounced in shallow water (<15m) and was most severe on rapidly growing species such as *Acropora, Montipora, and Echinopora.* Slower growing massive species, like *Porites*, also bleached, but many recovered within 1 or 2 months.

The mass bleaching of 1998 affected virtually all species of coral and was recorded at unprecedented depths (down to 42m and 50m in Sri Lanka and Maldives, respectively) (Wilkinson, 1998; Rajasuriya, 1999 *In* Souter and Lindén, 2000). The severity of the 1998 bleaching event was further exemplified by the deaths of massive corals (which may live for well over 1000 years), including some with an age up to 700 years (ISRS, 1998) (Hoegh-Guldberg, 1999).

Magnetic Island Bleaching, Great Barrier Reef, Australia

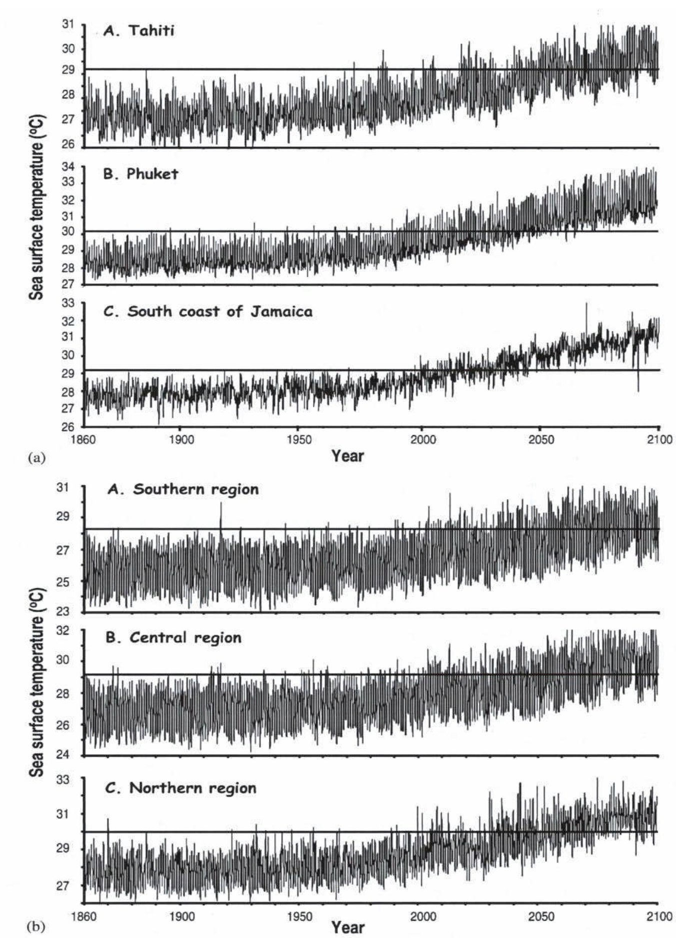
Coral bleaching events have occurred on the fringing reefs of Magnetic Island (Great Barrier Reef region), Australia, during the summers of 1979/80, 1981/82, 1986/87, 1991/92 and 1993/94. Continuous in situ water temperature recordings since 1991 suggest a close correlation between bleaching of corals and periods of average daily seawater temperatures approaching 32°C. Each of the bleaching events has occurred during periods of unusually high air temperatures, suggesting that ‘heat waves’ cause a warming of the inshore waters and are a contributory factor in the recurrent bleaching of corals at Magnetic Island. There has been a significant increase in annual summer and winter air temperatures in the Magnetic Island area since the middle of the present century. Air temperatures similar to those present during the 5 bleaching events which occurred at Magnetic Island, have not otherwise been experienced in this area since the 1930s (Jones et al., 1999)

Coral Bleaching in 2000

As reported by Clive Wilkinson at the 9th International Coral Reef Symposium, there is a worrying sign that severe bleaching has become more regular in parts of the southwest Pacific between February and April 2000. Satellite images from the National Oceanographic and Atmospheric Administration of USA showed a developing ‘HotSpot’ of increased seawater temperatures in the region in February and soon after severe bleaching often involving around 80% of the corals was seen in Fiji, and the Solomon Islands. Fortunately, the ‘HotSpot’ dissipated rapidly and many corals appeared to have recovered, although there were losses of up to 90% of corals in parts of Fiji. The Global Coral Reef Monitoring Network (GCRMN) and Reef Check teams are following these affected areas. However, encouraging reports of new recruitment on coral reefs in Eastern Africa, the Seychelles, the Maldives and Palau indicate that sufficient parent corals survived to provide some larvae for the spawning season.

As coral bleaching is a vital threat to the decline of coral reefs, one way to monitor this phenomenon is through modeling of global climate change. This information is a key ingredient that can help lead to effective monitoring and management of coral reefs. From this model below, the thermal tolerances of reef-building corals are likely to be exceeded every year within the next few decades (Hoegh-Guldberg, 1999). These models of global climate change are essential since they can be compared to past results. With coral cores taken from the central Pacific confirming the warming trend in the last few decades, many marine scientists (Brown, 1997) have pointed to the significance of this trend for reef-building corals and have stated variously that global climate change is likely to increase frequency and intensity of bleaching (Hoegh-Guldberg, 1999).

Figure 3 Predicted sea surface temperatures in the Northern Hemisphere (Hoegh-Guldberg, 1999)



An example of how models are helping predict coral bleaching around the world, can be seen on NOAA's Tropical Ocean Coral Bleaching Indices website: http://psbsgi1.nesdis.noaa.gov:8080/PSB/EPS/SST/dhw_news.html.

1.1.2 Threats of anthropogenic origin

Not only is coral bleaching a major threat to coral reefs, but also certain anthropogenic affects contribute to their decline (Table 1). With human population growth among coastal areas vastly rising, there lies the potential for many more anthropogenic threats to damage coral reefs. They include the following:

Table 1 Anthropogenic cause and effects on Coral Reefs

Cause	**Effects on coral reefs**
Pollution	Poor land use, increased sedimentation, chemical loading, marine debris, and invasive species, which smother coral tissue and nutrients. In turn promoting algae growth and suffocating the corals (Wilkinson, 2000; Cesar et al., 1997)
Over-fishing and related practices	Harm habitats by fishing gear and marine debris (White and Vogt, 2000; Cesar et al., 1997)
Destructive fishing practices	Cyanide and dynamite fishing destroy large sectors of reef and kill many species not yet harvested (White and Vogt, 2000; Cesar et al., 1997)
Dredging	Shoreline modification in connection with coastal navigation or development (Luttinger, 1997; Cesar et al., 1997)
Vessel groundings and anchoring	Directly destroy corals and reef framework (Birkeland et al. 1997; NOAA*b*, 2000)
Disease outbreaks	Infects healthy corals and degrades reef ecosystems (Sano et al., 1987; Birkeland and Lucas, 1990)

Harvesting live aquarium fish and coral	Depletes coral reef fish populations and coral communities (Birkeland et al. 1997)
Global climate change	Increases sea surface temperature and degrades coral reef ecosystems (Hoegh-Guldberg, 1999)

1.2 Serious decline or normal fluctuations in coral reefs?

How does one know when a reef is seriously declining and not just showing normal fluctuations in condition? As this is a question that puzzles many marine scientists today, it is inevitable to pinpoint one specific answer. What must be considered is the type of damage being done to the reef, physical due to human interference, an increase in SST, elevated light conditions, cold-water stress, El Niño Southern Oscillation (ENSO*)* events, and the location of the reef where the damage is occurring. As well, analyzing information on the surrounding reefs can help explain what might be occurring. Some responses that attempt to answer coral reef decline are explained below.

1.2.1 Anthropogenic Influence

Anthropogenic influences to coral reef ecosystems have caused degradation quicker than expected. Long before climate change became a major problem for coral reefs, burgeoning human populations, especially in coastal areas, and increasing prevalence of non-sustainable, exploitive activities have been degrading coral reefs throughout the world (Wilkinson et al., 1999). Indeed, as early as the 1930's Gardiner (1936) expressed concern regarding the apparent decline in species numbers on reefs he studied close to population centers in the Indian Ocean (in Souter and Lindén, 2000). With the continuance of anthropogenic influence into coral reef ecosystems, their decline will become substantial to the millions of people living within tropical coastal communities.

1.2.2 Elevated temperature and normal light

Although temperature in general has to be higher than normal for a coral reef to become stressed, light will cause damage to the photosystems even at normal intensities when water temperature is elevated above a critical maximum. Here, most coral bleaching starts on the upper, sunlit surfaces of corals (Salih et al., 1997 in Hoegh-Guldberg, 1999). This also links thermal-stress related bleaching directly to solar bleaching studied by Brown and co-workers (Hoegh-Guldberg, 1999).

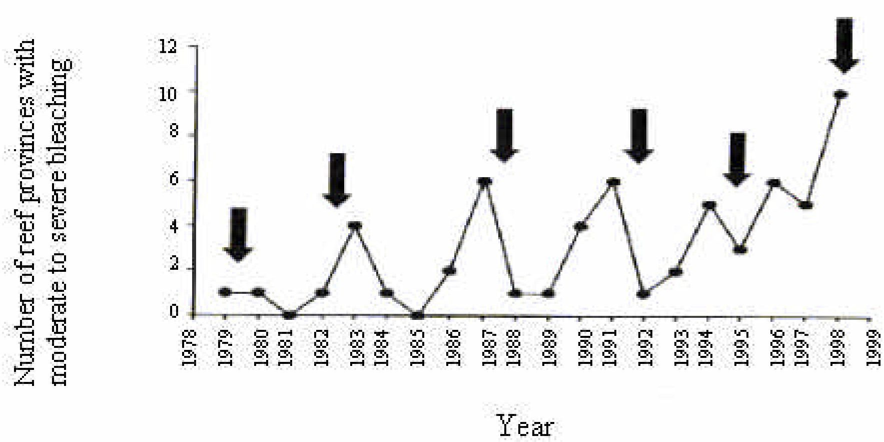
1.2.3 Cold-water stress

With corals trying to acclimate themselves to increased heat stress for survival, there lies a possibility of making them susceptible to cold-water stress. Not only are warming of the waters causing coral to bleach, but two different events to make note of, have caused coral bleaching due to cold-air fronts and cold-water temperatures. One, during January 1977 (Roberts et al. 1982) and the other one from December 1988 to March 1989 (Coles and Fadlallah), exhibiting extremely low water temperatures, 13^{o}C and lower. As a result, almost all of the coral was bleached and barley alive, or dead. There were also reported mass macroalgal blooms upon these cold events. To keep note, in these bleaching events faviids were one of the few coral species to survive the cold-water temperatures. Faviids, members of the brain coral group, are able to withstand conditions that would kill most other corals (Tibbetts et al., 1998).

1.2.4 El Niño Southern Oscillation (ENSO)

El Niño is a climatic state during which low air pressure systems in the tropical Pacific Ocean migrate from their usual location over the Australian/Indonesian region to the central tropical Pacific (Tahiti). As a consequence, the normal easterly trade winds become weaker producing relatively calm weather conditions near the equator. Subsequently, solar radiation that would otherwise be dissipated by surface winds, currents and mixing of oceanic waters is absorbed causing the sea temperature to rise. If these conditions prevail, then the sea temperature will increase to such an extent that it exceeds that, which can be tolerated by the corals and their zooxanthellae, leading inevitably to bleaching. Once bleached, the likelihood that a coral will die is proportional to the length of time for which the thermal limit of the coral is exceeded (Hoegh-Guldberg, 1999).

In the past, ENSO events have correlated with bleaching events that have occurred all throughout the world. In 1982-83, the El Niño-Southern Oscillation coincided with significant and widespread coral mortality (Hoegh-Guldberg, 1999). In 1987 and 1990 bleaching events in the Caribbean, as well as a massive worldwide bleaching event 1997-1998(Figure 4).



Number of reef provinces bleaching since 1979. (Graph modified from Goreau and Hayes (1994) with data added for 1992 onwards). Arrows indicate strong El Niño years.

Figure 4 Number of reef provinces bleaching since 1979 (Hoegh-Guldberg, 1999)

1. 3 Consequences of coral reef decline

Some corals may regain algae or pigmentation and survive, but when bleaching is severe the host coral dies. Coral bleaching events have increased dramatically in the last two decades, and coral reefs throughout the world have been extensively degraded as a result. (Meehan W.J.; Ostrander G.K.)

1.3.1 Reduced reproductive capacity and recruitment

An increased frequency of bleaching will obviously lead to greater mortality in mature colonies of coral. Bleaching is likely to inhibit reproduction through the reduction in fecundity and reproductive output thus limiting the chances of successful fertilization and settlement (Hoegh-Guldberg, 1999; Wilkinson et al., 1999).

For example, in a study done by Szmant and Gassman (1990) comparing the fecundity of 200 bleached and unbleached colonies of reef-flat corals at Heron Island after the 1998 bleaching event, bleaching reduced reproductive activity in most reef-flat corals examined. Bleached colonies of many important reef flat species (*Symphyllia* sp., *Montipora* sp., *Acropora humilis, Favia* sp., *Goniastrea* sp., *and Platygyra daedalea)* contained no eggs at all (Jones et al., 2000). These bleached corals, even though having recovered their zooxanthellae, did not spawn during their normal spawning period in November. In other reef-flat species (*A. aspera, A. palifera, A. pulchra* and *M. digitata)* there were significantly fewer eggs in bleached than n unbleached corals (Jones et al., 2000). These results may point to a number of insidious effects of bleaching events on corals that may not be immediately evident yet may play a very important role in how coral ecosystems recover.

1.3.2 Reduced rate calcification and growth

The loss of zooxanthellae because of bleaching reduces the amount of energy available for accretion of calcium carbonate and subsequently growth. This might lead to reduced competitive capacity and loss of space to algal competitors, ability to recover from disturbance, susceptibility to disease and attack from bio-eroding organisms and an inability to remove sediment (Hoegh-Guldberg, 1999; Wilkinson et al., 1999).

1.3.3 Survivals of some polyps on the colony

When corals bleach, often only polyps on the upper surfaces of the colony expel their zooxanthellae. If polyps situated on the shaded, underside of the colony survive they can regenerate and grow over the damaged portion of the colony and assist recovery (Souter and Lindén, 2000).

1.3.4 Survival of adult corals in deeper water

Coral in deeper water are often not exposed to the increased temperatures and high light intensities necessary to cause bleaching (except 1998). The survival of these colonies can assist recovery by contributing larvae for settlement and regeneration of damaged areas of reef. The differential ability of corals to cope with temperature change could lead to changes in community composition toward more heat-tolerant species. Goreau and Hayes (1994) suggested that coral species present on reefs at higher latitudes might be replaced by more temperature and heat-tolerant species from lower latitudes.

1.4 Why coral reefs are important (NOAA and the Department of the Interior)

When one thinks of coral reefs, the luminescent colors and intricate patterns are what might come to mind at first. However, coral reefs actually contribute to society more than just their aesthetic beauty. To show how vital coral reefs are to economies around the world, NOAA and the Department of the Interior illustrate some examples in Table 2.

Table 2 Why coral reefs are important

Coral reef provide services estimated as much as $375 billion annually, a staggering figure for an ecosystem covering less than one percent of the Earth's surface.
In the U.S. coral reef ecosystems support millions of jobs and generate over $1.2 billion in the Florida Keys alone.
In Hawaii, gross revenue from just a single, half square mile coral reef reserve are estimated to exceed $8.6 million each year
The dockside value of commercial U.S. fisheries from coral reefs is over $100 million and the reef dependent recreational fisheries probably exceeds $100 million per year.
In developing countries, coral reefs contribute about one-quarter of the annual total fish catch, providing food for about one billion people in Asia alone.
Coral reefs are considered to be one pf the primary sources of new medicines and biochemical's in the new century, such as anticoagulants and anticancer agents such as prostaglandins
Coral reefs buffer adjacent shorelines from wave action and thereby prevent erosion, property damage and loss of life. They further protect the highly productive mangrove fisheries and wetlands along the coast, as well as ports and harbors and the economies they support.

(NOAA*a* and the Department of the Interior, 2000)

1.5 Why we need community-based management

With evidence from NOAA*a* and the Department of the Interior, 2000 in Table 2, coral reefs play a major role in many communities around the world. As this is the case, effective monitoring is key in order to continue to have coral reefs provide all that they do. From here, community-based management can be drawn up preserve coral reefs. Moreover, this can lead to a constant flow of checks and balances; that being with the monitoring adjusting to reef conditions over time, more effective management can take place to compensate for the changes in reef health.

As stated by Renard (1991), community-based management is a vital part to the success of coral reefs because they: 1) Promote democracy and equity because it gives members of the community a greater opportunity to share in decisions about how resources are used, and thereby a greater share in the benefits that are gained from their use; 2) It is economically and technically efficient. Local responsibility also decreases the need for costly outside enforcement which many governments cannot afford; 3) It is adaptive and responsive to variation in local social and environmental conditions and changes in those conditions. Resource users are constantly aware of the condition of the resources upon which they depend, and they can be quick to respond and adapt to changes in the condition of those resources, and 4) Community-based management brings a measure of stability and commitment to management that a centralized government approach cannot duplicate.

According to Smith (1994), with a lack of monitoring and education programs in most countries, timely and accurate information upon which decisions can be based is imperative. Monitoring is an important ingredient in the planning and implementation of management. A common approach to management is to emphasize enforcement of existing regulations rather than to work toward acceptance of the need for management. Typically, the greater need for enforcement, the weaker the management planning that has taken place; the need for enforcement also implies the lack of acceptance by the resource users of the management measures that have been imposed.

For example, the Caribbean governments are on record as being committed to managing their reef resources. An inventory of marine and coastal protected areas in the Caribbean, including U.S. territories, showed 135 legally established areas. Of the 135 areas, only 29% can be considered fully protected. If U.S. territories are excluded, only 16% have good protection (Smith, 1994). Thus, that top-down approaches to monitoring appear to be limited in stature. With community-based management, you are hopefully eliminating the top authority and "leaving it to the locals," so to speak, who have direct use of the reefs. They (the locals) are the ones who will benefit the most from this management. Not to mention, tourism will benefit as well. With this in mind, to make management more effective, all communities and institutions concerned with the reef resources need to be able to participate in the planning and monitoring process.

1.6 What to look for in monitoring

In order to have successful monitoring of coral reef health, three important criteria must be included in all monitoring procedures:

1) Identification of the most likely sources of negative impacts to the reef
2) Selection of an appropriate group of reef organisms that would indicate change in reef health
3) Development of methods for the monitoring of selected factors and indicators that could be used by dive leaders.

With these three criteria included in community-based monitoring, management strategies will be that much more efficient.

1.7 Policy

In any proficient management program, clear and cut-to-the chase policy will make it easier for communities to understand exactly what is exactly going to take place. However, when non-direct users of the resource they are protecting and/or preserving draw up policy, the policy tends to be 'paper-policy,' that does not involve all necessary stakeholders. This can be seen in such top-down approaches to monitoring and managing coral reefs that don't involve the community, as they tend not be as effective as bottom-up approaches. Examples of top-down policies that will be discussed below include Agenda 21, developed by the United Nations Conference on the Environment and Development, Executive Order 13089 issued by President William J. Clinton, the U.S. Coral Reef Task Forces' first-ever National Action Plan, NOAA's initiatives for maintaining coral reefs and the International Coral Reef Initiative of 1994 developed by the U.S.

When you look at statistics on how many people visit areas to specifically see coral reefs and the revenue that they generate (Table 2), the economic incentives for monitoring them become clearer. For example, the Caribbean boasts annual revenue in excess of US$10 billion dollars (Serageldin, 1997). In the Seychelles, 70% of foreign exchange and 20% of the gross domestic product come from tourism (Serageldin, 1997). Thus, when statistics are indicating to the rest of the world the importance of coral reefs for the particular countries future economically, something must be done to preserve and protect these coral reefs from declining.

Although it is virtually impossible to preserve and protect every coral reef in the world, there are measures that can be taken to monitor coral reef health so that they are preserved and protected for the future. Even though every coral reef is unique and different in its own way, a general set of monitoring protocol can be established to evaluate reef conditions. However, in certain cases of reef decline, one might be subject to identifying a cause that has not been addressed or even heard of in the scientific community, with respect to the health of the reef. It is here, where these gaps need to be addressed, so that necessary measures can be adopted and applied when appropriate.

Now, on a global scale, the United Nations Conference on the Environment and Development (UNCED) developed Agenda 21, which calls for sustainable use and conservation of marine resources, addressing critical uncertainties in management of the marine environment and climate change, strengthening international cooperation and coordination, and promoting the sustainable development of small islands (Luttinger, 1997). This is a worthwhile agenda since it hits all the points that people want to hear and hope that some policy is going to solve the problem.

There is also the formation of U.S. President William J. Clinton's Executive Order 13089 issued in June 1998. In conjunction with the existing U.S. Islands Coral Reef Initiative strategy that covers approximately 95% of U.S. coral reef ecosystems, the executive order directs the U.S. Coral Reef Task Force, co-chaired by the Secretaries of the Interior and Commerce, to develop am implement a comprehensive program of research and mapping to inventory, monitor, and "identify the major causes and consequences of degradation of coral reef ecosystems." President Clinton's Fiscal Year 2001 budget to Congress included a total of $26 million, with $16 million going to the Department of Commerce (NOAA) and $10 million going to the Department of the Interior. This is an increase of $15.5 million over FY 2000 appropriations- specifically to implement recommendations of the United States Coral Reef Task Force (CRTF) and halt the rapid loss and degradation of coral reef ecosystems. This would significantly strengthen federal, state, territory and non-governmental efforts to protect, restore, and sustainably use U.S. coral reefs. The funding increases can be seen for: 1) mapping and monitoring coral reef ecosystems since less than 5% of all U.S. coral reefs have been adequately mapped or monitored; 2) to find solutions to reef decline by identifying causes and cures for coral reef diseases and other human impacts; 3) to reduce human impacts on reefs such as run-off pollution, fishing and other threats to coral reefs; 4) to improve public education and basic monitoring in existing protected areas and help fishery management councils, local communities and other partners establish new coral reef protected areas such as ecological reserves; 5) to reduce impacts over-fishing and fishing gear on coral reefs; and 6) to restore fragile coral reefs damaged by human impacts (U.S. Coral Reef Task Force *b*, 2000).

On March 2, 2000, the U.S. Coral Reef Task Force unveiled a groundbreaking plan that will tackle major risks to the economy, consumers and the environment. This plan calls for protecting 20% of all U.S. coral reefs by 2010. This first-ever National Action Plan that will address the challenges facing coral reefs today includes the U.S. Coral Reef task Force, the National Oceanic and Atmospheric Administration (NOAA) of the U.S Department of Commerce, the U.S. Department of the Interior and other federal agencies that are joining with coastal states and territories. This plan is vital to the future of coral reefs as “ if current conditions continue, an alarming 70% of the world’s reef may be gone by 2050; This rapid decline represents a serious threat to business, consumers, communities, and the environment," said D. James Baker, Task Force co-chair and NOAA Administrator.

The National Action plan is designed to understand coral reef ecosystems and reduce the adverse impacts of human activities by effectively:

1) Designating 20% of all U.S. coral reefs as no-take ecological reserves by 2010
2) Mapping all U.S. coral reefs by 2009 (Only 5% of all U.S. reefs have been adequately mapped)
3) Monitoring to build and integrated national reef monitoring system that profiles and tracks the health of U.S. coral reefs
4) An All-Islands Coral Reef Initiative to address the highest priorities of U.S. state and territorial islands.

(NOAA*b* and the Department of the Interior, 2000).

However, despite how many top-down approaches are presented, coral reefs are still going to continue to decline. Thus, it is up to us to accept this plan that has been presented and make sure every aspect of policy is followed through. As a result, coral reefs and us humans will both be able to benefit from their survival.

As we have seen management lead to the formation of "paper-parks," NOAA is still committed to coral reef health. On December 11, 2000, NOAA announced initiatives by Commerce Secretary Norman Y. Minyeta for:

1) Establishment of the first internationally recognized "no anchoring" zones for large ships, with the first one in NOAA's Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico.

2) Release of the final plan to establish the Tortugas Ecological Reserve to protect valuable coral reefs at the southern tip of the Florida Keys
3) A U.S. – Australia agreement to jointly study coral reef bleaching and the effects of climate change on coral reefs
4) A major undertaking by the agencies of the U.S. Coral Reef Task Force and broad-based partnerships to map 10% of the U.S. reefs.

(NOAA*a* and the Department of the Interior, 2000).

Also, the International Coral Reef Initiative, founded by the United States in 1994, of governments, intergovernmental organizations, multilateral development banks, non-governmental organizations, scientists, and the private sector whose purpose is to mobilize governments and other interested parties whose coordinated, vigorous, and effective actions are required to address the threats to the world's coral reefs. With this policy coming down directly from the President of the United States, it does set a tone for potential future actions on coral reefs, but in the end it is what the people want to hear so that they think coral reefs will always be protected.

I do agree with the five policies mentioned above, but in the end I still see coral reefs declining since there are not enough trained specialists to monitor and maintain coral reefs. Thus, it is right here, where I see a need for volunteer and community-based programs to be adopted and implemented worldwide to monitor coral reef health. As such top-down approaches have been unsuccessful in areas of the Caribbean, hope for coral reef ecosystems to survive rather than decline lies in the establishment of successful community-based monitoring and management programs (U.S. Coral Reef Task Force *b*, 2000).

This paper will focus on the establishment of guidelines and protocols on how to improve on or create volunteer, community-based coral reef monitoring programs so that effective management programs can be implemented in areas where coral reefs exist throughout the world. The goal of these guidelines for coral reef monitoring is to involve the community as much as possible in the process of collecting data that can be used for monitoring and managing coral reefs. This entails not only addressing the coral reef ecologist, but local community members as well, in that it will bring together the lines of communication that have been lacking in the past. My hope is that this will help preserve coral reef areas that are rapidly disappearing from our oceans ecosystem.

2.0 Methods

In order to determine guidelines and protocols on how to improve on or create volunteer, community-based coral reef monitoring programs so that effective management programs can be implemented in areas where coral reefs exist throughout the world, I reviewed current and past coral reef monitoring and management programs. As a result, a set of guidelines and protocols for monitoring techniques were generated. In analyzing the community-based programs, I developed a set of questions I applied to all the programs. They included:

Table 3 criteria to accurately assess the programs

1) Where is the program being done
2) Why was the program developed
3) What were the goals of the program

4) What is the structure of the program and how was it implemented
5) What reef policies were active at the time of developing the coral reef monitoring program, whether it be local, regional, national, and/or global level (if applicable)
6) Was the program successful in meeting its goals

3.0 Results

In reviewing the case studies, two distinct types of monitoring programs were identified; those with community involvement (case studies 1 and 2) and the other having outside volunteer involvement without the local community (case studies 3,4 and 5).

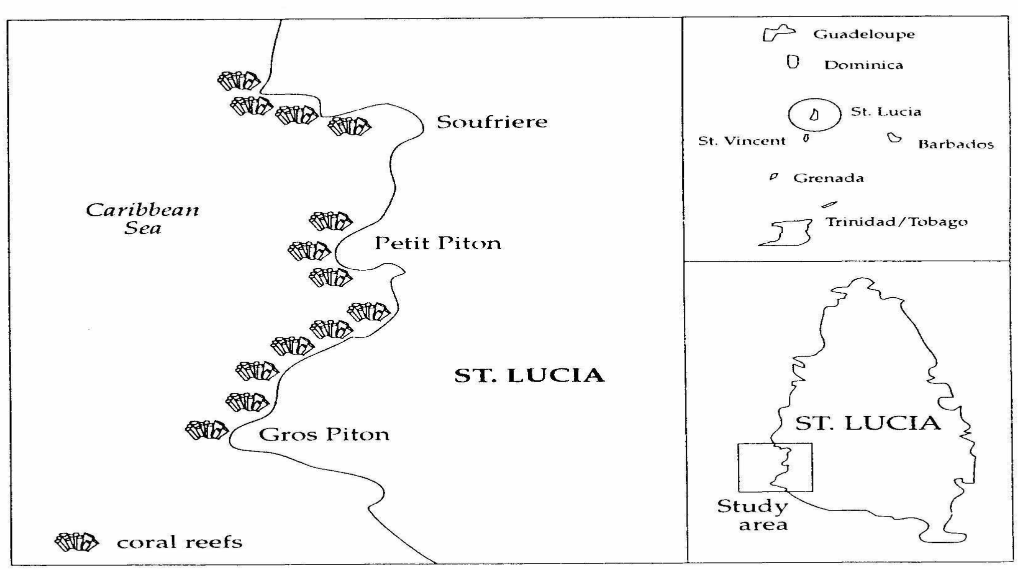
3.1 Case Study 1

Community involvement in coral reef monitoring for management in the Insular Caribbean (Smith, 1994).

Where is the program:

Soufriere lies on the west coast of St. Lucia in the Caribbean. Soufriere is known for

Figure 5 The study area at Soufriere, St. Lucia



its natural, historical, and cultural features that make it unique and potentially great for development of ecologically based tourism. The important marine resources of Soufriere are fisheries, tourism, and to a lesser extent, scenic anchorages for visiting yachts.

Why was the program developed:

The intention of the monitoring program was to monitor factors that were most likely to cause reef degradation, some environmental variables, and certain indicators of change in the structure and health of reefs.

What were the goals of the program:

The goals of the monitoring program were 1) to test reef monitoring techniques with relevance to the needs of local resource management and development planning; 2) to use local expertise, particularly the community of dive operators, and methods appropriate to that expertise and 3) to facilitate dive operators' contribution to and responsibility for coral reef monitoring and management programs that are appropriate and cost effective.

What reef policies were active at the time of developing coral reef monitoring?

The Department of Fisheries, through the Fisheries Act, is responsible for management of fisheries and the protection of living resources. In 1986, many of the major reefs in St. Lucia were declared Marine Reserve Areas (MRAs). Despite the establishment of the marine reserve areas, the boundaries were not defined, making effective management impossible. Fishing with spears, pots, gill nets and seine nets continues unregulated in all MRAs, negatively impacting the ecosystem. This negative impact led to various conflicts among fishing and diving communities over the use of certain areas. To date, no official policy of community participation or coordination exists, despite attempts of communication.

What is the structure of the program and how was it implemented:

Monitoring was planned in collaboration with local and regional institutions along with dive operators. The design of the program included 1) identification of the most likely sources of negative impacts on reefs in St. Lucia; 2) selection of an appropriate group of reef organisms that would indicate change in reef health and 3) development of methods for monitoring of selected factors and indicators that could be used by dive leaders.

To monitor the level of sport diving, the names and locations of dive sites used by all dive operators were identified, and dive operators recorded the total number of dives made each month. Also, three factors affecting water quality were measured: sedimentation, turbidity and temperature.

In determining changes in the coral reef community, a photographic method was chosen because of the availability of many trained dive operators and because it is a simple and rapid method that provides a permanent record for later analysis. Here, two photographs were taken of each quadrat, covering a total of 2 square meters. The photographs were reproduced in color. Coral colonies within the quadrat were traced and the projected area of each colony and species was determined using a digitizer and measurement program. As a final step, the calculation of diversity indices and percent cover were then carried out with spreadsheets from a data file in the measurement program.

Was the program successful:

A time came when the workers emphasized the difficulties of maintaining a reef monitoring program because of cost, travel, equipment needs, and the training of personnel. Consequently, the Organization of American States has stepped in and assisted with the development of Soufriere National Park. Dive operators and the Caribbean Natural Resources Institute (CANARI) made contributions to the reef monitoring. By the end of 1988, the names of the dive sites had been standardized, sedimentation on the various reefs were continuously monitored, and permanent photoquadrats were being taken every two to three months so that changes in the reef structure could be determined. Because of this joint partnership, the St. Lucia Dive Association was established. Not only does the association now have a mandate to assist with research and monitoring and to be involved in management activities, but also represents the interests of the diving community in the government's strategies for both coastal management and tourism development. This just goes to show that a bottom-up approach to community-based management can be accomplished when both fishing and diving communities communicate. Thus, this effective management can lead to efficient coral reef monitoring.

This crossroads, due to cost, travel, equipment needs, and the training of personnel was not to be expected, but it is what happened. Rather than downgrading the monitoring program, it is easy to say that it was successful for monitoring coral reef health for a few years. This is what maintaining and preserving the coral reefs for the future is all about. Yes, there were differences along the way. No program is going to run smoothly, without conflicts. And yes, communication between the dive operators and fishers should have explored every possibility to compromise on a suitable monitoring project that would benefit both groups. But what comes about is that it is possible to involve the community and monitor reefs, as the St. Lucia Dive Association exhibited and still do today. However all parties must be accounted for in the result of successfully monitoring coral reef health.

3.2 Case Study 2

Community-based coral reef conservation in the Bay Islands of Honduras (Luttinger, 1997).

Where is the program:

The main island of Roatán, in the Bay Islands of Honduras is 48km off the northern coast of Honduras the Bay Islands form 70 minor islands and 3 three larger islands. The total population consists of 20,000 for all the islands, where 15,000 reside on the island. There, local area reefs form part of the largest coral reef complexes in the world, second to Australia's Great Barrier Reef. The reef is extremely productive, forming the habitat for thousands of diverse marine organisms. Relative proximity of the shore to deep water and the main reef, diving quality, and inexpensive diving costs are features that distinguish the Bay Islands from numerous other Caribbean islands. Local islanders traditionally used the reef as a means of subsistence, harvesting lobster, conch, fish, crab, and other species.

Why was the program developed:

The main island of Roatán was undergoing rapid development to accommodate a surge in nature tourism. As tourist populations rose, prices for edible reef species also rose, creating a strong demand for species such as lobster and conch. As a result, not only were lobster and conch species overfished, other species declined near several concentrated resort areas. Moreover, coral reef health became obviously impacted and little regard to environmental conditions was taken into account.

<u>What were the goals of the program:</u>

To create and manage a marine protected area using a bottom–up approach from the community.

<u>What reef policies were active at the time of developing coral reef monitoring?</u>

Agenda 21, drawn up by the United Nations Conference on Environment and Development was active. It called for sustainable use and conservation of marine resources; addressing critical uncertainties in management of the marine environment and climate change; strengthening international cooperation; and promoting the sustainable development of small islands.

There were no national laws dictating proper use of the reef (rules that attempt to minimize user impacts). Thus, the reef received multiple assaults, from anchors, tourists walking on the reef, spearfishing, pollution, and direct breakage of coral for coral collection.

Past Roatán environmental policies, at the local level, have failed to guide sustainable development of the islands for the following reasons:

- Legislation neither fully regulated the whole range of environmentally damaging activities nor required environmental impact assessments of large-scale projects.

- Inadequate resources were allocated for detecting violations,
- Penalties were too low to discourage offenders
- A lack of the technical expertise to make fully informed decisions regarding the impacts of planned developments.

With these problems of insufficient policies and observable adverse impacts to the reef, it became evident to local community leaders that the community had to develop new polices to ensure the sustainability of this system.

What is the structure of the program and how was it implemented:

The community was beginning to see the decline of the reef health and certain marine populations. With their future livelihoods coming into question, a building consensus on the need to protect marine resources was critically linked to the community's role as stakeholders. Stakeholders primarily consisted of dive shop owners, resort and restaurant owners, and the fisherman who had always made their living from the reef. As a result, the two communities organized themselves to create and manage a marine protected area.

The first step was limiting the size of the marine reserve and re-training the fisherman with additional skills including those relating to employment in the expanding tourism industry. At this early stage of primary importance, commitment from one of the wealthiest resorts on the islands for a sizeable portion of the initial funds was needed. This commitment would ensure to the community that a local community member was concerned about the coral reefs, rather than a government official imported from the mainland and imposing a conservation plan devised from many miles away from the island. Once the resort gave its commitment, the community agreed to the establishment of a reserve, the Sandy Bay Marine Reserve in 1989, whose goal was to restore coral reef biodiversity and health that once was not an issue.

The community elected a Director, Treasurer, and General Secretary. Every three weeks meetings were held to discuss objectives of the reserve, boundaries of the reserve, monetary contributions from members, and alternative sources of income for the local fishermen who made their living from the reef. The local municipal government eventually recognized the marine reserve through a local ordinance, but did not support them financially. The national government too, recognized the marine reserve, but has provided no monetary support. Even though, the reserve was officially recognized, a majority of the funding came from the resort.

About 20 local fishermen were trained and certified by dive instructors, thus making them eligible to become dive masters. Others were trained to work in the service sector of the tourism industry, becoming waiters, cooks, guides, etc. Several others were trained to become patrol guards for the marine reserve. This effort of re-training the fisherman is a positive communication effort that shows with diligent education and understanding, local stakeholders can come together and workout their differences.

With the organization of the Sandy Bay-West End Marine Reserve, a few main objectives had to be put forth. They included: 1) to maintain the natural balance of the environment by protecting genetic resources and biological diversity and 2) to support sustainable economic development through non-consumptive resource uses such as tourism and recreation. With these objectives, the boundary of the reserve was regarded as the area with unusually high quality coral reefs and is an area of high human use, with previous evidence of severe impacts.

One aspect of this monitoring program was that the community had instituted a fee membership. This was criticized by the smaller businesses on the grounds that dive shops and other larger businesses that are direct users and beneficiaries of the coral reef, should be expected to pay more of the budget to run and operate the community-based program. In response, the diving industry argued that they bring in all the tourists, and therefore they should not have to pay extra at all. Other businesses do not appreciate a required fee and would rather keep the voluntary system.

Since the government had not carried out its policies, the community took it upon themselves to develop their own policies. The actual policies are not great in number, but primarily refer to individual behavior within the waters of the reserve. These policies included:

1) Prohibition of anchors (facilitated by a successful mooring buoy program that had been previously accomplished), spearfishing, coral collection or destruction, marine life harvesting, net fishing (line fishing still allowed), and disposal of garbage,
2) A requirement that yachts and sail vessels have holding tanks for sewage if staying within the reserve,
3) A ban on construction of new piers within the reserve,
4) Possible closure of over-visited sites that demonstrate heavy impact.

Enforcement of these policies, the marine reserve was officially recognized through a local municipal ordinance. If violators were caught, the reserve would report it to the municipality, who would then make the judgment on the penalty.

Was the program successful:

Within about two or three years, community members and return tourists began to notice a sizable improvement in the health, diversity, and abundance of the marine life within the reserve area. This recovery was so overwhelming that the adjacent community of West End got together and decided they wanted to protect their coral reef as a reserve. In 1993, the West End Marine Reserve officially joined the Sandy Bay Marine Reserve. Now this is what community-based programs are all about. With a little motivation and commitment, certain things can go a long way. In this case, a second marine reserve was created because of the success of the first one. In fact, no convincing of the community was necessary; they saw the difference protection had made in Sandy Bay. At the same time, the stakeholders had more to gain in the West End because there was a higher proportion of tourism related business in that community.

With overwhelming recovery in reef health as well as in lobster, conch, and fish populations, the marine reserve has been certainly successful in the gradual restoration of the coral reef ecosystem. As it would continue to regenerate, these populations could eventually spill over into neighboring areas, where the local community can harvest them for their own needs. What can potentially come about here is the increase in harvestable resources in areas outside the reserve. This should positively reinforce the participating communities about the benefits of setting aside a portion of the reef as a protected area. A current example of this "no-take" zone can be seen in the Florida Keys Natural Marine Sanctuary where the Tortugas ecological reserve has been designated a "no-take" ecological reserve, helping keep its healthy coral, clean water and fish spawning sites (NOAA*b*, 2000). Furthermore, a healthier reef ecosystem should translate into higher tourist satisfaction. This higher tourist satisfaction could mean more tourists will be returning, as well as talking about and publicizing the Bay Islands as a prime locale for diving and snorkeling.

Even though the coral reef ecosystem had a turn-around, the marine reserve eventually failed. The main contributor to the marine reserve budget (the original wealthy resort owner) has retracted his monthly contributions, apparently due to disagreement over management of the reserve. This prompted a large number of other businesses to retract their membership. Thus, an insufficient budget led to poorly maintained patrol equipment, reduced patrol capability, and poor payment schedules. Also, assaults to the reef, such as reef destruction (to construct a channel) and pier construction, had been permitted despite marine reserve rules that explicitly prohibit such activities. A cost-benefit analysis should have been drawn up that would have created equal fees to direct users and beneficiaries. This way, no one is complaining and monitoring can get underway.

As this is just one case, local community efforts led to municipality recognition. Every program has to start out somewhere, and the Sandy Bay Marine Reserve is a leader. However, despite the decline in the support of the reserve, a proposal to establish the Honduran National Park kept community members optimistic because the plan would allow the marine reserve to remain managed by the local community and would probably increase financial, legislative, and logistical support.

3.3 Case Study 3

Reef Check for long-term coral reef monitoring in Hawaii (Hodgson, 2000)

Where is the program being done: World wide, but coordinates from Hawaii

Why was the program developed:

Reef Check was developed for a one-time assessment of coral reef health.

What were goals of the program:

Using teams of recreational divers trained and led by a marine scientist, the first goal of Reef Check was to gather a snapshot of the health of reef corals, fish and other invertebrates. The second goal was to build up community support for a coral reef monitoring and management program in each area. Here, community members can develop a sense of stewardship towards the reefs they are monitoring. There is also the reward for scientist as they are able to show why coral reef science and ecology are important pursuits. This interaction helps generate public support for coral reef science and for scientists who carry out basic research.

What is the structure of the program and how was it implemented:

From Reef Check's success, a formal link was established under the International Coral Reef Initiative (ICRI) between Reef Check and the Global Coral Reef Monitoring Network (GCRMN), with GCRMN focusing on assisting government efforts Reef Check addressing community-based. It is expected that most countries with coral reefs will belong to the GCRMN/Reef Check network and will have long-term monitoring programs.

With advertising articles in the newspaper, posters and brochure mailings, community access television, as well as by word of mouth through local community networking, Reef Check was promoted to the different communities. Many dive masters were also contacted, and in turn donated tanks and other support for the volunteer operations. For the volunteers, the training consists of a three-hour classroom session given on one evening including lectures about coral reef ecology. A slide show of the indicator organisms, discussion of the survey methods, the use of computerized data sheets, and dry land simulation of reef check monitoring follow it.

Was the program successful:

Reef Check was successful in that the amount of volunteer divers and marine scientists participating in the surveys continued to increase year after year. As you will see below, each year surveyed more reefs. Between June 15th and August 31st, 1997, results were generated from over 100 marine scientists and 750 recreational volunteer divers who surveyed 300 coral reefs in 30 countries. It was confirmed that reefs in different parts of the world are sharing similar problems. Overfishing was shown to be far worse than expected, particularly at remote locations (Reef Check, 2001*a*). For 1998, several hundred volunteer divers and over 100 marine scientists contributed to the survey. The 1998 results confirmed those of 1997 that most reefs are severely over-fished, with most high-value organisms missing. For example, lobster were missing from 85% of the reef surveyed, no grouper at 63% of reefs, a 16% increase over 1997, and giant clams were completely missing at 53% of the reefs, a 30% increase over 1997 (Reef Check, 2001*b*). In 1999, 1500 divers, led by 160 scientists in 50 countries on 250 reefs, showed that there was a 10% decrease in live coral coverage and a corresponding increase in dead coral cover (Reef Check, 2001*c*). High-value species such as spiny lobster, grouper, giant clams and sea cucumbers were still missing on most reefs. However, there was some improvement since 1998. Also, 29% of the sites reported bleaching, with mortality ranged up to 95% on some reefs. Many old coral colonies (1000 years old) were killed. As some might think this is a setback to monitoring, it is not, as it gives a clear picture of where increased efforts need to be focused for reef surveys in the years to come. According to Reef Check Coordinator, Dr. Gregor Hodgson, “The absence of large fish such as the grouper, creates an ecological imbalance. Combined with other factors, this can lead to coral reefs being overgrown by algae as we are seeing in the Caribbean.”

Thus, one strength of Reef Check was that they were able to gather a snapshot of the health of reef corals, fish and other invertebrates and secondly, to build up community support for a coral reef monitoring and management program in each area. However, one weakness could be seen in that the methods should be adjusted to match the ability level of the team members and management needs. What must be considered is as more parameters and/or specificity are added to the Reef Check method, there is a potential to bore or burn the volunteer diver out.

As suggested by Hodgson, long-term monitoring of fish and mobile invertebrates will require additional replicates of fish and invertebrate belt transects. Three replicate surveys at each site (i.e. three repeat surveys of one transect deployment), are recommended at quarterly intervals. If the taxonomic requirements are not increased too much, this higher intensity survey could still be accomplished by recreational divers. Also, though reefs do not generally extend below 12m in many parts of the world, there are occasional occurrences. A third or fourth transect could be surveyed and the information used locally.

3.4 Case Study 4

Long term monitoring of coral reefs on Maui, Hawaii and the applicability of Volunteers (Brown, 1998)

Where is the program:

The primary work area is within the waters bounded by the islands of Maui, Kahoolawe, and Lanai, in the state of Hawaii. Long-term monitoring sites included Honolua Bay, Kahekili Park, Puamana, and Olowalu.

Why was the program developed:

To detect spatial and temporal changes of the coral reef community, coral coverage, reef fish density and diversity.

What were the goals of the program:

To test the hypothesis of whether intensively trained volunteers can collect equivalent data to professional staff scientists.

What is the structure of the program and how is it implemented:

Coordinated through Earthwatch, volunteers come from around the world for 2-week sessions and are trained in all phases of data collection techniques. Here, volunteers contribute financially, logistically, as well as scientifically. Presentations to volunteers included an orientation on the habitat of the local area, workshop on coral and fish identifications, fish transect methods, coral survey techniques, physical measurements, introduction to the PC computer and database fundamentals, general invertebrate biology (Maui Ocean Center), biology of corals and reef community dynamics, biology of Green sea turtles and Hawaiian Monk seals, and introductory data analysis. There were also on-site briefings for diving protocols, organization of teams and site orientation. The key to teaching volunteers is based on (Hodgson and Stepath, 1998):

1) Keeping it simple by totally immersing the volunteers in just the area of fish and coral identification
2) Conducting recognition exercises in the field following initial orientation to fish and coral families
3) Testing recall using quizzes in workshops conducted after the field experiences
4) Using common names to speed up the learning process
5) Maintaining a high staff-volunteer ration of at least 1:3

Earthwatch volunteers are asked to learn approximately 90-100 species of fish and 12-15 species of coral. Normally, only 2-3 days of training dives, combined with identification workshops for participants to learn most of the fish species at each site. The data sheets are included in the advance information packet that is mailed to volunteers 30-45 days prior to the project. The majority of data were collected on SCUBA at depths less than 20m. Specific sites were selected on the basis of prior surveys, levels of human use, accessibility and dive conditions.

Three 50m lines were laid out in parallel arrangement, separated by 5m intervals, which created two sample areas each 250m^2. Each 50m transect line was marked at 1m intervals with weights every 10m. The volunteer divers allowed 10 minutes for the fish to habituate and then proceeded down the transect and recorded the number of fish seen within the transect boundaries. Coral diversity and percent coverage were measured as well using the planar point-intercept quadrat method. Efforts were made in subsequent years to sample the same locations but variability in line placement produced a randomized sampling design.

Was the program successful in meeting its goals:

At Honolua Bay, fish density estimates were significantly lower for volunteers than staff members for three of the six transects surveyed although sample sizes were not equal. Other long-term core sites display similar trends for fish density data where volunteers' numbers are lower than staff estimates. In addition, species richness and species diversity were significantly lower for volunteers than staff members in the majority at Honolua Bay. In all the cases the mean values for each parameter were lower for the volunteer data when compared with staff numbers. A described in Table 5, the Pros and Cons on the applicability of long-term monitoring, one can see the benefits alongside the negatives of coral reef monitoring.

Table 4 The Pros and Cons on the applicability of long-term monitoring

Pros	**Cons**
Inexpensive and dynamic work force	Reliability of volunteer commitment an issue for long-term monitoring
Total immersion of motivated individuals for 2 weeks or longer	Extensive field training needed due to high variability of research and diving skills (varies with habitat complexity and nature of question)
Large sample size over extensive area	Quality control of the data is an issue so scientific acceptance is lower
Volunteers still able to track general trends in fish abundance, richness and diversity over time and space	Actual data values is significantly lower than data collected by the scientists

Allow researcher to review work at a more fundamental level	Time commitment for researchers is greater than in traditional research project.

The study indicates that volunteer numbers are often significantly lower than values collected by the staff. However, the benefits of using volunteers for the project outweigh the negatives since the volunteers appear to be tracking the same trends and relative numbers as trained professionals. This allows the scientific community an opportunity to get out in the field.

3.5 Case Study 5

A critical assessment of data derived from coral cay conservation volunteers (Mumby et al., 1995)

Where is the program being done:

South Water Cay in the central province of the Belize Barrier Reef

Why was the program developed:

The Coral Cay Conservation has a continual mission of correct management of many of the MPAs (Marine Protected Areas) in Belize.

What were the goals of the program:

Since 1986, the Coral Cay Conservation (CCC) has utilized a work force of over 900 specialty-trained volunteer divers to collect detailed topographic, bathymetric, and biological data for the establishment of management plans for selected areas of Belize barrier reef. The CCC is a UK-based non-governmental organization that has adopted the concept to assist the Coastal Zone Management Unit of Belize, Central America.

What is the structure of the program and how was it implemented:

Volunteers undergo an intensive 8-day training program in marine life identification and survey techniques. Lectures, practical exercises, video, slides and frequent testing are incorporated. Abundance estimates are based on an ordinal scale with ranges from 0 (absent) to 5 (abundant). This scale is applied to each of the five-substrate classes (live coral, dead coral, rubble, sand and silt) and each of the six principal biotic classes (Scleractinia, gorgonians, Porifera, other invertebrates, macroalgae and seagrass. Qualitative descriptions of topography and depths were defined for bathymetric profile. To ensure that the results of the validation program were compatible with CCC survey protocols, a stratified sampling regime was adopted to include the outer drop-off, inner drop-off, outer fore reef, inner fore reef and three lagoonal seagrass habitats. To standardize the area surveyed, volunteers were asked to confine their surveys of the benthic component to that estimated to lie within 1m either side of the transect line. Transects were laid in each of the major reef zones and in lagoon habitats. Each transect was surveyed independently by six teams of trained volunteers and compared to a reference obtained by experienced CCC staff.

Was the program successful in meeting its goals:

The overall accuracy of coral surveys varied from 52-70%, with poorer values obtained in deeper outer and inner drop-off reef zones. Intra-group variation was also high at approximately 20% per team. The ability of teams to identify coral species correctly showed a bathymetric trend of better identification in shallower sites. Also, volunteers were able to describe substrate and biological coverage at greater than 90%.

With the positive results above, there are still ways to improve volunteer techniques. As stated by Mumby et al., more intensive testing of volunteers' marine life identification skills would help standardize volunteer performance and reduce group variation. More communication is needed between the staff and the volunteer as to mis-identification of species. There was no mechanism for feedback, correction or learning that is carried out under normal survey conditions. Video footage could help improve transect training as well as diver familiarization with differing coral morphology and the identification pf species encountered in deeper areas. Direct feedback to areas of weakness and problems of species identification can be mentioned here.

4.0 Discussion

With coral reefs being threatened today at alarming rates both with natural occurrences and anthropogenic influences, it is vital that necessary steps be taken in order to preserve and maintain these fragile ecosystems. What must be looked at first are considerations for the volunteers that will take part in the research. From here direct users and beneficiaries to coral reefs must understand that community involvement is key. This will allow the community to come to a consensus that following monitoring and management protocols that adequately reflect all community stakeholders, will be extremely effective in assessing coral reef health. Once accomplished, the processes mentioned can be repeated and adjusted as coral reef health improves.

4.1. Considerations for volunteer divers:

For many years, volunteers have taken part in research and information gathering. Quality control of data is essential throughout any volunteer or community-based monitoring program. The accuracy and precision to which one collects this data is of extreme importance so that relevant data can be used for monitoring protocol. One thing that needs to be considered with volunteer divers are the ability to detect and recognize an object depends on both the amount of light available and on the contrast between the image of the object and its background (Ross, 1989 cited in Mumby et al., 1995). Also, declining levels of contrast are known to reduce visual acuity despite the image-enhancing effect of light refraction that causes 4/3 magnification of objects viewed through a face mask (Baddeley, 1971 cited in Mumby et al., 1995). Thus distance estimation is therefore a potential source of error in that divers may be impaired under different conditions of illumination.

The physiological condition nitrogen narcosis, that arises when divers breathe compressed air at depth, is widely regarded as constituting the overriding constraint to cognition (Ross, pers. comm. cited in Mumby et al., 1995).
Anxiety effects are also thought to explain the poorer manual dexterity of divers in open water relative to those in shallow, calm environments (Baddeley, 1966-67 *In* Mumby et al., 1995).

With deeper sites, training is based on studying identification guides that generally use flash photography to illustrate species found in deep water. Not only does this run the risk of the photographs to not be truly representative of the natural appearance of the organisms, but also there is a greater chance of volunteer divers to record inaccurate data.

4.2. What has to be accepted by direct users and beneficiaries to coral reefs:

As direct users and beneficiaries to coral reefs begin to realize that reef systems do not have adequate governmental support, they should begin to understand that community involvement is a key element to preserving the coral reefs. Some initiatives that direct users and beneficiaries will have to accept are 1) the lack of government support for conservation projects creates the need for communities to become more self-sufficient and self-regulating; 2) with a continuous monitoring program, sizable improvements in reef health and in the lobster, conch and fish populations have become the proud and public boast of community residents; 3) tourism-derived revenue will only be attainable if the marine resources continue to be protected; and 4) the need for ongoing environmental education campaigns that positively reinforce the community to maintain or possibly increase community support for the reserve.

4.3. What you need to have from the community for a program

As we begin to see how vital the community is for a coral reef health monitoring program, there are a few criteria that need to be exhibited by the local community: 1) willingness of one initial individual to do whatever it takes to get the communities awareness on the issue; 2) consensus on establishing the size of the area that is going to be monitored; 3) training or retraining of individuals who will be involved and affected by the monitoring program; 4) get local business support (dive shops, resorts) who will help fund initial start-up costs; 5) outline a plan that reflects both involvement from the community and the resorts to achieve a successful monitoring program; 6) maintaining an ongoing program of educating all stakeholders about the long-term economic and social issues resulting from permanent reef damage; 7) establish an on-going community educational campaign concerning the benefits of marine conservation and repercussions of heavy damages to the reef ecosystem; and 8) organize and raise an endowment that would be managed as a long-tem loan to account for an unfortunate event, sudden expense or any other emergency fund.

Although policy measures play an extremely vital role in protecting, preserving and maintaining coral reef health, it is with the community-based monitoring protocols where immediate impact will be most recognized.

4.4. Protocols for coral reef monitoring

After reviewing the five case studies, I have identified the best practices from different programs and combined them into a guide of protocols. These protocols for coral reef health monitoring were adapted from Reef Check (Hodgson and Stepath (in press)) and AIMS (Australian Institute of Marine Science) (English et al., 1997), as they have continuously shown positive results with coral reef monitoring programs and their global reach.

Pre-Dive Preparation

Before one goes out into the field for surveying, it is extremely important that one knows and understands the objectives of what he/she is going to be recording. Below are some elements that divers should be familiar with before going into the water.

1) An explanation of the goals for the survey
2) A review of the sampling design and rationale of the indicator organisms
3) Field identification training for all organisms and Reef Check definitions for substrata
4) An introduction to the data recording format and preparation of slates
5) An explanation of the difference between work diving and pleasure diving and how to avoid smashing into reef corals by proper buoyancy control

6) Explanation of the post-dive data entry, checking and submission procedures.
7) Site specific description: Anecdotal, observational, historical, locational and any other relevant data.

After pre-dive preparation is accounted for, there are six ways to monitor coral reefs that are adaptable to communities when participating in studies. In an ideal world, all six monitoring techniques would be used, but with time constraints and funding in the real world, either the broad scale monitoring method or line transects, will be able to give you a snapshot of coral reef health. However, one should note that when doing line transects, your fish belt transect, invertebrate belt transect, or photo-transect can follow your initial line, therefore providing you with an even clearer picture of reef health.

1) Broad scale monitoring

- Manta Tow or a (timed swim) or equivalent
    1) Develop a broad picture of the reef
    2) Observe unusual phenomena (i.e. blast, damage, plagues)

Consists of 2 minute snorkel tows (minimum of 9) behind a boat at a slow speed with stops to record percent cover of live and dead corals, soft corals and regional specific parameters (crown-of thorns starfish, Diadema, giant clams, large patches of damage to coral reefs). The whole reef boundary should be surveyed so it ensures a representative are of the whole reef. Where visibility is poor, SCUBA can be performed to assess deep slopes.

2) Line Intercept Transect or Equivalent

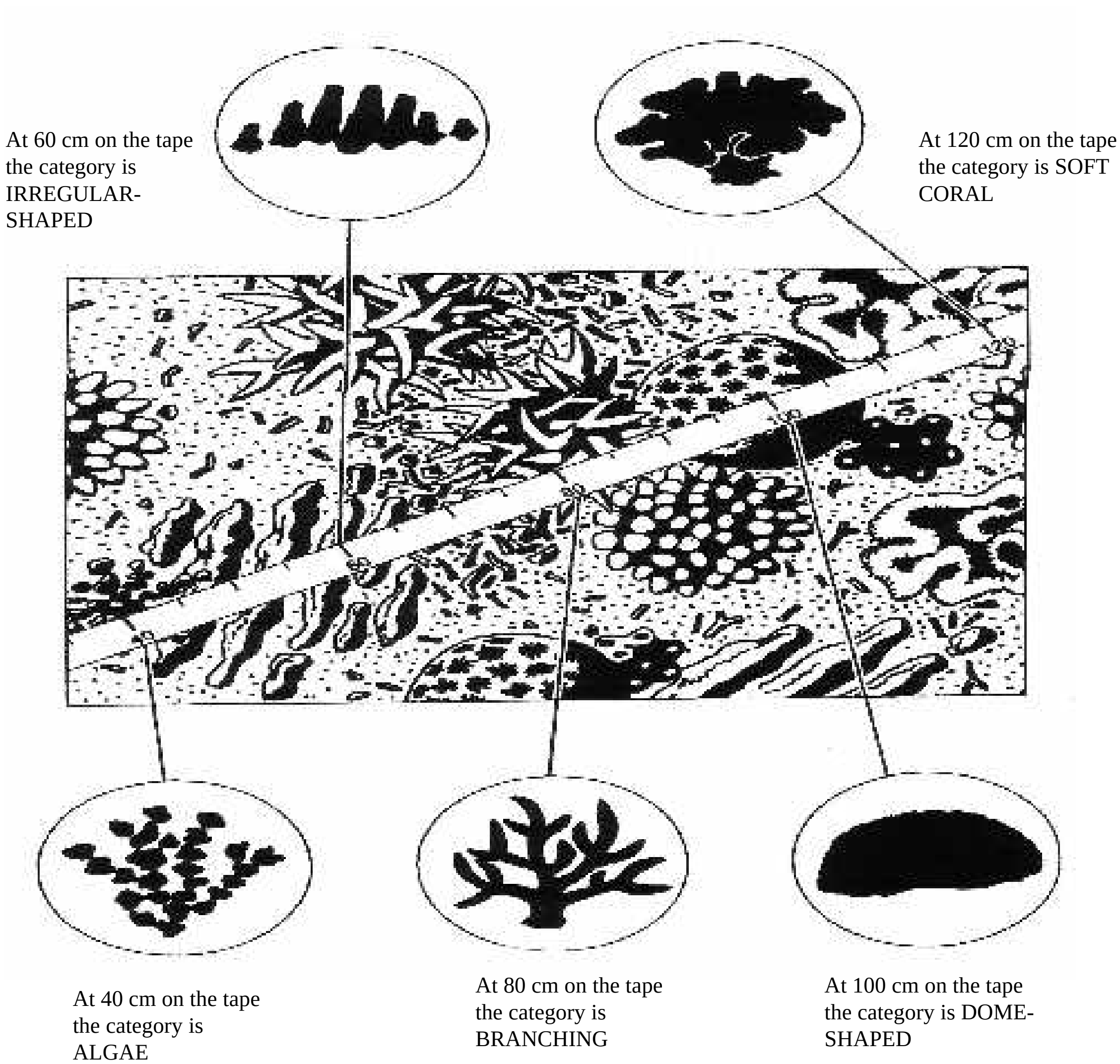
Assesses live coral, with an estimation of coral types, dead coral cover and sand, algae, etc. This method of sampling substrata is “point sampling.” It is the least ambiguous and fastest method that is easily learned by recreational divers. Divers can simply look at a series of points where the transect tape touches the reef and note down what lies under those pints. If the tape is hanging above the substratum, a 5mm nut or heavy metal object tied onto a 2m long cotton or nylon string can be used a plumb-line. The object is dropped at each designated point and it touches only one substrate type that can be recorded. Intervals will be recorded at 0.5m. (start at 0.0m, 0.5m, 1.0m, 1.5m, etc. up to 19.5). There will be 40 data points total. Still photos and videography both on land and in the water are recommended.

- The same transect for the Fish Belt and Invertebrate Belt transect can be used.
- 4 line transects each 20m long, with parameters 3 to 6m depth with another set done at 10m (record as lifeforms or species if possible). Transect start and end points should be separated by a 5m space.
- The estimated time to deploy the transect is 30 minutes. After deployment, the transect should be examined to ensure it is not snagged or floating too high off the bottom. Small marker floats should be marked to the start and end points.

An example of what a diver might encounter when doing a line-transect can be seen above (Musso and Inglis, 1998).

Figure 6 Line Intercept transect

This is an example of a section of a line transect laid on a reef



During training, the number of lifeforms or species categories might be reduced to help get people started. All lifeform and species must be capable being compared statistically.

Ex. Several life forms or species can be grouped into larger groups:

- Branching and digitate Acropora
- Branching non Acropora

Substratum categories include: hard coral, soft coral, dead coral, fleshy seaweed, sponge, rock, rubble, sand, silt/clay, other. What must be kept in mind is that after collection, larger groups can't be subdivided back into more detailed groups. Video transects are comparable and can assist with lifeform transects.

3) Fish Belt Transect - Live Fish Census

- Based on line transects
- Before attempting fish surveys, divers should practice estimating sizes using transect lines or measured sticks
- Work can be started after a 15 minute period during which no divers disturb the area
- The diver will swim slowly and stop to count target fish every 5m, and then wait 3 minutes for target fish to come out of hiding, before proceeding to the next stop point.
- 4 sections x 20m long x 5m wide = 400m^2. There are 16 "stop-and-count" points. The goal is to complete the entire 400m^2 belt transect in 1 hour.
- The maximum height for which to record fish is 5m
- Initial focus is counting all fish, especially those in the major target of fishers. Identifying indicator species like Chaetodonts is recommended.
- A note should be made of any sightings or rare animals such as large manta rays, sharks and turtles, and if these are off-transect records
- As more experienced is gained, more species level identifications can be attempted

With poor visibility or large numbers of fish, each diver should survey half of the 5m wide belt. One side of the transect line can record fish in a 2.5m wide strip with the buddy recording the other side (together the 5m wide belt will be surveyed).

4) Invertebrate Belt Transect

- same as Fish Belt Transect above
- The presence of coral bleaching or unusual conditions (diseases) along the transects should be noted.
- Teams are encouraged to look in holes and under overhangs to detect species, such as lobster, that may be hiding

5) Permanent Quadrats

- Permanent marked quadrats 1m^2, which are assessed regularly

→ photography or mapping to measure growth rates of corals and results of inter-specific interactions

- Quadrats are used to follow new coral recruits to determine the ability of a reef to recover from stress
- Areas of interest when doing permanent quadrats are reef areas that are almost bare of corals, wither due to storms, blast impacts, shipwrecks, crown-of-thorns, etc.
- 1x1 m^2 marked with steel stakes at around 3 to 5m depth (or where coral growth is normally highest

Once successful monitoring has been established, one can begin to look at if corals have settled in the area. By placing terracotta tiles before corals breed, one can examine for juveniles under a microscope at various interests throughout the year.

6) Photographic method

To determine changes in the coral reef community for long-term monitoring of coral cover and diversity, photography can be use. It is a relatively simple and rapid method and provides a permanent record for later analysis. Periodic groundtruthing is needed to verify the interpretation of the photographs, such as identifying new coral colonies. In the monitoring that went on in Soufriere, there was little difficulty in recognizing colonies from one photograph to the next over a period of years (Smith, 1994).

Post Dive Tasks

The team scientist shall gather the slates and data together to determine if some error has been mad that can be corrected while the team is still on site and the transect is in place. “Double-counting” of fish, misidentification of organisms or mis-labelling the slate are possible occurrences.

To be sustainable, monitoring programs must use methods that take advantage of available scientific and technical expertise in the collection and processing of data, and they must be capable of being maintained by small island and regional institutions and participating communities (Smith, 1994).

In developing community-based programs, you are inevitably positioned between trade-offs in the intensity of community involvement. On one hand, a few hours of training could be enough to go out and collect relevant information, such as Reef Check. On the other hand, there are community-based programs where a few weeks of your time is required to monitor the coral reefs, such as Earthwatch and Coral Cay Conservation. Is one collecting the same information? Due to the longer preparation period for learning about the reefs, is the collected information going to be that much more accurate?

Nevertheless, incorporating volunteers provides a new sense of appreciation for complex coral reef ecosystems. Moreover, respect and concern for the marine environment has grown as well.

What also is a must to any community-based program is to have the scientist be apart of the of the community program, bringing them into contact with the general public. Now, the public gains a greater appreciation of basic and applied science and the role of marine scientists. This ultimately helps science to gain a bigger share of funding from government sources (Hodgson, 2000).

With coral reefs declining and becoming scarcer, research funds are necessary to study natural and anthropogenic effects on coral reef ecosystems. More aggressive action needs to take place in the United States. There needs to be an increase in non-governmental organizations (NGOs). They should be active in promoting the overall concept of community management, in advocating community rights and in serving as "buffers" to facilitate the resolution of disputes and to give legitimacy to local concerns in cases of conflicts between a community and other interests (Renard, 1991).

4.5. Steps to management

With the right aggressive management, I feel community-based volunteer monitoring programs can be effective. Below, I have layed out the following management steps:

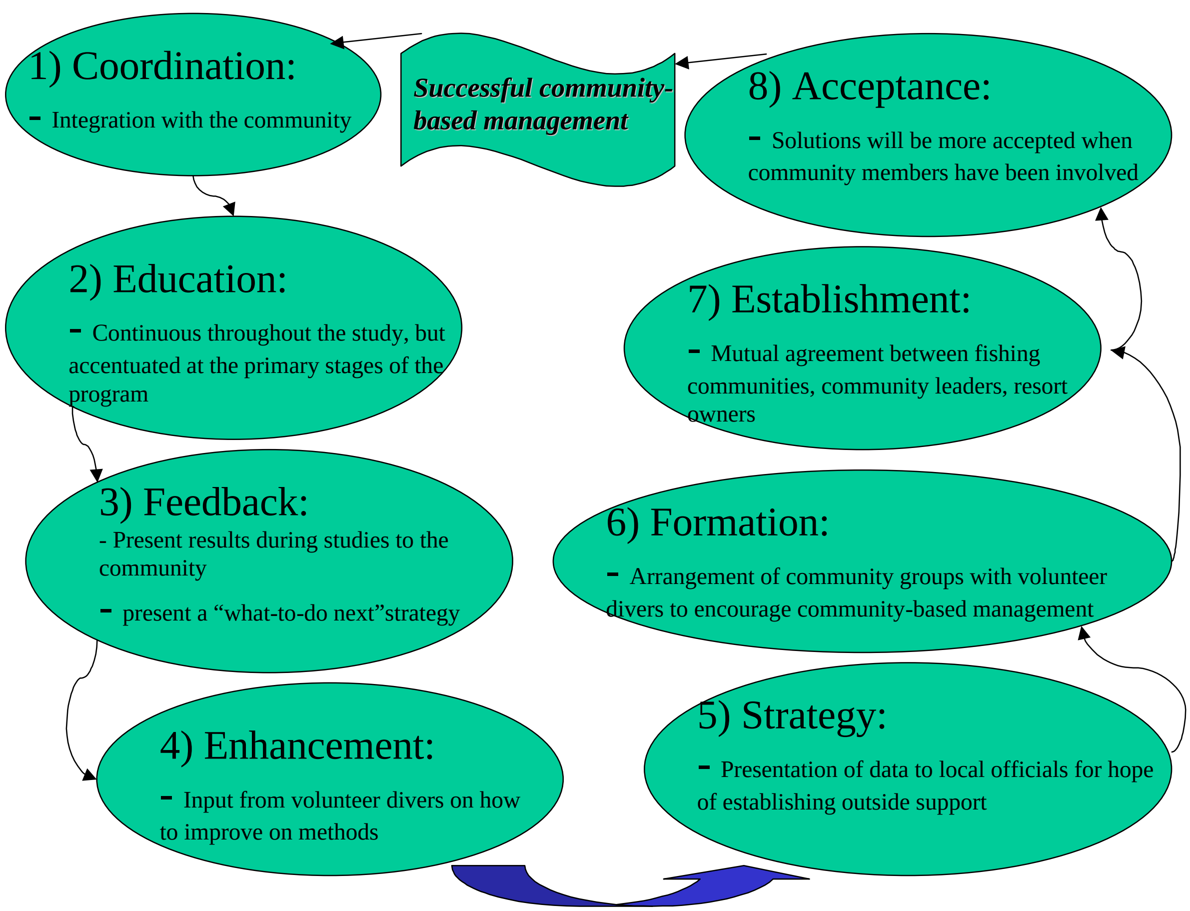
1) *Coordination:* Need to start with integration into the community. Marine field workers would introduce the project and meet with community leaders, attend community meetings and become accustomed to the marine environment they will be instituting the program.

2) *Education:* Should be continuous throughout the study, though accentuated at the primary stages of the program

3) *Feedback:* Should be shared with community results found during studies of the coral reef health. Also, present guidelines on a “what-to-do next” strategy for continued reef health monitoring.

4) *Enhancement:* Strengthening of community-based management with input from the volunteer divers as how to improve upon current methods of research.

5) *Strategy:* Presentation of relevant reef health data to local officials in the community for hope of establishing outside financial support from local government. This could lead to a healthier reef in the long-term, but provide short-term benefits of attracting tourism and increased revenue to the area.



6) *Formation:* of knowledgeable and respected community groups, starting with volunteered divers, to promote and encourage community-based management of reef health in the local area.
7) *Establishment:* of a working marine reserve that is honored by fisherman and used by divers with enforcement by the community leaders, resort owners and fishing communities.
8) *Acceptance:* of proposed solutions are more likely to be accepted when community members have been involved in the decision process

If coral reefs are going to continue to serve as economic and biodiversity resources, a major shift is needed in the activities of governments, private groups and individual citizens, towards actively monitoring and managing coral reefs (Hodgson, 2000). In an ideal world a small team of highly experienced individuals would conduct all surveys, but this is rarely the case due to a lack of funding and time. Thus, an increase in community-based management will only help us get to the point of having coral reefs that can be maintained well into the future.

4.6 Analysis

From the five case studies that were analyzed, there were two types of involvement, that of community and that of outside volunteer (Table 9). As both types of involvement have their own positives, there is one difference that immediately comes to mind. With outside volunteer monitoring, new people are brought into the equation every year to assess reef health. Even though you are able to monitor the reef, there lies room for error in that you do not have the same people and background of what is going on each time one assesses the reef. However, on the other hand with the local community, you are able to have direct users that have been around the reef for many years and as a result have a better understanding of how the reef operates.

Table 5 Synopses of Case Studies

Case Study	**Community Involvement**	**Outside Volunteers**	**Still Active**	**Type of Study**	**Findings**
Soufriere, which lies on the west coast of St. Lucia in the Caribbean	Yes	No	Yes, though limited to the St. Lucia Dive Association	Monitor factors that most likely cause reef degradation	Continuous support is key to long-term coral reef monitoring
Roatán: Bay Islands of Honduras	Yes	No	No	Create and manage a marine protected area	Reef recovery can be attained, but must have financial support
Reef Check: Hawaii	No	Yes, volunteer divers worldwide	Yes and in numerous countries around the world	Gather a snapshot of the health of reef corals, fish and other invertebrates	Successful snapshots can be accomplished with trained volunteers
Monitoring of coral reefs on Maui, Hawaii	No	Yes, coordinated through Earthwatch	Yes	Whether intensively trained volunteers can collect equivalent data	Significant lower values of findings, though the volunteers tracked the

				to professional scientists	same trends and relative numbers of professionals
South Water Cay in the Belize Barrier Reef	No	Yes, coordinated through Coral Cay Conservation	Yes, with a growing number of volunteers	Collection of topographic, bathymetric and biological data for establishment of management plans for the Belize Barrier Reef	Again, with proper volunteer training, successful surveying can be accomplished

As is the reliability of community vs. outside volunteer participants an issue to address, four others issues need to be addressed for community-based monitoring to be successful.

4.6.1. Policy

When taking a look at all the case studies, there is one overwhelming similarity, this being that there was no formal legislative policies in effect to protect the coral reefs. This seems hard to believe, especially in areas of the world where tourism to the reefs plays a large factor in their economies. However, in case study 2, the Bay Islands of Honduras, the local community came up with their own policies with respect to the monitoring and management of the reserve. As their policy was extremely successful, it is upsetting that money issues led to the decline of the monitoring.

4.6.2. Training the local community

In the case study 2, the Bay Islands of Honduras, 20 local fishermen were trained and certified by dive instructors, thus making them eligible to become dive masters. Others were trained to work in the service sector of the tourism industry, becoming waiters, cooks, guides, etc. Several others were trained to become patrol guards for the marine reserve. This is a prime example of what a community-based program should be, especially since they were able to incorporate the fishermen, who are normally objective to any interruption of their fishing practices. We see a similar comparison in the case of Soufriere, as community members helped form the St. Lucia Dive Association that helps monitor the coral reefs still today.

4.6.3. Money Contributions

In the Bay of Islands case, we see an implementation of membership fees as well as a more than half budget contribution to the marine reserve budget, assisted with other businesses picking up the rest. If this sounds to good to be true, you are right. In the end, the main contributor wanted to have a bigger say in what was being done on the reef. As no explanations are given, one can think that since he saw a steady increase in the amount of tourism revenue, he might have wanted to increase the amount of divers that would be on the reef daily. Now, if the whole objective of maintaining a healthy coral reef, one should realize that too many divers would bring too many negative impacts to the reef. Thus, the marine reserve failed since its budget was immediately lost.

In terms of the Bay of Islands, a cost-benefit analysis should have been drawn up that would have created equal fees to direct users and beneficiaries. This way, no one is complaining and monitoring can get underway.

One way I recommend for raising revenues can be seen in case study 3, long-term monitoring of coral reefs on Maui, Hawaii. What the organizers did was appeal to Earthwatch, a non-governmental organization, to draw in volunteer divers from around the world. Why this was a success, is that you are attracting not only the general public who know how to dive, but you are also bringing in money to run your monitoring program. All I can say here is that for a starting up community-based monitoring program is to try an appeal their case to an NGO and perhaps positive feedback will occur. If not, at least you have put your program out in the coral reef community and you never know what might happen.

There is also a combination of state and federal funding that might be available as it was provided as seed money for Hawaiian community groups to coordinate Reef Check training and surveys, the number of volunteers and the number of surveys could be increased dramatically

4.6.4. Time

As we saw in case study 4, a critical assessment of data derived from Coral Cay Conservation volunteers, as well as in case study 3, long-term monitoring of coral reefs on Maui, Hawaii, there is a longer time period of training community volunteers. The Coral Cay Conservation volunteers were trained for 8 days and the Earthwatch-based volunteer programs were trained for 2 weeks. For example, 90% of the volunteers from

Earthwatch were able to accurately describe substrate and biological coverage. This only goes to show that the more training one can have for assessing coral reef health, the more reliable and accurate the data will be for long-term data.

4.7 Conclusion

In the end, with most coral reef monitoring programs, money ends up being a key factor in ones decline. However, there is still an extreme amount of good that occurs even if the reef-monitoring program fails. This can be seen in that a systems framework of effective monitoring that lead to efficient management was established. Right here, you have essentially the key ingredients to a successful monitoring and management program. This can lead to a constant flow of checks and balances; that being with the monitoring adjusting to reef conditions over time, more effective management can take place to compensate for the changes in reef health. Therefore, this framework can be applied to all communities around the world where coral reefs are a part of individuals' livelihoods.

Now as we saw in the two case studies were the community was involved, the monitoring program eventually went under. But in the case studies where outside volunteers were organized to assess reef conditions, those programs are still around today. What this says is that there needs to be a greater commitment placed on financial backing where community monitoring programs are going to be established. If this does not occur, the program is going to experience the same type of ups and downs that the Roatán and Soufriere experienced.

After reviewing the community-based coral reef monitoring programs, I propose greater support is needed for coral reef monitoring and management programs. If one would incorporate table 4, Depth of reef and assessment criteria, more cost-effective programs can be implemented

Table 6 Depth of reef and assessment criteria

Height of Reef	**Type of transect**	**Number of divers necessary**	**Frequency of monitoring**	**Money contribution**	**Equipment**
Shallow (2-5m)	Broad-scale; Line Intercept; Fish and Invertebrate belt transect; photo transect	4	Every 3 months	Little or no money as volunteer divers already have necessary equipment (except for photo-equipment)	Water-proof slates and pencils, tape measure, possible underwater-camera or video recorder
Intermediate (5-11m)	Line Intercept; Fish and Invertebrate belt transect; photo transect	4	Every 5 months	Substantial amount of money due to potential number of tanks required for deeper depth; potential cost for underwater photography if deemed necessary on water conditions	Water-proof slates and pencils, tape measure, possible underwater-camera or video recorder
Deep (>11m)	Line Intercept; Fish and Invertebrate belt transect;	6	Every 6 months	Substantial amount of money due to potential number of tanks required for deeper depth	Water-proof slates and pencils, tape measure

Due to an increase in the number of tourists frequenting reef systems, I truly believe that volunteer divers are a key element in monitoring coral reefs. Thus, the guidelines and protocols I have proposed will allow coral reefs around the world to recover and flourish; moreover benefiting our global ecosystem.

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